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INSIDE THIS ISSUE

Editor's Corner

Not long after the review of the U. S. Global Change Research Program (USGCRP) by the National Academy of Sciences' Board on Sustainable Development was completed, a new study was initiated by NASA to examine implementation options for EOS. This study, co-chaired by Sam Venneri (Director of the Spacecraft Systems Division of NASA's Office of Space Access and Technology) and Charles Vanek (Acting Deputy Director of Flight Projects, Goddard Space Flight Center), was initiated to: (i) perform a fast-track study of the Mission to Planet Earth (MTPE) program to identify and evaluate mission architecture options that include technology infusion in advanced space system concepts, (ii) include determination of risk levels and life cycle costs for accomplishing the critical requirements of MTPE science in support of global change research, (iii) focus on mission architecture options that rely on technology infusion and commercial partnering, (iv) identify concepts for advanced instruments and opportunities to combine measurement requirements (e.g., advanced MODIS), and (v) review concepts for information processing and distribution of products.

Although one might question the motives for this study so soon after the NRC Review, the guidelines and boundaries of this study are clearly defined to avoid conflict with the NRC Report and Payload Panel meeting of last summer. These guidelines explicitly include: (i) clearly identifying science needs as distinct from commercial needs, hence articulating the strong emphasis on calibration and intercomparison of data sets unique to the MTPE program, (ii) not challenging or redefining the 24 measure-

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ment sets developed last summer, but instead focusing on developing new technology opportunities for elements such as spacecraft features, Ka-band transponders, and on-board processing. Furthermore, NASA Administrator Dan Goldin has indicated that he doesn't want to see a "warmed over" EOSDIS; instead, he wants something revolutionary that saves a considerable amount of money and uses commercially available services to the maximum extent possible. The results of this study are to be submitted to Mr. Goldin by December 20.

The NASA Research Announcement (NRA) for new investigations and investigators for the Earth Observing System was distributed via the Internet (through both the Mission to Planet Earth and EOS Project Science Office home pages on World Wide Web) on September 22. Since posting this announcement, there have been approximately 3656 downloads of this document as well as 270 requests via letter, electronic mail, and phone. There have thus far been 487 (non-mandatory) letters of intent received as a result of this solicitation, which can be categorized as follows:

Landsat Team Member/Leader	45
MODIS Team Member	50
AIRS Team Member	4
TRMM Team Member	4
Passive Microwave Team Member	14
Interdisciplinary Investigation	200
New Investigator Program	115
Science Education Grant Supplement	55

NASA aims to complete the evaluation and selection process by March 15.

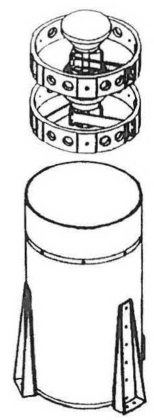
As reported in the last issue of *The Earth Observer*, NASA selected TRW Inc. of Redondo Beach, CA for a cost plus award fee contract valued at $398.7 M to provide two "common" spacecraft (PM-1 and Chemistry-1), along with options for two more spacecraft (for an additional $269.8 M). This contract has since been mired in a protest by losing bidders Hughes Space and Communications Co. of Los Angeles, and Lockheed Martin Missiles and Space of Sunnyvale, California. The General Accounting Office, which reviews all bid protests, has until mid-February to rule on this matter. This protest places additional uncertainty on the common spacecraft procurement, which has been part of NASA's strategy since rescoping the EOS program in 1992.

In late October, Dr. David Starr, EOS Validation Scientist, distributed a letter outlining the Project Science Office plan for development of EOS instrument team data validation plans. This important activity includes: (i) individual team contributions (in a common format) of their team's validation plans, (ii) a Validation Workshop during the week of May 13-17, including active participation of the IDS teams and other prospective national and international partners, (iii) submission of revised team validation plans in July, which will be used to define (iv) a NASA Research Announcement, to be released around August, calling for contributions to a correlative measurement program with specific descriptions of validation data sets to be acquired, and (v) a peer review of these EOS validation plans in Fall 1996. This important activity should lead to a better definition of what is, and is not, included within a given science team's validation plan, and where the overlap and gaps are between teams. Through this process, we should obtain a very sound, and affordable, validation program for EOS AM-1 and EOS-supported TRMM science teams (CERES, LIS), with additional teams to be added at a later date.

Finally, I am happy to report that Dr. Carl (Skip) Reber has agreed to serve as Deputy EOS Senior Project Scientist. This position will help me immeasurably, and will greatly benefit both from Skip's experience as UARS (Upper Atmosphere Research Satellite) Project Scientist from 1980-1993, and as senior scientist in the Mission to Planet Earth Office. His duties will include: (i) serving as Vice Chairman of the Performance Evaluation Board for the EOSDIS Core System (Hughes Applied Information Systems) contract, (ii) working closely with various EOS Project Scientists to coordinate algorithm development activities, (iii) working closely with the ESDIS Project and the EOSDIS Panel in reviewing and assessing the progress, and outstanding issues, with the data system, and (iv) being my back-up at innumerable staff meetings and reviews.

—***Michael King***
EOS Senior Project Scientist

Lightning Imaging Sensor (LIS) Science Team Meeting



— **Steven Goodman** (steven.goodman@msfc.nasa.gov), LIS Instrument Scientist, Marshall Space Flight Center

The Lightning Imaging Sensor (LIS) Science Team Meeting was held at the Global Hydrology and Climate Center (GHCC) in Huntsville, AL, on 5-7 June 1995. The primary objectives of the meeting were to discuss algorithm development, calibration/validation plans, geolocation issues, the needs of the science community, and the initial results from the Optical Transient Detector (OTD) experiment. The 35 attendees were offered a tour of the LIS/OTD Science Computing Facility (SCF), a demonstration of interuse tools for browsing OTD data, and a trip to the LIS calibration facility at the Marshall Space Flight Center.

Hugh Christian, LIS Principal Investigator, opened the meeting with a brief status report on the LIS instrument development. LIS is a PI instrument being developed for the NASA Earth Observing System (EOS) as a flight of opportunity aboard the Tropical Rainfall Measuring Mission (TRMM). LIS is scheduled for delivery to the Goddard Space Flight Center (GSFC) in December for integration on the TRMM spacecraft. The TRMM is a joint U.S.-Japan mission scheduled for launch in August 1997. For more information refer to:

1) The LIS Algorithm Theoretical Basis Document (ATBD), available on the World Wide Web at http://spso.gsfc.nasa.gov/spso_homepage.html.

2. The LIS/OTD home page at http://wwwghcc.msfc.nasa.gov:5678/otd.html.

OTD First Results

Christian presented the first results from the OTD experiment. OTD is a scientific payload on the Orbital Sciences Corp. (OSC) MicroLab 1 "small sat" satellite. The MicroLab 1 was launched by a Pegasus rocket in April 1995. The primary mission of the OTD is to improve our understanding of thunderstorm distributions, cloud processes, and storm variability by detecting and locating lightning activity over large areas of the Earth's surface. The nominal orbit is 740 km altitude with a 70° inclination, providing an instantaneous Earth view in excess of 1300 km x 1300 km. In comparison, the LIS on TRMM will have a nominal orbit of 350 km altitude with a 35° inclination and an instantaneous field of view of 600 km x 600 km. The OTD (and LIS) will detect lightning during both daytime and nighttime with spatial resolution of approximately 10 km (4 km) and temporal resolution of 2 milliseconds.

The OTD and satellite data are downlinked approximately twice a day to the OSC tracking station in Fairmont, WV. The data are transmitted from Fairmont via a T1 line to the OSC Science Operations and Control Center (SOCC) located at Dulles, VA. From Dulles, the OTD data are shipped overnight on 8 mm tape to the LIS/OTD SCF at the GHCC. Mission status reports are retrieved from the SOCC using ftp file transfers.

Raw OTD data are archived at the Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Center (DAAC) for Hydrology located at the GHCC . Science data processing and quality assurance are performed within the LIS/OTD SCF. OTD science products will be distributed from the DAAC.

Early results of the OTD experiment were presented at the International Union of Geodesy and Geophysics (IUGG) meeting held in Boulder, CO in July. Oral and poster papers will be presented in Session A10 at the fall American Geophysical Union (AGU) meeting in San Francisco.

OTD plans for FY 1996 are:

- Develop a comprehensive global data base of total lightning activity over land and ocean.
    - ◊ Extend sampling for an entire annual cycle.
    - ◊ Test the hypothesis for extreme ratio of in-cloud lightning-to-ground strokes in severe storms—3 tornadic storm cases so far in the Continental United States (CONUS).
    - ◊ Test hypothesis for the relationship between lightning and graupel/hail production; non-linear relation between cloud height and lightning rates.
- OTD Performance Assessment
    - ◊ Verify instrument concept for detecting lightning during day.
    - ◊ Develop filters for removing ghosts, boom in field of view, glint, and false events caused by South Atlantic Anomaly radiation.
    - ◊ Generate Hierarchical Data Format (HDF) test files and use Science Data Processing (SDP) PGS Toolkit — Compare geolocation using SPICE with ToolKit Version 5.
    - ◊ Continue calibration/validation activities with ground truth sites and increased international collaboration.

OTD Geolocation

The SDP Toolkit was not available to the LIS Science Team in early April when the OTD was launched. Therefore, the LIS Science Team worked in collaboration with the JPL NAIF Team and the EOSDIS Interuse Team at the University of Alabama in Huntsville to use the JPL-developed SPICE tools for OTD geolocation and orbit modeling. Bill Table of JPL presented an overview of the SPICE toolkit and its use in OTD geolocation. Custom software was developed for OTD kernel creation and geometry analysis. The OTD was brought into the SPICE environment quite readily. Having dynamic attitude and ephemeris data prior to launch was an important factor in producing early (within 48 hours) results from the OTD experiment. The Interuse Team presented visualization tools for browsing OTD data and calibration/validation data sets. Sample images are on the LIS/OTD home page.

SSM/I Studies

The LIS/OTD Science Team is collecting coincident observations from the OTD, the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I), geostationary satellite imagery, ground-based lightning networks, and WSR88-D NEXRAD sites to create proxy data sets for the TRMM sensor suite. Ed Zipser (Texas A&M University) presented results from on-going studies using radiances and products, e.g., 85 GHz polarization-corrected temperature (or PCT) to create climatologies of mesoscale weather systems and compare ice scattering signatures with lightning and radar observations. On a global scale we jointly plan on comparing mesoscale weather system structures observed by the SSM/I with the OTD data. Jim Weinman (GSFC) discussed on-going SSM/I and mesoscale model comparisons with the U.K. Meteorological Office long-range, low-frequency (9.8 kHz) lightning network. The LIS/OTD Science Team is using the U.K. system in calibration/validation and performance assessment studies.

Ground Truth and Field Campaigns

The plans of the TRMM ground-truth team were discussed. The LIS/OTD Science Team plans on obtaining additional ground-based lightning observations in the vicinity of the TRMM ground-truth sites having weather radars and a rain gauge networks. Existing lightning sensing systems are providing data from Cape Canaveral, Florida. The LIS/OTD Science

Team will be deploying a lightning network to Darwin, NT Australia in time for the Maritime continent Thunderstorm Experiment (McTEX) being conducted at the Tiwi Islands from November to December 1995 to better understand tropical cloud properties, microphysics, and kinematics. At the conclusion of McTEX, the lightning network will continue in operation on the mainland for the duration of the TRMM project (FY 2000). The system being deployed for McTEX is similar to the system provided by the LIS/OTD Science Team for the TOGA-COARE experiment. An additional lightning network is being considered for the TRMM site at Kwajalein Atoll. Collaborations with NOAA and industry and university scientists will provide additional calibration/validation data bases in the U.S. and overseas.

