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Editor's Corner

NASA has renamed the Mission to Planet Earth enterprise the Earth Science Enterprise. The Earth Science Enterprise is one of four strategic enterprises of the Agency, and is responsible for a long-term, coordinated research effort to study the total Earth system and the effects of natural and human-induced changes on the global environment. The Earth Science Enterprise is pioneering the emerging discipline of Earth system science, with a near-term emphasis on global climate change. As before, its goals are to expand scientific knowledge of the Earth system using NASA's unique vantage points of space, aircraft, and *in situ* platforms, thereby creating an international capability to forecast and assess the health of the Earth system; to widely disseminate information about the Earth system; and to enable the productive use of Earth science results and related technology in the public and private sectors.

The title "Mission to Planet Earth" originated ten years ago in a report on future directions for the U.S. civil space program by a commission led by former astronaut, Dr. Sally Ride. The term and concept of looking at the Earth as NASA looks at other planets were furthered by the *1990 Report of the Advisory Committee on the Future of the U.S. Space Program*, prepared by a team of experts chaired by Dr. Norman Augustine. Since that time, NASA has organized its activities into four strategic enterprises, including, in addition to the Earth Science Enterprise, Human Exploration and Development of Space, Aeronautics and Space Transportation, and Space Science.

NASA has selected Ball Aerospace and Technologies Corporation, Boulder, CO, to provide the satellite system for the Ice, Cloud, and land Elevation Satellite (ICESat-1),

now scheduled for launch in July 2001. Along with placing only the second delivery order under the Indefinite Delivery/Indefinite Quantity (ID/IQ) procurement method, NASA has chosen to rename the Laser Altimetry-1 mission ICESat-1 to more accurately denote its primary purpose of monitoring the elevation of glacier ice, clouds, and terrestrial vegetation. (See press release on page 15.)

On February 1, George Morrow was appointed EOS PM-1 Project Manager, replacing Marty Donohoe, who retired in early December. Prior to this assignment, Mr. Morrow served as Deputy Associate Director of Flight Projects for Hubble Space Telescope (HST), assisting in the overall management of HST hardware development, servicing activities, and ongoing operations. Prior management assignments included Deputy Project Manager for HST Flight Systems and Servicing and HST Observatory Manager. His technical expertise lies in battery systems, and he led the design, fabrication, and test efforts for flight Nickel-Cadmium and Nickel-Hydrogen battery systems for all Goddard Space Flight Center projects, including the Earth Radiation Budget Satellite, Landsat, Cosmic Background Explorer, Gamma Ray Observatory, Upper Atmosphere Research Satellite, and HST. The PM-1 spacecraft and instruments are now in development and on schedule for launch in December 2000.

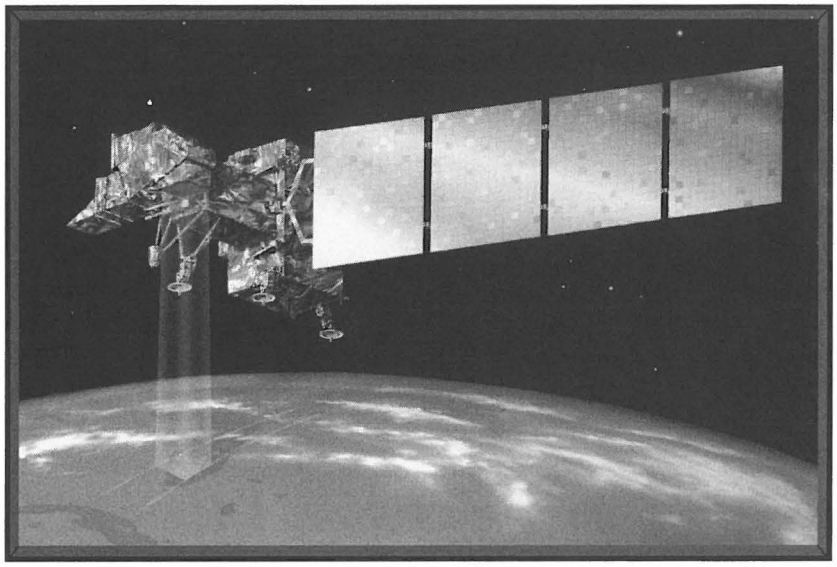
Dr. Byron Tapley has been named chair of the EOS Investigators Working Group (IWG) Science Executive Committee, replacing Dr. Eric Barron who has chaired this committee since January 1994. Tapley's many contributions to the Earth Observing System include serving as Principal Investigator of one of the Interdisciplinary Science Investigations as well as Principal Investigator of the ESSP proposal for Gravity Recovery and Climate Experiment (GRACE). I would like to welcome Byron Tapley as chair of this committee, and express my sincere thanks to Eric Barron for his excellent leadership over the past four years.

Dr. Ghassem Asrar, EOS Program Scientist in the Office of Earth Science, has been selected as Associate Administrator of Earth Science, succeeding Mr. William F. Townsend, who served as Acting Associate Administrator of the Office of Earth Science for the past year and a half (see the press release on page 13). Dr. Asrar is a well-established scientist with expertise in biosphere/atmosphere interactions and remote sensing of land surfaces from space, and is widely regarded by the Earth science community. I look forward to working with him during the next several years as we launch and analyze results from the EOS satellites and other Earth Science initiatives that have been under development for the past 10 years.

—Michael King
EOS Senior Project Scientist

Piers Sellers, formerly EOS AM Project Scientist, now an astronaut candidate at the Johnson Space Flight Center, accepting the 1997 Henry G. Houghton Award from Paul D. Try, 1996 AMS president. Due to Sellers' schedule, the award was not presented to him until November 1997.

Landsat-7 Science Team Meeting



— Darrel Williams (darrel@ltpsun.gsfc.nasa.gov), Landsat-7 Project Scientist

The Landsat-7 Science Team held its third semi-annual team meeting October 21-23, 1997 at the NASA Goddard Space Flight Center. Participants from the 14 research teams, as well as NASA, NOAA, and USGS attended the meeting, which was co-chaired by Landsat Project Scientist, Darrel Williams, and Landsat-7 Science Team Leader, Samuel Goward.

The first morning was dedicated to a briefing on the status of the Landsat platform, the ETM+ instrument, and the EOS Data and Information System (EOSDIS). At that time, Phil Sabelhaus, Landsat Project Manager, reported that development problems with the ETM+ instrument had delayed significantly its delivery to Lockheed Martin such that the launch date had to be pushed back from late May to July 9, 1998. [**NOTE**: *A status update, as this report goes to press in mid-February 1998, is that ETM+ power supply problems encountered during instrument thermal vacuum testing have caused further delays in the launch date. A new launch date will not be set until the instrument comes out of thermal vacuum testing successfully, but a launch before early October 1998 is unlikely.*] Progress on the Landsat ground system continues, despite major hail damage to the new X-band receiving antenna at the EROS Data Center in Sioux Falls, South Dakota.

James Ellickson of NOAA gave a brief report on NOAA's plans for Landsat-7 operations. Following a 90-day post-launch checkout, operations of the Landsat-7 satellite transfer to NOAA. Ellickson outlined plans to utilize licensing fees collected from international ground stations to help off-set NOAA's day-to-day operating costs. It was also announced that Landsat Level 0R data (uncalibrated, no geometric correction) will cost users $475 per scene, roughly an order of magnitude cheaper than current prices for non-governmental users. Level 1 data (calibrated, geometrically corrected) will cost no more than $600 per scene.

