The Earth Observer

An EOS Periodical of Timely News and Events

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EDITOR'S CORNER

New Director at Goddard

Dr. John Klineberg has been appointed the Director of Goddard Space Flight Center. Dr. Klineberg will succeed Dr. John Townsend who has announced his planned retirement effective June 30, 1990.

For the past few years, Dr. Klineberg has been the Director of the Lewis Research Center in Cleveland, Ohio. Dr. Klineberg's career with NASA spans two decades beginning at Ames Research Center. From 1974 to 1979, he was at NASA Headquarters, first as Head of the Low Speed Aircraft Branch in the Office of Aeronautics and Space Technology, and finally as Deputy Associate Administrator for Aeronatuics and Space Technology. In 1979, he went to Lewis Research Center as Deputy Director and was named Director in 1987.

John Klineberg was trained at Princeton and received his PhD in Aeronautical Engineering from the California Institute of Technolgy. He has a keen interest in physics and has been involved in all of NASA's programs. A strong advocate of the EOS mission, Dr. Klineberg understands its goals and importance to Mission to Planet Earth and how it fits into the overall goals of NASA's total science program. Dr. Klineberg has a rich sense of excitement about research and Goddard's future. This bodes very well for our project.

Welcome Dr. Klineberg!

Jerry Soffen
Senior EOS Project Scientist

Graduate Student Fellowships in Global Change Research

The Earth Observing System (EOS) budget contains a special fund earmarked for graduate students involved in Earth system science research. Announcements to solicit applications for a Graduate Student Fellowship program were distributed in March 1990, with an application deadline of May 15. Fellowship awards were announced on June 15. Students entering or already enrolled in a full-time Ph.D. program at accredited U.S. universities were eligible to apply, providing that their research interests were relevant to NASA's global change research program.

The purpose of the Fellowship program is to train a pool of highly qualified scientists to help analyze and interpret the wealth of data generated during the EOS era. NASA understands that the future of Earth science rests with today's students, who will be tomorrow's scientists. The financial wherewithal to pursue an advanced education obviously plays a vital role in securing the necessary talent to further Earth system science objectives.

Fellowships are given for an initial one year term and may be renewed annually for up to three years, based on satisfactory progress as reflected in academic performance and evaluations made by faculty advisors. The original announcement called for 25 Fellowships, but due to the overwhelming response and the high calibre of the applications, 37 awards will be made in 1990. It is intended that the program will scale-up to fund 150 Graduate Student Fellows per year prior to the launch of EOS-A in 1997. The amount of award for 1990 is $20,000 per annum, which may be used to defray living expenses, tuition, fees, and other educational expenses. An additional $2,000 may be requested by the faculty advisor to support the student's research. Students receiving these stipends must not receive other Federal funding.

Applications were considered for research on global biogeochemical cycles, radiation and physical climate interactions, the hydrological cycle, and solid Earth processes. Atmospheric and ocean physics, chemistry and biology, ecosystem dynamics, soil science, geology, geophysics, and cryospheric processes were also acceptable areas of concentration provided that the student indicated an adequate link to NASA global change research in the application.

Over 300 applications were submitted by interested students, whose citizenship represented 32 countries. In all, 92 universities from 43 states were represented. These applications were reviewed through a two-step process: first through mail review, and then by evaluation of a panel composed of members of professional scientific societies, academic institutions, NASA Centers, and the Educational Affairs and Earth Science and Applications Divisions of NASA Headquarters.

The 37 students, shown in the box below, were selected through a competitive review process that emphasized academic excellence and the scientific merit of the student's research topic. The citizenship of these students includes 11 different countries. They represent 27 universities from 19 states.

Mathew Schwaller and David Dokken
Earth Science Support Office
NASA Headquarters

Graduate Student Fellowships

ATMOSPHERIC CHEMISTRY

Brown	USA	University of Washington
Lloyd	USA	Harvard University
Sunwoo	Korea	University of Iowa
Zhang	China	MIT

ATMOSPHERIC PHYSICS

Del Sole	USA	Harvard University
Grotbeck	USA	University of Arizona
Klein	USA	University of Washington
Nelson	USA	University of Washington
Peterson	USA	Colorado State University
Salathe	USA	Yale University
Soden	USA	University of Chicago

BIOGEOCHEMISTRY

Bolgrien	USA	Un. of Wisconsin-Milwaukee
Braunschweig	USA	Un. of Minnesota-Twin Cities
Hamilton	USA	Un. of California-Santa Barbara
Kinzig	USA	Un. of California at Berkeley

DATA AND INFORMATION

Hardin	USA	Texas A&M

ECOSYSTEMS

Benning	USA	Kansas State University
Childress	USA	Texas A&M
Pierce	USA	Universityof Montana
Weishampel	USA	University of Virginia

HYDROLOGY

Alam	India	Pennsylvania State University
Barros	Portugal	University of Washington
Berg	USA	University of Colorado at Boulder
Nuth	USA	University of Texas at Austin
Peckham	USA	University of Colorado at Boulder
Turner	USA	Iowa State University
Wynne	USA	University of Wisconsin - Madison

OCEANOGRAPHY

Dickson	Canada	Oregon State University
Forbes	Argentina	University of Miami
Holen	USA	Stanford University
Landrum	USA	University of Washington
Mauritzen	Norway	MIT
Muench	USA	University of Washington
Wifjjels	Australia	Woods Hole Oceanographic Institution
Zaron	USA	Oregon State University

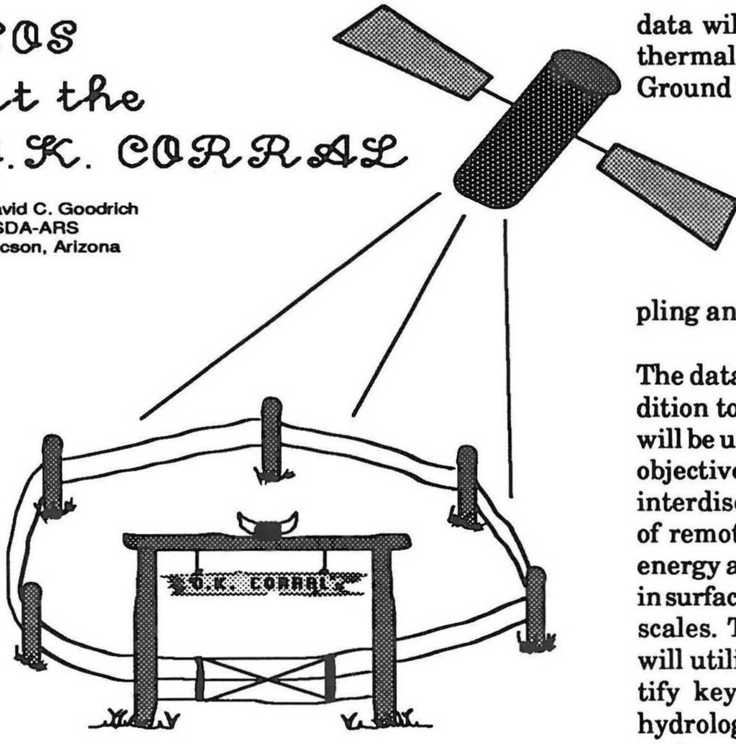
SOLID EARTH

Szilagyi	Hungary	Purdue University

An announcement for the 1991 Fellowships will be released in December 1990, and announcements regarding the Fellowship Program will be made in future issues of ***The Earth Observer***.

EOS at the O.K. CORRAL

by
David C. Goodrich
USDA-ARS
Tucson, Arizona



Tombstone, Arizona — the location of the famous gun battle at the OK Corral — will be the site of a major NASA-Agricultural Research Service (ARS), and EOS interdisciplinary field campaign this summer. Tombstone is located in the center of the USDA-ARS Walnut Gulch Experimental Watershed which has been operated by the Tucson, Arizona ARS research unit for over 30 years. Walnut Gulch is the focus of the "Monsoon '90," NASA-ARS interdisciplinary effort[2] and a primary study location of the LERTS[1]/University of Arizona (UA) EOS project.[3] Also collaborating in this campaign are investigators from the University of Arizona, additional ARS locations, USDOE, USGS, University of Maryland, Utah State University, JPL and France. This will be a truly interdisciplinary effort.

The 150km^2 Walnut Gulch watershed, with 93 rain gauges and over 30 subwatersheds, ranging in size from 0.003 to 113km^2 offers unparalleled basic hydrologic data. No other semi-arid watershed in the world exists with comparable instrumentation in time and space as well as length of high quality hydrologic record. This record and detailed knowledge of the watershed will provide a solid foundation for the upcoming field campaign.

The ground, aerial, and satellite-based remote sensing "shootout" will take place during the summer monsoon season in July and August. Remote sensing data will be collected in the visible, near-infrared, thermal and microwave portions of the spectrum. Ground truth data will be collected by a network of meteorological/flux stations in addition to the sampling of soil moisture (gravimetric, continuously recording, resistance soil sensors, time domain reflectometry) and atmospheric boundary layer profile data, including LIDAR. Detailed vegetation sampling and characterization will also be conducted.

The data collected during this field campaign, in addition to the existing detailed hydrologic data base, will be used as a basis to investigate several research objectives. The primary objectives of the NASA-ARS interdisciplinary effort will involve the assessment of remotely sensed information to perform surface energy and hydrologic balances and to infer changes in surface-atmospheric interactions at different length scales. The University of Arizona/LERTS EOS team will utilize remotely sensed data to attempt to identify key factors which control and dominate the hydrologic cycle as a function of basin and climatic scales. From the Walnut Gulch watershed scale, the University of Arizona/LERTS EOS study will proceed to scale-up to regional scales within Arizona to meet LERTS efforts, which are proceeding from larger scales down. Another important objective involves the cross validation of the methodology acquired in Walnut Gulch and southern Arizona, with findings of the LERTS group in the semi-arid regions of Africa.

With the cooperation of Mother Nature, the upcoming Walnut Gulch field campaign should provide the basis for important and unique research investigations for a better understanding of the hydrology and energy balances of semi-arid regions.

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[1] Laboratorie d'Etudes et de Research en Teledetection Spatiale

REFERENCES

[2]Kustas, W. P., L. E. Hipps, R. D. Jackson, and D. A. Woolhiser, 1988. (*Water and Energy Balance of a Semiarid Rangeland During the Summer "Monsoon" Season.*) NASA proposal submitted in response to NRA-88-OSSA-11, 35 p.

[3]Kerr, Y.H., and S. Sorroshian, 1990. *(Utilization of EOS Data in Quantifying the Processes Controlling the Hydrologic Cycle in Arid / Semi-Arid Regions.)* NASA proposal submitted in response to A.O. No. OSSA-1/88, 107 p.

BARC Symposium Presentations

The Beltsville Symposium XV: Remote Sensing for Agriculture, was held May 16-18 at the Goddard Space Flight Center (GSFC). Co-sponsored by the Beltsville Agricultural Research Center (BARC) and GSFC, the symposium emphasized research efforts in remote sensing dealing with the status of agriculture as related to the mathematical treatment of radiation in plant canopies and the atmosphere, the energy and moisture balance at the Earth's surface, and relationships of observed data to vegetation characteristics, such as crop yield.

