NATIONAL ICE CENTER VISITING SCIENTIST PROGRAM
Summary of Research

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LONG TERM GOALS

The University Corporation for Atmospheric Research supports the scientific community by creating, conducting, and coordinating projects that strengthen education and research in the atmospheric, oceanic and earth sciences. UCAR accomplishes this mission by building partnerships that are national or global in scope. UCAR's goal is to enable researchers and educators to take on issues and activities that require the combined and collaborative capabilities of a broadly engaged scientific community.

The long-term goal of the University Corporation for Atmospheric Research (UCAR) Visiting Scientist Program at the National Ice Center (NIC) is to recruit the highest quality visiting scientists in the ice research community for the broad purpose of strengthening the relationship between the operational and research communities in the atmospheric and oceanic sciences.

The funds awarded under this grant were authorized for reprogramming to support the Senior UCAR Visiting Scientist, Dr. Kim Partington, during his IPA appointment as the Manager of the NASA HQs Polar Programs Office.

OBJECTIVES

The objectives of the work done by Dr. Partington were to manage NASA's polar research program, including its strategic direction, research funding and interagency and international collaborations.

The objectives of the UCAR Visiting Scientist Program at the NIC are:
- Manage a visiting scientist program for the NIC Science Center in support of the mission of the NIC.
- Provide a pool of researchers who will share expertise with the NIC and the science

community.
- Facilitate communications between the research and operational communities for the purpose of identifying work ready for validation and transition to an operational environment.
- Act as a focus for interagency cooperation.

The NIC mission is to provide worldwide operational sea ice analyses and forecasts for the armed forces of the U.S. and allied nations, the Departments of Commerce and Transportation, and other U. S. Government and international agencies, and the civil sector. The NIC produces these analyses and forecasts of Arctic, Antarctic, Great Lakes and Chesapeake Bay ice conditions to support customers with global, regional and tactical scale interests. The NIC regularly deploys Naval Ice Center NAVICECEN Ice Reconnaissance personnel to the Arctic and Antarctica in order to perform aerial ice observation and analysis in support of NIC customers. NIC ice data are a key part of the U.S. contribution to international global climate and ocean observing systems.

APPROACH
The approach taken by Dr. Partington at the Polar Program's office was as follows:
(a) Strategic direction – to work with program managers from other disciplines at NASA HQ to coordinate on related activities, to hold meetings with program managers from other agencies, to establish reviews through the National Research Council
(b) Research funding – to establish panels to review proposals, to solicit mail reviews, to manage the process from end to end and make recommendations of funding to the Director of the Research Division. Also, to input programmatic considerations to the science review process.
(c) Interagency and international cooperation – to play a role in soliciting interagency collaboration in programs, to liaise with foreign space agency officials.

For the NIC program, the UCAR Visiting Scientist Program works with participating Federal agencies to recruit scientific visitors and recent PhDs who are interested in conducting applications-oriented research and product evaluation of relevance to the NIC ice-monitoring mission. The UCAR visiting scientists are a source of expertise for the NIC as well as mentors to the recent PhDs.

Participating agency representatives have been:
- Tony Beesley: UCAR Visiting Scientist
- Cheryl Bertoia: National Ice Center liaison to UCAR
- Dennis Conlon: Office of Naval Research, program sponsor
- CDR Michael D. Foster, PhD: Executive Officer, Naval Ice Center (visitor program sponsor/advisor)
- Phil Hovey: NOAA physical science technician
- Eric Lindstrom: NASA program sponsor
- John Marra: NASA program sponsor
- Ted Maksym: UCAR Visiting Scientist
- Walt Meier: UCAR Visiting Scientist

- CDR Gary M. Mineart: Director, National Ice Center & Commanding Officer, Naval Ice Center (visitor program advisor)
- Kim Partington: NIC Chief Scientist, then served as a NASA Polar Programs Manager (NASA advisor to program)
- John Powell: Executive Officer, Naval Ice Center (visitor program sponsor & advisor)
- Juanita Sandge: NRL Stennis Space Center program sponsor
- Eric Sogard: NRL Stennis Space Center program sponsor
- CDR Zdenka Willis: Director, National Ice Center & Commanding Officer, Naval Ice Center (visitor program advisor)
- Michael VanWoert: NESDIS program sponsor & now NOAA Senior Scientist serving as NIC's Chief Scientist
- Cheng-Zhi Zou: UCAR Visitor Agreement

