Goddard Visiting Scientist Program
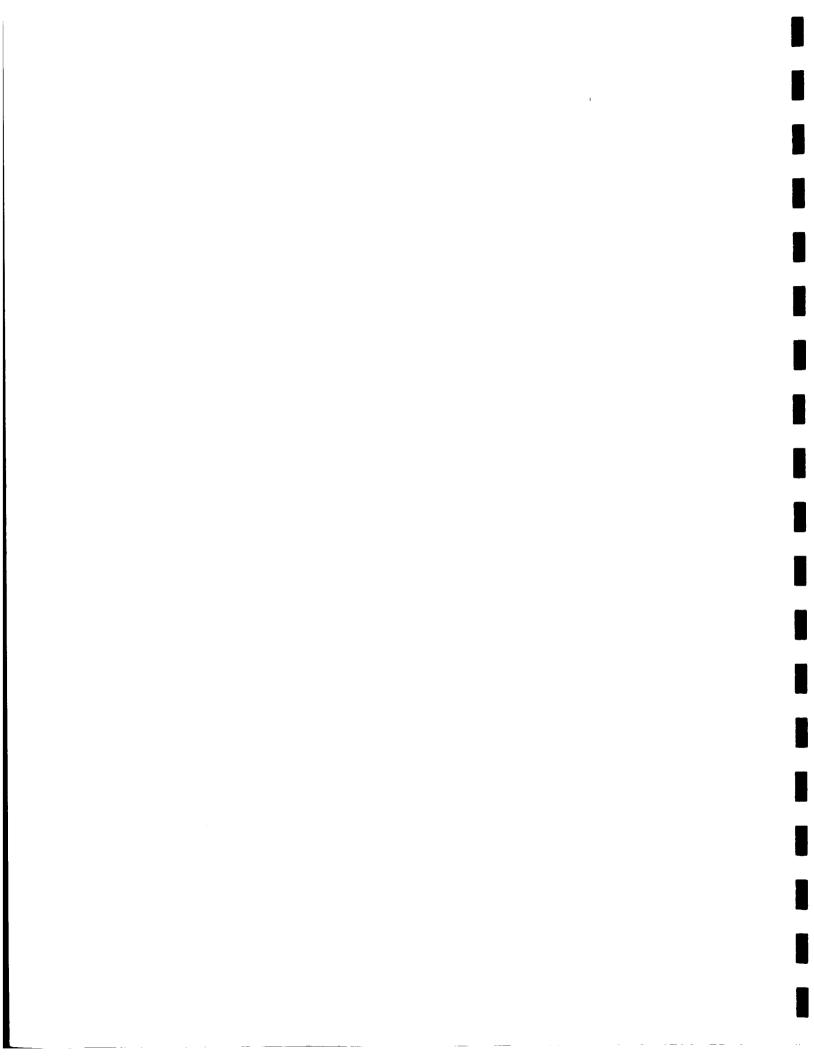
Dr. Michael Kalb, Director

Final Report

October 1998 – September 2000

INTRODUCTION

Under this Indefinite Delivery Indefinite Quantity (IDIQ) contract, USRA was expected to provide short term (from I day up to I year) personnel as required to provide a Visiting Scientists Program to support the Earth Sciences Directorate (Code 900) at the Goddard Space Flight Center. The Contractor was to have a pool, or have access to a pool, of scientific talent, both domestic and international, at all levels (graduate student to senior scientist), that would support the technical requirements of the following laboratories and divisions within Code 900:

- Global Change Data Center (902)
- Laboratory for Atmospheres (Code 9 10)
- Laboratory for Terrestrial Physics (Code 920)
- Space Data and Computing Division (Code 930)
- Laboratory for Hydrospheric Processes (Code 970)

The research activities described below for each organization within Code 900 were intended to comprise the general scope of effort covered under the Visiting Scientist Program. The next section is taken directly from the contract's statement of work.

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GLOBAL CHANGE DATA CENTER (CODE 902)

Research is conducted in the areas of image science and technology, including applications of concurrent processing and artificial intelligence techniques. Advanced network operating, systems, user interfaces, portable and device-independent software and techniques for image analysis and display and for utilization of high performance parallel processors are developed. Research is conducted in the applications of image processing and artificial intelligence techniques to the analysis of geographic and geocoded data systems. Advanced satellite sensor processing and analysis techniques for interdisciplinary research studies are developed. The Contractor will be responsible for conducting research in the areas described above.

LABORATORY FOR ATMOSPHERES (CODE 910)

The Laboratory for Atmospheres performs comprehensive theoretical and experimental research dedicated to advancing our knowledge and understanding of the atmospheres of, the Earth, and other planets. The research program is aimed at the following: advancing our ability to predict the weather and climate of the Earth's atmosphere; advancing our understanding of the structure, dynamics, and radiative and chemical properties of the troposphere, stratosphere, mesosphere and thermosphere; determining the role of natural and anthropogenic trace species on the ozone balance in the stratosphere; and advancing our understanding of the physical properties of the atmospheres and ionospheres of the Earth and other planets. The Laboratory identifies problems and requirements for observations of atmospheric processes by satellite and other techniques. A broad program of Laboratory research, including instrument development of mass spectrometers, solar radiation instruments, and remote sensing laser detectors, supports the program to observe the Earth and the planets. Overall, the Laboratory program embraces a wide variety of research opportunities, including research on the weather and climate of the Earth, planetary atmospheres physics, development of multi-dimensional atmospheric models, and implementation of measurement techniques for sounding the atmosphere and for detecting trace concentrations of pollutant gases. The Contractor will be responsible for conducting research in the areas described above, such as the following activities:

a. Develop and validate remote sensing techniques for ocean-air, heat and moisture flux, tropospheric and stratospheric state variables and trace species.

b. Test hypotheses related to induced coastal mesoscale circulation and other aspects of the ocean/atmosphere interface, tropospheric and stratospheric exchange of trace gases, and stratospheric ozone depletion.

c. Develop applications of high-speed vector or parallel processors to computational requirements of atmospheric research.

d. Apply cloud models to investigations of storm structure and development, and use the results to enhance interpretation of satellite-sensed data.

e. Conduct modeling simulations of Arctic and Antarctic surface and atmospheric radiation, and develop new models of sea ice albedo.

f. Provide expertise in numerical modeling of tropical heat sources, ozone depletion and their impact on global circulation, and assess and refine the Laboratory for Atmospheres General Circulation Models representations of atmospheric dynamics.

g. Provide guidance and conduct research in numerical weather prediction, atmospheric chemical change climate dynamics, and monthly and seasonal prediction of climate anomalies.

h. Extend and improve the physical basis of general circulation models, especially for such parameters as soil moisture, terrain, chemistry, etc.

i. Develop and extend mass spectrometer techniques for measurement of neutral and ion compositions and neutral winds and temperatures in the upper atmosphere of the earth and other planets.

j Develop and use a 3-D spectral, general circulation model, which solves the time dependent, non-linear, Navier Stokes equation to study thermosphere/mesosphere dynamics.

LABORATORY FOR TERRESTRIAL PHYSICS, CODE 920

The Laboratory carries out research to advance scientific knowledge of Earth and the terrestrial planets, and to aid in the improved management of the resources of the Earth, through the application of remote sensing and other space technology. Efforts include specific research in the following areas: Earth's geoid; gravity and magnetic fields, and their application to ocean and crustal dynamics, Earth structure, and earthquake mechanisms; motions and mechanics associated with plate tectonics, and their relationship to geologic resource provinces; spatial and temporal dynamics of land surface features such as topography, vegetation, dry and green biomass, land forms and other geological features, soils and soil moisture, and massed works of man. Instruments and data systems are developed; new, one-of-a-kind ocean, atmosphere, and Earth resources remote sensing instruments covering primarily the visible and infrared are designed, fabricated, calibrated, and tested. Observational studies using data acquired by ground-based, airborne, and space borne sensors are included along with the modeling and analysis of the sensor concepts that may be involved.

The contractor will be responsible for conducting research in the areas described above, such as the following activities:

a. Perform research in the areas of crustal dynamics, solid Earth physics, magnetic and gravity field studies, and modeling, regional tectonics, and coastal processes.

b. Perform research in biospheric sciences: ecosystem-atmosphere interactions; ecosystem patterns and processes occurring at local, regional and continental spatial scales and temporal scales ranging from seconds to decades; and radiative transfer modeling and testing.

c. Conduct research on organization and manipulation of large area and global data sets.

d. Work with engineers involved in the design and production of instrumentation in support of above research.

e. Evaluate and interpret data gathered from related experiments and projects.

EARTH AND SPACE DATA COMPUTING DIVISION, CODE 930

The Earth and Space Data Computing Division provides comprehensive research, development, and support in data handling and computing for NASA/GSFC space and Earth science research programs. The increasing complexity, variety, and volume of data needed for research in Earth and space sciences require the development and integration of advanced computing tools and techniques. The applications of advanced system architectures, such as massively parallel processors (e.g., the MASPAR MP-1) and the CRAY Y-MP vector processor, to data processing and analysis are being studied. Database management systems (DBMS) research investigates advanced concepts, techniques, and architectures for dealing with very large distributed, multi-source databases. Research is conducted on advanced systems for scientific data management, e.g., database machines, digital optical disk technology, and expert systems. Data systems that integrate data archiving, catalog, retrieval, manipulation, and transmission techniques are being developed. Examples include the version 0 Distributed Active Archive Center (DAAC), the National Climate Data System (NCDS), and the Pilot Land Data System (PLDS).

Systems analysis and systems engineering, support will be provided for the development, operation, and management of Science Data Operations Centers for flight mission projects such as: Sea Wide Field Sensor (SeaWiFS), Earth Observing System (EOS), Tropical Rainfall Measurement Mission (TRMM), and other Earth-observing satellites during the next several years, and for reprocessing consistently calibrated satellite data for monitoring long-term climate variations with Advanced Very High Resolution Radiometer (AVHRR) Path Finders.

The Contractor shall be responsible for conducting research in the areas described above, including the following activities:

a. Conduct research and apply advanced techniques to meet operational science requirements. This includes data processing and handling methods for atmospheric, oceanographic, and land data obtained from instruments including the sensors on the Nimbus-7 satellite and the future sensors/missions instruments such as the SeaWiFS, TRMM and the Moderate Resolution Imaging Spectrometer (MODIS) and other Earth-observing satellites.

b. Perform research leading to the development advanced database systems.

c. Conduct research on concurrent and parallel processing including such applications as image restoration, scientific data visualization, solution of sparse linear systems, recursive function generation, chaos theory and fractals, animated graphics and high-speed simulation of natural processes.

d. Develop and apply advanced networking methods and data flow technologies.

e. Develop and apply advanced algorithms for the extraction of information from image, spectral, and other data from spaceborne sensors.

f. Develop and apply advanced data compression algorithms for high data rate and volume data such as those expected from the Earth Observing System (EOS) mission.

LABORATORY FOR HYDROSPHERIC PROCESSES, CODE 970

The Laboratory for Hydrospheric Processes is responsible for a broad program of theoretical and experimental research in the oceanic, cryospheric, and hydrologic sciences. The Laboratory is involved in the development of remote sensing methods for hydrospheric variables, the incorporation of remote sensing data into numerical

models, and subsequently the utilization of these tools and techniques to understand better the role of hydrospheric processes in global and climate change. The comprehensive expertise within the Laboratory constitutes an end-to-end capability for instrument development, algorithm development, model development, the validation and analysis of remotely sensed data with in situ hydrospheric data, and ultimately the application of these data to geophysical process studies.

The Laboratory for Hydrospheric Processes will be a major participant in the upcoming NASA flight projects involving the following: the Ocean Topography Experiment (TOPEX); the Sea Wide Field Sensor (SeaWiFS) that will provide global ocean color data; the NASA Scatterometer (NSCAT) for ocean surface wind observations; and the Tropical Rainfall Measurement Mission (TRMM). Members of the Laboratory are actively preparing to use the data from these missions in support of their participation in the World Climate Research Program (WCRP) and the International Geosphere-Biosphere Program (IGBP) initiatives of the Tropical Ocean-Global Atmosphere (TOGA) Program, the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Study (JGOFS), and the Global Energy and Water Exchange Experiment (GEWEX). In conjunction with these activities the Laboratory is also preparing for the NASA Earth Observing System (EOS) in the areas of imaging spectrometry, passive microwave radiometry, radar and laser altimetry, scatterometry, and synthetic aperture radar.

The contractor shall be responsible for conducting research in the following areas:

a. Oceanography

    Physical Oceanography: Modeling and process studies of global, tropical, mid-latitude, and Polar Ocean circulation. Application of scatterometer and altimeter data to study ocean circulation.

    Ocean Color: Ocean color remote sensing and inference of primary productivity.

    Air-Sea Interaction: Modeling and process studies of air-sea interface. Study the air-sea interaction processes for improving scatterometer algorithm.

b. Cryospheric Science: Studies of seasonal and interannual variability of sea ice, snow cover, and ice sheets. Modeling and observational studies of air-sea-ice interaction. Investigation of ice sheet mass balance and dynarnics.

c. Hydrology parameterization of mesoscale hydrology of sernivegetated landscapes using satellite multispectral imagery: Land surface hydrology parameterization for Goddard Mesoscale Atmospheric Simulation System (GMASS) Soil moisture and snow pack determination using active and passive microwave approach. Use of 37 and 19 GHz satellite data have shown potential for measuring vegetation and moisture status of the surface; as part of this continuing research atrhospheric effects on these frequencies has been investigated and the correspondence between two 37 GHz sensors of the Special Sensor Microwave/Imager (SSM/I) and the Scanning Multispectral Microwave Radiometer (SMMR) have been compared so that the length of record can be expanded Modeling radiative transfer of vegetation canopies.

d. Precipitation research on techniques (active and/or passive) to measure soil moisture, rain, snow, lightning, and water vapor: Development of instrument concept and retrieval algorithm for the Tropical Rain Measurement Mission (TRMM).

e. Instrumentation development of future altimeter satellite using laser and radar altimetry, the Global Positioning System (GPS), and gravimetry to study oceans and ice sheets. Multibeam mode of Multimode Airborne Radar Altimeter (MARA) used to map Greenland icecap. Radar Ocean Wave. Spectrometer (ROWS) and Scanning Radar Altimeter (SRA) under flights for European Remote Sensing-I Synthetic Aperture Radar (ERS- I SAR) validation effort. Studies and measurement of ozone using rocket and balloon- borne instruments. Development of Doppler European Polar Orbiting Platform (EPOP) radar to study convection in severe storms Development of Microwave Imaging Radiometer (MIR), to study water vapor distribution and ice clouds. EDOP and MIR to be operated on the TOGA

Coupled Ocean-Atmosphere Response Experiment (COARE) Development of ESTAR to be carried on a future free flier to measure soil moisture

Ordering Procedures

Work accomplished under this contract will be further defined through the Task Ordering Clause of this contract The Contractor will be directed to provide specific research through the issuance of Task Orders by the Contracting Officer.
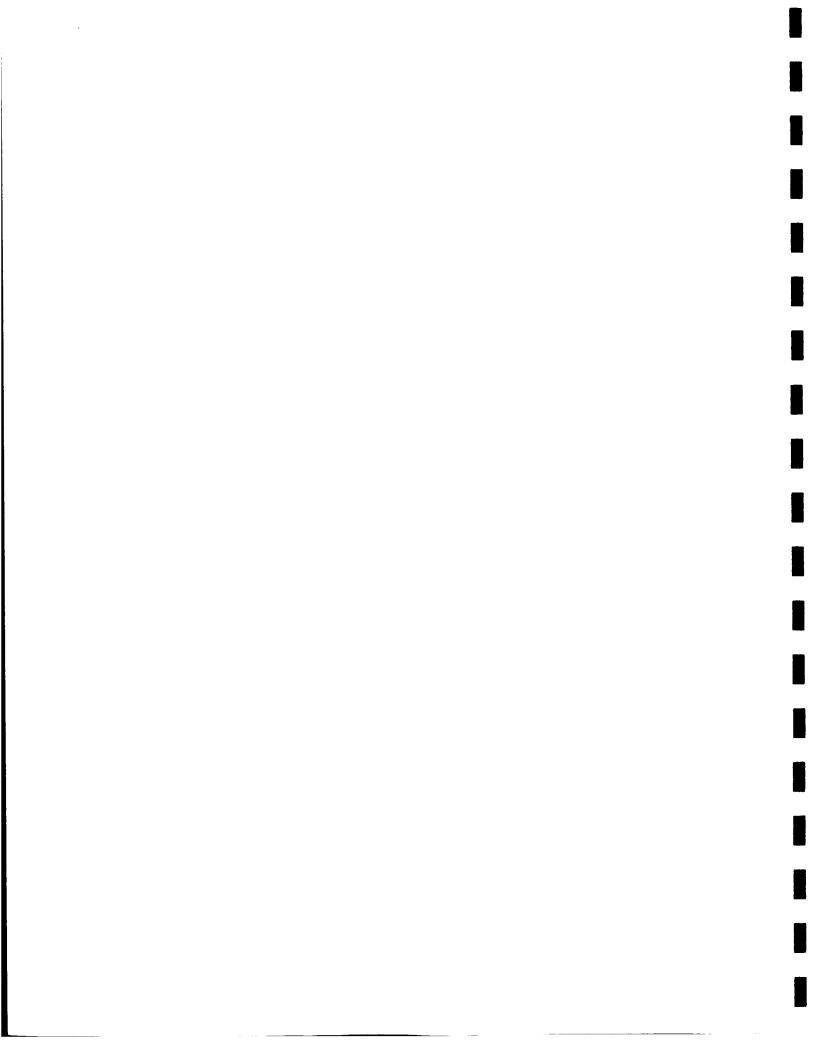
Additional Requirements

In support of all of the organizations within Code 900, the Contractor may also be required to participate as scientific technical advisors and speakers in seminars, colloquia, workshops, and conferences as necessary to support the technical research requirements.

The Contractor shall be responsible for making all necessary arrangements for international participants in the visiting Scientists Program, both long-term and short-term. This includes obtaining visas and passports, and coordinating all related activities in a timely manner.

The Contractor shall be responsible for collecting and assembling scientific, technical, and programmatic information; synthesizing the information; preparing written documents, such as reports, long range plans, and program documents; and organizing meetings, workshops, and reviews.

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The remaining sections of this report contain progress reports written by the scientists funded by this contract. Contained also are lists of visitors and travel supported. The report is organized by Code 900 laboratory, then by task in numerical order within each laboratory.

EARTH SCIENCES DIRECTORATE (900)

900-01
900-02
903-01

TASK 900-01: Climate and Radiation Branch Visiting Scientist

TASK DESCRIPTION

1. Set up ground based remote sensing automatic spectra sun/sky scanning radiometers; one approximately 500m (between Mombasa and Nairobi) and the other along the meteorological equator around Mt. Kenya <1200m above mean sea level. This will provide data that will be compared with the information to be generated during the intensive INDOEX campaign and the on-going validation of MODIS products.

2. Obtain measurements of ozone especially during the above period which are routinely taken at/by Kenya Meteorological Department (KMD). This can be done by intercomparing with King et al.'s (1980) algorithm described in "Spectral Variation of Optical Depth in Tucson" and other related work.

3. In light of ongoing work on aerosol measurements on Mt. Kenya and the season transport climatology earlier developed–Gatebe et al. (1998), it would be important to continue such measurements through the University of Nairobi and feed the information into NASA validation programs as may be required.

4. Participate in efforts/activities that may increase NASA's presence in the region–east, central and Horn of Africa, that are aimed at providing validations of remote sensing products including satellites.

USRA EMPLOYEE: DR. CHARLES GATEBE

Research focus: Measurement, distribution, and radiative/optical effects of atmospheric aerosol.

Accomplishments

<u>January – August 1999</u>

I prepared a publication based on data analyzed during this period. The analyzed data was collected using NASA Cloud Absorption Radiometer (CAR) during the Smoke, Cloud, Aerosol, and Radiation (SCAR) campaign conducted by the MODIS team in Brazil in 1995. My colleagues (Dr. Si-Chee Tsay, GSFC; Dr. Michael King, GSFC; and Dr. Qiang Ji, SSAI) and I have submitted an abstract to be considered for presentation at the 28th International Symposium on Remote Sensing of the Environment, March 27-31, 2000 in Cape Town, South Africa.

<u>October 1999 – June 2000</u>

During this period, additional surface bidirectional reflectance measurements obtained using CAR during the SCAR experiment for the period August 17-September 20, 1995, were processed and analyzed. The analysis has been used to study the surface BRDF pattern in the MODIS 2.1 μm band relative to the 0.47 and 0.68 μm bands, for use in remote sensing of aerosols over loand. The BRDF analysis emphasizes results for off-nadir view angles compared with nadir views. For the data anlayzed and for the view angles tested, results seem to suggest that the reflectance • 0.47 and • 0.67 are predictable from • 2.1 using : • 0.47 = • $2.1^{/6}$, which is a slight modification of Kaufman et al. (1997) and • 0.67 = • $2.1^{/2}$, similar to Kaufman et al. (1997). These results hold for target viewed from backscattered direction, but not for the forward direction.

Summary of the CAR Modification work that I have been coordinating:

1. Upgraded/replaced some electronics in the instrument. Changed from a 10 bit to a 16 bit data system. Built new data system to replace the exabyte data system. Used new commercial LabView software that supports more features like data analysis, visualization, visual instrument

control, etc. Improved data acquisition system and increased the SNR by digitizing the signal at the source, replaced old cabling, etc.

2. Installed two interference filters to correspond to the TOMS UVA channels at 340 and 380 nm . This involved modifying the optical train of the CAR by building a new mechanical/optical package. The intent here was to do some new science with the CAR that involved the aerosol index work of TOMS and SUNPHOTOMETERS.

We completed the modification work and carried out the calibration of the instrument at the UV Lab by June 30.

July-September 2000

CAR calibration: This activity took place at the NASA Ames Research Center's Airborne Sensor Facility at Moffett Field, CA. The mission was quite successful.

CAR test flights: My colleagues and I conducted test flights aboard the University of Washington's Convair 580 aircraft at Paine Field in Everett, WA. Some quick look images were prepared from data taken during the test flights. It's clear from the images that the instrument worked well for most of the channels.

SAFARI 2000: I participated in the SAFARI 2000 campaign from August 24 – September 19, and took measurements with the CAR instrument aboard the University of Washington plane. We collected comprehensive data in a variety of conditions and locations in Southern Africa which, when analyzed, should contribute significantly to meeting the scientific goals of SARARI 2000.

Participation in Workshops/Conferences/Meetings

- March 12, 1999. *Inter-Hemispheric Transport of Aerosols over Equatorial Africa*, in-house seminar at NASA Goddard Space Flight Center, Greenbelt.

- June 1-4, 1999. Presented a poster on aerosol transport over Equatorial Africa at the 1999 Spring Meeting of the American Geophysical Union, Boston, MA. The abstract of the poster was published in a supplement to the AGU *EOS*, April 27, 1999, page S37.

- July 26-30, 1999. Attended a planning meeting for SAFARI 2000, Gaberone, Botswana.

- March 27-31, 2000. Attended the 28th International Symposium on Remote Sensing of Environment (ISRSE) -- Cape Town 2000, Cape Town, South Africa.

- April 3-7, 2000. SAFARI 2000 dry season planning meeting, Pietersburg, South Africa.

- July 4-12, 2000. Traveled to NASA Ames Research Center to calibrate Cloud Absorption Radiometer (CAR) at the Airborne Sensor Facility.

- July 12-21, 2000. Traveled to Everett, WA to conduct test flights for the CAR aboard the University of Washington's Convair 580 aircraft at Paine Field. This was in preparation for the SAFARI 2000 dry season campaign to take place over southern Africa August 12-September 26, 2000.

- July 24-29, 2000. Participated in the 28th International Radiation Symposium, Pietersburg, Russia. I prepared a poster entitled *Sensitivity of MODIS 2.1 µm Channel for Off-nadir View Angles for Use in Remote Sensing of Aerosol* that was presented on my behalf by Dr. Tsay of Code 913.

- August 24-September 24, 2000. (Pietersburg, Namibia) Safari 2000 Campaign

Publications

Gatebe, C. K., Tyson, P. D., Annegarn, H. J., Piketh, S., and Helas, G. (1999). A seasonal air transport climatology for Kenya. *J. Geophys. Res. 104*(D12), 14237-14244.

Gatebe, C. K., and Tsay, S.-T. Sensitivity of off-nadir zenith angles to correlation between visible and near-infrared reflectant for use in remote sensing of aerosol over land. Provisionally accepted for publication in *IEEE Transactions on Geoscience and Remote Sensing* subject to response to reviewer comments.

Awards

Winner of the World Meteorological Organization's Young Scientist Award for 2000 following the presentation of Ph.D. thesis entitled *Characterization and Transport of Aerosols at a High Altitude on Mount Kenya.* This is a world-wide competition among the 185 member countries.

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TASK 900-02: Earth Science Education and Outreach

TASK DESCRIPTION

The objective of this task was to provide visiting scientist/educator support for the NASA Earth Science education and outreach activities and provide for consulting fees and travel reimbursement.

CONSULTANTS/VISITORS

Consultant: Barbara Butler
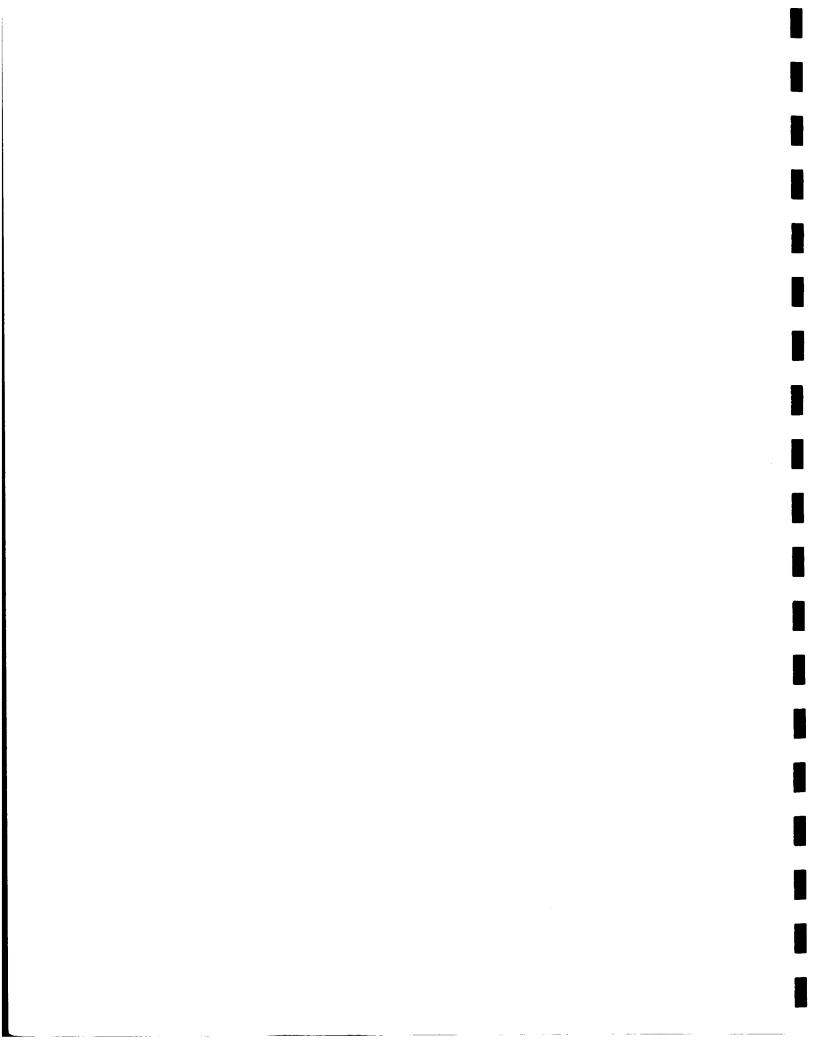
Collaborator: Blanche Meeson, Ming-Yei Wei

Purpose: 5/20/99-3/31/00 Travel in connection with the Earth Science education/outreach activities
                7/12-14/99 Participation in a meeting at the Denver Museum of Natural History
                9/21, 9/27/00 NASA HQ ESE education and outreach activities

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TASK 903-01: Administration of Graduate Student Summer Program

TASK DESCRIPTION

This task provided for the administration of a Graduate Student Summer Program whose primary aim was to develop graduate student interest in earth system science research. The main component of the program was to enable selected graduate students to pursue research projects in conjunction with GSFC scientific mentors during a ten-week period in the summer. A second element required coordination of the logistics of a week-long public lecture series as a means for orienting the students and for informing interested Goddard scientists, general scientists, and the general science community with respect to outstanding problems in earth science.

The contractors was responsible for coordinating all administrative aspects of the program which included the following:

- recruiting NASA and external scientists to serve on an advisory panel;
- recommending and recruiting speakers for the lecture series;
- distributing program announcements to the university community to encourage participation;
- coordinating the collection, collation, and initial review of applications and supporting materials;
- coordinating all logistics of housing, travel, and local transportation;
- providing financial support for students selected for the program;
- serving as a resource for student participants;
- coordinating travel, lodging, and consulting support for eligible members of the advisory committee and lecture series speakers;
- documenting program activities to facilitate objective evaluation of its success and to identify opportunities for improvement.

PROGRAM ANNOUNCEMENT, 1999 and 2000

GRADUATE STUDENT SUMMER PROGRAM IN EARTH SYSTEM SCIENCE

The Universities Space Research Association, in collaboration with the Goddard Space Flight Center's Earth Sciences Directorate, is offering a limited number of graduate student research opportunities for the summer. The program is designed to stimulate interest in interdisciplinary Earth science studies by enabling selected students to pursue specially tailored research projects in conjunction with Goddard scientific mentors.

Introduction

Universities Space Research Association (USRA) is a non-profit consortium of universities, chartered to establish and operate cooperative institutions and programs that advance research and education related to space science and technology. The Goddard Space Flight Center (GSFC) is recognized as a world leader in the application of remote sensing and modeling aimed at improving knowledge of the Earth system. The Goddard Earth Sciences Directorate is playing a central role in NASA's Earth Observing System (EOS) and the U.S. Global Change Research Program.

Planned for full implementation in the next ten years, EOS will require highly-trained professionals with significant interdisciplinary backgrounds for the design, implementation, and analysis of data from this comprehensive satellite system. The aim of this program is to attract and introduce promising students to Earth system science career options through hands-on educational research experiences in the Earth sciences at NASA.

Program Activities

Research Projects: Each student will be teamed with a NASA scientist mentor with parallel scientific interests to jointly develop and carry out an intensive research project at GSFC over the ten-week period. NASA mentors will be drawn from within the three participating Earth science laboratories at Goddard: the Laboratory for Atmospheres, the Laboratory for Hydrospheric Processes, and the Laboratory for Terrestrial Physics. Students will be expected to produce final oral and written reports on their summer research activities.

Examples of past summer research projects include the following: assimilation of satellite surface temperature data into a land surface model; investigation of Nazca-South America plate convergence with GPS; determination of Black Sea circulation from satellite data; analysis of Mars topography from Mars Orbiter Laser Altimeter (MOLA) data; characterization of forest canopy structure with a high-resolution imaging laser; assimilation of TRMM lightning and radar data in regional numerical prediction models; analysis of TOMS aerosol data with model based predictions; the use and modeling of SeaWiFS data to estimate dimethylsulfide flux in the Ross Sea.

In addition, students will participate in an introductory lecture series, informal weekly lunch discussions with GSFC researchers, and have the opportunity to tour key NASA facilities and meet with NASA and industry scientific leaders.

Eligibility and Selection Criteria: The program is open to students enrolled in or accepted to accredited U. S. graduate programs in the Earth, physical, or biological sciences, mathematics, or engineering disciplines. Students will be selected on the basis of academic record, demonstrated motivation, and qualification to pursue multidisciplinary research in the Earth sciences, clarity and relevance of stated research interests to NASA programs, and letters of recommendation. Preference will be given to students who have completed at least one year of graduate study. Minorities and women are encouraged to apply.

1999 STUDENT PARTICIPANTS

Student: **Ashwini G. Deshpande**, Massachusetts Institute of Technology
Mentor: Dr. Watson Gregg, Laboratory for Hydrospheric Processes, Oceans and Ice Branch

Determination of Circulation in the Black Sea from Satellite Remote Sensing Data

In recent years, the Black Sea has undergone significant ecological changes caused by human influence. River discharge, atmospheric pollution, and the introduction of non-native fauna have contributed significantly to the rapidly changing environment of the Black Sea. Concern regarding the economic and social impacts of its eutrophication has led to significant research interest in the physical, chemical, and biological processes in the Black Sea. Despite the considerable research in the Black Sea, there is a lack of high-resolution circulation data.

One possibility for acquiring such data is by applying edge detection algorithms to existing satellite data for sea surface temperature and ocean color. Variations in the blooming of phytoplankton can be the result of upwelling, and the movement of blooms can show the effects of surface circulation. Similarly, variations in temperature can also be caused by circulation features and can be used towards the study of these features to aid in the quantification of ecological deterioration.

Data from the SeaWiFS sensor as well as data from the MC-SST instrument were used to test edge detection techniques to study the temporal and spatial changes in chlorophyll and temperature distributions. Unfortunately, remote-sensing data for the Black Sea is strongly affected by noise caused by the unusual aerosol content over it. In many areas, ocean color and sea surface temperature data are unreliable, necessitating wide spread interpolation. This led to a need for the exploration of interpolation techniques to improve data coverage as well as more robust edge detection algorithms.

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Student: **Rumen D. Dimitrov**, George Washington University
Mentor: Dr. Si-Chee Tsay, Laboratory for Atmospheres, Climate and Radiation Branch

Coregistration of LEISA and VIFIS Data

LEISA (Linear Etalon Imaging Spectrometer Array) and VIFIS(Variable Interference Filter Imaging System) are part of the Small Spacecraft Technology Initiative which will allow for substantial cost reduction of Earth science projects.

The LEISA (EO1) airborne corrector has a 256 x 256 pixel detector focal plane and each row collects data in different wavelengths. The full spectral image of an object is obtained at different scan times along a track. The airborne image collection is subject to the movements of the airplane and, therefore, the consecutive frames should be registered for shifts in x and y directions as well as rotations. We developed a few methods(thresholding, laplace. And sobel) for preprocessing of the raw data to a level

suitable for registration of the frames. We also used two frame matching procedures: plain match and the gradient fields dot product.

The VIFIS airborne simulator has 3 cameras each with 48 bands and each band is a 16th subsample of the 768 lines in the 768 x 526 pixels field of view. Since the scan frames are not complete images, we have to use the best line match procedure for the first approximation of the registration. We showed examples of a good registration result and a good first approximation of the shifts.

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Student: **Petya Krasteva Entcheva (Campbell)**, University of New Hampshire
Mentor: Dr. James Irons, Laboratory for Terrestrial Physics, Biospheric Sciences Branch

Assessment of Forest Vitality at the Local and Regional Scale, Utilizing Data Acquired with an Airborne Imaging Spectroradiometer and Field Spectrometer

The Norway spruce forests along the northwest border between the former East Germany and the Czech Republic offer a unique opportunity to study the full gradient of forest decline conditions within a homogenous ecosystem and within a limited elevation range. Previous research conducted in 1991 and 1996 using a portable spectrometer, narrow-band video camera, forest survey and dendrochronological data provides evidence for recent recovery of the forests and demonstrates that the red edge portion of the spectrum provides early warning capabilities missing with broad-band sensor systems.

During the summer of 1998, an airborne effort was conducted to assess forest recovery in the Czech Republic, using Hyperspectral Advanced Solid-state Array Spectrometer (ASAS) and ground spectral data. A suite of forest attributes was collected to link vegetation physiological parameters to forest state and function and to provide the basis for inference of canopy chlorophyll levels and tree and forest health on a regional level.
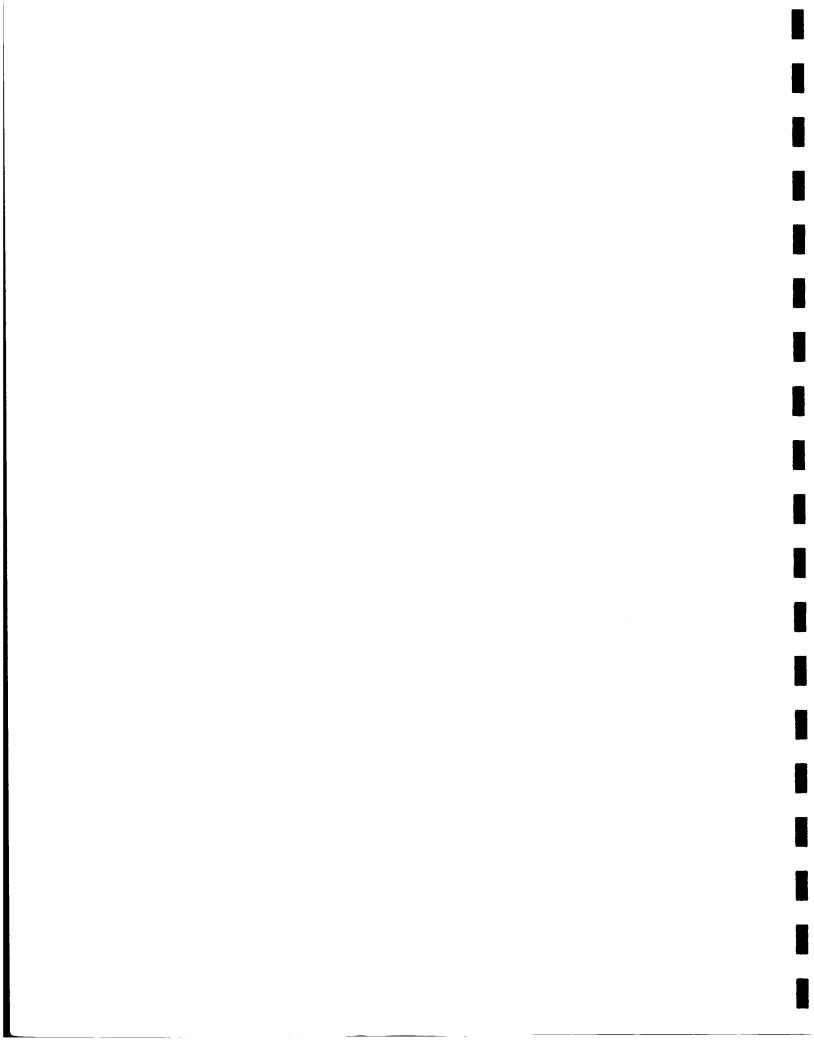
The current study investigates the relationships between spectral signatures acquired with airborne (ASAS) and field (GER) spectrometers, as well as forest stand parameters and health characteristics. Using ASAS and GER2600 data, algorithms are developed for monitoring forest conditions, and extrapolation of forest health from site to stand level. A number of reflectance ratios were tested as indicators of forest damage. Spectral sensitivity analyses of hyperspectral data was performed to identify the few narrow bands optimal for stress detection when using airborne multispectral systems.

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Student: **Amy Leigh Kaleita**, University of Illinois
Mentor: Dr. Paul Houser, Laboratory for Hydrospheric Processes, Hydrological Sciences Branch

Assimilation of Surface Temperature Data into a Land Surface Model

To understand the role of the hydrologic cycle in the climate system, it is important to improve our understanding and modeling ability for the processes at the land-atmosphere interface, for it is at this interface that the surface energy and water balance are linked through the processes of evaporation and transpiration. The key to such an understanding lies in the ability to determine surface energy and water balance components: surface temperatures, sensible, latent and ground heat fluxes, and soil moisture contents. Through a variety of techniques, remote sensing offers an avenue for determining aggregate values of these parameters over the land surface. For example, various platforms are capable of yielding ground-surface skin temperature observations, while vegetation indices are easily obtained from remote sensing data, providing valuable information about the state of the land surface.

A powerful use of remote sensing observations is to integrate these observations into a land surface model through a variety of data assimilation techniques. Data assimilation schemes attempt to estimate the best state of a system at any time, based on a combination of the predicted state of the model and

available observations at that time. The concept is that an imperfect model initialized and forced with imperfect observations will eventually diverge from the true state. However, if periodic or intermittent observations can be inserted into the model, we can obtain a more realistic state of the model. This insertion process achieves two objectives: the model prediction at any time provides a background field that serves to enable better estimates of the observations, and the model states corrected using these estimates give improved forecasts. In other words, the use of data assimilation leads to an estimate of the system that is more accurate than that obtained using a single set of observations utilized to initialize the model. The model is then used to predict the state of the system at a future time. The predicted states in turn serve as background fields for quality control and estimation using current observations. The model is subsequently updated using these estimates, and the cycle continues. Data assimilation techniques, though relatively well developed in meteorology, are still new to hydrology. However, they have the potential to provide a powerful framework for integration of hydrologic data in modeling.

An important descriptor of the land surface state is the land-surface skin temperature. As previously mentioned, surface temperature observations are readily available from a variety of remote sensing platforms and, thus, it is a natural candidate for data assimilation. This project centered around implementing the PSAS (Physical-space Statistical Analysis System) assimilation scheme for surface temperatures into the OLGA (Off-line Land surface GEOS Assimilation) system under development by the Data Assimilation Office at in the Goddard Laboratory for Atmospheres.
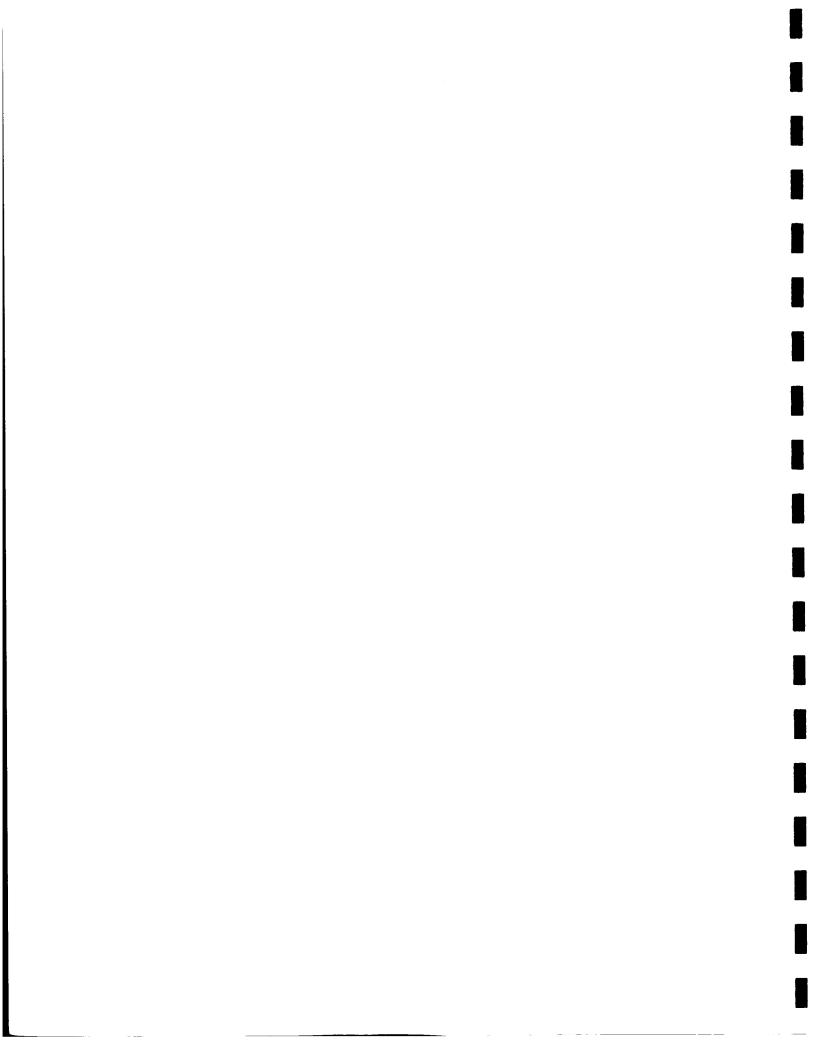
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Student: **Eryn R. Klosko**, Northwestern University
Mentors: Drs. Jeanne Sauber and Steve Cohen, Laboratory for Terrestrial Physics, Geodynamics Branch

Investigation of Nazca-South America Plate Convergence with GPS

The active convergent margin between the subducting Nazca plate and the overriding South American plate is a type example for the complex processes associated with ocean-continent convergence. Some of the largest known earthquakes occur along the subduction zone at this plate interface, and the high Andes illustrate the ongoing process of continental evolution and mountain building. Following the formulation of plate tectonics in the 1960's, it was recognized that the seismicity, bathymetry, topography, and volcanism were all consequences of plate convergence [Dewey and Bird, 1970]. Hence such active margins came to be viewed as diffuse zones of deformation, within which the motion between major plates is partitioned into various components.

Using a combination of space geodetic techniques (GPS, SLR, DORIS), new data from the South American-Nazca Plate Project (SNAPP) was gathered between 1994-1996, providing the first direct measurements of the total convergence between the stable portions of the Nazca and South American plates, in addition to the motion of 43 benchmarks within plate boundary zone. Observations show about 78 mm per year of motion between the Nazca and South American plates occurs. It is assumed that of the total motion, one component is transient elastic strain accumulation associated with the locked or partially locked seismogenic zone, which is released every hundred years or so in great trench earthquakes. The other component of motion is assumed to be crustal shortening in the foreland, resulting in permanent deformation building the Andes. We constructed forward dislocation models, dependent on the geometry and locking depth of the subduction zone, of interseismic strain on the plate interface, generating a predicted velocity field near the trench. Comparisons of such models with observations indicate that a trade-off exists between models of a partially locked plate interface versus a shorter locking down-dip fault width. In addition, we attempted to implement inversion methods to determine the best model fault parameters which could generate the observed displacements.

Additionally, we explored a possible contribution to the observations of motion within the plate boundary zone to strain diffusion tens to hundreds of years following large earthquakes at the trench. We use boundary element viscoelastic models of the subduction zone to test how this transient post-seismic deformation might bias these GPS observations.

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Student: **Alan Leonardi**, Florida State University
Mentor: Dr. Stephan Howden, Laboratory for Hydrospheric Processes, Oceans and Ice Branch

Remotely Sensed Observations of Oceanic Variability in the Vicinity of the Hawaiian Archipelago

The dynamics and variability of the circulation in the vicinity of the Hawaiian Archipelago are examined using TOPEX/Poseidon (T/P) sea surface height (SSH) anomalies and Advanced Very High Resolution Radiometer (AVHRR) Pathfinder+Erosion sea surface temperature (SST) anomalies.

(Complex) Empirical orthogonal function (EOF) analyses are performed on the SSH and SST fields separately to asses the dominant modes of variability inherent in each. The co-variability of SST and SSH are examined using a singular value decomposition on both fields simultaneously.

Comparison of these results with observational climate indices in the North Pacific ocean (southern oscillation index (SOI), Pacific North American Pattern (PNA) index, North Equatorial Current (NEC) index, and quasi-biennial oscillation (QBO) index) identify the dynamical processes leading the regional scale variability of the region. Large lag standard error calculations are utilized to assess the significance of the individual and coupled modes.

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Student: **Ricardo Molinero**, State University of New York at Buffalo
Mentors: Dr. James Garvin, Laboratory for Terrestrial Physics, Geodynamics Branch; and Dr. Susan Sakimoto, USRA

Mars Orbiter Laser Altimeter (MOLA) Topography and Preliminary Analysis of a South Polar Enigmatic Volcano
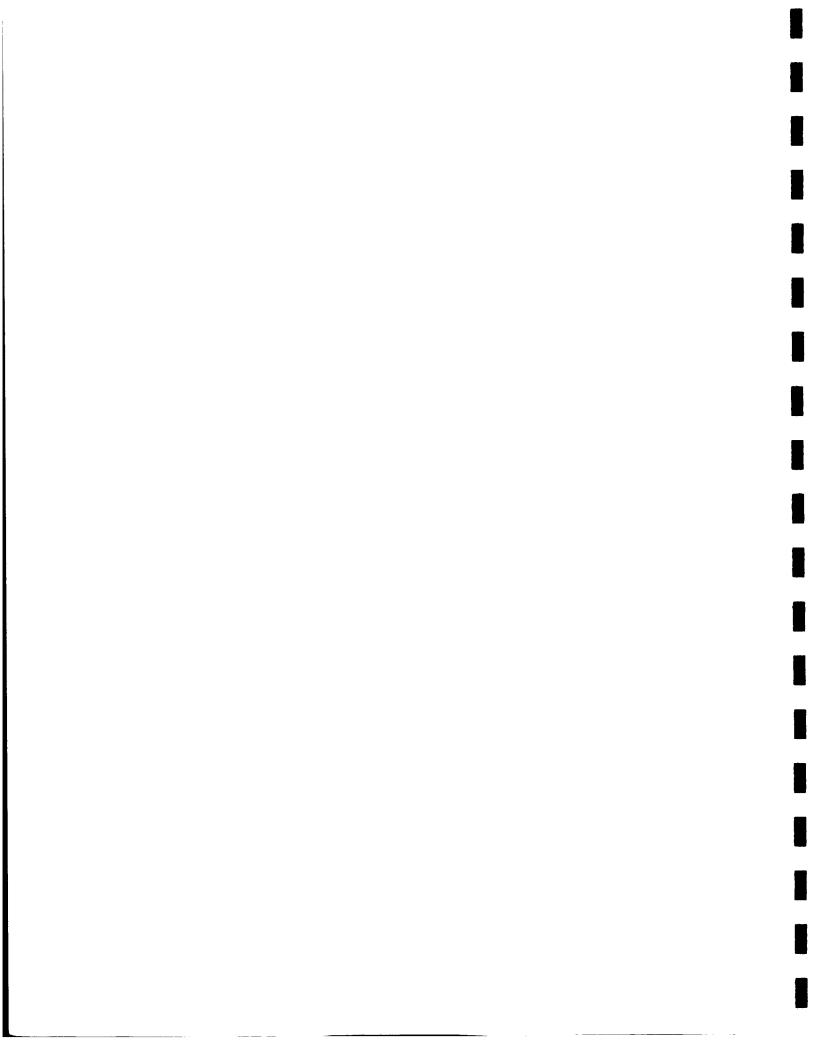
The Martian south polar region (55°S – 90°S) includes a handful of features mapped from Mariner 9 and Viking imagery as possible volcanic edifices. Assessing the eruption style, preservation state, and extent of these features is important for constraining the past regional activity. The recent acquisition of Mars Orbiter Laser Altimeter (MOLA) data from the Mars Global Surveyor Mission for this region allows a careful topographic assessment of these enigmatic features. This study focuses on one feature with better-than-average Viking image coverage, and several early MOLA mapping mission phase topography transects between 68°S – 70.5°S and 124°E – 131°E.

The basal diameter of this feature is 94 km with a height of 3447 m. with a relief of more than 2500 m above surrounding terrain. Local slopes up to 19° were obtained for distances of ~600 m along the MOLA profiles. Furthermore, flank slopes may reach up to 10° over 11 km. Average flank slope for the six analyzed MOLA profiles is 5.47° with a standard deviation of 6.9. Over 15% of the local slopes are above 10° and more than 44% are above 5°. Several arcuate flank scarps and a prominent terrace on the southern slope suggest sector collapse of the edifice. From our preliminary topographic analysis, we suggest that this feature is indeed volcanic and possibly has formed from effusive flows modified by subsequent sector collapse.

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Student: **Kathy Ann Tedesco**, University of South Carolina
Mentor: Dr. Charles McClain, Laboratory for Hydrospheric Processes, SeaWiFS Project

Remote Sensing Applications to the Climate Record of the Cariaco Basin, Venezuela

An enhanced understanding of natural climate variability is necessary to evaluate the anthropogenic influence on global climate change. In order to assess the ocean's role in the global carbon cycle it is necessary to quantitatively evaluate sources, sinks, and fluxes of carbon within the Earth system. In 1995, a multidisciplinary time series study, CARIACO (Carbon Retention In A Colored Ocean), was initiated in the Cariaco Basin, Venezuela as a collaborative effort between several U. S. and Venezuelan institutions. The primary objective of CARIACO is to study the relationship between surface

biogeo-chemical processes and the fluxes of carbon and nutrients in a continental margin setting. The program uses *in situ* measurements as well as observations provided by Earth remote-sensing satellites to help define the natural and human influences affecting seasonal and interannual variability.

The Cariaco Basin is an anoxic marine basin off the northern coast of Venezuela characterized by high sediment accumulation rates, well-preserved fossil plankton assemblages, and laminated sediments. The varves are believed to form as a result of climatically induced seasonal changes in clastic and biogenic sediment input and provide a high-resolution record of climate change. This region has a strong seasonal signal, primarily controlled by the migration of the Inter-Tropical Convergence Zone (ITCZ) about the equator. During the winter and spring, the ITCZ is in its most southerly position, rainfall is at a minimum, and strong easterly winds and intense upwelling occur along the Venezuelan coast. During summer and early fall the ITCZ migrates to the north, the trade winds diminish and upwelling ceases.

An array of four automated sediment traps has been deployed to measure the flux and composition of particulate matter sinking through the water column. In addition, monthly cruises are made to the location of the sediment trap mooring to collect measurements of hydrography, water chemistry, and primary productivity. CARIACO combines these *in situ* measurements with a NASA-funded study of satellite (ocean color: SeaWiFS ocean color, AVHRR temperature and TOMS aerosol index) observations and will play an important role in the development of satellite ocean color algorithms.

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Student: **Stephanie C. Vermillion**, University of Maine
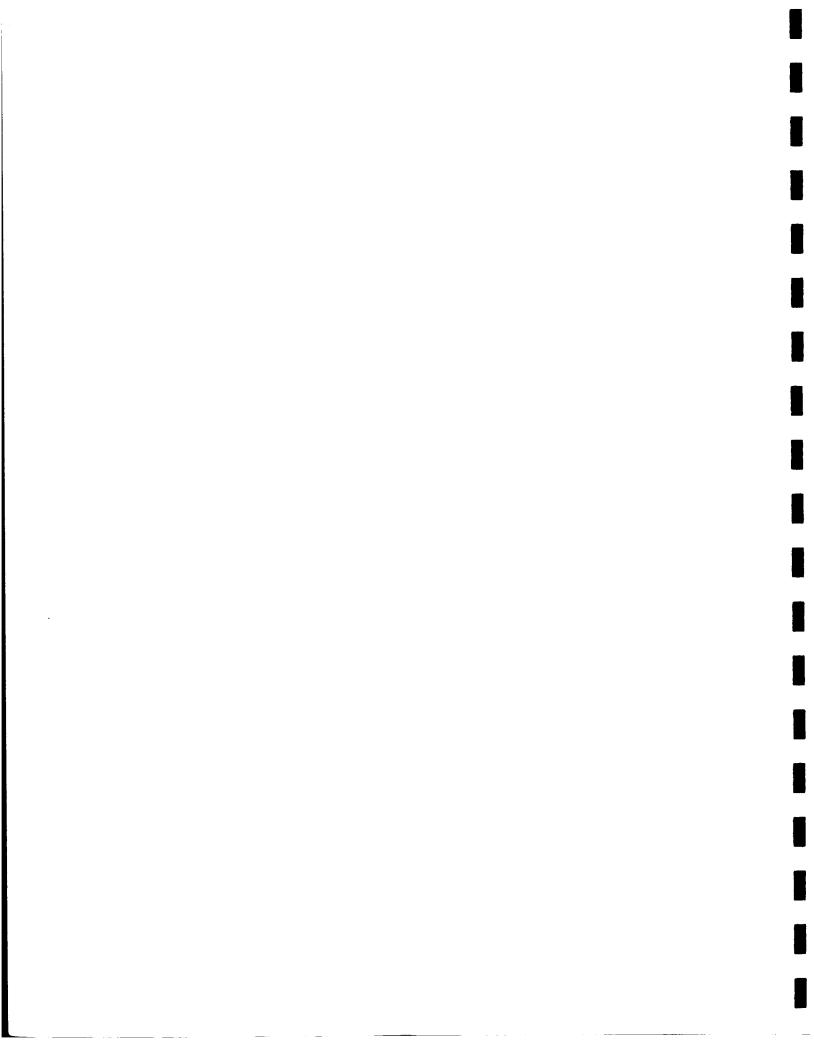Mentor: Dr. Thomas W. Brakke, Laboratory for Terrestrial Physics, Biospheric Sciences Branch

Evaluation of the Spectral Calibration of the VNIR Detector, HYPERION Imaging Spectrometer

The Hyperion hyperspectral imaging spectrometer is one of three instruments chosen to operate during the course of the Earth Observing-1 (EO-1) mission. EO-1 incorporates new spacecraft materials, high precision detector arrays, and spectrometers that provide calibration measurements not previously available. By positioning the EO-1 spacecraft in formation with Landsat 7, the EO-1 sensors can be tested, while serving to compare future technology with current data standards.

EO-1 is scheduled to launch on December 15, 1999. Before a satellite is launched for any application, the sensors must be tested and calibrated. The objective of this project was to quantitatively evaluate the spectral fidelity of the visible spectral (VNIR) detector, as well as propose an algorithm for correction of the internal lamps for final calibration.

Hyperion is a pushbroom scanner that incorporates two spectrometers, both at a 30m resolution. The sensors work concurrently to image a contiguous sample of data from 400-2500nm. Hyperion follows the LEWIS HSI design closely and will be the first spaceborne hyperspectral sensor. One of the unique features of Hyperion is its predicted radiometric quality. Solar calibration is performed when the sun is aligned with the solar baffle on the spacecraft. Sunlight is then reflected off the coating on the inside of the door onto the optics of Hyperion. This allows for periodic checks of the internal lamps on the sensor. The on-board lamps are used for internal calibration. The lamps provide a light source that is reflected into the field of view. A dark image is also acquired before and after each data a collection event. The dark image provides a zero reference value when the sensor is operated with the aperture cover closed. Lunar and ground targets are observed directly for calibration. Ground calibration is especially efficient because images are correlated with simultaneous ground and atmosphere instruments. Spectral calibration of Hyperion consists of atmospheric absorption lines (for SWIR) and solar spectrum measures (for VNIR).

The first aspect of the pre-launch spectral calibration was to assess the relationship of the instrument to a given energy standard. Three measurements from two independent data sets were provided for this study: sensor and lamp response (in sensor units) and the known radiant energy measurement for each channel (radiance). Dark images were also provided to account for electronic noise that enters into the data set. It was assumed that the calibration and source outputs met linearity requirements, and a

comparison between source and known spectral radiance was determined by direct substitution. To evaluate the error in internal lamp response, the measured values of both internal lamps operating at the same time were compared to the sum of the measured response for each individual lamp. Data from only one reference lamp source was available. Because the measured intensity of the reference lamp was at a different magnitude than the internal lamps, a new model was proposed to provide a better fit to the data. By examining the trends in the data with respect to the initial assumptions, a second order model was developed and tested using the same methods. The second order model reduces calibration error as well as compensates for the difference between detector arrays.

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Student: **Michael J. Wilson**, Purdue University
Mentor: Dr. Robert Cahalan, Laboratory for Atmospheres, Climate and Radiation Branch

Spectral Energy Transfer and Radiative Influence in the Boundary Layer

This project was developed into two distinct parts. The first study involved the energy transfer from the microscale into the mesoscale. This is important because some traditional techniques of boundary layer research would not apply to cloudy or turbulent atmospheres. The second study involved the analysis of cloud liquid water content variance on small scales, compared to overall estimations of cloud liquid water content on the large scale. The large scale models are forced to compensate for small scale deviations in clouds to get proper albedo values. Both studies show the interdependence of these scales.

In boundary layer meteorology, Reynold's averaging has been used to divide the energy spectra of the atmosphere into mean and turbulent parts. This can be done because, according to the classical theory of energy spectra, there is a peak of spectral energy at the large scale, and another one at the small scale corresponding to the height of the boundary layer. In between, there's a large gap of low energy, referred to as the mesoscale spectral gap. Therefore, the mean parts belong to the area under the curve at the large scale, and the turbulent parts are under the curve at the small scale, and there is essentially nothing in-between. This is very useful for the study of both large scale and microscale events independently of each other.

This theory tends to hold under clear conditions, where eddies can not become larger horizontally than the vertical height of the boundary layer for very long periods of time. However, cloudy conditions allow for the passing of energy towards the mesoscale. Observations from GATE, FIRE, and ASTEX demonstrate a significant mesoscale energy contribution. Clear, convective boundary layers have also shown this trend. In these cases, Reynold's averaging becomes only an approximation, worsening with increased convection. This means that studies of convective boundary layers can not easily rule out the mesoscale flow. One possible explanation for the transfer of energy is that convective clouds can extend beyond the boundaries of the mesoscale, leading to more energy in the mesoscale. This project shows the transfer of energy on a small scale, but no mesoscale analysis has yet been performed on the data.

Another difficulty with clouds is the estimation of albedo. As cloud water increases, the albedo also increases. However, the change in albedo lessens as the cloud water reaches higher concentrations. Therefore, those concentrations which are lower than the mean concentration cause a comparatively large drop in albedo, while concentrations which are higher than the mean cause a comparatively small rise in albedo. Therefore, if an albedo is based on the average liquid water content, the calculated albedo will be significantly higher than the true albedo. Models cope with this by either multiplying by some reduction factor, which takes away some of the correlation, or by reducing the amount of clouds in the model, which results in too much radiation reaching the ground and not enough radiation absorbed in the atmosphere.

The models studied in this project demonstrated the transfer of energy to larger scales in the microscale. However, mesoscale models were not used in this study, so the extent of energy transfer was not observed. Through the use of a large scale radiation model, the albedo bias could be shown.

2000 STUDENT PARTICIPANTS

Student: **Kristi Arsenault**, Ohio State University
Mentors: Drs. Jeff Walker and Paul Houser, Laboratory for Hydrospheric Processes,
Hydrological Sciences Branch

Application of the Catchment-based Land Surface Model: Comparison with the OPE3 Field Site

The main goals of this study are to evaluate the soil moisture and evaporation components of a catchment-based land surface model by applying the model to a real field site (OPE3) maintained by the USDA and NASA/GSFC. The OPE3 field site has four catchments, and has had corn planted there for the past two summers. Field measurements of soil moisture content, evaporation, and runoff have been maintained at the site and are compared to the model output. The model run begins in June of 1999 and continues to April 2000, being forced with meteorological data that are collected by two weather stations located at the field site. The model is run and generates output every twenty minutes and is compared to the observation data to capture the small scale effects of precipitation events on the soil moisture retention and to examine the interaction between the soil moisture content and the surface conditions.

The model simulation includes the drought conditions of summer of 1999, and this is reflected in the initial soil and corn parameters. In early September of 1999, Hurricane Floyd provided a very wet episode for the field site and is captured by the model output. The model produces a strong diurnal cycle of the soil moisture at the surface. Additionally, soil moisture decreases with time at lower levels in the model. These issues in the model are further explored and compared to various observation data to better understand the model physics and parameters.
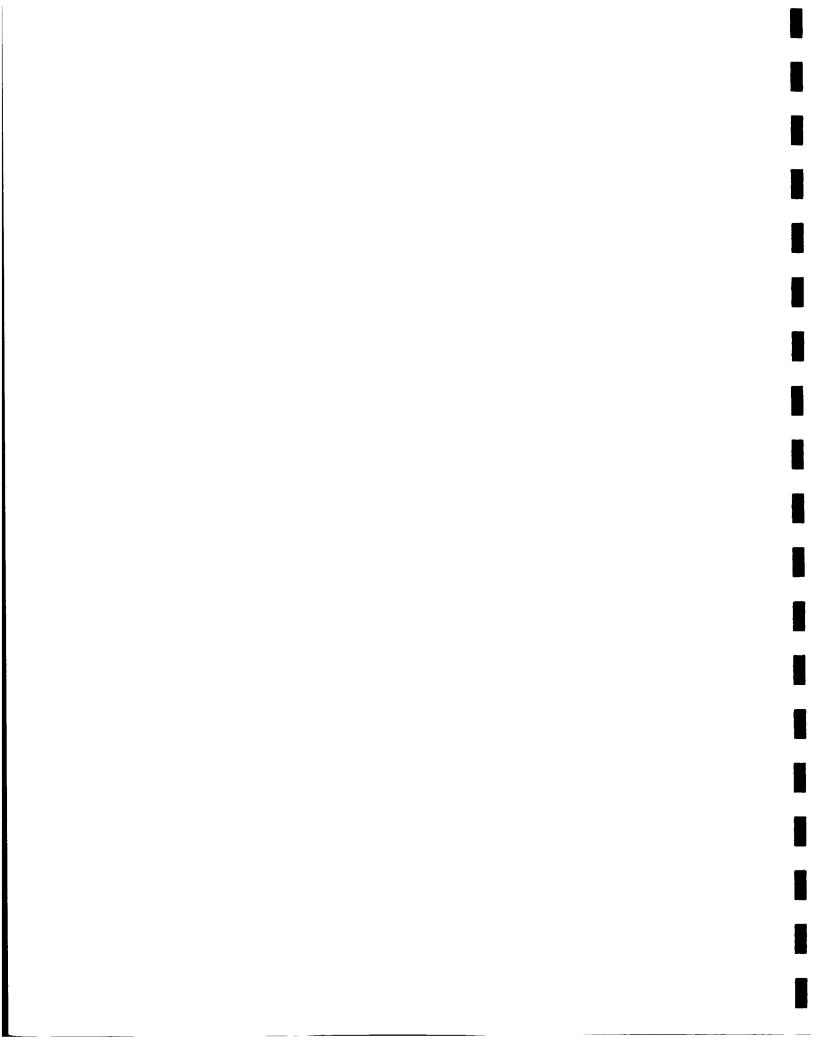
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Student: **Jui-Yuan Christine Chiu**, Purdue University
Mentors: Drs. William S. Olson, Wei-Kuo Tao, Scott Braun, Laboratory for Atmospheres,
Mesoscale Atmospheric Process Branch

Optimization of the Goddard Profiling Algorithm (GPROF) for Extra-Tropical Applications

Satellite passive microwave observations have been of interest for improving our knowledge of surface rainfall and three-dimensional precipitation and latent heating distributions over the globe. The Goddard Profiling Algorithm (GPROF), a physically-based inversion approach, was selected for the Tropical Rainfall Measuring Mission (TRMM) to provide precipitation and latent heating estimates on an operational basis from the TRMM Microwave Imager (TMI), and therefore GPROF has been optimized to obtain good performance in tropical regions. However, a version of GPROF will be implemented for applications to observations of the Advanced Microwave Scanning Radiometer (AMSR), which is scheduled to fly on the Earth Observations System (EOS) AQUA satellite. This radiometer will provide global coverage. Since cloud and precipitation structures in the subtropics and midlatitudes are quite different from those in the tropics, further evaluation and improvement of GPROF for applications at higher latitudes will be beneficial for TMI and AMSR applications.

The primary goal of the study was to extend the GPROF database, which contains candidate hydrometeor "solution" profiles for the algorithm, to include profiles representative of extratropical cyclones over the ocean. The NCAR/Penn State Mesoscale Model Version 5 (MM5) was used to simulate cloud and precipitation structures, and a 1-D Eddington radiative transfer method was applied to compute the corresponding upwelling radiances, as they might be observed by a satellite microwave radiometer. The sensitivity of the calculated radiances to variations in rain drop-size distribution and the presence of partially-melted ice-phase precipitation was investigated.

Results show that MM5 is able to capture the main frontal structure and produce reasonable sea level pressure and other meteorological fields. The corresponding calculated brightness temperatures from the radiative model were in good agreement with Special Sensor Microwave/Imager (SSM/I) data. The

simulations modified using a model for melting precipitation indicated a significant increase in radiances at 19.35, 22.235, and 37 GHz channels, and a lesser impact at 85.5 GHz. Sensitivity tests to the raindrop size distributions revealed that nominal variations of the size distribution will affect brightness temperatures, but to a lesser extent than the inclusion of melting precipitation.

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Student: **Dacian N. Daescu,** University of Iowa
Mentors: Drs. Peter Lyster, Laboratory for Atmospheres, Data Assimilation Office and Steven Pawson, USRA

*The Influence of the Stratospheric Chemical Oxidation of Methane
in Data Assimilation with Kalman Filter*

The complexity of modeling the dynamical processes and chemical transformations in atmosphere leads often to simplified atmospheric models. Data assimilation uses observational data and the forecast model to provide an analysis state of the atmosphere. We consider a practical example of the issues related with modeling errors in data assimilation using a Kalman filter for a stratospheric tracer model. In order to account for several uncertainties, the model error plays an essential role in the analysis. The influence of the perturbations in the dynamical operator and the role of the initial and model error covariances on the assimilation results together with filter divergence issues are presented. Using a chi-square diagnostic for parameter tuning and validation, it is shown that, under moderate assumptions, the effects of the diurnal chemical reactions on the analysis results can be balanced by an appropriate specification of the model error covariance matrix. A description of the influence of stiff transients of the state in the assimilation process is included. Implementation of the algorithm is based on the continuum equations for the conditional mean of the state and error covariance matrix which we present for a general advection-chemistry model. A full Kalman filter is used for a two dimensional Lagrangian model on the isentropic level 1100K, with data from the CLAES instrument on the Upper Atmosphere Research Satellite (UARS).
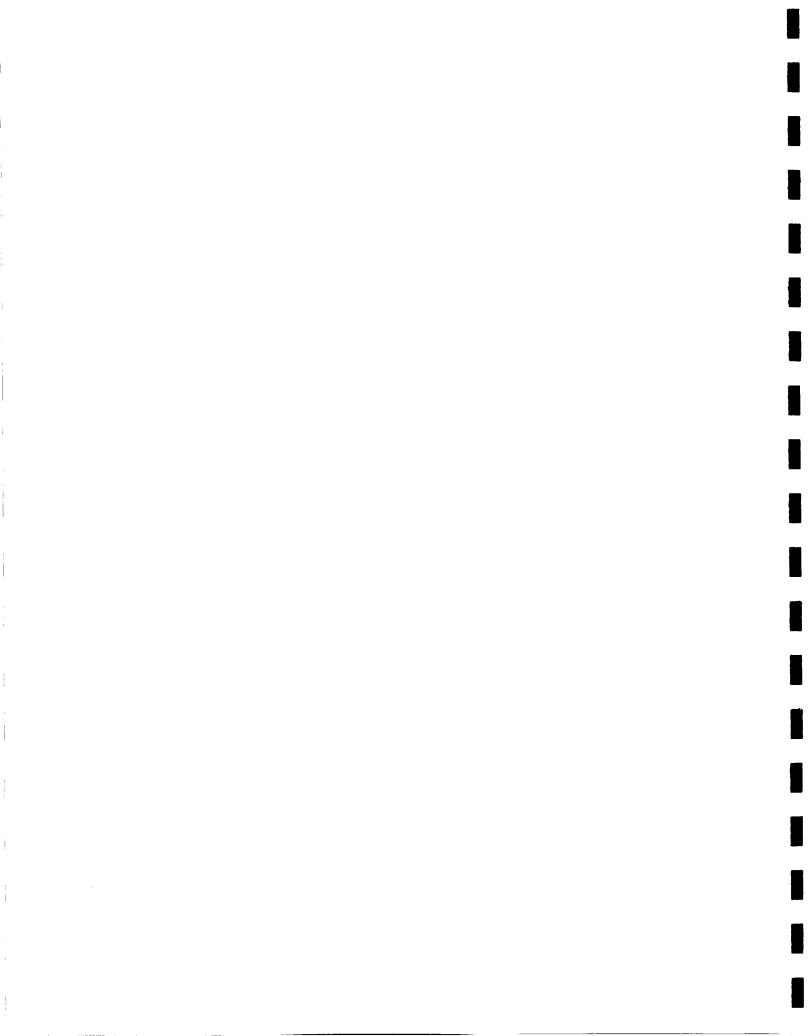
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Student: **Brynmor John Davis**, University of Arizona
Mentor: Dr. Edward Kim, Laboratory for Hydrospheric Processes, Microwave Sensors Branch

Stochastic Generation of Calibration Signals for Polarimetric and Interferometric Instruments

Many Earth-observing, radiometric instruments are based upon the concepts of either polarimetry or interferometry. For example, passive wind-vector sensing is performed with polarization sensitive instruments; while the latest generation of soil moisture sensors rely on interferometric techniques. In order to have these instruments operate successfully, it is important to have them accurately calibrated. Calibration is typically performed by observing a known signal and comparing its properties to the observed instrument data.

While polarimetric instruments and interferometric instruments measure fundamentally different physical phenomena, they share a similar receiver structure. Both instruments produce a measure of the correlation between a pair of signals. This commonality allows a single calibration-signal generation method to be applied to both systems.

Due to the inherent uncertainty present in physical signals, a statistical method is developed. Pairs of signals measured by the instruments are modelled as random processes. The statistical properties of these random processes are interpreted in terms of common radiometric properties (e.g., self- and mutual-coherence functions and Stokes parameters.) By specifying desired radiometric properties it is shown that the statistics of the random processes are completely defined. A generation method is developed in order to realize the model derived.

The resulting system is able to generate synthetic signals with fully user-specified radiometric properties. This provides a theoretical platform for calibration systems, as realistic signals can be generated with radiometric properties desirable for calibration testing.

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Student: **Yuka Muto**, University of Michigan
Mentors: Drs. Peggy O'Neill and Edward Kim, Laboratory for Hydrospheric Processes, Hydrological Sciences Branch and Microwave Sensors Branch

Engineering and Science of Passive Microwave Remote Sensing for Soil Moisture Retrieval and Land Surface Process (LSP) Studies: Implementation of ACMR for REBEX-7 and Analysis of SGP99 C-band and SGP97 S-band data

<u>Engineering</u>: The main focus of the project was to prepare the Airborne C-band Microwave Radiometer (ACMR) for the REBEX-7 (Radiobrightness Energy Balance Experiment) conducted by the University of Michigan Microwave Geophysics Group. The significance of REBEX-7 is that it is a rare opportunity that dual-polarized dual-frequency microwave measurements are taken at low frequency to study soil moisture under a controlled environment. Since ACMR has been operated only on aircraft in the past, it had to be adjusted such that it could be mounted on a truck with the University of Michigan's Direct-Sampling Digital Radiometer (DSDR). The data acquisition software was also modified to take non-continuous periodic measurements. During the one-week stay in Michigan, ACMR was assembled and the initial testing was completed. ACMR is now deployed for the field experiment. Currently, DSDR is being repaired for its noise problems. The ACMR and DSDR data will be analyzed after the end of GSSP.

<u>Science</u>: The original plan was to analyze C and L band passive microwave data taken during REBEX-7 to compare different soil moisture retrieval algorithms using a single-channel ESTAR/HYDROSTAR approach, a dual-frequency dual-polarized (C and X) AMSR approach, and a multi-frequency multi-angle SMOS approach. Due to the field experiment delay, the algorithms were studied but not evaluated with the REBEX-7 data. Instead, the Southern Great Plains '99 (SGP99) experiment data collected by ACMR were used to analyze the single-channel retrieval algorithm that has been used extensively at L-band. The effect of variance in optical thickness due to vegetation was studied as well as incidence angle and surface temperature. In addition, SGP97 S-band data collected by a truck-mounted S and L band Microwave Radiometer (SLMR) were examined to retrieve soil moisture.
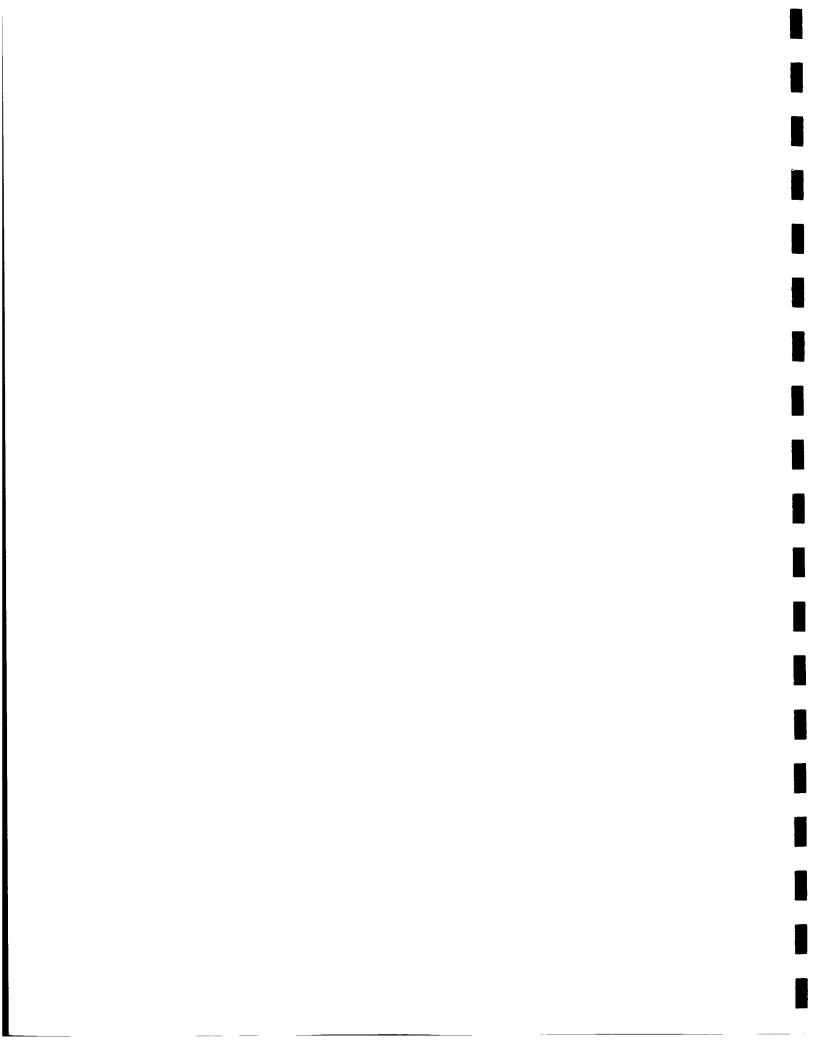
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Student: **Cristina Leuba Perez** , Department of Applied Mathematics, University of Colorado at Boulder
Mentor: Dr. Siegfried Schubert, Laboratory for Atmospheres, Data Assimilation Office

Estimating the Atmospheric Intraseasonal and Stochastic Components of Indo-Pacific Tropical Oceanic Forcing

For the past twenty years, climate scientists have been investigating the possibility of a link between the Madden-Julian Oscillation (MJO) and the El Nino-Southern Oscillation (ENSO). Current coupled models of the tropics produce unrealistically regular ENSO events. Many studies agree that high frequency atmospheric phenomenon can act to stochastically force the coupled ocean-atmosphere system and produce aperiodic ENSO episodes. We attempt to characterize the high frequency internal atmospheric variability of the tropical Indo-Pacific and its connection to the ocean.

Using eighteen years of Reynolds sea surface temperature (SST) and the National Centers for Environmental Prediction Reanalysis daily surface wind data, we decompose the ocean-atmosphere signal into coupled and noise components with Singular Value Decomposition (Bretherton, 1992). By applying a wavelet analysis (Weng and Lau, 1994, 1996), we find that the tropical Indo-Pacific has three distinct components of atmospheric variability in both space and time. Variability on the

interannual timescale is high in the central to eastern Pacific which is consistent with ENSO timescales. The intraseasonal variability is high in both the western Indian Ocean and in the Western Pacific. One of these modes shows significant coherence between the wind and SST in the intraseasonal band making it a strong candidate for the MJO signal. The highest frequency or synoptic signal originates in the extra-tropics.