Registered attendees totalled 166, with 19 foreign nations represented. EOS scientists who gave invited papers included Steve Running and Alfredo Huete, MODIS Team Members; Jeff Dozier, HIRIS Team Member and EOSDIS Panel Chairperson; Ted Engman and Jon Ranson, SAR Team Members; and Eric Barron, an Interdisciplinary Science Investigator and Chairperson of the Physical Climate and Hydrology Panel. Congressman George E. Brown of California, the ranking Democratic member of the House Science, Space, and Technology Committee gave an informative after-dinner speech at the symposium banquet, which included a discussion of past and future policy on Remote Sensing Technology.

Darrel Williams of the EOS Project Science Office and the Biospheric Sciences Branch, and John Price of BARC were co-chairmen of this very successful conference.

Darrel Williams
EOS Project Science Office

The Earth Observer is a monthly publication of the EOS Project Science Office, Code 900, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, telephone (301) 286-3411, FAX (301) 286-3884. Correspondence may be directed to Charlotte Griner at the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the meeting calendar should contain location, person to contact, and telephone number. Deadline for all submissions is the 20th of each month.

Software Development Guidelines

A document offering guidelines for data processing software developers is being developed, in draft form, by the Ground System and Operations Project. The draft document, which will be completed by October 1, 1990, will be distributed to the EOSDIS Service Advisory Panel and to the Principle Investigators, Team Leaders, Team Members, and Interdisciplinary Investigators for review and comment. The document will address issues such as standards and/or software tools for operating systems, programming languages, data formats, error messages, I/O routines, attitude/orbit interpolation routines, metadata structure, and browse data structure.

Tom Taylor
EOS Project Office

Calibration Advisory Panel Meeting

The next meeting of the IWG Calibration and Data Product Validation Panel will be held September 11-13, 1990 in Tucson, Arizona. The first day will contain meetings of the Working Groups (Visible/Near Infrared, Thermal Infrared, Active Microwave, Passive Microwave, Particles and Fields, and Time-of-Flight). The meeting is scheduled to end at noon on September 13. The preliminary agenda for the Plenary Group includes:

- Working Group Reports
- Draft Requirements for Cross-Calibrations
- Draft Peer Calibration Review Development
- Initial Data Product Validation Strategy

The Panel is jointly organized by Moustafa Chahine of JPL and Bruce Guenther of Goddard. Panel logistics are being handled by Debbie Critchfield of Birch and Davis. The "Announcement and First Call" for this meeting was sent to each designated Calibration Panel representative in mid-June. Representatives have been nominated to this Panel from each Instrument Investigation and several Interdisciplinary Investigations.

Bruce Guenther
EOS Project Science Office

SAGE II WATER VAPOR DATA ARCHIVED - CLIMATE CHANGE

The measurement of global change is an extremely urgent, albeit difficult, goal for the EOS program. For example, changes in stratospheric ozone, caused by man's activities, have to be separated from natural cycles (e.g., the solar cycle and dynamical changes such as the quasi-biennial oscillation), most of which produce variations in ozone greater than the net change to be measured. The same can be said for climate change and the other objectives of EOS. Therefore, it is of paramount importance to EOS to fly experiments that are robust, capable of producing accurate self-calibrated data, and, in the case of the atmosphere, capable of providing high-vertical-resolution data. If an instrument flown is not self-calibrating, great attention must be paid to the calibration. The commitment to re-fly such instruments and provide long-term data bases is recognized as a crucial aspect of EOS.

As with other instruments undergoing definition-phase studies, the SAGE III instrument fits well into the EOS goals and objectives. Its robust design has been proven by its predecessor instruments, SAM II, SAGE I, and SAGE II. In fact, SAM II has obtained over 11 years of continuous data. These measurements represent the longest continuous data set for stratospheric aerosols over the polar regions and allow us to detect and monitor the impact of volcanic eruptions, and study polar dynamics and polar stratospheric clouds (PSCs). Long-term stratospheric aerosol data are routinely being archived at the World Ozone Data Center for correcting ozone measurements by other sensors. This correction is especially necessary during periods of enhanced volcanic aerosol loading in the stratosphere. The Polar Stratospheric Cloud data base, produced by SAM II, has been crucial to understanding the Antarctic ozone hole. The ozone data from SAGE I and II were used intensively by the Ozone Trends Panel to examine long-term trends in global stratospheric ozone and were instrumental in forming their conclusions.

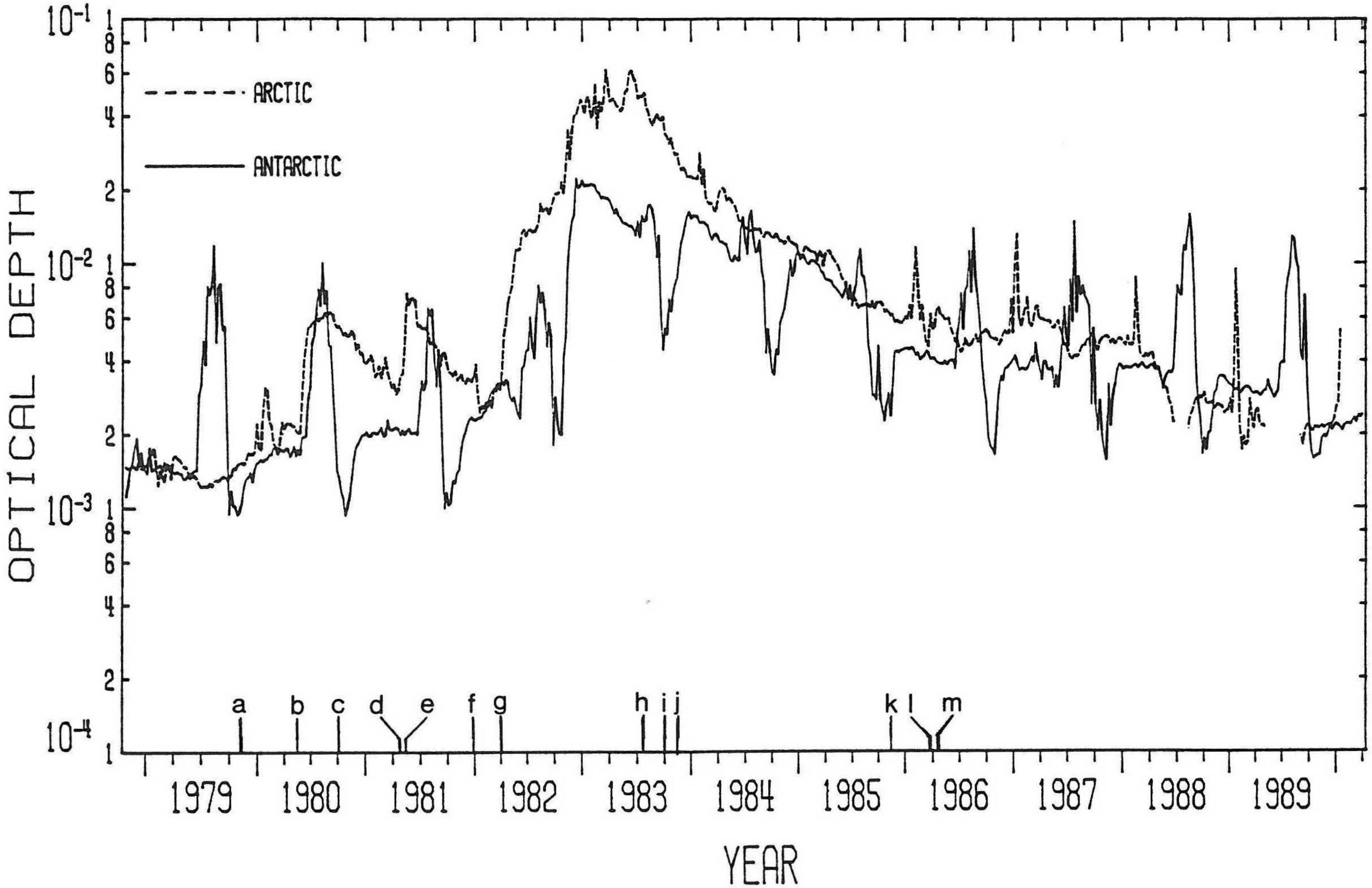
Aerosols, clouds, solar irradiance, vegetation and land albedo, and greenhouse gases, are climate forcers — they can change the planetary energy balance, which, in turn, can change temperature. Climate feedback agents such as clouds, tropospheric water vapor, sea ice cover, snow cover and land albedo, and ocean heat exchange, react to climate change. SAGE III can measure species important both to forcing and feedback in the climate system; aerosols, cloud top height and cloud frequency, ozone, water vapor, and temperature can all be measured by SAGE III. Its predecessor instruments measured all *but* temperature.

Figure 1 shows the long-term stratospheric aerosol optical depth measured by SAM II since its launch in October 1978. The effects of volcanic eruptions on stratospheric aerosols are readily evident. Violent volcanic eruptions spew large amounts of sulfur dioxide into the stratosphere, where it provides the source for small ($\approx$ 0.1 μm radius) sulfuric acid — water aerosols which disperse globally. These aerosols affect the Earth's radiation budget and represent a climate-forcing mechanism. After the 1982 eruption of El Chichon, temperatures near 30 mb ($\approx$ 24 km) in the tropics warmed, by a few degrees, for the entire latter half of 1982. However, the net effect of these volcanic aerosols is to cool the Earth's surface.

An example of an important feedback agent is water vapor. Since accurate global measurement of water vapor is such an important objective for climate and the Global Change Research Program, it is important to note that the SAGE II Science Team has completed their validation of the SAGE II water vapor measurements and are presently archiving the data at the National Space Science Data Center. SAGE II was launched aboard the Earth Radiation Budget Satellite (ERBS), October 1984, and along with ERBE, the other experiment aboard ERBS and the predecessor to the EOS experiment CERES, continues to collect data. SAGE II measures O_3, NO_2, and aerosols, in addition to water vapor. Five years of aerosol and ozone data have already been archived. The NO_2 data are also being archived at this time.