Anthony Janetos (Landsat Program Scientist at NASA Headquarters) detailed interactions between non-governmental organizations (NGOs) and NASA. Janetos emphasized that many NGOs could make good use of satellite data, but lack the resources and experience to handle the data. He solicited participation of Landsat-7 Science Team members as "mentors" for these organizations.

The second day was devoted to team-member presentations on recent research activities. Landsat-7 Science Team projects cover diverse areas of Earth System Science, including agricultural applications, deforestation, glacier dynamics, volcanic hazards, coastal processes, and cloud characterization. In addition, several team members are working to improve the radiometric calibration and atmospheric correction of

the ETM+ data. The following gives a brief synopsis of each science presentation:

◊ Robert Bindschadler (NASA GSFC) illustrated how Antarctic ice-stream motion could be mapped from multitemporal Landsat-TM imagery.

◊ Robert Cahalan (NASA GSFC) discussed the uses of Landsat for cloud studies, including the creation of cloud masks and the scaling of cloud properties.

◊ Luke Flynn (U. Hawaii) illustrated how Landsat-TM infrared data could be used to ascertain the volume and plume geometry of Hawaiian volcanoes.

◊ Alexander Goetz (U. Colorado) presented on-going research into landcover change in the Great Plains and its relation to climate variability.

◊ Samuel Goward and Jeffrey Masek (U. Maryland) discussed plans for an automated mass processing center for landcover change analysis.

◊ Susan Moran (USDA) presented recent work on the integration of SAR and Landsat-TM data for monitoring soil moisture and agriculture.

◊ Frank Muller-Karger (U. South Florida) discussed expanding the coverage of the Landsat-7 Long-term Acquisition Strategy for coastal regions.

◊ John Price (USDA, Ret.) discussed calibration/validation strategies for the EOS MODIS sensor using Landsat TM/ETM+ data.

◊ John Schott (Rochester Institute of Technology) presented on-going research into improved thermal calibration of the ETM+ using airborne sensors.

◊ Dave Skole (Michigan State University) presented recent work on tropical deforestation monitoring, and outlined priorities for the International Geosphere–Biosphere Program for landcover analysis.

◊ Kurtis Thome (University of Arizona) discussed field programs at Lunar Lake to establish cross-calibration with other EOS science teams.

◊ James Vogelman (USGS EROS Data Center) presented new approaches for filtering memory effects and coherent noise from Landsat imagery.

◊ Curtis Woodcock (Boston University) discussed the scaling of information content within satellite imagery and its relationship to ecosystem properties.

Joanne Gabrynowicz (University of North Dakota), an expert in space law, gave an informative overview of the new Commercial Space Act of 1997 (HR 1702) currently before Congress. The act, designed to facilitate commercial satellite launches and streamline licensing procedures, could have major implications for scientific remote sensing. Of some concern to the science team is a mandate that NASA turn to commercial data providers for future scientific missions whenever possible. It was not clear how this proposal meshed with the current requirement for the creation of a long-term, permanent archive of high-resolution satellite imagery for global change research.

Terry Arvidson (Lockheed Martin) and Jonathan Haskett (University of Maryland) presented an update on the Landsat-7 Long-Term Acquisition Plan (LTAP). Based on the recommendations of the Landsat Science Working Group (1991-1994), the Landsat Project is developing the LTAP which will, as much as possible, ensure seasonally refreshed acquisition of Landsat scenes for all land scenes on the globe. Determination of acquisition frequency based on vegetation state has been finished, with recent work concentrating on minimizing cloud contamination and optimizing ETM+ gain settings. An informal science team review of the LTAP was suggested, and Goward took the action to organize this review.

Team member Robert Cahalan (GSFC) gave a presentation on recent calibration activities at the DoE/ARM site in Oklahoma. This led to splinter discussions on atmospheric correction algorithms for Landsat-7 (led by Kurt Thome, University of Arizona) and precision georegistration techniques (led by Curtis Woodcock, Boston University). Thome noted that a variety of atmospheric correction algorithms are currently in use, ranging from simple dark-object subtraction methods to full radiative-transfer modeling. There was agreement that the Landsat-7 Science Team needed access to

a single set of atmospheric correction algorithms, packaged in a user-friendly format.

Woodcock also noted that precision georegistration was a vital part of Landsat analysis, but the team had no provision for creating georegistered products and no library of ground-control points. James Irons (NASA GSFC) noted that only a few ground-control points were required for each swath of Landsat data, provided that entire orbits were processed. While there was general consensus that image-to-image coregistration (using pattern matching techniques) was important, some members suggested that precision georegistration should be left to individual team investigations.

The next Landsat-7 Science Team meeting will be held April 14 - 16, 1998, at Goddard.

Earth Science Information Partners Will Prototype Environmental Information Federation Concepts

— Martha E. Maiden (martha.maiden@gsfc.nasa.gov), Earth Science Systems Program Office, NASA Goddard Space Flight Center, Greenbelt, MD.

Working Prototype Earth Science Information Partners (WP-ESIPs) Selected

A total of 24 proposals, in two categories, have been selected by NASA's Office of Earth Science (OES) to develop working prototypes of innovative uses and applications of Earth science data and related research. Twelve Type 2 and twelve Type 3 Working Prototype Earth Science Information Partners (WP-ESIPs) were selected for the experimental phase of defining, demonstrating, and validating the federation approach to performing selected major functions of the EOS Data and Information System (EOSDIS). Selection in both categories was made by Bill Townsend, then Acting Associate Administrator. Awards were announced in December 1997. As of early February of 1998, Cooperative Agreement negotiations for all projects were proceeding quickly.

NASA concluded that ESIPs can best be described as belonging to three types. Type 1 ESIPs are responsible for standard data and information products whose production, publishing/distribution, and associated user services require considerable emphasis on reliability and disciplined adherence to schedules. Type 2 ESIPs are responsible for data and information products and services in support of Earth system science (other than those provided by the Type 1 ESIPs) that are developmental or research in nature, where emphasis on flexibility and creativity is key to meeting the advancing research needs. Type 3 ESIPs are those providing data and information products and services to users beyond the global–change research community who enter into joint endeavor agreements with OES.

The WP-ESIP awards respond to a July 1996 National Research Council recommendation that NASA evaluate an alternative implementation of product generation, publication, and user services for possible future evolution of EOSDIS, and reflect two of the three envisioned types of ESIPs. (Type 1 ESIP functions are currently performed by the existing Distributed Active Archive Centers for EOS, or, in some cases and for

other Earth Science missions, by other NASA-supported project teams.) The evaluation of the federation concept will be initiated beginning with this limited set of prototype projects operating in a federated, rather than a centrally-managed architecture. These Type 2 and 3 WP-ESIPs, together with NASA, will determine the management, system interoperability, and organizational interfaces necessary to establish the Working Prototype-Federation. The future-oriented strategy proposed by the NRC is just becoming possible because of the tremendous pace of information technology innovation, and can be seen as comparable to our move toward principal investigator-driven spacecraft.

Type 2 WP-ESIPs are focused on new data and information products or services in support of global–change research that are developmental or research-oriented, with emphasis on flexibility and creativity in meeting advanced scientific applications. The Type 2 ESIPs concept is, in a way, a further development of the evolution of the Pathfinder Data Sets concept, with the additional feature of providing the stewardship for the near-term storage, distribution, and user services portion of the data–product management cycle.