Lightning and NO_x Production

Each LIS/OTD science meeting attempts to include a special topic or theme for general discussion amongst the participants. At this meeting, we chose "the role of lightning in NO_x production." Recent fall AGU meetings have had papers debating the role of lightning in the global budget of NO_x. Various atmospheric chemists have made inquiries on the existence of global lightning data bases (to support modeling and monitoring studies) and tropical oceanic data bases (to support field campaigns such as Transport and Atmospheric Chemistry near The Equator-Atlantic [TRACE-A] or Pacific Exploratory Mission [PEM]). The LIS/OTD global lightning data bases are expected to greatly improve the lightning data base for such investigations. Colin Price (formerly of the Lawrence Livermore National Laboratory) and Chip Levy II (NOAA/Geophysical Fluid Dynamics Laboratory) discussed their model parameteriations of the NO_x production rate by lightning. Laboratory and *in situ* data suggest a range of 1-100 Tg N per year. The GFDL model uses a production rate of 3 Tg N per year with assumptions that all storms have a single lightning distribution, that all cloud flashes and ground discharges have the same flash energy, and that NO_x production is proportional to flash energy. OTD and ground-based measurements will also help us to better understand the ratio of cloud flashes to ground flashes and factors controlling that ratio.

Multiple Satellite and Coincident Data Collection

One of the objectives of the OTD mission is to collect coincident data sets with other lightning and storm observing systems. For example, prior global lightning distributions at local midnight have been produced from the DMSP satellite Optical Linescan System (OLS). The OLS senses lightning only at night, and with low detection efficiency. OTD coincident observations are being used to help understand the sampling biases in this type of data base. A few coincident case studies have been acquired with the OTD so far.

The ALEXIS/Blackbeard satellite operated by Los Alamos National Laboratory (LANL) senses RF emissions that appear to be associated with thunderstorms. The satellite is in an 800 km, 60° inclination orbit. Tim Murphy of LANL presented Blackbeard observations of the recently discovered Trans Ionospheric Pulse Pair (TIPP) events. The TIPP emission is very different from typical lightning emissions. Collaboration with the LIS/OTD team will attempt to provide coincident OTD measurements to help confirm the coexistence or absence of optical emissions from lightning discharges in the vicinity. Murphy also discussed the status of the planned 1996 launch of the follow-on FORTE satellite. The FORTE spacecraft is unique in that it is an all-carbon-composite structure. FORTE sensors will collect simultaneous RF and optical signals. These data will be made available to the LIS/OTD Science Team.

The LIS/OTD Science Team is also collaborating with the Gamma Ray Observatory (GRO) Burst and Transient Source Experiment (BATSE) Science Team. A number of terrestrial gamma ray flashes have been observed by BATSE in association with thunderstorms. We are on the "look-out" for lightning associated with the storms producing these bursts, using a combination of OTD and ground-based lightning detection systems. An orbit modeling program, initially developed by the DAAC, has been enhanced in the LIS/OTD SCF to predict coincident observation periods for OTD with these various satellites.

There is great interest in the atmospheric chemistry and space physics communities in upward lightning discharges and so-called red sprite and blue jet phenomena in the upper stratosphere and middle atmosphere. OTD coincidence data collection with ground-based and airplane measurements of these phenomena is on-going and planned for the future. An additional opportunity may arise next year for coincident satellite observations of these events. David Pollock of the University of Alabama in Huntsville presented an overview and status of the Midcourse Space Experiment (MSX) mission. The MSX suite of UV and infrared sensors may provide information on various chemical species in the atmosphere as well as information on the temporal and spectral characteristics of sprites. Coincident OTD observations of lightning with these measurements are of interest and will help to further develop the competing theories proposed to explain these phenomena. ■

U.S. Department of Energy Announces Alexander Hollaender Postdoctoral Fellowship Program for 1996

The Alexander Hollaender Postdoctoral Fellow ship Program was established by the Office of Health and Environmental Research (OHER) in 1986 in memory of the late Dr. Alexander Hollaender. The fellowships are tenable at DOE laboratories having substantial research programs supportive of the OHER mission. This mission is directed at understanding the health and environmental effects associated with energy technologies, and developing and sustaining basic and applied research programs at the frontiers of biomedical and environmental sciences in which DOE has responsibilities or unique capabilities. Two of the six research areas are:

Environmental Processes and Effects

- ◊ Atmospheric chemistry and dynamics
- ◊ Physical, chemical, and biological oceanography
- ◊ Terrestrial sciences, including biogeochemistry and hydrogeology
- ◊ Theoretical ecology and ecosystem research

Global Change Research

- ◊ Long-term observation and data management
- ◊ Physical, geological, chemical, biological, economic, and sociological processes impacting Earth System behavior
- ◊ Integrated conceptual and predictive Earth system models
- ◊ Integrated assessments of scientific knowledge and their implications on policy-making decisions

Applicants must have received a doctoral degree in an appropriate discipline after April 30, 1994, or must complete all such requirements prior to starting the appointment. The starting date must be between May 1 and September 30, 1996. Disciplines appropriate to the fellowship program include those in the life, biomedical, and environmental sciences and other supporting scientific disciplines.

For additional information and application material, contact:

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Health Applications of Remote Sensing and Climate Modeling

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Editor's Note: This article is an adaptation of a paper presented to The International Astronautical Federation 46th International Astronautical Congress, Oslo, Norway. The original paper contained numerous citations, only a few of which are shown here. The rest will be supplied by the author on request.

Remote satellite sensing (RS) of the oceans, land masses, ice cover, and atmosphere has been used for understanding biogeochemical cycles and biotic feedbacks. This paper addresses "side effects" of biotic processes that relate to understanding the habitat, ecological dynamics, and climatic forces affecting diseases, their carriers (vectors), and animal reservoirs.

Applications of RS for disease surveillance include: 1) monitoring coastal algal blooms (using the Coastal Zone Color Scanner (CZCS), Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and Advanced Very High Resolution Radiometer (AVHRR)) and **toxic phytoplankton** for a **global cholera and marine biotoxic** Early Warning System (EWS); 2) observing terrestrial applications (using Landsat and Synthetic Aperture Radar (SAR)) for **mosquito and rodent-borne disease** EWS; 3) RS integrated into El Niño/Southern Oscillation (ENSO) models, using the teleconnections for predicting **conditions conducive to disease outbreaks**; 4) using RS as a component of models to project potential disease distribution as a function of **climate change**; and 5) using the Microwave Sounding Unit/High Resolution Infrared Radiation Sounder (MSU/HIRS) to detect tropospheric temperatures to help understand physical and biological changes occurring at **high altitudes.**

Coastal Algal Blooms

Since the 1960s, researchers in Bangladesh have associated the outbreaks of cholera with seasonal coastal algal blooms. Recently, a viable, non-culturable "dormant" form of *Vibrio cholerae* has been identified, which attaches to a wide range of marine life, and reemerges to an infectious state along with algal blooms.

Remote sensing from the CZCS and measurements of sea surface temperatures (SSTs) have been used to assess phytoplankton blooms and primary productivity (Aiken *et al.*, 1992) and are currently used to follow potentially toxic phytoplankton blooms (confirmed with targeted sampling) associated with fish and shellfish poisonings.

Thus one can correlate phytoplankton blooms and their aftermath with the appearance of cholera in coastal populations. Consequently, a system to predict and monitor cholera outbreaks can be devised, and an analysis of existing data can help define uses and requirements for future satellite monitoring systems.

Terrestrial Ecosystems: Eastern Equine Encephalitis (EEE)

Knowing locations of temporary pools of standing water, when they will appear, and perhaps how long they will last, is necessary so that more environmentally appropriate actions can be taken to control the population of EEE-infected *Aedes vexans* mosquitoes in Massachusetts. Early use of Bti (*Bacillus thuringiensis* **var.***israelensis*), a non-toxic, inexpensive larvicide, is the alternative to widespread spraying of the adulticide, malathion. Maturation of larvae to adults occurs in about seven days; therefore, accurate information on standing pools of water after a rain is necessary within two days to allow time for dip sampling and application of Bti (Epstein *et al.*, 1993).

The best approach to creating a dependable set of maps would be the acquisition of remotely sensed images. These and other data layers could then be used together in an appropriate Geographic Information System (GIS) for analysis. "Real-time" information following summer rains, from oblique-angled SAR, can penetrate vegetative and cloud cover to distinguish smooth water surfaces, thus helping to focus dip sampling and application of larvicidal treatment in a timely fashion.

Landsat, with 30 m spatial resolution and coverage every 16 days (at best), or SPOT imagery (which has the advantage of relatively more on-demand coverage and both 20 m and 10 m spatial resolution) will be helpful for developing a series of base-line GIS-generated "risk" maps.

SAR may be most appropriate for providing real-time accurate estimates of the locations of standing water. Aircraft-collected SAR data could be acquired and processed at an appropriate scale and processed for use in a timely fashion.

Remote sensing has also been used to delineate the habitats of the vector-borne diseases (VBDs), including African sleeping sickness (Epstein *et al.*, 1993).

ENSO Teleconnections

Dynamic atmospheric-oceanic coupled general circulation models (AOGCMs) involving remote sensing of sea surface temperatures have multiple applications for predicting conditions conducive to disease outbreaks. Teleconnections of ENSO events are based on the analysis of geographic patterns since 1887 (Glantz *et al.*, 1991).

During an ENSO warm event, specific areas of the globe are consistently affected by drought, while others have excessive precipitation. While Southeast Brazil has rain, for example, the Northeast has intensified drought. The signal is stronger (more consistent) in some areas; Southern Africa repeatedly experiences drought during an El Niño—as is happening again this year. All tropical oceans warm in relation to the ENSO pattern, and evaporation from the Atlantic can flood a warmer Central Europe.

ENSO warm events are correlated with new appearances of harmful algal blooms (HABs) in Asia and along the U.S. Atlantic coast.

Tracking ENSO events and epidemics is a key to unfolding the impacts of climate variability and weather on disease patterns. Associations in themselves are not "proof" of causation; but a preponderance of evidence, globally distributed, and a plausible mechanism (extremes of precipitation and temperature) lend credence to a strong role for climate in disease distribution.

El Niño warm events are associated with upsurges of cholera in Bangladesh; typhoid, shigellosis, and hepatitis in South America (after flooding); viral encephalitides (Murray Valley and epidemic polyarthritis, from Ross River virus) in Australia; and Eastern Equine Encephalitis in Massachusetts.

Other ENSO-related outbreaks of disease include: worldwide distribution of malaria outbreaks (Bouma *et al.*, 1994); malaria in Pakistan; malaria and dengue ('breakbone') fever upsurges in Costa Rica; dengue fever in northeast Brazil; epidemic malaria in the Indian subcontinent, India and Sri Lanka (1874-1945); agricultural rodent infestations in Zimbabwe (1973-1983, 1984); and monsoons (biennially related to ENSOs) directly related to the spread of brown plant hopper (*Nilaparvata lugans*) and rice pest in southeast Asia. Interannual variability may be related to upsurges of soil-borne organisms as well. There were 428 reported cases of San Joaquin Valley fever (due to the fungus *Coccidiomycosis immitis*) in the 1980s, 1200 cases occurred in 1991, and over 4000 in 1992 and 1993. An earthquake and a prolonged drought followed by torrential rains are considered to have been contributory factors.

Additionally, disease events across taxa appear to cluster during ENSO years. Disease events along the

U.S. Atlantic coast during 1987, an ENSO year, heralding the warmest year yet this century, include: a) extensive Caribbean coral bleaching; b) a large Florida sea grass die off; c) agent of neurological shellfish poisoning (*Gymnodynium breve*) transferred from the Gulf of Mexico to North Carolina; d) large die-off of sea mammals in New England (and the North Sea); e) emergence of amnesic shellfish poisoning in Prince Edward Island (new diatom toxin—domoic acid—later appearing worldwide); and f) an outbreak of spruce budworms in NE Canadian balsam forests.

Climate Change

Animals and plants have clear thresholds for viability and temperature and humidity ranges in which they mature, replicate, and thrive (Gill, 1920). Shifts in temperature isotherms in latitude and altitude with climate change could thus have profound impacts on ecotones, on biota and—in particular—on the distribution of pests and pathogens.

Several models using RS/GIS and GCMs have been used to project areas of the world where conditions conducive to vector-borne diseases may change with global warming scenarios. These include malaria, schistosomiasis, and dengue fever. The figure 1 shows the output of one such model for malaria.