In addition to validation papers on water vapor, in which the SAGE II products have been compared with frost point hygrometer data, Lyman-α data, standard sonde data, previous satellite data, and available climatologies, a number of "initial use" papers are nearing completion. For example, upper tropospheric H_2O was shown to be greatest during periods of greatest tropospheric convection (July versus January in the Northern Hemisphere), showing that increased convection moistens the mid- and upper-troposphere. Thus, the important water vapor feedback which amplifies the projected trace gas-induced climate warming in general climate models

SAM II (1 μm) POLAR STRATOSPHERIC OPTICAL DEPTH
October 1978 – April 1990



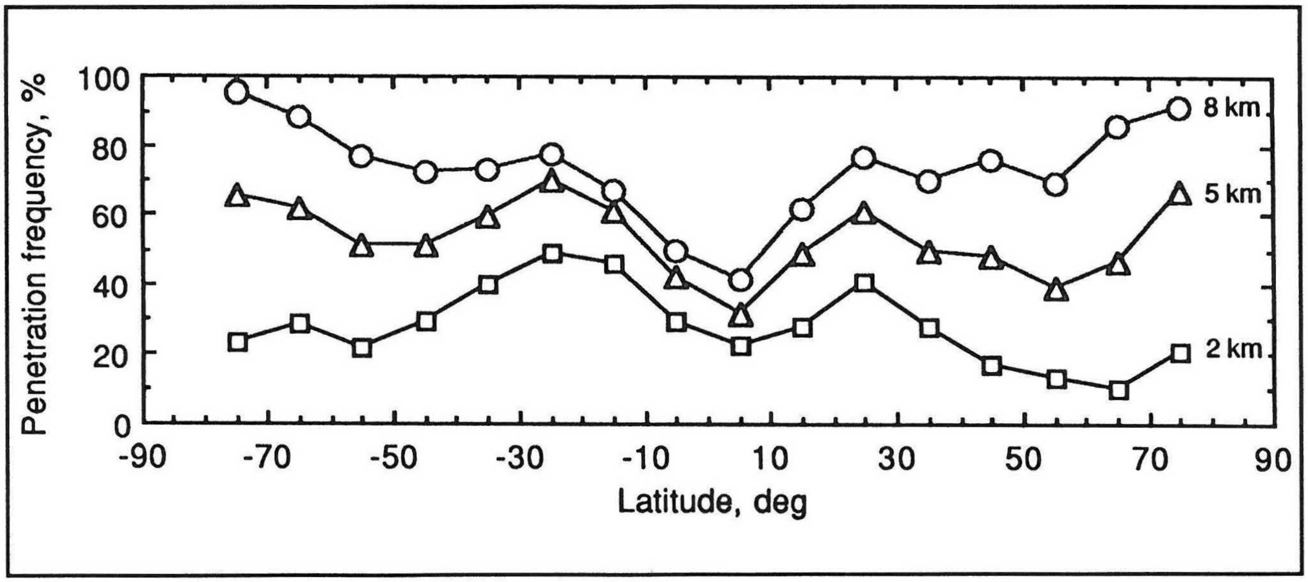


Figure 2. SAGE II tropospheric penetration frequency in percent of observations down to altitudes of 2, 5, and 8 km for 1989.

is qualitatively verified by the SAGE data set. This result is especially timely because of a recent article suggesting that increased convection caused by greenhouse warming would dry the upper troposphere, somewhat mitigating the increased greenhouse-induced warming.

The data also show minimum water vapor values of 2-3 ppmv in the tropical lower stratosphere above convective regions, with even lower values during Northern Hemisphere winter and spring. The appearance of low values in both hemispheres at the same time, January through March, suggests a common geographic source for low values of water vapor, perhaps through a "freeze-drying" mechanism located in the tropics. SAGE data also show the increase of water vapor with altitude reaching 5-6 ppmv or greater near the stratopause, supporting the idea of a high-altitude methane oxidation source. In the extratropics, individual profiles clearly indicate that water vapor minima do not coincide with the conventionally defined tropopause. These data and SAGE II's continued observations will provide a valuable source of information for understanding global circulation, stratosphere-troposphere exchange, cloud precursors, and atmospheric chemistry.

The EOS SAGE III instrument will improve on the SAGE II water vapor measurements with greater overall accuracy, especially in regions of high aerosol loading, and will provide the ability to extend these measurements over a greater height range. A remarkable result from SAGE II is its ability to make limb measurements deep into the troposphere. This will be important for other EOS limb-looking experiments. Figure 2 shows penetration frequency averaged over all of 1989 for different altitudes as a function of latitude. For example, SAGE II was able to make measurements to 5 km, 40 percent of the time everywhere except in a 10° latitude band over the equator. Just considering March 1989, SAGE II made measurements to 2-3 km, 50% of the time poleward of 20°S. This result indicates that a spaceborne solar occultation instrument is capable of producing a cloud-free mid- to upper-tropospheric climatology of aerosols and many gases. The inverse is also true; the frequency of occurrence of upper tropospheric clouds, including optically thin cirrus clouds is being routinely monitored by SAGE II with the archived data being used currently in a number of studies.

The EOS program offers a unique opportunity and challenge to the remote sensing and Earth science communities. Irrefutable information on which to build predictive capabilities is the challenge! This worthy cause will benefit generations to follow.

Len McMaster
Pat McCormick
Atmospheric Sciences Division
NASA Langley Research Center

SPECIAL REPORT

INTRODUCTION

Dear EOS Investigator,

As you have begun to get deeply involved in the exciting process of defining the scientific investigations and corresponding science instrument payload for the Earth Observing System, we at the International Geosphere Biosphere Program (IGBP) have also been hard at work. Our efforts have been focused on the architecture of a long term research program which we hope will answer important questions related to the future direction and extent of global change.

Of the various IGBP core projects which are now being defined, most have biospheric interactions with the atmosphere as a principal theme. These investigations involve the biosphere over both the land and oceans and are being studied on scales that range from seconds to decades in time and from pixels to global in space.

The problem is complex and, to a large extent, progress toward its solution is being paced by the availability of the data required to formulate and test models and make accurate assessments of trends in the biospheric functions which may be driving changes in the global environment.

In recognition of this situation, part of the IGBP activity has been devoted to defining the data requirements for a comprehensive international research program intended to last for decades. Remote sensing satellites will be a major tool of this data acquisition program. The pages which follow are, therefore, the first attempt to describe the IGBP Needs for Remote Sensing Data in the 1990's and Beyond.

In documenting these data needs, it was agreed that the requirements should also emphasize: (1) Reprocessing of existing data sets to rectify problems related to spacecraft sensor calibration and retrival algorithms; (2) Insuring against gaps in the space observing program which could preclude uninterrupted trend studies; (3) Planning the Earth Observing System (EOS) payload and observation program to meet the IGBP requirements for simultaneity, accuracy, long-term consistency and continuity of data; and (4) Initiating an EOS Data Information System (EOS-DIS) that, together with the IGBP's own planned IGBP-DIS, will deliver data on a timely basis and in a useable format to the international science community.

The document can only benefit from your consideration and I look forward to future discussions with you concerning its scientific content and the clarity of the message it contains.

S. I. Rasool
Chairman, IGBP-DIS
NASA Headquarters, Code S,
Washington, D.C. 20546

IGBP Needs for Remote Sensing Data in the 1990's and Beyond

Space Observations for Global Change

"At present there is enormous concern about the changes that are occurring on the surface of the Earth and in theEarth's atmosphere primarily due to human activities. These changes, particularly in the atmosphere, have the potential for altering the Earth's habitability. International programs unprecedented in scope, including the International Geosphere-Biosphere Program, have been initiated to describe and understand these changes. The global change program will call for coordinated measurements on a global scale of those interactive physical and biological processes that regulate the Earth system. The program will rely heavily on the emerging technology of remote sensing from airborne vehicles, particularly satellites. Satellites offer the potential of continuously viewing large segments of the Earth's surface, thus documenting the changes that are occurring. The task, however, is not only to document global change, which will be an enormous job, but also to understand the significance of these changes to the biosphere. Effects on the biosphere may cover all spatial scales from global to local. The possibility of measuring biosphere function remotely and continuously from satellite imagery must be explored quickly and thoroughly in order to meet the challenge of understanding the consequences of global change."

— H.A. Mooney and R. J. Hobbs in *Remote Sensing of Biosphere Functioning*, Springer-Verlag, New York, 1990.

As the underlying themes of the International Geosphere-Biosphere Program (IGBP) begin to be defined and a program of research becomes formulated, we must focus our attention on specific needs of the IGBP for global observation from space. A first study carried out by COSPAR (Rasool, 1987) describes, in some detail, existing space capabilities, the upcoming programs of various agencies, and how a number of key data sets, acquired from space satellites, can be useful in Global Change Studies.

Now, in early 1990, we are at a critical point, not only in the definition of a focused research program for the IGBP, but also in the formulation of plans of space agencies of the world for consolidating their activities for space for the decade of the 1990's through the International Space Year (1992) and beyond. A close coordination between the two is obviously imperative. It is for this reason that a two-day ad-hoc group meeting on "IGBP Needs for Remote Sensing Data in the 1990's and Beyond" was organized in April 1989 to take a first look at space observation requirements for IGBP. During the year since that meeting, the initial draft report has been reviewed extensively by scientists involved in the IGBP Coordinating Panels. The present report presents what the editors believe is a consensus of the views expressed by the scientists listed at the end of this article.

Elements of Global Change Observing System

IGBP has established five core projects and a number of others are in a definition phase. Four of the established Core Projects involve process studies on continental and global scales:

1. International Global Atmospheric Chemistry Project

2. Joint Global Ocean Flux Study

3. Biospheric Aspects of the Hydrological Cycle

4. Global Change and Terrestrial Ecosystem

The fifth core project deals with documenting global changes of the past several thousand years.

Although a measurement strategy for these projects is only beginning to be formulated, it is clear that measurement needs are going to be global, with varying temporal and spatial scales. Also, high quality measurements will be needed over the long-term (decades) for a large number of variables related to the physical state of the atmosphere, land and oceans; chemical changes in the atmosphere, oceans and land; and biological state of the land cover and of the upper layer of the oceans.

The measurement program will be derived from a variety of observation systems. These include satellite systems for long-term, global coverage and large scale field experiments for process studies using satellites, aircraft, balloons, and surface stations. It is essential to maintain high quality surface observing networks and that these be appropriately linked to remotely sensed data. These data sets will be instrumental to the development of Earth system models to improve our predictive capability because such data can be used both as an input to the models and as a test to the model predictions. An integral component of the data measurement activities is a data and information system. The IGBP Data Information System (IGBP-DIS) is proposed to facilitate data collation and dissemination of the various types and sources of data and users. Information flow between various research projects and scientific groups is essential to the success of the IGBP.

The IGBP needs space derived data for three overriding reasons. These are:

1. Document, precisely, global scale changes in key variables to assess the way the planet, as a whole, is evolving with time.

2. Measure the long-term trends in the forcing functions of the global change.

3. Simultaneous measurements of several parameters to study the interactive processes which regulate the Earth system. These are the measurements which are needed for the IGBP Core Projects and will be discussed in the following section.

Despite current availability of remote sensing data, many of the measurements are only loosely coordinated in time and space. The international collaboration to maintain and coordinate the collection of pertinent Earth system data for global change studies will need an evolutionary Earth Observing System to fulfill the IGBP needs.

In the near-term (1990-1995), the program will be based on:

- Continuing operational meteorological, geostationary and polar orbiting satellites (GOES, Meteosat, IRS, GMS, NOAA Landsat, Spot, etc.);

- Already planned research missions (ERS 1, UARS, TOPEX/POSEIDON, NASA-Scatterometer, JERS, Radarsat, ADEOS, Spot 4);

- Instrument development for space use by the mid-1990's (multi-channel imaging spectrometers, SAR, Lidar, Laser altimeter, high resolution imagers); and

- Ground validation and field experiment program.