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Student: **Karyn Tabor,** Boston University
Mentor: Dr. Compton (Jim) Tucker, Laboratory for Terrestrial Physics, Biospheric Sciences Branch

Relationship between NDVI Anomalies in Northeast Brazil and South Atlantic Sea Surface Temperature is Explained by ENSO

Knowledge of the interaction of energy between South Atlantic sea surface temperature, vegetation, and large-scale atmospheric events can aid forecasting of precipitation patterns in Northeast Brazil. An accurate growing season forecast would be valuable to the people in Northeast Brazil who suffer immensely from severe droughts and floods. Advanced warning of threatening weather would enable residents to take preventive measures that would save lives and money.

This study explores the relationship between precipitation in Northeast Brazil (Nordeste) and South Atlantic sea surface temperature (SST) and compares trends in the data to the El Nino Southern Oscillations (ENSO). NDVI, which represents vegetation dynamics, was used to indirectly estimate precipitation. The NDVI data used was monthly maximums from NOAA's AHVRR polar orbiting satellite with 8 km resolution.

The data showed the South Atlantic SST values correlated with NDVI in Nordeste. It was evident that NDVI increased when the South Atlantic Ocean was warmer. This occurred because the warm South Atlantic SST allowed the ITCZ to migrate further south bringing excess precipitation to Nordeste. This comparison, however, only shows the seasonal relationship in the data. Empirical Mode Decomposition (EMD) and Hilbert spectral analysis was then used to further analyze the data. This new method extracts main oscillations that are intrinsic to the data. It also finds a non-stationary trend over the entire data set. The resulting frequency components explained periodic energy fluxes in the South Atlantic SST and the Nordeste NDVI data.

The EMD analysis found similar frequencies in the South Atlantic SST and NDVI data that have periods coinciding with ENSO events. The South Atlantic SST component had minimums at the beginning of El Nino years whereas the NDVI component was the lowest at the conclusion of El Nino years. The method revealed a time lag of 15 months between the energy fluxes in South Atlantic SST and Nordeste NDVI that resulted from ENSO. This showed that SST in the South Atlantic was the coldest at the onset of El Nino and Nordeste experienced the least vegetation growth at the end of El Nino events. Further analysis of EMD with ENSO data such as NINO3 SST or SOI is desirable for a better understanding of the relationship of the frequency components found in the SST and NDVI data to weather in Nordeste.

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Student: **Paul Withers,** University of Arizona
Mentor: Dr. Gregory Neumann, Laboratory for Terrestrial Physics

Enigmatic Ridges in Martian Northern Plains

The surface of Mars has a topographic range of 30 km, the largest known in the solar system, yet its northern plains are the flattest known surface in the solar system.

Five years ago, topographical models had kilometre-scale vertical uncertainties. The Mars Orbiter Laser Altimeter instrument on the Mars Global Surveyor spacecraft has reduced these uncertainties to metre-

scale, discovering patterns of ridges on the northern plains. These ridges are tens of kilometres long, only hundreds of metres high, and have slopes of a few degrees at most.

When mapped and studied in detail, they will provide insight into martian stress and tectonics on a new scale, and test hypotheses as diverse as the existence of an ancient ocean and the epoch of the resurfacing of the plains.

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Student: **Elizabeth Wood,** Pennsylvania State University
Mentor: Dr. Scott Braun, Laboratory for Atmospheres, Mesoscale Atmospheric Process Branch

The Validation of a Hurricane Bonnie (1998) Simulation Using Tropical Rainfall Measuring Mission Data

Precipitation forecasting for tropical cyclones is a challenging aspect of tropical meteorology. Hurricanes Mitch (1998) and Floyd (1999) exemplify the destructive effects tropical cyclone rainfall can have and the need for better understanding and prediction of rainfall. A mesoscale numerical model such as the Penn State/NCAR Mesoscale Model (MM5) is a promising avenue for improved rainfall prediction.

To assess MM5 performance, it is crucial to verify the rainfall simulations with a high-resolution dataset. This is relatively simple over land where high-density observations are available, but much more difficult over the ocean. The Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar data is the best means of validating MM5 simulations over the ocean and assessing model prediction prior to a potential landfall.

Hurricane Bonnie (1998) is the test case for this comparison because there is a full TRMM overpass during the time of its intensification. To validate the model simulations, several precipitation fields in MM5 and TRMM are compared. These include radar reflectivity at 2 and 12 kilometers, reflectivity cross sections through the most intense convection, separation of stratiform and convective precipitation, and a statistical examination of reflectivity using contoured frequency by altitude diagrams (CFADs).
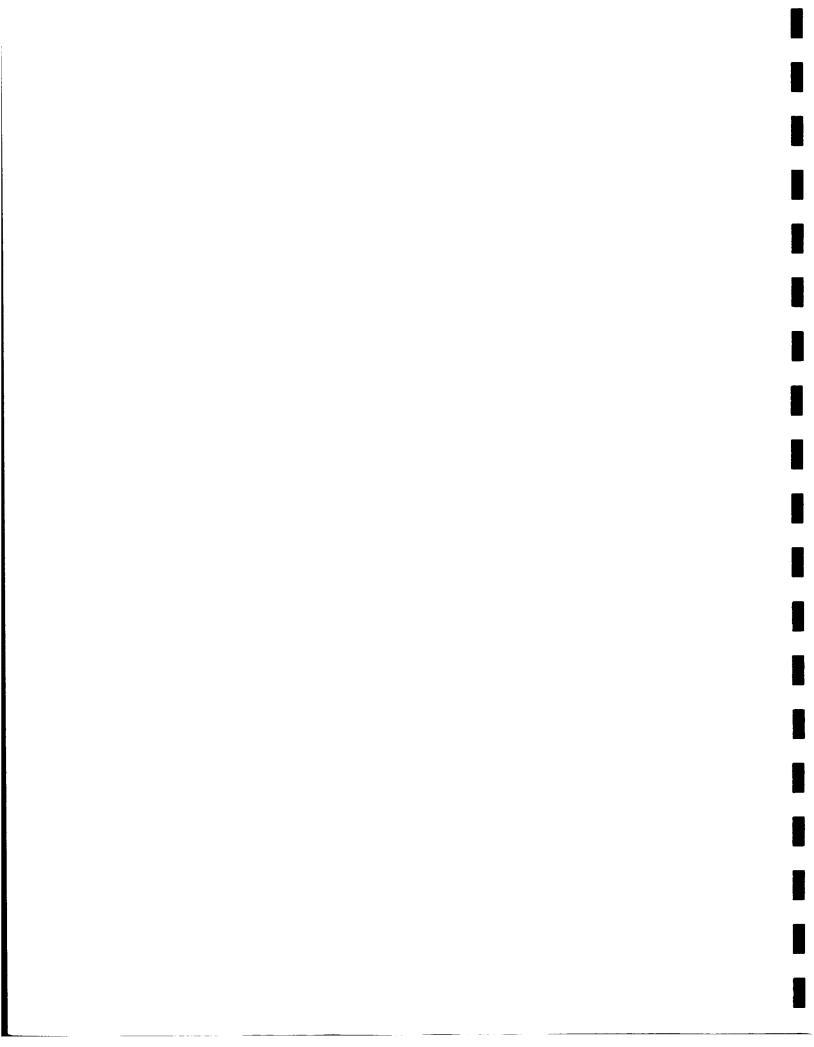
The MM5 general reflectivity pattern is similar to TRMM, but the model reflectivity values are too high in many areas. The reflectivity cross sections, stratiform/convective separation, and CFADs reveal that there is overproduction of convective precipitation relative to stratiform precipitation in the model. A likely culprit is that the microphysical scheme produces too much graupel and not enough snow. Graupel is denser and often larger than snow; therefore is has a higher reflectivity and larger fall velocity, so that
it is less likely to be advected horizontally in the model to form stratiform precipitation. Hopefully simulations such as this will lead to improvements in MM5 microphysics and higher confidence in model rainfall prediction.

1999 LECTURE SERIES

ACTION AT THE INTERFACES OF THE EARTH SCIENCES

In tandem with the 1999 Graduate Student Summer Program (GSSP) in the Earth System Sciences, the Universities Space Research Association (USRA) and the Earth Sciences Directorate of the Goddard Space Flight Center (GSFC) have organized a lecture series to be held at the Center in Greenbelt, MD, June 7-11, 1999. The Series is designed to provide a comprehensive introduction to the science and techniques of remote sensing and satellite observation and to foster scientific understanding of the

challenges being addressed by national programs in global change and NASA's Earth Science Enterprise.

Monday, June 7: Earth Science and Policy   Moderator: Frank Eden
    Nahid Khazenie, NASA Headquarters, *NASA and Earth Science*
    Richard Anthes, University Corporation for Atmospheric Research, *Global Weather Services in 2025*
    Robert Corell, National Science Foundation, *U.S. Global Change Research Program from Research to Assessment*
    William Merrell, Heinz Foundation, *Heinz Foundation Case Book*

Tuesday, June 8: Ocean / Atmosphere Interfaces   Moderator: William Lau
    Al Diaz, Director, NASA Goddard Space Flight Center, *Introduction*
    James Baker, National Oceanic and Atmospheric Administration, *A Look into the New Millennium: National Polar-orbiting Operational Environmental Satellite System (NPOESS)*
    Charles McClain, NASA Goddard Space Flight Center, *SeaWiFS Observations of Marine Ecosystems*
    Christian Kummerow, NASA Goddard Space Flight Center, *Satellite Rainfall Estimation- the past, TRMM, and the Future*
    Joel Picaut, French Institute of Research for Development, *El Nino, La Nina and the Pacific Warm Pool*

Wednesday, June 9: Land / Atmosphere Interfaces   Moderator: Edwin Engman
    Eric Wood, Princeton University, *Modeling the Hydrologic Controls of Land-Atmosphere Interactions*
    Yoram Kaufman, NASA Goddard Space Flight Center, *The Role of Satellites in Resolving Outstanding Issues in Climate- A Check-up of the Planet from Space at the Turn of the Millennium, from "Terra"*
    Forrest Hall, University of Maryland Baltimore County, *Carbon, Water and Energy Exchange Between Earth's Land Surface and Atmospheric Boundary Layer*
    Ronald L. Ritschard, University of Alabama, Huntsville, *Integrated Assessments of Climate Variability and Change: A Southeastern U.S. Perspective*

Thursday, June 10: Ocean / Solid Earth Interfaces   Moderator: James Heirtzler
    John Delaney, University of Washington, *Volcanoes, Ocean and Life in our Solar System*
    Kathryn Moran, Joint Oceanographic Institutions, Inc., *Understanding Our Planet's Record of Deep Time: The Ocean Drilling Program*
    Wilson Shaffer, National Weather Service, *Forecast Errors and their Impact on Hurricane Evacuation*
    Stephen Leatherman, Florida International University, *Sea Level and Society*

Friday, June 11: Sun / Earth Interfaces   Moderator: Frank Eden
    Judith Lean, Naval Research Laboratory, *Solar Variability and Climate Forcing*
    Gerald North, Texas A & M University, *Detecting the Solar Cycle in the Climate Record*
    Daniel Baker, University of Colorado, *Sun-Earth Connections: How is the Weather in Space?*
    James Heirtzler, NASA Goddard Space Flight Center, *The South Atlantic Anomaly and Radiation Damage*

2000 LECTURE SERIES

THE ENVIRONMENT PAST, PRESENT, AND FUTURE

In tandem with the 2000 Graduate Student Summer Program (GSSP) in Earth System Science, the Universities Space Research Association (USRA) and the Earth Science Directorate of the Goddard Space Flight Center (GSFC) have organized a lecture series to be held at the Center in Greenbelt, MD, June 12-14, 2000. The series is designed to foster scientific understanding of the challenges being addressed by national programs in global change and NASA's Earth Science Enterprise.

Monday, June 12: The Past as prologue: The Last Millennium
    Jonathan Overpeck, University of Arizona, *Abrupt Climate Change; Climate Changes and Society*
    Wallace Broecker, Lamont-Doherty Earth Observatory, *The Big Climate Amplifier*
    Alan Robock, Rutgers University, *Volcanic Eruptions and Climate: Winter Warming and Summer Cooling*
    Judith Lean, Naval Research Laboratory, *Solar Variability in the Last Millennium: What We Know and Don't Know*

Tuesday, June 13: The Present as Baseline: The National Environmental Assessment
Roger Pielke, Jr., National Center for Atmospheric Research, *Societal Impacts of Weather and Climate Extremes: Implications for Research and Policy*
Rosina Bierbaum, Office of Science and Technology Policy, Earth Division, *The First National Assessment of the Impacts of Climate Change on the U. S.*
Dennis Lettenmaier, University of Washington, *U. S. National Assessment—Hydrology and Water Resources*
Cynthia Rosenzweig, NASA Goddard Institute for Space Studies, *Assessing Climate Impacts in Rural and Urban Regions*
Daniel Jacob, Harvard University, *Atmospheric Pollution: From Smog to Climate Change and Back*

Wednesday, June 14: The Future as Imperative: Prediction
Seasonal to Interannual Prediction
Edward Sarachik, University of Washington, *Seasonal-to-Interannual Predictability and Prediction*
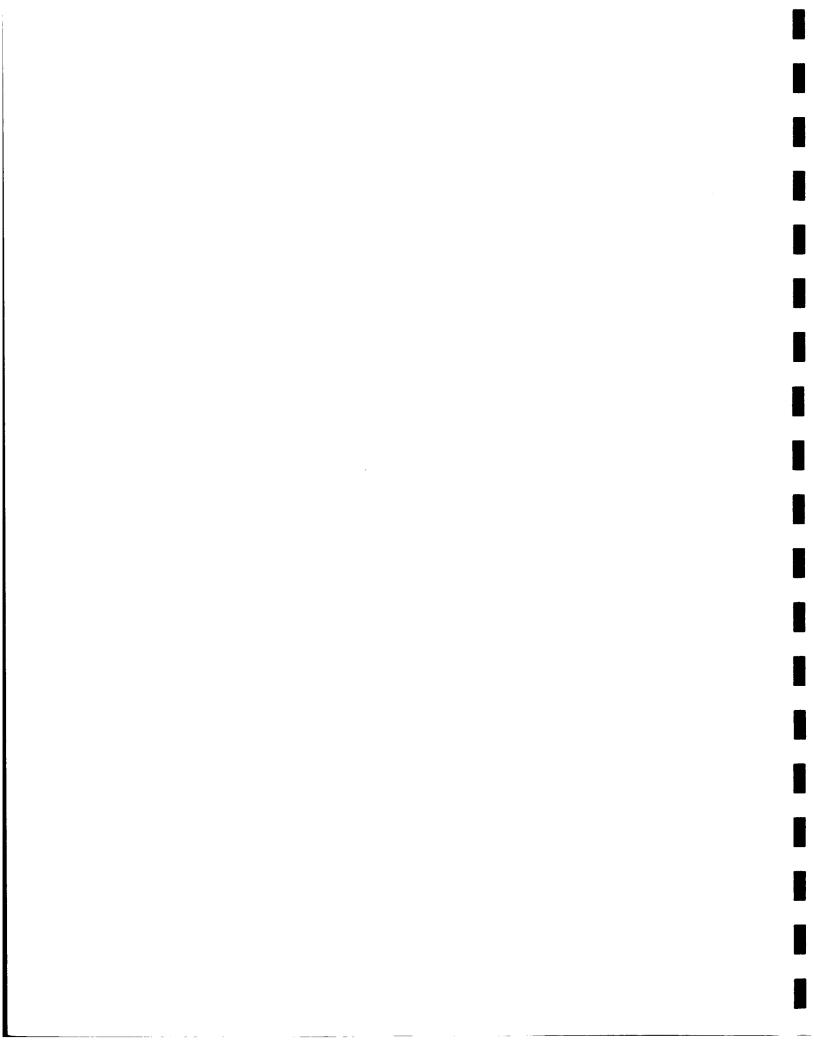
Counterpoints
Ming Ji, National Center for Environmental Protection, *Numerical Climate Prediction—Using Coupled GCMS and Ocean Data Assimilation*
Michael Glantz, National center for Atmospheric Research, *What People (and Researchers) Ought to Know About ENSO*

Decade to Centuries Climate Forcing and Prediction
Anthony Broccoli, NOAA Geophysical Fluid Dynamics Laboratory, *Future Climate Projections: What Will the 21st Century Bring?*

Counterpoints
Alan Robock, Rutgers University, *Evidence in Support of Anthropogenic Impacts on Climate*
Roy Spencer, NASA Marshall Space Flight Center, *Uncertainties in Global Warming Prediction*

LABORATORY FOR ATMOSPHERES (910)

910-01	910-11
910-02	910-14
910-03	910-19
910-07	910-20
910-20	

Mesoscale Atmospheric Processes Branch (912)

912-02	912-16
912-04	912-17
912-08	912-18
912-12	912-19
912-13	912-20
912-15	912-21

Climate and Radiation Branch (913)

913-01	913-16
913-05	913-17
913-09	913-18
913-14	913-19

Atmospheric Chemistry and Dynamics Branch (916)

916-04
916-05
916-08

TASK 910-01: Laboratory for Atmospheres Visiting Fellows Research Program

TASK DESCRIPTION

The objective of this task was to facilitate scientific exchange between the external research community and the Laboratory for Atmospheres at NASA/GSFC. This was to be accomplished through competitively selected research programs that enable scientists from the university community and other research organizations to visit the NASA/GSFC Laboratory for Atmospheres to collaborate directly with scientists in atmospheric related activities and programs.

Specific responsibilities included sponsorship and coordination of external research personnel appointments at various levels of seniority for NASA scientific programs. The contractor was to provide logistical coordination and support as required in conducting searches for qualified applicants as well as provide scientific assessments and evaluation of visiting professionals as required to achieve the scientific objectives of the Laboratory.

USRA EMPLOYEE: DR. DAVID ERICKSON

Research focus: Global CO_2 exchange and GCM budget studies.
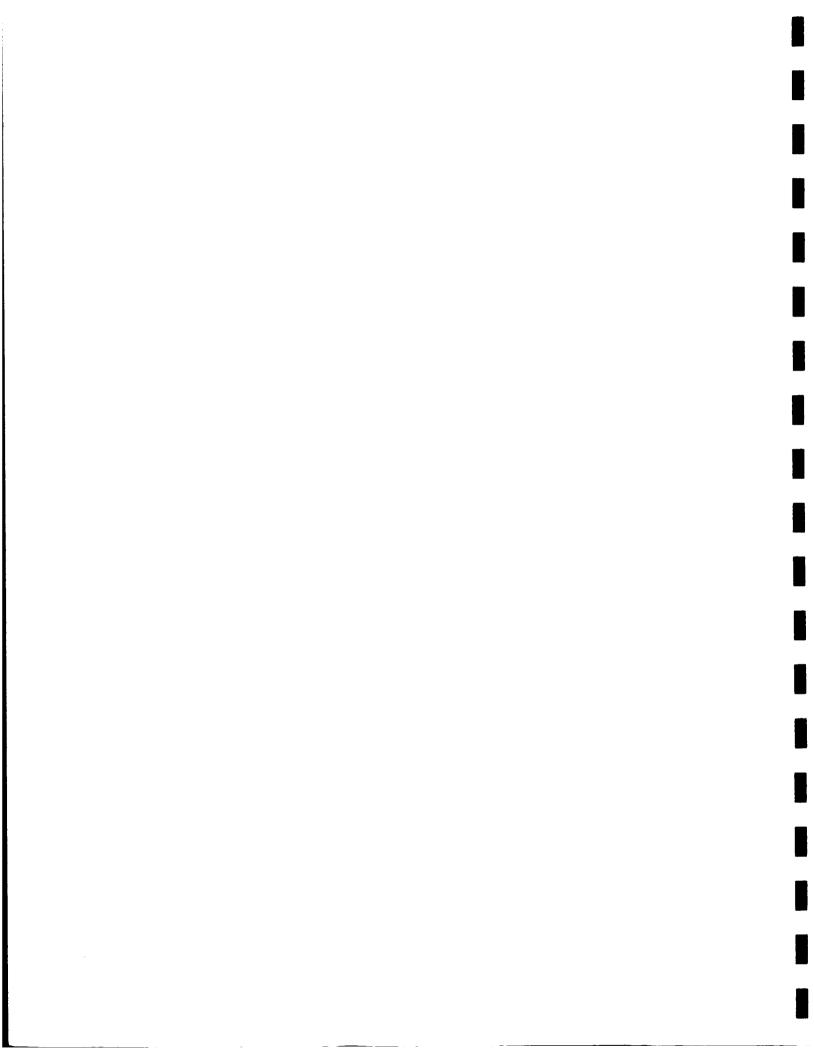
Accomplishments

October 1999 – January 2000

I extracted DAO data products (surface meteorology/radiation, etc.), extracted 970 SeaWiFS satellite data, and began working on a program that merges these two quantities to do air-sea flux calculations. These calculations will allow the air-sea flux of CO_2 to be simulated globally. I will also simulate global fluxes of CO, OCS, and isoprene. I have started to collaborate with W. Gregg (970) on using his global ocean model to simulate DMS fluxes from ocean to atmosphere. I have also given the surface flux/exchanges of CO_2 to S. J. Lin et al. for inclusion in the 910 GCM model runs.

February – June 2000

- Continued to edit and write the 910 carbon cycle document.

- Hosted R. Oglesby (Purdue University) and took TOMS data and started to put into GCM at NCAR.

- Went to the University of Virginia and worked with Bill Keene on new version of Marine Aerosol-Gas Phase Interactions (MAGPI) model.

- Took on Jose Hernandez as post doc and got him working on air-sea gas flux model.

Participation in Workshops/Conferences/Meetings

- October 27, 1999. Gave a presentation on anticipated research to Franco Einaudi and 910 branch heads.

- November 30 – December 1, 1999. At Richard Rood's request, served as a member of a proposal review panel.

- December 2, 1999. Gave a one-hour lecture to 916 on global modeling of fluxes and transport.
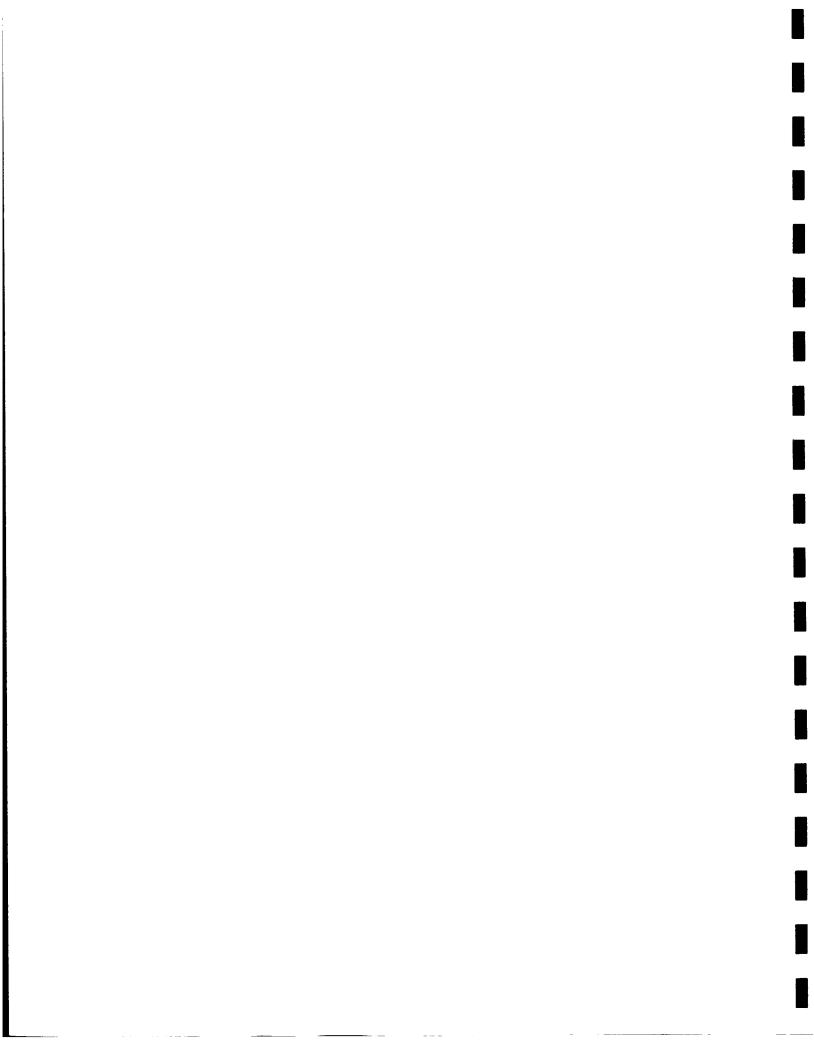
- December 13-16, 1999. Attended American Geophysical Union meeting in San Francisco. Met with Prof. R. Oglesby (Purdue University), J. Taylor (Argonne National Laboratory/DoE), P. Matrai (Bigelow) to outline some future collaborations.

- January 14, 2000. Met with J. Absire (920) about using 3-D atmospheric simulations of CO_2 to assess laser feasibility.

- January 19, 2000. Gave one-hour lecture to Oceans and Ice Branch (970) about global modeling and air-sea flux calculations.

- February 16-25, 2000. Attended the SOLAS conference in Hamburg, Germany.

- May 30-31, 2000. Attended the Spring AGU meeting in Washington, DC.

- June 3-8, 2000. Attended 4th International Symposium on Gas Transfer in Miami, FL.

Publications

Erickson, D. J. (1999). Nitrogen deposition, terrestrial carbon uptake and changes in the seasonal cycle of atmospheric CO_2. *Geophysical Research Letters, 26*(21), November 1.

CONSULTANTS/VISITORS

Consultant:	**K. Franklin Evans** (University of Colorado)
Collaborator:	Franco Einaudi and Warren Wiscombe
Purpose:	Collaboration on research involving use of realistic 3-D cloud structure from ARM instruments, Landsat, and numerical cloud models (4/1-9/30/00)
	Travel to U. of CO to meet with Ph.D. candidates being mentored (6/7-19/00)

Consultant:	**Sonia Kreidenweis**
Collaborator:	Franco Einaudi
Purpose:	Continue support of sabbatical and appointment to work under the USRA/Goddard Laboratory for Atmospheres Visiting Fellows Program (11/1-12/31/99)

Consultant:	**Richard Lindzen** (Massachusetts Institute of Technology)
Collaborator:	Arthur Hou
Purpose:	Scientific collaboration within the Laboratory for Atmospheres (10/199-6/30/00)

Visitor:	**Pinhas Alpert** (Tel Aviv University, Israel)
Collaborator:	Yoram Kaufman
Purpose:	Comparison of MODIS Saharan dust outbreaks to TOMS dust model predictions (7/24-8/20/00)

Visitor:	**Arlyn Andrews** (Harvard University)
Collaborator:	Randy Kawa
Purpose:	Present seminar and participate in scientific discussions on SOLVE data analysis (5/11/00)
	Comparison of GSFC CO_2 model simulations with Harvard aircraft data (6/25-28/00)

Visitor:	**Allesandro Battaglia** (Instituto ISAO-CNR, Spain)
Collaborator:	Chris Kummerow
Purpose:	Collaboration on research involving radar and radiative transfer calculations through 3-D clouds (10/199-3/31/00)

Visitor: **Ron Gelaro** (NRL)
Collaborator: Franco Einaudi
Purpose: Scientific discussions about mesoscale atmospheric processes at GSFC (10/31-11/4/99)

Visitor: **Michael Reeder** (SUNY, Albany)
Collaborator: Franco Einaudi
Purpose: Scientific discussions with Laboratory for Atmospheres (11/22-23/99)

Visitor: **Chad Rue** (University of Utah)
Collaborator: Franco Einaudi
Purpose: Present seminar and participate in scientific discussions with the Laboratory for Atmospheres (4/18-20/00)

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TASK 910-02: Short-term Visiting Scientists

TASK DESCRIPTION

The purpose of this task was to support short-term visiting scientists with the objectives of making available to the university research community and other non-U. S. government scientists data from the Tropical Rainfall Measuring Mission (TRMM) Ground Validation Program (GVP) and to encourage collaboration in the interpretation of these data.   The task was also intended to support the attendance of collaborating university and non-U. S. government scientists to TRMM Science Team Meetings, workshops, symposia, and conferences of interest to TRMM, and expenses related to invitees for special seminars.

CONSULTANTS/VISITORS

Consultant: **Rafael Rincon** (PREST/George Washington University)
Purpose: Participate in TRMM Brazil field campaign involving the NASA ER-2 aircraft; specifically to provide his microwave engineering expertise to calibrate, operate, and repair the ER-2 Doppler Radar instrument (12/15/98-2/15/99)
               To California to repair the ER-2 Doppler Radar Instrument for the TRMM Brazil Field Campaign (12/13-18/98)
               To Brazil to attend the TRMM Brazil Field Campaign (1/19-2/1/99)

Consultant   **Daniel Rosenfeld** (Hebrew University, Israel)
Purpose: Research analysis of rain measurements from ground based radars as part of the PR Algorithm Development for the Tropical Rainfall Measuring Mission (TRMM) (11/1/98-9/30/99)
               Attend the TRMM Science team meeting in Pasadena, CA (11/14-18/98)

Visitor: **David Short** (Nagoya University, Japan)
Purpose: Present seminar to members of TRMM group; 6/30-7/6/99

Visitor: **Ali Tokay** (St. Louis University)
Purpose: To present a seminar at St. Louis University on surface observations and remote sensing
               (12/1-12/3/99)

Visitor: **Thomas Tworek** (St. Louis University)
Purpose: Travel to GSFC to conduct research on TRMM ground validation radar data
               (10/26-29/99)

This task also provided travel reimbursement for the following individuals who traveled to Brazil to participate in the TRMM Brazil Field Campaign:

David Ahijevych (Colorado State University), 2/2-3/2/99
John Beaver (Colorado State University), 1/22-3/6/99
Steve Bolen (Colorado State University), 1/20-2/8/99
Alin-Andrei Carsteanu, 2/11-3/2/99
Christine Chiu (Purdue University), 2/4-3/2/99
Chrisma Derewa, 1/4-2/4/99
Emad Habib (University of Iowa), 1/21-2/6/99
Ross Heikes (Colorado State University), 1/1-1/29/99
Ben Johnson (Purdue University), 1/2-2/9/99
Carlitos Lambrada (Massachusetts Institute of Technology), 1/10-1/29/99
Nadia Madden (Massachusetts Institute of Technology), 1/4-1/28/99
Jonathan Meagher (Jet Propulsion Laboratory), 1/1-26/99
Delwyn Moller (Jet Propulsion Laboratory), 2/9-3/3/99
Renae Onstad (University of North Dakota), 1/25-2/15/99
James O'Sullivan, 1/25-2/15/99
Robert Pasken, 2/8-2/28/99
Jesse Ryan (Colorado State University), 2/6-3/3/99
Dimitri Tsintikidis, 1/20-2/10/99
James Wygand, 2/11-3/6/99

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TASK 910-03: TRMM Kwajalein Experiment

TASK DESCRIPTION

This task supported the activities of a number of university and other institutional scientists and students/graduate students to participate in a major TRMM field campaign, identified as the TRMM Kwajalein Experiment (KWAJEX) in the Marshall Islands of the Pacific. Most of the activity was at the Kwajalein Missile Range (KMR), operated by the U. S. Army and on board the R/V *Ron Brown* operated by NOAA. The objective of the experiment was to acquire airborne (3 aircraft) and surface-based atmospheric and ocean surface measurements to verify TRMM satellite algorithms and validate the satellite data products. The individuals who participated were involved with research weather radars, atmospheric soundings, and instrumentation on the research aircraft.

VISITORS/CONSULTANTS

The following individuals all traveled to the Marshall Islands of the Pacific to participate in the TRMM Kwajalein Experiment (KWAJEX).

Robert Beaufait (University of Washington), 7/10-9/18/99
John Beaver (Colorado State University), 7/17-8/21/99
George Bieberbach (Florida State University), 7/17-8/21/99
Steven Bolen (Colorado State University), 8/17-9/17/99
Chris Gardner, 7/17-8/21/99
Sara Godsey, 7/16-9/17/99
Nathan Heinert (University of North Dakota), 8/18-9/17/99
Ian Horton (University of Washington), 7/10-9/18/99
John Hubbert (Colorado State University), 8/24-9/11/99
Connie Klimczak (Florida State University), 7/17-8/21/99
Collen Leary (Texas Tech University), 7/17-9/18/99
David Marsalek (Texas Tech University), 7/17-9/16/99

Adam Sobel (University of Washington), 7/20-8/17/99
Catherine Spooner (University of Washington), 7/10-8/21/99
Kevin Sullivan (University of Virginia), 7/16-9/17/99
Daniel Valle (St. Louis University), 8/15-9/15/99

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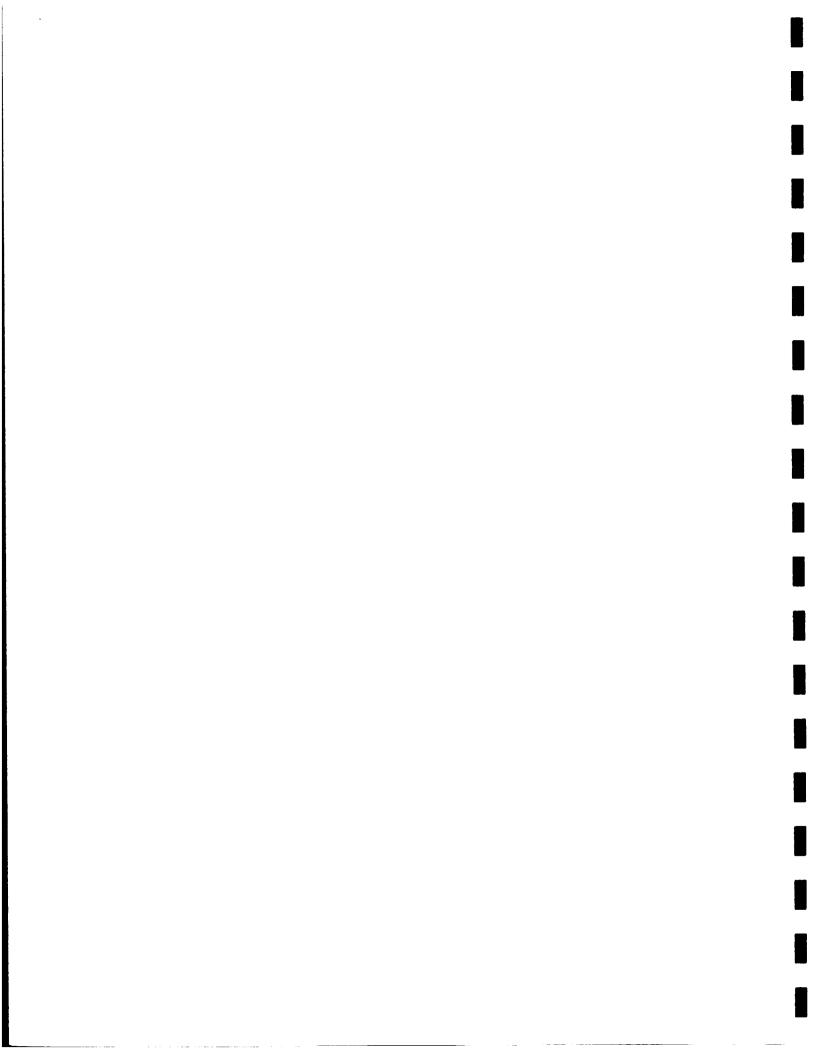
TASK 910-07: Short-term Visiting Scientists for the Data Assimilation Office

TASK DESCRIPTION

The objective of this task was to support short-term visiting scientists in the Data Assimilation Office (DAO). The objectives of the short-term visitor program included the following:
- Encouragement of collaboration between DAO and broad scientific community;
- Facilitation of transfer of DAO algorithms to broad scientific community;
- Transfer of scientific expertise from the broad scientific community to DAO;
- Visits of the DAO Advisory Panel.

CONSULTANTS/VISITORS

Consultant:	**Michael Ghil** (Laboratoire de Meteorologie Dynamique (LMD), France)
Collaborator:	Ricardo Todling
Purpose:	Present seminar on ENSO and participate in discussions with the DAO (9/12-14/99) Collaborative meeting with Drs. Einaudi, Atlas, Cohn, and Dee concerning a range of DAO planning activities (12/2/99)

Consultant: **Daniel Keyser** (SUNY/Albany)
Purpose: Participate in scientific discussions and present a seminar on the topic of the use of high resolution GCMS (5/13-14/99)

Consultant: **Dan Marchesin** (Instituto de Matemaica Pura E Aplicada, Brazil)
Purpose: Collaborative research with members of the Data Assimilation Office relating to Kalman Filtering (11/30-12/4/99) and (12/17-18/99)

Consultant **Bram Van Leer** (University of Michigan)
Collaborator: Richard Rood and Shian-Jian Lin
Purpose: Consult in research on the technical details of new advection schemes for the GCM in collaboration (5/12-17/99)
Collaborative discussions on General Circulation Modeling and a present seminar entitled "Genuinely Multi-dimensional Methods in Computational Fluid Dynamics" (8/8-12/99)
Discussions on technical details of advection schemes (10/13-18/99)

Consultant **Noah Wolfson**
Collaborator: Richard Rood
Purpose: Engage in scientific research on the predictability and large-scale atmospheric effects of the El Niño phenomenon over US and Europe (2/16-3/5/99)
Perform research on the ENSO and Arctic oscillation (8/9-26/00)

Visitor: **Pinhas Alpert** (Tel Aviv University, Israel)
Purpose Discuss research with members of the Data Assimilation Office (8/2-11/99)

Visitor: **George Blaha**
Purpose: Discussions on General Circulation Modeling with DAO (8/9-12/99)

Visitor: **Jiun-Dar Chern** (Purdue University)
Collaborator: Arthur Hou
Purpose: Scientific discussions on regional climate modeling work (6/12-16/00)

Visitor: **Elizabeth Espinoza** (Instituto Nacional de Pesquisas Espaciais, Brazil)
Collaborator: Joanna Joiner
Purpose: Investigate assimilation strategies for remote sounding data (12/1/98-4/8/99)

Visitor: **Luc Fillion** (National Center for Atmospheric Research)
Purpose: Collaborate with members of the DAO on model error estimation (4/2-8/00)

Visitor: **Michael Fiorino** (Lawrence Livermore National Laboratory)
Purpose: Collaborative work on DAO reanalysis efforts (8/28-31/00)

Visitor: **Dirceu Herdies** (CPTEC/INPE, Brazil)
Collaborator: Arlindo DiSilva
Purpose: Collaborate with Dr. DaSilva of DAO on development of high-resolution assimilated
                data sets in the Amazonian Basin (2/28/00-9/30/00)

Visitor: **T.N. Krishnamurti** (Florida State University)
Collaborator: Arthur Hou
Purpose: Present seminar on *Superensemble based skills of assimilation and forecasts using
                TRMM/SSMI rainrates* (4/2-5/00)

Visitor: **Zhijin Li** (Florida State University)
Purpose: Present seminar on the relationship of 4D-Var with Kalman filter and Kalman smoother
                (6/20-22/99)

Visitor: **Anthony McNally** (Europeon Center for Medium-Range Weather Forcasting, UK)
Collaborator: Robert Theis
Purpose: Participate in scientific discussions with members of the DAO (8/23-27/99

Visitor: **Michael Navon** (Florida State University)
Purpose: Scientific discussions with members of the Data Assimilation Office (3/24-29/00)

Visitor: **Chaojiao Sun** (University of California, Los Angeles)
Purpose: Collaborative discussions with members of DAO and present a seminar (7/28-81/00)

Visitor: **Wei-Wu Tan** (SUNY, Stoney Brook)
Purpose: To discuss research results concerning lower stratospheric subtropical transport in the
                GEOS assimilation (8/1-6/99)

Visitor: **Michael Tippett** (Centro de Previaso de Tempo E Estudos Climaticos, Brazil)
Purpose   Collaborative research with the Data Assimilation Office on Kalman filtering
                (12/1/98-1/28/99)

Visitor: **Marina Tsidulko** (Tel Aviv University, Israel)   (8/1-8/7-99)
Purpose: Collaborative research with DAO on the Data Assimilation of Dust (8/1-7/99)

Visitor: **Haroldo Velho** (National Institute of Space Research, Brazil)
Purpose: Collaborative discussions with DAO and NCEP (6/3-8/00)

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TASK 910-08: Short-term Visiting Scientists for Data Assimilation Office

TASK DESCRIPTION

The objective of this task is to support short-term visiting scientists in the Data Assimilation Office. The objectives of the short-term visitor program include the following:
- Diagnostics and interpretation of DAO data sets and model output;
- Model development;
- Diabatic initialization; and
- Development of algorithms for atmospheric analysis and models.

USRA EMPLOYEE: DR. SHIAN-JIANN LIN

Research focus: Development of a next-generation GCM for data assimilation.

Accomplishments

Development of a massively parallel finite-volume dynamical core for the proposed joint NASA/NCAR General Circulation Model (GEOS-GCM and NCAR CCM).

Development of an advanced finite-volume numerical algorithm for Chemistry Transport Model and numerical weather prediction.

Workshops/Conferences

- April 11-14, 1999. Attended the CSM Atmosphere Model Working Group Meeting in Denver, CO.

- April 17-25, 1999.   Attended the European Geophysical Society XXIV General Assembly in the Hague, Netherlands.

USRA EMPLOYEE: DR. STEVEN PAWSON

Research focus: Stratospheric dynamics and data assimilation studies with the Goddard GCM.

Accomplishments

September 1998 – September 1999

I now hope to stay with DAO on a longer-term basis so I think that I have been able to look at their activities, form opinions on the science as well as the needs of the larger community, and to form quite definite ideas about how I can contribute to the DAO in the future. I have established a good working relationship with a number of people in DAO and 916, and have started a number of science projects which should lead to sound publications and to a good progression of DAO middle atmospheric science.

One major research effort is the importance of radiative balance in the middle atmosphere of the assimilation system. I have identified clear anomalies in the radiative forcing related to the ozone distribution and have started working with Larry Takacs on reducing these. The first experiments using a new ozone climatology, which is considerably newer (and more accurate) than the data they were using, suggests that there are considerable improvements to the assimilations around the stratopause and possible improvements in other locations. I have also identified imbalances in the region of the ozone hole in the Antarctic spring and ongoing work is attempting to establish whether

this can also be corrected when a more representative ozone climatology is used. A consequence of these results is that Bob Atlas has asked me to work towards coordinating the ozone assimilation work of Dr. Ivanka Stainer with the main assimilation system, which I believe is an important goal for the DAO. (There are sound scientific reasons for doing this, especially when one is interested in the radiative forcing of climate, and one additional motivation is that ECMWF are stating to assimilate ozone in their operational system and for reanalysis.) Alongside ozone, there are signals in the tropical lower stratosphere which can tentatively be identified as arising because the Mt. Pinatubo aerosols are not included: while the temperature shows the expected increase following the eruption in 1991, the physical properties of anomalous radiative absorption by aerosols are not included in the assimilation system. I am planning work to include these effects in some detail.

However, a stumbling block in the assimilations in the tropical stratosphere is that there are spurious signals, which I have identified as coming from the mass-wind balance assumptions. This is a "fix" which needs to be made when one has observations relating to the thermal structure (as provided by conventional satellite data), but needs wind information; in middle latitudes, the assumption of geostrophic balance is adequate to good approximation, but in the tropics, this breaks down. DAO recently changed the assumptions they made, but it seems that in the stratosphere this has had a negative impact (the previous performance was already poor); more quantitative deductions are not possible because the work is not documented properly, and the staff who implemented it seem reluctant to give any information about how it was done. The bottom line of this research is that more attention needs to be given to the admittedly sparse sonde information on winds and, at least until some reasonable assumptions can be derived, the satellite-based data should be given a very low weighting.

An important scientific aspect of this which I have realized is that for such long-term motions as the quasi-biennial oscillation, it is important to force the winds correctly and let the thermal anomalies result from the adiabatic adjustments. Currently, these thermal anomalies are forced by additional diabatic forces (through the incremental analysis updates) which means that they are physically misrepresented; this has a profound impact on tracer transport calculations, because such anomalous diabatic forcing leads to spurious cross-isentropic transport of gases and hence to incorrect mean meridional circulations. I am currently involved with scientists in the analysis part of the DAO in the hope that more sensible methods can be introduced into the assimilation system.

My other main effort within the DAO has been devoted to studies with the new NASA/NCAR general circulation model. This has been developed by Shian-Jiann Lin and Ricky Rood in the DAO, who used their dynamical core, and the NCAR team who contributed their physical parameterizations. I had already started some analysis of the water vapor budget in the upper troposphere and lower stratosphere with the GEOS-2 model and have repeated some of this work with the new model (known as the Finite-Volume Community Climate Model [FVCCM]). The transport in the new model clearly outperforms that in the old one, and I have a much better confidence in the physical background of the model. Comparison of the FVCCM with all of the GRIPS models has shown that the model is always among the most accurate when it comes to the meteorological structure, and I believe that the transport is represented more accurately than in any other current model. This model will be integrated into the data assimilation system within the next months and should form a central part of GSFC science over the next years.

Through the work with the water vapor transport in FVCCM, I have built up a good working relationship with Shian-Jiann Lin which is intensifying. I am currently working on implementing trace gases into the model. The first experiment required some technical assistance from Sharon Nebuda, but I have now succeeded in running the model with a suite of trace gases, using simplified production and loss rates derived from the parameterized chemistry scheme I the Atmospheric Chemistry and Dynamics Branch (916). This work has progressed in collaboration with Eric Nielsen (who provided production and loss rates, as well as initial fields for the trace gases) and Anne Douglass and forms the basis for many science studies using tracers which should ultimately lead to a fully coupled chemistry-climate model which should benefit all climate and chemistry branches at GSFC, as well as DAO who should be aiming for a full meteorology-chemistry assimilation system before the launch of EOS-Chem in 2003.

Alongside those major projects in DAO, I have also devoted some time to evaluating the middle atmospheric component of several trial systems, which are the stopping stones between GEOS-2

(TRMM) and GEOS-3 (TERRA). While much of this work is inherently for internal consumption only, I think it has helped me to form good working relationships with many DAO staff members and has helped me in the science-based issues described above. I have also started an informal set of seminars for DAO and 916, with speakers from inside and outside GSFC. External speakers have included Darryn Waugh (Johns Hopkins University), Joan Alexander (Colorado Research Associates) and Takeshi Horinouchi (Kyoto University); local speakers were Paul Newman (916), Susan Strahan (DAO), and me representing DAO. These should continue over the next months as they form a good basis for discussions among an important cross-section of the middle atmospheric research community in GSFC.

October 1999 – January 2000

Development and analysis of the FVCCM. This model has been developed by S-J. Lin and his group in the DAO in collaboration with NCAR scientists. I have continued to contribute to the analysis of long simulations of this model. I have demonstrated that this model has a much less noisy vertical velocity field than the 'old' GEOS model, and this impacts trace gas transport in a substantial and beneficial manner. I have continued to implement various trace gases as prognostic variables in the model, with a view towards developing a full coupled circulation-chemistry model within the next few years.

Participation in the Solve campaign. I traveled to Kiruna in January 2000 to participate as a meteorologist in the Stratospheric Ozone Loss and Validation Experiment. I was able to bring the DAO's products into the field, helping with the planning of flight paths for the ER-2 aircraft. This campaign is coupled to my validation efforts of the GEOS-3 data assimilation system in the stratosphere; I am still working on validation of the analyses and forecasts.

Intercomparison of climatologies. I have been working on completing two papers which examine the degree of certainty with which we can estimate the climatological structure of the stratosphere. This work has evolved over several years and is now nearing completion. This work is in collaboration with scientists at several research institutes.

Reviewed submitted manuscripts for the *Journal of Geophysical Research* and *Journal of Atmospheric. Science*. I also reviewed a research proposal for the UK Natural Environmental Research Council.
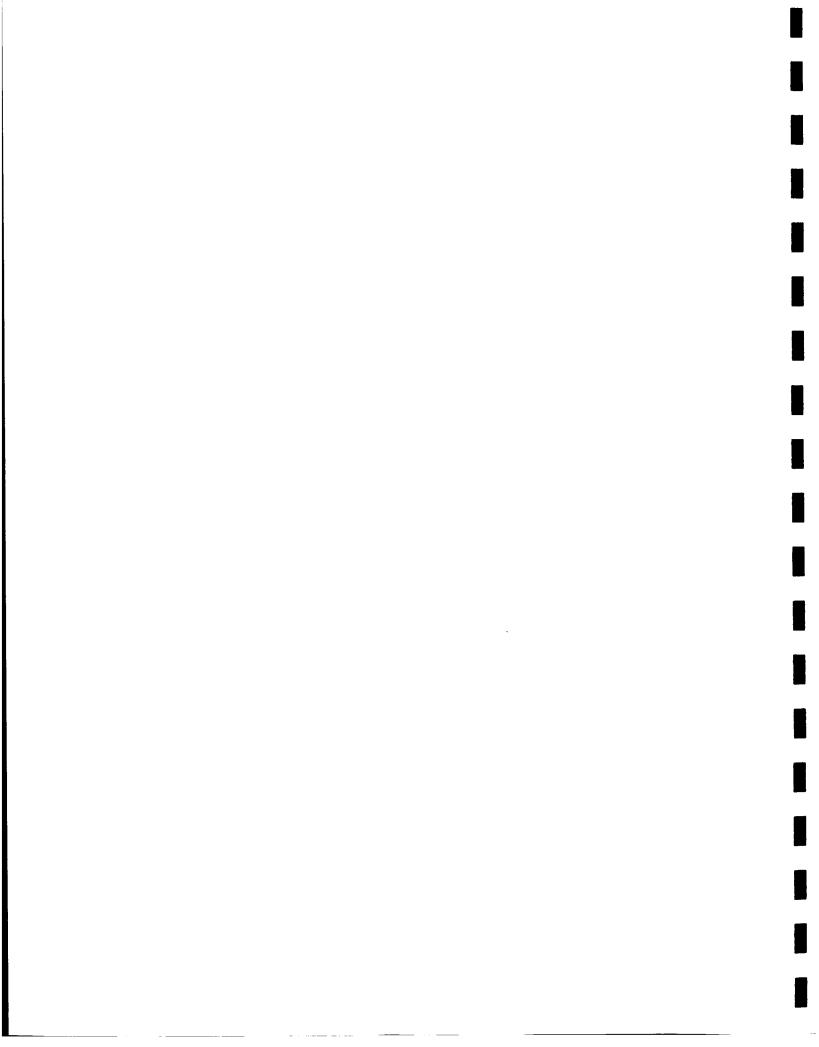
February – June, 2000

Quantitative assessment of the GEOS-3 Data Assimilation System developed and operated by the DAO. I have been assessing the quality of the analyses in the stratosphere and upper troposphere (in comparison to the input observations and to analyses from other centers, such as ECMWF). I have been validating the 5-day forecasts produced by the DAO, using the DAO's analyses as a reference point. The main result being that the predictability in the stratosphere is generally quite good, but the model tends to zonalize the flow. At higher levels the DAO system is noisy. I expect to write a paper describing the performance of the GEOS-3 system in the stratosphere during the Solve mission. I presented a poster at the AGU Spring meeting and a talk at the Western Pacific Geophysics meeting.

Assessment and application of the new numerical model developed in the DAO. I have continued my analyses of the meteorological structure in the middle atmosphere, with an emphasis on the lower stratosphere and the tropopause region, and of the transport of trace species in the middle atmosphere. I have continued my studies of middle atmospheric water vapor and am currently working on a paper describing this work. I gave a presentation at the AGU Spring Meeting and invited seminars at the University of Sapporo and the Meteorological Research Institute in Japan.

Model studies of stratosphere-troposphere exchange. I am developing idealized tracer experiments for this, in the hope of clarifying some issues raised by recent ozone observations in the Atlantic. I am collaborating with Dr. Anne Thompson and have had numerous discussions with her on this topic.

Studies of stratospheric climatology, especially on comparisons of different datasets and on planetary waves. I attended a SPARC meeting in Stony Brook, where we discussed a 'definitive' climatology which assesses and compares different datasets. The draft is being prepared by W. Randel (NCAR)
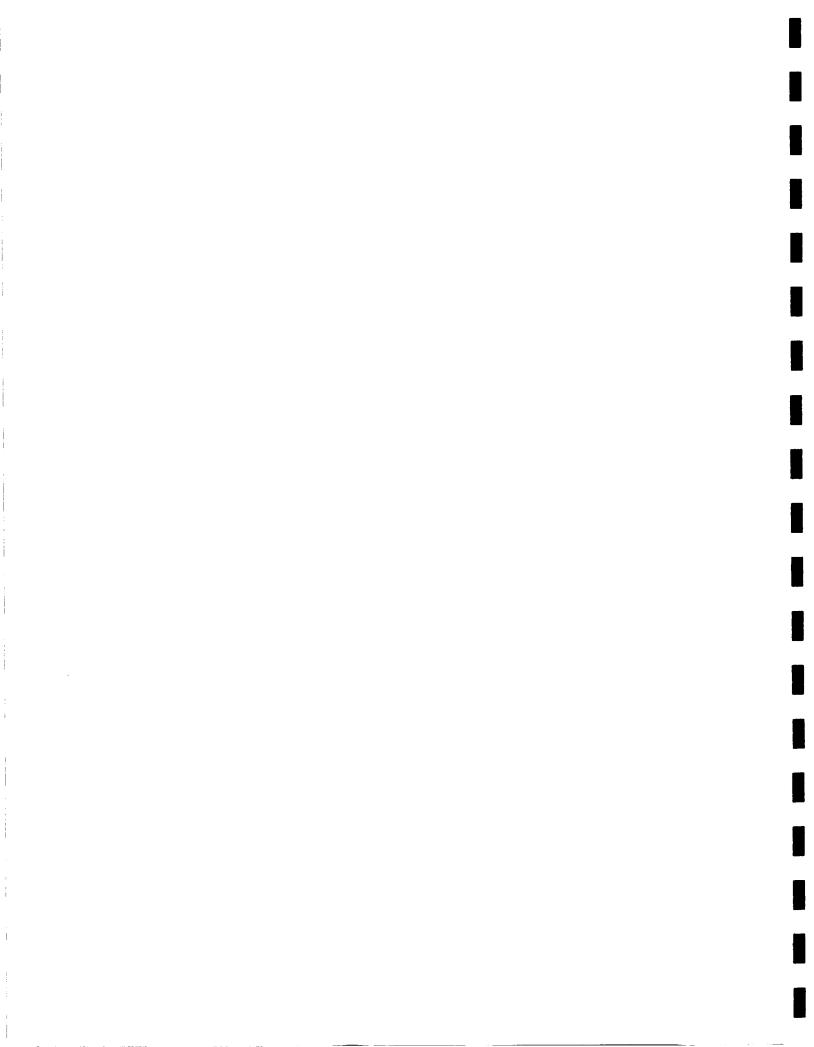
using data and plots provided by many individuals, including me. I continue to collaborate with Kirstin Krueger in Berlin; we expect to complete a paper quite soon.

<u>Leadership for stratospheric research in the DAO</u>. I have devoted a lot of effort to group leadership, one of the main objectives being to establish the group effectively. There is also the issue of liaison with other groups and direction towards developing national and international programs. The main issue is how to direct DAO research to the forthcoming EOS-Aura (formerly Chem) platform. One of the main steps is to develop the new model into a complete dynamics-radiation-chemistry model, as a prelude to species assimilation; I attended the EOS-Aura workshop in Boulder in March. I am also beginning collaborations with Prof. M. Shiotani in Hokkaido, Japan, for data studies in the Pacific region. I also lead the DAO's involvement in the stratospheric component of a planned national reanalysis effort, which met in College Park in June.

<u>Leadership of GRIPS</u>. Apart from the annual workshop, held in March in Toronto, this has required a modest effort these last few months. I have occasional contact with GRIPS members regarding data. I am working on some new intercomparison projects, concentrating on the forcing mechanisms in the models, and liaising with task leaders to study perturbation impacts. With the forthcoming SPARC meeting, I will spin up this effort again.

Participation in Workshops/Conferences/Meetings

- November 12-15, 1998. Attended discussions and colloquium at Columbia University. (Not funded through USRA.)

- November 23, 1998. Presented a seminar on *Variability and Trends in Lower Stratospheric Temperatures* at Columbia University in New York.

- December 10, 1998. Presented poster on *The GCM-reality Intercomparison Project for SPARC* at the fall meeting of the American Geophysical Union.

- December 13-16, 1998. Attended Canadian Modeling Initiative meeting in Toronto.

- March 14-25, 1999. Gave several presentations on updates to the GRIPS Project at the GRIPS Modeling Workshop as part of the Royal Meteorological Society Meeting held at the University of Reading in the United Kingdom.

- July 19-28, 1999. Presented first results from the radiation intercomparison project for GRIPS and the IUGG, Workshop MW01 in Birmingham, UK.

- July 23, 1999. Presented a poster on *The Climatological Structures of the GRIPS Models: Mean States and Forcing* at the IUGG, Workshop MW01.

- July 26, 1999. Presented talk on *Middle Atmospheric Transport Properties of Assimilated Datasets* at the IUGG, Session JSM26.

- August 10, 1999. Presented a seminar on *Some Mean Features in the Stratosphere of DAO Assimilations* at GSFC.

- August 21-27, 1999. Attended the 2nd International Reanalysis Conference in Reading, UK.

- September 4-10, 1999. Attended 1999 ECMWF annual seminar in Reading, UK.

- October 12-15, 1999. Attended AGU Chapman conference on water vapor in the climate system in Potomac, MD.

- December 10-16, 1999. Attended Brewer-Dobson Workshop; participated in discussions at Imperial College, London, England.

- January 10-21, 2000. Attended the deployment of the SAGE 3 ozone loss and validation experiment in Sweden.

- March 13-16, 2000. Attended annual GRIPS meeting in Toronto, Ontario.

- March 27-31, 2000. Visited modeling group at NCAR and attended EOS-CHEM Science Team meeting at NCAR in Boulder, CO.

- May 30-June 3, 2000. Attended the AGU Spring Meeting in Washington, DC.

- June 5-6, 2000. Attended National Reanalysis Meeting in College Park, MD.

- June 14-15, 2000. Attended the SPARE climatology group meeting, SUNY Stony Brook, Port Jefferson, NY.

- June 20-30, 2000. Met with Prof. Shiotani of the University of Sapporo (Japan) and attended the Western Pacific Geophysics meeting in Tokyo.

Publications

Kodera, K., Kuroda, Y., and Pawson, S. (2000). Stratospheric sudden warmings and slowly propagating zonal-mean zonal winds. *J. Geophys. Res.*, *105*, 12351.

Pawson, S. and Fiorino, M. (1999). The tropical lower stratosphere in atmospheric reanalyses. Part 3: Inclusion of the pre-satellite data era. *Clim. Dyn.*, *15*, 241-250.

Pawson, S., Kodera, K., Hamilton, K., Shepherd, T. G., Beagley, S. R., Boville, B. A., Farrara, J. D., Fairlie, T. D. A., Kitoh, A., Lahoz, W. A., Langematz, U., Manzini, E., Rind, D. H., Scaife, A. A., Shibata, K., Simon, P., Swinbank, R., Takacs, L., Wilson, R. J., Al-Saadi, J. A., Amoudei, M., Chiba, M., Coy, L., de Grandpre, J., Eckman, R. S., Fiorino, M., Grose, W. L., Hoide, H., Koshyk, J. N., Li, D., Lerner, J., Mahlman, J. D., McFarlane, N. A., Mechoso, C. R., Molod, A., O'Neill, A., Pierce, R. B., Randel, W. J., Rood, R. B., and Wu, F. (2000). The GCM-reality Intercomparison Project for SPARC: Scientific issues and initial results. *Bull. Am. Meteorol. Soc.*, *81*, 781-796.
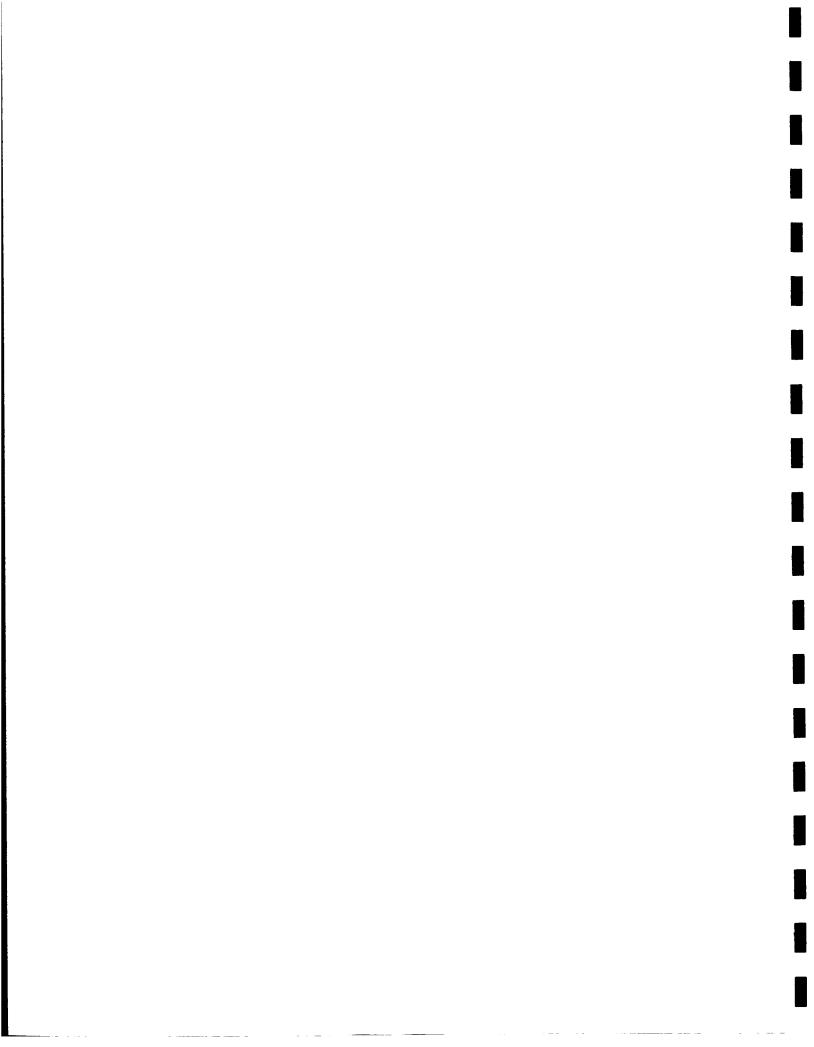
Pawson, S. and Naujokat, B. (1999). The cold winters of the middle 1990s in the northern lower stratosphere. *J. Geophys. Res.*, *104*, 14209-14222.

Pawson, S., Kruger, K., Swinbank, R., Bailey, M. J., and O'Neill, A. (1999). Intercomparison of two stratospheric analyses: Temperatures relevant to polar stratospheric cloud formation. *J. Geophys. Res.*, *104*, 2041-2050.

Pawson, S. and Langematz, U. (1998). Uses of satellite observations to validate climate/middle atmosphere models. *Adv. Space. Res.*, *22*, 1483-1492.

Waugh, D. W., Randel, W. J., Pawson, S., Newman, P. A., and Nash, E. R. (1999). Persistences of the lower stratospheric polar vortices. *J. Geophys. Res.*, *104*, 27191-27201.

Yoden, S., Yamaga, T., Pawson, S., and Langematz, U. (1999). A composite analysis of the stratospheric sudden warming simulated in a perpetual January integration of the Berlin TSM GCM. *J. Meteorol. Soc. Japan*, *77*, 431-445.

USRA EMPLOYEE: DR. RICHARD SWINBANK

Research focus: Refinement of data assimilation strategies for new high resolution Goddard GCM

Accomplishments

October – December 1998

These three months have been a period of change at the Data Assimilation Office, with a change of leadership and a change of emphasis to focus work more closely on the requirements of instrument teams. Specifically, there is now a push towards running the assimilation at high horizontal resolution and acceleration of the development of the next generation general circulation model. It has meant that the reanalysis project, which I was starting to work on, has now been postponed until various improvements are incorporated into the data assimilation system.

Mass wind balance. It had been pointed out by several people (notably Jim Stobie, GSC) that the wind- and mass- field increments generated by the GEOS-2 data assimilation system (DAS) were not well balanced. (In mid-latitudes the geopotential wind field is, to good approximation, in geostrophic balance with the height fields; it is well documented that wind and height assimilation increments should be similarly balanced to avoid the spurious excitation of gravity waves). I have been working with Guang Ping Lou (GSC) and Arlindo da Silva (NASA) to improve this aspect of the GEOS-2 DAS. We have performed a number of "static runs" (assimilation experiments for a single time with the same set of observations) to test out a range of different approaches. We believe that we have developed a scheme that is a significant improvement over the current formulation Ð and which is also better in some respects than the approach which was outlined in the G EOS-2 Algorithm Theoretical Basis Document (ATBD), but never implemented.

At the time of writing we have also essentially completed a set of extended assimilation and forecast experiments, which we are in the process of analyzing. We plan to write the results up as an Office Note. This development should help reduce the problem of excessive noise in the analyses (though it seems clear that there are a number of other sources of noise).

Other analysis improvements. With the move towards a higher horizontal resolution, it is becoming increasingly important to improve the assimilation system in a number of ways. The time-resolution, the treatment of error covariances, and the vertical resolution of the system all need to be improved.

At present, the GEOS-2 DAS uses all observations within a six-hour time window as if they were valid at the central time. So, many observations (notably asynoptic data, e.g., from satellites) are being used at a time that is up to 3 hours out. This is a significant error when dealing with rapid variations (associated with atmospheric tides Ð discussed in previous reports Ð or movement of small scale features such as fronts). There are essentially two different approaches that we are considering: first, moving to a shorter update cycle; or second, "asynoptic deltas". The latter approach is a hybrid algorithm in which observation minus first-guess differences are calculated close to the observation times, but still applied using a six-hour assimilation cycle. I have carried out some calculations with an idealized 1-D assimilation system, which suggest that the first approach would be better. It would also be cheaper to implement with the GEOS assimilation system. (Although it is not without potential problems; for example, the IAU (Incremental Analysis Update) would probably not work so well with a shorter cycle.) Over the next few months, I plan to collaborate with Arlindo da Silva on experimenting with implementation of a rapid update cycle in the GEOS DAS.

As reported previously, I am doing some work on the improvement of modeling error covariances. Specifically, it appears to be possible to represent the correlations with quite a simple advection model (and obtain similar results to those given by Richard Menard's (UMBC JCET) Kalman Filter results). Although I have not been able to spend much time on that project during the last 3 months, I plan to develop these ideas further in the new year, as part of the work on a "Parameterized Kalman Filter", to be led by Lars-Peter Riishojgaard (UMBC JCET). Flow-dependent correlations will be of increasing importance as we move to higher horizontal resolution because they allow the generation of realistic small-scale structures. The isotropic correlation model currently used implies analysis increments that can be unrealistically broad in some circumstances. For example, if observations

imply that a front is in the wrong place, the current assimilation system cannot move it, but only smooth it out. By contrast, a system using flow dependent correlations (which would tend to be elongated along the frontal shear zones, and narrow across the frontal zone) would allow the front to be moved in a more realistic manner.

The third aspect mentioned above was the need for improved vertical resolution. I raised this issue in the context of improving the assimilation system in preparation for the proposed reanalysis project, and proposed a way to use significant-level information in radiosonde reports to help produce analyses on more levels than the current set of 18 pressure levels (which I believe are woefully inadequate, particularly bearing in mind the push towards high horizontal resolution). However, work in this area has been deferred, while other developments are in progress.

January-June 1999

I have continued my work on the effect of anisotropic error covariances and on several other topics reported on previously. A new topic is the use of a novel type of grid for global numerical modeling that we refer to as a Fibonacci Grid.

Fibonacci grids. At the end of last year, Jim Purser (National Centers for Environmental Prediction) and I had been discussing idealizations of the arrangements of seeds in sunflower heads which leads to a simple algorithm for distributing an arbitrary number of points evenly over a disk. In the "sunflower grid", the points are arranged in two sets of arcs, with the number of each set of arcs being a Fibonacci number (i.e., a member of the sequence 0, 1, 1, 2, 3, 5, 8,..., in which each number is the sum of the previous two numbers). It occurred to me that the algorithm could be generalized quite simply to produce a uniform distribution of points over a sphere (similar to a pineapple or pine cone, for example). The resulting distribution of points turns out to have a number of attributes that suit it to global numerical modeling, notably its geometric regularity and its homogeneous and approximately isotropic resolution. The only regions where non-standard numerical methods need to be applied are the polar caps.

Jim has previously worked on the use of various non-standard grids, and he suggested that we should write a model using the shallow-water equations to demonstrate the feasibility of using Fibonacci Grids for global modeling. Using Jim's expertise on numerical methods, we have now essentially written a Eulerian finite-difference model using a Fibonacci Grid. At present we have carried out a number of tests of the model's advection scheme. While the model performs well away from the poles, we still need to do more work on the numerics of the polar caps. In the future we plan to write semi-implicit and semi-Lagrangian versions of the model.

Anisotropic error covariance modeling. As discussed in previous reports, it appears that the lack of anisotropic representation of forecast error covariances is a critical shortcoming of current data assimilation systems. This shortcoming is likely to become more critical as the resolution of data assimilation models is improved. While free-running, high-resolution numerical models can simulate realistic small-scale structures, such as fronts, the current data assimilation algorithms cannot properly deal with them. For example, if observations imply that a front is in the wrong place, the current assimilation system cannot move it, only smooth it out.

In order to confirm the potential impact of anisotropic forecast error covariances, I have written a simple two-dimensional data assimilation system. The system is designed to analyze measurements of a passive tracer; the forecast model component of the system uses the 2-D Lin and Rood code to transport the tracer using predetermined winds. The analysis is a simplified version of the code from the ozone data assimilation system. The novel aspect of the assimilation system is the inclusion of different methods of representing the forecast error correlations. As an alternative to isotropic error correlations, we can assume that the correlations evolve using an advective model, consistent with Steve Cohn's 1993 paper on the evolution of error covariances. Rather than explicitly calculating the advection of each correlation field, we use a more economical approach based on back-trajectory calculations (suggested by Richard Ménard). Alternatively, the system can use Lars Peter Riishojgaard's approach, in which the correlations are a function of the tracer values.

Results from the assimilation system confirm the benefit of both approaches to anisotropic error correlations. In the future, I hope to be able to extend the work of examine the impact of forecast error variances. The work forms part of the DAO project to develop a parameterized Kalman Filter.

Other work. The report of the SPARC Stratospheric Temperature Trends Assessment group (of which I am a member) has been issued as chapter 5 of the WMO/UNEP report *Scientific Assessment of Ozone Depletion: 1998*. The work also forms the basis of a paper submitted to *Reviews in Geophysics*.

Dave Ortland (NWRA) and I are collaborating on the production of wind data for the UARS reference atmosphere project. The main data sources are the HRDI wind measurements in the mid-stratosphere and mesosphere, and the UKMO assimilated date in the troposphere and stratosphere. In addition, we have used balanced winds derived from the UARS reference atmosphere temperatures. The input datasets have various gaps and inconsistencies and need to be blended together to get the optimal results. We have produced several prototypes of the UARS reference winds, but the final version awaits the final version of the temperature data, and some more work needs to be done on the compilation of the HRDI winds.

The work on the improvements to the mass-wind balance has been completed. The improvements are being incorporated into the operational GEOS-2 data assimilation system. An Office Note has been drafted.

I have continued my involvement in the GRIPS project (GCM Reality Intercomparison Project for SPARC) albeit at a lower level than when I was responsible for the UKMO model.

I contributed to a paper on the December 1998 stratospheric sudden warming. The evolution of the stratosphere during the winter of 1998-99 was quite unusual. There was an early major warming in December (the first in several years), followed by a major and early final warming in February.

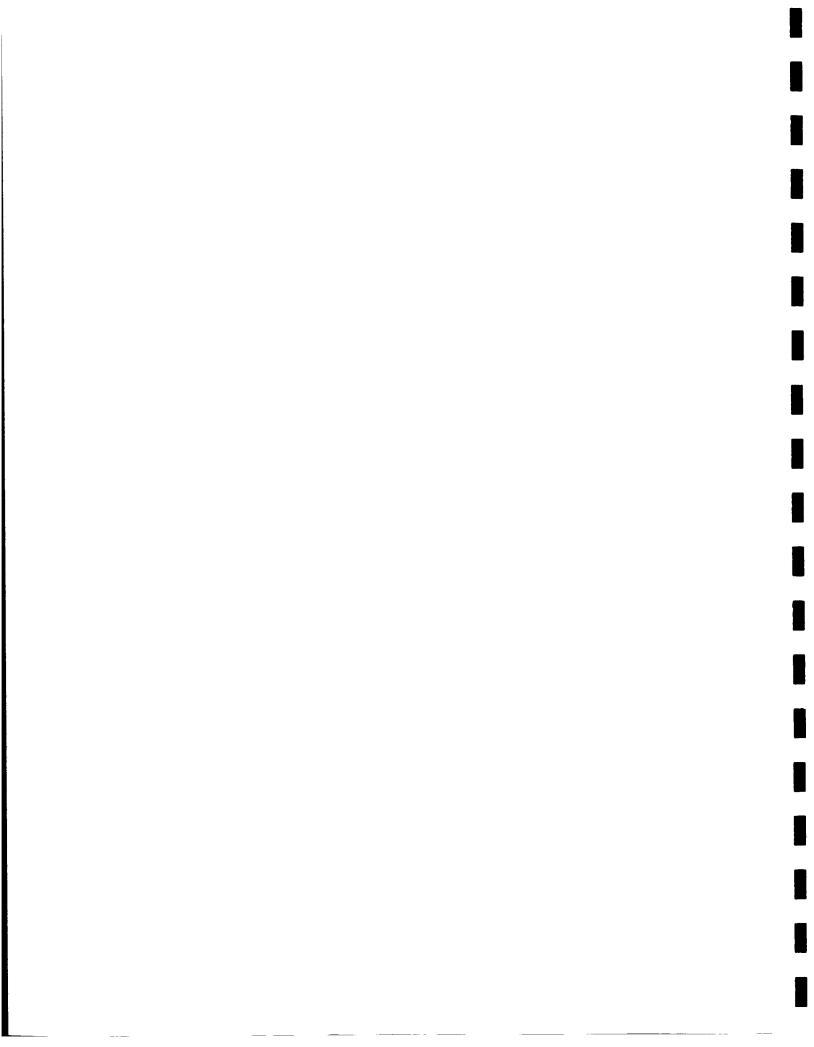**Participation in Workshops/Conferences/Meetings**

- November 1998. At the invitation of the ULDB (Ultra Long Duration Balloon) project team, I was invited to give a talk on stratospheric weather forecasting at the send ULDB technical workshop held at GSFC.

- June 6-11, 1999. Attended the 3rd WMO Symposium on Data Assimilation in Quebec, Canada.

- July 16-24, 1999. Attended the IUGG General Assembly, Birmingham, UK.

- September 9-17, 1999. Attended the 13th Conference on N. W. P., Boulder, CO.

Publications:

Bowman, K. P., Hoppel, K., and Swinbank, R. (1998). Stationary anomalies in stratospheric meteorological data sets. *Geophys. Res. Lett*, 25, 2429-2432.

Pawson, S., Krueger, K., Swinbank, R., Bailey, M., and O'Neill, A. (1999). Intercomparison of two stratospheric analyses: Temperatures relevant to polar stratospheric cloud formation. *J. Geophys. Res.*, 104, 2041-2050.

Swinbank, R., Lahoz, W., Douglas, C., Heaps, A., O'Neill, A., and Podd, D. Middle atmosphere variability in the Met Office Unified Model. *Quart. J. R. Met. Soc.*, 124, 1485-1525.

USRA EMPLOYEE: DR. JEFFREY WALKER

Research focus: Involving data assimilation and modeling land surface hydrological processes in coupled atmosphere/ocean/land models.

Accomplishments

February – June, 2000

Development of land surface model. The driver for the NSIPP (NASA Seasonal to Interannual Prediction Project) land surface model has been rewritten to be more versatile and user friendly. This land surface model has also been added to the list of models available to the LDAS (Land Data Assimilation Schemes) project.

Passive microwave measurement of soil moisture. A methodology for estimating both the soil moisture and optical depth from the MPDI (Microwave Polarization Difference Index) has been developed through collaboration between Dr. Manfred Owe, Mr. Richard DeJeu, and me. A peer-reviewed paper on this methodology is currently in preparation with Dr. Owe as the lead author.

Soil moisture assimilation. A peer-reviewed paper on the algorithm development and synthetic study of assimilating near surface soil moisture observations in the NSIPP land surface model is in preparation with me as the lead author. A second study that examines the amount of error that near surface soil moisture observations may have and still be of benefit within an assimilation framework is underway.
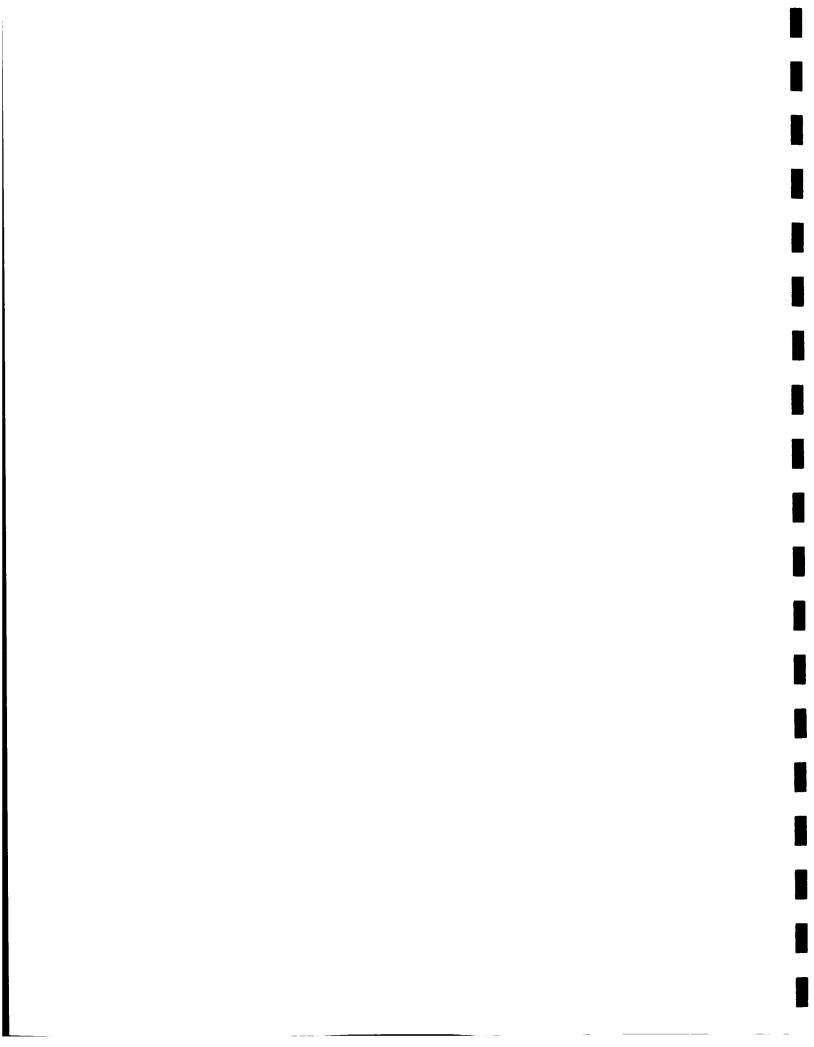
Interpolation software. The NSIPP land surface model utilizes catchments for its land surface discretization rather than a regular grid. A faster and simpler approach for performing the interpolation from grid to catchment (and vice versa) has been developed for interpolations on a fine regular grid. This was important for the LDAS application of the NSIPP land surface model.