High Altitudes

Recent reports indicate that malaria and dengue fever are apppearing at higher latitudes and altitudes than at any time during this century. In addition, plants have been observed to be moving to new altitudes on 26 Alpine peaks, in the U.S. Sierra Nevada and Alaska, and in New Zealand. Moreover, summit glaciers are retreating on many continents, and ice caps show evidence of accelerated warming this century. (Additionally, Antarctica shows signs of instability, with significant breakages in 1995.)

An initial examination of Microwave Sounding Unit (MSU) and HIRS/2 data provided by Joel Susskind of the NASA/Goddard Space Flight Center suggests that, in El Niño years, warming in the upper atmosphere may exceed warming occurring on Earth's surface.

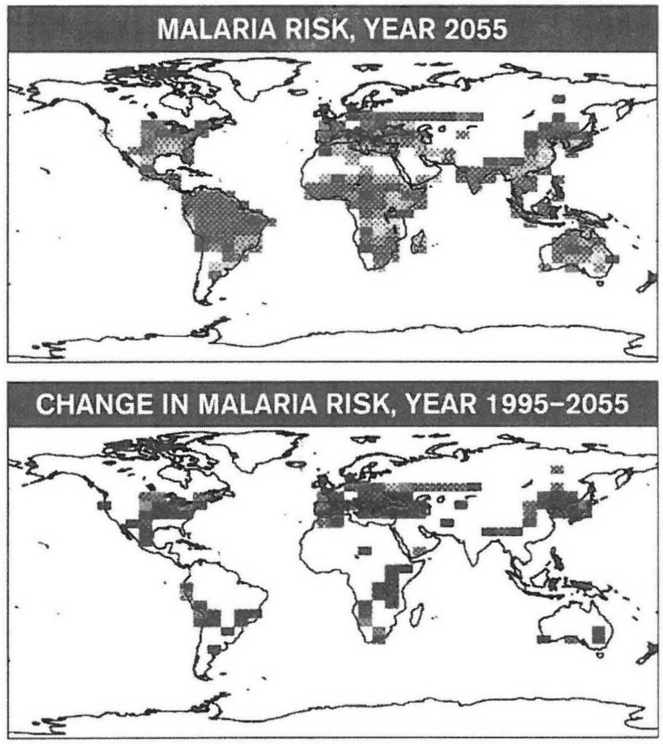

Figure 1. Projected changes in malaria risk associated with potential pattern of global warming

[There are several possible contributing factors to explain these observations. One is the increased relative heat absorption by carbon in the upper troposphere, because it is cooler at higher altitudes. Second, increased tropospheric water evaporation due to deep oceanic warming (SW Pacific, Atlantic, and Indian) (Parilla *et al.*, 1994), and exaggerated during El Niño years (Graham, 1995), may augment greenhouse warming and increase high, heat-trapping, clouds. Third, sulfur-enriched lower clouds may also increase with increased atmospheric water vapor, and may reflect and absorb solar energy and thus cool Earth's surface.]

Conclusions

The costs of not understanding present climate instability and likely changes in climate due to human activities may be enormous. Disease outbreaks cause disability and mortality, and the impacts can ripple through societies and economies. To date, the dengue outbreak has cost Central American nations $7.5 million in control efforts alone; Peruvian fisheries lost $750 million in seafood exports during the 1991 cholera epidemic; and airline and hotel industries lost an estimated $2 billion from the Indian plague last fall. The global resurgence of malaria, dengue fever, and cholera—and emergence of relatively new diseases like Ebola—can impact development, trade and tourism, agriculture, and livestock.

Remote sensing alone or integrated into GISs and GCMs has multiple applications for understanding biological processes and, in particular, disease phenomena. A cholera EWS using RS to detect coastal algal blooms and target surveillance has immediate relevance to protecting populations. Prediction of conditions conducive to VBD outbreaks—associated with climate variability and teleconnections to ENSO events—can also be of use to public health authorities.

Additionally, RS can help project future potential disease distribution due to climate change. Finally, RS can play a central role in a multidisciplinary exploration of current physical and biological changes occurring at high altitudes, thus providing important information on climate trends and their impacts to better inform policymakers.

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Scientists Say El Niño Can Now Be Predicted A Year In Advance

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Recent advances in computer models and how they use ocean data now allow predictions of El Niño — a dramatic climate shift that can affect weather and economies worldwide — to be made more than a year before the event, new NASA, NOAA and university research indicates.

"Certain aspects of El Niño, such as equatorial Pacific sea-surface temperatures and related changes in precipitation patterns can now be predicted with confidence more than one year in advance," said Dr. Antonio Busalacchi of NASA's Goddard Space Flight Center, Greenbelt, MD.

The new study used data from the ten-year Tropical Ocean Global Atmosphere (TOGA) project, an international research program that studied how Earth's oceans and atmosphere affect one another. The team's paper will be published today in the journal *Science*. Busalacchi's co-authors are Dr. Dake Chen, University of Rhode Island, and Dr. Stephen Zebiak and Dr. Mark Cane of Columbia University's Lamont Doherty Earth Observatory, Palisades, NY.

TOGA has successfully completed its decadal mission, and the world legacy of the Tropical Atmosphere Ocean array and all the research infrastructure are in place. New programs will continue to move this research into operational application mode. In November, an "International Forum on Forecasting El Niño" will be held in Washington, DC. The forum will launch an International Research Institute for climate prediction.

El Niño, which can occur every two to seven years, originates in the tropical Pacific ocean and causes global-scale disruptions in normal weather patterns. When an El Niño occurs, torrential rainfall and flooding is common along the coasts of Ecuador, Peru, and southeast Brazil. At the same time, Australia, Indonesia, northeast Brazil, and southeast Africa experience extreme drought and famine conditions.

The impact of El Niño on the continental United States is less direct than in the tropics, but still distinct. Increased precipitation over the Gulf Coast states and warmer winter temperatures over the north-central tier of Gulf Coast states are common, with important implications for the agricultural sector of the economy.

A common indicator of El Niño occurs when the warmest water of the global ocean shifts from the International Dateline in the Pacific eastward by 3,100 miles (5,000 kilometers), increasing sea-surface temperature by 4-7° Fahrenheit (2-4° Centigrade). This eastward migration of a heat source critical to the atmosphere changes global weather patterns, including precipitation and temperature, far beyond the equatorial Pacific.

Forecasts of El Niño have commonly started with scientists introducing ocean-wind data models into a computer model of the ocean, which is then used separately to "force" a model of the atmosphere. At that point the two models are joined, and the likelihood of an El Niño is forecast. The new approach mathematically joins the models before introducing the data. Since the real ocean and atmosphere are closely linked, this approach yields results that lead to a more-accurate forecast.

"That's the breakthrough." said Busalacchi. "This is the first time data are being assimilated into a coupled model, and that's what gives us this expanded forecasting capability. Developing and developed countries are getting this data through one-on-one contacts and through NOAA. They're beginning to use these forecasts to adapt to these events and to mitigate their dangers. Advances such as these suggest that it is time to implement a process to issue El Niño forecasts on a routine basis, so that the affected countries may benefit from this information."

This kind of computer model, and its use to predict changes in the Earth's environment, is the heart of NASA's Mission to Planet Earth and the U.S. Global Change Research Program. A long-term, coordinated research program, Mission to Planet Earth is designed to provide near-term benefits. The program provides improved forecasting of economically threatening climate changes such as El Niño, with improved understanding of the Earth's climate and how it changes.

Mission to Planet Earth combines surface measurements and computer models with space-based measurements to provide a view of the Earth's global environment. Busalacchi's model, for example, will increase in importance when the NASA Scatterometer begins returning worldwide data on sea-surface winds. The instrument is scheduled for launch in August 1996 aboard a Japanese satellite. ■

Workshop on Thermal Remote Sensing of the Energy and Water Balance Over Vegetation in Conjunction with Other Sensors

Report of NASA-EOS, CETP, CEMAGREF, CNES, CNRS, USDA-ARS, ESA-sponsored Workshop held September 20-24, 1993 at la Londe les Maures, France.

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1. INTRODUCTION

The Workshop on Thermal Remote Sensing of the Energy and Water Balance Over Vegetation in Conjunction with Other Sensors was created by a small community of international scientists who felt that the potential of thermal remote sensing of the surface energy balance for studying land surface climate had not been fully realized by the larger scientific community. Various international field programs (FIFE, 1987, 1989; HAPEX-MOBILHY, 1986; MAC-HYDRO '90, MONSOON '90, 1990; HAPEX-SAHEL, 1992) (a list of acronyms appears at the end of this report) have been conducted since 1986 expressly to study the issue of scaling up from point- to regional-scale estimates of the surface energy fluxes over heterogeneous terrain. Still, there have been conflicting results, e.g., Hall *et al.* (1992), on the utility of thermal infrared to satisfactorily resolve important land surface parameters. In light of this, the principal goal of the workshop was to appraise the current state of the science with consideration not just given to thermal infrared measurement but also to consider and incorporate other spectral, e.g., surface reflectivity, and sensor, e.g., radar, data as a means for addressing some of the challenges posed in the area of climate change. Further complexities of terrain, which might consist of a mixture of vegetation (including forests), sloping surfaces, water bodies, bare soil, and urban landscapes were also incorporated into the workshop theme.

This report condenses the contents of the workshop proceedings[1]. It broadly identifies a set of critical problems and/or issues in the field of thermal infrared remote sensing, i.e., electromagnetic measurements within the 8-14 μm window region. It also addresses the use of additional measurements coupled with thermal remote measurements — the so-called synergistic or multispectral approach. We present such topics within the context of the future programs of Mission to Planet Earth/EOS, CNES (French Space Agency), and the European Space Agency (ESA). These agencies intend to employ many new sensors aboard their next-generation satellites.

2. SCIENTIFIC ISSUES

2.1 Determination of Surface Radiant Temperature and Surface Reflectance

The accuracy of the measurements recorded at the satellite sensor (radiometer) is determined by several

[1]Workshop Proceedings (ISBN 2-85362-371-8, 17x24, 330 pages. Price 275FF.) may be ordered from: LAVOISIER, 14 rue de Provigny, 94236 CACHAN Cedex, France. Tel. 33/1 47 40 67 00. FAX: 33/47 40 67 02 or, by contacting Dr. Alain Vidal, CEMACREF-ENGREF, Remote Sensing Lab, 500 rue J.F. Breton, 34093 MONTPELLIER Cedex 5, France. Tel. 33/67 54 87 19. FAX: 33/67 54 87 00 or, Dr. Toby Carlson, Dept. of Meteorology, The Pennsylvania State University, University Park, PA 16802-5094, USA. Tel. (814) 863-1582. FAX: (814) 865-3663.

factors. These are a function of instrument design and the physics which relates the measured quantity (radiance) at the sensor to that at the surface. In general, accurate estimates of surface radiant temperature and reflectance involve calibrating the data into physical units and then correcting the data to account for a host of other effects which are due to the physical properties of the surface and the atmosphere. In addition, other geometric properties of the system, e.g., scan angle of the satellite, have to be considered. Some of the more important of these factors are listed here along with the corresponding workshop recommendations as appropriate.

Sensor Calibration

The fundamental observable in the field of remote sensing is radiance; so sensor calibration is crucial. All attendees at the workshop were in agreement that some type of onboard sensor calibration was ideal. Validation work with *in situ* measurements is being carried out, but these validations are always dependent on atmospheric corrections (see below) since sensor calibration and atmospheric correction cannot be deconvolved in comparisons between ground-based measurements and satellite measurements. Such inter-dependencies mean that it is particularly difficult to make a definitive statement about the overall accuracy of the measurements.

Emissivity

Surface emissivity can vary due to many factors. Moreover, the emissivity in the 8-14 μm window region may differ significantly from the emissivity within smaller spectral bands. In general, the emissivity of land surfaces in the 10-12.5 μm band is slowly varying with wavelength and lies between 0.94-0.98. A reasonable estimate of emissivity for vegetation-soil systems with a leaf area index greater than 0.5 is 0.97 ±0.03; thus, associated uncertainties in temperature measurements are usually less than 1-2° C.

Recommendation: Estimates of emissivity are not a priority when considering vegetation; however, care must be taken when considering partial vegetation cover and variations in emissivity with radiation wavelength.

