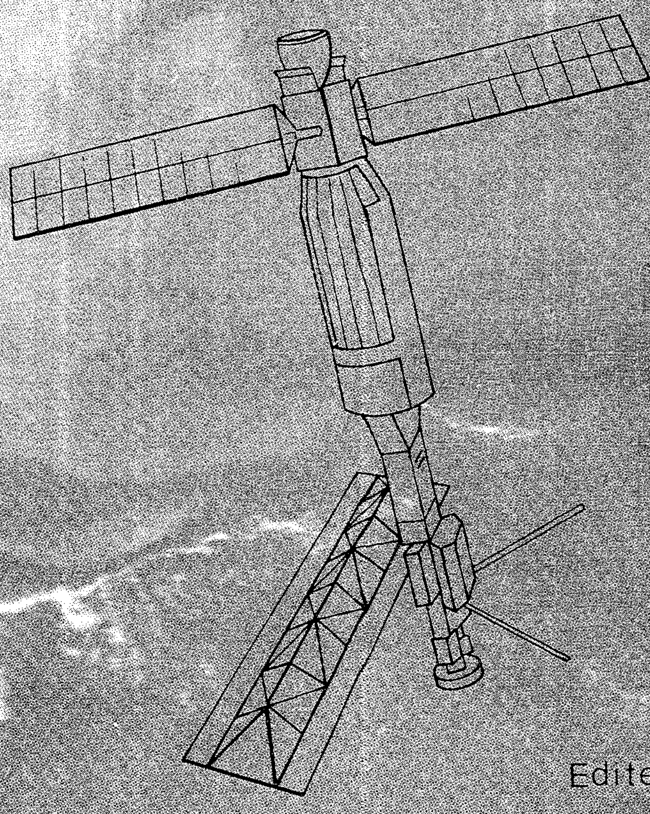
REMOTE SENSING IN THE COASTAL AND MARINE ENVIRONMENT

West Greenwich, Rhode Island, May 30 - June 1, 1979



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REMOTE SENSING IN THE COASTAL AND MARINE ENVIRONMENT

PROCEEDINGS OF THE FIRST U.S. NORTH ATLANTIC REGIONAL WORKSHOP
HELD AT THE W. ALTON JONES CAMPUS, UNIVERSITY OF RHODE ISLAND
MAY 30 - JUNE 1, 1979

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PREFACE

The First U.S. North Atlantic Regional Workshop on Remote Sensing in the Coastal and Marine Environment was held at the W. Alton Jones Campus, University of Rhode Island, May 30 - June 1, 1979. The objectives of the meeting were to determine and document regional user needs for marine environmental data that might be acquired by remote sensing and to further the interchange of information between the developers of remote sensing technology, suppliers of remote sensing data products, and users of coastal and marine information.

The workshop was structured to expose coastal specialists and users of marine data to the potentials of remote sensing and to provide a mechanism through which representatives of the remote sensing community might gain knowledge of the priorities of the potential users. A mutual awareness of the perspectives of each group is essential for beginning a dialogue and for overcoming one of the major obstacles to technology transfer - communications.

In planning the remote sensing workshop, a committee was organized to insure a balanced review of the technology and to invite the involvement of the user community. The members of the planning committee represented scientific, private, and federal interests.

The activity documented in this report consists of invited presentations that were grouped in the following categories: (1) a technical orientation of earth resources remote sensing, including data sources and processing, (2) a review of the present status of remote sensing technology applicable to the coastal and marine environment, (3) a description of data and information needs of selected coastal and marine activities and (4) an outline of plans for marine monitoring systems for the U.S. East Coast and a concept for an East Coast remote sensing facility. In addition to these invited presentations, one of the evening sessions was devoted to three working groups that addressed user needs and remote sensing potentials in the areas of coastal processes and management, commercial and recreational fisheries, and marine physical processes. The results of these working group sessions were presented and discussed on the morning of the final day. The recommendations of the workshop, which are provided in the executive summary and in the body of this document, represent a cross-section of needs for present and future consideration for remote sensing data. They concern improvement in addressing user remote sensing data needs, defining deficiencies, and in specifying research areas.

The two and one-half day meeting provided an effective mechanism for establishing new dialogue between operational and research regional marine data users and the appropriate federal agencies and private interests developing remote sensing technology. Participants in this workshop reflected a cross section of U.S. North Atlantic interests, with representation from state, federal, academic research, and commercial activities. The ultimate goal of the workshop will be continued input and association with remote sensing programs by the marine user.

The workshop was organized and conducted by the Center for Ocean Management Studies of the University of Rhode Island (URI) and the Marine Policy and Ocean Management Program of the Woods Hole Oceanographic Institution (WHOI) with assistance from the planning committee. The workshop was funded by the National Aeronautics and Space Administration (NASA), URI, and WHOI. NASA technical monitorship was provided by Gene Zetka, NASA, Earth Resources Laboratory.

Planning Committee:

Peter Cornillon, CoChairman
James Zaitzeff, CoChairman
David Aubrey
J. Lockwood Chamberlin
Robert Macomber
Virginia K. Tippie
Gene Zetka

Acknowledgements:

We would like to express our appreciation to a number of people and organizations that not only made the workshop possible but also contributed to its significant success.

First, Virginia Tippie receives our heartfelt thanks for her role in coordinating the entire effort. Second, we would like to express our appreciation to Lynn Howell for typing the entire manuscript. We would also like to express our thanks to Nancy Ingham for editing the papers and to Tanya Skorohod, Richard Kowalski and Carol Dryfoos for their participation during the workshop itself.

Next, we would like to thank those members of the planning committee who, although they did not participate in editing this volume, in many other respects contributed significantly to the entire effort both in helping to structure the workshop as well as in chairing sessions, contributing papers, etc. A special thanks goes to Gene Zetka, a committee member as well as technical monitor of the project, for his excellent support.

Finally we acknowledge the financial support for the project which came from the Office of Resource Observation Division of the National Aeronautics and Space Administration, the Center for Ocean Management Studies of the University of Rhode Island, and the Marine Policy and Ocean Management Program of the Woods Hole Oceanographic Institution.

Peter Cornillon

James Zaitzeff

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INTRODUCTION

The application of remote sensing technology, satellite and aircraft, to the measurement and assessment of coastal and marine parameters and processes has made tremendous advances during the last half of this decade. Quantitative information on sea surface temperature, water color (phytoplankton pigments and total suspended particulates), water depth, sea ice, the geoid, and wetlands classification can be derived from remote sensor data operating over various portions of the electromagnetic spectrum. Routine information on sea surface temperature and ocean fronts and current boundaries are now being prepared from satellite data.

During this year we saw the launch of satellites with dedicated oceanographic sensors. Seasat-1 was the first satellite with the primary objective of observing the coastal and marine environment. The Nimbus-7 satellite includes in its sensor package the Coastal Zone Color Scanner, the first instrument dedicated to the determination of phytoplankton pigments in the oceanic environment. TIROS-N, a prototype third generation meteorological satellite should provide improved measurements of the thermal characteristics of the ocean surface. The planned launch in 1981 of the Landsat-D experimental earth resources monitoring system should further benefit the users of coastal zone data. Future environmental satellite systems (to support operational and research needs in the oceans) are now in the planning stages for the 1980's.

In addition to the recent development in remote sensing, there has been a substantial increase in the use of both onshore and offshore coastal regions of the U.S. for a variety of activities. Recreation, offshore oil, power plant siting, and fisheries exploration are a few. With the increased activity has come the development of marine resource management programs through legislative direction, such as the Coastal Zone Management Act of 1972, the Fisheries Conservation and Management Act of 1976, and the Ocean Pollution Research Development and Monitoring Act of 1978. With these responsibilities there is an increasing need to design and initiate improved monitoring programs for resource management. Certainly the capabilities of evolving remote sensing technology, combined with conventional data collection techniques, offer a substantial tool to aid in the assessment and accurate measurement of environmental parameters for addition to the scientific framework necessary for the intelligent management of our oceans as well as for use in research applications.

As remote sensing technology develops and data output increases, there will be an increased involvement by users of this capability. There is, however, generally a lag between increased user involvement and technological advances, the magnitude of this lag depending on the answers to such important questions as: Who are the potential users? How do they become involved? What are the data needs? What is the format and timeliness of output products which would be useful to them? How will the information products derived from the remote sensing data find its way to the diversity of final users? How will the cost of the product compare with information obtained by other methods?

This workshop was structured to address these questions with some of the following ideas contributing to its organization.

1. Who are the potential users? Why isn't there greater involvement?

   Within the North Atlantic coastal region of the United States there are a great many existing and potential users of remotely sensed data. These include planners and managers of coastal zone resources, enforcement agencies, scientists, individuals in all levels of government, private industry, academia, and other research bodies, and private citizens. The diversity of this user community and wide range of data needs makes establishing user requirements of remotely sensed data very difficult. To date, there have been no successful mechanisms or efforts to define and focus coastal marine user data/information requirements or needs which are compatible with remote sensing capabilities. There is a significant communications gap between users and developers of remote sensing technology concerning the definition of user needs, present and planned satellite systems for resources applications, data processing capabilities, output products, and procedures for obtaining timely remotely sensed data suited for specific regional needs. The significant omission of remote sensing from coastal management and environmental assessment activities has resulted. The omission is partly because of insufficient motivation of the users and partly because of a communications gap between user and producer. Another problem is gaining the user's confidence in the validity and accuracy of remote sensing data. The fact that many coastal planners, marine advisory specialists, researchers, and others are unacquainted with satellite programs and types of marine parameters which may be measured or inferred from remotely sensed data has slowed progress in transferring such technology to coastal and offshore data users.

2. What are the data needs? How often? What format?

   In the development of an adequate space program for earth observations, it is clear that the user of its information must be involved in its definition through the specification of his environmental needs, i.e., parameters and temporal and spacial requirements, and must maintain a continued association with remote sensing programs. Ulitmately, the user will require timely access to data and a data processing capability.

   In order to involve the user in systems design, developers of remote sensing technology and the operational and research user community must establish a closer dialogue that will lead to the identification of the informational data specifications and information products that are required and the research areas that are to be emphasized. Within this process the academic research institutions must play an essential role in linking the remote sensing capabilities to research problems, in developing interpretative techniques and procedures which will be transferred to the operational mode, and in educating future workers in the area of remote sensing.

3. How will remote sensing data find its way to the user?

Basically, both technically and in a policy sense, we are at the point where a major emphasis should be placed on the problems of the transfer of methods and technologies to an operational system where warranted. A few states are now integrating Landsat information into their coastal management programs. The application of sensors to ecosystems monitoring was demonstrated in the New York Bight. Finally, a substantial demonstration/experiment (which is in progress along the United States East Coast for fisheries assessment utilizes both satellite and aircraft remote sensing instrumentation.)

One of the first considerations of a system designed to make remote sensing methodologies and techniques available to the potential user is the level at which the system should be established. The inaccessibility of systems established at the national level is a serious drawback. On the other hand the high cost of image processing and data reception hardware does not justify the establishment of such systems at the local level. The logical compromise therefore is a system at the regional level sufficiently local to be readily accessible while at the same time servicing a sufficiently large user community to be cost effective. In order to properly explore the regional concept in remote sensing technology transfer attention must be devoted to the following:

a. The need for increased joint studies between the technical and user communities, i.e., research institutions, state and federal agencies, and commercial interests;

b. The need for a continuing mechanism to coordinate and focus present, continuing, and projected user needs for remotely sensed coastal and marine data with the appropriate federal agencies to insure proper integration of data and research requirements into remote sensing programs; and

c. The present or projected need for the establishment of an East Coast remote sensing data reception, processing, and analysis facility that is responsive to regional and local interests.

James Zaitzeff

Peter Cornillon

EXECUTIVE SUMMARY

Following two days of intense review of remote sensing technology and application to marine problems, the conferees divided into three working groups: Coastal Processes and Management, Commercial and Recreational Fisheries, and Marine Physical Processes. These working groups deliberated on two problem areas: 1) the data needs of the group, and 2) the potential application of remote sensing tools in addressing these data needs. In this executive summary, the conclusions and recommendations of the working groups are summarized with a focus towards identifying common elements in the various observations made. There appears to be four such areas. These are outlined below. In addition to these recommendations which showed a commonality among the groups there were also several recommendations that were characteristic of only one group. The reader is referred to the individual workshop reports for details on these.

Areas of common observation are:

1. Access to Regional Expertise and to a Regional Information/ Analysis and Processing Center

Both the Coastal Process and Management and Marine Physical Processes Groups identified this high priority area. Specifically the Coastal Processes and Management Group defined the need for (a) a data base management system capable of storing and manipulating remote sensing data, and (b) a regional information source containing a remote sensing data library staffed with an expert in remote sensing. The Physical Processes Group underscored the need for (a) a source document of remote sensing which identifies regional remote sensing experts, types of remote sensors (aircraft, satellite) available, their use, etc. and (b) a regional data and analytical facility for analyzing and distributing remote sensing information.

2. Remote Sensing Data Atlas

Both the Coastal Processes and Management and Marine Physical Processes Groups saw the need for some sort of catalog of remote sensing data. The Physical Processes Group proposed an atlas which summarized on a monthly basis such quantities as cloud cover, ocean color, water mass locations, sea ice, sea surface temperature. The requirements of the Coastal Processes and Management Group were substantially more detailed and included such items as Coastal Zone base maps on a 1:25,000 scale and a Coastal Resource inventory, using among other things, aircraft and LANDSAT to define ground cover in the coastal zone.

3. Near-Real Time Meteorological and Oceanographic Forecasts

The Marine Physical Processes Group and the Commercial and Recreational Fisheries Group both identified a need for near-real time meteorological and oceanographic forecasts. In particular, the Physical Processes Group sought such improvements in several forms; (a) non-preprocessed imagery for operational needs with a one day or less time lag (b) instrumentation capable of receiving remotely sensed data while at sea, and (c) the increased use of satellites as communication platforms capable of relaying oceanographic variables measured by buoys or other remote acquisition platforms.

4. Need for a Formal Regional Communications Mechanism

All groups agreed that a regional workshop on remote sensing should be conducted on a yearly to eighteen month basis. In addition there is a substantial need for the development of a formal and sustaining mechanism to insure communications between the U.S. North Atlantic region users of remote sensing data and the responsible agencies for developing and operating remote sensing technology and the suppliers of its data and informational products. This would better insure user involvement in system design criteria for future environmental satellites, and for the integration of oceanographic field research and operations in remote sensing activities.

WORKING GROUP REPORTS

Marine Physical Processes

Coastal Processes and Management

Commercial Research and Recreational Fisheries

MARINE PHYSICAL PROCESSES

The working group on marine physical processes convened for approximately four hours on Thursday evening, 31 May 1979. The following outline summarizes the working group session, arbitrarily dividing the information into two major groupings. The first group, Categorization of User Needs, summarizes the major findings of the working group, and is similar to the summary presented and endorsed on Friday morning, 1 June 1979, during the summary presentations of each working group before the entire workshop. The second group, Catalogue of User Needs, specifies those individual user needs enumerated during the working session; these include, in some cases, specific requirements for parameter accuracy, as well as broad unsolved marine-related problems which might be clarified using remote sensing as a tool.

CATEGORIZATION OF USER NEEDS

1. <u>Operating Needs</u>

   1. <u>Source Document for Remote Sensing</u>. This document would include information on whom to contact for specific remote sensing products, types of sensors available and their use, what environmental parameters can be measured, etc. This should be in the form of a short, concise, easily readable document, not a long, all-inclusive manual.

   2. <u>Increased Availability of Remote Sensing Products on Two Levels</u>. Data distribution would be divided into two categories. The first category would be near realtime, (lag time of one day or less), coarse spatial scale, non-preprocessed imagery for operational needs (planning experiments, ship routing and scheduling). The second category would be increased spatial (and temporal) resolution, preprocessed, calibrated data in both analog and digital form available at a later time for use in data intercomparison and cruise analysis at the laboratory or office (lag time of about one month).

   3. <u>Data Transmission and Receiving Devices</u>. A need exists for instruments to send and receive remotely sensed data for near realtime examination; for instance, while at sea. The unit should be low cost and versatile so the user could select the type of information desired for any given region of interest.

   4. <u>Atlas of Remote Sensing Data</u>. Particularly with respect to satellite data, atlases should be compiled of various environmental parameters broken down on a regional basis for different time intervals. For instance, mean monthly values of cloud cover, sea ice, ocean color, and

sea surface temperature could be catalogued for all ocean regions of the globe. This task would be archival and updated periodically, to be used extensively in cruise planning and other marine operations (fishing, shipping, etc.).

5. Routine Quality Verification of Remotely Sensed Data. On both the realtime and time-lagged remote sensing products, a routine quality evaluation would be useful for assessing the utility and accuracy of of the data. Some uniform quality scale would facilitate a quick scan to select the most reliable data to use.

6. Regional Data and Analytical Facility. A need was expressed for having a central regional facility for analyzing and distributing remote sensing information to users. A regional facility would facilitate interaction between processors and users, as well as minimize time lag between sensing and distributing the data in a usable format.

7. Increased Use of Satellites as Communications Platforms. Within the oceanographic community there is a need to transmit data in near realtime to a shore-based unit. This data link could be simplified by using satellites as a transmitting/receiving station to relay data. Although such systems are currently available, increased capabilities in this area appear necessary.

II. Data Needs

1. Three-dimensional Current Measurements. Various time and space scales are required for this data need.

2. Water Mass Identification. For a variety of purposes, including research, fishing, and pollutant dispersal, water masses need to be identified and followed.

3. Sea Surface Temperature.

4. Sea Level Pressure and Other Interfacial Measurements. To be used in part for establishing heat, salt and water budgets.

5. Frontal Activity. For research fisheries, and others.

6. Bathymetry

7. Storm Surge

8. Geological and Seismic Characteristics of Ocean Floor. This need, although poorly defined, includes remote sensing (from aircraft or satellites) of various geological/geophysical characteristics, including rock type, sediment thickness, earthquake activity, etc.

9. Sea Surface Roughness Characteristics. Such as sea state, sea ice, oil slicks, etc.

10. Surveillance. Primarily for Coast Guard use, but also for other monitoring agencies involved with shipping, pollution control, etc.

CATALOG OF USER NEEDS

Following is a listing of specific needs brought out during the working group session on physical processes. The items cover a wide range of topics, reflecting the make-up of the participants. This list is by no means comprehensive, but may be helpful in determining additional areas of remote sensing application.

I. Operating Needs

1. Merge Existing Lists for Sensor Requirements, Rather Than Initiate New List. Previous lists for specific sensor requirements have been generated by other groups. Rather than trying to synthesize a new list drawing only on the participants in the working session, a better idea would be to synthesize existing lists, perhaps updating the lists at the same time. This synthesis was not done at the workshop, and would be a useful exercise for a future workshop.

2. Synthesis of Global Atlases of Remotely Sensed Data. Much data on a global scale spanning many years exist from satellite overflights, but it is not in a readily usable form. A useful tool would be an atlas representing all the data, for instance, on an areal basis for different seasons (sea surface temperature, for example).

3. Use of the Satellite As a Communications Relay Station. Increased oceanographic pressure for using remote systems enhances the potential for using satellites as communications relays between the data-gathering system and the observer on shore. Although the relay capability now exists, there is ample need for increasing its scope and reducing the cost of such systems.

4. Availability of Near Realtime Remote Imagery for Planning and Reconnaisance. There is a tremendous need in both research and fisheries for near realtime imagery on coarse spatial scales for aid in cruise planning and fishing activities. The near realtime need would likely involve a loss of spatial resolution and signal processing (calibration, etc.), but this appears to be acceptable to the user (parameters such as sea surface temperature, color, pressure, salinity, wind speed, wave action).

5. Availability of Data Transmission Facilities. For the individual user, the ability to request a specific type of remote imagery for a specific region would be helpful. The ability to select the desired imagery is important, so that needless, costly, undesired imagery does not tie up the data lines. This need ties in directly with 4 above.

6. Availability of Calibrated, Verified Remote Products. For research needs and other needs, the ability to obtain on a routine basis calibrated, verified, remote imagery is critical. The spatial resolution and calibration routines should be state-of-the-art, and the time lag should be no more than a month. This information is helpful in final data analysis and in cruise shakedown and evaluation.

7. A Source Document for Remote Sensing. A tremendous need was evident for a concise, compact document describing the remote sensors available for specific tasks, remote sensing product availability, and detailed instructions for obtaining these products. Existing manuals are either too comprehensive, or are incomplete in their coverage of user information.

8. Synthetic Aperture Radar (SAR). Interest was expressed in reviving the SAR system for future satellites, both operational (such as NOSS) and research. Most participants considered the SAR information to be useful in their work, based on aircraft-mounted SAR performance.

9. Maintain Flexibility in Sensor Requirements. Since the user community is not certain at this point which remotely sensed products are most helpful to them, a reevaluation of user sensor needs should be routine on a yearly basis.

10. Increased Spatial Resolution. In many instances the spatial resolution of satellite-sensed data is inadequate; for instance, in any type of near-shore work. Aircraft imagery may be used to make up this deficit, but it lacks the global coverage of satellites. Increased emphasis on increasing spatial resolution for visual and other imagery would be helpful. The spatial scales desired depend strongly on the particular task, so no guidelines are listed here.

11. Verification of Data Quality. On both the near realtime and the time-lagged data, good indicators of data quality are useful to the user. This information would help markedly in filtering the large quantities of data to select the most useful pieces.

12. Regional Data and Analytical Facility. Interest was expressed in establishing and coordinating a regional facility for routine processing of remote sensing imagery. The facility would be regional, making it more accessible to the user, and would allow various levels of processing complexity. The facility could also act as a distribution center for these data products.

II. Data Needs

1. Satellite Data for Coastal Physical Oceanographic Models. Large areal coverage with reasonable resolution could provide excellent input data for coastal physical oceanographic modeling efforts, by providing both initial and boundary conditions. Some examples are Gulf Stream transport estimates, water mass boundaries, and sea surface height.

2. Sea Surface Temperature. This widely useful parameter is presently measured remotely with up to one-half degree centigrade relative accuracy, or one degree absolute accuracy. These limits appear acceptable to most users, with perhaps an improved spatial resolution.

3. Bioluminescence Production. Aircraft can now sense bioluminescence on a small areal extent; extending this capability to satellites would be useful to various marine life investigations as well as to surveillance efforts.

4. Ship Routing. Use of various remotely sensed parameters (such as sea surface height, wind speed) would aid in more profitable ship-routing practices. This is both of industrial and research concern.

5. Water Mass Identification. Various parameters could be applied in concert to estimate water mass identification, preferably three-dimensionally. Suggested parameters might include temperature, salinity, transparency, and speed of sound. An interest was expressed for spatial resolutions on the order of one mile.

6. Salinity Measurements. For water mass identification and speed of sound estimates, salinity needs to be measured to one-half part per thousand, with a spatial scale of one mile.

7. Internal Wave Activity. Both surface and subsurface expressions of internal wave activity would be useful for quantifying oceanic mixing processes, as well as clarifying bathymetric control of these wave fields.

8. Speed of Sound in Water. For various research and surveillance purposes, the measurement of speed of sound in water down to at least the seasonal thermocline is useful.

9. Pollutant Monitoring. A wide variety of remotely sensed parameters can be applied to the study of pollutant dispersal of various types. A more complete listing of the various requirements for this task is available in the Applications II session of this workshop.

10. Marine Life Mortality. In an effort to quantify the effects of pollutants on marine life, some technique to monitor marine life parameters (e.g., chlorophyll) is required. Spatial resolution of such systems must be of the order of a kilometer or less.

11. Water Column Transparency. A depth profile of water column transparency would yield information on pollutant dispersal, particulate distribution, and perhaps biological activity, as well as water column identification.

12. Measurements of Material Flux Across the Ocean Interface. Measurement of CO_2, H_2O, and heat fluxes across the ocean surface would provide needed data on global budgets of these quantities. It would greatly enhance air-sea interaction studies.

13. Near-Surface Temperature Profile in Atmosphere. A vertical profile of near-surface atmospheric temperature would be a useful quantity for air-sea interaction studies.

14. Bathymetry. Remote sensing of bathymetry in coastal regions is needed. This would include various scales of accuracy, from several-meter accuracy offshore to centimeter accuracy for looking at short-term beach changes, in a wide range of weather conditions and sea states. Offshore shoal migration could also be monitored.

15. Dispersion of Heat from Power Plants. With a spatial resolution of hectares, and a thermal resolution on the order of a degree centigrade, dispersal of waste heat can be monitored in coastal areas.

16. Circulation Studies. In both coastal and offshore regions, areal measurements of circulation in a three-dimensional framework is desirable. This could stand alone as an oceanographic measurement, or be combined with various modeling efforts.

17. Geological and Geophysical Parameters. Specifically in coastal areas, there is an increased need for monitoring geological/geophysical conditions over a period of time. Satellite or aircraft sensing could provide good areal coverage of these parameters, such as fault activity, slumping, etc.

18. Real-Time Data Requirements for Coastal Disaster Situations. Water level (storm surge) and flooding potential are required during coastal disasters by federal agencies as well as by local concerns. This information requires fine spatial resolution and near real-time data availability.

19. Wave Climate. For shipping, coastal design, offshore construction, and a variety of other concerns, an accurate, seasonal directional wave climate is needed. Because of large areal requirements, satellite sensing is particularly appealing.

20. Tidal Inlet Processes. Various mixing and exchange processes occurring within tidal inlets can be remotely sensed. Such information is invaluable when combined with *in situ* inlet measurements.

21. Estuarine Discharge. With application to pollutant dispersal and coastal circulation, the sensing of estuarine discharge into the ocean is needed.

22. Dynamic Topography. Sea surface elevation measurements can be included into geostrophic calculations of large-scale ocean circulation.

23. Estimates of Littoral Drift. Requiring a small spatial scale (less than a kilometer), indirect evidence for littoral drift accumulation can be used to estimate longshore sediment motion in a given region.

24. Grain-Size Information. Remotely sensed grain size data (mean, median, distribution, for instance), both subaerial and subaqueous, would be useful for many coastal problems, including storm effects on beaches.

25. Coastal Erosion. With increased spatial resolution, the long-term migration of shorelines could be monitored and input into planning criteria for coastal development.

26. Wind Activity. For shipping, research, and other needs, an accurate knowledge of wind conditions (preferably vertical profile) is extremely useful.

27. Fog Distribution. The occurrence of fog curtails many activities, including search and rescue operations. A spatial map of fog extent in near real time would be useful to both marine and airborne operations.

28. Ice. The measurement of ice cover in lakes and the oceans is of vital concern to shipping and to the United States Coast Guard. The movement of these features, their vertical and horizontal extent, and their persistence would be useful information.

29. Surveillance. The U.S. Coast Guard has a mission to monitor certain shipping activities. Remote imagery could provide the broad spatial coverage for this requirement, considerably easing their surveillance burden.

30. Frontal Activity. For research and fisheries purposes, monitoring of position and strength of oceanic fronts is desirable. This information would strongly enhance climate and short-term weather studies.

David Aubrey
Rapporteur

COASTAL PROCESSES AND MANAGEMENT

Within the coastal processes and management working group, potential users of remote sensing interfaced with "experts" in the application of this technology to their field. A series of recommendations for future direction of user programs to include remote sensing was to be the result. The working group members represented a wide variety of local, state, and federal agencies. Thus, the needs that ultimately evolved from the three hour discussion were equally varied.

The working group agreed on several general directives and was successful in listing many coastal zone data requirements that remote sensing could help fulfill.

General Directives

Coastal Zone Base Map Series. A Coastal Zone Base Map Series that included both onshore and offshore areas is needed. The presently available USGS quadrangle maps and 1:250,000 series and the USSTETGS navigation map series do not fill this need. The working group emphasized the need for a Base Map Series at a scale of approximately 1:25,000 that could be used to map coastal zone resources and establish an integral data base and future management systems.

Coastal Zone Resource Inventory. The need for maximizing the use of the coastal zone while minimizing adverse ecological impact has always been a goal of coastal zone management. To do this, a resource inventory was recognized by the working group as a first step, followed by a data base management system. The resource inventory classification scheme, which is partially developed in the Coastal Zone Management Act, would need to be further developed by each state office of coastal zone management. The inventory could be developed from a compilation of existing data and new data interpreted from aerial photography. The working group discussed the resolution requirements. Aerial photography seemed to be more universally required to fulfill the resolution requirements than Landsat. Future higher resolution Landsat systems were cited as an immediate need. The advantage of digital data,as offered by Landsat over aerial photography was recognized.

Data Base Management System. Next, a digital data base was cited by the working group. Digitized map data stored in the management system could be combined according to multi-parametric queries, and a mapped output of areas satisfying management criteria could be produced. Digital data base management software systems are commercially available from many sources, and, combined with today's lower cost mini-computers, they offer a powerful and cost-effective management capability. Several states represented by the working group are presently reviewing the state-of-the-art of data base management systems and will shortly select and obtain their own capability.

Coastal Zone Regulation, Enforcement, and Monitoring. Following the development of management decisions in the coastal area, a regulatory structure needs to be promulgated with sufficient enforcement and monitoring mechanisms to insure its adherence. The working group discussed the monitoring capabilities of repetitive coverage remote sensors such as Landsat, successive aerial photo coverage, and various change detection systems. Specific requirements for monitoring a variety of coastal activities were considered beyond the scope of the working group discussions, but it was concluded that remote sensing would have an obvious role in monitoring and enforcement.

Specific Mapping or Inventory Needs. A discussion of specific mapping or inventory needs and remote sensing systems required to fulfill these needs followed the general directives resolution. Specific mapping needs were widely varied and are presented in these preceedings in the same order as they evolved during the discussion. The following is a list of specific mapping needs in the coastal zone as discussed by the working group:

Coastal Inventory Needs

1. Coastal wetlands

    a. Upper wetland boundary
    b. Areal extent
    c. Vegetation type or species association
    d. Productivity/nutrient transport systems
    e. Interstitial water quality

2. Coastal dunes

    a. Shape
    b. Position
    c. Migration

3. Erosion hazard

    a. Erosion/accretion
    b. Storm surge
    c. Wind, wave direction
    d. Subsidence
    e. Ice scour

4. Land and water use/cover

    a. Recreational use
    b. Urbanization

5. Submersed aquatic vegetation
    a. Distribution
    b. Species association and percent cover
6. Major facility siting
7. Public right-of-way
8. Estuarine hazard
    a. Salt wedge shift
    b. Thermal inertia
9. Topography, Bathymetry, and substrate type
10. Water quality
    a. DO, BO, P, Ph, heavy metal, toxicity
    b. Thermal pollution
    c. Turbidity
    d. Point source pollutant origin
    e. Non-point source pollutant origin
11. Air quality
12. Sea level-mean low water datum plane
13. Oil spill location, tracking, and cleanup monitoring
14. Wildlife habitat/fish habitat
15. Fisheries stock, inventory, and monitoring
16. Non-renewable resources location and monitoring
17. Shellfish beds
18. Shoreline position and riverine and coastal configuration

Regional Information Source

A need for a regional remote sensing data library staffed by an expert in the technology with a background in coastal resources was cited. Such a remote sensing center could be located at a university or within a single state government, and be funded jointly by all interested users in the northeast region. The center would physically house aerial photography, Landsat imagery and tape, digital and mapped data and might include a computer and a data base management system. A director and a knowledgeable remote sensing scientist could advise individual state users of remote sensing potential, lead users to contractors, interface during the request-for-proposal and contract negotiation process, and monitor mapping contracts.

Second U.S. North-Atlantic Regional Workshop on Remote Sensing in the Coastal and Marine Environment

The working group was in unanimous agreement that there should be another workshop during the spring of 1980. The interchange between users and technologists was a start toward widespread remote sensing utilization in the northeast. An annual interchange with an influx of new people each year will foster dissemination of technology and sophistication of the users.

With this resolution, the working group session was declared over and more informal discussions in smaller mutual interest groups continued.

Robert Macomber
Rapporteur

COMMERCIAL AND RECREATIONAL FISHERIES

Discussion centered on how remote sensing can be better applied to the needs of fishermen and fisheries researchers in the offshore waters of the continental shelf and beyond. Attention focused on remote sensing from satellite, rather than from aircraft, because only the former can provide the large area, continuous coverage needed, at reasonable cost. Requirements for the productive inshore waters (estuaries and coastal lagoons) were only briefly considered, but it was recognized that these bodies of water have individual characteristics which are much influenced by local conditions and, with the exception of the larger estuaries, are probably better surveyed with aircraft (in conjunction with small boats) rather than with satellites. Attention was also directed more to applications of existing remote sensing technology than to possible applications of future technology.

Early in the discussion, it was realized that fishermen and fisheries researchers need basically the same remote sensing information in regard to the principal subjects of interest: weather and sea state forecasts, ocean front locations, resource assessment, fishery models, location of fishing vessels, and effects of climatic instability.

Weather and Sea State Forecasts

More accurate forecasts of weather, as well as forecasts and "nowcasts" of sea state, on the outer shelf and beyond, are the requirements most stressed by fishermen who need this information for safety at sea and efficiency of operations. Dykstra gave an example: Southern New England fishermen often find "another world" regarding weather when they are about an hour beyond Block Island. He also stated that some fishermen find that the forecasts from some coastal weather stations can often be applied to the offshore grounds by allowing an appropriate time lag. They consider the forecast to be better from some weather stations than from others, but also report a general decline in the quality of forecasts in recent years. It was noted that providing sea state information is, in part, a separate problem, because rough seas generated by distant storms often occur where the wind is calm.

It was agreed that at the present time the limiting factor in the quality of weather forecasts for offshore waters is the lack of analysts assigned to the task, rather than the quantity or quality of data available. For satisfactory sea state forecasts or "nowcasts," however, the presently available data may be less adequate. In this regard, thought was given to the possibility of obtaining sea state and weather observations from the numerous fishing vessels that operate in the outer shelf and adjacent slope water region off the northeast coast. Here the principal difficulty may lie in the reluctance of fishermen to reveal their positions.

Improvement of Distribution System for Ocean Frontal Analysis Charts Derived from Satellites

The need was discussed for radio facsimile broadcasts of oceanographic information, and particular consideration was given to surface frontal analysis charts. Such charts based principally on infrared imagery from NOAA satellites, have already been produced for several years by the U.S. Naval Oceanographic Office and the NOAA National Environmental Satellite Service in sufficient detail to be useful to fishermen for increasing operating efficiency, and to fishery researchers for planning vessel cruises, interpreting cruise data, and analyzing frontal movements. Some fishermen and researchers have found these charts of value for cruise planning even though they generally can receive them only by mail, a week or more after their date of preparation. The frontal analysis charts for the waters off the northeast coast depict the boundaries of water masses at the sea surface: (1) the slope front located between the shelf water and the warmer slope water farther offshore; (2) the "perimeters" of warm and cold core Gulf Stream eddies; (3) the northern and southern edges of the Gulf Stream itself; and (4) transient strong temperature gradients which relate to processes within the water masses and to interactions between the water masses.

Positions of these boundaries fluctuate widely. For example, the slope front varies in its distance offshore by over 100 kilometers and the Gulf Stream by over 200 kilometers. Furthermore, the Stream meanders widely northward from Cape Hatteras, and the meanders tend to move several kilometers per day in the same direction as the Stream and increase in amplitude. The eddies, on the other hand, are transient features forming from detached meanders of the Stream. Movement of eddies is irregular, but over a period of weeks or months, particularly in the case of the warm core eddies, is opposite in direction to the Stream, at speeds of several kilometers per day. All of these boundaries, however, move so slowly compared, for example, to atmospheric fronts (which can move hundreds of kilometers per day) that the changes can be readily followed through preparation of frontal analysis charts once or twice a week.

Information from frontal analysis charts on the positions of these oceanographic boundaries is important to two kinds of fishermen, but for opposite reasons. Longliners for pelagic apex predators (swordfish, tunas, and sharks), when operating far offshore, often try to set their gear in the vicinity of the slope front or the boundaries of warm core eddies, because they have found conditions there to be productive. Conversely, trap fishermen for offshore lobsters and deep sea red crabs have reason to avoid the warm core eddies, whose strong currents interfere with fishing and have often caused losses of gear by submerging and deflating the surface buoys.

The majority of fishermen in the Northeast, however, are the draggers who tow otter trawls along the bottom, locate the groundfish they seek largely from experience, and have, as yet, found little application of oceanographic information in their operations. On the one hand the subsurface oceanographic observations that might directly serve their needs are made almost entirely from ships, but not frequently enough to guide fishing from day to day, or even from trip to trip. Remote sensing, on the other hand, although providing observations far more frequently than is practical from ships, has not been felt to have much application to groundfishing strategy, because the kinds of observations are limited, and essentially restricted to conditions at the sea surface. Nevertheless, consideration should be given to how much can be inferred about near-bottom conditions from surface frontal patterns. Some inferences are substantial, on the basis of existing oceanographic knowledge. For example, when slope water is observed to intrude from offshore onto the continental shelf at the surface (displacing the colder shelf water) it may be inferred that this intrusive water probably extends to the bottom, because slope water is more dense than shelf water. Knowledge is limited, however, of the effect this warm water may have on the availability of harvestable species to other trawls. Another example relates to warm core eddies. When an eddy is observed to intrude onto the continental shelf at the surface, it may be inferred from present knowledge of eddy circulation that the strong clockwise eddy currents and warm eddy water extend to the bottom. Again, it is not known what effect strong bottom currents and a rise of bottom temperatures may have on the availability of fish to otter trawls.

First consideration regarding the eddies, however, should probably be given to the effect of their currents on gear efficiency. The direction of eddy currents near the edge of the shelf and the directions in which trawls are towed both tend to parallel bathymetry. Consequently, a fisherman should be able to deploy his gear more effectively, if he knows when he is operating within the influence of one- to two-knot eddy currents.

Fishery researchers have the same need as fishermen for routine, timely information on the location of oceanographic boundaries, although for different purposes. Heretofore, most shipboard investigations have followed sampling strategies based on past experience with the stations to be occupied, prescribed prior to the cruise. Now, with the advent of frequently updated frontal analysis charts, it has become possible to design the sampling strategy on a more informed basis prior to a cruise, and to modify this strategy in terms of changing conditions during the cruise. This procedure has been followed in a limited way during a few research cruises, through special communication arrangements. But the utility of frontal analysis charts will not be fully realized for fishery research any more than for fishermen until the charts are routinely broadcast by radio facsimile soon after their preparation. Although the range of application of these charts to research remains to be seen, it is probably safe to predict that they will eventually be used during investigations of (1) fish and plankton distributions, concentrations and movements: (2) fish migrations; (3) nutrient enrichment and transport; (4) primary productivity; and (5) the efficiency of physical, chemical, and biological sampling gear.

Improvement of Fish Stock Assessments

Consideration was given to whether or not remote sensing could be used to improve assessments of some fish stocks, such as herring, which come near the surface at night. It was agreed that possibilities were limited to aircraft remote sensing, because the resolution from satellites is too course. No specific approach to the problem was suggested, although the use of satellites for locating fishing vessels was considered as a possible way to improve estimation of fishing effort.

Fishery Models

Consideration was given to how remote sensing might provide inputs to single and multi-species fisheries models. Some of the more feasible future applications of remote sensing to modeling might be in providing data on surface water temperature and frontal locations, solar insolation estimated from cloud cover, chlorophyll concentration, and circulation. Fishing vessels could, in theory, provide environmental data as well as catch statistics for the models.

Locating Fishing Vessels

The practicality of obtaining real-time biological and environmental observations from fishing vessels was considered during discussion of each of the topics above. Such observations could be used to improve weather and sea-state forecasts, frontal analysis charts, current charts, resource assessments, and fishery models. In all cases, however, there appears to be a conflict between the necessity of knowing the locations of the observations and the traditional reluctance of fishermen to reveal where they are fishing. Only one solution to this problem was regarded as remotely feasible; namely, the development of an electronic device ("black box") that could transmit, via satellite, the location of the vessel and its observation data, without revealing the identity of the vessel. Such an automatic vessel location system was also recognized as having potential value for safety at sea.

Climatic Instability -- Implications to Fisheries

In view of evidence, largely derived from satellite remote sensing, that unusual oceanographic conditions in the Northwest Atlantic since 1976 are a reflection of developing global climatic instability, it was felt that discussion of remote sensing applications to fisheries is particularly appropriate at the present time. We may be certain that climatic instability will affect fish stocks (probably, some favorably and others unfavorably) and make the work of both the fisherman and the fishery researcher more complicated and difficult. On the other hand, we have no certainty as yet of the kinds of effects that this instability may be having on each of the different fish stocks or whether these effects will be of significant magnitude. Equally uncertain is how long the climatic instability will last and whether it will end with return to a relatively stable climate much like we have been used to for several decades or to a significantly different climatic regime.

Regardless of the changes in climate that may develop,remote sensing will provide much of the best information on the associated changes in oceanographic conditions, and this information should improve as new advances in remote sensing technology are put into operation.

RECOMMENDATIONS

1. Greater emphasis should be placed on more accurate marine weather and sea state forecasting for offshore fishing areas. This is needed to increase safety at sea and to increase the efficiency of fishing operations and fishery research.

2. There is a need for an improved and more timely distribution system of frontal analysis charts such as have been prepared weekly in recent years. Accurate locations of water mass boundaries for the water off the northeast coast would be very helpful. Locations of the 68 to 70 deg. F. isotherms gradient are important in the locations of swordfish for commercial fisheries. The frontal analysis charts should be prepared on a real-time schedule, disseminated by radio facsimile broadcasts to vessels at sea, and augumented to a semiweekly schedule. These charts have proven very useful to some type of commercial fisheries and fishery research operations and have potential for most fishing operations.

3. Special consideration should be given to the potential of remote sensing information for:

    a. Improving fishery resource assessment of fish that occur near the sea surface. Direct sensing should be explored.

    b. Improving single and multi-species fishery models. Research should be conducted to determine the usefulness of remote sensing parameter measurements such as sea surface temperature, frontal position, solar insolation (estimated from cloud cover) chlorophyll concentrations and circulation in model development.

4. Attention should be given to:

    a. The potential utility of fishing boats for obtaining environmental observations for use in interpreting data from environmental satellites and aircraft. Joint experiments between the developers of remote sensing technology and commercial east coast fishermen should be explored. The correlation of fish catch to ocean color, frontal activity, sea surface temperature, and the utilization of near-real time remote sensing data could be an experiment area.

    b. The feasibility of developing an electronic system that would be installed on fishing boats to allow radio transmission of environmental observation data via satellite without revealing the identity of the vessel.

5. In planning application of remote sensing to fishing and fishery research greater attention should be given to evidence, largely derived from satellite remote sensing, that unusual oceanographic conditions in the northwestern North Atlantic since 1976 are a reflection of developing global climatic instability.

J. Lockwood Chamberlin
Rapporteur

U.S. EAST COAST MONITORING SYSTEMS

Peter Cornillon
Chairman

LARGE AREA MARINE PRODUCTIVITY EXPERIMENTS

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The first of a series of Large Area Marine Productivity Experiments (LAMPEX) to test the feasibility of mapping chlorophyll a and concentrations of total suspended solids concentrations in surface waters of the continental shelf from Cape Hatteras to the Canadian border was conducted jointly by the National Aeronautics and Space Administration (NASA) (Langley Research Center-Marine Environments Branch) and the National Marine Fisheries Service (NMFS) (Northeast Fisheries Center-Division of Environmental Assessment) during the period of 17-21 April 1979 as part of the Ocean Pulse Program. Twenty-one state, federal, and private institutions, from North Carolina to Maine, participated. These included Cape Fear Technical Institute, Virginia Institute of Marine Science, Hampton Institute, The Marine Science Consortium (Pennsylvania), University of Delaware, New Jersey Marine Science Consortium, New Jersey Department of Environmental Protection, Rutgers University, U.S. Environmental Protection Agency, Brookhaven National Laboratory, Atlantic Oceanographic and Meteorological Laboratories, Marine Ecosystems Analysis (MESA) New York Bight Project, Suffolk County Department of Health Services, State University of New York at Stony Brook, New York Ocean Science Laboratory, University of Rhode Island, EG&G, University of Massachusetts, Bigelow Laboratory for Ocean Science, State of Maine Department of Marine Resources, and Northeast Fisheries Center facilities at Sandy Hook, Milford, Woods Hole, and Gloucester.

The objectives of this joint research were 1) initially to advance the development of improved systems and techniques for monitoring and assessing regional marine resources and environmental quality; 2) to increase our understanding of regional marine ecosystem processes; and 3) ultimately to provide an extensive, synoptic, integrated and timely data base for application to problems of ocean resource and environmental management. Under the program, NASA was responsible for the remote sensing systems, data collection, and reduction. The NMFS was responsible for the organization, collection, and reduction of sea-truth data to calibrate the remote sensors.

During this particular experiment (17-21 April 1979) NASA accomplished its remote sensing using two aircraft: a NASA U-2 flown at 19.7 km (65,000 ft) with an Ocean Color Scanner (OCS) and Mitchell-Vinton cameras using aerial color and multispectral film (Principal Investigator - Craig Ohlhorst) and a NASA C-130 flown at 3.0 km (10,000 ft) with a multispectral scanner

(Modular Multispectral Scanner M2S) and Zeiss mapping camera using aerial color film (Principal Investigator - Dr. Robert Johnson.) The sea-truth data were collected at 19 locations depicted in Figure 1. Additionally Landsat imagery for these same locations and approximate times will be examined by Dr. Vic Klemas, University of Delaware, in an attempt to interrelate Landsat, U-2, and C-130 data based on sea-truth observations.

NASA U-2 inflight observations suggest successful cloud-free coverage of a 14-mile-wide swath along the coast between 19 and 21 April from Oregon Inlet, North Carolina, to the Canadian border including Long Island Sound, but not Georges Bank.

NASA C-130 inflight observations on 17 and 19 April suggest successful quantitative coverage where concurrent sea-truth data were available from Chesapeake Bay to Cape Cod, except for the coastal zone of New Jersey off Barnegat Inlet and Long Island at Fire Island Inlet where cloud cover prevented data collection. Cloud and light conditions hindered or prevented data collection north of Cape Cod and over Georges Bank.

Initial data reduction and preliminary analyses will take approximately one month for the sea-truth data, two months for the aerial photography, and three to six months for the multispectral scanning data. The program is looking for additional cooperators to participate in the collection of sea-truth data in both the nearshore and offshore waters of the continental shelf during future experiments.

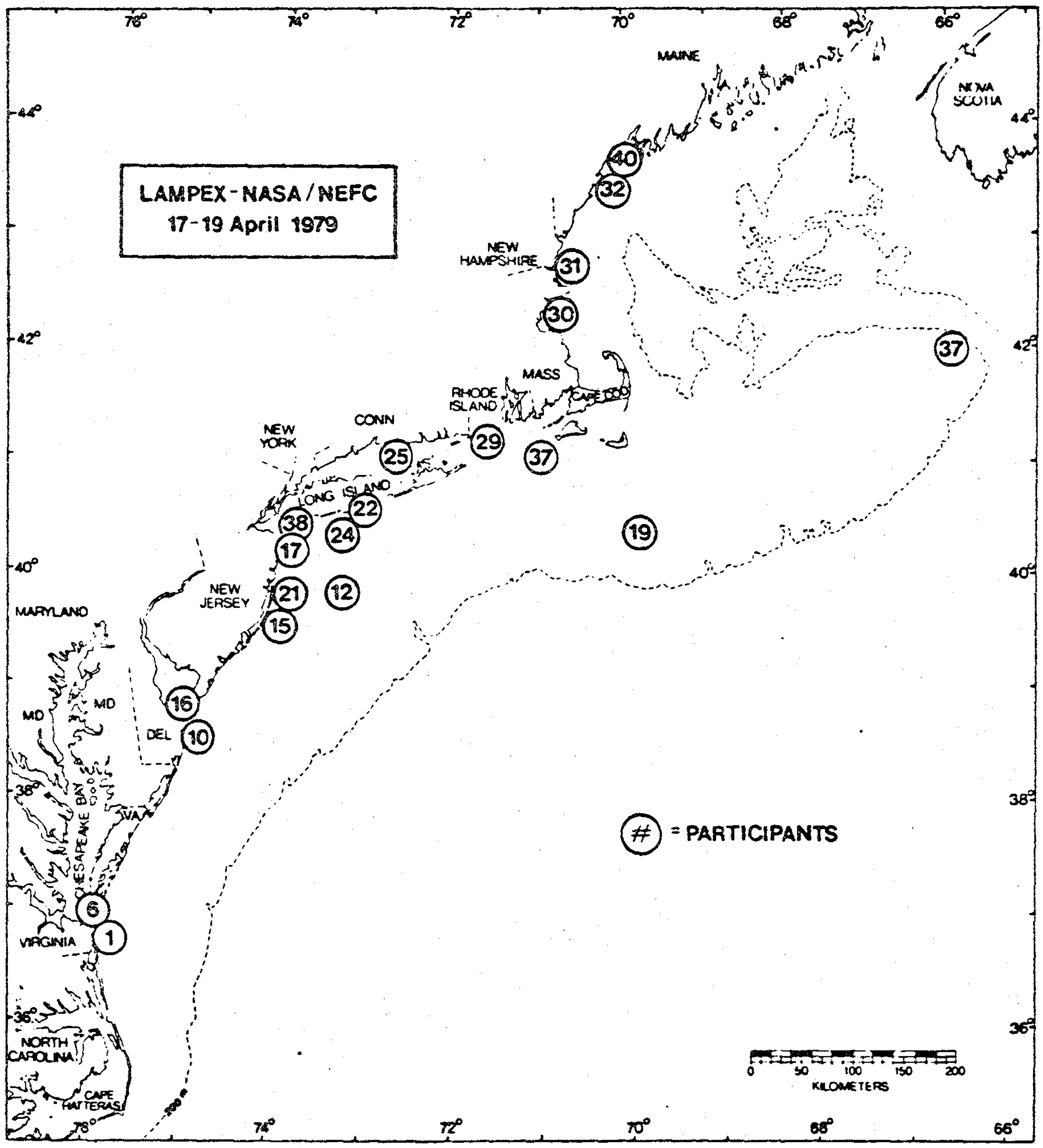

Figure 1. Locations where sea-truth data were collected. One, 6, 10, 16, 15, 21, 17, 38, 24, 12, and 22 collected 17 April. Twenty-five, 29, 19, 37, 40, 32, 31, 30, and 17 collected 19 April.

A MONITORING PLAN FOR THE NEW YORK BIGHT

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The quality of the New York Bight is a result of what has happened or is now happening in the environment. Numerous changes in the amounts, kinds, and locations of nutrient and pollutant inputs to the Bight are projected for the next decade. Other changes will occur under conditions for which there are no present plans. Some of these changes will affect various components of the New York Bight ecosystem. The impact of such changes on the Bight ecosystem can be determined by monitoring the condition of the ecosystem as the changes are occuring. In additon, assessment of some of the less obvious and/or chronic impacts of people on the ecosystem can be obtained through a monitoring effort designed to measure deviations from the long-term norm.

Bight quality is a function of natural phenomena as well as people-related activities. Both vary with time, and the conditions that result may never be exactly repeated. Even under such situations, monitoring must provide a series of generalized observations having a sufficient degree of reliability to aid in making decisions related to management and control of the New York Bight environment.

The Marine EcoSystems Analysis (MESA) New York Bight Project has been tasked with the role of developing a plan for establishing a monitoring program for the New York Bight. The Project is particularly suited to the task. Since mid-1973, it has been conducting a multi-disciplinary, regional research effort to determine the condition of the ecosystem of the New York Bight and to identify where significant environmental problems exist or may develop in the future. The MESA Project has already contributed significantly to the understanding of the New York Bight ecosystem, and has provided technical quidance for numerous environmental management decisions. The Project is scheduled to be completed at the end of fiscal year 1981; one of its major products is to be the development, test, and evaluation of the New York Bight Monitoring Plan.

A draft plan has been developed from a Bight-wide perspective--it proposes the coordination and cooperation of present, generally beach-related efforts of the states of New Jersey and New York with the broader-scale monitoring addressed herein. These broader-scale efforts are comprised of both near-shore and offshore activities. The product of all these efforts will be the first regional coastal monitoring program, one which will provide an integrated continuous picture of conditions of the New York Bight.

Two principal objectives of the New York Bight Monitoring Program are:

(1) To continuously diagnose the health of the Bight in order to signal the occurrence of perturbations; and,

(2) To predict, insofar as possible, responses of the Bight ecosystem to changes in environmental variables.

The outputs of efforts related to these objectives are to focus on information and guidance to the public and to those responsible for management of New York Bight resources.

In addition to needing a continuing diagnosis of the state of health of the New York Bight and prediction of responses of the Bight ecosystem, those involved in environmental management require input from a separate effort which must be conducted, in parallel, by the appropriate agencies. This parallel effort is an assessment of the kinds and amounts of waste materials released directly and indirectly to the Bight. Then and only then can management of wastes and management of the New York Bight be addressed properly.

In general, four approaches to monitoring can be considered:

(1) The measurement of independent variables, such as water temperature, polychlorinated biphenyls, sea color, mercury levels, etc.;

(2) The measurement of influential factors, such as direction, intensity, and consistency of winds;

(3) The measurements of effects, such as fin-rot disease, population decrease, etc.; and

(4) The measurement of response of indicator parameters or organisms, such as presence or absence of organisms, bioaccumulation, etc.

In some cases, the two approaches of measurement of effects and response of indicator parameters or organisms tend to overlap. Examples are changes in species diversity, communities, or rate processes such as photosynthetic assimilation.

The first approach to monitoring assumes that the measured variable, or some combination of variables, is environmentally significant and reflects a present or projected condition. As an example, salinity alone may provide little valuable information; however, as an indicator of flow or, in conjunction with temperature, as an indicator of density and stratification, salinity can be quite valuable.

Measurement of influential factors, the second approach to monitoring, implies having a general understanding of the response of the New York Bight ecosystem to that factor. Such an understanding now exists for certain factors, as a result of the efforts of the MESA Project and of those of other-than-MESA-sponsored investigators, as well. This approach must really be taken in conjunction with one or more of the other three, due to present limitations in the state-of-the-art of mathematical modeling of ecosystems. Earlier than normal seasonal warming can influence stratification which, in turn, can isolate bottom waters from surface waters. Reversal of bottom currents, when bottom waters are relatively isolated, can increase the time that these waters are subject to certain impacts. The importance of a single influential factor may not be large, but deviations in the norm of several influential factors may portend certain potential problems in the ecosystem.

In its highest form, the third monitoring approach, that of measuring effects, can be used to relate observations back to natural and/or people related happenings. This requires that:

(1) A unique cause-effect relationship already be established between a stress and an effect; and

(2) The effect not have more than one cause.

There are many different types of activities affecting the New York Bight. In those cases where a cause-effect relationship has been demonstrated, or is demonstrated in the future, monitoring of such effects can be of maximum benefit in providing guidance to environmental management. An example is the nutrient load-organic production-depleted oxygen-demise of living resources relationship. While the initial program will include only minimal effects monitoring, it is anticipated that future endeavors will make use of far more of this kind of effort, based on results of New York Bight Project synthesis activities.

In its lowest form, the examination of effects, without having a cause-effect relationship, reduces to the fourth general approach to monitoring, measuring the response of indicator organisms or parameters to the quality of the environment or a particular portion of it. Change in the response of organisms to changes in the quality of the environment are not necessarily linear. Higher order relationships and step functions are well known. Monitoring of the physiological functions of specific organisms should provide useful information on present and near-recent aspects of environmental quality. On the other hand, monitoring of organism behavior or certain facets of its reproduction and development should indicate an integrated response to the environment over a longer period.

The basic strategy for monitoring the quality of the New York Bight will be to make use of all four approaches, but to a different extent for each. Emphasis will be on the first, second, and fourth approaches. The third approach, however, will be used in those cases where unique cause-effect relationships are known. Actual monitoring of field measurements for the second approach dealing with influential factors, will be of two parts. Most data on influential factors will be obtained from other ongoing programs (wind data from the National Weather Service, fresh water runoff data from the Geological Survey, etc.).

In regard to environmental concerns, monitoring of the New York Bight must take into account known and fairly well-defined environmental problems, as well as warning signs of potentially significant and serious unanticipated situations in the future. The respective efforts to do so are quite different, in terms of strategy, approaches, and degree of concern. While it is probably safe to predict that more unpleasant surprises will develop in the New York Bight, their exact nature cannot be estimated. Therefore, it is necessary to monitor in a general surveillance mode for early indications of such happenings, as well as in a directed manner for known ecosystem disorders.

The following lists past and projected disturbances and monitoring periods of immediate interest in the New York Bight ecosystem which are planned for surveillance as part of the monitoring program. Matters considered in formulating the list are public health, ecosystem degradation, public concern, and economics.

Monitoring Periods for Environmental Concerns

Environmental Concerns	Period of Immediate Interest
Nearshore Water Quality	Short-Term (Bi-Weekly)
Oxygen Depletion	Seasonal (April-September)
Modification of Fish Distributions	Long-Term (Semi-Annual)
Degraded Benthic Communities	Long-Term (Annual)
Chemical Contamination of Fishes and Shellfish	Long-Term (Annual)
Pathogenic Contamination of Shellfish	Long-Term (Annual)
Contaminated Sediments	Long-Term (Annual)

Sampling Frequencies and Parameters for Environmental Concerns/Responses.

TABLE 1. Sampling

Environmental Concern/Response	Parameter	Sampling Frequency
Nearshore Water Quality	Dissolved Oxygen	Bi-weekly
	Nutrients	"
	Turbidity	"
	Coliform	"
	Floatables	"
	Temperature	"
	Salinity	"
Oxygen Depletion	Dissolved Oxygen	4 times/year (seasonal)
	Temperature	"
	Salinity	"
	Nutrients	"
	Plankton	"
	Currents	Continuous
Contaminated Sediments	Cadmium	Annual
	Mercury	"
	Coliform	"
	TOC	"
	Artifacts	"
	PCB	"
	Coprostanol	"
	Plutonium *	Every 3 years
Degraded Benthic Communi-ties	Abundance	Semi-annual
	Diversity	"
	Gill Clogging	"
Contamination of Demersal Fishes and Shellfish	Fishes	
	Cadmium	Semi-annual
	Mercury	"
	PCH	"
	PHAH	"
	Shellfish	
	Cadmium	"
	Mercury	"
	Coliform (total) fecal, E. coli)	"

Sampling Frequencies and Parameters for Environmental Concerns/Responses. (Con't)

TABLE I

Environmental Concern/Response	Parameter	Sampling Frequency
Contamination of Demersal Fishes and Shellfish	Pathogens	
	Fecal Strept.	Semi-annual
	Salmonella	"
	Claust. Perf.	"
	Klebsiella	"

CONCEPTUAL DESIGN OF AN EAST COAST OCEANS REMOTE SENSING DATA RECEPTION AND ANALYSIS FACILITY

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INTRODUCTION

One conclusion which emerges from this workshop is that the oceans community needs opportunities to validate, for themselves, the utility of remote sensing data through experiments and applications demonstrations involving surface truth in which they have confidence. In order to evaluate the use of remote sensing in their own programs, the oceans community requires access to multisource/multitemporal data in an effective, convenient, and timely manner.

NASA's Goddard Space Flight Center has developed two systems, the Atmospheric and Oceanographic Information Processing System (AOIPS) and the VISSR Atmospheric Sounder (VAS) processing system, to support similar research and applications demonstration requirements for earth resources and weather-related investigations. These systems provide the basic information processing, data display, data analysis, and information management capabilities needed to support near real-time demonstrations involving remote sensing technology.

These systems, with minor enhancements, can be used as a test bed to demonstrate the information-handling capabilities needed to evaluate remote sensing technology for oceans applications. The remainder of this summary describes one approach for the design and development of an East Coast Oceans Remote Sensing Data Receptive and Analysis Facility.

APPROACH

The development of a remote sensing oceans analysis facility should proceed in several phases over a three-year or longer period. The objective of the initial development phases should be to utilize existing technology, with minor enhancements, to provide opportunities for coordinated use of combined remote sensing/surface truth data sets in near real-time (6 to 12 hour turnaround) oceans demonstrations. Such demonstrations on existing equipment will provide a low-cost environment to evaluate remote sensing technology for oceans applications, and will provide opportunities to evolve detailed oceans data system requirements which are needed prior to designing an oceans data analysis facility.

Goddard's AOIPS facility could be used to conduct a limited number of cooperative, near real-time oceans demonstrations with qualified, East Coast investigators. Since the primary thrust of Goddard's existing oceans program is oriented toward research which relates ocean processes to weather and climate phenomena, cooperative efforts with East Coast investigators, who complement this orientation, are encouraged.

In an effort to evolve a definitive design for an East Coast oceans analysis facility, a three-phased effort is suggested. As part of Phase 1, Goddard would supply training, satellite data, software development support, and limited use of the existing AOIPS facility to conduct a few near real-time oceans demonstrations. The Phase 1 cooperating institutions would supply surface truth, related ancillary data, oceans discipline expertise and man-power to work with Goddard personnel in preparing for and conducting oceans demonstrations. Goddard would also develop the data base archive required to conduct the selected demonstrations, as well as capabilities needed to acquire, process, display, analyze, combine, and manage needed data sets. Data sets which could be made available in Phase 1 include Nimbus-7, SMS/GOES VISSR, GOES VAS, TIROS-N AVHRR, Landsat MSS, and a variety of surface truth and ancillary data. Output products could be made available within 12 hours to cooperating investigators by low-cost user terminals, FAX, or digital communications lines.

The experience gained under Phase 1 would provide the requirements and technology assessments needed to design a prototype, minicomputer-based facility dedicated to oceans research and development and near real-time applications demonstrations. We would hope to secure funding to actually develop a prototype oceans analysis facility during Phase 2. Figure 1 depicts a functional block diagram of a system which would be developed under Phase 2 acitvities to support the oceans community.

Phase 3 would involve the transfer of technology, including the system design evolved during Phase 2, to a non-NASA, East Coast institution for operational support of the oceans community.