Atmospheric forcing data sets. Atmospheric forcing data from the ECMWF (European Center for Medium-range Weather Forecasts) re-analysis data set on a Gaussian grid has been interpolated into the catchment space through a collaborative effort with Prof. Famiglietti and Mr. Aaron Berg from the University of Texas.

NSIPP land surface model evaluation. A summer student under my supervision (Kristi Arsenault) has been evaluating the NSIPP land surface model forecasts of soil moisture and evapotranspiration at a local field site.

OhmMapper. A second summer student under my supervision (Brandy Rutledge) has been evaluating the OhmMapper instrument (see http://www.geometrics.com for more information) for measuring soil moisture in the root zone over large areas.

Participation In Workshops/Conferences/Meetings

- December 11-17, 1999. Attended the AGU meeting in San Francisco, CA.

- May 14-20, 2000. Attended Southern Great Plains science meeting in Oklahoma City, OK; attended GEWEX/BAHC International Workshop in Norman, OK; met with GEOMETRICS in San Jose, CA.

- May 30-June 3, 2000. Attended AGU spring meeting in Washington, DC.

CONSULTANTS/VISITORS

Consultant: **Jeffery Walker** (University of Newcastle, Australia)
Purpose: Collaborate with members of Data Assimilation Office (6/26-30/99)
Collaborate with Data Assimilation Office on research in data assimilation and modeling land surface hydrological processes in coupled atmosphere/ocean/land models (7/1-9/30/99)

Visitor: **Takeshi Horinouchi** (Kyoto University, Japan)
Purpose: To present a seminar and participate in scientific discussions with members of the Data Assimilation Office (6/13-16/99)

Visitor: **Michael Kelly** (Colorado State University)
Collaborator: Richard Rood
Purpose: To present a seminar and participate in scientific discussions with members of the Data Assimilation Office (4/27-29/99)

Visitor: **Dinush Kurera**
Purpose: Scientific research using European Remote Sensing in comparison with ground measured soil moisture (12/1/99-2/29/00)

Visitor: **Zhan Zhang** (Florida State University)
Collaborator: Richard Rood
Purpose: To present a seminar and participate in scientific discussions with members of the Data Assimilation Office (4/29-30/99)

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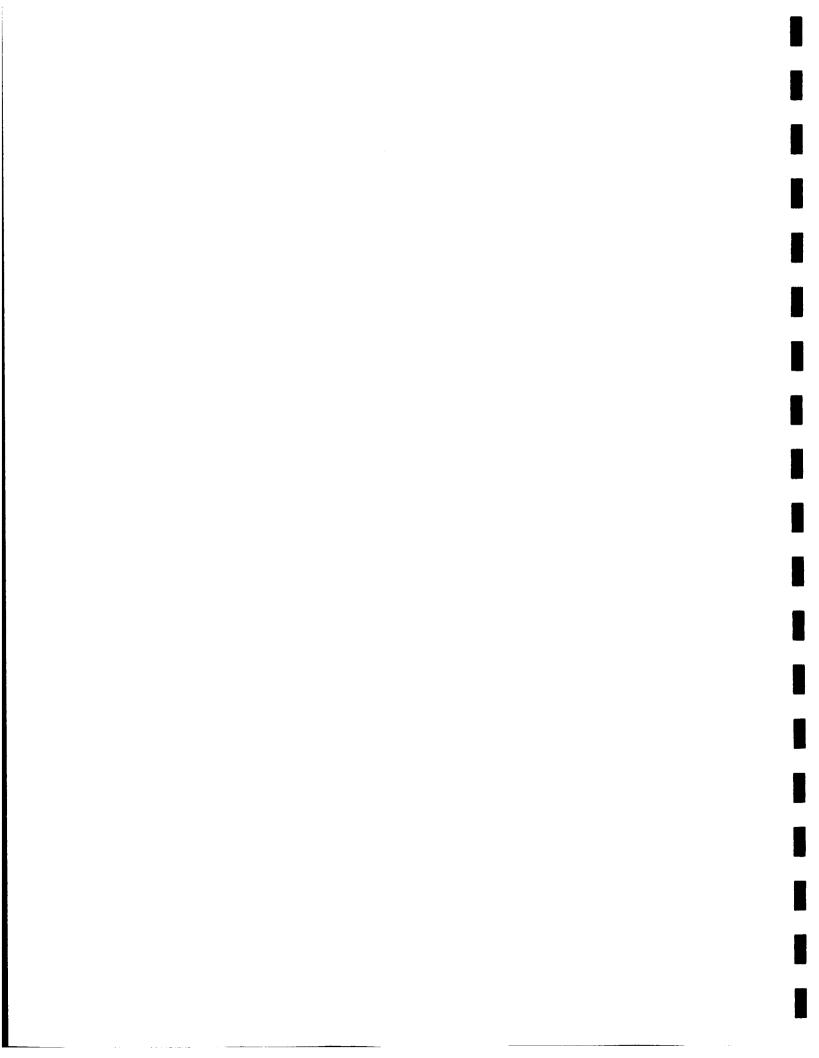# TASK 910-11: Laboratory for Atmospheres Visiting Fellows

TASK DESCRIPTION

The objective of this task was to facilitate scientific exchange between the external research community and the Laboratory for Atmospheres at NASA GSFC. This was to have been accomplished by providing mechanisms for university and external scientists and students to visit NASA GSFC to collaborate directly with scientists in atmospheric related activities and programs.

Specific activities were to include sponsorship and coordination of external research personnel in NASA scientific programs on appointments at various levels of seniority. Contractor was also to provide scientific and logistical assessments related to these activities and in conducting searches for, and evaluation of, visiting professionals as required to achieve the scientific objectives of the Laboratory.

CONSULTANTS/VISITORS

Consultant: **Sonia Kreidenweis**
Collaborator: Franco Einaudi
Purpose: To support a sabbatical visit to GSFC and work under the USRA/Goddard Laboratory for Atmospheres Visiting Fellows Program   (8/1-31/99)

Consultant: **Richard Lindzen** (Massachusetts Institute of Technology)
Collaborators: Arthur Hou and Richard Rood
Purpose: Scientific collaboration within the Laboratory for Atmospheres (10/1/98-9/30/99)

Consultant:	**Minghua Zhang** (SUNY)
Collaborator:	Richard Rood
Purpose:	To support a six-month research sabbatical at the NASA GSFC Laboratory for Atmospheres and Data Assimilation Office (1/2-6/30/99)

Visitor:	**Allesandro Battaglia** (Instituto ISAO-CNR, Spain)
Collaborator:	Chris Kummerow
Purpose:	Collaborate with scientists in the Mesoscale Atmospheric Processes Branch (9/1-9/30/99)

Visitor:	**Alex Kostinski**
Collaborator:	Andrew Negri
Purpose:	To support a sabbatical visit to GSFC and work under the USRA/Goddard Laboratory for Atmospheres Visiting Fellows Program (10/1/98-5/31/99)

Visitors:	**Robert Gall** (National Center for Atmospheric Research)
	Michael Hardesty (Environmental Technology Laboratory)
	Frank Marks (Hurricane Research Division)
	Eric Smith (NASA Marshall Space Flight Center)
Collaborator:	Franco Einaudi
Purpose:	Serve on a review panel for the Mesoscale Atmospheric Processes Branch (9/26-30/99)

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TASK 910-14: Diagnosis of the Near-surface Performance of the GEOS General Circulation Model

TASK DESCRIPTION

The focus of this work is on the diagnosis of the near-surface performance of the GEOS general circulation model (GCM) and data assimilation system (DAS). Primary scientific issues being studied are modeling of the heterogeneous land-surface, the diurnal development of the PBL in the GCM, and sources of precipitation and surface temperature bias in the DAS. The work will involve comparative and validation studies using LIDAR In-space Technology Experiment (LITE) data, and *in situ* field experiment observations such as those from BOREAS, ARM, and FIFE. A river routing model will be applied to the GCM and DAS output to infer errors in the hydrological cycle. Additional work involves the testing and validating of new physical processes in the data assimilation system and general circulation model, specifically related to the land-surface and planetary boundary layer.
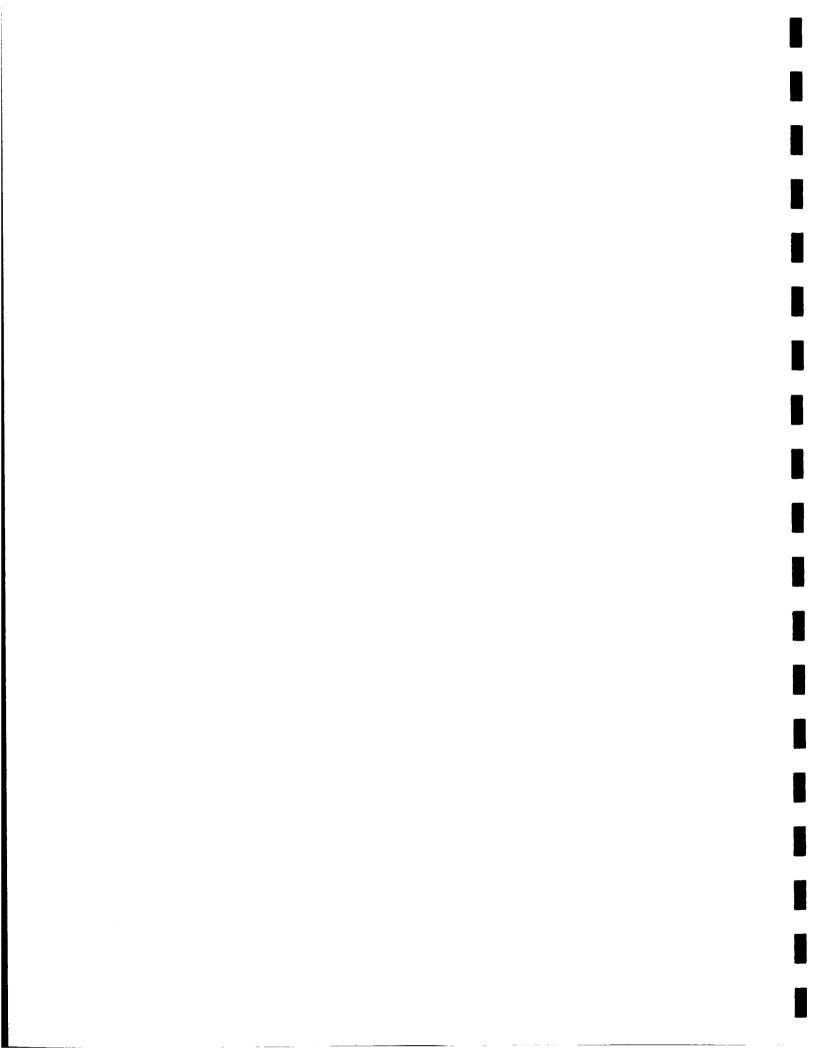
USRA EMPLOYEE: DR. MICHAEL BOSILOVICH

Research focus: Development of a mosaic land-surface model for use in Goddard GSM and data assimilation systems.

Accomplishments

October 1998 – August 1999

GEOS DAS validation. In the last year, the validation of the GEOS DAS has progressed in two ways: validation of the Mosaic heterogeneity parameterization and the global surface validation. Mosaic heterogeneity has been investigated for case studies at the Atmospheric Radiation Measurement program (ARM) Southern Great Plains site. The ARM data contains numerous observing stations within a single GCM grid point. This provides an estimate of the spatial heterogeneity that can occur in reality, and can provide a base of comparison to the Mosaic heterogeneity parameterization.

Throughout this year, various results from this work have been presented at AMS, AGU, and WCRP scientific meetings.

The global validation of the GEOS DAS surface has been a more recent project, but has been rather fruitful. NCDC provides a data set of global near surface meteorology that is not assimilated into the DAS. Monthly biases and errors indicate that the land-surface has improved several mean biases in the assimilation system. These results were presented at the 2nd Conference on Reanalyses.

Hydrologic study using passive tracers of water vapor. Earlier this year I began researching a new project. Passive tracers have been implemented in the GEOS GCM and DAS. We intend to use the passive tracers to track different sources of water vapor in the atmospheric system. Evaporation from a region can provide the source of water vapor for a tracer. If it precipitates within the same region we can compute the recycling of precipitation, a potential climate feedback mechanism. We can also determine the remote origination of precipitation for regions of interest. This concept is not particularly new, but has generally been considered for only course resolutions. What is potentially a new and important use of tracers in the assimilation system is to use the analysis increments as the source-of tracers. By analyzing the tracers this way we can determine how the analysis increments affect the precipitation and water vapor. Only preliminary cases have been run with the GCM. The preliminary cases have been presented to the DAO for input and consideration.

Bulk diagnostic of precipitation recycling in the GEOS-1 DAS. While working on background research for the tracer project (above), I found previous work on the bulk diagnostic approach to quantifying precipitation recycling (defined as evaporation that contributes to precipitation within the same region). While these bulk diagnostic models provide quantitative estimates of the precipitation recycling, they suffer from strong assumptions (monthly mean vertically integrated atmospheric hydrology, which neglects the shorter time scales and physical processes). Their advantage is that they can be applied to existing atmospheric data sets. Therefore, I applied bulk diagnostic models to the GEOS-1 DAS data set, specifically investigating the precipitation recycling in the central United States. The results are particularly interesting. They show that the local source of water for precipitation may not be as strong as originally thought. The fraction of recycled precipitation is strongest for low moisture transport, but the total recycled precipitation is largest for small values of convergence (neither diverging nor converging) and high evaporation. These results are currently being prepared for publication, and will be presented at the next AMS conference on hydrology (January 2000).

Common Land Model development and testing. The Common Land Model (CLM) is an international effort to develop a land-surface model for atmospheric numerical simulation. The advantage of such an extensive collaboration is that the model will benefit from the experience of many world-class scientists. Experts will develop areas in which I have little experience, such as the carbon cycle. Eventually, the DAO will use the CLM, so as to take advantage of these benefits. Presently, the CLM is still in beta testing, but I have performed some offline simulations in collaboration with Paul Houser's research group. Also, I have attended two CLM development meetings, and presented the preliminary results from my offline simulations.

October – December 1999

Precipitation Recycling in the GEOS-I DAS. Previous research on precipitation recycling in the GEOS DAS is nearing completion of the first part. An AMS journal manuscript was largely completed and should be submitted during the first quarter of 2000. The major findings were prepared for presentation at the AMS Conference on Hydrology (January 2000). This effort is the first part of a much more detailed investigation of the regional sources of precipitation (local compared with remote). The second part consists of implementation and testing of water vapor tracers in the GEOS GCM. These tracers will be used to follow water evaporated at the surface until the water is precipitated.

Common Land Model. Collaboration on the development of the Common Land Model (CLM) continues. During this quarter, I tested some sensitivity of the CLM to various methods of determining soil surface specific humidity. Results were presented at a two-day workshop hosted by COLA. In the long term, CLM may be the land model used in the next generation of the GEOS data assimilation system (developed by the DAO), hence my active participation with the CLM will benefit the DAO. To that end, I volunteered to convene a special session on the CLM and advances in land modeling at

the Spring 2000 AGU meeting. During the 4th quarter of 1999, Paul Houser (coconvener) and I outlined the scope of the special session and submitted an abstract (it has since been accepted).

Land modeling in the DAO. Since joining the DAO through USRA, I have been very active in testing the land atmosphere interactions in the data assimilation system that is supporting the EOS Terra mission. I have been actively involved in verifying the surface properties of the data assimilation system. Recently, I have been asked to be a point of contact between the DAO and the MODIS instrument team, who will be using surface data from the assimilation system. In addition, I have been working with the land data assimilation team (headed by Paul Houser). Eventually, their assimilation methods will need to be incorporated into the fully coupled G EOS system.

January – June 2000

Major activities included the following: the continuation of DAO land surface validation exercises; analysis of GEOS-1 reanalysis atmospheric circulation; a new effort to integrate land temperature assimilation into the GEOS-3 reanalysis system.

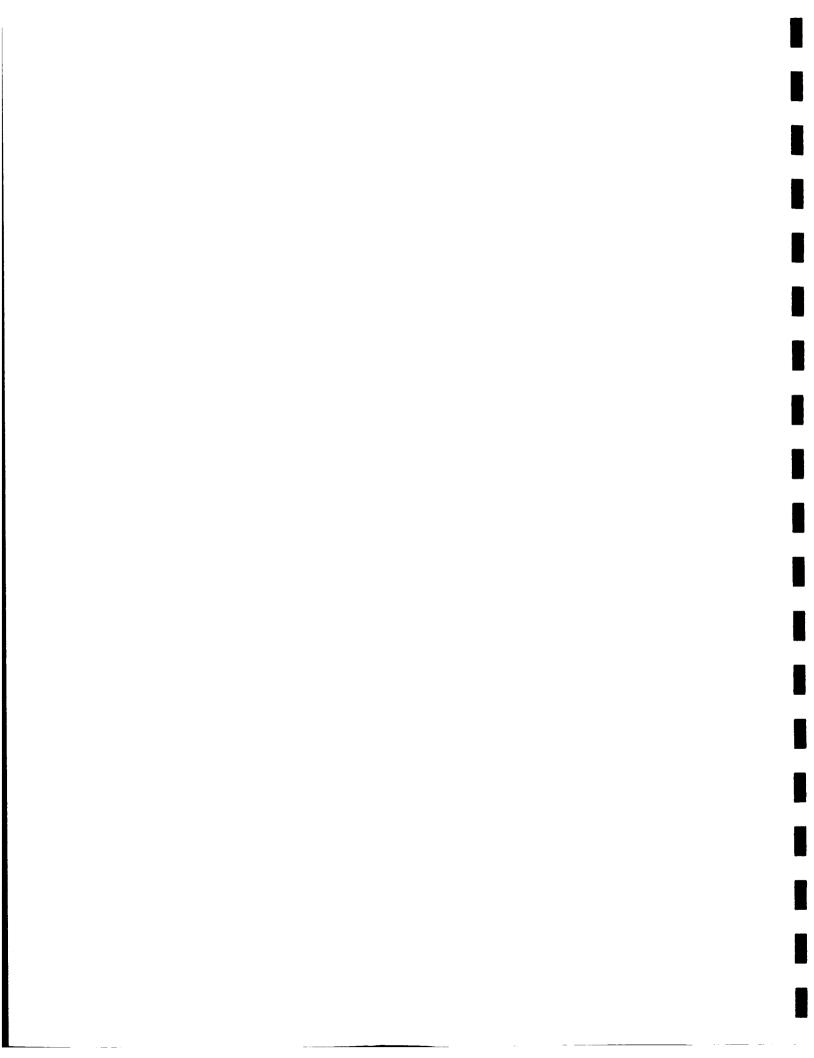Significant events and milestones included the following:

Contributed to the writing of the DAO Algorithm and Theoretical Basis Document

Gave a presentation to the DAO on the implementation of passive tracers in the GCM and reanalysis system as diagnostics for the hydrologic cycle.

Served as DAO representative for summer student interns and their mentors (also mentored a student).

Hosted Dr. Rick Lawford, NOAA Program Manager for GCIP, for a visit to the DAO to discuss possibilities of DAO contributions to GCIP science and data in the near future.

Participation in Workshops/Conferences/Meetings

- December 6-10, 1998. Attended the AGU meeting in San Francisco, CA. Poster session: Bosilovich, M. S., Houser, P. R., Molod, A., and Nebuda, S. (1999). *Comparison of FIFE Observations With GEOS Assimilated Data Including a Heterogeneous Land-surface Model.*

- January 9-14, 1999. Attended the 14th Conference on Hydrology in Dallas, TX. Presented paper: Bosilovich, M. S., Houser, P. R., Molod, A., and Nebuda, S. (1999). *Comparison of FIFE Observations With GEOS Assimilated Data Including a Heterogeneous Land-surface Model.*

- March 1999. Traveled to the University of Arizona for Common Land Model development meeting.

- May 1999. Presented seminar on *Land-atmosphere Interactions in Hydrometeorology* at Florida State University.

- June 22-24, 1999. Attended the 4th annual Climate System Model Workshop, sponsored by NCAR, in Breckenridge, CO.

- August 1999. Presented seminar on *Land-atmosphere Interactions in Hydrometeorology* to members of GSFC Code 970.

- August 20-27, 1999. Attended the 2nd Annual WCRP Conference on Reanalyses in Reading, UK. Presented papers: Bosilovich, M. G., Molod, A., Houser, P. R., and Schubert, S. D. (1999). *Validation of Mosaic Heterogeneity in the GEOS DAS*; Bosilovich, M. G., Schubert, S. D., Molod, A., and Houser, P. R. (1999). *Validation of land-surface processes in the GEOS DAS*; Bosilovich, M. G., Houser, P. R., and Schubert, S. D. (1999). *Interannual Variability of the Mosaic Land-surface Model.*

- September 1999. Presented seminar on *Land-atmosphere Interactions in Hydrometeorology* to members of GSFC Code 910.

- January 9-13, 2000. Attended the AMS Meeting in Long Beach, CA. Gave a presentation entitled *Precipitation Recycling in the NASA GEOS Data Assimilation System.*

- March 28-29, 2000. Attended the GEWEX American Prediction Program Science Plan Workshop in Potomac, MD.

- June 1-2, 2000. Attended the Spring AGU Meeting in Washington, DC. Gave presentation entitled *Validation and Variability of Mosaic Land-surface Heterogeneity.* Organized a special session on the Common Land Model.

- June 5-6, 2000. Attended the Interagency Reanalysis Workshop sponsored by the University of Maryland College Park.

- June 9, 2000. Gave presentation on DAO validation strategies to the MODIS Land Science team.

Publications

Bosilovich, M. G., Schubert, S., Molod, A., and Takacs, L. L. (2000). Precipitation recycling in the NASA GEOS Data Assimilation System. *Proceedings of the 15th AMS Conference on Hydrology*, Long Beach, CA, January.

Bosilovich, M. G., and Sun, W-Y. (1999). Numerical simulation of the 1993 Midwestern flood: Land-atmosphere interactions. *J. Climate, 12,* 1490-1505.

Bosilovich, M. G., and Sun, W-Y. (1999). Numerical simulation of the 1993 Midwestern flood: Local and remote sources of water. *J. Geophys. Res., D 104,* 19415-19424.

Bosilovich, M. G., Yang, R., and Houser, P. (1999). River basin hydrology in a global off-line land-surface model. *J. Geophys. Res. D 104,*19661-19674.
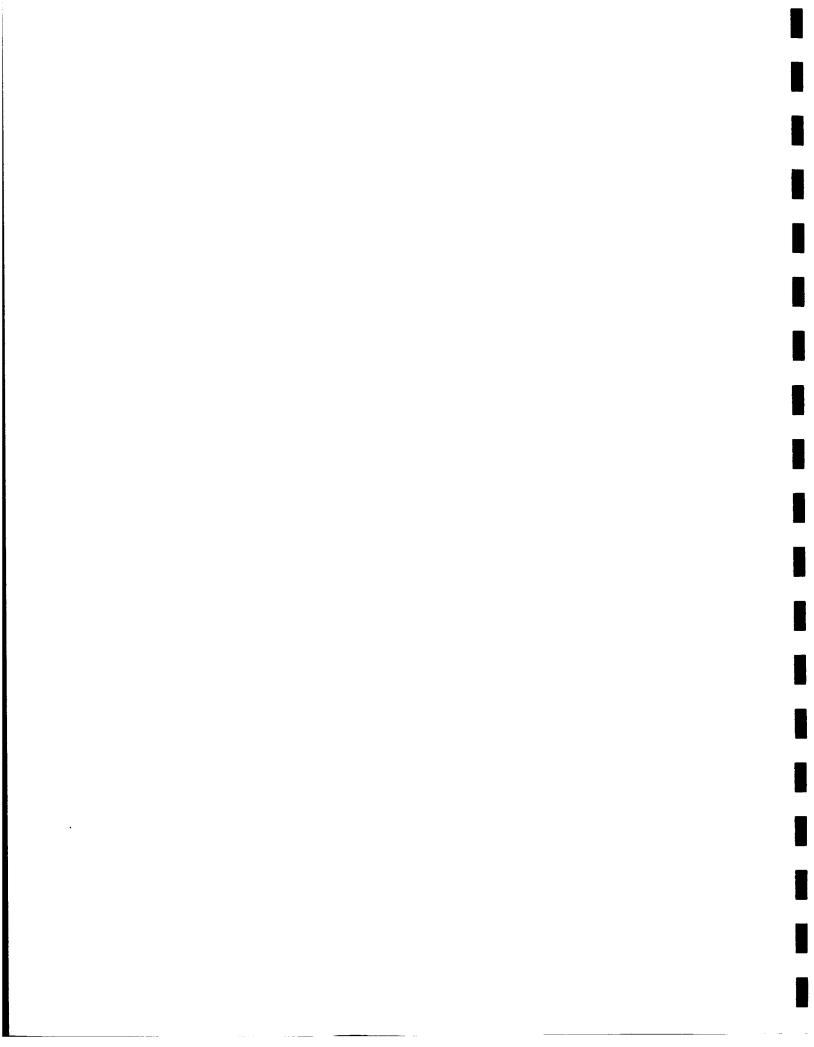
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TASK 910-19: Transport of Exhaust Products and Water Vapor

TASK DESCRIPTION

The purpose of this task was to investigate the transport of exhaust products from aircraft using a trajectory calculation in support of an overall AEAP effort. Trajectory parcels were to be released along flight tracks and tracked for several years to develop a climatology of trace gas perturbation. In addition, the task required looking at the transport of water vapor in the tropics. This involved the analysis of tropical water vapor soundings and satellite data, like MLS data from UARS. Trajectory calculations were to be performed on the water vapor data to estimate where sinking regions in the tropical upper troposphere were occurring. The objective of the calculation was to estimate the impact of global warming on upper tropical troposphere water vapor. It was expected that feedbacks in tropical water vapor might magnify the extent of global warming.

USRA EMPLOYEE: DR. STEVEN SHERWOOD

Research focus: Numerical and observational studies of upper tropospheric water vapor transport.

Accomplishments

October 1998 – September 1999

The trajectory studies of water vapor have yielded one paper with Andy Dessler. I am continuing to work on troposphere-stratosphere interactions which is now becoming a strong new focus within Code 916 at GSFC. I believe I am on track to make significant progress in this area, together with my collaborators in Code 916 and at the University of Maryland College Park. In addition, I have developed a data analysis method that I will submit for publication and which I hope will find use not only in my own work, but generally in climate studies and in the use and validation of satellite data.

During the summer of 1999 I served as a mentor for a student participating in the high school/high tech program which is designed to expose high school students with disabilities from Prince Georges and Montgomery counties to career possibilities in high technology. My student was engaged in a project to research the scientific literature using the World Wide Web and to build a useful database of previous work on atmospheric water vapor.

October 1999 – January 2000

Upper-tropospheric water vapor transport. Andy Dessler (GSFC/University of Maryland) and I collaborated on a project to quantify transport of water vapor in the uppermost troposphere using MLS data from UARS. A paper entitled "Trajectory Simulations of Upper Tropospheric Humidity" is in review at the *Journal of Geophysical Research*.

Behavior of the tropical tropopause. In other work with Andy, we have examined data from the NASA ER-2 aircraft, and found evidence in favor of a new hypothesis on the exchange of mass between the troposphere and stratosphere, and concomitant dehydration of air, in the Tropics. This work is relevant for the water vapor budget near the tropopause, and the possible role of aerosols and near-tropopause vapor sources in affecting climate.

Extraction of climate signals from incomplete data. In a related project, I have completed work on a method for the optimal estimation of climate signals from incomplete data. This method appears to be promising for a variety of purposes, including estimation of the time-mean mass divergence field in the upper troposphere and lower stratosphere, and the accurate determination of trends and their uncertainty from radiosonde data and possibly from satellite data. I have so far used it to infer mass transport between the troposphere and stratosphere.
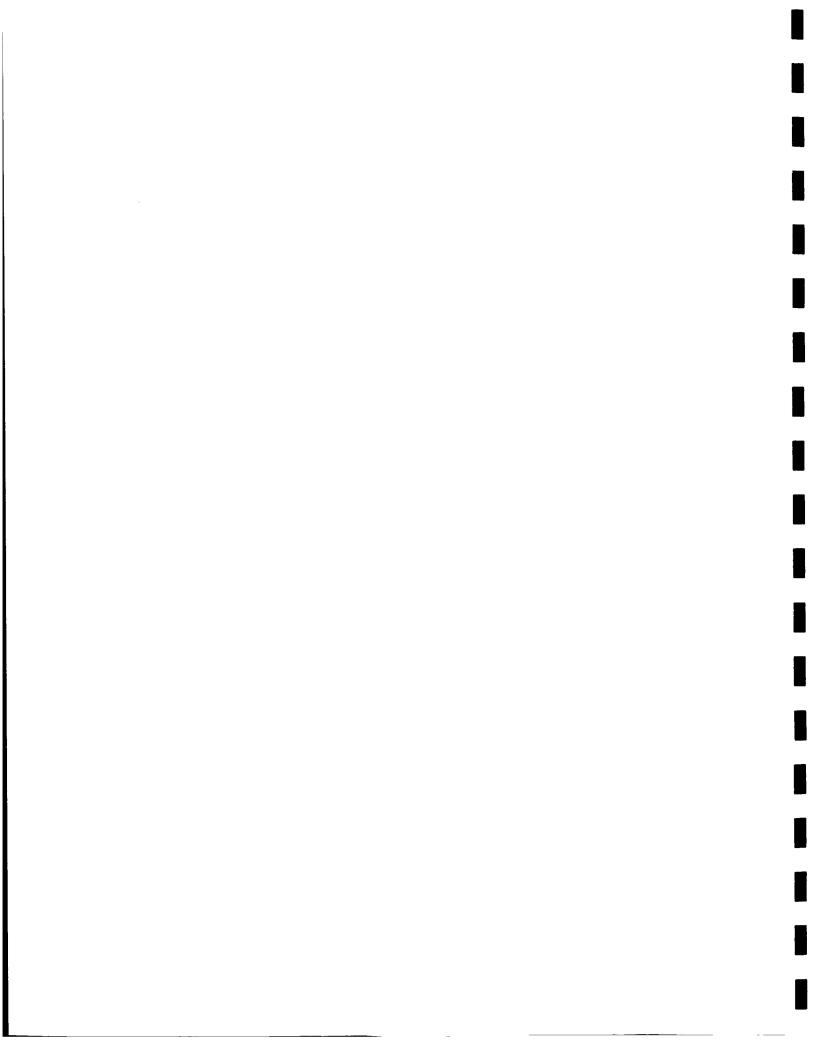
February – June 2000

Behavior of the tropical tropopause. I have continued work with Andy of ESSIC (University of Maryland College Park) which examined data from the NASA ER-2 aircraft, and found evidence in favor of a new hypothesis on the exchange of mass between the troposphere and stratosphere, and concomitant dehydration of air, in the Tropics. This work is relevant for the water vapor budget near the tropopause, and the possible role of aerosols and near-tropopause vapor sources in affecting climate.

One paper, entitled "On the control of stratospheric humidity", was accepted by *Geophysical Research Letters* in June. An earlier paper, "A 'stratospheric drain' over the maritime continent" appeared in *Geophysical Research Letters* in March. A paper detailing a model developed last year for describing the new mechanism quantitatively is in revision with the *Journal of Atmospheric Sciences*. Further work on this topic will occur as part of a funded 3-year EOS-IDS proposal to NASA with collaboration from Andy Dessler and other researchers at NASA and the University of Maryland College Park.

I have begun analysis of a long-term cloud dataset to look for signals of interannual variations in the properties of the highest and coldest tropical clouds that may provide clues to long-term climate variations in the stratosphere.

Extractions of climate signals from incomplete data. In a related project, I have completed work on a method for the optimal estimation of climate signals from incomplete data. This method appears to be

promising for a variety of purposes, including estimation of the time-mean mass divergence field in the upper troposphere and lower stratosphere, and the accurate determination of trends and their uncertainty from radiosonde data and possibly from satellite data. I have so far used it to infer mass transport between the troposphere and stratosphere.

Two papers relating to this method are currently in revision or were recently resubmitted: "Climate signal mapping and an application to atmospheric tides" to *Geophysical Research Letters* and "Climate signals from station arrays with missing data, and an application to winds" to the *Journal of Geophysical Research*.

Participation in Workshops/Conferences/Meetings

- January 14, 1999. Gave presentation entitled *A Stratospheric Drain Over the Maritime Continent* as part of the GSFC Code 916 weekly seminar series.

- June 1-4, 1999. Attended the Spring AGU Meeting in Boston, MA. Presented paper entitled *A Stratospheric "Drain" Over the Maritime Continent.*

- June 28-July 2, 1999. Attended the 10th AMS Conference on Atmospheric Radiation in Madison, WI. Presented paper entitled *On Moistening of the Tropical Troposphere by Cirrus Clouds.*

- August 12, 1999. Gave presentation entitle *An Analysis of Stratospheric Wind and Temperature Data* as part of the GSFC Code 916 weekly seminar series.

- October 12-15, 1999. Attended the Chapman conference on water vapor in Potomac, MD. Gave a presentation entitled *A Model for Transport Across the Tropical Tropopause.*

- March 30, 2000. Attended the USGCRP Water Cycle Workshop in Potomac, MD.

- April 2000. Gave an invited talk, entitled *Cold Traps, Convective Physics, and the Climatology of Water Vapor* at Colorado State University and Yale University.

- May 5-15, 2000. Attended the AMS 15th Conference on Statistics and Probability in the Atmospheric Sciences in Ashville, NC.

- June 2000. Attended the AGU Meeting in Washington, DC.

- June 2000. Gave an invited talk, entitled *Cold Traps, Convective Physics, and the Climatology of Water Vapor* at Harvard University.

Publications

Sherwood, S. C. (1999). Feedbacks in a simple prognostic tropical climate model. *Jr. Atmos. Sci., 56*(13), 2178-2200.

Sherwood, S. C. (1999). On moistening of the tropical troposphere by cirrus clouds. *Jr. Geophys. Res., 104*(D10), 11949-11960.

Sherwood, S. C., and Wahrlich, R. (1999). Observed evolution of tropical deep convective events and their environment. *Mon. Wea. Rev., 127*(8), 1777-1795.

CONSULTANTS/VISITORS

Visitor: **Ian Faloona** (Pennsylvania State University)
Purpose: To present a seminar and participate in scientific discussions with members of the Laboratory for Atmospheres (10/27-29/99)

Visitor: **Lisa Neef**
Purpose: Participate in scientific research with members of the Laboratory for Atmospheres (5/19-8/5/99)
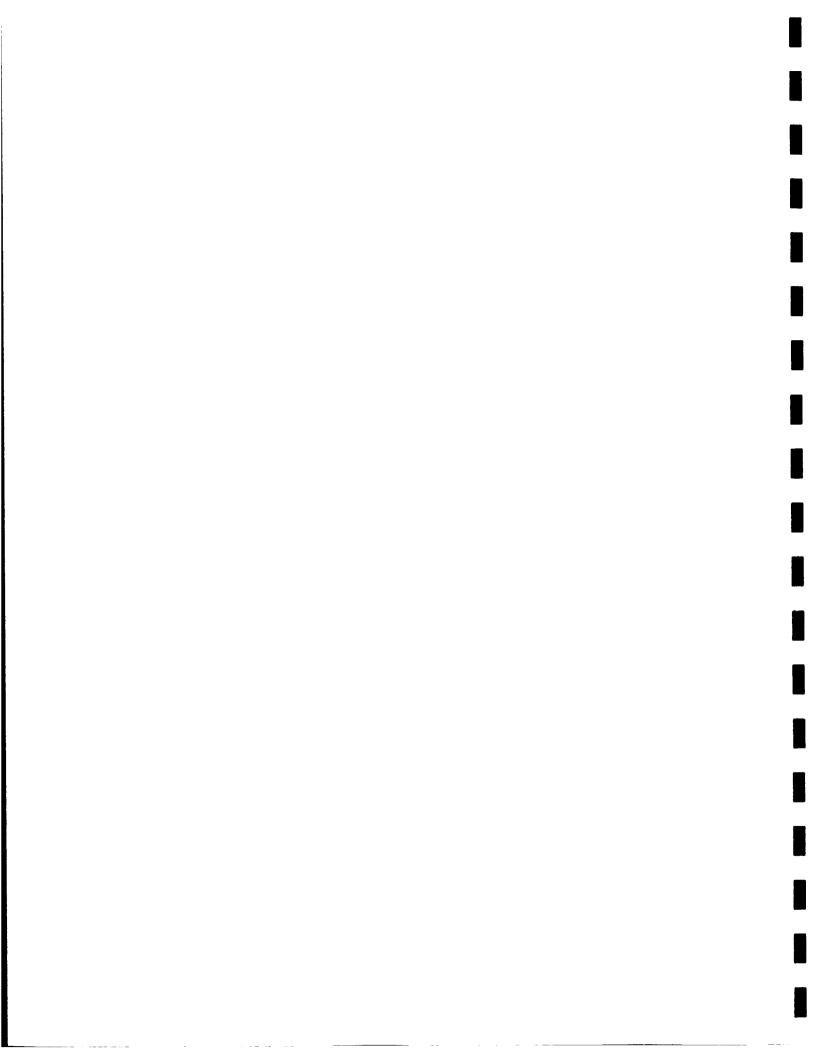
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TASK 910-20: Short-Term Visiting Scientists

TASK DESCRIPTION

This task was used to support short-term visiting scientists with the objective of making data from the Tropical Rainfall Measuring Mission (TRMM) Ground Validation Program (GVP) available to the university research community and to other non-U. S. government scientists as well as to encourage collaboration in the interpretation of these data. The collaboration with short-term scientists was to include the participation of the scientists and their research associates in TRMM field campaigns. Typically, a field campaign required 8 to 10 scientists with a minimum of two round trips each. This task was also intended to support the attendance of collaborating university and non-U. S. government scientists at TRMM Science Team meetings, workshops, symposia, and conferences of interest to TRMM, and expenses related to invitations for special seminars. Travel and related expenses were expected to include approximately 5 international scientists and 10 domestic scientists with visits ranging from a few days to several weeks. It was also expected that the task would support a 3- to 4-month long visit by an Australian scientist to collaborate on TRMM science.

CONSULTANTS/VISITORS

Visitor: **David Atlas**
Collaborator: Kris Kummerow
Purpose: Collaboration with scientists and attendance at TRMM Science Team meeting (10/24-11/11/99)

Visitor: **Larry Belcher** (Colorado State University)
Collaborator: Gerald Heymsfield
Purpose: Present a seminar entitled, "Classification of Tropical Precipitation Regimes" to scientists in the Mesoscale Atmospheric Processes Branch (4/22-27/00)

Visitor: **Alexander Khain**
Collaborator: Joanne Simpson
Purpose: Research on the numerical cloud model, Goddard Cumulus Ensemble (8/20-9/18/00)

Visitor: **Daniel Rosenfeld** (Hebrew University, Israel)
Collaborator: Yoram Kaufman and Chris Kummerow
Purpose: Participate in TRMM/GPM meeting at the University of Maryland College Park (10/24-31/99). Present a seminar relating to satellite measurements of the impact of smoke and regional pollution on precipitation (4/6-18/00)

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TASK 912-02: Climate and Hydrologic Cycle Research

TASK DESCRIPTION

The purpose of this task was to gather and assemble scientific, technical, and programmatic information; evaluate merit, form synthesis, and prepare written documents, such as reports, long-range plans, and other documents pertaining to the program; organize meetings, workshops, and reviews. The contractor was expected to have knowledge of the current state of a broad range of subjects in NASA's research program on climate and the hydrologic cycle, including mesoscale and global-scale processes in both hydrology and atmospheric sciences. It was expected that the contractor might assist in the planning, logistics, and implementation of field experiments in which NASA investigators participated.

CONSULTANTS/VISITORS

Consultant: **Barbara Butler**
Collaborator: Ming-Yei Wei
Purpose: Attend NASA Earth Science Enterprise Outreach meeting, give presentation, and participate in follow-up discussions at GSFC (3/22-24/99)
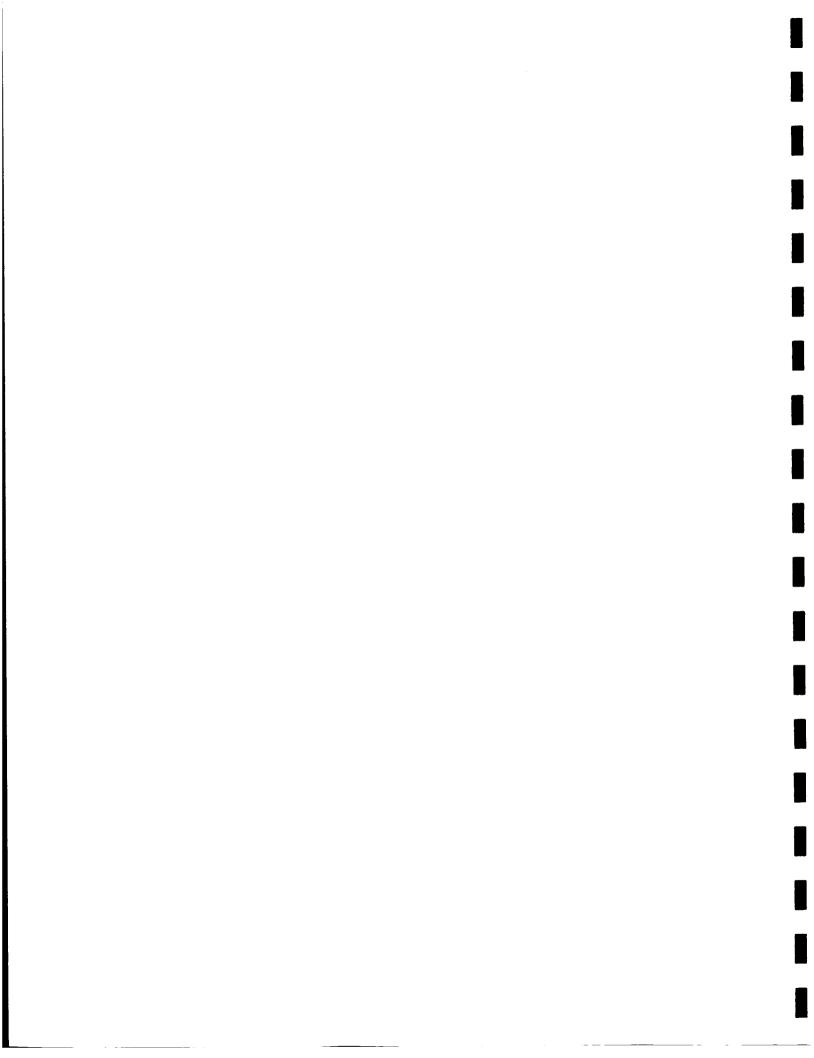
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TASK 912-04: Mesoscale Atmospheric Processes Branch Visiting Scientists
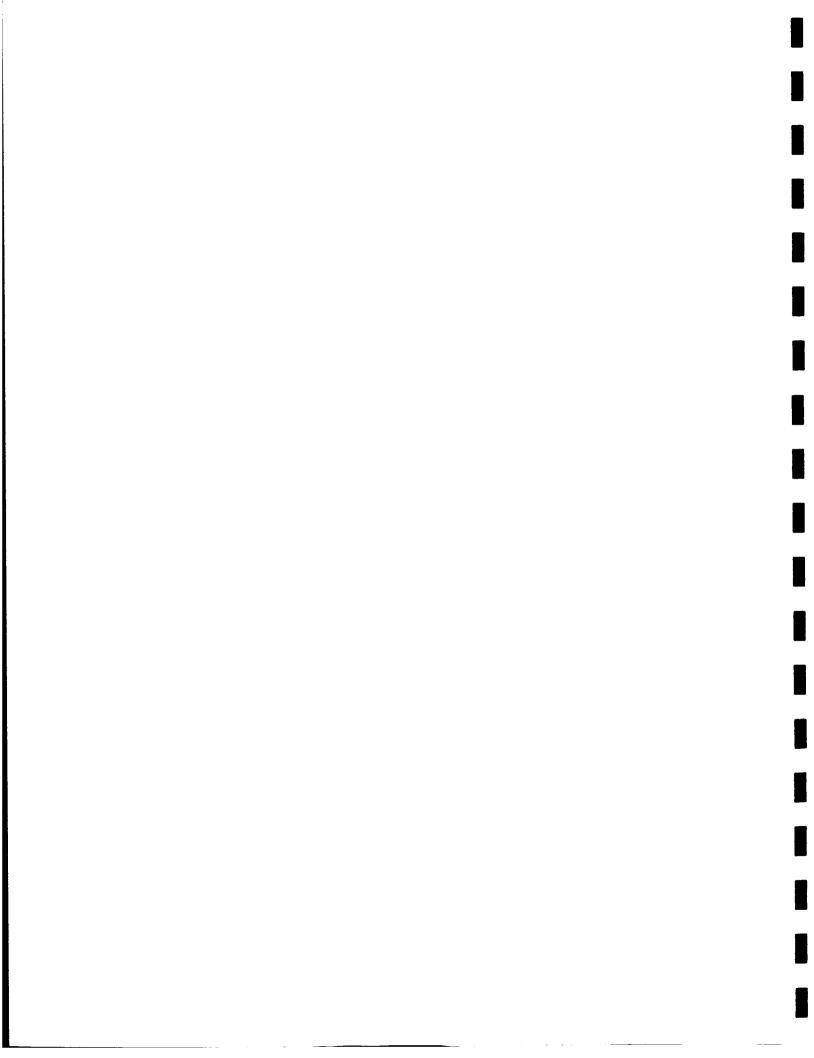
TASK DESCRIPTION

This task was used to support short-term visiting scientists with the objective of collaboration between the university research community and other non-U. S. government scientists and the Mesoscale Atmospheric Processes Branch. The areas of interest were physics and dynamics of atmospheric precipitation systems from individual clouds through mid-latitude and tropical cyclones and the impact of those systems on regional and global climate. The task was also intended to support the attendance of collaborating university and non-U. S. government scientists at seminars, workshops, symposia, and conferences of interest to the Mesoscale Atmospheric Processes Branch.

CONSULTANTS/VISITORS

Consultant: **Richard Johnson** (Colorado State University)
Collaborator: Wei-Kuo Tao
Purpose: Present a seminar entitled *Convection and Radiation in Toga Coare: Implications for Tropical Atmospheric Circulations* (3/31/00)

Consultant: **Reto Stockli**
Collaborator: Fritz Hasler
Purpose: Participate with Dr. Hasler and other NASA/GSFC scientists in the visualization of scientific data related to the EOS-AM-1 program (11/1-30/98)

Consultant: **Otto Thiele**
Purpose: Participate with NASA in coordination and planning for aircraft and surface measurement activities for CAMEX 3 field campaign (2/14-6/30/00)
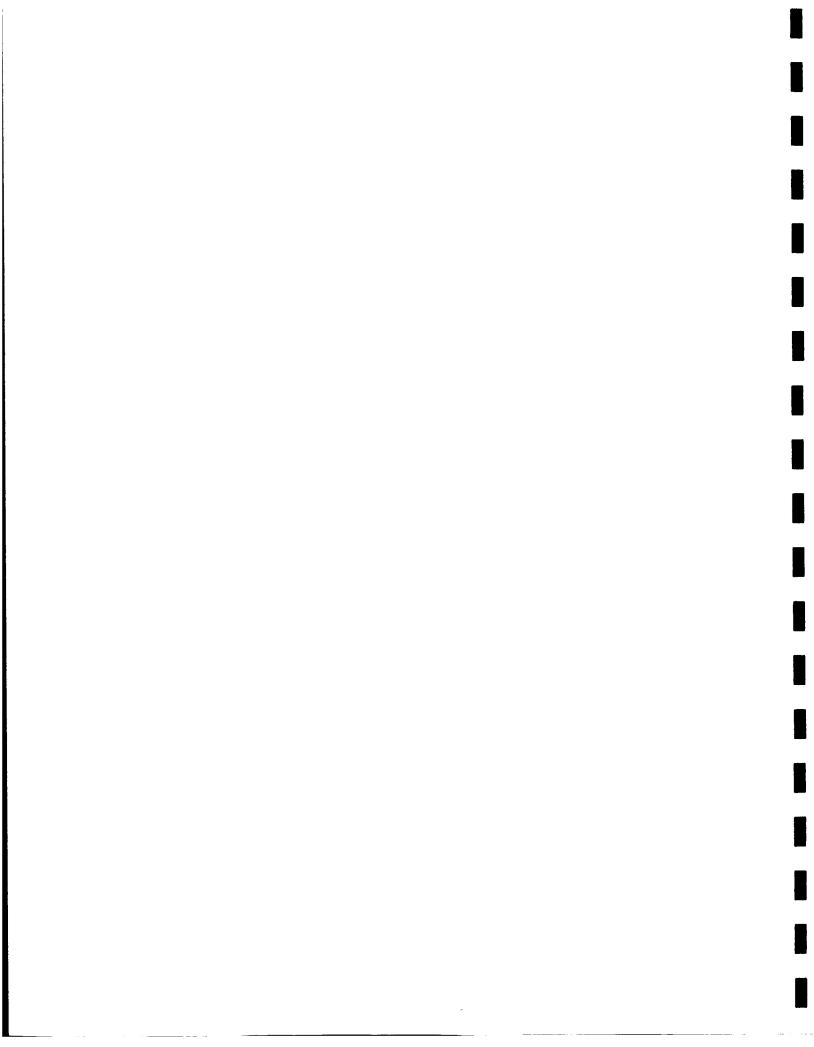
Consultant:	**Xiaolei Zou** (Florida State University)
Collaborator:	Wei-Kuo Tao
Purpose:	Present a seminar entitled *Some Thoughts on Mesoscale Data Assimilation* and to train MM5 users to use MM5 adjoint model (12/13-19/98).

Visitor:	**Emmanouil Anagnostou** (University of Connecticut)
Purpose:	Collaborative discussions with the Mesoscale Atmospheric Processes Branch (4/28-5/2/99)

Visitor:	**Edward Brandes** (National Center for Atmospheric Research)
Purpose:	Collaborate on ground-validation activities with members of TRMM (7/24-26/00)

Visitor:	**Shuhua Chen** (National Center for Atmospheric Research)
Collaborator:	Wei-Kuo Tao
Purpose:	Discussions with members of the Goddard mesoscale modeling group on the status and use of the WRF prototype (7/25-31/00)

Visitor:	**Tufa Dinku** (University of Connecticut)
Purpose:	Work on IR/TRMM Data (7/29-8/12/99)

Visitor:	**Jeremy Dobler** (University of Arizona)
Purpose:	Research involving methods of estimating wind profiles from Lidar observation (7/23-8/5/00)

Visitor:	**Anne Garnier** (CNRS, France)
Collaborator:	Bruce Gentry
Purpose:	Present a seminar on measuring wind using a Rayleigh lidar (6/14-16/99)

Visitor:	**Wojciech Grabowski** (National Center for Atmospheric Research)
Collaborator:	Wei-Kuo Tao
Purpose:	Present seminar and participate in scientific discussions on tropical convection (5/5-7/99)

Visitor:	**Mircea Grecu** (Institute of Hydraulic Research)
Purpose:	Collaborative research on rainfall and lightning (11/19-11/29/98)

Visitor:	**Jose Hernandez** (University of Puerto Rico)
Collaborator:	Sue Chou
Purpose:	Present a seminar to the Mesoscale Atmospheric Processes Branch (7/5-8/99)

Visitor:	**Jonathan Jiang** (York University, Canada)
Collaborator:	Sue Chou
Purpose:	Present a seminar to the Mesoscale Atmospheric Processes Branch (6/24-25/99)

Visitor:	**Christopher Kidd** (University of Birmingham, UK)
Purpose:	To attend the NASA TRMM Science Meeting in Pasadena, CA (11/14-20/98)

Visitor:	**Martin Kohler** (Geophysical Fluid Dynamics Laboratory)
Collaborator:	Wei-Kuo Tao
Purpose:	Present a seminar to the Laboratory for Atmospheres (11/14-15/99)

Visitor:	**William Kuo** (National Center for Atmospheric Research)
Collaborator:	Wei-Kuo Tao
Purpose:	Present a seminar on the U. S. and Taiwan satellite program (4/15-16/99)

Visitor:	**Arlene Laing** (University of South Florida)
Purpose:	Present a seminar on rainfall estimation (3/8-9/99) Collaborative discussions with scientists in the Mesoscale Atmospheric Processes Branch (12/19-30/99)

Visitor: **Massimo Menenti**
Collaborator: Chaudhury
Purpose: Scientific investigations on the Aral Sea (10/25-11/13/98)

Visitor: **Sean Miner** (Pennsylvania State University)
Collaborator: Chris Kummerow
Purpose: Participate in scientific discussions of rainfall estimation (3/17/00)

Visitor: **Roger Pielke, Sr.** (Colorado State University)
Collaborator: Wei-Kuo Tao
Purpose: Present a seminar and collaborative discussions on numerical modeling of storms to the Mesoscale Atmospheric Processes Branch (3/30/00)

Visitor: **Anil Rao** (Florida State University)
Purpose: Present a seminar to Mesoscale Atmospheric Processes Branch (12/9-11/98)

Visitor: **Yvette Richardson** (University of Oklahoma)
Purpose: Collaborative discussions with Dr. Wei-Kuo Tao and Joanne Simpson (3/11-18/00)

Visitor: **Wilbert Skinner** (University of Michigan)
Collaborator: Matthew McGill
Purpose: Collaborative scientific discussions with members of Mesoscale Atmospheric Processes Branch regarding doppler lidar (12/13-15/98)

Visitor: **Matthais Steiner** (Princeton University)
Collaborator: Chris Kummerow
Purpose: Discussion on automating TRMM Ground Validation software (6/10-11/99)
Present a seminar to the Mesoscale Atmospheric Processes Branch (8/5-6/99)

Visitor: **Wen-Yih Sun** (Purdue University)
Purpose: Present seminar on the regional climate and air-sea interaction (5/14/17/00)

Visitor: **Nicholas Viltard**
Purpose: To attend the NASA TRMM Science Meeting in Pasadena, CA (11/14-8/98)

Visitor: **Stephen Warren** (University of Washington)
Purpose: Discussions on lidar remote sensing (5/14-17/00)

Visitor: **Matthew Wheeler** (National Center for Atmospheric Research)
Purpose: Present a seminar entitled *Convectively-Trapped Equatorial Waves: Real-Time diagnosis* (11/15-17/99)

Visitor: **Jun-ichi Yano** (New York University)
Collaborator: Wei-Kuo Tao
Purpose: Present seminar on the use of TRMM products for studying ENSO (5/13-14/99)

Visitor: **Shuliang Zhang** (Woodshole Oceanographic Institute)
Purpose: Present a seminar to the Mesoscale Atmospheric Processes Branch and Climate and Radiation Branch (6/21-23/99)

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TASK 912-08: Numerical Modeling of Mesoscale Convective Systems

TASK DESCRIPTION

This task involved research in the numerical modeling of mesoscale convective systems to better understand the physical processes responsible for the type, frequency, spatial distribution, and intensity of precipitation. The impact of land surface-atmosphere interactions including land-sea breezes, soil moisture, and vegetation on the development of convective systems was of particular importance. Convection-wave interaction and the influence of convection on the large-scale environment were also to be investigated. Applications of this research include land use influence on the hydrological cycle, prediction of extreme flood events, regional water and energy budgets, and regional climate change.

USRA EMPLOYEE: DR. DAVID BAKER

Research focus: Development of (and studies with) a coupled cloud resoling mesoscale model and surface hydrology process model.

Accomplishments

October – December 1998

My primary task during this period involved coupling the PLACE soil-vegetation model of Wetzel and Boone (1995) to the 3-D Goddard Cumulus Ensemble (GCE) cloud model of Tao and Simpson (1993). The GCE-PLACE coupled model has been successfully tested with cyclic boundary conditions, and results from this coupled model will be presented at the AGU 1998 Fall Meeting. Coupling of PLACE and GCE with open boundary conditions has begun, and we expect this version of the coupled model to be tested and completed within the next few months. In addition I trained Karen Mohr, a graduate student from the University of Texas, to run the GCE-PLACE model.
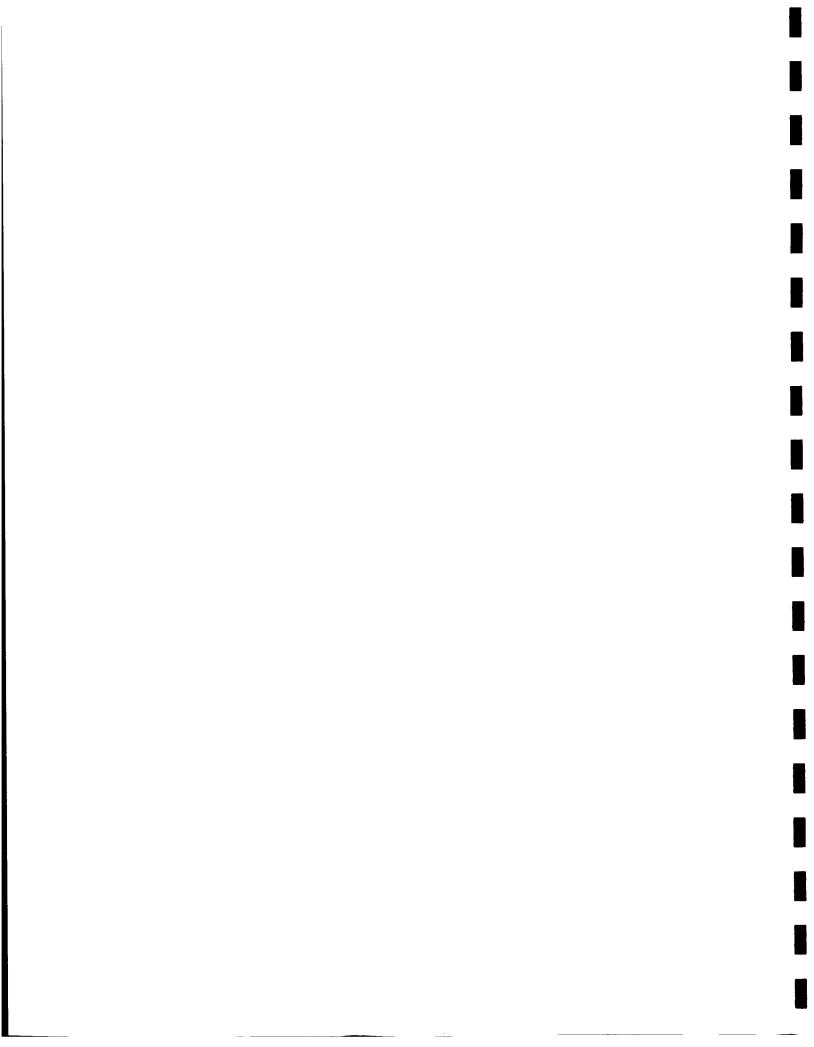
Dr. Brad Ferrier, Dr. Jeff Halverson, and I were awarded a NASA TRMM grant to utilize TRMM data in numerical cloud models to better understand the relationship between heating and wind divergence in convective systems. I also submitted a NOAA/NASA GCIP proposal entitled *Mesoscale Modeling of the Influence of Topography, Soil Moisture, and Vegetation on Season and Episodic Precipitation in the LSA-E Region* with Dr. Wei-Kuo Tao of NASA and Dr. Henry Juang of NCEP.

January – December 1999

Model development
- Coupled new version of PLACE land surface model to 3D GCE cloud model.
- Updated microphysics within GCE-PLACE code (with Dr. Scott Braun).
- Modified PLACE land surface module for coupling with "frozen" version of GCE.
- Modified and tested 3D GCE cloud model with open boundaries (with Dr. Wei-Kuo Tao).
- Began coupling of PLACE with 2D GCE cloud model with open boundaries.

Once model modifications and enhancements are complete, the coupled GCE-PLACE model will be used for a wide variety of applications involving atmosphere/land-surface interaction and its impact on the hydrological cycle. Future projects which will utilize GCE-PLACE include investigation of MCTEX Hector development, TRMM/LBA convection, flash flood events, soil moisture initialization for numerical weather prediction, initiation of severe storms in Oklahoma, and climate impacts of surface-air interaction of the Arctic Ocean.

<u>Scientific research</u>
- Conducted numerical simulations with 3D GCE-PLACE model of sea breeze initiated convection in Florida to assess the role of soil moisture, land breezes, and coastline curvature on the location and intensity of precipitation.
- Assessed potential case studies of Hector development in the Tiwi Islands during the MCTEX field experiment to investigate sea-breeze/gust-front interaction and subsequent convective development (with Dr. Joanne Simpson (NASA/GSFC) and Dr. R. Narbone (NCAR)).
- Performed objective analysis of Florida rain gauge measurements for validation study of new MM5-TKE-PLACE coupled model.

<u>KWAJEX Field Experiment</u>
- Helped develop sounding personnel schedule during KWAJEX Intensive Operational Period.
- Released MSS radiosondes during KWAJEX IOP

<u>October 1999 – January 2000</u>

My primary task for this period has been to understand the impact of soil moisture on the development of severe storms in Florida and in the Tiwi Islands north of Darwin, Australia. A coupled atmosphere/land-surface model (GCE-PLACE) developed at Goddard has been used for this research. Data from the Convection and Precipitation Electrification (CaPE) field experiment in Florida and the Maritime Continent Thunderstorm Experiment (MCTEX) in Darwin have been used. A key result is that soil moisture can either promote or inhibit convective growth depending on existing atmospheric conditions.

Participation in Workshops/Conferences/Meetings

- November 12, 1998. Presented a seminar entitled *Weather on Venus, Jupiter, and Earth* for the Department of Physics at Loyola College in Baltimore, MD.

- December 5-14, 1998. Attended the Fall AGU Meeting in San Francisco, CA. Presented paper: Baker, R. D., Lynn, B. H., Boone, A., and Tao, W-K. *The Influence of Soil Moisture and Wind on Rainfall Distribution and Intensity in Florida.*

- January 8, 1999. Presented seminar entitled *Soil Moisture, Wind, and Rainfall in Florida* as part of the GSFC Mesoscale Atmospheric Processes Branch Seminar Series.

- August 28-29, 1999. Attended the TRMM/LBA Workshop in Charlottesville, VA.

- June 22-25, 1999. Attended the MM5 User's Workshop in Boulder, CO. Presented paper at NCAR Workshop on Land-Surface Modeling and Applications to Mesoscale Models: Baker, R. D., Lynn, B. H., Boone, A., and Tao, W-K. *Sensitivity of Florida Precipitation to Soil Moisture and Wind: Results from the GCE-PLACE Atmospheric-Land Surface Model.*

- August 24 – September 14, 1999. Participated in the TRMM/KWAJEX Field Experiment on Kwajalein in the Marshall Islands.

- November 18, 1999. Presented seminar entitled *Land-Atmosphere Interaction in Florida and in Darwin, Australia: Soil Moisture, Sea Breezes, and Severe Storms* at the Joint Center for Earth Systems Technology at the University of Maryland Baltimore County.

- December 12-18, 1999. Attended the Fall AGU Meeting in San Francisco, CA. Gave presentation entitled *Atmospheric Dynamics of Venus: Scales Large and Small.* Presented paper: Baker, R. D., Lynn, B. H., Boone, A., and Tao, W-K. *Soil Moisture, Coastline Curvature, and Sea Breeze Initiated Precipitation over Florida.*

Publications

Baker, R. D., Schubert, G., and Jones, P. W. (2000). Convectively generated internal gravity waves in the lower atmosphere of Venus. Part 1: No wind shear. *J. Atmos. Sci., 57,* 184-199.

Baker, R. D., Schubert, G., and Jones, P. W. (2000). Convectively generated internal gravity waves in the lower atmosphere of Venus. Part 2: Mean wind shear and wave-mean flow interaction. *J. Atmos. Sci., 57,* 200-215.

Baker, R. D., Schubert, G., and Jones, P. W. (1999). High Rayleigh number compressible convection in Venus' atmosphere: Penetration, entrainment, and turbulence. *J. Geophys. Res., 104,* 3815-3832.

Baker, R. D., and Schubert, G. (1998). Deep convective entrainment by downdrafts in Jupiter's atmosphere. *Icarus, 136,* 340-343.

Baker, R. D., Lynn, B. H., Boone, A., Tao, W-K., and Simpson, J. The influence of soil moisture, coastline curvature, and land-breeze circulations on sea-breeze initiated precipitation. Submitted to *J. Hydrometeor.*

Lynn, B., Stauffer, D. R., Wetzel, P. J., Tao, W-K., Alpert, P., Perlin, N., Baker, R. D., Munoz, R., Boone, A., and Jia, Y. Mesoscale simulations of a Florida sea breeze using the PLACE land surface model coupled to a 1.5-order turbulence parameterization. Submitted to *Mon. Wea. Rev.* August 1999.

USRA EMPLOYEE: DR. ZHAO-XIA PU

Research focus: Application of data assimilation techniques in mesoscale model studies of cyclones and mesoscale convective systems.

Accomplishments
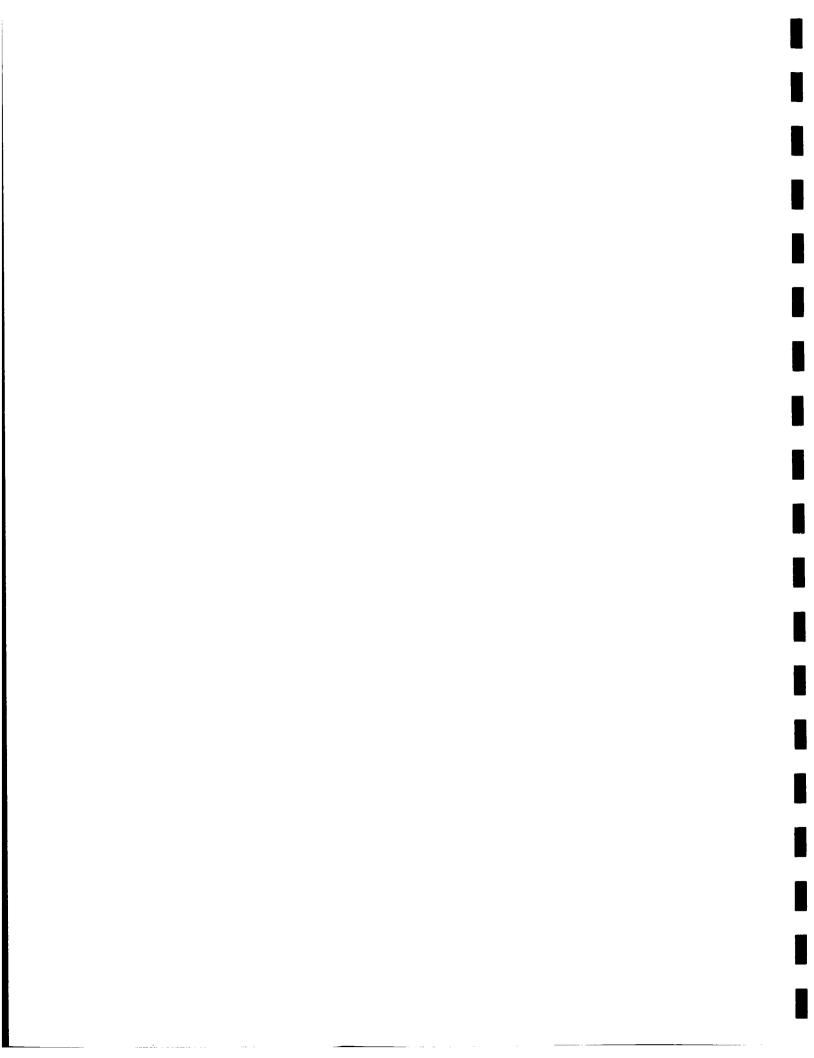
October 1998 – August 1999

The goal of my research is to use the mesoscale data in numerical simulations in order to evaluate the impact of data assimilation on hurricane forecasts. My work is focused on developing and testing a 4-D VAR data assimilation system.

Testing and updating the NCAR MM5 four dimensional variational data assimilation (4-D VAR) system with current GSFC computer. This includes: 1) changing the I/O formats; and 2) updating a part of the programs and compilers in order to execute the 4-D VAR system in both the workstation and GSFC's Cray J90. In particular, the updated programs made it possible to apply the 4-D VAR to the model with relatively high resolution.

Developing/testing an effective "bogus" method for hurricane simulation. With MM5 and 4-D VAR systems, we have tried three ways to generate the initial vortex for hurricane simulation: 1) assimilating the "bogus" surface pressure data only, 2) assimilating the "bogus" wind data only, and 3) assimilating both "bogus" winds and surface pressure data. We found that by assimilating both "bogus" wind and surface pressure data, we obtained a reasonable initial vortex which led to significant improvement in the forecast.

Developing the observation operator and related programs to bring the satellite derived wind data into MM5 4-D VAR system. This is also a significant step towards using many inhomogeneous distributed data (not only the wind data, but also the other data types) in the data assimilation system.

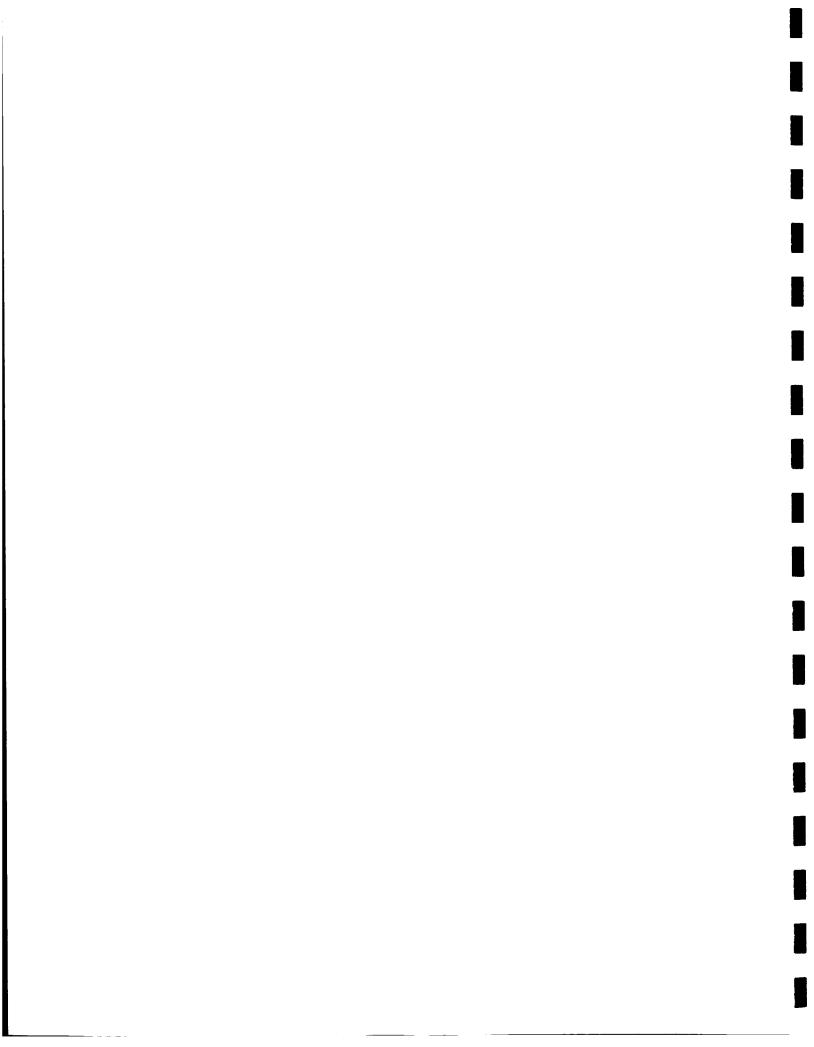Prepared to assimilate TRMM rainfall data into the mesoscale model by the 4-D VAR system. My research continued on evaluation of the bogus vortex techniques with four- dimensional variational data assimilation. Based on our early study, three types of studies have been done .

<u>October 1999 – January 2000</u>

My research continued on evaluation of the bogus vortex techniques with four-dimensional variational data assimilation. Based on our early study, three types of studies have been done during this period:

1) With Hurricane George (1998), efforts continued on testing the impact of different data assimilation strategies for improving initial vortex representation and hurricane forecasts.

2) An additional numerical experiment indicates that a relatively larger vortex size assignment that allows for improved resolution of the vortex on a mesoscale grid leads to a more realistic depiction of the vertical motion field and to significant improvement of the hurricane track forecast.

3) The bogusing methodology was further evaluated by applying it to Hurricane Bonnie (1998) just prior to its rapid intensification. The bogus vortex improves the track and intensity forecasts for Bonnie, but is not quite able to capture the correct rate of deepening. These results stress the need to incorporate additional information from satellites and aircraft. Using all of the results above, I have prepared a draft of the paper, which we plan to submit to *Monthly Weather Review.*

<u>February – June 2000</u>

1. Developed the cost-function program that brings rain rate data into the four-dimensional variational data assimilation.

2. Started the initial experiment for assimilating the TRMM/TMI rain rate into the meso-scale numerical model.

3. Investigated the availability of the TRMM/TMI observations for Hurricane Bonnie and tried to assimilate the surface rainfall data into MM5 model.

4. I have also done some further studies in evaluation of bogusing vortex schemes. A series of four-dimensional data assimilation experiments was done for the Hurricane Bonnie (1998) case. The results were very good.

Participation in Workshops/Conferences/Meetings

- January 9-15, 1999. Attended the AMS 3rd Symposium on Integrated Observing Systems in Dallas, TX. Presented paper: Pu, Z-X., Lord, S., and Kalnay, E. *Forecast Error Sensitivity and Adaptive Observations With Quasi-inverse Linear and Adjoint NCEP Global Models.*

- April 13-14, 1999. Attended the NCEP/NOAA special workshop on The Use of Ensemble Forecasts in Data Assimilation in Camp Springs, MD.

- June 7-11, 1999. Attended the 3rd WMO International Symposium on Assimilation of Observation in Meteorology and Oceanography in Quebec City, Canada. Presented 3 papers: 1) Pu, Z-X., Braun, S., and Tao, W-K. *Four-dimensional Data Assimilation and Numerical Simulation of Hurricanes.* 2) Pu, Z-X., and Kalnay, E. *Examination of the Quasi-inverse Linear Technique in Targeting Weather Observations.* 3) Park, S-K., Kalnay, E., Pu, Z-X. *Applications of the Inverse 3-D VAR Method to Data Assimilation.*

- June 22-25, 1999. Attended the MM5 User's Workshop sponsored by NCAR in Boulder, CO. Presented paper: Pu, Z-X., Braun, S., Tao, W-K. *Four-dimensional Data Assimilation and Numerical Simulation of Hurricane George.*

- July 26-27, 1999. Visited the Chinese Academy of Meteorological Sciences in Beijing and presented an invited lecture entitled *Four-dimensional Variational Data Assimilation: From Theory to Practice.*

- July 28, 1999. Presented an invited seminar entitled *Some Thoughts on Improving the Current Data Assimilation System* at the Chinese Meteorological Administration in Beijing.

- August 23-26, 1999. Attended the NOAA/NASA/NRL workshop on satellite data assimilation at the University of Maryland College Park.

- May 28 – June 4, 2000. Attend the American Meteorological Society's 24th Conference on Hurricanes and Tropical Meteorology in Ft. Lauderdale, FL. Presented paper: Pu, Z-X., and Braun, S. *Evaluation of Bogus Vortex Techniques Using a Four-dimensional Variational Data Assimilation System.*

Publications

Pu, Z-X., and Kalnay, E. (In press). Targeting observation with the quasi-inverse linear and adjoint NCEP global models: performance during FASTEX. *Quarterly Journal of Royal Meteorological Society.*

Kalnay, E., Park, S., Pu, Z-X., and Gao, J. (In press). Application of the quasi-inverse method to accelerate 4-D Var. *Monthly Weather Review.*

USRA EMPLOYEE: DR. JIN-HUA QIAN

Research focus: Development of a regional land-atmosphere climate simulation system to study multi-scale land, cloud and atmospheric radiative interactions.

Accomplishments
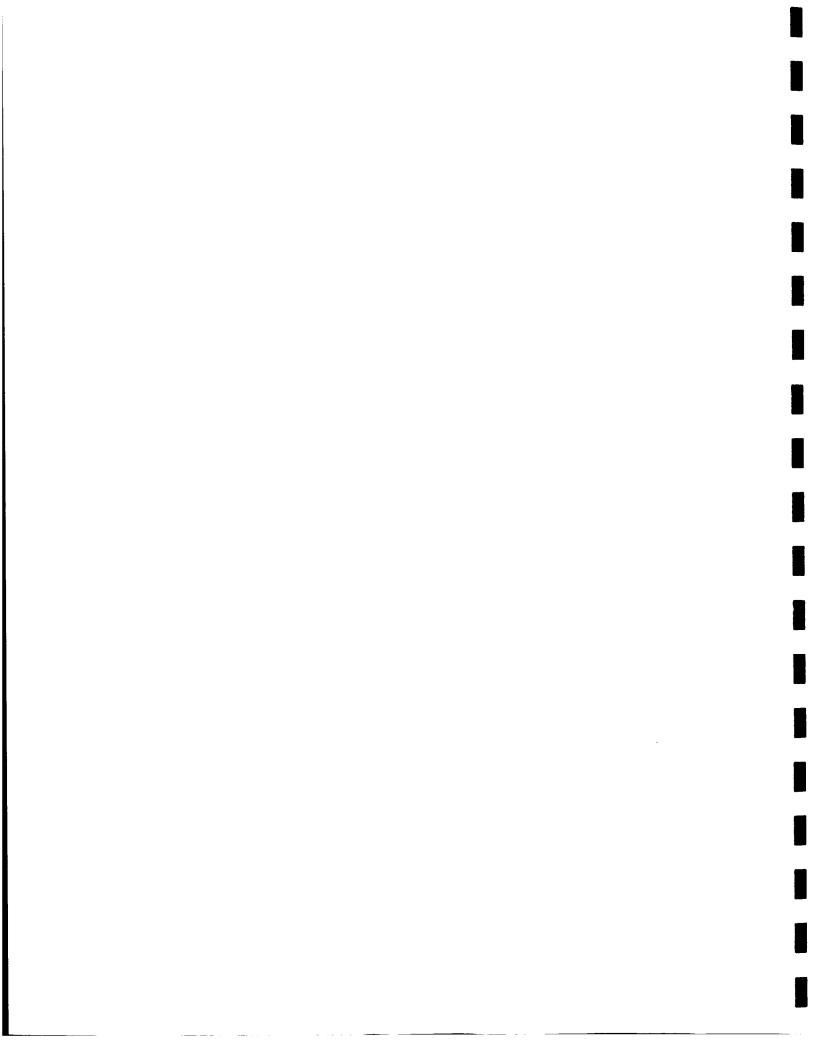
October 1998 – August 1999

I have been working on the NASA/GSFC Regional Land-Atmospheric Climate Simulation System (RELACS) project. My task is the regional climate modeling study on the onset and development of the southeastern Asian summer monsoon. By applying MM5 (NCAR/Penn State University Mesoscale Model Version 5) and the Goddard land-surface model PLACE (Parameterization for Land-Atmosphere-Cloud Exchanges), I have carried out a series of numerical experiments.