Sensor and Surface Geometry

Model results in conjunction with measurements indicate that angular effects on the radiant temperature and the reflectivity measurements are certainly significant at the local scale and depend on such factors as the water stress level of the vegetation and the canopy structure. Angular effects seem to be insignificant over dense well-watered vegetation and over many plants such as alfalfa. Over bare soil, e.g., plowed fields, the row effects are noticeable in small-scale measurements. It is not clear at what point the effects related to sensor view angle are manifested in the data or if they are important on the scale of the AVHRR, which has viewing angles in excess of 25 degrees from nadir. It is still not known if, or how, one can use local results to correct satellite data or to what extent the correction is related to other parameters such as emissivity. It may be useful to obtain measurements at different angles (as proposed for next-generation sensors such as AATSR, IRSUTE, and the middle-spatial-resolution optical scanner on PRIRODA). Despite these questions, it was generally felt that multi-angle measurements would improve present methods. Acquisition of measurements at two or three angles would allow some sort of extrapolation to nadir, which could then represent an *a priori* standard value.

Atmospheric Correction

Much of the work reported at the workshop showed generally positive results in comparing satellite-based and ground-based radiant temperatures. Schemes for computing and testing atmospheric corrections depend to some extent on the sensor being used. For sensors with multiple bands, various split-window approaches are generally practicable. Applied initially for sea-surface temperature correction where the split-window coefficients are widely applicable, there is evidence to suggest that local calibration of these coefficients is necessary over land surfaces if desirable precision is to be obtained. For sensors with only one thermal band, one-channel procedures — those which use radiosonde data and a radiative transfer model — are required. In this case, a 1° C accuracy is possible with appropriate local measurements of atmospheric structure. Another approach, proposed for Landsat

TM thermal infrared data, performs an atmospheric correction based upon the surface energy balance, and avoids the requirement for atmospheric or ground-based measurements. For proposed and new sensors with multiple view angle capabilities, e.g., AATSR, techniques involve a combination of bands and view angles to obtain the atmospheric correction. All methods of atmospheric correction for thermal infrared data, however, require knowledge of the surface emissivity and are also a function of viewing angle and the radiometer.

Accuracy of Surface Radiative Temperature Estimation

In general, the measurement error for the surface radiant temperature, considering only those errors associated with instrument calibration, emissivity, angular effects, and atmospheric correction, tends to lie between 2° and 3° C, at best. This raised the question as to whether it would be productive to make corrections of this magnitude if there are multiple sources of error with the same magnitude. For example, the magnitudes of errors in conventional meteorological radiosonde data are also between 1° and 2° C, and so we should not expect to determine radiant temperatures at the surface with an accuracy of much better than 1° C. Corrections which account for errors less than this magnitude are probably not worth considering. Errors of this magnitude are likely to be less serious over dry, bare soil than over unstressed vegetation, where the differences between surface and air temperature are of this magnitude. In addition, limitations in the accuracy of measurements due to the digital nature of instruments employed should be considered.

2.2 Energy Flux Estimation

One of the challenges in thermal infrared remote sensing is to apply such satellite observations to yield land surface parameters. Such data are useful in broader scientific studies associated with the surface energy balance and are important in climate, meteorological, hydrological, ecological, and environmental studies as required input to such modeling, as verification studies, or simply as an improved description of the Earth's surface. Central to this though are some critical issues regarding the capability of thermal remote sensing to infer the surface energy balance to acceptable accuracies.

Improvement in Energy Flux Estimation

There has been substantial progress over the last 15 years in the use of thermal infrared measurements to infer surface energy fluxes (sensible and latent). Many problems with current techniques are related to an inconsistency in the science, i.e., the fact that the aerodynamic temperature (which is used in the formula for computing sensible heat flux) is defined differently from the radiant temperature, which is the measurement from the satellite. Various papers indicated that the inclusion of an additional term (cited in the literature as kB^{-1}) greatly improved the accuracy of the surface energy flux estimates. The kB^{-1} factor is a useful parameter which not only accounts for the difference between aerodynamic and radiant temperatures, but also a combination of other effects — the vertical distribution of thermal radiation fluxes within the vegetation, the angular effect on radiative temperature measurements, energy exchanges between different surfaces (bare soil and vegetation in partial canopies), and perhaps even the effect of surface roughness on the transition layer at the top of the plant canopy. All these factors change with canopy structure and in particular with the leaf area index or the fractional vegetation cover and also with air-surface temperature differences or as a function of scale or viewing angle.

The parameter kB^{-1} is well defined for smooth surfaces. It is, however, more difficult to define for more-complex surfaces such as vegetation canopies and partially vegetated areas. Nevertheless, it is possible to obtain useful bulk estimates of kB^{-1} by comparison with surface field measurements or with a detailed energy balance model; however, such estimates tend to be restricted to the type of surface conditions for which they were obtained. In general, a value of kB^{-1} set at "seven" seems to suit a wide variety of applications over partial vegetation cover, whereas others suggest values closer to "three" for full cover.

Recommendation: The present empirical approach must be reassessed. A more-rigorous analytical approach must be developed for complex surfaces with partial vegetation cover. It was recommended that the FIFE results be re-examined in light of new ideas on the use of kB^{-1}.

Accuracy of Flux Estimates

Accuracy is generally good for high evapotranspiration since the sensible heat flux can be found within 20% accuracy with a model and an infrared surface temperature measurement. Note that this estimate of error pertains to ground level, without including the inherent errors associated with making atmospheric corrections, etc.

The perceived relative accuracy in measuring the correct surface radiant temperature at the regional and local scales is a maximum of 2-3° C when all uncertainties are factored in (1° C gives 10-20% accuracy in the fluxes). Errors in sensible heat flux are likely to be larger in dry conditions but are more important in wet conditions; the reverse is true with regard to evapotranspiration. Anticipated errors of 20% in surface flux estimates are more optimistic than those published by Hall *et al.* (1992). The accuracy of the fluxes depends not only upon the accuracy of the measurement of the surface radiant temperature but also upon other parameters and there are also issues of magnitude to be considered. A target of better than 30% accuracy in the fluxes is certainly realistic and would be considered acceptable given the accuracy of flux measurements is generally 20%. Thus, errors in estimates of kB^{-1} up to 100% may be acceptable to maintain the aforementioned level of accuracy in the surface fluxes.

Validation of Flux Estimates

References were made to the need to validate the estimated surface fluxes with field data. This should be done by using existing data sets such as those from FIFE, 1987, 1989; HAPEX-MOBILHY, 1986 ; MAC-HYDRO '90, MONSOON '90, 1990; and WASHITA '92.

2.3 Scale and Aggregation

Another primary topic that was raised continually was the spatial and temporal scaling of surface radiant temperature measurements and resultant fluxes. This, however, was never satisfactorily resolved, and it was suggested that larger problems lie in understanding the changes in parameters, variables, and functional relationships at the intermediate scale (10 m up to 1 km). This is a particularly relevant question pertaining to the treatment of current and future satellite data.

The complexity that scale introduces lies in the difficulty in defining prerequisite surface parameters, e.g., roughness, air temperature, emissivity, etc., other than the surface radiant temperature, with precision or uniqueness with increasing scale. As a result, it seems that methods applicable to deriving fluxes at the local scale may not be wholly appropriate at the larger scale. Some results presented at the workshop did, however, suggest that for some applications the microscale variability seems to be integrated into the macroscale.

Recommendation: In general, more work is required to understand and develop procedures for scaling up from the canopy scale to regional scales. There is a need to utilize data from large-scale experiments to evaluate new large-scale parameters and variables as well as relationships between them.

3. NEW ITEMS AND CONCEPTS

It seems feasible to use mid-morning temperatures (corresponding to the overpass of Landsat-TM) rather than the later NOAA-AVHRR overpass (≈1400 LST) temperature, without losing much information. However, it may be important to consider and investigate the influence of the onset time for water stress in vegetation. This tends to be limited to the period from roughly 1000 to 1400 hrs.

New sensors will have significantly greater spatial resolution. IRSUTE will have a surface resolution of 50 m; ASTER-90 m ; AATSR/ERS-1 (launched in 1991)-1 km; MODIS-250 m, 500 m, and 1 km; MSG (Meteosat Second Generation)-3 km; and ESA-PRISM-30-50 m. Some of these sensors will also have look-back capability, i.e., viewing at 2 angles, which is an essential addition if improvements in existing techniques are to be made.

It also seems possible to use the relationship between a vegetation index and surface (canopy) radiant temperature to deduce a regional air temperature. This will tend to be very close to the surface radiant temperature in densely vegetated regions, provided that there is no contamination of the pixel by clouds or standing water.

Research has shown the existence of a strong mid-day depression in surface evapotranspiration over stressed vegetation, suggesting that the differences between vegetation temperature and air temperature may be large for a period of time around mid-day during periods of plant water stress. It appears that differences between air and surface temperature can be up to 5° C, which corresponds to theoretical values. Studies suggest, however, that such large differences are not observed in remotely sensed aircraft or satellite measurements.

A water deficit index was presented which extends the crop water stress index to partial canopies.

A new idea brought up independently by several participants in one form or another was that by placing constraints on remotely sensed measurements it is possible to reduce the number of unknown factors, thereby improving the accuracy of estimated parameters. It was suggested that by analyzing patterns of multispectral plots of vegetation indices versus surface radiant temperature, limits can be placed on the data with the aid of physical reasoning and/or numerical models. An example of this constraining technique was demonstrated in the so-called "triangle" (or trapezoid) methods based on the observed (theoretical) plots of vegetation indices versus surface radiant temperature.

Synergy between microwave and optical data would be different for high-resolution, watershed-scale, process-based studies, typically using data with a spatial resolution on the order of 100 meters or better, than the approaches for synergy of these data types using sensors with coarse spatial resolution, e.g., SSM/I and AVHRR.

In this context (taking advantage of different sensors), it is possible to augment measurements in the thermal infrared and gain alternative or supplementary information. For example, Landsat-TM thermal data coupled with ERS-1 radar data can be used to assess, respectively, water stress and small branch water content. Taken together, these factors constitute a reasonable index for the so-called forest "flammability" — the implied susceptibility of forests to fire.

Recommendations : New indices — one should be aware of new indices related to surface conditions. Multi-source approaches — new approaches should involve a combination of different information sources, i.e., multi-spectral, multi-domain and multi-viewing angle sources. The synergy of microwave and optical data should be further explored using available measurements, e.g., FIFE, MONSOON '90, HAPEX and global-scale satellite measurements. It was also recommended that the scientific community study and address the possible problems arising from combining data from different sensors.

4. USE AND APPLICATIONS

A brief attempt was made to classify uses of thermal remote sensing over vegetation, listing the requirements for each application and outlining a hierarchy of models (Carlson *et al.*, 1995) used to obtain the results, i.e., land surface parameters or indices.

In general, all the models can be used to simulate fluxes (hourly or daily) and other variables concerning vegetation, ecosystem, or atmospheric behavior. In addition, some models can simulate thermal infrared temperature and other remote sensing variables — optical reflectance, microwave brightness temperature, and radar backscatter reflectance.

Uses and applications of these models to analyze surface radiant temperature (surface energy fluxes) were presented with regard to equating surface thermal infrared temperatures to surface aerodynamic temperatures (determination of kB^{-1}), simulation of thermal infrared and microwave brightness temperatures, or surface soil water content. Very little emphasis was placed on combining passive microwave measurements with thermal infrared temperatures and vegetation indices. In fact, it was pointed out that any comparison or integration between the two does not seem to have been attempted.

The simulation models can also be used for inverse and assimilation procedures and this topic was discussed extensively. These models may be used to obtain leaf area index and evapotranspiration using measurements of vegetation indices and surface radiant temperatures, but they can also be used as components in crop simulation or hydrological models. Assimilation methods, in which derived parameters are introduced into atmospheric prediction, crop, or hydrological models, have the potential to contribute significantly to these longer-term models.

Recommendations: Satellite data should be assimilated in regional-scale hydrological, meteorological, ecological, environmental, crop, weather forecast models, and climate models as this is the ultimate goal of obtaining the satellite-derived quantities. Such quantities may not be obtainable on an operational basis, but they can be used to update such models as the opportunity arises. Perspectives should be identified precisely for different types of applications, such as land surface climatology, agriculture, and landscape ecology.