SUMMARY

A several-year phased effort to design and develop an East Coast oceans analysis facility should be undertaken. Existing data systems, such as

Goddard's AOIPS facility, would provide a test bed for evaluating the utility of remote sensing data for oceans applications and for evolving the requirements for a dedicated oceans analysis facility.

Using existing systems for a limited number of oceans applications can demonstrate the feasibility of and aid in the definition of a dedicated East Coast oceans analysis facility.

OCEANOGRAPHIC DEMONSTRATIONS - PHASE II

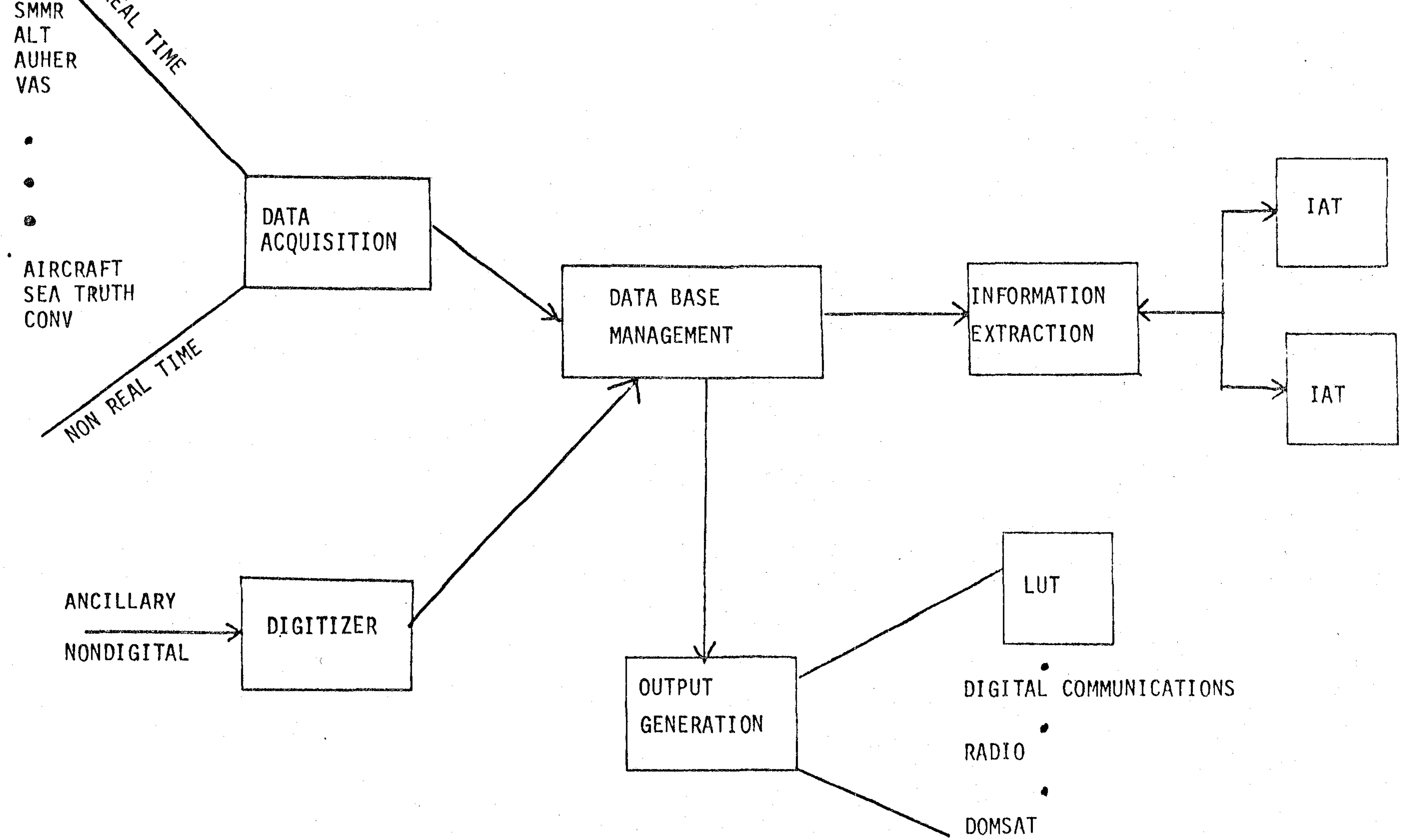

FIGURE 1

APPENDIX A

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APPENDIX B

TECHNICAL PRESENTATIONS

TECHNICAL ORIENTATION

Peter Cornillon
Chairman

TECHNICAL ORIENTATION: EARTH RESOURCES REMOTE SENSING

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INTRODUCTION

The objective of this, the first session of the workshop, is to provide all participants with a minimum background in remote sensing. The target audience of this session is the potential user who has had little or no exposure to remote sensing in the past. Basic terms that will be used throughout the workshop as well as some of the underlying physical concepts involved will be briefly introduced. Copies of the viewgraphs presented will be given to all participants at the outset of each presentation to serve as reference material during the rest of the workshop. In the first presentation I will define remote sensing and then briefly describe the electromagnetic spectrum and the various physical phenomena involved in the propagation of electromagnetic radiation in our environment.

After my presentation, Charles Olson will discuss in more detail the physics involved in the interaction of electromagnetic radiation with the environment as well as the various sensor systems available for observing the marine environment and how these sensors work. Charles McClain will then follow with an overview of existing and funded satellite systems. His presentation will summarize the various satellite orbits and the characteristics, such as accompanying sensors, altitude, etc., of each of the environmental satellites. Finally Edward Zeitler and Robert MaComber will discuss aircraft platforms, with Zeitler describing NASA aircraft and MaComber describing commercial aircraft. They will limit their presentations to such parameters as altitude, flight speed, sensors typically flown in these aircraft, etc. The speakers as well as their topics are summarized pictorially in Figure 1.

OVERVIEW OF ELECTROMAGNETIC REMOTE SENSING

Remote sensing has been defined as the observation of an object or phenomenon by a recording device that is not in physical contact with the object or phenomenon. Examples of remote sensing include subbottom profiling of the seafloor with sonar, aerial photography of the earth's surface, etc. In this workshop the definition of remote sensing will be restricted to the use of electromagnetic radiation only.

Electromagnetic radiation consists of waves, varying quantities being the electric field in one direction and a perpendicular magnetic field. Both electric and magnetic fields are perpendicular (at right angles) to the direction in which the radiation is moving. Figure 2 shows such a wave. The crest of this wave moves at the speed of light, 3×10^8 meters per second. The distance between two adjacent crests of the wave is called a wavelength. For an observer standing at some location, the time that it takes for two wave crests to pass him is called the period of the wave. The inverse of this length of time is called the frequency of the wave. Thus, the speed of the wave, its frequency and its wavelength are related. This is shown in Figure 2.

Electromagnetic waves may assume any length. The electromagnetic spectrum refers to the distribution of the wavelengths of electromagnetic waves. Figure 3 shows that part of the electromagnetic spectrum of interest to the remote sensing of earth resources. Various parts of the spectrum have been given different names, and these are also shown in the figure. For example the portion of the spectrum from .45 micrometers (μm) to .7μm is referred to as the visible part of the spectrum because this is electromagnetic energy that we see with our eyes-light.

Because of its importance to remote sensing, the visible and infrared portion of the spectrum has been expanded in Figure 4. Visible light starts at the short wavelength with blue and goes to red at the longer wavelength end. The infrared is broken up a number of different ways. Some refer to the portion between .7μm and .9μm as the photographic infrared because it can be photographed, captured on film. Others refer to the portion from .7μm to 3 μm as the reflective infrared because over this range most such radiation in our environment comes from reflected solar radiation. The thermal infrared extends from 7μ to 14μ and is named because it consists mainly of radiation emitted by the earth.

The two major natural sources of electromagnetic radiation in our environment are shown in Figure 5. The taller curve on the left with a peak at .5μm is the solar spectrum at the top of the earth's atmosphere. That is, it represents, as a function of wavelength, the amount of radiation arriving from the sun at the top of the earth's atmosphere. The most radiation per unit wavelength emitted by the sun is emitted at about .5μm. At 3μm the radiation received from the sun is a small fraction of that received at .5μm. The second smaller curve is ten times the radiation emitted by the earth. The earth emits radiation because it is warm, much as a brick wall does after dark following a hot day. The earth emits the most radiation at about 10μm. If the two curves had been drawn to scale they would be seen to cross at about 5μm. This means that at 5μm approximately the same amount of radiation is emitted by the earth as is received from the sun. At shorter wavelengths more radiation is received from the sun than is emitted by the earth, and at longer wavelengths the inverse is true. It is also of interest to note in this figure the very large difference in the amplitudes of the two curves.

Figure 6 is given as an indication of the amount of radiation transmitted through the atmosphere as a function of the wavelength of the radiation. This curve shows the fraction of radiation that leaves the bottom of the atmosphere, moving up (or the top of the atmosphere, moving down) that will arrive at the top of the atmosphere, unaffected, still moving up (or at the bottom of the atmosphere still moving down). At .5μm almost all of the radiation passes through the atmosphere. This region is referred to as a "window," because the atmosphere is transparent in the region but opague on both sides. Another important "window" occurs at 10μm. It is interesting and extremely important to remote sensing of the environment that these two "windows" exist at the peaks of the solar spectrum and earth's spectrum (see Figure 5). There are other "windows" which are coming under increased scrutiny for use in the future, for example the one at about 2.3μm. Note also that beyond about 1 millimeter (mm) the atmosphere is quite transparent. This is of great importance for microwave and radar devices.

The final concept that will be introduced in this presenatation is that of the active vs. passive sensors. A passive sensor relies on radiation either emitted or reflected from an object, where the source of radiation is not part of the sensor. For example, the source could be the sun, a forest fire, etc. An active sensor provides the source of radiation as well as detects the reflected signal. Radar is an example of an active sensor. Figure 7 shows the various satellite systems and the nature of the primary sensor of interest in marine studies. In particular, LANDSAT and NIMBUS-7 have passive sensors in the visible although each also has one detector in the thermal infrared. The military satellites, DMSP, the NOAA systems, SMS/GOES and NOAA and NASA's HCMM, all have their primary sensors in the thermal infrared. GEOS-3 and SEASAT depend primarily on active sensors in the microwave region.

Figure 8 is a summary of some of the applications of remote sensing to marine related problems. These activities have been broken down both by region of the spectrum and type of sensor, active or passive. There have been a number of applications in the passive region of the microwave, but I am not sufficiently familiar with these to include them. Cal Swift shall discuss several such applications tomorrow in the fourth session. Most of the other applications shall be discussed at one point or another during the workshop.

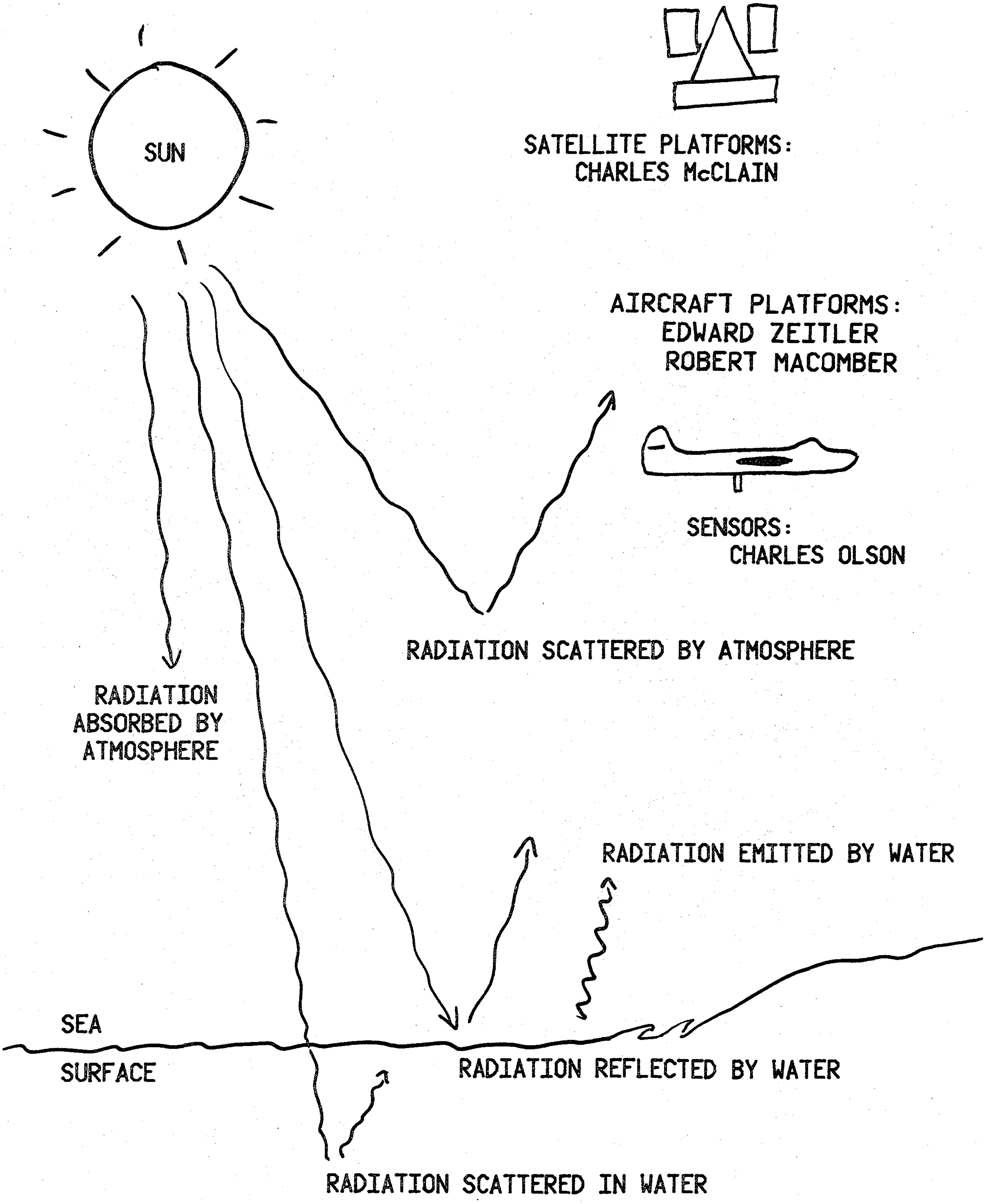
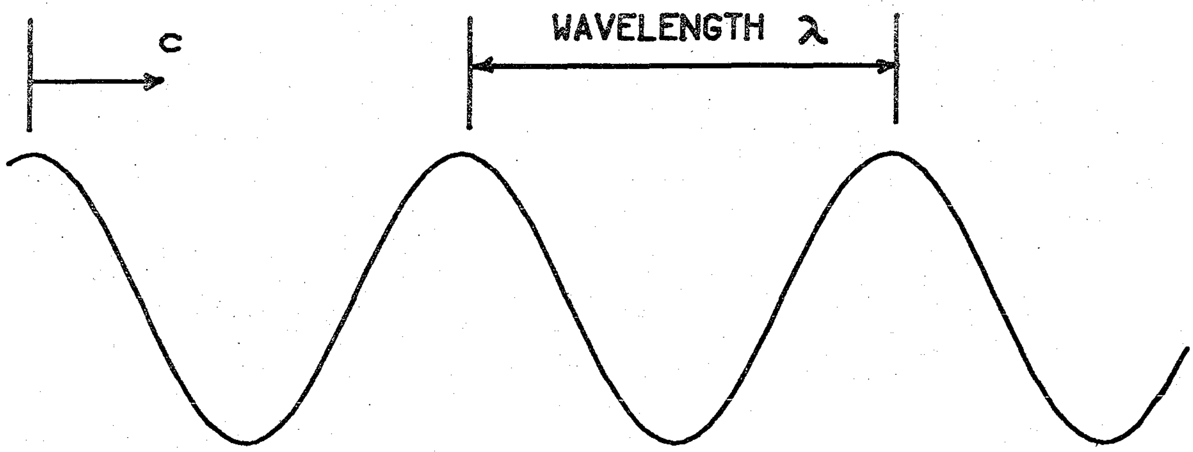


Figure 1. Session Overview

ELECTROMAGNETIC WAVES



λ = WAVELENGTH (m)

f = FREQUENCY (Hz OR CYCLES/SECOND)

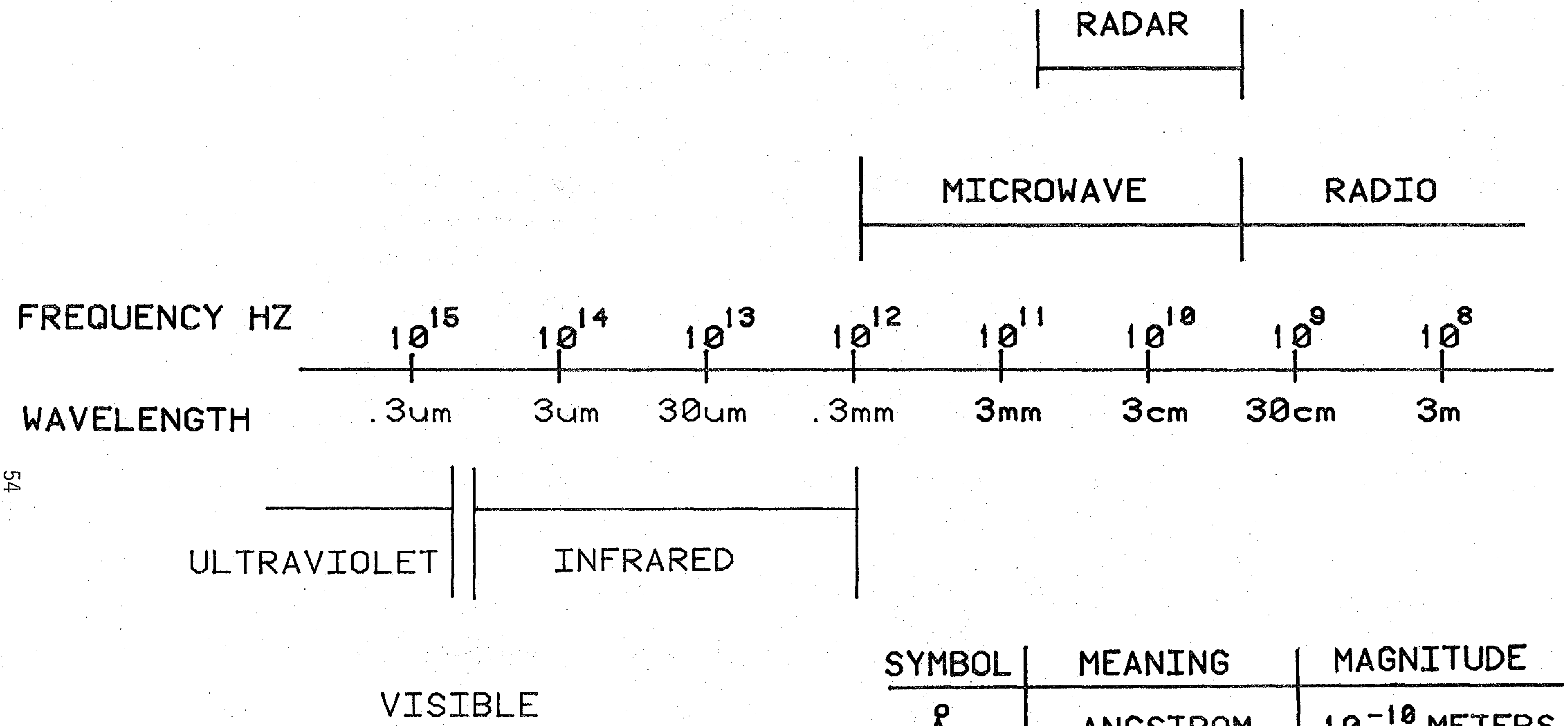
c = SPEED OF LIGHT = 3×10^8 m/sec

$\lambda = c/f$

m = METERS = 39.4 INCHES

Figure 2. Electromagnetic Waves

ELECTROMAGNETIC SPECTRUM



SYMBOL	MEANING	MAGNITUDE
Å	ANGSTROM	10^{-10} METERS
nm	NANOMETERS	10^{-9} METERS
µm	MICROMETERS	10^{-6} METERS
mm	MILLIMETERS	10^{-3} METERS
cm	CENTIMETERS	10^{-2} METERS

Figure 3. Electromagnetic Spectrum

VISIBLE AND INFRARED SPECTRUM

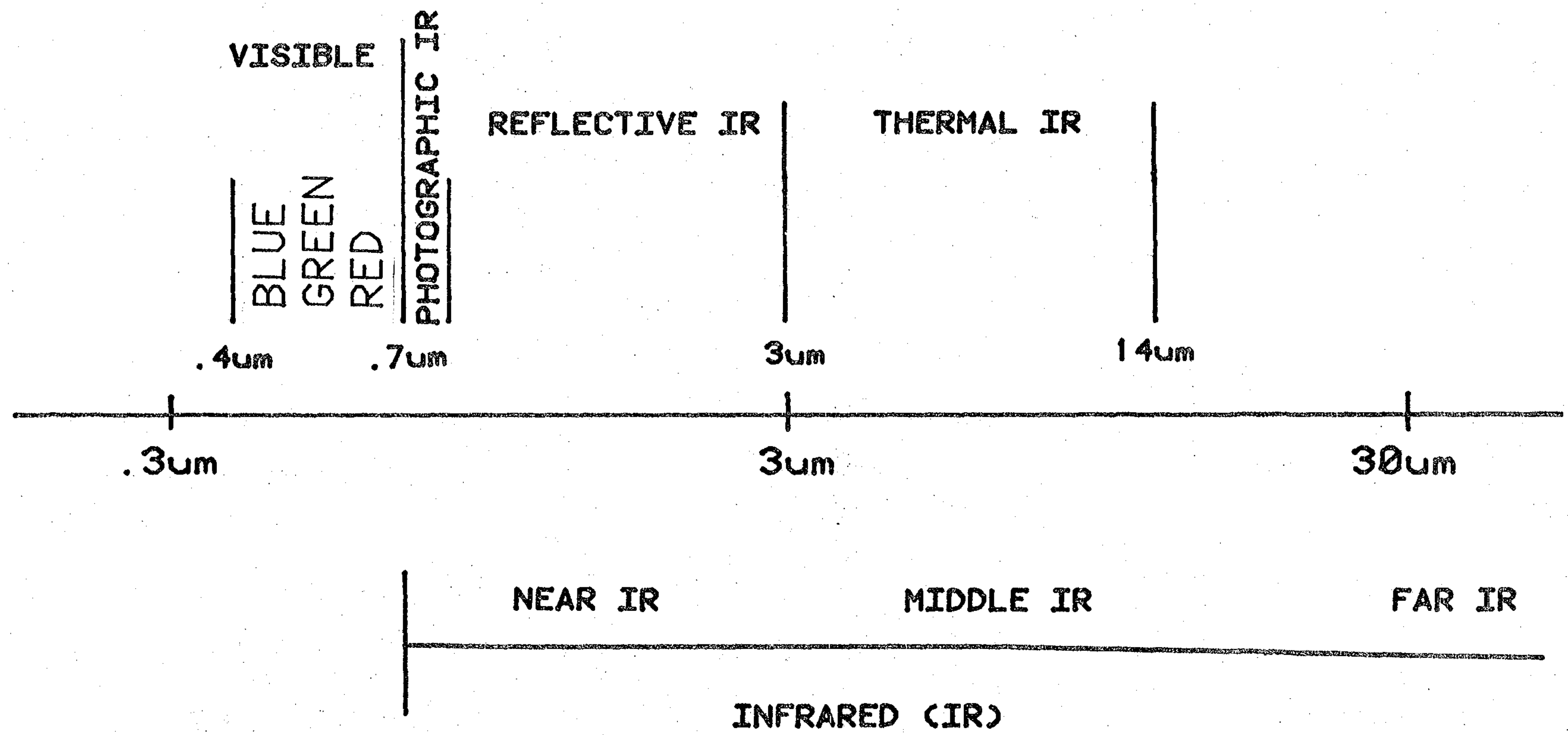


Figure 4. Visible and Infrared Portion of the Electromagnetic Spectrum

SOURCES OF ELECTROMAGNETIC RADIATION

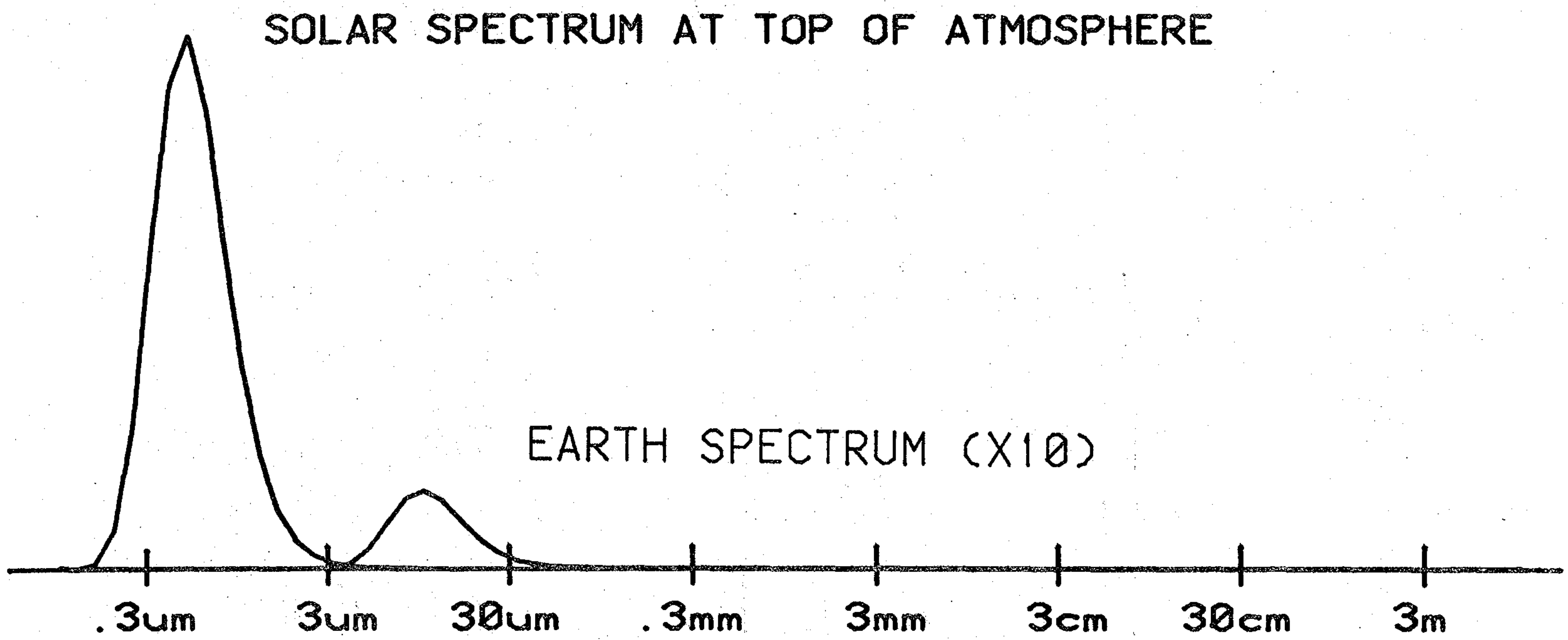


Figure 5. Primary Natural Sources of Electromagnetic Energy

ATMOSPHERIC TRANSMISSION FUNCTION

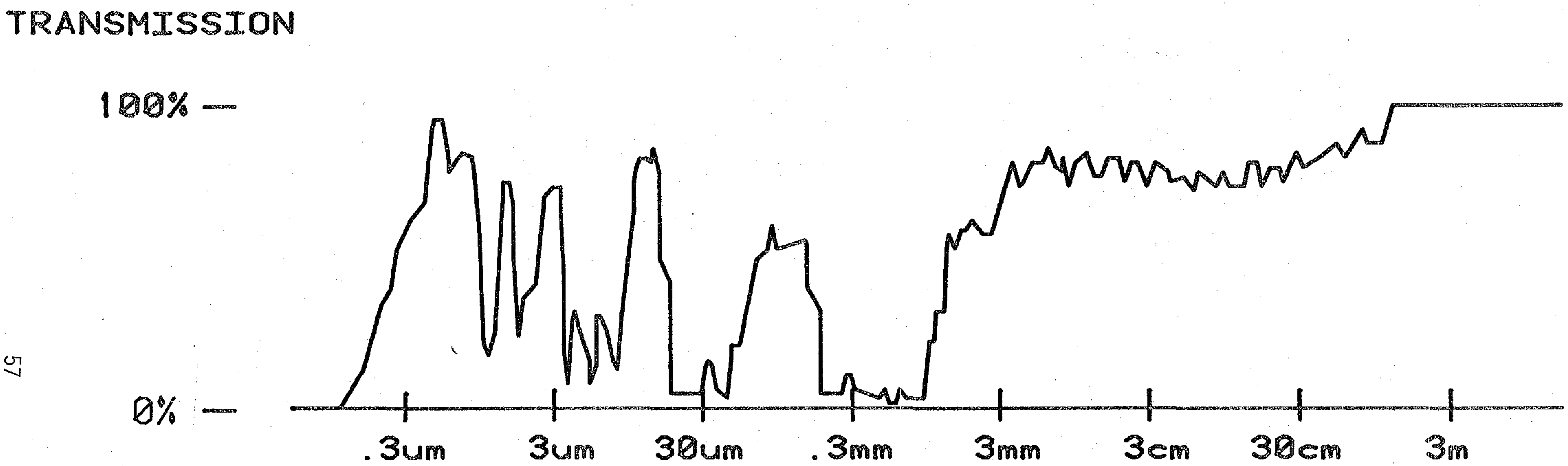


Figure 6. Atmospheric Transmission of Electromagnetic Radiation

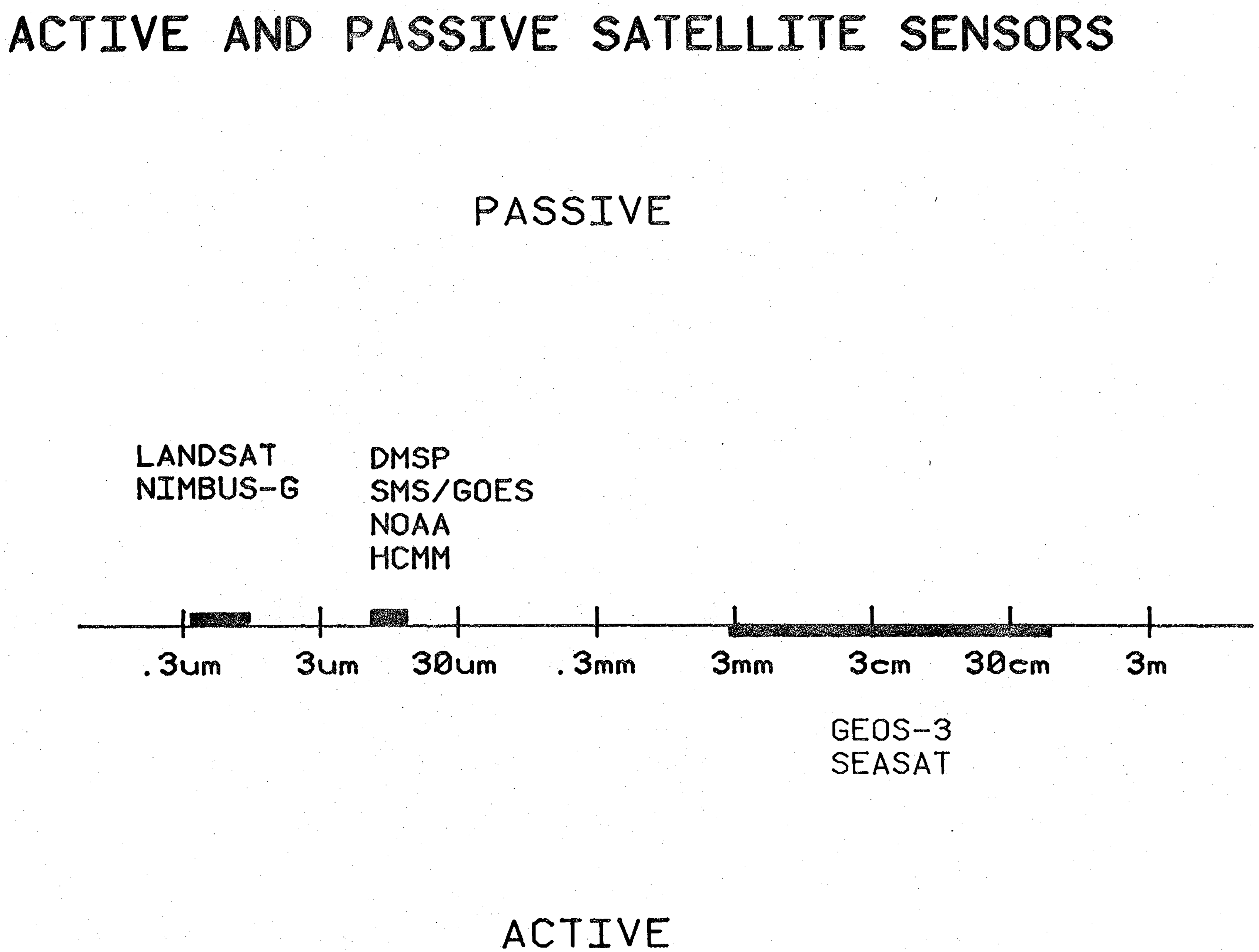


Figure 7. Environmental Satellites Versus the Region of the Electromagnetic Spectrum Viewed by the Satellite's Primary Sensor(s)

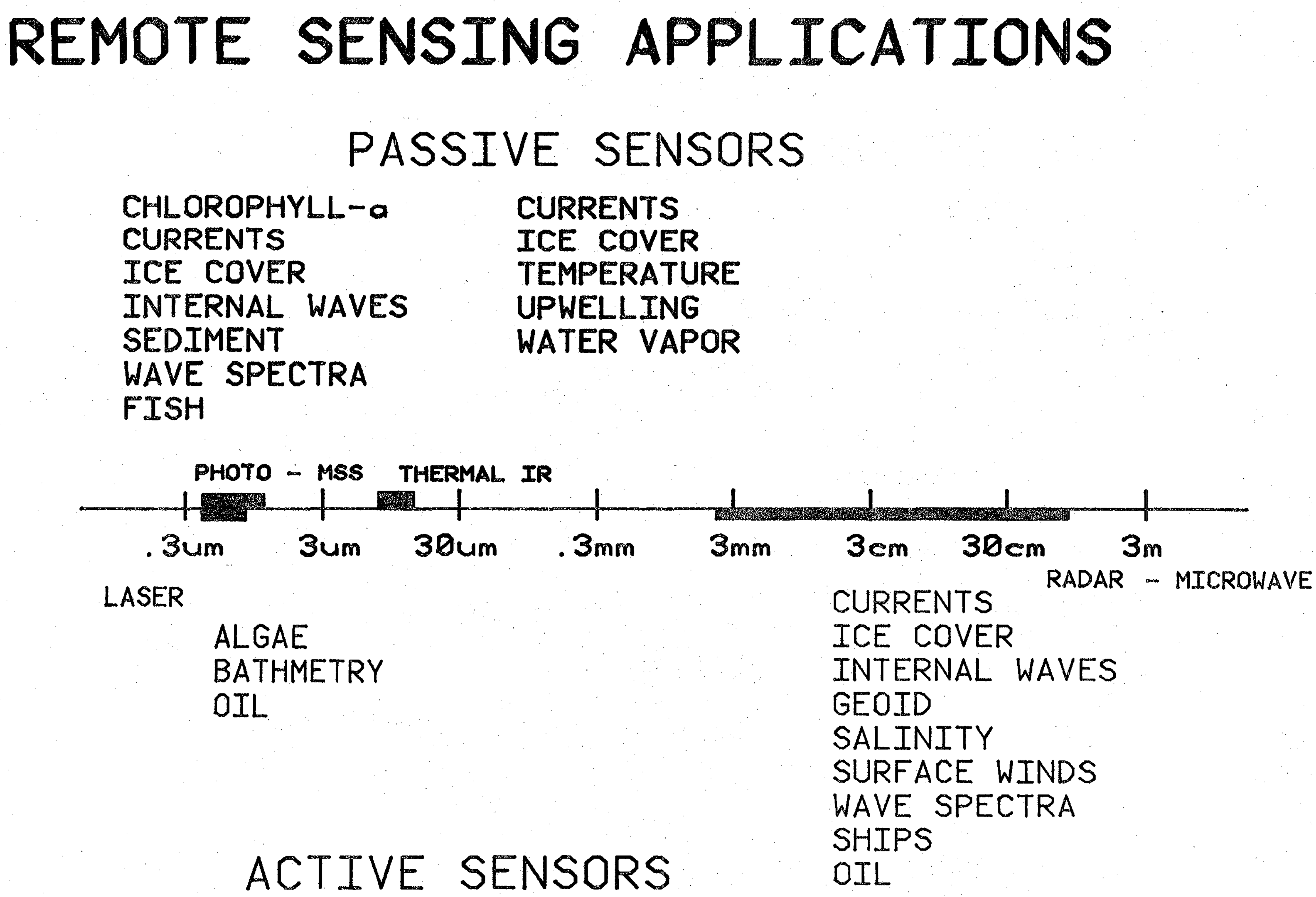


Figure 8. Applications Versus the Region of the Spectrum Employed in the Application

IMAGE FORMATION

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The complex processes involved in image formation are of direct concern to the photographic interpreter who must extract useful information from the imagery. If we confine ourselves to image-forming systems that produce pictorial type imagery, there are only three basic types to consider: cameras, line scanners, and radars. Imagery formed in each of these systems is nothing more nor less than a graphic record of energy intensity. Thus, the interpretation problem reduces itself to an interpretation of the differences in energy intensity recorded in different parts of the image.

Image forming systems record the intensity of electromagnetic energy reaching the sensor from a particular direction at a particular time. However, no one sensor is sensitive to the entire spectrum of electromagnetic radiations and differences in spectral range give specific characteristics to each image-forming system. Since the spectral ranges of different systems often overlap, it seems appropriate to review some of the properties of electromagnetic energy before going on to specific treatment of the individual image-forming systems.

The Electromagnetic Spectrum

Electromagnetic energy travels as transverse waves and requires no particular medium for its propagation. These radiations form a continuous spectrum of wavelengths (or frequencies) and include cosmic rays, gamma rays, X-rays, light, infrared radiations, radio waves, and electric waves. A graphic portrayal of the electromagnetic spectrum is presented in Figure 1 with the approximate spectral range of the three types of image-forming systems indicated along the right hand side. Notice that visible light represents a very small part of the total range of electromagnetic radiations.

From a geometrical point of view, electromagnetic energy is considered as traveling in straight lines within any one medium, and we commonly speak in terms of rays. Now, if a ray traveling in one medium encounters a medium of different effective density, its path will be altered. The form of the alteration varies with the wavelength of the energy and the properties of the two media but will fall into one, or a combination of three categories. The rays may be reflected at the interface, absorbed in the second medium, or refracted and transmitted through the second medium. In many cases all

*Abstracted with modification from "Elements of Image Interpretation".

all three effects operate on a single ray with some of the energy being reflected, some absorbed, and some transmitted (Figure 2).

Relection

Reflected rays "bounce off" of the reflector at the same angle they approach it, for the angle of incidence is always equal to the angle of reflectance (Fig. 3). When the reflector has a smooth surface, as in Figure 3a, rays that are parallel at incidence will still be parallel after reflection, and specular reflection results. When the surface is rough, as in Figure 3b, the angle of reflection still equals the angle of incidence for each ray, but the rays are reflected in different directions, because of the surface irregularities, giving rise to diffuse reflectance. At this point it is natural to ask: How smooth is smooth? The answer depends upon the wavelength of the energy being considered, for electromagnetic waves tend to treat a surface as smooth as long as the surface irregularities are smaller than about one-quarter of their wavelength.

Absorption

Absorption is a commonly observed phenomenon in the visible part of the spectrum. The color of a piece of green glass results from the fact that the glass absorbs those wavelengths that create the visible appearance of blue and red, and green is what is left. Absorption is important in remote sensing for it is the basis for many of the filters used to limit the spectral range of the sensing system.

Refraction

Refraction results when the velocity of electromagnetic energy changes when it passes from one medium to another of different effective density. In air, its velocity is approximately 186,000 miles per second, but it slows down whenever it enters a medium of higher density. Such changes in speed cause a change in direction of any wave motion with the wave being refracted (or bent) towards the normal to the surface of the interface when velocity slows, and away from the normal to the interface when it accelerates. This is illustrated in Figure 2 where some of the incident rays are refracted towards the normal when entering the glass and away from the normal on leaving the glass and reentering air.

The amount of refraction which will occur at any interface varies with the wavelength of the incident energy,short wavelengths being refracted more than the longer ones. This is why a beam of white light passing through a prism can produce a colored spectrum on a screen placed behind the prism, as in Figure 4. As indicated in the figure, refraction is not limited to visible light.

Reflection, absorption, and refraction all influence images formed by remote sensors. Since the magnitude of each effect varies with wave length, and the influence they exert on the imagery will also vary with wave length and, hence, will vary from one image-forming system to another. These effects will be considered in subsequent discussions of image formation in each of the three basic sensor types.

Before turning to detailed considerations of image formation by sensor type, recall that electromagnetic radiations move, and move dynamically. Our consideration of them in image formation must be dynamic, too, for energy flow is what the sensors actually detect. The path of energy from its source to the sensor is complex, resembling an obstacle course with reflection, absorption, and refraction continuously at work. The following discussions treat each image-forming system in terms of this complex path, called the energy flow profile (Olson 1963).

The Energy Flow Profile in a Camera System

A generalized energy flow profile for a camera system mounted in an orbiting satellite is shown in Figure 5. The energy source is assumed to be the sun. Energy must flow through spatial debris and atmospheric components between the sun and objects on earth, be reflected by these objects, flow through the atmosphere and spatial debris again on its path back to the satellite, and pass through a camera window to enter the satellite, before finally entering the camera through the camera filter and lens system. The energy flow profile really does not end until the energy strikes the light-sensitive emulsion, or film, on the camera focal plane.

Careful consideration of Figure 5 should lead to the realization that the basic pattern of energy flow is not changed by moving the camera. Changes in camera position merely shorten or lengthen the path of the reflected energy.

Form this brief introduction to the energy flow profile, we can proceed to detailed consideration of some of the important factors that affect the quantity and quality of energy at all succeeding points in the profile.

The energy source

Anything that generates electromagnetic radiations with wavelengths between 380 and 900 namometers can be used as an energy source in photography. The sun, electric lights, explosives, flares, glowing charcoal, and luminescent plants and animals all give off visible radiations and are potential energy sources. All of those named are continuous sources which give off energy with wavelengths that vary continuously over some part of the total spectrum, as opposed to line sources (mostly gases) that radiate at only one or two specific wavelengths and produce line spectra. The list includes the most important sources of the photographic interpreter. The sun is the most important source of energy for camera systems, but various electric lights and pyrotechnic devices also deserve mention.

The sun. Solar energy forms a continuous spectrum of radiations that vary in intensity from one part of the spectrum to another. Peak radiation occurs in the visible spectrum (Figure 6) which we refer to as light, but significant amounts of ultraviolet and infrared energy are also received from the sun. Solar energy is so intense that photographs can be obtained even when the camera system is filtered so that it is sensitive to only a narrow band of wavelengths. Excellent aerial photographs have been obtained from solar energy using a spectral band only 50 millimicrons wide. This high intensity of solar radiation permits selective filtering in the ultraviolet, visible, and infrared regions and provides opportunities for enhancing certain types of image detail.

Electric lights. Flash bulbs, photoflood lights, household lights, and street lights are examples of incandescent sources often used in photography. With the exception of some types of flash bulbs and photofloods, all of these sources produce visible energy that is relatively yellow when compared with solar radiation. This difference is seldom significant, except in color photography, and the most serious drawback to these sources is their generally low intensity which results in rapid degradation of images of objects located some distance from the source.

The path from source to object

Energy radiated by any source must travel across a distance before reaching a camera. In most cases the energy travels to an object and that portion of the energy that is reflected then travels on towards the camera. The resulting path is a broken one, and our treatment of it will be simplified by breaking the path in the same way. This discussion will deal exclusively with solar energy, but the analogy to other light sources is apparent.

Considering only the satellites and expended rockets sailing around in space, it is obvious that some of the energy leaving the sun will never reach the earth. Spatial particles of all kinds intercept some solar radiations which results in a net loss of energy from the profile. These losses are believed relatively minor compared to atmospheric losses, however.

Several factors result in significant energy loss within the atmosphere, and the loss increases as the length of the atmospheric path increases, as it does towards sunset every day. Conversely, the path decreases as the altitude above sea level increases. The net effect of these changes is indicated by the six curves in Figure 6. Curve number one represents the approximate distribution of solar energy outside the atmosphere; curve number two indicates the distribution of incident energy at noon for a point in Chile, located on a mountain top 7,435 feet above sea level. The last four curves reveal the changing radiation levels as solar altitude decreases for a point close to sea level. As the amount of atmospheric travel increases, the total energy reaching the ground decreases the wavelength of maximum radiation increases (and the visible effect is a yellowing or reddening as at sunset). Some of the principal factors causing this loss of energy are discussed in the following paragraphs.

Ozone. In the upper atmosphere, energy from the sun encounters a layer of ozone, a molecular oxygen that is opaque to energy with wavelengths shorter than about 3,000 Ångstroms. The loss at the ozone layer is responsible for the sharp drop in energy at 0.3 microns exhibited by curves 2 through 6 of Figure 6.

Water. Water in the atmosphere produces an effect commonly referred to as haze and is a major factor in atmospheric attenuation of solar energy. Water droplets refract light much as the prism shown in Figure 4. Shorter wavelengths are refracted most, (Figure 7) and this scattering, or haze effect, declines rapidly at wavelengths longer than 4,750 Ångstroms. At wavelengths between 7,000 and 10,000 Ångstroms, the effect of haze is almost negligible.

Unfortunately, atmospheric haze is not constant but varies with weather conditions, altitude, and a multitude of other factors which often interact. Typical variations in haze effects on different days are shown in Figure 8.

Clouds. When atmospheric water condenses into clouds the reduction in energy reaching the earth is quite significant but varies from one type of cloud to another. Scattered cumulus clouds tend to form in the afternoon and interfer with aerial photography, but low stratus decks can make aerial photography practically impossible. For some purposes, however, the diffuse lighting under a high, thin overcast creates weak shadow conditions which facilitate the interpretation of certain information from aerial photographs.

Smoke and smog. Smoke and smog conditions can completely obscure an area but result in energy loss from the profile even when less severe. Small amounts of smoke in the air scatter incoming energy with the magnitude of the effect controlled by the chemical composition and size of the smoke particles.

To sum up what has happened, stop and consider the energy incident upon the atmosphere. Some of it has been absorbed and is lost from the energy flow profile and some has been scattered and apparently lost but could reenter the profile on a more-or-less random line. This scattered energy is predominately of the shorter visible wavelengths and can be considered "noise" if it actually enters the camera. The energy that successfully negotiates the obstacle course from source to object undergoes further modifications on reflection at the object.

Reflection at the object

Energy striking an object may be absorbed, transmitted, or reflected but energy reflected from an object may pass back through the atmosphere and space, and, if a camera is placed in the right position, the camera may intercept some of this reflected energy. In most cases, reflected energy is the energy that produces the photographic record.

Objects differ in their reflectivity. Some produce specular reflections and some diffuse reflections. Moreover, each type of object reflects some wavelengths more strongly than others (Figure 9). Thus, the nature of the object controls both the quantity and quality of light reflected from it. A basic understanding of light reflectance characteristics of objects shown in aerial photography is a tremendous help in photointerpretation.

<u>The path from object to camera</u>

Energy reflected from terrestrial objects must pass through at least some of the atmosphere, and possibly into space, before reaching the camera. Because this part of the energy flow profile includes the same attenuating factors that influenced the incoming solar radiation, the reflected energy will reach the camera with a lower intensity than it had as it left the surface of the reflecting object. This attenuation increases with increasing atmospheric travel and is a more severe obstacle in high altitude than low altitude photography.

However, energy reaching the camera is not confined to the light reflected from terrestrial objects. Some of the light scattered by atmospheric haze reenters the energy flow profile and reaches the camera. This scattered light increases the total energy reaching the camera and reduces the relative difference in intensity of the energy reflected from different objects on earth. The amount of scattered light reaching the camera tends to increase with altitude and is largely responsible for the relatively poor tonal contrast usually obtained in high altitude and satellite photography. Thus, scattered light plays the same role in photography that static plays in radio reception.

<u>The energy path in the camera system</u>

Energy reaching the camera may encounter a series of camera windows, filters, lenses and other camera elements as it enters the camera. These components are considered parts of the overall camera system. Since they are man-made, their properties and resulting effects can be controlled. This opportunity for control is virtually non-existent in any other part of the energy flow profile. Because of this, the camera system deserves careful consideration by the photointerpreter.

Camera windows. Camera windows are transparent sheets of plexiglass, glass, or other material relatively close to the camera but placed between the camera and the objects being photographed. The window of a building or the windshield of an automobile become camera windows when a photograph is taken through them. In aircraft and satellites camera windows may be placed over the camera opening to reduce wind pressures in the vehicle, to protect the crew or other equipment from external conditions, or to maintain the structural strength of the vehicle. Regardless of the reason for its presence, energy entering the camera must pass through the camera window if one is present. While camera windows are never perfectly transparent, energy absorbed by them is usually ignored in photointerpretation. While this may be permissible with most panchromatic and near-infrared photography, some camera windows absorb significant amounts of energy at certain wavelengths and may produce significant effects on photographs taken through them.

Filters. Filters are similar to camera windows in several respects but are used to produce a definite effect on the energy flow profile. Filters are thin, transparent materials that absorb energy at some wavelengths and transmit energy at others. They are essentially subtractive and cannot add energy to the profile. The haze-filter commonly used in aerial photography is virtually opaque to energy with wavelengths shorter than 500 millimicrons and is called a minus-blue filter. Its function is to minimize the attenuating effects of scattered blue light, described in preceding paragraphs, by absorbing this light or subtracting it from the profile. Transmission data for six Wratten filters applicable to aerial photography are presented in Figure 10. Filters are usually made of thin layers of colored gelatin mounted in glass, or of specially colored glass, and generally are attached to the outside of the camera directly over the outer lens element.

Aerial cameras. Problems associated with photography from aircraft have led to aerial cameras with specialized components. The need to photograph large areas in a single exposure was solved by providing large format size. To hold the large pieces of flexible film flat during exposure, aerial cameras are equipped with a vacuum system built into the camera focal plane. Once an exposure has been made, however, the vacuum must be broken so that the film can be advanced without scratching.

Most aerial cameras are electrically operated and incorporate a series of motors and controls that can release the vacuum, advance the film, cock the shutter, and close the vacuum system between exposures. When properly connected, these operations are performed automatically as soon as the shutter is released. In some aerial cameras producing square photographs on 9 1/2 inch wide film, time required to complete these recycling operations is only 0.3 seconds.

To insure complete coverage of an area, aerial photographs are taken so that the ground coverage of any one photograph overlaps that of the preceding and succeeding photographs. This requires accurate timing of the interval between exposures, based on aircraft speed and altitude. This task is usually handled by an electrical intervalometer, which is built into some cameras but is a separate component attached to many others.

This concludes the discussion of the separate parts of the energy flow profile in a camera system. Although the discussion has been brief, the importance of a thorough understanding of this profile should not be minimized. Seemingly, minor changes in one part of the energy flow profile in a camera system can exert major changes in the resulting photograph. Energy striking the light-sensitive emulsion on the focal plane of a camera has been altered considerably in its journey from the energy source. Figure 11 shows the path of two solar rays striking the earth and the path of the reflected rays up to a camera in an orbiting satellite. One ray strikes the smooth surface of the Mississippi River and is reflected specularly to the camera. The second ray strikes a rough earth surface and is reflected diffusely. Some of the diffuse reflectance reaches the camera. The energy reaching the camera from the surface of the river will have a much higher intensity than the diffuse ray from the ground. Because of this, a positive print would show this spot on the river in lighter tones than the ground surface.

If the satellite moves to the position shown in Figure 12 and takes a second picture, the specular reflection from the river will vanish into space without entering the camera. However, some of the diffuse reflection from the ground will still reach the camera. Now, the ground surface will appear on the positive print in lighter tones than the water.

The Energy Flow Profile in Line Scanning Systems

The generalized energy flow profile shown in Figure 5 is applicable to line scanners as well as cameras, for line scanners can produce graphic records from visible light. In fact, the energy flow profile for a line scanning system sensitive to visible light is identical with the profile just described for a camera system, up to the point where the energy reaches the camera lens.

Image Formation in a Line Scanner

Line-scanning devices are more closely related to television cameras than to conventional photographic systems. As with television, the images produced by line scanners closely resemble photographs. This resemblance is sometimes confusing and often misleading. Line scanners have three principle components: an optical-mechanical scanning system, a detector, and a signal processing and display system.

The Optical-Mechanical Scanning System. This system includes a series of front-surfaced mirrors which concentrate light and/or infrared energy at the focus of a parabolic mirror. Limiting apertures are deliberately constructed to restrict the instantaneous field-of-view of the optical system to a very small solid angle -- 3 milliradians, for example. Since a 3-milliradian field-of-view is restricted to an area 3 ft. across for each 1,000 ft. of distance from scanner to object, the focusing optics must be moved to obtain coverage of larger areas. This is accomplished by mounting the collecting mirror on a rotating shaft. As the shaft and mirror rotate, the field-of-view moves and a narrow strip of terrain is scanned. When mounted in an aircraft with the scanning direction perpendicular to the direction of flight, the forward motion of the aircraft and the scanning action of the optical system permit a large area of terrain to be scanned in a short period of time (Figure 13).

The Detector. A detecting device is mounted at the focus of the parabolic mirror. Its function is to transform the energy focused upon it into an electric signal which can be transmitted to the signal processing and display system. Thus, the detector is a transducer which converts energy from one form to another. As the field-of-view moves, it scans terrain objects of different emittance or reflectance characteristics, and the amount of energy focused on the detector varies. The strength of the electric current generated varies in direct proportion to the strength of the signal focused on the detector.

A major advantage of line-scanning systems stems from the many types of detectors that can be used in them. Some are sensitive to ultraviolet wavelengths, others to energy in the visible spectrum, and others to wavelengths out to 20 micrometers, but no single detector is sensitive over this entire spectral range.

Photomulitiliers can be used to record visible and ultraviolet radiation. By appropriate filtering, the actual spectral range can be sharply restricted when desired. Because of the amplification capability inherent in line-scanning systems, it is possible to obtain usable imagery from the energy in a wavelength band only 20 nanometers wide. More often, however, the spectral range will include a band of wavelengths 40 or more nanometers wide. In either case, the energy flow profile will be essentially the same as for a camera system, other things being equal.

A major use of line-scanning systems in aerial reconnaissance is associated with their infrared detecting capabilities. Several detectors are available, but the best of these require cryogenic cooling, for they become sensitive enough for aerial reconnaissance use only when cooled below 90°K (-183°C). Liquid nitrogen and liquid helium are used in achieving these temperatures, and the physical and mechanical requirements imposed by the cooling process make infrared line-scanning systems formidable devices. At one time the two most common infrared detectors were Indium Antimonide and specially treated forms of Germanium. With any of these detectors, appropriate filters permit narrowing the total spectral range when desired.

The Signal Processing and Display System

This system amplifies the relatively weak signals from the detector and then uses the amplified signals to produce a visible image. The visible image can be produced on a cathode ray tube (as with normal television) or through a glowtube printer as shown schematically in Figure 14. In a glow-tube printer the amplified electrical signals from the detector activate an incandescent light source having a very rapid reaction time. The light source (or glow-tube) flickers as the signal varies. A second optical system synchronized with the scanning optics focuses the flickering output of the glow-tube onto a strip of photographic film which moves through the printer at a rate which compensates for the forward motion of the aircraft. Once the negative has been processed, a permanent record of the glow-tube output is available with each scan adjacent to the scan which preceded it. The resulting imagery is a "strip map".

Since the detector output is an electric current, it is possible to record this output before the signal reaches the glow-tube printer. When recorded on magnetic tape, a single set of signals can be used in ground-based equipment to generate repeated series of imagery. During this "playback" process, it is possible to change the electronic controls before each run. This makes it possible to accentuate or suppress certain types of targets, and provides an electronic image-enhancement capability that can be very useful in analyzing questionable image details.

Any piece of equipment having numerous, synchronous moving parts is subject to errors of adjustment. These errors are often significant with line-scanning systems. Those desiring information on such errors may find a paper by Hirsch (1965b).

The energy flow profile in thermal infrared systems

Growing use of infrared sensing systems in natural resource inventory makes it appropriate to consider thermal infrared sensing at greater length. Many of the factors affecting camera systems and light sensitive line scanners are not of great importance with thermal infrared systems, but other factors come into play that we have ignored until now. Since any energy flow profile must start with an energy source, our consideration of thermal infrared systems will begin with a look at sources of infrared energy.

Infrared sources. Any substance whose temperature is above absolute zero ($-273^{\circ}C$ or $0^{\circ}K$) emits infrared radiation. The power of the energy emitted depends upon the temperature and the emissivity of the object surface and is defined by the Stefan-Boltzmann Law:

$$M = \sigma \cdot \varepsilon \cdot T^4$$

Where M = exitance (power given off) in Watts per cm^2

σ = Stefan-Boltzmann constant

ε = emissivity (ratio of exitance of real surface to exitance of the surface of a perfect black body at the same temperature)

T = absolute temperature of the surface in $^{\circ}K$

Of the two variable factors, temperature is usually most important, for the exitance (M) is nearly proportional to the fourth power of the absolute temperature (T), but the first power of the emissivity (ε). Since the absolute temperature under ambient summer conditions is near 300°K and emissivity ranges from zero to one, small changes in temperature can result in large changes in exitance. Emissivity is essentially governed by surface material and texture (Suits, 1960).

Gases usually radiate in several narrow spectral bands and are said to have line spectra, but most objects of interest to image interpreters radiate in continuous spectra having a common form. This form is similar to that of the theoretically perfect emitter, called a black body. While no true black body emitter is known, one can be approximated. This approximation serves as a valuable reference. Theoretical radiation curves for a perfect black body at temperatures of 300, 400, 500, and 600°K are shown in Figure 15. The curve for 300°K approximates the spectral exitance of black soil, a charred log, or similar materials at a temperature of approximately 80°F.

Infrared systems work with natural emissions from all objects. Thus, for practical purposes the energy flow profile for an infrared sensor starts at the object and is not affected by the obstacle course that solar energy must traverse before striking an object on earth. The path from the object to the detector, however, deserves the attention of infrared interpreters.

<u>The path from object to sensor</u>. Data presented during our consideration of camera systems showed that water vapor and other components of the atmosphere reduce the amount of energy reaching the ground, and also reduce the amount of reflected energy reaching the camera. These effects are not constant, but vary with wavelength and from day to day. Similar variations occur in the infrared wavelengths.

Water vapor and carbon dioxide have distinct absorption bands at some infrared wavelengths and atmospheric gases radiate at others. The net effect of this is a filtering of infrared energy during atmospheric transmission. This filtering is so severe that the atmosphere is nearly opaque at some wavelengths. At other wavelengths, however, the atmosphere is highly transparent, and we commonly refer to these areas as infrared windows (Figure 16). Infrared reconnaissance is essentially confined to the areas of the infrared windows.

Day to day variations in infrared sensing effectiveness are observed repeatedly, but are not adequately understood. Poor results are often obtained when relative humidities are high, and clouds are opaque to infrared radiation. The fact that infrared scanning systems have shown a marked ability to penetrate smoke (Hirsch 1963, 1965a, 1965b) tends to give added weight to the significance of liquid water in the atmosphere as a major factor reducing effectiveness of infrared reconnaissance systems.

The Energy Flow Profile in Radar Systems

Radar is a contraction of the phrase Radio Detection and Ranging. Radar systems transmit bursts of radio frequency energy and measure the time required for the transmitted energy to travel the round trip distance from the radar to a target. Radar transmissions travel at the speed of light and complete the round trip to a target one nautical mile away in approximately 12.4 microseconds (millionths of a second).

A generalized energy flow profile for a radar would be quite similar to that shown in Figure 5 if the energy source and the recording system (camera in Figure 5) were at the same location. Thus, the basic energy flow profile for radar systems closely parallels the profile for a camera system.

The energy source

Radar systems contain transmitters that generate short, high intensity bursts of radio frequency energy. After each burst, or pulse, of energy is transmitted, the radar transmitter shuts off, and the receiver "listens" for energy of the same frequency returning to the radar. Systems are available that operate at different frequencies, and some transmit at two different frequencies. Radar systems are usually grouped into designated bands of frequencies (Table 1). Longer wavelength (lower frequency) radars tend to have better vegetation penetration capabilities than shorter wavelength systems.

Some radars transmit plane polarized radiation, with the electric vector oscillating either horizontally or vertically. These same radars usually have two receivers for each transmitter; one records energy returning with the same polarization, and the other records energy returning with a 90-degree change in polarization. Such systems usually transmit a horizontally polarized signal and have horizontally polarized and vertically polarized receivers. The resulting two images are designated as HH (horizontally polarized, and HV (vertically polarized).

Even though carefully designed and calibrated to generate energy at a designated frequency and wavelength, conventional transmitters yield a narrow band of frequencies and require a small time interval to build up to full power and have a short transmit delay time at the end of the pulse. All of this results in a pulse containing some variations in frequency (and wavelength) with wave trains starting at slightly different times. If we attempted to diagram such a pulse, the overlap in wave forms because of frequency and time differences would produce a nearly incoherent diagram. Such a pulse is termed incoherent, in contrast to a pulse from a laser transmitter which generates a signal frequency with all wave trains starting at the same instant.

Coherent radars, which may be polarized or non-polarized, have special advantages which we shall discover later.