The comparison among different experiments revealed that the monsoon modeling results are very sensitive to the lateral boundary and initial conditions. Experiments with the same model domain but different initial times gave very different results. Likewise, the experiments with the same initial time but shifted domain locations also produced very different outputs. This sensitivity problem is critical for regional climate modeling because the error resulting from the imbalance between numerical model and physical reality will be accumulated with time. This suggests that the ensemble forecasting strategy is probably needed to catch the monsoon variability signals impacted by various factors.

Domain size and resolution are also examined for this specific problem. In the double nesting case, if the outer domain is too large, the distorted large scale circulation pattern over the central fine-resolution region will contaminate the transient synoptic and mesoscale features, such as the Mei-Yu front in the Asian summer monsoon case.

Different cumulus parameterization schemes are also tested for the southeastern Asian Monsoon case. For the middle latitude area with medium resolution (45km), the Betts-Miller scheme produces more results. However, the Kain-Fritts scheme gave better results for the resolution of 20km over the land.

On the basis of the above sensitivity studies, we finally chose the best model setup to simulate the South China Sea Monsoon (SCSM) onset and the Mei-Yu front development. The model successfully produced one of the key components of the Southeastern Asian Monsoon system (Mei-Yu front precipitation belt), which caused heavy floods in June 1998 in Southeastern China. The SCSM onset

has also been simulated, featuring the development of low level westerly over the South China Sea and the convective precipitation shift from the Bay of Bengal to the South China Sea. The high-resolution MM5 provided more detailed local circulation, for example, the mesoscale cyclone vortex along the Mei-Yu front, which is missing in the large scale ECMWF real analysis data and most GCM simulations.

The coupled MM5and PLACE simulation has been compared with the MM5 slab-soil model. The coupled version produced more precise precipitation than the MM5 slab-soil version. This implies that land-surface processes are important to model hydrology.

Overall, the regional climate modeling of monsoons with MM5 has succeeded. We have reproduced the major events in the regional monsoon variation and formed the basis for future mechanism analysis. It is also proved that the dynamic downscaling by a nonhydrostatic high-resolution model is feasible.

The Asian monsoon is a very difficult system to simulate. Most GCMs failed to produce monsoon precipitation patterns. We have successfully simulated the fine-resolution monsoon precipitation system with the new approach at GSFC.

September 1999 – February 2000

Monsoonal precipitation study. During this period a case of the torrential precipitation process in the Mei-Yu front, an Asian monsoon system east to the Tibetan Plateau, is studied with a coupled mesoscale atmospheric model MM5 and a land-surface model PLACE (Parameterization for Land-Atmosphere- Cloud Exchange). Local and remote impacts of water vapor on the location and intensity of Mei-Yu precipitation are studied by sensitivity experiments. The precipitation-evaporation interaction acts to shift the Mei-Yu rainbelt to the upstream direction of the moisture flux by about 100km, which can be interpreted by the theory of slantwise vorticity development (SVD) on isentropic surfaces. The water vapor resource for the heavy precipitation is proved from the Bay of Bengal, transported by the southwesterly low level jet (LLJ) southeast to the plateau.

Participation in Workshops/Conferences/Meetings

- June 1999. Attended AMS 8th Mesoscale Conference. Presented poster: Qian, J-H., Giorgi, F., and Tao, W-K. *A Regional Stretched Grid System for Mesoscale Models.*

- September 10-17, 1999. Attended the AMS numerical weather prediction conference in Denver, CO.

- January 10-14, 2000. Attended AMS 15th Conference in Hydrology in Long Beach, CA. Gave presentation entitled *On Mei-Yu Precipitation Precipitation Processes--Case Study of 1998 Yangtze River Flood with MM5 and PLACE.*

USRA EMPLOYEE: DR. ANIL RAO

Research focus: Application of satellite data in studies of atmospheric precipitation systems.

Accomplishments

October 1998 – August 1999

The requirements and expectations of my position are to acquire and analyze geostationary satellite data that will be used in numerical simulations (MM5) of tropical cyclones. To accomplish this, I obtained GOES water vapor (WV), infrared (IR), visible (VIS) imagery for the several cyclones that will be simulated. In addition, I acquired GOES WV, IR, and VIS winds along with full thermodynamic

retrievals from researchers at the University of Wisconsin. To better display, manipulate, and analyze the data, the McIDAS software package was installed on a Code 912 computer. This software is now available to all Code 912 researchers.

I performed an in-depth comparison between the GOES quantitative data (i.e., winds and retrievals) and ECMWF model analyses. The comparison led to the calculation of GOES error characteristics that are necessary for the 4-D variational assimilation of the satellite data into MM5. The satellite data and their corresponding error calculations were provided to the researchers.

In conjunction with calculating the error characteristics described above, I investigated better uses for the data. Specifically, statistics between the GOES winds and entire vertical profiles of the ECMWF data were determined under the assumption that the final GOES winds actually represent a layer averaged value, rather than a specific level. (They are distributed and typically used as level data.) The statistics showed a well-defined signature over a relatively broad layer. In addition, after stratifying the data into specific categories (e.g., low vs. high shear, low vs. high humidity, etc.), more unique vertical distributions of errors were seen. The above suggests that it may be possible to assimilate the GOES winds as layers profiles, rather than level values. This will be tested as the research progresses.

September 1999 – January 2000

I continued evaluating GOES satellite data. More specifically, I compared GOES-water vapor tracked winds with collocated radisonde data to determine their characteristics and tendencies. It was found that the winds represent finite layers in the atmosphere rather than specific levels. In addition, by stratifying the collected pairs into various categories, it was determined that the moisture gradient structure and vertical wind shear are critical in characterizing the depth of the sensed layer (i.e., whether or not the satellite wind represents a single level or layer). This is important not only to increase our knowledge of these data, but also to determine its best use in numerical weather prediction.
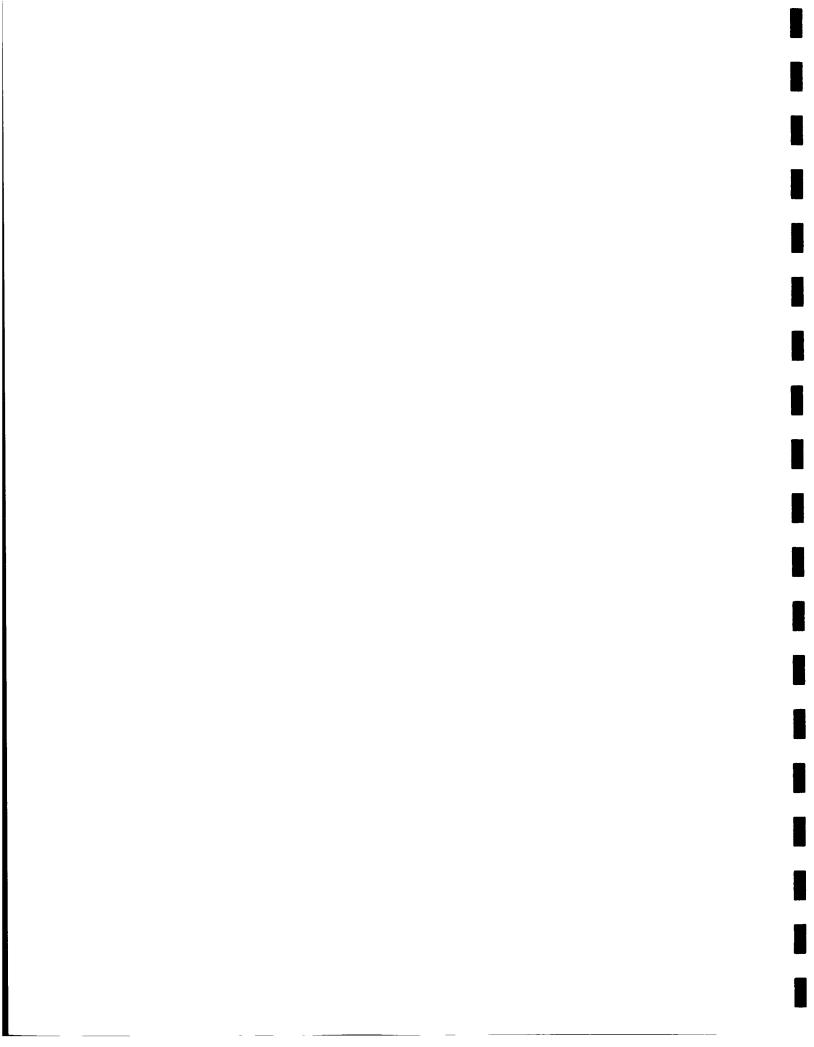
This work was done in collaboration with Dr. Chris Velden of the University of Wisconsin. Dr. Velden is the foremost expert on GOES satellite-derived winds, and he has proven critical to this work. Dr. Velden and I have worked very closely on the methodology of this project and in the interpretation of results. To help facilitate this work, Dr. Velden has been providing the operational GOES-8 and –10 satellite winds at 3 hour intervals.

I presented this research in poster format (co-authored by Drs. Velden, Scott Braun, and Zhao-Xia Pu) at the 10th Conference on Satellite Meteorology and Oceanography (held in Long Beach, CA in January). During the conference, Dr. Velden and I met to discuss the work and to lay out our next course of action. In addition, many other researchers voiced their interest in this work. The feedback provided by these researchers made attending the conference very worthwhile.

The next phase of this research is to investigate the impact of the GOES satellite data in numerical weather prediction. More specifically, I will determine the impact of GOES water vapor winds used in a traditional sense (as single level values) on the evolution and structure of an eastern Pacific storm. (An ocean system was chosen to maximize the chance of satellite data impact.) Then, based on the research previously described, the winds bill be assimilated as "layers", (i.e., will be vertically distributed by adjusting the vertical weighting parameter in the model assimilation package). These results will then be evaluated and compared to the previous experiments. The MM5 model will be used for this research. Its assimilation package has been modified to input the satellite winds as desired. A storm that occurred during late January 2000 has been chosen for study due to the interesting evolution o the storm, the location of the storm, and the coverage of the GOES data. Model simulations will begin within the next few weeks.

February – June 2000

I continued evaluating GOES satellite data. Previously, I compared GOES derived winds with collocated radiosondes to determine their characteristics and tendencies. It was determined that the wind data actually represent layers (rather than single levels) of varying depth. The thickness of the layers was dependent on vertical moisture gradients both above and below the level of the wind.

The above conclusions have now been tested in MM5 simulations of mid-latitude storms. Specifically, several MM5 runs were made, each using the satellite data in a different manner. The runs performed were as follows:

1. Control run--no satellite data.
2. Using all wind data at 1 level.
3. Using all wind data at multiple levels.
4. Based on the comparisons discussed above, the satellite data was used at either 1 or multiple levels.

It was determined that run #4 performed best in both storm track and intensity. Although the improvements were modest, this research demonstrates that satellite winds can be used in a more realistic manner than done currently.

GOES precipitable water (PW) also was tested in both mid-latitude storms as well as tropical cyclones. The PW data was found to have NO effect on the simulation of a hurricane. This is most likely due to the lack of PW data near the storm center where the most important physics are occurring.

In the mid-latitude case, the PW drastically improved the track of the storm, but overall statistics were actually degraded. Thus, it seems that the PW created the right answer for the wrong reasons. The effect of the PW is still being investigated.

July – September 2000

During this period I initiated a collaboration with Dr. Jenni Evans of Pennsylvania State University. We are in the process of formulating a plan to utilize GOES data in numerical simulations of tropical cyclones. We plan to test different assimilation techniques and their ability to simulate tropical systems.

Participation In Workshops/Conferences/Meetings

• August 23-25, 1999. Attended Workshop on Satellite Data Assimilation held at the University of Maryland College Park.

• January 9-14, 2000. Attended AMS 10th Conference on Satellite Meteorology and Oceanography in Long Beach, CA. Presented a poster co-authored by Dr. Chris Velden, Scott Braun, and Zhao-Xia Pu.

Publications

Rao, P. A., Fuelberg, H. E., and Droegemeier, K. K. (1999). High-resolution modeling of the Cape Canaveral area land-water circulations and associated features. *Mon. Wea. Rev., 127,* 1808-1821.

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TASK 912-12: Microwave Remote Sensing

TASK DESCRIPTION

This task requirement the development of techniques leading to the retrieval of precipitation and latent heating profiles from passive microwave sensors. The contractor was to develop and evaluate algorithms for EOS and TRMM microwave remote sensing of precipitation as well as develop radiative transfer modeling software for comparison with observations.

Consultant: **Nicolas Viltard**
Purpose: Continue scientific research on climate and the hydrologic cycle (10/198-1/31/99)

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TASK 912-13: Precipitation Studies

TASK DESCRIPTION

This task required research that focused on the retrieval of precipitation information from satellites and the use of that information to study atmospheric convective systems on time scales from instantaneous to monthly. The researchers were to endeavor to develop and apply techniques to combine information from low-orbit passive microwave data and geosynchronous infrared data to produce improved precipitation estimates. The results were to be applied to studies of convective systems over tropical oceans and tropical and mid-latitude land areas to determine system evolution and other characteristics, diurnal variations, and climatologies.

USRA EMPLOYEE: DR. EMMANOUIL ANAGNOSTOU

Research focus: Satellite precipitation estimation studies.

Accomplishments

October 1998 – January 1999

I've worked on a technique for quantifying nonlinear adjustments to the half-degree monthly rainfall estimates over land, derived from the Special Sensor Microwave/Imager (SSM/I) observations. The technique utilizes a function of the distortion between the probability distributions of SSM/I and raingauge rainfall, estimated using maximum likelihood. The proposed adjustment procedure is assessed and evaluated on a ten-year period (1988-1997) of SSM/I observations over the northern region of South America that includes the Amazon Basin.

The rain estimates are derived from NASA's Goddard PROFiling (GPROF) algorithm instantaneous rain-rate retrievals, averaged in half degree areas and aggregated into monthly accumulations. Monthly rain accumulations from a network of 650 rain gauges distributed across the Amazon Basin and the state of Ceara in northeast Brazil are used for calibration and validation respectively. Assessment of the adjustment relationship on the validation data set shows an overall 45% GPROF-gauge root-mean-square (RMS) difference reduction with respect to no adjustment, which is mainly due to elimination of the mean bias, and a respective 10% increase in GPROF-gauge correlation. The RMS difference between 5 degree grid box monthly rain averages of adjusted GPROF and rain gauges is 23% of the mean rain, and the corresponding correlation coefficient is 0.94.

Participation in Workshops/Conferences/Meetings

• November 15-19, 1999. Participated in the annual TRMM Science Team Meeting in Pasadena, CA.

Publications:

Anagnostou, E. N., Krajewski, W. F., Seo, D-J., and Johnson, E. R. (1998). Mean-field rainfall bias studies for WSR-88D. *Jr. Hydro. Eng.*, 149-159.

Anagnostou, E. N., Krajewski, W. F., and Smith, J. (1998). Uncertainty quantification of mean-field radar-rainfall estimates. *Jr. Atmos. and Oceanic Tech.*

Anagnostou, E. N., and Krajewski, W. F. (1998). Calibration of the WSR-88D precipitation processing subsystem. *Weather and Forecasting, 13,* 396-406.

Anagnostou, E. N., and Krajewski, W. F. (1998). Real-time radar rainfall estimation: 1. Algorithm formulation. *Jr. Atmos. and Oceanic Tech.*

Anagnostou, E. N., and Krajewski, W. F. (1998). Real-time radar rainfall estimation: 2. Case study. *Jr. Atmos. and Oceanic Tech.*

CONSULTANTS/VISITORS

Consultant: **Arlene Laing** (University of South Florida)
Purpose: Participate in scientific discussions on rainfall variability, storm tracks, and monsoonal circulations in the tropical Interamericas (6/1-7/9/99)
Discussions on rainfall, variability, storm tracks and monsonal circulations (7/12-23/99)

Visitor: **Tristan L'Ecuyer** (Colorado State University)
Collaborator: Chris Kummerow
Purpose: Collaborate on rainfall estimation (7/28-30/99)

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TASK 912-15: Airborne Radar

TASK DESCRIPTION

Contractor was to conduct research with measurements from the ER-2 Doppler Radar (EDOP) in support of the Tropical Rain Measuring Mission. Analyze the EDOP reflectivity measurements and the problems associated with attenuation. Contractor was also to evaluate various retrieval approaches and improve rain rate estimates.

USRA EMPLOYEE: DR. LIN TIAN

Research focus: Calibration and algorithm development for dual Doppler and airborne precipitation studies.

Accomplishments

October – December 1998

The surface echo from the DOP nadir and forward beams in the cloud-free region was processed for 8 cases over land and 11 cases over oceans. These cases were selected from April 15 and 18, May 4, August 4 and 8, and September 13 and 22, 1998, during TEFLUN-A, CAMEX-3, and TEFLUN-B field campaigns. The statistics from the ocean surface echo were compared with those from dry land. The data showed that the surface echo at nadir incidence has rather small fluctuations of ± 1 dB, while the echo at 33 degree incidence were more variable, having a standard deviation of ± 2 dB.

The situation is very different over land in that the nadir echo becomes highly variable with a standard deviation of ± 4 dB. However, it is clear that the surface echo over land for the forward beam shows a

very similar distribution, a standard deviation of ± 2 dB, to that over open ocean. The importance of these results to the surface reference technique is that variability of the surface echo along the flight track limits the minimum path integrated attenuation that can be observed. And while the observations in the nadir direction are degraded over land, there is the potential that non-nadir incidence angles may provide as good an estimate of PIA over land as they do over the ocean.

January – September 1999

I provided support for an LBA field campaign in Brazil in February. Support activities included analysis and plotting of flight observations and archiving of the data.

I processed all EDOP data from three field campaigns: TEFLUN-A, TEFLUN-B, CAMEX-3, and LBA. The processing of the raw binary file included converting raw power to reflectivity, surface echo detection, correcting for surface leakage, removing aircraft motion from Doppler velocity, and unfolding and converting to Universal Format.

I examined the surface observations from the TRMM field campaigns (TEFLUN-B and Brazil). Under the rain-free conditions, the statistics of the ocean surface echo were compared to those on land. The results showed that while the observations in the nadir direction are highly variable over land, at a 33 degree incidence angle, the variability in the surface return decreased significantly. The situation was reversed over the ocean where the surface return at nadir incidence was more stable than that at a 33 degree incidence. These findings suggest that a combination of nadir and off-nadir observation should be used to obtain the accurate estimate of the PIA. The results also suggest that values of PIA larger than 2 dB at 3 cm can be accurately estimated over land and ocean surfaces.

October 1999 – June 2000

Observations on a deep convective storm in the Amazon showed a very large path integrated attenuation of 30 dB. Such attenuation can not be explained using reflectivity observed in the same storm by an S-band ground-based radar and an empirical relationship between an attenuation coefficient and reflectivity. I have been trying to explain the observed attenuation in terms of non-typical raindrop size distribution, wet hail, non-spherical particles, and cloud attenuation. I use auxiliary data from ground-based S-band polarimetric radar and drop size distribution from the ground network.

I analyzed reflectivity and differential reflectivity observed from an S-band ground based radar to examine the drop size distribution in the storm. I performed some calculations to study the effect of a large number of smaller drops on the attenuation.

I conducted research on the effect of raindrop size distribution and melting ice particles on X-band attenuation observed by ER-2 airborne Doppler radar (EDOP).

I studied the role of melting ice particles in attenuation using reflectivity, Doppler velocity, and linear depolarization from EDOP.

Participation In Workshops/Conferences/Meetings

- November 16-18, 1998. Attended the TRMM Science Team meeting at the California Institute of Technology's Beckman Institute in Pasadena, CA.

- November 20, 1998. Met with Prof. Ramesh Srivastava at the University of Chicago to discuss research on using EDOP data to examine the characteristics of the melting band.

- February 1-23, 1999. Participated in the LBA field experiment in Brasillia, Brazil.

- July 11-17, 1999. Attended the American Meteorological Society's 29th International Conference on Radar Meteorology in Montreal, Quebec, Canada. Presented 2 papers and a poster: 1) Tian, L., Heymsfield, G. M., and Bidwell, S. *Potential Application of the Surface Reference Technique Over*

Land at Large Incidence Angle; 2) Heymsfield, G. M., Tian, L., and Geerts, B. *Rain Fallspeed and Rates Derived from Airborne Nadir-pointing Doppler Radar Measurements;* 3) Geerts, B., Heymsfield, G. M., and Tian, L. *High Resolution Reflectivity Profiles in Various Convectively Generated Precipitation Systems.*

- October 25-29, 1999. Attended TRMM science meeting at the University of Maryland College Park.

- May 22-26, 2000. Attended the TRMM field campaign data workshop in Salt Lake City, UT.

- August 12-21, 2000. Attended the International Conference on Cloud and Precipitation in Reno, NV.

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TASK 912-16: Techniques for Remote Sensing of Atmospheric Wind Profiles

TASK DESCRIPTION

This task required the development of techniques for the remote sensing of atmospheric wind profiles using the Double-edge molecular lidar method. The contractor was also expect to be available for consultations, perform numerical simulations, participate in technology demonstrations, and assist the principal investigator in the analysis of instrument design and performance. Results were to be reported in scientific literature and through interim and final reports.

CONSULTANTS/VISITORS

Consultant: **Daniela Fua** (Universia "La Sapienza")
Purpose: Collaborate with NASA scientists on the development of doppler lidar techniques, to include technical consulting, development of simulations, participation in technology demonstrations, and analysis of instrument design and performance (10/1/98-9/30/99)

Consultant: **Alexander Khain** (Hebrew University of Jerusalem, Israel)
Purpose: Conduct research on the numerical cloud model and the Goddard Cumulus Ensemble (GCE) model (7/22-8/31/99)

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TASK 912-17: Rainfall and Latent Heat Structure

TASK DESCRIPTION

This task required the contractor to do the following: support the TRMM Project Scientist in the visualization of scientific data sets; assist in the archiving of TRMM products and imagery; and generate products from the TRMM multi-spectral dataset for use by the Public Affairs Office and by the electronic and print media.

CONSULTANTS/VISITORS

Consultant: **Carlos Morales**
Purpose: Analytical research on data from a VLF lightning monitoring network in support of the TRMM program (10/1/98-3/31/99)
Work with members of the Mesoscale Atmospheric Processes Branch on conducting research on data from a VLF lightning monitoring network (4/1/99-6/30/00)
Attend the TRMM science team meeting in Pasadena, CA (11/14-20/98)
Attend the LBA/TRMM Meeting in Sao Paolo, Brazil (10/1-5/99)
Attend the Brazilian Meteorological Conference, South American Meteorological Symposium in Brazil (10/24-11/24/99)
Participate in the TRMM-LBA field Campaign in Ji Paranana, Brazil (2/1-3/1/00)

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TASK 912-18: Rainfall Data Assimilation

TASK DESCRIPTION

This task had two major components:
1) Produce global 3 hourly IR rainfall estimates at a resolution of 2.0 x 2.5 degrees for data assimilation purposes with involved the following:
    - Reading and extracting IR data from ISCCP tapes;
    - Mapping IR data to rectilinear lat/lon projection (1/4 degree resolution)
    - Correcting geostationary limb cooling effect;
    - Deriving monthly GPI totals from the mapped data;
    - Generating GPI/GPCP ratio for monthly totals; and
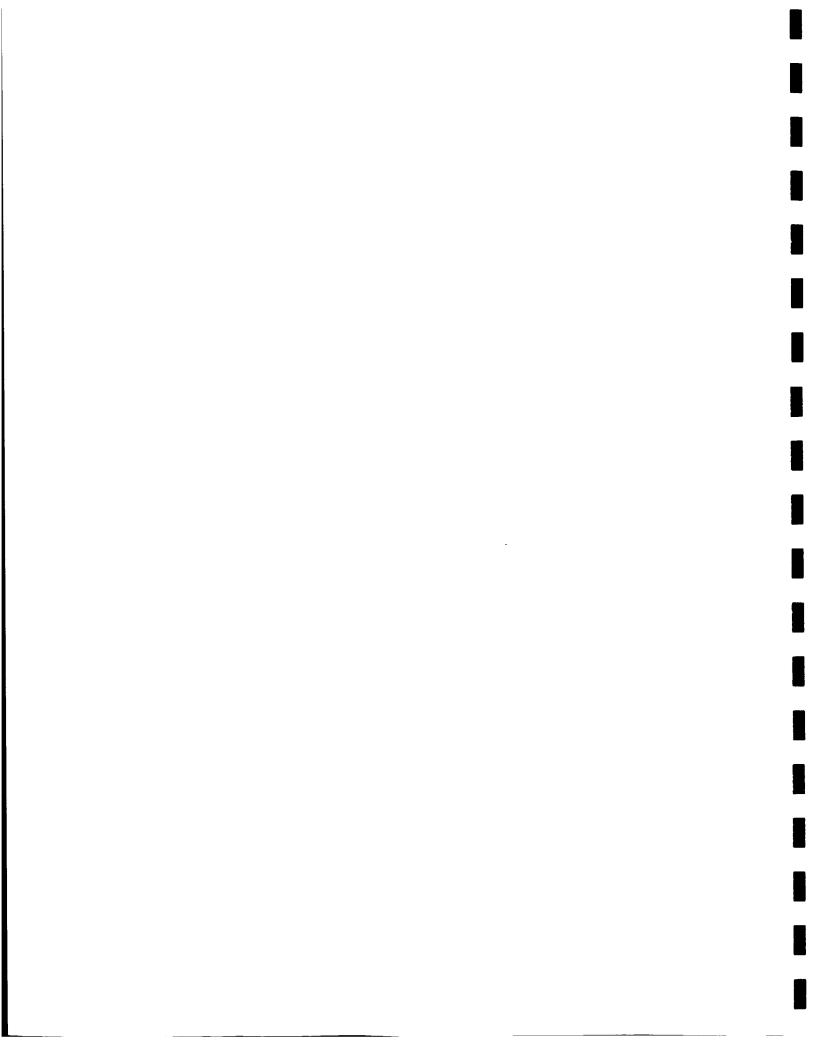   - Applying the ratios and GPI algorithms to the 3 hourly IR data.

2) The Tropical Rainfall Measuring Mission (TRMM), launched in November 1997, carries the TRMM Microwave Imager (TMI) and the Precipitation Radar (PR). A more comprehensive study of the utilization of the 85 GHz for over-land-rainfall-estimation can now be made, using the PR data as 'truth". The contractor was expected to do the following:
    - Data and software preparation: choose case studies, write software for extraction and comparison of data sets;
    - Investigate the delineation of rainfall by the 85 GHz for a variety of scenarios;
    - Estimate rainfall using the 85 GHz channels paying particular attention to the saturation of the rainfall signature by ice particles.

CONSULTANTS/VISITORS

Consultant: **Christopher Kidd** on a subcontract through the University of Birmingham, United Kingdom (10/1/98 – 3/31/00)

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TASK 912-19: EOS AM-1 Visualization

TASK DESCRIPTION

This task required the contractor to provide support to the EOS AM-1 program in the visualization of scientific data sets. Contractor was to generate visualization products from EOS and other multi-spectral data, and of the satellite itself video products, quick-time digital animations of high-end graphical images used for network television release and high-level NASA presentations and on NASA web sites.

CONSULTANTS/VISITORS

Consultant: **Reto Stockli**
Purpose: Collaborate with Dr. Fritz Hasler and other NASA GSFC scientists on visualization of scientific data related to the EOS-AM-1 program (12/1/98-3/31/00)

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TASK 912-20: Satellite Estimates of Global Air-Sea Fluxes

TASK DESCRIPTION

This task had two focuses: 1) Production and analysis of satellite-based surface heat budgets and wind stresses measurements over global oceans and intercomparison with results from atmospheric general circulation models, emphasizing intraseasonal to interannual variability; and 2) Impact of satellite-based surface fluxes on ocean response in relation to El-Niño/Southern Oscillation prediction.

USRA EMPLOYEE: JOSE HERNANDEZ

Research focus: Studies of satellite-derived oceanic wind stress and heat budgets in relation to GCM simulations.
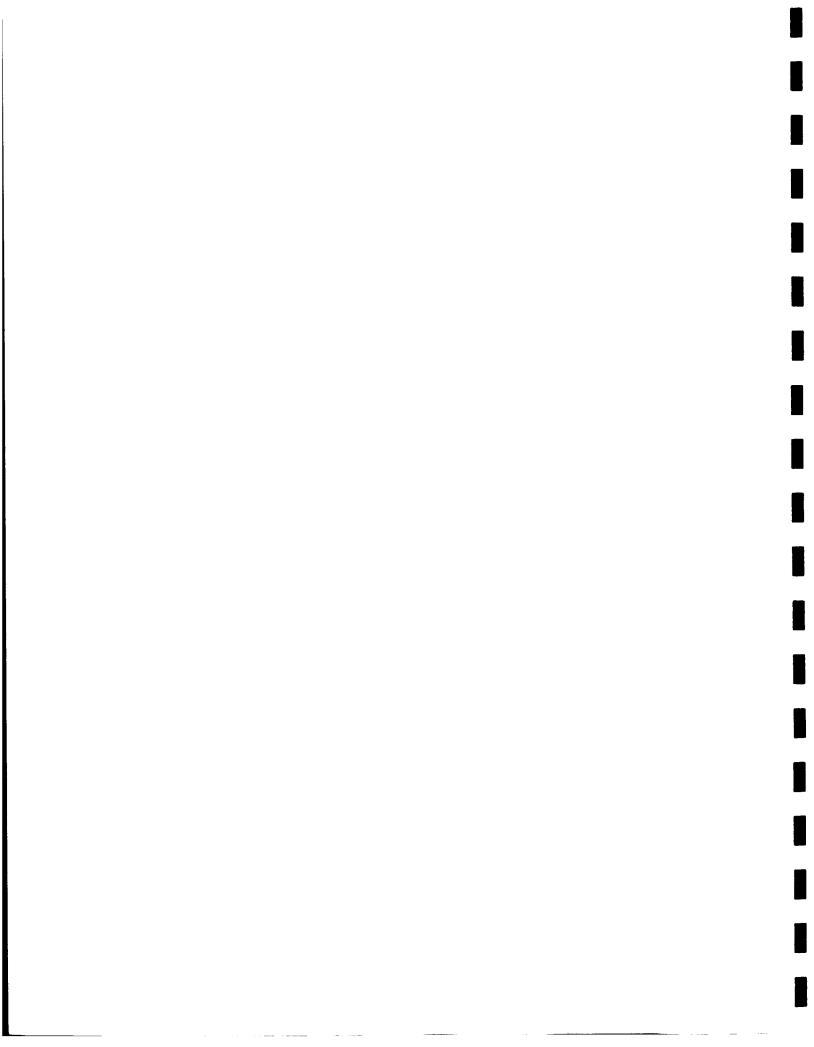
Accomplishments

February – June 2000

I collaborated in the processing of data and produced about 100 of plots for Dr. Sue Chou on global climate parameters and energy fluxes. This data come from 1988-1994 SSMI satellite data and 1990-93 COADS data. At a request from Dr. Chou, I prepared a report of plots and programs that I used to carry out this work.

I collaborated in processing data and producing plots of greenhouse gases and their global ocean-atmosphere exchange in collaboration with Dr. David Erickson.

Participation in Conferences/Workshops/Meetings

- June 5-8, 2000. Attended 4th International Symposium on Gas Transfer at Water Surfaces. Presented a paper: Erickson, D., and Hernandez, J. L. *A Global, High Resolution, Satellite-based Global Model of Air-Sea Trace Gas Flux.*

Publications

Erickson, D., and Hernandez, J. L. (2000). A global, high resolution, satellite-based global model of air-sea trace gas flux. *AGU Geophysical Monograph Series*.

Hernandez, J. L., Erickson, D., Capella, J., Morell, J., Bauza, J., and Corredor, J. (2000). Nitrous oxide air-sea exchange in the Caribbean Sea and the adjacent Atlantic Ocean. Submitted to *JGR-Oceans*.

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TASK 912-21: Satellite Estimates of Global Air-Sea Fluxes

TASK DESCRIPTION

The focus of this task was two-fold: 1) production and analysis of satellite-based surface heat budgets and wind measurements over global oceans and intercomparison with resultsfrom atmospheric general circulation models, emphasizing intraseasonal to interannual variability; and 2) impact of satellite-based surface fluxes on ocean response in relation to El Niño/Southern Oscillation prediction.

CONSULTANTS/VISITORS

Consultant: **Carlos Morales** (University of Connecticut)
Purpose: esearch on data from the VLF lightning monitoring network (8/21-9/30/00)

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TASK 913-01: Visiting Scientists for Cloud, Radiation, and Climate Research

TASK DESCRIPTION

The objective of this task was to support short-term visits by scientists who would collaborate on research involving clouds, radiation, and climate to do the following:
- Develop and validate remote sensing techniques for estimation of radiational, sensible, and latent heat fluxes at the Earth's surface;
- Study the effect of cloud-radiation-dynamics feedback using cumulus ensemble models and GCM and satellite data products;
- Provide expertise in numerical modeling of the regional and global distribution of clouds and water vapor in relation to the global hydrologic cycle.

CONSULTANTS/VISITORS

Consultant: **yu-Tae Lee** (National Kangnung University, South Korea)
Collaborator: Ming-Dah Chou
Purpose: Cnduct research on radiation and cloud related climate studies (1/7-2/22/99)
Work with Dr. Ming-Dah Chou to develop parameterizations for clouds and radiation (7/7-8/21/99)

Consultant: **Suhasini Ravipati**
Purpose: Collaborate with Dr. Thomas Bell on extending the "PMV" statistical method for decomposing time-varying histogram of data into a few fixed distributions (2/1-4/15/99)

Visitor: **J. Ray Bates** (University of Copenhagen, Denmark)
Collaborator: Yogesh Sud
Purpose: Present a seminar on the topic of climate modeling and climate feedbacks (1/27-30/00)

Visitor: **Reinout Boers** (CSIRO Division of Atmospheric Research, Australia)
Collaborator: Robert Cahalan
Purpose: Present seminar on Ground-based remote sensing of cloud microphysics (8/22-24/99)

Visitor: **Jen-Cheng Chang** (Central Weather Bureau, Taiwan)
Collaborator: Chung-Hsiung Sui
Purpose: Participate in discussions about seasonal to interannual climate prediction and the best uses of GMS-II data (6/27-29/99)

Visitor: **Roger Davies** (University of Arizona)
Originator: Lorraine Remer
Purpose: Present a seminar on the impact of cloud radiative forcing on climate

Visitor: **Chang-Hoi Ho** (Seoul National University, South Korea)
Purpose: Develop an ocean mixed-layer model to be coupled to Goddard atmospheric general circulation model (1/18-2/26/99)

Visitor: **Christian Jakob** (ECMWF, England)
Purpose: Present seminar on cloud-radiation parameterization (10/5/98)

Visitor: **Raghunath Jha** (University of Tokyo, Japan)
Purpose: Collaborative research on regional climate modeling/MM5 Place model at GSFC (10/25-11/27/98)

Visitor: **Kwang-Yul Kim** Florida State University)
Originator: Yogesh Sud
Purpose: Present a seminar on climate system research (3/29-31/00)

Visitor: **Zhanqing Li** (Canada Center for Remote Sensing, Canada)
Collaborator: Ping Yang
Purpose: Present a seminar on radiative transfer (4/6-8/99)

Visitor: **Xin-Zhong Liang** (University of Illinois)
Collaborator: Lorraine Remer
Purpose: Present a seminar entitled *Midwest Seasonal-Interannual Climate Predictability* (4/24-28/00)

Visitor: **Po-Hsiung Lin** (National Taiwan University, Taiwan)
Collaborator: Ming-Dah Chou
Purpose: Analysis of Japanese Geostationary Meteorological satellite (6/30-8/2/99)

Visitor: **W. Tim Liu** (Jet Propulsion Laboratory)
Collaborator: Ping Ping Yang
Purpose: Present a seminar entitled *Application of NSCAT Data* (2/9-10/99)

Visitor: **Rodger Marchand** (Pennsylvania State University)
Collaborator: Warren Wiscombe
Purpose: Participate in discussion about the Triana Satellite Project (5/9-10/99)

Visitor: **Andy Moore** (University of Colorado)
Collaborator: Ping Ping Yang
Purpose: Present a seminar to the Climate and Radiation Branch on ENSO & intraseasonal variability (2/2-4/99)

Visitor: **Taikan Oki** (University of Tokyo, Japan)
Purpose: Collaborative research on climate modeling/MM5-Place model (10/25-11/26/98)

Visitor: **Klaus Pfeilsticker** (NOAA)
Collaborator: Lorraine Remer
Purpose: Present a seminar entitled *Recent observations on 3D effects of clouds on radiative transfer* (11/9-11/99)

Visitor: **Samuel Shen** (University of Alberta, Canada)
Collaborator: Ping Ping Yang
Purpose: Present a seminar on climate downscaling problems (3/2-4/99)

Visitor: **Georgiy Stenchikov** (Rutgers University)
Collaborator: Lorraine Remer
Purpose: Present a seminar entitled *GCM Simulation of Climate Impact of the 1991 Mt. Pinatubo Eruption* (2/22-24/00)

Visitor: **Ina Tegen** (Columbia University)
Purpose: Present a seminar to the Climate and Radiation Branch (11/3/98)

Visitor: **Jun-ichi Yano** (New York University)
Collaborator: Ping Yang
Purpose: Present a seminar entitled *Aspects of the Tropical Atmosphere Dynamics* (3/8-9/99)

Visitor: **Chidong Zhang** (University of Miami)
Collaborator: Lorraine Remer
Purpose: Present seminar on tropical dynamical and thermodynamical meteorology (5/8-12/00)

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TASK 913-05: Special Sensor Microwave Imager

TASK DESCRIPTION

The objective of this task was to develop theoretical techniques involving microwave radiative transfer to analyze the data from the Special Sensor Microwave Imager (SSM/I) to derive rain rate over land and ocean. Based on statistical models of the rain rate distribution in the field of view, simulate weighted mean brightness temperature and rainfall rate which can be applied to the satellite rain sending.

CONSULTANTS/VISITORS

Consultant: **Guiseppe Dalu**
Purpose: Discussion regarding theoretical techniques involving microwave radiative transfer used to analyze data from Special Sensor Microwave/Imager (11/2-16/98)

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TASK 913-09: Visiting Scientists for Radiation and Climate Research
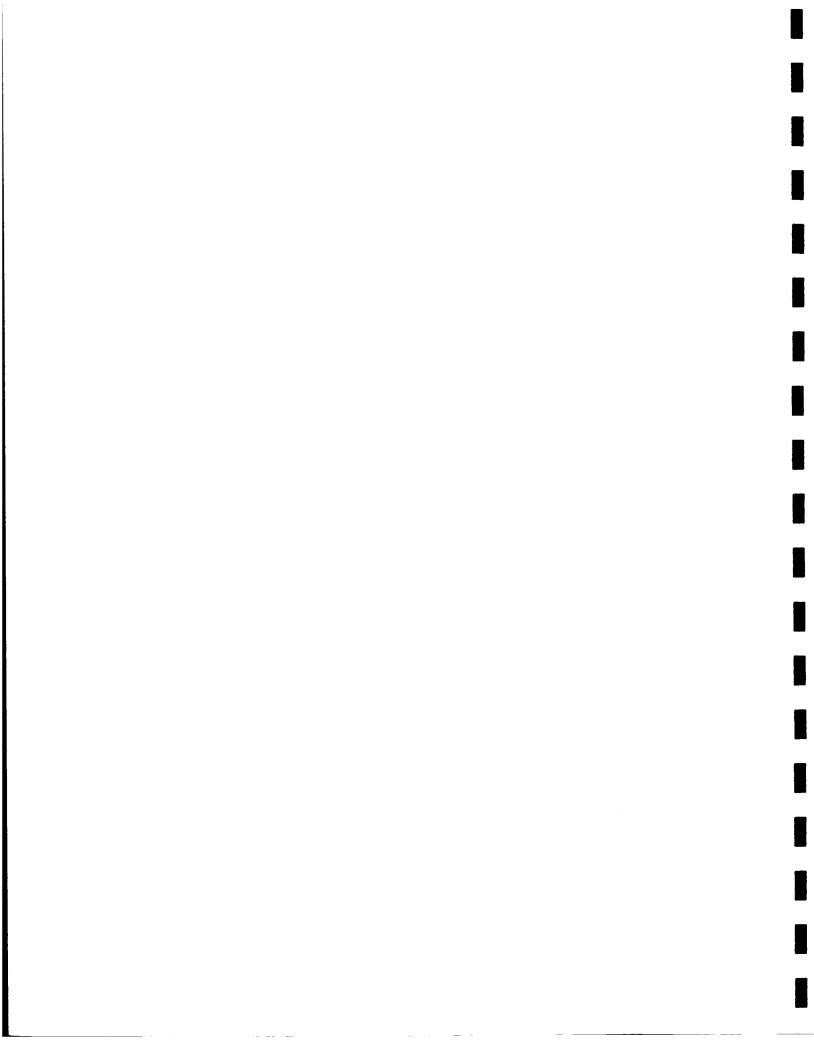
TASK DESCRIPTION

The objective of this task was to support short-term visiting scientists for the purpose of collaboration on research involving radiation and climate. Specifically the visitors were to participate in the development of algorithms for remote sensing of aerosol, water vapor, and fires from space. In order to do so, data from the SCAR, TARFOX, Israeli Desert transition Zone Experiment and the EOS Rapid Response to Mexican Biomass Burning was to be analyzed for validation of current algorithms, confirmation of spectral surface properties, and deviation of aerosol properties, especially aerosol absorbation and single scattering albedo. Existing data, both collected in field campaigns and publicly available data sets, such as satellite archives and assimilated data, were to be analyzed to better quantify the climate forcing of the different aerosol types.

CONSULTANTS/VISITORS

Consultant: **Zev Levin** (Institute for Atmospheric Physics, Switzerland)
Purpose: Study the morphology of clouds in the southern Atlantic and their susceptibility to aerosol effect (8/15-9/30/99)

Consultant: **Ismail Sabbah** (Faculty of Education, Kuwait)
Purpose: Acquiring aerosol data of Egypt and Kuwait in a joint program needed by EOS (12/1-15/98)
Analysis of data acquired with the microtops sun photometer in the Middle East (8/8-16/99)

Consultant: **Didier Tanre** (Laboratoire d'Optique Atmospheres, France)
Purpose: Collaborate with Climate and Radiation Branch on research involving clouds, radiation, and climate (10/1/98-6/30/99)

Visitor: **Louis Gonzales Alvarez** (Centre National D'Etude Scientifique, France)
Purpose: Analyze software development for MODIS/PARASOL comparison (7/17-29/00)

Visitor: **Amon Karnieli** (Ben Gurion University of the Negev, Israel)
Purpose: Review surface reflectance data collected in Israel (7/14-27/99)

Visitor: **Jose V. Martins** (University of Sao Paolo, Brazil)
Purpose: Analysis and paper on AVIRIS data , analysis of data from aerosols and gases emitted by biomass burning in Brazil and Indonesia (8/18-20/99)

Visitor: **Paulo Artaxo Netto** (Universidade de Sao Paulo, Brazil)
Purpose: Research on remote sensing of aerosols (4/16-22/00)

Visitor: **Aline Procopio** (Federal University of Rio de Janeiro, Brazil)
Purpose: Research on the indirect effect of aerosols on clouds using NASA datasets (10/1/99-12/31/99)

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TASK 913-14: Visiting Scientists for Cloud Research

TASK DESCRIPTION

This task served as a vehicle for short-term visiting scientists in conjunction with Dr. Si-Chee Tsay's research and for the purpose of collaboration on research involving aerosols, clouds, surface features, radiation, and remote sensing, utilizing graduate students, Ph.D. candidates, and post-doctoral fellows. In particular, these visitors were to be involved in the following:
- Analysis of radiative fluxes measured at the surface during the Intensive Observing period of the South China Monsoon Experiment; and
- Retrieval of surface radiation budgets using Japan's Geostationary Meteorological Satellite radiance measurements.

CONSULTANTS/VISITORS

Consultant: **Rumen Dimitrov** (George Washington University)
Purpose: Continue to process data acquired from the Aeorsol Recirculation and Rainfall Experiment (8/19-31/99)
Develop co-registration algorithms for the next generation Earth-Observing Imagers Particularly working with the LEISA and VIFIS data (12/1/99-5/31/00)

Visitor: **Jeffrey Reid** (SPAWARSYSCEN SAN DIEGO)
Purpose: Collaborative data analysis of EOPACE/DUCK'99, preparation of paper (5/5-6/4/99)

Visitor: **Norm Wood** (NOAA/CMDL)
Purpose: Discussions about broad band radiometers (3/7-10/00)

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TASK 913-16: Research on Physics of Cirrus Clouds

TASK DESCRIPTION

The purpose of this task was to provide support for the conduct of research on the physics of cirrus clouds at NASA Goddard Space Flight Center through a postdoctoral position. The funding project was particularly concerned about the effects of aerosols on the microphysical and other properties of cirrus clouds, including cloud radiative properties and effects. The goal was to develop and implement an explicit, size-resolved, microphysical scheme accounting for nucleation and ice particle growth processes in cirrus clouds for incorporation into an existing multi-dimensional high-resolution cloud dynamics model. This numerical model was then to be used to investigate aerosol effects on cirrus clouds in conjunction with analysis of various field observations. Corresponding improvements of the radiation components of the model consistent with the newly developed microphysical sophistication was also required. Besides the model development, implementation and documentation aspects, this task was expected to make substantial contributions to the development of scientific papers and communication of the results of scientific meetings.

USRA EMPLOYEE: DR. RUEI-FONG LIN

Research focus: Numerical modeling of cirrus cloud development, microphysics, and radiative effects.

Accomplishments

October – December 1998

Wrote a code that uses a steady state axial symmetric model to simulate near-field contrails.

Performed the warm and cold unstable case studies for GCSS WG2 Idealized Cirrus Model Comparison Project.

Am actively involved in designing and organizing the GCSS WG2 Parcel Model Comparison Project.

January – September 1999

Cirrus model. A parcel version and an axis symmetric version were developed. I reconstructed the frame structure of the model so that the model will be able to easily adopt new schemes and parameters in the future and different versions of the model can share a common library. I completed detailed documentation of the cirrus model. I also developed a trajectory analysis code to analyze parcel movement in the 2-D cirrus model.

GEWEX Cloud System Studies Working Group 2: Cirrus Cloud System.

- Cirrus parcel model comparison project (CPMC)
  Worked on the design of phase 1: http://eos913c.gsfc.nasa.gov/gcss_wg2/projects/parcel/CPMC.html
  Completed parcel simulations for CPMC.
  Analyzed phase 1 results: http://eos913c.gsfc.nasa.gov/gcss_wg2/projects/parcel/p1_survey.html;
  http://wos913.gsfc.nasa.gov/gcss_wg2/projects/parrcel/p1_survey.html

- Idealized Cirrus Model Comparison Project
  Completed required simulations.

October 1999 – January 2000

Cirrus Parcel Model Comparison (CPMC). Simulation results from participants of the first phase of CPMC have been processed and analyzed to pinpoint the key components of the models resulting in the differences. Numerous sensitivity tests on model parameters have been performed.

2-D Cloud Resolving Model. Simulation results of the model are being used to determine whether the commonly used Gamma distribution assumption (hydrometeor) is robust. Codes based on statistics or measurement viewpoint are developed. Corresponding visualization schemes are under construction.

February – June 2000

Cirrus Parcel Model Comparison. Preliminary analysis of the second phase of CPMC is finished. Sensitivity tests on the deposition coefficient has been conducted.

2-D Cloud Resolving Model. More numerical experiments have been conducted to see if the gamma-distribution assumption of hydrometeors is valid. Sensitivity tests on the aggregation coefficient on the hydrometeor distribution have been performed. Preliminary results show that in the turbulent region of the cirrus, the variation of hydrometeor distribution is prominent. In the updraft regions, the distributions appear to be more log-normal and narrow. In contrast, in the downdraft regions, the distributions appear to be broader. The gamma-distribution assumption is challenged. IDL routines to visualize the simulated hydrometeor distributions have been developed.

Participation in Workshops/Conferences/Meetings

- October 6-8, 1998. Attended the CIRRUS Topical Meeting in Baltimore, MD. Poster: Lin, R-F., and Starr, D. *Effects of Ambient Aerosols on Aircraft Contrail Evolution.*

- April 20-22, 1999. Attended the Atmospheric Effects of Aviation Project Annual Meeting in Virginia Beach, VA. Poster: Lin, R-F., Demoz, B., and Starr, D. *Effects of Aerosols on Cirrus Clouds.*

- May 19-21, 1999. Attended the GEWEX WGII Workshop in Geesthacht, Germany. Present paper: Lin, R-F., Starr, D., and Demoz, B. *Results of Parcel Model Comparison.*

- June 1, 2000. Attended the Spring AGU Meeting in Washington, DC. Presented a poster on the Cirrus Parcel Model Comparison.

- July 15-23, 2000. Attended the GISS WG2 Workshop at Met Office College (United Kingdom)

- August 12-19, 2000. Attended the 13th International Conference on Clouds and Precipitation in Reno, NV.

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TASK 913-17: Modeling and Theoretical Study of Large-scale Atmospheric Circulations

TASK DESCRIPTION

The objectives of this task were the following:
- Maintain and modify Goddard atmospheric general circulation model;
- Numerical simulation of large-scale atmospheric phenomena such as the Madden-Julian oscillation, monsoon, tropical-mid latitude interaction and the theoretical interpretations of them.
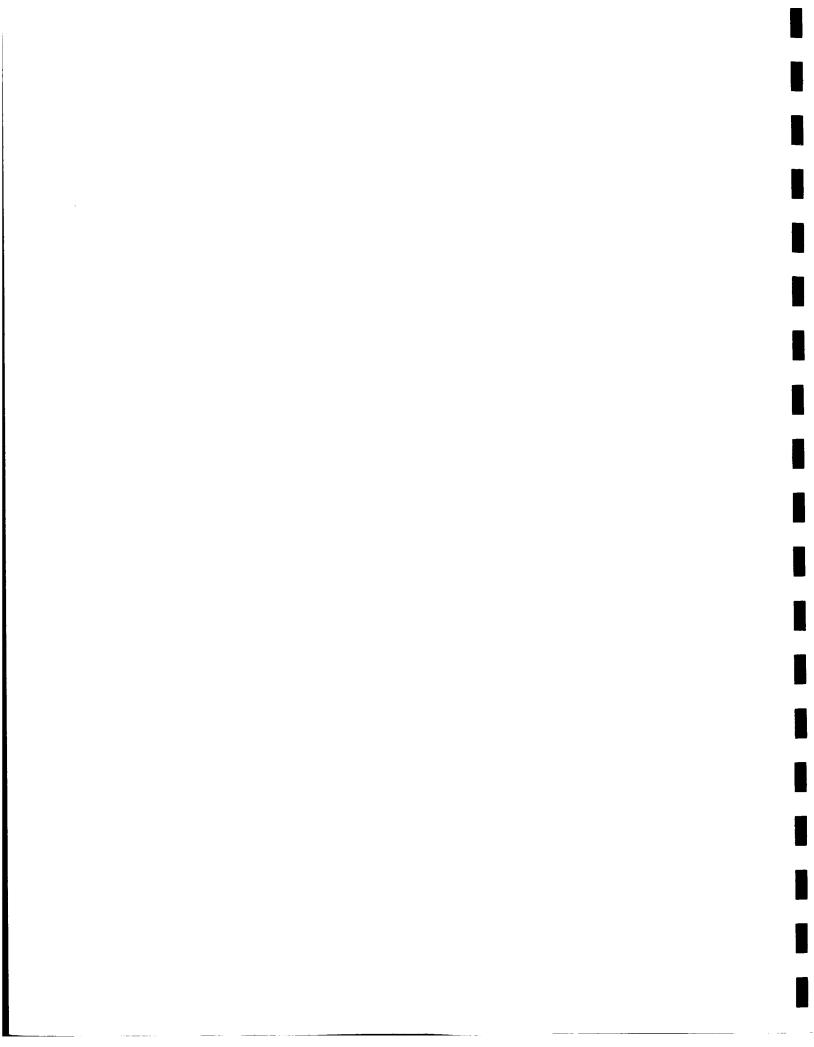- Study of cumulus parameterization in support of general circulation and climate studies.

USRA EMPLOYEE: DR. BAODE CHEN

Research focus: Model and data studies of the Madden-Julian oscillation and large scale atmospheric dynamics.

Accomplishments

October 1998 – September 1999

I have been working on a numerical study of large-scale tropical atmospheric circulation with Dr. Winston Chao at GSFC since May 1, 1998. During this period, we extensively examined the role that surface friction played in the initiation and maintenance of the Madden-Julian oscillation (MJO) by using the Goddard Laboratory for Atmospheres General Circulation Model (GLA GCM). We made use of the existing data, an aqua-planet version of the GLA GCM, and theoretical arguments to embark on a study of the structure of the Hadley circulation, including the approximate co-location of westerlies and tropical precipitation in the monthly means as well as the intensity of the intertropical convection zone (ITCZ). Based on the numerical experiments of the aqua-planet GLA GCM, we also provided a more comprehensive explanation for a theory of monsoon onset previously proposed by Dr. Chao.

<u>October 1999 – January 2000</u>

In collaboration with Dr. Winston Chao, I finished a study on multiple-equilibria of the ITCZ and proposed a mechanism that determines whether a single or a double ITCZ appears in an aqua-planet model.

Dr. Chao and I are continue to work on the origin of monsoon onset, focusing on the role of land-sea contrast in the origin of monsoons. This work will fundamentally change some long-held concepts in interpreting monsoon onset.

We also provided a proposal to interpret the latitudinal dependence of intensity of the ITCZ. It was pointed out that the Coriolis force is a determining factor in the intensification of ITCZ at higher latitudes.

In addition, by using (PSU/NCAR) Mesoscale Model 5 (MM5), we have investigated the role of surface friction in tropical cyclogenesis. The results do not support the concept of a dual role of surface friction as proposed by Charney and Eliassen in their CISK theory.

<u>February – September 2000</u>

In collaboration with Dr. Chao, I started to analyze the detailed structure of ITCZ, simulated by the GEOS-II GCM, and an aqua-planet version of it. The analysis will provide some insights for interpreting the latitudinal dependence of intensity of the ITCZ.

The role of the Earth's rotation in the relationship of tropic convection with the SST distribution was investigated by the ensemble run of GEOS-II GCM. It was pointed out that a smaller Coriolis force will result in more linear relation.

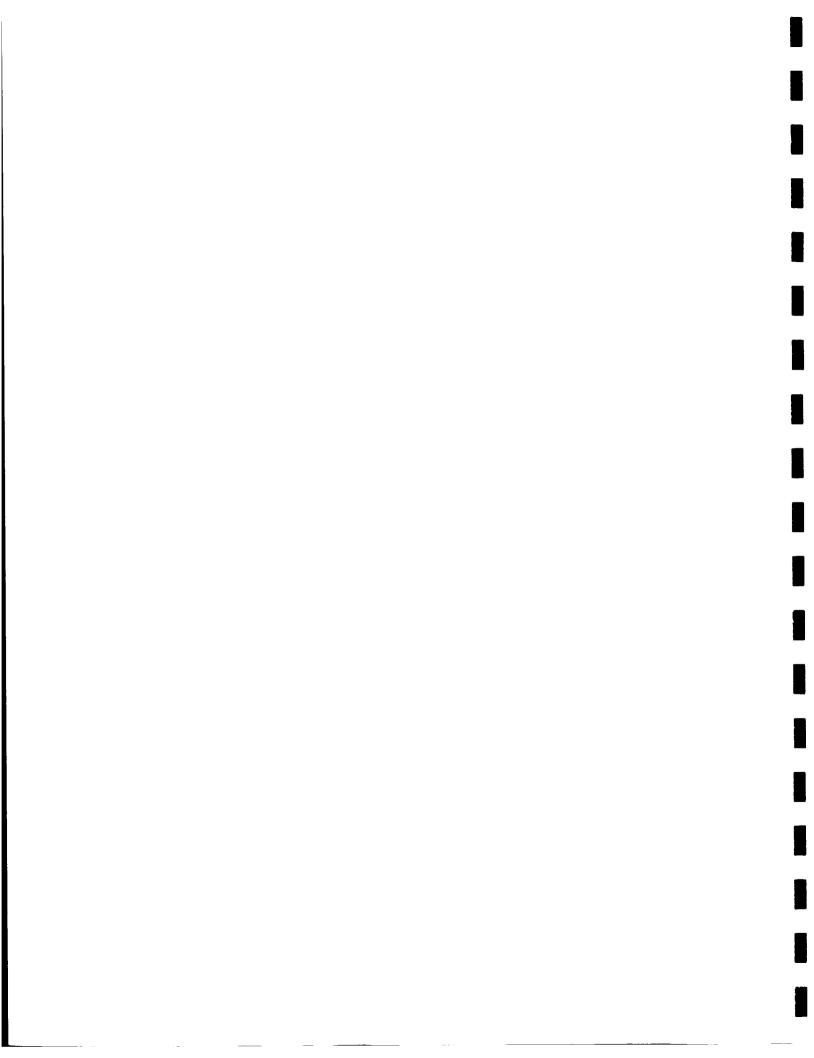**Participation in Workshops/Conferences/Meetings**

- January 10-15, 1999. Attended the AMS 23rd Conference on Hurricanes and Tropical Meteorology in Dallas, TX. Presented paper: Chen, B., and Chao, W. *On the Role of Surface Friction in Tropical Intraseasonal Oscillation.*

- December 5-9, 1999. Attended the Monsoon symposium at the University of Hawaii in Honolulu. Gave presentation entitled *Approximate Co-location of Precipitation and Low-level Westerlies in Tropical Monthly Means.*

- May 28-June 2, 2000. Attended the 24th Conference on Hurricanes and Tropical Meteorology in Ft. Lauderdale, FL.

- September 6-8, 2000. Attended CIVAR PAN American PI meeting in Potomac, MD.

Publications

Tung, W. W., Lin, C. C., Chen, B., Yanai, M., and Arakawa, A. (1999). Basic modes of cumulus heating and drying observed during TOGA-COARE IOP. *Geophys. Res. Let., 26*(20), 3117-3120.

Chen, B., Yanai, M., and Tung, W. W. The Madden-Julian Oscillation (MJO) observed during the TOGA-COARE IOP: Global view Accepted by *Jr. Atmos. Sci.*

Chen, B., and Yanai, M. (2000). Comparison of the Madden-Julian Oscillation (MJO) during the TOGA COARE IOP with a 15-year climatology. *Jr. Geophys. Res., 105*(D2), 2139-2149.

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TASK 913-18: Coupled Ocean Atmosphere System

TASK DESCRIPTION

This task was aimed at studying the interannual-to-interdecadal variability of the coupled ocean atmosphere system using NCP reanalyses data and models. Three specific objectives need to be accomplished:

- Study the sensitivity of the Cane-Zekiak type perturbation coupled ocean-atmosphere model to seasonal forcings and changes in the basic states;
- Carry out diagnostic study using 40 years of NCEP reanalysis data and satellite-derived long term rainfall product to provide a dynamical classification of the Asian monsoon system that will be used for long-term climate impact studies; and
- Develop an intermediate coupled ENSO-thermocline model to study modulation of ENSO by interdecadal variability and study the secular changes of ENSO predictability on decadal to interdecadal time scales to provide better understanding and interpretation of data and results from complex coupled models.

USRA EMPLOYEE: DR. KYU-MYONG KIM

Research focus: Studies on interannual variability of the Asian monsoon and tropical cyclones.

Accomplishments

October – December 1998

Interannual variability of the Asian summer monsoon. The first part of this work is finished. In this study we have investigated the internal dynamics and boundary forcing characteristics of two major subcomponents of the Asian summer monsoon. We describe the Asian monsoon subsystem based on the new monsoon-climate paradigm in which the variability of the Asian summer monsoon is considered as the outcome of the interplay of a "fast" and an "intermediate" monsoon system, under the influence of "slow" varying external forcings.

Interannual variability and long-term change of tropical cyclone genesis and track over western tropical Pacific. We are studying interannual variability and long-term change of tropical cyclone genesis and track using JTWC's best track data for the period 1945-1997. When sea surface temperature over the eastern tropical Pacific is increased, typhoon genesis is decreased and the region of major genesis is moved further east. We also found that there is a very strong 32-year periodicity of total typhoon numbers. To study the impact of typhoons on six major cities of east Asia, we investigated the change of typhoon number and track on the time scale of El Niño and climate change. Especially in the northern part of east Asia, Seoul and Tokyo are very sensitive to the climate change. The other cities in the southern part show increased numbers of typhoon hits, but the track is not changed significantly.

January – September 1999

Tropospheric Quasi-Biennial Oscillation (QBO) : Theoretical Study. In this study, we attempt to provide some theoretical understanding of possible impacts of East Asian monsoons using intermediate tropical atmosphere-ocean coupled model. The monsoon wind forcing is parameterized as a function of SST anomalies in the eastern Pacific Ocean and is introduced to the model as external forcing. The result shows that the enhanced negative feedback of equatorial Kelvin wave causes the acceleration of El Niño evolution and the period of El Niño is shortened. When the external forcing is increased, the evolution of El Niño shows QBO like features. This result is consistent with the observation results of the analysis of ocean sub-surface temperature variation.

<u>Tropospheric Quasi-Biennial Oscillation (QBO) Modeling Study</u>. For the extended study on tropospheric QBO, the more realistic atmospheric model is coupled to the linear reduced gravity ocean model. To avoid the climate drift, the anomaly ocean model is improved to simulate the seasonally varying mean fields as well as interannual variabilities. So far, the total ocean model of the equatorial Pacific Ocean is developed and the coupled model is under development.

<u>Interannual and long-term change of Typhoon genesis over western Pacific</u>. Using the best track data provided by JTWC and NCEP/NCAR reanalysis data, the interannual variability of typhoon genesis is investigated. This study is focused on the interannual change of genesis region, track. and intensity of typhoon. The chance of landing at six big cities in East Asia is also investigated.

<u>Interannual variabilities of East Asia winter monsoon and jet stream</u>. It is found that the interannual variation of Asian winter monsoons is closely related to the variation of East Asian jet stream intensity. It is also found that the jet stream intensity is highly correlated to the meridional surface temperature gradient over East Asia. However, no significant relation to El Niño is found. These results suggest that the interannual variation of East Asia jet stream is not directly influenced by El Niño. But El Niño affects the jet stream indirectly through the change of East Asian winter monsoons.

<u>Dynamical classification of the Asian monsoon system</u>. In this study, we present a description of the internal dynamics and boundary forcing characteristics of two major subcomponents of the Asian summer monsoon (ASM), i.e., the South Asian monsoon (SAM) and the East-southeast Asian monsoon (EAM). Results show that the internal dynamics of SAM are representative of a "classical" monsoon system in which the anomalous circulation is governed by Rossby wave dynamics, where anomalous vorticity induced by an off-equatorial heat source is balanced by the advection of planetary vorticity. On the other hand, the internal dynamics of EAM is characterized by a "hybrid" monsoon system featuring multi-cellular meridional circulation over the East Asian sector, extending from the deep tropics to the midlatitudes. These meridional cells link tropical heating to extratropical circulation systems via the East Asian jet stream, and are responsible for the observed zonally oriented anomalous rainfall patterns over East and Southeast Asia and the subtropical western Pacific. In the extratropical regions, the major upper level vorticity balance is between advection and generation by the anomalous divergent circulation and the basic state circulation. A consequence of the different dynamical underpinnings is that EAM is associated with stronger extratropical teleconnection patterns to regions outside ASM compared to SAM.

<u>Sensitivity of intermediate coupled model to seasonal and long-term forcing</u>. The effects of the phase and amplitude of seasonal cycle and long-term forcing over the western Pacific on the evolution of El Niño are investigated using the intermediate atmosphere-ocean coupled model. The results indicate that northern spring and summer mean conditions in the tropical atmosphere-ocean provide a favorable basic state for interannual variations of sea surface temperature (SST) in the eastern Pacific. A strong seasonal cycle shortens the periodicity of El Niño but intensifies its amplitude. Effect on the change of the mean thermocline depth due to the climate change is also studied. When the cold tongue is extended to the central Pacific and/or the mean depth of equatorial eastern Pacific Ocean is shallow, the El Niño index shows very distinctive quasiperiodic features. On the other hand, model El Niño is damped out when the cold tongue shrinks.

<u>Asian-Australian Monsoon AGCM intercomparison study</u>. The main purpose of this work is to investigate whether or not the atmospheric models are able to distinguish the regional features of Asian monsoons studied in the work described above, as well as large scale features. So far 10 AGCMs are participated and 10 ensemble run results of each AGCM are sent to SNU (Seoul National University), the data archive center of this study.

<u>October 1999 – January 2000</u>

<u>Dynamics of tropospheric biennial oscillation</u>. Based on previous results from an intermediate coupled model, the simple dynamics of TBO is suggested. Further study is being conducted using observations and assimilation data. Using ocean assimilation data, it is found that the TBO signal in the ocean subsurface has very similar propagating features to those of El Niño. The relations between ocean TBO signal and surface winds over the western Pacific Ocean are also being investigated.

<u>February – June 2000</u>

<u>Dynamics of tropospheric biennial oscillation</u>. Based on recent work by Lau and Wu, the relationships between TBO and the basin scale and regional scale of monsoons are being studied. Because NCEP ocean assimilation data is too short to study the TBO-Monsoon-El Niño relationships, we recently added the Simple Ocean Data Assimilation (SODA) data from the University of Maryland. Using this longer dataset, the relationships between ocean TBO signal and surface winds over the western Pacific Ocean are also being investigated.

<u>AMIP Monsoon Intercomparison</u>. Study of the predictability of Asian summer monsoons are being conducted using 11 AMIP type runs for two years (Sep 1996 - Aug 1998). In general, the models reproduce the linear response to El Niño forcing very well. However, the models could not simulate the regional features of Asian monsoons. Using various indices, the predictability of regional and global features of monsoons is considered.

<u>Long-term change in ENSO-monsoon relation</u>. This is a new study just started. We are investigating whether the ENSO-monsoon relationship is invariant or not. First of all, the effect of long-term trends due to climate change on the ENSO-monsoon relationship is investigated with simple statistics. Even small changes in climate trends can cause a large change in the ENSO-monsoon relationship. However, it is not clear if the ENSO-monsoon relationship is invariant or not.
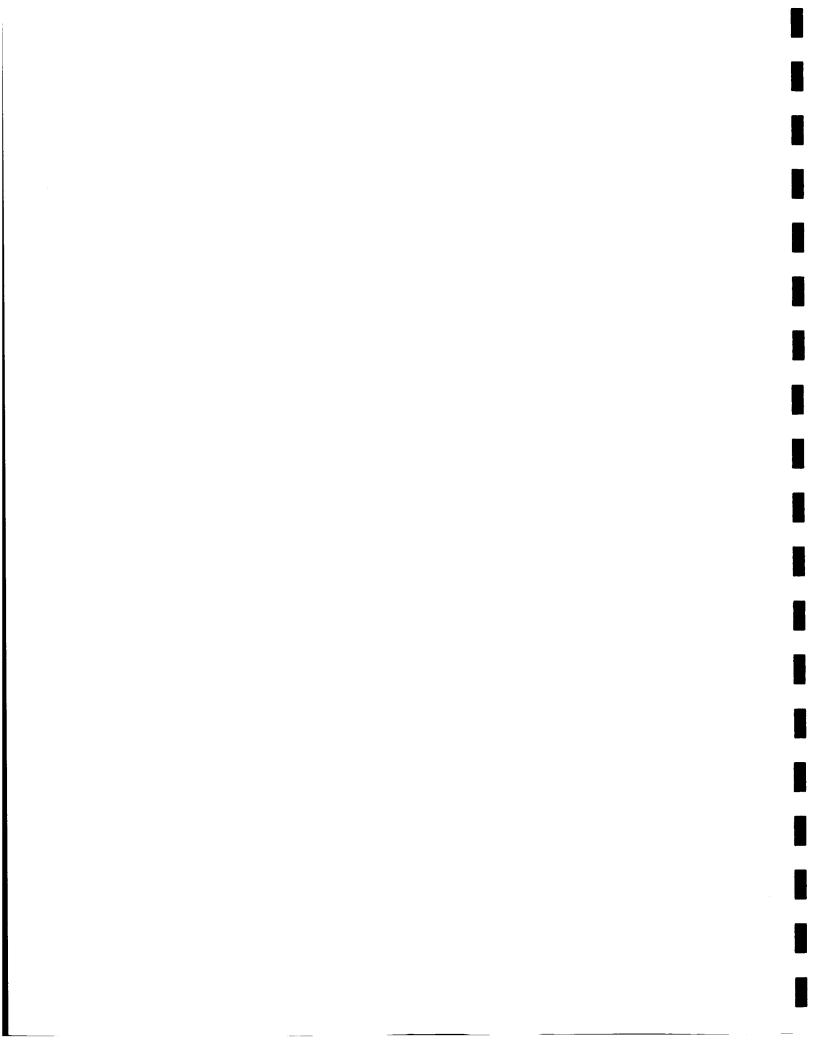
<u>Statistical prediction of U. S. precipitation</u>. Using Canonical Correlation Analysis between SST and U. S. precipitation data, the statistical model for the seasonal forecasting of U. S. precipitation is developed. The theoretical part of this work is being conducted by Dr. Shen, NRC Research Associate with GSFC. My role in this study is to develop and test the model. The model is already developed and it is being tested with various predictors. The interannual variability of U. S. precipitation is also studied to get some basic ideas for developing the model.

<u>July – September 2000</u>

<u>Dynamics of tropospheric biennial oscillation</u>. The relationship between the intraseasonal oscillation and biennial oscillation has been studied using simple Ocean Data Assimilation data from the University of Maryland. It has been found that two modes of intraseasonal oscillation play different roles in the evolution of biennial rhythm. One plays a role in the initiation and the other in the termination. Further work is needed.

Participation in Workshops/Conferences/Meetings

- January 10-15, 1999. Attended the AMS 10th Symposium on Global Change Studies in Dallas, TX. Presented paper: Kim, K-M., and Lau, K-M. *Sensitivity of the Tropical Ocean-atmosphere to Season and Long-term Climate Forcing.*

- June 1-4, 1999. Attended AGU Spring Meeting in Boston, MA. Poster: Yang, S., Lau, K-M., and Kim, K-M. *Regional Monsoon Components: Variability, Predictability, and Sensitivity to Boundary Forcing.*

- August 24-28, 1999. Attended International Workshop on the Western Pacific Warm Pool and Monsoon in Huangshan, China. Presented paper: *Predictability of Regional Components of the Asian Summer Monsoon.*

- November 1-5, 1999. Attended NOAA 24th Annual Climate Diagnostics and Prediction Workshop in Tuscon, AZ. Presented paper: Kim, K-M., and Lau, K-M. *Dynamics of Quasi-biennial Oscillations in Tropical Ocean-atmosphere Coupled Systems.*

- December 6-10, 1999. Attended the Monsoon/CLIVAR Scientific Conference in Honolulu, HI.

- March 14-17, 2000. Attended the MJO-Monsoon Workshop with Dr. Lau in Princeton, NJ.

Publications

Lau, K.-M., Kim, K.-M., and Yang, S. (2000). Dynamical and boundary forcing characteristics of regional components of the Asian summer monsoon. *Jr.of Clim.*, *13*, 2461-2482.

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TASK 913-19: Climate Variation and the Energy Budgets in the Western Tropical Pacific and South China Sea

TASK DESCRIPTION

This task was to study the atmospheric and surface energy budgets in the western tropical Pacific and South China Sea. The relationship between the energy budgets and the variations in clouds, aerosols, the sea surface temperature, and atmospheric circulation was to be investigated using data measured from the surface and satellites, as well as data from atmospheric assimilation systems. The physical processes involving changes in water vapor, clouds, and radiation budgets during climate variations were to be studied.

USRA EMPLOYEE: DR. PUI-KING CHAN

Research focus: Studies on effects of clouds and aerosols on the energy budgets of the western tropical Pacific and South China Sea.

Accomplishments

October 1998 – September 1999

Developed a case study on the relationship between brightness temperature at 10.5 micron, sea surface temperature, and atmospheric water vapor content.

Computed the daily average surface radiation budget over the domain (90E, 170W, 40S-40N) for the period January 1998 - June 1999 using Chou et al.'s empirical formula (1998), GMS-5 satellite measured radiances, NCEP sea surface temperature, and SSMI water vapor content data. Compared surface radiation budgets derived from empirical formula with measurements made at Dungsha Island.
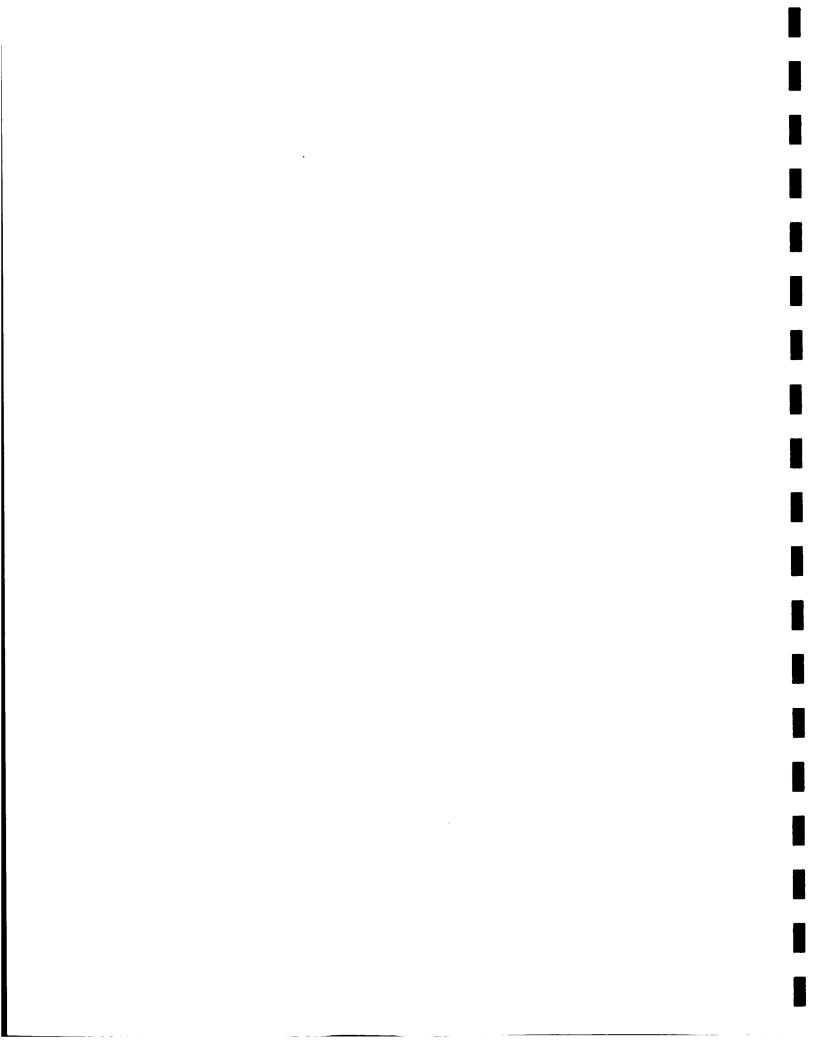
Retrieved and analyzed SeaWiFS (Sea-Viewing Wide Field of View Sensor) aerosol optical thickness data.

October 1999 – January 2000

Computed aerosol radiative forcing for the four seasons in 1997-1998 and over the globe. Conducted sensitivity studies of the asymmetry factor and single scattering albedo on aerosol radiative forcing. Also estimated the effect of the 1997 Indonesian forest fire on aerosol forcing.

Compared ARM measurement at Manus Island with satellite-retrieved downward shortwave and longwave surface fluxes for the period January 1998 to March 1999.

Analyzed the temporal and spatial variations of satellite-retrieved surface radiation budget for the period January 1998-June 1999 and over the domain (40S-40N, 90E-170W).

February – June 2000

Surface radiation budget project.   Recomputed the shortwave surface radiative fluxes with GMS-5 albedo adjusted. Computation is for the period January 1998 – August 1999 and over the domain (40S-40N, 90E-170W). Interpreted the computed surface radiation budget. Assisted Dr. Ming-Dah Chou in preparing a journal paper on the satellite-retrieved surface radiation budget data set.

Aerosol project. Computed aerosol radiative forcing for the period January-August 1998 over the globe. Analyzed reprocessed SeaWiFS global aerosol optical thickness data for the period September 1997 – October 1998. Interpreted aerosol radiative forcing results.

Wrote documentation on surface radiation budget, ARM, SeaWiFS aerosol optical thickness and aerosol forcing data sets.

CONSULTANTS/VISITORS

Visitor: **Chang-Hoi Ho** (Seoul National University, South Korea)
Purpose: Work with Dr. Chou and Dr. Suarez on developing an ocean mixed-layer model (6/19-8/27/99)

Visitor: **Kyu-Tae Lee** (National Kangnung University, South Korea)
Purpose: Develop parameterization for cloud and radiation (1/5-2/29/00)

Visitor: **Byung-Ju Sohn** (Seoul National University, South Korea)
Purpose: Collaborative discussions and presentation of a seminar to the Climate and Radiation Branch (8/3-5/99)

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TASK 916-04: Visiting Scientists for Atmospheric Chemistry and Dynamics Branch
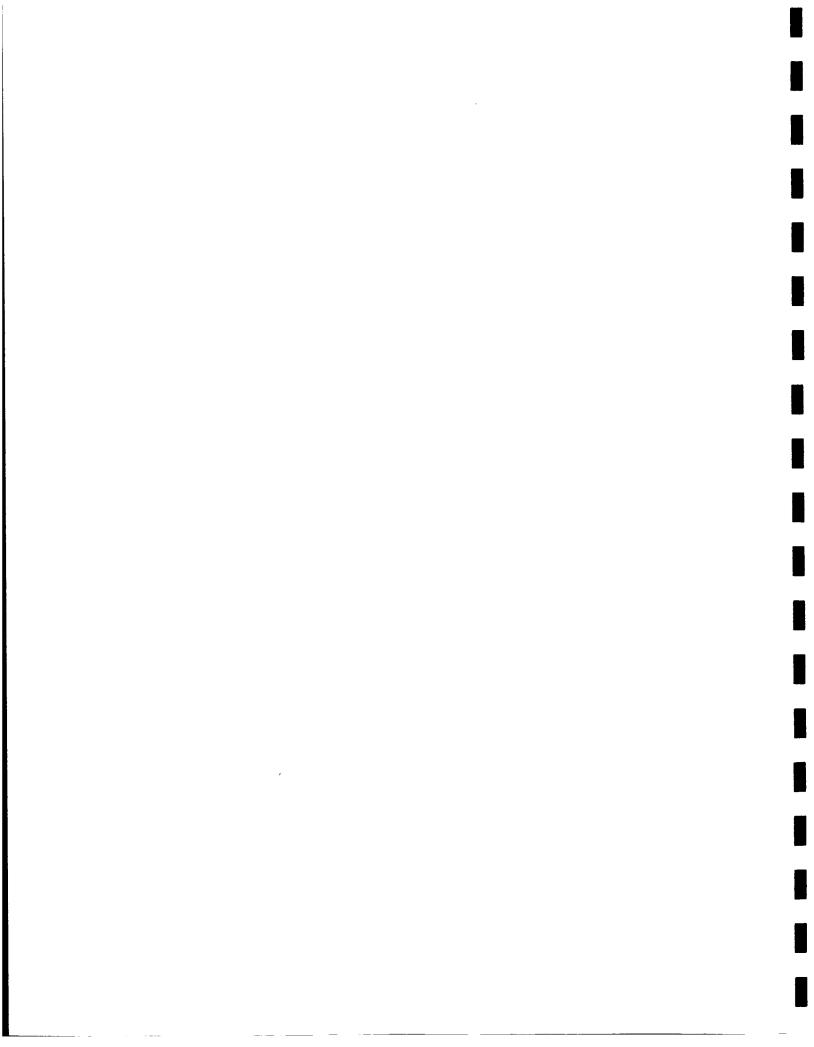
TASK DESCRIPTION

This purpose of this task was to support temporary appointments for outside scientists to visit GSFC and to collaborate with scientists in the Atmospheric Chemistry and Dynamics Branch (Code 916). The visiting scientists were expected to work on research projects relating to processes that affect stratospheric or tropospheric constituents and aerosols. Generally, the primary purpose of the research was to obtain a better understanding of atmospheric ozone and the processes that affect it. These projects could include algorithm developments/improvements, instrument developments/improvements, data analysis of measurements, or use of atmospheric models. The typical visit period was expected to last from a few days to no more than 6 months.