In the longer term (1996 and beyond), we will have a new generation of space observing systems based on polar orbiting platforms, which will become available in 1998. Observational requirements for the IGBP are being identified now so that they can be incorporated in the design of the Earth Observing System. The following is a preliminary attempt to outline the need for remote sensing from space for the established Core Projects.

IGBP Core Project on International Global Atmospheric Chemistry

A major challenge for the Core Project, International Global Atmospheric Chemistry (IGAC), will be to acquire information on a number of trace gases in the troposphere. Data on the concentration and vertical distribution, with good time and space resolution of these trace gases, are needed. It will be important to be able to measure the magnitudes of the terrestrial and oceanic sources and sinks for radiatively and chemically important tropospheric trace gases, in particular, CO_2, CO, CH_4, O_3, N_2O) and other hydrocarbons, NO_2, NH_3, $(CH_3)^2S$, H_2S, OCS, and SO_2. We will need to know their atmospheric distributions, annual and latitudinal variations, and regionally and globally averaged long-term trends. Because H_2O plays such a key role in tropospheric chemistry, time variation measurements of global water vapor distribution are an important requirement as well.

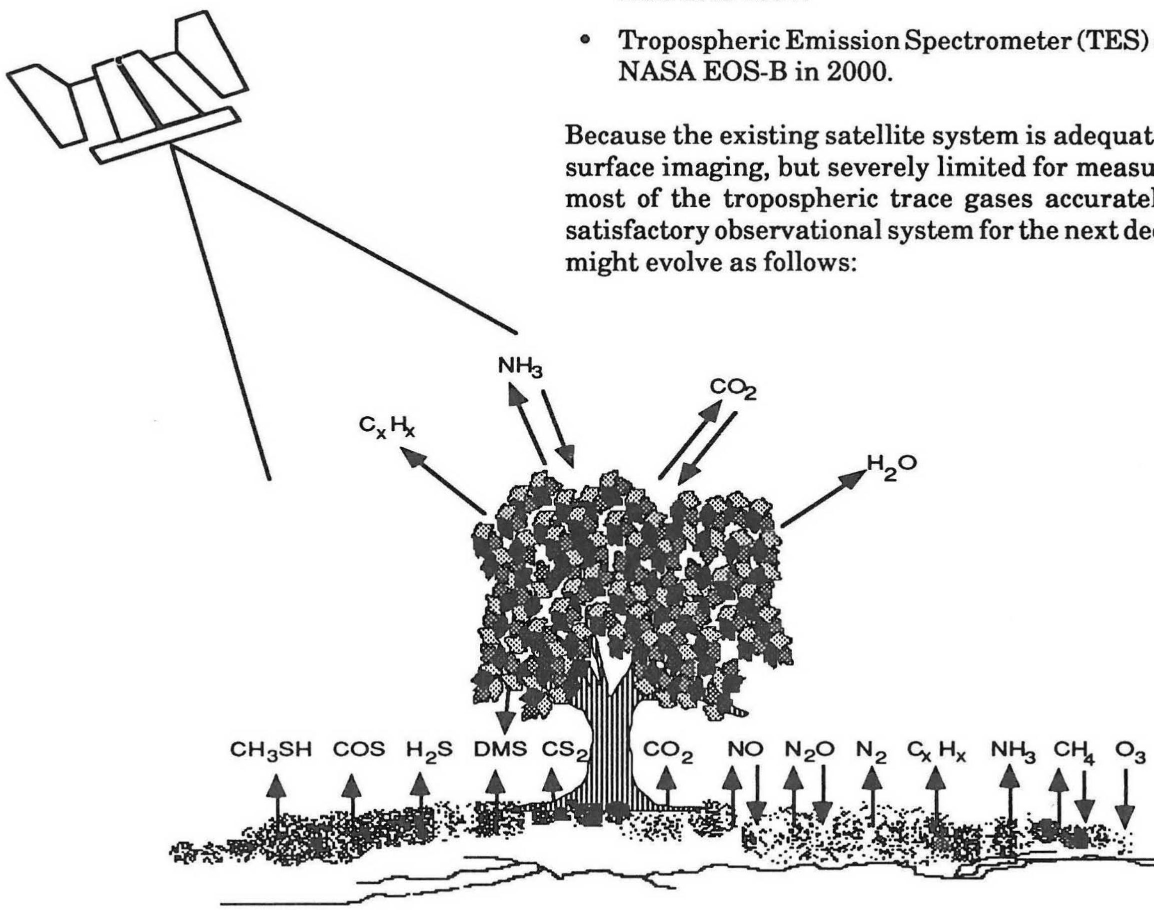
In order to quantify the fluxes of these trace gases at the land and ocean surface, we will need to make, simultaneously, a variety of measurements from ground, aircraft and space to assess the rate of change of land cover and the ocean biosphere. The measurements needs will include characterization of land cover types, canopy heights and density, biomass burning and net primary productivity on land and oceans, together with measurements of temperature, albedo and moisture.

So far, most satellite experiments to detect and measure trace gases in the atmosphere have been confined to the stratosphere. Gross estimates of tropospheric water vapor are obtained from current meteorological satellites. The only trace gas in the troposphere with a relatively low mixing ratio, detected up to now, is CO. This has been measured with the MAPS (Measurement of Air Pollution from Satellites) experiment during the OSTA-1 Space Shuttle mission, in November 1981 and October 1984, for a one week period only. The results showed differences between northern and southern hemispheres with higher concentrations noticed in the area of South America, possibly caused by tropical fires. Such measurements were never repeated. On the other hand, surface imaging from NOAA/AVHRR, along with high resolution measurements from the SPOT and Landsat series, have been available for the last 10 years and are being used for an IGBP Land Cover Change project (IGBP 1989, Report 8) which should begin to lay the foundation of a long-term assessment of changing land surface characteristics.

Efforts of several space agencies to develop new instrumentation for measuring and monitoring tropospheric trace gases from satellites and to provide better characterization of the biosphere functions are noteworthy.

- Vegetation Mapping Instrument (VMI) on SPOT 4 for global daily coverage at 1.1 km resolution in 1994.
- Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) on ESA polar platform for trace gas measurements in the troposphere in 1997.
- Moderate Resolution Imaging Spectrometer (MODIS) for high temporal detailed investigation of biosphere for NASA/EOS-A and High Resolution Infrared Spectrometer (HIRIS) for high spectral and spatial detail of biogeochemical conditions.
- Measurements of Pollution in the Troposphere (MOPITT) and/or Tropospheric Radiometer for Atmospheric Chemistry (TRACER) on NASA/EOS-A in 1997.
- Tropospheric Emission Spectrometer (TES) on NASA EOS-B in 2000.

Because the existing satellite system is adequate for surface imaging, but severely limited for measuring most of the tropospheric trace gases accurately, a satisfactory observational system for the next decade might evolve as follows:



1. Ground based measurement network of high accuracy for troposheric gases and complementary data.

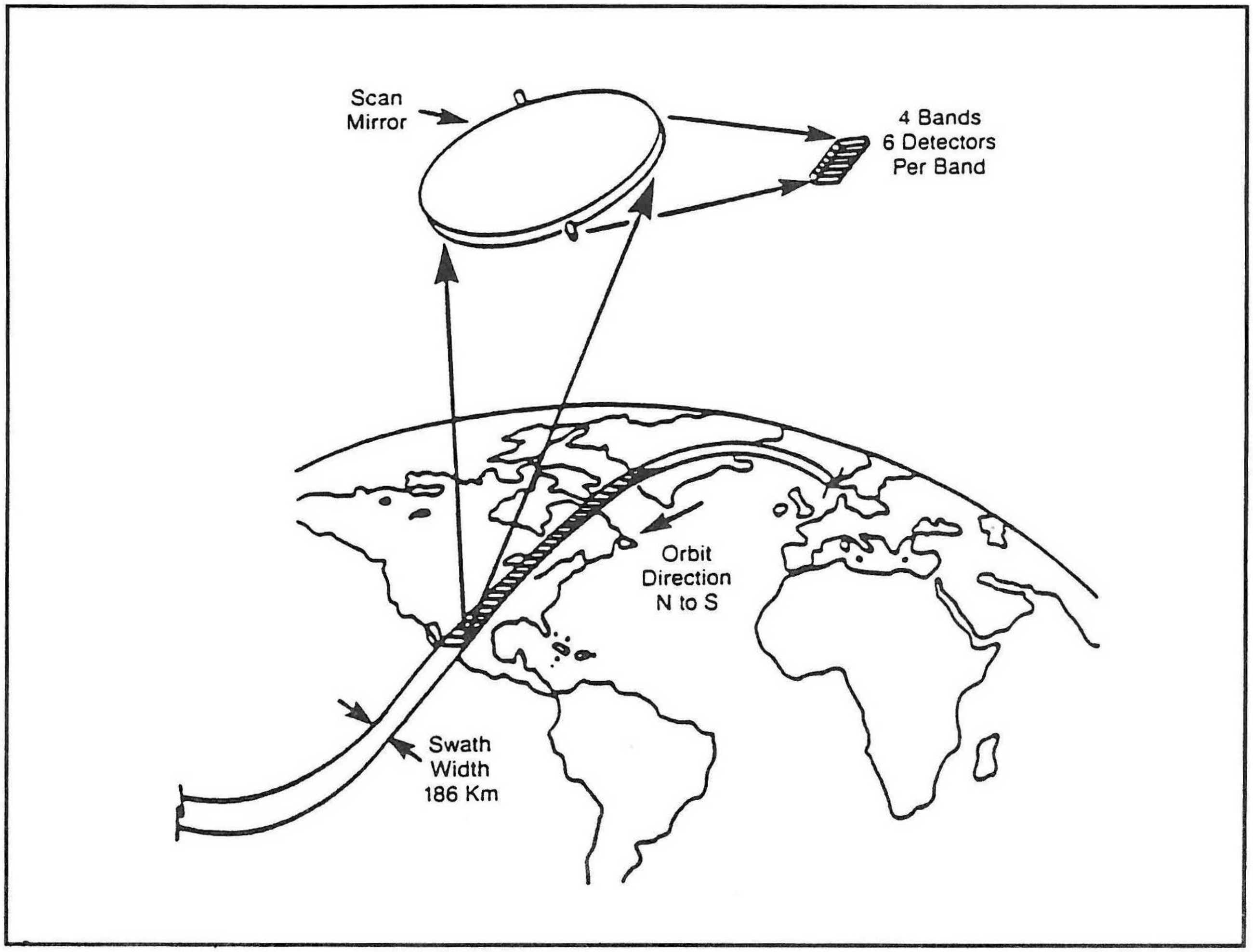
2. Balloon and aircraft measurements for field studies, for complementary measurements, or for instrument technique testing along with overlapping observations from space for surface imaging and radiances.