Beam width. Reconnaissance radars have long antennae, often stretching the full length of the aircraft, and transmit a beam of energy perpendicular to the flight direction of the aircrat. Successive pulses are transmitted as the aircraft moves along its ground track, permitting the system to build up a continuous strip of imagery (line by line) in a manner somewhat similar to that of a line scanner. Radars, however, only look to the side - - not directly beneath the aircraft - - and are referred to as "side-looking-airborne-radars", or SLAR, for short.

The actual width of the beam is determined by the characteristics of the antenna. Narrow beams concentrate more energy on the target (other things being equal) and increase the strength of the returning signal. Narrow beams can also provide better resolution parallel to the aircraft track then can a wider beam. For example, when two objects at the same range (distance from the aircraft) are in the radar beam at the same time, the radar will receive the returning signal from both objects simultaneously and may not be able to distinguish between the two returns.

Pulse length. If a transmitter takes one microsecond to transmit a pulse, the leading edge of the pulse will travel approximately 980 feet before the trailing edge leaves the antenna. Therefore, a one microsecond pulse is 980 feet long and its pulse length can be described in terms of either time or distance. No single pulse length is best for all radar uses. Long pulse lengths increase the amount of energy striking a target per pulse and increase the probability of detection, but short pulses increase the ability of the radar to resolve as separate targets objects on the same azimuth and close together in range. If the leading edge of a pulse strikes a second object before the center of the pulse passes a first object, then energy reflected from the two targets will merge into one returning signal. It should be noted that pulse length remains constant regardless of range and that range resolution is not dependent upon the total range to the targets.

The path from source to target

Energy at radar frequencies has a pronounced tendency to penetrate atmospheric components that block ultraviolet, visible, and infrared radiations. Thin layers of stratus clouds, which can prevent visual photography and most infrared reconnaissance from above the overcast, are often penetrated by radar systems, but dense cloud banks and thunderstorms are as opaque to radar energy as they to light. Although the fulleexplanation for this variability is not known, penetration ability seems to go up as radar frequency goes down.

Radar energy which will also penetrate considerable quantities of smoke, shows a variation in penetrating ability similar to that with clouds. However, if the smoke contains metallic particles, radar penetration falls off sharply.

Since radar energy travels in straight lines, objects hidden behind hills or other objects will not be illuminated by the radar beam. Radar shadows can be more pronounced than solar shadows, which are illuminated by diffused sky light (which is largely blue). Radar shadows, which are not illuminated by scattered radio frequency energy, can be perticularly useful, for they help emphasize relatively minor terrain features which are often of great geological interest.

Reflection at the target

Radar wavelengths are considerably longer than those we have discussed before, as much as 100,000 times longer than the wavelength of green light. Considering a rough surface as one that has surface irregularities greater than one-quarter of the wavelength being considered, many surfaces that are rough to visible light, appear smooth when irradiated with radar wavelengths. Radar reflectors supplied in life rafts take advantage of this and employ fine-mesh chicken wire or window screening as radar targets. As long as the mesh diameter is less than one-quarter of the wavelength, radar energy bounces off the reflector as if it were solid sheet metal.

Almost all objects of interest to the interpreter reflect radar energy, while the intensity of the radar return is controlled by target size, target shape, surface material, reference angle and antenna tilt.

Target size. Quite naturally, the larger the target the stronger the radar return it produces, up to the point where the target completely fills the radar beam. Size in this case, can be restated as "proportion of beam intercepted". Height becomes especially important, as does the orientation of the object with respect to the beam. Range, or distance from radar to target, also influences the proportion of the beam intercepted by any given object.

Target shape. Objects with smooth surfaces may be excellent radar reflectors, but unless they are oriented perpendicular to the incident energy, the reflected energy never returns to the radar smooth water surfaces are excellent examples. Because of this, rough objects usually produce stronger radar returns than smooth ones. The best reflectors of all, however, are corner reflectors, which consist of three mutually perpendicular planes. Small corner reflectors are common in most buildings for each window contains several of them, and imperfect corner reflectors occur between the bricks and mortar of brick buildings.

Antenna tilt. Since radar antennas can be tilted through small vertical angles, the amount of energy transmitted towards nearby objects can be increased by tilting the antenna downwards. However, this reduces the amount of energy striking distant objects. Antenna tilt affects the maximum radar return obtainable from both close and distant targets.

The path from target to receiver

The return path which is essentially identical to the incoming one for a radar system, will not be considered in greater detail.

Radar displays

Energy returning to the receiver is transformed into an electrical current and amplified. This amplified signal is applied to a cathode ray tube (CRT) or glow tube where it is transformed again into visible light in much the same way as in a line-scanning system. The visible signal is recorded on photographic film for subsequent interpretation.

Summary

During the discussion in this presentation, we have seen that cameras, line-scanning systems, and radars all utilize electromagnetic radiations for image formation.

Camera systems and light sensitive line-scanners record energy that originates at some source (usually the sun), travels through space and the atmosphere to an object and back through the atmosphere, and possibly space, to the recording device. In each part of the energy flow profile some energy is lost, and these losses influence the final graphic records produced by the system.

Infrared scanning systems differ from visible light systems in the wavelengths of energy recorded and in the fact that the object is the energy source. Thus, the energy flow profile for an infrared scanner starts at the object rather than at the sun or other external energy source.

Radar systems have energy flow profiles that resemble those of light sensitive systems with the energy source and receiver at the same location.

In all these systems a photographic recording system is used to preserve the graphic records for future study and reference. These are the records that the image interpreter must handle.

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Table 1. Wavelength units, their symbols, and equivalents.

Wavelength Unit	Symbol	Equivalent Part of a Meter	Archaic Terms for the same Unit
meter	m		
centimeter	cm	1×10^{-2} m.	
millimeter	mm	1×10^{-3} m.	
micrometer	μm	1×10^{-6} m.	micron
nanometer	nm	1×10^{-9} m.	millimicron
	Å	1×10^{-10} m.	Ångstrom

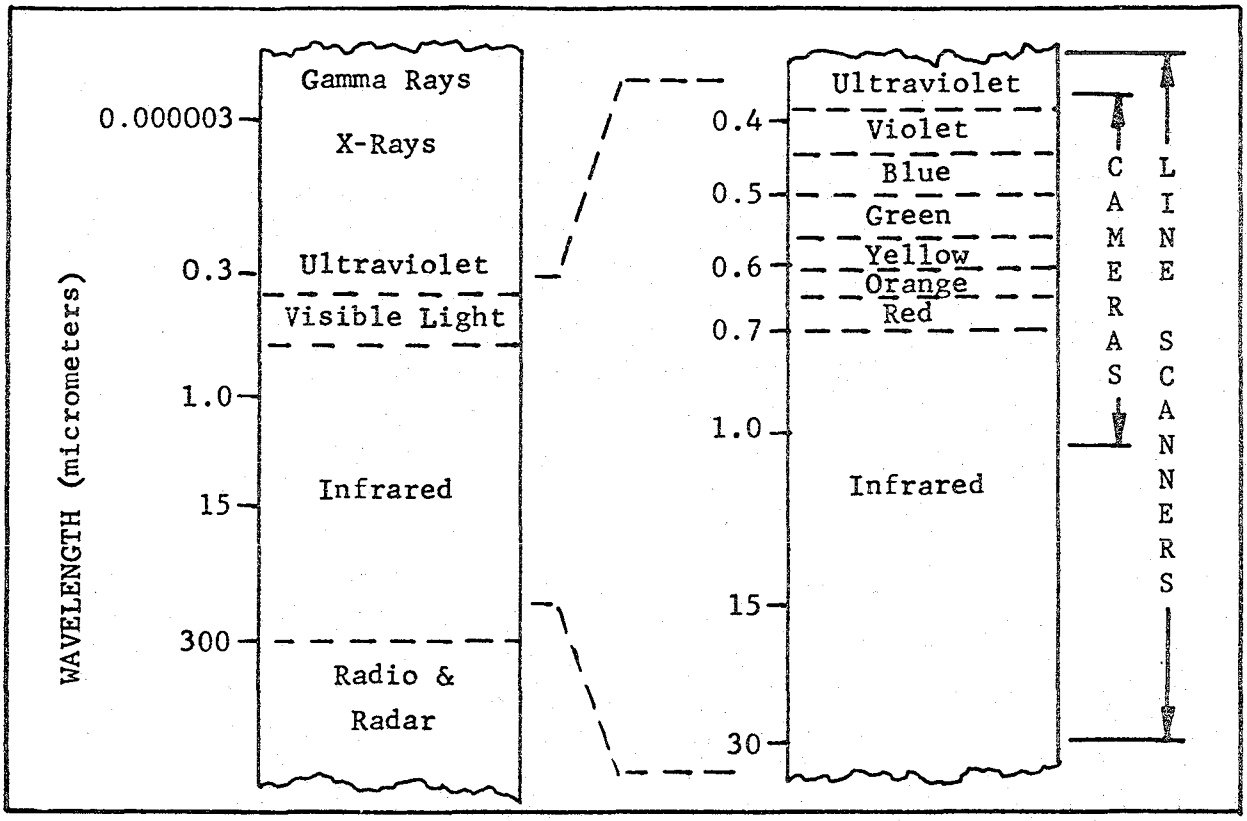


Figure 1. The electromagnetic spectrum and operating regions of some types of remote sensors.

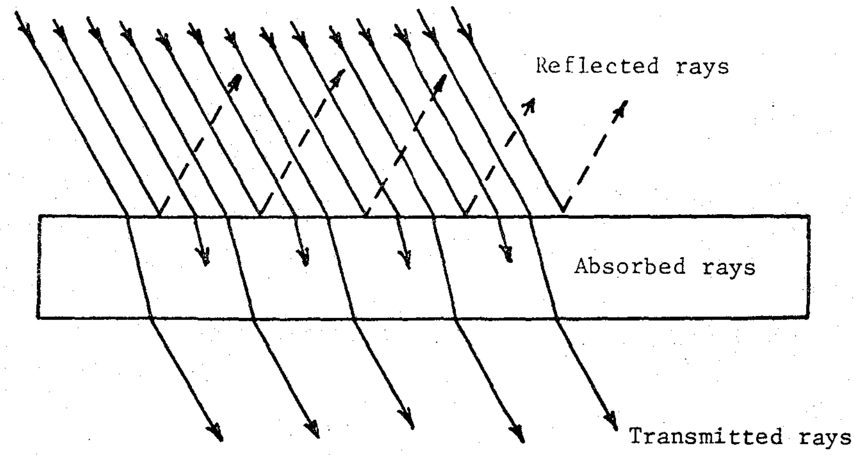


Figure 2. Ray alterations at medium boundaries.

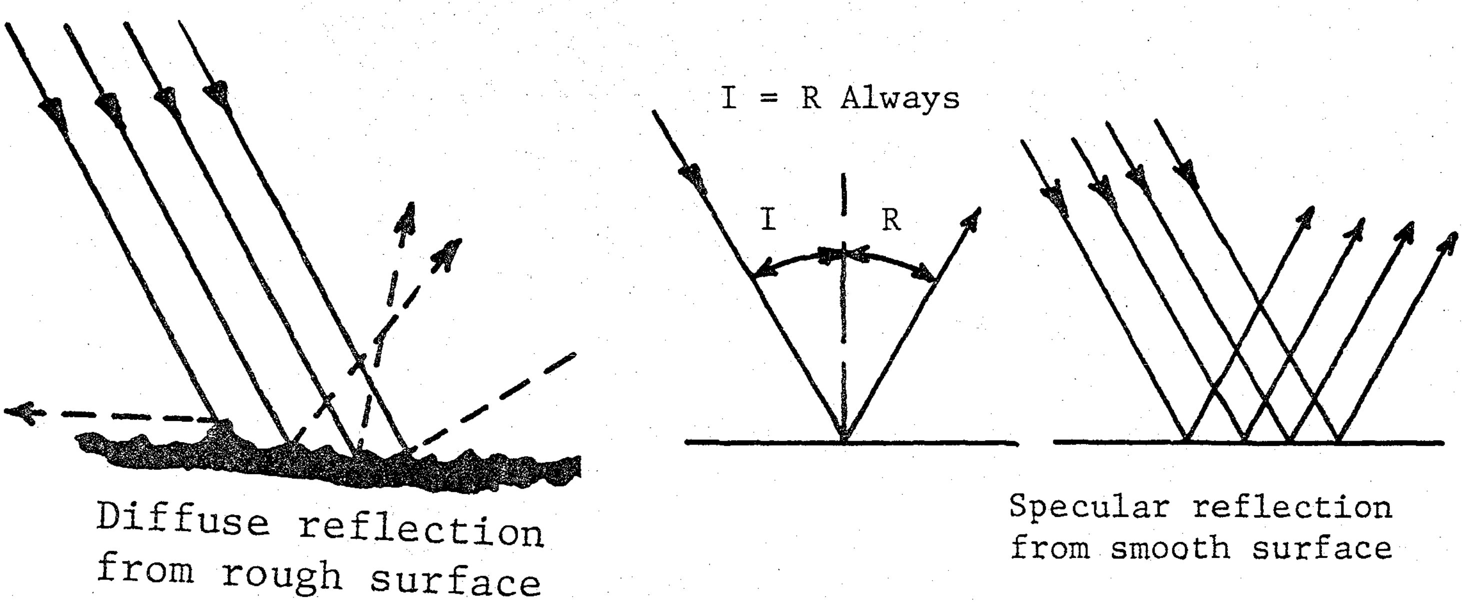


Figure 3a and 3b. Ray reflection.

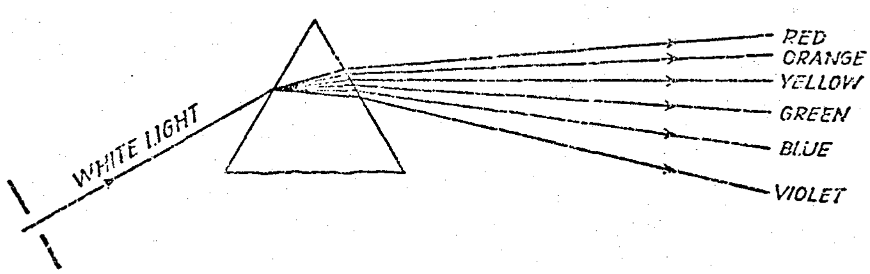


Figure 4. The effect of a prism on white light is due to refraction.

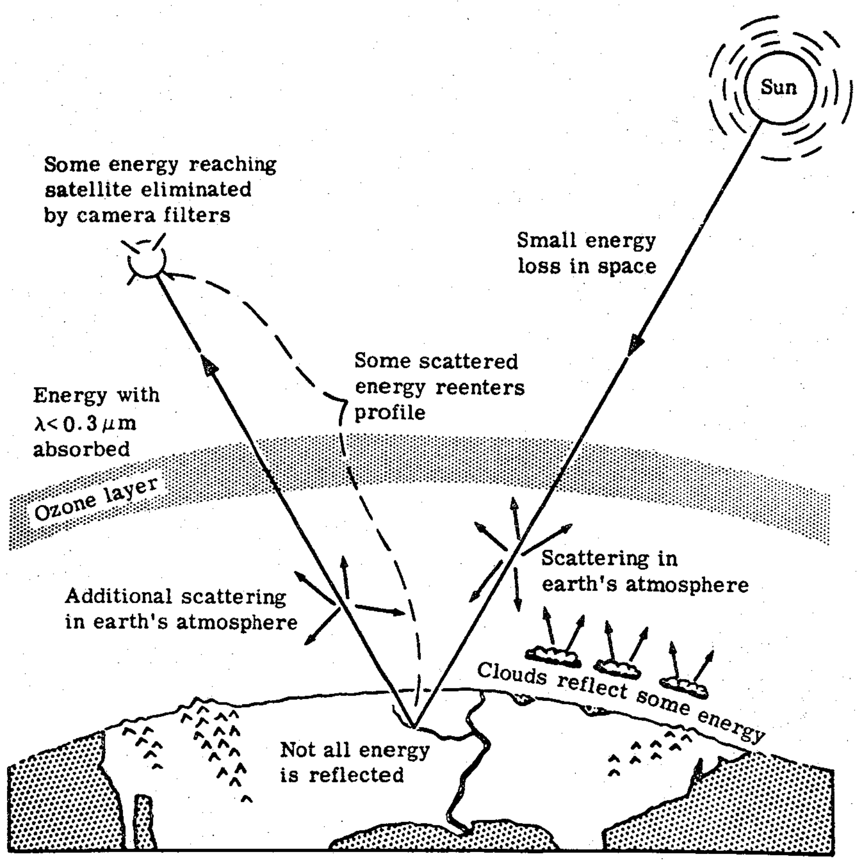


Figure 5. Energy flow profile for satellite borne-camera.

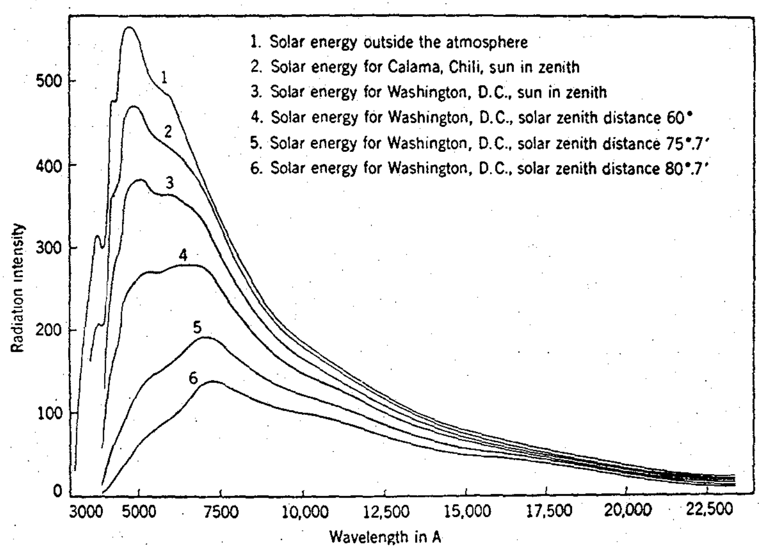


Fig. 6. Effect of the altitude of the sun on the spectral distribution of its energy as received at the surface of the earth.

(*From H. H. Kimball*)

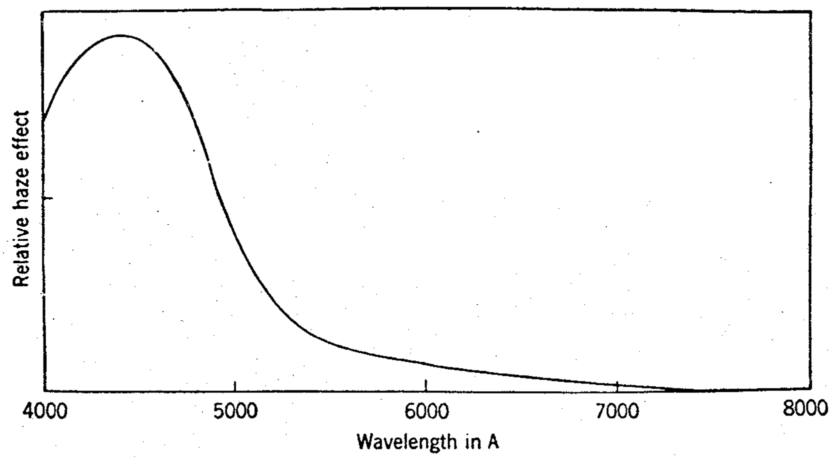


Fig. 7. Curve showing relation between haze and wavelength.

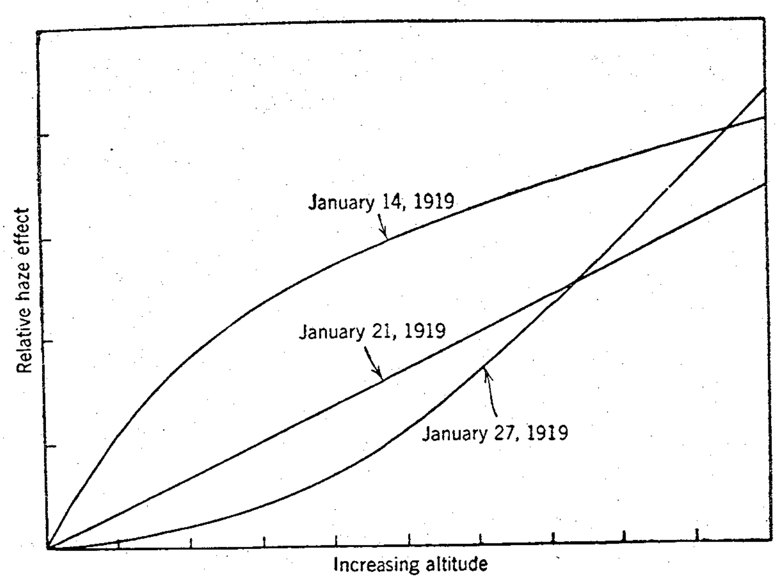


Fig. 8. Curves showing relation between haze and altitude.

From CLARK

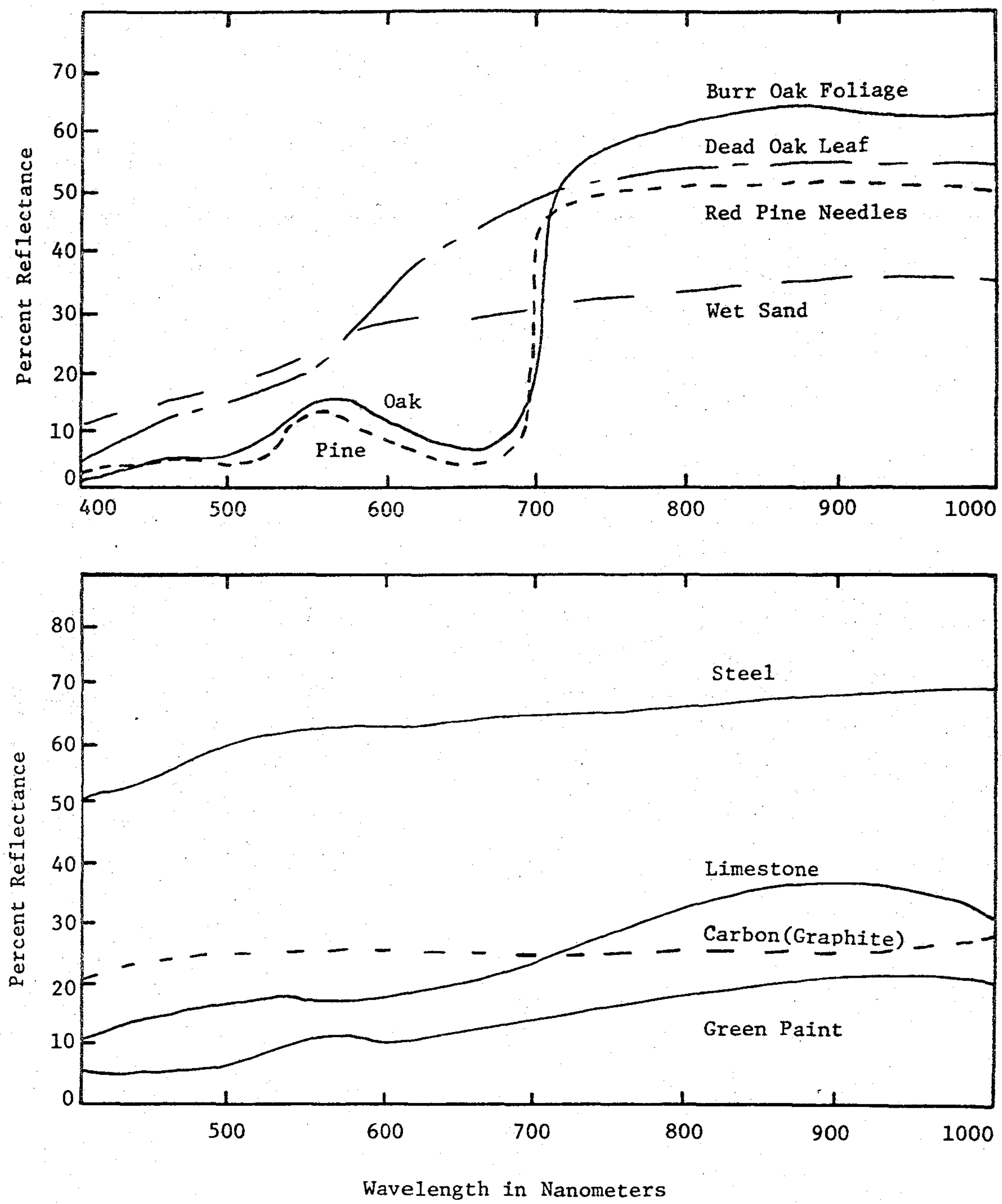
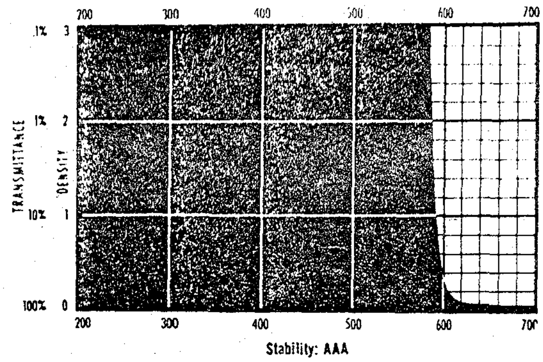
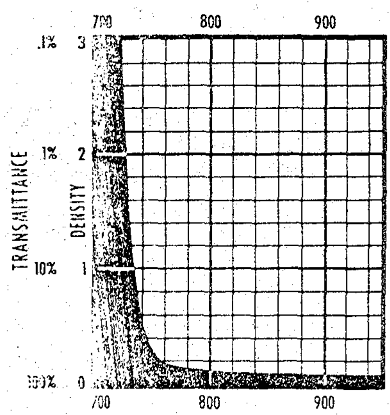


Figure 9. Percent reflectance for various materials.

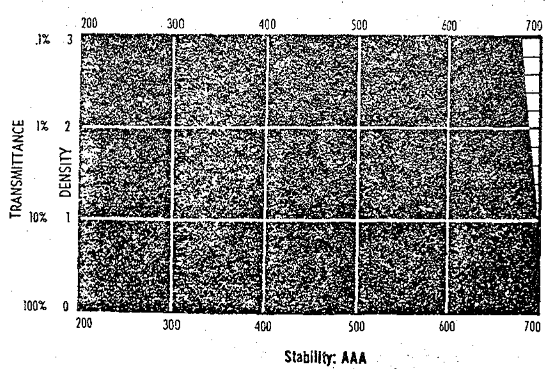
Figure 10. Transmission diagrams and transmission percentages for selected Wratten filters. (From Kodak Scientific and Technical Data Book B-3, Kodak Wratten Filters.) (Cont.)



25
(A)



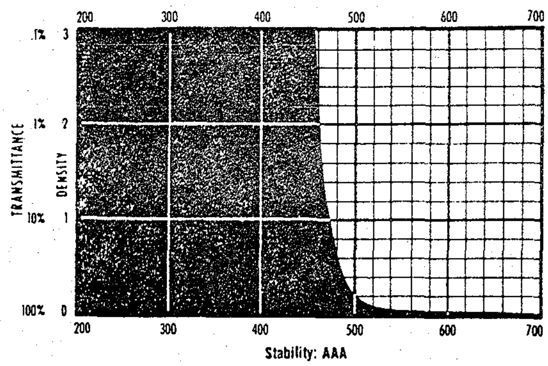
88A



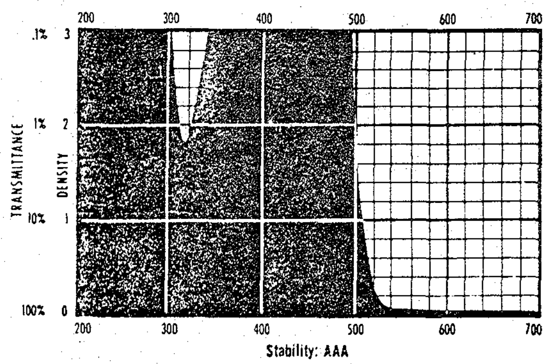
89B

Wave length	Percent transmittance 25a	88A	89B
580	--	--	--
590	12.6	--	--
600	50.0	--	--
610	75.0	--	--
620	82.6	--	--
630	85.5	--	--
640	86.7	--	--
650	87.6	--	--
660	88.2	--	--
670	88.5	--	--
680	89.0	--	0.10
690	89.3	--	1.58
700	89.5	--	11.2
710	--	--	32.4
720	--	--	57.6
730	--	7.4	69.1
740	--	32.8	77.6
750	--	56.3	83.1
760	--	69.2	85.0
770	--	74.2	86.1
780	--	77.6	87.0
790	--	79.7	87.7
800	--	81.4	88.1
810	--	82.6	88.4
820	--	83.7	88.6
830	--	84.7	88.8
840	--	85.5	89.0
850	--	86.1	89.2
860	--	86.6	89.4
870	--	87.2	89.6
880	--	87.5	89.8
890	--	87.8	89.9
900	--	88.0	90.0
910	--	88.2	90.1
920	--	88.4	90.2
930	--	88.6	90.3
940	--	88.8	90.4
950	--	89.0	90.5
Dominant wave-length (Source C)	615.3	748.0	718.0

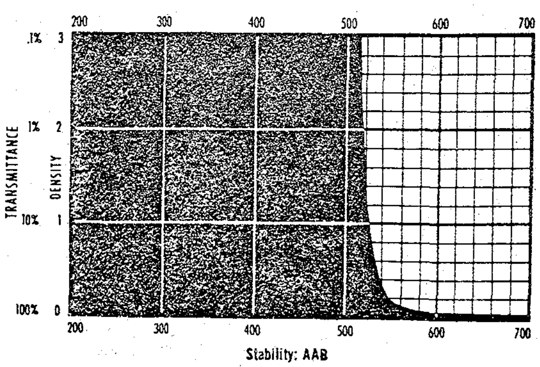
Figure 10. Transmission diagrams and transmission percentages for selected Wratten filters. (From Kodak Scientific and Technical Data Book B-3, Kodak Wratten Filters.)



8
(K2)



12



16

Wave length	Percent transmittance 8	12	16
400	--	--	--
410	--	--	--
420	--	--	--
430	--	--	--
440	--	--	--
450	--	--	--
460	0.25	--	--
470	5.50	--	--
480	19.0	--	--
490	41.0	--	--
500	63.5	1.50	--
510	78.0	17.3	--
520	84.1	55.0	3.00
530	86.5	77.8	22.0
540	87.7	86.0	48.0
550	88.4	88.4	69.5
560	88.8	89.4	79.5
570	89.2	89.7	84.0
580	89.5	90.1	86.3
590	89.8	90.3	87.8
600	90.1	90.4	89.0
610	90.3	90.5	89.6
620	90.5	90.7	90.0
630	90.7	90.8	90.2
640	90.9	90.9	90.3
650	91.0	91.0	90.4
660	91.1	91.1	90.5
670	91.2	91.2	90.6
680	91.3	91.2	90.7
690	91.4	91.2	90.8
700	91.5	91.3	90.8
Dominant wave-length (Source C)	572.0	576.3	582.7

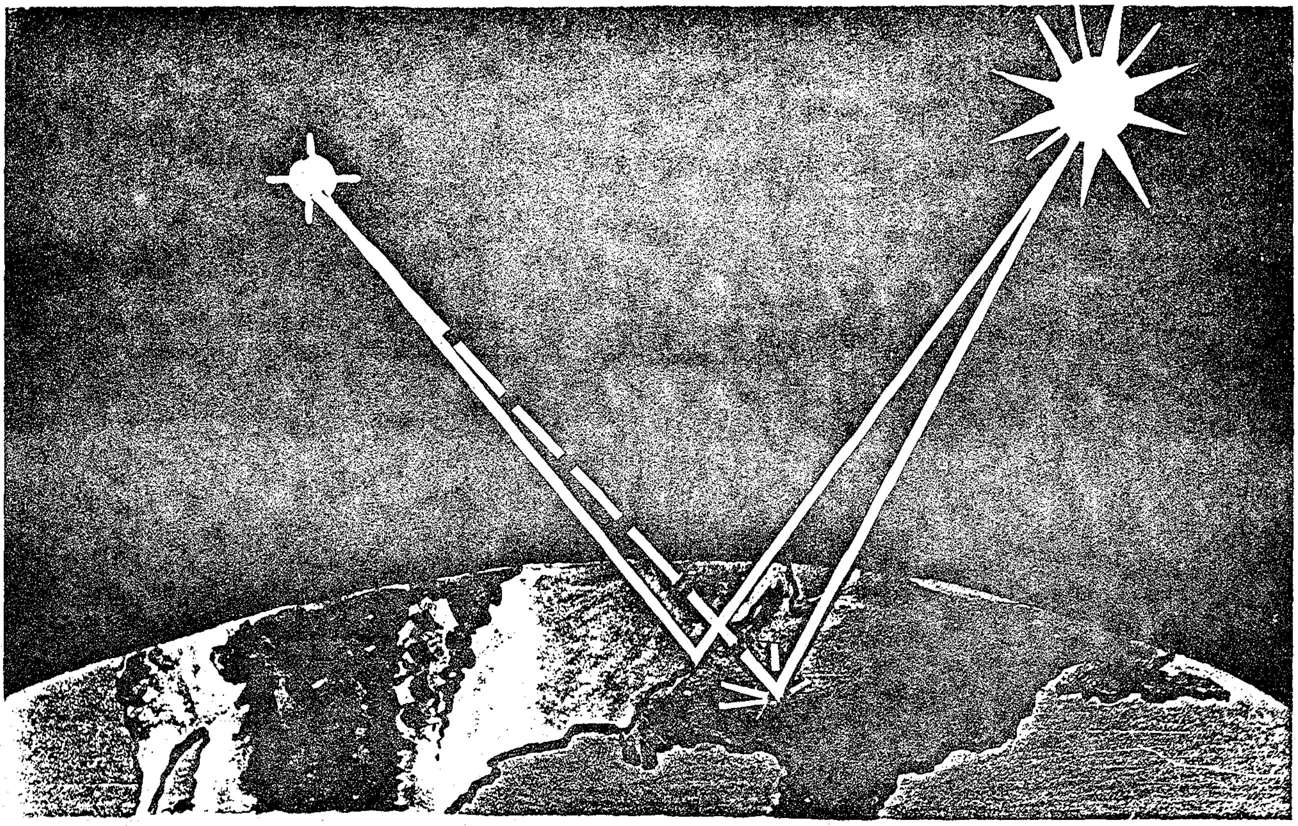


Figure 11. Solar rays reflected to a satellite looking near the specular reflection of the sun.

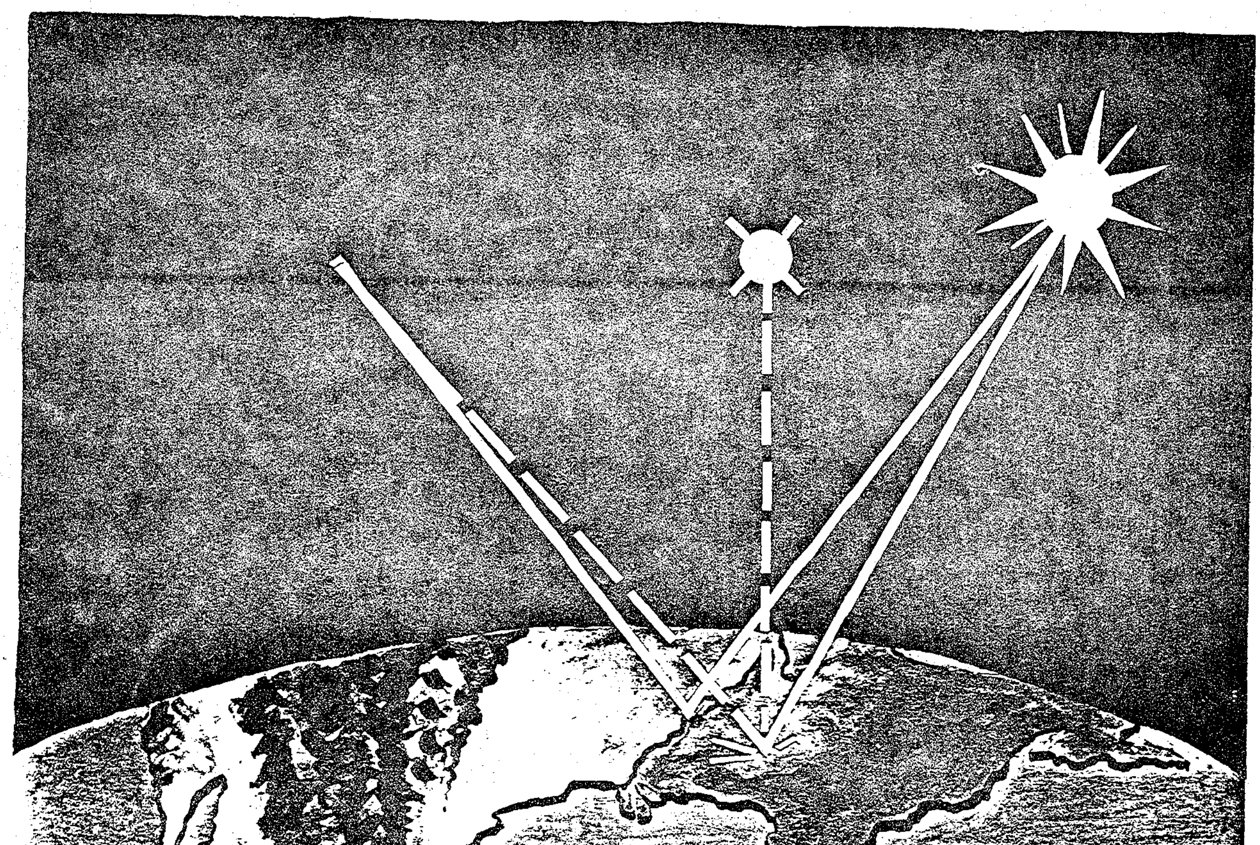


Figure 12. Diffuse reflection of solar rays to a satellite looking straight down (nadir viewing).

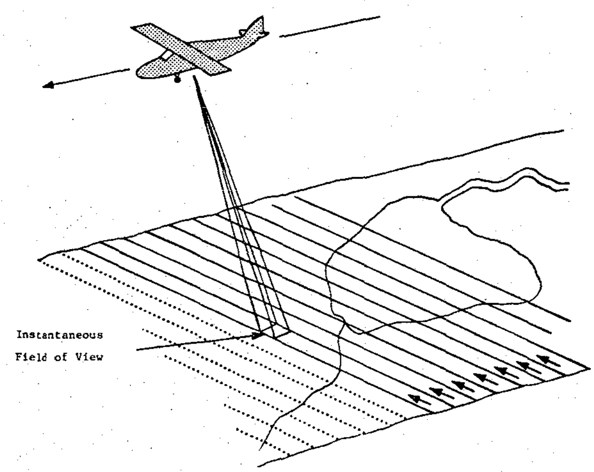


Figure 13. Optical-mechanical scanning.

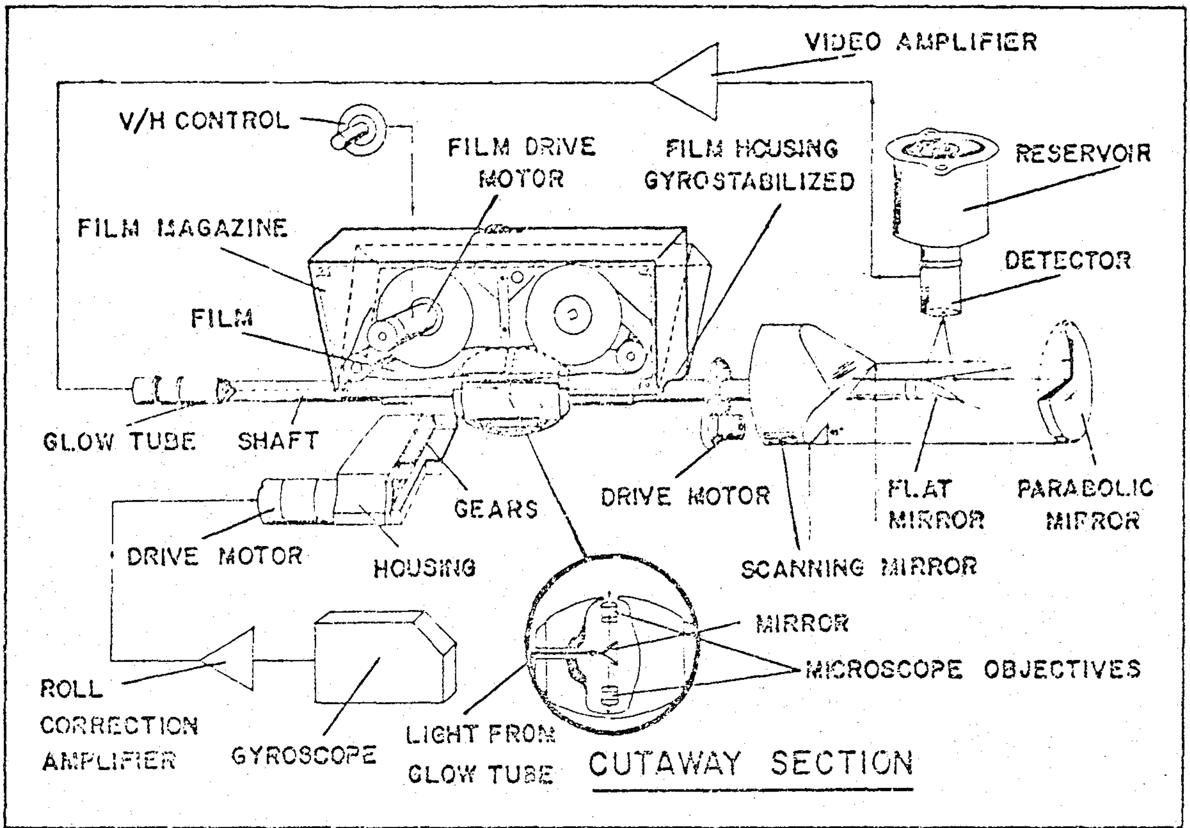


Figure 14a. Schematic of a line scanner using a glow tube printer.

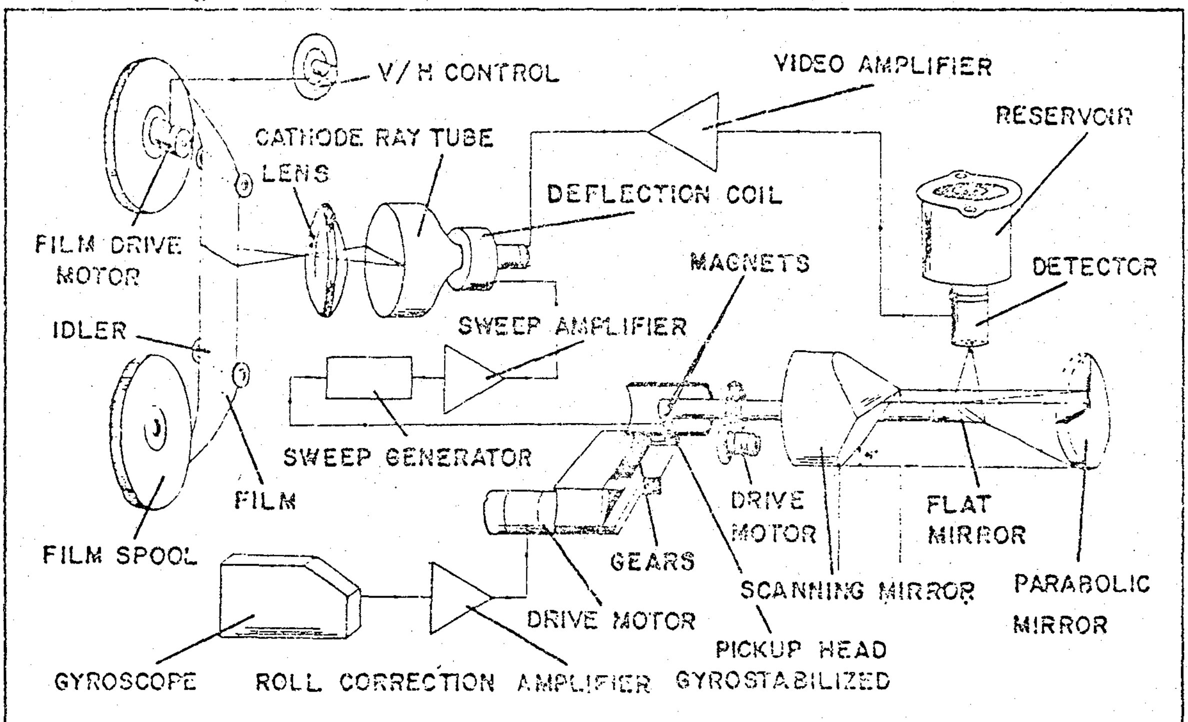


Figure 14b. Schematic of a line scanner using a CRT printer.

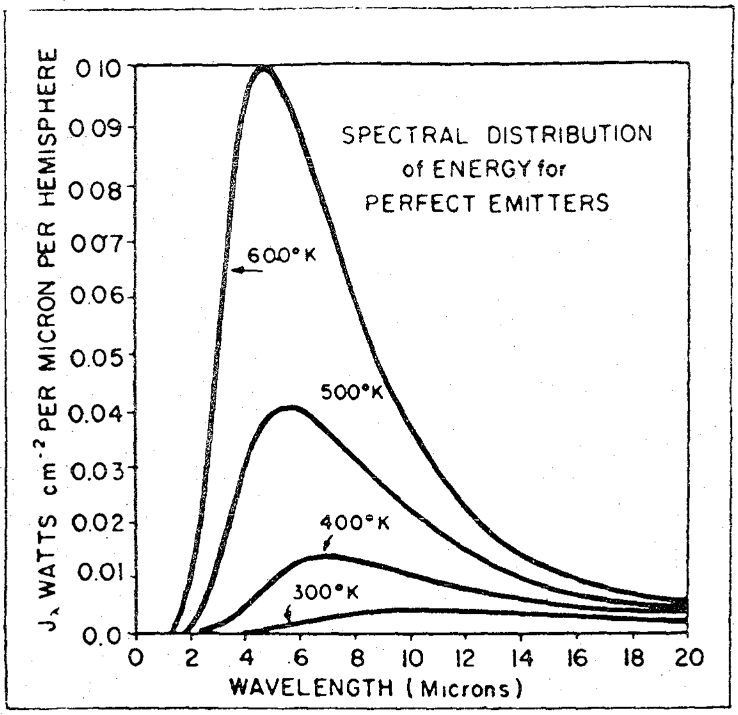


Figure 15. Exitance of black bodies at various temperatures.

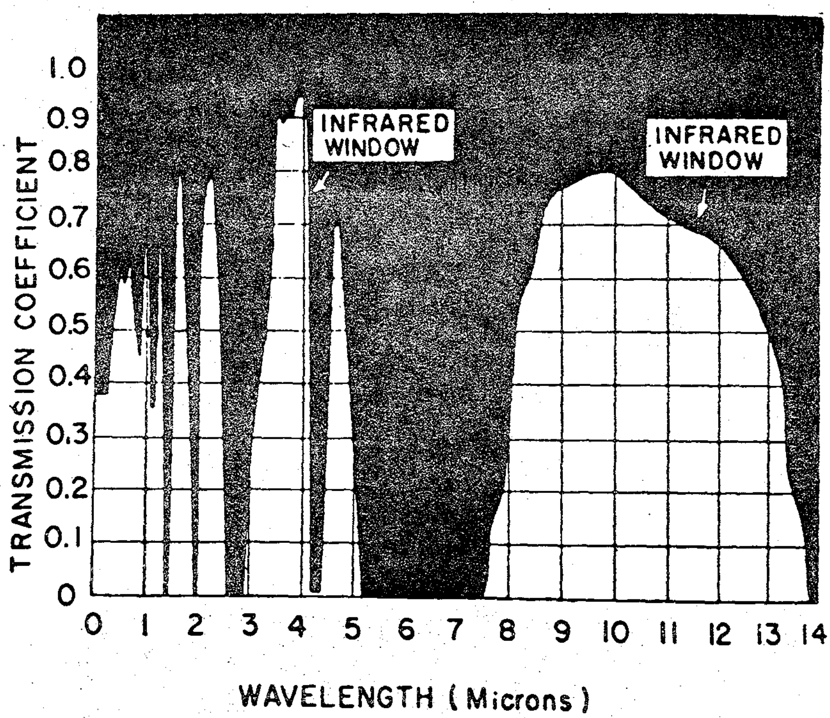


Figure 16. Atmospheric transmission coefficient for infrared radiation.

ENVIRONMENTAL SATELLITES

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I have been asked to discuss the essential features of the various environmental satellite systems, to include earth resources satellites and meteorological satellites. There is obviously insufficient time here to discuss the details of all the satellite systems of interest. I shall therefore summarize the salient features in tabular form, discussing in detail only those satellites which have special application to the oceans.

The first overhead (Table 1) is an outline of those subjects I will be discussing. The first item of importance is to describe the various types of orbits. This is done in Table 2. Table 3 organizes the satellites into two major groups: (1) research and development and (2) operational. The following table (4) shows the chronological sequence of the various satellites. In Tables 5 to 8 parameters of the different satellite systems are presented: Table 5 covers primarily the orbital characteristics of polar orbiting, sun-sychronous satellites; Table 6, sensor characteristics of these same satellites; Table 7, orbital characteristics and sensors of the geostationary satellites; and Table 8 presents in somewhat more detail the various characteristics of the two oceanographic satellites, GEOS-3 and SEASAT-1. Table 9 is a summary of SEASAT-1 design criteria, the measurements made and their anticipated accuracies. Finally, Table 10 is a partial list of the acronyms used in remote sensing and is included here primarily as reference material for persons who are unfamiliar with remote sensing of the oceans.

*Synoposis by: Peter Cornillon

TABLE 1

ENVIRONMENTAL SATELLITE PROGRAMS

ORBIT OPTIONS

ONE DAY'S GLOBAL SWATH PATTERN (LANDSAT)

LANDSAT SWATH COVERAGE AND 18–DAY REPEAT FREQUENCY

ENVIRONMENTAL SATELLITE CLASSIFICATION

ENVIRONMENTAL SATELLITE CHRONOLOGY

SUN–SYNCHRONOUS SATELLITE COVERAGE INFORMATION

MARINE–RELATED SENSORS ON SUN–SYNCHRONOUS ENVIRONMENTAL SATELLITES

GEOSTATIONARY ENVIRONMENTAL SATELLITES

OCEANOGRAPHIC SATELLITES

DESIGN CRITERIA FOR SEASAT

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TABLE 2.

ORBIT OPTIONS

I. POLAR:

ALLOWS VIEW OF POLAR REGIONS, IE. ICEX.

TIME OF SATELLITE OVERPASS CHANGES WITH SEASON OF THE YEAR. THIS TYPE OF ORBIT IS NOT APPROPRIATE FOR VISIBLE IMAGERY.

II. GEOSTATIONARY:

TWENTY–FOUR HOUR ORBIT PERIOD WITH $\approx$ 36,000 km ALTITUDE.

KEEPS SPACECRAFT OVER FIXED EQUATORIAL GROUND POINT.

III. SUN–SYNCHRONOUS:

FOR A GIVEN ALTITUDE, INCLINATION CAN BE DETERMINED SO THAT ORBIT PLANE PRECESSION CANCELS SEASONAL VARIATION OF SUN ANGLE. SATELLITE PASSES OVER GROUND POINT AT SAME LOCAL TIME EACH DAY. THE ALTITUDE ALSO DETERMINES THE NUMBER OF ORBITS PER DAY.

CONSIDERATIONS FOR SUN–SYNCHRONOUS ORBIT DETERMINATION

1. ORBITAL DRAG
2. INSTRUMENTATION SWATH AND RESOLUTION
3. GROUND STATION PASS TIME
4. DESIRED REPEAT COVERAGE PERIODICITY
5. DESIRED SUN ANGLE
6. PATTERN OF ORBITAL COVERAGE DESIRED

IV. SPECIAL ORBITS:

AN ORBIT WITH AN INCLINATION OF 108 DEGREES COVERS ALL UNFROZEN OCEANS AND PROVIDES 42 DEGREE TRACK CROSSING ANGLES AT EQUATOR. THIS TYPE OF ORBIT IS USEFUL FOR THE STUDY OF THE MARINE GEOID AND SEA SURFACE TOPOGRAPHY AND WAS ADOPTED FOR SEASAT.

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TABLE 3.

ENVIRONMENTAL SATELLITE CLASSIFICATION

- ENVIRONMENTAL SATELLITES
  - RESEARCH AND DEVELOPMENT (NASA)
    - NEAR POLAR SUN SYNCHRONOUS
      - TIROS 9&10 (MET)
      - NIMBUS 1–7 (MET)
      - LANDSAT 1–3 (ER)
      - ITOS–1 (MET)*
      - TIROS–N (MET)*
    - GEOSTATIONARY
      - ATS 1–3
      - SMS 1–2 (MET)*
    - OTHER
      - TIROS 1–8 (MET)
      - SKYLAB (3 MISSIONS)
      - GEOS–3 (O)
      - SEASAT (O)
  - OPERATIONAL (NOAA)
    - NEAR POLAR SUN SYNCHRONOUS
      - TOS/ESSA 1–9 (MET)
      - ITOS/NOAA 1–5 (MET)
      - NOAA 6 (MET)
      - DMSP (MET)/DOD
    - GEOSTATIONARY
      - GOES 1–3 (MET)
      - METEOSAT (MET)/ESA
      - GMS (MET)/JAPAN
  - PROPOSED

(1980–85)	NOAA B–G (MET)/NOAA	NEAR–POLAR
(1981)	LANDSAT–D (ER)/NASA	NEAR–POLAR
(1984)	SPOT (ER)/FRENCH	NEAR–POLAR
(1981)	USSR GOES (MET)	GEOSTATIONARY
(1980+)	GOES D,E,F (MET)/ NOAA	GEOSTATIONARY
(1981)	INDIA GOES (MET)	GEOSTATIONARY
(≈ 1984)	NOSS (O)/NASA	(ORBIT UNDETERMINED)

(MET – METEOROLOGICAL, ER – EARTH RESOURCES, O – OCEANOGRAPHIC)

* USED OPERATIONALLY BY NOAA

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TABLE 4.

ENVIRONMENTAL SATELLITE CHRONOLOGY

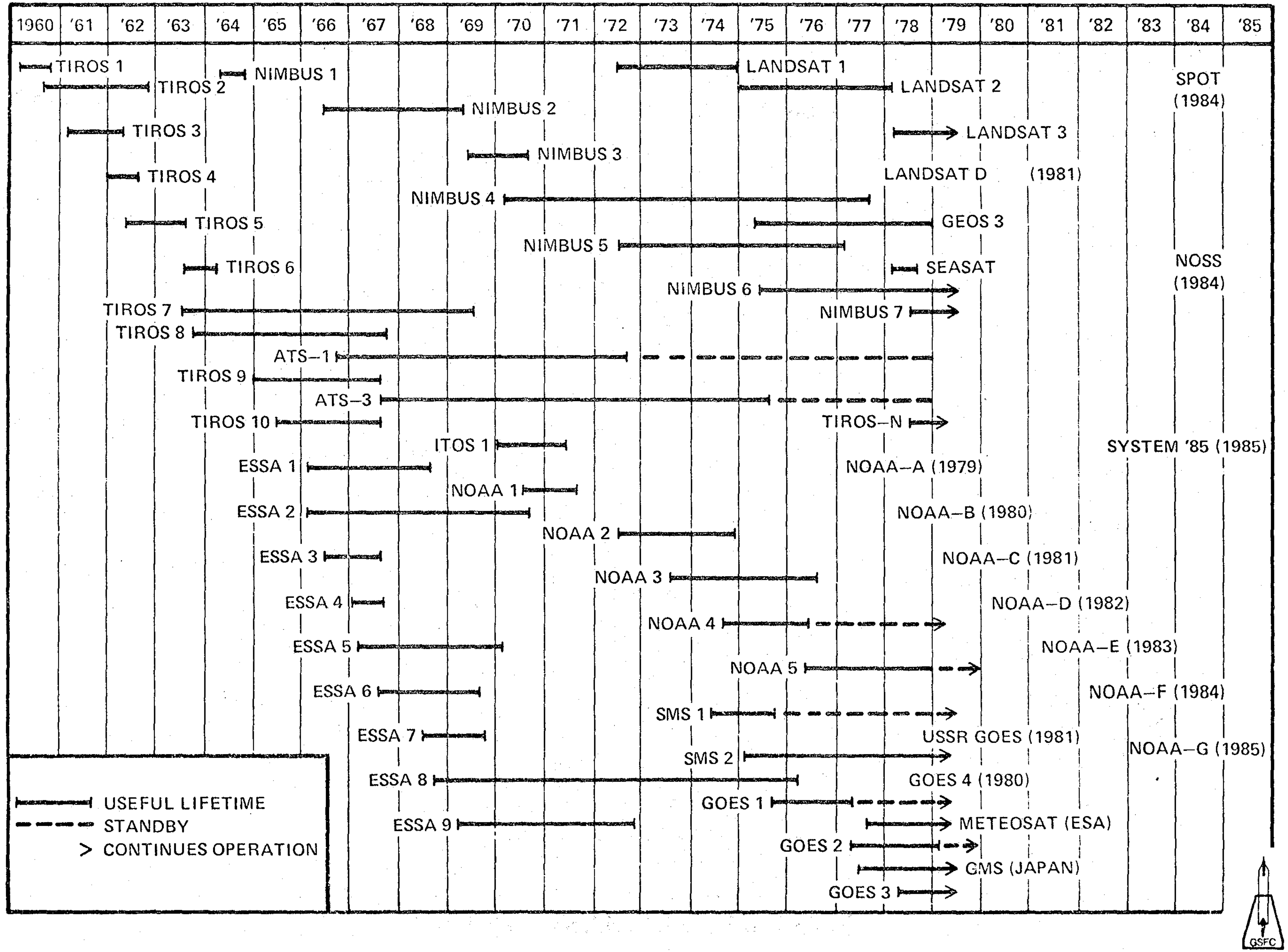

TABLE 5.

SUN-SYNCHRONOUS SATELLITE COVERAGE INFORMATION

NAME	ALTITUDE	REPEAT CYCLE	ORBIT PERIOD ORBITS/DAY	INCLINATION OVERPASS TIME	INSTRUMENT	SWATH	RESOLUTION
NOAA–5 (NOT OPERA–TIONAL)	1464 km	VIS: 24 hr IR: 12 hr	116 min 12.4	101.6°	VERY HIGH RESOLUTION RADIOMETER VHRR	HORIZON TO HORIZON	≈1 km
TIROS–N NOAA–A	854 km 833 km	SAME AS ABOVE	102 min 14.25	≈ 99° TIROS 3:10 NOAA–A 7:30	ADVANCED VHRR (AVHRR)	HORIZON TO HORIZON	4 km–GLOBAL 1 km–REGIONAL
LANDSAT 3	912 km	18 DAYS (251 ORBITS)	103 min 14.0	99.1° 9:30 am	MULTI–SPECTRAL SCANNER (MSS)	185 km	VISIBLE AND NEAR–IR: 57m THERMAL IR: 171m
LANDSAT D	705 km	16 DAYS	≈99 min 14.6	≈101° ?	THEMATIC MAPPER	185 km	VIS/NIR: 30m THERMAL IR: 120m
NIMBUS–7	955 km	VIS: 24 hr IR: 12 hr	≈110 min	≈81° NOON	CZCS	1500 km	800m
					SMMR	780 km	CHANNEL DEPENDENT
DMSP BLOCK 5D (2 SATEL–LITES)	830 km	SAME AS ABOVE	102 min 14.25	98.75° ≈ 7.00 ≈10–11:00	OPERATIONAL LINESCAN SYSTEM (OLS)	3000 km	VIS: 0.55 km IR: 0.8 km

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TABLE 6. **MARINE-RELATED SENSORS ON SUN-SYNCHRONOUS ENVIRONMENTAL SATELLITES**

NAME	SENSOR	CHANNELS	DERIVED PRODUCT	ESTIMATED ACCURACY
LANDSAT 3	MULTISPECTRAL SCANNER (MSS)	0.5–0.6 μm 0.6–0.7 " 0.7–0.8 " 0.8–1.1 "	VISIBLE AND INFRARED (IR) SIGNATURES OF TERRESTRIAL, AQUATIC AND NEARSHORE MARINE REGIMES	NA
LANDSAT D	THEMATIC MAPPER	0.45–0.52 μm 0.52–0.60 " 0.63–0.69 " 0.76–0.90 " 1.55–1.75 " 10.4–12.5 "	SAME PRODUCTS AS LANDSAT–C PLUS SURFACE TEMPERATURE	TO BE LAUNCHED IN 1981
ITOS–1 NOAA 2–5	VERY HIGH RESOLUTION RADIOMETER (VHRR)	0.6– 0.7 μm 10.5–12.5 "	DAY AND NIGHTTIME CLOUD COVER SEA SURFACE TEMP. (SST)	SST–0.5° C SENSITIVITY TO RELATIVE CHANGES
TIROS–N SERIES (NOAA–A THRU G)	ADVANCED VHRR (AVHRR) NOTE: NOAA SERIES CHANNEL 1 0.55–0.68 CHANNEL 5 ONLY ON D,F AND G	0.55 – 0.90 μm 0.725– 1.10 " 3.55 – 3.93 " 10.5 – 11.5 " 11.5 – 12.5 "	DAY AND NIGHTTIME CLOUD AND SURFACE MAPPING, SURFACE WATER DELINEATION, SST	SST–0.2° C SENSITIVITY TO RELATIVE CHANGES
NIMBUS–7	SCANNING MULTI– CHANNEL MICROWAVE RADIOMETER (SMMR)	6.63, 10.69, 18.0, 21.0, 37.0 GHz DUAL POLAR– IZATION	SST SEA SURFACE WIND SPEED	≈1.5° C ≈1 m/s
	COASTAL ZONE COLOR SCANNER (CZCS)	0.43– 0.45 μm 0.51– 0.53 " 0.54– 0.56 " 0.66– 0.68 " 0.70– 0.80 " 10.5 – 12.5 "	MARINE CHLOROPHYLL AND SEDIMENT DISTRIBUTION SEA SURFACE TEMP.	PARAMETERS PRESENTLY UNDER INVESTIGATION
DMSP BLOCK 5D	OPERATIONAL LINE– SCAN SYSTEM (OLS)	0.41– 1.1 μm 8–13 μm	SAME AS TIROS–N	SOMEWHAT LOWER THAN TIROS–N

TABLE 7.