CONSULTANTS/VISITORS

Visitor: **Dominique Jeker** (Swiss Federal Institute of Technology)
Purpose: Collaborative analysis of SONEX and Polinat Mission papers (6/26-30/99)

Visitor: **Cheng-Hsuan Lu**
Collaborator: Mark Schoeberl
Purpose: Research on the simulation of aircraft exhaust emission scenarios (9/12-24/99)

Visitor: **Ruben Piacentini** (Fundacion Planetario de Rosario, Argentina)
Collaborator: Jay Herman
Purpose: Attend TOMS Science Team meeting and present a seminar (4/5-10/00)
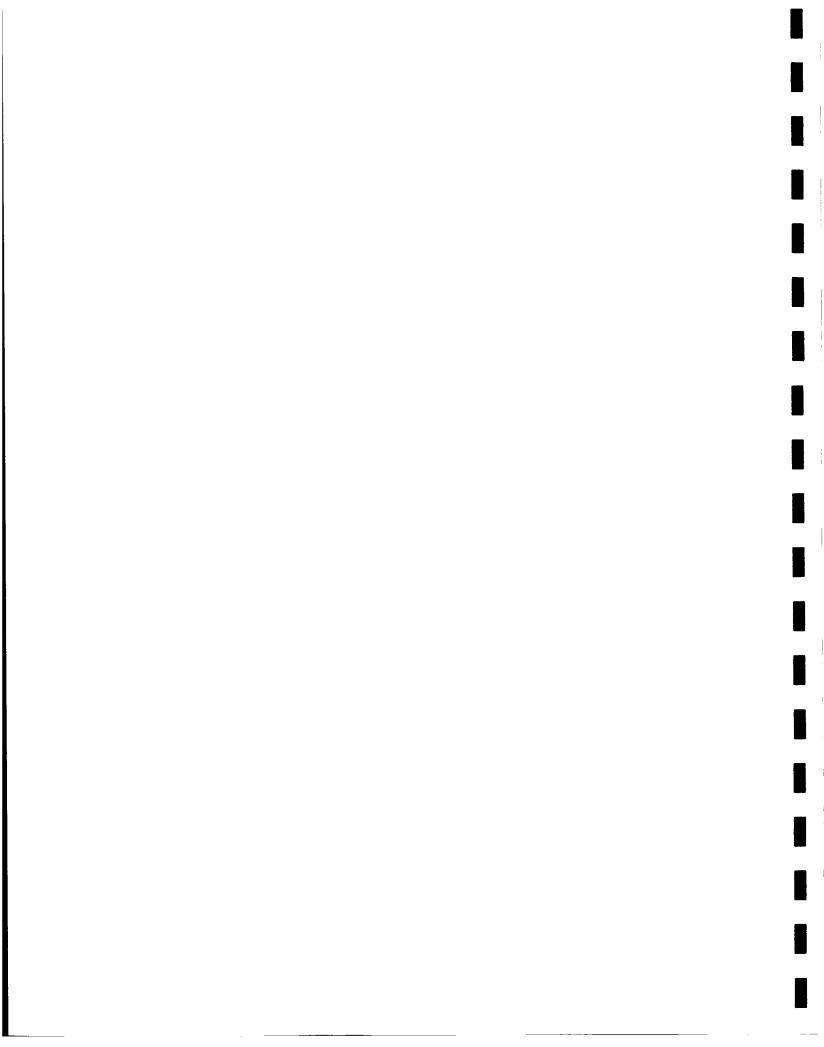
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TASK 916-05: Visiting Scientists for Atmospheric Chemistry and Dynamics Branch

TASK DESCRIPTION

Temporary appointments were to be provided to outside scientists to visit GSFC and to collaborate with scientists in the Atmospheric Chemistry and Dynamics Branch (Code 916). The visiting scientists were expected to work on research projects relating to processes that affect stratospheric or tropospheric constituents and aerosols. Generally, the primary purpose of this research was to obtain a better understanding of atmospheric ozone and the processes that affect it. These projects could include algorithm developments/improvements, instrument developments/improvements, data analysis of measurements, or use of atmospheric models. The visits were to last for a few days or a few months.

CONSULTANTS/VISITORS

Visitor: **Richard Anthes** (National Center for Atmospheric Research)
Collaborator: Mark Schoeberl
Purpose: Work with scientists in code 916 on the future of weather forecasting (2/2-4/00)

Visitor: **Miguel Rivas** Avila (Universidad de Tarapaca, Chile)
Collaborator: Jay Herman
Purpose: Work with AERONET aerosol data obtained in Arica, Chile (3/5-18/00)

Visitor: **Alexander Cede** (Insitut for Medizinische Physik, Austria)
Collaborator: Jay Herman
Purpose: Run ground-based instruments (Ultra Violet and Lidar) (8/14-9/30/00)

Visitor: **Edward Crino** (University of San Luis, Argentina)
Purpose: To attend the TOMS Science Team meeting (5/6-11/00)

Visitor: **Kostas Kourtidis** (Aristotle University of Thessaloniki, Greece)
Collaborator: Anne Thompson
Purpose: Research with ozone, UV, and aerosol data from PAUR-II campaign (6/11-28/00)

Visitor: **Jean-Baptiste Marcovici** (Institut National des Telcommuncations, Italy)
Collaborator: Thomas McGee
Purpose: Modeling the GSFC ozone lidar and the aerosol and temperature lidar (7/1-9/2/00)

Visitor: **Ruben Piacentini** (Instituto de Fisica Rosario, Argentina)
Collaborator: Jay Herman
Purpose: To attend the TOMS Science Team meeting (5/6-11/00)

Visitor: **Seong Soo Yum** (Desert Research Institution)
Collaborator: Mark Schoeberl
Purpose: Discussions related to NASA funded research on cloud physics (8/30-31/00)

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TASK 916-08: Analysis of Stratospheric Constituent Observations

TASK DESCRIPTION

The objective of this task was the analysis of stratospheric constituent observations in comparison to numerical models of the atmosphere. The overall objective of this research was to gain a better understanding of the processes that produce ozone loss so that more reliable predictions can be made of future anthropogenic changes. The approach was to use models to develop temporal, spatial, and chemical continuity of the observations in order to apply them to specific atmospheric questions. The primary topics to be addressed were the chemistry of the midlatitude stratosphere, stratospheric winter polar chemistry and its effect on midlatitudes, stratospheric and mesospheric transport, and the effect of external influences on middle atmosphere chemistry. An understanding of chemical, dynamical, and microphysical processes in the atmosphere was a fundamental requirement.

USRA EMPLOYEE: DR. JAMES PIERSON

Research focus: Development and validation of atmospheric chemistry transport model against aircraft observations of radical chemical species.

Accomplishments

October 1998 – September 1999

The primary research task activity was the comparison of the Goddard trajectory chemistry model with aircraft data from the POLARIS (Polar Ozone Loss in the Arctic Region In Summer) campaign. The POLARIS mission focused on understanding the processes associated with the decrease of polar stratospheric ozone from spring to fall at high latitudes. This decrease is linked primarily to *in situ* photo chemical destruction by reactive nitrogen species, NO and NO_2, which are interlinked the HO_x (OH and HO_2) and ClO_x (ClO and $Cl2O2$ catalytic ozone loss cycles.

Steady state models have been used to test photochemistry and radical behavior, but are not always adequate in simulating radical species observations, most notably underestimating NO and NO_2 abundances compared to measurements along the ER-2 flight track. Trajectory models can be used to understand the observations by investigating the changes that have occurred in air parcels sampled along the flight track.

The results of the trajectory chemistry model with and without trajectories are used to identify cases where steady state does not accurately describe the measurements. Over the entire mission, using trajectory chemistry reduces the variability in the modeled NO_x comparisons to data by 25% with respect to the same model simulating steady state. Although the variability is reduced, NO_x/NO_y trajectory model results were found to be systematically low relative to the observations by 20-30% as seen in previous studies. Using new rate constants for reactions important in NO_y, partitioning improves the agreement of No_x/NO_y with the observations, but a 5-10% bias still exists. OH and HO_2 individually are underpredicted by 15% of the standard steady state model and worsen with the new rate constants. Trajectory chemistry model results of OH/HO_2 were systematically low by 10-20%, but improve using the new rate constants because of the explicit dependence on NO. This suggests that our understanding of NO_x is accurate to the 20% level and HO_x chemistry is accurate to the 30% level in the lower stratosphere or better for the POLARIS regime. An almanac documenting all the cases has been compiled in hard copy and is available at GSFC and by FTP access from the POLARIS mission site. Interaction during these task activities has been with Dr. Randy Kawa.

A draft of a paper was prepared for submission in early April, but an error was discovered in the model runs, requiring further analysis. Although this is postponed we were able to bring closure to several discrepancies between the Goddard trajectory chemistry model and the steady state model that were unrelated to this error.
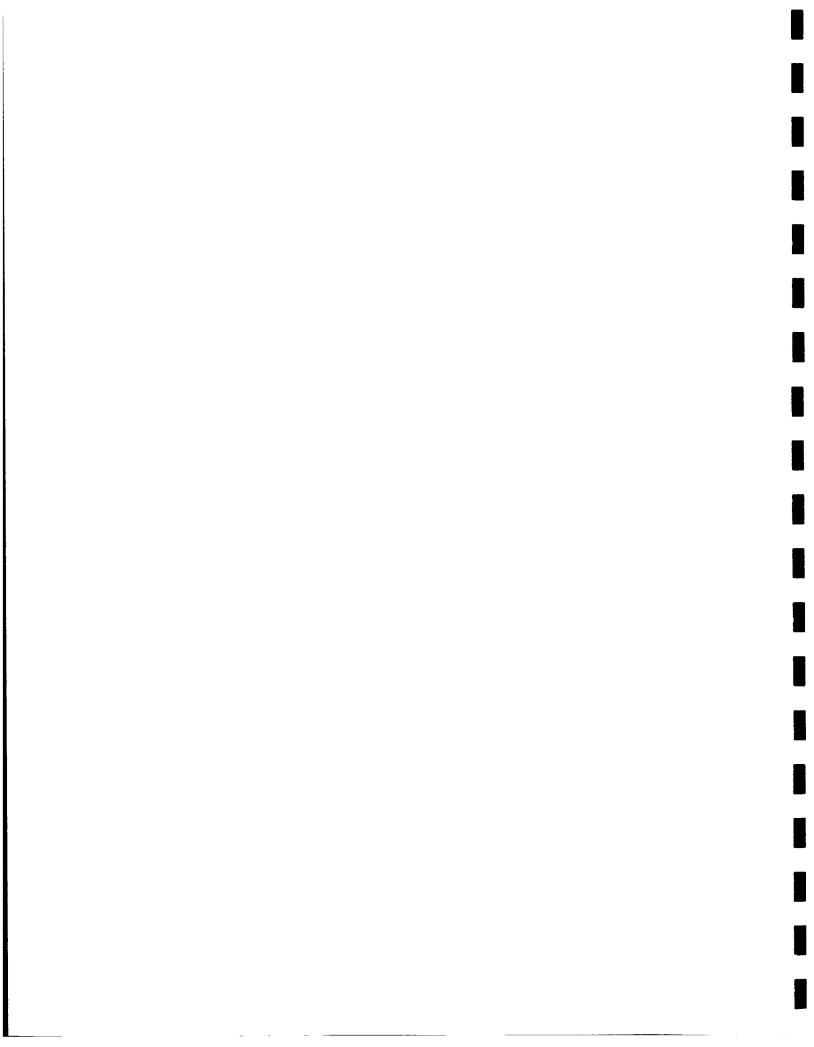
The second research task activity involves investigating chemical and dynamical issues associated with the 1997 Antarctic ozone hole. Modeling ozone loss in the polar regions must properly account for the catalytic loss cycles and the recovery of reactive chlorine to stable reservoirs. A chemical transport model simulation from March 1997-March 1998 was completed using a comprehensive representation of stratospheric photochemical processes with assimilated winds. The modeled polar vortex evolution and recovery in the Southern Hemisphere is tested by comparison with measurements from the UARS, MLS, and HALOE instruments, TOMS, and model diagnostics. Analysis of potential vorticity, winds and temperature show that the model vortex erodes sooner at higher altitudes (900 K) than at lower altitudes, consistent with our current understanding of vortex structure and dynamics. Comparison of model CH4 with HALOE CH4 shows that while the model simulates the CH4 gradient across the vortex edge, the model does not exhibit enough descent. Early October increases in the ozone mixing ratio between 74 and 80ºS, seen in both the UARS MLS data and in the model, result from the displacement of the vortex away from the pole and the advection of mid-latitude, high-ozone air into the region as temperatures increase. Within the vortex, the model simulation shows that at lower altitudes (500 and 650 K) in early October, ozone mixing ratios decrease or remain constant, but on the 900 K surface ozone mixing ratios begin to increase. An analysis of the ozone flux divergences, production and loss processes demonstrates that the increase results from transport. A first draft of a paper discussing the results has been prepared and reviewed bv GSFC scientists. Primary interaction on this project was with NASA scientist Dr. Anne Douglass.

October 1999 – April 2000

Completed drafts of a paper discussing the work I have completed comparing the 3D chemical transport model output with observations to investigate the relative roles of chemistry and transport in the recovery of ozone inside the polar vortex at different altitudes. It was found that the model agrees fairly well with the observations. Both the model and observations show ozone decreasing from August to November at lower altitudes and a gradual but noticeable increase higher up starting in mid-September. At the lower altitudes, the model shows chemical loss occurs as expected through September, but continued decrease into October and November is due to upward motion (an unexpected result). At higher altitudes, the increase in ozone is due partly to transport, but photochemical production plays a major role in the increase. This work was presented at the Upper Atmosphere Research Satellite Science Team Meeting in Virginia Beach October 26-28, 1999.

Initiated a model study using a parameterized chemistry model to examine the issue of transport of short-lived organic bromine compounds to the stratosphere. A previous model study in the literature has proposed that rapid convection transports short-lived organic bromine compounds (specifically bromoform, $CHBr_3$) to the stratosphere where they photolyze and result in ozone depletion. Although lower in concentration, the bromine released upon photolysis is roughly 50-100 times more efficient than chlorine as an ozone depleter. I have been working with Dr. Anne Douglass and Eric Nielsen to establish the loss mechanisms and proper model parameterization. Along with bromoform, we will use CO_2 (a long-lived gas) to examine the transport. Observations show that stratospheric CO_2 lags tropospheric CO_2 by several months. By examining the stratospheric and tropospheric CO_2, we can see if rapid convection in the model destroys the lag in CO_2. If it does, then the model winds are inaccurate and therefore transport of bromoform to the stratosphere is inaccurate. Preliminary results of a model without convection show that the loss mechanisms in the troposphere are strong enough to prevent bromoform from being transported to the stratosphere. We are in the process of adding the convection.

Prepared for and provided modeling support for the SAGE-III Ozone Loss and Validation Experiment (SOLVE) campaign in Kiruna, Sweden. This involved testing the trajectory model used in (1) above for any problems and developing code to examine 3D chemical transport model (CTM) output on a daily basis. Pre-Kiruna efforts were then used to examine ozone loss and other species while in the field. The trajectory chemistry model was initialized with aircraft data and run forward to predict the extent of ozone loss that could be observed in subsequent flights. The model showed good agreement with other models and subsequent flight observations. The 3D-CTM was used to determine where interesting chemical and dynamical features may form and in planning of aircraft flight patterns.

Began <u>characterization of heterogeneous chemistry</u> during SOLVE. Using the chemistry on trajectory model, I have examined several flights of the ER-2 to investigate chlorine and hydrogen chemistry. I am in the process of incorporating routines from the Naval Research Laboratory to fill in missing data essential to initializing the model. Due to a delay in the response from the NRL people, I was not able to complete this work before leaving. Preliminary analysis has shown that current heterogeneous chemistry reaction rates do not describe the observations of chlorine and hydrogen species during SOLVE.

Participation in Workshops/Conferences/Meetings

- December 6-11, 1998. Attended the AGU Meeting in San Francisco, CA.

- October 25-28, 1999. Attended the UARS Meeting in Virginia Beach, VA.

- February 21-March 8, 2000. (Kiruna, Sweden)

CONSULTANTS/VISITORS

Visitor: **Jun Ma**
Purpose: Present a seminar and conduct discussions with the Atmospheric Chemistry and Dynamics Branch (6/9-10/99)

LABORATORY FOR TERRESTRIAL PHYSICS (920)
920-03
920-04
920-06

Geodynamics Branch (921)
921-01
921-02

Biospheric Sciences Branch (923)
923-07
923-08
923-09
923-10
923-11

Space Geodesy Branch (926)
926-01

TASK 920-03: Visiting Scientists for Laboratory for Terrestrial Physics

TASK DESCRIPTION

The objective of this task was to provide short-term visiting scientists and engineers to assist and work jointly with members of the Laboratory for Terrestrial Physics on the interpretation of remote sensing field, aircraft, and satellite data. These visitors were to work in an interactive mode with staff members and utilize data archives and computer engineering facilities at GSFC. It was expected that approximately 3-4 scientists would spend 3-5 day periods at GSFC, or at a symposium venue, to perform this task.

CONSULTANTS/VISITORS

Consultant: **Inna Pashkewich** (Institute of Geophysics, Russia)
Purpose: Participate in scientific study of magnetic anomalies of the Kursk Region (3/3-10/99)

Consultant: **John Rong Sun**
Purpose: Conduct research in remote sensing data analysis using analysis tools such as ENVI, IDL, and geographic information systems (10/1/98-9/30/99)

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TASK 920-04: Advanced Sensor Requirements

TASK DESCRIPTION

The contractor was expected to provide a scientist at the postdoctoral level to work on advanced sensor requirements and algorithm development for analysis of surface and atmospheric properties using data from MODIS and related sensors. Science requirements for global monitoring studies were derived from the literature and interaction with the science community. Appropriate algorithmic solutions were to be developed using published results and original work. Sensor design concepts were to be compared against algorithmic capabilities. The task was also to support the development of algorithms for, and acquisition of, MODIS and MODIS-like data from foreign ground stations for studies of the global carbon budget. The focus was to be on the Russian and Canadian Boreal forest. Support was also to be provided for visiting international experts as required.

USRA EMPLOYEE: DR. ALEXEI LYAPUSTIN

Research focus: Modeling surface bi-directional reflectance and radiative effects of aerosols for land remote sensing.

Accomplishments

Developed a new rigorous algorithm for computation of atmospheric optical transfer function (OTF) for the problem with Lambertian reflectance. OTF is a Fourier transform of the atmospheric point spread function, and it describes photon transport over a spatially non-uniform surface. The boundary-value

problem for OTF is obtained from the 3D radiative transfer problem linearized in the spatial albedo variation. This problem is then solved with an efficient SVD modification of the spherical harmonics method with the smoothing procedure of the source function integration. This combination allowed us to develop a fast stable algorithm allowing calculations in arbitrary directions in horizontally homogeneous atmosphere with arbitrary optical thickness, scattering function and vertical stratification.

Most contemporary analysis of satellite data is based on the classical Chandrasekhar formula for the mean radiance, which is valid only when the surface is infinite and uniform. Over an inhomogeneous surface, the measured radiance will also contain two variational terms describing the direct and diffuse atmospheric transmission of the radiance reflected from surface albedo variation. Calculation of the diffuse transmission requires knowledge of the atmospheric point-spread function (PSF) or its Fourier-transform, optical transfer function (OTF), which is a solution of the 3-d radiative transfer problem. Based on an extensive numerical study, we tried to answer the question of how the interaction between three characteristic spatial scales, namely, the scale of surface inhomogeneity, size of a pixel, and an effective height of the atmosphere, define the accuracy of atmospheric correction based on a 1-D radiative transfer theory.

For practical applications, we have studied the effect of discretization of the BRDF angular grid on the accuracy of calculation of reflected diffuse radiance. Simulations conducted for a large number of vegetative covers, soils, and sand, show that an accuracy of 0.2% can be achieved with M-11 azimuthal harmonics at N=21 grid knots in cosine of zenith angle. Calculations over a ruffled water surface are much more demanding. For wind speed v≥10m/s, an accuracy of 0.2% requires discretization of M≥40, N≥51.

Participation in Workshops/Conferences/Meetings

• December 11-12, 1998. Attended the International IFB BRDF meeting in San Francisco, CA. Gave presentation on atmospheric effects on experimental BRDF measurements.

• June 2-4, 1999. Attended the Spring AGU Meeting in Boston, MA.

• August 4-5, 1999. Attended the VIIRS Workshop in Boston, MA.

• August 9-September 3, 1999. Attended the Interim NPOESS VIIRS meeting in Santa Barbara, CA.
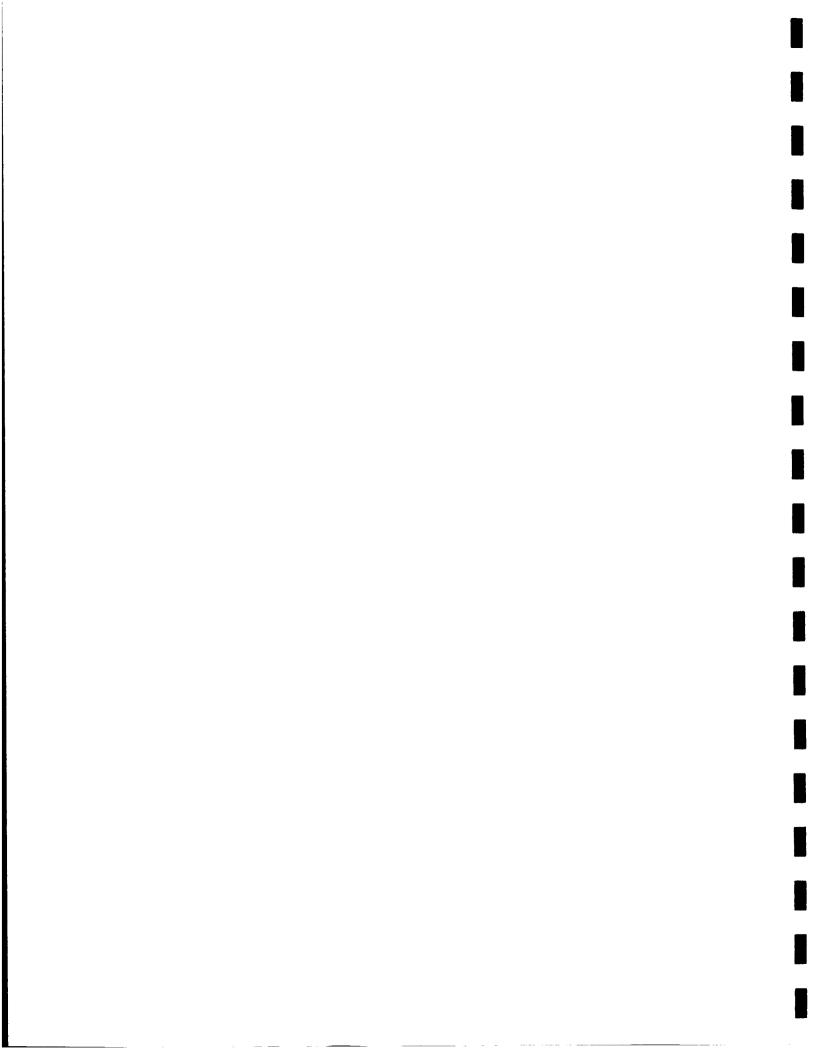
Publications

Lyapustin, A. I., and Privette, J. L. A new method of retrieving surface BRDF from ground measurements: Atmospheric sensitivity study. Submitted to *Jr. Geophys. Res.* 1998.

Lyapustin, A. I., and Muldashev, T. Z. Solution for atmospheric optical transfer function using spherical harmonics method. Submitted to *JQSRT.* 1999.

Lyapustin, A. I. 3-D effects in the remote sensing of surface albedo. Submitted to *IEEE Trans. Geosci. Remote Sens.* 1999.

Lyapustin, A. I., and Muldashev, T. Z. Generalization of Marshak boundary condition for non-Lambert reflection. Submitted to *JQSRT.* 1999.

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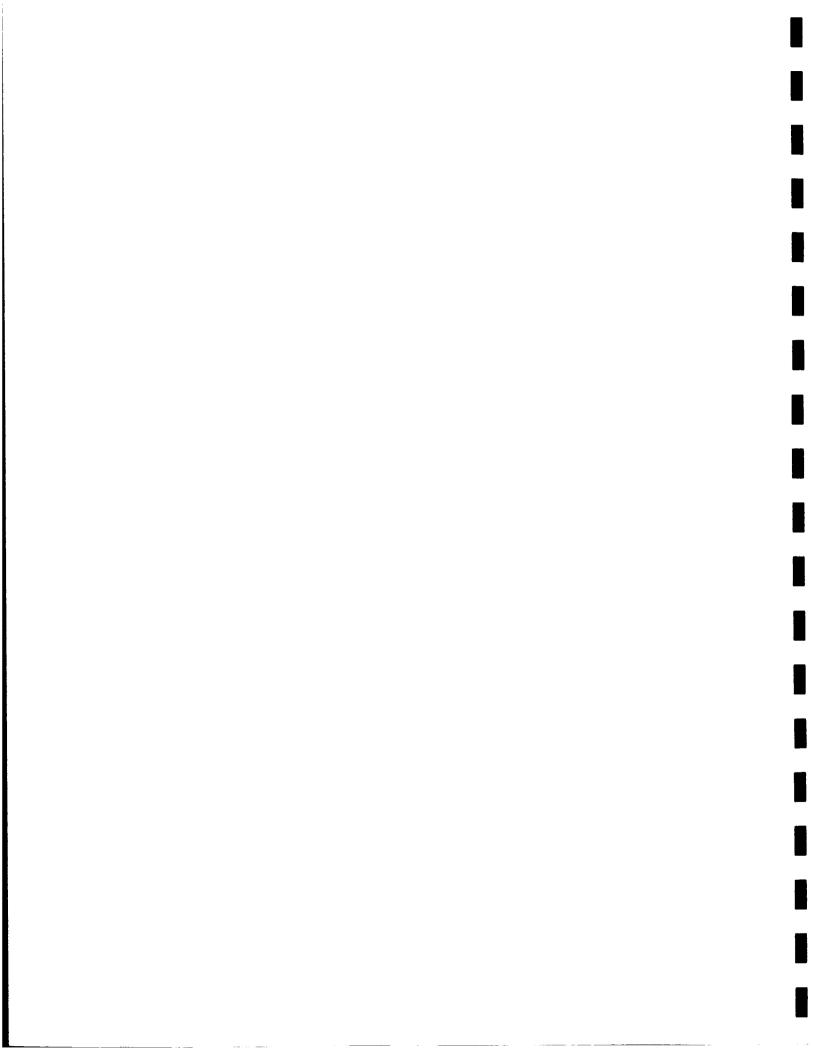# TASK 920-06: Visitors for Laboratory for Terrestrial Physics

TASK DESCRIPTION

The specific objective of this task was to solicit the research support of a number of scientists in existing and proposed programs: Mars Observer Laser Altimeter, Mercury Messenger, and Europa Missions. Required support enabled researchers to make short term visits (generally two weeks or less), and attend mission-specific conferences, workshops, and planning meetings. Research efforts to develop and define data analysis techniques, to develop and publish results, and define mission parameters, through visiting scientist's on-site presence and consultation with the GSFC PI were viewed as imperative to the success of planned missions.

CONSULTANTS/VISITORS

Visitor: **Oded Aharonson** (Masachusetts Institute of Technology)
Purpose: Assist with activities associated with the MOLA instrument turn on (2/26-3/2/99)
              Attend the MOLA Science Team Meeting, GSFC (4/28-30/99)
              Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/30-9/2/99)
              Attend the MOLA Science Team Meeting, Brown University (11/1-4/99)
              Attend the MOLA Science Team Meeting, Toulouse, France (6/17-24/00)

Visitor: **William Bottke** (Cornell University)
Purpose: Present seminar on asteroids and meteoroids in the inter-solar system (2/22-23/00)

Visitor: **James Head** (Brown University)
Purpose: Attend the Mars Exploration International Symposium, Paris, France (1/29-2/6/99)
              Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-24/99)
              Attend the MOLA Science Team Meeting, GSFC (4/28-4/30/99)
              Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/30-9/2/99)
              Attend the MOLA Science Team Meeting, University of Maryland College Park
                 (5/10-13/00)
              Attend the MGS Water Workshop (6/11-13/00)

Visitor: **Anton Ivanov** (California Institute of Technology)
              Assist with MOLA data processing (3/7-14/99)
              Help with MOLA data processing (6/6-10/99)
              Attend the MOLA Science Team Meeting, Toulouse, France (6/17-24/00)

Visitor: **Duane Muhleman** (California Institute of Technology)
Purpose: Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-24/99)
              Attend the MOLA Science Team Meeting, GSFC (4/29-5/1/99)
              Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/30-9/2/99)
              Attend the MOLA Meeting at Scripps Institute of Oceanography (2/8-11/00)
              Attend the MOLA Science Team Meeting, University of Maryland College Park
                 (5/10-13/00)

Visitor: **Gregory Neumann** (Massachusetts Institute of Technology/GSFC)
Purpose: Attend AGU Fall Meeting in San Francisco (12/11-16/98)
              Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-25/99)
              Attend Lunar and Planetary Science Conference, Houston, TX (3/15-17/99)
              Attend the Spring AGU Meeting and present a paper (6/1-3/99)
              Present paper at 5th Internationall conference on Mars, JPL, CA (7/17-21/99)

Attend the MOLA Science Team Meeting at Brown University (11/1-4/99)
Attend the AGU Meeting in California (12/5-10/99)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/7-11/00)
Attend 31st Lunar Planetary Science Conference, Houston, TX (3/12/17/00)
Attend the AGU Spring Meeting (5/30-6/2/00)
Attend the MOLA Science Team Meeting, Toulouse, France (6/17-24/00)

Visitor: **Gordon Pettengill** (Massachusetts Institute of Technology
Purpose: Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-25/99)
Attend the MOLA Science Team Meeting, GSFC (4/29-5/1/99)
Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/30-9/2/99)
Attend the MOLA Science Team Meeting at Brown University (11/3-5/99)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/7-11/00)
Attend the MOLA Science Team Meeting, University of Maryland College Park
   (5/10-13/00)
Attend the MOLA Science Team Meeting, Toulouse, France (6/17-24/00)

Visitor: **Roger Phillips** (Washington University)
Purpose: Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-25/99)
Attend the MOLA Science Team Meeting, GSFC (4/29-5/1/99)
Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/29-9/4/99)
Attend the MOLA Science Team Meeting at Brown University (11/3-5/99)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/8-12/00)
Attend the MOLA Science Team Meeting, University of Maryland College Park
   (5/10-13/00)
Attend the MOLA Science Team Meeting, Toulouse, France (6/17-24/00)

Visitor: **Sean Solomon** (Carnegie Institution of Washington, DC)
Purpose: Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-25/99)
Attend the MOLA Science Team Meeting, Grouse Mt. Lodge, MT (8/30-9/2/99)
Attend the MOLA Science Team Meeting at Brown University (11/3-5/99)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/7-11/00)

Visitor: **David Spiegel**
Purpose: MOLA data reduction (10/11-23/99)

Visitor: **Philip Tracadas** (Massachusetts Institute of Technology)
Purpose: Participate in MOLA discussions (10/5-8/98)
Participate in MOLA discussions (1/11-16/99)
Attend the MGS Radio Science Team Meeting (3/25-26/99)
MOLA Data Reduction (9/20-24/99)
MOLA Data Reduction (10/18-22/99)

Visitor: **Rebecca Williams** (Washington University)
Purpose: MOLA Data Reduction (10/3-9/99)

Visitor: **Maria Zuber** (Massachusetts Institute of Technology)
Purpose: Attend the NEAR Science Team Meeting (11/13/98)
Attend the Earth and Moon conference in Monterey, CA (12/4-10/98)
Attend the NEAR Meeting (12/16-17/98)
Attend the EUROPA and MGS meetings at GSFC (1/10-14/99)
Attend the MGS FSG meeting at JPL, Pasadena, CA (1/18-20/99)
Attend the MOLA Operations Meeting (2/11/99)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/22-25/99)
Attend the MOLA turn-on activities (3/1-2/99)
Attend the MOLA data gathering activities (3/9-11/99)

Attend LPSC in Houston and present a paper (3/14-17/99)
Attend the MGS Radio Science Team meeting (3/26/99)
Attend the Near Earth Asteroid Rendezvous (NEAR) data meeting (3/31/99)
Attend the MOLA Meeting (3/31-4/2/99)
Attend the MOLA meetings (4/15/99)
Attend the NEAR Meeting at APL, Laurel, MD (4/19/99)
Attend the MOLA Meeting (4/23/99)
Attend the NEAR Meeting at APL, Laurel, MD; MOLA Meeting at GSFC (4/29-30/99)
Attend the EUROPA Meeting (5/12/99)
Attend the MGS Project Sciences Group meeting (AZ); talk at MIT Club, NY
    5/18-21/99)
Attend the MOLA press conference at NASA HQ (5/27/99)
Attend the AGU Spring Meeting (5/29-6/3/99)
Attend the NEAR mtg. at APL (6/8-10/99)
Attend the MOLA meeting (6/17/99)
Attend the NEAR meeting (6/22/99)
Attend the MOLA meeting (7/1-2/99)
Attend the Mars 98 Lander Site Selection meeting at UCLA (7/8-9/99)
Attend the MOLA meeting (7/12-13/99)
Attend the 5th International Conference on Mars at JPL, CA (7/18-25/99)
Attend the Auropa Instrumentation System (EIS) meeting in Boulder, CO (8/4-7/99)
Attend the MOLA Science Team Meeting (8/30-9/2/99)
Attend the NEAR Laser Ranging (NLR) meeting (9/6/99)
Attend the NEAR Science Team meeting at APL (9/14/99)
Mars talk, University of California, Berkeley; MOLA meeting, Stanford U. (9/22-25/99)
Attend the MOLA meeting (10/7/99)
 Attend the Mars Polar Processes Conference in Houston, TX (10/18-21/99)
Attend the Europa Preproposal conference in Houston (10/21-22/99)
Attend meeting at University of Arizona, Tuscon on Messenger laser altimeter
    (10/25-27/99)
Attend the Europa Meeting, University of Arizona; MOLA talk at UCLA (11/3-6/99)
Attend the MGS Radio Science and Project Science Group meetings (11/22-25/99)
Attend the NEAR Science Team meeting at GSFC; attend Mars Global (11/30-12/3/99)
Attend the Fall AGU meeting and present a paper in California (12/11-17/99)
Launch of MARS '98 Polar Lander and subsequent meetings (1/1-7/00)
Conduct GSFC/MIT course at GSFC (1/18-19/00)
Attend the MOLA Meeting at Scripps Institute of Oceanography (2/7-11/00)
Attend the NEAR Meeting at APL (2/14/00)
Attend the MGS Mapping Readiness Review Meeting at JPL (2/15-17/00)
Attend the Lunar and Planetary Science Conference (3/12-14/00)
Attend the EUROPA proposal team meeting at JPL (4/7-10/00)
Attend the Near Earth Asteroid Rendezvous (NEAR) data meeting (4/6-7/00)
Attend the European Geophysical Society XXV General Assembly   (4/23-28/00)
Attend the MESSENGER Meeting (5/3-4/00)
Attend the MOLA Science Team Meeting at University of Maryland College Park
    (5/10-13/00)
Attend the MESSENGER meeting at APL (5/20-23/00)
Attend the MGS Water Workshop (6/11-16/00)

The following Massachusetts Institute of Technology students attended a course taught by Maria Zuber
at University of Maryland Inn and Conference Center, College Park, MD (1/17-22/00).

Christopher Beland	Jason James	Jessica Bowles-Martinez	Danielle Morese
Richard Camilli	An Nguyen	Susan Dunne	Michael O'Hara
Ophelia Goatson	Ian Ross	Gavin Gong	Enrique Vivoni

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TASK 921-01: Analysis of MOLA Data

TASK DESCRIPTION

The objective of this task was to analyze MOLA (Mars Orbiter Laser Altimeter) data and to develop mathematical models for volcanic eruptions on planetary and terrestrial surfaces and of lithospheric response to loading and unloading at the crust. MOLA studies involve topographic characterization of impact craters and basins, the crustal dichotomy boundary zone, and likely volcanic deposits and flows. Modeling studies were to include terrestrial field examples and the use of digital topographic data, including that from MOLA.

USRA EMPLOYEE: DR. SUSAN SAKIMOTO

Research focus: Modeling and observational studies of Martian volcanic flows and landforms.

Accomplishments

October 1998 – September 1999

Research collaboration with Dr. Eric Grosfils (Pomona College). Eric and I proposed for and obtained funding for our KECK Summer 2000 student research program at Goddard on Mars Geology. We continue to discuss logistics and research topics for this. The KECK project work includes ongoing discussions with Cathy Manduca (Keck Geology Consortium Coordinator, Carleton College) on setting up a long-term relationship between USRA, the Keck Geology Consortium, and NASA Goddard. As part of this, I am also discussing with Judy Gobert (Salish-Kootenai College) potential student and faculty collaborations from some of the Tribal Colleges. I made a brief visit to Salish--Kootenai College with my MOLA meeting trip to Whitefish, MT, August 30, 1999, where we discussed several potential faculty collaborators from tribal colleges, and the possibility of one of them coming to Goddard with several tribal college students for the KECK Mars Geology Program.

Worked with Eric and his student (Beth Bradley) during his Goddard Visiting Faculty Fellow appointment this summer on several Mars Orbiter Laser Altimeter research projects in conjunction with ongoing work with H. Frey and J. Garvin (Goddard). This will continue through the 1999-2000 academic year.

Research Collaboration with Dr. Tracy Gregg (SUNY/Buffalo). Our NSF-funded volcanology work has moved slightly more slowly this year, as Tracy switched institutions (from WHOI to SUNY-Buffalo), and then went on a oceanographic cruise. Our NSF research grant has been granted a no-cost extension until December 1999 We are preparing a paper (Sakimoto, S.E.H., and T.K.P. Gregg, Channel velocity distributions and flow rates: Analytic solutions, laboratory experiments, and applications to lava flows, to be submitted to *Journal of Geophysical Research-Solid Earth* late this Fall or early next Spring, possibly in conjunction with the AGU special session "Symposium on Modeling of Volcanic Transport Processes We are planning to extend collaboration into the NASA Mars Data Analysis Program in conjunction with Tracy's ongoing work with Dr. Dave Crown, at the Univ. Pittsburgh.

Teaching. I taught *Understanding and Teaching the Solar System, 3* credit Johns Hopkins Universitycourse 881.632, JHU School of Continuing Studies, Division of Graduate Education. This is a core course in the Maryland Space Grant Earth/Space Science Internship Program for Elementary and Secondary Mathematics and Science Teachers.

Mentoring. I mentored/supervised four students who worked with Jim Garvin and me for summer 1999. All are expected to present results at the March 2000 LPSC meeting as well as continue collaborations and joint paper authorship through the coming year (e.g., Jacob will do his senior thesis project with us this year by commuting from Franklin and Marshal one day a week)

Audeliz Matias, University of Puerto Rico Mayaguez (UPRM)
Research Project: Comparison of morphology of northern and southern simple to transitional impact craters on Mars with images and MOLA topography

Heather Wright, Whitman College, Walla Walla, WA
Research Project: Morphology of small volcanic edifices (near-polar and selected mid-latitude) on Mars from images and MOLA topography

Jacob Bleacher, Franklin and Marshal College, PA
Research Project: South Polar impact crater morphology from images and MOLA topography

Ricardo Molinero, SUNY Buffalo
Research Project: Morphology and slope stability of some South Polar Martian volcanoes from images and MOLA topography, with comparisons to laser altimetry data for selected terrestrial volcanoes.

Provided research assistance with 1999 summer project work for two Space Club Students (L. Hutchinson, M. Doman)

Engaged Julia Saul, Franklin and Marshal College, over winter break (December 28, 1998 to January 8, 1999) as a short-term research assistant in searching for impact craters on Mars' polar caps.
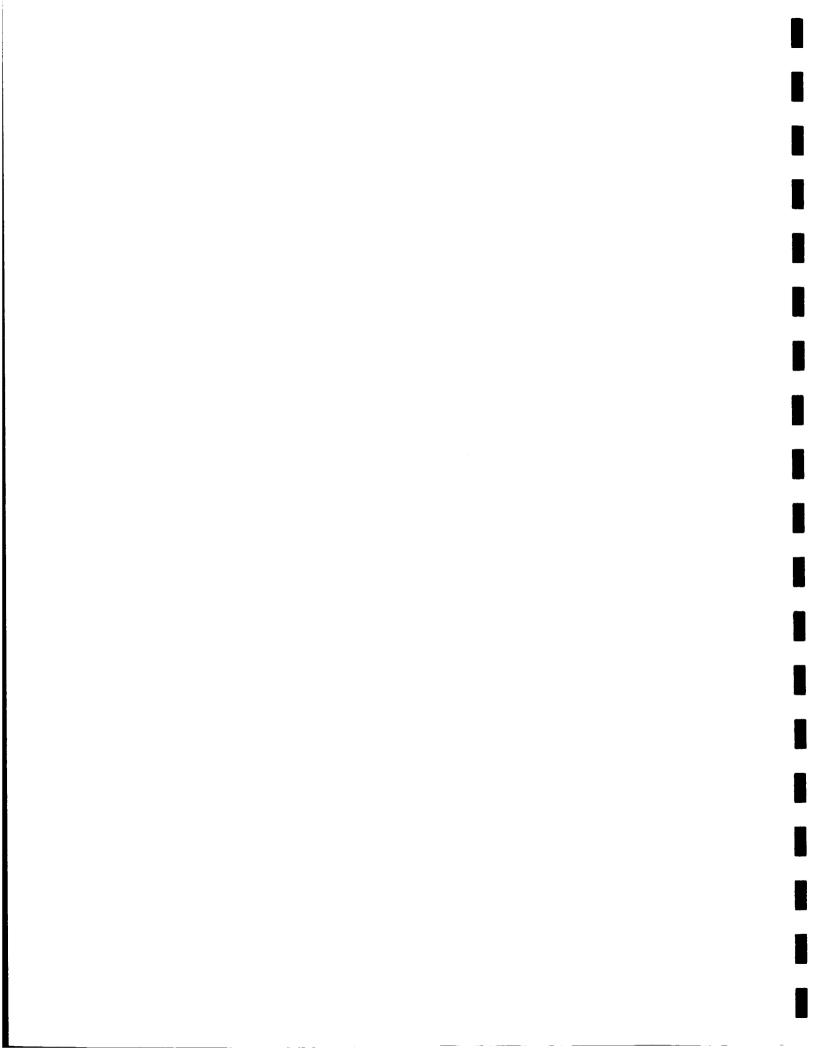
James R. Zimbelman (Center for Earth and Planetary Studies, Smithsonian Air and Space Museum), Herb Frey (NASA/Goddard) and I are currently collaborating on a study of the Medusae Fossae Formation on Mars. We are listed on each other's grants as collaborators, have jointly authored a few conference papers, and look forward to combining MOLA data and Jim's geologic mapping efforts to untangle the complex history of this enigmatic formation.

October 1999 – June 2000

Teaching. Taught 881.632, Spring Semester 2000, *Understanding and Teaching the Solar System*, at the Johns Hopkins University, School of Professional Studies in Business and Education and the Maryland Space Grant Consortium, (Course is for Secondary Mathematics and Science Teachers)

TV Filming: May 30, 2000. Provided/Filmed volcano commentary for the *"Volcano Blast"* Roller Coaster ride for use in The Learning Channel series on "The Ultimate 10".

KECK Project. Faculty member, KECK Undergraduate Geology Consortium Summer 2000 "Mars Project" June 7-July 9, 2000, NASA/GSFC. This project included 10 sophomore students (including one each of African-American, Navajo, Hispanic, and Pacific Islander Students). We expect to submit 5-6 LPSC abstracts (5 student-author) as a result of the research. This project also included organizing seminars given by approximately one dozen visitors. I expect to eventually see a few of the students again as summer interns or senior thesis advisees.

<u>Summer Intern</u>. Supervised summer research intern, Beth Bradley, 8 weeks, Pomona College '00, Mars MDAP research on the Medusae Fossae Formation and the Dichotomy Boundary. We are hoping to keep Beth here for the 2000-2001 academic year to assist with data processing after Martin Wong leaves for graduate school. She has deferred entering her Ph.D. program at Brown University for one year in order to do so.

<u>Summer Intern</u>. Supervising summer research intern, Jake Bleacher, 3 weeks, Franklin and Marshal College '00, Mars research on South Polar Erosion (continuing work from Jake's Senior Thesis).

<u>Ph.D. Advising</u>. Devon Burr, University of Arizona, in Ph.D. project for NASA Graduate Student Researchers Program (GSRP) in project comparing Icelandic glacial floods with Mars channels in the Marte Valles region. This is unofficial, as J. Garvin was initial advisor, and D. Smith is current official advisor since Jim's departure for NASA/HQ.

<u>Intern Updates</u>. *Martin Wong* will continue on to U C Santa Barbara in their geology Ph.D. program after his year working with us here. *J. Bleacher* is headed to the planetary geology Ph.D. program at Arizona State after his summer internship and senior thesis work with us. *Audeliz Matias* successfully defended her master's thesis at University of Puerto Rico, Mayaguez, and is headed for Northwestern University this fall for a Ph.D. program. She spent two summers working with J. Garvin and me on Mars cratering. *Heather Wright* (MDAP intern for me last summer) continues to work with the USGS.

Participation in Workshops/Conferences/Meetings

- October 21-24, 1998. Attended the Conference on Mars Polar Science and Exploration at USRA's Lunar and Planetary Institute in Houston, TX. Presented paper: Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., Matias, A. *Martian Polar Region Impact Craters: Geometric Properties from Mars Orbiter Laser Altimeter (MOLA) Observations.*

- October 26-29, 1998. Attended the Geological Society of America meeting in Toronto, Ontario, Canada. Presented 2 papers: Frey, H. V., Sakimoto, S. E. H., and Roark, J. H. *MOLA Topography of the Crustal Dichotomy Boundary Zone, Mars*; Sakimoto, S. E. H., Frey, H. V., and Roark, J. H. *Topographic Analysis of the Medusae Fossae Formation, Mars: Implications for Mapping Units and Emplacement Theories.*

- November 19-20, 1999. Attended the 3rd Volcanologists of the East Coast Gathering at the Center for Earth and Planetary Studies, Smithsonian Institution, Washington, DC. Presented a 1-hour presentation of recent research results in Mars cratering and hydrovolcanism research.

- December 6-10, 1998. Attended the AGU Fall meeting in San Francisco, CA. Contributed papers: Sakimoto, S. E. H., and Garvin, J. B. *Mars Crater Facies Analysis With the Combined MOLA and MOC Data Sets.*
  Frey, H., Sakimoto, S. E. H., and Roark, J. H. *MOLA Topography of Impact Basins in the Northern Hemisphere of Mars.*
  Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., and Matias, A. *Martian Polar Region Impact Craters: Topographical Perspectives From the Mars Orbiter Laser Altimeter.*
  Gregg, T. K. P., and Sakimoto, S. E. H. *High Effusion-rate Channeled Lava Flows on Mars: Results from Laboratory and Analytical Modeling.*

- February 22-25, 1999. Attended MOLA science meeting San Diego, CA.

- March 15-19, 1999. Attended annual lunar sciences meeting at NASA Johnson Space Center in Houston, TX. Contributed abstract #1497: Frey, H., Sakimoto, S. E. H., and Roark, J. *Discovery of a New Cassini-size Basin on Mars from MOLA Topographic Data.*

  Abstract #1500: Frey, H., Sakimoto, S. E. H., and Roark, J. *MOLA Topographic Structure of the Isidis and Utopia Impact Basins.*

  Abstract #1501: Frey, H., Sakimoto, S. E. H., and Roark, J. *MOLA Topographic Variations Along the Crustal Dichotomy Boundary Zone in Eastern and Western Mars.*

  Abstract #1798: Frey, H., Roark, J., and Sakimoto, S. E. H. *McGovern, the Crustal Dichotomy Boundary West of Tempe Terra: Speculation on Where it Lies Beneath Alba patera Based on MOLA Topography.*

  Abstract #1492: Garvin, J. B., and Sakimoto, S. E. H. *Near-Polar Cratered Cones on Mars: MOLA Measurements and Implications for Volcanic Origins.*

  Abstract #2026: Garvin, J. B., and Sakimoto, S. E. H. *Near-Polar Ice-associated Impact Craters on Mars: Implications from MOLA Observations.*

  Abstract #1721: Garvin, J. B., Frawley, J. J., and Sakimoto, S. E. H. *North Polar Dunes on Mars: MOLA Measurements and Implications for Sediment Volumes.*

  Abstract #1490: Gregg, T. K. P., and Sakimoto, S. E. H. *Reality Check: Using Analytic Rectangular Channel Flow Solutions to Interpret and Predict Channelized Lava Flow Behavior on Earth and Mars.*

  Abstract #2008: Matias, A., Garvin, J. B., and Sakimoto, S. E. H. *Mid-latitude vs. Polar-latitude Transitional Impact Craters: Geometric Properties from Mars Orbiter Laser Altimeter.*

  Abstract #1993: Sakimoto, S. E. E., and Garvin, J. B. *Topography of Impact Structures on the Northern Polar Cap of Mars.*

  Abstract #1652: Zimbelman, J., Hooper, D., Crown, D., Grant, J., Sakimoto, S. E. H., and Frey, H. *Medusae Fossae Formation, Mars: An Assessment of Possible Origins Utilizing Early Results from Mars Global Surveyor.*

- June 1-4, 1999. Attended MOLA meeting 6/1; AGU Spring Meeting 6/2 in Boston, MA. Contributed papers: Sakimoto, S. E. H., and Garvin, J. *Impact Craters on the Mars North Polar Cap;* Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., and Schnetzler, C. *First Global Assessment of Topographic Characteristics of Impact Craters on Mars.*

- July 11-16, 1999. Contributed paper to 62nd Annual Meteoritical Society meeting in South Africa: Garvin, J. b., Schnetzler, C., Frawley, J. J., and Sakimoto, S. E. H. *Global Geometric Characteristics of Fresh Impact Craters on Mars: A New Perspective From the Mars Orbital Laser Altimeter (MOLA).*

- July 19-23, 1999. Attend 5th International Mars Conference in Pasadena, CA. Contributed 2papers: Sakimoto, S. E. H., and Garvin, J. B. *Martian Polar Impact Craters: A Preliminary Assessment Using Mars Orbiter Laser Altimeter (MOLA);* Garvin, J. B., Sakimoto, S. E. H., Schnetzler, C., and Frawley, J. J. *Global Geometric Properties of Martian Impact Craters: A Preliminary Assessment Using Mars Orbiter Laser Altimeter (MOLA) Topography.*

- July 24-25, 1999. Presented MOLA cratering work to the Mars crater morphology consortium meeting at the U. S. Geological Survey, in Flagstaff, AZ.

- August 30-September 3, 1999. Attended MOLA science meeting in Whitefish, MT. Presented recent Mars polar volcanism research results.

- October 18-19, 1999. 4th Annual Volcanologists of the East Coast Gathering at the Center for Earth and Planetary Studies, Smithsonian Institution, Washington, DC. Presented talk: *Recent Mars Medusae Fossae Formation and Small Polar Volcanoes Research Results*

- October 24-27, 1999. Attended annual Geological Society of America meeting in Denver, CO. Frey, H. V., Hutchison, L., Roark, J., and Sakimoto, S. E. H. *New Candidate Ancient Impact Basins on Mars Found Through Analysis of MOLA Profile and Gridded Data.*

- December 15, 1999. AGU Fall Meeting. Poster presentation: Gregg, T. K. P., and Sakimoto, S. E. H. *Lava Flow Emplacement in Tubes, Channels, and Sheets.* Presented by Gregg.
    Poster: Sakimoto, S. E. H., Garvin, J. B., Wright, H., Molinero, R. *Topography of Small Volcanic Edifices in the Mars Polar Regions: Early Results from Mars Orbiter Laser Altimeter (MOLA).*
    Talk: Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., Matias, A., Bleacher, J. *Geometric Properties of Impact Craters on Mars: A Synthesis from Mars Orbiter Laser Altimeter (MOLA) Observations.*
    Poster: Frey, H., Hutchison, L., Roark, J. H., and Sakimoto, S. E. H. *Evidence for (a Large Population of) Buried Impact Basis on Mars from MOLA Data.*

- February 8-11, 2000. Attended Mars Orbiter Laser Altimeter science meeting at Scripps Oceanographic Institute in La Jolla, CA.

- March 12-17, 2000. Attended Lunar and Planetary Sciences meeting at NASA Johnson Space Center in Houston, TX. Abstracts: #1964: Bleacher, J. E., Garvin, J. B., and Sakimoto, S. E. H. *South Polar Pedestal Craters on Mars: Implications for the South Polar Erosional Regimes from Mars Orbiter Laser Altimeter (MOLA) Data.*
    Abstract #2055: Bradley, B. A., Grosfils, E. B., and Sakimoto, S. E. H. *Boundaries and Stratigraphy of the Medusae Fossae Formation and Elysium Basin Materials Using Mars Orbiter Laser Altimeter (MOLA) Data.*
    Abstract #1736: Frey, H., Hutchison, L., Sakimoto, S. E. H., and Roark, J. *A Large Population of Possible Buried Impact Basis on Mars Revealed by MOLA Topographic Data.*
    Abstract #1748: Frey, H., Roark, J., and Sakimoto, S. E. H. *Detailed Topographic Structure of the Isidis Impact Basin from MOLA Data.*
    Abstract #1619: Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., and Schnetzler, C. *Global Geometric Properties of Martian Impact Craters: An Assessment from Mars Orbiter Laser Altimeter (MOLA) Digital Elevation Models.*
    Abstract # 1758: Gregg, T. K. P., and Sakimoto, S. E. H. *Marte Valles Lava Channel Flow Rates and Rheology from MOC and MOLA Data.*
    Abstract #1311: Grosfiles, E. B., Sakimoto, S. E. H., and Garvin, J. B. *Using Mars Orbiter Laser Altimeter (MOLA) Data to Assess Impact Crater Modification in the Ahrrenius Region of Mars.*
    Abstract #1787: Matias, A., Garvin, J. B., and Sakimoto, S. E. H. *Mid-latitude Simple to Transitional Impact Craters on Mars: From Viking Images and Mars Orbiter Laser Altimeter (MOLA) Topographic Data.*
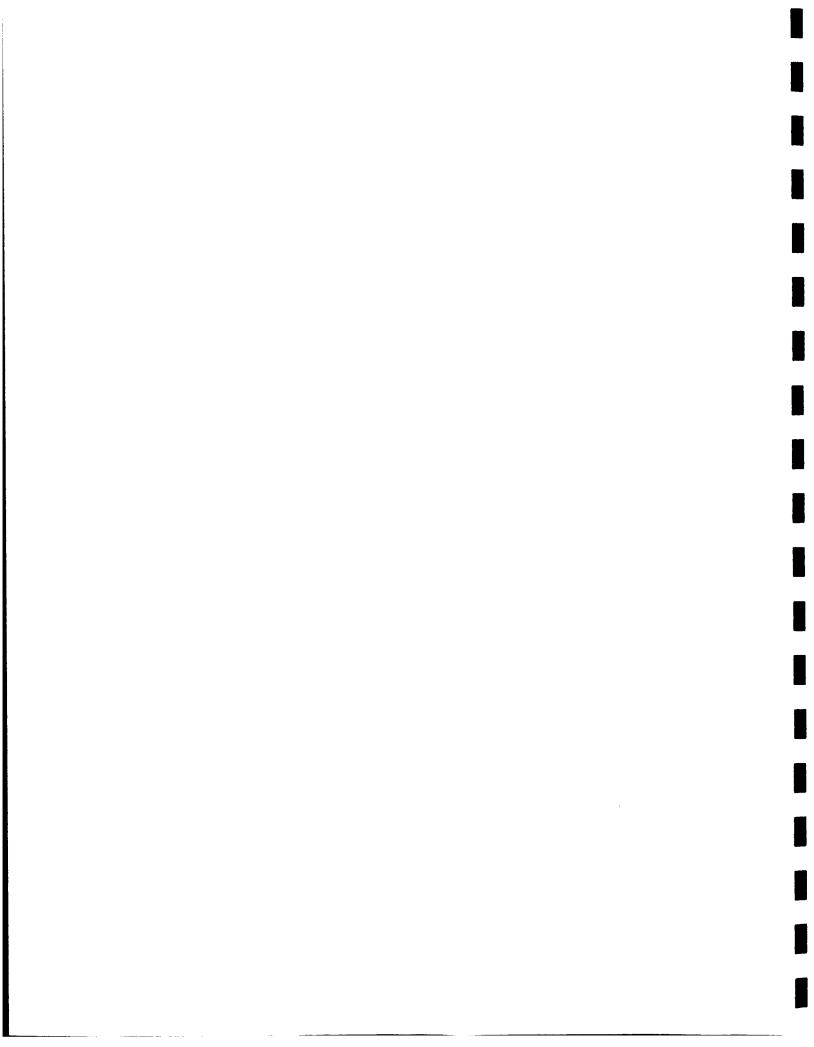   Abstract #1895: Molinero, R. J., Sakimoto, S. E. H., and Garvin, J. B. *Mars Orbiter Laser Altimeter (MOLA) Topography and Preliminary Analysis of a South Polar Enigmatic Small Volcano.*
    Abstract #2026: Roark, J., Frey, H., and Sakimoto, S. E. H. *Interactive Graphics Tools for Analysis of MOLA and Other Data.*
    Abstract #1971: Sakimoto, S. E. H., Garvin, J. B., and Wright, H. *Topography of Small Volcanic Edifices in the Mars Northern Polar Region from Mars Orbiter Laser Altimeter Observations.*
    Abstract #1894: Wright, H., Sakimoto, S. E. H., and Garvin, J. B. *Morphology of some small Mars North Polar Volcanic Edifices from Viking Images and MOLA Topography.*

- May 4, 2000. Presented invited talk on *Volcanism on Mars* to the Mid Atlantic Planetarium Conference in Solomon's Island, MD.

- June 1-2, 2000. Attended AGU Spring meeting in Washington, DC. Presentations: Sakimoto, S. E. H., Frey, H. V., and Zimbelman, J. R. *Topography of the Medusae Fossae Formation, Mars: Evidence from MOLA Data for Possible Layering and Removal.*

Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., Wong, M., and Schnetzler, C. *Geometric Properties of Impact Craters on Mars: An Assessment from Digital Elevation Models from MOLA.* Frey, H, et al. *Impact Craters and Basins at the Boundary: Windows into the Evolution of the Martian Dichotomy.*

- August 21-25, 2000. Attended 2nd International Conference on Mars Polar Science and Exploration in Reykjavik, Iceland. Presented paper: Garvin, J. B., Frawley, J. J., and Sakimoto, S. E. H. *Vertical Roughness of the Polar Regions of Mars from Mars Orbiter Laser Altimeter Pulse-Width Measurements.*

Publications

Garvin, J.B., Sakimoto, S. E. H., Frawley, J. J., and Schnetzler, C. (2000). North polar region craterforms on Mars: geometric characteristics from the Mars Orbiter Laser Altimeter. *Icarus, 144*(2), 329-352.

Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., Schnetzler, C. C., and Wright, H. M. (2000). Topographic evidence for geologically recent near-polar volcanism on Mars. *Icarus, 145* (June), 648-652.

Grosfils E., Aubele, J., Crumpler, L. Gregg, T. K. P., and Sakimoto, S. E. H. (2000). Volcanism, on Earth's seafloor and Venus. In J. R. Zimbelman and T. K. P. Gregg (Eds.), *Environmental Effects on Volcanic Eruptions: from the Deep Oceans to Deep Space.* New York: Plenum Publishing. p. 276.

Sakimoto, S. E. H., Frey, H., Garvin, J. B., and Roark, J. H. (1999). Topography, roughness, layering, and slope properties of the Medusae Fossae Formation from Mars Orbiter Laser Altimeter (MOLA) data. *Jr. of Geophys. Research-Planets, 104*(E10) 24141-24154.

Frey, H., Sakimoto, S. E. H., and Roark, J. (1999). Discovery of a 450 km diameter, multi-ring basin on Mars through analysis of MOLA topographic data. *Geophys. Res. Let., 26*(12), 1657-1660.

Sakimoto, S. E. H., and Zuber, M. T. (1998). Flow and convective cooling in lava tubes. *Jr. of Geophys. Res.--Solid Earth, 103* (B 11), 27465-27487.

Frey, H., Sakimoto, S. E. H., and Roark, J. (1998). The MOLA topographic signature at the crustal dichotomy boundary zone on Mars. *Geophys. Res. Let., 25*, 4409-4412.
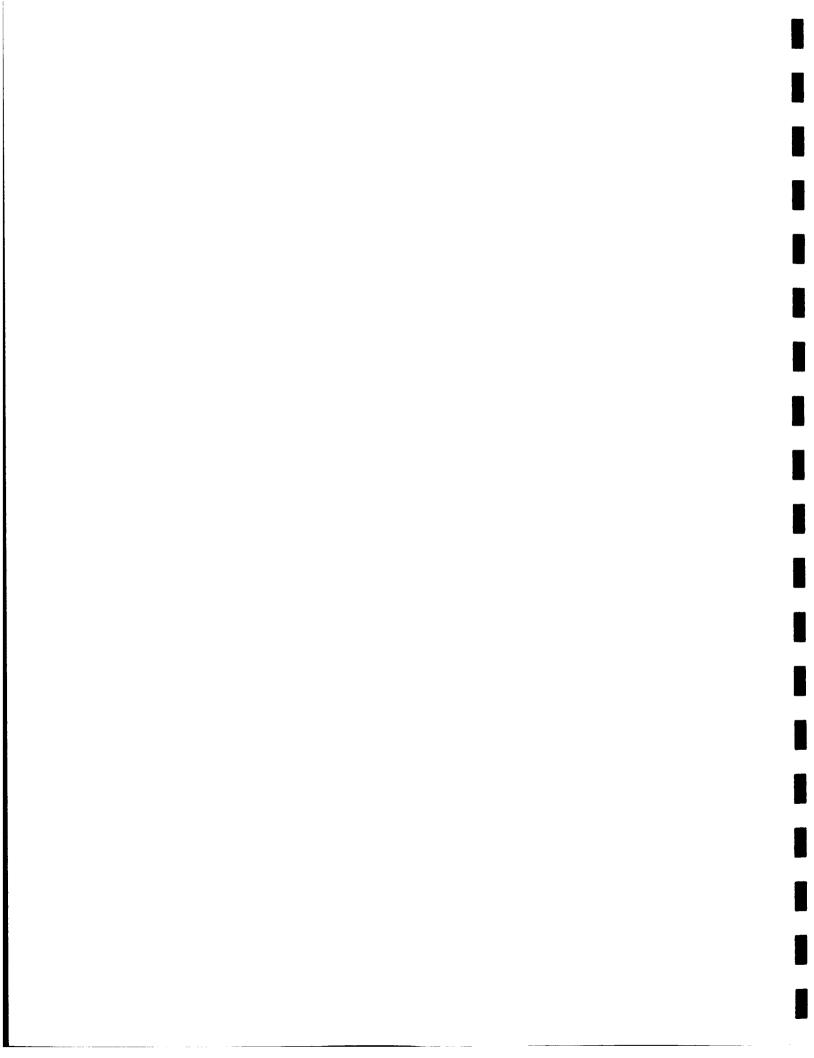
USRA EMPLOYEE: MARTIN WONG

Research focus: Processing, analysis, and validation of data for MOLA project.

Accomplishments

October 1999 – January 2000

During this period, I have been working exclusively with Mars Orbiter Laser Altimeter (MOLA) data. My time has been divided between two tasks: data validation of primary MOLA data and making measurements and producing images of geologic features using this data.

Data validation of MOLA data has been conducted in conjunction with Dr. Gregory Neumann (MIT). This data validation process involves examining each track for possible errors, since the main goal of the project is to collect topographic information of the surface of Mars, and the laser is unable to

differentiate between laser returns from the ground and those from clouds and dust storms. Corrected tracks are then available for use by the MOLA science team. This editing is also important because it allows the use of MOLA data as an atmospheric LIDAR, providing information on the location and altitude of those clouds and dust storms.

The other main project that I have been involved with is using the MOLA data to study impact craters on Mars, which has been done in collaboration with Dr. Susan Sakimoto and Dr. James Garvin (NASA GSFC). This involves producing grided topography data of individual impact craters, which allows us to create color digital elevation models of the craters and also to measure the geometric properties of these craters in three dimensions. Individual tracks of MOLA data are also registered to Viking photographic images of the craters to compare the crater morphology with the topography.

<u>February – June 2000</u>

I have continued to work with Greg Neumann on data validation for MOLA data, and with Jim Garvin and Susan Sakimoto on research primarily related to MOLA measurements of impact craters and volcanics on Mars. This work has primarily involved producing digital elevation models, registering MOLA data tracks with both Viking era and new MOC images, and measuring geometric parameters of these various features using MOLA profiles.

The results of some of this work were presented at the 31st Lunar and Planetary Science Conference at the Johnson Space Center, Houston, TX (March 13-17). Jim Garvin presented a talk entitled *Global Geometric Properties of Martian Impact Craters: An Assessment from Mars Orbiter Laser Altimeter (MOLA) Digital Elevation Models* and Susan Sakimoto presented a talk entitled *Topography of Small Volcanic Edifices in the Mars Northern Polar Region from Mars Orbiter Laser Altimeter Observations.* My work contributed to both of these presentations.

Participation in Workshops/Conferences/Meetings

- March 12-13, 2000. Attended Lunar and Planetary Science Conference at USRA's Lunar and Planetary Institute in Houston, TX.

- May 30-June 3, 2000. Attended AGU Spring Meeting in Washington, DC.

Publications

Sakimoto, S. E. H., Frey, H., Wong, M. (2000). MOLA topography of large volcanic channels or tubes from Syrtis Major into Isidis Basin, Mars. *EOS Trans., 81*(18), S293.

Garvin, J. B., Sakimoto, S. E. H., Frawley, J. J., Wong, M, and Schnetzler, C. (2000). Geometric properties of impact craters on Mars: An assessment from digital elevation models from MOLA. *EOS Trans., 81*(18), S292.

CONSULTANTS/VISITORS

Visitor:	**T.H. Jacka** (Antarctic Division Glaciology Program, Australia)
Collaborator:	James Garvin
Purpose:	To attend the Fall AGU meeting in San Francisco, CA (12/6-10/98)

Visitor:	**Sveinn Jakobson** (Icelandic Museum of Natural History, Iceland)
Collaborator:	James Garvin
Purpose:	To attend the Fall AGU meeting in San Francisco, CA (12/6-10/98)

Visitor: **Audeliz Matias** (University of Puerto Rico)
Collaborator: Susan Sakimoto
Purpose: To attend the 30th Lunar and Planetary Science Meeting in Houston, TX (3/15-19/99)
Work on Mars Orbiter Lasar Altimeter research (11/7-14/99)

Visitor: **Kathy Whaler** (University of Edinburgh, Scotland)
Purpose: Develop and test sparse matrix/conjugate gradient techniques for global downward
continuation and inversion with remanence (8/23-9/23/99)

Visitor: **Heather Wright** (U. S. Geological Survey)
Purpose: Work on the topography of Mars Polar volcanic edifices (2/24-28/00)

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TASK 921-02: Visiting Scientists in Geomagnetism, Planetary Volcanism, MOLA Topographic Studies

TASK DESCRIPTION

The objective of this task was to provide for visiting scientists to collaborate on studies at GSFC in the areas of geomagnetism, planetary volcanism, MOLA topography, and other areas closely aligned with ongoing activities in the Geodynamics Branch. Visits were expected to range from 1 day to several months, including summer appointments, for personnel at various academic levels (graduate students, post-docs, senior scientists). Visitors were expected from U. S. and foreign institutions. The contractor was expected to arrange for airline tickets, local travel, housing, and meals, and if necessary, visas.

CONSULTANTS/VISITORS

Consultant: **Julia Saul**
Purpose: Assist Dr. Sakimoto in the reduction and analysis of Mars mission data (12/28/98-1/8/99)

Visitor: **Desmond Darby** (Institute of Geological and Nuclear Sciences, New Zealand)
Collaborator: Steven Cohen
Purpose: Collaborative research in geodynamics (1/24-2/13/99)

Visitor: **Dennis Fatland** (Vexcel Corporation)
Purpose: To present a seminar on Bering Glacier and work with Jeanne Sauber (5/17-18/99)

Visitor: **Richard Grieve** (Earth Science Center)
Collaborator: James Garvin
Purpose: Discussions concerning impacts and climate changes on Earth and Mars (5/16-18/99)

Visitor: **Frank Lowes** (University of Durham, UK)
Purpose: Assist Dr. Sabaka with the preparation of an international Geomagnetic Reference Field (10/11-16/99)

Visitor: **Art Richmond** (National Center for Atmospheric Research)
Collaborator: Michael Purucker
Purpose: Scientific discussions of the comprehensive model of near-Earth Magnetic field (11/8-10/98)

TASK 921-03: Visiting Scientists for Planetary Geology and Geophysics

TASK DESCRIPTION

The objective of this task was to provide for visiting scientists to collaborate on studies at GSFC in the areas of planetary geology and geophysics, laser altimetry, MOLA topography, and other areas closely aligned with ongoing activities in the Geodynamics Branch. Visits were to be primarily summer appointments for personnel at various academic levels (graduate students, post-docs, and senior scientists). The contractor was responsible for making travel arrangements, providing airline tickets, local travel, housing, and meals, and if necessary, visas.

CONSULTANTS/VISITORS

Consultant: **Jacob Bleacher** (Franklin and Marshall College)
Purpose: Summer Intern working on the analysis of Mars impact crater topography (6/5-8/14/99 and 7/9-21/00)
Attend the Lunar and Planetary Conference in Houston, TX (3/11-17/00)

Visitor: **Audeliz Matias** (University of Puerto Rico)
Purpose: Summer Intern working on the analysis of Mars impact crater topography (6/5-8/14/99)
Attend the Lunar and Planetary Conference in Houston, TX (3/11-17/00)

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TASK 923-07: Research in Terrestrial-ecology

TASK DESCRIPTION

This task was to support research in terrestrial-ecology, land surface atmosphere interactions, and remote sensing. Support was to include participation in workshops, seminars, and symposia, as well as access to data not readily available in the public domain. There was also to be collaborative research on the preparation and publication of joint research papers. The contractor was to provide visiting fellows, consultants, and sabbatical faculty. The task provided travel, local per dia, and honoraria for participants in workshops, seminars, symposia, guest lectures, and for consultants. Visiting fellows and sabbatical university faculty were to be provided supplemental housing allowances, travel, and supplemental salary.

CONSULTANTS/VISITORS

Consultant: **Slava Kharuk** (Sukachev Forest Institute, Russia)
Collaborator: Jon Ranson
Purpose: Discuss and review joint research results on the Siberian Mapping Project and plan the next phase of the analysis (12/3-16/98)
Discuss and review joint research for mapping forest type and condition in Siberia (4/26-5/1/00)

Consultant: **Zengyuan LI** (Chinese Academy of Science, China)
Collaborator: Jon Ranson
Purpose: Collaborate on NASA project to study Chinese forests and agriculture with remote sensing (3/13-27/99)

Visitor: **Ulrike Lohman** (Dalhousie University, Canada)
Collaborator: Brent Holben
Purpose: Collaborative research on EOS-Ids (6/6-24/99)

Visitor: **Stefan Sandmeier** (University of Zurich, Switzerland)
Collaborator: Donald Deering
Purpose: Collaborative research involving the assessment of LAI in boreal forest fire chronosequences (7/1-9/30/99)

Visitor: **Guoging Sun** (University of Maryland)
Collaborator: Jon Ranson
Purpose: Attend FRINGE '99, present research results in China (11/8-14/99)
Attend Digital Earth symposium and present research results in Belgium (11/27-12/10/99)

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TASK 923-08: LBA-Ecology Module

TASK DESCRIPTION

This task provided support for activities and training programs related to the implementation of NASA's LBA-Ecology module of the Large-scale Biosphere-Atmosphere (LBA) Experiment in Amazonia and related projects. The contractor was to provide support for U. S. and non-U. S. scientists and technicians who were performing science and implementation functions at the request of the LBA-Ecology Project Manager. Contractor support included, but was not limited to, reimbursement of travel expenses, housing, per dia, and other related expenses.

One activity was database management training for LBA staff members who were managing the LBA database at CPTEC. It was expected that INPE/CPTEC employees might be in residence at GSFC, and possibly ORNL, to learn how NASA has conducted operational large experiment database activities.
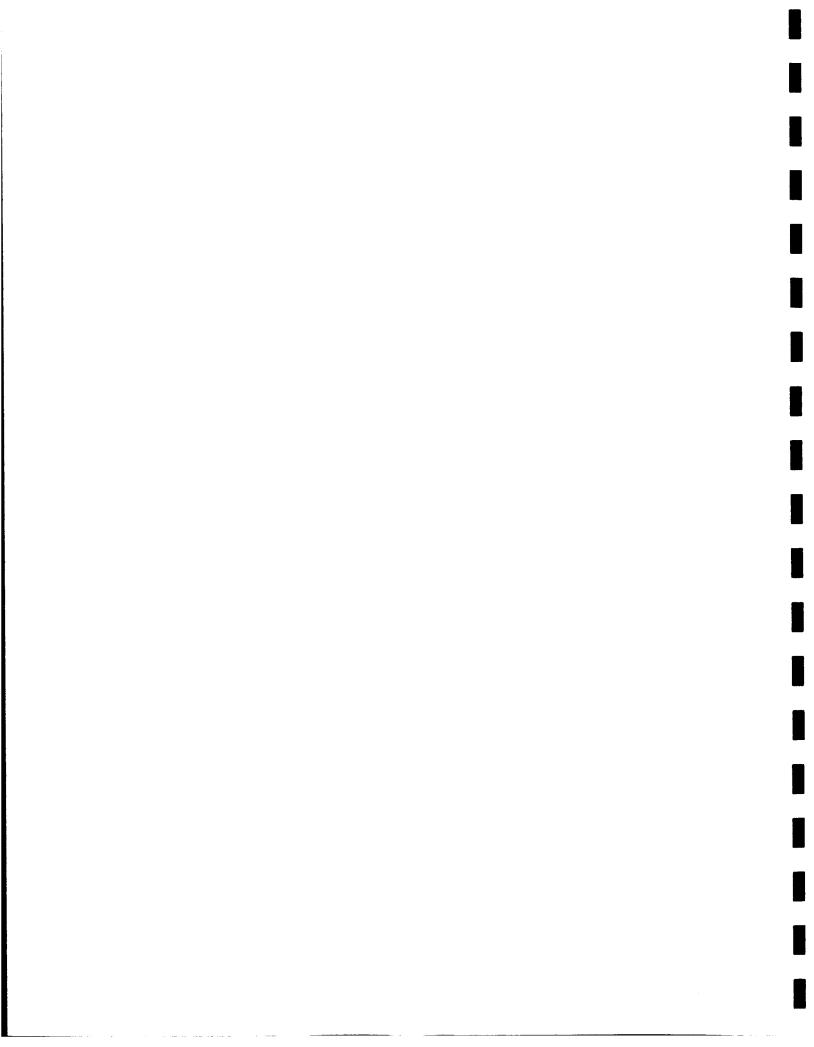
The contractor was also expected to provide reimbursement of travel expenses for members of the science team in the LBA and Northern Eurasia Study (NES) programs to include participation in site selection, scientific symposia, workshops, training modules, and modeling studies. The science team was comprised of citizens of the U. S., Brazil, Europe nations, and Russia.