WORK COMPLETED
Polar Programs (3/1/00-2/28/01):
(a) Multi agency planning for the Study of Environmental Arctic Change (SEARCH), for which I was Vice-Chair. Plans were established for coordinated agency Arctic programs in FY01 and FY02.
(b) Working with the Alaska SAR Facility to plan commercialization as the NASA budget reduces. This will set a precedent for the NASA Distributed Active Archive Centers.
(c) Contributed to NASA's Earth Science Implementation Plan, which provides the framework for NASA earth science satellite missions and research programs. Compiled and edited NASA's contribution to the Multi-agency Biennial Report to Congress on Arctic Research.
(d) Funded and set terms of reference for a National Research Council review of NASA's polar geophysical data-sets. The aim is to ensure that NASA provides good quality geophysical data-sets to investigators that support science research questions outlined in NASA's Science Implementation Plan.
(e) Attempted to ensure that PIs in polar research were aware of, and responded to, opportunities from other NASA programs for research funding, such as unmanned aerial vehicle program, pathfinder program, etc.
(f) Encouraged coordination between satellite programs to facilitate planning for joint use of data (e.g. ICESAT and CRYOSAT and ICESAT and GRACE). Funded US participation in the European CRYOSAT science team and obtained European funding for European participation in ICESAT science team.

National Ice Center (3/1/99-2/29/00):
1. Completed evaluation of SSM/I ice concentration algorithms. Significance of this is that NIC operations depends on SSM/I when other data sources are unavailable, including vast areas of the Southern Ocean. There are significant differences between different algorithms and a knowledge of their relative merits and deficiencies can assist analysts greatly in attempting to counteract these biases in their analyses.

2. Completed development of new data fusion SSM/I ice concentration algorithm. The aim of this algorithm is to make use of SAR, AVHRR and OLS data in "optimizing" the SSM/I

algorithm. This is a novel and automated algorithm that will, effectively, tune the SSM/I algorithm to the time and region of interest.

3. Supported evaluation and modification of Advanced Knowledge Based System for Sea Ice Classification (ARKTOS). This algorithm is a highly advanced, rule-based, artificial intelligence system for SAR data developed by the University of Kansas. My role was to help in optimizing the rules of the system to help its performance.

4. Other tasks.
   - reviewed papers for journals
   - contributed to selection of NIC/UCAR post-doctoral fellows
   - served on Joint US-Canada Ice Working Group
   - 2 training lectures for NIC ice analysts
   - assisted in monitoring technical contracts from NIC and planning Navy research budget 5 year plan for NIC

National Ice Center (3/1/98-2/28/99):
1. The recruitment process (search, selection and appointment) of postdoctoral fellows resulted in two new fellowship awards, which will begin in the near future. A search for a new lead senior scientist is currently underway.

2. Following consultation with NASA, a white paper was written in collaboration with Dr. K. Steffen of the University of Colorado. This was entitled "Proposed development of a joint scientific-operational Arctic-wide sea-ice product" and was circulated to relevant agencies. The document described how, at the wide coverage "strategic" scale, scientific and operational requirements for sea-ice information overlap sufficiently that a single product could go some way towards addressing the requirements of both communities. The paper reviewed data assimilation techniques for moving sea-ice monitoring forward, and showed how such a program could build on already-funded developments in operational sea-ice modeling through the ONR PIPS program and would directly benefit this program. This activity was aimed at addressing medium term objectives including publicizing operational requirements within the scientific community and recommending new algorithm and technique developments.

3. A prototype operational SSMI algorithm, based on data fusion, has been implemented and is undergoing evaluation. Initial results are encouraging. This scheme (called the "SSMI interpolation scheme)" has been designed in consultation with NIC operational personnel to ensure that it meets their requirements in terms of fitting in with the current analysis procedure, whilst at the same time improving the quality of the product. The scheme operates by taking ice charts generated at the National Ice Center using RADARSAT, OLS and AVHRR data (and any reconnaissance data), converts these to a raster ice concentration format and then fits a mapping function that relates the principal components of the SSMI brightness temperature data to the ice chart ice concentrations. This is a simple, linear function. This mapping function is then used to "interpolate" ice concentrations elsewhere in the ice chart where cloud or imaging limitations preclude the use of high resolution data. The use of such a mapping function ensures that the algorithm is tuned to the region and time of

interest and, in principle, will go some way towards counteracting the physical limitations of the SSMI sensor by (for example), enhancing the mapping coefficients during summer to compensate for the effect of melt water on the ice. The conventional analysis procedure would involve the use of ice concentrations derived using the NASA Team algorithm, which is not tuned to the region or area of interest and does not make use of any ancillary data.