The Type 2 WP-ESIPs also have the objective of enhancing innovation and creativity in the provision of environmental information services, and of identifying and testing new or emerging information technologies, techniques and/or approaches which offer promise of significantly reducing the future costs of EOSDIS. It is hoped that marrying these science and technology objectives within the Type 2 WP-ESIPs will promote very close teamwork and interactions between scientists and system designers and implementers, resulting in highly effective science data centers.

From 50 Type 2 proposals submitted, NASA has selected three proposals focusing on land-cover and land-use change issues, three proposals focusing on oceanography or hydrology, three proposals concentrating on atmospheric research data, and three proposals that integrate interdisciplinary issues, including one on environmental factors in public health. Two proposals have a U.S. regional focus. Type 3 ESIPs will be responsible for extending the benefits of NASA Earth science data and information beyond basic research to a broader user community including private industry, value-added companies, state and local governments, and non-profit organizations. NASA required that all for-profit organizations must cost-share to at least the 50% level. Successful Type 3 -ESIP organizations are expected to become financially self-sustaining by the end of their nominally 5-year projects. The participation of Type 3 WP-ESIPs in the Working Prototype-Federation will test the flexibility and extensibility of such a system.

From 65 Type 3 proposals submitted, NASA has selected 12 proposals that cover roughly 15 scientific disciplines: Five proposals deal with regional applications; three proposals focus on agriculture; two proposals focus on coastal and marine applications; three proposals deal with education and public outreach; and two proposals provide special applications to extend Earth Science Enterprise data to non-Earth–science research communities.

A list containing titles and project leaders can be found on Page 37 of the November/December 1997 issue of *The Earth Observer* (http://eospso.gsfc.nasa.gov/earth_observ.html).

NRC To Hold Federation Workshop in Late February

The National Research Council's (NRC's) "Workshop on a Federated EOSDIS" will be held on February 23-25, 1998 in the Washington D.C. area. There will be about 70 participants in the 3-day workshop, including invitations for all Project Leaders of the 24 projects selected to participate in NASA's Working Prototype Earth Science Information Partners resulting from the peer-review process of two Cooperative Agreement notices. The NRC has sought a rich range of expertise to be represented in the workshop, including Earth scientists, political scientists, social scientists, organizational experts, information scientists, and management and organization specialists. Other attendees will include senior NASA management and representatives of industry, government, and academia that have dealt with federation approaches.

NASA asked the NRC to conduct the workshop to explore possible approaches to establishing a "federated" structure for managing the EOSDIS. The NRC suggested that the federation may be a means to

empower new levels of achievement in Earth science research, applications, and data stewardship, and in a wide range of activities in both private and public sectors. The NRC agreed to conduct the workshop to educate current and potential future users and producers of EOSDIS data about federations, and to evaluate the strengths and weaknesses of different governance models for such an environmental information federation.

The workshop report, which the NRC will put through a "fast-track" publication process, will describe the governance scenarios considered and summarize the presentations and discussions. The report will not include policy or research recommendations.

The Federation Experiment

Both the NRC and NASA have acknowledged that there are indeed serious risks involved with this nascent federated approach, which would transfer major scientific functions outside the Government. As the Office of Earth Science has stated, NASA has a continuing responsibility to ensure that EOSDIS is operated fairly and provides the highest levels of support to the diverse interests of the research community, while pursuing attractive ideas, such as this one, which might make EOSDIS more useful to and more integrated with its users. NASA's OES has resolved to make peer-review and competition a more recurrent feature in all our projects, including our data centers' activities. It is useful to examine where the best level in an organization really is for salient types of decisions to be made. By their submission of proposals, these projects have expressed an interest in prototyping how a move to a federated environmental data system might occur. Since this experiment is organized through **working prototype** data centers, which are all mandated to make their services available on a non-discriminitory basis, it is an experiment in which all of NASA's user community can participate.

Kudos

The following EOS colleagues were recipients of 1998 awards from the American Meteorological Society:

The Verner E. Suomi Award — The Remote Sensing Lecturer

William L. Smith, Chief, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA "for his outstanding contributions to the advancements in remote sensing from space and the application of these data," and "for his lecture, 'Satellite Remote Sensing-The Evolution of a Global Observing System.' "

The Charles Franklin Brooks Award for Outstanding Services to the Society

Donald R. Johnson, Professor Emeritus, Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison; and Director of the Earth Sciences Division, Universities Space Research Association, Columbia, MD "for his dedication as an Editor and President, and for his leadership and innovation to improve education."

The Henry G. Houghton Award

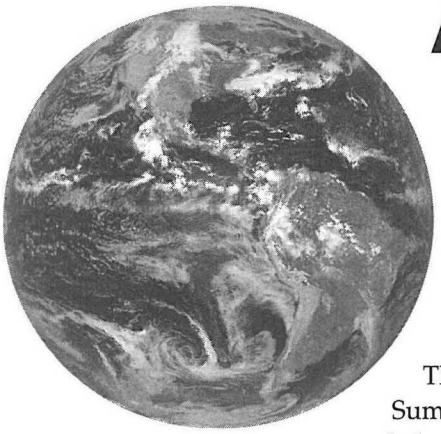
Patrick Minnis, Senior Research Scientist, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA "for making outstanding contributions to understanding the effects of clouds and aerosols on the earth's radiation budget."

The Editor's Award, Journal of Climate

Dennis L. Hartmann, Professor, Department of Atmospheric Sciences, University of Washington, Seattle, WA "for his conscientious, thorough, and insightful reviews on a wide range of subjects."

Elected Fellows for 1998:

Thomas P. Charlock, NASA Langley Research Center, Hampton, VA
Anne R. Douglass, NASA Goddard Space Flight Center, Greenbelt, MD
Ying-Hwa Kuo, National Center for Atmospheric Research, Boulder, CO
Dennis P. Lettenmaier, University of Washington, Seattle, WA
Thomas T. Wilheit, Texas A&M University, College Station, TX



A Blueprint for Improved Global Change Monitoring of The Terrestrial Biosphere

— Steven W. Running (swr@ntsg.umt.edu), Numerical Terradynamic Simulation Group, University of Montana

The Kyoto Earth Summit recently ended, amid substantial disagreement over current and future global change, and their significance to humankind. The core of the problem is that many global leaders are unconvinced that significant global change is now occurring. Further, there is insufficient confidence in the accuracy of global-scale computer models that project future changes to initiate the political and economic redirections that would be required to alleviate the problem. As was first said years ago, we are conducting the first global-scale biogeochemistry experiment, the outcome of which is not known, and which could severely impact the habitability of the planet. Conversely, any meaningful reduction in fossil fuel consumption will require the redirection of trillions of dollars of the world economy. The decision to embark on a serious redirection of world energy consumption is, along with population control, possibly the most fundamental global policy of the next century.

Global climate change is to some extent the environmental equivalent of the national debt to economics. Most economists agree that a little debt is harmless, maybe in certain circumstances even helpful. But at some level, the debt becomes too high, the trajectory of additional debt too relentless, and the consensus slowly has emerged that too much national debt, in the long run, should be avoided. Ethically, we are having a party today paid for on our "national credit card," and leaving it to our children and grandchildren to pay off the resulting bills, with interest. National debt has the advantage of being easily measured, although agreement on how much is too much is more difficult. In global-change science, not only does society have no agreement of when change is too much, we do not even have a clear idea of what environmental variables can and should be measured to monitor change. Are we now building a global "environmental debt" that our descendants will have to clean up? The root of the disagreement in Kyoto was that there just was not sufficient hard-measured evidence of damaging global change to warrant the profound policy actions that would be required.