CONSULTANTS/VISITORS

Consultant: **Weldon Mitchell** (Mitchco Productions)
Purpose: Provide video recording services for First Aid and Tower Safety Training Workshop in Santarem, Brazil (1/30-2/7/00)

Consultant:	**Ivani Pereira** (Sao Paolo University, Brazil)
Purpose:	Serve as interpreter/translator to Project Manager meeting with Brazilian organizations. Become familiar with LBA Ecology project (9/18-9/29/99)
Consultant:	**Stefan Sandmeier** (University of Zurich, Switzerland)
Purpose:	Collaborative research involving the assessment of LAI in boreal forest fire chronosequences (1/1-6/30/99)
	Research in terrestrial ecology, land surface-atmosphere interaction (10/1-12/31/99)
	Attend IEEE IGARSS '99 conference and present a seminar in Germany (6/28-7/2/99)
Visitor:	**Gregory Asner** (University of Colorado)
Purpose:	Attend the LBA workshop on Remotely Sensed Land Surface Properties in Brazil (3/8-13/99)
Visitor:	**Jeffery Chambers** (University of California, Santa Barbara)
Purpose:	Travel to Brazil as the Instructor, LBA Site Operations course (10/12-27/98)
Visitor:	**Jing Chen** (Canada Centre for Remote Sensing, Canada)
Purpose:	Present a seminar on recent work in the Canadian Forest (12/15-/17/99)
Visitor:	**Mark Cochrane** (Woods Hole Research Center)
Purpose:	LBA-Ecology Science Team meeting in Brazil (12/11-19/98)
Visitor:	**Patrick Crill** (University of New Hampshire)
Purpose:	LBA Ecology site reconnaissance and decision making in Brazil (12/11-19/98)
Visitor:	**Eric Davidson** (Woods Hole Research Center)
Purpose:	LBA Science Steering Committee mtg. in Cachoeira Paulista , Brazil (10/29-11/21/98)
	LBA Science Steering Committee Meeting in Belern, Brazil (5/17-6/5/99)
	Participate in large-scale Biospheric Atmosphere Experiment in Amazonia (11/6-14/99)
Visitor:	**M. Craig Dobson** (University of Michigan)
Purpose:	LBA workshop on Remotely Sensed Land Surface Properties in Brazil (3/9-13/99)
Visitor:	**Saulo Roberto dos Santos** (Saulo Roberto dos Santos Enterprises, Brazil)
Purpose:	Participate in the LBA-Ecology Project at GSFC (10/14-19/98)
Visitor:	**Thomas Dunne** (University of California, Santa Barbara)
Purpose:	LBA Science Steering Committee meeting in Cachoeira Paulista, Brazil (10/31-11/4/98)
Visitor:	**David Fitzjarrald** (SUNY, Albany)
Purpose:	LBA-Ecology Science Team, decision making on various sites in Brazil (12/9-27/98)
Visitor:	**Michael Goulden** (University of California, Irvine)
Purpose:	LBA-Ecology Science Team, decision making on various sites in Brazil (12/12-19/98)
Visitor:	**Michael Keller** (USDA Forest Service, University of New Hampshire)
Purpose:	Travel to Brazil for LBA Ecology Science team meeting (10/10-11/27/98)
	Attend the AGU meeting in San Francisco, CA (12/4-11/98)
	Attend the LBA-Ecology Project in Brazil (12/12-28/98)
	Semi -annual LBA Ecology Progress Meeting (1/13-16/99)
	Attend AVIRIS Earth Science and Applications Workshop in California (2/7-12/99)
	LBA Secondary Forest Workshop (2/24-26/99)
	LBA Remote Sensing meeting, follow-up on site selection (3/8-28)
	Attend the meeting with LBA project office (4/7-8/99)
	To Chair 3rd LBA-Science Ecology Meeting in Belem, Brazil (4/17-29/99)

Visitor: **Anastasia Kozhuhovskaya** (Sukachev Institute of Forest Research, Russia)
Purpose: Collaborative research with Dr. Deering on data analysis and planning activities for upcoming field activities in Russia (3/23-4/19/00)

Visitor: **Sylvain LeBlanc** (Canada Center for Remote Sensing, Canada)
Purpose: Collaboration on Siberian Boreal Forest Study (4/9-15/00)

Visitor: **John Melack** (University of California, Santa Barbara)
Purpose: LBA Science Steering Committee meeting in Cachoeira Paulista, Brazil (10/31-11/5/98) Participate in large-scale Biospheric Atmosphere Experiment in Amazonia (11/10-15/99)

Visitor: **Osvaldo Moracs** (Universidade Federal de Santa Maria, Brazil)
Purpose: Represent the LBA Ecology Science Team in Site Decision making (12/13-18/98)

Visitor: **Emilio Moran** (Indiana University)
Purpose: Participate in large-scale Biospheric Atmosphere Experiment in Amazonia (11/9-15/99)

Visitor: **J. William Munger** (Harvard University)
Purpose: LBA-Ecology Science Team, decision making on various sites in Brazil (12/12-19/98)

Visitor: **Jeffrey Richey** (University of Washington)
Purpose: Participate in large-scale Biospheric Atmosphere Experiment in Amazonia (11/7-19/99)

Visitor: **Humberto Rocha** (University of Sao Paolo, Brazil)l
Purpose: Participate as a member of the LBA-Ecology Science Team (12/13-20/98)

Visitor: **Whendee Silver** (University of California, Berkeley)
Purpose: LBA Ecology site reconnaissance and decision making (12/7-18/98)

Visitor: **Peter Thornton** (University of Montana)
Purpose: Installation of Biom-BGC ecosystem model and to train A. Conley (2/15-19/99)

Visitor: **Gerald Urquhart** (Michigan State University)
Purpose: Attend LBA-Ecology ESIP workshop (4/7-9/99)

Visitor: **Iara Weissberg** (Centro de Previsao de Tempo & Estudos Climaticos, Brazil)
Purpose: LBA-Ecology Project - Negotiate field office space (12/23/98-1/3/99)

Visitor: **Steven Wofsy** (Harvard University)
Purpose: LBA-Ecology Science Team, decision making on various sites (12/12-19/98)

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TASK 923-09: Support for Earth Orbiter Mission

TASK DESCRIPTION

The objective of this task was to provide research, as part of the New Millenium Program's Earth Orbiter Mission (NMP-EO-1) on evaluation of data from the Advanced Land Imager (ALI). The general objective was to validate the spectral and spatial performance of the ALI relative to the performance of the LANDSAT-7 Imager, ETM+, in support of selected EO-1 investigators, and as part of the activities conducted within the EO-1 Science Data Center.

The task covered research in support of the NMP/EO-1 mission to evaluate the utility of Hyperion imaging spectrometer data for meeting future needs of the LANDSAT science community. Research consisted of aggregating hyperspectral observations into LANDSAT-like bands as well as developing/modifying algorithms for exploiting the spectral nature of the data. Both approaches were needed to evaluate the capability of hyperspectral remote sensing for addressing questions of interest to the LANDSAT community.

USRA EMPLOYEE: DR. CHANG-WOO AHN

Research focus: Development of techniques for calibration and modeling of hyperspectral remote sensing data response to spacecraft motions.

Accomplishments

October – December 1998

Work continued on testing the Constrained Energy Minimization (CEM), Spectral Angle Mapper (SAM). We modified CEM (MoCEM), and Normalized Spectral Difference (NSD) mappers for spectral purity in terms of detectability with various AVIRIS scenes. NSD is an effective tool for measuring spectral purities of mixed pixels although not for detecting albedo differences for the same class. Based on these findings, I have been working on the manuscript for the submission to any remote sensing related journals.

For the efficient analysis of hyperspectral data, a forward stepwise searching technique with Spectral Angle Mapper (SAM) has been developed for prescreening potential endmember candidates although this approach was suboptional. These endmembers can be refined by orthogonalization and rotation procedures (factor analytical inversion process). This tool can be used as an automatic process for evaluating the information content of ETM+ and EO-1/Hyperion data.

Work continues on evaluating the simulated data sets for the effects of spacecraft yaw attitude error on performances of classification with several tools. Band sensitivity to yaw attitude error was measured with a semivariance approach. Omission and commission errors for the differenced thematic image between the original and simulated were calculated for each class with several classifiers.
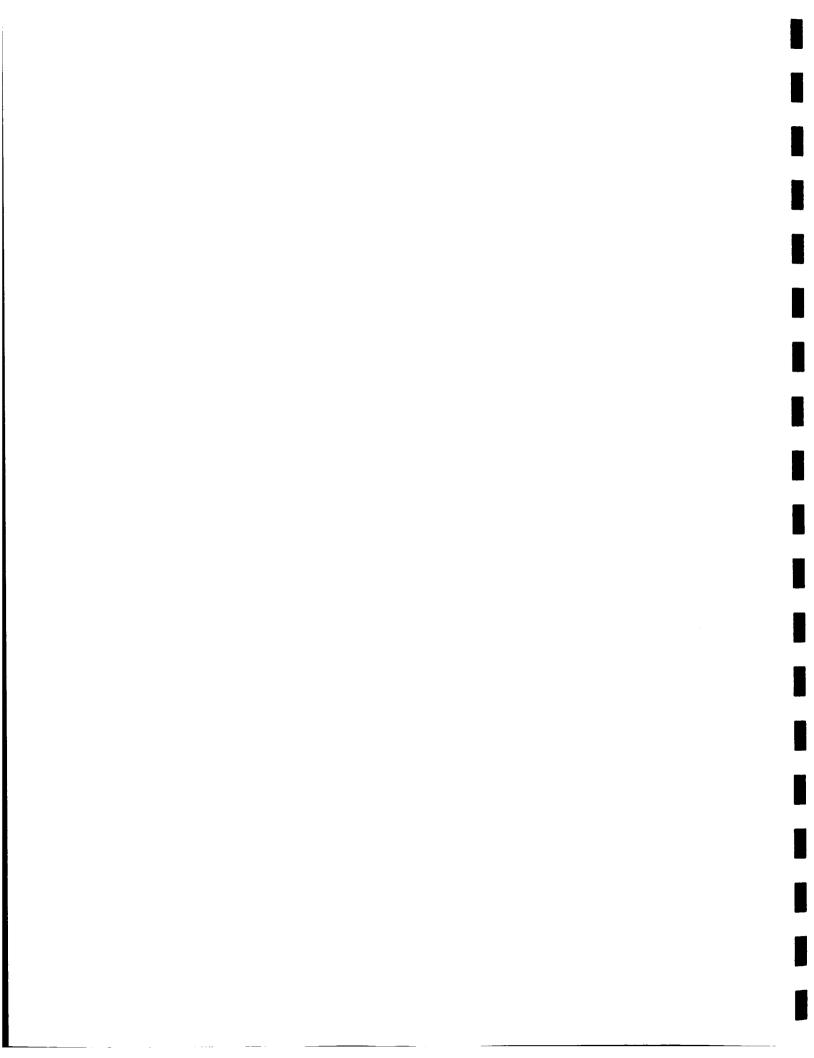
EO-1 MS/Pan data were simulated from 1997 AVIRIS Jasper Ridge data with a weighted interpolation method.

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TASK 923-10: Research on Hyperspectral Remote Sensing Data

TASK DESCRIPTION

The objective of this task was to support collaborative research on the analysis of multi-angle and hyperspectral remote sensing data in conjunction with models of solar radiation scattering by forest canopies to retrieve biophysical forest parameters, and to map forest characteristics, forest stand types and species, and forest ecosystems. There was to be participation in on-site international field experiments, including the operation of airborne sensors, the collection of data in the field, collaboration on the preparation and publication of joint research papers, and preparation and presentation of methods and results at seminars, workshops, and scientific symposia.

The contractor was expected to provide travel expense reimbursement for participants in field campaigns. These campaigns involved operation of instruments mounted in planes, helicopters, towers, booms, or hand held, and the collection, processing, and analysis of various data.

USRA EMPLOYEE: DR. ABDELGADIR ABUELGASIM

Research focus: Remote sensing algorithm and modeling studies of biophysical forest parameters.

Accomplishments

October 1998 – September 1999

I have continued my research work on the inversion of physically-based models and the investigation of the different procedures of estimating vegetation biophysical parameters from multiangle satellite measurements. Two new added research works since the last review which are already done are: 1) a review research work about the different paradigms of estimating vegetation parameters from satellite data, and 2) comparison between two methods widely used for inverting physically based BRDF models. Two other research topics I am currently undertaking (just started) are 1) estimating the fraction of absorbed photosynthetically active radiation using narrow band spectra and second derivative of the reflectance curve, and 2) use of hyperspectral multiangle data for estimating leaf area index.

The findings from the first two topics undertaken show that artificial neural networks offer many advantages for the inversion of physically-based models and the estimation of vegetation biophysical parameters in comparison to the simplex multidimensional optimization technique. Among the key findings were that neural networks were shown to be more practical and useful in handling satellite data on a pixel by pixel basis. Neural networks do not need initial guesses and work adaptively by examples to approximate the relation between input and output parameters. Another important finding is that for most conventional optimization methods, model simplification is necessary to reduce its complexity for the inversion. In the case of using neural networks, this is not important, and they can be applied to the most complicated model without the need for reducing a model dimensionality.
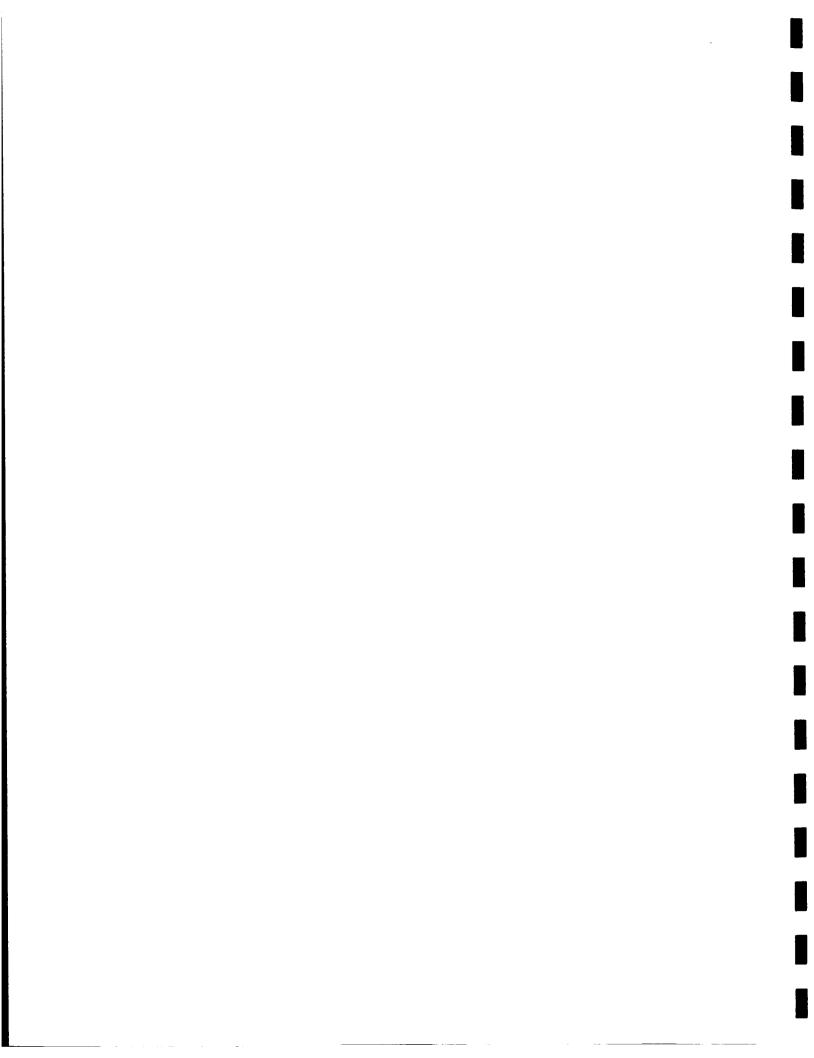
With respect to the research involving model inversion and vegetation parameter estimation, I believe the findings are significant in terms of providing a new approach that is more practical and accurate. A few refinements are still needed to the neural network approach that are summarized in the research articles.

October 1999 – January 2000

I am currently working on articles in two research areas:

1) An investigation of the relation between fpar and the second derivative of the spectral reflectance curve, using ASAS and AVIRIS BOREAS data.

   The basic idea is to statistically explore the relation between fpar and the second derivative of the spectral reflectance curve. I am using ASAS and AVIRIS data for calculating the second derivative. The image processing part involves geometric registration, atmospheric correction, and the location of the ground measurement transects on the image. Field measured values of fpar will be compared with the second derivative to derive the statistical relation at 690 nms and at 740 nms.

So far most of the image processing for ASAS is done, and I am trying to locate the measurement locations on the images. For AVIRIS data, most of the image registration has been done. Remaining are atmospheric correction and measurement transects identification on the images.

2) Noise effects on the estimation of canopy parameters using neural networks.

The underlying idea for this research is to incorporate a level of noise in the directional reflectance during training of a neural network. This is thought to reduce the effect of noise within sensor measurements and yield better estimates of canopy parameters during inversion. The process involves modeling the bidirectional reflectance of various vegetation sites and adding a random noise to the generated data. So far the modeling part has been done, and I am in the process of building the canopy inversion neural networks.

Publications

Kimes, D., Knjazikhin, Y., Privette, J., Abuelgasim, A., and Gao, F. (In press). Inversion methods for physically based models. *Remote Sensing Reviews*.

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TASK 923-11: Satellite Date From Ground Meteorological Stations

TASK DESCRIPTION

This task supported a team of Goddard Earth and computer scientists studying the Earth's surface using satellite data from ground meteorological stations, the NOAA polar-orbiting meteorological satellites, SeaWiFS, and the Terra platform. Analytical methods used in these analyses included time series analysis, principal components, wavelets, and related decomposition techniques. The processing of satellite data into retrieved surface parameters such as vegetation index, out-going long wave radiation, sea surface temperature, and related parameters were to be used to obtain information about the global land surface and how it varies in time.

USRA EMPLOYEE: DR. ASSAF ANYAMBA

Research focus: Research on interannual African climate variability.

Accomplishments

October 1998 – June 2000

The specific position requirements were to carry out research in collaboration with other scientists in the GMIMS group on interannual variability of vegetation over Africa and its relation to El Niño/Southern Oscillation (ENSO).

During the period of performance of this task, I co-authored a paper that was published in the journal *Science*, which received widespread attention within and beyond the scientific community. In particular this article was the first unique demonstration of the explicit close coupling between extreme weather events (ENSO) and the outbreak of disease. This paper received an excellent and supportive review in *Science* by Paul R. Epstein, (Harvard Medical School), one of the outstanding

researchers on climate-related and tropical diseases. This research has provided momentum to NASA/HO Human Health Initiative Program.

During this task period, I completed a thorough evaluation of our Africa 8-krn NDVI product (1982-1998) and started work on the North American product. I have developed research links with Walter Reed Army Institute of Research (WRAIR). As a result of this effort, WRAIR has agreed to provide funding to support the research initiative on Climate and Human Health.

I also successfully co-advised a summer student on the GSFC VSEP program. This was a very productive experience. We accomplished a lot during the student's internship period.

Participation in Workshops/Conferences/Meetings

- August 20, 1999. Presented talk entitled *Seasonal and Interannual Climate Signals Inferred From NDVI Time Series Data for Africa: 1982-1998* at the GSFC Hydrospheric Sciences Branch seminar.

- September 20-22, 1999. Attended the International Conference on Integrated Drought Management: Lessons for Sub-Saharan Africa in Pretoria, South Africa. Gave presentation: *Warm ENSO Event of 1997/98: NDVI Precursor and Drought Pattern Prediction for Southern Africa.* Presented poster: *Botswana Seasonal Prediction of NDVI Anomalies: 1997/98 Drought Patterns and Post-season Assessment.*

- November 6-13, 1999. Invited by the United Nations Environmental Program (UNEP), the International Development Research Center (IDRC), and the Pan-American Health Organization (PAHO) to attend the international meeting on Ecosystems Approaches to Human Health: Communicable and Emerging Diseases held in Rio de Janeiro, Brazil. This meeting was hosted by the Brazil National School of Public Health of the Oswaldo Cruz Foundation (ENSP-FIOCRUZ). The purposed of the meeting was to bring together an interdisciplinary team of scientists to discuss the current state of research and ecosystem approach methodologies to public health and tropical diseases. There was a lot of interest in linking remote sensing data and GIS applications into the human/public health fields. I presented our recent work (Linthicum, et al. *Climate and Satellite Indicators to Forecast Rift Valley Fever Epidemics in Kenya*) as an example of what remote sensing data can do to help the field of human health and disease monitoring.

- November 15-26, 1999. Attended the Ecosystems Health Analytical Workshop (ESHAW) for Mapping Malaria Risk in Africa (MARA) hosted by the West Africa Rice Development Association (WARDA) at Bouke, Cote d'Ivoire. I represented Monica Myers (GSFC Human Health Initiative) at this meeting in part to evaluate what NASA can do to assist researchers in the human health community and build research linkages with scientists involved in the MARA Program. In addition, I provided technical "hands-on" support to MARA scientists and analysts in classifying remotely sensed LANDSAT Thematic Mapper™ data for specific study sites in West Africa. One of the critical issues identified at this workshop was this: unlike in eastern and southern Africa where the prevalence of malaria is largely a function of altitude and thus low resolution data can be used in time series studies of malaria/climate linkages, in west Africa the undulating topography demands the use of high resolution satellite data to characterize wetlands and small scale rice fields where mosquitoes breed and there is the proximity of human settlements to these habitats. It was realized that in order to carry out any kind of malaria risk mapping in west Africa, there is need for a case study approach to:
  - Characterize wetland density (extract river/stream networks from LANDSAT TM data);
  - Sample case study sites along a precipitation gradient from the humid zones in the equatorial rainforest along the coast, the savanna, and semi-arid zones in the Sahel;
  - Explore the possibilities of using AVHRR Thermal Data in malaria risk mapping;
  - Develop a humid zone area map for west and central Africa;

- Explore the possibilities of obtaining some new LANDSAT-7 data scenes for some of the MARA sites.

- March 12-16, 2000. Attended 66th Annual Meeting of the American Mosquito Control Association in Atlantic City, NJ. Presented paper: Sithiprasasna, R., Endy, T. P., Endy, K. J., Anyamba, A., Tucker, C. J., Myers, M., Wilson, J. M., and Kelley, P. W. *Linkages Between Climate Indicators and Dengue Hemorrhagic Fever Transmission in Southeast Asia.*

- March 22-30, 2000. Attended 28th International Symposium on Remote Sensing of Environment in Cape Town, South Africa. Presented paper: Anyamba, A., Demoz, B., and Giorgis, H. *Climate Variations at Asmara, The Horn of Africa: 1930-1999.*

- May 7-12, 2000. Attended the 10th Annual Asia-Pacific Military Medicine Conference in Singapore. Presented paper: Sithiprasasna, R., Endy, T. P., Linthicum, K. J., Anyamba, A., Tucker, C. J., and Kelley, P. W. *Potential Role of Climate Indicators in Assessing the Risk of Dengue Infection to Military Operations in Hyperendimic Regions of Southeast Asia.*

- May 17, 2000. Attended GSFC/National Institute of Environmental Health Sciences Workshop on Environment and Health. Gave presentation of Mapping RVF outbreaks using satellite data.

- July 16-19, 2000. Attended the Center for Disease Control's 2000 International Conference on Emerging Infectious Diseases in Atlanta, GA. Presented paper: Linthicum, K. J., Anayamba, A., Tucker, C. J., and Kelley, P. W. *Variations in SSTs and Their Impact on the Frequency on Rift Valley Fever Outbreaks in East Africa.*

Publications

Anyamba, A., Tucker, C. J., and Eastman, J. R. (In press). NDVI anomaly patterns over Africa during the 19997-98 warm ENSO event. *International Journal of Remote Sensing.*

Linthicum, K. J., Anyamba, A., Tucker, C. J., Kelley, P. W., Myers, M. F., and Peters J. (1999). Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science, 285,* 397-400.
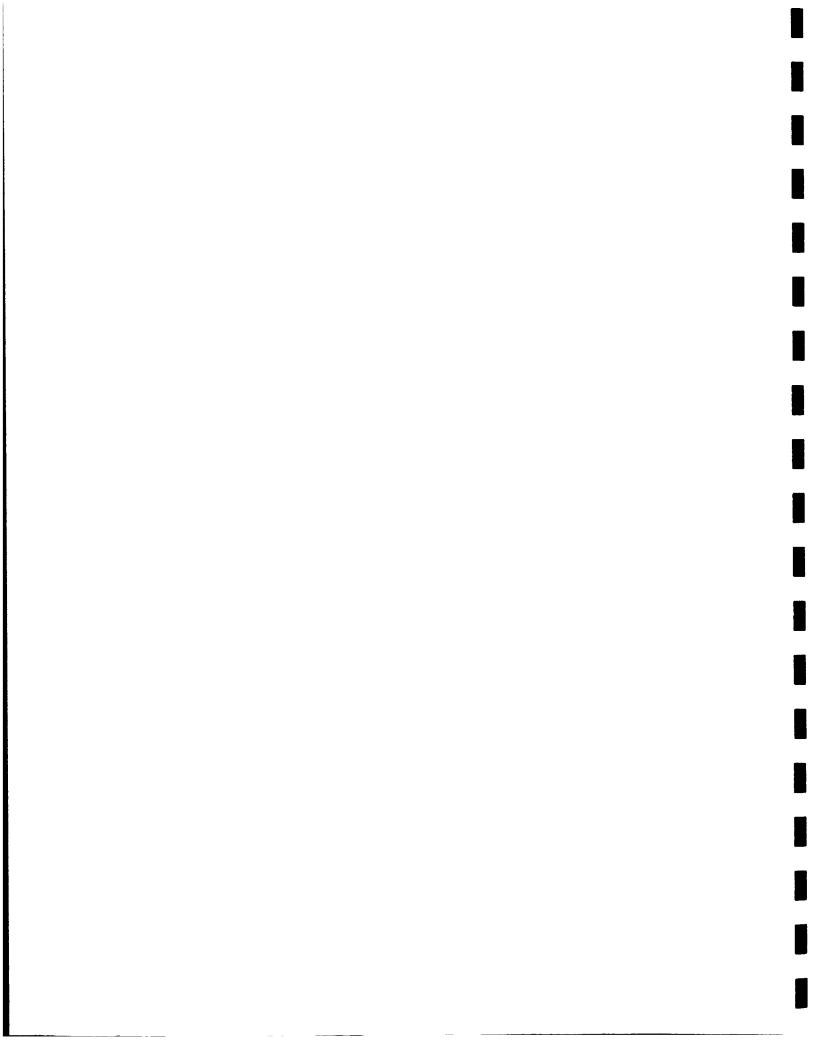
Young, S. S., and Anyamba, A. (1999). Comparison of NOAA/NASA PAL and NOAA GVI data for vegetation change studies over China. *Photogrammetric Engineering and Remote Sensing, 65*(6), 679-688.

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TASK 926-01: Geodynamics of the Earth's Rotational Variations

TASK DESCRIPTION

The objective of this task was to support short-term visiting scientists to assist and work jointly with the task originator on research problems relating to the geodynamics of the Earth's rotational variations. The visitors were expected to analyze global geophysical data in conjunction with the Earth's rotation data, and help prepare technical reports for publication.

The purpose of the task was to support domestic and international visiting scientists for travel and living expenses to spend a period of time at GSFC to conduct research or to attend professional meetings at GSFC or other locations. The general subject of the research was global geodynamics, including Earth rotation and gravitational changes in geophysical fluids, supported by NASA's Earth and Natural

Hazards Program and its related outreach activities. This research was to be conducted in collaboration with the Laboratory for Terrestrial Physics scientists, making use of GSFC on-site computing facilities and GSFC's scientific database. The outcome of the collaborative research was to be scientific publications in professional journals and/or presentations at professional meetings.
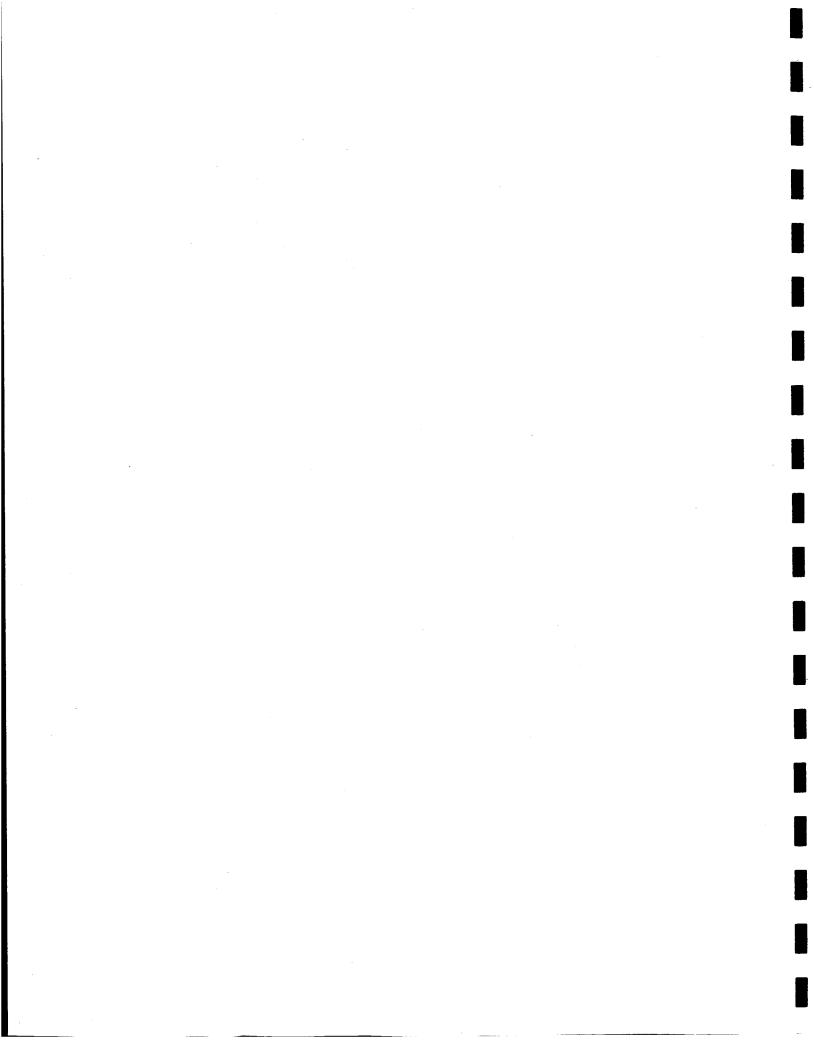

CONSULTANTS/VISITORS

Consultant: **Richard Allenby**   (University of Maryland)
Purpose: Assist with updating and maintaining space geodetic site catalogue and site information charts, and participate on the Geodetic and Geophysical Site Subcommission (GGSS) (10/1/98-3/31/00)
Attend the International Geodetic and Geophysical Site Subcommission meeting during AGU Meeting in San Francisco, CA (12/4-10/98)

Consultant: **Oscar Colombo**   (University of Maryland)
Purpose: Develop, test, and refine software for kinematic GPS positioning of spacecraft and its applications in the Topex/Poseidon project (11/25/98-3/31/99 and 8/26/99-9/30/00)

Consultant: **Dawei Zheng** (Shanghai Astronomical Observatory, Japan)
Purpose: Collaborative research on Earth rotation dynamics and data analysis (1/10-2/9/99)

Visitor: **M. Isabel Vigo-Aguiar** (Univeridad de Alicante, Spain)
Purpose: Analyze satellite laser ranging data using GEDDYN software (2/22-3/28/99)
Analyze Spanish geodetic station positions using GEODYN software and analyze new Mediterranean sea level data acquired by Spanish buoy program (2/14-4/15/00)

EARTH AND SPACE DATA COMPUTING DIVISION (930)

930-04
934-01

TASK 930-04: Support for NASA HPCC/ESS Project

TASK DESCRIPTION

The objective of this task was to support the NASA High Performance Computing and Communications, Earth and Space Science Project with a computational scientist at the professional level of postdoctoral fellow. The individual selected was expected to engage in a program of independent scientific research leading to publication in refereed journals. He/she was expected to work closely with the HPCC/ESS visualization group using his/her own research results for demonstrations of the talents and resources of that group. The incumbent was to serve as the technical liaison between the visualization group and the HPCC/ESS Grand Challenge Teams.

It was thought that the individual might serve as backup technical liaison for one of the HPCC/ESS Grand Challenge Teams. In that role, the individual would have worked with the teams toward the achievement and verification of their negotiated milestones, identify modules within the teams' software exchange submissions that had broad utility, and work with the teams to make those routines part of an HPCC software library with possible inclusion in benchmark suites.

The incumbent was expected to proactively engage the broader GSFC and NASA scientific community to maximize the impact of the unique HPCC/ESS expertise and computational resources. This was to include joint seminars and workshops and attendance at seminars and workshops of other scientific groups. The individual was also expected to present lectures as part of the NASA Summer School for High Performance Computational Physics.

USRA EMPLOYEE: DR. MICHAEL GROSS

Research focus: Scientific visualization
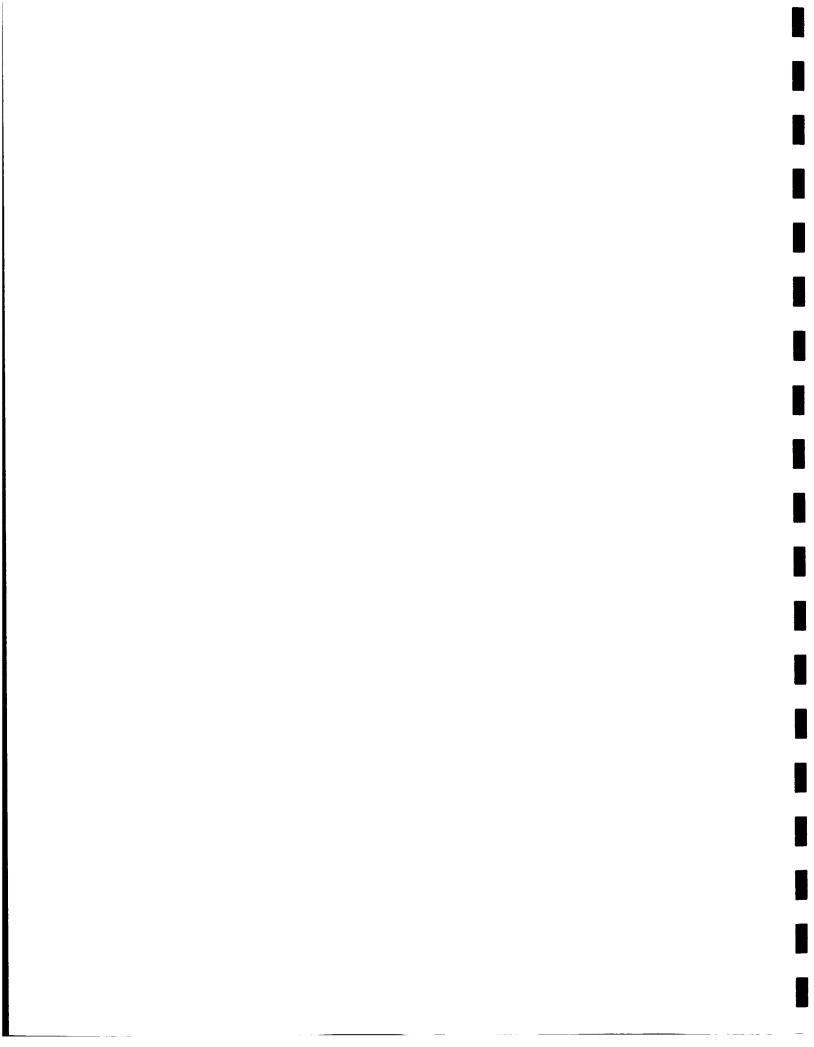
Accomplishments

October 1998 – March 1999

Particle-mesh codes as a finite element process. The original formulation from the summer does not solve simple test cases well enough. Problems are traceable to the use of "hanging" nodes. This is solvable, but messy, and it requires four different types of nodes at refinement boundaries. These results will eventually be submitted to the *Journal of Computational Physics*.

Generated a formalism for "emission weighting" x-ray temperatures for spherical non-isothermal clusters of galaxies. With assumptions for the total mass and the gas density distributions, and the assumption of equilibrium, this allows an x-ray temperature to be related to a virial mass without resorting to simulations. Given a virial mass, well-known semianalytic methods can calculate the number density of such objects. Thus, we can predict the number of x-ray clusters above a given temperature. This can be compared to Einstein and ASCA surveys to constrain cosmological parameters. Of particular interest is to compare a high-redshift survey with a low redshift survey, using the same instrument. Such data exists in the HEASARC archive, using ASCA. Help was provided by Keith Arnaud and Keith Jahoda, both of Code 660.

Used simulations to probe the evolution of number density of clusters of galaxies, when such clusters are observed using a constant fiducial radius rather than the "natural" dynamical radius. The results change substantially at higher redshifts.

Gave interview to Jarrett Cohen (Raytheon) about experiences with large Beowulf computers for very large supercomputer problems.

Corrected serious normalization error in some of the N-body runs. The problem could be traced to a corrupted input file. They were rerun.

<u>Scaled Beowulf N-body code up to full size</u>. Found occasional corrupted messages at random locations in the code. The errors never occurred on other architectures (tested on SP2 and T3E) at the same problem size, and were neither reproducible nor restricted to any particular routine. The problem was traced back to the TCP specification itself. TCP is allowed to drop packets if it gets overloaded. This points out the need for a guaranteed resource protocol on Beowulf computers.

<u>Recompiled microwave background data</u> for comparison to models with input from Ed Wollack (Code 681). This is a bread-and-butter first-cut comparison for cosmological models, to be done before any simulation.

<u>Discussed a "weird" cosmology</u> with Demos Kazanas (Code 660), where the scale factor grows linearly with time, independent of cosmological parameters. Such a cosmology can be ruled out quickly, because gravitational perturbations do not grow.

Participation in Workshops/Conferences/Meetings

* November 8-10, 1998. Attended the HPCC Science Team meeting at Supercomputing '98 in Orlando, FL.

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TASK 934-01: Visiting Scientist Support for the HPCC/ESS Project

TASK DESCRIPTION

The objective of this task was to provide visiting scientist support for the High Performance Computing and Communications (HPCC), Earth and Space Science (ESS) Project. The contractor was expected to support the short-term travel requirements of scientists associated with the GSFC-led ESS applications project within the NASA HPCC Program. Most of the scientists involved were expected to be members of the ESS Grand Challenge Investigator Teams located at universities around the U. S. , with a few residing outside the U. S. Anticipated travel was expected to be several days in length for attendance at ESS Science Team meetings, ESS technical reviews, or other meetings associated with the HPCC Program.

CONSULTANTS/VISITORS

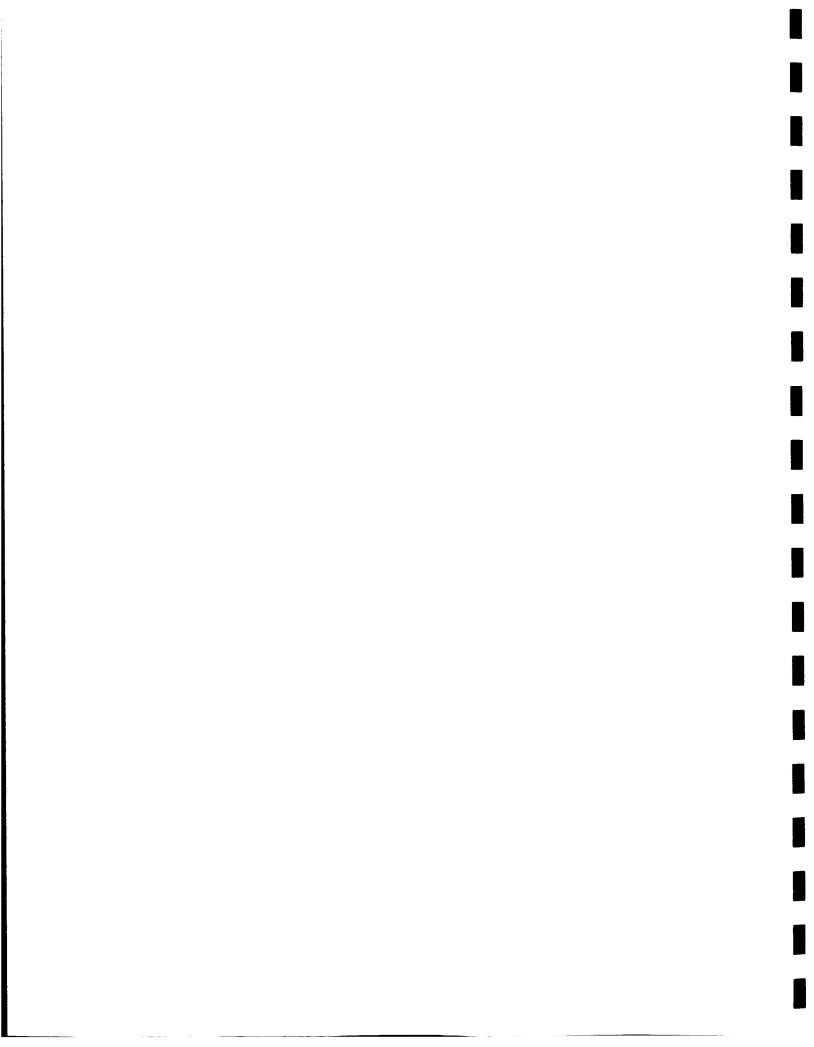Visitor: **Peter MacNeice** (Drexel University)
Purpose: Attend the HPCC Science Team meeting and Supercomputing'98 conference in Orlando, FL. (11/8-11/98)

Visitor: **Anil Deane** (University of Maryland)
Purpose: Attend the HPCC Science Team meeting and Supercomputing'98 conference in Orlando, FL. (11/8-11/98)
Attend the International Conference on High Performance Computing in India and present a seminar (12/17-20/98)
Attend the Parallel CFC '99 in Williamsburgh, VA and present a paper (5/22-26/99)
Attend the HPCC/ESS Round 2 Grand Challenge Team meeting with A. Malagoli at the University of Chicago and the University of Minnesota (6/21-24/99)

LABORATORY FOR HYDROSPHERIC PROCESSES (970)

970-02
970-06
970-07
970-08
970-10

Oceans and Ice Branch (971)

971-01
971-03
971-08
971-09
971-10
971-15

Observational Science Branch (972)

972-01
972-02

Hydrological Sciences Branch (974)

974-04
974-05

Microwave Sensors Branch (975)

975-03
975-05

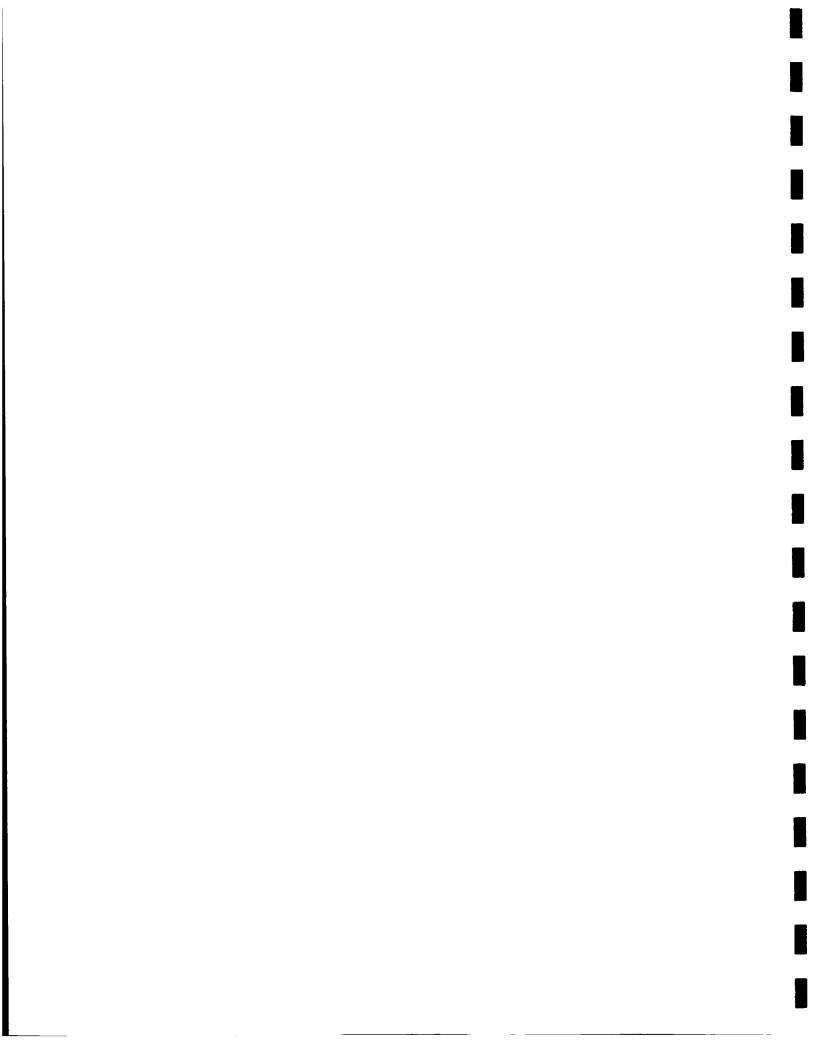# TASK 970-02: Workshop, Conference, Seminar Support

TASK DESCRIPTION

The objective of this task was to provide coordination support for workshops, conferences, and seminars directly related to the technical effort being performed under this contract for the Laboratory for Hydrospheric Processes. The meetings to be supported were to be specific, non-recurring events, where the coordination activities were incidental to the technical effort involved. The contractor was expected to make all arrangements, including the following:
- Identify and send invitations to speakers and participants;
- Arrange for conference rooms;
- Make travel arrangements (including visas, if necessary);
- Provide logistical support at the conference;
- Provide documentation of the conference proceedings, as required by the ATR.

The contractor was also invited to participate in these workshops, conferences, and seminars as speakers and/or advisors and to collaborate with Laboratory scientists as required in preparing for the meetings.

CONSULTANTS/VISITORS

Consultant: **William Emery** (University of Colorado, Boulder)
Purpose: Participate in the external review of the Observational Sciences Branch (12/20-22/98)

Consultant: **Carl Friehe** (University of California, Irvine)
Purpose: Participate in the external review of the Observational Sciences Branch (12/20-22/98)

Consultant: **William Plant** (University of Washington)
Purpose: Participate in the external review of the Observational Sciences Branch (12/20-22/98)

Consultant: **Robert Stewart** (Texas A & M University)
Purpose: Participate in the external review of the Observational Sciences Branch (12/20-22/98)

Visitor: **Michael Anderson** (University of California, San Diego)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (7/14-16/99)

Visitor: **Edmo Campos** (Universidade de Sao Paulo, Brazil)
Purpose: Present a seminar entitled *The Subtropical Shelf Front off Eastern South America* (5/20-21/99)

Visitor: **Scott Harper** (Princeton University)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (8/2/99)

Visitor: **Peter Hildebrand** (National Center for Atmospheric Research)
Purpose: Scientific discussions with Dr. A. Busalacchi (1/18-22/99)
Scientific discussions with the Laboratory for Hydrospheric Processes (4/14-16/99)

Visitor: **Rui Xin Huang** (Woods Hole Oceanographic Institution)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (3/21-25/99)

Visitor: **Tiffany Moisan** (Scripps Institution of Oceanography)
Purpose: Seminar/discussions with Observational Science Branch at Wallops (7/1-2/99)

Visitor: **John Molson** (Southampton College)
Purpose: Seminar/discussions with Observational Science Branch at Wallops (7/1-2/99)

Visitor: **Jian Cheng Shi** (University of California, Santa Barbara)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (7/15-17/99)

Visitor: **Niels Skou** (Technical University of Denmark, Denmark)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (8/22-9/5/99)

Visitor: **Eric Yang** (Massachusetts Institute of Technology)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (7/28-29/99)

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TASK 970-06: Research on Meso- and Large-scale Oceanic Features

TASK DESCRIPTION

The objective of this task was to provide original research with a small team of scientists investigating meso- and large-scale oceanic features, with a particular focus on coastal and marginal areas. The scientific research was to be divided between investigating the vortical complexity of the mesoscale eddy field and establishing the large-scale distribution of biogeochemical properties with some attention given to the interaction of the eddy field with the broader biogeochemical distribution. It is envisioned that numerical and analytical models will be employed to describe the eddy field data. Emphasis was to be upon the nonlinearity and application of a number of different eddy models to represent the data, including elliptic vortices, quasi-geostrophic (QG) vortex expansions, rotating modons, constant vorticity patches, and Rossby solutions. Wherever possible, results were to be validated using situ data sets.

This task required a remote sensing scientist who was familiar with at least some of the current and planned platforms (AVHRR, TOPEX, CZCS, and SeaWiFS) and their products. The scientist was expected to have the following qualifications:
- Ph.D. in physics or physical oceanography;
- Demonstrated expertise with more than one remote sensing data set;
- Well-developed programming skills (C, FORTRAN, or RATFOR);
- Capability in numerical or analytical modeling;
- Familiarity with climatological databases;
- Experience with multivariate data analysis.

USRA EMPLOYEE: DR. JERRY WIGGERT

(Moved to task 970-08 March 1, 1999.)

Research focus: Development of an analytical framework for modeling interacting ocean vortices.

Accomplishments

October 1998 – February 1999

Research task in collaboration with Dr. Stan Hooker: Development and verification of an elliptic vortex model. Deriving an analytical solution to the two-vortex problem has been the focus of my research on this task. So far, some tantalizing results have been generated. The solution that was developed has resulted in the introduction of a new parameter that we have termed the distortion coefficient. Dipole eddies observed in the ocean are not always easily identified because there is generally an obvious main ring and a significantly smaller secondary vortex that can be extremely difficult to discern. The newly derived distortion coefficient indicates that the effects of the secondary vortex should manifest within the shape perturbations of the main vortex that may be realizable with present remote-sensing technology. I presented these results at the last Ocean Sciences meeting.

However, the solution process has also resulted in terms that indicate the presence of energy at other modes (our result and previous work targets only the mode 2 oscillations). This has delayed preparation of a manuscript reporting on our findings until the questions posed by the appearance of these terms are resolved. Our present approach is to investigate alternative analytical methods to apply to this problem and I look forward to reporting on future progress that resolves our present concerns.

In addition to Stan's input and enthusiasm, the development of this solution has benefited greatly from the following: discussions with Jim Brown (RSMAS), who developed the framework for the tools used to derive the analytical solution; Richard Mied (NRL), who is an expert within the field of modon research and applied mathematics; and, Denny Kirwan (ODU), who has also considerable experience in the field of dipole eddy research.

Initiation of a collaboration with Chuck McClain (GSFC) and Ragu Murtugudde (University of Maryland, JCESS) to study physical/biological interactions in the Indian Ocean. The planned research will proceed on several fronts. This will consist of:
1) utilizing presently available *in situ* data that characterizes spatial (especially vertical) hydrographic and biogeochemical parameters and their seasonal evolution;
2) utilizing remote sensing measurements that provide synoptic distribution of physical and ocean color parameters along with their seasonal and interannual variations; and
3) developing and applying interdisciplinary models in which planktonic ecosystems have been coupled to dynamical models.

A 1-D interdisciplinary model is already available and has been applied to studying nutrient cycling and phytoplankton growth in the Arabian Sea during the northeast monsoon. This model will be useful in aiding the development of the ecosystem to be used in the full 3-D version. Also, its ability to study processes at significantly higher temporal and spatial resolution will provide a means of identifying and parameterizing the most relevant processes for inclusion within the 3-D model, the resolution of which is limited by finite computational resources. However, the latter will allow for studies of basis scale interactions and interannual variability. Dr. Murtugudde has recently applied a 3-D ocean general circulation model (OGCM) in numerical experiments designed to advance the understanding of the dynamics of interannual variability in the Indian Ocean. The model will serve as the dynamical framework for the interdisciplinary model.
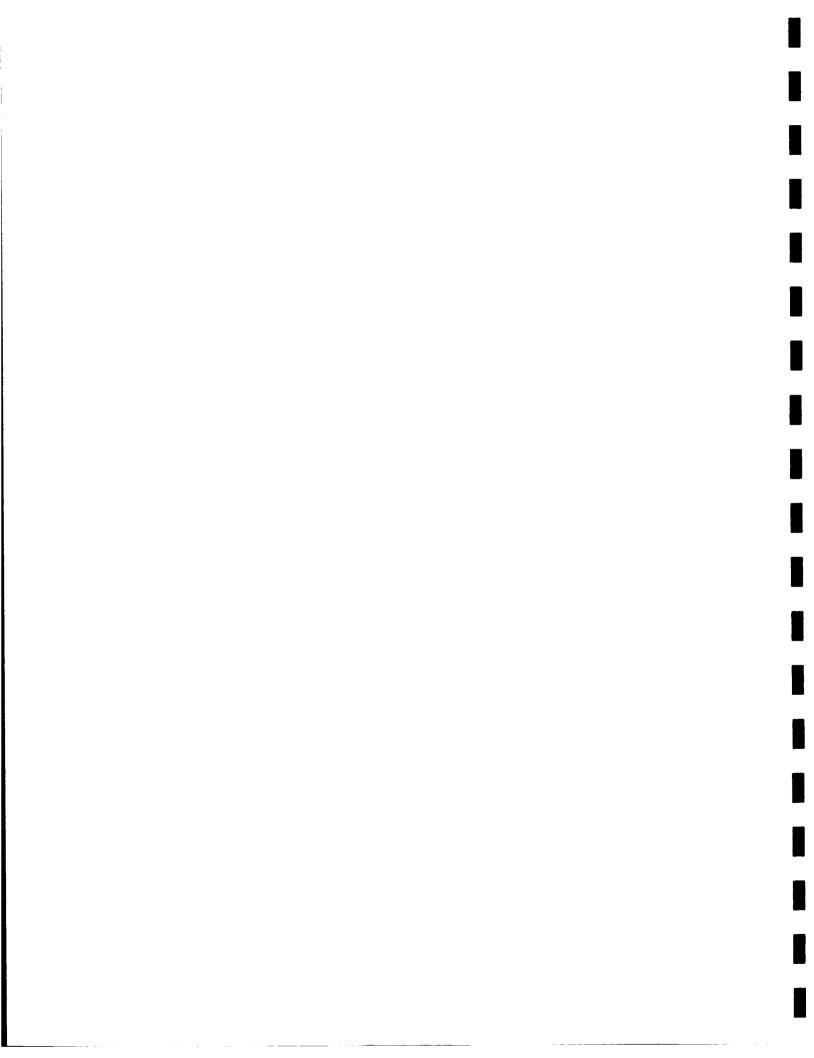
Description of co-located physical and bio-optical time series in the Arabian Sea. I have also contributed to an analysis of the *in situ* physical and bio-optical time series that were collected as part of ONR's Arabian Sea Forced Upper Ocean Dynamics Experiment that took place in conjunction with NSF's Joint Global Ocean Flux Study.

Fourier analysis of Biowatt mooring time series. The following paper (Wiggert, J. D., Granata, T., Marra, J., and Dickey, T. A seasonal succession of physical/biological interaction mechanisms in the Sargasso Sea) describes a sequence of physical/biological interaction mechanisms inferred from extensive time series analysis of coincident physical and bio-optical time series measurements made from an oceanic mooring. A highlight of this report was the long-term, high temporal resolution time series within the euphotic zone that allow for observation of the development and seasonal evolution of the deep chlorophyll maximum (DCM). The results of the Fourier analysis provide insights into how the interaction of the DCM with the internal wave field also undergoes a seasonal evolution.

This paper was submitted to *Deep-Sea Research*, but was rejected due to length considerations that we feel are unavoidable and due to some concerns that one reviewer had about the statistical viability of our analysis technique that we have addressed. We subsequently submitted the manuscript to the *Journal of Marine Research*.

Participation in Workshops/Conferences/Meetings

- January 1999. Attended symposium and training course in Bangalore, India, sponsored by the International Joint Global Ocean Flux Study. Course focused on biogeochemical processes, developing interdisciplinary models, and applying the available remote sensing data sets to the study of biogeochemistry of the Arabian Sean. Presented paper: Wiggert, J., Jones, B., Dickey,

T., Weller, B., Brink, K., Marra, J., and Codispoti, L. *The Northeast Monsoon's Impact on Mixing, Phytoplankton Biomass, and Nutrient Cycling in the Arabian Sea.*

Publications

Dickey, T. D., Marra, J., Sigurdson, D. E., Weller, R., Kinkade, C. S., Zedler, S. E., Wiggert, J. D., and Langdon, C. (In press). Seasonal variability of bio-optical and physical properties in the Arabian Sea: October 1994-October 1995. *Deep-Sea Research.*

Wiggert, J. D., Hooker, S. B., Brown, J. W., and Mied, R. P. (1998). The development of a dipole eddy model. *1998 Ocean Sciences Meeting.* San Diego, CA: American Geophysical Union.

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TASK 970-07: Research in Support of the Laboratory for Hydrospheric Processes

TASK DESCRIPTION

To satisfy the requirements of this task, the contractor was expected to provide an individual to conduct independent research in collaboration with scientists at the Laboratory for Hydrospheric processes in which the individual would contribute their expertise in one or more of the following scientific areas:
- Numerical modeling and observational analyses of ocean circulation (mesoscale to global scale), marine ecosystems and primary productivity, wave field evolution, sea surface topography, and other surface properties;
- Development of data assimilation systems to fully utilize satellite data for ocean circulation and process studies;
- Coupled ocean-atmosphere-land climate studies;
- Remote sensing techniques for discriminating and monitoring spatial and temporal distribution and state of snow, glaciers, sea ice and polar ice sheets, and the relation of observed changes to climate variability on seasonal to decadal time scales;
- Development of microwave techniques and instrumentation for the following topics: monitoring, mapping, and characterizing precipitation and atmospheric water vapor, measurement of surface moisture and the impact of vegetation on measurement, and the study of energy budgets;
- Multispectral techniques for characterizing ocean biology, land vegetation cover, or related biophysical parameters and biological productivity of the land surface and ocean, with emphasis on the ocean color data from the SeaWiFS mission.

SUBCONTRACTED RESEARCH

USRA entered into a subcontract with the University of California, San Diego, for the services of Dr. Maria Vernet, Associate Research Biologist, Marine Research Division, Scripps Institution of Oceanography. Dr. Vernet submitted a proposal for a 3-month Visiting Senior Scientist Fellowship to collaborate with Dr. Frank Hoge of the Wallops Flight Facility and a member of the MODIS Science Team to evaluate the remote sensing of phycoerythrin-containing phytoplankton by ocean color, as it related to SeaWiFS and MODIS missions.

The objective of this collaboration was to combine Dr. Hoge's experience on active and passive sensing of phycoerythrin fluorescence using NASA Airborne Oceanographic Lidar (AOL), SeaWiFS, and MODIS with reflectance of phycoerythrin concentration obtained from the California Current in order to study the contribution of phycoerythrin-containing phytoplankton, mainly cyanobacteria, to remotely sensed ocean color.

In order to identify and quantify the effect of phycoerythrin on upwelled radiance, Dr. Vernet planned to study the relationship between phycoerythrin concentration, phycoerythrin absorption, and fluorescence and water-column optics. By combining two data sets (data from the North Atlantic in March 1993, collected in conjunction with two AOL overflights, and from the California Current (CalCOFI)), Dr. Vernet planned the following:

1. Analyze the CalCOFI data for algorithm development and compare with previous algorithms developed by Dr. Hoge. They would then test the newly developed algorithm with the data collected in the North Atlantic.

2. Estimate the level of detection of phycoerythrin from space, using SeaWiFS and MODIS sensors, by modeling phycoerythrin absorption and fluorescence yield with data published from laboratory experiments based on the measured *in situ* phycoerythrin abundance.

The collaborative effort would combine *in situ* phycoerythrin measurements at sea from Dr. Vernet with algorithm development for phycoerythrin by Dr. Hoge. It was expected to provide a theoretical framework based on present day knowledge. Drs. Vernet and Hoge believed that once SeaWiFS, and later MODIS, were launched, the algorithms developed for phycoerythrin would be tested further with newly collected data on CalCOFI cruises and remote sensing images on the same time-frame.

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TASK 970-08: Tropic-Subtropic Ocean Interactions

TASK DESCRIPTION

The objective of this task was to provide a scientist at the post-doctoral level to perform a research study of tropic-subtropic ocean interactions in the Atlantic Ocean. Both numerical ocean models and remote sensing data were to be used in support of these investigations of ocean water pathways on seasonal to decadal time frames. In particular, thermal anomalies in the Atlantic Ocean were to be studied by performing general circulation model experiments and analyses of *in situ* and satellite data. The results of the work were to be presented at national and international meetings.

USRA EMPLOYEE: DR. JOAQUIM BALLABRERA

Research focus: Sensitivity studies for data assimilation strategies in a coupled ocean-atmosphere system.

Accomplishments

October 1998 – September 1999

The goal of the present project is to initialize a coupled model for ENSO predictions. The idea is to use an assimilation method able to build initial conditions of the current state of the equatorial tropical Pacific which (a) gives an accurate representation of the current state of the system, and (b) provides accurate time predictions of ENSO.

Previous work focused on familiarizing myself with the Zebiak and Cane (1987) coupled ocean-atmosphere model. Then the statistical properties of the model were studied in terms of the multivariate EOFs of such a model. These EOFs were also used to give a numerical approximation of the linear tangent model, i.e., the model that gives the linear evolution of small perturbations. Such a model can be used to obtain the most rapidly growing perturbations during a given time interval. On the other hand, the programs for blending the coupled model and the observations were constructed and validated with synthetic data, i.e., data furnished by the model itself.

The method we use to blend the model and the observations is based on the singular evolutive extended Kalman (SEEK) filter, developed by Pham et al. (1998). The principle of this method is to reduce the degrees of freedom of the problem by restricting the analysis to a subspace defined by a family of vector functions. For convenience, each one of these basic elements is considered as a column of the matrix N .

It is common to use the multivariate EOFs of the model as a such basis. As the processes solved by the numerical models are simplified because of practical or cognitive reasons, we may expect that the statistical properties of the model differ from the ones of the observed fields. Therefore, if we want to use the EOFs of the model to extract information from the observed fields, we have to examine the compatibility between the data and the model.

The data to be assimilated are: surface wind stress monthly fields provided by Florida State University; sea surface temperature (SST) analysis of Reynolds and Smith (1994), and maps of sea level derived from the TOPEX/POSEIDON altimeter.

Once the compatibility between the data and the model is assessed, the data has been assimilated onto the model. The assimilated fields are then used as initial conditions of the coupled model. Therefore, we have obtained a set of 15-month predictions of ENSO during October 1992 through June 1999. One of the main results derived from these results is that the preconditions of the warm event of 1997-98 were already present at least 15 months before the onset of the event.

During this period, several task were accomplished:

Data collection and processing: Monthly averaged fields of the sea surface temperature, surface wind stress, and sea level were collected, and pre-processed: interpolation onto the grid of our particular modeling, computation of the climate fields, and the computation of the anomalies (the model used here computes the time evolution of the anomalies, not the complete field), and spatial and temporal filtering. This work needed a large amount of time, especially for verification purposes. Therefore, a large number of programs for data treatment and data visualization have been constructed.
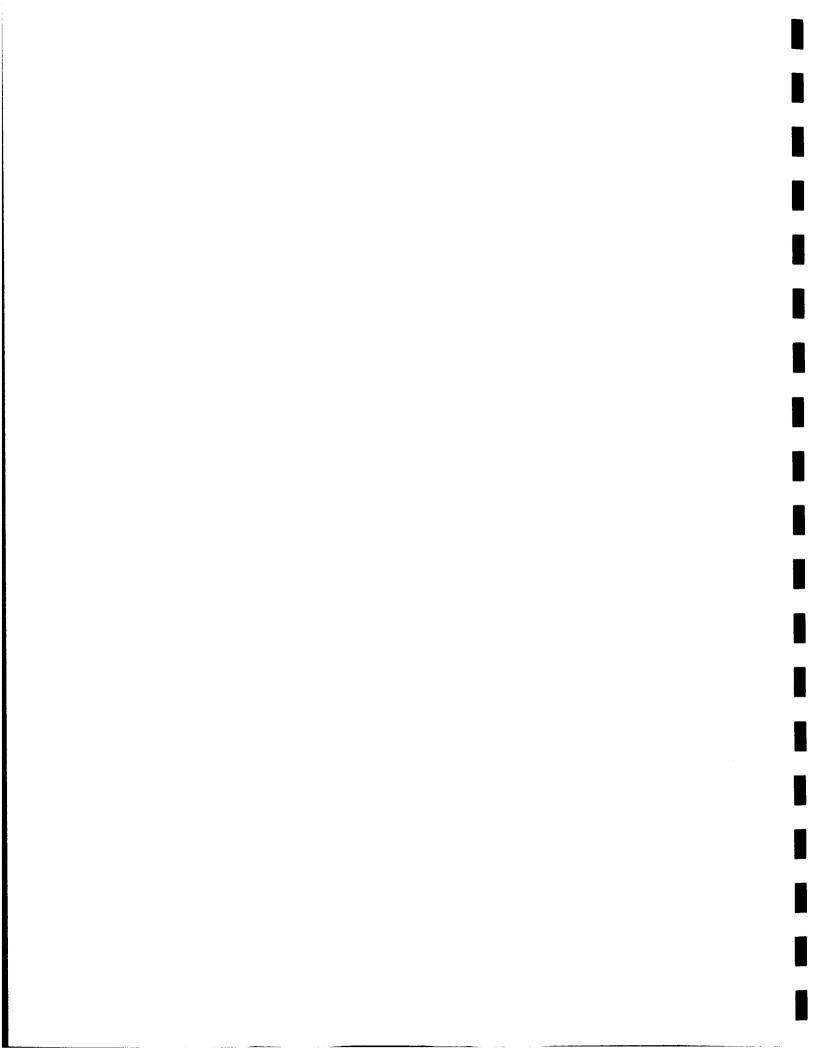
Model data compatibility: The compatibility between the coupled model and the observed fields is assessed by the projection of the observed fields onto the EOFs of the model. However, as not all the components of the state vector are observed, the classical principal component analysis cannot be done. A method of projecting observations had to be developed.

The results have been submitted for review to Mark Cane and Alexey Kaplan (Columbia University, Lamont-Doherty Laboratory) and presented at international conferences and seminars.

Estimating the error of the background field: The main idea of the Kalman filter is to provide a weighted combination of a background state and the observations. The weights are related to the error estimates of the background state, the observational error, and what is being observed. The Kalman filter algorithm (Kalman and Bucy, 1960) provides a method to compute the time evolution of the background error, which evolves according to the physics of the system as is a function of the current state of the system. However, the numerical cost associated with the time evolution of the background error demands, in our case, thousands of millions of model integrations.

A solution proposed by Pham et al. (1998), is to substitute the time evolution of the complete background error covariance matrix, by the time evolution of the columns of the basis N. However, this approach is based on hypotheses which are not verified in our case: linearity of the model, completeness of the matrix N (that is, any state of the system can be expressed as a linear combination of the columns of N), and that the model is exact. None of these conditions are verified here, and an alternative methodology has been used to provide an estimate of the error of the background state evolving in time, and depending on the state of the system.

The results have been submitted for review to Mark Cane and Alexey Kaplan, and presented at international conferences and seminars. They have also been presented personally to Robert Miller (Oregon State University) and Yan Xue (NCEP).

ENSO predictions: The methodology developed for the preceding sections, has been used to obtain the initial conditions for ENSO predictions. Every month, the observations were assimilated onto the model and used as initial conditions for a 15-month prediction of ENSO. The results show a good agreement between the value of the initial conditions and the observed value. Note that the onset of the warm event is well identified. This means that the preconditions of the warm event in 1997 were present in the equatorial region at least 15 months prior to the event. A striking feature is the success of the system to predict the correct amplitude of the warm 1997 event more than one year in advance.

These results have been submitted for review to Mark Cane and Alexey Kaplan, submitted for publication to *Aviso Newsletter*, and presented at international conferences and seminars.

Sensitivity to the number of EOFs. The results described above were obtained using an ensemble of 50 EOFs. When the number of EOFs was modified, it was found that the methodology was robust only for predictions of no more than four to six months. In order to investigate the reason for this, a new problem was investigated. We have largely verified that by increasing the number of EOFs, we increase the ability of the method to provide more accurate descriptions of the state of the system. The, we have investigated whether the convergence of the initial conditions is directly translated on the accuracy of the time evolution of the system.

In order to do this, we use the EOFs of the model to perform a principal component decomposition of the solutions of the model itself. Then we have compared the evolution of the system when initialized from one solution of the model, and when initialized by a truncated expansion of principal components. We have recorded the results for different degrees of truncation (ranging from one single EOF up to 60 EOFs). The results clearly show that there is no relationship between the number of EOFs and the accuracy of the time evolution for time periods longer than four months. This result indicates that the lack of robustness of the results of the previous sections are not related to the assimilation scheme itself, but to a property of the coupled models. Note that this behavior is not shared by a forced model, where the evolution of the system is eventually driven by the forcing instead of the initial conditions. This result helps us to better understand our previous studies, and the method is currently under revision in order to use the new results.
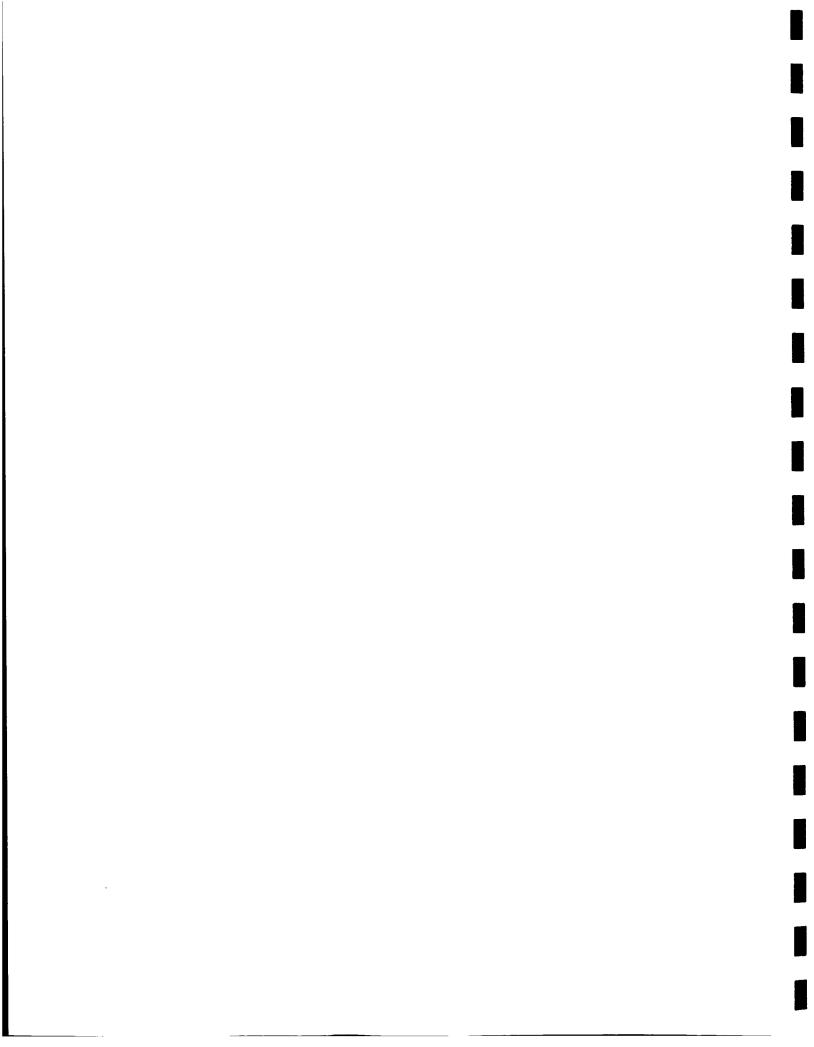
October 1999 – January 2000

Implementation of the breeding method. An inexpensive method for the identification of fast growing perturbations has been applied to the coupled model. The method is known as the breeding method *(Toth and Kalnay,* 1997). The method is initialized with a completely random perturbation, and sequentially discards decaying error modes. Thus, the method is supposed to provide a large-scale perturbation pattern that is supposed to have a rapid error growth. The results are going to be compared with the singular vectors of the model. The interest in this comparison comes from the fact that singular vectors are computed from a reduced subspace of the state vector space, and breeded vectors are supposed to span the full space dimension. This may allow us to determine the impact of the neglected subspace onto the subspace defined by the truncated set of EOFs. This work is done in conjunction with Dr. Eugenia Kalnay, Professor and Chair, Department of Meteorology, University of Maryland.

Developing a statistical atmospheric model. The Kim and North (1998) statistical extrapolation method has been applied to the construction of a statistical atmospheric model. The monthly averaged SST and surface wind stress fields of NOAA NCEP-NCAR reanalysis (1958-2000) are used to compute the statistical relationships used on the model. After validation studies, this model is planned to be coupled to the Gent and Cane ocean model currently used in the LHP at NASA GSFC.

February – June 2000

Implementation of the breeding method. The impact of breeding vectors and the singular vectors on the predictability of the Zebiak and Cane model have been studied. Singular vectors have been computed using the method present by Xue et al. (1997), based on the identification of the singular vectors inside the subspace defined by the EOFs of the system. It has been shown that pure singular vectors presented a spurious trend. This has been explained because the methodology used

disregarded the nonlinear coupling between the EOF subspace and its complementary. An alternative method has been used in which a linear, autoregressive Markov model was constructed from the breeding vectors. The new singular vectors are free of such a trend. Results of this work have been presented at an international conference.

Statistical atmospheric model. The Kim and North (1998) method was used to construct a statistical atmospheric model. The potential of the model to perform process studies was tested in a case in which an isolated structure of SST was used as input for the atmospheric model. The results have shown that the model is not well suited for this kind of problem.

July – August 2000

Potential role of salinity on ENSO predictions. A very preliminary analysis of the potentials of sea surface salinity (SSS) for ENSO predictions was performed during this period of time. The analysis has analyzed the correlation between the temporal variability of the NOAA-NCEP salinity analysis with the time evolution of the NINO3 index. The results have been encouraging, indicating that statistically significant linear relationships may exist between the SSS and the NINO3 index. Therefore, I have been constructing a new set of programs for the multivariate analysis of variance (ANOVA), and the use of canonical correlation analysis (CCA), which will provide more information about the specific role of the SSS for ENSO predictions.

Participation In Workshops/Conferences/Meetings

- April 19-25, 1999. Attended the 24th General Assembly of the European Geophysical Society in the Hague, Netherlands. Presented paper: Ballabrera, J., and Busalacchi, A. J. *Kalman Filter Initialization of a Coupled Ocean-atmosphere Model.*

- June 5-12, 1999. Attended the 3rd WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography in Quebec City, Canada. Poster presentation: Ballabrera, J., Busalacchi, A. J., and Murtugudde, R. *Kalman Filter Initialization of a Coupled Ocean-atmosphere Model.*

- November 2-6, 1999. SEAWIFS group meeting in Norfolk, VA.

- April 24-May 5, 2000. Attended the 25th General Assembly of the European Geophysical Society in Nice, France. Presented paper: Ballabrera, J., Busalacchi, A. J., and Murtugudde, R. *ENSO Predictions with a Reduced Order Kalman Filter and a Coupled Ocean-atmosphere Model. Impact of the Identification of the Fastest Growing Error Modes.*
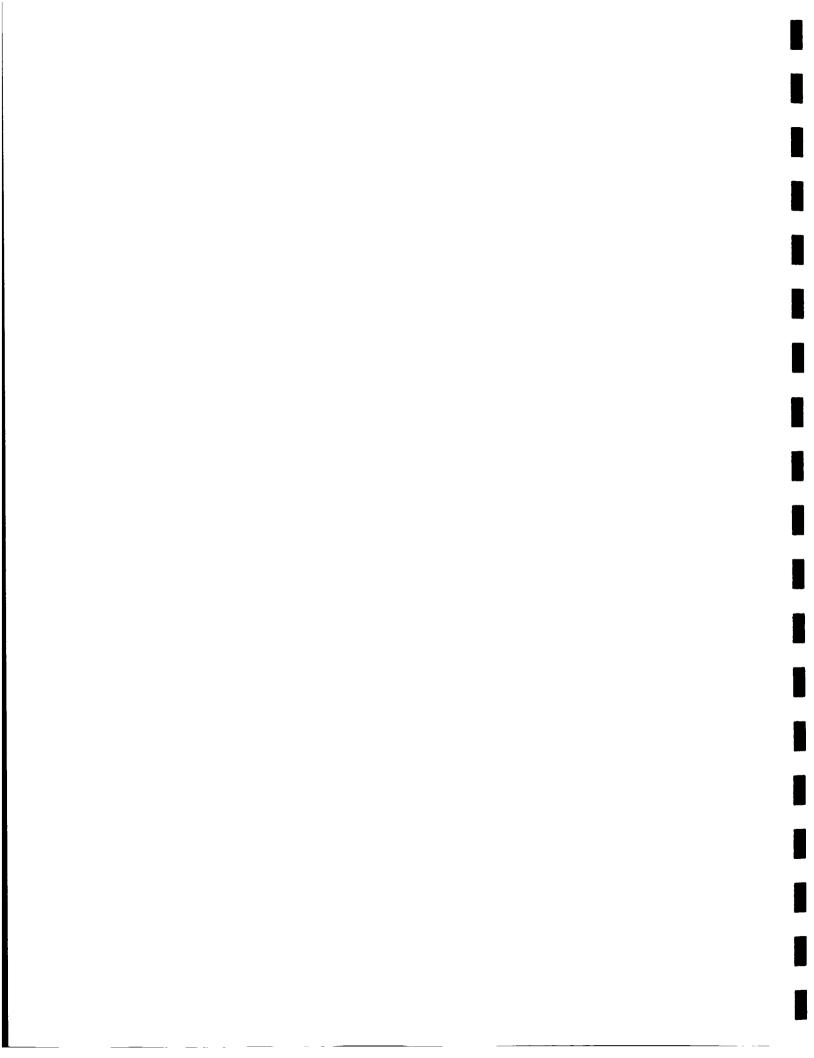
Publications

Ballabrera, J., Busalacchi, A. J., Murtugudde, R., and Verron, J. (2000). Multivariate assimilation with a reduced order Kalman filter to initialize a coupled ocean-atmosphere model. *AVISO Newsletter, 7,* 35-39.

USRA EMPLOYEE: DR. ALBAN LAZAR

Research focus: Modeling studies of interactions between Atlantic tropical and sub-tropical circulations.

Accomplishments

Numerical experiments strategy. In order to reduce the initial adjustment process (Rossby waves) in response to an imposed sea surface temperature (SST) anomaly, I performed new runs with a smoother morphology of the heat anomaly, i.e., generate progressively a 1°C negative anomaly over

several months. New initial locations have been chosen in function of the results of the Bernoulli function analysis and an anomaly has been found to reach the equator (with a significant remaining amplitude of 2ºC) in subsurface (around 300 m depth) from the southern hemisphere subtropics. This is an important result since no model nor data have

Modelling study of the physics of heat anomaly (HA) propagations within the atlantic thermocline. This part of my work is focused on the mechanisms at play in several numerical experiments of subsurface propagation of HAs. The goal is to be capable of predicting the trajectories over 5 to 10 years as well as their potential impact on the decadal variability of the ocean-atmosphere interactions in tropical region. The principal question is: how different are these trajectories from purely advective trajectories? The following diagnostics have been therefore carried out:

- releases of lagrangian floats in the simulations to compare their purely advective trajectories with those of the HAs
- study of the isopycnal character of the HA trajectories
- analysis of the role of the salt in the compensation of the density signal associated with the HA
- determination of the heaving signal associated with the wave component of the HAs by using two types of projection (horizontal vs isopycal)
- implementation of passive tracers in the numerical model in order to better distinguish the advective and wave processes
- releases of passive tracer at different stages of the HA propagation (at the surface and after the first year below the mixed layer), these for runs with and without HAs.

