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AIRCRAFT EXPERIMENTS: Summer 1989 and Beyond

In this month's issue, we begin an ongoing series of articles regarding the various flight experiments, both planned and in progress, that will lead up to the Eos mission in the late 1990's. The editor welcomes contributions to this column from anyone planning missions that will be of interest to the Earth science community at large.

In this issue, we take a look at FIFE, an ongoing series of experiments, and AVIRIS, the precursor instrument for HIRIS.

FIFE
Dr. Forrest Hall, GSFC

The First ISLSCP Field Experiment (FIFE) is an international, land-surface-atmosphere experiment which was conducted in the summer of 1987 at and around the Konza Prairie Long Term Ecological Research (LTER) site near Manhattan, Kansas. The objectives of the experiment were to understand better the role of the land surface in controlling the interactions between the atmosphere and the "vegetated" land surface and to investigate the use of satellite remote sensing observations to infer climatologically significant land-surface parameters. FIFE is an interdisciplinary, coordinated effort as these objectives require the cooperation of researchers working in the fields of remote sensing, atmospheric physics, meteorology and biology. FIFE is entering into its third year. During 1989 additional field data will be collected over the Konza prairie in order to study the effects of drought stress on energy balance.

The 1989 experiment will be followed by two additional years of data analysis. Two key experiments within FIFE will help better understand the use of satellite remote sensing in monitoring surface energy balance. These are the Advanced Solid State Array (ASAS) experiment -- Jim Irons of GSFC Principal Investigator -- and the AVIRIS experiment -- Dr. David Schimel of Colorado State University Principal Investigator. The objective of the ASAS experiment is to better understand the bi-directional reflectance properties of surface vegetation. With the ASAS instrument mounted on the NASA C-130, vegetated surface targets will be overflown and multispectral data acquired at multiple view angles ranging from nadir to 60 degrees off-nadir. Data will be collected for a range of solar illumination angles and coincidentally with Landsat, SPOT and AVHRR satellite overpasses. In conjunction with the ASAS missions, surface energy balance data, vegetation and soil biophysical data as well as atmospheric optical properties data will be acquired. The bi-directional reflectance data so obtained will be analyzed to better understand how surface albedo depends on vegetation and soil state, and how these parameters affect surface energy balance.

The AVIRIS instrument (see next item) will be flown on the NASA ER2. The objective of the AVIRIS experiment will be to investigate the use of narrow-band spectral data to detect biochemical changes in the vegetated canopy which are indicative of other processes such as below-ground processes and fluxes of N2O.

AVIRIS
Rob Green, JPL

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) is an imaging spectrometer accurately measuring the total Earth-leaving radiance in 210 unique contiguous spectral channels, each having a 10 nm spectral radiance response function. The instrument flies on-board a NASA ER2 at an altitude of 20,000 meters, resulting in an 11 km ground swath and a 20 m ground resolution.

During the month of April an in-flight calibration experiment was performed with the AVIRIS. The experiment consisted of nine separate imaging overpasses of a calibration surface at Rogers Dry Lake on Edwards Air Force Base, California. In conjunction with these flights, concurrent atmospheric and surface measurements were collected by JPL division 32