GEOSTATIONARY ENVIRONMENTAL SATELLITES

NAME	COVERAGE	PRESENT LOCATION	INSTRUMENTS	RESOLUTION	DATA PRODUCTS
SMS–1 SMS–2 GOES–1 GOES–2 GOES–3	FULL DISK EVERY ½ HOUR ≈ ¼ EARTH'S SURFACE	75°W (STAND BY) 75°W 59°E 75°W (STAND BY) 135°W	VISIBLE AND INFRARED SPIN–SCAN RADIOMETER (VISSR) CHANNELS 0.55– 0.70 μm 10.50–12.6 "	VISIBLE – 1 km INFRARED – 8 km	DAY/NIGHT CLOUD COVER WIND FIELDS
GMS (JAPAN)		140°E	SAME		
METEOSAT (EUROPEAN SPACE AGENCY)		0°	SAME CHANNELS PLUS ADDITIONAL CHANNEL FOR WATER VAPOR		
USSR GOES	TO BE LAUNCHED IN 1981. APPROXIMATE LOCATION WILL BE 70°E.				
GOES–D	TO BE LAUNCHED IN 1980.		VISSR ATMOS– PHERIC SOUNDER (VAS) CHANNELS 0.55–0.73 μm 3.73 4.28 6.71 7.25 11.10 12.7–14.7	VIS: IR: ≈ 8 km	DAY/NIGHT CLOUD COVER SURFACE TEMPERATURE CLOUD H_2O TEMP. SOUNDING WIND FIELDS

ALL ALTITUDES 35,780 km

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TABLE 8.

OCEANOGRAPHIC SATELLITES

NAME	ALTITUDE	ORBIT PERIOD	INCLINATION	INSTRUMENTS	DATA PRODUCTS	ESTIMATED ACCURACY
GEOS–3	843 km	101.7 min 14.2 ORBITS PER DAY	115°	RADAR ALTIMETER	MARINE GEOID SIGNIFICANT WAVE HEIGHT SEA SURFACE TOPOGRAPHY	± 1–2 m ± 10% ± 20 cm
SEASAT	790 km	100.8 min ≈14 ORBITS PER DAY	108°	RADAR ALTIMETER SYNTHETIC APERATURE RADAR (SAR) RADAR SCATTEROMETER (SASS) SCANNING MULTIFREQUENCY RADIOMETER (SMMR) VISIBLE–IR RADIOMETER (VIRR)	(NEXT TABLE)	

TABLE 9.

DESIGN CRITERIA FOR SEASAT

MEASUREMENT			RANGE	PRECISION	RESOLUTION OR IFOV	TOTAL FOV	COMMENTS
TOPOGRAPHY	ALTIMETER	GEOID	7 cm–200 m	±10 cm	1.6–12 km SPOT	NADIR ONLY	2 GRIDS SAMPLED THROUGHOUT ONE YEAR
		CURRENTS, SURGES, ETC.	7 cm–10 m	±10 cm	1.6–12 km SPOT	NADIR ONLY	ALONG SUBSATELLITE TRACK ONLY
SURFACE WINDS	MICROWAVE RADIOMETER	AMPLITUDE	7–50 m/s	±2 m/s, ±10%	121 km SPOT	679–km SWATH OFFSET 22° FROM NADIR	
	SCATTER–OMETER		4–28 m/s	±2 m/s, ±10%	< 50 km SPOT	250/500/400 /500/250 km	400 km CENTER BLOCK 500 km FULL WINDS 250 km HIGH WINDS ONLY
		DIRECTION	0–360°	±20°			
GRAVITY WAVES	ALTIMETER	HEIGHT	1.0–20 m	±0.5 m OR ±10%	1.6–12 km SPOT	NADIR ONLY	ALONG SUBSATELLITE TRACK ONLY
	IMAGING RADAR	LENGTH	50–1000 m	±10%	25 m RESOLUTION	100 X 4000 km	SELECTED COVERAGE (IN VIEW OF COMPATIBLE STATION)
		DIRECTION	0–360°	±15%			
SURFACE TEMPERATURE	V & IR RADIOMETER	ABSOLUTE	−2° TO +35°C	±2°C	4 km (IR) IFOV	2127*–km SWATH ABOUT NADIR	(CLEAR AIR ONLY)
	MICROWAVE RADIOMETER	ABSOLUTE	0° TO 35°C	±2°C	121 km SPOT	638–km SWATH OFFSET 22° FROM NADIR	(CLOUDS, LT RAIN)
SEA ICE CLOUDS LOCATION AND OCEAN FEATURE	MICROWAVE RADIOMETER	EXTENT	N/A	21 km	21 km	636–km SWATH OFFSET 22° FROM NADIR	GLOBAL IMAGES, ALL WEATHER
	V & IR RADIOMETER		N/A	2 km	2 km (VISIBLE) 4 km (IR)	2127*–km SWATH	BROADLY SAMPLED IMAGES, CLEAR AIR
	IMAGING RADAR	LEADS	N/A	±25 m	25 m	100 km	REAL TIME TRANS–MISSION WEATHER
		ICEBERGS					

* DATA SWATH WIDTH FOR QUOTED ACCURACIES IS ONLY ABOUT 1500 km

TABLE 10. ACRONYMS

AASIR	Advanced Atmospheric Sounding and Imaging Radiometer
AEM	Application Explorer Mission
AFGWC	Air Force Global Weather Control
AFC	Air Force Communications
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
APT	Automatic Picture Transmission
ATC	Air Training Command
ATS	Applications Technology Satellite
AVHRR	Advanced Very High Resolution Radiometer
BSU	Basic Sounding Unit
CCT	Computer Compatible Tape
CDA	Command and Data Acquisition
CDC	Control Data Corporation
CDDS	Central Data Distribution System
CZCS	Coastal Zone Color Scanner
DAPAF	Data Processing and Analysis Facility (NOAA)
DCS	Data Collection System
DCS/RSE	DCS Receiving Site Equipment
DDHS	Digital Data Handling System
DDS	Data Display Segment
DIPS	Digital Image Preprocessing System
DPPS	Digital Image Processing System
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense

DS	Digital Subsystem
EBR	Electron Beam Recorder
EDC	EROS Data Center
EDR	Experimental Data Records
ERB	Earth Radiation Budget
EREP	Earth Resources Experiment Package (SKYLAB)
EROS	Earth Resources Observations Systems (Program)
ERTS	Earth Resources Technology Satellite
ESMR	Electrically Scanning Microwave Radiometer
FOFAX	Forecast Office Facsimile (Network)
FNWC	Fleet Numerical Weather Central (U.S. Navy)
GEOS	Geodynamic Experimental Ocean Satellite
GOES	Geostationary Operational Environmental Satellite
GOSSTCOMP	Global Operational Sea Surface Temperature Computations
GSFC	Goddard Space Flight Center
HCMM	Heat Capacity Mapping Mission (also AEM-A)
HCMR	Heat Capacity Mapping Radiometer
HDT	High Density Tape
HRIRS	High Resolution Infrared Radiation Sounder
HRPT	High Resolution Picture Transmission
IERG	Imagery Enhancement Review Group (NESS)
IFOV	Instantaneous Field of View
IIGS	Initial Image Generation System
IPF	Image Processing Facility
IPD	Information Processing Division (GSFC)
IPS	Image Processing System

IR	Infrared
ITOS	Improved TIROS Operational Satellite
ITPR	Infrared Temperature Profile Radiometer
KHz	Kilohertz
LAGEOS	Laser Geodynamics Satellite
LANDSAT	Land Satellite
LEST	Large Earth Survey Telescope (on SEOS)
LIMS	Limb Infrared Monitoring of the Stratosphere
LRIR	Limb Radiance IR Radiometer
MASR	Microwave Atmospheric Sounding Radiometer
MDHS	Meteorological Data Handling Station (GSFC)
MHz	Megahertz
MOCS	Mission Operations and Control System (GSFC)
MPP	MSS Preprocessor
MSS	Multispectral Scanner
MSU	Microwave Sounding Unit
NAFAX	National Facsimile (Network)
NASCOM	NASA Communications (Network)
NBTR	Narrow Band Tape Recorder
NCIC	National Cartographic Information Center
NDPF	NASA Data Processing Facility
NESS	National Environmental Satellite Service
NEMS	NIMBUS-E Microwave Spectrometer
NMC	National Meteorological Center
NOAA	National Oceanographic and Atmospheric Administration
NTTF	NASA Test and Training Facility

NWS	National Weather Service
OCC	Operations Control Center
OLS	Operational Linescan System
OFT	Operational Flight Test
PCM	Pulse Code Modulation
PCM-NRZL	Pulse Code Modulation - Non-Return to Zero Level
PDPS	Project Data Processing Subsystem (SEASAT)
PDR	Processed Data Records
PMR	Pressure Modulator Radiometer
RBV	Return Beam Vidicon
RTD	Real Time Data
SAC	Strategic Air Command
SAGE	Stratospheric Aerosol and Gas Experiment
SAMS	Stratospheric and Mesospheric Sounder
SAMSO	Space and Missiles Systems Organization
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications (NOAA)
SBUV/TOMS	Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer
SCAMS	Scanning Microwave Spectrometer
SCMR	Surface Composition Mapping Radiometer
SCR	Selective Chopper Radiometer
SDSB	Satellite Data Services Branch (NOAA)
SDPS	SAR Data Processing Subsystem (SEASAT)
SEASAT	Sea Satellite
SEOS	Synchronous Earth Observations Satellite

SFSS	Satellite Field Service Station
SEM	Space Environmental Monitor
SINAP	Satellite Input to Numerical Analysis and Prediction
SIRS	Satellite Infrared Sounding
SLAR	Side Looking Airborne Radar
SMMR	Scanning Multi-frequency Microwave Radiometer
SMS	Synchronous Meteorological Satellite
SOCC	Satellite Operations Control Center (NOAA)
SSOS	Severe Storms Observational Satellite
SPM	Solar Proton Monitor
SR	Scanning Radiometer
SRR	Scanning Radiometer Recorder
SSE	Supplementary Sensor E
SSH	Special Meteorological Sensor-H
SSL	Supplementary Sensor-L
SST	Sea Surface Temperature
SSU	Stratospheric Sounding Unit
STDN	Space Tracking and Data Network (NASA)
STORMSAT	Storm Satellite
TDAS	Tracking and Data Acquisition Subsystem (NASA)
T&DRE	Tracking and Data Relay Experiment
THIR	Temperature Humidity Infrared Radiometer
TIROS	Television Infrared Observational Satellite
TM	Thematic Mapper
TWERLE	Tropical Wind Energy Conversion and Reference Level Experiment

USB	Unified S-Band
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VIRR	Visible-IR Radiometer (SEASAT)
VISSR	Visible-Infrared Spin Scan Radiometer
VTPR	Vertical Temperature Profile Radiometer
VTR	Video Tape Recorder
WBVT	Wide Band Video Tapes
WBTR	Wide Band Tape Recorder
WEFAX	Weather Facsimile
WSFO	Weather Service Forecast Offices (NOAA)

RESEARCH AIRCRAFT PLATFORMS

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Bob Macomber will discuss commercial aircraft and their capabilities. I shall therefore restrict my comments to NASA research aircraft. I should further add at the outset that NASA represents just one segment of the research community in aircraft remote sensing with other organizations, among them the Environmental Protection Agency at Las Vegas and The Environmental Research Institute of Michigan, also maintaining a significant fleet of aircraft and remote sensing instrumentation.

I have outlined on the first overhead (Table 1) the major objective of our program. The implementation of the program appears in the next overhead (Figure 1), which shows the entire sequence from experimental design to the final data products. Each of the aircraft used in the program are summarized on separate fact sheets. The primary aircraft used are the WB57F, a high altitude, moderately large payload turbofan (Table 2); the NC 130B, a mid-altitude, large payload, turboprop (Table 3); the U2, the highest altitude, small payload jet (Table 4); and the CV990 A, a second mid-altitude, large payload turbofan (Table 5). The next two Tables, 6 and 7, indicate the types of projects flown on the WB57F and the C130 in fiscal 1979. The various output data products from these aircraft are summarized in Table 8 and the operational aspects, common to all research programs are presented in Figure 2.

*Synopsis by P. Cornillon

NASA-S-79-2008

TABLE 1.

BASIC OBJECTIVE

- DATA ACQUISITION IN SUPPORT OF OFFICE OF TERRESTRIAL APPLICATIONS (OSTA) RESEARCH, APPLICATIONS, SPACECRAFT UNDER FLIGHT AND SATELLITE/ SPACECRAFT SENSOR DEVELOPMENT IN:
  - EARTH RESOURCES
  - WEATHER AND CLIMATE
  - ENVIRONMENT
  - OCEAN PROCESSES

TABLE 2.

PROGRAM AIRCRAFT -WB57F

ENGINE:	2 TURBOFAN (2 JET)
ALTITUDE:	63, 000 FEET
DURATION:	6 HRS; 4 HRS DATA ACQUISITION
PAYLOAD:	UNIVERSAL PALLET SYSTEM; 5, 000 POUNDS NOSE; 500 POUNDS
CREW:	PILOT AND SCIENTIFIC EQUIPMENT MONITOR

REMOTE SENSING EQUIPMENT

CAMERA:	METRIC-6/12-INCH FOCAL LENGTH HIGH RESOLUTION - 24-INCH FOCAL LENGTH MULTIBAND - 6 CAMERAS - 6-INCH FOCAL LENGTH
SCANNER:	5-CHANNEL, 0.5 - 12.5 MICROMETERS (LANDSAT-C SIMULATOR)
MICROWAVE:	APQ-102 SIDELOOKING RADAR (X BAND)
OTHER:	INERTIAL NAVIGATION CENTRAL RECORDING
FEATURES:	UNIVERSAL PALLET STANDARD INTERFACE REMOTE INTEGRATION CAPABILITY

NASA-S-78-3987 A

TABLE 3.

PROGRAM AIRCRAFT -NC130B

ENGINE:	4 TURBOPROP
ALTITUDE:	30, 000 FEET
DURATION:	8 HRS; 6 HRS DATA ACQUISITION
PAYLOAD:	STANDARD AND EXPERIMENTAL; 20, 000 POUNDS MAX
CREW:	3 CREW, PLUS OPERATORS AND PRINCIPAL INVESTIGATORS
REMOTE SENSING EQUIPMENT:	
CAMERA:	METRIC - 6 INCH MULTIBAND - 6 CAMERAS - 6-INCH FOCAL LENGTH
SCANNER:	11 CHANNEL, 0. 33 - 13. 5 MICROMETERS 8 CHANNEL, 0. 45 - 12. 4 MICROMETERS (THEMATIC MAPPER)
MICROWAVE:	ACTIVE (4)/PASSIVE (2) SYSTEMS
OTHER:	INERTIAL NAVIGATION CENTRAL RECORDING
FEATURES:	STANDARD COMPLEMENT WALK-ON PAYLOAD CAPABILITY REMOTE INTEGRATION CAPABILITY

NASA-S-79-2009

PROGRAM AIRCRAFT - U2

TABLE 4.

ENGINE:	1 JET
ALTITUDE:	70, 000 FEET
DURATION:	6 HRS
PAYLOAD:	750 POUNDS INTERNAL + 600 POUNDS EXTERNAL
CREW:	PILOT

REMOTE SENSING EQUIPMENT

CAMERA:	METRIC - 6/12 - INCH FOCAL LENGTH
	9" X 18" FORMAT - 24 - INCH FOCAL LENGTH
	18" X 18" FORMAT - 36 - INCH FOCAL LENGTH
	OPTICAL BAR 4 1/2" X 50" FORMAT
	1^2 SMS - 4 SEPARATE LENS/FILTERS ON 9" FORMAT
	VINTEN MS - 4 CAMERAS 1 3/4" FOCAL LENGTH
	HIGH RES PAN DUAL CAMERA STEREO 2 1/4" X 30" FORMAT
SCANNER:	OCS - 10 OPTICAL SPECTRAL BANDS
	HCM - 1 VISIBLE BAND; 1 THERMAL BAND
	2 BAND THERMAL IR
	DAEDALUS - 10 OPTICAL BANDS; 1 THERMAL BAND
	1 BAND LINE SCAN CAMERA

NASA-S-79-2010

PROGRAM AIRCRAFT - CV990A

TABLE 5.

ENGINE: 4 TURBOFAN

ALTITUDE: 41,000 FEET

DURATION: 6.5 HRS

PAYLOAD: 14,000 + POUNDS

CREW: 4 PLUS P.I.S.

REMOTE SENSING EQUIPMENT

WALK ON EXPERIMENTS

NASA-S-79-1467 A

TABLE 6.

FY79 INVESTIGATION SUPPORT - WB57F

DISCIPLINE	PROJECT	SENSORS REQUIRED
FLIGHT PROJECTS	HCMM	SCANNER PHOTO
GEOLOGY	RADAR GEOLOGY GEOSAT	ACTIVE M/W (SLAR)
WATER RESOURCES	MODELING APPLICATIONS	ACTIVE M/W (SLAR) SCANNER PHOTO
LAND RESOURCES	APPLICATIONS RADAR LAND STUDY	ACTIVE M/W (SLAR) SCANNER PHOTO
LAND USE	AGRICULTURE INITIATIVE RANGE LAND INVENTORY	ACTIVE M/W (SLAR) SCANNER PHOTO
WEATHER & CLIMATE	SEVERE STORMS	SCANNER M/W SOUNDER PASSIVE M/W LIDAR
UNIV AFFAIRS	APPLICATIONS TRANSFER	SCANNER PHOTO

NASA-S-79-1466A

FY79 INVESTIGATION SUPPORT - C130

TABLE 7.

DISCIPLINE	PROJECT	SENSORS REQUIRED
FLIGHT PROJECTS	LANDSAT HCMM	SCANNER PHOTO
GEOLOGY	GEOSAT	SCANNER PHOTO
WATER RESOURCES	SNOW SOIL MOISTURE	PASSIVE M/W ACTIVE M/W SCANNER PHOTO
LAND RESOURCES	APPLICATIONS	SCANNER CAMERA
LAND USE	AGRICULTURE INITIATIVE BI-LATERAL PROGRAM RANGELAND INVENTORY	PASSIVE M/W ACTIVE M/W SCANNER PHOTO
OCEANS	ICE STUDIES	ACTIVE M/W
WEATHER & CLIMATE	SNOW STUDIES STORMS	SCANNER PHOTO
ENVIRONMENTAL	POLLUTION COASTAL ZONE	SCANNER PHOTO

NASA-S-79-2011

TABLE 8.

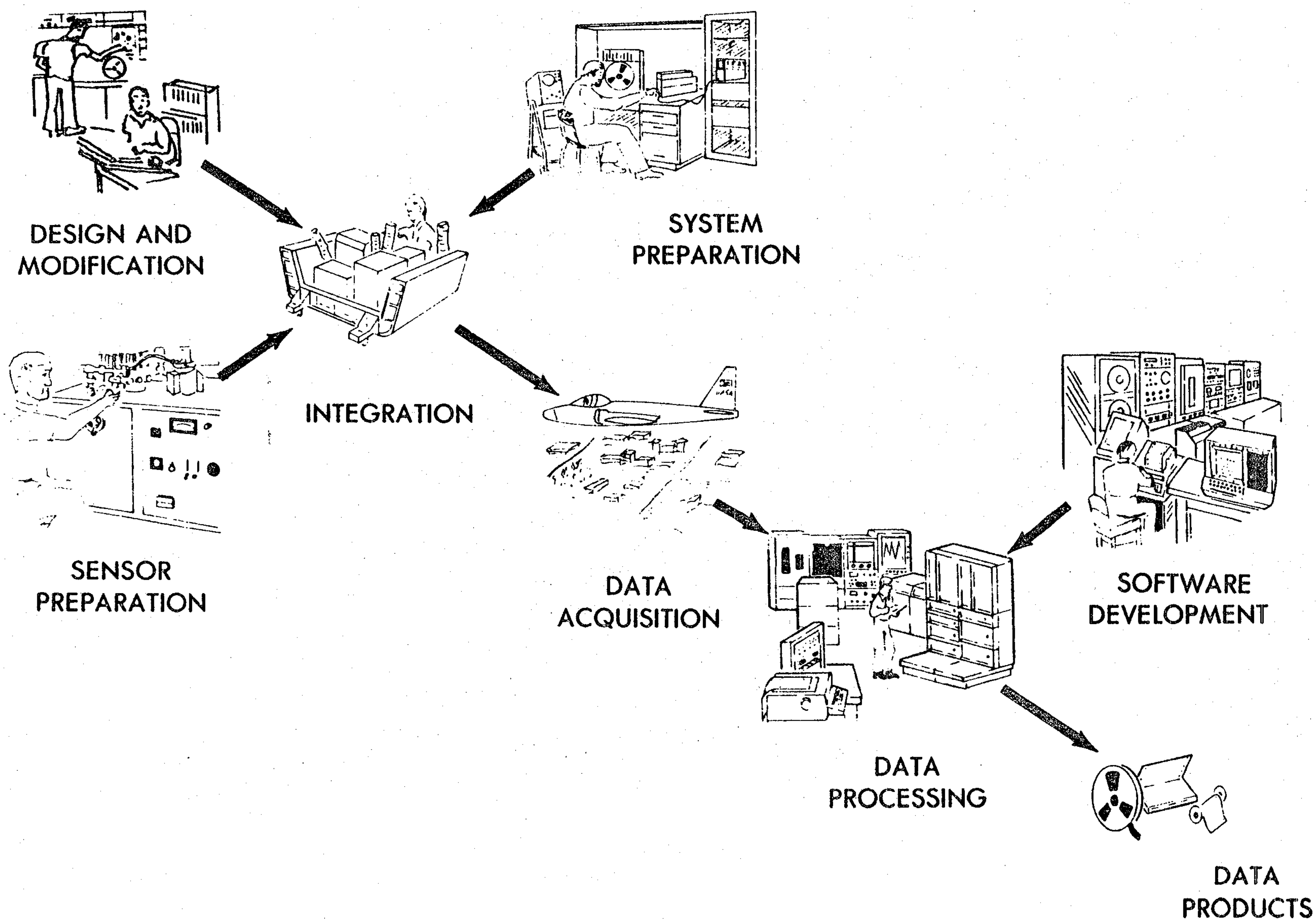
DATA OUTPUT PRODUCTS

- FILM PRODUCTS
  - POSITIVE AND NEGATIVE TRANSPARENCIES
  - CONTINUOUS AND FRAME PAPER PRINTS; COLOR AND BLACK & WHITE
  - TRANSPARENCY AND PAPER PRINT ENLARGEMENTS
  - FILM CALIBRATION AND ANALYSIS (DENSITOMETRY & SENSITOMETRY)
  - IMAGE ENHANCEMENT
  - FILM/FILTER SELECTIONS
- ELECTRONIC SENSOR DATA PROCESSING PRODUCTS
  - DIGITAL TAPE (CCT)
  - HARD COPY TAB
  - BLACK & WHITE 70 MM FILM
  - STRIP CHART
- ANCILLARY DATA
  - ALTITUDE
  - SPEED
  - HEADING
  - LAT/LONG VS TIME
  - CAMERA CORRELATION TABS

NASA-S-79-2003

FIGURE 1.

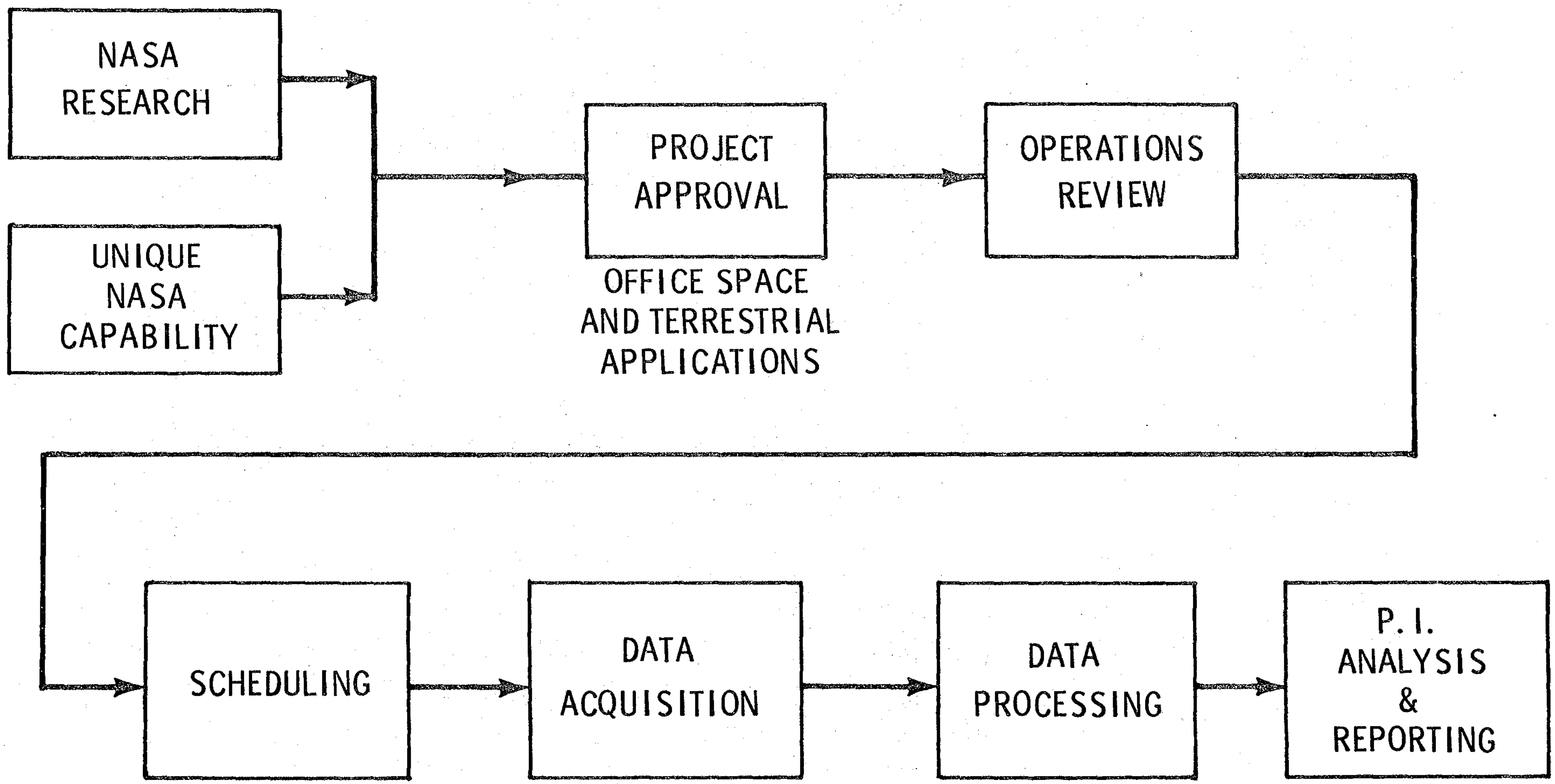
AIRBORNE INSTRUMENTATION RESEARCH PROGRAM



NASA-S-79-2012

FIGURE 2.

THE SYSTEM



COMMERCIAL AIRCRAFT REMOTE SENSING

Robert Macomber *
Earth Satellite Corporation
Washington, DC 20015

So far this morning you have been introduced to the physics of remote sensing, remote sensing devices, satellite platforms, and NASA research aircraft platforms. I shall now complete this brief introduction to remote sensing by describing the various aircraft platforms available from the commercial sector. In particular, the user can expect that one or more of the aircraft that shall be discussed will be used on his mission if flown by a commercial remote sensing company.

I have decided that the most efficient way of describing the data regarding commerical aircraft would be in matrix form. The first matrix (Table 1) deals primarily with the operating characteristics of the various aircraft. The aircraft have been listed on the left, with such characteristics as size, air speed, etc., listed across the top. Also in this table is the minimum scale (aircraft flown at its maximum certified altitude) available using a 9" x 9" metric mapping camera. The table also includes an estimate for the approximate cost per hour of flying such aircraft. It should be stressed, however, that these costs are approximate, being subject to such variables as remote sensing gear on board, navigation system, weather region, number of days required for complete mission, controlled airspace proximity, film type, scale, and more recently, the cost of fuel. Finally, the various types of navigation used on such aircraft are delineated. Pilotage here refers to "seat-of-the pants" flying.

Table 2 summarizes the photographic options available for each of the aircraft systems. This table is largely self-explanatory.

In Table 3 the non-photographic remote sensing alternatives as well as the ground-truthing capabilities of each of the aircrafts is included. I do not believe that enough attention is generally devoted to the ground-truthing alternatives. As you will see in my presentation tomorrow afternoon, the capability of landing on the water with a sea plane may prove invaluable to obtaining the accuracy that a mission requires to make it a success. In the ground-truthing section of the table, the term STOL refers to Short Take-off and Landing while off-airport landing refers to an aircraft's capability of landing on a grass strip--often a valuable asset when classifying in remote regions.

*Synopsis by: Peter Cornillon

Table - 1 COMMERCIAL REMOTE SENSING AIRCRAFT CAPABILITY/COST MATRIX: OPERATING CHARACTERISTICS

Aircraft Category	Typical Aircraft Make & Model	Size (# seats)	Min/Max Airspeed mph	Max Certified Service Ceiling (1000')	Min Scale 9" x 9" metric 3½" (at sea level)	Min Scale 9" x 9" metric 6" (at sea level)	Approx. Cost/Hour	NAVIGATION SYSTEMS Pilotage	Area NAV	Omega VLF	Loran C
Single Engine Land Piston	Piper Super Cub	2	15/115	19.0	NA	NA	30/40	X			
	Cessna 172	3-4	50/125	14.2	NA	NA	30/40	X	X		
	Cessna 180-206	5-6	60/160	17.7	1:60,000	1:35,000	150/250	X	X	X	X
	Turbo 206	6	60/200	30.0	1:100,000	1:60,000	200/400	X	X	X	X
Single Engine Sea Piston	Piper Super Cub EDO 89-2000 Floats	2	15/100	18.0	NA	NA	50/60	X	X		
	Cessna 180-206 EDO Amphibious Floats	4	60/140	16.5	NA	NA	60/80	X	X		
Multi-Engine Land Piston	DC-3	30	60/180	25.0	1:80,000	1:50,000	1000	X	X	X	X
	Cessna 337	5	80/170	16.1	1:55,000	1:32,000	150/250	X	X	X	X
	Piper Aztec	6	80/190	17.6	1:60,000	1:35,000	250/500	X	X	X	X
	Cessna 310	6	80/190	19.8	1:67,000	1:40,000	250/500	X	X	X	X
	AeroCommander 500S	7	90/200	19.4	1:66,000	1:39,000	250/500	X	X	X	X
	Turbo Aztec F	6	80/240	24.0	1:80,000	1:48,000	350/600	X	X	X	X
	Turbo 310	6	80/270	30.0	1:100,000	1:60,000	350/600	X	X	X	X
	Turbo Commander 690B	7	90/340	32.8	1:110,000	1:65,000	350/600	X	X	X	X
	Cessna 421 (Pressurized turbo)	8	90/300	30.2	1:110,000	1:60,000	350/700	X	X	X	X
Multi-Engine Land Turbo Prop	Mitsubishi (Pressurized)	7-9	85/370	31.0	1:105,000	1:62,000	7500	X	X	X	X
	DeHavilland Twin Otter	20	65/200	26.7	1:90,000	1:52,000	200/400	X	X	X	X
Multi-Engine Jet	Cessna Citation (Pressurized)	8	100/400	41.0	1:140,000	1:80,000	700/1000	X	X	X	X
	Lear Jet 25D (Pressurized)	10	120/480	51.0	1:170,000	1:100,000	1000/1500	X	X	X	X
	Gulf Stream American II	12-19	125/555	43.0	1:146,000	1:86,000	1000/2000	X	X	X	X
Helicopter	Hughes 300 C (Piston)	3	/95	6.0	NA	NA	100	X	X		
	Hughes 500 D (Turbine)	5	/160	15.0	NA	NA	300	X	X	X	X
	Bell Jet Ranger III (Turbine)	5	/135	13.5	NA	NA	300	X	X	X	X
	Aerospatial Dauphin 2	10-14	/155	15.9	NA	NA	450	X	X	X	X

Table - 2 COMMERCIAL REMOTE SENSING AIRCRAFT CAPABILITY/COST MATRIX: PHOTOGRAPHIC SENSORS

Aircraft Category	Typical Aircraft Make & Model	RECONNAISSANCE CAMERA 35 mm Nikon	2-1/4x2-1/4 Hassleblad	9" x 9" Fairchild T-12	PRECISION METRIC MAPPING CAMERA 9" x 9" e.g. Wild/Zeiss/Jena			2(9") camera capability	MULTISPECTRAL CAMERA SYSTEM 2 or more Hassleblads	4 lense 9" x 9
Single Engine Land Piston	Piper Super Cub	X	X	X					X	
	Cessna 172	X	X						X	
	Cessna 180-206	X	X	X	X	X	X		X	X
	Turbo 206	X	X	X	X	X	X		X	X
Single Engine Sea Piston	Piper Super Cub									
	EDO 89-2000 Floats	X	X						X	
	Cessna 180-206									
	EDO Amphibious Floats	X	X						X	
Multi-Engine Land Piston	DC-3			X	X	X	X	X		X
	Cessna 337	X	X	X	X	X	X	X		X
	Piper Aztec				X	X	X	X		X
	Cessna 310				X	X	X	X		X
	AeroCommander 500S				X	X	X	X		
	Turbo Aztec F				X	X	X	X		
	Turbo 310				X	X	X	X		
	Turbo Commander 690B				X	X	X	X		
	Cessna 421 (Pressurized turbo)				X	X	X	X		
Multi-Engine Land Turbo Prop	Mitsubishi (Pressurized)									
	DeHavilland Twin Otter									
Multi-Engine Jet	Cessna Citation (Pressurized)									
	Lear Jet 25D (Pressurized)									
	Gulf Stream American II									
Helicopter	Hughes 300 C (Piston)	X	X						X	
	Hughes 500 D (Turbine)	X	X						X	
	Bell Jet Ranger III (Turbine)	X	X						X	
	Aerospatial Dauphin 2	X	X						X	

Table - 3 COMMERCIAL REMOTE SENSING AIRCRAFT CAPABILITY/COST MATRIX: NON PHOTOGRAPHIC SENSORS AND GROUND TRUTHING

Aircraft Category	Typical Aircraft Make & Model	MAGNETOMETER ELECTROMAG	THERMAL SENSING SYSTEMS			RADAR SAR/SLAR	GROUND TRUTHING CAPABILITY		
			Radiometer	Thermal Scanner	Multispectral Scanner		STOL	Off-Airport Landing	Water Surface Sampling
Single Engine Land Piston	Piper Super Cub		X				X	X	
	Cessna 172		X						
	Cessna 180-206		X	X	X		X	X	
	Turbo 206		X	X	X		X		
Single Engine Sea Piston	Piper Super Cub EDO 89-2000 Floats		X				X		X
	Cessna 180-206 EDO Amphibious Floats		X				X		X
Multi-Engine Land Position	DC-3	X	X	X	X	X			
	Cessna 337		X	X	X				
	Piper Aztec			X	X				
	Cessna 310			X	X				
	Aerocommander 500S			X	X				
	Turbo Aztec F			X	X				
	Turbo 310			X	X				
	Turbo Commander 690B			X	X				
	Cessna 421 (Pressurized turbo)			X	X				
Multi-Engine Land Turbo Prop	Mitsubishi (Pressurized)					X	X		
	DeHavilland Twin Otter								
Multi-Engine Jet	Cessna Citation (Pressurized)		X	X	X				
	Lear Jet 25D (Pressurized)		X	X	X	X			
	Gulf Stream American II			X	X	X			
Helicopter	Hughes 300 C (Piston)		X				X	X	X
	Hughes 500 D (Turbine)		X	X	X		X	X	X
	Bell Jet Ranger III (Turbine)		X	X	X		X	X	X
	Aerospatial Dauphin 2	X	X	X	X		X	X	X

DATA SOURCES AND PROCESSING SYSTEMS

James Zaitzeff, Chairman

THE EROS DATA CENTER: PRODUCTS AND SERVICES

William Anderson*
Earth Resources Observations Systems Data Center
U.S. Geological Survey
Sioux Falls, SD 57198

The EROS Data Center is a part of the Earth Resources Observation Systems (EROS) Program of the Department of the Interior, managed by the U.S. Geological Survey.

It is the national center for the processing and dissemination of photographic imagery and electronic data of the Earth's resources taken from aircraft and spacecraft. The center also trains and assists users in the application of such data.

The EROS Data Center provides access to Landsat data, aerial photography acquired by the U.S. Department of the Interior, and photography and other remotely sensed data acquired by the National Aeronautics and Space Administration (NASA) from research aircraft and from Skylab, Apollo, and Gemini spacecraft.

At the heart of the Data Center is a central computer complex that controls a data base of more than 6 million images and photographs of the Earth's surface, performs searches of specific geographic areas of interest, and serves as a management tool for the entire data reproduction process. The computerized data storage and retrieval system is based on the goegraphic system of latitude and longitude, supplemented by information about image quality, cloud cover, and type of data. Guided by customer requirements, a computer geographic search will print out a listing of available imagery and photography from which the requester can make a final selection.

Periodically, training sessions in remote sensing are given at the EROS Data Center. Normally, the sessions are up to one week long and stress the use of data for a particular application, such as agricultural inventory or water management. About twice a year, a three-week course is offered for foreign nationals. This course stresses the fundamentals of remote sensing and introduces the application of remotely sensed data to the solution of various natural resource management problems. Formal training is supplemented by color slides and recorded tapes that cover the basic methodology of remote sensing and selected applications.

The EROS Data Center has an expanding capability to perform computer-assisted analysis of imagery. Special devices permit the experimental use of digital analysis techniques to classify phenomena by their reflectance or emittance in different parts of the electromagnetic spectrum.

* This report has been taken from an EROS publication.

The center also maintains a technical library of information on remote sensing of Earth resources for the use of students who are attending training courses, visitors, and data center personnel.

LANDSAT DATA

NASA's Landsat satellites are unmanned space observatories orbiting the Earth at an altitude of approximately 570 miles [920 kilometers (km)]. Each Landsat circles the Earth every 103 minutes and repeats its orbital path every 18 days, thus providing repetitive coverage of almost the entire globe. The satellites transmit data by telemetry to NASA ground receiving stations in Alaska, California, and Maryland. The data are recorded on magnetic tapes and subsequently converted to computer compatible tapes and photo-like images. Each individual scene covers a ground area of 115 by 115 statue miles (185 by 185 km). Copies are stored at the EROS Data Center for reproduction and sale to users throughout the world.

SKYLAB DATA

The NASA Skylab Program consisted of one unmanned and three manned missions. The unmanned space vehicle was placed in orbit in May 1973. The manned missions to the space vehicle were launched on May 25, July 28, and November 16, 1973.

The spacecraft traveled in an orbit 270 miles (430 km) above the Earth and acquired photography, imagery, and other data of selected areas between latitudes 50° N. and 50° S. The data cover a number of scattered test sites selected to support Earth resources experiments.

NASA AERIAL PHOTOGRAPHY

NASA aerial photography is the product of surveys carried out by the NASA Earth Resources Aircraft Program. The program primarily tests remote sensing instruments and techniques in aerial flights generally over certain preselected test sites within the continental United States.

Imagery is available in a wide variety of formats from flights at altitudes of a few thousand feet up to U-2 and RB-57F flights at altitudes above 60,000 feet.

Aerial photography is available in black and white, color, or false-color infrared. Because these data are acquired at relatively low altitudes, ground features such as roads, farms, and cities are easily identifiable. Electronic data from the more sophisticated research sensors on the aircraft may also be obtained through the Data Center.

AERIAL MAPPING PHOTOGRAPHY

For the past 25 years, aerial photography has been acquired by the U.S. Geological Survey and other Federal agencies for mapping of the United States. The photography is black and white and the aerial-survey altitude ranges from 2,000 to 40,000 feet, depending on the planned use of the photographs.

Orders for photos and images, inquiries on the availability of coverage over specific areas, and requests for price information should be directed to:

EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57198
Phone: (605) 594-6511, ext. 151
FTS: 784-7151

MARINE SERVICES AND PRODUCTS SUPPLIED BY NOAA'S SATELLITE FIELD SERVICES STATIONS

Robert L. Mairs
National Oceanographic and Atmospheric Administration
National Environmental Satellite Service
Camp Springs, MD 20031

In 1974 the National Environmental Satellite Service (NESS) took a bold step toward meeting the needs of the operational marine community by establishing Satellite Field Services Stations (SFSS's) and hiring round-the-clock meteorologists and oceanographers to man these stations. Prior to this time NESS's operational services were primarily geared toward the terrestrial meteorological community, but in 1974 a solid commitment was made to expand into the marine environment. NESS has stations located in Washington, DC; Miami, FL; Kansas City, MO; San Francisco, CA; Anchorage, AK; and Honolulu, HA. These SFSS's act as links between their respective regional users and the satellite technology available. A thorough examination of user needs and problems and a subsequent attempt to format existing satellite information in such a way that is useful,fall within the mission of the SFSS's. For example, many different user groups may need information on one particular oceanic parameter, such as sea surface temperature, but it may be necessary to present these data in a different way to each user. This is the function of the SFSS's: to provide useful information products and services that will meet the needs and make sense to the users themselves.

Satellite data available to these SFSS's come from NOAA's two operational satellite systems: the polar orbiting NOAA and TIROS series and the geostationary GOES series. Each collects visible imagery during daylight hours and thermal infrared at all times. The polar orbiting satellites pass over any particular point twice daily whereas the geostationary satellites are "parked" in orbit at particular longitudes, 75°W and 135°W, which allows for the transmission of imagery over the same spot every thirty minutes.

With qualified field personnel utilizing this new technology, charged to meet regional marine needs, many new operational products and services are now available to the public. The following will provide details about several of these significant application areas.

FISHERIES

Many species of fish are known to be temperature sensitive for comfort, food, or for predator cover, and their food chain is also often found concentrated along satellite detected ocean thermal fronts. It has long been known by U.S. West Coast fishermen that they catch more salmon and albacore at what they call temperature "edges." The "edges" are actually boundaries between upwelled cold water and the adjacent warm oceanic water. Upwelling along the West Coast occurs seasonally and this upwelled water is usually rich in nutrients and therefore thought to attract fish. However, many fish, salmon and albacore included, seem to be attracted to temperature boundaries purely because of the temperature difference. Knowing where these fronts are would eliminate much of the time otherwise expended in searching for them. Our San Francisco SFSS began experimenting with ways to enhance the visibility of these fronts and providing the information to fishermen in late 1974-early 1975 using satellite images. Since NOAA's satellites can measure the temperature of the sea surface, various means were explored to better discern and subsequently display this frontal information in a format that would be useful to the fishermen.

Since 1975 the product has evolved to its present form (Figure 1) and is provided via telecopier 24 hours a day and also by radiofacsimile twice daily. According to the fishermen themselves, it has greatly assisted them in locating fish productive areas. Charts are now produced that cover an area from the tip of Baja California north to the Canadian border.

An example of how the fishing community has received this product is indicated in a quotation from the Summary of Pacific Input to the Eastland Fisheries Survey prepared by the Pacific Marine Fisheries Commission for a report to Congress dated May 1977:

> "Commercial salmon and albacore trollers emphasized that the federal government should not be involved in developing new equipment and methods for locating fish with one exception. They support the use of satellite pictures which display temperature gradients and indicate that the federal government should continue to use existing satellites to provide this information. Present methods for developing and providing advisories are adequate and existing advisories for the albacore fleet should continue. More emphasis should be placed on provision of practical information such as water temperature, weather, and currents...."

In addition to this program being of immediate benefit to the salmon and albacore fishery, it is beginning to help in that the U.S. East Coast swordfishery is beginning to participate through our Washington, DC, SFSS.

MARINE TRANSPORTATION

In 1974 NESS began an experiment with the EXXON Oil Company in an attempt to better utilize the velocity of the Gulf Stream for tanker transits between the Gulf Stream and the Northeastern U.S. The plan was for NESS analysts to determine the exact position of the Gulf Stream twice weekly, code this position into a voice broadcast and then give the information to EXXON, which transmitted it to half its fleet. In a period of six months those tankers that had the information were doing so much better than those without, that EXXON deemed the experiment a success and began giving the information to all its ships. Since that time NESS has evolved the program into a thrice-weekly analysis and subsequent radio broadcasts as part of the NWS/Coast Marine weather broadcasts available to any mariner.

NESS also does an analysis for the Loop Current in the Gulf of Mexico and is exploring a means of analyzing the Pacific equatorial currents.

Another phenomena of concern to marine transportation is ice. NESS prepares analyses of ice for the Arctic seas, the Great Lakes, and the Labrador coast.

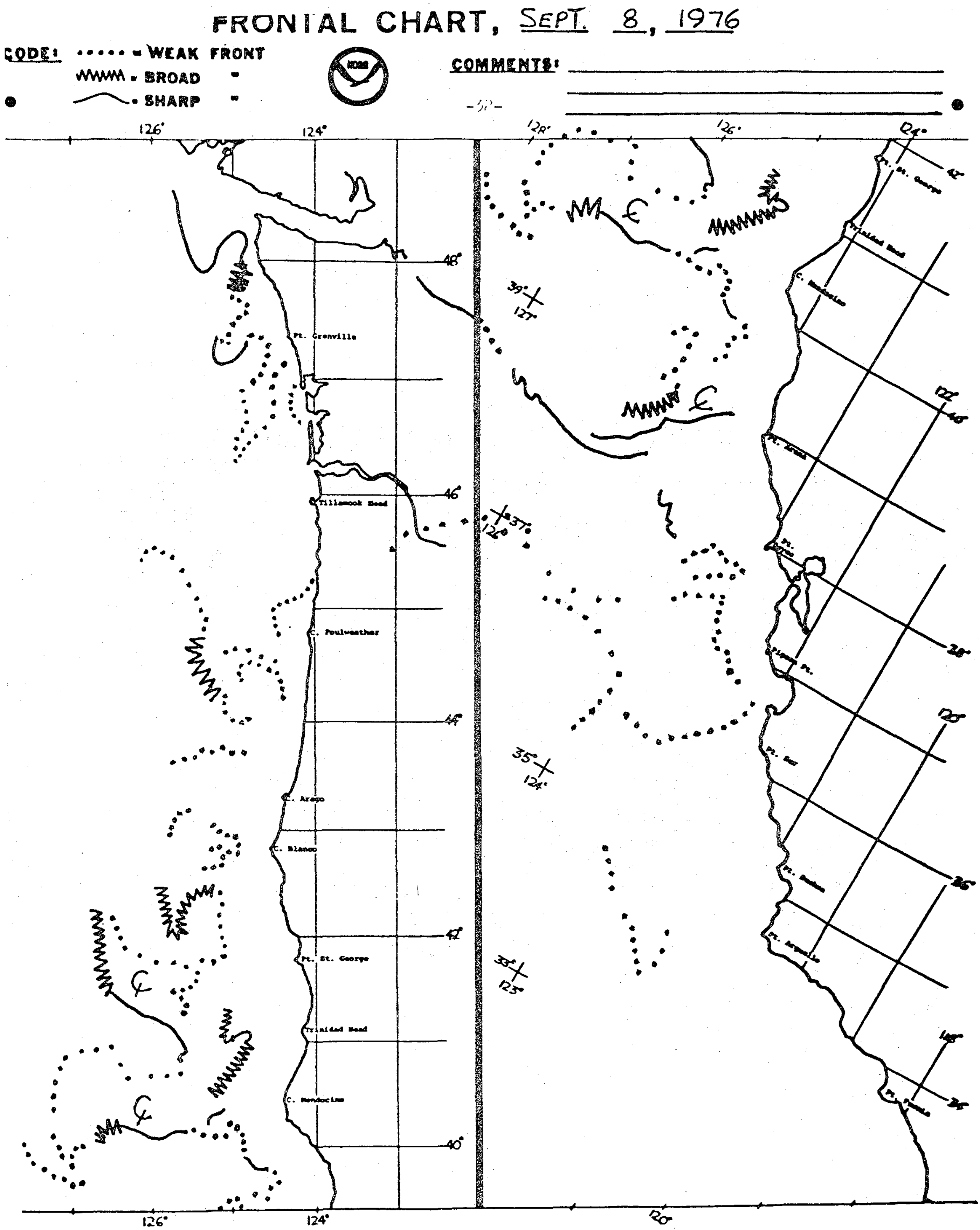
SEARCH AND RESCUE (SAR) OPERATIONS

NESS has always had a close working relationship with the U.S. Coast Guard. The SFSS's provide regional support for SAR operations with satellite analyses of present weather, sea surface temperature, and current boundaries. This allows the U.S. Coast Guard to plan its search efforts in the most efficient manner.

We also work with the Civil Air Patrol in trying to locate downed aircraft. At the time of an alert, personnel at our SFSS's try to pinpoint areas of severe weather as likely spots to begin search activities.

These are a few of our present marine activities within the Satellite Services Division. Each of the SFSS's has personnel that are ready to discuss the needs of the marine community and try to help through the use of NOAA's operational satellite data.

FIGURE 1.


FRONTAL CHART, SEPT. 8, 1976
CODE: WEAK FRONT
BROAD
SHARP
COMMENTS:
126°
124°
48°
Pt. Grenville
46°
Tillamook Head
C. Foulweather
44°
C. Arago
C. Blanco
42°
Pt. St. George
Trinidad Head
C. Mendocino
40°
128°
126°
124°
39°
127°
37°
126°
35°
124°
33°
123°
Pt. Arena
Pigeon Pt.
Pt. Sur
Pt. Arguello
120°
122°
38°
36°
34°

NASA EASTERN REGIONAL REMOTE SENSING APPLICATIONS CENTER (ERRSAC)

Phillip Cressy
Goddard Space Flight Center/NASA
Greenbelt, MD 20771

To help state and local governments learn to apply space-developed earth technology, National Aeronautics and Space Administration initiated the Regional Remote Sensing Applications Program in 1977, dividing technology transfer responsibility among three NASA field installations.

The Eastern Regional Remote Sensing Applications Center (ERRSAC) at Goddard Space Flight Center in Greenbelt, Maryland, has responsibility for this program in 19 northeastern and north central states: Connecticut, Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin, as well as in the District of Columbia, Puerto Rico, and the Virgin Islands.

The other Regional Centers are Ames Research Center, Moffett Field, California; responsible for 14 western states, and Earth Resource Laboratory of National Space Technology Laboratories (NSTL), Mississippi; responsible for 17 south central and southeastern states.

The Regional Applications Program has dual objectives: to make potential users aware of the benefits of Landsat data and to assist them in becoming self-sufficient users of the technology. The Centers have the equipment and expertise to assist both new and experienced users in making effective use of the technology.

At ERRSAC, the focus of the technology transfer program is on helping users plan and carry out their own remote sensing applications projects as part of a cooperative ERRSAC/user program involving training, demonstration projects, and technical assistance. Cooperative programs are ERRSAC's core activity. They provide users with a low-cost, low-risk opportunity to examine Landsat applications and to identify aspects consistent with their resources and needs. To do this, the user becomes fully involved in the process of converting raw Landsat data into useful management information.

The cooperative process begins with the initial contact between ERRSAC and the user organizations. Users may hear of the programs through ERRSAC's publications or they may attend one of the introductory workshops that ERRSAC conducts throughout the region. User and ERRSAC staff next sit down to discuss the state's information needs, the resources and facilities ERRSAC can provide, and the benefits and limitations of Landsat technology. Together, state and ERRSAC staff develop a statewide program, including identification of a set of demonstration projects using Landsat data that will provide users with useful resource management information. ERRSAC encourages involvement in these projects by several agencies and disciplines with separate but related information needs. This approach permits the sharing of equipment and expertise and stretches scarce dollar resources--an important factor in eventual state adoption of the technology.

In preparation for the demonstration projects, ERRSAC provides intensive one or two-week training courses at the Goddard Space Flight Center.

Users learn about:

1. Remote sensing principles.
2. Data gathering systems.
3. Data processing systems.
4. Pertinent applications.
5. Information extraction and analysis.
6. Development of instate programs and systems.

During the training courses, users have the opportunity and option of performing computer-assisted data processing and classification on several different interactive and batch mode image analysis systems. Whenever possible, students work with systems that are similar or compatible with instate resources. Opportunities for integrating Landsat with other data are provided.

At the completion of the training, students return home to gather field and laboratory information to assist in Landsat data interpretation. For the duration of the project, ERRSAC is on call when needed for technical advice and assistance and will also provide a telephone tie-in to its computer facilities, if appropriate for further Landsat data processing. Participants may return to ERRSAC for additional training or for additional project work on ERRSAC's interactive image analysis system. ERRSAC also provides consultation and assistance on software development and incorporation of new techniques or data sources into operational use.

In developing this working partnership, both ERRSAC and the user groups must make important contributions.

ERRSAC provides:

1. Understanding of technical performance of remote sensing.
2. Technical personnel, facilities, materials, and equipment for training.
3. Remotely sensed data for training.
4. Access to image analysis systems.
5. Assistance in addressing institutional issues affecting user adoption of Landsat technology.

The user provides:

1. Understanding of information needs for resource management.
2. Staff release time in order to work with ERRSAC.
3. Travel as needed for training and projects.
4. Supporting data from the field and laboratory.

It is anticipated that these cooperative programs will lead to an instate capability to mix commercial and university contributions with inhouse resources in an ongoing statewide Landsat applications program. ERRSAC's role will evolve into that of assisting users in upgrading their capabilities to use new techniques and new satellite data sources.

ERRSAC offers an array of additional services to assist prospective and current users to learn more about Landsat technology.

Through the Remote Sensing Information Center ERRSAC maintains a library of all Landsat imagery acquired to date. This imagery is available for viewing on 70 mm positive film, microfilm cassettes, and microfiche cards. The Center also maintains historical files of Landsat false color composites. Landsat data are assessed through an INORAC on-line system at the U.S. Department of the Interior's EROS data Center in Sioux Falls, South Dakota. By querying this data base, a computer listing can identify all available imagery for a particular region and list pertinent information such as date of acquisition, product quality, and percentage of cloud cover for each scene. ERRSAC also maintains a file of maps and other reference and orientation materials.

The Center also maintains a reference library that provides efficient access to information on Landsat research and projects needed by ERRSAC staff and by state and local participants in the ERRSAC program. The Center also has the capability of accessing numerous computerized data files to conduct literature searches, and can obtain material through interlibrary loans from other remote sensing libraries throughout NASA and the Federal Government.

Literature available from ERRSAC includes: (1) quarterly newsletter, REFLECTIONS, that reports on remote sensing applications planned or in progress throughout the region, and new capabilities in computer image analysis techniques; (2) Application surveys that describe available products and services of use in remote sensing applications, and (3) Application bulletins that provide capsule reports on applications of remote sensing technology to state and local issues.

In a related activity ERRSAC invites university faculty from its region to participate in a summer internship program. The purpose is to enhance university capabilities to undertake remote sensing applications programs and to assist them to introduce remote sensing technology into their curricula. Emphasis is placed on user-related projects selected by the participants. ERRSAC provides formal training in remote sensing principles and computer processing and a great deal of hands-on image processing experience. A stay of up to ten weeks is encouraged.

INTERACTIVE REAL-TIME IMAGE PROCESSING SYSTEMS FOR RESEARCH APPLICATIONS

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Background

This presentation describes two interactive image processing systems developed by the Goddard Space Flight Center: the Atmospheric and Oceanographic Information Processing System (AOIPS) and the Visible Infrared Span Scan Radiometer Atmospheric Sounder (VAS) processing system. Both systems were designed to ingest Geostationary Operational Environmental Satellite (GOES) data in real time and to process, display, and analyze the GOES images using digital processing techniques in support of weather-related research activities.

The AOIPS is used to support a variety of non-weather-related applications investigations in the earth resources, hydrology, geology, forestry, land use, and oceanography disciplines.

System Overview

The AOIPS-VAS system configurations and their interconnections are shown in Figure 1. Both systems use Digital Equipment Corporation PDP 11/70 minicomputers, and incorporate the normal complement of standard computer peripherals including magnetic tape drives, disk storage units, alphanumeric display terminals, and punched card readers. The systems also contain several unique peripherals such as interactive color TV image analysis and display terminals (IAT), very high density digital tape recorders, a digital TV input scanner, real-time satellite data acquisition subsystems, and shared disk units used to interconnect the system.

Detailed descriptions of the AOIPS/VAS hardware configurations and of the AOIPS software capabilities are presented in Bracken et al.(1977).

System Capabilities

The AOIPS and VAS systems provide extensive capabilities for:

a. inputting data, including Landsat, SMS/GOES, CZCS, ground-based radar, and aircraft scanner image data, as well as a variety of surface truth measurements and ancillary data

b. registering and correcting data sets

c. overlaying images, and image related ancillary data

d. displaying plots, contours, and graphic data separately and overlayed on images

e. processing, analyzing, and enhancing images

f. performing data analysis operations, including deriving wind vector fields, temperature and humidity profiles, parameter classifications, and statistical analyses

g. generating final, hard copy output products of analysis results

Both systems provide modular, menu-driven softward packages for interactive processing, display and analysis of remote sensing, and related ancillary data. In addition, the VAS processing system provides extensive interactive data management capabilities for cataloging, searching, storing, retrieving, and manipulating GOES-D/VAS data as well as TIROS, Nimbus, ground radar, and aircraft data.

System Applications

The AOIPS and VAS systems are used by scientists to support the data analysis and information extraction requirements of research programs and applications demonstrations. The primary applications supported include:

a. severe storms research

wind vector field generation and analysis

severe storm development and dynamics

generation of atmospheric temperature and humidity profiles

b. oceanography

sea surface temperature studies

bathymetry

ocean color mapping

c. hydrology

flood plane mapping

snow cover mapping

hydrological modeling

d. earth resources

forestry

geology

agriculture

land use studies

Summary

The AOIPS and VAS systems allow investigators to interact with digital image data, to combine multisource/multitemporal data sets, and to extract desired information rapidly. These capabilities can serve as a test bed to demonstrate the utility of remotely sensed data, in combination with surface truth measurements, for a variety of oceans-related research and demonstration programs.

References

Bracken, P.A., J. T. Dalton, J.B. Billingsley, and J.J. Quann. "Atmospheric and Oceanographic Information Processing System (AOIPS) System Description," NASA/GSFC Technical Report X-933-77-148, Greenbelt, MD, March 1977.

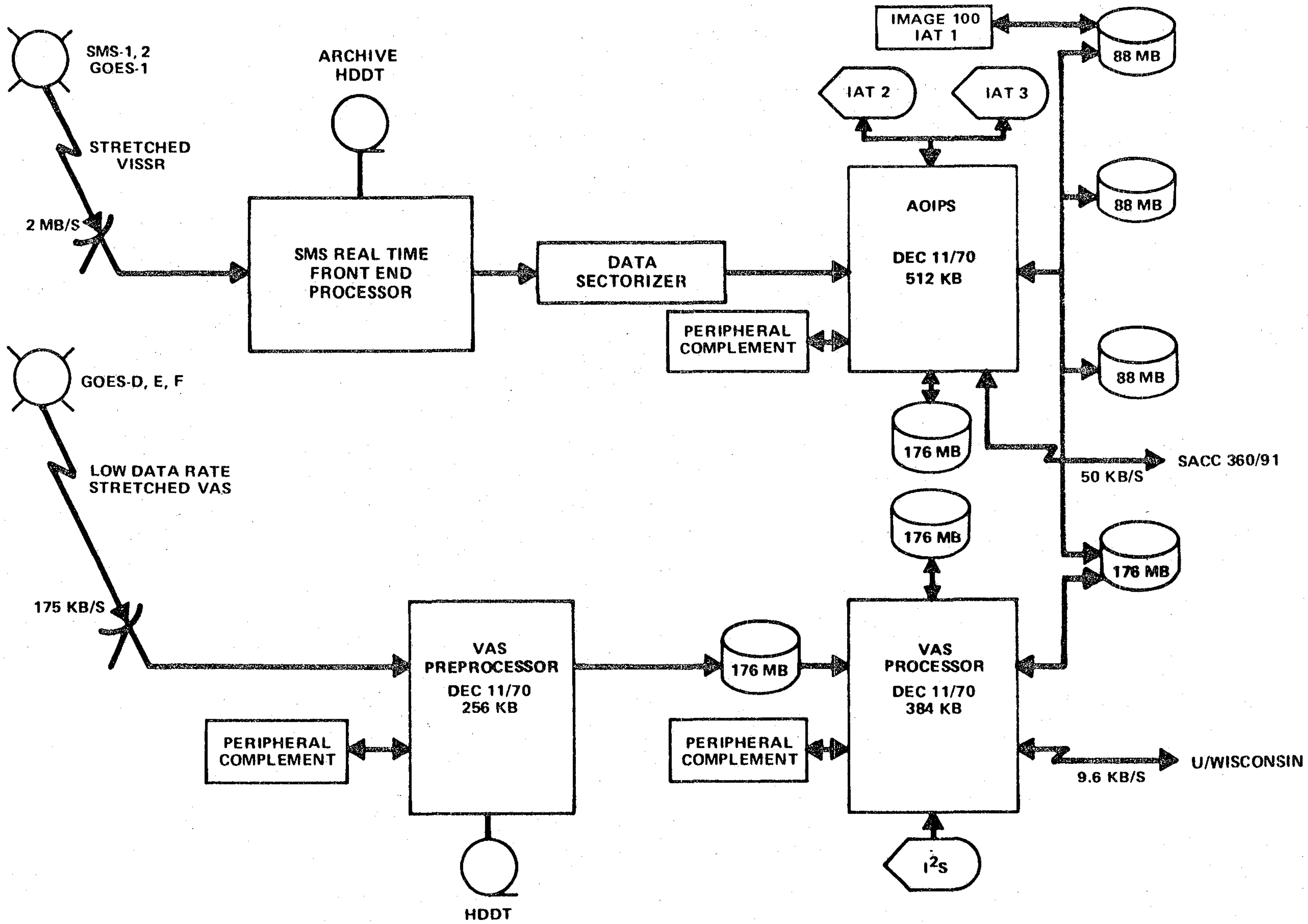

FIGURE 1 **AOIPS—VAS SYSTEM CONFIGURATION**

IMAGING PROCESSORS FOR EARTH OBSERVATIONS ANALYSIS - PRESENT AND FUTURE

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EARTH RESOURCES DATA CENTER (ERDC)

The Earth Resources Data Center (ERDC) of the Environmental Research Institute of Michigan (ERIM) is producing maps and datagraphics from aircraft and satellite systems for resource and environmental planners worldwide. Since the launching of the first Landsat satellite in 1972, the ERDC has been used to develop operational applications of Landsat data and is believed to be the largest non-government processing facility in the world. ERDC is analyzing over 200 scenes from digital tapes yearly and is known for its high quality, user-oriented maps and images resulting from its drum film recorder. User satisfaction with the quality and cost of the ERDC products has been universal.