4. NOW campaign. The NIC science team was involved in the North Water campaign in collaboration with the Canadian Ice Service and others. This involved the collection of a comprehensive test data set including a wide range of remote sensing data, both satellite-, helicopter- and ship-borne, plus surface measurements. The test data set has been organized so that it will provide a resource for future algorithm testing and research, in line with our stated mission of assisting the scientific community with resources for evaluating their techniques. In addition, specific projects are underway including the analysis of data from the ship-borne radiometer system, which has been tied in with digital video data and ground survey sites to test new SSMI algorithms and the sensitivity of the sensor to new ice. A theoretical model of passive microwave signatures has been implemented as part of the NIC contribution to this project, which treats the sea ice as an ice layer overlain by snow.

5. A collaboration with the Danish Meteorological Institute is underway. This has already resulted in the working visit of a scientist - Soren Andersen - from that institute. Sources of funding have been identified for a return visit by one of the new science program post-doctoral fellows, early in 1999. The area of joint research is related to SSMI and the improvement of atmospheric corrections. The precise direction of the research is to be refined further pending completion of the appointment of the post-doctoral fellow at NIC. This activity feeds directly into our objective of evaluating US and foreign algorithms and products, with the Danish Met. Institute probably being the most active European center for development of operational ice products.

6. Scientific support to the National Ice Center. The science program has involved providing scientific support to the Director of Operations, in monitoring of contracts related to development of SAR algorithms and future planning issues. This activity is valuable in ensuring that the senior scientist is aware of evolving operational requirements.

7. We have taken on a student assistant to manage and support the data and software facilities of the science program. This student is funded separately through NIC.

National Ice Center (3/1/97-2/28/98):
The objectives listed above have been partially met through the recruitment of Dr. Kim Partington as the UCAR senior visiting scientist. Kim began his appointment in June 1997.

Recruitment for two or more postdoctoral fellows is currently underway. The search and selection process will last through the spring, and we plan to make appointments by early summer.

Several federal agencies have expressed interest in participating in the NIC Visiting Scientist

Program. Proposals are under review, and we expect two or three sponsor participants this year.

RESULTS
Polar Programs:
(a) Extension of the US-Canada MOU for access in the US to SAR data from RADARSAT. I was involved in encouraging such an agreement at NASA.
(b) Completion of two NASA research announcements – on research using SAR data (coordinated with a similar announcement from the Canadian Space Agency) and on oceanographic research (coordinated with NASA's physical and biological oceanography programs).
(c) Completion of the Modified Antarctic Mapping Mission (MAMM) funded through my program and involving negotiations with the Canadian Space Agency for satellite resources and tight orbit control. The mission has been a success despite severe technical challenges.

National Ice Center
1. The evaluation of SSM/I ice concentration algorithms involved the NASA Team algorithm and the Bootstrap algorithm (the two most popular algorithms in the science community) and the CAL/VAL algorithm (the algorithm used in the operational community). Substantive conclusions were:

- differences in ice concentrations predicted by the algorithms vary by up to 50% ice concentration in the Sea of Okhotsk in winter.
- the NASA Team algorithm treats thin ice as open water. The CAL/VAL algorithm treats thin ice as low concentration sea ice. The Bootstrap algorithm has intermediate behavior. None of these deal effectively with thin ice. The NASA Team algorithm modified for thin ice is effective only when no old ice is present, for example in the Sea of Okhotsk.
- the NASA Team algorithm has a very conservative ice edge as it is based on the low resolution 19 GHZ channel. The NASA Team ice edge is generally some 20 km further equatorward than the CAL/VAL and Bootstrap ice edges. The Bootstrap and CAL/VAL algorithms, which use the 37GHz channel at the ice edge, resolve the ice edge better than the NASA Team algorithm.
- the CAL/VAL algorithm saturates away from the ice edge and therefore is not effective at locating open water in pack ice.
- all algorithms under-estimate ice concentration in summer, but to varying degrees. CAL/VAL algorithm under-estimates concentration the least and the NASA Team algorithm the most.
- use of laboratory studies of passive microwave signatures, combined with algorithms, suggest that the algorithms in general have a "noisy" response to ice during the growth stage up to about 30 cm and have some sensitivity to snow thickness and ice type.
- use of passive microwave algorithms for old ice concentration are insufficiently reliable for operational use.