DATE	SITE NAME, STATE	TITLE	NAME, AFFILIATION
26-May-89	MONO LAKE/MAMMOTH, CA	CALIBRATION	DOZIER,JEFF, NASA/JPL
26-May-89	OAK CREEK/PINE CREEK, CA		ADAMS/GILLESPIE
2-Jun-89	DOLLY VARDON MTNS, NV	CALIBRATION	VANE/GREEN, NASA/JPL
30-May-89	YUMA, CA	EOLIAN PROCESSES	BREED, CAROL S., USGS
30-May-89	N. DEATH VALLEY, NV		KRUSE/CLARK
31-May-89	PHOENIX/KELSO/GRAND CNYN, AZ	RADIOMETRY AND GEOMETRY	KIEFFER, HUGH H., USGS
30-May-89	MOJAVE DESERT, CA	TECTONICS	BLOM, RON, NASA/JPL
1-Jun-89	OREGON TRANSECT, OR	CARBON/NITROGEN FLUX	SWANBERG, NANCY, NASA/ARC
30-May-89	BLACK MTN., NV	MINERAL COATINGS	TARANIK, JAMES V., UNR
30-May-89	KANE SPRINGS, NV	MINERAL COATINGS	TARANIK, JAMES V., UNR
TBD	ITASCA, MN		RANSON, JON
TBD	SCHEFFERVILLE, QUEBEC		PETZOLD, DON
TBD	OKA, QUEBEC	CARBONATITE COMPLEXES	ROWAN, LAWRENCE, USGS
26-Jun-89	GAINESVILLE, FL	FOREST CANOPY	PETERSON, DAVID, NASA/ARC
26-Jun-89	TARGET OF OPPORTUNITY, NC	FOREST CANOPY	PETERSON, DAVID, NASA/ARC
17-Jul-89	WHITE INYO MTNS., CA	AVIRIS IN FLIGHT CALIBRATION	VANE/GREEN, NASA/JPL
17-Jul-89	MIST, OR	SURFACE ALTERATION	LANG/SETTLE, NASA/JPL
17-Jul-89	BIG HORN, WY	SEDIMENTARY BASINS	LANG, HAROLD R., NASA/JPL
17-Jul-89	WIND RIVER, WY	MAPPING PROGRAM	ABRAMS,MIKE, NASA/JPL
24-Jul-89	LUNAR CRATER, CA	GEOMORPHIC INDICATOR	FARR/BALTUCK, NASA/JPL
24-Jul-89	UBEHEBE/DEATH VALLEY/CIMA, CA	GEOMORPHIC INDICATOR	FARR/BALTUCK, NASA/JPL
25-Jul-89	PROVIDENCE FAN/KELSO, CA	GEOMORPHIC INDICATOR	FARR/BALTUCK, NASA/JPL
25-Jul-89	LUNAR LAKE/DEEP SPRINGS, CA	AVIRIS IN-FLIGHT CALIBRATION	VANE/GREEN, NASA/JPL
TBD	OWENS VALLEY/COSO VOLC., CA	GEOMORPHIC INDICATOR	FARR, TOM G., NASA/JPL
31-Jul-89	CRIPPLE CREEK, CO		KRUSE/CLARK
31-Jul-89	IRON HILL, CO	CARBONATITE COMPLEXES	ROWAN, LAWRENCE, USGS
31-Jul-89	DRUM MTNS., UT		BAILEY, BRYAN
2-Aug-89	DUKE FOREST, NC	EOS SYNERGISM	CIMINO, J. B., NASA/JPL
2-Aug-89	PELLSTON, MI	EOS SYNERGISM	CIMINO, J. B., NASA/JPL
20-Jun-89	WHITEFACE MTN./ACADIA, NY	STRESS IN VEGETATION	ROCK, U NEW HAMPSHIRE
20-Jun-89	MA/ME/NH	FOREST CANOPY	PETERSON, DAVID, NASA/ARC
7-Aug-89	BLACK HAWK ID., WI		ABER
21-Aug-89	SIERRA NEVADA, CA	PLUTONIC ROCKS	TARANIK, JAMES V., UNR
11-Sep-89	GYPSUM/CEMENT, TX/OK	SURFACE ALTERATION	LANG/SETTLE, NASA/JPL
18-Sep-89	JORNADA, NM	EOLIAN PROCESSES	BREED, CAROL S., USGS

TABLE 1: AVIRIS CALIBRATION RESULTS

Parameter	Requirement	In-Flight Determination
Spectral		
Coverage	410 - 2450 nm	410 - 2450 nm
Response Function	<= 10 nm	~= 10 nm
Channel Position	<= 5 nm	~= 2 nm
Sampling Interval	<= 10 nm	~= 10 nm
Radiometric		
Transfer Function	<= 10%	~= 8%*
Relative Response	<= 0.5%	~= 0.5%**
Geometric		
GFOV	>= 10 km	~= 11 km
GIFOV	<= 30 m	<= 30 m
Linearity	<= 0.1 pixels	<= 0.1 pixels**
Signal-to-noise		
700 nm (A)	>= 100:1	~= 190:1
700 nm (B)	>= 100:1	~= 110:1
2200 nm (D)	>= 50:1	~= 26:1

* Based on in-flight determined radiometric transfer function.
** Based on instrument or laboratory measurements

scientists, representatives of the University of Arizona remote sensing program and scientists from the USDA at Phoenix. With these data and the LOWTRAN 7 radiative transfer code, analyses of the spectral, radiometric, geometric and signal-to-noise characteristics of AVIRIS were completed.

Based on the results of this rigorous calibration experiment, AVIRIS has been designated operational for the summer flight season of 1989. A summary of these results is shown above. A flight manifest, current as of June 5, is shown on page 2.

To date, 15 science experiments have been flown resulting in over 10 gigabytes of data. These data are presently being distributed to the investigators. Disciplines being addressed with AVIRIS include geology, hydrology, botany, ecosystem research, atmospheric science, oceanography, inland water, and cloud studies. During 1989, the sensor will be deployed throughout much of the United States in addition to several data runs in Canada. The AVIRIS project is prepared for a full summer flight season in 1989 and is looking forward to operations through the launch of Eos in the late 1990's.

NAR UPDATE

The Non-Advocacy Review was held on June 12-16 in Greenbelt, MD. In the science area, questions covered mostly the areas of science requirement defintion and science synergism (both in terms of timing and linkage between the many instruments) as well as the linkage between the two platforms. Recommendations are expected mid-July.

"The Meatball Chart"

The Project Science Offices at both JPL and GSFC have constructed what has come to be known as "The Meatball Chart" to show how the instruments chosen in the Announcement of Opportunity meet the 39 science objectives detailed in the AO. This chart was presented at the NAR (June 12-16), and is included in the newsletter both for your information and your review. Please address any comments to the editor on telemail.