3. Experimental Instrumentation on Polar Platform and/or on Special Research free flyers for testing new techniques for measuring trace gases in the lower troposphere.

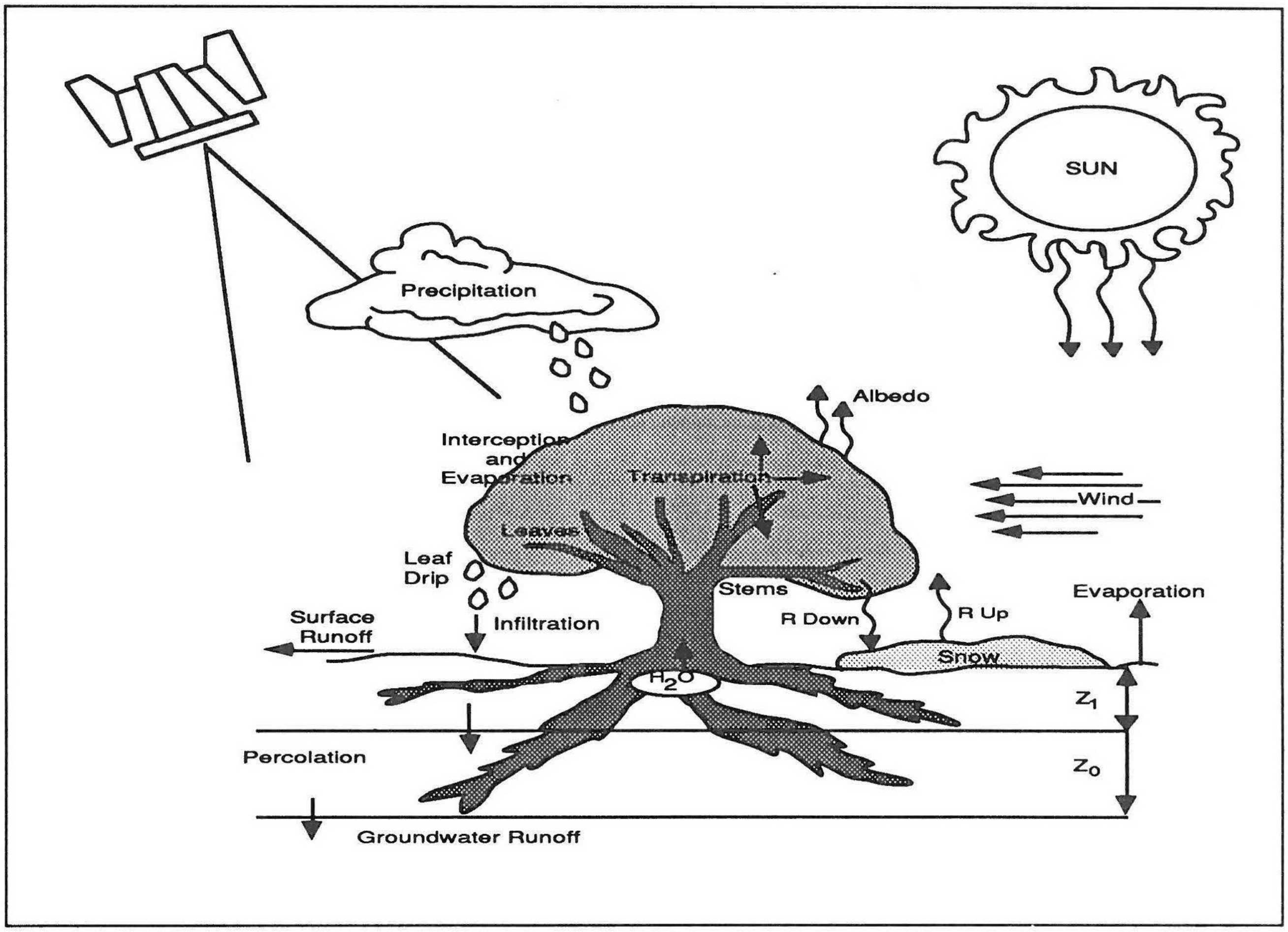
4. "Permanent" baseline instrumentation in orbit on a polar platform to measure gases in the stratosphere and troposphere, simultaneously with the detail characterization of the land and ocean biosphere.

IGBP Core Project on Joint Global Ocean Flux Study

The feedbacks between climate, ocean primary production and ocean CO_2 storage depend on global as well as regional characteristics of the biogeochemical cycles of carbon, nutrients and key trace elements and on the climate control of the physical environment in the euphotic zone. A much better knowledge of the basic processes that couple physical, chemical and biological processes in the sea, based upon *in-situ* and remote-sensing methods of observation, is needed to make it possible to understand and to model this coupled marine-climate system. It is important to know the consequences of these climate-induced changes on euphotic zone physical properties and their effects on global biogeochemical cycles, including feedback to atmospheric concentrations of radiatively active trace gases of biogenic origin.



Current observational studies in the ocean sciences support the goals of the IGBP to the extent that they focus on ocean surface temperatures and how they might vary with climate change, ocean color and how these relate to seasonal blooms, and on how the oceans store and exchange radiatively important trace gases. Complementing the sparse data coverage by the many ship-based programs, satellites provide regular global observations over the ocean surface of temperatures, sea-ice cover, and in the future, wind stress from roughness, winds over the ocean, sea-level height, and ocean color. Long-term monitoring of these marine characteristics is essential in the development of our understanding of how the ocean system interacts with other components of the global system.



The capability for such long-term observations will be achieved through the proposed research programs such as the Tropical Ocean and Global Atmosphere (TOGA) Program, the World Ocean Circulation Experiment (WOCE) and the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Program (WCRP).

Satellites approved for deployment in the near future include ERS-1, TOPEX/Poseidon and NASA-Scatterometer, while important oceanographic data are already being acquired by NOAA, Japanese MOS-1 and by the Defense Meteorological Satellite Program (DMSP). Ocean and ice measurements will also be provided from the ERS-1 of ESA, scheduled for launch in 1990, and the US/French Ocean Topography Experiment (TOPEX/POSEIDON) in 1992. Together, these satellites will provide the necessary global coverage of ocean and ice surface properties needed for understanding global change. The properties to be measured or inferred include surface wind stress (scatterometer); sea-surface temperature (infrared-microwave imager); ocean currents, fronts, and eddies (altimeter); ice extent, surface properties, and temperature (microwave imager); and detailed ice and ocean surface mapping (synthetic aperture radar).

One critical area of measurement specific to IGBP and important for the success of JGOFS is ocean color mapping, pioneered by the Coastal Zone Color Scanner (CZCS) on Nimbus 7. It has been shown that ocean color measurements can provide quantitative maps of near surface phytoplankton pigment concentration. Data analysis and processing techniques are well developed and are being improved, and the links between the satellite measurements and the total water column productivity are being better determined. Continuation of such measurements have been planned through the deployment of instruments such as the Sea-viewing, Wide Field-of-View Sensor (SeaWiFS), Ocean Color and Temperature Scanner (OCTS) and Polarization and Directionality of Earth Reflectances (POLDER). However, in the early 1990's, none of these satellite missions are presently on a firm schedule, particularly SeaWiFS which was initially planned for launch in 1992 and now may slip beyond 1994! This will be a major setback to the JGOFS ocean surface observing program which was initiated in 1989 in the North Atlantic and, as shown in Figure 1, will reach the period of peak activity in 1994-1995. Minimizing this gap should be one of the major concerns of the space agencies.

Plans beyond the late 1990's appear adequate. For the IGBP, it is important that ocean color be measured simultaneously with ocean surface temperature, wind stress and other euphotic zone properties. With the advent of the Earth Observing System, the Moderate Resolution Imaging Spectrometer (MODIS) in 1997, EOS-A and MERIS on the ESA-1 platform, along with other atmosphere and ocean viewing instruments, will largely fulfill this requirement.

IGBP Core Project on the Biospheric Aspects of the Hydrological Cycle

The climate and land surface subsystems are dynamically coupled through the physical processes of energy and water supply, transformation, and transport at the land-atmosphere interface. The biosphere interacts with these physical processes to further modify this coupling. Large-scale patterns of climate are influenced by regional variability of the surface processes of the water cycle. Current physically based models need developments which reflect the dynamic coupling in the climate-soil-vegetation system.

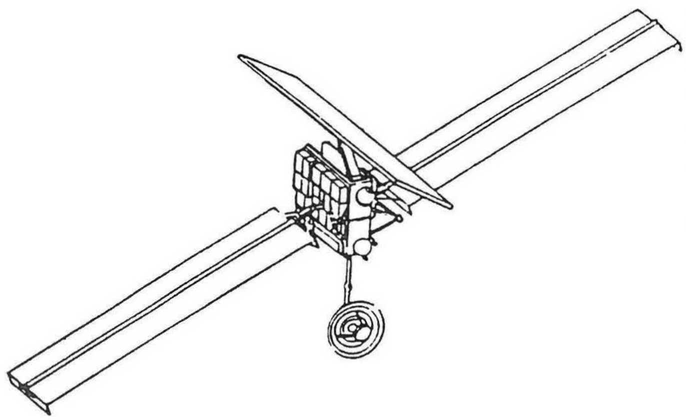
The definition of global hydrological balances requires measurements of three key hydrologically active components: the climate as a forcing function, the soil as a storage function, and the vegetation as a partitioning point for interception versus throughfall and as a consumption function for evapotranspiration. For global-scale research, the first general variable is studied by the GCM, which may be able to define the Earth in approximately 100 x 100 km cells. For this purpose, satellites can provide important, and in many cases the only, means of data collection. Certain surface meteorological conditions can be directly calculated from optical and infrared satellite sensors, including albedo, shortwave and longwave radiation balance, surface temperature, surface dew point and surface wetness. Satellites can provide an important extrapolation of point measurements, particularly of precipitation. ISLSCP was designed to measure these variables, first in FIFE on grassland, with a second experiment being planned for boreal forests. Accurate, consistent and compatible data sets are crucial to validating remotely sensed data and developing and evaluating models. Field experiments are also required to develop new algorithms and validate existing ones.

The most hydrologically important surface variables measurable by satellite are land and vegetation characteristics, topography (best done currently with stereo SPOT data or Landsat TM), and snow cover. Highest spatial detail in a static condition can be achieved with SPOT or TM data. However, temporal dynamics at 1 km resolution are best done with the AVHRR or the next EOS generation MODIS sensor at 250m - 500m, with twice daily overpasses.Current satellite NDVI products may provide good measures of seasonal vegetation phenology, but must be calibrated for viewing conditions and differing bi-directional reflectance properties of different biome types (e.g., forest vs. grassland). Initial efforts to obtain land-cover and vegetation characteristics are now being conducted in the IGBP Land-Cover study (IGBP Report #8, 1989).

A current research need is the incorporation of these variables directly measurable by satellite into hydrological models. Snowmelt models could incorporate repetitive snow-cover data with surface temperature and radiation conditions. Vegetative canopy partitioning into interception (and evaporation) or throughfall and soil storage could be modeled using satellite vegetation indices with the appropriate surface meteorological conditions (incident solar radiation, vapor pressure deficit) to drive an evapotranspiration equation (e.g., Penman-Monteith equation).