These projects have included inventories of natural and productive resources of areas the size of a single province and smaller to statewide land use, including inventories of Ohio and North Dakota, Orissa India, Bangladesh, and most of Burma. The digital analysis and processing techniques used have shown that the interpreted Landsat data can be combined with data from other sources to provide cartographically accurate digital files over large geographical areas. These files can be used for natural resources planning and management, land use planning, and estimating agriculture (crop) yields, and with periodic resurveys they can be used for monitoring environmental and resource changes. The digital files can also be used to provide the basic structure of a geographically oriented data base for containing any information useful to the planning and management of earth resources.

HISTORY OF ERDC

ERDC had its beginning in the late 1960's when it was established by the Bendix Corporation under the name of MIRIA Laboratory to process multispectral data from a nine-band analog aircraft scanner built by Bendix as an experimental system. Over the years the Center grew to a complete, advanced multispectral data processing facility capable of handling data from all known digital multispectral sensors. During the last few years the Center has processed data from Landsat (via EROS, Telespazio, and INPE), Skylab S-192, MSDS (the 24-channel scanner), and airborne scanners (ERIM M-7, Bendix M^2S, and Daedalus).

In May 1978 the ERDC was transferred to the Environmental Research Institute of Michigan (ERIM) from the Bendix Corporation through a gift-sale agreement. The facility, together with its key people, now form the ERDC Department with ERIM's Applications Division. In this new environment the facility offers unmatched capabilities for the processing and analysis of remote sensing data.

PRESENT DATA USES AND FUTURE TRENDS

Landsat data, by itself and in combination with other sources of data, has received increasing acceptance as a low cost and effective approach to land cover and vegetation mapping and inventory. Although both photointerpretation of Landsat imagery and computer processing of Landsat digital data are in common usage, more development emphasis is currently being placed on computer processing techniques because of the adaptability of digitally processed data for computerized information management systems.

Assuming that the current workload in the Earth Resources Data Center (ERDC) at ERIM is somewhat representative of activity in the private remote sensing sector, current Landsat processing and expected future activities are as shown in Table 1. Although at present over one third of the processing performed is generation of high quality imagery from Landsat CCT's, the trend will be away from this product and is expected to be 20% or less of the throughput in the next few years, primarily from foreign countries. The expected cause of this trend is twofold: 1) the dramatic improvement in image quality from the EROS Data Center; and, 2) the more rapid growth rate of digital data products than imagery products.

Further, the level of sophistication of the digital files and maps is increasing with time. In the early days of Landsat, efforts were concentrated on reduction of applications to practice and early products were geometrically crude images representing relatively simple processing techniques. Current products, both maps and files, are geometrically precise, offered at a wide range of scale, map projections and sampling intervals, and are generally composed of data from a number of sources besides Landsat. A typical map or digital file can incorporate data derived from both Landsat and digitized aerial photography, as shown in Figure 1, to combine the low cost of processed Landsat data with needed information which cannot be derived from Landsat, such as urban land use. Future trends in data products will see further growth along these lines, with Landsat data being merged with a wide range of other data sources, such as topography, soils, watershed boundaries, and precipitation patterns to derive such information as suitability for agricultural development, resource management, and environmental impact.

In addition to trends in data products, there are trends in the facilities used to generate these products. The ERIM Earth Resources Data Center is a typical Landsat digital processing facility of today. It is composed of a medium to large minicomputer (DEC PDP 11/70) with digitally refreshed color displays, input/output tape transports, fairly large capacity disc storage, a high quality film recorder, and supporting facilities, such as digitizing tables, photographic labs. A facility such as this will cost between one-half million and one million dollars and require a supporting staff of 5-10 professionals. An expected trend is the development of low cost microprocessor based distributed data processing systems, networked with high cost peripherals, such as mass storage and high quality mapping devices. It is in the context of these trends, both in terms of products being generated and techniques for generating them, that data handling, present and future, is discussed.

TABLE 1

ERDC LANDSAT PROCESSING

	Present	Future (5 years)
Foreign	33%	50%
Domestic	67%	50%
Mix by Customer		
Government	40%	40%
Consulting Firms	40%	40%
Exploration Firms	20%	20%
Mix by Product		
Imagery	35%	20%
Digital Files	35%	50%
Maps	30%	30%

DATA HANDLING - FUTURE

Digital land cover files and maps are becoming more sophisticated. They are offered in a wider range of scales, projections, and sampling intervals, and they comprise a number of sources of information combined in a common or registered format. In addition to requiring more flexible handling of multiple sources, remote sensing sensor improvements will increase the volume of remote sensing data to be handled through both resolution improvements and increase in the number of bands. Also, new sensors providing new kinds of information, such as Stereosat, will be developed.

Fortunately, due to the current explosion in digital processing equipments, the capabilities of data handling hardware are increasing more rapidly than the data handling requirements. We are at the beginning of an era of rapidly improving information handling capabilities whose impact on our culture will, in all likelihood, be greater than the industrial revolution.

MULTISOURCE MAPPING

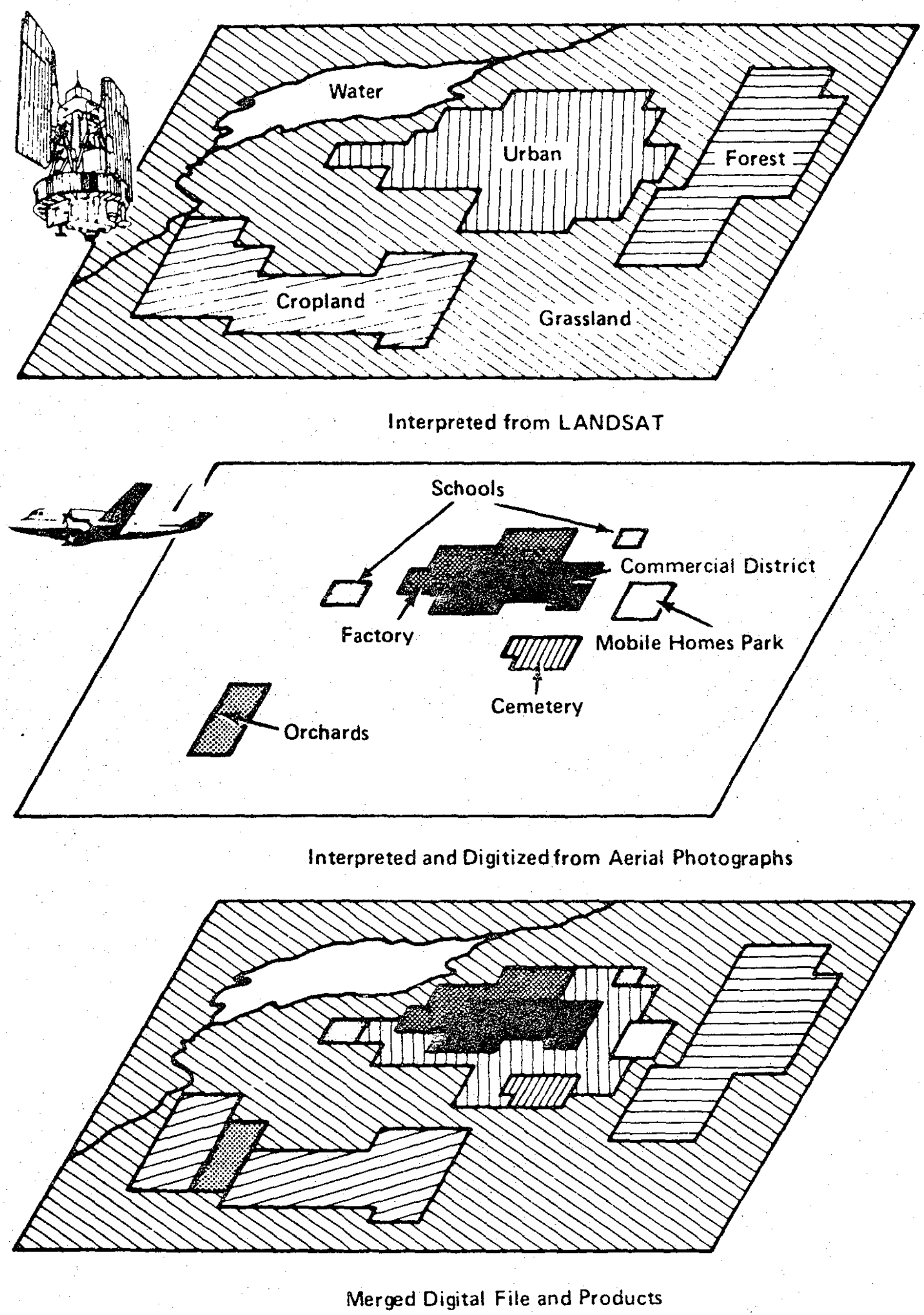

FIGURE 1

THE AVAILABILITY OF U.S. ENVIRONMENTAL SATELLITE DATA

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ABSTRACT:

The United States Archive of environmental satellite data at the Satellite Data Services Division of the National Oceanic and Atmospheric Administration (NOAA) represents a unique source of information for various investigations within many scientific disciplines. While primarily intended for meteorological purposes, many sensors orbited on the more recent spacecraft, such as SEASAT and NIMBUS-7, also provide data of great value to the marine sciences. The data held within the Archive consist of imagery in both photographic and digital tape formats, and derived parameters, (wave heights, wind speed, wind direction, sea-surface temperature, etc.) on digital tapes and paper printouts. Initiated only in late 1974, the archive includes photographic imagery from the earliest meteorological satellites of the 1960s through the latest polar orbiting and geostationary spacecraft.

INTRODUCTION:

Nearly everyone is aware that the United States and other nations have various satellites in orbit around the earth. Not many people, however, are aware of the many uses of the data from these satellites, what types of data are available, and where they may be obtained.

Within the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) is the Satellite Data Services Division (SDSD) which acts as the United States Archive of environmental satellite data, and is collocated with the operations center of NOAA's National Environmental Satellite Service (NESS) which manages the National Operational Environmental Satellite Program. Collocation expedites SDSD's acquisition of satellite data and allows SDSD personnel to monitor the latest applications of satellite data, to note outstanding environmental events which may be of interest to subsequent users, and to ensure that original imagery negatives and magnetic tapes reach the Division in good condition and as economically as possible.

ORGANIZATION OF FILES:

The files within the Archive have been indexed and arranged to facilitate retrieval of data to answer requests. The arrangement has been based on experience gained in the past several years from the type and extent of requests serviced. Most requests have been concerned and primarily identified with a geographic area, a specific date or time period, a certain sensor and region of the spectrum, a specific phenomenon of interest, and a specified data resolution; in that order. Thus, our data are first separated by individual satellites with their unique areal coverage, further broken down by date and sensor type, and finally by resolution or scale. Specific data formats, such as magnetic tape and 35 mm, 70 mm, and 25 x 25 cm film, are also maintained in individual files.

OCEANOGRAPHIC USES:

During the relatively short existence of the Archive, we have seen substantial increases in the use of these data by oceanographers, marine biologists, and other investigators within the oceanographic community.

The Scanning Radiometer daily Infrared and Visible data held on digital tape since 1972 in Polar-Stereographic Hemispheric Mosaic format have been steadily gaining in use for climatological purposes. The Sea-Surface Temperature digital data contain the daily sea-surface observations from the Scanning Radiometer from which weekly isoline charts for all ocean areas are prepared. These charts are used quite extensively to chart certain fish migrations which seem to be temperature related and controlled.

The addition of the Very High Resolution Radiometer (VHRR) Infrared Sensor to the operational polar-orbiting NOAA satellites provided a much better look at the sea-surface temperatures over much of the ocean areas. These 0.8 km-resolution data are being used effectively by the fisheries industry and sea transport companies and in the investigation of oceanic currents and other marine phenomena.

Geostationary satellites were first orbited experimentally in 1966 (ATS-1), but since only data in the Visible region of the spectrum were received, no great impact was felt by oceanographers. However, in 1974 SMS-1 was launched with an Infrared Sensor onboard, and with the experience gained using the data during GATE, the marine community began seeking uses for these data with their one-half hour periodicity. Even with its low resolution (8 km), it found a definite use in following the meanderings of the Gulf Stream, temperature variations in the Gulf of Mexico, and upwelling along the coasts. In August 1976 a digital Archive of geostationary satellite data consisting of five Infrared and One Visible full-disk images per day from each of the two U.S. satellites (GOES/EAST and GOES/WEST) was started. This was expanded in September 1978 to include a total of thirteen Infrared and five Visible images per day per satellite. Since then use of these quantitative data has been rapidly expanding. By mosaicking the 5 to 13 sequential IR images per day, investigators have decreased the problem of Sea-Surface Temperature Analysis due to cloud cover.

With the launch of SEASAT in June 1978, NIMBUS-7 and TIROS-N in October 1978, and NOAA-6 in June 1979, the oceanographic community has been afforded the opportunity of acquiring data of specific design for marine studies. Although SEASAT met an untimely demise only 3½ months after launch, its Microwave Sensors have collected a wealth of unique data. Imagery and digital tapes from the imaging Synthetic Aperature Radar (SAR), with its 25-meter resolution, allow quantitative investigations to be done on ocean wave dynamics, internal waves, coastal zone studies, and more. The short pulse radar Altimeter (ALT) allows measurements to be made on significant wave heights (± 10 cm), tidal heights, and geioidal heights. The Scatterometer (SASS) allows measurements of backscatter coefficients and derived wind stress direction and magnitude. The Microwave Radiometer (SMMR) permits measurements of sea-surface temperature, wind speed, rain rate, atmospheric liquid water, and water vapor. These unique Microwave Sensors allow day/night coverage of the world's oceans under all weather conditions.

The Coastal Zone Color Scanner (CZCS) onboard NIMBUS-7 was specifically designed to sense oceanographic parameters at six narrow band wave lengths. Observable and derived parameters at 825-meter resolution include sea-surface temperatures, chlorophyll content, gelbstoffe, and surface vegetation. CZCS data are available in tape and imagery formats.

Data from TIROS-N and NOAA-6, the third-generation polar-orbiting satellite system, allow continuous measurements of sea-surface temperature (1.1 km) through its Advanced Very High Resolution Radiometer (AVHRR).

DATA PRODUCTS AND COSTS:

As mentioned previously, the satellite data in our Archive are held in various formats: magnetic tape, 16mm, 35mm, 70mm, and 25x25 cm negatives. Costs for these products vary according to the size of the end product. Basically, a full 9-track, 1600-bpi CCT costs $60. Photographic products in 25x25 cm format cost $3.25 for a black and white print, $4.50 for a positive transparency, and $6.75 for a duplicate negative. SEASAT SAR product prices vary according to the physical length of the archive negative and end product. Average prices range from $84 to $168 for a 70mm paper print, $90 and $180 for a 70mm positive transparency, and $160 to $320 for a 70mm duplicate negative. In addition to this, smaller lengths may be reproduced at lesser rates. Prospective data users are encouraged to contact the Division directly for specific price quotations.

HOW TO ORDER SATELLITE DATA:

Data requests are handled by the Division through letters, telegrams, and telephone calls. When ordering any satellite data, users should furnish as much of the following information as possible:

1. Name of Satellite.
2. Date, time, and location of data needed.
3. Type of data (Visible or Infrared).
4. Format desired (print, transparency, negative or magnetic tape).
5. How the data will be used (to be sure that what you are ordering will acutally suit your needs).
6. Person or organization to be billed.
7. Address where data is to be sent and telephone number.

In addition to maintaining the satellite data as an Archive and reproducing these data for retrospective users, the SDSD staff, which includes data processing specialists, meteorologists, and oceanographers, can assist the users in interpreting the data, selecting the correct data for each specific investigation, or in producing any special product required. Present or prospective satellite data users are encouraged to contact the SDSD at National Climatic Center, Satellite Services Division, Room 606, World Weather Building, Washington, DC, 20233 or telephone (301-763-8111 or FTS 763-8111) for any additional information or to place an order. All users are invited to stop by our office to see sample imagery holdings and to tour the Archive and Reproduction Facility.

CONCLUSION:

Various quantities and quality of satellite data are available from the SDSD commencing with TIROS-1 in April 1960 through the present. During the past 19 years the scientific, academic, and industrial communities have seen an increase in the quality and availability of satellite data. Our lists of users include government agencies, universities, private research institutions, shipping firms, oil and gas companies, fishery and ocean mining industries, sportsmen, sailors, lawyers, journalists and editors, students, foreign concerns, and private individuals. Data from the U.S. environmental satellites are available to everyone in the world at the cost of reproducing the data.

INFORMATION NEEDS AD HOC PRESENTATIONS BY CURRENT AND POTENTIAL USERS

G. Zetka, Chairman

NEW ENGLAND COMMERCIAL FISHERIES

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There are some potential applications to fishing, but in the Northeast Atlantic they are presently limited. One should try to understand the fishermen of New England, most of whom are draggermen. Possibly up to 90% of the fishing in New England involves dragging a trawl for demersal species. The fishermen who can apply advanced technology are certainly doing it. The swordfishermen have facsimile receivers on board to receive the NOAA data. There are still a lot of fishermen who fish by intuition ("think like a fish") and are reluctant to depend on electronics. However, when the applications become apparent, and with the resurgence of the industry, the fishermen will adopt equipment if it is demonstrated to be helpful.

It is suggested that past fishing activities (catches) be examined and data correlated to waterfronts and eddies in the Northeast. Perhaps a correlation can be established and an area found where remote sensing can be of value.

The primary need now is for weather information, principally for safety, and for reduction of search time.

Fishermen are not satisfied with the present weather information they are receiving; the stations are not reporting accurately. Fishermen need to know sea state and wind. This helps them determine where to go, and also, once there, what is coming.

As previously stated, the bulk of New England fishing is demersal trawling. For coastal pelagic species, the need is to assess the biomass of the species (e.g., mackerel and herring) so that reasonable quotas can be established for the industry.

Long-line fishing fleets and harpooners work on temperature. They have been using the eddies on the outside of the Gulf current for their sets, and when this information is available, they have found it very useful. Fishermen look for fronts; therefore, frontal analysis information through radio facsimile transmission could be used.

FISHERY OCEANOGRAPHY

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Most of the research and monitoring endeavors of fishery oceanography are based on the axiom that environmental variation has a significant effect on abundance and distribution of marine organisms and the postulate that most of the effect on abundance occurs during the early life history of the organisms.

• What environmental conditions or processes can be effective in causing variations in abundance?

Larval Transport: A good example of the effect of a variable transport mechanism on abundance is found in Atlantic menhaden. In the winter months south of Cape Hatteras these fish spawn up to 100 km offshore, near the edge of the Gulf Stream. The larvae resulting from the spawning activity have to reach the coastal estuaries to mature, and they must rely on wind-driven surface layer transport to do so. A significant correlation has been found between strong year classes on menhaden and favorable (westward) wind-driven transport south of Cape Hatteras during January-March.

Extreme Temperature: Year classes of many organisms particularly those species with estuarine nursery grounds, can be strongly influenced by extremes in temperature. A good example of this is found in the severe impact the last two unusually cold winters have had on juvenile croakers in Chesapeake Bay. Two successive year classes have been virtually decimated.

Match-Mismatch with Food Supply: Larvae of marine organisms often require a paritcular type or size of planktonic food for survival at particular stages of development. If the critical food type is available too early or too late or not in suitable concentrations (a mis-match), then an unusually heavy mortality of the larvae will occur, and the year-class size will be small. The timing of the spring phytoplankton bloom, for example, is largely controlled by environmental factors, thus influencing the timing of the succession of phytoplankton and zooplankton species to follow.

Pollution Effects: Pollution, especially in very near shore or estuarine environments, can influence abundance and distribution of marine organisms. There is evidence that estuarine pollution is one factor responsible for the reduction of the abundance of striped bass. Also, data have been collected in the New York Bight area which suggest that Atlantic mackeral eggs produced there show higher than expected death and mutation rates as a consequence of pollution.

Upwelling: In many coastal areas upwelling provides the nutrient substances required for phytoplankton production, often causing a bloom in the phytoplankton, which leads to a succession of blooms or pulses in the zooplankton, including fish larvae. However, with some species untimely upwelling can be detrimental because of the offshore transport of eggs and larvae away from nearshore nursery grounds.

Turbulent Dispersal: The larvae of many marine organisms require food organisms of the right kind in a certain minimum concentration to survive. When turbulent mixing from unusually strong winds disperses the larvae and the food organisms, available forage concentrations are reduced below critical levels, and high larval mortalities and weak year classes result.

- What conditions or processes can affect distribution of marine organisms, principally adults?

Shifting Water Mass Boundaries: Changing locations of water mass boundaries (fronts) can influence locations of migratory pathways and forage concentrations.

Species Range Extension: Gradual long-term changes in the environment can lead to significant extensions in the ranges of marine organisms. Such changes in distribution may directly or indirectly affect availability or abundance of resource species. An example of an indirect effect is the extension of the range of the green crab into the Gulf of Maine in response to a warming trend. Because the green crab is a predator of the soft shell clam, which is a resource species, the crab's extension into the gulf seriously reduced the clam population there. Thus, the decline of the clam population was not due to the warming trend per se but to the range extension of the green crab which was triggered by the warming trend.

Shifting Forage Concentrations: It has long been recognized that the highly mobile pelagic species migrate to areas of relatively high concentrations of forage organisms. These areas of concentration frequently are found in zones of surface convergence which accumulate floating and planktonic organisms and materials. The convergence zones generally are transitory and their displacement or appearance and disappearance can easily influence the distribution of pelagic organisms.

- What variables should be monitored to describe the environmental conditions and processes which influence distribution and abundance of marine organisms?

The variables of interest to a fishery oceanographer are no different from those of interest to oceanographers in general:

Temperature and salinity throughout the water mass
Chlorophyll concentration in the photic zone

Nutrients throughout the water column
Pollutants in coastal areas
Wind stress and Ekman transport
Insolation and cloud cover
Sea state and mixing energy over large areas
Sea surface topography

Some of these may be measureable with satellite or airborne sensor systems, which is the only feasible means of regularly monitoring large areas of ocean.

APPLICATION OF REMOTE SENSING TO POWER PLANT SITING

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Electric utilities today, unlike years ago, must do more than find several hundred acres of land which meet certain engineering requirements in order to find sites for new generating facilities.

Today's potential sites for power plants must meet certain minimally acceptable environmental qualities in order to be seriously considered for development. Additionally, because of the mandate of the National Environmental Policy Act of 1969 that all alternatives be considered and given recent revisions in regulations which emphasize the decision-making process, (Council of Environmental Quality 43FR55978), it is becoming increasingly important to make detailed comparisons of alternate sites using the best information possible.

The types of information required fall into two broad categories, which have some overlap: (1) engineering features, and (2) environmental considerations. Within each of these categories there are differences in topical areas requiring study depending on whether fossil station or nuclear station are being chosen for development. However, for the purposes of this presentation, we will not make any great distinction between fossil and nuclear generation.

Drawing upon several guidance documents published by agencies, Table 1 lists the general topical areas which must be considered when evaluating and comparing potential power plant sites. As illustrated, the areas cover a broad spectrum of matters, some of which are water-oriented, some land-oriented, and others man-made.

The intended uses of these data are twofold. Engineering data are used to assure that a safe, reliable power station can be built for a reasonable cost, and environmental data are used in order to make some predictions of potential impact. Often some impacts can be mitigated by prudent engineering practices.

In the final decision-making process, all factors are identified, evaluated, and weighed. Each alternate site is compared to the other, on the basis of potential reliability, safety, economics, and environmental impact. Utilities today know that their decision-making process will be scrutinized in great detail by both regulatory agencies and public interest groups. It is obvious that the decisions made are no better than the data upon which they are based.

Here the crux of the problem is data quality. But data quantity is also becoming a managerial nightmare. Say, for example, that a utility begins searching for a site within a 100-mile square box. This box contains 10,000 square miles; and this relatively small region of interest mathematically contains 10,000 possible locations for a power plant. Similarly, the land area of New England has been put at 63,000 square miles. Again, we now have 63,000 possible sites. Obviously, much of the land mass is unsuitable, but there are still hundreds or thousands of square miles which need to be screened.

Traditionally, data sources for screening large land areas have been 7.5 minute USGS topographic maps, aerial photographs, and volumes of federal and state planning documents. A problem often comes in that (1) topograph maps are updated with irregular frequency (some are 10 to 20 years out of date); (2) readily available aerial photographs cover limited areas, and thousands may be required for screening; and (3) other documents can take many man-months of labor to analyze, if you can get a copy without having a small army of people spending a small fortune in dimes at reproduction machines at state or university libraries.

Therefore, certain basic characteristics concerning the data are desirable, if not essential. The data should be:

of high quality
up-to-date
cover broad areas
manageable and readily interpretable
available on a timely basis
relatively economic

Accordingly, we feel the application of remote sensing to power plant siting provides an essential, effective, and efficient tool. To date, many of the desired data characteristics described above apply to remote-sensed data, especially with regard to aerial coverage. Other characterics, of course, require improvement; for example, the availability of products on a timely basis.

Referring to Table 1 again, many topical areas can presently be reviewed by employing remote-sensed data, principally from satellites (e.g., LANDSAT). Geology, seismology, land use, and to a limited extent demography are the areas which have the most historical and real-time data available. Air quality, etc., on the other hand, are areas in which additional resources are required before they can become easily available.

Regardless, we feel the basic tools are presently functional and applicable. With improved information on product availability, resolution, frequency of overflights, etc., an enhanced program of remote sensing utilization will evolve in the siting of power plants.

TABLE 1

TOPICAL AREAS OF CONSIDERATION

FOR

POWER PLANT SITING

ENGINEERING

Topography
Water Availability
Transportation for Construction Materials
Transmission Line Corridors
Geological Conditions
Seismological Hazards
Man-made Hazards
Water Source Bathymetry

ENVIRONMENTAL

Dedicated Lands (Parks, National Forests, etc.)
Air Quality
Meteorology
Aquatic Ecology
Noise Intrusion
Land Use
Demography
Water Quality
Terrestrial Ecology
Hydrography

MASSACHUSETTS COASTAL ZONE MANAGEMENT
MAPPING PROGRAM AND NEEDS

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The Massachusetts Coastal Zone Management Program (MCZMP) was developed over the last five years. It received federal approval on April 24, 1978, the fourth state in the country and the first East Coast or Gulf Coast state to be approved. We are now entering our second year of implementation. The MCZMP uses the networking approach--tying existing laws and programs together more effectively.

In the planning phase of the program, the first mapping priorities were in identifying relevant resources and coastal processes in the coastal zone and developing a suitable library of information. This information was gathered from existing state inventories, local residents and aerial photography. Using 1:24,000 USGS topographic maps as a base, an adequate library for planning and some management needs was developed. In June 1977, an Atlas of Coastal Resources was published, indicating in text and on maps the coastal zone boundary, and significant resource areas such as salt marshes, beaches, dunes, and fish runs, erosion and accretion areas, ports and areas proposed for reservation and restoration, or, as we refer to them in Massachusetts, Areas of Critical Environmental Concern. This Atlas, together with less detailed, specific subject maps in our Final Environmental Impact Statement, were widely distributed and are in constant use by citizens, developers, and state and federal regulatory agencies. The Atlas and maps continue to serve as invaluable tools in implementing the policies they were created to help develop.

As we enter our second year of implementation, we are constantly striving to improve the accuracy of our mapping and to maintain the quality of our final map products. The following is a brief discussion of some of our current mapping programs and needs.

1. Base Mapping Needs

For mapping on land, we use USGS topographic maps with scales of 1:24,000 and 1:250,000. For mapping ocean information, we use National Ocean Survey nautical charts at various scales, and for mapping offshore information related to OCS development, the Bureau of Land Management's protraction diagram for Georges Bank. While all three of these sources are the best available, there is still room for improvement, both in the form of the product and in the delivery of services.

We use both color prints and film positives of the 1:24,000 topographic maps. The color prints, an essential tool for any planning agency, are used primarily as locus maps, providing general geographic and land use information. The film positives are used for the mapping of resource or thematic information. They were used in preparing the Atlas and are used on an ongoing basis for preparing maps for site-specific issues. Without them, production costs would be much higher, and the quality of the product would suffer.

The 1:250,000 scale map is adequate for illustrating coastwide issues. In its film positive form it provides an excellent base for wall maps. It is also easily and cheaply reproducible in blueprint form, an excellent base of quick mapping projects.

One of our needs in this area is to reduce the amount of time required to obtain film positives. In many instances resource maps need to be produced in a short-time frame and these delays hinder our production.

Nauctical charts are valuable as locus maps and for clarifying boundary questions. These maps were used as a base for delineating the state's ocean-sanctuaries boundaries and the seaward boundary claims. However, it is very difficult to reproduce a film positive line copy from an opaque color print. There is a need for the nautical charts to be in reproducible form. The availability of nautical charts as film positives would reduce cost and time of map production and improve the final quality.

Another type of base map which we have used extensively is a protractor diagram for Georges Bank. This rich fishing area sitting off the Massachusetts coast may soon be subject to oil and gas development, and there is a constant need to illustrate diverse resource and geologic information for the area. Presently, this information exists only at different scales and projections. The compiling and production process has thus been slow and less accurate than if more standardized maps had been available. The first step would be to have a precise, reproducible protraction diagram readily available. We have done two major mapping projects on Georges Bank, and both times we had to draft our own base map. As the Atlantic OCS becomes subject to more and more development, other states will also need better base maps.

2. Standardizing Resource Information

There is also a need to standardize the resource information, which now exists largely on maps of differing scales and projections. We have done two major mapping projects for Georges Bank, and the compiling and production process has been slowed because we had to draft our own base map and transfer information from unstandardized sources. This is an area where a number of agencies should meet to exchange and standardize information. These should include BLM, NMFS, CEIP, and the state's CZM and energy offices.

3. Wetlands Program

The primary example in Massachusetts of the most up-to-date mapping of boundaries is the wetlands program in the Department of Environmental Management. Under this program, all the significant wetlands of a particular municipality are put under a recorded restriction order. High-altitude, controlled orthophoto maps are produced upon which the wetlands boundaries are superimposed by the zoom transfer scope process from low-altitude uncontrolled photographs. The resulting 1:4,800 scale maps are the most detailed ones in use for resource mapping within Massachusetts. While no more accurate than recent line and symbol maps produced from aerial photographs, these maps are much more useful in explaining to landowners where their restricted wetlands are.

Finding an adequate base map is, of course, an essential first step in the cartographic process. Our efforts to produce satisfactory boundary maps have often been slowed by inadequate base maps and a lack of technical expertise.

Immediate mapping needs would include:

a. base maps at 1:4,800 scale for the coastal areas in Bristol County (southeast Massachusetts), Boston, lower and upper North Shore, with a high degree of accuracy.

b. maps which would pinpoint pollution sources in the coastal embayment.

c. experimentation to see if color orthophoto maps would more accurately delineate the various coastal wetlands (beaches, dunes, barrier beaches, coastal banks, salt marshes, and rocky intertidal shores).

4. Areas of Critical Environmental Concern

One element of the Massachusetts Coastal Zone Management Program calls for special recognition and care for critical environmental resources. The federal Coastal Zone Management Act of 1972 calls these complexes of natural resources Areas for Preservation and Restoration (APRs). Under the Massachusetts Program, they are called Areas of Critical Environmental Concern (ACECs). The basic function of the ACEC designation is to coordinate and focus state environmental programs (such as preserving water quality, wetlands protection, and wildlife protection) with federal programs, and to encourage all levels of government to act consistently within ACECs.

In order to ensure that ACECs in fact are truly unique valuable natural systems, areas for nomination must include at least five of the following features: barrier beaches, dunes, beaches, salt marshes, shellfish beds, salt ponds, estuaries, coastal embayments, flood plains, anadromous fish runs, erosion areas, historic sites and districts, public recreational beaches, habitats for rare or endangered species, fish spawning and nursing areas, other significant wildlife habitats, or scenic values.

We are constantly trying to improve our techniques of mapping these coastal features. Any assistance in improving our mapping procedures would be very useful to our program.

5. Coastal Hazards Maps

We have an exciting program underway in Massachusetts during our second year of implementation that is an example of what needs to be done. In the past two years, the Massachusetts coast has been hit hard by winter storms. With more data in map form, more sophisticated preventive measures could have been taken and can be taken in the future to minimize damages. As a first step, the National Ocean Survey has teamed up with us in a project which will identify and map coastal hazards. The National Ocean Survey will fly those parts of the coast not presently covered by aerial photography and will assist us with the technical specifications in the mapping process.

Massachusetts will have a product which is more precise and comprehensive than it could have produced on its own, and the National Ocean Survey will be able to develop standards which can be applied to similar coastal hazards projects in other states. This cooperative venture will meet both state and federal concerns for coastal hazard mitigation.

In Massachusetts, there already exist environmental regulations which address storm damage prevention and flood control. Our aim is to illustrate cartographically the coastal processes that relate to storm damage prevention and flood control in order to pinpoint areas which are vulnerable.

The final maps would include the following information:

a. position of historical shoreline 5 times in the past (color-coded)

b. show the average rate of retreat for different time intervals

c. topographic lines

d. present coastal resource areas color-coded; i.e. beaches, dunes, barrier beaches, banks, salt marshes, and rocky intertidal shores. (Table 1 contains a chart of the critical characteristics of each of these resource areas which we are interested in learning more about and mapping, if possible.)

e. predictive shoreline position 100 years in the future

f. direction of littoral drift

g. 100-year HUD flood line with wave elevations shown

h. coastal structures

At this time, we plan to digitize the inventory data. Information stored in a computer in this fashion can be printed at various cartographic scales. As the computer can be programmed for scale and projection changes, data from various sources can be compared quickly and accurately. This process has the potential of being an effective new environmental management tool.

TABLE 1. RESOURCE AREAS CRITICAL TO STORM DAMAGE PREVENTION AND FLOOD CONTROL
(As Outlined in the Coastal Wetlands Guidebook)

RESOURCE AREA	CRITICAL CHARACTERISTIC	PROTECTION FUNCTION
Land Under the Ocean	Bottom Topography	Reduction of Wave Energy
Coastal Beaches	Volume & Form of Beach	Sediment Transport & Littoral Drift
Coastal Dunes	Ability to Erode in Response to Wave Action	Sediment Transport to Coastal Beaches during Storm Conditions
	Volume & Form of Dune	Natural Buffer for Landward Areas
	Vegetative Cover	Growth & Stability of Dunes
Barrier Beaches	Volume & Form of Coastal Beaches & Coastal Dunes	Natural Buffer for Landward Areas
	Ability to Respond to Wave Action & Storm Wave Overwash	Sediment Transport to Coastal Beaches during Storm Conditions
Coastal Banks	Ability to Erode in Response to Wave Action	Sediment Transport to Coastal Beaches, Coastal Dunes, Barrier Beaches, & Land Under the Ocean
	Natural Resistance to Erosion Caused by Wind & Rain	Vertical Buffer to Storm Waters & Waves
Rocky Intertidal Shores	Sloping Shores and/or Boulders	Reduction of Wave Energy & Natural Buffer for Coastal or Inland Areas
Salt Marshes	Natural Resistance to Erosion of Salt Marsh Cordgrass & Underlying Peat	Reduction of Wave Energy
	Ability to Store Storm Waters	Natural Buffer for Landward Areas

U.S. COAST GUARD MISSIONS AND NEEDS RELEVANT TO REMOTE SENSING

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COAST GUARD OVERVIEW

The U.S. Coast Guard is part of the Department of Transportation. During the past decade, the Coast Guard has been getting new missions and increased responsibilities. As the maritime arm of the Department of Transportation, oceanography permeates all of our missions. Remote sensing is one area in which we hope that some of our missions and responsibilities can be accomplished with the same or fewer resources.

MISSIONS

1. Search and Rescue

Search and Rescue is responsible, among other things, for locating vessels and downed aircraft. The need usually applies to floating objects; however, occasionally it applies to sunken objects. There is a need to augment the conventional visual search with a more sophisticated technique, one that can render the same results with less effort. Most of the search and rescue targets are passive. It's conceivable that we could have cooperative targets if a method were developed which made it easy for vessels to signal to satellites. To reiterate, the USCG has a major search and rescue mission and could use a method for locating vessels and craft that are uncooperative targets or a method for making the targets cooperative.

As part of the search and rescue mission, we need surface current information for search planning. Where is the object? Where might it drift? Presently used are current charts, historical data, predictive data based on local wind conditions, and current metering devices (dye packages) dropped by air.

2. Aids to Navigation

We have the responsibility for approximately 20,000 buoys and need to know if the buoys are where we want them to be. That is:

a. Have the buoys initially been put in the right place?
b. Have the buoys remained in the right place (after a storm, for example)?

The Coast Guard has considered some techniques for buoy monitoring but has not found them to be cost-effective; however, the technology is changing and perhaps new ideas will be presented.

3. Marine Environmental Protection

This mission is to detect, identify, quantify, and forecast the movement of the pollutants such as oil and hazardous chemical substances.

Remote sensing may help detect, identify, and track the material and determine where sufficient cleanup of the substance has been accomplished. The need is for both open waters and ice-infested areas. More emphasis has been placed on oil because of the massive interest in the problem. We have remote sensing systems to detect and track oil spills. However, we don't have adequate means to monitor hazardous chemical substances.

We are also interested in techniques for pollution surveillance in local areas of high interest; e.g., New York Harbor. This system would have to provide the data in very near real time.

Oil pollution in open waters is well covered, but ice-infested waters are inadequately monitored. Where the oil goes after it enters the ice field and is submerged under the ice is a real problem for us.

4. Law Enforcement

A. Marijuana is a massive problem which ties up a substantial portion of our resources. We could use remote sensing technology to detect and track contraband carriers. This is a real need due to the legal restriction on vessel boarding.

(1) How can we know if a vessel is carrying contraband? Is is possible to detect marijuana remotely in a low ambient "noise" background offshore?

(2) We need to track vessels in places where they ordinarily do not go--vessel screening process.

B. Difficulties in monitoring the fishing fleet have developed due to the extension of federal jurisdiction to the 200-mile zone.

(1) How do we locate the fishing fleet?

(2) Is there any way to determine the fish being caught or the nets being used without boarding the craft?

5. Domestic and Polar Marine Transportation

A. The Coast Guard has the U.S. icebreaker fleet. We are interested in all facets of ice trafficability and ship routing, both Coast Guard and commercial vessels. Offshore ice thickness determination from the air is extremely desirable.

B. Can remote sensing extend the useful coverage of present land-based Vessel Traffic Management Systems?

6. Marine Science Activities

International Ice Patrol, a major activity, locates and tracks icebergs. Before the iceberg season begins, we could use forecasts on what type of season it will be; e.g., iceberg "calving rates" from glaciers.

In a comment from the floor, Lieutenant Commander James White, USCG Office of R&D, Washington, DC (accompanying Dr. Breslau), stated that in the International Ice Patrol, aircraft surveillance of icebergs is often severely hampered by weather grounding the aircraft even though the airborne MW systems have weather penetration. Therefore, it would be beneficial to the Coast Guard to be able to discriminate icebergs from surface vessels using a satellite system.

7. Recreational Boating Safety Program

As with the Coast Guard Search and Rescue requirement mentioned before, we need an inexpensive way for recreational boaters to signal distress and perhaps even the degree of distress.

APPLICATIONS I

David Aubrey, Chairman

SEA SURFACE SALINITY AND TEMPERATURE BY MICROWAVE TECHNIQUES

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The thermal emission from the ocean at microwave frequencies is a first-order function of the reflectivity of the ocean. The reflection coefficient, in turn, is uniquely determined from the dielectric constant of sea water. The first figure gives the expression for the dielectric constant of sea water. In this equation, we note that the imaginary part of the dielectric constant is dependent upon the ionic conductivity of sea water, which is known to be a strong function of both temperature and salinity. Furthermore, the conductivity is divided by the electromagnetic frequency. This term in the equation is therefore dominant as the electromagnetic wavelength becomes small. At microwaves, this term is of the order of 50, and the dielectric constant is therefore a first-order function of the ionic conductivity.

The frequency dependence also suggests a retrieval scheme, whereby the two geophysical unknowns (temperature and salinity) can be derived by measuring the thermal emission at two widely spaced electromagnetic frequencies. Figure 2 shows a plot of the thermal emission (T_B) vs thermometric temperature with salinity, in parts per thousand, as a parameter at an electromagnetic frequency of 2.65 GHz. Note that the emission changes by 10° as the salinity varies from 0 to 38 ppt. at 30° C. A similar plot is shown in Figure 3 for an electromagnetic frequency of 1.43 GHz. This curve shows that the salinity variations cause more substantial changes in the emission, as compared with the previous figure.

A two-frequency nadir viewing radiometric system was fabricated and installed on a remote sensing aircraft. In August 1976 the aircraft was flown over the lower Chesapeake Bay. A mapping mode was achieved by flying the aircraft along parallel east-west flight lines as shown in Figure 4. The circled points in the figure indicate the coordinates where in situ measurements of temperature and salinity were obtained.

Figure 5 shows a map of the retrieved isotherms as derived from the microwave data. The temperature of the bay is fairly uniform in late summer; hence, there is very little to comment on the results other than that the temperature is 2 to 4 degrees warmer in the bay than in the open ocean. On the other hand, the isohalines shown in Figure 6 exhibit substantially more contrast. The results indicate a southerly flow of fresh water into the Atlantic Ocean, mixing due to the outflow of rivers into the bay, and a convergence of isohalines on the bay side of Virginia's eastern shore resulting from Coriolis force.

Figure 7 is a plot of temperature vs latitude, comparing ground-truth (solid line) and those values derived from the radiometers. The statistics indicate that a $1^{o} \pm 0.6^{o}$ retrieval was achieved by remote sensing techniques. Figure 8 shows salinity vs latitude. In this case, the retrieval has an accuracy of 0.3 ppt ± 0.7 ppt. More additional flight experiments are required to determine the ultimate accuracy, because natural fluctuations in salinity of 1 ppt. occurred within the spatial resolution cell.

FIGURE 1.

DEBYE EQUATION FOR THE MICROWAVE DIELECTRIC CONSTANT OF SEA WATER

$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + (j\omega\tau)^{1-\alpha}} - j\,\frac{\sigma}{\omega\varepsilon_0}$$

$\omega = 2\pi x$, MICROWAVE FREQUENCY

ε_0 CONSTANT $= 8.854 \times 10^{-12}$ fd/m

$j = \sqrt{-1}$

$\alpha =$ CONSTANT DETERMINED BY ANALYSIS

$\varepsilon_\infty =$ CONSTANT $= 4.9$

$\varepsilon_s(S,T) =$ STATIC DIELECTRIC CONSTANT, DETERMINED BY ANALYSIS

$\tau(S,T) =$ RELAXATION TIME, SEC.

$\sigma(S,T) =$ IONIC CONDUCTIVITY

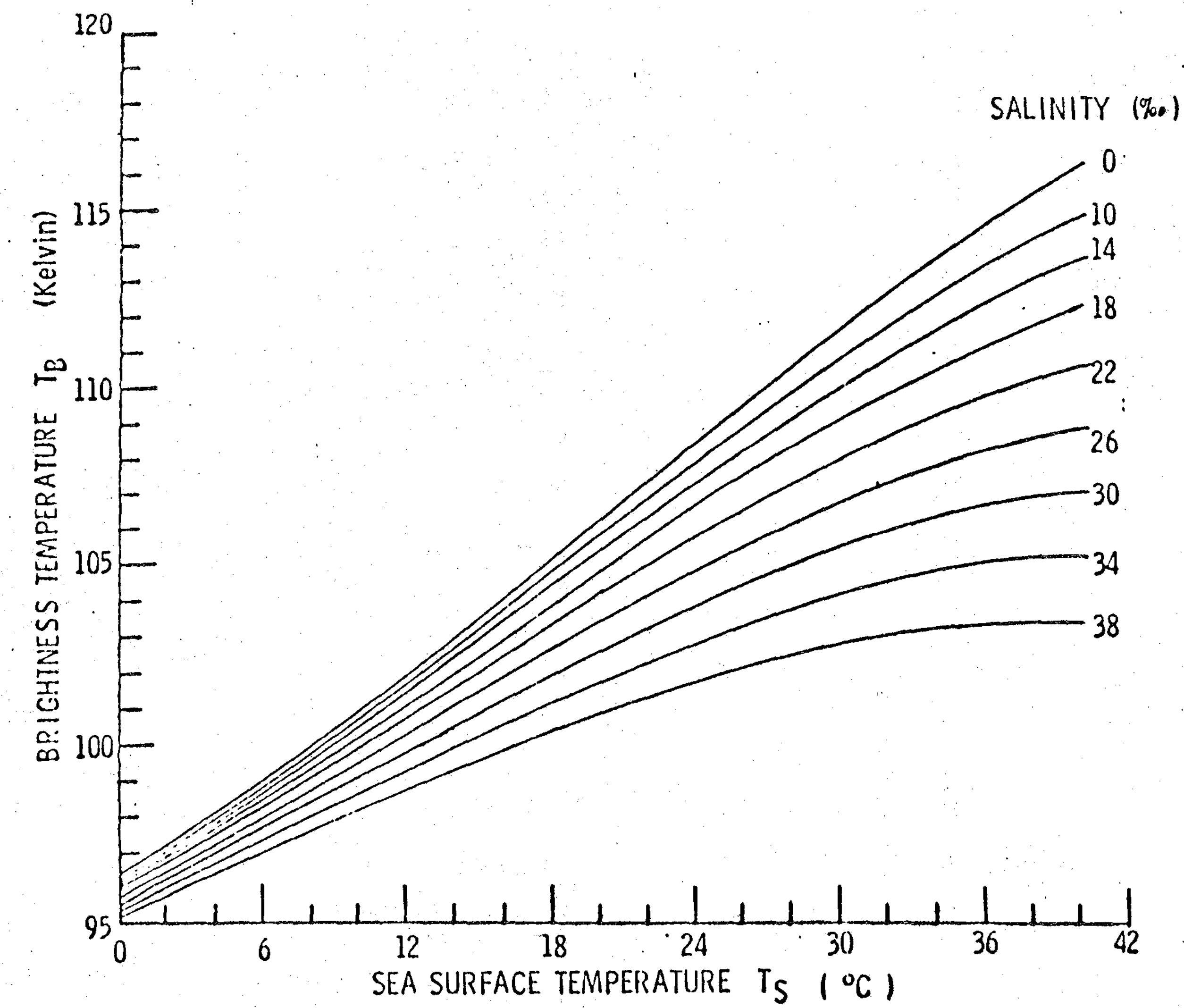


Figure 2. Thermal emission vs. thermometric temperature with salinity in parts per thousand. Measured at 2.65 GHz.

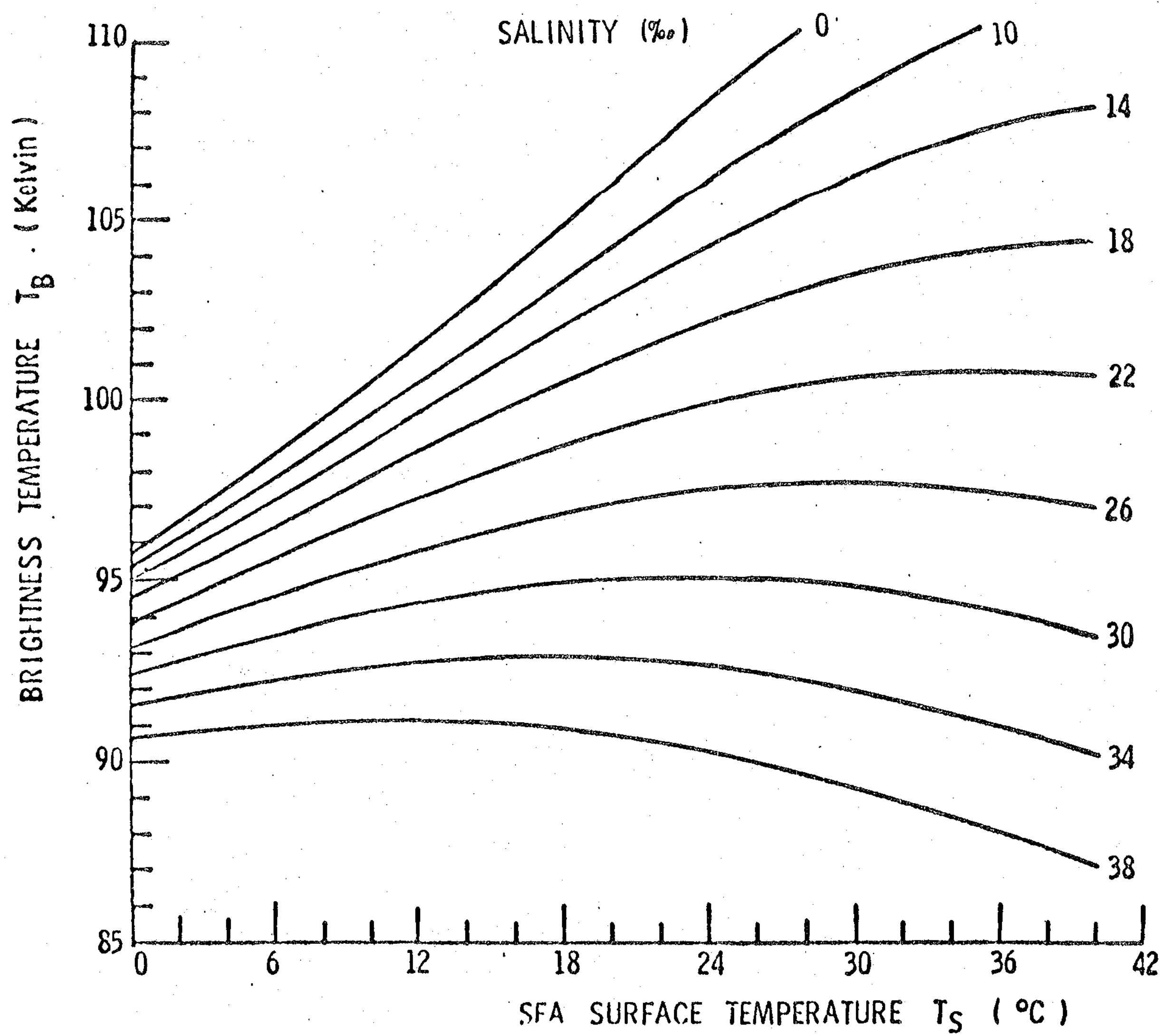


Figure 3. Thermal emission vs. thermometric temperature with salinity in parts per thousand. Measured at 1.43 GHz.

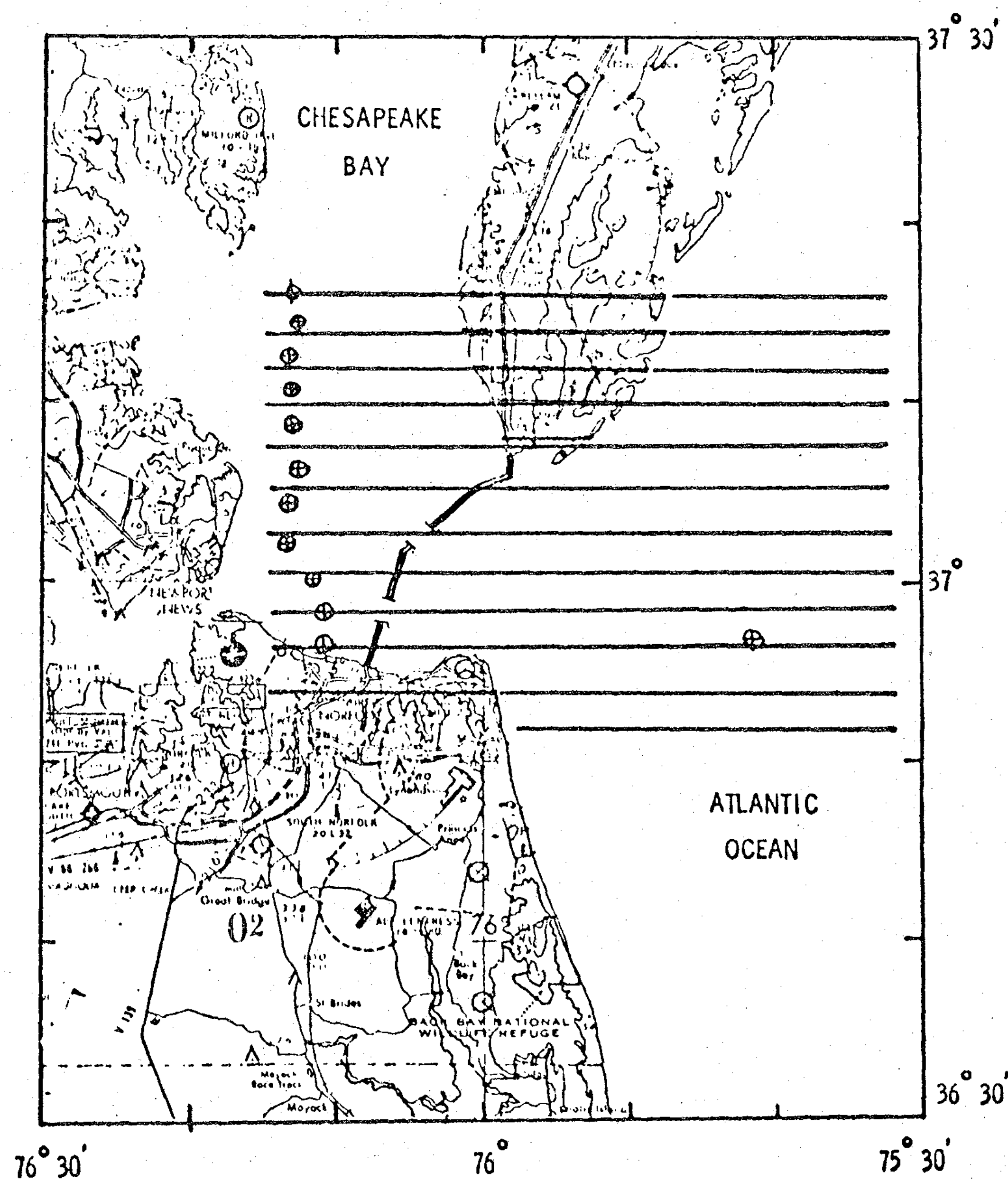


FIGURE 4.

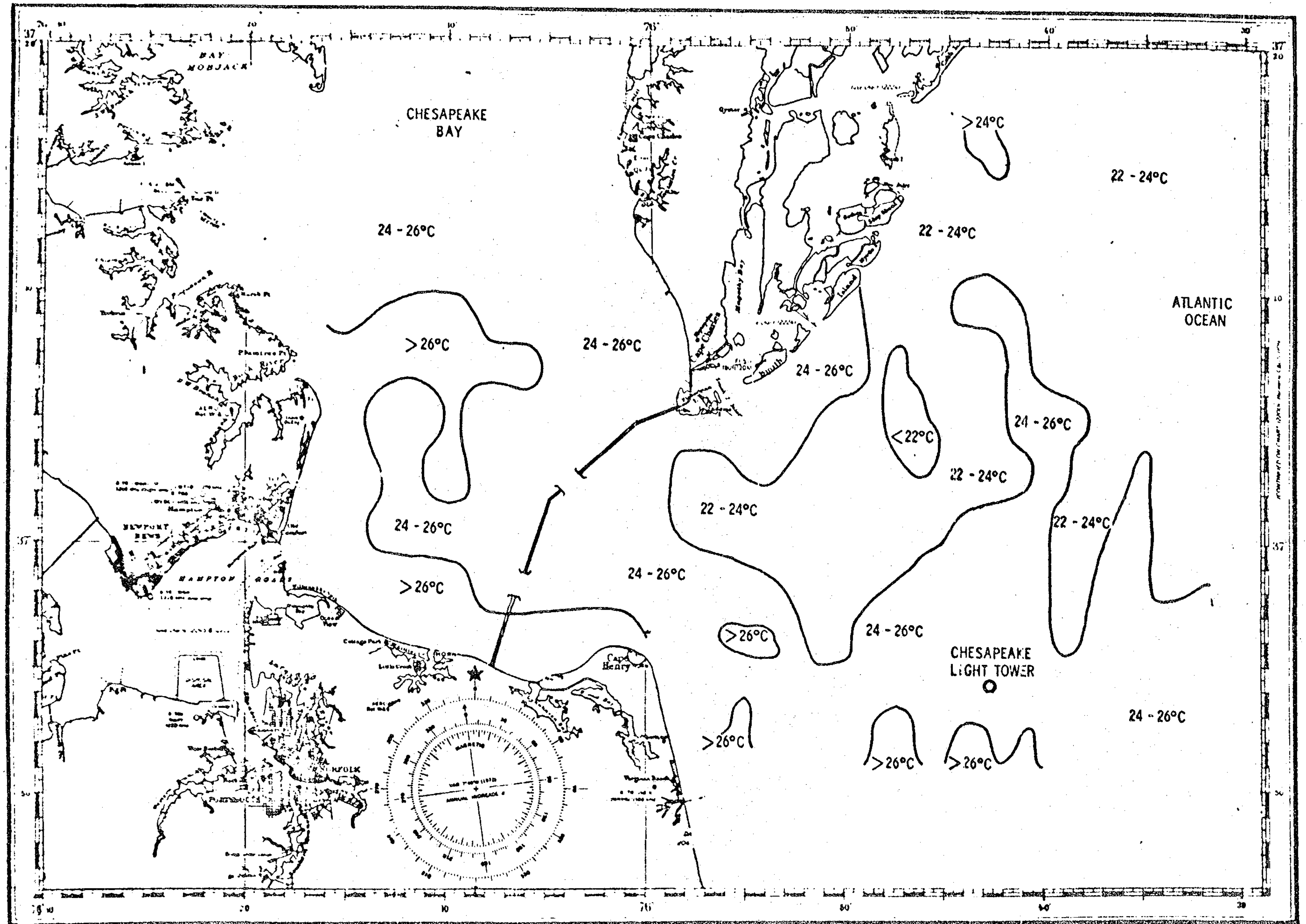
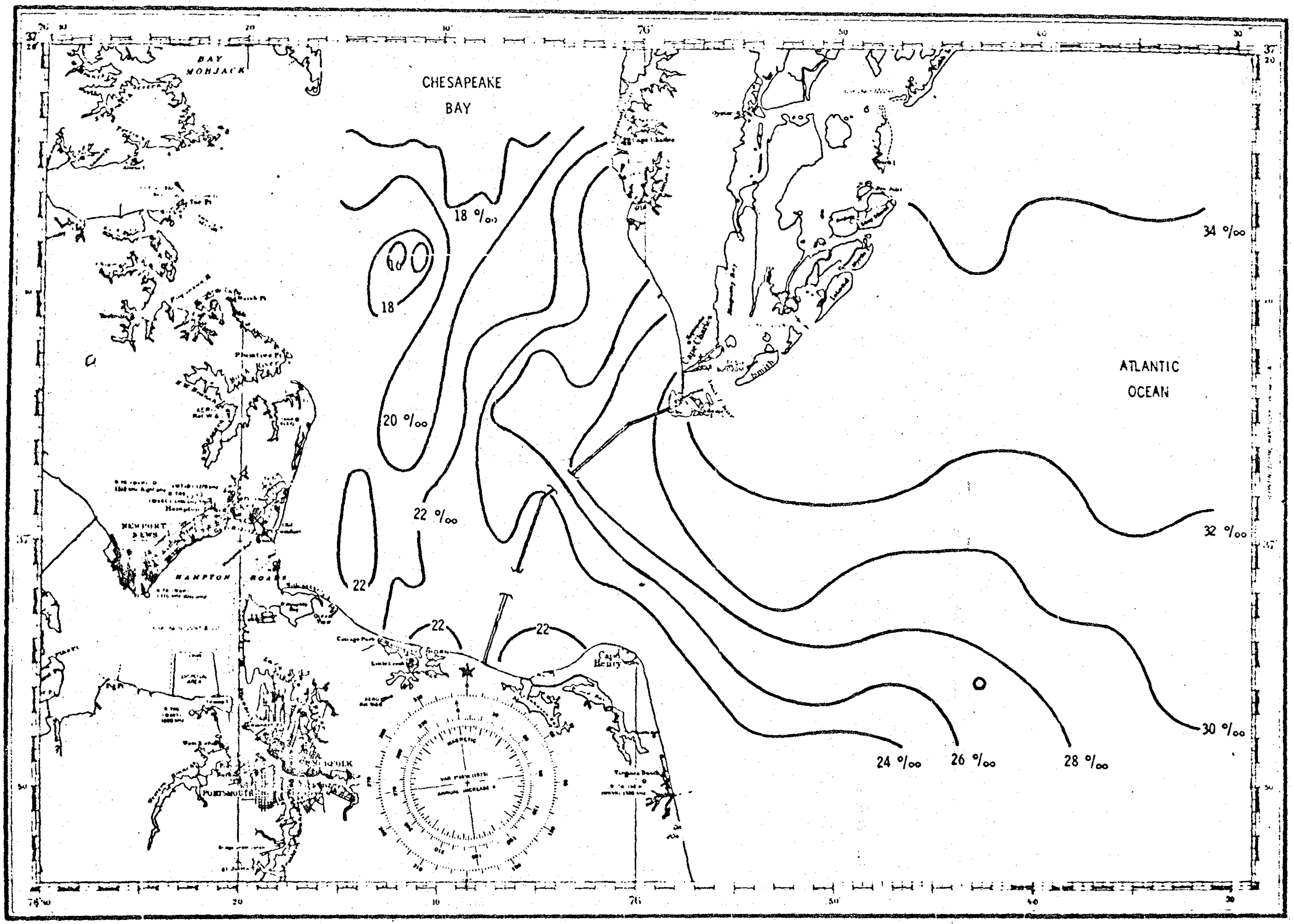

MOBJACK BAY
CHESAPEAKE BAY
24 - 26°C
>26°C
24 - 26°C
24 - 26°C
>26°C
24 - 26°C
NEWPORT NEWS
HAMPTON ROADS
NORFOLK
PORTSMOUTH
Cape Henry
>24°C
22 - 24°C
22 - 24°C
ATLANTIC OCEAN
24 - 26°C
<22°C
24 - 26°C
22 - 24°C
22 - 24°C
22 - 24°C
24 - 26°C
>26°C
24 - 26°C
CHESAPEAKE LIGHT TOWER
24 - 26°C
>26°C
>26°C
>26°C

FIGURE 5.