5. CONCLUSION

By the end of the workshop, virtually all of the ideas on current and future scientific methodologies that permit conversion of remotely sensed measurements to useful land surface parameters, as well as existing problems and achievements, had been touched upon and discussed in some depth. In general, a strategy that includes thermal infrared temperature measurements in a multispectral/synergistic approach seems to be desirable, if not essential, in future remote sensing endeavors over the land surface. Such approaches furnish additional degrees of freedom which not only improve the accuracy of useful geophysical parameters but also improve our understanding of the underlying processes which control the partitioning of the energy balance at the Earth's surface.

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7. ACRONYM LIST

AATSR	Advanced Along-Track Scanning Radiometer.
AVHRR	Advanced Very High Resolution Radiometer.
CEMAGREF	Centre National du Machinisime Agricole du Genie Rural des Eaux et des Forets (The French Institute for Agricultural and Environmental Engineering Research).
CETP	Centre d'Etudes des Environnements Terrestre et Planétaires.
CNES	Centre National d'Etudes Spatiales (Agence Française de l'Espace).
CNRS	Centre National de la Récherche Scientifique.
ERS-1	European Remote Sensing Satellite.
ESA	European Space Agency.
ESA-PRISM	European Space Agency - Process Research by Imaging Space Mission.
FIFE	First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment (in Kansas, USA).
HAPEX-MOBILHY	Hydrologic Atmospheric Pilot Experiment — Modélisation de Bilan Hydrique (in southwest France).
HAPEX-SAHEL	Hydrologic Atmospheric Pilot Experiment (in west Niger, West African Sahel region).
IRSUTE	Infra Red Satellite Unit for Terrestrial Environment.
Landsat-TM	Landsat Thematic Mapper.
MAC-HYDRO '90	Multisensor Airborne Campaign - Hydrology (in Pennsylvania, USA).
MODIS	Moderate-resolution Imaging Spectroradiometer.
MONSOON '90	Walnut Gulch Experiment Watershed (in Arizona, USA).
MSG	Meteosat Second Generation.
NOAA	National Oceanographic and Atmospheric Administration.
PRIRODA	a remote sensing module designed to be attached to the Russian space station MIR.
SSM/I	Special Sensor Microwave/Imager.
USDA-ARS	United States Department of Agriculture - Agricultural Research Service.
WASHITA '92	Watershed Experiment in Oklahoma. ■

EOSDIS Core System Holds Successful Critical Design Review

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The EOSDIS Core System (ECS) Release A supports the Tropical Rainfall Measuring Mission (TRMM), scheduled for launch August 1997. This first operational release of ECS will be delivered to NASA by December 1996, and provides a core set of functionality that will be enhanced by subsequent releases. The ECS Release A system will provide:

◊ An integrated suite of computers, archival storage, networks, and software to ingest, process, index, and distribute TRMM data products, at an approximate rate of 50 gigabytes per day.

◊ Distributed Active Archive Centers (DAACs) with the capability to store approximately 10 terabytes of data and to provide service annually to thousands of Internet users.

◊ Interfaces for EOS and Landsat-7 satellites.

Consistent with EOS's 15-year observation plan, ECS Release A has a long-term evolutionary architecture to support satellite launches beyond TRMM. The Release A design team must balance system objectives and design drivers against the Release A schedule feasibility, bearing in mind that Release B follows only nine months later.

On August 14-18, 1995, the EOSDIS Core System project completed a highly successful Release A Critical Design Review in its Landover, Maryland facility. Total registration for the Critical Design Review included 350 representatives from Mission To Planet Earth-related NASA organizations, other government agencies, and Earth scientists and computer technologists from several universities.

The ECS Release A team presented details for the design of the Science Data Processing Segment and Communications and System Management Segment. The Science Data Processing Segment design addresses four main areas:

1. *Data Storage and Management — represented by the Data Server Subsystem, which provides the functions needed to archive science data, search for and retrieve archived data, manage the archives, and stage data resources for production.*

A key driver in the architecture of this subsystem is the expected decline in costs for data storage and processing capacities concurrent with improvements in throughput and response times. In the long term, therefore, ECS will be best served with an approach which affords the full capabilities of database management to science data even though this approach cannot be fully implemented in the near future. Therefore, the Data Server Subsystem provides access to Earth science data in an integrated fashion through an Application Programming Interface that is common to all data/information layers. The Release A team has chosen to use Sybase as the Data Base Management System to manage Earth science data and implement spatial searching.

2. *Data Search and Retrieval — represented by the science user interface functions in the Client Subsystem, data search support functions in the Data Management Subsystem, and capabilities in the Interoperability Subsystem which assist users in locating services and data of interest.*

A key driver in the architecture of these subsystems is the need to evolve to meet the needs of a wider user community. Also, ECS should provide the basic underpinning for an Earth science workbench, the assumption being that some of the science community will be in a better position to develop local data visualization, search, and analysis tools that fit into the workbench. The client subsystem software will consist of graphic user interface programs, tools for displaying the various kinds of ECS data, and libraries representing the client Application Programming Interface of ECS services. ECS will also re-use an enhanced version of the Version 0 System Client to provide data search and access functions.

3. *Data Processing — represented by the Data Processing Subsystem, which provides a processing environment for science software; and capabilities for long- and short-term planning of science data processing as well as management of the production environment provided by the Planning Subsystem.*

In the near term, data processing and reprocessing will occur routinely in accordance with the established production plans. However, in the long-term ECS should be able to provide "production on demand," where higher level products are produced only when there is explicit demand for their creation. Release A provides an evolutionary path to a mix of routine production and on-demand processing as users ask for data not currently stored by the data architecture. The need to provide highly scalable and configurable processing resources is the main driver in the hardware architecture. ECS has selected Autosys as a Commercial Off The Shelf (COTS) product for managing production in a distributed, heterogeneous UNIX environment, and Release A is integrating the product with custom software designed to manage distributed, heterogeneous computing resources.

4. *Data Ingest — represented by the Ingest Subsystem, which provides interfaces to external applications, data staging capabilities and storage for a buffer of Level 0 data for approximately one year (so that reprocessing can be serviced from local storage).*

The number of ECS external interfaces is potentially very large, and the interfaces can serve very diverse functions, such as high-volume ingest of Level 0 data and low-volume ingest of data from field campaigns. Thus, the ability to dynamically configure all or a large part of an external interface from standardized components is a key driver of the subsystem's software architecture. Resiliency against failure and loss of ingested data is also a key driver for the hardware configuration.

Science Data Processing Segment applications follow a distributed object-oriented design, where software objects are distributed across many platforms at a given site or across several sites. For the software objects to communicate with each other requires a "distributed object" communications environment. The Communications and System Management Segment design provides this environment using off-the-shelf technology (Object Oriented-Distributed Computing Environment from Hewlett-Packard) augmented with some custom software. The Communications and System Management Segment infrastructure services are based on the Distributed Computing Environment from the Open Software Foundation. In the area of enterprise management, ECS has selected Hewlett-Packard Openview as the centerpiece of its system management solution, and is augmenting it with other commercially available agents, as well as custom-developed software.

During the Critical Design Review (CDR), board members raised issues concerning the ECS operations scenarios screens and DAAC involvement in the screens design; distribution media; support for user services; enterprise management; and several other topics. In response to these concerns, the ECS Release A team has taken a number of actions including: the establishment of an Enterprise Management Concept to explore industry standards and innovations in fault and performance management; publishing the ECS schedule for HDF-EOS development; the addition of 4 mm tapes as a distribution medium; plans to publish an ECS security plan in February 1996; and the ECS Requirements Traceability Matrix to show the mapping from system requirements to certain COTS products.

In addition, ECS Release A team also explored the possibility of extending the functionality of the Autosys/Autoexpert COTS product to replace the custom code planned for the Planning Workbench Component. After more-detailed analysis of the Autosys/Autoexpert capabilities, the ECS Release A team decided that the product was not mature enough to warrant the technical and schedule risk inherent in extending the COTS to Planning Workbench function. They presented the analysis in a meeting in September, 1995 and decided to proceed with the approach presented at the CDR.

Details of the Release A design presented at the review, results of prototypes and trade studies, and the

ECS response to issues raised during the review can be found on the ECS Data Handling System via the World Wide Web at http://edhs1.gsfc.nasa.gov.

After a challenging spring and summer, the ECS team takes pride in its accomplishment: a highly successful Release A Critical Design Review and recommendation to proceed from an extensive review community. We now look to new challenges: the implementation, testing, and deployment of the first ECS operational system. ■

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Supersonic Aircraft Exhaust Measurements To Help Future Ozone, Aircraft Studies

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Environmental scientists and aircraft engineers should benefit from the first direct measurements of an airliner's exhaust at supersonic speed, the results of which are being published this week.

In October 1994, a NASA ER-2 aircraft flew through the trail of an Air France Concorde that was in flight at twice the speed of sound near New Zealand. Instruments aboard the aircraft measured carbon dioxide, water vapor, particles and nitrogen compounds in the exhaust.

Certain nitrogen compounds are a major concern because of their known role in depleting the ozone layer, said David Fahey of NOAA's Aeronomy Laboratory, Boulder, CO, lead author of a paper on the experiment in the October 6 issue of Science. The amounts of these chemicals in the plume were consistent with previous laboratory tests of the Concorde engines, suggesting that pre-flight engine tests are likely to give good estimates of the actual in-flight emissions of new supersonic aircraft.

However, the level of aerosols — very fine droplets or solid particles — in the plume was higher than expected, a result that will also affect the predictions of the impact on the ozone layer. "The result that became evident in this study is that particles could alter the impact of nitrogen oxides on ozone," Fahey said.

Particles form when sulfur in the aircraft fuel is converted, either in the atmosphere or during combustion in the engine, to other forms that may contain a complex mixture of many substances.

From their particle measurements, the authors of the science study calculate that a future possible fleet of 500 supersonic passenger aircraft could increase the surface area of particles in the atmosphere by an amount similar to that following small volcanic eruptions. In the mid-latitudes, such particle emissions may increase ozone loss more than would be expected from nitrogen oxide emissions alone.

The increase in the number of particles may also affect the ozone-related processes occurring on wintertime polar stratospheric clouds (PSCs) in the polar regions. Scientific studies have shown that the Antarctic ozone hole occurs when the ozone depletion caused by human-made chlorine and bromine compounds is enhanced by the presence of PSCs.

Scientists from the National Oceanic and Atmospheric Administration (NOAA), NASA, the French Office National d'Etudes et Recherches Aerospatiales (ONERA), and many universities took part in the experiment. The flight through the Concorde trail took place during an international study of ozone-depletion processes that was conducted throughout 1994 from New Zealand.

The ER-2, loaded with scientific instruments, flew S-patterns along the Concorde flight track, encountering the exhaust plume several times. Because carbon dioxide is the principal product of the jet fuel combustion, the scientists were able to compare the measured amounts of the emitted gases and particles directly with the amount of fuel burned by the Concorde engine. This allows scientists to use the known fuel loads of supersonic aircraft to estimate total emissions of gases and particles to the atmosphere.

Further study will be needed to determine the ultimate effects on stratospheric ozone and to evaluate the effectiveness of possible options for controlling the sulfur content of aircraft fuel. But the first-of-a-kind, direct measurements reported in Science will substantially improve the reliability of those studies.

"We didn't know if we could do this before. Now we do," said NASA's Michael J. Kurylo, who managed the space agency's portion of the ozone research. "We know that this unique suite of instruments, which were developed for atmospheric ozone research, can step up to these critical measurements."

"These results will be especially useful for NASA's High-Speed Research Program," said Howard Wesoky, who manages NASA's program to study the atmospheric effects of aircraft. "HSRP is designed to develop advanced technologies for a future American supersonic transport. The program includes not only efforts to measure the environnmental effects of supersonic aircraft, but also partnerships with industry to develop cleaner-burning engines."

The Concorde study is an example of the effectiveness of international cooperation in the analysis of the atmospheric effects of aviation. Program managers and scientists at NOAA, NASA, ONERA, and universities, seized upon a unique opportunity posed by the timing of the Concorde charter flight and NASA's ER-2 research plane. The Concorde and ER-2 pilots worked closely together to arrange details of the combined aircraft operation. ■

EOSDIS V0 IMS WWW Gateway Version 1.0 Beta

— **Yonsook Enloe** (yonsook@killians.gsfc.nasa.gov), NASA/GSFC, Code 505 Greenbelt, MD 20771.