New studies suggest that a satellite derived surface resistance factor may also be entered into the equation of evapotranspiration (ET). These simple satellite driven models must be validated with "point" measurements and mechanistic soil-plant-atmosphere models. If precipitation and ET can be calculated adequately at GCM grid scales, reasonable estimates of runoff, or hydrological discharge, would be possible if the basin storage could be assessed At some future time, efficient testing and operation of these capabilities will demand a computerized global GIS to organize available surface meteorology, topography, vegetation cover, soils and other data, at least to GCM grid spatial detail.

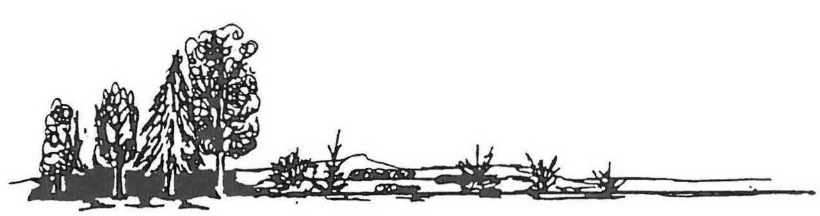
Perceived needs for future advancement in satellite measurements have been classified in terms of the feasibilities of meeting the needs with existing or firmly planned remote-sensing data from satellites. Using the dual criteria of importance and likelihood of achieving useful goals in the foreseeable future for satellite application in hydrology, the following priority items are proposed: vegetation and land-surface characterization; rainfall monitoring, surface-water monitoring and inventory (e.g., of rivers, lakes, marshes, reservoirs); snow mapping, monitoring, accurate soil moisture measurements, mainly for non- or sparsely-vegetated areas, estimation and monitoring of evapotranspiration. The remote sensing satellite needs for these parameters are summarized in conjunction with the requirements for the IGBP Core Project on Global Change and Terrestrial Ecosystems which follows.



IGBP Core Project on Global Change and Terrestrial Ecosystems

The overall objective of the Core Project on Global Change and Terrestrial Ecosystems is to develop the capacity to interpret and predict effects of global change phenomena on terrestrial ecosystems. Global change phenomena include changes in climate, atmospheric composition and land use. This capacity is required for two reasons. The first, to forecast the consequences of global change for ecosystem structure and function, since these ecosystem attributes have direct effects on human welfare including primary productivity, future land use and biotic diversity. The second reason is to be able to predict the potential feedbacks of the terrestrial changes on further atmospheric, climate and land use change.

One of the most important means of measuring terrestrial ecosystem change will be through remote sensing, and data derived from remote sensing will be a central part of the necessary GIS data base developed for the IGBP. The initial and most basic data set is that of land-cover vegetation characteristics of the Earth. Currently, satellite coverage exists, but continuity and spatial resolution of remote sensing data sets must be maintained for the long-term interpretation of ecosystem change. Coverage with instruments such as the AVHRR, with higher resolution data (e.g., SPOT) nested within the grid cell to enhance interpretation, should continue and be archived. Long-term calibration of the instruments is essential. Equally important is ground validation of the remote sensing data.



The research design for this and the previous Core-Project, would involve a hierarchy of measurement and prediction on scales that will allow researchers to interpolate between global and local scales and is needed for appropriate modeling and prediction testing. Remote sensing data will be essential for inter-scalar studies. For example, to predict change in plant cover, simulation models coupled with environmental conditions set by GCM derived scenarios will be run to give a range of future system states across landscapes for various regions of the Earth. These will be extrapolated upward in scale with a GIS system, and will be compared with data derived from remote sensing. Remote sensing will be even more central to the process of observing Earth system changes over extensive areas and over time.

Ecosystem properties to be addressed will be both structural and functional in nature. Examples of structural properties are leaf area and the distribution of leaf area in the canopy profile. Functional examples include standing biomass, live-dead ratio of plant material, canopy chemical concentration (e.g., leaf N, chlorophyll a, and lignin), net primary production, evapotranspiration and trace gas flux. Remote sensing is most directly adaptive for measuring structural properties, but some functional attributes will be estimated across extensive areas by coupling remotely sensed data to ecosystem models (e.g., remotely sensed surface temperature and soil moisture as inputs for simulation models to estimate evapotranspiration).

Different kinds of remotely sensed data will be vital to meeting this core project and the previous core project objectives. These are:

- A moderate resolution capability for measuring gross structural attributes of vegetation and soils with high temporal frequency but medium spatial resolution. This role is presently filled by the AVHRR for areas with complete canopy cover, but with development of EOS instruments, this role will be filled even better by MODIS. For areas with incomplete canopy cover and mixed pixel problems of rock, soil, and plant signals, other low resolution methods need to be improved. It is possible that passive microwave methods for semi-arid and arid lands will be the method of choice. This is being tested with SMMR data at present and, if it seems satisfactory, will be fulfilled by AMSR in the EOS suite.

- A high resolution sensor with low temporal frequency for detailed analysis at the landscape level, and for chemical assessment of canopy and soil properties, is required. The spatial component is presently served by Landsat 4 and 5, but there is no routine sensor for chemical analysis. At present, AVIRIS is being used as a test system for very detailed spectrometry that may measure chemical properties. High Resolution Infrared Spectrometry (HIRIS) may provide reliable estimates of canopy nitrogen and lignin concentrations. These estimates are extremely useful for assessing the metabolic condition of foliage, which, together with leaf area measurement, provides a good estimate of primary production. In addition, canopy chemistry may be useful to estimate the chemistry of below-ground parts and litterfall and provide a means for calculating biogeochemical properties of ecosystems such as decomposition and nutrient turnover. In the EOS suite of sensors, HIRIS will fill this role. In addition, high resolution data on canopy structure may be provided by SAR.

- Digital evaluation data are fundamental to the GIS data set required for global modeling of terrestrial ecosystem structure and function. Present digital elevation data are inadequate and new models based on better altimetry are essential. An Earth probe mission, separate from the EOS, is required to obtain the needed data. In the meantime, stereo imaging by SPOT can begin to provide source information in this parameter.

- Principle driving variables for terrestrial ecosystems are air temperature, canopy surface temperature, soil temperature and soil moisture. Air temperature is not presently measured by any remote sensing device below the planetary boundary layer; it must be calculated from models driven by surface temperature (see below).

- Remote sensing will be extremely useful for assessing structural ecosystem properties and, of lesser value, for estimating driving variables as described above. Many of the driving variables necessary for predicting changes in terrestrial ecosystems will have to be calculated indirectly from simulation