CHESAPEAKE
BAY
MOBJACK
BAY
18 °/oo
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24 °/oo
26 °/oo
28 °/oo
30 °/oo
32 °/oo
34 °/oo
ATLANTIC
OCEAN
NEWPORT NEWS
HAMPTON ROADS
NORFOLK
PORTSMOUTH
Cape Henry

FIGURE 6.

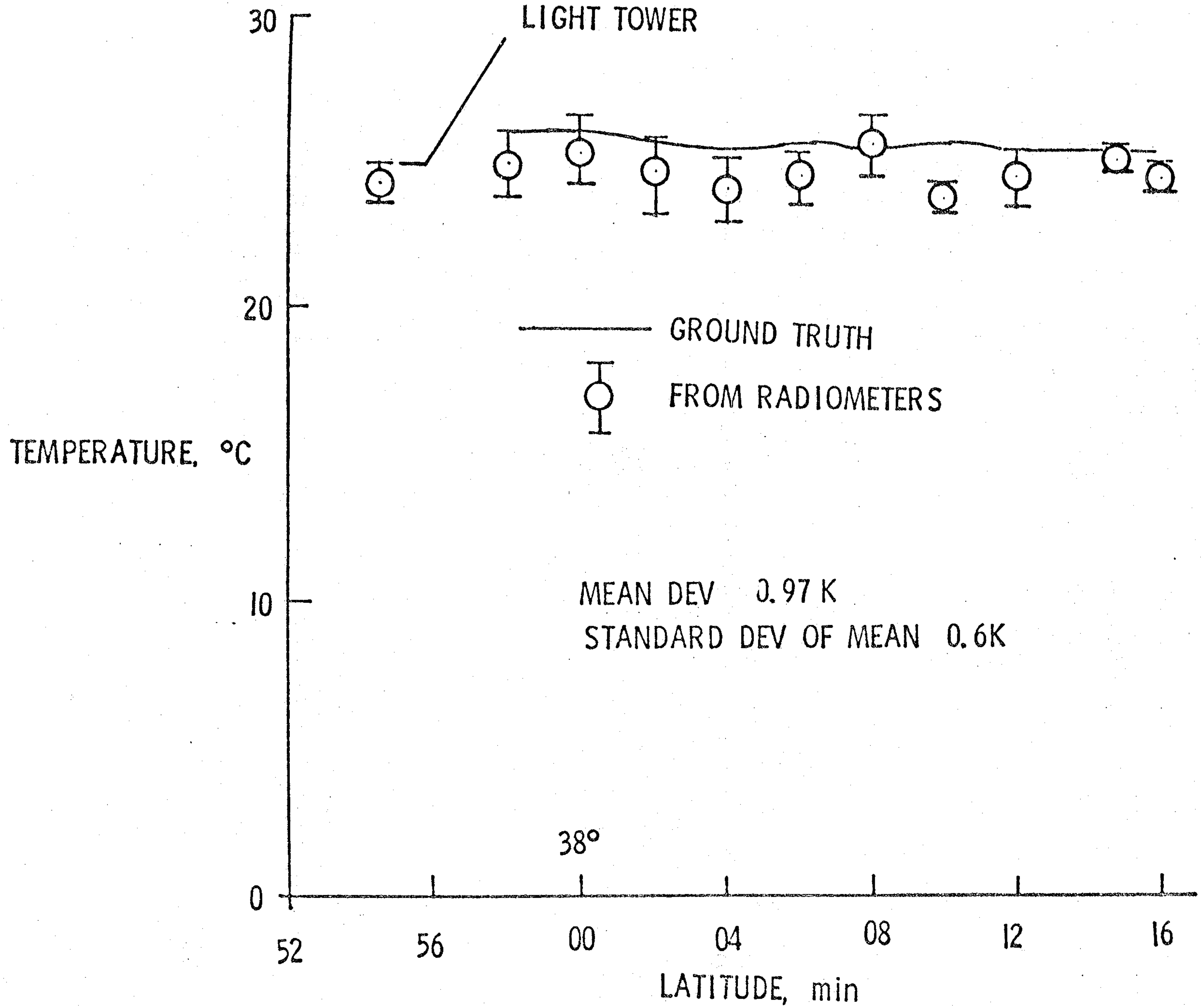
LIGHT TOWER
GROUND TRUTH
FROM RADIOMETERS
TEMPERATURE, °C
MEAN DEV 0.97 K
STANDARD DEV OF MEAN 0.6K
38°
30
20
10
0
52
56
00
04
08
12
16
LATITUDE, min

FIGURE 7.

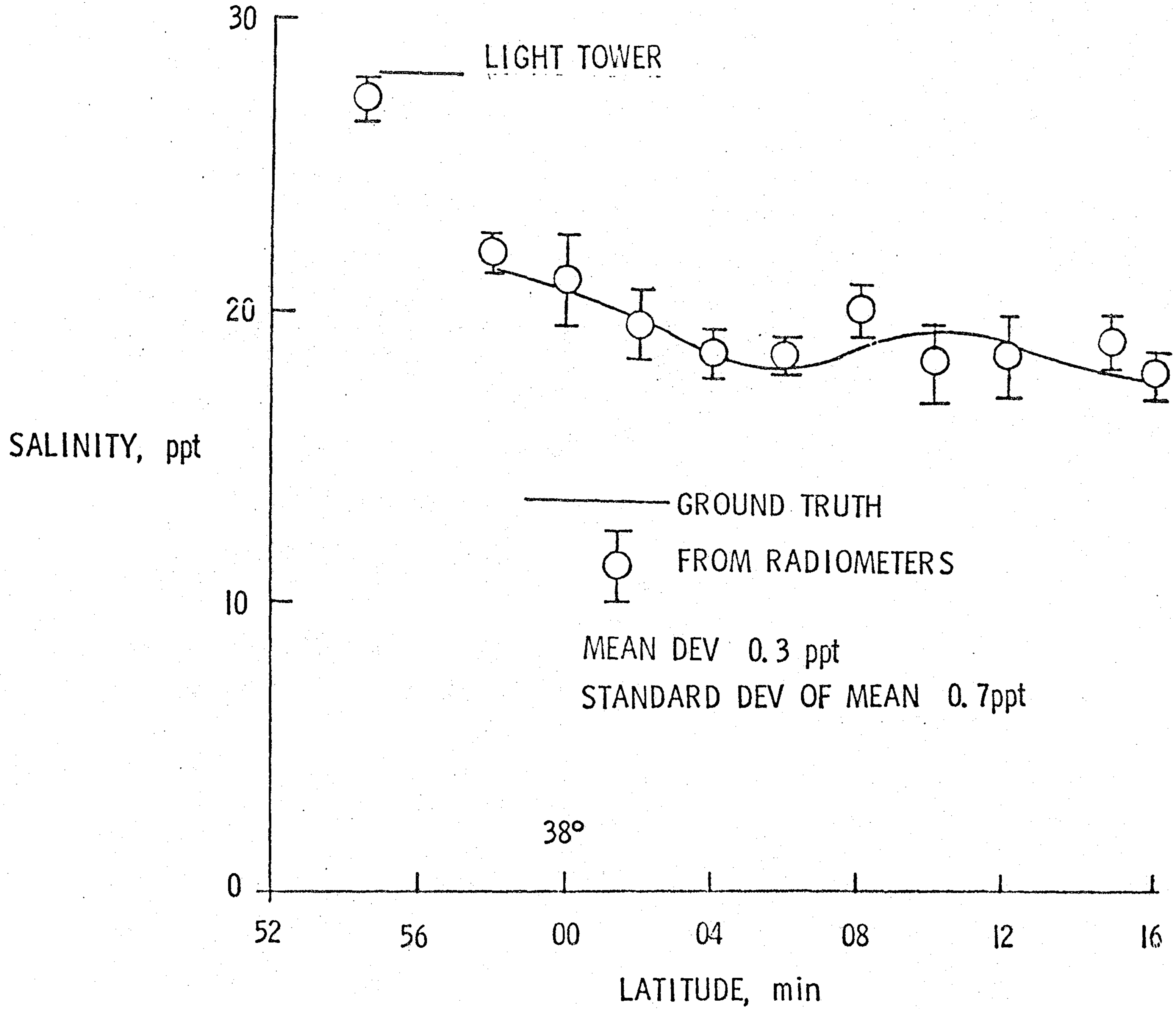
30
20
10
0
LIGHT TOWER
SALINITY, ppt
GROUND TRUTH
FROM RADIOMETERS
MEAN DEV 0.3 ppt
STANDARD DEV OF MEAN 0.7ppt
38°
52
56
00
04
08
12
16
LATITUDE, min

FIGURE 8.

SEA SURFACE TEMPERATURE DETERMINATION USING INFRARED TECHNIQUES

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Infrared radiation in the wavelength region between 10μm and 13μm is both emitted and reflected from the ocean. The emission is from a microlayer less than 20μm thick, and is therefore affected by sensible heat flux, evaporation, and the many other exchange processes at the air-sea interface. It is not unusual for the radiation temperature to be from -1.5^{o}C to +0.5^{o}C different from the water temperature 10 cm below the surface. Reflection at 11μm is less than 1%, and except at the specular point of the sun, reflection is not a serious problem in surface temperature determination. RMS error associated with reflection and emission at the sea surface, compared with the bulk water temperature, is between ±0.4^{o}C and ±0.5^{o}C.

Radiation that has left the ocean interacts with the atmosphere before being detected at the aircraft or the satellite. In the 10-13μm region, the most significant absorbing atmospheric gas is water vapor. Typically, about 40% of the radiation leaving the ocean is absorbed by atmospheric vapor and re-emitted at the temperature of the gas. The radiometer measures the net effect of radiation that has interacted with the atmosphere and the non-interacted fraction; atmospheric effects of 2^{o}C to 10^{o}C are not uncommon, depending on the temperature and the amount of water vapor in the path. If atmospheric profiles of temperature and relative humidity are available, single-channel infrared sensors can be corrected for this effect. In the future, multi-wavelength radiometers hold the promise of self-correcting for atmospheric water vapor. RMS errors associated with very careful application of radiative transfer calculations are about ±0.4^{o}C to ±0.6^{o}C.

Infrared radiation from the sea is strongly absorbed by clouds, and it is necessary to detect clouds in order to obtain accurate sea surface temperatures. Since low clouds have temperatures very near to surface values, temperature alone is not adequate as a detection technique. Dual-channel (visible and infrared) radiometers provide the necessary data for cloud detection, but recent studies show that automatic computer clustering techniques will not work because the temperature-reflectance correlations for clouds is not uniquely separated from the correlation for cloud-free areas. If as little as 10% of the radiometer's field of view is cloud-contaminated, an error of -0.5^{o}C may result; this error is almost always negative.

Temperature gradients as well as absolute temperatures are affected by atmospheric water vapor. Surface temperature gradients are reduced by as much as 50% when measured by a satellite through a moist atmosphere. The effect can be quantified, and is equal to the atmospheric transmissivity. Typical values of transmissivity off New England (Ocean Station H) are 0.73 ± 0.07 in February and 0.54 ± 0.05 in August for the geostationary satellite. The standard deviations of these transmissivity values suggest temperature gradient variability of $\pm 0.6^{\circ}C$ per unit horizontal distance.

Summarizing the inherent errors associated with infrared measurement of sea surface temperature, it is reasonable to expect that satellite detection is in the range $\pm 0.8^{\circ}C$ to $\pm 1.6^{\circ}C$ with current understanding of the physics. Instrumental noise is less than $\pm 0.3^{\circ}C$ in many radiometers today. High-quality shipboard measurements for surface truth by immersion thermometers are within $\pm 0.1^{\circ}C$; ship-of-opportunity surface truth measurements are probably an order of magnitude RMS higher. If surface truth is judiciously used to least squares adjust satellite observations of ocean temperature, and corrections are carefully applied for radiative transfer and radiometric-thermometric temperature differences, it appears possible to keep the RMS error below $1^{\circ}C$.

DIRECTIONAL OCEAN WAVE AND WIND SENSING

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The following charts and key references outline remote sensing systems which can provide specific derived parameters useful to the study of ocean surface waves and wind. The parameters are defined as follows:

$\overline{H}_{1/3}$	Significant Wave Height
$S\ (f,\ \theta)$	Directional Wave Spectrum
$S\ (f_1,\ \theta)$	Directional Wave Characteristics at frequency f_1.
$S\ (f)$	Wave Frequency (power) Spectrum
$\vec{V}c$	Water Current Velocity
V_{dir}	Wind Direction
L_w	Wavelengths of Water Waves
θ_w	Direction of Water Waves
$\vec{V}_{sfc}$	Surface Wind Speeds
U_k	Friction velocity = $\sqrt{\text{(wind stress)/(air density)}}$

REMOTE SENSING OF OCEAN SURFACE WAVES AND WIND

Ground Based Systems	Derived Parameter	References
HF Surface Wave Radar	$\overline{H}_{1/3}, S(f,\theta), \vec{V}_c$	Barrick (1978), Lipa (1978)
HF Synthetic Aperture Antenna	$S(f_1,\theta), \sum_{\theta} S(f_1,\theta)$	Teague (1979)
HF Skywave	$\overline{H}_{1/3}, S(f), V_{dir}, \vec{V}_c$	Maresca (1979)
Aircraft Based Systems		
Altimeter/Profilometer		
Radar	$\overline{H}_{1/3}, S(f)$	Barnett and Wilkerson (1967)
Laser	$\overline{H}_{1/3}, S(f)$	Ross, Cardone, Conaway (1970)
Imaging Radar	L_w, θ_w	Bondarenko et al. (1967), Brown et al. (1976)
Dual Frequency Radar	$S(f,\theta)$	Alpers and Hasselmann (1977)
Aerial Photography	$S(f,\theta)$	Stilwell (1969), Cote et al. (1960)
Inertial Navigation System	$\vec{V}_h$	Ross and Cardone (1974)
Radar Scatterometer	$\vec{V}_{sfc}, U_*$	Jones et al. (1978)
Microwave Radiometer	$\lvert\vec{V}_{sfc}\rvert$	Webster et al. (1976)
Satellite Based Systems		
Radar Altimeter	$\overline{H}_{1/3}, \lvert\vec{V}_{sfc}\rvert$	Parsons (1979), Tapley et al. (1979)
Radar Scatterometer	$\vec{V}_{sfc}, U_*$	Jones et al. (1979)
Microwave Radiometer	$\lvert V_{sfc}\rvert$	Lipes et al. (1979)
Imaging Radar	L_w, θ_w	Brown et al. (1979)
Visible Imagery	$\lvert V_{sfc}\rvert$	Strong and Ruff (1970)

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LARGE SCALE OCEAN CIRCULATION

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Present day thinking about the large scale features of the general circulation of the oceans is shaped to a considerable degree by climatological means of the dynamic topography of the type seen in Figure 1 (Ref.1). An analogous picture in terms of current patterns is seen in Figure 2 (Ref. 2). Time-varying features, such as Gulf Stream meanders, rings, and eddies have been observed over limited regions of space and time in local studies. Mid-ocean eddies have been investigated in the Mode-1 observing region of Figure 3, which is of mesoscale size (Ref. 3).

Space techniques offer the prospect of greatly expanding the temporal and spatial scales which are amenable to investigation to the point, even, of the study of planetary scale features. The essence of the space approach is to observe departures of the free surface from the geoid, such as the one indicated in Figure 4 (Ref. 4). The causes of these separations, of course, may not be related to geostrophy, such as those associated in one way or another with the atmosphere. Uncertainties in the latter are in the range of a few centimeters in a great many cases of oceanographic interest. Atmospheric time constants are also generally much shorter than oceanic response times for features of comparable scale. Thus, determinations of the departures of the free surface from the geoid can frequently be of value in helping us learn more about ocean circulation.

Space approaches for determining the location of the free surface are depicted in Figures 5 and 6. Favorable geometry is provided, for example by satellite altimeter tracks which pass nearly orthogonally over branches of the meandering Gulf Stream, in the manner indicated in Figure 7 (Ref. 5). The configuration of Figure 5 shows a geometric determination of the location of the satellite relative to the three laser stations as a result of simultaneous tracking of the satellite from the trio of lasers. Coverage of this type has been furnished for altimeter satellite passes over the Gulf Stream region from lasers at Goddard, Bermuda, Patrick Air Force Base, and Grand Turk. These four stations provide reasonably good coverage, even allowing for clouds. Lasers and altimeters both have noise figures in the 5-10 cm range (Figure 8)(Ref. 6).

Lasers and suitable islands are not available in sufficient numbers to cover all oceanic regions of interest. Orbit determinations must thus be relied upon to provide knowledge of the satellite altitudes over much of the ocean surface. The accuracy of orbit determination is often limited largely by imperfect knowledge of the gravity field, although in the case of a satellite such as Seasat, which has a large area/mass ratio and a very complicated aerodynamic shape, atmospheric drag effects are also significant contributors to the overall error budget. (Fig. 9). An orbit error spectrum for Seasat is seen in Figure 10 (Ref. 6). Other principal elements in the orbit determination process are indicated in Figure 11.

Two altimeter tracks crossing the same point at different times should imply the same height for the sea surface, to within errors associated with the altimeter and the orbit and actual variations of the sea surface altitude with the time. The orbit error dominates. It is seen in Figure 12 that the RMS value of the altimeter track crossing residuals is about 1 1/3 meters, which implies global orbit accuracies of better than a meter, even if all the error is assumed to be due to the orbit modeling (Ref. 6). The actual orbit error is, accordingly, still smaller, since some of this total error is contributed by changes in the actual free sea surface height. Figure 13 lists principal characteristics of recent gravity models, such as those which underlie the results of Figure 12 (Ref. 7).

Dense sets of altimeter tracks, of the type indicated in Figure 14, can be used as the basis for constructing a mean geometric reference surface. Much of the orbit error associated with each of the 374 orbital arcs indicated can be eliminated by simultaneously adjusting the orbital altitude and slope of each one at a convenient point so as to minimize the RMS value of the altimeter crossover differences. A set of accurate laser orbits provides the reference for this type of adjustment. Further details of the technique are outlined in Figure 15. The improvement in the orbit accuracies and the corresponding crossover differences resulting from the adjustment is seen in the histograms of Figure 16 (Ref.6). The RMS value of the crossover differences drops sharply to a third of a meter, corresponding to orbit accuracies of better than a quarter of a meter. Again, these differences also reflect the actual changes in the sea surface height between the times of the crossing arcs of each pair. The mean geometric reference surface constructed by this technique is portrayed in Figure 17 (Ref. 6).

The differences between this reference surface and the altitudes observed during a Seasat altimeter pass are seen in Figure 18 (Ref. 8). A similar reference surface constructed in the Western Pacific from GEOS-3 altimetry data is seen in Figure 19 (Ref. 6). A global geometric reference surface has also been generated on the basis of altimeter data indicated in Figure 20.

The global geoid of Figure 21 is based on a combination of satellite tracking data and surface gravimetry. A detailed geoid for the Western North Atlantic, with five-minute resolution for the most part, is shown in Figure 22 (Ref. 6). It thus serves as a good reference surface against which to compare Seasat altimeter tracks of the type indicated in Figure 23. The differences between the one-second altimeter measures on these two passes and the geoid of Figure 22 are seen in Figure 24 (Ref. 8). The classic geostrophic slope of the Gulf Stream North Wall stands out. Also visible are the topographic signatures of cold-core rings. Their position correlate well with in situ data.

Thus, two alternative types of reference surface are available for circulation topography determination: the ocean geoid and the mean geometric surface determined from satellite altimetry (Fig. 25). An example of each type is seen in Figure 26 (Ref. 8). Several points are made by the curves of this figure. The geoid, based on the GEM 10B solution for the geopotential, which yields gravity harmonics through degree and order 36, has a spatial resolution of about 5°, as the figure shows. Its lack of finer geoidal structure near the Gulf Stream gives rise to an altimeter difference trace which has a spuriously large amplitude near the Gulf Stream. This probably results from the juxtaposition of the true Gulf Stream slope and a mesoscale geoidal slope.

On the other hand, a Gulf Stream signal which is discernible, but somewhat attenuated, is obtained by taking the differences between the Seasat altimeter data points and the mean geometric reference surface of Figure 17, which was based on GEOS-3 altimeter data (Figs. 18 and 26) (Refs. 6, 8). This diminution of the Gulf Stream signature is, again, to be expected, since the geometric reference surface already contains a mean representation of the meandering Gulf Stream.

Detailed geoids derived from surface gravimetry and satellite data serve as fine references in the few limited regions of the world, such as the Western North Atlantic, where they are available. Gravity field and geoid information from a possible Gravity Satellite mission would provide an improved reference surface in a great many ocean areas around the globe (Ref. 9). The further investigation of sea surface topography offers the prospect of significantly enhancing our understanding of ocean circulation.

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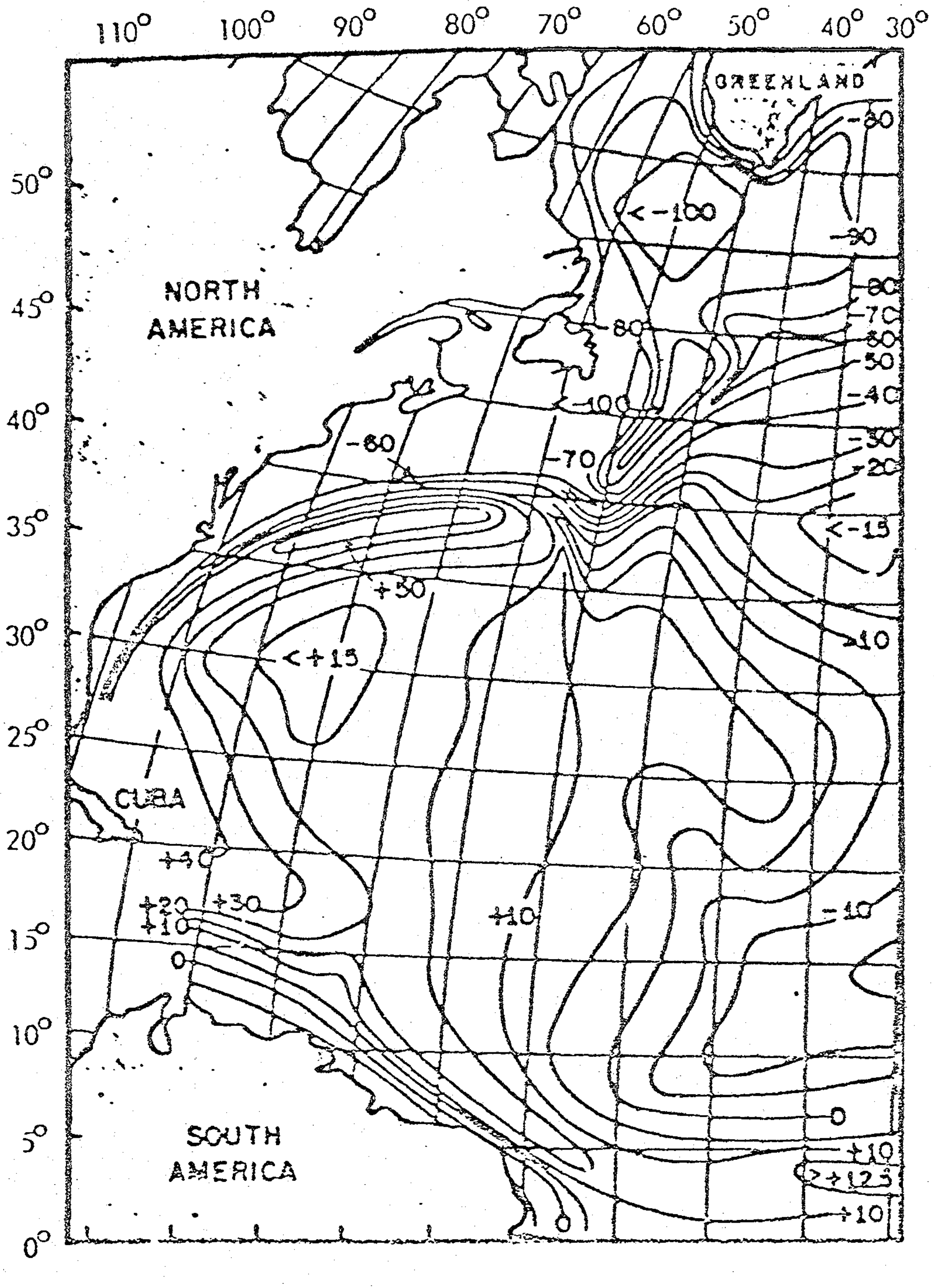


Figure 1. Sea surface topography in the western Atlantic (elevation in centimeters).

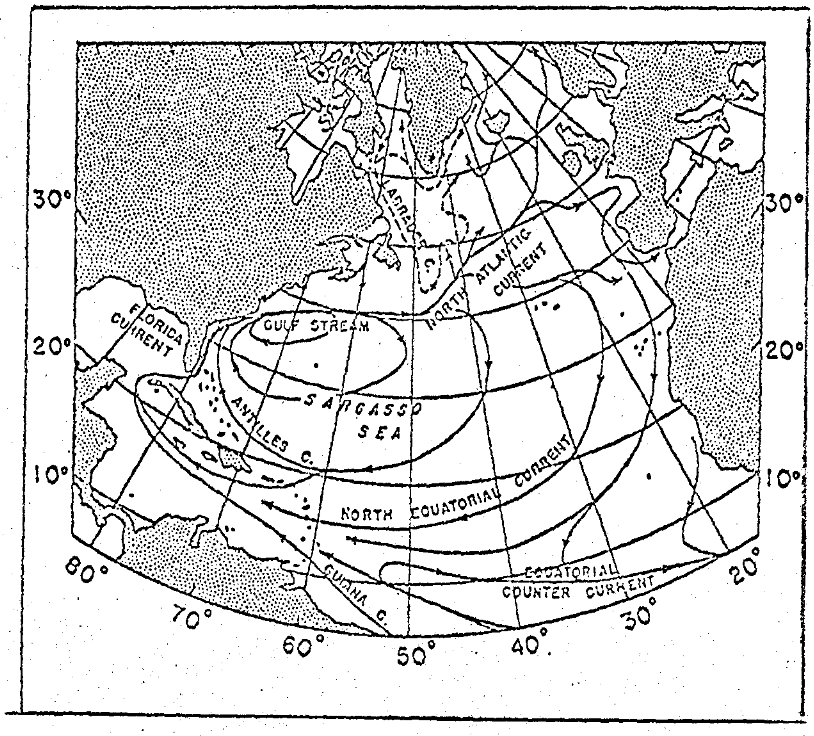
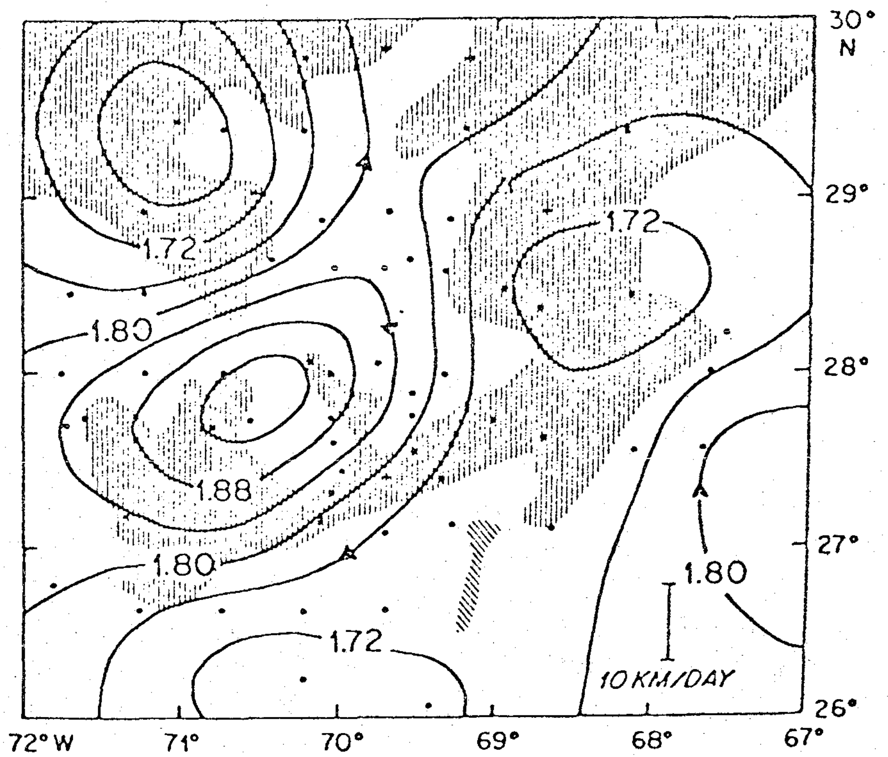


Figure 2. Estimated circulation pattern of North Atlantic.



May 30–June 13, 1973, yeardays 150–164.

Dynamic Topography (m) and Geostrophic Currents
in Mode-1 Region

Figure 3 Ref. 3

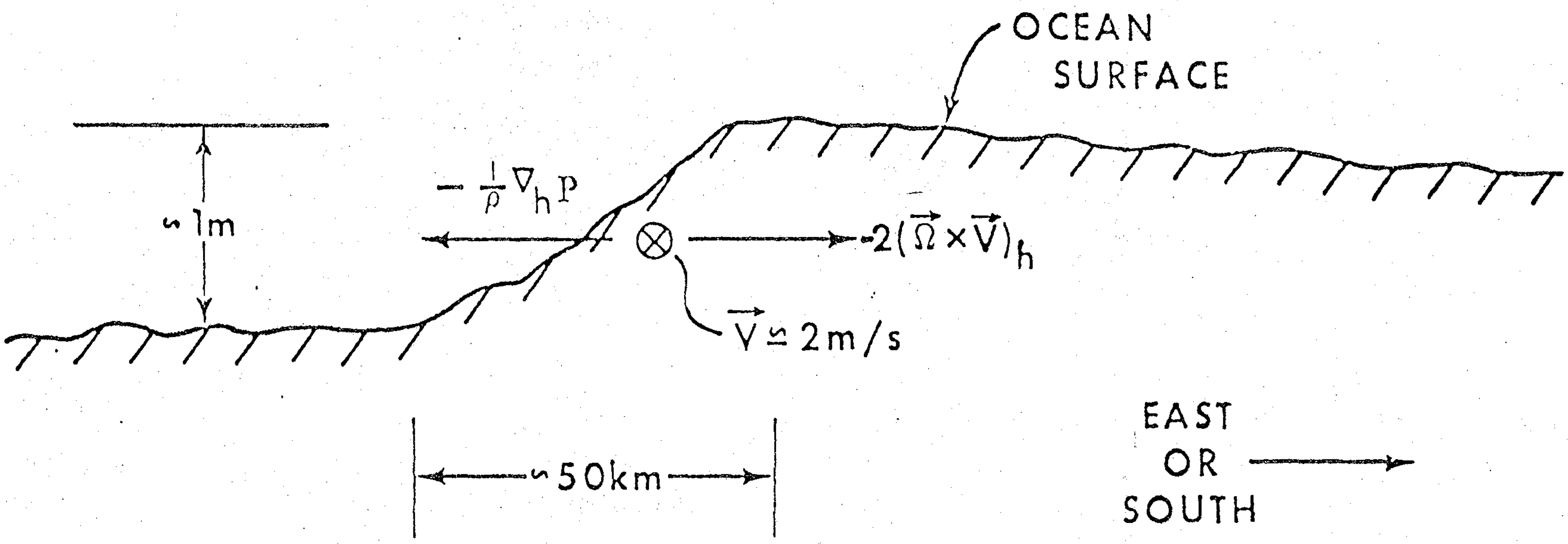


Figure 4. Sea-surface topography across the Gulf Stream. The surface of the ocean departs from the geoid when a steady current flows on a rotating earth, because of the requirement for a balance between the Coriolis force and a horizontal pressure gradient. For intense systems like the Gulf Stream, the elevation is of the order of 1 m over a horizontal distance of some 50 km.

Ref. 4

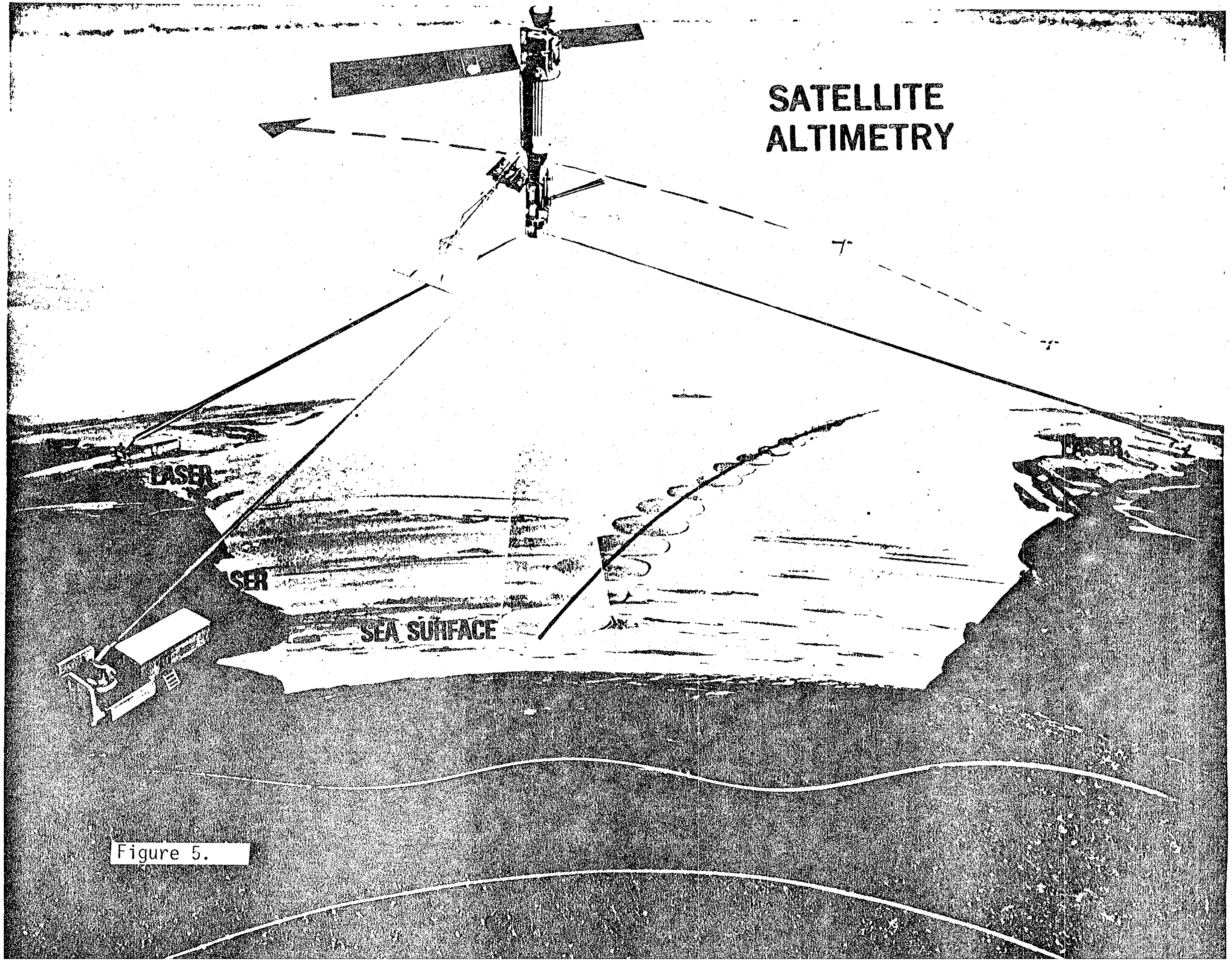


Figure 5.

OCEAN TOPOGRAPHY USING GEOS-3 AND SEASAT ALTIMETER DATA

- PRECISION ORBIT COMPUTATIONS
- GRAVITY MODEL/GEOID DEVELOPMENT
- OCEAN TOPOGRAPHY

Figure 6.

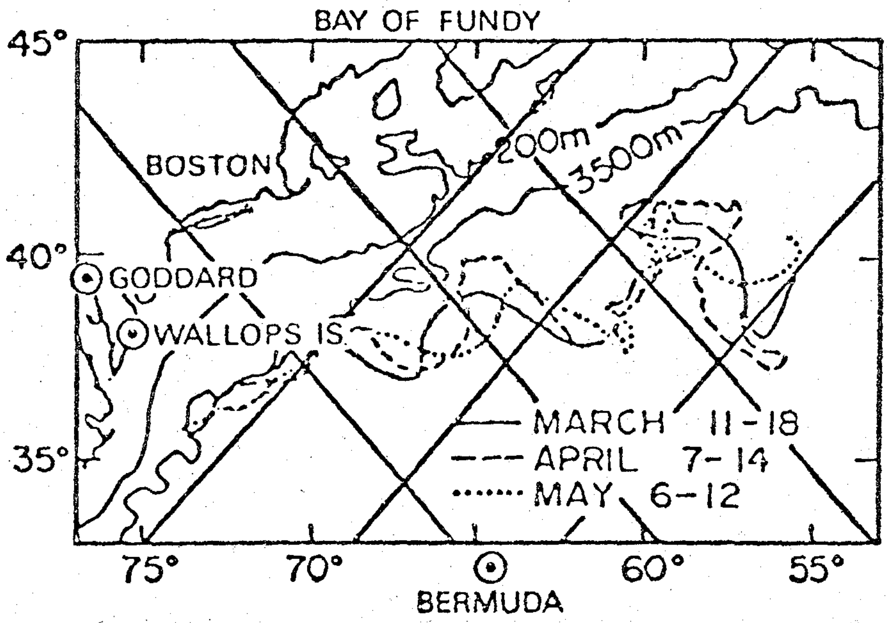


Figure 7. Gulf Stream meanders and satellite altimeter sampling density.

SEASAT SINGLE PASS SHORT ARC ORBIT SOLUTION
SAN DIEGO LASER RANGE RESIDUALS

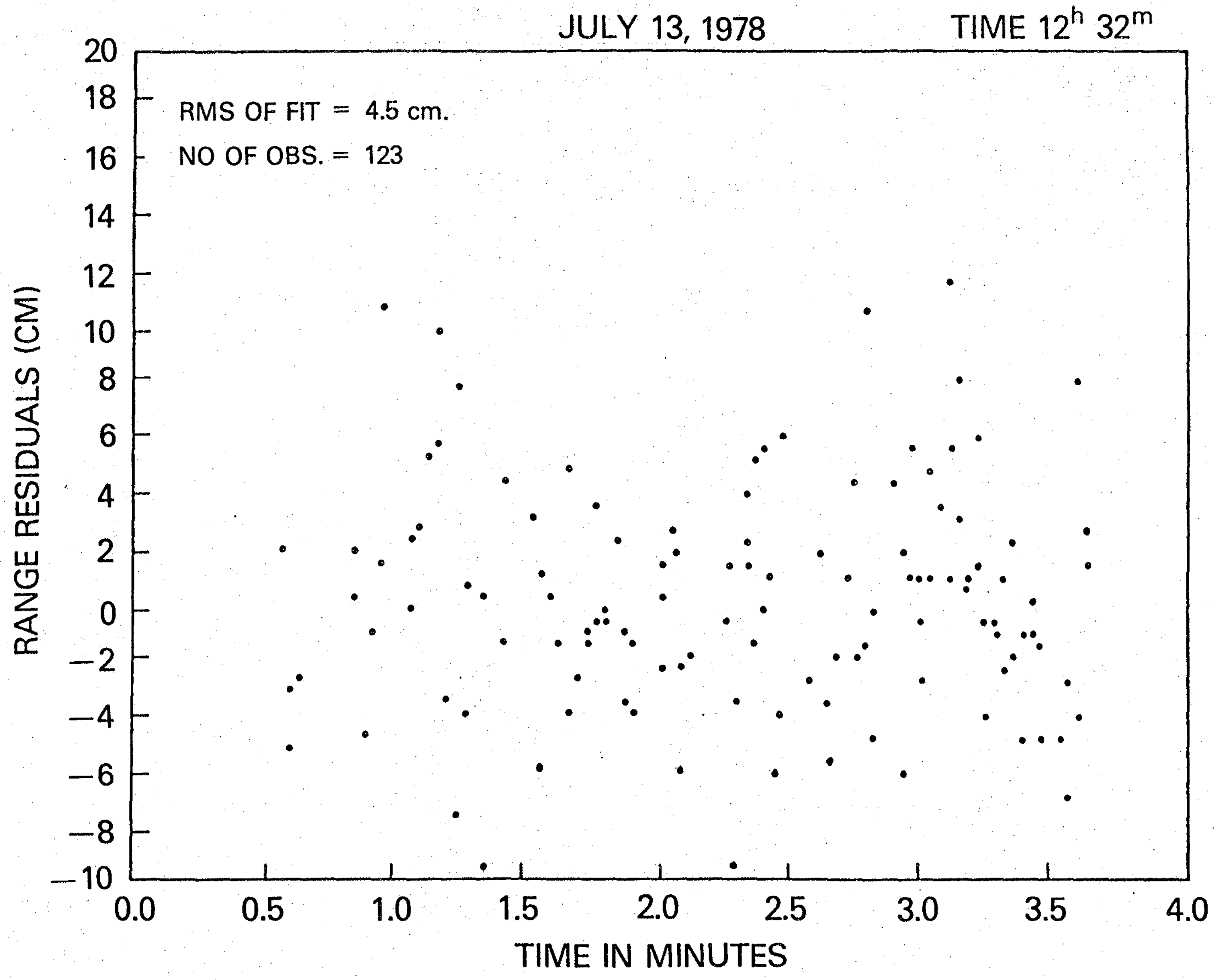
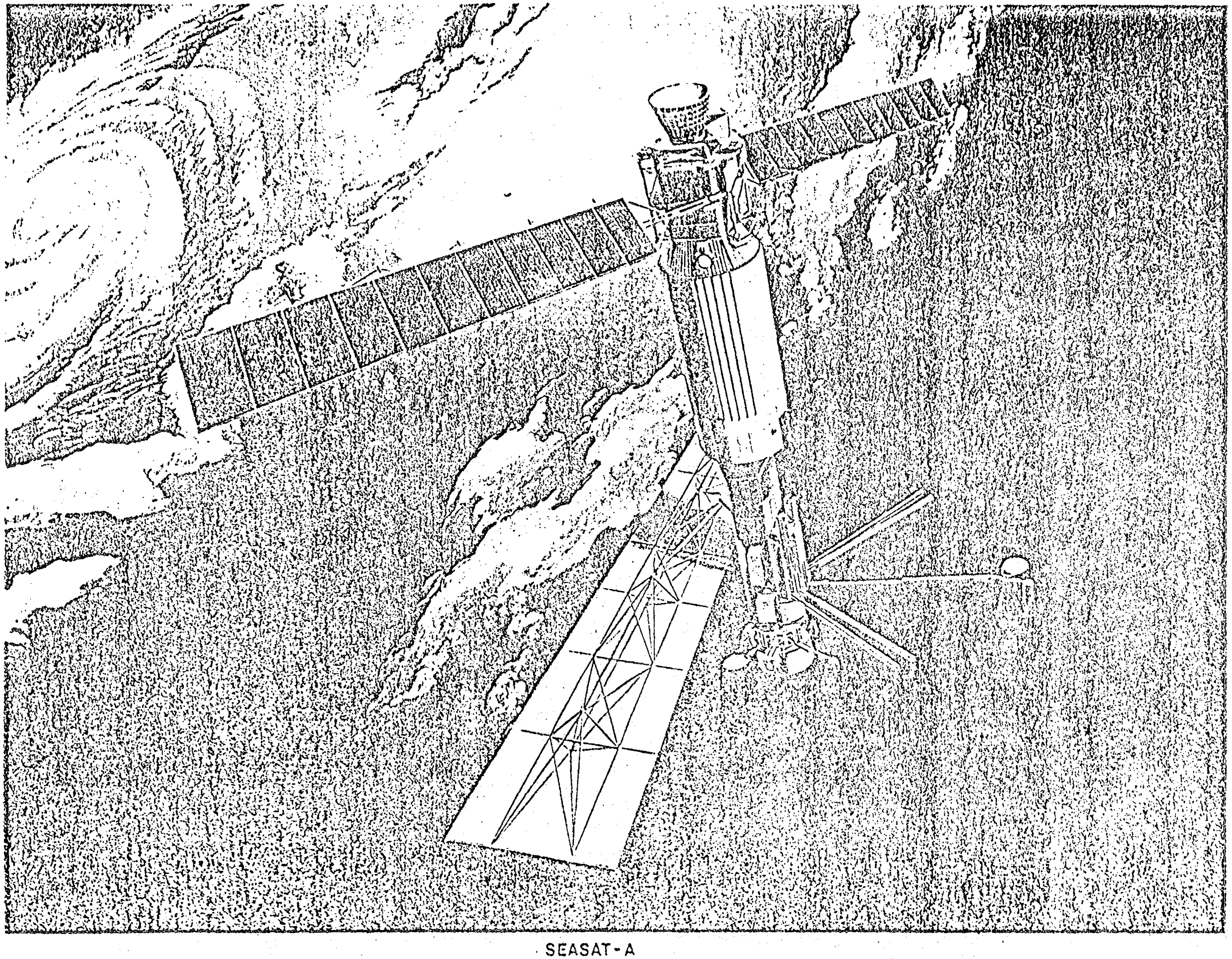


FIGURE 8.



SEASAT-A

AMPLITUDE SPECTRUM OF SEASAT ALTITUDE ERRORS

SIMULATED ERRORS DUE TO GRAVITY, DRAG, SOLAR RADIATION PRESSURE ON A THREE DAY ARC

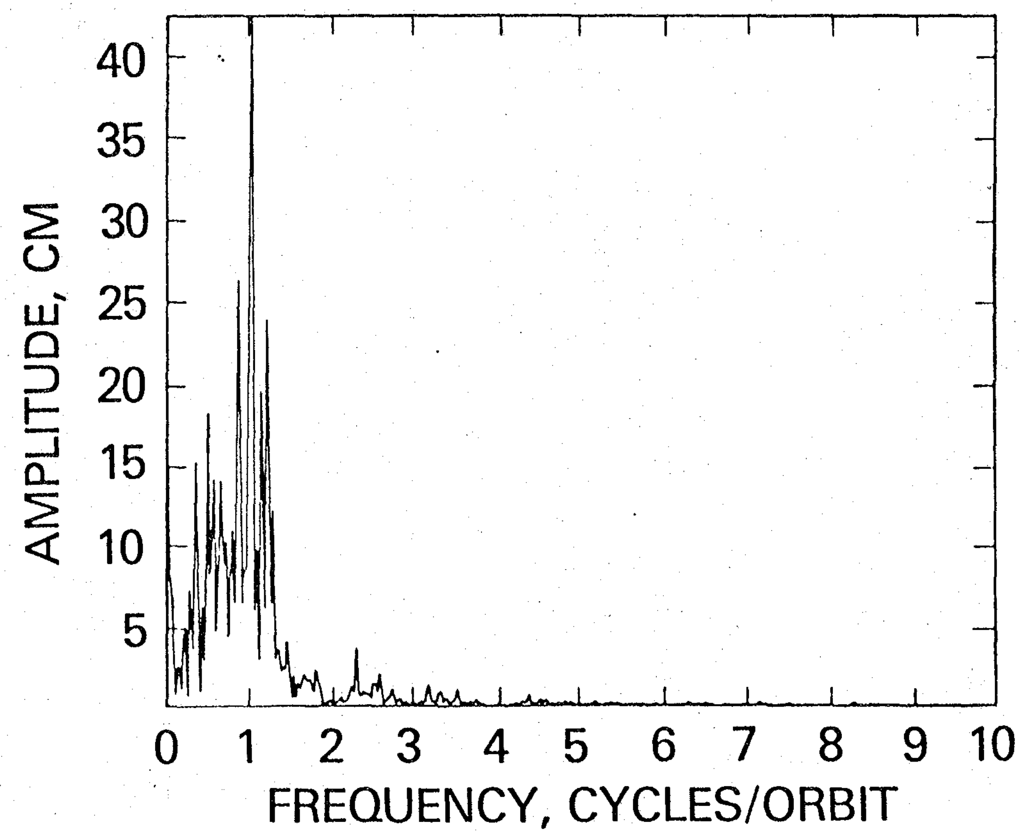


FIGURE 10.

ORBIT DETERMINATION OVERVIEW

- SPACECRAFT INITIAL POSITION AND VELOCITY
- EPHEMERIS GENERATION – NUMERICAL INTEGRATION OF FORCES INCLUDING:
  - EARTH GRAVITY
  - ATMOSPHERIC DRAG
  - ETC.
- MEASUREMENT MODEL – GEOMETRICAL RELATIONSHIP OF
  - TRACKING STATION COORDINATES
  - SATELLITE POSITION
  - EARTH ORIENTATION
- MEASUREMENT CORRECTIONS
  - REFRACTION
  - TRANSPONDER DELAYS
  - ETC.
- RESIDUAL COMPUTATION AND PARTIAL DERIVATIVE COMPUTATION
- LEAST SQUARES ADJUSTMENT AND ITERATION

FIGURE 11

ALTIMETER CROSSOVER DIFFERENCES FOR LASER REFERENCE CONTROL PASSES

	MEAN (cm)		RMS (cm)	
	GEM-10	GEM-10B	GEM-10	GEM-10B
NORTH WEST ATLANTIC OCEAN	-45	-29	136	96
NORTH EAST PACIFIC	-101	-110	224	170
PHILIPPINE SEA	-68	-76	162	137
WESTERN INDIAN OCEAN	2	-39	186	87
SOUTH WEST PACIFIC OCEAN	128	46	286	153

Figure 12.

EARTH GRAVITY MODELS

MODEL	HARMONICS	DATA
GEM-9	20 x 20	SATELLITE TRACKING
GEM-10	22 x 22	SATELLITE TRACKING & SURFACE GRAVITY
GEM-10B	36 x 36	SATELLITE TRACKING & SURFACE GRAVITY & ALTIMETRY

SATELLITE TRACKING — 30 SATELLITES INCLUDING GEOS-3

SURFACE GRAVIMETRY — 1654 5° (EQUAL AREA) MEAN GRAVITY ANOMALIES (RAPP 1977)

GEOS-3 ALTIMETRY — 700 PASSES GLOBALLY DISTRIBUTED WITH 1° SPACING

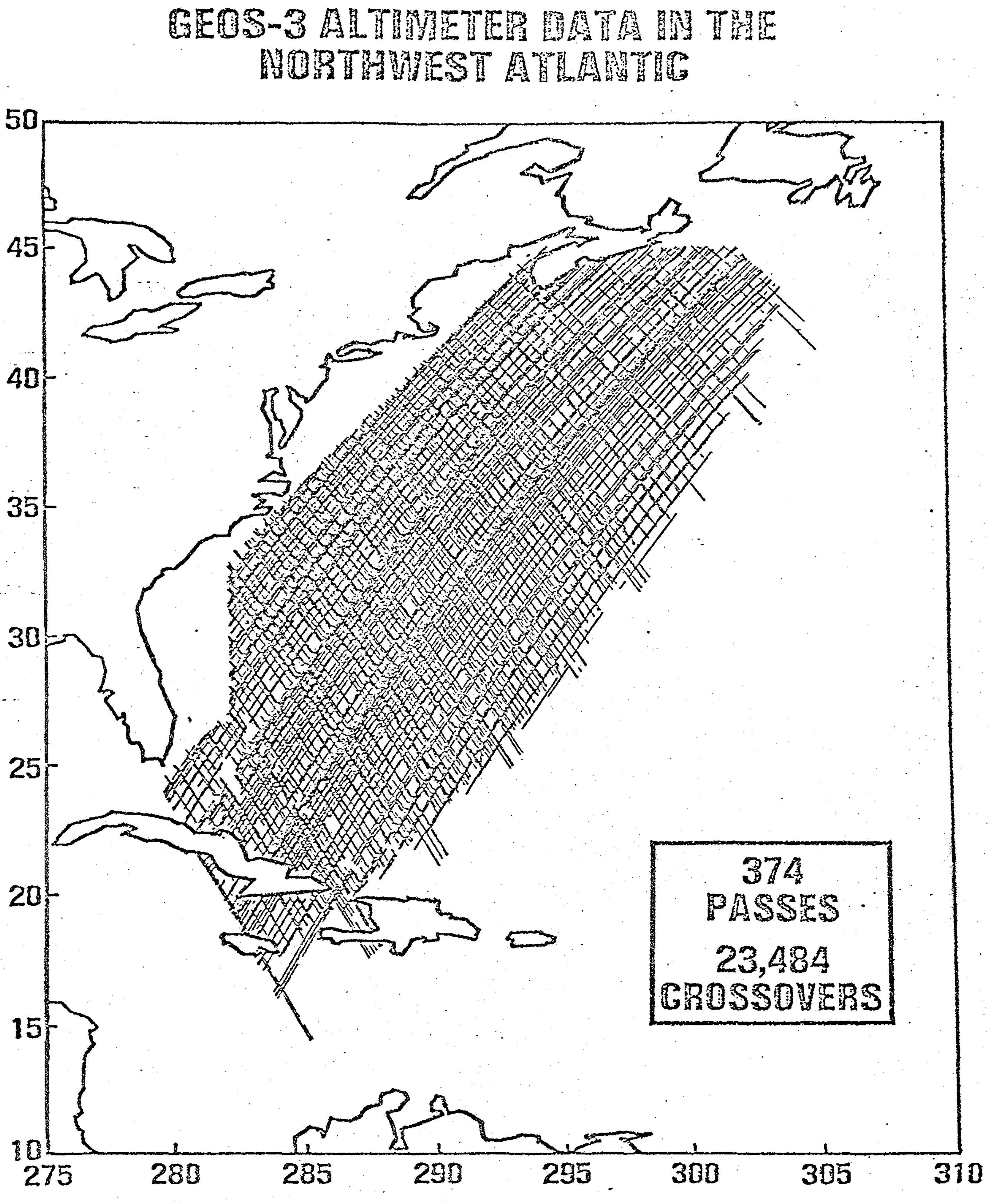

GEOS-3 ALTIMETER DATA IN THE
NORTHWEST ATLANTIC
374
PASSES
23,484
CROSSOVERS
50
45
40
35
30
25
20
15
10
275
280
285
290
295
300
305
310

Figure 14.

SEA SURFACE COMPUTATION TECHNIQUE

- RAW ALTIMETER DATA SMOOTHED TO A POINT APPROXIMATELY EVERY SECOND BY A POLYNOMIAL FIT OVER A FRAME.
- MINIMIZATION OF ALTIMETER DERIVED SEA SURFACE HEIGHT CROSSOVER DIFFERENCES.
- ADJUSTMENT OF BIAS AND TILT FOR EACH PASS TO ABSORB UNMODELED ERROR (ORBIT ERROR).
- ORIENTATION WITH RESPECT TO GRID OF LASER REFERENCE CONTROL ORBITS.
- LASER REFERENCE CONTROL ORBITS DETERMINED USING GLOBALLY DISTRIBUTED LASER DATA IN FIVE DAY ARCS.
- COMPARISONS OF ALTIMETER DERIVED SURFACE WITH DETAILED GRAVIMETRIC GEOID AND LONG ARC AND SHORT ARC ORBITAL SOLUTIONS.

Figure 15.