The results of this study essentially advocate for a physics dominated by advection (i.e., speed of the mean currents and isopycnal movement), but suggest the presence of wave effect with a smaller role. The salt compensation is presented to be one of the main responsible processes for diminishing the perturbation of the density structure and permitting advection to dominate.
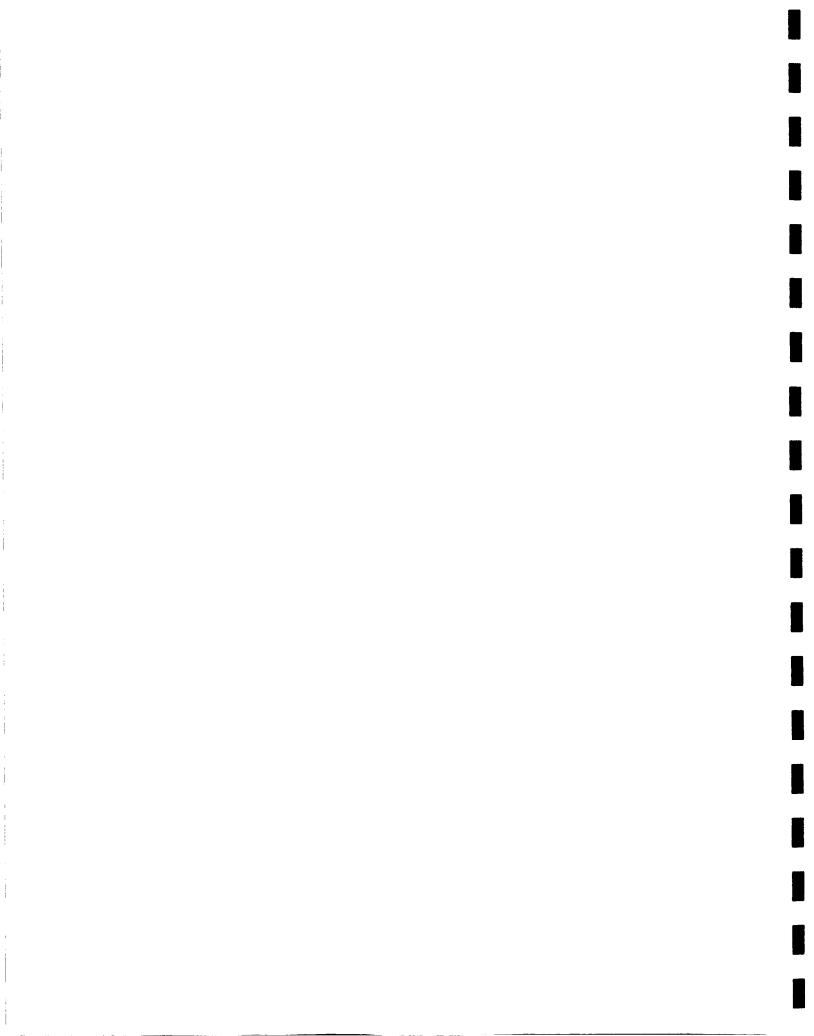
Following these conclusions, a second study is carried out in parallel in which the aim is to determine the pathways set by the currents in the tropical thermocline and particularly their variability at seasonal and longer time scales. The understanding and quantification of this variability should allow us to better determine the potential movements of HAs at subsurface and eventually study their effect on the equatorial thermocline.

Modelling study of the seasonal cycle of the water mass pathways in the atlantic thermocline. We used conservative quantities (Bernoulli function mainly) and Lagrangian floats extensively, passive tracer experiments are planned for the end of first half of october. They allow us to inspect the seasonal variability of the pathways and particularly the existence or not of interior pathways (expected to be important for a greater impact of HAs on the equatorial band). This work is done in collaboration with Drs. Tomoko Inui and Paola Rizzoli from MIT. The effect of different wind forcings was also investigated in order to broaden the spectra of variability studied.

The results improved our understanding of the role of the wind (its intensity and its spatial structure) in setting the geometry of the pathways. They also showed that the water masses pathways are not strongly affected by the seasonal cycle of the circulation. To determine the trajectory of a subducted passive tracer, it seems therefore that is enough to combine maps of annual-mean circulation to analysis of the seasonal cycle of the outcrop position of the isolines. This study is being reported in two papers in preparation and was partly carried out at MIT during a two week trip in August 1999.

Propagation of heat anomalies in the ocean. I submitted an article to *Geophysical Research Letters* outlineing some of my progress on the understanding of the subsurface propagation of heat anomalies with an annual mean forcing (no seasonal forcing). They are: the existence of a clear advective component of the propagation determining the trajectory, the likely simultaneous existence of wave processes modifying the intensity of the heat anomaly, and the essential salt compensation phenomenon.

Following this work, I ran several numerical simulations of heat anomaly propagation with a seasonal forcing. The results suggest that the anomalies have a very similar behavior compared to the situation without seasonal forcing, regardless the month they are injected in the mixed layer. Particularly the

trajectories were weakly affected. On the other hand, the shape of the signal is more complicated, probably due to the seasonal modulations of the subduction process as well as the seasonal modulations of the thermocline structure. It is understood that the subduction was previously controlled by the wind Ekman pumping, and is now strongly controlled by the seasonal cycle of the mixed layer. These recent results were presented to French laboratories during a series of seminars in France (January 2000).

Seasonal cycle of subtropics-tropics connections in the Atlantic ocean. In order to understand better the possible impact of the seasonal forcing on propagating signals within the Atlantic mixed layer, I applied a series of diagnostics to a seasonal run of the Atlantic (Bernoulli function, Lagrangian floats, passive tracer and subduction cycle). First these diagnostics pointed out to the weak influence of the seasonality of the circulation on the several years long subsurface trajectories of floats as well as passive tracers, compared to the annual mean circulation. It is an essential result easing the analysis of the tropics-subtropics connections. Indeed, it means that the information drawn from the annually averaged subsurface circulation (Bernoulli function essentially) is sufficient regarding the predictability of the trajectory of a subsurface passive signal.

In the same time, I began the study of the other component of the problem, namely the subduction cycle. The interesting result that I am focusing on is that the occurrence of subduction is much more complex in time and space than the rather simple meridional back-and-forth cycle of the isopycnal outcrop lines. It likely involves local strong currents more dynamically influent as well as local water masses more thermodynamically influent. This work is carried out in collaboration with Paola Rizzoli and Tomoko Inui (MIT) should lead to the submission of two papers before end of Spring 2000.

Improvement of the Gent and Cane model. During the course of my work, potential weakness of our code may appear to me and I usually discuss them with R. Murtugudde. After having been tested by R. Murtugudde, some of the recent points I made will be retained in new versions of the code:
- use of full formulation of the Coriolis parameter (instead of a constant beta term)
- improvement of the boundary conditions in term of restoration to Levitus (monthly fields instead of seasonal)

Some points are still in discussion: slip or no slip boundary conditions, too weak deep mixing maybe resulting in too warm subtropical thermocline water.

Seasonal cycle of subtropics-tropics connections in the Atlantic ocean. The seasonal cycle of the subduction was analyzed extensively in term of effective subduction season, subduction rate and subduction period. This information is known for the North Atlantic, but was missing in the literature for the Tropical and South Atlantic and are important for understanding the process of propagation of signal from tropics to subtropics in subsurface. Along this diagnostic study, I looked into the mechanisms at work in the control of the subduction process, namely the competition between wind stirring and buoyancy stabilizing or stirring effects. I especially emphazised the difference it makes with the commonly used interpretation dealing with migration of the isopycnal outcrop lines.

Participation in Workshops/Conferences/Meetings

- December 3-8, 1998. Presented a seminar at LOP in Paris, France, in collaboration with the director, M. Revault d'Allonnes.

- December 8-10, 1998. Attended the AGU Meeting in San Francisco, CA.

- October 17-23, 1999. Attended Ocean Observing System for Climate Conference in St. Raphael, France.

- April 5-13, 2000. Attended the PIRATA meeting in Natal, Brazil.

- April 28-May 8, 2000. Attend meeting at LODYC in Paris, France. Presented seminar at Laboratoire d'Oceangraphique Physique.

- September 9-14, 2000. Attended the PIRATA meeting in Fortaleza, Brazil.

Publications

Lazar A., Madec, G., and Delecluse, P. (In press). The deep interior downwelling; the Veronis effect and mesoscale tracer transport parameterizations in an OGCM. *Phys. Oceanogr.*

Lazar, A., and Rancher, J. (1999). Simulation of radionuclide dispersion in the Pacific Ocean from Mururoa Atoll. *Jr. Environmental Radioactivity, 43,* 31-49.

USRA EMPLOYEE: DR. JERRY WIGGERT

Research focus: Development of an analytical framework for modeling interacting ocean vortices.

Accomplishments

Initiation of a collaboration with Chuck McClain (NASA/GSFC) and Ragu Murtugudde (University of Maryland/JCESS) to study physical/biological interactions in the Indian Ocean. The planned research will proceed on several fronts. This will consist of:
1) utilizing presently available in-situ data that characterize spatial (especially vertical) hydrographic and biogeochemical parameters and their seasonal evolution;
2) utilizing remote sensing measurements that provide synoptic surface distribution of physical and ocean color parameters along with their seasonal and interannual variations; and
3) developing and applying interdisciplinary models in which planktonic ecosystems have been coupled to dynamical models.
A 1-D interdisciplinary model is already available and has been applied to studying nutrient cycling and phytoplankton growth in the Arabian Sea during the NE monsoon (see item 3). This model will be useful in aiding the development of the ecosystem to be used in the full 3-D version. Also, its ability to study processes at significantly higher temporal and spatial resolution will provide a means of identifying, and parameterizing, the most relevant processes for inclusion within the 3-D model the resolution of which is limited by finite computational resources. However, the latter will allow for studies of basin scale interactions and interannual variability. Dr. Murtugudde has recently applied a 3-D ocean general circulation model (OGCM) in numerical experiments designed to advance the understanding of the dynamics of interannual variability in the 10. This model will serve as the dynamical framework for the interdisciplinary model.

I will be attending a symposium and training course in Bangalore, India in January, sponsored by International/JGOFS (Joint Global Ocean Flux Study), that will focus on biogeochemical processes, developing interdisciplinary models and applying the available remote sensing data sets to the study of biogeochemistry of the Arabian Sea. I will be presenting the results of my 1-D modeling research on the NE monsoon (citation below) at this symposium as well as attending the follow-on training course.

Analysis of observations from the JGOFS/ Arabian Sea experiment *NE Monsoon modeling experiments*. I have investigated the dynamics behind the development of the phytoplankton nutrient fields during the NE monsoon within the northern Arabian Sea. This research has been submitted as a manuscript (citation below) for inclusion in the second volume of the forthcoming Deep-Sea Research special issue on the Arabian Sea with papers reporting on the recent JGOFS/Arabian Sea expedition.

Description of co-locatedphysical and bio-optical time series in the Arabian Sea. I have also contributed to an analysis of the in-situ physical and bio-optical time series that were collected as part of ONR's Arabian Sea Forced Upper Ocean Dynamics Experiment that took place in conjunction with NSF's JGOFS/Arabian Sea Study. This manuscript (citation below) has been accepted for publication within the first volume of the forthcoming Deep-Sea Research special issue on the Arabian Sea.

Publications

Wiggert, J., Jones, B., Dickey, T., Weller, B., Brink, K., Marra, J., and Codispoti, L. The northeast monsoon's impact on mixing, phytoplankton biomass and nutrient cycling in the Arabian Sea. *Deep-Sea Res.,* submitted 1999.

Dickey, T.D., J. Marra, D.E. Sigurdson, R. Weller, C.S. Kinkade, S.E. Zedler, J.D. Wiggert, and C. Langdon. Seasonal variability of bio-optical and physical properties in the Arabian Sea: October 1994-October 1995. *Deep-Sea Res.,* in press, 1998.

Wiggert, J., T. Granata, J. Marra, and T. Dickey. A seasonal succession of physical/biological interaction mechanisms in the Sargasso Sea. *J. Mar. Res.,* submitted, 1999.

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TASK 970-10: El Niño Research

TASK DESCRIPTION

The objective of this task was to provide visiting scientist to Dr. Joel Picaut related to El Niño research efforts using remote sensing data as part of a joint NASA/CNES altimeter project. This is mainly in the category of travel support to attend NASA meetings related to this joint satellite project.

CONSULTANTS/VISITORS

Visitor: **Garth Paltridge** (University of Tasmania, Australia)
Purpose: Present a seminar to the Laboratory for Hydrospheric Processes (8/8-11/99)
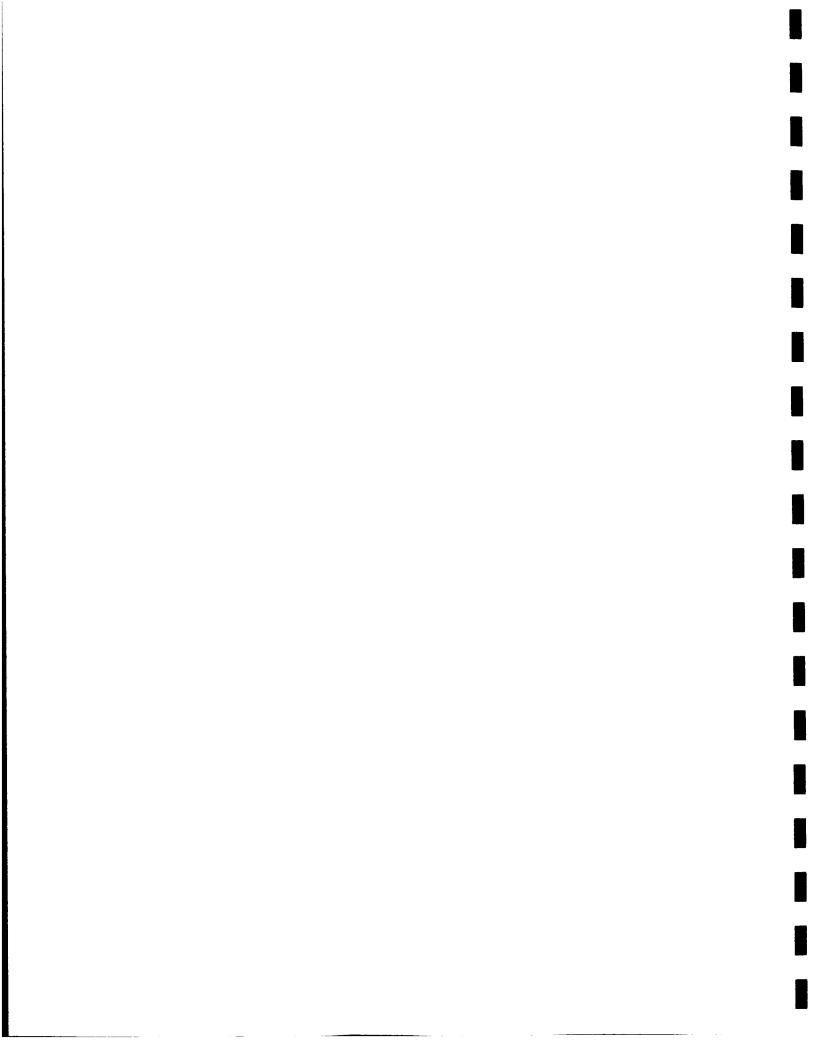
Visitor: **Joel Picaut** (NASA/GSFC Code 970)
Purpose: Attend the TOPEX/Poseidon Science working team meeting in Keystone, CO (10/11-16/98)
Scientific discussions with the ORSTOM and LODYC directors in Paris and attend the ECOPA meeting in Toulouse, France (10/28-11/16/98)
Attend the PIRATA-5 and TIP-7 meetings in Abidjan (11/6-16/98)
Attend the CLIVAR Conf.-Paris / LEGOS meetings-Toulouse, France (11/27-12/3/98)
Attend the AGU Meeting in California (12/5-11/98)
Attend the Ocean Planning Meeting at JPL (1/26-29/99)
Attend the Equatorial Theoretical Panal Meeting, visit of the IPRC in Hawaii (3/21-28/99)
Attend the PIRATA-6 and Climate Observing System for the Tropical Atlantic Meeting (5/2-9/99)
Meet with the Directors of IRI and IRD/ORSTOM in France (6/22-23/99)
Continue scientific discussions with Dr. Busalacchi (9/15-26/99)

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TASK 971-01: Study of Nonlinear Ocean Wave Processes

TASK DESCRIPTION

The objective of this task is to provide numerical and analysis support for the study of nonlinear ocean wave processes. This project is concerned with wavelet analysis and its applications to the field and satellite data. This work involves (1) to extend the wavelet transform to a localized spectral analysis; (2)

to apply two- dimensional wavelet transform for Synthetic Aperture Radar (SAR) image analysis to track the mesoscale features; (3) to study wind-wave interaction non-linear processes. The task involves travel for visiting Goddard and for technical meetings.
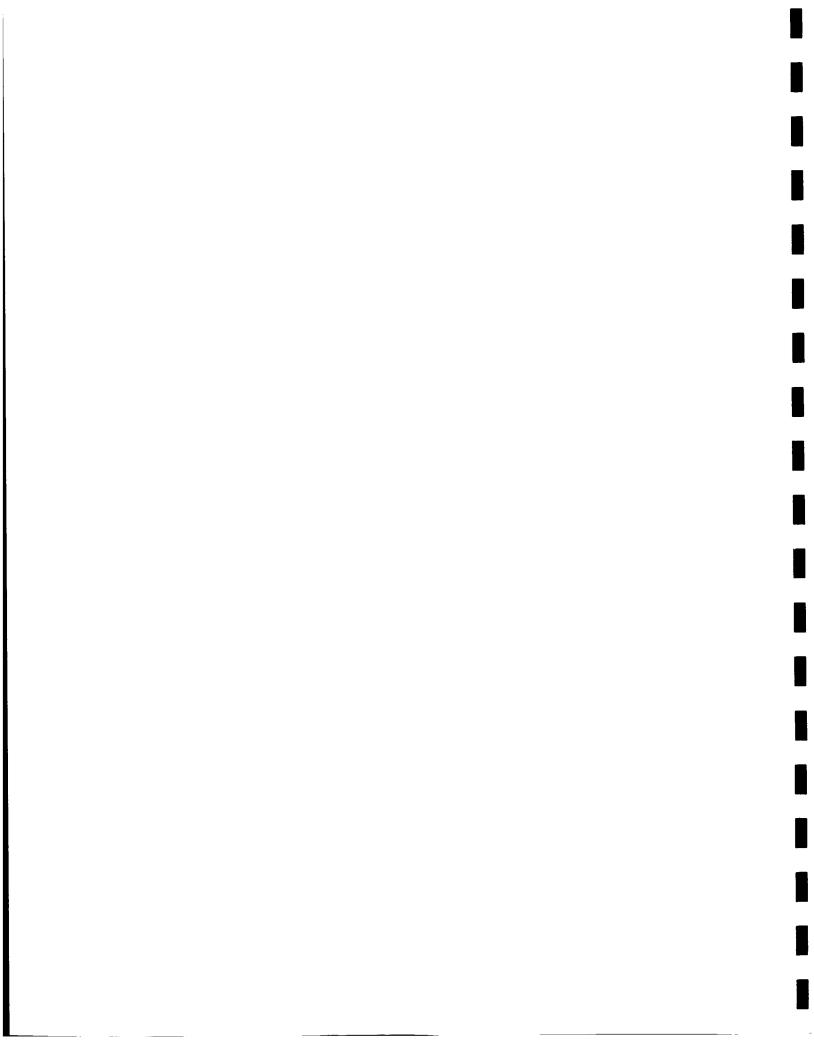
CONSULTANTS/VISITORS

Consultant: **Cathleen Geiger** (University of Delaware)
Purpose: Conduct sea ice motion process study based on buoy data and satellite-derived ice drift to compare with theoretical and model results (10/31/98-9/30/00)
Collaborative mtg. to work on JGR manuscript (11/5/98)
Monthly seminar, work on JGR manuscript (12/3/98)
Collaborative mtg. w/ Liu, Zhou and Geiger re: JGR manuscript (12/10/98)
Final meeting on JGR manuscript paper , attend seminar (12/17/98)
Present talk of recent TGR submission (2/4/99)
Consult on Sea Ice Modeling & organize project (2/11/99)
Scientific discussions with Tony Liu, present seminar (2/25/99)
Attend ICE Brown Bag Seminar & scientific discussions (3/17/99)
Work on paper recently accepted to JGR pending revisions (4/7/99)
Revise paper recently accepted to JGR pending revisions (4/14/99)
Revise paper recently accepted to JGR pending revisions (4/22/99)
Revise paper recently accepted to JGR pending revisions (5/2/99)
Discuss with Tony Liu paper recently accepted to JGR (5/26/99)
Discuss paper with Tony Liu (6/16/99)
Discussions regarding recent results on strain-rate analysis of wavelet derived ice velocity vectors in the Beaufort Sea (7/22/99)
Discuss recent results of higher order deformation analysis of SSM/I motion vector products w/ T. Liu & Y. Zhao (9/2/99)
Meet w/ Dr. Liu and Dr. Zhao to discuss current work in Beaufort Sea (9/29/99)
Conduct sea ice motion process study (10/27/99)
Discussion re: atmospheric pressure field relative to sea ice interaction (11/3/99)
Continued discussions on air-ice interaction in the Beaufort Sea (11/18/99)
Collaborate with Dr. Tony Liu on a paper dealing with sea ice motion in the Beaufort Sea (8/30/00, 9/6/00, 9/13/00, and 9/20/00)

Consultant: **Gregory H. Leonard** (Clarkson University)
Purpose: Conduct research and provide support on the analysis of the sea-ice motion from wavelet analysis of satellite data (10/1/98-1/31/99 and 5/15-9/30/99)
Present a seminar entitled, "Analysis of Sea-Ice Dynamics Using Remote Sensing Data" (12/22/98-1/10/99)
Conduct research on the analysis of sea-ice motion from wavelet analysis (5/16/99 and 8/21/99)
Conduct research and data analysis on sea-ice motion from wavelet analysis of satellite data (AVHRR) (1/2-8/00)

Visitor: **Hayley Shen** (Clarkson University)
Purpose: Discussions on wavelet analysis of SAR images (10/4-5/98)

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TASK 971-03: Large-scale Global Ocean Circulation

TASK DESCRIPTION

The objective of this task is the study of the large scale global ocean circulation, including the investigation of techniques for effective analysis and assimilation of altimeter and AVHRR data into a

global primitive equation ocean model. It includes the preparation of forcing data sets, especially from scatterometer observations and use of in situ data sets for model/assimilation validation. It may also include the assimilation of various other data types into the global model.

USRA EMPLOYEE: DR. JULIO BACMEISTER

Research focus: Development of GCM boundary conditions, parameterizations and initialization procedures.

Accomplishments

I have been primarily involved in developing the atmospheric component of the NSIPP coupled climate model (hereafter referred to as the Aries AGCM). During Sept. 98-Jan 99 a preliminary version of the Aries AGCM (v1.0) was completed. My contributions to this effort consisted in revising the gravity wave drag parameterization in Aries to include background drag in the stratosphere and re-tuning the existing mountain wave parameterization to yield acceptable NH winter planetary wave climatologies. I also diagnosed and corrected errors in the AGCM's top-of-atmosphere radiation budget produced in the diagnostic cloud scheme. Extended atmosphere-only (forced with observed SST's) as well as fully coupled atmosphere-ocean runs with Aries v1.0 were completed by Jan. 99.
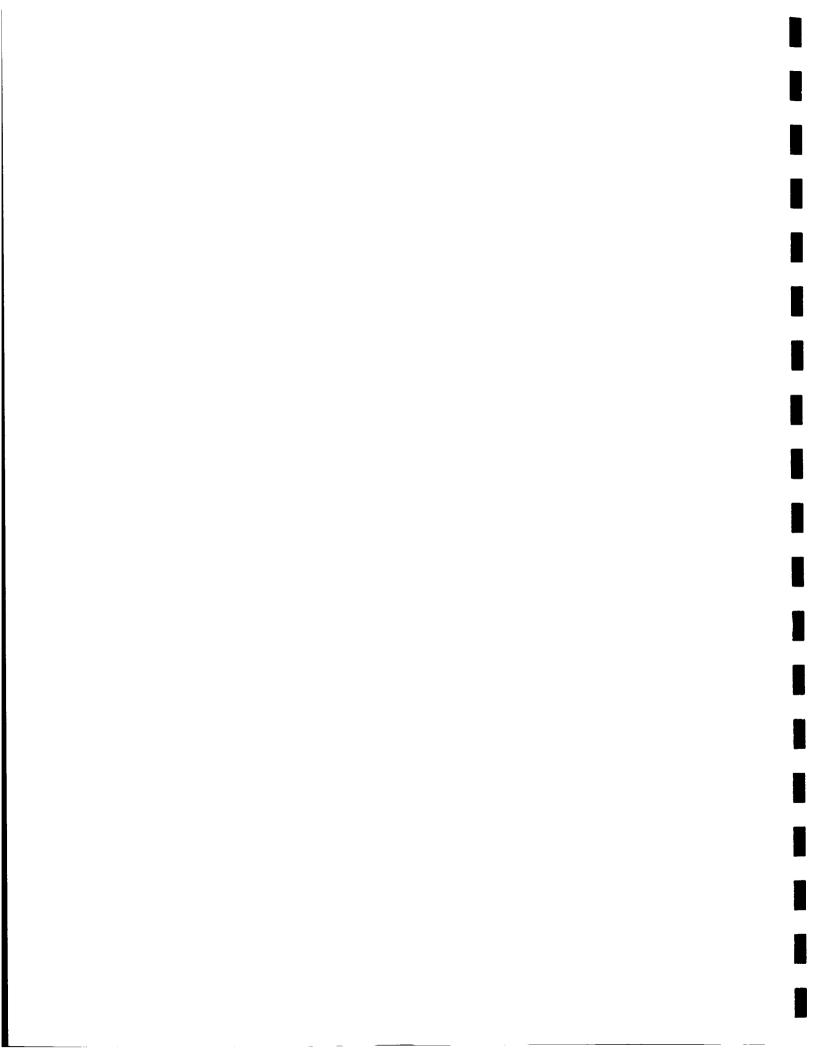
Analysis of these experiments revealed further deficiencies in the Aries v1.0 AGCM including:
(1) unrealistic tropical precipitation patterns - persistent "double ITCZs" with no SPCZ (south pacific convergence zone);
(2) unrealistic water vapor profiles - dry upper troposphere, and
(3) unrealistic behavior of surface wind stress along the equatorial pacific - excessive semi-annual variation, lack of coherence with eastern pacific SST in atmosphere-only runs, and overall excessive annual mean stress.
All of these problems, in particular those under (3), represent serious obstacles to producing successful coupled atmosphere-ocean climate forecasts. Thus, since the completion of the extended runs with Aries v1.0, most of my effort has been directed at eliminating these problems in the AGCM.

Problems 1 and 2 appear to be related to the lack of re-evaporation of convective rainfall in Aries v1.0. Inclusion of a simplified version of the Sud and Molod (1988) parameterization of rain re-evaporation has largely removed both the upper-tropospheric dry bias in Aries as well as the tendency to form double ITCZ's straddling the equator. Further improvements were found by lowering re-evaporation rates in the boundary layer to mimic the effect of mesoscale downdrafts. The net effect of re-evaporation in Aries is to increase the stabilization effect of convection for a given precipitation rate. Simulations with re-evaporation exhibit lower values of convective available potential energy (CAPE) than those without re-evaporation. A preliminary analysis of space-time frequency distributions of precipitation of experiments with and without re-evaporation suggests that this reduction in CAPE diminishes the role of transient disturbances in producing tropical rainfall. Hess et al (1993) has argued that transient equatorial waves with off-equatorial convergence maxima are responsible for producing double ITCZ in an aquaplanet GCM. So the apparent reduction in transient precipitation events with re-evaporation may be responsible for the elimination of the double ITCZ in Aries.

The deficient simulation of equatorial wind stress (Problem 3) is a common problem in GCMs, and is also the most significant problem in Aries v1.0 from the standpoint of coupled atmosphere/ocean climate prediction. Unfortunately, it has also proven to be the most intractable. Aries vl.0 has generally excessive wind stress along the equator, an excessive semi-annual component of wind stress, and an incorrectly positioned annual component with maxima in stress located too far west. Simply including re-evaporation effects had significant effects on the equatorial stress, reducing somewhat the semi-annual component, but also moving the maximum in the annual component further west., away from its observed position around 120W. Wind stress along the equator, at least away from the vicinity of deep convection, is thought to be the result of a simple balance between a boundary layer averaged pressure force produced by vertically mixing SST through the boundary layer, and the stress at the sea surface (Lindzen and Nigam, 1987). In order to understand why Arigs is unable to

capture this seemingly simple dynamic, an exhaustive diagnosis if the AGCM's horizontal momentum budget was undertaken. This diagnosis has led to two conclusions. The first is not surprising and appears fairly certain, namely, that the vertical resolution used in Aries vl.O is insufficient in the lower troposphere. The layer thicknesses of 50-75 mb used below 850 mb are simply to coarse to capture the horizontal variations in boundary layer thickness that occur over the eastern Pacific cold tongue. The second conclusion is that vertical advection of zonal momentum in the lower troposphere is a non-negligible component of the equatorial momentum budget in Aries. Adequate representation of this process in Aries requires higher vertical resolution in the region between 700 mb and 850 mb than was used in vl.0. Also, the role vertical momentum advection means that the strength of subsidence over the eastern Pacific is an important element in determining the surface wind stress. We have also found that differences in parameterized low-level cloud cover can change radiative cooling rates, and thus subsidence rates, enough to significantly alter wind stress distributions along the equatorial pacific. At present, we have begun an extended run with Aries using re-evaporation and increased vertical resolution (subsequently referred to as Aries v1.1).
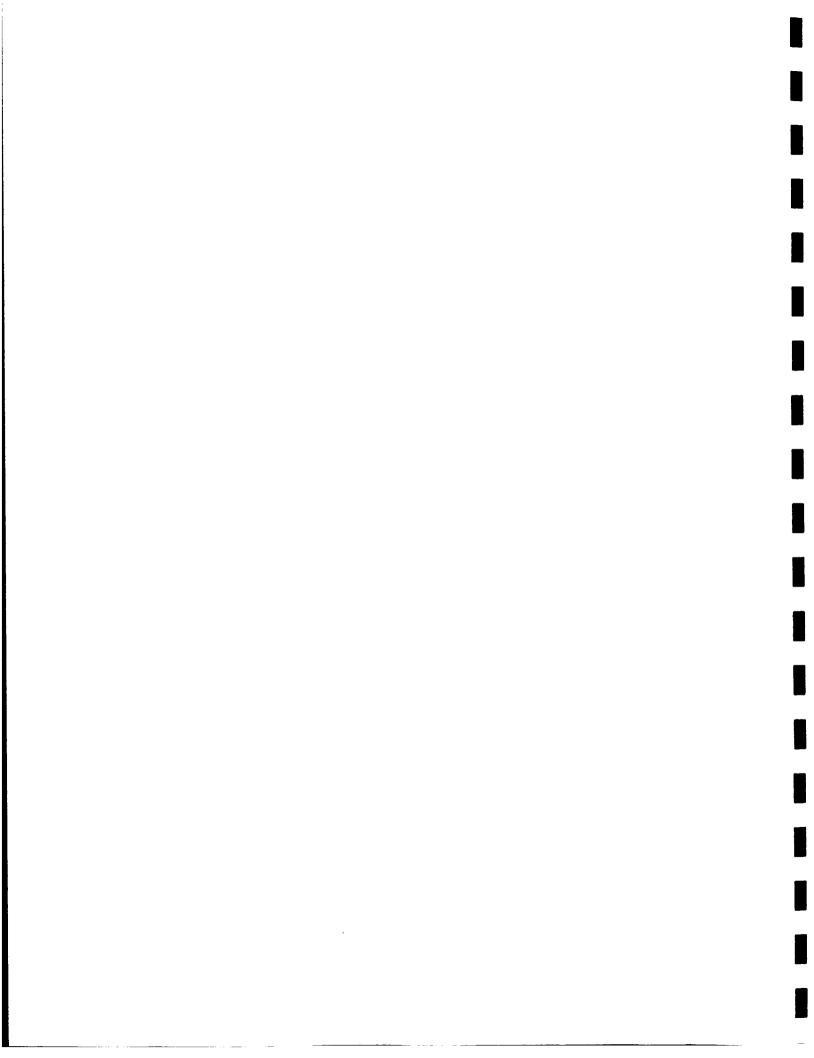
Our conclusions regarding the role of vertical momentum advection in determining wind stress are still tentative. In particular, it is not yet clear whether such a dynamic occurs in nature, and if it does how it is to be reconciled with the apparently simple relationship between stress and SST anomalies in nature. On the other hand, if vertical advection of momentum is not as important in nature as in our model, it remains to be explained why. Subsidence rates and vertical wind gradients along the equator in Aries v 1. 1 appear reasonable when compared to analyses. Thus, it seems unlikely that vertical advection of momentum is grossly misrepresented in Aries vl. 1. One possibility is a momentum source such as gravity wave drag or cumulus friction, which partially cancels vertical momentum advection in the equatorial troposphere, but is not correctly represented in the Aries AGCM.

The efforts described above represent something of a departure from the work I expected to have completed by this time. I had originally expected to spend most of the year completing and implementing a new prognostic cloud scheme for Aries. In fact, much of the work described above will facilitate the implementation of the cloud scheme, since the relative humidity climatology of Aries v1.1 is substantially improved over that in vl.O. Also, boundary layer processes are better represented than in vl.0, and cloud water is now explicitly calculated by the convective scheme, so that representing formation of large-scale clouds by convection is much easier. A preliminary version of the prognostic cloud with full sources (i.e. convective, large-scale, and boundary layer), but simplified loss mechanisms for cloud condensate, has actually been implemented in Aries and used in a one-year simulation. The results of this experiment, which was conducted using an earlier version of our boundary layer scheme, were encouraging except for excessive cloudiness in the boundary layer. It remains to be seen whether these problems persist with the updated PBL scheme used in v 1. 1, or whether additional losses of cloud water such as cloud-top entrainment at the PBL top will have to be implemented.

Co-mentored (with Rosana Ferreira) summer student Colleen Burrichter of Buenavista University, Stormlake Iowa. Ms. Burrichter's project involved analysis of pineapple production in Hawaii. Relationships between meteorological quantities and parameters such as pineapple maturation times were examined. An obvious but apparently previously unrecognized annual cycle in maturation time was identified. Maturation typically requires around 6 months but may be 2-3 weeks longer or shorter depending on the season. This knowledge may be of practical use to plantation managers in deciding when to artificially stimulate flowering of pineapple plants, in order to ensure adequate supplies of fruit at times of peak demand.

Preliminary collaborations have occurred with Dr. Sumant Nigam. of the University of Maryland. Dr. Nigarn and his former student Dr. Eric DeWeaver (now at the University of Washington, Seattle) will conduct diagnostic studies of Aries AGCM output using a linear steady state model of the global atmosphere. This is expected to help clarify the role of various heat and momentum sources in determining the equatorial wind stress.

Collaboration has been established with Drs. Anthony Delgenio and James Hansen of GISS. We will submit a joint proposal to NASA H2 to examine and improve cloud processes in the Aries and the GISS
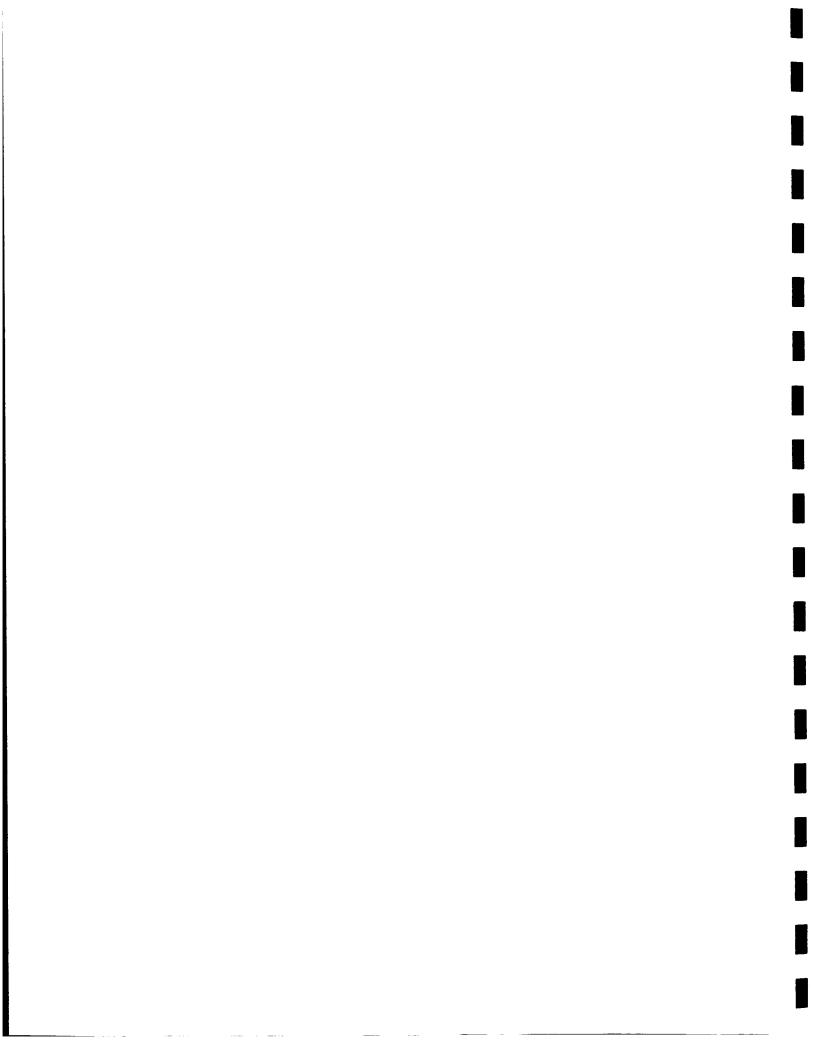
Finalizing the new version of the NSIPP atmospheric General Circulation Model (AGCM) in collaboration with Dr. Max Suarez of Code 913. This work entailed reformulating the model's diagnostic cloud scheme to accommodate high vertical resolution and large-scale cloud formation by detraining convection. A time-splitting approach was incorporated into the model's vertical diffusion scheme to increase computational efficiency at high vertical resolution. Finally, we found dramatic improvements in simulations of the wintertime Asian Jet when wavelet filters were applied to the topographic forcing. This improvement may result from reducing the generation of poorly resolved gravity wave modes by steep topography on the Eurasian landmass. The new AGCM has been used to conduct a 20-year AMIP-type simulation using observed SST's for the period 1979 to 1999. The performance of the model in this AMIP experiment was excellent. We have compared results from the new NSIPP AGCM with those of NCAR/CCM3, Goddard DAO's GEOS II, as well as COLA and GFDL AGCM's. Our simulation of precipitation is significantly better than that of the other models when compared against observations (Xie-Arkin), particularly in its reproduction of interannual precipitation variation associated with El Nino/La Nina events. Interannual variations in wintertime stationary planetary wave amplitudes are also in excellent agreement with observations. This version of the NSIPP AGCM has been coupled to the NSIPP Ocean GCM, and is currently being used in an extended free running coupled climate simulation, which should be completed by March 1. Initial results from the simulation show improvements in the coupled system's simulation of the SST seasonal cycle in the tropics. This improved seasonal cycle may prove critical to successful seasonal forecasts.

In addition to the effort above, I have continued with my analysis of the equatorial momentum budget and its sensitivity to model parameters. I have extended the analysis to include results of the multiyear AMIP experiment and a comparison with analyzed momentum budgets using NCEP reanalyses. I have begun work on a manuscript describing this work, The manuscript should be ready for submission to *Journal of Climate* within a month.

I focused on analysis of multi-year simulations with the new version of the NSIPP Atmospheric General Circulation model (AGCM) NSIPP-1. An extensive analysis of the basic model climatology and a brief model description are given in Bacmeister et al. 2000. In addition to the first 20-year AMIP-type simulation completed in 1/2000, a second 20-year and two 50-year AMIP-type simulations were conducted this quarter. The second 20-year simulation was conducted with an enhanced suite of outputs to assist in the analysis of the tropical atmospheric dynamics in the model. The focus of this analysis has been to tie atmospheric heating due to deep and shallow convection and turbulence to the seasonal variation in surface wind stress across the pacific. I now believe there is a connection between errors in the model's simulation of precipitation in central and eastern Pacific, and remaining biases in the surface wind stress.

I also participated in the design and analysis of fully coupled atmosphere/ocean climate (CGCM) simulations using NSIPP-1. The coupled model's simulation of the seasonal cycle of SST in the equatorial pacific improved markedly over previous version using an older version of the AGCM. Our initial coupled experiments exhibited a cold-bias in the western pacific warm pool region. A minor change to the AGCM parameterization of surface evaporation in weak wind regions was made, which largely eliminated this bias. However, numerous other deficiencies have been identified in the coupled model which may involve the atmospheric component. These include a strong warm-bias in the far eastern equatorial Pacific and Atlantic, and interannual variability that is too strongly biennial in frequency. The second problem may be related to insufficient sub-seasonal tropical variability in the AGCM.

I have also begun to examine shorter time-scales (days-weeks) of variability in the AGCM. In particular I am examining the simulation of African easterly waves, and its dependence on model parameterization of evaporation and convection. Initial examination of the interannual variation of wave activity is promising. This may be a first step towards predictions of Atlantic hurricane activity using the AGCM.

Participation in Workshops/Conferences/Meetings

- 7/24-30/99 (Birmingham, UK) Attend the IUGG 1999 Meeting. *Contributed Papers: Impact on convection parameters in the Aries GCM*

- 5/28-6/1/00 (Ft. Lauderdale, FL) Attend the AMS mtg. on Hurricanes and Tropical Meteorology, present paper.

- 7/18-23/00 (Chile) International Space University (ISU) course on El Nino Impacts

Publications

Carslaw, K.S., Tsias, A., Bacmeister, J. T., and Peter, T. (1999). Widespread solid particle formation by mountain waves in the arctic stratosphere. J. *Geophys. Res., 104,* 1827-1836.

Bacmeister, J. T., Eckermann, S. D., Tsias, A., Carslaw, K. S., and Peter, T. (1999). Mesoscale cooling rates and temperature fluctuations in the stratosphere induced by a spectrum of gravity waves: A comparison of parameterizations and their impact on stratospheric microphysics. J. *Atmos. Sci., 56,* 1913-1924.

Bacmeister, J. T., Kuell, V., Offermann, D., Riese, M., and Elkins, J. W. (1999). Intercomparison of satellite and aircraft observations of long-lived tracers using trajectory mapping. *J. Geophys. Res., 104*(16), 379-390.

Bacmeister, J., Pegion, P. J., Schubert, S. D., and Suarez, M. J. Atlas of seasonal means simulated by the NSIPP 1 Atmospheric GCM. In M. J. Suarez, ed., Technical Report Series on Global Modeling and Data Assimilation, NASA/TM-2000-104606, vol. 17.

USRA EMPLOYEE: DR. KEN CASEY

Research focus: Correlative studies of sea surface temperature and heights from AVHRR and TOPEX data.

Accomplishments

These goals involved my research with TOPEX/Poseidon altimeter and Pathfinder Advanced Very High Resolution Radiometer (AVHRR) data and in developing collaborations with other scientists.

I have maintained and updated both my NSIPP TOPEX Data Archive (http://mohawk.gsfc.nasa.gov/topexdat/) and my NSIPP AVHRR Data Archive (http://mohawk.gsfc.nasa.gov/avhrr/). Sea surface height (SSH) data and sea surface temperature (SST) data were added to these archives, and numerous other improvements were made. The extension of both of these data sets allowed me to extend my analysis of Pacific SST and SSH correlations to include the latest El Nino of 1997-98.

In October I presented my research on these correlations at the Joint TOPEX/Poseidon and Jason-1 Science Working Team Meeting in Keystone, Surface Temperature and Sea Surface Height Modes in the Pacific Ocean from 1993-1996,11 and I have included a small version of the poster with this report. This presentation focused on the characteristics of the eddy field during two dynamical regimes between 1993 and 1996, as identified by 'a singular value decomposition analysis. Extending the analysis with the 1997 and 1998 data allowed me to prepare my presentation for the 1998 Fall AGU meeting in San Francisco, California. I have also included a small version of this poster, which was presented in early December. The title of that work was "North Pacific Dynamical Regimes from SST and SSH Correlations with Application to Eddy-Mean Flow Interactions." During the review

period, I continued working on the first of two or possibly three manuscripts which I expect to result from this research. It describes the 1993-1996 periods and details the analytical techniques. The second manuscript will focus on the 1997-1998 El Nino period, and the third manuscript will deal with the seasonal changes observed.

I also made progress collaborating with Jorge Vazquez of JPL/Caltech to evaluate SST climatologies. I completed an initial evaluation of a climatology he created from Pathfinder AVHRR SST data, and found that it did not perform as well as a more highly resolved SST climatology which I created from the same original dataset. We met during the AGU meeting to discuss these results and future work in this area of research.

Participation in Workshops/Conferences/Meetings

- 10/12-17/98 (Keystone, CO) Attend the Joint TOPEX/Poseidon and Jason-1 Science Working Team Mtg.

- 12/5-11/98 (San Francisco, CA)
  Attend the AGU Meeting

USRA EMPLOYEE: DR. VICTORIA COLES

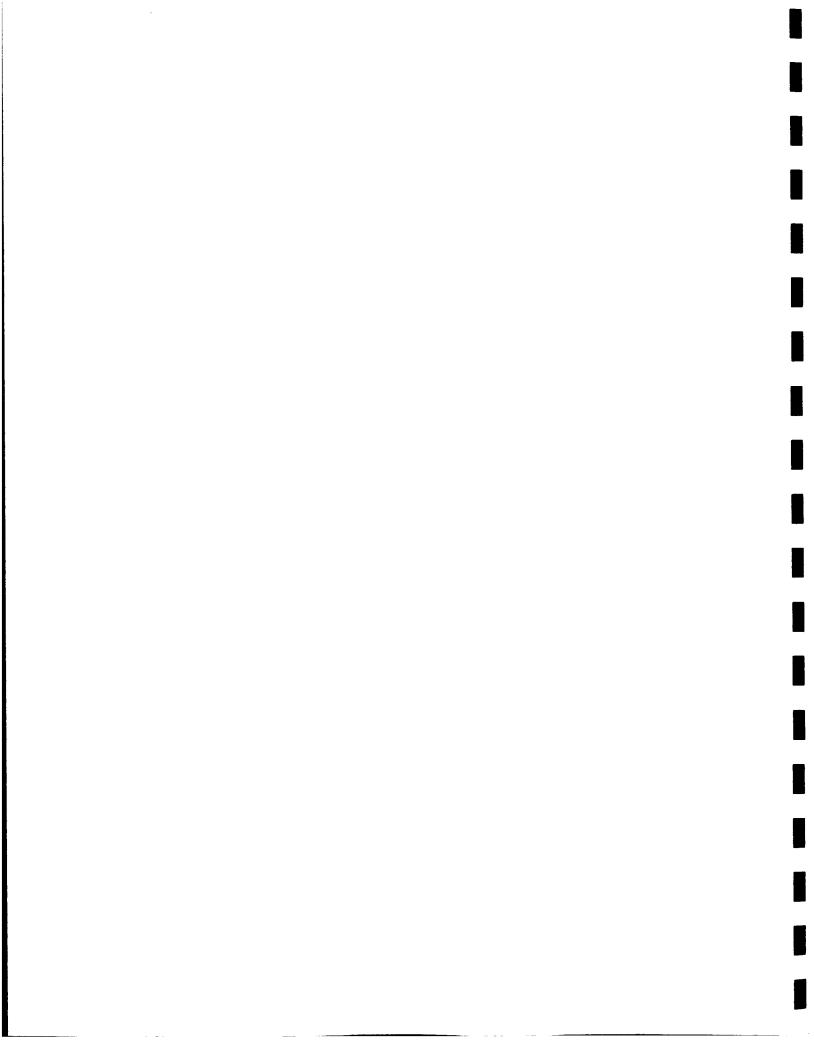**Research focus:** Coupled ocean-atmosphere modeling and assimilation studies.

Accomplishments

My primary scientific focus has been in studying the exchange of water masses between the Pacific subtropical and subtropical and tropical gyres. I discovered a strong seasonality to the exchange which has not previously been recognized, and have proposed a mechanism which explains the seasonally. This is exciting, because the exchange appears to be concentrated in time and space which implies a potentially more significant impact on the equatorial thermocline than had been recognized. Further, the mechanism we propose may tend to be very sensitive to interannual variability, and thus may tie this
process to ENSO variability.

Much of my effort focused on numerical issue relating to decreasing the time required to run model simulations. As mentioned in the interim progress report, model code has been ported to J90 and T3E supercomputers, and a spun up simulation with good model flow fields, and reasonable parameter choices was finally obtained in late March.

In collaboration with the NSIPP project, this run has been extensively compared with the NSIPP ocean model, Poseidon, run in a similar configuration. In particular, both models have been compared to available transport observations very extensively, and we have shown differences in the seasonality of the equatorial transports which relate to wave propagation differences between the models due to the reduced gravity configuration of Poseidon. Comparing model results to current transport rather than velocity is more difficult, and less common, however my results illustrate that correctly simulating mean velocity fields in the equatorial region may tend to overestimate the transport of heat, salt, and mass.

I have also been involved in writing 2 proposals and a white paper this year, with the goal of securing my own funding, and becoming involved in the broader scientific community, while still maintaining a tight collaboration with NASA and the NSIPP group. One proposal submitted with Michele Reinecker and David Adamec was sent to the NASA ocean vector winds science team, in essence to do the work I proposed in the USRA GEST proposal. The other proposal involves combining tropical ocean modeling with a bio-geo-chemical model to investigate the interaction of physics and biology as part of the NSF's bio-complexity initiative. This proposal was funded and becomes active in January. The white paper, detailed plans for combining physical, biological, and chemical, as well as crustal

heatflux models to simulate the dispersion of hydrothermal vent communities. I attended a meeting to discuss reformulating the RIDGE program (NSF), with of course the goal of including this research. NASA is interested in vent communities through primarily the astrobiology and LexEn programs, and RIDGE hopes to foster a closer collaboration with NASA in the future.

NSF Bio-complexity proposal, Bio-physical modeling of tropical Atlantic. Primary Collaborators: Don Olson (RSMAS), Mercedes Pascual (COMB), Raleigh Hood (UMCES), Doug Capone (USC), Ed Carpenter (SUNY)

RIDGE2000 White Paper, Collaborators: Craig Cary (Udel), Raleigh Hood (UMCES).

<u>Visiting Faculty position at the Horn Point Laboratory, University of Maryland Center for Environmental Science</u>. We have been working on a few model related as well as scientific problems since September. We have been testing some mixed layer parameterizations for the Poseidon model relating to the transport of water in the Subtropical Cell (STC). One of these simulations is incorporated into the paper with Michele.

We have also been working on improving the freshwater representation in the Poseidon model. This is directly related to the goals of the NSIPP project, and also will impact the STC work. Here, we have been incorporating riverine input into the global ocean model, and studying issues relating to surface salinity, and the formation of water masses. This will be a major focus over the next 6 months.

I also expect to continue the STC work, we want to see whether the mechanism that we found for the seasonality of the STC exchange in the basin interior is variable on interannual timescales. This may potentially have an impact on interdecadal variability in the ENSO system.

My primary focus has been on submitting a proposal to the NASA NRA, entitled " Synoptic scale momentum and buoyancy forcing impacts on Pacific Tropical Watermasses". We also spent some time developing a proposal to the NSF which focused more specifically on ventilation processes which influence Subtropical-tropical exchange, although we didn't feel the proposal was mature enough to meet the August 15th deadline.
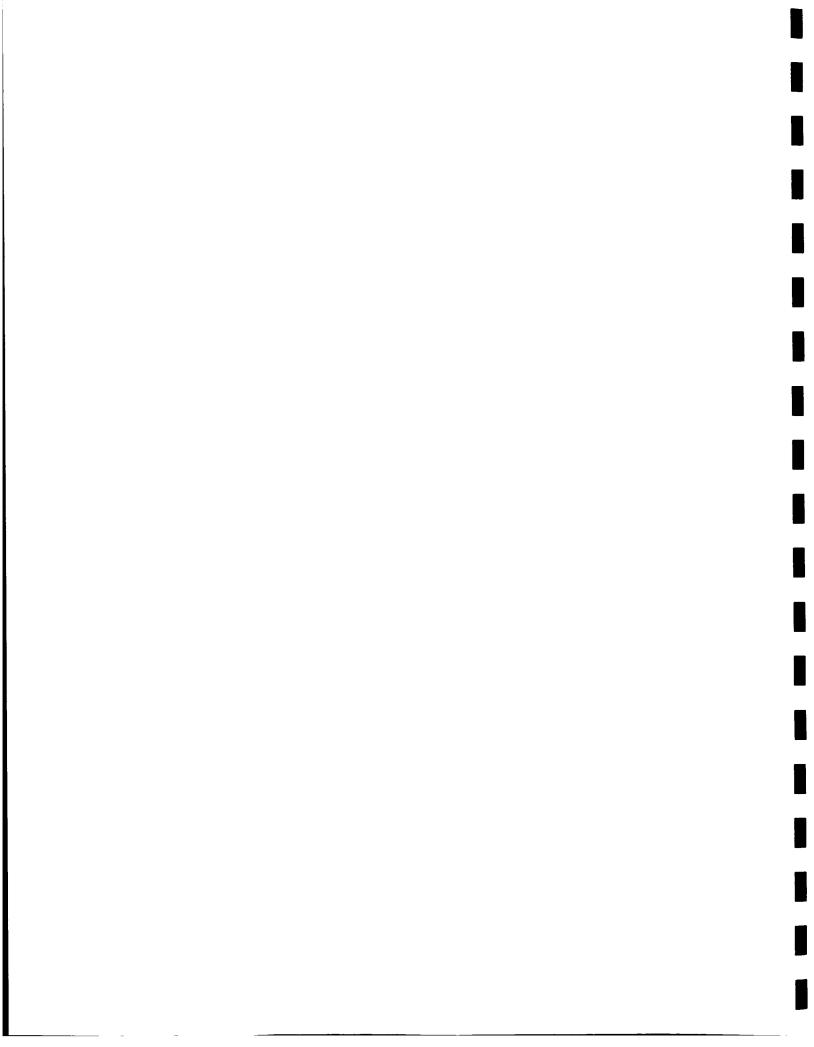
On the science front, I have been revising a manuscript on Subtropical-tropical exchange, and working on a new interannual variability in Subtropical-tropical exchange paper. Part of this work will be presented at an October workshop on global subtropical-tropical exchange processes (the work for which was completed under USRA funding). We have also been focusing on a study of the Tropical Pacific salinity and current variability over the decade from 1988 through 1998, as a comparison with observations which show significant salinity variability. Some of this work, as well as a model intercomparison, and a study of temperature and salinity variability in the western Pacific warm pool was presented at the NSIPP Science Team Meeting in early July. We hope to complete this work for a special issue of Journal of Geophysical Research, which is due in December.

Public outreach work continued, with 2 presentations to Anne Arundel teachers on the new Goddard Earth System Sciences curriculum which I was involved in developing, and a third presentation to Delmarva teachers in August.

I have also been continuing collaborations with scientists at FSU on the tropical thermocline circulation.

Participation In Workshops/Conferences/Meetings

- 12/5-11/98 (San Francisco, CA) Attend the AGU Meeting

- 2/18-24/99 (Miami, FL) Attend the Layer Ocean Model Workshop

- 1/23-29/00 (San Antonio, TX) Present talk at 2000 AGU Ocean Sciences meeting. Presented: "Seasonal variability in North Pacific subtropical-tropical exchange in two layer ocean models."

- 2/28-3/5/00 (Miami, FL) Attend Layered Ocean Modeling Workshop. Presented: "An isopycnal -- quasi-isopycnal comparison: Modeling subtropical - tropical exchange in the North Pacific thermocline."

USRA EMPLOYEE: DR. ROSANA FERREIRA

Research focus: Development of GCM boundary conditions, parameterizations and initialization procedures.

Accomplishments

ARIES GEOS Model Stretched Grid Simulations. Performed pioneering, longterm GCM simulations using a stretched horizontal grid configuration. Successful simulations with grids that have a l degree (0.5 degree) horizontal resolution in the region of interest, stretching to 4 degrees (4 degrees) at the antipodal region. These simulations are four (eight) times less costly than their uniform resolution counterparts. The simulations on the stretched grids reproduce the general circulation climatology as well as the 2.5 x 2.0 degree ARIES GEOS benchmark simulations.

The region of interest has been centered over South America in order to pursue our studies of the 'Role of land-surface processes and regional and global interactions in the seasonal to interannual variability of the atmosphere in the Amazon region.

We have assessed the model's seasonal and diurnal cycles of winds and precipitation, with special attention to the South American Northerly Low Level Jet which plays an important role in the water balance of South America. Other circulations of interest are the SACZ and Amazonian squall line systems.

UBA observations. Data collected in the recent LBA TRMM field campaign which was conducted in Rondonia, Brazil, earlier this year can be useful for validation of the model's results. In collaboration with Drs. Jeff Halverson (JCET/UMBC) and Tom Rickenbach (JCET/UMBC) we are using TRMM LBA radiosondes and DAO Analyses to define regimes of convection-in Rondonia.
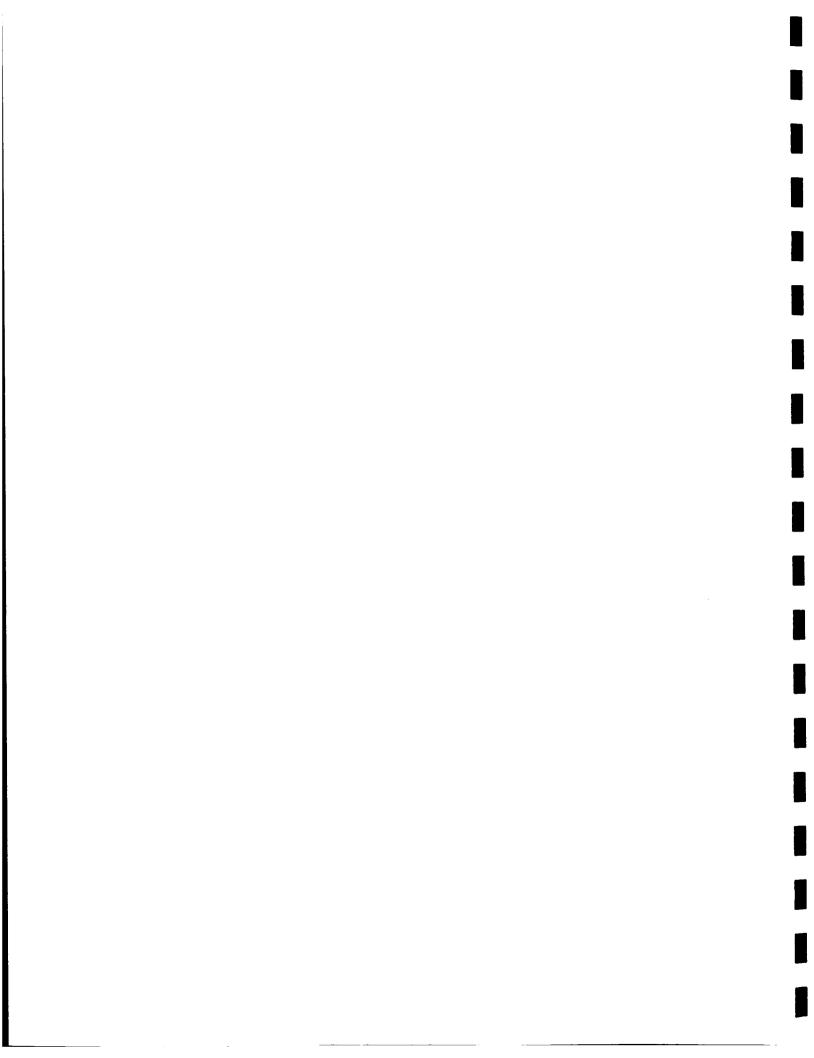
Simple physics simulations. Simulations with a simpler version of the GCM, which includes only dynamics with a very simple parameterization of physical processes are also under way to study the SACZ (in collaboration with Dr. Edward Colon from Howard University) and the African Easterly Jet and African Easterly waves (in collaboration with Dr. Julio Bacmeister from USRA)

La Nina interviews with the Spanish and Portuguese weather channels. Participated in the NASA GSFC Laboratory for the Atmospheres Summer Student Institute as a Coordinator and as a Mentor jointly with Dr. Julio Bacmeister.

In collaboration with Collen Burrichter (an undergraduate student at Buena Vista University, Storm Lake, Iowa) we studied the season al to interannual variability of a pineapple crop in Oahu, Hawaii. Our goal was to assess the potential benefits of using Seasonal to Interannual Atmospheric Prediction Products in the plantation's management practices (namely the optimal timing of the flower forcing procedure) in order to improve productivity.

The results of this ongoing study are being passed on to Ms. Joyce Friedenberg (who is one of the managers of the subject plantation) for implementation.

I have concentrated on a study of the South Atlantic Convergence Zone (SACZ) using the dynamical core of the ARIES/GEOS GCM. This work has used a number of diagnostic tools for studying the effect of Amazon convection on baroclinic waves and the feedback of baroclinic waves to the SACZ. Some of these tools are EOF analysis, cross-correlation, and compositing techniques. We see that

the Amazon convection produces a region of increased baroclinic wave activity to its southeast with stronger waves that have stronger low level convergence in the SACZ region.

A paper on this subject is in preparation to be submitted to the Journal of the Atmospheric Sciences. A short paper entitled 'Effects of baroclinic waves on the South Atlantic convergence zone' was submitted to be published in the preprints of the 6th Conference on Southern Hemisphere Meteorology and Oceanography, to be held in Santiago, Chile, in April 2000.

The initialization package for the full GCM which I developed a couple of years ago has needed additional work during this quarter. It is now almost fully 'operational' for NSIPP's general use.

Performed and analyzed results of stretched-grid GCM simulations for three consecutive Southern Hemisphere summers. Preliminary results can be seen at: http://janus.gsfc.nasa.gov/~ferreira/LBA.html

Completed simulations and nearly completed manuscript on the effects of Amazon convection and baroclinic waves on the South Atlantic convergence zone.

Idealized simulations of the effects of ITCZ convection, Sahara heating, and easterly waves on the African Easterly jet are almost completed.

Just finished installing a stretched-grid polar filter in the GCM and will soon be performing GCM simulations with stronger grid-stretching.

Continued stretched-grid GCM simulations of the Southern Hemisphere Summer circulation. Preliminary results can be seen in: http://janus.gsfc.nasa.gov/~ferreira/LBA.html

Participation in Workshops/Conferences/Meetings

- 11/2-4/98 (MD) Attend the Land Surface Hydrology Program Investigation Meeting

- 4/2-4/00 (Chile) Attend the 6th International Conference on Southern Hemisphere Meteorology and Oceanography

- 5/28-6/3/00 (Ft. Lauderdale, FL) Attend the 24th Conference on Hurricanes and Tropical Meteorology

- 6/25-7/3/00 (Belem, Brazil) First Scientific LBA conference in Belem, Brazil
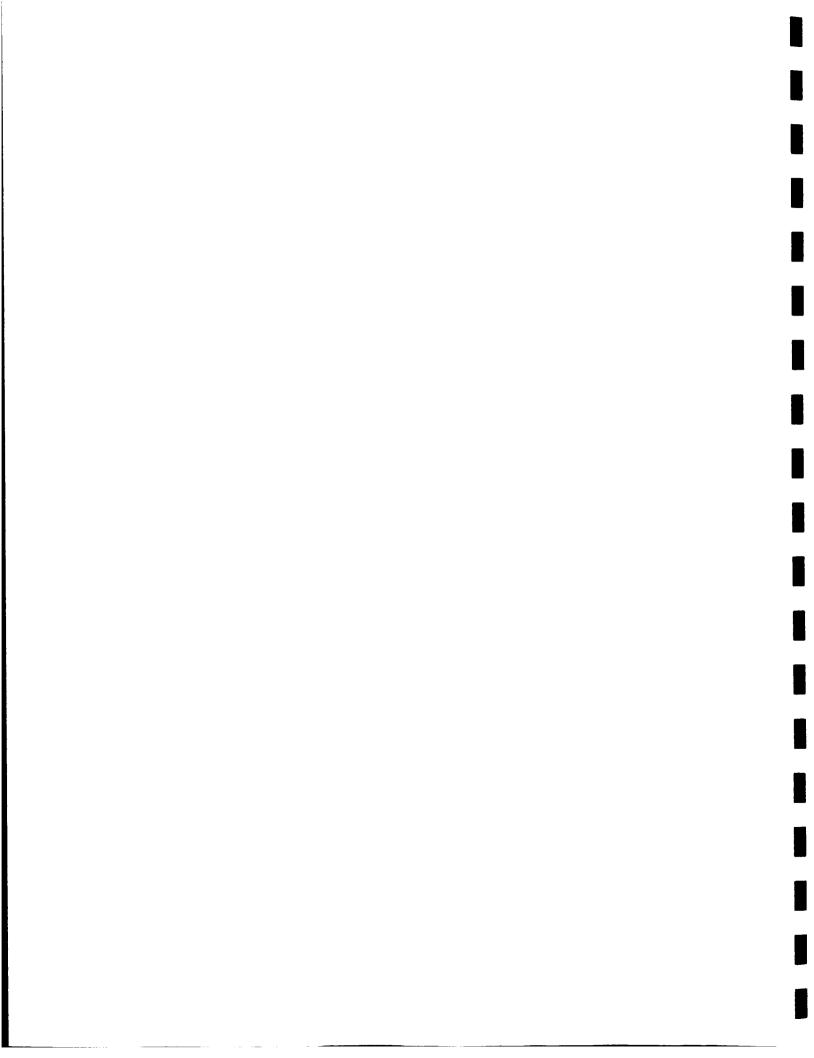

USRA EMPLOYEE: DR. AUGUSTIN VINTZILEOS

Research focus: Studies in seasonal to interannual climate prediction.

Accomplishments

I continued research relevant to the development of the NSIPP El Nino – Southern Oscillation forecasting system. This system is based on the NSIPP global atmosphere – ocean coupled model and therefore understanding and improvement of systematic biases helps not only to increase our knowledge on interannual variability but also for reaching the target of successful seasonal forecasting.

Prior to October 1999, a series of hindcast experiments covering the 1981-1999 period was performed. These experiments, for which no data assimilation was used, serve as the baseline for assessing improvements of the skill of our system related to the introduction of data assimilation as well as corrections of the modeled physics. The central finding was that the onset phase of all El Nino events that occurred during the 1981-99 period was not correctly captured in contrast with the decay

phase. Since October 1999 we introduced assimilation of three-dimensional temperature data from the TAO array for initializing the coupled model. Data from the period 1993-1999 were used. This time the onset phase of the 1997-98 El Nino was correctly captured. The fact that the physics of the coupled model remained unchanged between the baseline and with-assimilation experiments suggests that there is a systematic bias in the way that the ocean model interprets wind stress observations (during the forced part of initialization). A comparative study is underway focusing on the detection of structures responsible for the differences between the two sets of experiments. Their detection will lead to further corrections in the physics of the ocean model and therefore to improvements in the simulated coupled climate. This study will be submitted for publication in early summer 2000. Results will also be presented at the annual meeting of the European Geophysical Society in Nice, France in April 2000.
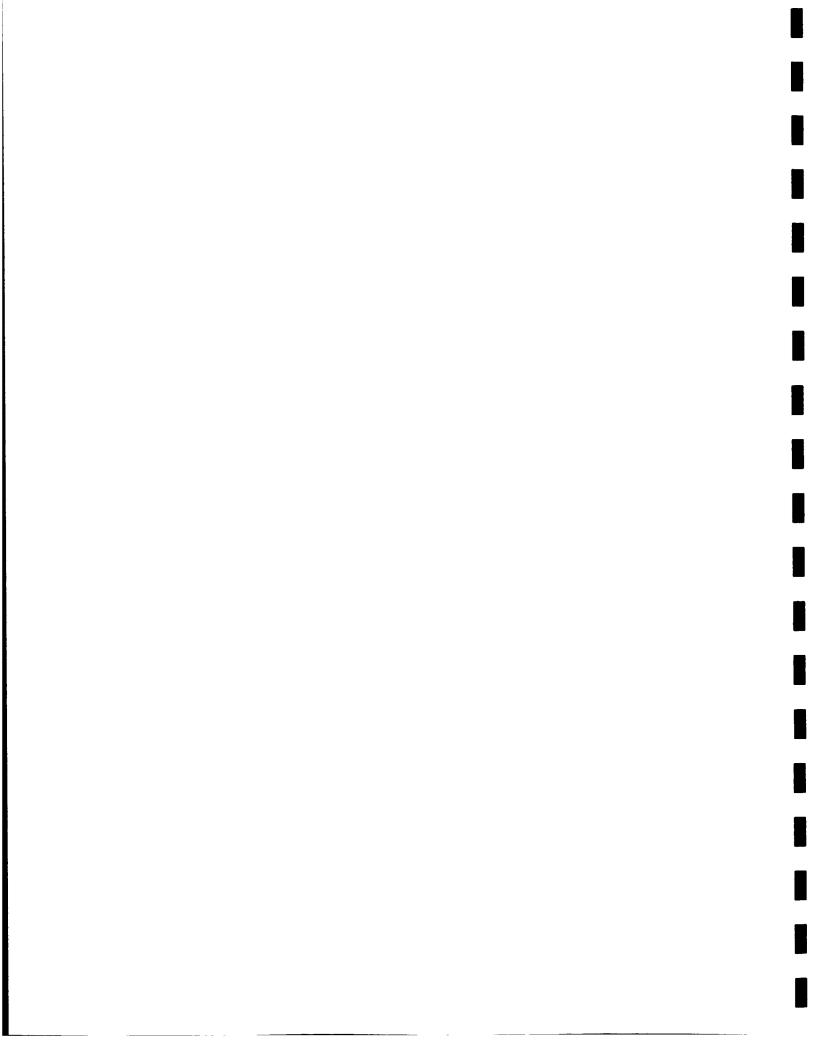
Before issuance of real time ENSO forecasts, research on the generation of ensembles of coupled predictions must be accomplished. We first generated ensembles of initial states by perturbing the atmospheric state. Results from these experiments did not present a significant spread of predicted sea surface temperatures. We then used perturbations of parameters of the assimilation technique. Assimilation of temperature data for two months instead of one before initialization of the coupled model produced a huge spread in the predictions. We currently investigate if this spread is due to poor predictability or if it is related to the assimilation technique. Upon completion of this study we will be able to issue real time 12- month forecasts for tropical Pacific conditions.

Meanwhile, efforts to improve the coupled model continue. Currently, a new version of the model is running in "free" coupled mode. This model resulted from corrections in both the atmospheric and ocean components of the version used for the hindcast experiments. Preliminary results show significant improvements in the mean state e.g., no double ITCZ, and in simulated annual variability of SST. Nevertheless, the eastern Pacific near the coast suffers from unrealistic warming and subsurface annual variability is not very well correlated with the observed one. At this time, experimentation with this model is extended in order to assess its capacity to simulate ENSO. Analysis of results from "free" coupled runs and hindcast experiments and comparison with results obtained from the earlier version of the model will eventually lead to an even better forecasting system.

Although ENSO is the most important mode of interannual variability that affects weather statistics, successful seasonal forecasts also depend on sea surface conditions in other regions e.g., tropical Atlantic and Indian ocean and other modes of variability like the NAO and interannual variations of the intensity of the Indian monsoon. In the longer run, I intend to investigate the ability of the NSIPP model to simulate and predict these important climate modes.

I continued research relevant to the development of the NSIPP El Niño – Southern Oscillation forecasting system. I analyzed the series of hindcast experiments that I designed and portrayed before the period covered by this report. These experiments consist of using two sets of ocean initial states for initializing the coupled ocean – atmosphere model. Both of these sets are provided by the ocean model in forced mode. For obtaining the first set, the ocean model is forced with observed wind stresses and its surface temperature restored to observed values. The second set of initial conditions was produced by the same configuration with, additionally, assimilation of TAO temperature data. Atmospheric initial states are identical for both sets of experiments and taken from a simulation where the atmospheric model was forced with observed SSTs. The coupled runs, named BSLN for the case without data assimilation and ASSIM with assimilation, cover the period 1993 to 1999 starting every two months and extend on a twelve month period. It was previously shown that the forecasting skill of ASSIM experiments is considerably improved when compared to the BSLN one.

Analysis of the above experiments resulted to the detection of a new coupled mode that is responsible for the adjustment of the coupled system from the initialization shock. This coupled mode is based on the relation between SST gradients and atmospheric boundary layer motion in the tropics, on the two dimensional SST pattern of the shock which provides such gradients (Figure 1) and on equatorial ocean wave dynamics. When the eastern equatorial Pacific cools at the moment of coupling waters at latitudes 10S and 10N and along the central and eastern Pacific warm up. Equatorial easterlies are then relaxed and the thermocline is depressed in the central Pacific. The thermocline depression travels eastwards and increases the eastern Pacific SST. This part of the coupled mode can be affected by the mean depth of the thermocline along which the depression propagates. Indeed,

recovery from the cold shock is less effective for the BSLN experiment because of a shallower mean thermocline and the subsequent damping of the propagating warm thermocline signal. It is shown that the weaker effectiveness of the restoring coupled mode in the BSLN experiment has negative impacts on prediction of interannual anomalies.

Participation in Workshops/Conferences/Meetings

- 9/11-18/99 (Denver, CO) Attend the 8th Conference on Climate Variation, Short course on Tropical Extratropical Interaction and Prediction

- 4/25-30/00 (Nice, France) Attend the European Geophysical Society meeting

- 5/31/00 (Washington, DC) Attend the AGU Meeting

USRA EMPLOYEE: DR. CARA WILSON

Research focus: Ocean circulation dynamics research, emphasizing global mesoscale ocean variability using TOPEX- Poseiden data.
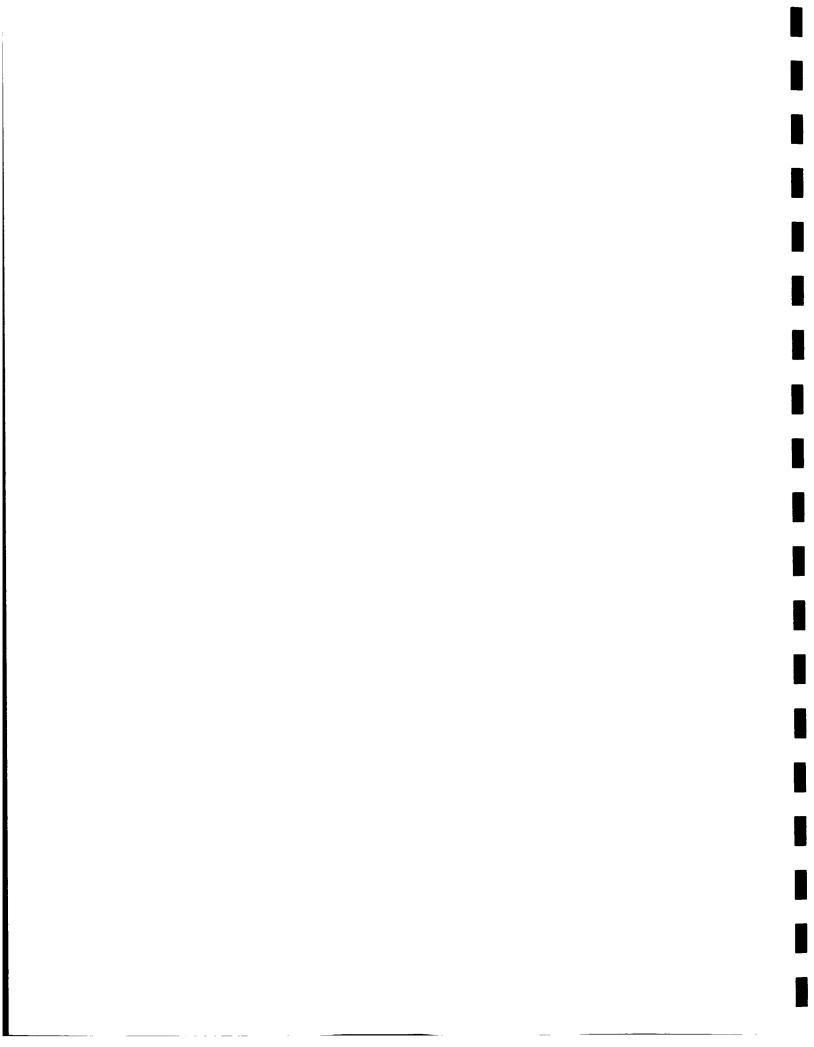
Accomplishments

I'm analyzing global mesoscale ocean variability using sea surface height (SSH) data from TOPEX/Poseidon ocean color (chlorophyll a) from the SeaWiFS (Sea-viewing Wide Field of view Sensor) satellite. While there have been some regional studies examining the connections between the physical and biological dynamics indicated by these two data records, there has not been a statistical correlation examining the physical and biological dynamics on a global scale.

Both the SeaWiFS and the TOPEX/Poseidon satellites are still collecting data. The SeaWiFS record started in Sept. 1997 and thus there is a more than two year record of sea surface chlorophyll to compare against the sea-surface height (the TOPEX/Poseidon record started in 1992). This time period includes the very strong 1997-1998 El Nino.

As this is a new field of study for me, I have spent a considerable amount of time since starting with USRA on Dec. 6 1999 getting acquainted with the literature. I have also spent time familiarizing myself with the computer and software resources here, in particular learning IDL, a software graphics package.

I have obtained the global record of SeaWiFS data which are binned into 8 day intervals and I've processed it into a format similar to the format of the existing TOPEX/Poseidon files. The TOPEX/Poseidon cycles corresponding to the time after the start of the SeaWiFS record were rebinned from their original 9.9156 day cycle to the same cycle interval as the SeaWiFS data for ease in comparing the records. I have deseasoned both records by removed the annual and semi-annual cycle calculated by a harmonic fit of the data. I have performed an empirical orthogonal function (EOF) analysis on both records. EOF analysis is a method to describe the temporal and spatial variability of a data series in terms of a few statistical modes. These analyses are still in the preliminary stages, and will be refined in the coming months.

After having performed separate and joint EOF analysis on TOPEX/Poseidon sea-surface height and SeaWiFS surface chlorophyll data for the Pacific, Indian, and Atlantic Oceans, I'm currently concentrating on analyzing the results from the Pacific. The SeaWiFS satellite was launched in Aug. 1997, and I've been using data from Sept. 1997-Dec. 1999. This time period includes the very strong 1997-1998 El Nino and the subsequent La Nina. From EOF analyses of the longer time series of TOPEX/Poseidon data starting in 1993 it is clear that all of temporal variability in the EOF modes are heavily influenced by the 1997-1998 El Nino.

One of the most interesting results of the EOF analysis is that the dominate chlorophyll response to the El Nino is a symmetrical off-equatorial chlorophyll decrease in the central and eastern Pacific during El Nino followed by an off-equatorial chlorophyll increase during la Nina. This result is unexpected as the best-known biological effect of an El Nino is decreased chlorophyll at the equator. While an equatorial chlorophyll decrease is seen in the EOF analysis, it is seen in a lower mode, which accounts for less of the overall variability, and its temporal variability is not correlated with El Nino, as defined by the NINO3 index. The differences in these two responses arises from a combination of ecological and physical dynamics. Biological production in most of the Pacific is nitrate limited, and the deepening of the thermocline in the central and eastern Pacific during an El Nino will reduce nitrate availability, and thus reduce surface chlorophyll. However the equatorial ecosystem is different in that it is limited by iron,
which is not supplied by local upwelling, but by the Equatorial UnderCurrent (EUC) which carries iron-rich water from the western Pacific. During El ñ the EUC is often weakened or shut down completely. Using ADCP (Acoustic Doppler Current Profiler) data from the TOGA/TAO equatorial arrays it is clear that the equatorial chlorophyll increase after the peak of the El Nino is linked to the recommencement of the EUC which had been previously shut down.