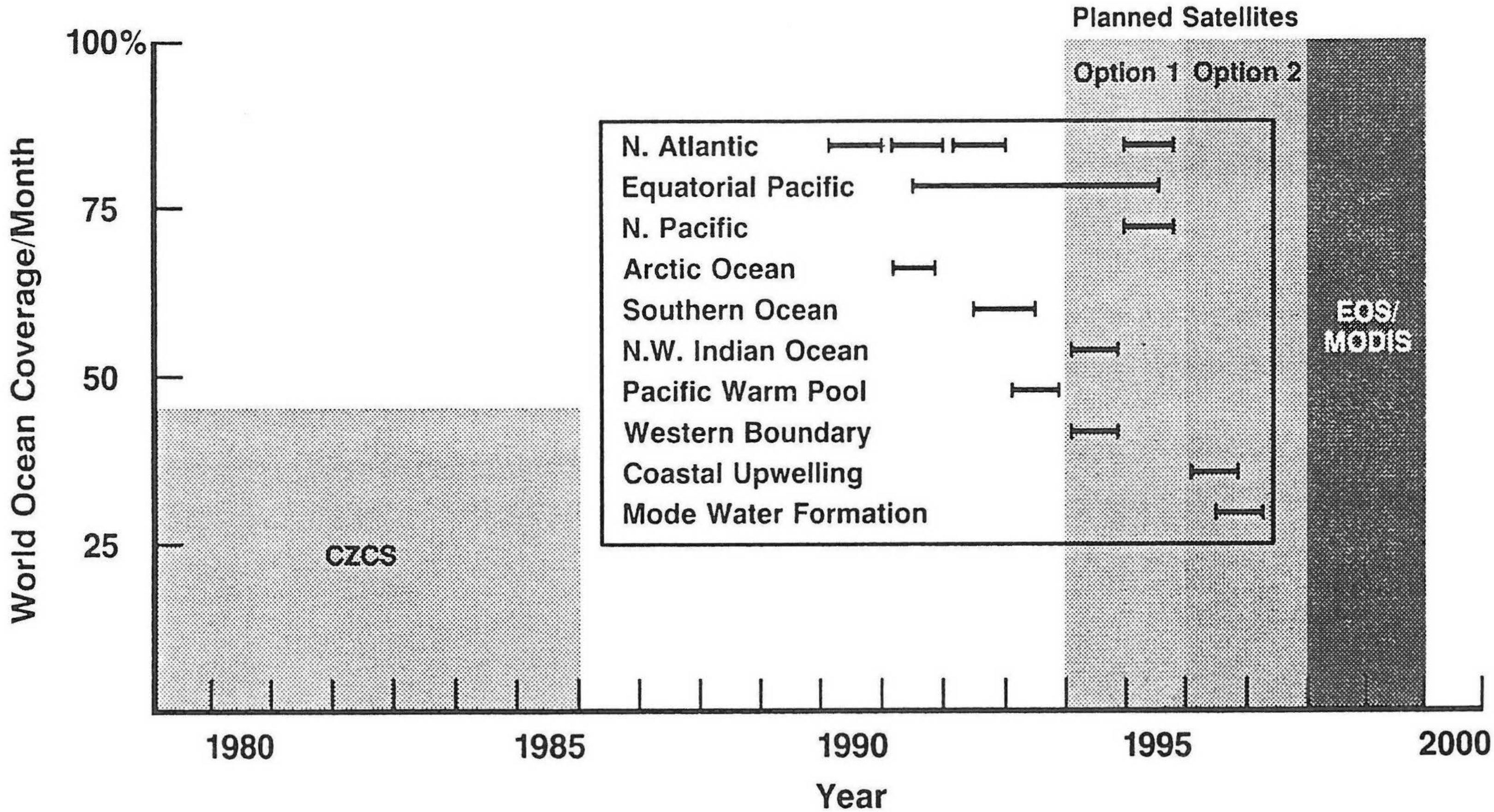


Figure 1. Satellite Coverage for Ocean Color and IGBP/JGOFS Process Cruises

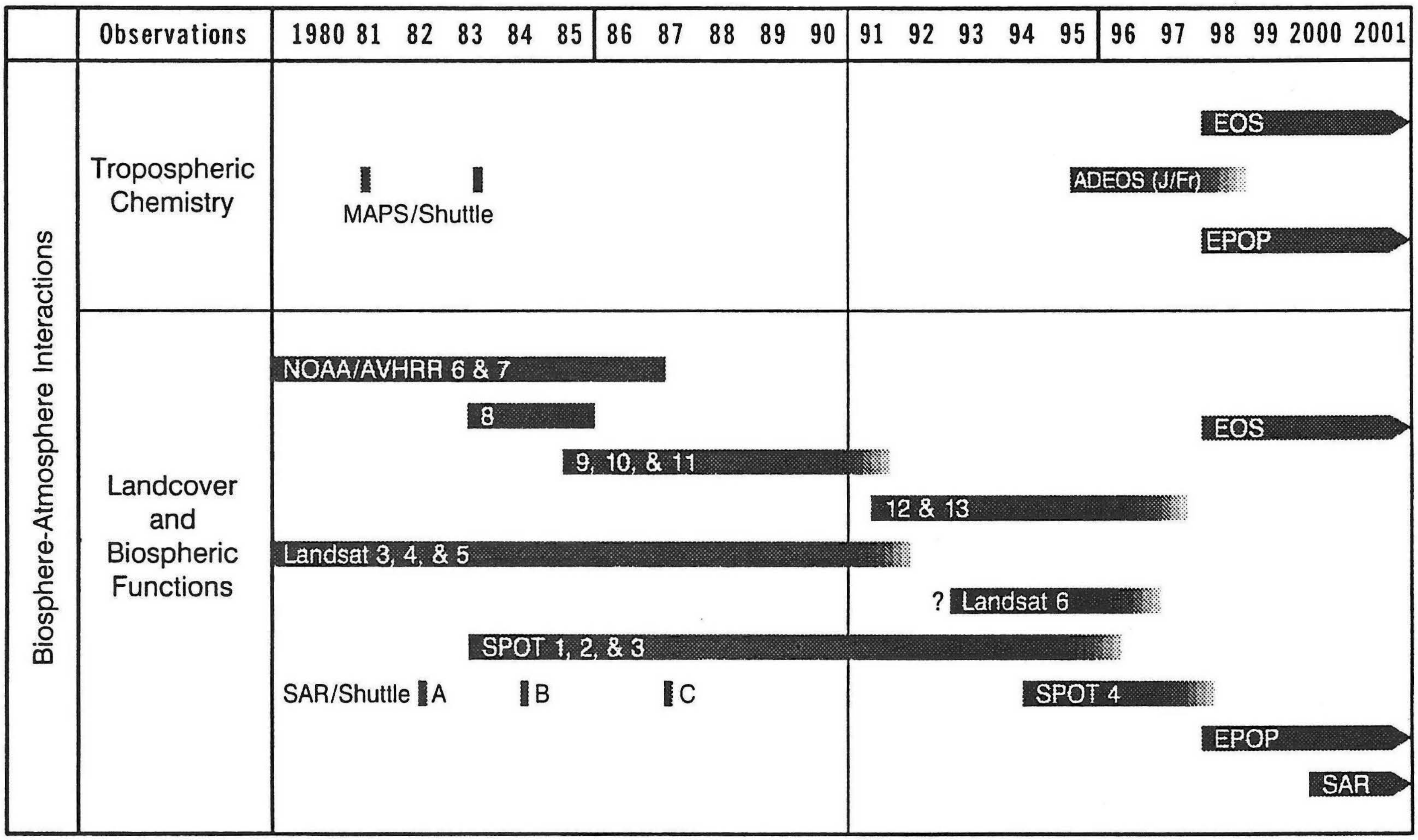


Figure 2. IGBP Highest Priority Global Data Product Continuity From Satellite Measurements

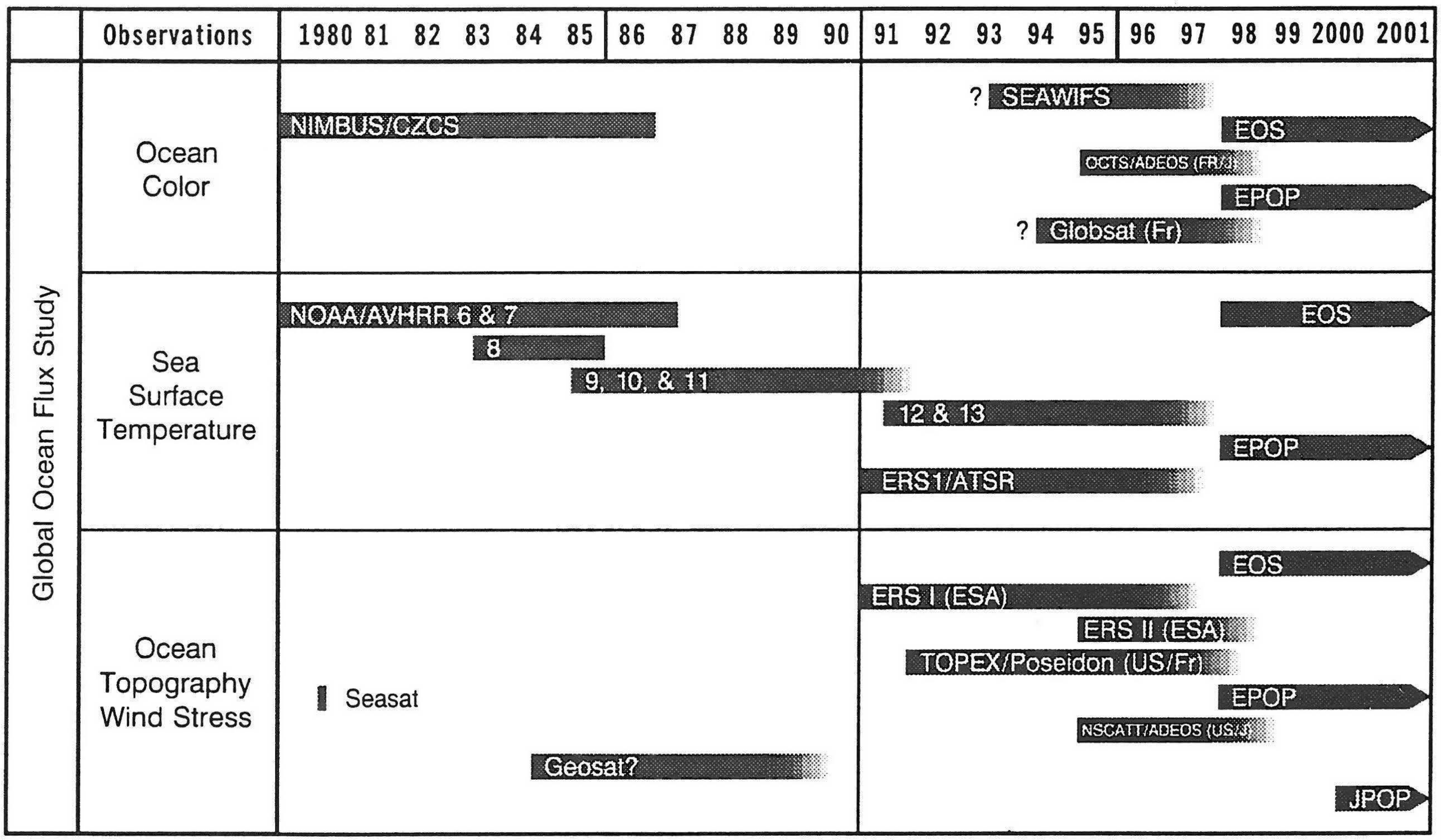


Figure 3. IGBP Highest Priority Global Data Product Continuity From Satellite Measurements

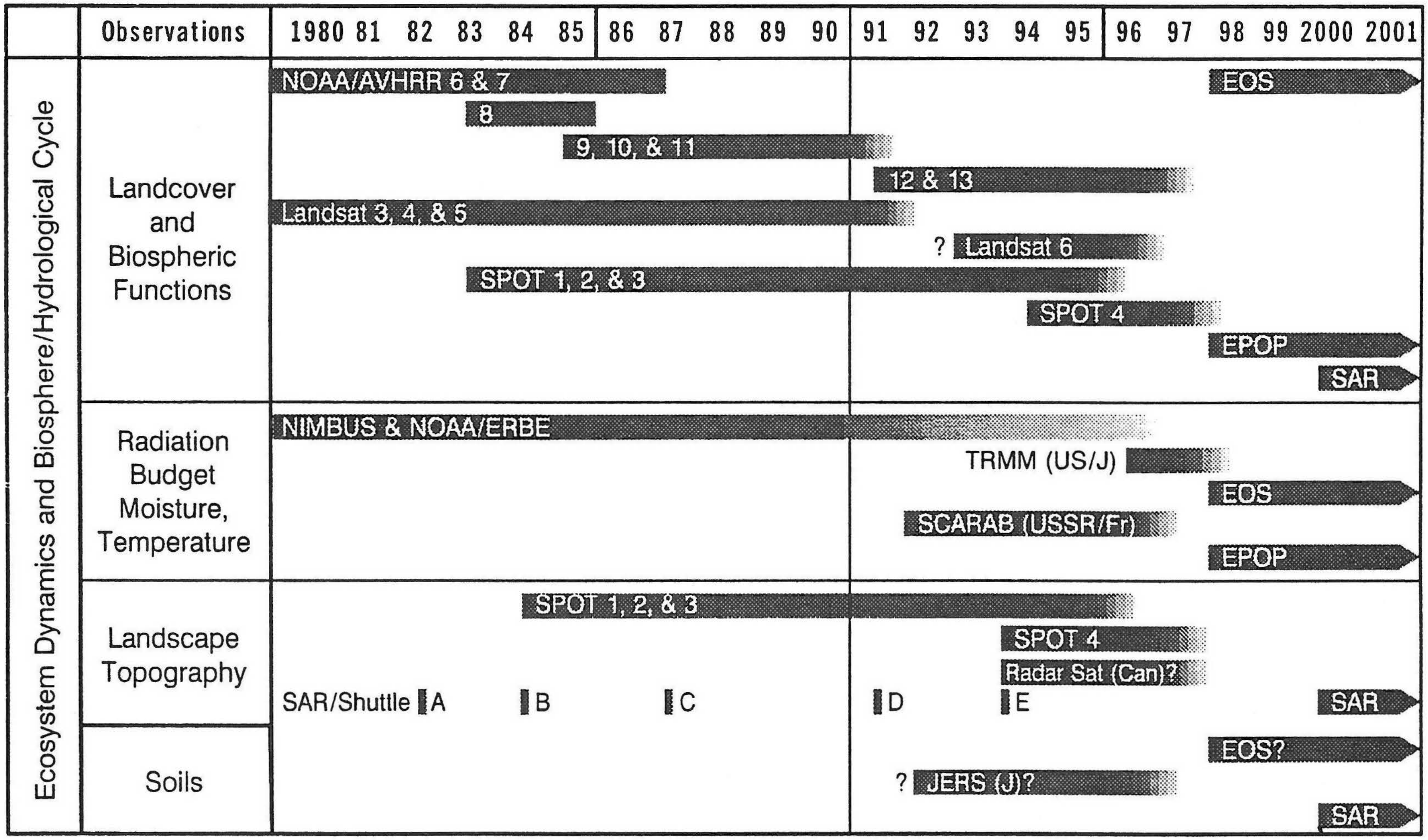


Figure 4. IGBP Highest Priority Global Data Product Continuity From Satellite Measurements

models, algorithmic routines, or by direct ground measurement. This last process will be vastly facilitated by robotic samples that can measure a variety of environmental variables at one point and relay them to geostationary satellites such as GOES for retransmission to ground stations. This will give researchers nearly "real time" direct measures that can be extrapolated across landscapes to estimate functional processes. Robotic sensor systems and satellite relay systems might play a large role in achieving the objectives of this Core Project.