The lack of pertinent global-change data should be taken as a professional challenge to every global environmental scientist. If there is another Kyoto Earth Summit in, say, 2017, will there be an array of critical, well-replicated measurements that can definitively illustrate whether important and detrimental global change is occurring? If there is not, I submit that we as a science community will have failed in our responsibility to humanity.

The purpose of this letter is to suggest a small, critically chosen set of variables for which I feel immediate, coordinated global monitoring networks could and should be established, if we expect to be ready for the hypothetical Kyoto summit in 2017 with better answers than we can offer today. I restrict my suggestions to the terrestrial biosphere, as atmospheric and oceanic monitoring are covered elsewhere. There are wide and ongoing discussions on monitoring of climate itself, so here I am more concerned with the responses of the biosphere to changing climate. In the terrestrial sciences, I will restrict my suggestions to vegetation and hydrologic processes, and particularly to processes that have both tight connection to climatic drivers, and have high relevance to human welfare. To meet my standard as a critical and achievable monitoring variable, a methodology must be available that is either very simple and has a long history of prior measurements, or it must be a newer technology that can be calibrated, propagated widely, and have uniform, automated data processing. An appropriate methodology must have sufficient precision to clearly

quantify responses to seasonal and/or interannual variability in climate if we are to expect it to have relevance for global climate-change monitoring.

The best current examples of the monitoring I am suggesting are the atmospheric CO_2 flask network begun at Mauna Loa in 1958 by C. D. Keeling and now coordinated globally by NOAA, and the global monitoring of glacier-lengths reported by Oerlamans (1994). The Mauna Loa atmospheric CO_2 record is undoubtedly the most important data set in global change science today. Although it is a measure of atmospheric chemistry, the dynamics it follows are predominantly those of the land and ocean surface carbon exchanges of the biosphere, and the additional anthropogenic loading produced by humankind. The glacier-length data sets are an excellent example of a tightly climatically-influenced hydrologic measurement that is sufficiently simple that it has been recorded for over 150 years at certain locations. Imagine attempting to discuss global change without these two critical data sets for clear quantitative evidence. Yet, as we saw in Kyoto, these data alone are insufficient to trigger the massive policy shifts that would be needed if human-caused global change is imminent. Clearly, a wider array of biospheric monitors is needed.

Vegetation

We must clearly separate variables that are a first-order response to climatic forcing from variables that are contaminated by direct human disturbance unrelated to climate. Both may be meaningful measures of global change, but the former has greenhouse gas emissions as a component of causality, while the latter does not, which implies huge differences in the appropriate remediation measures.

I suggest that we need a fundamental on-going measure of the global extent of vegetation cover. This simple measure would quantify desertification and deforestation dynamics, and also track changes in natural disturbance frequency such as wildfire extent, etc. This can be a difficult variable to define with precision, as land-cover conversion from natural to agrarian uses has been part of human habitation for millennia, and does not necessarily imply a degradation of the land ecologically. In order to avoid the imprecisions of complex multiple biome land-cover classification schemes (Running *et al.* 1994), I suggest merely an annual global mapping of vegetated versus non-vegetated area, with a single further discrimination to forest and non-forest vegetation (which would include all grasslands and croplands). We currently estimate there are 90 million km^2 of vegetated area (Nemani and Running 1997, Waring and Running 1998), and up to 0.1 million km^2, is possible. The precision gained by these measurements, 0.1%, is much better than normal *in situ* process data can ever attain. This simple designation will be possible to monitor with the new Earth Observing System AM-1 satellite that will be launched in the summer of 1998. One sensor on this system, MODIS, will map global land cover annually to 1 km^2 spatial resolution, as part of a suite of remote-sensing observations of the land surface (Running *et al.* 1995). It is currently the intent of the Earth Observing System science community to sustain this measurement for the next 20 years, pending regular replacement of the necessary satellites.

Probably no biospheric variable has more direct relevance to humankind than net primary productivity (NPP), the growth of vegetation that provides the renewable food/forage/fiber/fuel for all human life. Recent estimates are that we co-opt 40% of global NPP for human use already (Vitousek *et al.* 1997). Terrestrial NPP has been measured locally for many decades as merely the annual growth of various types of vegetation, albeit with variable methodology and precision. Global NPP averages 500 gC $m^{-2} yr^{-1}$, with absolute measurement precision of maybe 50 gC $m^{-2} yr^{-1}$. Because the precision of the NPP measurement is rather low, only vegetation sampled with identical protocols at exact locations every year can provide relative measures of variability. Crop NPP is frequently changed by fertilization, irrigation, weed control, and genetic improvements, all of which are unrelated to climatic conditions. Productivity of natural vegetation such as forests more directly reflects climate, but must be corrected for reductions in productivity that occur naturally as forest stands age, called "age detrending" in dendrochronology research. A greater problem is that most forest productivity determinations measure the commercially-valuable portion of the tree only, not total productivity. It would be highly valuable to global-change research to identify stable historical records of any vegetation

NPP that avoids the above confounding influences. Currently, only dendrochronology of carefully selected ancient trees in severely climate-limited growing environments have shown the methodological precision required for global-change monitoring (Jacoby *et al.* 1996).

Two recent technologies have the potential to provide a different measure of vegetation carbon balances from very different perspectives, but of high relevance to global-change monitoring. Recent developments in micrometeorology have produced the ability to continuously monitor the fluxes from the land surface of both CO_2 and H_2O year round (Wofsy *et al.* 1993). This technology measures net ecosystem exchange (NEE) of CO_2, not net biomass productivity, but has the advantage of being repeatable, independent of any particular vegetation type and being highly automated. NEE ranges 10 gC m^{-2} day^{-1} either positively or negatively, as any point in the biosphere can be either a source or sink of CO_2 under given circumstances. Measurement precision is about 5%, or 30 gC m^{-2} yr^{-1}, better than direct biomass measures. A global network of CO_2 flux towers is being planned (Baldocchi et al. 1996), and may provide the best next-generation measurement of biospheric carbon dynamics to augment the atmospheric CO_2 measurements begun by Keeling et al. (1996).

The advantage of the CO_2 flux tower is that it provides a direct measure of ecosystem CO_2 balance; the liability from a global perspective is that only a small plot, < 1 km^2 is monitored. The Earth Observing System will provide a satellite-derived estimate of NPP that will cover every square kilometer of global vegetation. Although the precision of a satellite-derived estimate of NPP is lower, errors are on the order of 30%, the more-precise quantification of areal extent of productivity provided by satellites ultimately gives a more-complete analysis of biospheric activity as a whole. The logic for relating absorbed photosynthetically active radiation by vegetation to primary productivity originated with J. L. Monteith, and the application to remote sensing has been pursued by many groups (Field *et al.* 1995, Ruimy *et al.* 1994, Prince and Goward 1995). Again, it is the intent of the EOS science community that an annual estimate of global NPP will be sustained over the next 20 years, pending regular replacement of aging satellites.

Hopefully, the combination of carefully selected direct vegetation measurements, continuous carbon flux measurements from a global network of towers, and satellite estimates of total global NPP will, in combination, allow an answer in 20 years to the question of whether biospheric productivity is changing.