I have also been examining wind data from the Special Sensor Microwave Imager (SSM/I) to look at how the variability in sea-surface height and chlorophyll is related to physical forcing terms. I have been involved with collaborations with Chuck McClain and Sergio Signorini in the SeaWiFS Project. Using temporal and spatial correlation scales provided by them for the SeaWiFS data, I used optimal interpolation to fill in the missing data in the SeaWiFS grids which resulted from cloud coverage.

Currently I'm concentrating on writing the first draft of a paper discussing the results of the sea-surface height and chlorophyll EOF analysis for the Pacific. I plan to present this work in poster form at the Oceans from Space meeting in Venice in October 2000 as well as at the TOPEX/POSEIDON Science Working Team Meeting in November 2000.

USRA EMPLOYEE: DR. DON YUAN

Research focus: Development of inverse adjoint techniques for assimilating sea surface temperature in numerical ocean models.
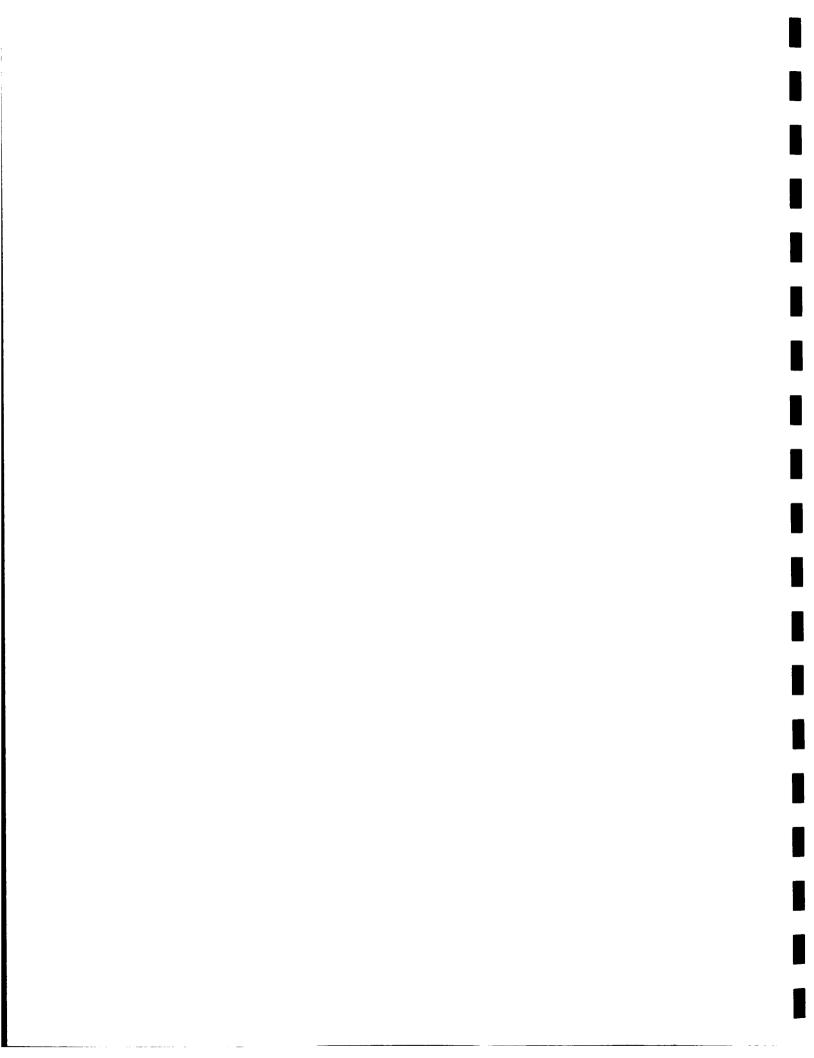
Accomplishments

I have been writing two manuscripts out of the assimilation study during this period. The assimilation has achieved the expected goals and scientific results are abundant. At present, two manuscripts are in their final stage of preparation. The titles of the papers are: *A numerical hindcast of the equatorial Pacific ocean circulation in the 1990s* and *Inverse estimation of sea surface heat flux over the equatorial Pacific ocean from sea surface temperature data*.

The hindcast study compares the Poseidon model simulation with the TOGA-TAO mooring measurements and the consistency of existing ENSO theories with the hindcast results is discussed.

In the assimilation study, sea surface heat flux is calculated inversely from the SST data and is compared with existing estimations based on the bulk formula. It is found that the calculated sea surface heat flux are far from the existing estimations in some seasons and during certain years. Model deficiencies in simulating the SST seasonal variations are identified with the TOGA-TAO observations. Interannual variations of the sea surface heat flux that have never before been disclosed are observed in the calculated sea surface heat flux.

The two papers are to be submitted together for publication.

I have been working with Professor William K. Dewar on the diagnosis of the spurious diffusion in the Poseidon ocean model. Dr. Dewar has visited the Goddard center twice. Each visit lasted for about two weeks. During his visit, we worked together very hard, frequently skipped lunches. So far we have achieved the following:

The Poseidon model is deployed onto a rectangular basin enclosed by the longitudes and latitudes of the Pacific basin. The model is driven by zonally averaged Hellerman-Rosenstein zonal windstress and the relaxation to the Levitus climatological temperature and salinity at the sea surface and runs stably for over 20 years. However, the model simulated fields seem a little too noisy and we are trying to fix the problem.

At the end of year 6 and year 20, short runs of the model are conducted with the surface buoyancy fluxes and vertical diffusion shut off. The spurious mixing in the Poseidon model is then diagnosed.

The program to sort the density and calculate the global averaged vertical diffusion coefficient is successfully written and the diagnosis appears reasonable.

Participation in Workshops/Conferences/Meetings

*   12/6-10/98 (San Francisco, CA) Attend the AGU Meeting

*   7/17-8/1/99 (Birmingham, UK) Attend the IUGG 1999 Meeting

CONSULTANTS/VISITORS

Visitor: **Trevor McDougall** CSIRO Marine Research, Australia)
Purpose: Conduct scientific research on vertical mixing processes in the ocean model as part of the NSIPP science team (7/8-31/99)

Visitor: **Cara Wilson** Universite Pierre et Marie Curie, France)
Purpose: Present a seminar to the Oceans and Ice Branch (7/21-25/99)

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TASK 971-08: Oceanographic Research in the Global Oceans
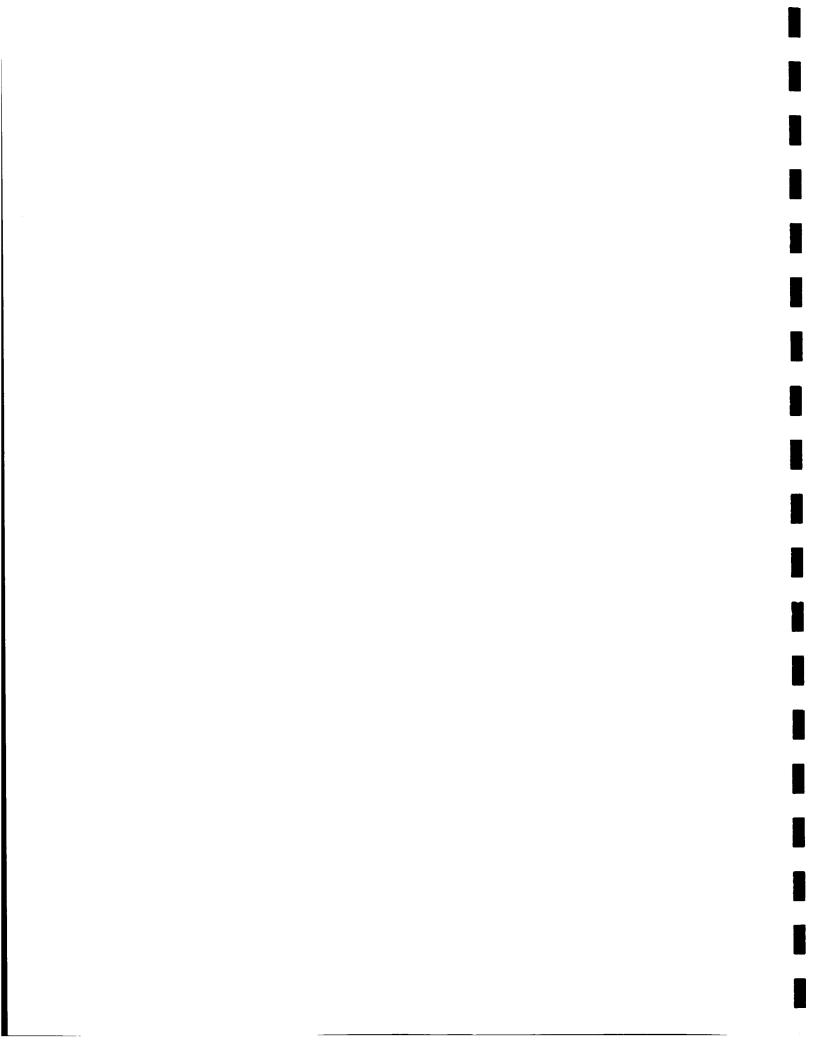
TASK DESCRIPTION

The objective of this task is to support a visiting fellow at GSFC to assist with ongoing oceanographic research in the global oceans. The specific objectives are the following:
*   Study the influence of physical, oceanographic, and meteorological processes on biological processes within the surface layer with particular attention to seasonal and interannual variability.
*   Estimate total and new primary production on seasonal and annual scales.
*   Investigate biological feedback on physical processes.

The research program will utilize an assortment of satellite and in situ observations and coupled physical and biological models. The work will be coordinated with a team of investigators working at GSFC and several universities. Some travel to scientific meetings is anticipated. Also, travel support for other investigators is also required.

USRA EMPLOYEE: DR. JAMES CHRISTIAN

Research Focus: Development of 3-D ocean biological- geochemical models and ocean color algorithms.

Accomplishments

I have completed extensive analyses of the output of the biogeochemical model that I have been developing for the past 2 years. Two papers on this are almost ready for submission. In addition I helped develop a carbon chemistry model in a 1D context (Signorini et al., submitted) and wrote a proposal to extend this to the large scale biogeochemical model. I also did extensive analysis of various algorithms for estimation of ocean primary production from satellite ocean color (McClain et al., submitted).
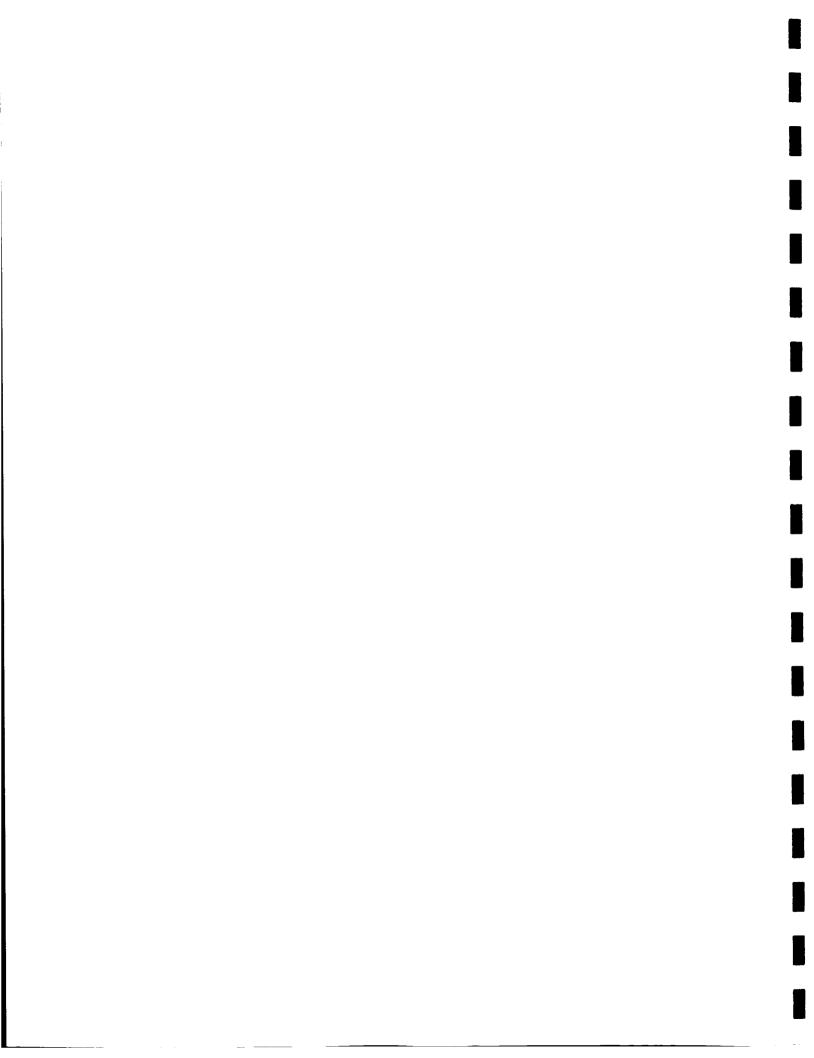
I just completed a proposal for a further 3 years of NASA funding, and have attended meetings with several groups planning large programs into which my present projects may be integrated as funding opportunities arise. The CAF group is concerned with climate effects on agriculture and fisheries, the NOPP group is a consortium of ocean modelling groups planning the next generation of ocean models, and the HALE-ALOHA group is planning moored instrumentation at a North Pacific Ocean site where I have NSF funding to do modelling.

Participation in Workshops/Conferences/Meetings

- 12/5-11/98 (San Francisco, CA) Attended the AGU Meeting

- 5/17-22/99 (Moss Landing, CA) SeaWiFS Science Team meeting

- 7/11-18/99 (Keystone, CO) Attend US-JGOFS

- 11/2-5/99 (Norfolk, VA) Attend Tropical Oceans Team mtg., US-JGOFS Synthesis & Modeling mtg.

- 1/23-24/00 (San Antonio, TX) Attend AGU/ASLO Ocean Sciences meeting

- 3/22-26/00 (San Diego, CA) Attend "Beyond El Nino" meeting of North Pacific Marine Science Organization

- 4/12-18/00 (Bergen, Norway) Attend International JGOFS meeting

CONSULTANTS/VISITORS

Visitor: **Hajime Fukushima** (Tokai University, Japan)
Purpose: Testing OCTS Algorithms in the SeaDAS environment (5/31-7/20/99)

Visitor: **Olivier Hagolle** (Centre Nationale d'Etudes Spatiales, France)
Purpose: Collaborate with SIMBIOS project members to process Polder Data (3/13-21/99)

Visitor: **Marlon Lewis** (Dalhousie University, Canada)
Purpose: Attend a meeting of Tropical Oceans IDS (4/12-14/99)

Visitor: **Jean Marc Nicholas** (Universite de Lille, France)
Purpose: Collaborate with SIMBIOS project members to process Polder Data (3/12-28/99)

Visitor: **Daniela Turk** (Dalhousie University, Canada)
Purpose: Tropical Oceans research group in conjunction with AGU meeting in San Francisco, CA (12/5-18/98)
              Attend meeting of the Tropical Oceans Research Group (4/10-16/99)

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TASK 971-10: Coupled Ice-ocean Modeling

TASK DESCRIPTION

This task covers charges related to the research of the coupled ice-ocean modeling. The specific tasks will include model development and analysis of the results. The first version of the new ocean model has been tested in simple geometries, but requires refinement and application to realistic simulation experiments. This part of the task covers work performed by Prof. George Mellor of Princeton University.

Analysis of model hindcasts for the period 1951 to the present and observations from various sources are to be performed by a postdoctoral associate. The salary of the individual will be covered under this task. Presently Dr. Cathleen Geiger is covered by this part of the task.

This task will also cover travel expenses for scientists working on similar projects to visit GSFC who will be specifically invited to work on joint publications and/or give a seminar. Names of visitors will be put forward before such visits are arranged.

USRA EMPLOYEE: DR. JINRO UKITA

Research focus: Ocean ice modeling and analysis.

Accomplishments

I have been working with Dr. Sirpa Hakkinen on a project that involves with data analysis on model results over the Arctic Ocean from an ice-ocean coupled model.
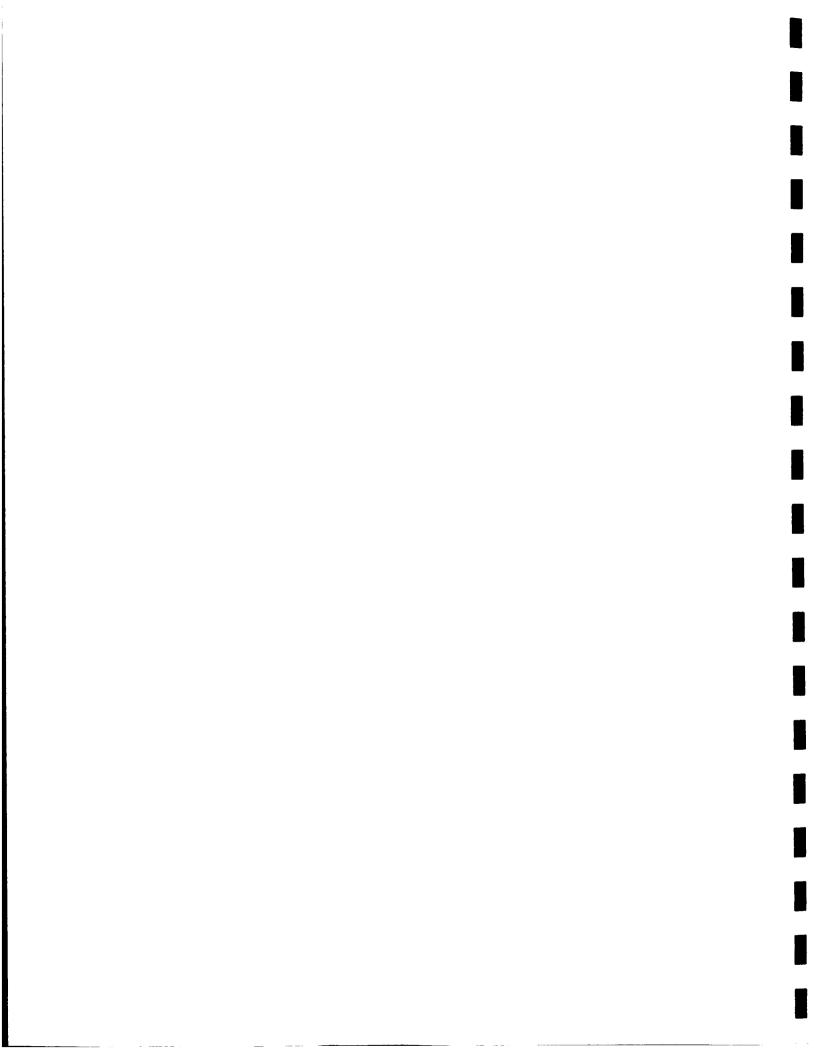
Participation in Workshops/Conferences/Meetings

* 6/12-23/00 (Fairbanks, AK) Presentation at IUTAM Ice Mechanics and Ice Dynamics mtg.,

Publications

Overland, J. E., and J. Ukita. Arctic Sea Ice Dynamics Workshop. *EOS Trans.*, 81, 309, 314, 2000.

CONSULTANTS/VISITORS

Consultant:	**George Mellor** Princeton University)
Purpose:	Conduct collaborative research with NASA in coupled ice-ocean modeling of the South Ocean and the North-Atlantic-Arctic system (10/198-9/30/99)
Visitor:	**Thomas Haine** (Johns Hopkins University)
Purpose:	Present a seminar to the Oceans and Ice Branch (5/16/00)
Visitor:	**Igor Polyakov** (GFDL/NOAA)
Purpose:	To present a seminar and discuss research interests in high latitude physics (4/24-28/99)
Visitor:	**Andrey Proshutinsky** Naval Postgraduate School)
Purpose:	Collaborate with Dr. Hakkinen on the "Arctic Ocean Model Intercomparison Project" (1/30-2/5/00)

Visitor: **Jinro Ukita** (International Arctic Research Center, Japan)
Purpose: Participate in discussions with members of Ocean and Ice Branch (7/20-23/99)

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TASK 971-13: Large-scale Mean and Time Varying Ocean Circulation

TASK DESCRIPTION

The objective of this task is to carry out research on the large scale mean and time varying ocean circulation using satellite altimeter and in situ measurements, and numerical models. This task will also support short visits by non-NASA scientists.

USRA EMPLOYEE: DR. CHARON BIRKETT

Research focus: Application of ERS/TOPEX altimetry data to inland water bodies.

Accomplishments

Primary output of the work has been several peer-reviewed and general literature publications, the creation of the prototype NASA Pathfinder Lakes Database, gaining PI status on two satellite missions, and the acquisition of several NASA NRA grants.

The NASA Pathfinder Lakes Database is currently housed at http://nemo.gsfc.nasa.gov/home/paulr/web/ lakes.html. PI status has been obtained on the ENVISAT and ERS I/ERS2 missions

The following NASA grants have been acquired:

NASA/Pathfinder
PI: Koblinsky/Code 971 GSFC; Co-I: Birkett
Title: Construction of the NASA Pathfinder Altimetric Lakes Database
Total Awarded Funding: 5 months during 1999

NRA-98-MTPE-01
PI: Birkett; Co-I: Jasinski/Code 970 GSFC
Title: Altimetric Remote Sensing of the Amazon
Total Awarded Funding:. 5 months per year for 3 years

NRA-98-OES-11
PI: Vorosmarty/University of New Hampshire; Co-I: Birkett
Title: The Contribution of Satellite Radar Altimetry to the Determination of River Discharge
Total Awarded Funding: 4months per year for 3 years

NRA 98-OES- 11
PI: Bradley/University of Iowa; Contracter: Birkett
Title: Coupling Satellite Remote Sensing and Unsteady Flow Modelling for Discharge Estimation
Total Awarded Funding: 1 month per year for 3 years

Health RTOP
PIs:.Maynard/Meyers; Contractor: Birkett
Title: Application of Remote Sensing Derived Environment Variables for Malaria Prediction
Total Awarded Funding: 2.5 months during year2000

Significant Recognition of the Work

The work is being highly recognized by the Hydrology Division at NASA HQ. This has been most noted via the subsequent e-mailing lists and invitations to all surface water meetings and workshops. In particular the invitations to the NASA HQ Post-2002 Missing Planning meetings at Easton and Irvine.

Participation in Workshops/Conferences/Meetings

- 10/12-15/98 (Denver, CO) TOPEX/Poseidon Science Working Team Meeting

- 12/5/10/98 (San Francisco,CA) Attend the AGU Meeting, presentation of poster

- 1/18-19/99 (NY) Attend mini-workshop on wetlands and methane production

- 12/11-15/99 (San Francisco, CA) Attend LRA meeting, attend AGU meeting, delivery of seminar and poster

Publications

Birkett, C.M., Murtugudde, R. and Allan, T. Indian Ocean Climate Event brings Floods to East Africa's Lakes and the Sudd Marsh GRL, 26(8), pp. 1031-1034, 1999
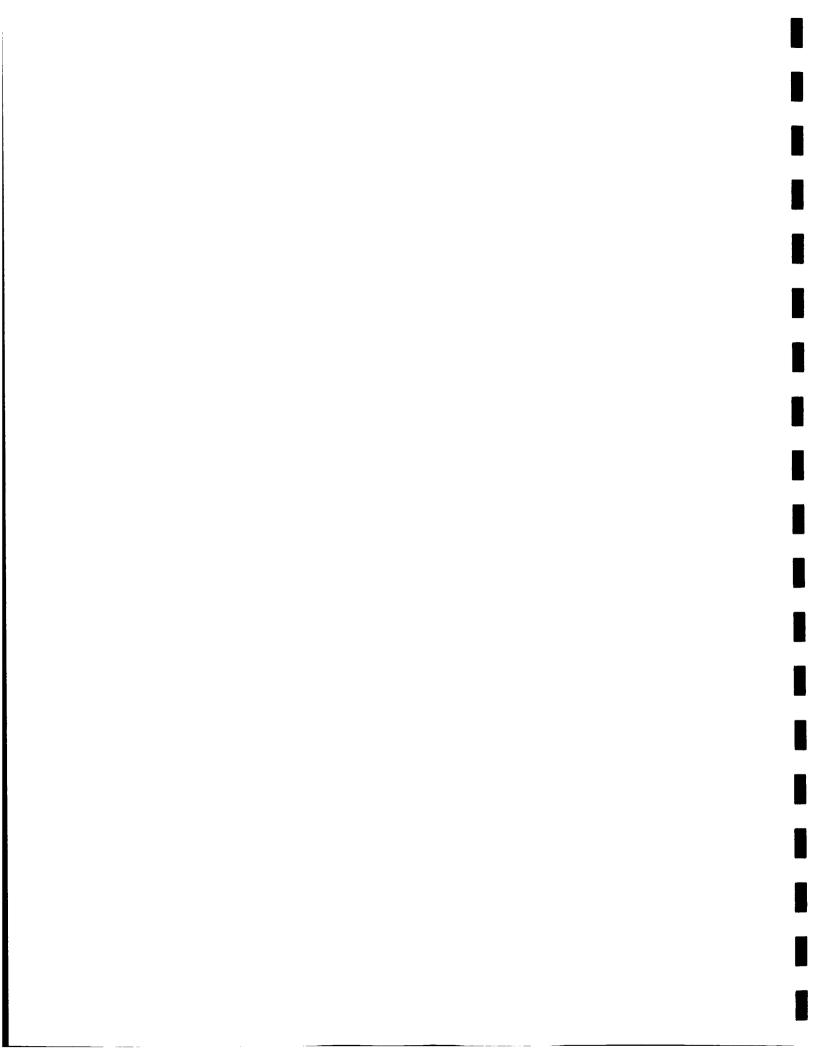
CONSULTANTS/VISITORS

Consultant: **Arthur von Cresce**
Purpose: Modification of the NASA Pathfinder Lakes Database World Wide Web Site (9/9-10/31/99)

Visitor: **Jiayan Yang (Woods Hole Oceanographic Institute)**
Purpose: Conduct research on ocean circulation (1/7-16/99)

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TASK 971-15: Utilization of Satellite Radar Altimetry Data

TASK DESCRIPTION

This task is centered on the utilization of satellite radar altimetry data over large inland water bodies. It is specifically aimed at contributing new information to correlation studies linking environmental factors with outbreaks of malaria and influenza. The derived satellite products are time-varying surface water level variations which will be derived from ERS and TOPEX/POSEIDON (T/P) for observation periods within the 1990's decade. For applications within the malaria RTOP, specific target dates will be identified by the study team, site locations (geographical coordinates) distributed, and malaria case data made available. The satellite radar altimetry thus provides two inputs: 1) it gives some measure of the seasonal and interannual variation of water balance of the large water bodies within the study regions, thus presenting an overall view of the status of surface water, and 2) it serves as a proxy measurement of the combined effects of the climate, hydrology, and topography.

USRA EMPLOYEE: DR. CHARON BIRKETT

Research focus: Application of ERS/TOPEX altimetry data to inland water bodies.

Accomplishments

Submission of 3 new proposals in response to NASA NRA's.

NRA-99-OES-03
PI: Murtugudde, Co-I Birkett, 3 months per year for 3years
Title: Effects of Rainfall on Seasonal-to-Interannual Variability of Tropical Oceans and Ecosystems

NRA-99-OES-04
PI: Birkett, 7months per year for 2 years, then 2months for 3rd year
Title: The NASA Pathfinder North America Lakes/Reservoirs Database

NRA-99-OES-04
PI: Mathews, Co-1: Birkett, 1.5months per year for 3 years.
Title: Wetlands and their Role in Global Hydrological and Biogeochemical Cycles

Start of a PI project determining the tracking performance of the RA instrument onboard the ERS-I satellite.

Review of submitted paper for IEEE. 4. Revision and resubmission of Sarch and Birkett, Lake Chad paper.

Participation in Workshops/Conferences/Meetings

* 4/1-7/00 (Santa Fe, NM) Present poster at Remote Sensing & Hydrology 2000 conference
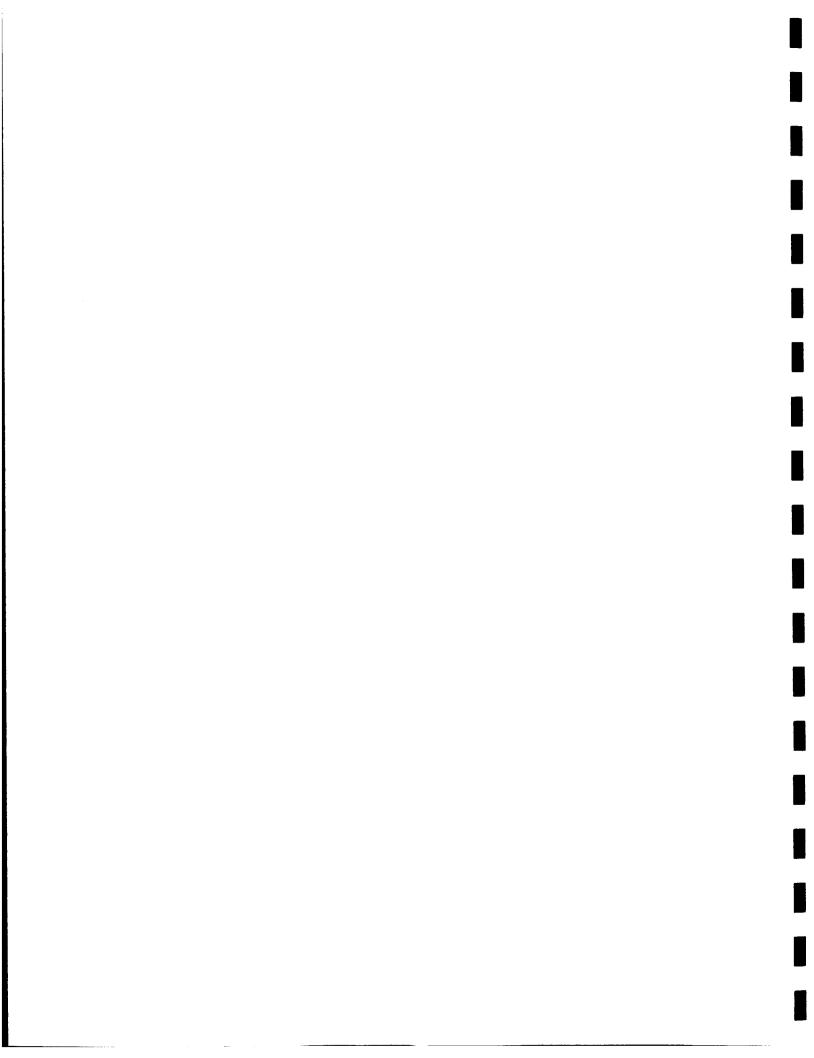
Publications

Sarch. M.T., and Birkett, C.M. Fishing and farming at Lake Chad: Responses to lake level fluctuations The Geographical Journal, In Press. 2000

Birkett, C.M., Synergistic remote sensing of Lake Chad: Inundation variability in the basin, Remote Sensing of the Environment, In Press.

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TASK 972-01: Radar Ocean Wave Spectrometer Program

TASK DESCRIPTION

The objective of this task is to provide support in collaboration with D. Vandemark (Code 972) on the Radar Ocean Wave Spectrometer (ROWS) Program. The work will consist of data processing of aircraft measurements collected in the Standard EIGER experiment. The primary focus of the task is for a specialist in electromagnetic scattering theory and fluid mechanics to develop a model for the satellite altimeter electromagnetic range bias phenomena. Work includes the numerical simulation of ocean waves and a numerical model for altimeter radar backscatter. The task also includes the processing of radar ocean wave spectrometer data sets including software developments in C and data archiving. The task is to modify existing data processing programs and process a series of ROWS flight experiment data sets including the summary of results.

USRA EMPLOYEE: DR. TANOS ELFOUHAILY

Research focus: Modeling the effects of nonlinear ocean wave interactions on microwave ocean altimetry errors.

Accomplishments

Recently, I have derived a new theory for the electromagnetic bias (EMbias). A 40-page manuscript was submitted to JGR on March 1, 1999. Right after the submission, I started working on improving this new theory which is already an improvement on previous theories. The idea is that the two-scale philosophy exploited in this theory can be generalized further to include hydrodynamic and aerodynamic modulations of short waves by longer ones. Inside a surface patch, short wave statistics can vary due to the tilting generated by the underlying field. In addition to this tilting effect, the local wind glowing over the long scale facets is changing. When these two mechanisms are included, the theory of the Embias will be advanced enough to explain most of the observations performed today with conventional altimetry or with future altimetry based on sources of opportunity such as the GPS constellation.

In parallel to the theoretical work, I have worked on improving the quality of the data we acquired in North Carolina last year. The problem is that the platform on which the instruments were mounted is a moving airplane. Therefore, one must account for the attitude of the aircraft in order to infer a correct estimate of elevation and slopes of the ocean surface from the laser data. I have developed a new code that complements the attitude data provided by the GPS system aboard the airplane. Basically, the accelerometer data were integrated in time and used as high frequency information that the GPS could not provide. The elevation measured by the laser contains both motions of the surface and of the aircraft itself. In order to remove the aircraft motion, I had to patch the altitude data with the accelerometer data at the location of the three lasers. Needless to say, this a very complicated geometry problem. Several matrices of rotations are needed in order to transfer the elevation measurements from one instrument to another by accounting for the pitch, roll, and heading of the airplane.
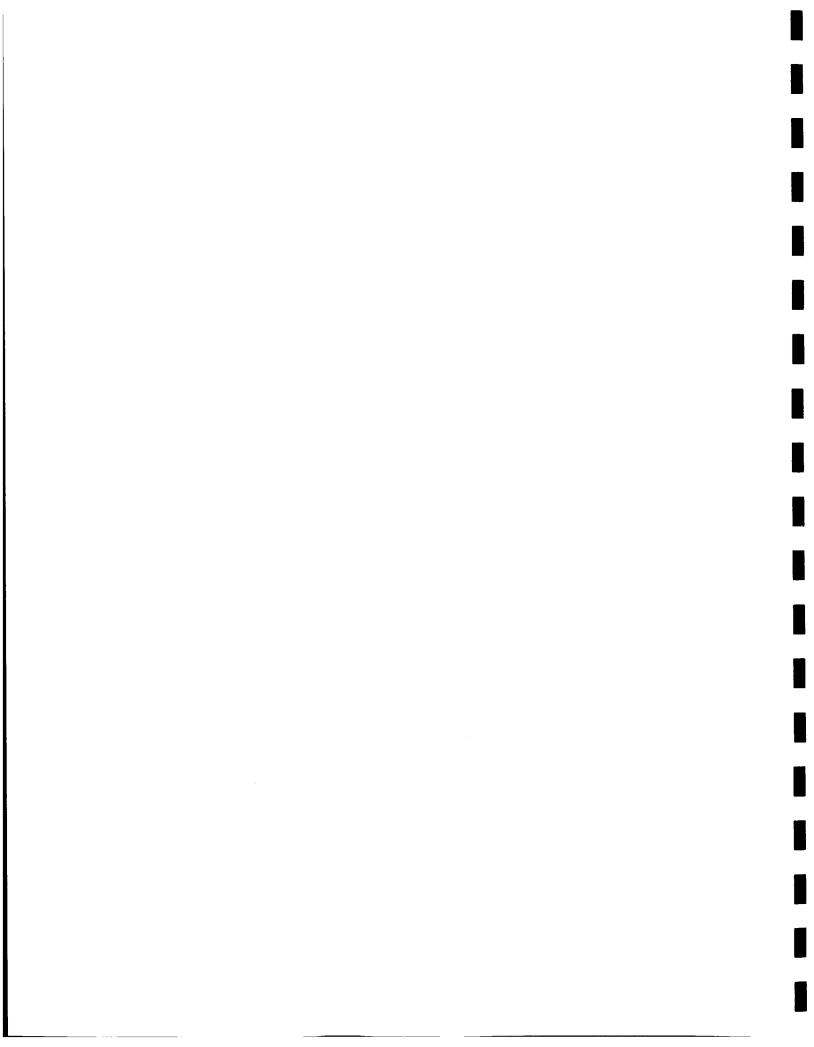
In addition to this theoretical and practical work, I have traveled to several meetings inside the U. S. and abroad. The URSI meeting was very insightful. My trip to France was very helpful in working on the publication and on correcting the laser data. I have also worked on preparing a paper for the IGARSS conference in Hamburg, Germany in June 1999.

Participation in Workshops/Conferences/Meetings

- 10/12-20/98 (Keystone, CO) Presentations at JASON meeting. Visit NOAA lab in Boulder, CO

- 11/30-12/12/98 (Pasadena, CA) Workshop at JPL; (San Francisco, CA) Attend the AGU Meeting

CONSULTANTS/VISITORS

Consultant: **Bertrand Chapron** (IFREMER, France)
Purpose: Research related to time series analysis of oceanic field measurements collected last year during WAPEX (3/22-29/99)

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TASK 972-02: Support for Rain-Sea Interaction Facility

TASK DESCRIPTION

This task is to provide support to collaborate with L. Bliven (Code 972) for (a) experiments at the Rain-Sea Interaction Facility and (b) for numerical simulation of radar returns from rain-roughened seas. These efforts contribute to refined measurements of wind and rain over the oceans from satellite data sets such as the TOPEX altimeter and NSCAT scatterometer.

CONSULTANTS/VISITORS

Consultant: **Elizabeth McNamara**
Purpose: Research in the Rain-Sea Laboratory at NASA/Wallops Flight Facility (5/10-7/23/99)

Consultant **Carlos Morales** (University of Connecticut)
Purpose: Research on data from the VLF lightning monitoring network (8/21-9/30/00)

Consultant **Kevin Postlewait**
Purpose: Participate in research with Unmanned Aircraft to help develop and implement an optical imaging technique for measurement of rain drop size distributions (6/1-9/30/99)

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TASK 974-04: Modeling of Large-scale Land Surface Processes

TASK DESCRIPTION

This task supports a Goddard team (collaborating with the university community) in the modeling of large-scale land surface processes and their influence on natural climate variability. Model development will focus on improvements in the characterization of the effects of subgrid soil moisture of various satellite-derived data into the land surface model as boundary conditions. Research with global coupled model of the land-atmosphere system (a GCM) will aim to quantify land surface control over hydrological (e.g., precipitation variability).
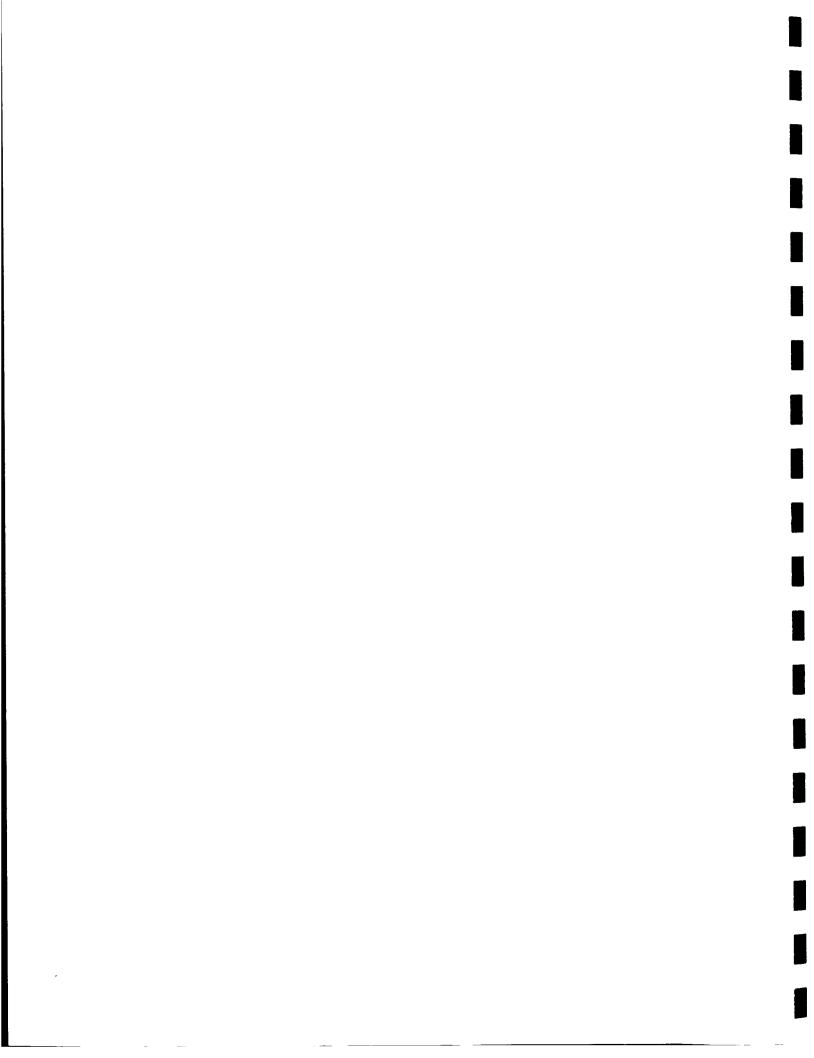
USRA EMPLOYEE: DR. AGNES DUCHARNE

Research focus: Development of catchment-based land surface models for GCM s.

Accomplishments

The realistic representation of land surface processes is critical for the realistic simulation of the global hydrologic cycle and climate, as indicated by numerous sensitivity studies using general circulation models (GCMs). Land surface models (LSMs) have, therefore, increased in sophistication and realism over the last decade. An important effort has focused on the modeling of vegetation and evaporation, but the accurate representation of soil hydrological processes (including soil moisture lateral redistribution, runoff, and baseflow) have long been neglected.

In particular, most LSMs consider uniform soil moisture within GCM grid-cells, the lateral extent of which about 400 km. The spatial scales of soil moisture variability are, however, much smaller in the real world, and the climate is sensitive to this small-scale variability. To address this fundamental deficiency, the project I am involved in consists of developing a new GCM-scale LSM that explicitly

models subgrid soil moisture variability and its effects on evaporation and runoff. My principal collaborator in this research is Dr. R. Koster in the Laboratory for Hydrospheric Processes, Hydrological Sciences Branch (Code 974).

Overview of the new LSM. In a break from traditional modeling strategies, the continental surface in the GCM is separated into a mosaic of hydrological catchments, with boundaries that are not dictated by the grid of the atmospheric model but by topography. In every catchment, we follow an approach based on the concepts of TOPMODEL (Beven and Kirkby, 1979; Sivapalan et a., 1987), and use the distribution of topographic index to define the spatial distribution of the root zone moisture. The latter is then used to separate the catchment into three areal fractions, each having a distinct hydrological character: saturated, unsaturated, stressed. Evaporation and runoff are calculated independently over each areal fraction, using formulations relevant to each fraction's specific hydrological regime. The most important advantage of the approach is the potential for improved surface fluxes through the explicit consideration of soil moisture heterogeneity. In addition, the specification of the catchment as the fundamental land surface element provides a more direct link to basic hydrological science, for which the catchment is a natural unit of study.

Developmental work. It would be possible, but memory and computationally very consumptive, to determine the exact distribution of the root zone moisture at each stop from the distribution of the topographic index and the bulk catchment moisture. My recent work has therefore been to idealize the actual distribution of root zone moisture into a simple analytical probability distribution, function of the bulk soil moisture and the topography only.

Evaluation of the new LSM. The new model has been tested off line in the Red-Arkansas River Basin. Both the meteorological forcing data and the observational validation data required for such an evaluation were compiled over the 1980-86 period for the PILPS Phase 2c Red-Arkansas River Basin Experiment. The results are very promising.

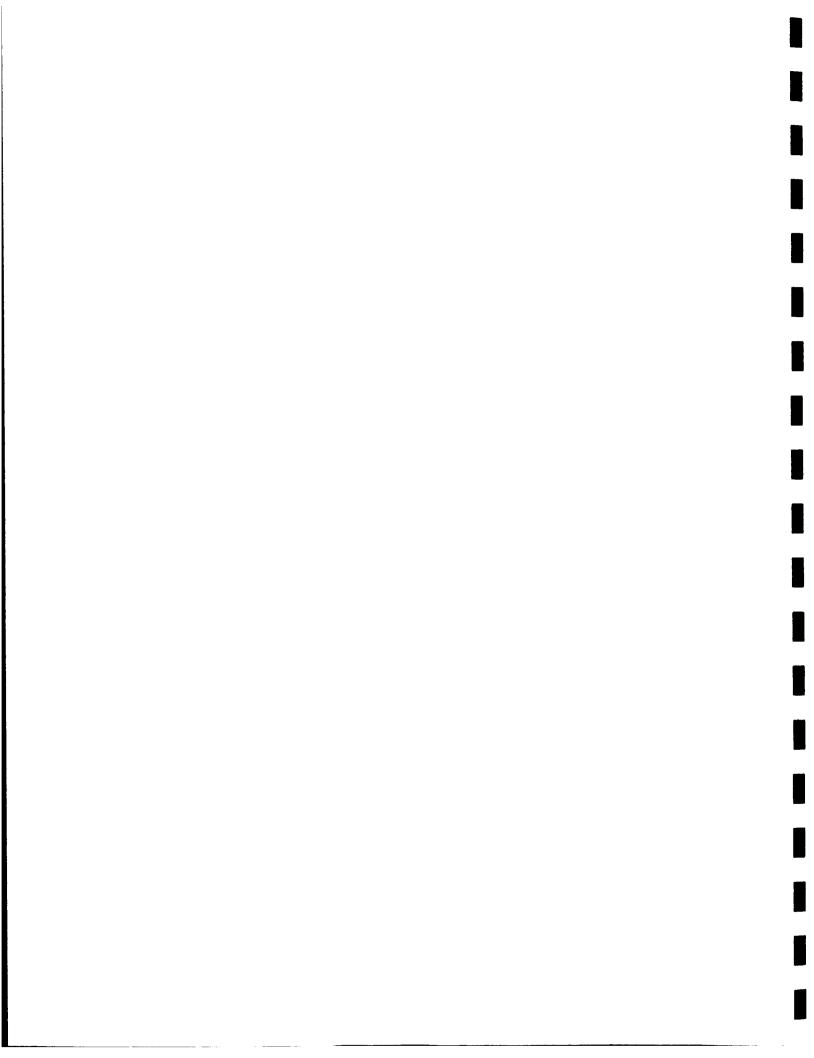
Participation in Workshops/Conferences/Meetings

- 12/5-10/98 (San Francisco, CA) Attend the AGU Meeting

- 4/19-23/99 (Netherlands) Attend the EGS 24th General Assembly

- 6/26/99 (Boulder, CO) Workshop on Land-Surface Modeling and Applications

USRA EMPLOYEE: DR. PIERRE GUILLEVIC

Research focus: Development and integration of physiologically-based transpiration schemes into hydrological land surface models.

Accomplishments

Influence of vegetation on land surface hydrological processes and precipitation variability. The NASA Seasonal-to-Interannual Prediction Project (NSIPP) is developing a seasonal forecast system based on coupled atmosphere, ocean, land, and ice models. The system emphasizes the assimilation of satellite-derived observations and in situ measurements to improve model initial conditions and thereby the seasonal forecast. Prior studies made by Drs. R. D. Koster and M. J. Suarez show that through water and energy feedback processes with the atmosphere, land surfaces contribute significantly to the variance of annual precipitation over continents. The potential for precipitation predictability has been shown in these studies to depend strongly on the ability to forecast land surface moisture state. However, vegetation phenology (emergence and senescence of leaves, Leaf Area Index (LAI), greenness fraction, etc.) also varies interannually and these variations themselves may contribute significantly to climate variability. Within this framework and during the time period from February 22-June 30, 2000, I have studied the contribution of vegetation variability to variability in land surface moisture fluxes and precipitation. This work is divided into three parts :

1) A better representation of water fluxes (i.e., transpiration) between the vegetation and the atmosphere. This part represents the improvement and the integration of a physically based photosynthesis and stomatal conductance parameterization (Collatz et al., 1991). The scheme includes a new formulation of water stress due to the amount of water in the root zone and an analytical calculation of the stomatal conductance that allows to decrease the time of simulations.

2) Assimilation of observed interannual variations of vegetation cycle. Global, monthly, 8km by 8km biophysical land surface datasets for 1982-1999 were derived from data collected by the Advanced Very High Resolution Radiometer (AVHRR) (Los et al., 2000). The following parameters are estimated: fraction of Photosynthetically Active Radiation (PAR) absorbed by the vegetation, vegetation cover fraction, Leaf Area Index (LAI) and fraction of green leaves. The biophysical land surface datasets were resampled in a regular grid at the Global Circulation Model (GCM) resolution (i.e., 2 by 2.5), taking into account that one pixel can be composed by different vegetation types.

3) Impact of vegetation on land surface hydrological processes. The analysis of climate variability through a series of General Circulation Model (GCM) simulations is used to quantify the impact of seasonal variations in vegetation phenology on meteorological processes. The GCM used consists of the ARIES atmospheric GCM coupled to the Mosaic land surface model. To assess the impact of global vegetation phenology on simulated meteorology, two ensembles of simulations are performed – one in which the mean seasonal cycle of vegetation phenology is prescribed, and one in which the observed interannual variations of global biophysical land surface dataset from NOAA AVHRR data are used. Differences between the two sets of simulations (e.g., in their precipitation) directly reflect the role of interannual phenology variations, subject to tests of statistical significance. This work is still under completion.

NASA/GSFC collaborators: R. D. Koster, Hydrological Sciences Branch. M. J. Suarez, Climate and Radiation Branch. G. J. Collatz and S. O. Los, Biospheric Sciences Branch.

Other collaborators: L. Bounoua, Department of Meteorology, University of Maryland. J.P. Gastellu-Etchegorry, Centre d'Études Spatiales de la biosphère, Toulouse, France.

Participation in Workshops/Conferences/Meetings

• 7/22-29/00 (Honolulu, HI) Attend the IEEE 2000 International Geoscience and Remote Sensing Symposium
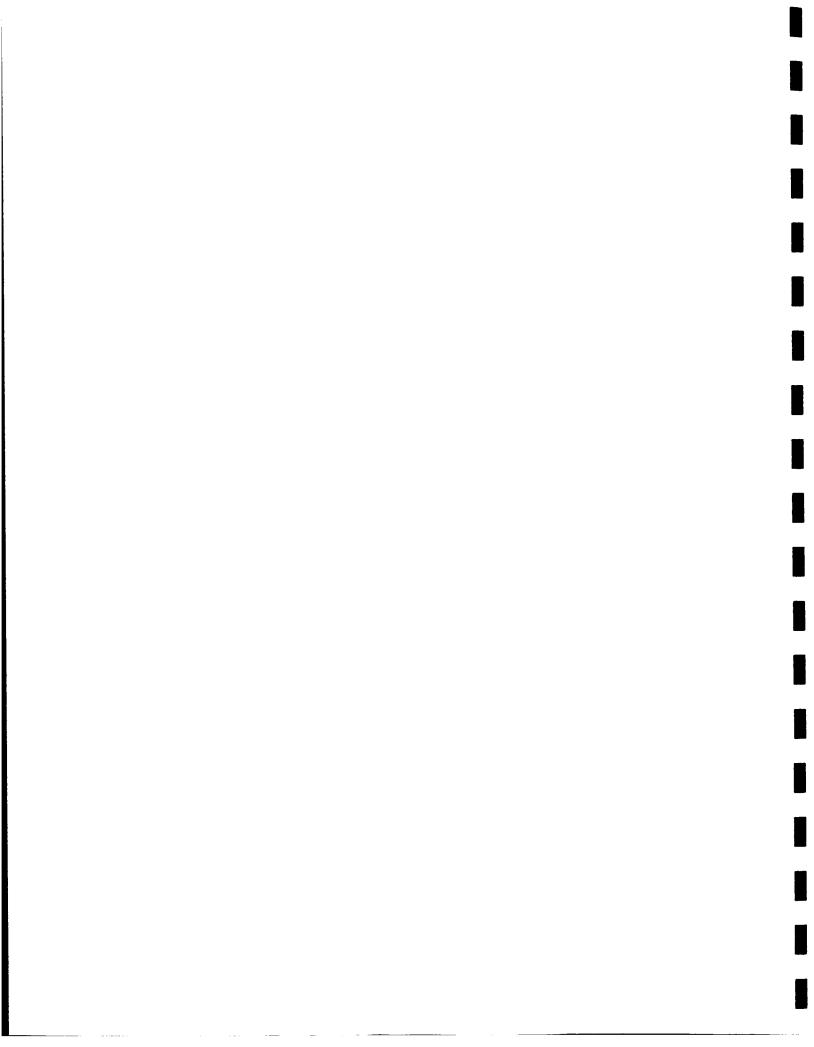

Publications

Guillevic P., and Gastellu-Etchegorry J. P. (2000). Modeling thermal infrared radiative transfer within 3-D vegetation covers. *Proceedings of IGARSS'00*, 24-28 July 2000, Honolulu, Hawaii.

Guillevic P., Koster R. D., Collatz, G. J., Suarez, M. J., Los, S. O., and Gastellu-Etchegorry J. P. Influence of vegetation on land surface hydrological processes and precipitation variability. *8th International Symposium in Physical Measurements and Signatures in Remote Sensing*, January 8-12, 2001, Aussois, France.

USRA EMPLOYEE: DR. SARITH MAHANAMA

Research focus: Involving land surface hydrological process analysis and modeling related to NASA's Seasonal to Interannual Prediction Project (NSIPP)

Accomplishments

I was mainly involved in familiarizing with the catchment based land surface model of NASA/GSFC during the same period.

In one sense, the catchment model is a novel concept in representing the land surface boundary for atmospheric general circulation models. The model uses the hydrologic catchment as the fundamental unit instead the grid-based approach widely used. Firstly, catchment model was driven by observed atmospheric forcings for a period of 1979-1988 on Arkansas Red River basin. The river basin was represented with 126 catchment units. Then, the model was applied to whole North America using ISLSCP atmospheric forcings. In this exercise, North America continent was divided into 5002 catchment units.

CONSULTANTS/VISITORS

Consultant: **Agnes Ducharne-Menous** (UMR Sisphe, France)
Purpose: Conduct research on land-surface hydrological processes modeling (12/1-11/99)

Visitor: **Sarith Mahanama**
Purpose: To present a seminar to the Hydrological Sciences Branch (11/21-24/99)

Visitor: **Sharika Senarath** (University of Connecticut)
Purpose: To present a seminar to the Hydrological Sciences Branch (4/11-13/99)
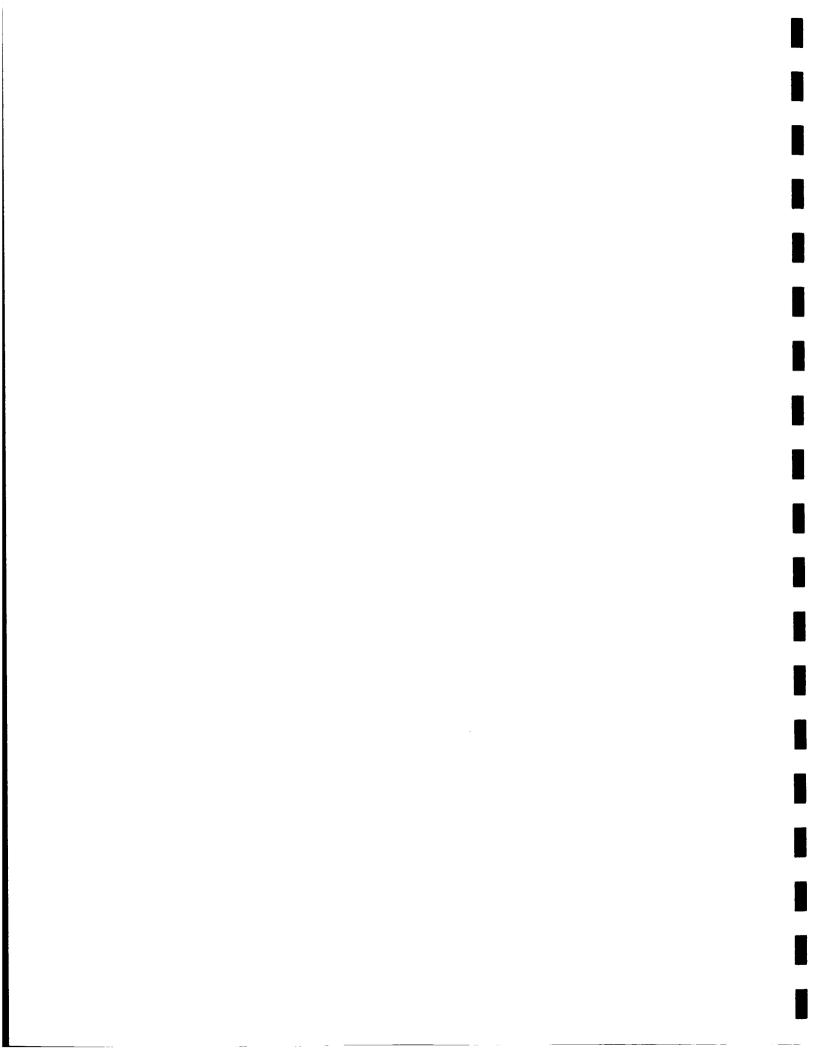
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TASK 974-05: Development and Validation of Snow and Ice Mapping Algorithms

TASK DESCRIPTION

The objective of this task is to assist in the development and validation of MODIS and AMSR snow and ice mapping algorithms. Work will include, but not be limited to the following:
1) Review of the existing algorithms;
2) Analysis of existing MAS and SSMI, and future MODIS and AMSR data;
3) Development of methods for combining SSMI and MODIS, and in the future, AMSR and MODIS, data to map global and snow extent and depth;
4) Perform error analysis on number 3 to determine the accuracy of the snow extent and depth measurement.

The individual will review the existing algorithms that have been derived in order to calculate snow cover and snow water equivalent from satellite data. This information will be incorporated into the existing document entitled "Algorithm Theoretical Basis Document for the MODIS Snow and Ice Products". The individual will then utilize existing satellite data, i.e., SSMI and Landsat TM data, and recently-acquired aircraft measurements to run existing algorithms. These results will be written up in the form of a paper. The individual should study the algorithms that have been derived to map snow cover and depth, utilizing future EOS MODIS and AMSR data. He/she should devise a scheme for combining those algorithms such that they can be used together to map snow cover and depth. Analysis of theoretical errors should then be performed on the expected products.

USRA EMPLOYEE: DR. ANDREW TAIT

Research focus: Development of satellite (MODIS) algorithms for measuring and mapping of snow properties.

Accomplishments

My task here at NASA/GSFC is to collaborate with Dr. Dorothy Hall and other scientists in Code 974 (Hydrological Sciences Branch) toward developing algorithms for the estimation of snow cover and snow depth using satellite-attained MODIS and AMSR data. During the past year I have made significant advancements on this task.

As MODIS and AMSR are yet to be launched, I have been working with either simulated data (e.g., MAS (MODIS Airborne Simulator)) or AVHRR, MIR (Millimeter-wave Imaging Radiometer) and SSMI data. I have had two papers published (see below) combining MAS, MIR and ground data to detect snow cover in Alaska and the Northeast USA. My primary research over the past year has been on the development of a multispectral snow cover model that uses optical (e.g., AVHRR and in the future MODIS), microwave (e.g., SSMI and in the future AMSR), and surface-based (e.g., meteorological and physiographical) data.

I have been working closely with Drs. James Foster and Al Chang on the estimation of snow depth from SSMI data. I have submitted a research proposal to NRA-98-OES-13 (Solid Earth and Natural Hazards Research and Applications Scientific Investigations) with myself as PI and Dr. Chang and Mr. Alan Basist (NCDC) as Co-Is. This proposal is to study snowmelt-induced flooding in the Red River basin using passive microwave data of August 12, 1999 the recipients of funding from this NRA have still not been notified.

I accompanied Dr. Foster on two field trips in February (North Dakota and Montana) and March (Wyoming) to study the snow conditions. I took measurements of the snow at different depths and locations using a hand-held passive microwave radiometer. I also assisted in measurements of snow depth, crystal shape and size, and water equivalent. In addition, prior to the second trip, I designed and built a carry case for the radiometer so that it could more effectively be used in the field. Collaborating with Dr. Ed Josberger (UW§) and Mr. Eric Erbe (USDA), I have written a paper on the results of the field experiments (see below.) We are waiting to hear back from Dr. Matthew Sturm (CRREL - Alaska) before we submit this to IEEE Transactions on Geoscience and Remote Sensing.

I am also presently working with Dr. Josberger (USGS) and Dr. Chang on snow water equivalent estimation using SSMI data, in preparation for future AMSR data. We are working-on -ways of representing the ground data more-accurately by krigging (an optimum interpolation method), before comparison with the satellite data. This is a new approach to passive microwave snow water equivalent (and snow depth) modeling and we expect to derive excellent results.

We have had several delays getting MODIS into orbit, but finally Terra was launched on the 18th of December. We thought we would have some data by now, but they are having difficulties getting the satellite into the correct orbit. So, we have been playing the waiting game.

In the meantime, I have completed a report which summarizes the work I was doing for Dr. Al Chang, titled: "Snow depth and snow water equivalent data comparison with SSM/I brightness temperature data for the northern Great Plains of the USA." It is a 65 page document, not meant for publication. It was prepared for the specific purpose of having a record of the work I did for him over the previous 6 months, so that whoever continues the work has a good starting point. I spent a lot of time organizing my data files, programs, and image files so that the next person can access them easily and understand what I have already done on this project. I do intend to develop part of this work further on my own and hope to write a paper on it.

I am going into the field in February (to Minnesota), where I will lead the field campaign to collect data on snow depth, percent cover, and reflectivity. I have spent a lot of time organizing this field trip. I also go into the field in March (to Colorado), where I will be collecting passive microwave data of various snow fields

I have been busy planning two field campaigns to collect data on the snow conditions in the mid-west. The first trip was to Minnesota and the second was to Colorado. Unfortunately, the Minnesota trip was cancelled due to poor snow cover. The Colorado trip in March was a success, and the passive microwave brightness temperature data that were collected, along with similar data from the last four years, have been sent out to interested scientists around the world.

Participation in Workshops/Conferences/Meetings

- 1/11-15/99 (Dallas, TX) Attend the AMS Meeting

- 6/1-3/99 (Boston, MA) Attend the AGU Meeting

- 4/3-8/00 (NM) Attend the Remote Sensing & Hydrology conference

Publications

Tait, A. B., .Barrett, E. C., Beaumont, M. J., Brown, P. A., Taberner, M. J., and Todd, M. C. (1999). Evaluation of an atlas of passive microwave-derived rainfall over the eastern North Atlantic Ocean and North Sea. *International Journal of Climatology, 19,* pp 231-252.

Tait, A. B, Hall, D. K., Poster, J. L., Chang, A. T. C., and Klein, A. G. (1999). Detection of snow cover using Millimeter-wave Imaging Radiometer (MIR) data. *Remote Sensing of Environment, 68,* pp 53-60.

Tait, A. B., Hall, D. K., Foster, J. L., and Chang, A. T. C. (1999). High frequency passive microwave radiometry over a snow-covered surface in Alaska. *Photogrammetric Engineering and Remote Sensing, 65*(6), pp 689-695.

Tait, A. B., Hall, D. K., Foster, J. L., and Armstrong, R. L. (2000). Utilizing multiple datasets for snow cover mapping. *Remote Sensing of Environment, 72,* pp 111-126.
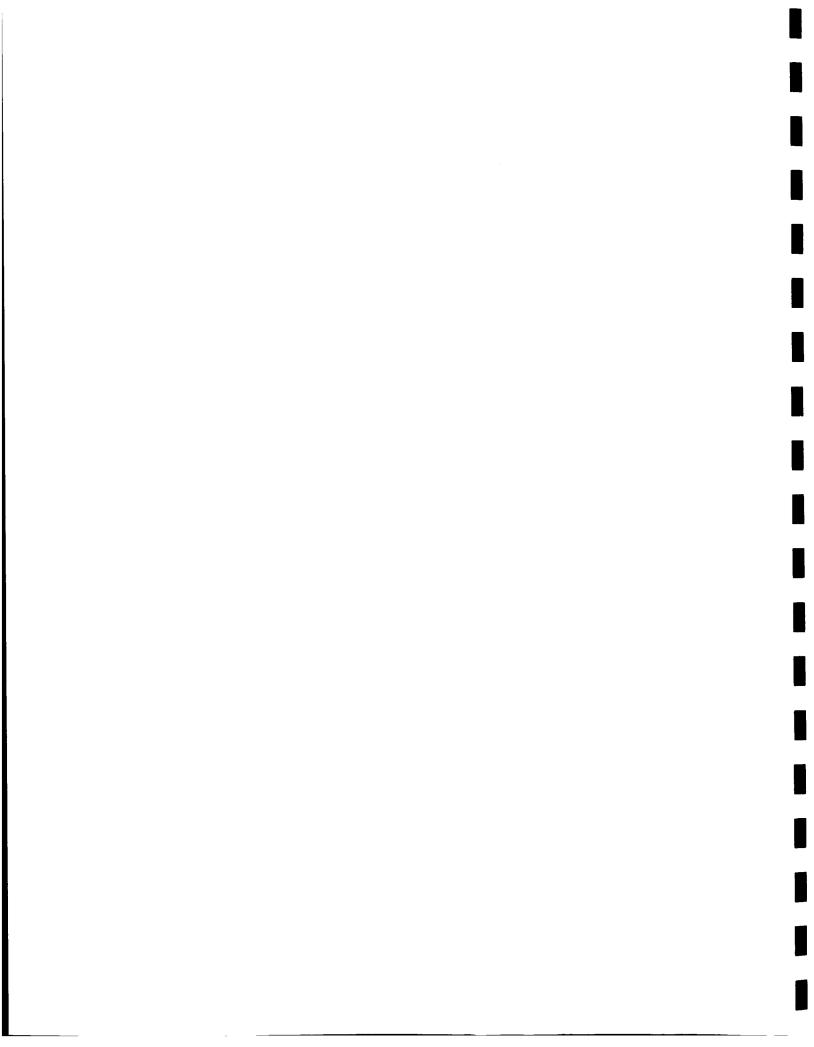
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TASK 975-03: Tropical Rainfall Measuring Mission

TASK DESCRIPTION

The objective of this task is for the contractor to use data from sensors on the Tropical Rainfall Measuring Mission (TRMM) satellite and from complementary sensors on other satellites as well as ground-based sensors to derive rainfall distributions. Those distributions will assimilate into mesoscale forecast models. Those complementary measurements will include, but shall not be limited to, sea surface temperature, rainfall and water vapor profile distributions from microwave radiometers and lightning distributions from VLF radio receivers.

USRA EMPLOYEE: DR. DONG-EON CHANG

Research focus: Assimilation of TRMM microwave data and lightning sferics measurements in synoptic forecast models.

Accomplishments

<u>Effect of combined spaceborne microwave and continuous lightning measurements on forecasts of the 1998 Ground Hog Day storm.</u> The lack of sufficient data to correctly specify initial divergence and moisture conditions has contributed to the often-encountered spin-up problem in numerical forecast models. Because the distribution of latent heating has been shown to be a major factor affecting the development of extratropical cyclones, continuous assimilation of convective heating rates during the early stages of cyclogenesis can improve model casts.

Planar rainfall and integrated water vapor (IWV) distributions were retrieved from data provided by the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Special Sensor Microwave/Imager (SSM/I) radiometers. Unfortunately, it has been difficult to acquire precipitation data over oceanic regions at all necessary times. Lightning generates Very Low Frequency (VLF) radio noise pulses called sferics. Those pulses propagate over large distances so that they could be continuously monitored with a sparse network of ground-based radio receivers.

Histograms of coincident sferics probability distributions were matched to those of convective precipitation from microwave radiometric data to develop a relationship between sferics and convective rainfall rates. That regression was then used to derive convective rainfall rates from the sferics measurements at those times when no satellite data was available. Continuous latent heating distributions derived from those bogus convective rainfall distributions were assimilated into the MM5 mesoscale forecast model during the model spin-up. The model was used to predict the planar distribution of all rainfall and profiles wind shear associated with an intense winter cyclone that passed over Florida and the U. S. gulf coast on February 1998. This technique significantly improved the short-term forecasts of precipitation and convective updraft velocity.

A geostationary Lightning Mapping Sensor (LMS) has been proposed by Christian et al. (1989) to provide continuous lightning measurements over the Western Hemisphere in the next decade. The present analysis suggests how continuous data from LMS might improve weather forecasts. Meanwhile sferics measurements could provide guidance for the use of those data in weather prediction models. A global sferics monitoring network could provide weather hazard warnings until the time when geostationary satellites of all countries will carry LMS sensors.

Participation in Workshops/Conferences/Meetings

• 4/23-5/3/00 (Seoul, Korea) Attend the International Conference on MCSs and Heavy Rain in East Asia
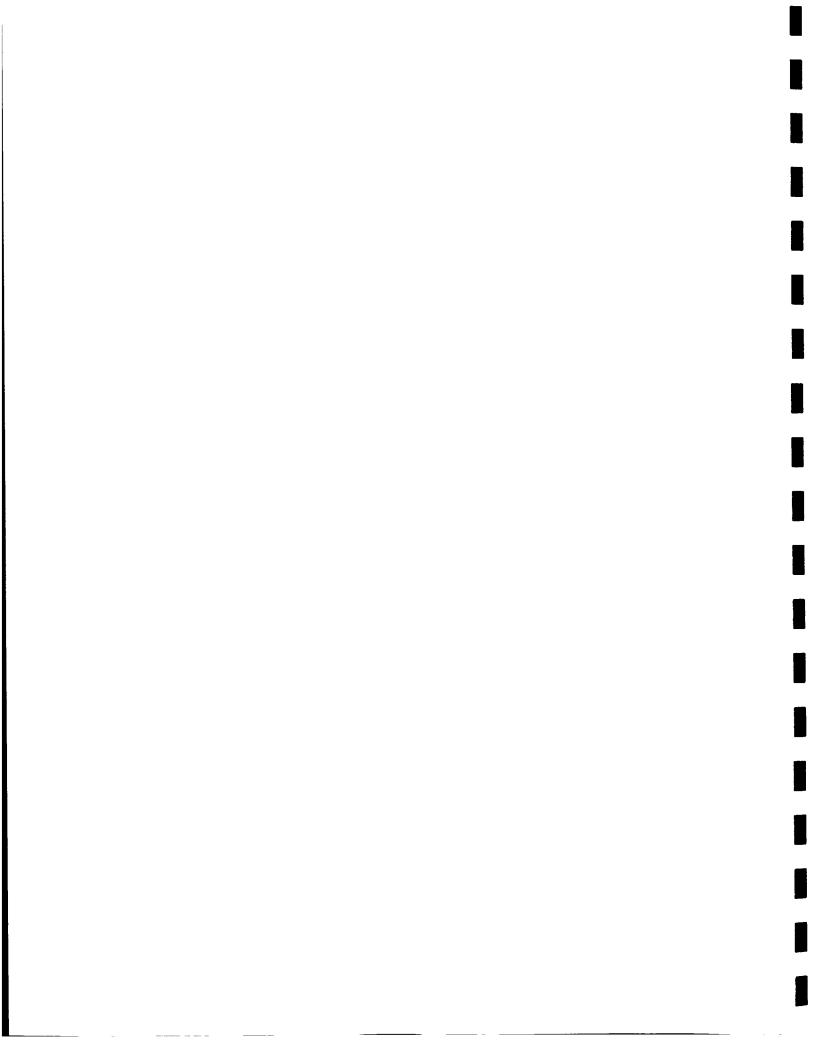
CONSULTANTS/VISITORS

Consultant: **Carlos A. Morales** (University of Connecticut)
Purpose: Analytical research on data from a VLF lightning monitoring network in support of the TRMM program.

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TASK 975-05: Microwave and Millimeter Wave Remote Sensing of Clouds and Precipitation

TASK DESCRIPTION

The objective of this task is to provide modeling and data analysis support in the areas of microwave and millimeter wave remote sensing of clouds and precipitation. This requires a post-doctoral scientist

who is knowledgeable in the radiative transfer of the Earth's atmosphere. He/she must be familiar with the processes of scattering and absorption of radiation by various atmospheric constituents (vapor, liquid water, ice, graupel, etc.) and capable of modifying and improving the existing radiative transfer codes for calculations of brightness temperatures. Analysis of experimental data is also required. Specific tasks include the following:

- Modification to existing radiative codes so that brightness temperature depressions in the millimeter-wave region caused by cirrus clouds or storm-associated hydrometers can be simulated.
- Analysis of data acquired by airborne/spaceborne microwave instruments and comparison of results with calculations
- Participation and presentation of scientific results in professional meetings.

USRA EMPLOYEE: DR. GAIL JACKSON

Research focus: Microwave retrieval of cloud vertical structure and microphysical properties.

Accomplishments

Finalizing a portion of my research of estimating microphysical properties and parameters of vertical cloud structures given wide-band aircraft brightness temperature observations. Microphysical properties and parameters estimated for the 20+ level vertical profile include both the densities and drop size distributions for cloud water, rain, and two types of frozen hydrometeors. Once three cloud cases (anvil, convective, and convective updraft) were estimated, I submitted for publication to the *Journal of Applied Meteorology.*
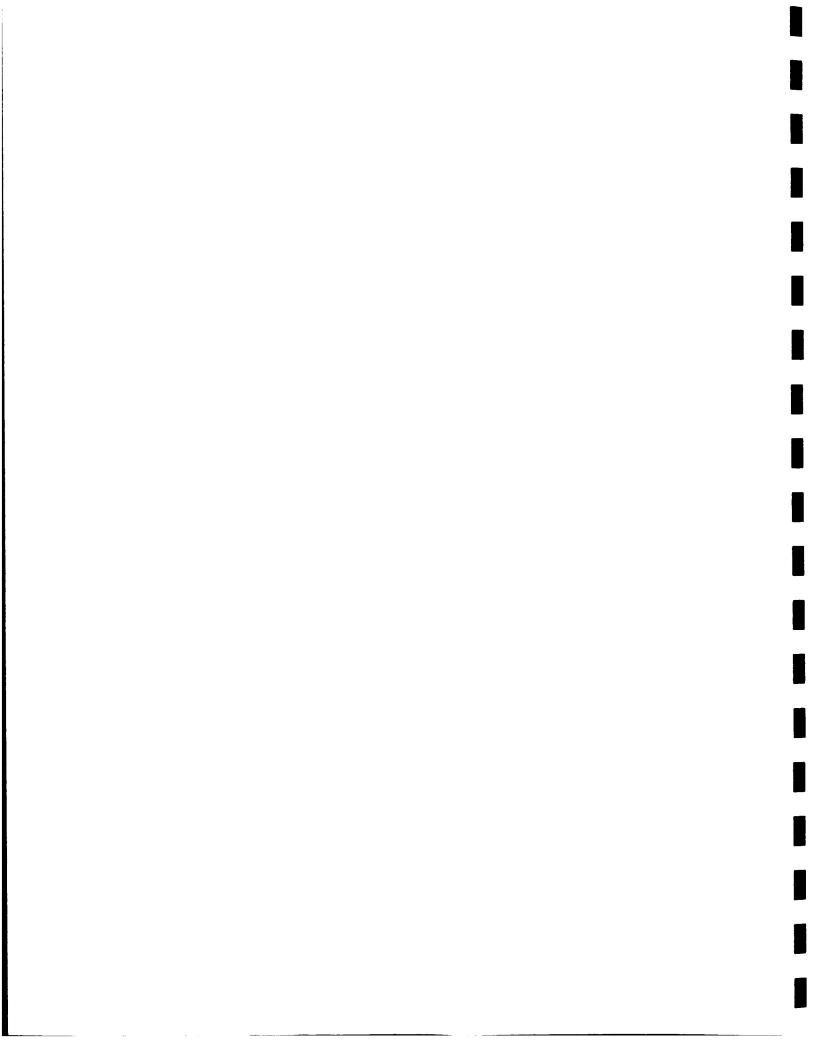
I also began research to understand and incorporate radar reflectivity observations into the estimation process. The idea is to calculate radar reflectivities from estimated profiles and compare these calculated profiles to coincident aircraft-based observations of radar reflectivities for additional validation of the estimated profiles.

My proposal as PI to NASA headquarters for the TRMM project (entitled "Validation of Cloud Model Microphysics and Rain Rate Estimation with High-Resolution Microwave Observations from TRMM Field Campaigns") was accepted in October 1998 for approximately 300K/3years of funding. Jim Wang (Code 975) is Co-PI.

I began collaborations with Dr. Dave C. Jones of the UK Met Office. We hope to enhance our individual research results by comparing how different cloud resolving. models must be modified in order that the model's simulated microphysical cloud properties produce brightness temperatures that match a single specified set of aircraft radiometer brightness temperature observations.

In my work retrieving microphysical profiles using wide-band passive microwave imagery, I completed modifications to Dr. Bob Meneghini's (Code 975) radar reflectivity code. The modifications include converting from calculating/simulating TRMM Precipitation Radar reflectivities to calculating reflectivities for the ARMAR (on the DC-8) and the EDOP (ER-2). Another modification was to use exact drop size distributions for the five+ hydrometeors in the microphysical. cloud profile (instead of the parameterized drop size distributions used in the original Meneghini code). These modifications and the changes to the programming code were verified and validated.

Once the radar code was validated, the three microphysical cloud and hydrometeor profiles I previously estimated from wide-band radiometer observations were read into the radar code and reflectivities (Z) computed for the anvil, convective, and updraft regions (the 3 profiles). The comparison of the computed Zs with colocated observed Zs does show that the radar data can provide additional information to improve the profile retrievals. The convective and updraft storm region comparisons show reasonable agreement between the calculated and observed Z profiles at higher altitudes, at mid and low altitudes the agreement worsens, probably due to mixed phase (heterogeneous) hydrometeors in the melting layer and/or the affects of attenuation and surface reflectivity seen in the observed Z but not the computed Z. Further analysis is underway to determine the cause of the discrepancies and to improve the estimated profiles such that there is a better

agreement. The development of an improved retrieval algorithm to iteratively incorporate both radar and radiometer data is in progress.

I continued my research work of estimating microphysical profiles of clouds using an iterative algorithm that uses both radiometer and radar observations in the retrieval process. The algorithm minimizes the error between observed and calculated brightness temperatures, and observed and calculated radar reflectivities. The calculations use the iteratively estimated microphysical cloud profile for the atmospheric conditions. The rain and ice particle sizes and densities are adjusted to reduced the differences between the calculated and observed data. The observed data comes from both the TOGA-COARE experiment (Nov 1992-March 1993) and the CAMEX experiment (Aug-Sept 1998). The retrieval algorithm is unique in that it includes high frequency brightness temperatures that provide more information about the high altitude ice microphysics of convective clouds. The algorithm is performing well, however, revisions are still underway to further improve the "size and density" adjustment algorithm.

In addition to the above work, I also began collaborations with Dr. James Weinman, Code 975. We are attempting to determine what microphysics causes extremely low brightness temperatures (< 100 Kelvin) for a CAMEX flight. We are also trying to model the forward radiative transfer process using a simplified expression in order to reduce CPU processing time and to reduce the number of variables in the forward (and backward) calculations.

Participation in Workshops/Conferences/Meetings

- 3/14-19/99 (Italy) Attend and present research at 6th Specialist Mtg., MICRORAD '99)

CONSULTANTS/VISITORS

Visitor: **David Jones** (UK Meteorological Office, England)
Purpose: Collaborative development with Paul Racette (11/14-20/99)