In summary, remote sensing will be vital to developing models for predicting changes in terrestrial ecosystems and for observing the changes over long time periods and across the vast areas of the globe. Further development of remote sensing technology and ground validation of the information for interpretation of biosphere function and changes in the coming years must be continued. It is also important to point out that an efficient data access system and a long-term record are necessary for our success. The hiatus in remote sensing data now facing the scientific community, because of the uncertainty in the future launches of Landsats, represents a serious detriment to our ability to predict or observe global change on land systems. It is essential that at least the present data base be maintained through the years before EOS instruments come on line to develop the foundations of understanding the simulation models themselves, and for providing a data set with which to observe global change.

Current Impediments and Strategies for the Future

Discussions among the IGBP scientists made it clear that international satellite observing capabilities currently existing, and those likely to develop over the coming decade, will be critical for the success of the IGBP (see Figures 2, 3, and 4). However, several impediments are currently limiting us from the most effective use of the satellite data.

Existing Data: 1980 - 1990

There are about six operational geostationary satellites which provide global data on cloud cover and temperatures on a near continuous basis. In the near Earth polar orbits, there are a number of operational remote sensing satellites including LANDSAT/NOAA/AVHRR and SPOT which collect a variety of remote sensing data in the visible and IR spectral regions, providing more or less continuity of data already available over the last ten years or so, including close to six years of global vegetation index. In addition, there are a number of research satellites like SMM/I, ERBE, and Nimbus which provide data on many other parameters such as solar flux, sea surface temperature, atmospheric moisture, ocean chlorophyll, snow cover, sea ice extent, earth radiation budget, and atmospheric ozone and stratospheric dust.

Together these data sets are of unique value for the WCRP and for the IGBP studies provided they are quality controlled and are continuous over at least a decade. Only a few of the above mentioned parameters pass this test. These are the measurement of solar irradience, stratospheric ozone, stratospheric dust and sea surface temperature. Efforts are now underway to reprocess the data and reassess the algorithms and consistent global data sets for ocean chlorophyll, vegetation index, radiation budget and snow and ice cover for the entire decade of the 1980's. Eventual availability of these data will be of substantial benefit to the IGBP community and were given the highest priority in our deliberations. In order to achieve this we will have to give serious attention to the problems related to spacecraft sensor calibration. A drift in sensor response and changing algorithm for atmospheric correction can easily be interpreted as an indication of global change on the surface of the Earth. Without a thorough evaluation of such discrepancies, satellite data is of practically no use to a student of global change.

1990-1995

As we enter the decade of the 1990's, a number of new satellites with new sensors relevant to IGBP studies are planned by about a dozen countries (see Figures 2, 3 and 4). The challenge for the space agencies and for the IGBP community will be to assume that the data acquired in the 1980's and those acquired, on the same parameter but by different satellites, in the 1990's, are consistent with each other and can be used to derive an uninterrupted time series to document accurately long-term changes in the state of atmosphere, ocean and land. Some pitfalls loom on the horizon such as a 'datahole' of at least five years on ocean color between the CZCS on Nimbus 7 (which stopped functioning in 1987) and SeaWIFS which is now planned for 1994 but is not yet funded!

For Global Change Studies, the challenge will be to combine data from several of these satellites to be able to do process studies. For example, ocean color data from SeaWIFS combined with data on surface winds (from either ERS-1 or NASA Scatterometer) and with accurate sea surface temperature measurement by ERS-1 or a NOAA type satellite will be essential for the study of marine biosphere-atmosphere exchange.

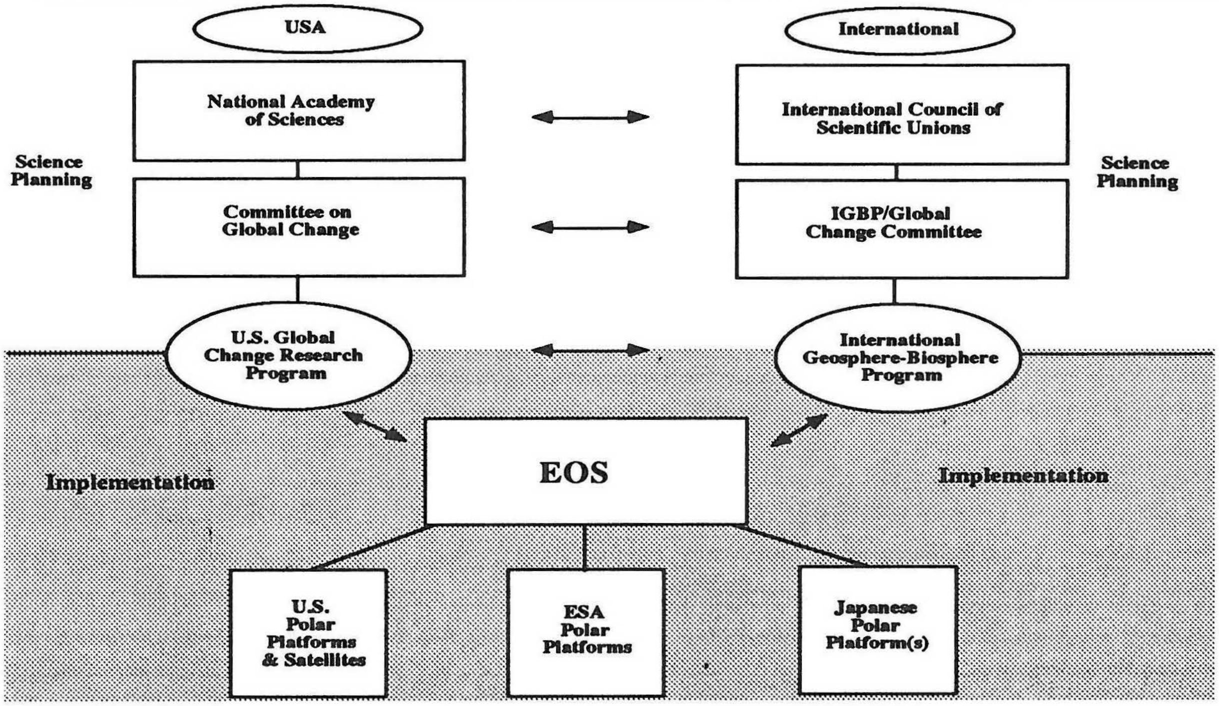
An ocean color monitoring instrument less sophisticated than SeaWIFS is planned for the ADEOS mission in 1995. Originally, these missions were planned to be coincidental in time with the international oceanic campaigns for JGOFS scheduled for 1990 through 1996. Unfortunately, it now appears that at best we will only get the satellite data toward the end of the JGOFS observing program (see Figure 1)! A concentrated effort by the space agencies to narrow the data gap in ocean color measurements should receive the highest priority.

Beyond 1995

Simultaneity, accuracy, long-term consistency and continuity are the key IGBP requirements for space observation of several parameters. These conditions are proposed to be met by the launch of polar platforms, starting in 1997. While the payload combination of these platforms is being defined, we would like to re-emphasize the IGBP requirements for data from the Earth Observing System. For the projects shown in Figures 1, 2, 3 and 4, data on tropospheric chemistry, land biospheric functions, ocean color, temperature and wind stress, land topography and soil moisture are of critical importance.

One of the principle impediments in the use of space data by the international science community has been its non-availability in a usable format. It is, therefore, encouraging to note the plans for initiating an Earth Observing System Data Information System. For the IGBP scientists to benefit from the information and data archived in EOSDIS, plans for establishing an IGBP-DIS are in progress. The sooner the two systems are put in place and become functional, the better the global change scientific community will be able to investigate the Earth system in its totality.

— IGBP Article Edited by S. I. Rasool and Dennis S. Ojima. Written contributions from Joseph Cihlar, Siegfried Dyck, Pam Kennedy, Marlon Lewis, Luis Molion, Stephen Running, Gilbert Saint, Paul Uhlir, Volodja Viskov, and Diane Wickland. Participants: R. R. Daniel, James McCarthy, William Reiners, Vincent Salomonson, and Brian Walker.



The Role of EOS in the U.S. Global Change Research Program and the International Geosphere-Biosphere Program

EOS Science Meetings 1990

	Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
JULY	2	3	4	5	6	1 7 8
	9	10	11 ← HIRDLS Team Meeting →	12 ← HIRDLS CDCR	13 →	14 15
	16	17 ← SAFIRE Team Meeting, LaRC	18	19	20 →	21 22
	23	24 ← MODIS-N CDCR → (Science & Data Only)	25 ← MODIS-T CDCR →	26 ← AIRS CDCR	27 →	28 29
	30 ← HIRIS CDCR	31 →	1 ← ALT CDCR → ← LAWS Team Meeting, Boulder, Colorado	2	3 →	4 5
AUGUST	6	7	8	9 ← POEMS CDCR →	10	11 12
	13 ← EOSDIS Advisory Panel, Snowmass Panel Members Only ← LIS CDCR →	14 →	15	16	17	18 19
	20	21	22	23	24	25 26
	27	28 ← Payload Advisory Panel and SEC Meetings, Durham, New Hampshire	29	30	31 →	1 2
SEPTEMBER	3	4	5	6	7	8 9
	10	11 ← Calibration Advisory Panel Meeting, University of Arizona, Tucson, Arizona	12	13 →	14	15 16
	17	18	19	20	21	22 23
	24	25	26	27	28	29 30

Global Change Meetings

October 16-19 — NOAA Conference "Operational Satellites: Sentinels for the Monitoring of Climate and Global Change", Washington, D.C. Call Frances C. Holt, OPSAT Committee, NOAA/NESDIS, (301) 763-8251.

October 23-24 — Earth Observations & Global Change Decision Making: A National Partnership Fall Conference. , National Press Club, Washington, D.C. Contact Nancy Wallman, ERIM/Global Change Conference, (313) 994-1200 ext. 3234

January 1991 — 2nd Symposium on Global Change Studies, January 13-18 in New Orleans. Contact Eric Barron, (814) 865-1619. [Abstracts no later than August 1, 1990.]

Future EOS Science Meetings

October 23-24 — TES Science Team Meeting, Cambridge, Massachusetts
Nov. 6 — AIRS Science Team Meeting, Langley Research Center, Hampton, Virginia
Nov. 6-9 — IWG, Langley Research Center, Virginia

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