HISTOGRAMS OF CROSSOVER DIFFERENCES

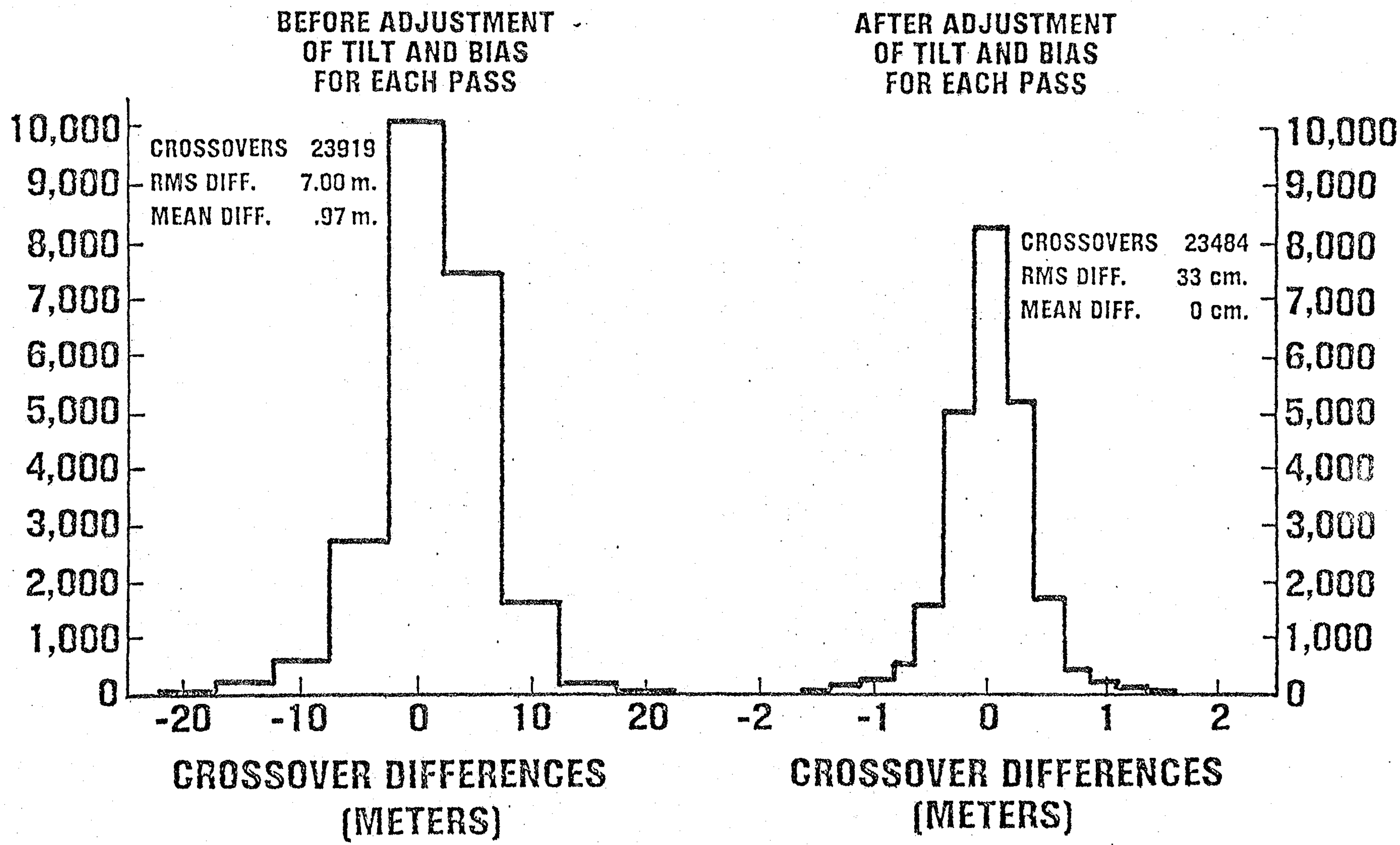


FIGURE 16

REF. 6

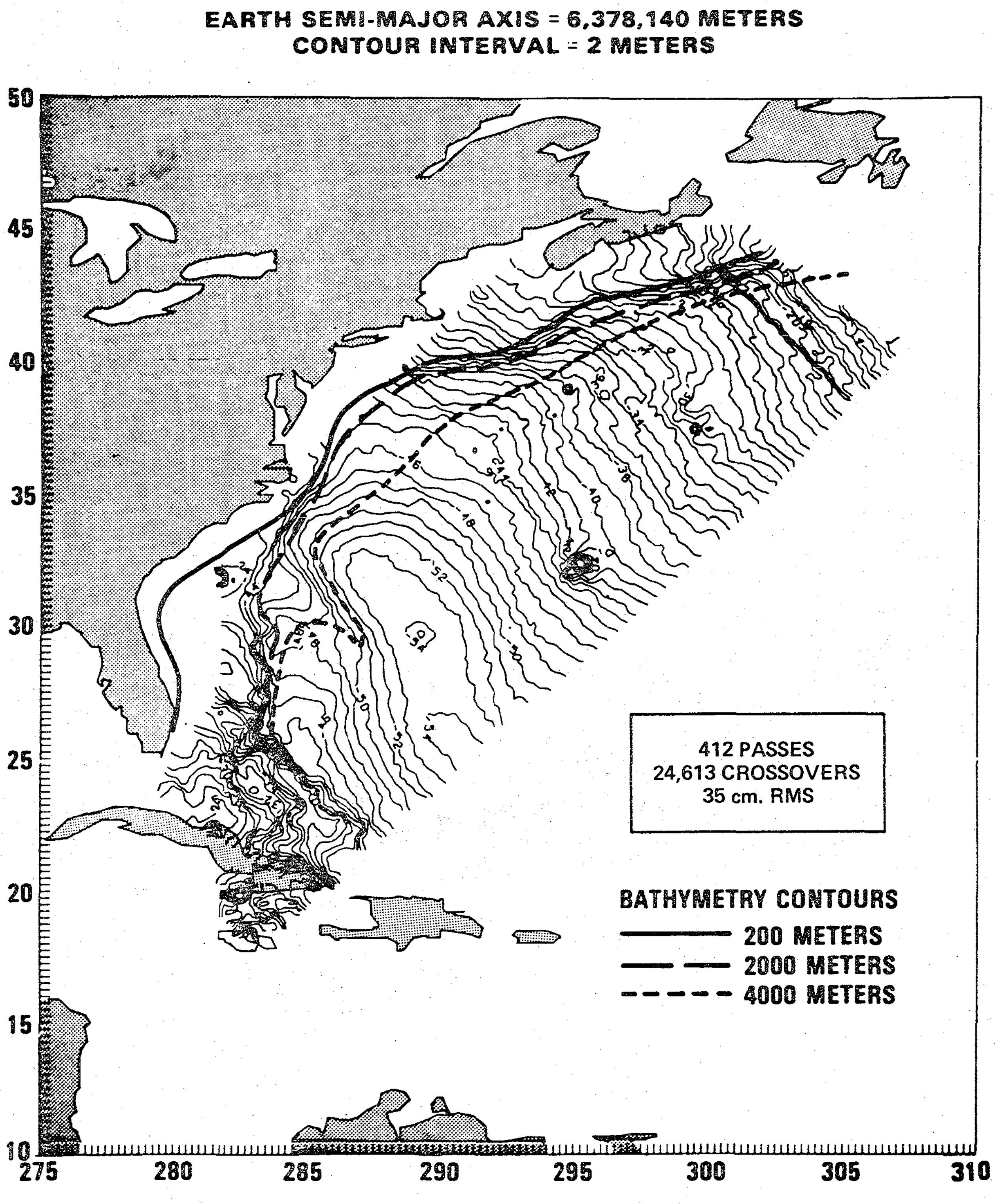


FIGURE 17. Contour Map of the Ocean Surface Derived from GEOS-3 Altimeter Crossover Data—Northwest Atlantic Ocean

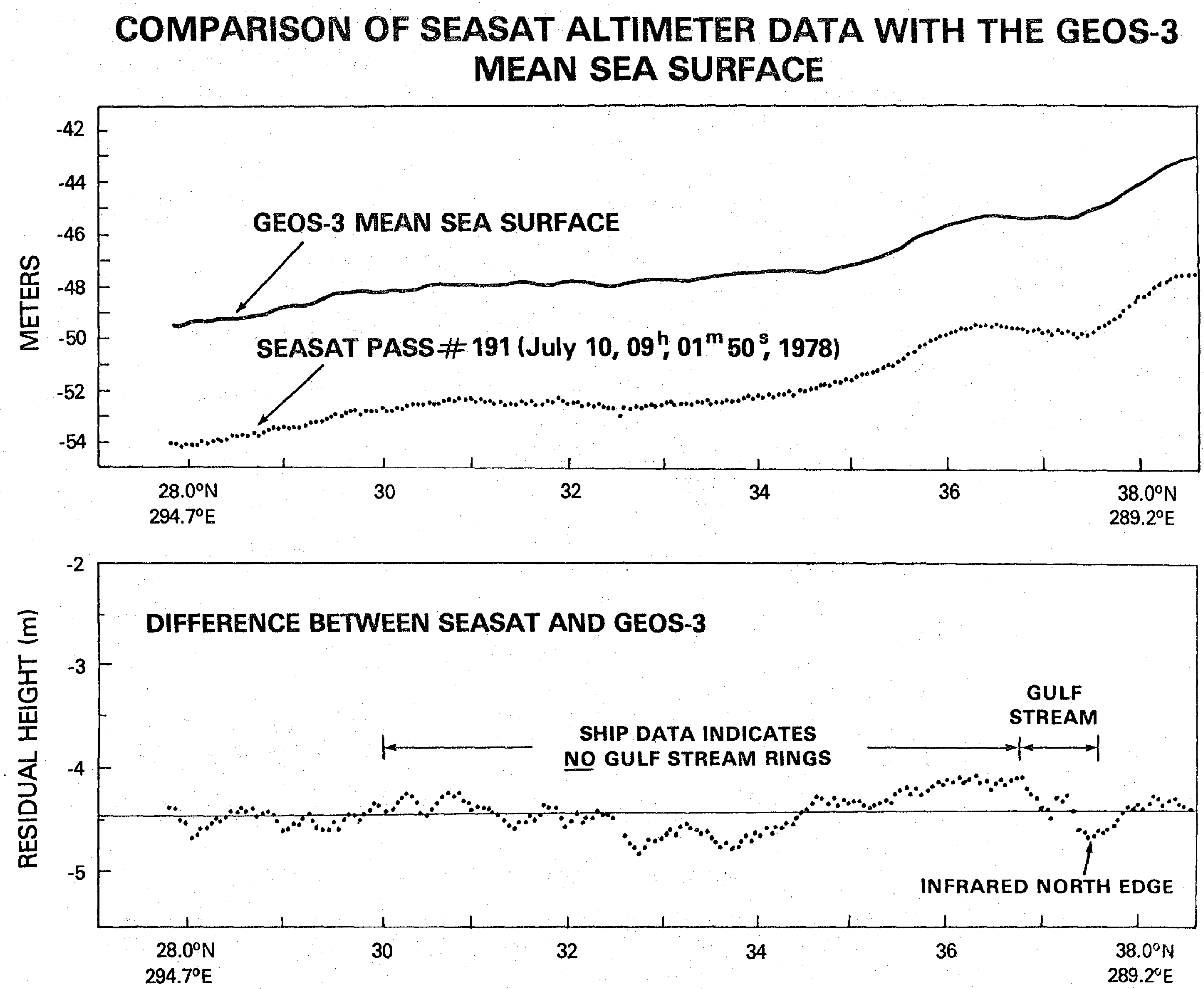

COMPARISON OF SEASAT ALTIMETER DATA WITH THE GEOS-3 MEAN SEA SURFACE
METERS
-42
-44
-46
-48
-50
-52
-54
GEOS-3 MEAN SEA SURFACE
SEASAT PASS # 191 (July 10, 09h, 01m 50s, 1978)
28.0°N
294.7°E
30
32
34
36
38.0°N
289.2°E
RESIDUAL HEIGHT (m)
-2
-3
-4
-5
DIFFERENCE BETWEEN SEASAT AND GEOS-3
SHIP DATA INDICATES
NO GULF STREAM RINGS
GULF
STREAM
INFRARED NORTH EDGE
28.0°N
294.7°E
30
32
34
36
38.0°N
289.2°E

Figure 18.

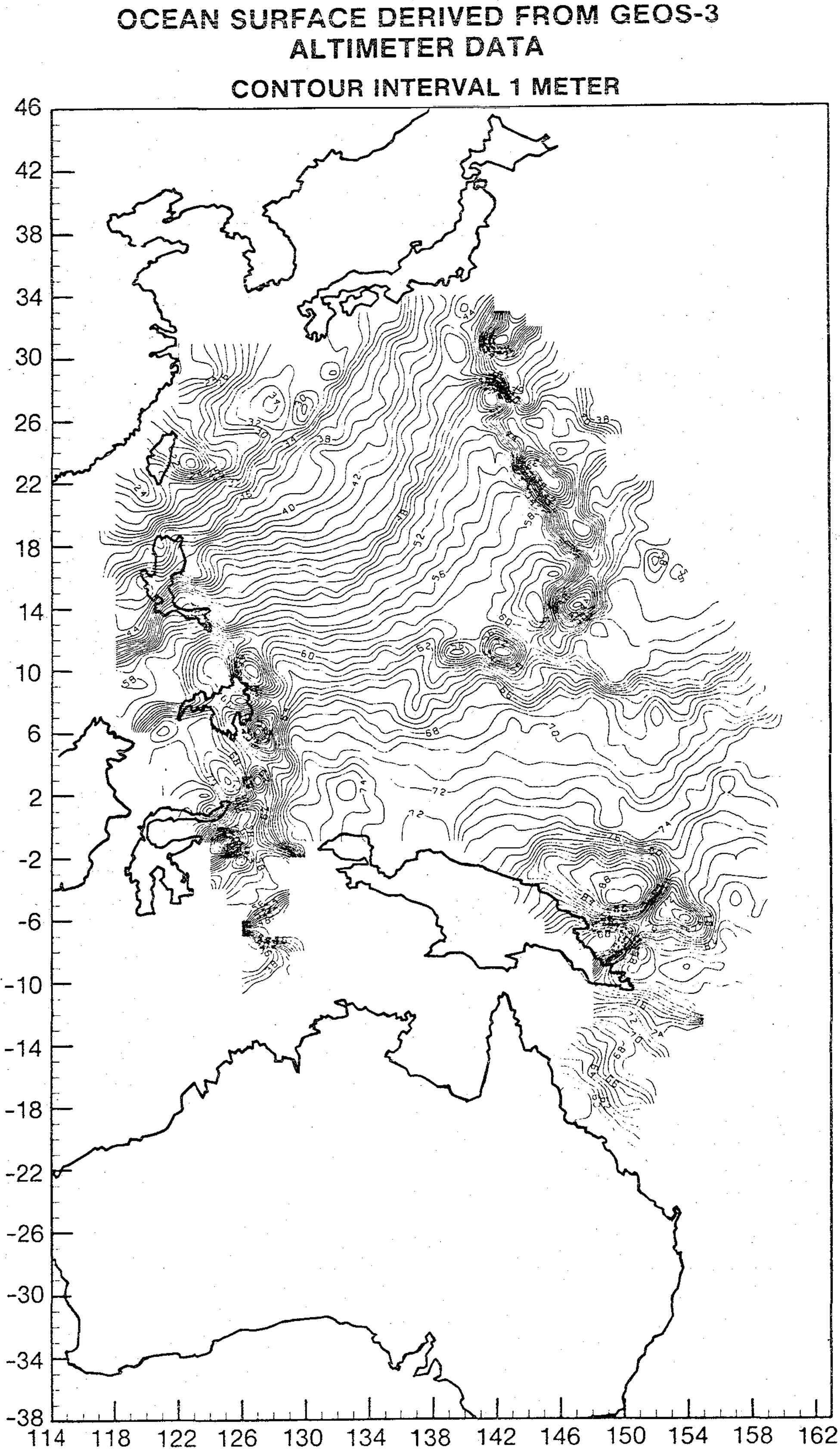

OCEAN SURFACE DERIVED FROM GEOS-3
ALTIMETER DATA
CONTOUR INTERVAL 1 METER
46
42
38
34
30
26
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
-30
-34
-38
114
118
122
126
130
134
138
142
146
150
154
158
162

FIGURE 19.

GEOS-3 ALTIMETER DATA AVAILABLE AT GSFC
JANUARY 1978

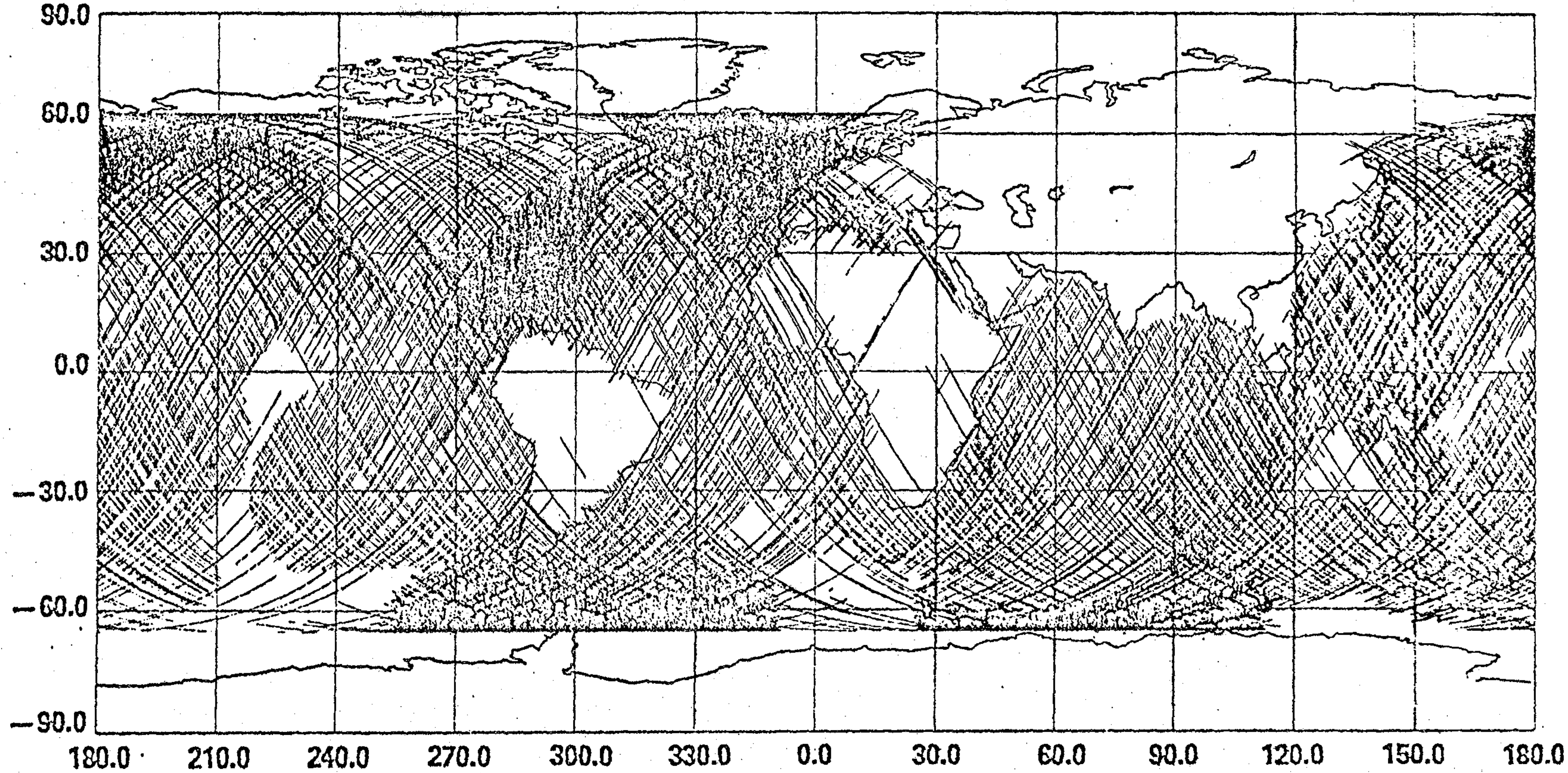


FIGURE 20

NASA/GODDARD SPACE FLIGHT CENTER

GLOBAL DETAILED GRAVIMETRIC GEOID BASED UPON A COMBINATION OF THE GSFC GEM-8 EARTH MODEL AND 1° x 1° SURFACE GRAVITY DATA

CONTOUR INTERVAL = 2 METERS

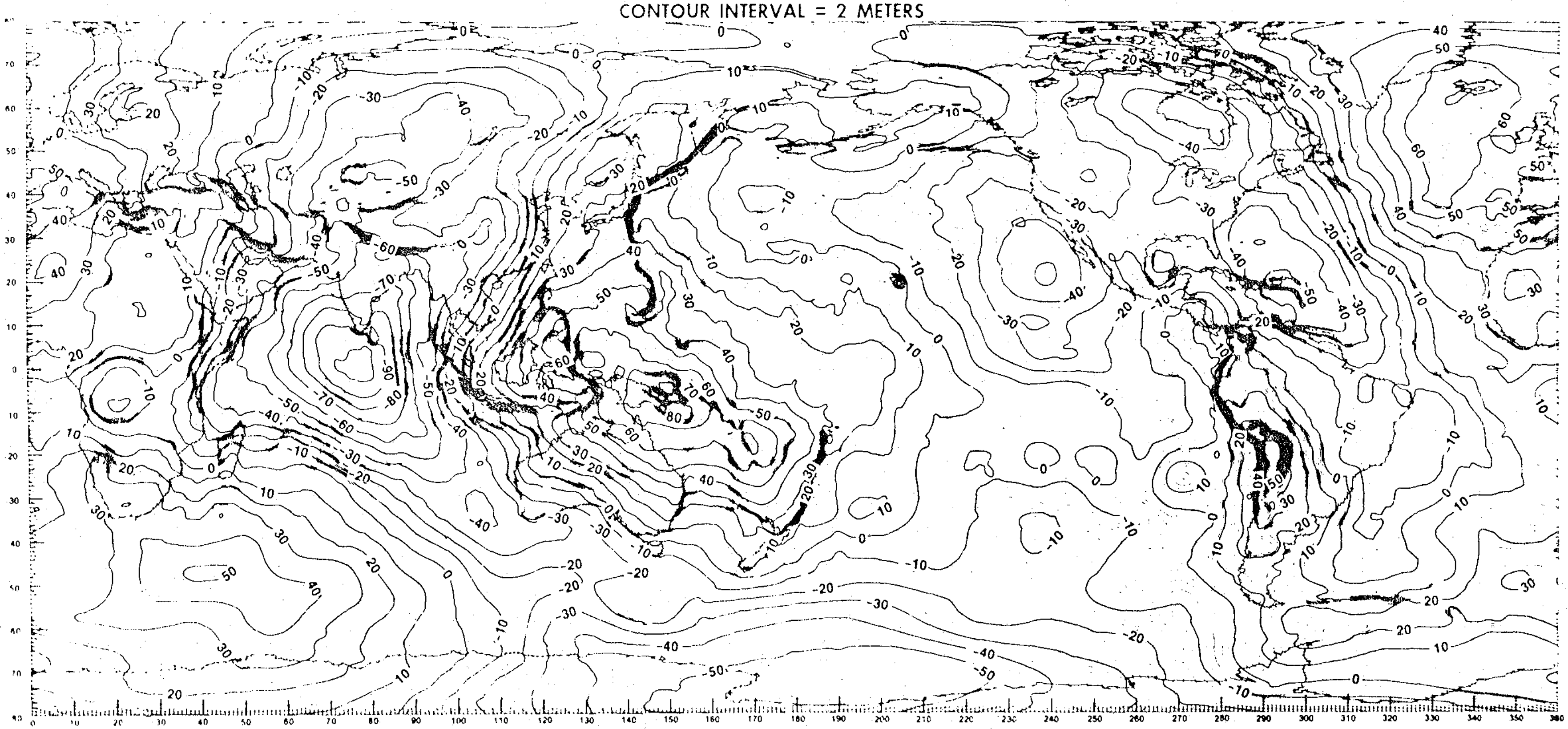


FIGURE 21.

NASA/GODDARD SPACE FLIGHT CENTER
DETAILED GRAVIMETRIC GEOID FOR THE GEOS-C ALTIMETER CALIBRATION AREA BASED UPON A COMBINATION OF 5' X 5', 15' X 15' AND 1° X 1° SURFACE GRAVITY DATA AND THE GSFC GEM-8 EARTH MODEL

CONTOUR INTERVAL = 2 METERS

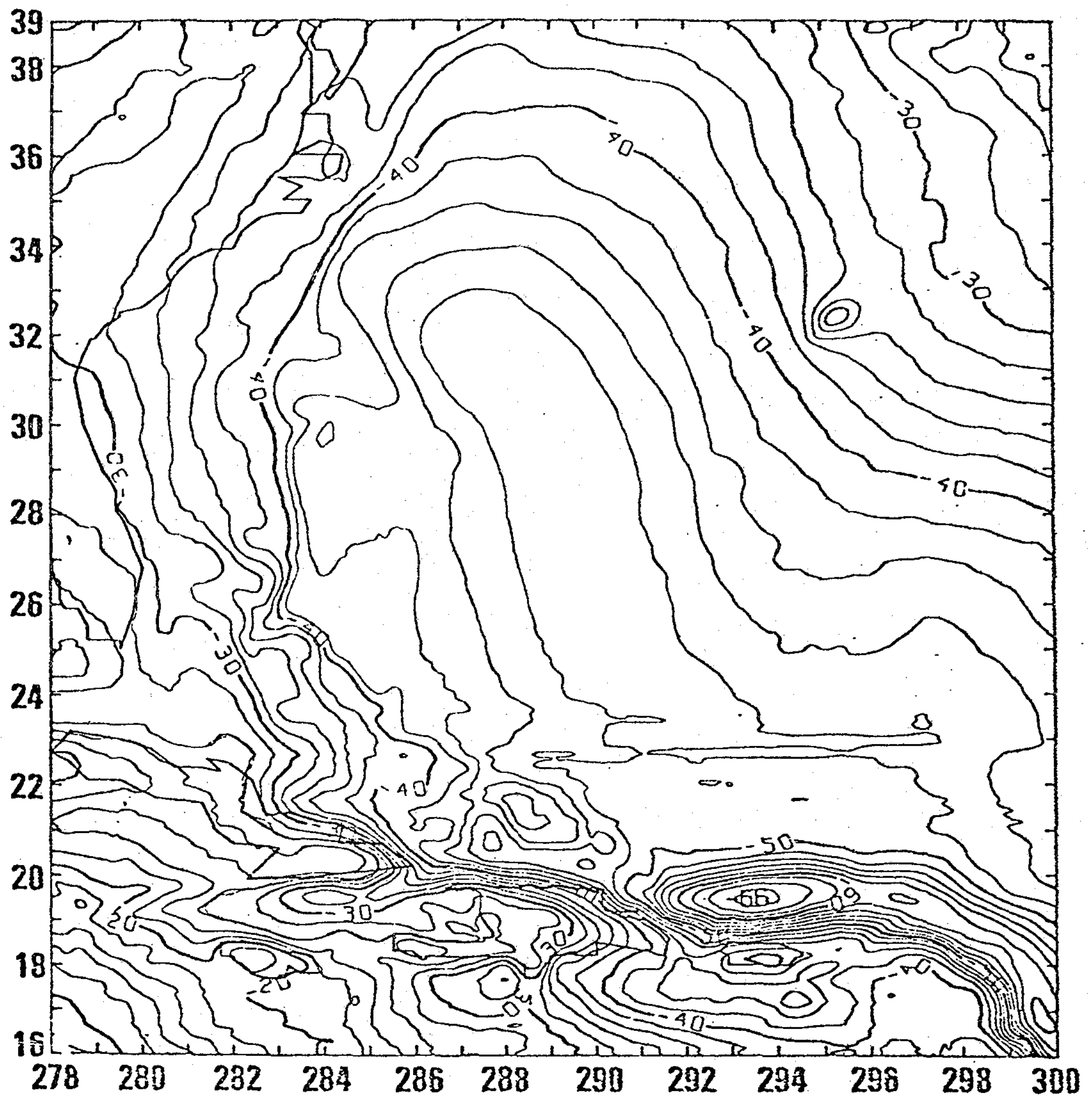


FIGURE 22 REF. 6

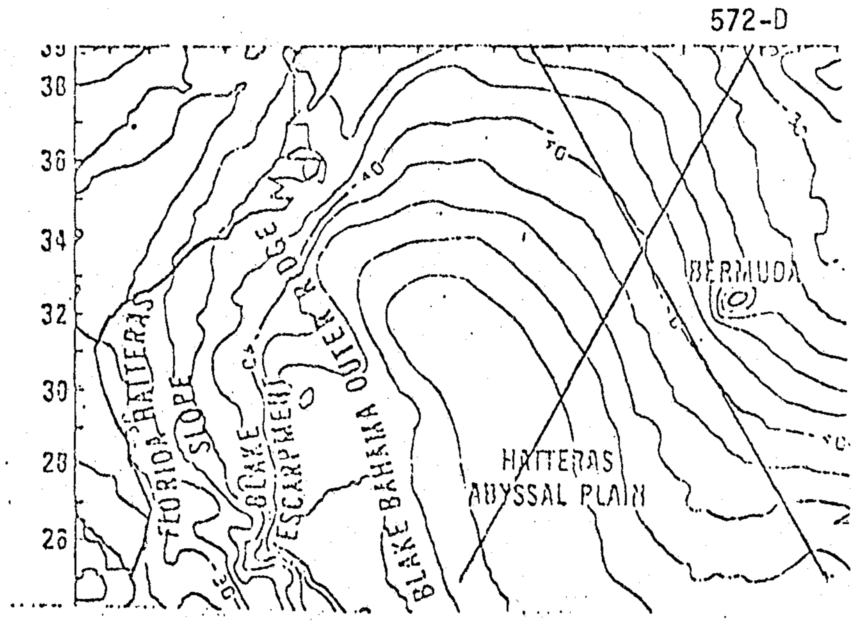

572-D
234-A
38
36
34
32
30
28
26
FLORIDA HATTERAS
SLOPE
BLAKE
ESCARPMENT
BLAKE BAHAMA OUTER RIDGE
HATTERAS
ABYSSAL PLAIN
BERMUDA

FIGURE 23

COMPARISON OF OCEANOGRAPHIC OBSERVATIONS WITH ALTIMETER DATA

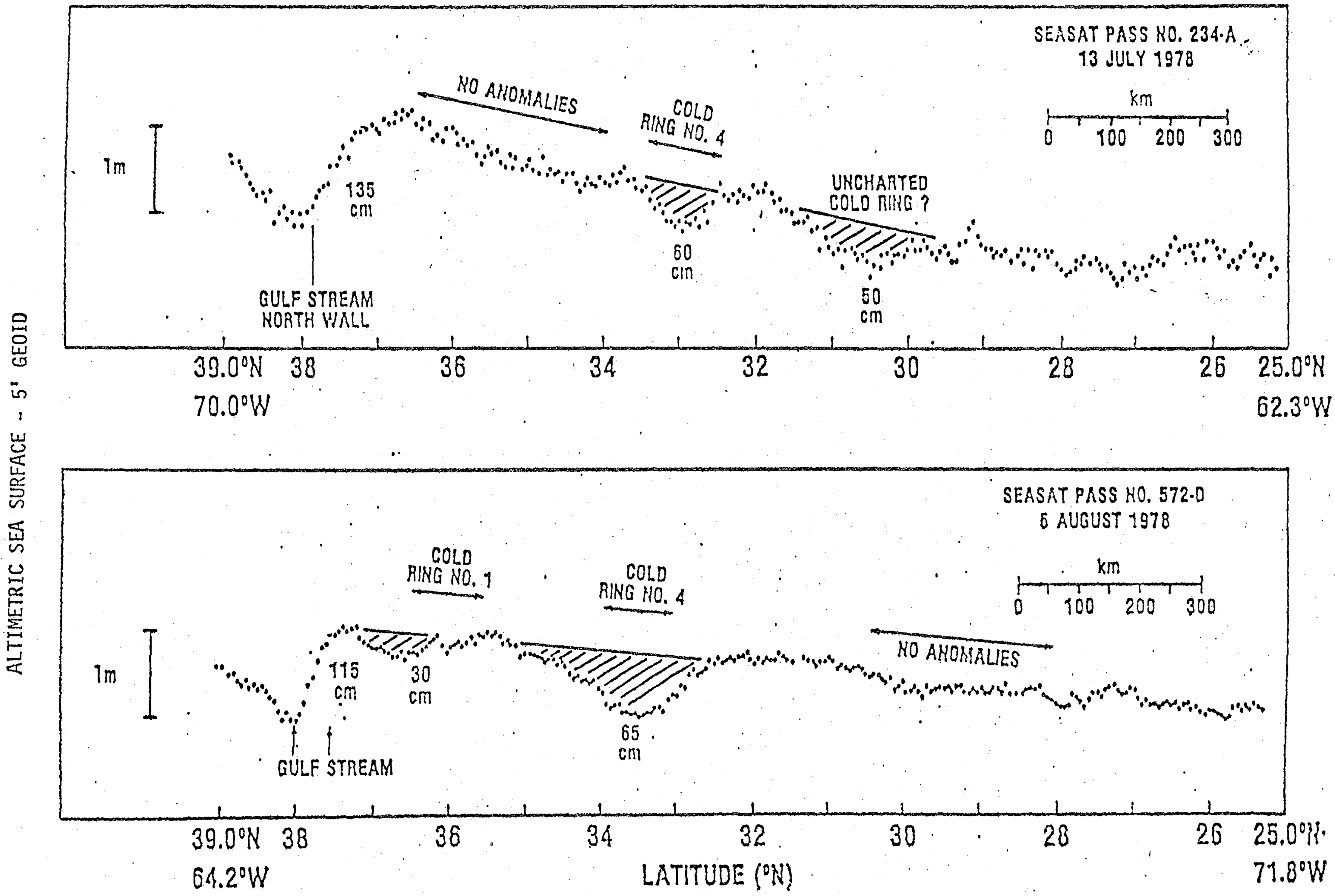


FIGURE 24

REF. 8

ALTERNATIVE REFERENCE SURFACES FOR

CIRCULATION TOPOGRAPHY DETERMINATION

THE OCEAN GEOID

THE MEAN GEOMETRIC SURFACE DETERMINED FROM

SATELLITE ALTIMETRY

FIGURE 25

HEIGHT
ABOVE ELLIPSOID

TOPOGRAPHY
ALIMETRY DATA

-REF. SURFACE

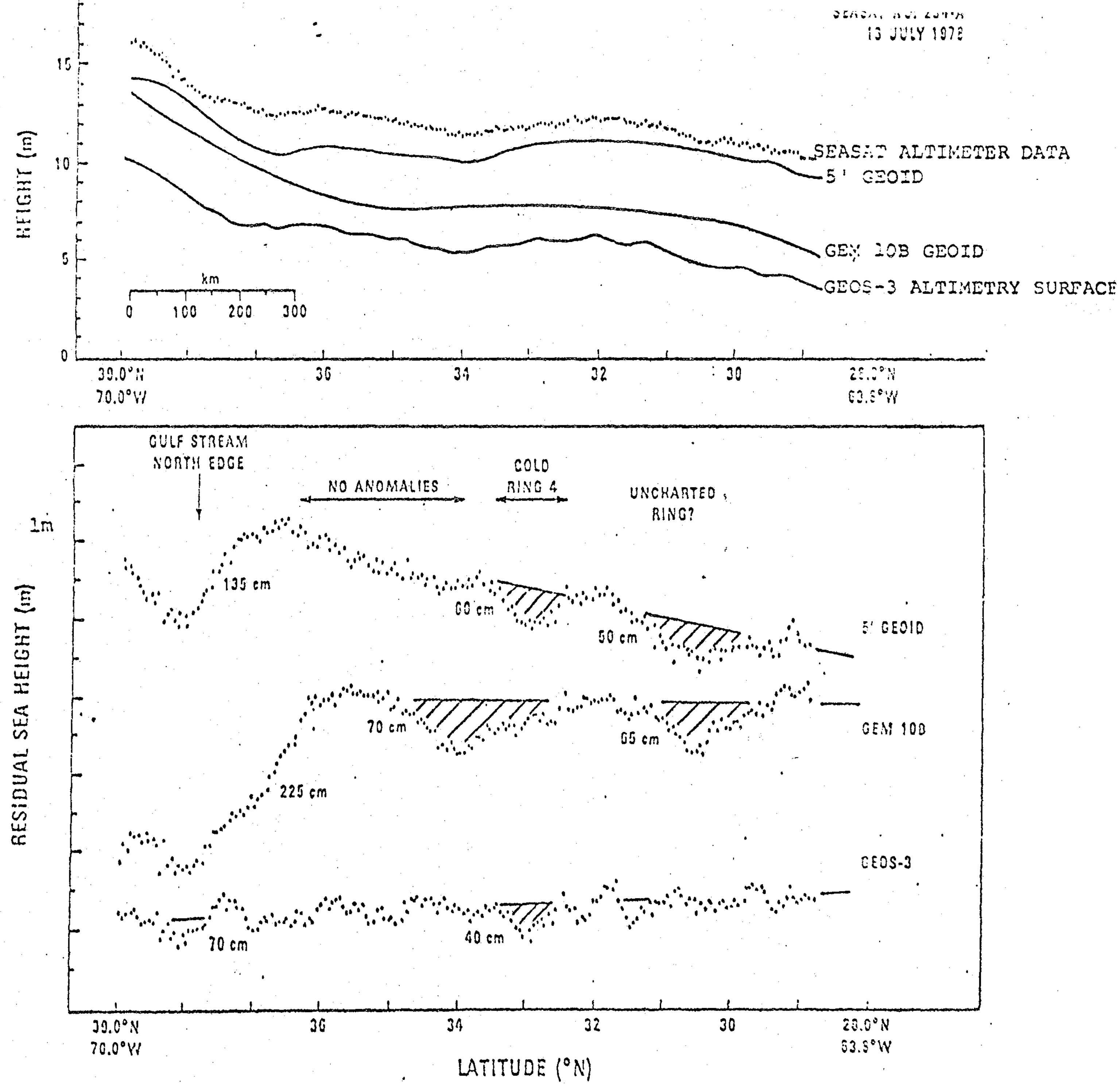


FIGURE 26

REFLECTIONS ON THE CURRENT LIMITED USE OF SATELLITE DATA FOR OCEAN APPLICATIONS

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INTRODUCTION

The absence of aggressive use of satellite imagery for ocean applications is not related to a general unfamiliarity with satellite sensor technology and products. During the last five years many oceanographers have been exposed to the unique satellite infrared pictures revealing dynamic ocean features. Certainly, this synoptic information has been instructive and stimulating and has provided new insights into ocean dynamics. The bulk of these products are provided by the National Oceanic and Atmospheric Administration's National Environmental Satellite Service (NOAA/NESS) and are enhanced non-linearly. Thus, they contain valuable qualitative reconnaissance information. However, as oceanographic data they appear to have little appeal. Evaluation of satellite technology as a platform for acquisition of calibrated quantitative oceanographic data and assessment as to how well in situ surface and related subsurface ocean conditions can be characterized using satellite data have not received adequate attention. Many of the ongoing user activities are fractionated and result from personal interests and initiatives rather than as a result of top-down directed, long-term structured programs. These are among the major factors which have impeded utilization of satellite data for ocean studies.

DISCUSSION

The following discussion is directed primarily to water mass delineation and characterization using satellite technology. In particular, how well can satellite data be used to locate, track, and characterize ocean front and eddy features and circulation patterns? The discussion largely addresses infrared and visible imagery data, since these data represent the bulk of our experience, similar considerations for emerging microwave and laser sensor data use are strongly implied.

While it appears that the major categories of ocean users today are Research and Development and Operational, I contend that the real division is between Global and Regional interests; R&D and Operational users are found in both Global and Regional categories. Global here is defined as attempting to provide climatological data to characterize the world's oceans synoptically. In order to satisfy the attendent requirements using a reasonable amount of data, the incoming data tends to be averaged over fairly large grid areas, on the order of 60-100 km^2. The Regional user is generally interested in viewing an area of the ocean less than 900 km^2, equivalent to about two-days' steaming time, and is interested in using full resolution (pixel) data. These two interests have been incompatible in terms of data volume, handling, and processing.

The volume of raw data required for an individual Regional user's satellite data processing is less than that of the Global user. Dissemination of raw data to many and diverse Regional users for processing and analysis is a major problem. A question frequently posed is: If the tape data were readily available could most small institutions afford to have their own man-computer interactive image processing systems? Among some of the related questions being asked by potential users are: What is the minimum size computer system required to view an area 1000 km^2 or less, and with individual pixel resolution? What associated peripheral equipment is necessary? What are typical annual maintenance costs? Can such sites expect to receive calibrated tape data within 48 hours of the satellite pass? On this last note it should be recognized that many scientists are wary of receiving fully processed "final" data, particularly when there are elements of interpretation involved in producing the final data set to the user.

Up until very recently the raw satellite data available for ocean applications has been controlled by large Operational oriented institutions in which Operational has been equated with Global requirements. I maintain that the largest potential user market, in terms of numbers of users, is the Regional user category. It is fair to say that the type of data that the Regional R&D user requires has not been readily available to him.

Consider the concerns of fisheries, offshore petroleum, or tactical Navy administrators or technical decision makers who must assess the relative merits and cost effectiveness of a major commitment to the use of satellite technology. For the Regional users two questions immediately come to mind:

1. How well can synoptic quantitative satellite data be used to improve data input to dynamic oceanography/acoustic prediction models, i.e., time and space varying conditions?

2. Will the use of satellite data (and sparse remotely relayed <u>in situ</u> data) significantly influence technical management decision making, relative to the combined use of climatological data and present standard data acquisition?

Scant accrued experimental evidence precludes definitive answers. To answer these questions the following must be considered with respect to specific geographic areas:

1. Determination of repeatably accurate relative (and absolute) values of ocean surface properties. Determine limiting environmental conditions for achievable accuracies. In the vicinity of ocean fronts and eddies even relative gradients may be suspect because of atmospheric variability in the marine boundary layer.

2. Reliable interpretation of critical in-water vertical profiles of desired properties from satellite imagery. Correlate surface values with those within or above the seasonal thermocline. What is sea surface temperature? When

strong vertical gradients are present, values obtained are largely dependent upon the measurement technique used. Measurement techniques used for comparison with satellite data should be evaluated and standardized.

3. In real time (less than 24 hours) the effectiveness of disseminating calibrated and corrected satellite data to small institution users. How well can these data be received and used directly by most small institution users?

The deficiencies and needs of satellite related ocean programs are outlined in Figure 1.

Sensor Box: Cloud cover continues to plague ocean experiments using satellite infrared imagery. The "footprint" of the atmospheric sounder is too large for valid correction of infrared data in dynamic ocean areas. All-weather microwave sensors for accurate monitoring of water mass boundaries produce some different problems. For example, the Scanning Multifrequency Microwave Radiometer (SMMR) spatial resolution of approximately 100 km precludes accurate detection of frontal boundaries. The Synthetic Aperture Radar (SAR) data look intriguing, but analyses and interpretation evaluations are incomplete. As a result, use of the SAR in the National Oceanic Satellite System is not being seriously considered. Radar altimetry provides the most immediate promise, but it is not an imaging system and must be used in combination with infrared and visual imagery for water mass boundary detection. It should be noted, however, that there has been very little interdisciplinary intercourse between sensor data analysts.

With respect to satellite infrared imagery data some of the questions being asked today are similar to those asked about ten years ago: Are we looking at ocean surface or atmospheric features? How well do we see the ocean surface and what are the limiting conditions for valid detection, particularly in oceanic frontal regions? Progress in this area is inadequate largely because priority attention and support is generally directed to 1.) new sensor development rather than to verification of existing sensor systems to meet ocean requirements and 2.) Global operational data requirements.

Imagery and Ground-Truth Boxes: The triangle represented by atmospheric and ocean imagery and ground-truth data is the critical focus of Figure 1 of this paper. There is a need to coordinate (forcibly if necessary) these three ingredients in the ocean application of satellite data. Meteorological analyses over the ocean cannot continue to be conducted independent of oceanographic analyses in the same geographic areas. Similarly, satellite derived ocean data should not be analyzed without regard to the transmission through the atmospheric column. Commonly, satellite-derived ocean data analyses are conducted independent of on-going at-sea measurements in coincident geographic areas. These deficiencies reflect a woeful lack of planning and control at management levels. If a valid standardized satellite-derived ocean data base is to be established, the three legs of this triangle must be working in unison and toward mutual goals.

In situ data obtained at remote (and unmanned) platforms (ships, buoys, aircraft, etc.) can be relayed between these platforms and shore based analyses facilities via meteorological satellite data communications channels. These channels are currently underutilized.

Aircraft used as multi-sensor, quasi-synoptic remote sensing and ground-truth data collection platforms, in conjuction with ships and buoys, provide rapid spatial coverage necessary for satellite data verification in dynamic ocean areas. Rejuvenation of aircraft oceanography deserves consideration.

Applications Box: The importance of this box in Figure 1 is the commonality of requirements of diverse Regional users, i.e., spatial and parametric value resolutions, and surface to subsurface correlations.

SUMMARY

An idealized approach to effective uses of satellites in ocean investigations is shown in Figure 2. It emphasizes integration and coordination of existing available data collection resources. Implementation of this approach will provide the critical path to proper evaluation, standardization, and utilization of satellite data in the ocean community.

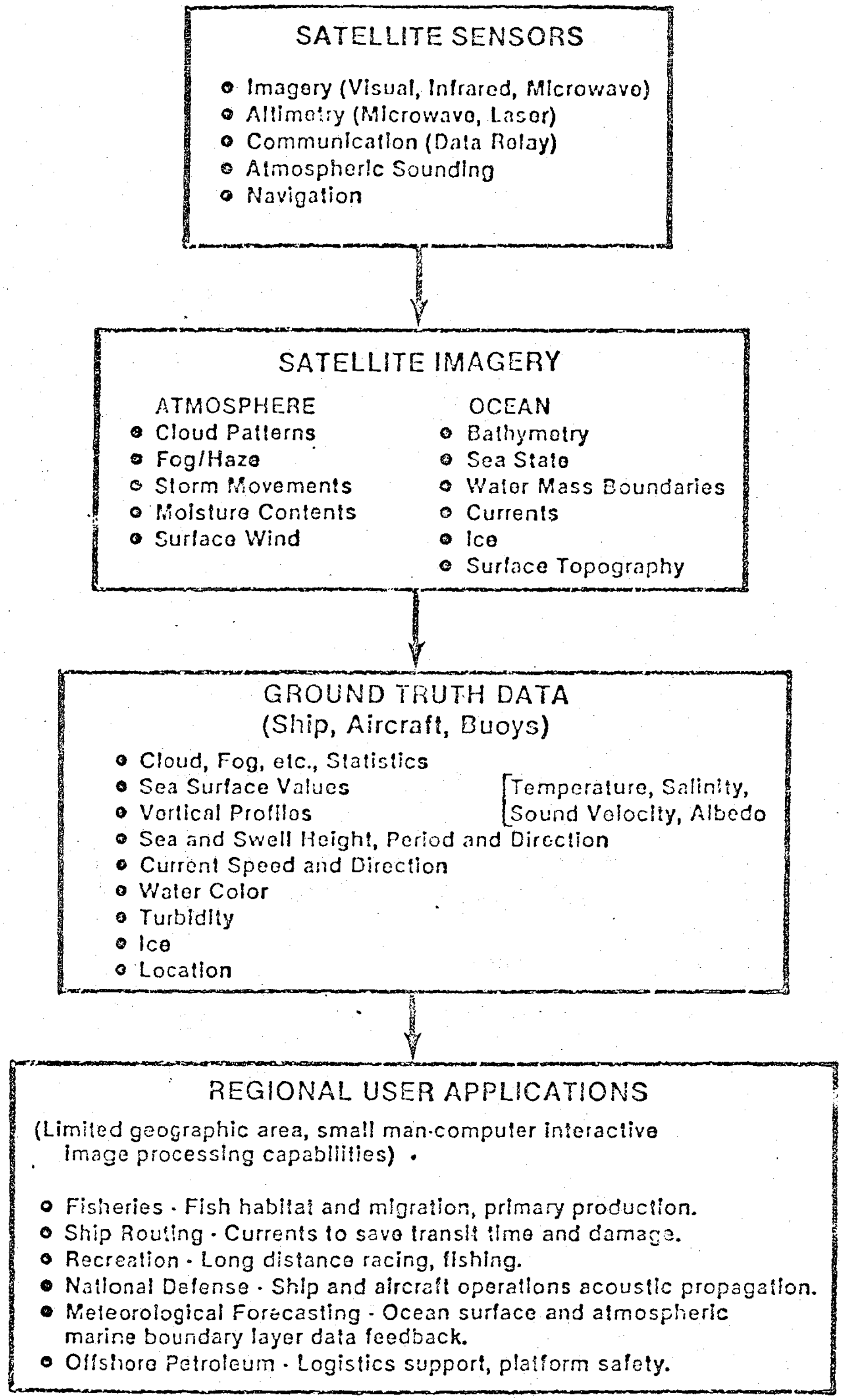
SATELLITE SENSORS
• Imagery (Visual, Infrared, Microwave)
• Altimetry (Microwave, Laser)
• Communication (Data Relay)
• Atmospheric Sounding
• Navigation
SATELLITE IMAGERY
ATMOSPHERE
• Cloud Patterns
• Fog/Haze
• Storm Movements
• Moisture Contents
• Surface Wind
OCEAN
• Bathymetry
• Sea State
• Water Mass Boundaries
• Currents
• Ice
• Surface Topography
GROUND TRUTH DATA
(Ship, Aircraft, Buoys)
• Cloud, Fog, etc., Statistics
• Sea Surface Values
• Vertical Profiles
Temperature, Salinity, Sound Velocity, Albedo
• Sea and Swell Height, Period and Direction
• Current Speed and Direction
• Water Color
• Turbidity
• Ice
• Location
REGIONAL USER APPLICATIONS
(Limited geographic area, small man-computer interactive image processing capabilities)
• Fisheries - Fish habitat and migration, primary production.
• Ship Routing - Currents to save transit time and damage.
• Recreation - Long distance racing, fishing.
• National Defense - Ship and aircraft operations acoustic propagation.
• Meteorological Forecasting - Ocean surface and atmospheric marine boundary layer data feedback.
• Offshore Petroleum - Logistics support, platform safety.

Figure 1

INTEGRATED OCEAN DATA COLLECTION AND COMMUNICATION

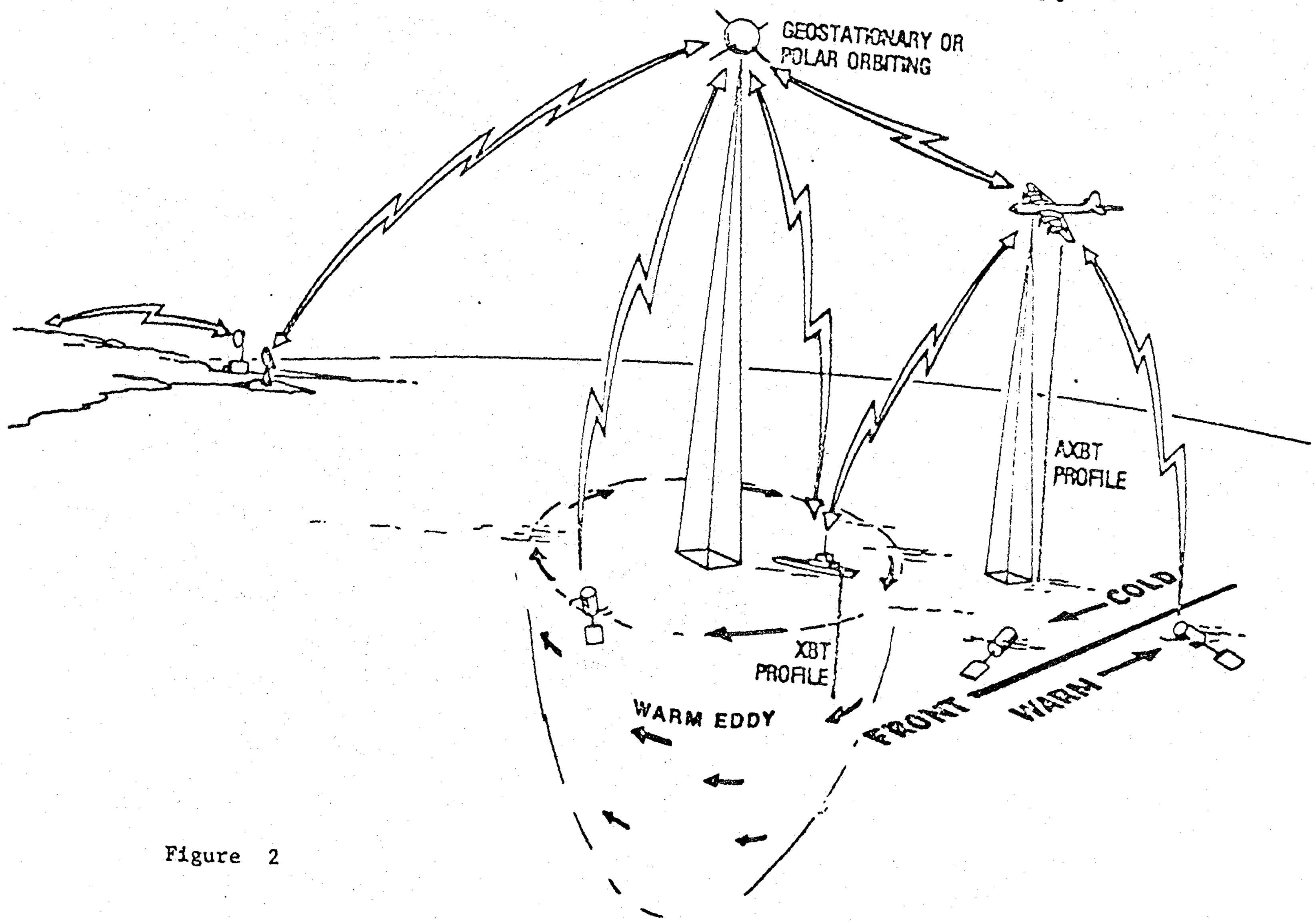

Figure 2

APPLICATIONS II

Robert Macomber, Chairman

REMOTE SENSING OF OCEAN COLOR; APPLICATION TO COASTAL OCEANOGRAPHY

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ABSTRACT

Useful ocean color monitoring from space is now much nearer reality with the successful operation of the Nimbus-7 Coastal Zone Color Scanner (CZCS). Preliminary data have been obtained in the Gulf of Mexico. Numerical procedures which extract atmospheric effects from the data have been applied. These procedures use a Raleigh scattering model and a standard haze/aerosol profile as input. The results to date indicate that many dynamic features are discernable in the variations of ocean color. For example, fine scale eddies along the Florida Loop current have been identified. Work performed to date also suggests that it is probable that phytoplankton, chlorophyll, and sediment concentrations may be estimated from the CZCS data.

REMOTE SENSING FOR FISHERIES

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INTRODUCTION

The era of space technology brought new perspectives in remote sensing for fisheries. Man acquired the ability to view entire oceans and seas in a matter of minutes. The resolution capabilities of remote sensing systems carried by most spacecraft, however, will not be adequate probably for years to come for direct detection of fish. This lack of resolution has forced investigators to look for ocean features that can be measured with spaceborne sensors and in turn be used to predict the distribution and abundance of fish stocks. Unfortunately, while there is a wealth of information in the literature covering the development and use of methods for measuring ocean features (e.g. chlorophyll, currents, etc.) there is a paucity of information on attempts to actually use these measurements to predict fish distribution and abundance. The principal difficulty seems to be a general inability of investigators to acquire fisheries information of adequate quantity and quality to make statistically valid comparisons. However, the few studies reported have demonstrated good potentials for satellite remote sensing in fisheries research.

Remote sensing systems and techniques applied to fisheries can be separated into two categories: indirect and direct. Indirect refers to the measurement of environmental parameters which can be used to infer or predict the distribution and abundance of a given species and direct sensing refers to the detection of the animal itself. The scope of this report is a synopsis of selected remote sensing investigations and applications conducted by the National Fisheries Engineering Laboratory. Its intent is to document, by example, remote sensing potentials for fisheries so that the reader can judge and evaluate these potentials for related or comparable applications.

INDIRECT FORMS OF REMOTE SENSING

Indirect forms of remote sensing for living marine resources are used more for sensors operating in spacecraft than from aircraft. This is due to the lack of spatial resolution provided by most spacecraft sensors which prevents detection of most marine animals. Because of this lack of resolution, investigators have concentrated on remote measurements of oceanographic parameters assumed to influence the distribution and abundance of some fishes.

SeaSat-A Surface Layer Transport

The National Fisheries Engineering Laboratory initiated a four-year study to determine if wind stress measurements derived from SeaSat-A scatterometer data can be used for improved estimates of surface transport. Accurate estimates of wind-induced surface transport during spawning periods can serve as a basis for yield models which will provide forecasts of standing stock in advance of fishing season. Knowledge of transport mechanisms can therefore satisfy basic mission requirements of the National Marine Fisheries Service for management of national fisheries and for negotiation and establishment of international agreements.

The most critical survival period for many marine fishes is during the time of egg and larval drift. Over 90 percent of the shellfish and finfish caught in the northern Gulf of Mexico are shrimp, menhaden, and groundfish, which spawn offshore and depend upon surface currents to transport their eggs and larvae into estuarine nursery grounds (Figure 1). When surface currents do not provide favorable transport during critical spawning periods, it is reasonable to assume the respective fishery will be severely affected. A recent investigation demonstrated that surface transport was the most important oceanographic factor affecting menhaden recruitment along the Atlantic Coast (Figure 2).

The increase in spatial and temporal observational data provided by sensors aboard SeaSat-A should improve descriptive and predictive capabilities for fishery recruitment. Currently, surface transport for fishery applications consists of estimating geostrophic wind fields from surface atmospheric pressure fields prepared by the U.S. Navy Fleet Numerical Weather Central. Sea surface stress is approximated considering air density, an empirical drag coefficient, and an estimated wind vector near the surface. Sea surface stress is then inserted into an appropriate Ekman model, which includes the coriolis parameter, for an estimate of surface transport.

The advantages of using the SeaSat-A are 1) a "direct" measurement of stress; 2) increased resolution (50 km); 3) synoptic coverage (1000 km swath width); and 4) a 36-hour repeat coverage. Figure 3 shows the comparison of the standard technique for deriving surface transport with the proposed SeaSat-A approach. The latter limits the number of assumptions involved in the calculation and, presumably, would give more accurate estimates of surface circulation.

In support of the SeaSat Project, the West Coast Experiment was conducted off San Diego, California in March - April 1977, to provide fundamental data for evaluating the capability of microwave remote sensors in measuring ocean parameters. The objective of the scatterometer wind stress investigation was to determine the relationship between aircraft equivalent SeaSat-A radar scatterometer signatures and wind stress measurements at the air/sea interface.

Wind stress and ocean roughness (cross section of radar backscatter) data were acquired by a precision three-dimensional sonic anemometer mounted on a rigid offshore tower and a C-130 aircraft equipped with an Advanced Applications Flight Experiment Radiometer-Scatterometer (AAFE RADSCAT). Six days of anemometer wind stress data were collected with concurrent overflights of the airborne scatterometer. Sea surface wind stress measurements using the direct covariance technique was compared with airborne scatterometer measurements to establish the accuracy of remotely sensed data and assist in the definition of geophysical algorithms for the scatterometer sensor aboard SeaSat-A.

Results of this investigation are 1) comparisons of scatterometer and sonic anemometer wind stress (U_*) measurements are good for the majority of cases; however, a tendency exists for scatterometer U_*, to be somewhat high for higher wind conditions; 2) the scatterometer wind speed algorithm tends to over-compute the higher wind speeds by approximately 1 m/s. This is a direct result of the scatterometer over-estimate of U_* from which wind speeds are derived; 3) algorithmic derivations of wind speed and direction are in most comparisons, within accuracies defined by SeaSat-A scatterometer sensor specifications.

The relevance of this study to fisheries is the establishment of confidence levels of scatterometer data to be used as input to a model of Surface Transport. Emphasis is now on SeaSat-A SASS data for estimates of surface transport in the Gulf of Mexico.

LandSat Menhaden and Thread Herring Investigation

The LandSat Menhaden and Thread Herring Investigation was conducted from 1975 to 1977. It was designed to verify environmental relationships and in particular to emphasize ocean color for inferred fish distribution patterns. Menhaden were the primary target species in three study areas in the Mississippi Sound and off Louisiana. Thread herring were considered but could not be acquired for them during periods of LandSat coverage. The three study areas characterized most menhaden habitats in the northern Gulf of Mexico.

A significant factor in this investigation was almost total reliance on the menhaden industry (approximately 80 vessels and 40 spotter aircraft) for fish distribution and abundance data. Scientific observers were aboard selected vessels during periods of LandSat coverage to sample sites of menhaden capture for salinity, temperature, turbidity, color, and chlorophyll-*a*. Two or three research vessels also were used to acquire surface truth information on selected days of satellite coverage for development of chlorophyll and turbidity algorithms.

Oceanographic preferences of menhaden were estimated through comparisons of oceanographic conditions sampled at capture locations (i.e. from the fishing vessels). Ideally, this analysis should have been done based on comparisons of oceanographic conditions from areas with and without menhaden. Unfortunately, very few samples were collected from areas without menhaden because the fishing vessels tended to remain in or near areas where fish had been caught or observed. An alternative was to examine spatial (between study areas) and temporal (between sampling periods) variability in the data. The assumption was that if menhaden were caught in the same type of water with respect to one or more parameters, these parameters were influencing the distribution of the fish. Data from the research vessels were used to ensure that consistency was a function of fish preference and not a result of a homogeneous environment.

Secchi disc visibility and Forel-Ule color measurements were relatively consistent at locations of menhaden capture over time and between study areas. There also appeared to be differences between these measurements and those from the research vessels. These analyses suggested concomitance between menhaden distribution and water turbidity and color. Little or no consistency was found with any of the other parameters.

Because of the apparent relationship between menhaden distribution and water color and Secchi disc visibility, an attempt was made to use LandSat MSS data for inferring the distribution of these fish. Both parameters should manifest in MSS data although attempts to infer them directly were relatively unsuccessful. Correlation coefficients computed from regression analyses of menhaden distribution against radiance values in each spectral band generally were significant at levels exceeding 90 percent (Table 1).

Table 1. Correlation Coefficients for the Relationship Between Menhaden Distribution and LandSat MSS Spectral Bands (1975)

	Mississippi Sound		Louisiana
Spectral Range (nm)	May 20	June 25	July 24
500-600	0.65**	0.46*	0.42**
600-700	0.74**	0.82**	0.36*
700-800	0.67**	0.69**	0.28*
800-1100	0.61**	0.30*	0.20
Sample Size	36	18	33

* Significant at the 90 percent confidence level
**Significant at the 99 percent confidence level

Several analytical approaches were evaluated for classification of LandSat MSS data into charts of inferred menhaden distribution. Essentially, they consisted of first establishing an MSS data training set composed of radiance measurements in each spectral band for 10 to 15 areas with and without reported menhaden observations. These areas, selected plus or minus two hours of satellite coverage, were used to construct a statistical algorithm composed of radiance value ranges for each spectral band associated with known fish locations.

Normally, spectral ranges were established as the mean plus or minus one or two standard deviations. The final step was to classify portions or all of the LandSat scene into high and low probability menhaden areas by comparing all spectral measurements against the ranges of radiance values established for menhaden locations. Areas satisfying the range criteria, (i.e. with radiance measurements falling within the range of values established for known fish locations) were classified as high probability areas; those that failed were classified as low probability areas.

Table II summarizes results from six classification attempts of LandSat MSS data into high and low probability fishing areas. The July 19, 1976, classification was unique in that it was designed to demonstrate the value of a satellite-aided fishery harvest and assessment system through near real time processing and analysis of LandSat MSS data into high probability fishing areas for distribution to the fishing fleet. The intent was for the fleet to verify the high probability areas through monitored fishing operations.

Table II. Summary of LandSat Classification Results for Menhaden Distribution

	Day of LandSat Coverage		Day After LandSat Coverage	
Date	Number of Menhaden Schools	Classification Accuracy	Number of Menhaden Schools	Classification Accuracy
05/20/75	53	91	19	68
06/23/75	18	83	23	74
07/24/75	30	87	30	84
07/19/76	14	86	20	70
07/27/76	11	91	3	0
07/28/76	3	100	-	-
TOTALS	129	88	95	74

The reason why menhaden could be inferred from ocean color measurements is uncertain. A behavior pattern for these fish, however, was postulated based on analyses of fishing and remotely sensed data which does provide a reasonable explanation. These analyses suggested that the menhaden were responding to light intensity and possibly to intensity in certain regions of the light spectrum by moving into waters with specific optical properties. (The literature contains many examples of fish responses to varying light levels). In the morning, when light intensity was low, most fish were caught near shore in relatively clear water. As light intensity increased (i.e. the sun appraoched its zenith) the fish moved offshore into deeper and more turbid waters ($\bar{x}$ Secchi disc 1.1 m; period of LandSat coverage). Catch rates declined during this period and then increased in the late afternoon (after 1500 hours). Catches also were made further offshore and in clearer waters in the late afternoon. At night, the schools tended to fractionate and move inshore.

An attempt was made to demonstrate that light intensity did affect fish behavior by comparing catch locations under several conditions of cloud cover. It was assumed that increases in cloud cover caused concomitant decreases in ambient light levels. The comparison showed that average daily capture locations were significantly further offshore when the skies were overcast than when they were clear.

LandSat - Brazillian Shrimp Investigation

In support of the U.S. - Brazil Agreement of May 9, 1972, a preliminary study was implemented to ascertain if a relationship existed between the distribution of shrimp and a relatively constant high turbidity zone along the northeast coast of South America. Using LandSat imagery, the study showed that the shrimp grounds could be divided into general regions of primary and secondary turbidity. The stratification of the turbidity patterns was found to be similar to the distribution of the shrimp fishery located off the coasts of Guyana, Surinam, and French Guiana. The four species of shrimp found in the area are distributed in distinct bands generally parallel to the coastline. Not only were the bands of shrimp distribution similar in orientation and shape to the primary and secondary turbidity regions, but also the entire shrimp fishery was located within the general seaward limits of the turbidity region which ranges from 18 to 71 nautical miles from shore. Delineation of fishing grounds by a shrimp turbidity relationship may enhance the tactical efficiency of fishery surveys.