Version 1.0 Beta of the EOSDIS V0 IMS WWW Gateway has been installed and is now ready for access. Best viewed through Netscape (v1.1N or better) or a HTML 3.0 savvy browser, this version of the Gateway can be found at the following URL: http://eos.nasa.gov/imswelcome.

For the first time via the World Wide Web, this version provides end-to-end functionality,including a basic product ordering capability. Following is a synopsis of the functionality that is now available:

- Inventory Search by: Parameter, Source, Sensor, Dataset ID, Data Center, Date Rangem and Geographic Region
- Dataset Listing
- Granules Listing
- Granules Attribute Comparison
- Integrated Browse
- Access to Definitions
- Guide Information
- Access to Master Directory Information
- Ability to Select Packages for Ordering
- Product Ordering (including User Profile information)
- User Interface Customization
- Comments Facility
- Online, Integrated and Context-sensitive Help

Though some of these services were available in previous versions of the Gateway, many have been modified and improved, and are now available with enhanced capability. Many improvements have resulted from comments that were received from Users.

We encourage you to use the Gateway again, try out the new features, and continue to send us your comments. The Gateway will continue to evolve and improve and we will make new version available as soon as they are ready to be released. The Gateway is now hosted by a server class SGI and is capable of handling a high volume of accesses.

Global Data Sets for Land-Atmosphere Models are Now Available

B. W. Meeson (1,2), **F. E. Corprew** (1,3), **J.M.P. McManus** (1,3), **D.M. Myers** (1,3), **J.W. Closs** (1,3), **K.-J. Sun** (1,3), **D.J. Sunday** (5), **P.J. Sellers** (2,4)

(1) EOSDIS Goddard Distributed Active Archive Center
(2) NASA Goddard Space Flight Center
(3) Hughes STX Corporation
(4) International Satellite Land Surface Climatology Project
(5) Sundancer Communications

A 5-volume CD set of temporally and spatially consistent global data sets for global climate studies is now available free of charge. Responding to needs of modelers, algorithm developers, and field experiment scientists within the land-atmosphere interaction research community, the set's creators compiled a consistent collection of high-priority global data sets using existing data sources and algorithms. These data are currently being used to drive land-atmosphere models and to support soil moisture modeling, modeling of net primary productivity for the terrestrial component of Earth, and global climate models. They may also be used for a wide variety of other research and educational purposes including teaching Earth systems science. We anticipate many more uses for these data.

The data sets on this 5-volume CD set cover five areas:

1. Vegetation
2. Hydrology and Soils
3. Snow, Ice, and Oceans
4. Radiation and Clouds
5. Near-Surface Meteorology

They span the 24-month period 1987-1988, and all but one are mapped to a common spatial resolution and grid (1° x 1°). Temporal resolution for most data sets is monthly. The data within each of these areas were acquired from a variety of sources including model output, satellites, and ground measurements.

What Makes This CD Set Different From Others?

It provides a diversity of parameters in a uniform and consistent manner that has undergone a comprehensive peer review by potential users of these data. This CD set contains a suite of global (1° x 1°) images for 67 parameters derived from satellite and ground measurements, model output, and one ground-based, point measurement data set (river runoff). The full suite of parameters available on these CDs is shown in Table 1 along with the contributing organizations and the temporal resolution of the parameters.

The data were compiled from a variety of sources throughout the world. Several of the parameters that appear here were produced specifically for this CD set, while others were assembled from existing, yet-uncollated data sets or obtained from archives or individuals' private collections.

These data are especially useful because they have a simple structure and a high degree of uniformity, thereby enabling similar handling and use of all the data sets. The data are consistent in composition, format, and documentation. In composition, they have similar temporal and spatial coverages and resolutions and similar fill values, masks, and treatment of holes (Table 2).

The format is identical for all of the data sets except one (river runoff), they are all gridded to exactly the

Table 1

Data Sets on the CD

Notes:

- "Monthly 3-hourly" refers to values that are monthly means of 3-hourly data. Thus, all the 0000Z values for a month are averaged into a single value, also the 0300Z values, etc.
- The snow-free albedo data set in section A is based on NDVI fields and a model calculation; the albedo field in section D is based on ERBE data; and the fields in section E originate from a survey of *in-situ* work.
- The documentation for the vegetation class data in section A includes vegetation morphological and physiological parameters associated with each vegetation type in the SiB2 model of Sellers *et al.* (in prep.).

A. VEGETATION: LAND COVER AND BIOPHYSICS (NASA/GSFC, CSU, U. Maryland)			
NDVI, FASIR-NDVI	Monthly	Background (soil/litter) reflectance (Vis, NIR) *	Fixed
FPAR, LAI, Greenness	Monthly	Vegetation class *	Fixed
Surface roughness, snow-free albedo	Monthly		
B. HYDROLOGY AND SOILS (GPCP, GRDC, U. Arizona, Trent U., NCAR, FAO, NASA/GSFC, NASA GISS)			
Precipitation (GPCP)	Monthly	Lake, river, marsh cover percentage *	Fixed
River runoff (GRDC; 14 basins)	Monthly	Soil texture, depth, slope *	Fixed
C. SNOW, ICE AND OCEANS (NOAA/NESDIS, Rutgers U., NCAR, FAO, NASA/GSFC, NASA GISS)			
Snow cover	Weekly	Sea ice, SST *	Monthly
Snow depth	Monthly	Land-ocean boundary *	Fixed

D. RADIATION AND CLOUDS (U. of Maryland, NASA/LaRC, ISCCP, NASA/GISS)	
Surface and TOA incoming and outgoing shortwave shortwave	Monthly 3-hourly
Surface incoming PAR fluxes	Monthly 3-hourly
Surface incoming shortwave and longwave radiation fluxes	Monthly
Surface net shortwave, net longwave, net radiation fluxes *	Monthly
Cloud amount, cloud top pressure *	Monthly
Optical thickness, water path *	Monthly
Clear-sky albedo (ERBE) *	Monthly
E. NEAR-SURFACE METEOROLOGY (ECMWF, NASA/GSFC, NOAA/NMC, NASA/LaRC, GPCP)	
(i) Prescribed/diagnostic fields	
Soil moisture	Monthly
Deep soil temperature and soil wetness	Monthly
Snow depth	Monthly
Albedo, surface roughness	Fixed
(ii) Monthly 6-hourly forcing fields	
Surface pressure, air temperature,dew point	Monthly 6-hourly
Surface temperature	Monthly 6-hourly
Mean sea level pressure	Monthly 6-hourly
u, v wind speed and stress	Monthly 6-hourly
Surface sensible and latent heat fluxes *	Monthly 6-hourly
Net surface and TOA shortwave, longwave fluxes *	Monthly-6 hourly
(iii) Diurnally-resolved (6-hourly) forcing fields *	
Surface pressure, air temperature, dew point, wind magnitude *	6-hourly
Hybrid longwave and shortwave incoming radiation fluxes *	6-hourly
Hybrid total precipitation and convective precipitation *	6-hourly

*=temporal resolutions

same grid, and the format is extremely simple (ASCII and ISO 9660 standards are used throughout), so that no platform-dependent hardware or software is required to use them. Finally, the documentation uses a common outline for all data sets (Table 3).

To illustrate this consistency, examples of parameters from each of the five groups listed above are shown in Figure 1.

Table 2. Uniformity of Data Files

DATA
- All same time period: 1987-1988
- Temporal resolution, driven by models
  - † Most Monthly; some Monthly 3 hrly, Monthly 6 hrly, and 6 hrly
- All same coverage; Global
- All same grid scale; 1° x 1°
- All same fill values
- Most no holes (i.e., no missing values)
- All same land/sea mask

FORMAT
- All in exactly the same format
- All gridded to the same grid
- Format extremely simple
- Requires no special software to read

DOCUMENTATION
- All are thoroughly and uniformly documented

Table 3. Standardized Documentation Format for the Data Sets

1. TITLE
   - 1.1 Data Set Identification
   - 1.2 Data Base Table Name
   - 1.3 CD-ROM File Name
   - 1.4 Revision Date of this Document
2. INVESTIGATOR(S)
   - 2.1 Investigator(s) Name and Title
   - 2.2 Title of Investigation
   - 2.3 Contacts (for Data Production Information)
   - 2.4 Requested Form of Acknowledgment
3. INTRODUCTION
   - 3.1 Objective/Purpose
   - 3.2 Summary of Parameters
   - 3.3 Discussion
4. THEORY OF MEASUREMENTS
5. EQUIPMENT
   - 5.1 Instrument Description
   - 5.2 Calibration
6. PROCEDURE
   - 6.1 Data Acquisition Methods
   - 6.2 Spatial Characteristics
   - 6.3 Temporal Characteristics
7. OBSERVATIONS
   - 7.1 Field Notes
8. DATA DESCRIPTION
   - 8.1 Table Definition with Comments
   - 8.2 Type of Data (Parameters, Units, Range)
   - 8.3 Sample Data Record
   - 8.4 Data Format
   - 8.5 Related Data Sets
9. DATA MANIPULATION
   - 9.1 Formulas
   - 9.2 Data Processing Sequence
   - 9.3 Calculations
   - 9.4 Graphs and Plots
10. ERRORS
    - 10.1 Sources of Error
    - 10.2 Quality Assessment
11. NOTES
    - 11.1 Known Problems With the Data
    - 11.2 Usage Guidance
    - 11.3 Other Relevant Information
12. REFERENCES
    - 12.1 Satellite, Instrument, Data Processing Documentation
    - 12.2 Journal Articles and Study Reports
    - 12.3 Archive, DBMS Usage Documentation
13. DATA ACCESS
    - 13.1 Contacts for Archive, Data Access Information
    - 13.2 Archive Identification
    - 13.3 Procedures for Obtaining Data
    - 13.4 Archive, Status, Plans
14. OUTPUT PRODUCTS AND AVAILABILITY
    - 14.1 Tape Products
    - 14.2 Film Products
    - 14.3 Other Products
15. GLOSSARY OF ACRONYMS

Users of these CDs can feel confident that at publication in April 1995 these data represented the best

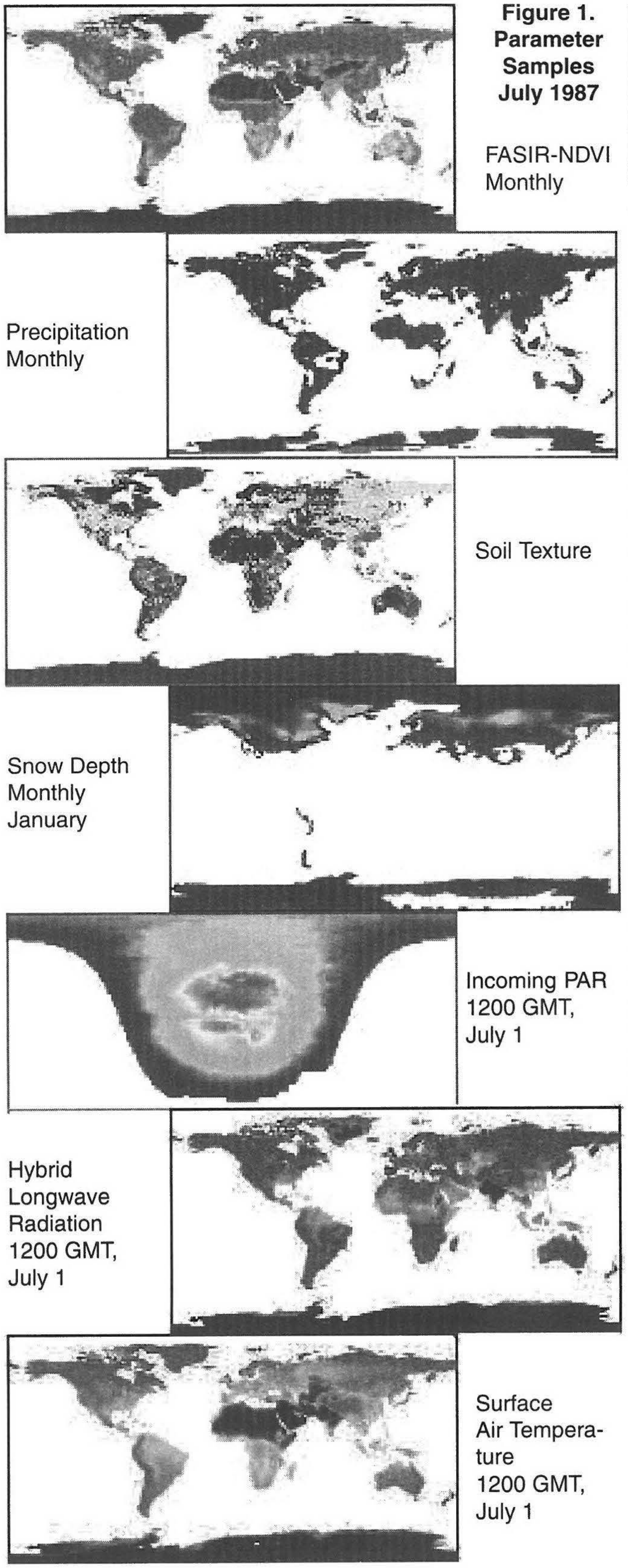


Figure 1. Parameter Samples July 1987

global data available for each parameter covered herein for the 1987-1988 period. These data and companion documentation have gone through an extensive five-stage peer-review process by current and potential users that included individual hands-on use of individual data sets and workshops where data sets were compared for consistency. Where reviewers deemed necessary, corrections to data sets and documentation were made to address their comments. Moreover, a formal peer review is published on the CD to address items found during the reviews whose corrections were not considered essential before publication.