Probably the most readily observable climate-controlled activity of vegetation is the onset of bud and leaf growth in the spring after winter dormancy in temperate and boreal latitudes. Simple observations of the "beginning of spring" have been recorded by naturalists for centuries, and the U.S. Dept. of Agriculture operated a formal phenology network from 1961-1980. Interannual differences for a single location have been recorded of up to 2 months from the earliest to the latest date when vegetation bud growth was initiated, and year-to-year variability is regularly 10-14 days. Vegetation canopy measurements can be expanded to define growing-season length by measuring the senescence of vegetation in autumn, but with less precision. These simple measurements could be renewed, possibly with automated digital cameras, to provide very direct evidence of any climatic warming responses by vegetation.

Once again, new technology has produced a satellite equivalent of spring bud-burst and growing season length, the weekly recording of a Normalized Difference Vegetation Index, or NDVI. Many vegetation remote-sensing scientists have studied the rapid increase in the NDVI value that can be quantified by satellite, particularly for deciduous forests, grasslands, and croplands (Schwartz 1994, Reed *et al.* 1994, White *et al.* 1997). A twelve-year record of NDVI data suggests that the spring growing season in boreal forests of Canada may begin 7-10 days earlier now than in the early 1980s (Myneni *et al.* 1997). EOS will provide the global 1-km data set to compute this spring onset of growth annually for the next 20 years. However, this satellite record needs a ground-monitoring network to validate the computed spring-vegetation dynamics.

Hydrology

Many global climate predictions emphasize that a large and poorly understood climate feedback may occur through the hydrologic cycle, so a clearly planned monitoring program is essential. As men-

tioned earlier, monitoring of glacier length is a simple repeatable hydrologic observation that has been carried out on glaciers around the world, and now provides important evidence of climatic change. The global archival and distribution of glacier data have been organized at the World Glacier Monitoring Service in Zurich, Switzerland. The compilation, error checking, archival, and distribution of comparable data sets from around the world is an important aspect of turning any array of global data into a useful global-change monitor, yet is often difficult to get funded.

River discharge is the hydrologic equivalent of NPP for vegetation. It is the most fundamental measure of water availability from a landscape for human use, and has been measured with simple continuous recording devices for over 100 years all over the world with rather high precision, on the order of 5% from the best stations (Georgakakos *et al.* 1995). However, both the magnitude and seasonal timing of river discharge are profoundly influenced by land-use changes in the watershed above the gauging device. Changes in vegetation cover, consumption of water for irrigation, and reservoir impoundments all cause most river gauging to be an inadequate global-change monitoring system. There exists a subset of high-mountain gauged watersheds, often in wilderness areas or national parks, that have endured no land-use changes and minimal changes in vegetative cover that could provide an excellent network of global-change monitors. These watersheds could provide both consistent monitoring of frozen/unfrozen precipitation and of annual streamflow dynamics. Their location in high, uninhabited mountain regions provides the sort of regional-scale monitor uncontaminated by local influences that was the rationale for choosing the original atmospheric CO_2 site to be at Mauna Loa.

Another readily observable and highly relevant hydrologic variable for climate-change monitoring is the seasonal extent and duration of snowpacks. Snow depth and water-equivalence surveys have been undertaken with simple hand measurements for about 50 years in many mountainous and boreal regions of the world. These simple measurements have a precision of 1 cm or better. A compilation, archive, and distribution of relevant comparable snowpack data could provide a critical climate change hydrologic monitor (Robinson *et al.* 1993). EOS satellites cannot estimate snow depth or water equivalence adequately, but can provide regular global monitoring of snow areal extent. The weekly satellite-derived snow extent monitoring combined with ground snowpack surveys is a critical global-change monitor that can be developed with existing systems.

A highly dynamic and easily observable hydrologic variable is lake levels, measurable to accuracies of at least 5 mm. Once again, only certain lakes whose levels have not been changed by human water-management schemes, or adjacent land-use changes could be relied upon for a global-change monitor. Again, high mountain regions may contain lakes fitting these criteria. Also, both Australia and Africa have shallow ephemeral lakes of thousands of square kilometers in desert regions that literally appear and disappear altogether in response to the regional water-balance dynamics (Graetz et al. 1992). Because the precision of measuring simple lake areal extent is often higher than water balance processes, monitoring of these ephemeral lakes may be advantageous. Identifying critical lakes, and building a network for reporting and archiving data in a comparable way would be required to make these observations useful.

Implementation Needs

Implementation needs fall into two areas. First, for variables that have a history of measurement, such as stream discharge or snow depth, an assessment of critical sites must be done, to identify only the sites best suited for global-change monitoring, those with stable, calibrated data in areas unperturbed by local influences. While we often focus on maximizing the number of global stations taking certain data, for global-change monitoring it may be better to concentrate on a smaller number of very formally organized and calibrated stations, and concentrate on temporal precision of the measurements, rather than on attempting coordination of a large number of stations. Possibly, spatial sampling should be consciously left to satellite measurements alone, which limits the variables measured but provides complete global sampling. From this subset of sites a global network can be developed with a centralized archiving and distribution facility, as was done with the World Glacier Monitoring Service. Networked computers and Internet now make global data transmission infinitely

easier than a mere decade ago, and an archive center could reside in any country willing to host it.

For the new measurements suggested, such as the CO_2 flux towers, an array of global sites taking consistent calibrated measurements must be encouraged. International scientific organizations such as the International Geosphere-Biosphere Program, World Climate Research Program, Global Climate and Terrestrial Observing Systems (GCOS/GTOS) and International Association of Hydrologic Sciences are virtually the only coordinating mechanisms to develop a global network of consistent data collection. The international cooperation required is large, and organization is often slow, but no alternative exists.

Satellite data are inherently globally consistent, and archive and distribution points are established by the country that launches the satellite. The Earth Observing System was designed specifically as a global-change monitoring system, so many of the data archiving and distribution requirements are part of the programmatic plan. Only when regular, precise, point measurements can be combined with satellite-derived measures of areal extent of key observable properties, extrapolated with terrestrial simulation models, can an analysis of global terrestrial change be complete.

There is a near endless list of measurements that might be taken to detect and monitor global change in the terrestrial biosphere, some done by the general public. For example, organized annual bird counts may be valuable data. However, while scientists sit in endless meetings deciding what can and should be measured, time is ticking away. I have elected to identify a short, critical list of variables that could begin right now to build a consistent record of terrestrial response to global change. Certainly, more and better ideas will arise in the future, but I feel it is imperative that we begin today to build a global monitoring system that can provide quantitative answers 20 years from now, when policy makers most assuredly will ask us again "what evidence is there of global change?" We must have more data than only air temperatures and atmospheric CO_2.

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Asrar Named Associate Administrator for Earth Science

— Douglas Isbell (disbell@mail.hq.nasa.gov), NASA Headquarters, Washington, DC

Dr. Ghassem Asrar has been selected as the new NASA Associate Administrator for Earth Science, according to Administrator Daniel S. Goldin.

Asrar currently serves as the chief scientist for the Earth Observing System in the Office of Earth Science at NASA Headquarters. In this position, he has led an international team developing the scientific priorities and measurements to be obtained from a series of advanced Earth-orbiting satellites that promise fundamental new insights into the connections between Earth's land, oceans, atmosphere, ice, and life.