DIRECT FORMS OF REMOTE SENSING

Considerable success has been achieved in applications of direct remote sensing techniques to living marine resources. Each technique has specific capabilities and limitations and all are limited to surface or near surface organisms.

Low-Light-Level Television

The phenomenon of bioluminescence and the development of tactical night vision devices for the military in Vietnam led to an investigation of the applicability of low-light sensors for detection of fish schools. A number of system components have been tested and evaluated. The system we currently use consists of a television camera fitted with an intensifier tube that amplifies light approximately 120,000 times, a 12.7 - cm (5-inch) television monitor, a video tape recorder, and a power source. The system is used from aircraft operating at night during dark-of-the-moon periods. It detects and amplifies the bioluminescence caused by fish agitating dinoflagellates in the water. The effect is a faint glow surrounding each fish and, in turn, the fish school. This glow can be easily observed with the low-light-level television.

Aerial Photography

Aerial photography is probably used more than any other remote sensing technique for direct detection of surface schooling pelagic fish. A commonly used system is a standard aerial mapping camera equipped with 22.86-cm film and a 15.24-cm focal length lens, although practically any camera system can be used.

Generally, color film is used for fish detection because many pelagic species exhibit unique spectral signatures, which can be used to assist in their identification and discrimination against the light-absorbing water background. For example, chub mackerel reflect highly in the yellow-green portion of the light spectrum (500-600 mμ), blue fish in the blue portion (400-500 mμ), and menhaden in the red portion (600-700 mμ). These color differences can be enhanced through proper selection of film and filters to produce contrasting fish school images.

Aerial photography of the marine environment requires clear, cloudless skies for optiumum results. Unlike terrestrial photography, high sun angles are detrimental to marine photography. Once the sun angle approaches about 50 degrees (15.25-cm lens and 22.86-cm film format) the mirrored image of the sun, or its halo, will occur on the photograph. At sun angles of less than about 20 degrees, insufficient light is available for good photography. Marine photography requires more film speed than terrestrial photography because of the relatively high absorption of light by water. An increase in exposure as much as 2.5 f stops over ordinary terrestrial photography has been found necessary for maximum water penetration and fish detection.

In 1975 a multispectral photography experiment was conducted off the Bahamas to select an acceptable film and filter combination for surveys of giant bluefin tuna. Four Hasselblad cameras were clustered and mounted in a twin-engine aircraft flown at an altitude of 304 m and at an airspeed of about 130 km/hr over schools of bluefin tuna. Most of the fish encountered were at depths of 10 to 15 m in waters optically characteristic of offshore oceanic areas. The blue and green portions of the light spectrum produced good quality photographs with the green preferred due to better contrast. The red and near infrared portions failed to image tuna, presumably due to rapid attenuation of these longer wavelengths in water.

A second multispectral photography test was conducted in May 1976 over waters 40 km off the coast of California to identify an acceptable combination of film and filters for imaging dolphin. The objective was to develop a technique to enumerate and size schooled dolphin. Similar to the bluefin tuna test, four Hasselblad cameras were clustered in a twin-engine aircraft, which was flown at 130 km/hr at an altitude of 300 m over schools of bottlenosed and whitebelly dolphin. Contrast measurements made on an SIS VP-8 image analyzer from photographic transparencies showed that red light was optimum for photography, green light was acceptable, and blue and near infrared portions of the spectrum were unacceptable.

An unfortunate aspect of aerial photography is that without a priori knowledge of the spectral signature of a fish, its depth and schooling characteristics, and the optical properties of the water, it is difficult to predict the assessment value of a survey mission. There are many questions yet unanswered about how to identify fish photographically and how biomass should be calculated.

Animal Tracking

The National Marine Fisheries Service (NMFS) is developing a transmitter, based on an operational buoy transmit terminal, that is small enough to be attached to a marine animal, has sufficient power to operate for one year, and can transmit to a satellite for position data. Initially the system will be used for attachment to porpoises, but turtles, whales and other marine animals will receive future consideration. Current tests are being conducted with the NIMBUS-6 RAMS system, and the design goal is a system to operate through TIROS-N.

The device, called the Marine Mammal Transmitter (MMT) weighs 900 grams and has a seawater switch which activates the transmitter, sending a signal each time the mammal comes to the surface for air. The process takes 0.9 seconds. The 401.2 megahertz signal is sent to the Nimbus satellite, which computes its geographic position. All information from the satellite is relayed to a ground station in Alaska, microwaved to the Goddard Space Flight Center, and then provided to various users by telephone or mail (Figure 4).

If the experiment is successful, NMFS plans to outfit approximately 20 porpoises with transmitters in March 1980 in the tuna grounds near the island of Clipperton, 700 miles west of Acapulco, Mexico. Nationally, NMFS is responsible for the protection of all porpoises, and specifically those found in association with yellow-fin tuna in the eastern tropical Pacific. It is essential to have data on porpoise stocks to assure that proper conservation and management measures are taken to protect the animals without imposing unnecessary hardship on the tuna fishery.

CONCLUSIONS

Remote sensing offers potentials for living marine resources in areas of research, management, and utilization. Information on resource assessment, distribution, prediction, yield forecast, movement, and utilization is available from remote sensing. The full value of this information, however, has yet to be realized. This realization will depend on conscious efforts by investigators to diligently explore applications of remote sensing as means to solve diversified and critical problems.

Direct forms of remote sensing will continue to provide valuable information primarily for surface and near surface pelagic fishes and marine animals. Indirect remote sensing techniques for management and utilization of living marine resources are still in their infancy but have shown sufficient promise to warrant increased research. More research in bio-environmental relations is essential, however, before indirect remote sensing can achieve even a small fraction of its true potential.

Technology is advancing at an unprecedented rate, and the potential for remote sensing applications to fisheries problems are limitless. The advent of SeaSat provides the first opportunity to use data acquired by satellite systems designed specifically for oceanographic purposes. Data management techniques will be expanded and improved to provide more comprehensive, workable data bases to process and analyze massive quantities of integrated data. The key to the future lies, however, in the successful transfer of new techniques to user groups and the recognition by users that the new techniques can successfully replace the old standards.

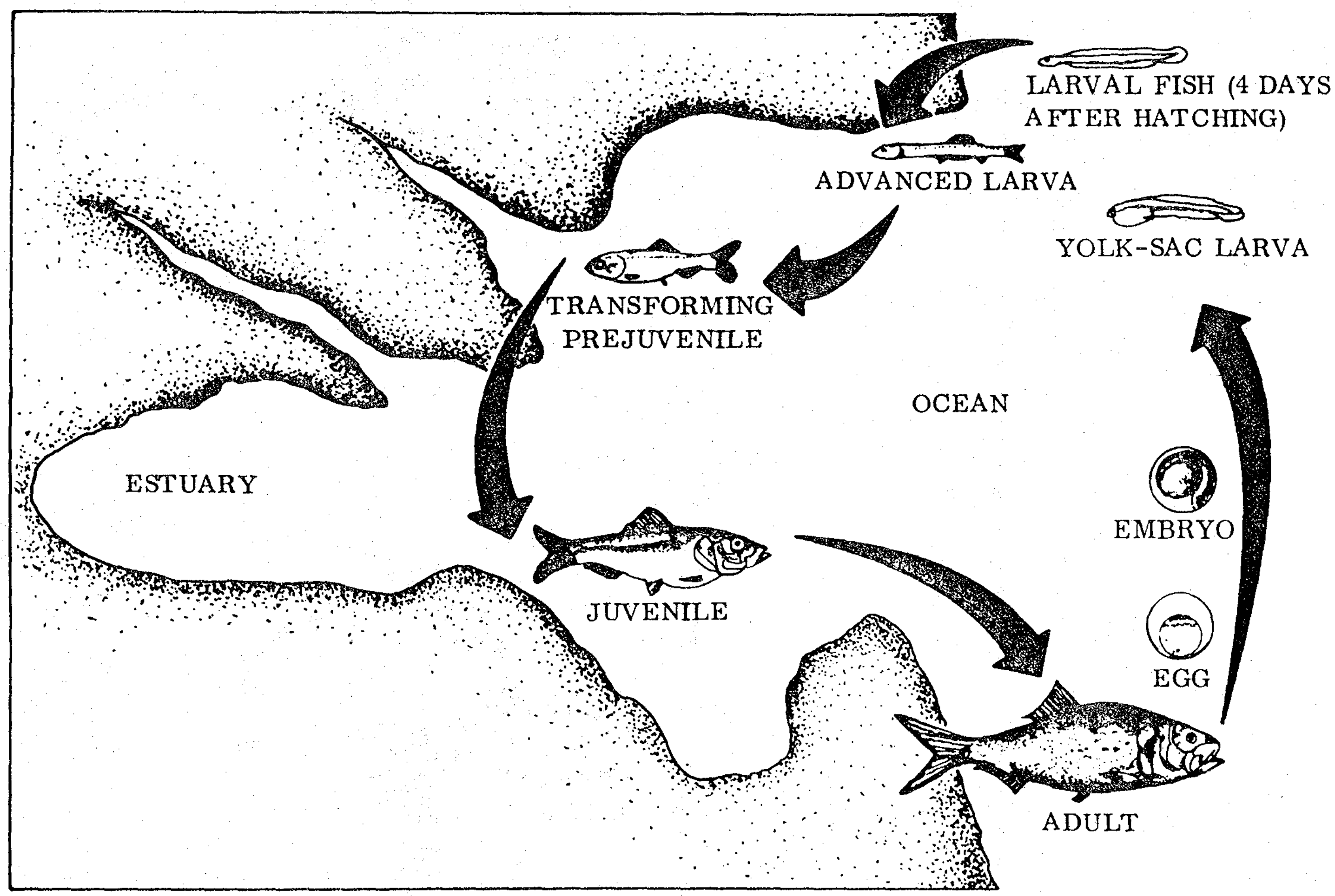
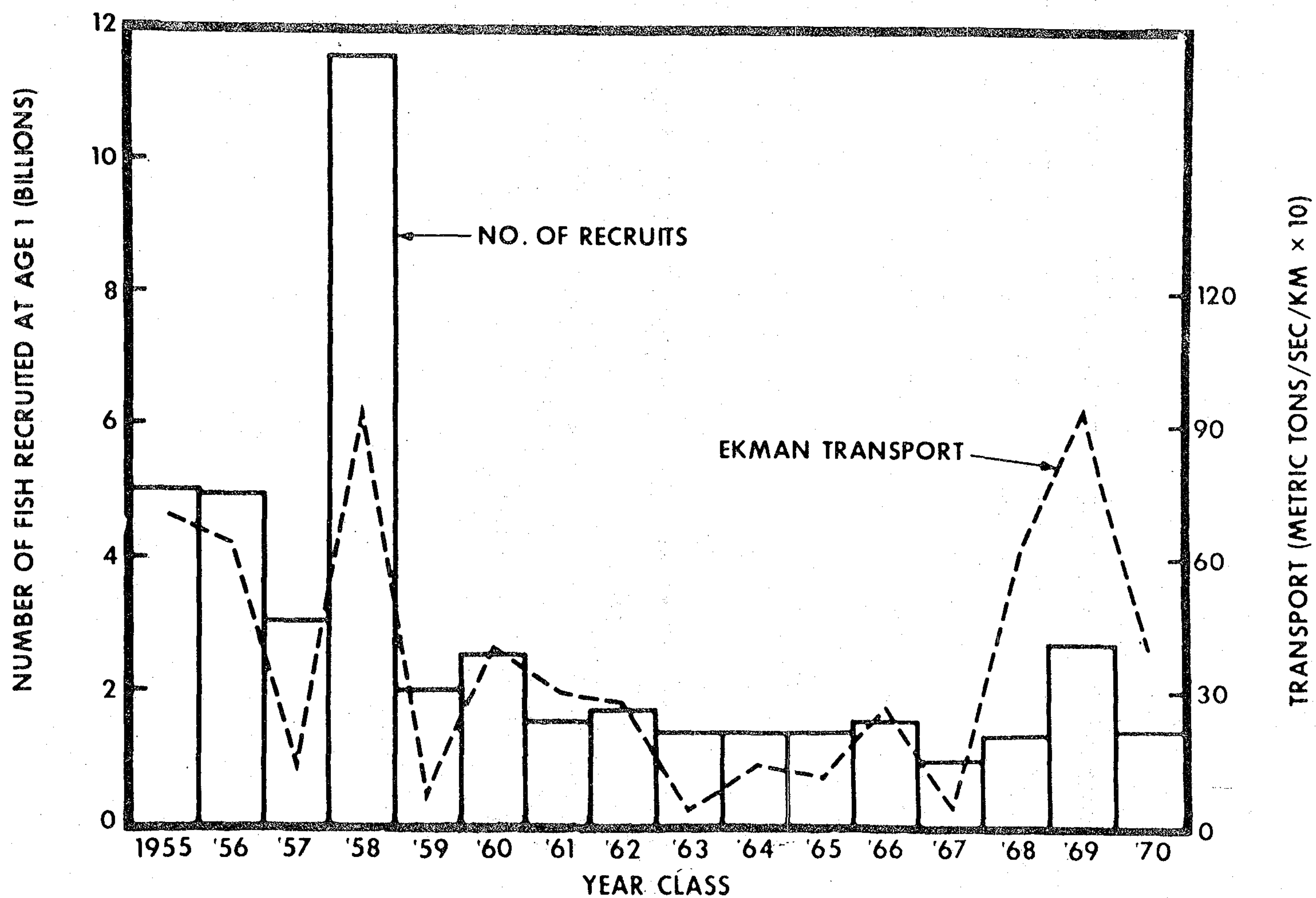


Figure 1. Typical Life Cycle of Estuarine Dependent Fishes Which Spawn Offshore.

FIGURE 2.

INFLUENCE OF WIND DRIVEN CURRENTS UPON YEAR CLASS STRENGTH OF MENHADEN



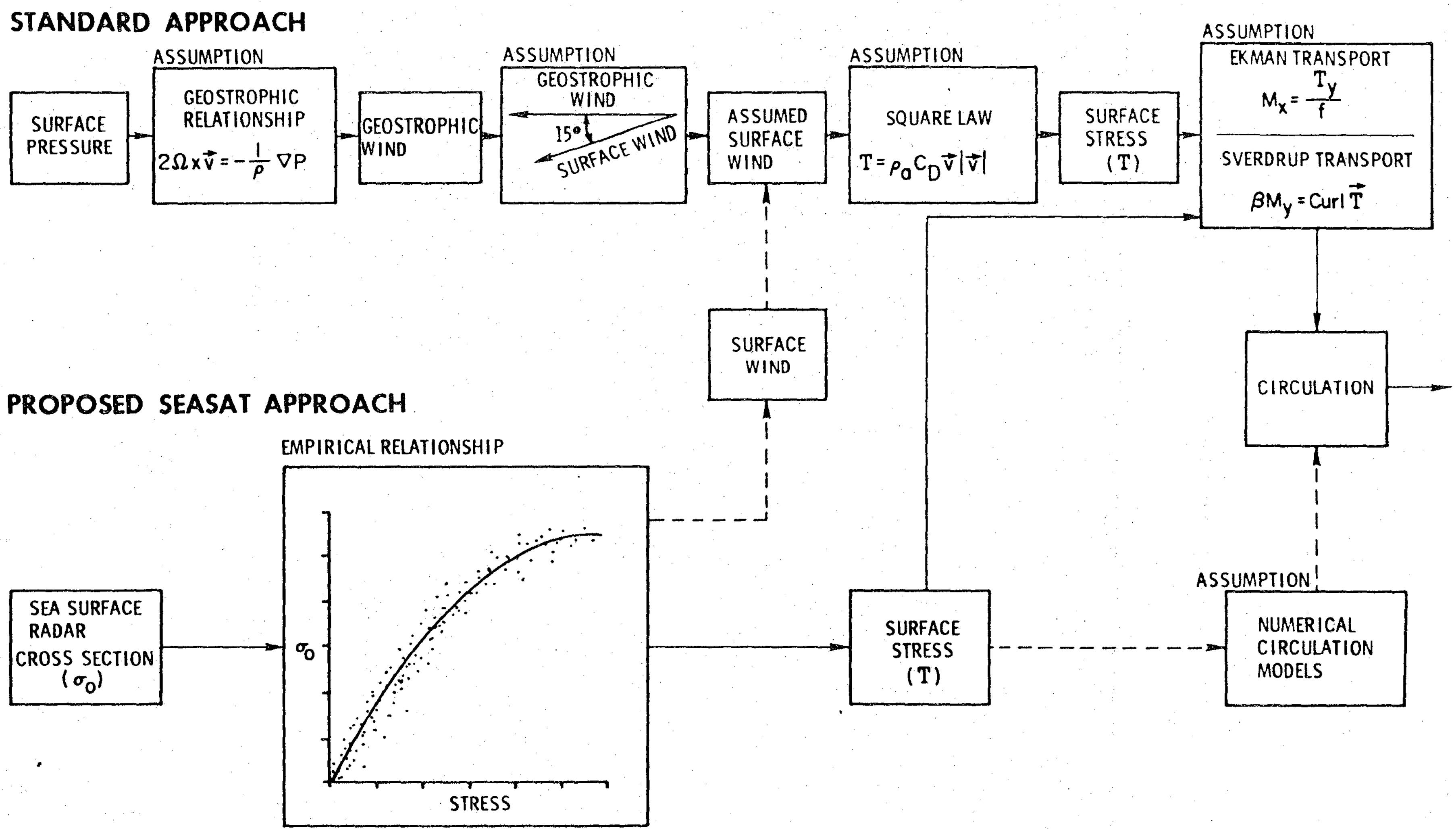


Figure 3. Standard approach compared to proposed SeaSat-A approach for deriving surface transport

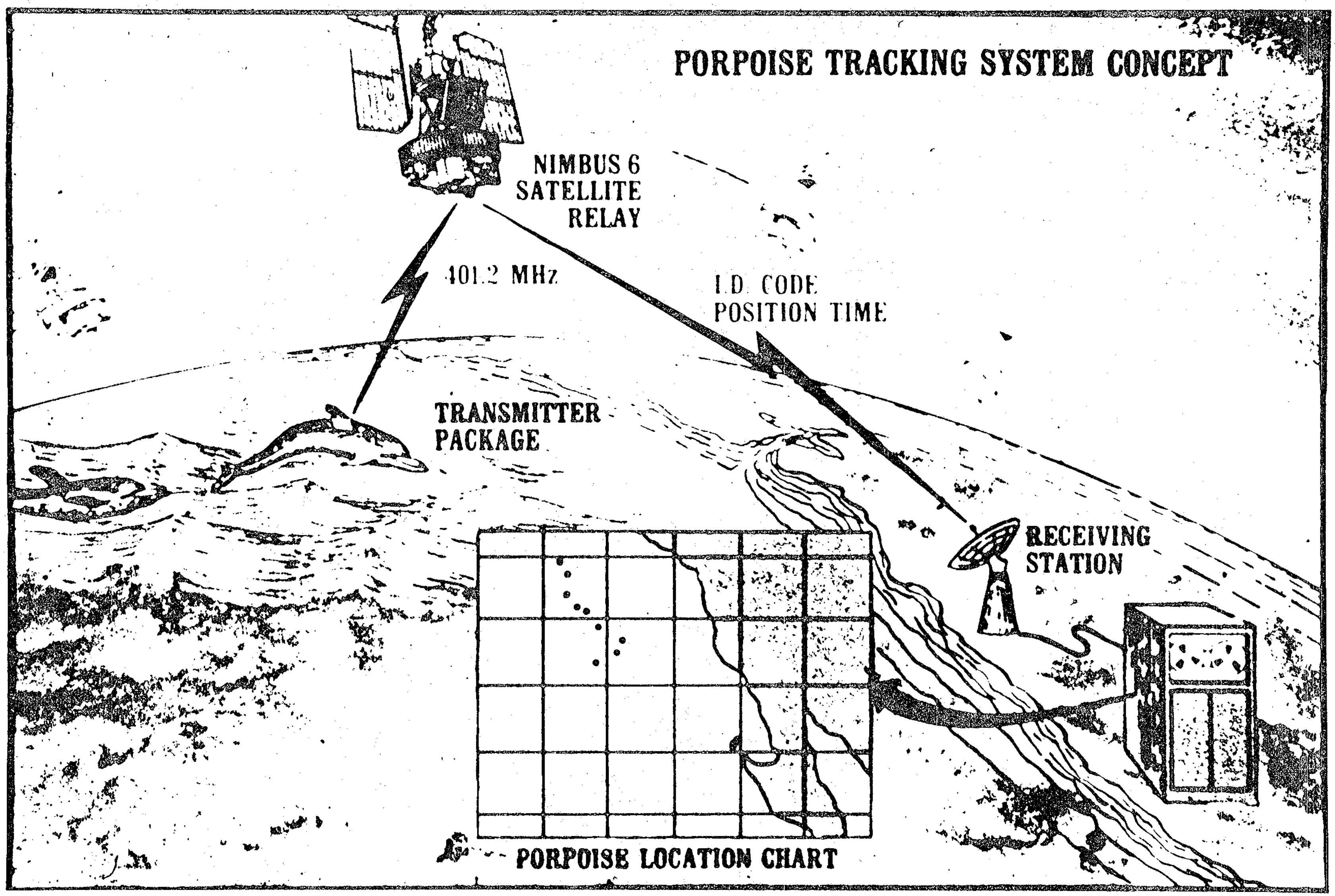


Figure 4. Overview for Satellite Tracking of Marine Mammals.

POLLUTANT MONITORING

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The Space Division of the General Electric Company recently received a contract from the National Aeronautics and Space Administration to investigate the potential of satellite sensing of oil spills. Specifically the major objectives of this study are to 1) determine the potential of satellite systems to detect and monitor oil spills and ocean pollution within the context of user needs and a projected total ground-air-space monitoring system and 2) determine how other space-age technologies (e.g. communications and data handling) can aid in meeting the user objectives.

The key issues to be addressed are 1) user needs: Can remote sensing from space play a significant role in meeting user requirements? 2) the technology of space monitoring: Is the sensing, space communications and data processing state of the art sufficiently advanced? What areas need development? and 3) the pollution monitoring system: What is a realistic evolution for the system? What is the capability of the near-term and mid-term data processing system? Which of the elements of the system should be dedicated or shared? What high impact areas will result from implementation of the system?

Prior to addressing these issues, it is necessary to identify the users (and potential users) of ocean pollution data and what the specific requirements of these users are. The users identified thus far are United States government: U.S. Coast Guard, National Oceanic and Atmospheric Administration, Maritime Administration, Environmental Protection Agency, Department of Health, Education, and Welfare, U.S. Geological Survey, Bureau of Land Management, U.S. Navy, and Department of State. 2) United Nations: Intergovernmental Oceanographic Commission (within UNESCO), UN Environmental Programme, International Global Ocean Survey, and Mediterranean Action Plan (17 nations and European Economic Community).

The ocean pollution data requirements of these users have been synthesized into a cohernet data set summarized in Table 1.

The criteria imposed on the selection of a sensor to meet the ocean pollution requirements are:

1. Weather capability
2. Day-night capability
3. Multiple usage
4. Degree of certainity in meeting requirements
5. Sensor techonology heritage
6. Sensor relative cost

*Synopsis by: P. Cornillon

7. Demand of spacecraft resources
   (e.g. wt., vol., power)
8. Number of satellites required to measure
9. Operational ease - degree of automation possible
10. Complexity of information extraction
11. Data dependence - Need for auxiliary or complementary sensors, ground baseline data

With this list of sensor selection criteria each of the measurement requirements was individually examined in some detail. The results of this analysis are presented in several different forms. First in Table 2 the sensor(s) most appropriate in meeting each of the measurement requirements is identified along with the probable time frame in which the sensors might be available. In Table 3 the application of existing and planned satellite, aircraft, and shipboard observations to categories of oil spill requirements is outlined.

The preliminary conclusions reached at this point with regard to the monitoring of pollution from space are summarized in Table 4.

GENERAL ELECTRIC

space division

TABLE 1. SUMMARY OF MEASUREMENT REQUIREMENTS

PARAMETER	MISSION TYPE	RANGE OR SCOPE	PRECISION (±)	ACCURACY (±)	SPATIAL RESOLUTION OR GRID SIZE	FREQUENCY (EVERY N HRS)	DATA DELAY (HRS)
1. OIL SPILL AREAL DISTRIBUTION	SURV. & MONITOR	>10m	5%	5%	10m	12	3
	MODELING	>15m	10%	10%	15m	12	3
2. OIL SPILL COORDINATES	SURV. & MONITOR	US COASTAL AREA	0.5Km	1Km	N/A	12	6
	MODELING	US COASTAL AREA	-	250m	N/A	12	6
3. OIL SPILL THICKNESS	SURV. & MONITOR	0.1μm - 2mm	-	5%	-	12	6
	MODELING	0.1μm - 2mm	-	-	-	12	3
4. OIL CLASSIFICATION	SURV. & MONITOR	MAJOR TYPES	N/A	N/A	-	12	6
	MODELING	GROSS CLASSIFICATION	N/A	N/A	-	12	6
5. POLLUTANT DUMP AREAL DISTRIBUTION	SURV. & MONITOR	>30m	-	-	30m	24	½ to 3
6. POLLUTANT DUMP COORDINATES	SURV. & MONITOR	US COASTAL ZONE	200m	200m	N/A	12 (FOR ACIDS)	3
7. POLLUTANT DUMP CLASSIFICATION	SURV. & MONITOR	ACID/INDUSTRIAL OR SEWAGE	GENERIC CLASS	GENERIC CLASS	N/A	12 (FOR ACIDS)	3
8. POLLUTION SOURCE (E.G. VESSEL) IDENTIFICATION	SURV. & MONITOR	TANKERS, BARGES, RIVER EFFLUENT, NATURAL SOURCE	SUFFICIENT FOR LEGAL EVIDENCE		N/A	12	3

GENERAL ELECTRIC

TABLE 1. SUMMARY OF MEASUREMENT REQUIREMENTS (CONTINUED)

space division

PARAMETER	MISSION TYPE	RANGE OR SCOPE	PRECISION (±)	ACCURACY (±)	SPATIAL RESOLUTION OR GRID SIZE	FREQUENCY (EVERY N HRS.)	DATA DELA (HRS.)
9. WIND SPEED	MODEL	0-50m/sec.	0.5m/sec	2m/sec	10Km	3	3
10. WIND DIRECTION	MODEL	0-360^o	5^o	10^o	10Km	6	3
11. OCEAN CURRENT SPEED	MODEL	0-300cm/sec	5cm	5cm	10Km	6	3
12. OCEAN CURRENT DIRECTION	MODEL	0-360^o	10^o	10^o	10Km	6	3
1 . ICE COVER AREAL EXTENT	MODEL	0-100%	-	2%	10m	24	6
1 . ICE THICKNESS	MODEL	0-50m	0.2m	0.5m	10m	24	6
15. SIG. WAVE HEIGHT	MODEL	0.3-25m	0.3m	0.3m	10Km	3	3
16. WAVE LENGTH	MODEL	0.3-1000m	10%	10%	10Km	3	3
17. WAVE DIRECTION	MODEL	0-360^o	10%	10%	10Km	3	3
18. AIR TEMPERATURE	MODEL	-30^{o}to40^{o}C	1^{o}C	1.5^{o}C	10Km	12	3
1 . WATER TEMP. (SURFACE)	MODEL	-2^{o}to30^{o}C	0.25^{o}C	1^{o}C	10Km	24	6
20. WEATHER FRONTS	MODEL	-	-	-	10Km	12	6
21. PRECIPITATION	MODEL	-	-	-	10Km	12	6
22. SUSPENDED SEDIMENT	MODEL				10Km	12	6

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TABLE 2. SELECTED SPACE SENSORS VS. TIME FRAME

MEASUREMENT	SENSORS FOR 1984-87 SYSTEM	SENSORS FOR 1988-91 SYSTEM	SENSORS FOR 1992-2000 SYSTEM
MARINE WASTE DUMP AREAL DISTRIBUTION AND CLASSIFICATION (5,7)	• POINTABLE OPTICAL LINEAR ARRAY • COASTAL ZONE COLOR SCANNER/AVHRR • THEMATIC MAPPER	• POINTABLE OPTICAL LINEAR ARRAY • COLORIMETER (ADVANCED CZCS) • MULTI-SPECTRAL LINEAR ARRAY (OERS)	• HIGH RESOLUTION OPTICAL/IR GEO-SYNCHRONOUS SENSOR
MARINE WASTE DUMP COORDINATES (6)	• GLOBAL POSITIONING SYSTEM	• GLOBAL POSITIONING SYSTEM • PRECISION ATTITUDE DETERMINATION SYSTEM	• GLOBAL SERVICES SYSTEM FOR POSITIONING AND POINTING
POLLUTION SOURCE (8)	• SYNTHETIC APERTURE RADAR* • POINTABLE OPTICAL LINEAR ARRAY* (TO AID HIGH RESOLUTION OBSERVATIONS BY AIRBORNE INSTRUMENTS)	• SAME AS PREVIOUS TIME FRAME*	• HIGH RESOLUTION SAR • SYNTHETIC APERTURE PASSIVE MICROWAVE RADIOMETER
WIND SPEED (9)	• MICROWAVE SCATTEROMETER • PASSIVE M-WAVE RADIOMETER	• MICROWAVE SCATTEROMETER • PASSIVE M-WAVE RADIOMETER	• MICROWAVE SCATTEROMETER • WIND LIDAR • PASSIVE M-WAVE RADIOMETER
WIND DIRECTION (10)	• MICROWAVE SCATTEROMETER	• MICROWAVE SCATTEROMETER	• MICROWAVE SCATTEROMETER • WIND LIDAR
OCEAN CURRENT SPEED & DIRECTION (11,12)	• MICROWAVE ALTIMETER* • COASTAL ZONE COLOR SCANNER*	• MICROWAVE ALTIMETER* • COLORIMETER*	• WIDE-SWATH ALTIMETER • ADVANCED OCEAN CURRENT SENSOR
ICE COVER AREAL EXTENT (13)	• SYNTHETIC APERTURE RADAR • PASSIVE M-WAVE RADIOMETER*	• SYNTHETIC APERTURE RADAR • PASSIVE M-WAVE RADIOMETER*	• SYNTHETIC APERTURE RADAR • SYNTHETIC APERTURE PASSIVE M-WAVE RADIOMETER
ICE THICKNESS (14)	• NO SUITABLE SENSOR AVAILABLE	--	--
SIGNIFICANT WAVE HEIGHT (15)	• MICROWAVE ALTIMETER	• MICROWAVE ALTIMETER	• WIDE-SWATH ALTIMETER • SWEPT FREQUENCY M-WAVE RADIOMETER
WAVE LENGTH (16)	• SYNTHETIC APERTURE RADAR	• SYNTHETIC APERTURE RADAR	• SYNTHETIC APERTURE RADAR
WAVE DIRECTION (17)	• SYNTHETIC APERTURE RADAR	• SYNTHETIC APERTURE RADAR	• SYNTHETIC APERTURE RADAR
AIR TEMP (NEAR SURFACE) (18)	• VERT. TEMP. PROFILE RADIOMETER	• VERT. TEMP. PROFILE RADIOMETER	• ADVANCED VTPR
WATER TEMPERATURE (19)	• PASSIVE M-WAVE RADIOMETER	• PASSIVE M-WAVE RADIOMETER	• HIGH RESOLUTION PASSIVE M-WAVE RADIOMETER
WEATHER FRONTS (20)			
PRECIPITATION (21)	• PASSIVE M-WAVE RADIOMETER	• PASSIVE M-WAVE RADIOMETER	• HIGH RESOLUTION PASSIVE M-WAVE RADIOMETER
SUSPENDED SEDIMENT (22)	• COASTAL ZONE COLOR SCANNER/ADV. VERY HIGH RESOLUTION RADIOMETER	• COLORIMETER (ADVANCED CZCS)	• COLORIMETER (ADVANCED CZCS)

*NUMBERS IN PARENTHESES REFER TO PARAMETER NUMBERS IN MEASUREMENT REQUIREMENTS.

TABLE 3. PLATFORMS AND SENSORS (EMPLOYMENT CONCEPT)

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			SPACECRAFT													AIRCRAFT										IN SITU					
			ICESAT					NOSS					OERS		METSATS	ARI			AARI						USCG	BUOYS		SHIPS		COASTAL	
	SUB-MISSIONS		SCAT	ALT	SAR	PMR	POLA	SCAT	ALT	SMMR	C/A	CLR	TM	MLA	VARIOUS	SLAR	UV/IR	TV	SAR	UV/IR	TV	PMR	ALT	LSF	VISUAL	MB	DB	M/O	ODSS	CCR	MS
SURVEILLANCE & MONITORING	DETECTION	N			X								X			X	X	X							X						
		M			X		X							X					X		X	X			X						
	MAPPING & TRACKING	N			X	X				X	X		X			X	X	X							X		X				
		M			X	X	X			X		X		X					X		X	X			X	X	X				
	QUANTIFICATION	N									(X)		(X)				(X)								X						
		M					(X)					(X)		(X)						(X)	X	X			X						
	POLLUTANT CLASSIFICATION	N									(X)		(X)																		
		M					(X)					(X)		(X)										X							
	POLLUTER IDENTIFICATION	N																X							X				(X)		
		M																			X				X				(X)		
	SYNOPTIC U.S. COASTAL POLLUTION MON'G. & DATA BASE BUILD	N			X	X				X	X		X			X	X	X							X				(X)		
		M			X	X	X			X		X		X					X		X	X			X	X			(X)		
	SYNOPTIC GLOBAL POLLUTION MON'G & DATA BASE BUILD	N			X	X				X	X		X																		
		M			X	X	X			X		X		X																	
MODELING	FATE MODELING	N	X	X	X	X		X	X	X	X		X		X	X	X	X								X	X	X			X
		M	X	X	X	X	X	X	X	X		X		X	X				X	X	X	X	X			X	X	X		X	X
	IMPACT/RISK MODELING	N	X	X	X	X		X	X	X	X		X		X	X	X	X								X	X	X			X
		M	X	X	X	X	X	X	X	X		X		X	X				X	X	X	X	X			X	X	X		X	X
	SYNOPTIC O/M/E MONITORING AND DATA BASE BUILD	N	X	X	X	X		X	X	X	X		X		X	X	X	X								X	X	X			X
		M	X	X	X	X	X	X	X	X		X	X		X				X	X	X	X	X			X	X	X		X	X

N = NEAR TERM (1984-87)
M = MID-TERM (1988-91)

X = FOR OIL AND OTHER OCEAN POLLUTANTS
(X) = FOR POLLUTANTS OTHER THAN OIL ONLY

AARI - ADVANCED AIRBORNE REMOTE INSTRUMENTATION
ALT - ALTIMETER
ARI - AIRBORNE REMOTE INSTRUMENTATION
C/A - COASTAL ZONE COLOR SCANNER/ADV VERY HIGH RESOLUTION RADIOMETER (CZCS/AVHRR)
CCR - COASTAL CURRENT RADAR
CLR - COLORIMETER
DB - DRIFTING BUOYS
LSF - LASER STIMULATED FLUOROSENSOR
MB - MOORED BUOYS
METSATS - METEOROLOGICAL SATELLITES
MLA - MULTISPECTRAL LINEAR ARRAY
M/O - METEOROLOGICAL & OCEANOGRAPHIC SENSING SYSTEMS
MS - METEOROLOGICAL STATIONS
NOSS - NATIONAL OCEANIC SATELLITE SYSTEM
ODSS - OCEAN DUMPING SURVEILLANCE SYSTEM
OERS - OPERATIONAL EARTH RESOURCES SYSTEM
PMR - PASSIVE MICROWAVE RADIOMETER
POLA - POINTABLE OPTICAL LINEAR ARRAY
SAR - SYNTHETIC APERTURE RADAR
SCAT - SCATTEROMETER
SLAR - SIDE-LOOKING AIRBORNE RADAR
SMMR - SCANNING MULTICHANNEL MICROWAVE RADIOMETER
TM - THEMATIC MAPPER
USCG - U.S. COAST GUARD
UV/IR - ULTRAVIOLET/INFRARED LINE SCANNER

TABLE 4. PRELIMINARY CONCLUSIONS ON KEY ISSUES

- SPACE REMOTE SENSING CAN PLAY A SIGNIFICANT ROLE:
  - IN POLLUTION DETECTION, UTILIZING AIRCRAFT AND SPACECRAFT IN COMPLEMENTARY WAYS
  - IN PROVIDING INPUTS TO THE OIL FATE AND IMPACT MODELS

<u>TECHNOLOGY OF SPACE MONITORING</u>

- A FEW TECHNOLOGY AREAS REQUIRE DEVELOPMENT EMPHASIS
  - REDUCTION OF AMBIGUITIES IN OIL SPILL DETECTION THROUGH SAR
  - MEASUREMENT OF OIL THICKNESS WITH IMPROVED SPATIAL RESOLUTION TO PERMIT QUANTIFICATION
  - IMPROVEMENT OF ACCURACY AND SPATIAL RESOLUTION IN OCEAN CURRENT MEASUREMENTS
  - INCREASE IN ACCURACY OF WASTE-DUMP POLLUTANT CONCENTRATION

TABLE 4. PRELIMINARY CONCLUSIONS ON KEY ISSUES (cont'd)

POLLUTION MONITORING SYSTEM

- EVOLUTION: FROM LIMITED CAPABILITY PLUS TECHNIQUE DEVELOPMENT & DEMONSTRATION IN NEAR-TERM;
  - TO A FULL CAPABILITY SYSTEM UTILIZING PLANNED OPERATIONAL SATELLITES, AIRCRAFT & SURFACE-BASED ELEMENTS IN THE MID-TERM;
  - TO A GLOBAL SYSTEM, UTILIZING ITS CAPABILITIES TO SUPPORT BROADER APPLICATIONS RE THE OCEAN ENVIRONMENT
- DATA PROCESSING SYSTEM

1984-1987	1988-1991	1992-2000
. Partially centralized, with decentralized models	. Centralized, dedicated	. Same as 1988-1991 plus expanded capabilities for expanded global missions
. Accepts data from existing sensors, after various degrees of processing	. Supports dedicated sensor	
. Primarily manned correlation of multiple data sources	. Automatic correlation of multiple data sources	

- MOPS SHARES OTHER SYSTEM CAPABILITIES:
  - ALL SPACE PLATFORMS ARE FROM OTHER SYSTEMS (e.g., NOSS, ICESAT)
  - SENSORS ARE SHARED, EXCEPT FOR OPTICAL SENSOR (POLA)
  - DATA DERIVED FROM OTHER SYSTEMS WILL BE PARTIALLY PROCESSED

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TABLE 4. PRELIMINARY CONCLUSIONS ON KEY ISSUES (cont'd)

- HIGH IMPACT AREAS: ICESAT SAR, INCORPORATION OF POLA ON ICESAT, DEDICATED DATA PROCESSING SYSTEM

OPERATIONS

- RELATIVELY WIDE-SWATH & POINTABLE SENSORS (i. e., SAR AND POLA) SIGNIFICANTLY ENHANCE COASTAL COVERAGE
- DAILY COASTAL COVERAGE WITH SINGLE SATELLITES IN ICESAT & NOSS WILL HAVE SOME GAPS. NEED FOCUS ON CRITICAL REGIONS
- COMPLEMENTARY OPERATION OF SATELLITES AND AIRCRAFT IS ESSENTIAL

IMPLEMENTATION PLANNING (TO BE ADDRESSED IN REMAINDER OF THE STUDY)

- LONG RANGE PROSPECT IS FOR REDUCED FOSSIL HYDROCARBON SPILLAGE, WITH SOME COMPENSATION DUE TO INCREASED SYNTHETIC FUEL TRANSPORTATION
- EVOLUTIONARY,"SHARED" SYSTEMS APPROACH MAY BE COST EFFECTIVE, BUT REQUIRES ADDITIONAL ANALYSIS

NEW TECHNIQUES AID STUDY OF LONG-RANGE COASTAL CHANGE

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If we are to effectively manage the coastal zone we must first know what changes have occurred in these areas over long periods of time. The pattern of past change can then be the basis for predicting and evaluating future changes in the shoreline, for planning coastal development and for drafting wise zoning regulations. Mapping these long-term changes also helps coastal geologists determine how land forms such as beaches and spits are formed.

Recent developments in aerial and satellite photography have made it possible to accurately map coastal changes. The LANDSAT satellites, the first of which was launched in 1972, provide large-scale global coverage, but the images from these satellites are not useful at present for shoreline surveys. One cannot detect features smaller than about 300 feet (100 meters) in size, and the period of time covered so far is too short to be meaningful. Fortunately, however, vertical aerial photography suitable for coastal surveys has been available for more than 40 years and the detail is sufficient for mapping to the nearest 10 feet (3 meters).

Using all available photographs, we have carried out a study of Rhode Island barrier beaches from 1938 to 1975. This study, supported by Sea Grant and carried out with the assistance of graduate students, indicates that the Rhode Island coast is retreating at an average rate of 8 inches (0.2 meters) per year, and that all parts of this coast are undergoing similar erosion. Erosion along Charlestown Beach since 1975 shows, however, that in some cases this average rate can be exceeded dramatically.

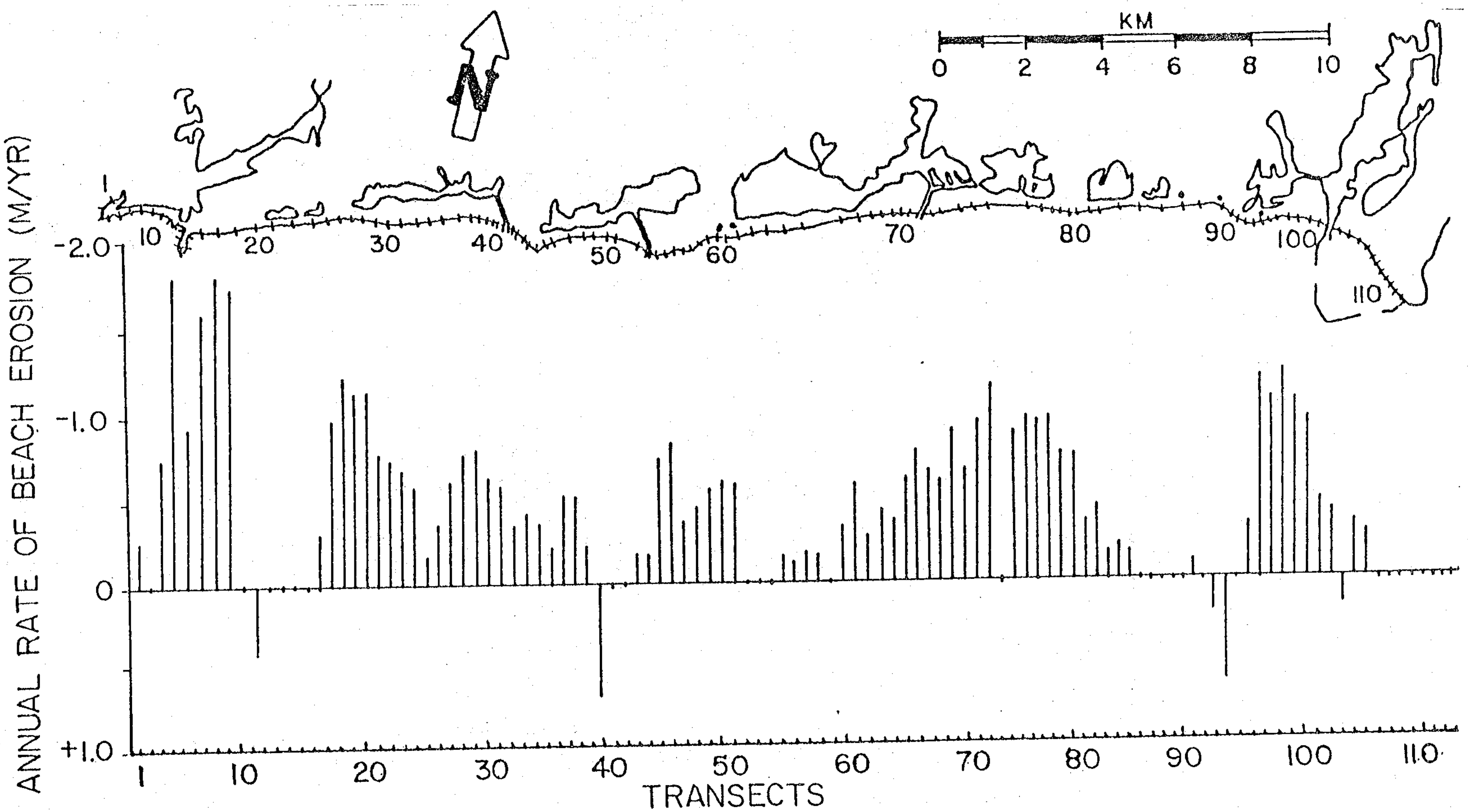
Aerial photography has certain advantages over maps, in that the surveys are flown more often than maps are revised, and the exact date, time and stage (low tide or high tide) of the photograph can be determined. Aerial photographs also show dune lines, overwash channels and other features not usually shown on maps. Unfortunately, the scale of the photographs differs from year to year and from photo to photo. We have succeeded in overcoming this problem by developing a technique that uses the Zoom Transfer Scope originally developed for satellite mapping. In addition to allowing continuous scale changes during mapping, it can optically correct for photographic errors such as lens distortion, camera tilt and film shrinkage. A digital electronic planimeter measures changes on the different aerial photographs to allow detailed mapping of shoreline changes.

As a check on the accuracy of our control of changing photographic scales, graduate students conducted ground surveys and for a year we carried out baseline studies of beach profiles and sediment types. We also determined the percent of eroded beach material that is washed over the south shore barrier beaches (26%) and the percent of the same material that fills salt pond inlets (35%).

Moving into Narragansett Bay in the next phase of the study, we are producing a similar inventory of erosion and accretion on the Bay and Newport Beach shorelines. We found that erosion over a 40-year period at Conimicut Point in Warwick near the head of Narragansett Bay has been proceeding at a rate similar to the average for ocean beaches along Rhode Island's south shore.

Inventories of shoreline changes have also been conducted at Nantucket Island and the Boston Harbor islands by geology graduate students. The Boston Harbor field work is supported by Earthwatch. Another student has recently completed one of these shoreline change inventories as part of the Environmental Impact Study for the first proposed offshore nuclear power plant off the New Jersey coast.

We plan to request funds for a study of changes in the Block Island shoreline which will complete the Rhode Island coastal inventory. The completed inventory should prove invaluable in flood hazard zoning, determining construction setback limits and in engineering shore protection structures. Indeed, such a state-wide study is basic to a long-range coastal land-use plan.



Annual rate of beach erosion on Rhode Island's south shore for 1939 to 1975 determined from remote sensing survey based on aerial photographs. Measurements at left are in meters. Numbers 1 to 110 indicate locations surveyed on the 25 miles of shoreline.

AERIAL PHOTOGRAPHY AND SEAPLANE RECONNAISSANCE TO PRODUCE THE FIRST TOTAL DISTRIBUTION INVENTORY OF SUBMERSED AQUATIC VEGETATION IN CHESAPEAKE BAY, MARYLAND

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ABSTRACT

The first complete inventory of submersed aquatic vegetation (SAV) on Chesapeake Bay, Maryland, was successfully conducted during the 1978 growing season. An innovative approach to ground truth and aerial photo procurement resulted in significant photointerpreter benefit and cost savings. A float equipped reconnaissance aircraft and a photo aircraft were both operated by the field biologist/photointerpreter team, thus eliminating all stand-by costs and facilitating proper timing of photo coverage to the phenologic growth stage of the vegetation. Seventy-seven 7-1/2 minute USGS quadrangles were used as a base map series and delineations showing the location and configuration of SAV beds were interpreted from 1:24,000 B&W photography. Species association information was annotated wherever float plane surface confirmation was collected. The 3,825 square mile inventory was completed in seven months at a cost of less than $40/sq. mile. Research within the 1978 program determined that lower altitude aerial photography timed to the growth stage of the plant can provide the more accurate distribution, percent cover and species association information needed for future management of SAV on a bay-wide scale.

INTRODUCTION

Interest in distribution and abundance of submersed aquatic vegetation in the Chesapeake Bay has been steadily growing since the late 1950's. Parallel to increased awareness of the value of emergent wetlands, the value of the submersed vegetation has been recognized in the bay ecosystem.

As primary producers, submersed aquatic vegetation (SAV) represents the first tropic level in the bay's aquatic ecosystem. Most of the above ground biomass decomposes annually to detrital food particles available to higher level herbivors. The dependence of the crabbing and fisheries industries on the nursery and shelter functions provided by the grass beds has been better understood. Value of SAV to waterfowl has been recognized intuitively and through research started on the bay in 1959.

In the last 30 years, realization of the possible value of grass beds and their apparent population dynamics has been achieved, and the need for more in-depth research to provide orderly management of this resource has been identified.

1977 MULTISPECTRAL RESEARCH RESULTS

The purpose of this mini research project was to determine what film/filter combination would provide the greatest discrimination of submersed aquatic vegetation (SAV) from its associated water and substrate background in an operational large area inventory of Chesapeake Bay.

An I^2S four lens camera was used as a means of separating broad spectral bands in the blue, green, red and near IR regions of the spectrum. The I^2S addcol viewer was used to view individual bands separately and to color code two or more band combinations of maximum information content.

A test site was chosen in Warehouse Creek on the Kent Island quad sheet in Eastern Bay. The SAV species association in this area included:

- Potomogeton perfoliatus = redhead grass
- Potomogeton pectinatus = sago pondweed
- Ruppia maritima = widgeon grass
- Vallisneria americana = wild cherry
- Myriophyllum spicatum = Eurasian watermilfoil
- Elodea canadensis = waterweed

Areas of different species associations and different percent cover existed within the site.

The results of individual band interpretation on the addcol viewer are as follows:

Band	Vegetation/Background Discrimination	Water Penetration
Blue	Poor/low contrast	Poor
Green	Good	Good
Red	Best	Best
Near IR	N/A	None

A red/green band combination was better than either single band alone. The addition of the near IR band added no information in the water since all infrared energy was absorbed by the water leaving no SAV reflected light. Addition of the blue band lessened the interpretability of red and green band combination by decreasing contrast.

The conclusions were that operational mapping of SAV could best be accomplished by combining the green/red bands on either black and white or color film, a yellow filter could be used with either emulsion to remove the blue light, and clear water (and clear air) would lessen the degradation in the blue band.

1978 DISTRIBUTION INVENTORY

The 1978 distribution of SAV in Chesapeake Bay, Maryland, was conceived as a high altitude "snap shot" to show the location of grass beds during a particular growing season. It was not designed to obtain percent cover or species information. Since no complete inventory of SAV on the bay had ever been accomplished, it was deemed useful to first locate the grass beds and thus define the areas of the bay where more detailed mapping would be required for management purposes.

Chronaflex copies of 77 USGS 7-1/2 minute quadrangles were selected as the base mapping medium. It was determined that SAV beds could be interpreted on photographs at a scale of 1:24,000 to match the scale of the quad sheets.

Color (Kodak 2448) and black and white (Kodak 2405) emulsions were considered in combination with a yellow filter as described above. Kodak 2405 Double-X Aerographic was selected due to its greater spectral responsivity in the green/red band, its greater effective aerial film speed (320 for 2405 versus 32 for 2448), its higher resolving power, and its lower initial and printing costs. Since most of the atmospheric haze is contained in the air column below 12,000 feet, unfiltered color film was considered much less operationally acceptable for a high altitude distribution inventory than black and white. Color infrared film is flown with a minus blue filter, but it has an even lower film speed than color, offers no advantage, and is more expensive. Since all SAV photography is flown at lower sun angles to reduce sun glitter, film speed can operationally narrow the A.M. and P.M. time windows to a point of diminishing returns.

SEAPLANE GROUND TRUTH

Since timing of the aerial photography to the growth stage of the plant is critical to the success of the inventory, it is necessary to be able to view grass beds from above as well as on the surface. The areal distribution and bed density must be monitored and the phenologic growth stage must be examined to determine when the grass beds in an area are reaching maximum density. At that point, aerial photography can begin whenever and wherever weather and tidal windows coincide and water turbidity/wind velocity is not too great.

A Piper Super Cub on oversized floats was used as a reconnaissance and ground truth vehicle. It is the ultimate STOL aircraft, used around the world for bush operations where slow flight, maximum control, and safety are paramount. It can take off at 15 mph in 200 feet and circle an area at 20 mph, allowing photointerpreters helicopter-like opportunity to view SAV at one quarter the cost. It is more stable and safer than a helicopter at low altitudes in the event of power failure and has three times the fuel to remain on the job all day. With a draft of eight inches, it was operated routinely up in the headwaters of creeks and inlets where the grass beds concentrate on Chesapeake Bay. As rated pilots, the field team was able to transport itself from the Annapolis base of operations to any work area on the bay within one hour.

Slow flight reconnaissance of the shoreline at altitudes ranging from 50 to 5,000 feet and at speeds down to 15 mph, enabled the interpreters to see grass bed distribution from above. Field prints were annotated to show any new growth of vegetation that occurred or any beds that were obscured by local turbidity conditions. Areas having an unusual signature on the field prints were viewed first from above and then on the surface. A rake was used as a sampling tool from the side of the float. Species association information was noted at any location where a landing was made. The interpreters developed a visual signature extension capability to recognize species from 500 feet or less with an accuracy of approximately 70%. More frequent landings will allow 95% accuracy in future and more detailed inventories.

Experiments were conducted early in the inventory with the Super Cub to insure that the interpreters were seeing any and all vegetation. Along shorelines and in coves that appeared unvegetated, extensive along-shore and off-shore transects were made on the surface while dragging the bottom with the SAV rake. In no instance were the visual observations from above inaccurate. If there was vegetation there, it was visible from the Super Cub. In areas of high non-point source run-off, sparse beds were noted in the extreme shallows along the shoreline and validated on the surface. In typically highly turbid waters, light attenuation limits photosynthesis and SAV colonization. In areas of temporal and localized turbidity caused by shoreline erosion, grass beds were sometimes hidden from view. The interpreters soon learned what combinations of shoreline morphology, aspect, and fetch conditions would cause this, and curtailed ground truth operations until more suitable conditions arrived.

AIR PHOTO ACQUISITION

The field crew also served as the aerial photography crew. The photography aircraft, a Cessna 180H STOL with a Wild metric mapping camera, was based at the Annapolis airport for the duration of the growing season. Having a daily knowledge of SAV growth stage and turbidity conditions around the bay, the crew was able to plan photo missions for maximum efficiency. When proper aerial photography conditions arrived, seaplane ground truthing missions ceased, and a customized aerial photography mission was conducted. This combination of talents and aircraft has resulted in the lowest cost approach to this type of inventory in that all aerial photo stand-by costs were eliminated. Resulting line mile costs for photo procurement were four to five times less expensive than conventional aerial survey firms currently charge. Over 1,600 flight line miles of 1:24,000 photography was procured under very specialized conditions of sun angle, tide, turbidity, wind, and plant growth stage. The following table presents aerial photography specifications required for SAV distribution mapping:

Aerial Photographic Specifications for SAV Distribution Mapping

• Scale	-	1:24,000, 1" = 2,000 feet
• Flight lines	-	need land for reference
• Atmospheric conditions	-	minimum haze, visibility greater than 10 miles, no cloud cover
• Tidal stage	-	low tide ± 2 hours at the location being photographed
• Turbidity	-	minimum, the entire perimeter of SAV beds must be visible. This can only be determined by the pilot and photographer at the time the photos are acquired
• Wind	-	less than 15 knots or off-shore to minimize shoreline erosion and associated turbidity
• Sun angle	-	10^{o} to 40^{o} to minimize sun glitter
• Plant distribution	-	must be at maximum growth stage and distribution

With photo specs as tight as these, good photo windows may never occur during the high turbidity hazy summer growing season. Thus, the photo team must establish priorities from a photointerpreter's standpoint and obtain photos during the best available set of conditions. For example, if the water is turbid, low tide would have a high priority. In clearer waters, tidal stage may not be so critical.

PHOTOINTERPRETATION/MAP PRODUCTION

Black and white contact prints annotated with ground truth information were also used as the primary photointerpretation medium. Delineations of the distribution of SAV beds was made directly on the field print under four power magnification. SAV signature keys were based on photo tone, texture, shape, size, as well as location, shoreline configuration and ground truth. Beds appear as dark tone areas near shore having a different texture from turbidity or substrate and a different shape than from schools of fish. Having spent numerous hours in the air ground truthing the photography, the interpreters had little difficulty with the interpretation process.

Delineations of all SAV beds on the prints covering a given quad sheet having been completed, a direct transfer process to the final base map was performed in ink using a technical drafting pen. Since this process was still part of the photointerpretation task, it was most accurately and efficiently accomplished by the photointerpreter. Making the transfer in ink eliminated the substantial cost of final drafting of the maps. An ink transfer was possible since nearly all of the PI decisions had already been on the print. Kooh-i-noor lettering guides were used to standardize map annotations of species associations where seaplane landings had been made. Application of a press film title block and map legend to each of the 77 quad sheets completed map production.

The original set of base maps can be reproduced at contact scale photographically and ozlid blue print copies at 80 cents a piece or chronaflex copies at five dollars a piece will be available to management agencies and land owners and the research community.

FUTURE MANAGEMENT LEVEL INVENTORY

Multi-scale (1:3,000, 1:6,000 and 1:12,000) black and white and color aerial photography was acquired under ideal conditions in two typical SAV areas during the Distribution Inventory. Each scale and film type was interpreted carefully to determine what future SAV management level information could be obtained. Management level maps will contain more accurate and complete SAV distribution information, percent cover classifications and species association percentages within SAV beds.

In addition to the need for accurate distribution information, there is an equal need to quantitize the relative value of individual SAV beds to waterfowl, fish and the aquatic food chain. Submersed aquatic vegetation is an integral part of the bay ecosystem in that:

- SAV constitutes the principal source of food for waterfowl and many herbivorous fish species.
- SAV provides nursery areas and shelter from predation for many species of fish at various growth stages.
- SAV is the host for epifaunal and infaunal species associations of copepods and shellfish that are second trophic level food source for waterfowl and fish.
- SAV as a primary producer of vegetative biomass contributes nearly 100% of the above-ground standing crop annually to the detrital food chain.
- SAV serves a wave damping function, reducing shoreline erosion and allowing settling of sediments.

The ability of a SAV bed to provide these functions is directly proportional to the percent cover within the bed and the plant species association.

1:6,000 color was selected for future management level mapping because species associations are more interpretable than on black and white emulsions. Species and percent cover interpretability was directly proportional to scale. Cost considerations and mapping detail requirements are best compromised on 1:6,000 scale photography. Percent cover and species association percentages will be mapped for beds down to the minimum mapping unit of 0.1 x 0.25 inches (50 x 120 feet). Smaller beds will be recognizable (5 x 5 feet minimum) and delineated to show distribution only.

A bi-modal maximum distribution species association occurs during each growing season on Chesapeake Bay. Thus, two sets of properly timed photography, one in June-July and the other in August-September, will be flown. The same customized approach using the seaplane will be required in 1979 to monitor the development stage of the vegetation and collect species association ground truth.

In future years, the seaplane and the management maps will be used to conduct research sampling on SAV biomass, productivity, epifaunal associations, and substrate preference.

COASTAL MAPPING TECHNIQUES DERIVED FROM REMOTELY ACQUIRED MULTISPECTRAL SCANNER DATA

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The coastal zone is an environment with two interactive components: coastal waters and adjacent wetlands. This paper summarizes remote-sensing techniques developed by the National Aeronautics and Space Administration/Earth Resources Laboratory to characterize coastal wetlands, in particular.

The constancy of certain vegetational communities in the wetlands facilitates the application of remote-sensing techniques to geographically disparate areas. For instance, wiregrass, *Spartina patens*, and oystergrass, *Spartina alterniflora*, are two common species that dominate extensive areas of marsh along the Gulf and Atlantic coasts from 26^{o} to 29^{o}N. Similarly, cypress-tupelo, *Taxodium distichum-Nyssa aquatica*, is a common association indicative of freshwater swamp. Since vegetation type is an expression of local environmental factors, vegetation mapping can be used to infer information about such factors. Thus, remote-sensing of the multispectral reflectance characteristics of the coastal vegetation species can be used as an indirect method for identifying salinity zone boundaries, mosquito breeding habitat, extent of tidal influence, or wetland productivity.

The LandSat multispectral scanner (MSS) furnishes remotely sensed digital data that can be readily processed by computer and geo-referenced. The processing that typically results in a classification of the MSS data includes four phases: (1) reformat, (2) select training samples, (3) classify, and (4) geo-reference, an optional fourth step. The geo-reference capability offers the advantage of being able to combine different remotely and non-remotely sensed data in a data base using the LandSat format. This same capability also allows the overlaying of MSS multitemporal data sets to detect changes in surface conditions, such as shoreline orientation and length.

Because of the inherently consistent scale of LandSat MSS data, the distance between any two points can be measured automatically by using the appropriate computer program. One existing technique measures the distance between the center of each digital unit (resolution cell) of marsh to the nearest land/water interface. Such a measurement is an indication of the nutrient contribution made by any point in the marsh to the estuarine food chain. These distance measurements can be stored in the data base and combined with productivity values inferred from a marsh species classification to arrive at a nutrient availability factor for any point or defined area in the marsh.

LandSat techniques have been demonstrated for the coastal areas of many states. South Carolina used a LandSat-derived map of land cover originating from merged multitemporal data sets to assess the feasibility of altering the flow in their Santee/Cooper drainage basin to control sediment deposition. Florida incorporated LandSat information to evaluate the environmental status of Appalachicola Bay. Georgia, Mississippi, and Louisiana have used LandSat data in varying degrees to produce ecological maps and acreage values for their coastal zones. Some of these states intend to use the satellite data as a source both for producing base line and then updated future maps and information systems.

The NASA/Earth Resources Laboratory has available representative color-coded, classified maps that can be distributed upon request. High reproduction costs have prohibited inclusion of these LandSat products in the conference proceedings.

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