Browse Sample Data and Documentation

Uncertain if these CDs meet your need? You can examine the documentation and browse sample images from the publisher's World Wide Web page. Just connect to the following URL address: http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/ISLSCP/islscp_i1.html

Note: The URL address is case sensitive, so enter it exactly as shown here.

How To Obtain the Free CD Set

Call, FAX, or send e-mail to the NASA Goddard Space Flight Center Distributed Active Archive Center (DAAC) help desk or connect to our above-mentioned World Wide Web page to place an online order. These data are free. There is no charge.

NASA Goddard Space Flight Center
Goddard DAAC Help Desk
Code 902.2
Greenbelt, MD 20771
Voice: (301) 286-3209
FAX: (301) 286-1775
e-mail: daacuso@daac.gsfc.nasa.gov

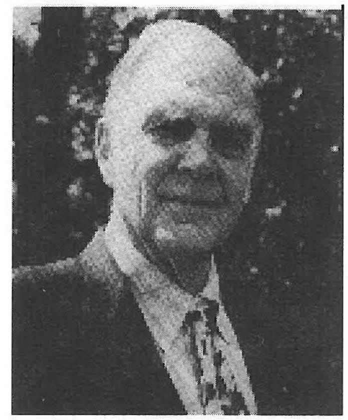
Acknowledgments

The support of NASA Headquarters; Office of Mission to Planet Earth; the Operations, Data, and Information Systems Division; and the Science Division are gratefully acknowledged. ■

EARTH SCIENTISTS AWARDED NOBEL PRIZE IN CHEMISTRY

Professor Paul Crutzen

Professor Mario Molina



Professor F. Sherwood Rowland

Reprinted from The Nobel Foundation homepage (URL: http://WWW.nobel.se)

The Royal Swedish Academy of Sciences has decided to award the 1995 Nobel Prize in Chemistry to

Professor **Paul Crutzen**, Max-Planck-Institute for Chemistry, Mainz, Germany (Dutch citizen)

Professor **Mario Molina**, Department of Earth, Atmospheric and Planetary Sciences and Department of Chemistry, MIT, Cambridge, MA, USA

Professor **F. Sherwood Rowland**, Department of Chemistry, University of California, Irvine, CA, USA

for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

THE OZONE LAYER — THE ACHILLES HEEL OF THE BIOSPHERE

The atmosphere surrounding the earth contains small quantities of ozone — a gas with molecules consisting of three oxygen atoms (O_3). If all the ozone in the atmosphere were compressed to a pressure corresponding to that at the Earth's surface, the layer would be only 3 mm thick. But even though ozone occurs in such small quantities, it plays an exceptionally fundamental part in life on Earth. This is because ozone, together with ordinary molecular oxygen (O_2), is able to absorb the major part of the sun's ultra-violet radiation and, therefore, prevent this dangerous radiation from reaching the surface. Without a protective ozone layer in the atmosphere, animals and plants could not exist, at least upon land. It is, therefore, of the greatest importance to understand the processes that regulate the atmosphere's ozone content.

Paul Crutzen, **Mario Molina** and **Sherwood Rowland** have all made pioneering contributions to explaining how ozone is formed and decomposes through chemical processes in the atmosphere. Most importantly, they have in this way showed how sensitive the ozone layer is to the influence of anthropogenic emissions of certain compounds. The thin ozone layer has proved to be an Achilles heel that may be seriously injured by apparently moderate changes in the composition of the atmosphere. By explaining the chemical mechanisms that affect the thickness of the ozone layer, the three researchers have contributed to our salvation from a global environmental problem that could have catastrophic consequenses.

How this knowledge evolved

Ozone is formed in the atmosphere through the splitting of ordinary oxygen molecules (O_2) by ultraviolet radiation from the sun. The oxygen atoms thereby liberated react with the molecular oxygen according to :

$$O_2 + \text{uv-light} \Rightarrow 2O$$
$$O + O_2 + M \Rightarrow O_3 + M$$

where M is a random air molecule (N_2 or O_2).

The English physicist Sidney Chapman formulated in 1930 the first photochemical theory for the formation and decomposition of ozone in the atmosphere. This theory, which describes how sunlight converts the various forms of oxygen from one to another, explains why the highest contents of ozone occur in the layer between 15 and 50 km, termed the ozone layer (Fig. 1). Later measurements, however, showed appreciable deviations from Chapman's theory. The calculated ozone contents were considerably higher than the observed ones. Thus, there must be other chemical reactions contributing to the reduction of the ozone content. Some years later the Belgian Marcel Nicolet contributed important knowledge of how the decomposition of ozone was enhanced by the presence of the hydrogen radicals OH and HO_2.

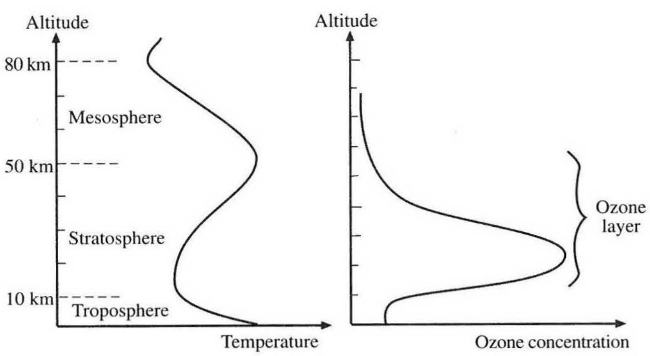


Fig. 1. Variation in temperature and ozone concentration up through the atmosphere

The scientist to take the next fundamental step towards a deeper understanding of the chemistry of the ozone layer was Paul Crutzen. In 1970 he showed that the nitrogen oxides NO and NO_2 react catalytically (without themselves being consumed) with ozone, thus accelerating the rate of reduction of the ozone content.

$$NO + O_3 \Rightarrow NO_2 + O_2$$
$$NO_2 + O \Rightarrow NO + O_2$$
$$O_3 + \text{uv-light} \Rightarrow O_2 + O$$

Net result: $2O_3 \Rightarrow 3O_2$

These nitrogen oxides are formed in the atmosphere through the decay of the chemically stable nitrous oxide N_2O, which originates from microbiological transformations at the ground. The connection demonstrated by Crutzen between microorganisms in the soil and the thickness of the ozone layer is one of the motives for the recent rapid development of research on global biogeochemical cycles.

The first threat noted: supersonic aircraft

The power of nitrogen oxides to decompose ozone was also noted early by the American researcher Harold Johnston, who carried out extensive laboratory studies of the chemistry of nitrogen compounds. In 1971 he pointed out the possible threat to the ozone layer that the planned fleet of supersonic aircraft and supersonic travel (SST) might represent. These aircraft would be capable of releasing nitrogen oxides right in the middle of the ozone layer at altitudes of 20 km. Crutzen's and Johnston's work gave rise to a very intensive debate among researchers as well as among technologists and decision-makers. This was also the start of intensive research into the chemistry of the atmosphere which has made great progress during the past several years. (The subsequent cancellation of plans for a large SST fleet had other reasons than the environmental risks they involved.)

Spray cans and refrigerators damage the ozone layer

The next leap in our knowledge of ozone chemistry was in 1974, when Mario Molina and Sherwood Rowland published their widely noted Nature article on the threat to the ozone layer from chlorofluorocarbon (CFC) gases - "freons" - used in spray bottles, as the cooling medium in refrigerators and elsewhere and plastic foams. Molina and Rowland based their conclusions on two important contributions by other researchers: James Lovelock (England) had recently developed a highly sensitive device of measuring extremely low organic gas contents in the atmosphere, the electron capture detector. Using this he could now demonstrate that the exclusively man-made, chemically inert, CFC gases had already spread globally throughout the atmosphere. Richard Stolarski and Ralph Cicerone (USA) had shown that free chlorine atoms in the atmosphere can decompose ozone catalytically in similar ways as nitrogen oxides do.

Molina and Rowland realized that the chemically inert CFC could gradually be transported up to the ozone layer, there to be met by such intensive ultraviolet light that they would be separated into their constituents, notably chlorine atoms. They calculated that if human use of CFC gases was to continue at an unaltered rate the ozone layer would be depleted by many percent after some decades. Their prediction created an enormous attention, for the CFC gases were used in many technical processes and their very chemical stability and non-toxicity were thought to render them environmentally ideal. Many were critical of Molina's and Rowland's calculations but yet more were seriously concerned by the possibility of a depleted ozone layer. Today we know that they were right in all essentials. It was to turn out that they had even underestimated the risk.

Ozone content over Antarctica

Molina's and Rowland's report led to certain restrictions on CFC release during the late 1970s and early 1980s. Not until 1985, when the real shock came, was there any real urgency in the international negotiations on release restrictions. Then the Englishman Joseph Farman and his colleagues noted a drastic depletion of the ozone layer over the Antarctic, the "ozone hole" (Fig. 2). The depletion was, at least periodically, far greater than expected from earlier calculations of the CFC effect. The debate among researchers now intensified. Was this a natural climatic variation or was it chemical decomposition brought about by mankind? Thanks to pioneering research by many researchers, among them Crutzen, Molina and Rowland, as well as Susan Solomon and James Anderson, both from the USA, the picture has now cleared. The depletion is caused chiefly by ozone reacting chemically with chlorine and bromine from industrially manufactured gases.

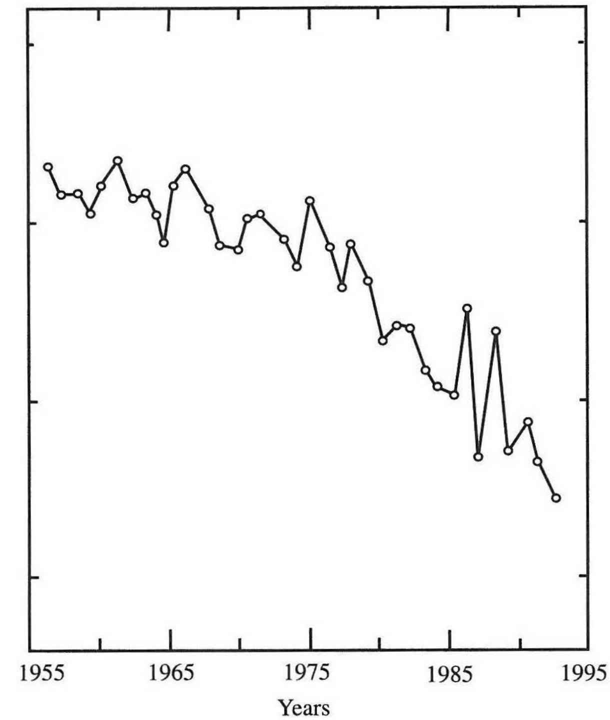


Fig. 2. Thickness of the ozone layer (mean monthly value for October) over Halley Bay, Antarctica. Note the drastic depletion since the end of the 1970s.