"Dr. Asrar brings first-class interdisciplinary research skills and the respect of the scientific community to this challenging position," Goldin said. "Our Earth Science program is poised to enter a new era with the launch of the first Earth Observing System mission this summer. This is an ideal time for Dr. Asrar to assume the leadership of this key NASA enterprise." Asrar's appointment is effective immediately.

Asrar has authored more than 70 peer-reviewed scientific papers, primarily in the fields of land surface studies and biosphere/atmosphere interactions, and has edited several remote-sensing reference books. He conducted research and trained undergraduate and post-graduate students for nine years in academia prior to joining NASA as a senior scientist in 1987. He has continued his interest in developing the next generation of Earth scientists by establishing the NASA Earth System Science Fellowship Program, which has trained more than 400 young scientists to date. Prior to his research career, he earned graduate degrees in civil engineering and environmental physics from Michigan State University, East Lansing.

Asrar is an active member of several professional societies, including the American Geophysical Union, the American Meteorological Society, and the Geoscience and Remote Sensing Society. He has received numerous awards and honors, including the Distinguished Visiting Senior Scientist Award from NASA's Jet Propulsion Laboratory in 1991 and a NASA Exceptional Performance Award in 1997.

He and his wife Naimeh Razzaghi-Asrar live in Montgomery County, MD, and have one child.

NASA Radar Reveals Hidden Remains At Ancient Angkor

Excerpts from NASA Press Release 98-28
— Douglas Isbell (disbell@mail.hq.nasa.gov), NASA Headquarters, Washington, DC.
— Mary Hardin, Jet Propulsion Laboratory, Pasadena, CA

New evidence of a prehistoric civilization and remnants of ancient temples in Angkor, Cambodia, have been discovered by researchers using highly detailed maps produced with data from an airborne imaging radar instrument created by NASA.

Experts say the findings, made possible by the Airborne Synthetic Aperture Radar (AIRSAR) developed by NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA, may revolutionize the way archaeologists view the ancient city's development.

Angkor is a vast complex of some 1,000 temples covering about 100 square miles of northern Cambodia. Little is known of the prehistoric occupation of this fertile flood plain, but at its height the city housed an estimated population of one million people. The famous temples were built from the eighth to thirteenth century AD and were accompanied by a massive hydrological system of reservoirs and canals. Today, much of the civilization of Angkor is hidden beneath a dense forest canopy and is inaccessible due to poor roads, land mines, and political instability.

"The radar data have enabled us to detect a distribution of circular 'prehistoric' mounds and undocumented temples far to the northwest of Angkor," said Dr. Elizabeth Moore, Head of the Art and Archaeology Department at the School of Oriental and African Studies at the University of London. "The site's topography is highlighted by the radar, focusing our attention on previously neglected features, some at the very heart of the city.

Angkor's beauty is seen in its temples, but the greatness of the Khmer city lies in the multitude of water-related constructions, according to Moore. The Khmer kings nominally dedicated temples to Hindu and Buddhist deities, but the underlying significance was veneration of ancestral spirits, ensuring fertility of the land. Management of water was essential, both for control during the monsoon rains and conservation during the dry season and involved the construction of moats, dikes, canals, tanks, and reservoirs. The largest of these reservoirs, dated to the 12th century AD, is five miles long and its function remains a matter of archaeological debate.

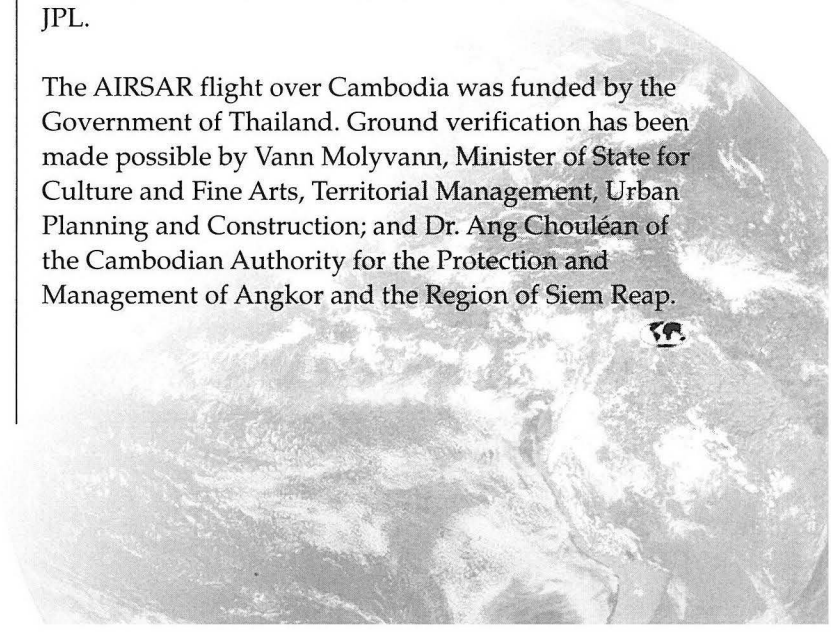
"These new detailed topographic maps have shown us many more hydrological features and highlighted how they function in the rituals and daily life of the Khmer people," Moore explained.

The Angkor radar images were taken in late 1996 as part of the AIRSAR Pacific Rim Deployment and were a follow-up to the 1994 study of Angkor with data collected by the Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar (SIR-C/X-SAR) that flew on NASA's Space Shuttle Endeavour.

AIRSAR images of the Angkor region can be found on the Internet at http://www.jpl.nasa.gov/news/.

AIRSAR flies on a NASA DC-8 aircraft that is now managed at NASA's Dryden Flight Research Center, Edwards, CA. The AIRSAR instrument is managed by JPL.

The AIRSAR flight over Cambodia was funded by the Government of Thailand. Ground verification has been made possible by Vann Molyvann, Minister of State for Culture and Fine Arts, Territorial Management, Urban Planning and Construction; and Dr. Ang Chouléan of the Cambodian Authority for the Protection and Management of Angkor and the Region of Siem Reap.



Ball Aerospace To Provide ICESat Spacecraft

— Douglas Isbell (disbell@mail.hq.nasa.gov), NASA Headquarters, Washington, DC
— Tammy Jones (tjones@pop100.gsfc.nasa.gov), NASA Goddard Space Flight Center, Greenbelt, MD

Ball Aerospace and Technologies Corp., Boulder, CO, has been selected to provide the spacecraft for the Laser Altimetry Mission scheduled to be launched in a near-polar orbit in July 2001.

Total cost of the mission is set at under $200 million, including the launch vehicle and three years of science and data analysis. Total value of Ball Aerospace's delivery order is $39.4 M.

The Laser Altimetry Mission, recently designated ICESat for Ice, Cloud and land Elevation Satellite, will accurately measure the elevations of the Earth's ice sheets, clouds, and land, and answer fundamental questions about the growth or shrinkage of the Earth's polar ice sheets and future global sea-level rise or fall. ICESat also will measure the heights of clouds for studies of Earth's temperature balance and will measure land topography for a variety of scientific and potential commercial applications.

In addition to providing the spacecraft, Ball Aerospace will integrate and test the primary instrument on the ICESat satellite, the Geoscience Laser Altimeter System. The laser altimeter is being developed at NASA's Goddard Space Flight Center, Greenbelt, MD, and will provide precise elevation of the land, ice, and clouds that are overflown.