2. Development of new data fusion algorithm for ice concentration from SSMI. This algorithm appears to be (a) stable (b) successful in creating convergence between the SSM/I algorithm and ice concentrations derived from cloud-free visible data and SAR data.

3. Tuning of ARKTOS. The performance of this system improved markedly after iteration with the rule base to which I contributed. The performance in summer remains shaky, but winter performance is now at the point where the system could be migrated to the operations floor at NIC.

4. New post-docs selected and appointed.

5. A suite of image analysis algorithms has been developed and installed under AVS - a visual programming and data visualization display tool. Some 60 programs have been written, broadly divided into (a) data ingestion programs, (b) statistical programs (eigenvector analysis, least squares, etc.), (c) theoretical modeling (passive microwave) and (d) data visualization.

6. Initial results of the SSMI Interpolation Scheme described above are encouraging. For summer data, the scheme has a bias of +2.8 in ice concentrations compared to a signle ice chart, compared to -8.0% for the NASA Team algorithm. However, this is a very early result - the evaluation needs to be extended significantly before any firm conclusions can be drawn.

7. As background work to the SSMI interpolation scheme, some analysis of the principal components of the SSMI data have been carried out which suggest that whilst the two principal components of the 7 channel SSMI data relate to total and old ice concentration, a third principal component has variance above the noise level and probably is related to snow conditions (albeit with weather artifacts included - this component is strongly related to the 85 H Ghz and 37V channels). Theoretical modeling is being used to attempt to clarify the most significant influences on the SSMI channels in ice after the presence of open water and fresh (old) ice. If this third component is related to some other geophysical characteristic of the ice, then this could be very useful, even with weather sensitivity.

8. Although the science program has provided only a supporting role, two SAR image classification systems that NIC has sponsored have been delivered to NIC and are undergoing evaluation. These include systems from the Univ. Kansas and the Univ. Colorado for classifying sea-ice using RADARSAT data. The science program has been involved providing advise into the evaluation and tuning of these systems.

IMPACT/APPLICATIONS
Polar Programs:
I have attempted to work with other program managers at other federal agencies to create a coordinated program of Arctic research. This is well underway as I complete my position, with workshops planned and planning documents written. A fully coordinated agency program is planned to be implemented starting in FY03 (when the budget cycle allows). I have worked to ensure the US researchers have continued access to SAR data in support of their research. With

the signing of the US-Canada MOU on RADARSAT, this has come to fruition.

National Ice Center:
1. SSM/I algorithms. As a result of my analysis, recommendations were sent to Fleet Numerical Modeling and Oceanography Center (FNMOC) for alteration of the operational SSMI produce provided to NIC.

2. New data fusion algorithm for SSMI. This algorithm is currently being implemented on the Operations Floor at NIC for operational testing and use.

3. ARKTOS. This system is currently being evaluated further by two NIC ice analysts prior to full operational use.

A paper was submitted to IEEE Transactions on Geoscience and Remote Sensing called "A new data fusion algorithm for derivation of sea ice concentration from SSMI data", currently under review. A poster and two oral papers were presented at IGARSS 99 in Hamburg, July 1999.

UCAR's Visiting Scientist Programs have served many federal agencies in developing valuable partnerships between the research and operational communities. The benefits have included an influx of new ideas and collaborations, and the improvement of products for the agency, the scientific community and for society at large.

TRANSITIONS
Polar Programs:
As Polar Program Manager, Dr. Partington helped raise awareness of the NIC among several NASA offices, which resulted in several NIC projects receiving NASA funding. This work is aimed at transitioning some of NASA's research to the operational environment, and also benefiting from the unique data resources of that environment.

National Ice Center:
SSM/I ice motion vectors are an important source of data for constraining sea ice models (Meier et al., 2000). Code was recently transitioned to FNOC to operationally produce sea ice motion vectors.

PUBLICATIONS
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