The surprisingly rapid depletion of the ozone layer over Antarctica could not be explained by transport processes or by gas phase chemical reactions. An alternative mechanism must exist which could accelerate the decomposition of ozone. Crutzen and colleagues identified this mechanism as chemical reactions on the surface of cloud particles in the stratosphere. Thus, the Antarctic ozone depletion appears to be connected with the extremely low prevailing temperatures, which lead to condensation of water and nitric acid to form "polar stratospheric clouds" (PSCs). The ozone-decomposing chemical reactions are greatly reinforced by the presence of cloud particles. This understanding has led to an exciting new branch of atmospheric chemistry: "heterogeneous" chemical reactions on particle surfaces.

The ozone layer and the climate

The ozone problem also has interesting connections with the issue of how mankind is affecting the climate. Ozone, like carbon dioxide and methane, is a greenhouse gas that contributes to high temperatures at the surface of the Earth. (CFC gases have a similar effect.) Model calculations have shown that the climate is specially sensitive to changes in the ozone content in the lower layers, the troposphere. Here the ozone content has increased markedly during the past century, chiefly because of the release of nitric oxide, carbon monoxide and gaseous hydrocarbons from vehicles and industrial processes and from the combustion of biomass in the tropics. The elevated ozone content in lower atmospheric layers is itself an environmental problem for the damage it can cause to crops and human health. Paul Crutzen has been the world's leading researcher in mapping the chemical mechanisms that determine the ozone content at these levels.

What can we expect in the future?

Thanks to our good scientific understanding of the ozone problem (and very largely to Crutzen, Molina and Rowland) it has been possible to make far-reaching decisions on prohibiting the release of gases that destroy ozone. A protocol on the protection of the ozone layer was negotiated under the auspices of the United Nations and signed in Montreal, Canada, in 1987. Under the latest tightening-up of the Montreal Protocol, the most dangerous gases will be totally banned from 1996 (developing countries have a few years' grace to introduce substitutes that do not harm the ozone layer). Since it takes some time for the ozone-destroying gases to reach the ozone layer we must expect the depletion, not only over Antarctica but also over parts of the Northern Hemisphere, to worsen for some years to come. Given compliance with the prohibitions, the ozone layer should gradually begin to heal after the turn of the century (Fig. 3). Yet it will take at least 100 years before it has fully recovered.

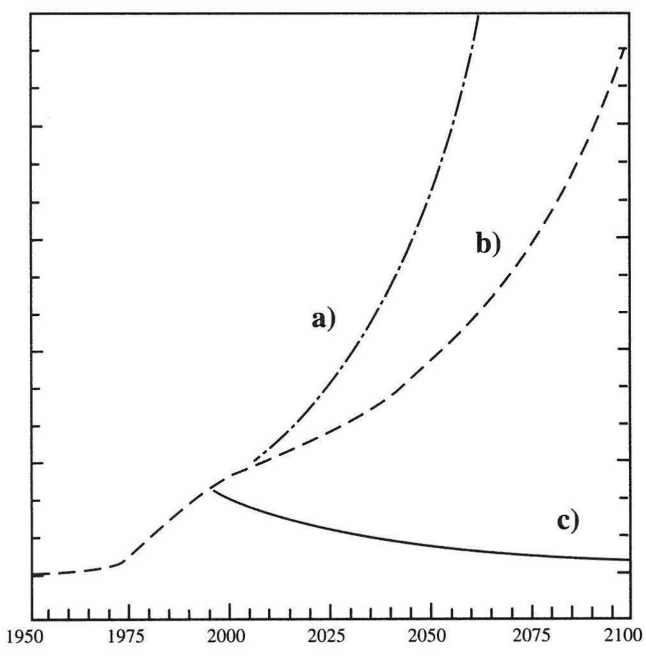


Fig. 3. Change in the chlorine content in the stratosphere up to the present and three different future scenarios:
- **a) Without restrictions on release,**
- **b) Limitations according to the original Montreal Protocol of 1987**
- **c) The release limitations now internationally agreed. (Chlorine content is a measure of the magnitude of ozone depletion.)**

Paul Crutzen was born in 1933 in Amsterdam. Dutch citizen. Doctor's degree in meteorology, Stockholm University, 1973. Member of the Royal Swedish Academy of Sciences, the Royal Swedish Academy of Engineering Sciences and Academia Europaea.

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Max-Planck-Institute for Chemistry
P. O. Box 3060
D-55020 Mainz, Germany.

Mario Molina was born in 1943 in Mexico City, Mexico. PhD in physical chemistry, University of California, Berkeley. Member of the U.S. National Academy of Sciences.

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F. Sherwood Rowland was born in Delaware, Ohio, USA, 1927. Doctor's degree in chemistry, University of Chicago, 1952. Member of the American Academy of Arts and Sciences and of the U.S. National Academy of Sciences, where he is currently Foreign Secretary.

Professor F. Sherwood Rowland
Department of Chemistry
University of California
Irvine, CA 92717, USA ■

1996 USRA/GSFC Graduate Student Summer Program In Earth System Science

— **Paula Webber (paula@gvsp.usra.edu)**, USRA/Student Programs Coordinator

The Universities Space Research Association, in collaboration with the NASA/Goddard Space Flight Center's Earth Sciences Directorate, is offering a limited number of graduate student research opportunities for the Summer of 1996. The Program is scheduled for June 6 to August 14, 1996. Now in its sixth year, the program is designed to spur interest in interdisciplinary studies within the Earth system sciences, and will enable selected students to pursue specially-tailored research projects in conjunction with Goddard scientific mentors.

Students will work at GSFC conducting an intensive research project for the majority of the Program period. Project topics will be developed and implemented in conjunction with NASA scientist mentors within the three Earth Science laboratories at Goddard: The Laboratory for Atmospheres, The Laboratory for Hydrospheric Processes, and The Laboratory for Terrestrial Physics.

Five days (June 10-14, 1996) of the Program will be dedicated to an intensive public lecture series entitled "Global Change and The Americas." The series is designed to provide a comprehensive introduction to the science and techniques of remote sensing and satellite observations. Well-known experts from Goddard and the community will present lectures on the remote sensing, atmospheric, oceanographic, biological and societal impact aspects of Global Change. One day will be devoted to each of these major topics. The lecture series is an annual event sponsored by USRA and NASA/GSFC. It is open to the general public; however, off-site attendees must register prior to June 3 in order to guarantee admittance to the Goddard Space Flight Center. There is no registration fee.

The program is open to students enrolled in or accepted to a U.S. accredited graduate program in the Earth, physical or biological sciences, mathematics, computer science, or engineering. Students will be selected on the basis of academic record, demonstrated motivation and qualification to pursue multidisciplinary research in the Earth sciences, clarity and relevance of stated research interests to NASA programs, and letters of recommendation. Minorities and women are encouraged to apply. Students must commit for the full-ten week period (June 6 - August 14, 1996). Because of NASA/GSFC security regulations, citizens of certain proscribed nations may be ineligible.

Students selected for the Program will receive a stipend of $8.50 per hour for the 10-week period. In addition, USRA will reimburse reasonable domestic travel expenses for participants needing to relocate to the Greenbelt, MD area. Students requiring accommodations will be housed at The University of Maryland at USRA's expense. Accommodations outside the university will not be provided.

Contact Ms. Paula Webber at the address below to receive a formal application. Along with the application, an updated resume, at least two letters of reference, and undergraduate/graduate transcripts must be received by February 12, 1996. Selectees will be announced by March 22, 1996.

Ms. Paula L. Webber
Program Coordinator
USRA/GSSP
7501 Forbes Boulevard, Suite 206
Seabrook, MD 20706
(301) 805-8396 phone
(301) 805-8466 fax
paula@gvsp.usra.edu

USRA is an equal opportunity/affirmative action employer. Minorities and women are encouraged to apply. ■

Science Calendar

• 1996 •

January 17-19	SAGE III Science Algorithm Review, NASA/Langley Research Center, Hampton, VA. Contact Lelia Vann (l.b.vann@larc.nasa.gov) at (804) 864-9356.
February 27-29	AIRS Science Team meeting, Santa Barbara, CA. Contact George Aumann (hha@airs1.jpl.nasa.gov).
March 1996 (Date TBD)	EOS Investigators Working Group (IWG). Contact Kelly Whetzel (whetzel@ltpmail.gsfc.nasa.gov) at (301) 220-1701.

Global Change Calendar

• 1996 •

Jan. 28-Feb. 2	American Meteorological Society (AMS), Atlanta, GA. Contact Monica Walters, Tel. (202) 466-6070, FAX: (202) 466-6073.
February 8-13	American Association for the Advancement of Science (AAAS) Annual Meeting, Baltimore, MD, Contact Suzanne Snyder, Tel. (703) 671-1400, FAX: (703) 671-7695.
February 27-29	Eleventh Thematic Conference on Geologic Remote Sensing, Las Vegas, Nevada. Contact Robert Rogers, ERIM, Box 134001, Ann Arbor, MI 48113-4001. Tel. (313) 994-1200, ext. 3453; FAX: (313) 994-5123; e-mail: raeder@vaxc.erim.org.
March 5-8	Oceanology International 96 — The Global Ocean, Brighton, UK. Contact Bob Munton at Bob_Munton@spearhead.co.uk.
March 6-8	ISPRS Workshop on New Developments in Geographic Information Systems, Milan, Italy. Call for Papers. Contact James B. Johnston, Tel. (318) 266-8556, FAX: (318) 266-8616, e-mail: johnstonj@nwrc.gov.
March 25-29	8th Australasian Remote Sensing Conference, Canberra ACT. Call for Papers. Contact Secretariat: ACTS, GPO Box 2200, Canberra ACT 2601, Tel. (06) 257-3299, FAX: (06) 257-3256, e-mail: acts@ozemail.com.au.
April 8-9	IEEE Southwest Symposium on Image Analysis and Interpretation, San Antonio, TX. Call for Papers. Contact Jeff Rodriquez (rodriquez@ece.arizona.edu), Tel. (520) 621-8732, FAX: (520) 621-8076. For further information see URL: http://www.ece.arizona.edu/conferences/swsymp96.
April 9-13	AAG Conference, Charlotte, NC. Contact Kevin Fitzpatrick, Tel. (202) 234-1450, FAX: (202) 234-2744, e-mail: GAIA@AAG.ORG.
April 22-24	ASPRS/ACSM Annual Convention, Baltimore, MD. Contact Convention Coordinator, 5410 Grosvenor Lane, Suite 100, Bethesda, MD 20814.
May 12-15	ICASSP '96, Atlanta, GA. For information see WWW at http://www.ee.gatech.edu/conferences/icassp96 or e-mail: icassp96-info@eedsp.gatech.edu.
May 27-31	1996 International Geoscience and Remote Sensing Symposium (IGARSS'96), Lincoln, NE. Call for papers. See IGARSS'96 WWW at http://doppler.unl.edu/igarss96, e-mail: stein@harc.edu, Tel. (713) 291-9222, or FAX: (713) 291-9224.
June 4-7	Ninth Annual Towson State University GIS Conference, Baltimore, MD. Contact Jay Morgan, Tel. (410) 830-2964, FAX: (410) 830-3888, e-mail: e7g4mor@toe.towson.edu.
June 17-21	Second International Scientific Conference on the Energy and Water Cycle, Washington, D.C. Contact International GEWEX Project Office at (202) 863-0012, e-mail: gewex@cais.com or Judy Cole, e-mail: cole@stcnet.com, FAX: (804) 865-8721.
June 24-27	Second International Airborne Remote Sensing Conference and Exhibition: Technology, Measurements, and Analysis, San Francisco, CA. Contact Robert Rogers, ERIM Conferences, Box 134001, Ann Arbor, MI 48113-4001; Tel. (313) 994-1200, ext. 3234, FAX: (313) 994-5123, e-mail: raeder@erim.org. Infromation available on WWW at http://www.erim.org/CONF/.

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