The laser is completely eye-safe to individuals on the ground. It works by transmitting short pulses of infrared light and visible-green light to measure ice sheet elevation and land topography (infrared light) and to measure clouds and aerosols (green light). The distance from the spacecraft to clouds and to Earth's surface will be determined from measurements of the time taken for the laser pulses to travel to these targets and return. Similar instrumentation has been flown on aircraft over the Greenland ice sheet for proof-of-concept experiments.

The Greenland and Antarctic ice sheets cover 10 percent of the Earth's land area, and contain 77 percent of the Earth's fresh water and 99 percent of its glacier ice. Measurements of the ice sheets are essential for assessing whether future changes in ice volume will add to the sea-level rise, which is already occurring, or whether the ice sheets might grow and absorb a significant part of the predicted sea-level rise.

ICESat is one in a series of spacecraft for NASA's Earth Science program, which will study the Earth's system and the effects of natural and human-induced changes on the global environment.

ICESat is being developed by a partnership of NASA, industry, and university teams. ICESat will be placed into an orbit 705 km above the Earth with an inclination of 94 degrees to the equator. A launch vehicle for the ICESat mission will be selected from the stable of medium-light expendable launch vehicles. ICESat's designed lifetime is for three years of operation with a five-year goal.

Ball Aerospace's selection was made through an innovative procurement program developed at NASA to procure, build, and deliver spacecraft faster and more cheaply than ever before. The Indefinite Delivery/Indefinite Quantity contract will make it possible to go from procurement to launch in less than four years.

The ICESat mission and the development of the laser altimeter instrument will be managed by Goddard for NASA's Earth Science Enterprise. More information is available via the Internet at the following URL: http://1am1.gsfc.nasa.gov/1amhome.htm.

EDUCATION HIGHLIGHTS

NASA Earth Science Enterprise Education Program Update

Earth Science Education Products Workshop

— Nahid Khazenie (nkhazeni@pop100.gsfc.nasa.gov), Earth Science System Program Office, NASA Goddard Space Flight Center

From December 11-13, NASA's Office of Earth Science and the Institute for Global Environmental Strategies (IGES) conducted the second NASA Earth Science Education Products Workshop at Goddard Space Flight Center (GSFC). Participants included 27 representatives from NASA's Educator Resource Center Network (ERCN), Aerospace Education Services Program (AESP), and NASA's Teaching from Space Program. Products that were included require training for their most effective use. The products and their presenters were:

◊ Earth's Energy Balance Brochure (Steve Graham, Raytheon STX).

◊ EOS Posters/Slide Set (Stephanie Stockman, GSFC).

◊ Geomorphology from Space CD-ROM (Carla Evans, Raytheon STX and Linda McNeely, Raytheon ITC).

◊ Glacier Power CD-ROM (Chip McMillan, University of Alaska Fairbanks).

◊ Global System Science Guides (Cary Sneider, Lawrence Hall of Science).

◊ Looking at Earth from Space Teacher's Guide and Glossary (Bill Ryan, University of Maryland and Colleen Steele, IGES).

◊ Our Mission to Planet Earth Teacher's Guide (Joan Sanders, GSFC).

◊ Sea Ice in Polar Regions/Arctic Observatory CD-ROM (Claire Parkinson, GSFC, and Farzad Mahootian, Gonzaga College High School).

In addition, presentations were included on: the NASA Earth Science Program (Robert Price, GSFC); Ozone (Gary Morris, GSFC); a tour of the GSFC Global Change Data Center (Blanche Meeson, GSFC); the GSFC Educator Resource Center (Lynda Matys, GSFC); and an overview of the new GSFC Earth Science Exhibit, which is planned to open in February 1998 (by Mitch Hobish, Consulting Synthesist).

These workshops are intended to aid participants in developing and conducting their own teacher training workshops; each participant will conduct a minimum of three teacher workshops using these products. This activity is also planned to be an annual event. The objective is to cycle all of the NASA ERCN and AESP representatives, who are nominated by their Center Education Program Officer, through the training workshop. For more information, contact Nahid Khazenie, nkhazeni@pop100.gsfc.nasa.gov, or Theresa Schwerin, IGES, theresa_schwerin@strategies.org.

Duval High School Aerospace Technology Program

DuVal High School (located near Goddard Space Flight Center) has adopted an Aerospace Technology theme for its curriculum, which received the 1997 Maryland High School Program Excellence designation by the Technology Education Association of Maryland.

For students electing the Aerospace Technology strand, the school paired the student's science course in the fall term with an Aerospace Technology Appli-

cations course in the spring term. For their current 9th-grade Aerospace students, the applications course in the spring is subtitled "Mission To Planet Earth." The program is actively developing the curriculum around materials that have already been published by NASA. An objective of the applications course is to give students an appreciation of how current satellite missions are providing a global picture of how our environment is changing. The environmental science theme, in conjunction with current and evolving information from the ongoing NASA Earth science initiatives, provides a bridge from the students' 9th-grade Earth Science course to their 10th grade Biology course.

The program is interested in field testing educational programs being developed by NASA Earth science researchers. For example, representatives participated in a Total Ozone Mapping Spectrometer (TOMS) workshop at GSFC this past August, and data from the CD-ROM that were provided are being used to develop computer lab activities to expose the students to NASA satellite data. Course content is structured around NASA Earth Science themes.

The program would welcome input from any interested individuals or groups. Contact Carolyn S. Harden, Aerospace Instructional Coordinator, DuVal High School, 9880 Good Luck Road, Lanham, MD 20706. Phone: (301) 918-8600, x284; E-mail: scite@erols.com.

NASA Earth Science Education Product Review
During late summer 1997, NASA requested submissions of education products developed at NASA Centers, grantee, or contractor organizations, to be included in its annual review of education products. The purpose of this review was to determine which Earth science education products were appropriate for national and targeted distribution by the NASA Earth Science Enterprise (ESE).

The results of the 1997 NASA Earth science education products review have been finalized and distributed to the individual product developers and appropriate Center contacts. A description of the overall review process and evaluation forms will be included on the NASA Earth Science Enterprise WWW site at: http://www.hq.nasa.gov/office/mtpe. If you are developing a product for potential NASA distribution, you are strongly encouraged to use these review criteria in testing and evaluating your product. For more information, please contact: Nahid Khazenie (nkhazeni@pop100.gsfc.nasa.gov).

First Educator/Mission Specialist
NASA has selected Barbara Morgan, an elementary school teacher from McCall, ID, to join the next astronaut candidate class as a mission specialist.

In a decision that re-emphasizes the importance of NASA's strong commitment to education and its unique position to advance the nation's goals to improve science, mathematics, and technology education, the Agency has determined that it is appropriate to include educator mission specialists in the astronaut corps.

In addition to meeting the astronaut selection requirements, mission specialists with education and teaching backgrounds in science, mathematics, and technology will be selected and trained in the astronaut corps. These mission specialists will carry out educational programs in addition to their other assigned flight duties.

On the Internet
JPL's El Niño Watch
http://www.jpl.nasa.gov/elnino

This page presents the latest images and news releases based on observations of the El Niño phenomenon in the Pacific Ocean by the U.S./French TOPEX/Poseidon and other JPL satellites and instruments.

Liftoff To Learning Guides Online
http://spacelink.nasa.gov/Instructional.Materials/Video.Materials/Video.and.Activity.Guides/Liftoff.to.Learning.Series/

New and updated Liftoff To Learning Video Resource Guides are now available on-line. These Resource Guides provide valuable background information for teachers, resources for additional study, and practical hands-on demonstrations of some of the concepts presented in the Liftoff To Learning videotapes. The Liftoff To Learning videos capture the excitement of space flight and explain, in basic and practical terms, the scientific,

mathematical, and technological concepts that make space flight possible.

SeaWiFS Images Online
http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/usa_regions.html

Full–resolution (1 km) chlorophyll and true–color images derived from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data acquired by receiving stations around North America are available on-line at the SeaWiFS home page.

TRMM
http://trmm.gsfc.nasa.gov

The latest information on the TRMM project is located at this Web site.

Center for Clouds, Chemistry, and Climate (C4)
http://www-c4.ucsd.edu

The Center for Clouds, Chemistry, and Climate has developed "Forecasting the Future," a classroom curriculum and activity guide focusing on global climate change, with an associated teacher-training program, and "Next Wave," an interactive environmental education center that teachers and students can access via the Internet at http://aqua.ucsd.edu/nextwave/.

The Remote Sensing Tutorial

— William Campbell (campbell@sauquoit.gsfc.nasa.gov), Head, Applied Information Sciences Branch, Goddard Space Flight Center

A textbook-sized CD-ROM entitled THE REMOTE SENSING TUTORIAL: AN OUTLINE HANDBOOK, sponsored by NASA Goddard Space Flight Center, Code 935, and prepared by Nicholas M. Short, is now available.

This disk contains 21 sections covering a wide range of topics, with emphasis on satellites (mainly Landsat) and other space platforms. The sections include: Basic Principles; Image Interpretation and Analysis (emphasizing computer processing); Discipline Applications; Radar and Thermal Remote Sensing; Aerial Photogrammetry and Topographic Mapping; Ground Truthing; Astronaut Photography; Meteorological Satellites; Geographic Information Systems; The EOS Program; Basic Science Studies; Planetary Remote Sensing (including a subsection on Cosmology); and the Future of Remote Sensing and Commercialization. This format allows use of color illustrations that make up many of the hundreds of figures included in the tutorial.

The wide audience to which this work is directed includes both pre-college and college educators, professionals entering or active in the field of remote sensing in both government and private sectors, and the interested general public.

The tutorial can also be accessed on the Internet at http://code935.gsfc.nasa.gov/Tutorial/TofC/Coverpage.html. For those who wish to avoid downloading the tutorial, or to use it in an instructional mode, a limited number of CD-ROMs are available at no cost. After this supply is exhausted, copies can be obtained for $10 each (check or money order payable to GSTI) to cover materials, preparation, and mailing. Order from:

Global Science and Technology, Inc.
6411 Ivy Lane, Suite 300
Greenbelt, MD 20770
Attention: William Dickinson, Jr.
Tel. 301-474-9696, e-mail: wdickins@gst.com

EOS Science Calendar

March 26-27	SAGE III Science Team Meeting, Hampton University, Hampton, VA. Contact M. Patrick McCormick, tel. (757) 728-686, e-mail: mcc@hamptonu.edu.
March 31	AMSR-E Science Team Meeting, NASA/Goddard Space Flight Center. Contact Elena Lobl, tel. (205) 922-5912, e-mail: elena.lobl@msfc.nasa.gov.
April 1-2	EOS PM-1 Science Data Validation Workshop, University of Maryland Inn & Conference Center, College Park, Maryland. Contact Mary Floyd, tel. (301) 220-1701, e-mail: mfloyd@pop200.gsfc.nasa.gov.
April 2	Mini-SWAMP, Lockheed Martin Missiles and Space, Valley Forge, PA. Contact Mary Floyd, tel. (301) 220-1701, e-mail: mfloyd@pop200.gsfc.nasa.gov.
April 14 - 16	Landsat Science Team Meeting, NASA/Goddard Space Flight Center, Greenbelt, Maryland. Contact Jeff Masek, e-mail: jmasek@geog.umd.edu.
April 21-23	CERES Science Team Meeting, NASA Langley Research Center, Hampton, VA. Contact Theresa Hedgepeth, e-mail: t.c.hedgepeth@larc.nasa.gov.
June 24-26	MODIS Science Team Meeting, location TBD. Contact Mary Floyd, tel. (301) 220-1701, e-mail: mfloyd@pop200.gsfc.nasa.gov.

Global Science Calendar

March 30 - April 4	ASPRS-RTI Annual Convention, Tampa, FL. Contact Dan French, tel. (301) 493-0290, fax: (301) 493-0208, e-mail: dfrench@asprs.org.
April 2-4	Johns Hopkins conference in Environmental Fluid Mechanics, Baltimore. Contact Haydee Salmun, e-mail: haydee@jhu.edu.
June 1-4	Eleventh Annual Towson University GIS Conference, Baltimore, MD. Contact Jay Morgan, tel. (410) 830-2964, e-mail: jmorgan@towson.edu.
June 8-11	9th Global Warming International Conference & Expo, Hong Kong. Contact Sinyan Shen, tel. 1-603-910-1551, e-mail: Syshen@Megsinet.net, URL: http://www2.msstate.edu/~krreddy/glowar/glowar.html.
June 8-12	27th International Symposium on Remote Sensing of Environment. Tromso, Norway. Contact Norwegian Space Centre, P.O. Box 113 Skoyen, N-0212 Oslo. Norway. fax: +47 22 51 18 01, e-mail: isrse@spacecentre.no, URL: http://www.spacecentre.no/.
July 6-10	International Geoscience & Remote Sensing Symposium, Seattle, WA. Contact Tammy Stein, tel. (281) 251-6067; fax: (281) 251-6068, e-mail: tstein@phoenix.net.
July 19-24	SPIE International Symposium, Optical Science, Engineering, and Instrumentation, San Diego, CA. Contact William L. Barnes, e-mail: wbarnes@NEPTUNE.GSFC.NASA.GOV, URL: http://www.spie.org/info/sd/.
July 20-24	9th Australasian Remote Sensing Photogrammetry Conference, Sydney, Australia. Contact Gramme Tupper, tel. 063.913.143, fax: 063.913.767, e-mail: tupperg@agric.nsw.gov.au.
August 17-21	International Conference on Satellites, Oceanography & Society, Lisbon, Portugal. Contact David Halpern, e-mail: halpern@pacific.jpl.nasa.gov, or URL: http://www.unesco.org/ioc/iyo/icsos/.
September 14-17	SPIE's First International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment & Space, Beijing, China. Contact Jinxue Wang, e-mail: jwang@eos.ucar.edu.
September 21-25	Conference on Sensors, Systems & Next Generation Satellites, the European Symposium on Remote Sensing, Barcelona, Spain. Call for papers. Contact Steve Neeck, e-mail: steve.neeck@gsfc.nasa.gov.
October 5-7	Fifth International Conference on Remote Sensing for the Marine and Coastal Environments, San Diego. Contact Robert Rogers, tel: (313) 994-1200, ext. 3234, fax: (313) 994-5123, e-mail: marine@erim-int.com, URL: http://www.erim-int.com/CONF/conf.html.
October 25-28	Geological Society of America, Toronto. Call (303) 447-2020; fax: (303) 447-0648.
Oct. 29-Nov. 1	First International Conference on GIS Education, Ypsilanti, MI. Contact Jay Morgan, tel. (410) 830-2964, e-mail: jmorgan@towson.edu.

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