Hydrologic Cycle

1. Eos shall address the quantification of the processes of precipitation, runoff, evaporation, and evapotranspiration on a global basis.

2. Eos shall address determination of which factors control the hydrologic cycle.

3. Eos shall address the determination of the effects of sea and land ice upon the global hydrologic cycle.

4. Eos shall address the quantification of the interactions between the vegetation, soil, and topographic characteristics of the land surface and the components of the hydrologic cycle.

Biogeochemical Cycles

5. Eos shall address the understanding of the biogeochemical cycling of carbon, nitrogen, phosphorous, sulfur, and trace metals.

6. Eos shall address the determination of the global distribution of biomass and what controls both its heterogeneous distribution in space and its change over time.

7. Eos shall address the determination of the global distribution of gross primary production and respiration by autotrophic and heterotrophic organisms and the annual cycle and year-to-year variation of these processes.

8. Eos shall address the determination of transport of sediments and nutrients from the land to inland waters and oceans.

9. Eos shall address the quantification of the global distribution and transport of tropospheric gases and aerosols and determine strengths of their sources and sinks in the ocean, land surface, coastal and inland waters, and upper atmosphere.

10. Eos shall address the understanding of the processes controlling acid precipitation and deposition.

Climatological Processes

11. Eos shall address the determination of the modes of large-scale and low-frequency variability

(month-to-month and year-to-year time scales) of meteorological variables such as: wind, pressure, temperature, cloudiness, and precipitation.

12. Eos shall address the quantification of the large-scale and low-frequency variability of net incoming solar radiation and net outgoing long-wave radiation and their relationships to cloudiness.

13. Eos shall address the determination of the relationships between large-scale and low-frequency variability of meteorological observables and the variability of sea surface temperatures and current systems.

14. Eos shall address the quantification of the influences of changes in land surface evaporation, albedo, and roughness on local and regional climate.

15. Eos shall address the assessment of the influence of sea and land ice cover on global climate.

16. Eos shall address the improvement and extension of knowledge of past climates.

17. Eos shall address the determination of the role of land biota as sources and/or sinks of carbon dioxide and other radiatively important trace gases.

18. Eos shall address prediction of climate on a probabilistic basis.

Geophysical Processes

Atmospheric Processes

19. Eos shall address the understanding of the coupling of the chemical, radiative, and dynamic processes of the troposphere, stratosphere, and mesosphere.

20. Eos shall address the determination of the coupling between the lower and upper atmosphere.

21. Eos shall address the improvement of the quantitative understanding of the variability of atmospheric ozone, including the influence of anthropogenic perturbations.

22. Eos shall address the improvement of the understanding of the mechanisms for the maintenance and variability of atmospheric electric fields.

23. Eos shall address the improvement of the accuracy of deterministic weather forecasting and extend the useful forecast periods.

Oceanic Processes

24. Eos shall address the measurement of the mesoscale to large-scale circulation of the ocean and acquire a better understanding of the long-term variability in this circulation.

25. Eos shall address the determination of the global heat, mass, and momentum coupling between the ocean and atmosphere.

26. Eos shall address the understanding of the processes controlling the dynamics of sea ice and its interaction with the underlying water.

27. Eos shall address the characterization of the upper ocean response to thermal and atmospheric forcing, including the effects of persistent horizontal variability in the ocean and atmosphere.

28. Eos shall address the understanding of the interaction of physical and biological processes, including the effects of horizontal and vertical variability.

29. Eos shall address the characterization of the exchange processes between surface and deep waters.

Solid Earth Processes

30. Eos shall address the measurement and mapping of the global distribution, geometry, and composition of continental rock units.

31. Eos shall address the understanding of the causes of the morphology and structure of the continental crust.

32. Eos shall address the understanding of how episodic processes such as rainfall, runoff, dust storms, earthquakes, and volcanism modify the surface of the Earth.

33. Eos shall address the understanding of the dynamics of inland ice sheets.

34. Eos shall address the quantification of the relation between the factors of climate, topography, vegetation, and geologic substrata and the processes of soil formation and degradation.

35. Eos shall address the understanding of the temporal variations in plate velocities.

36. Eos shall address the identification of the planform, vertical structure, and time variation of mantle convection.

37. Eos shall address the measurement of the global gravity and magnetic fields to reveal with greater accuracy the structure of the upper mantle.

38. Eos shall address the explanation of secular variations, including reversals, of the Earth's magnetic fields.

39. Eos shall explain the secular variations in the Earth's long-wavelength gravity field in terms of the viscosity structure of the mantle.

Eos/SCIENCE
LEVEL 0 SCIENCE REQUIREMENTS vs INSTRUMENTS REQUIREMENTS

		HYDROLOGIC CYCLES				BIOGEOCHEMICAL CYCLES						CLIMATOLOGICAL PROCESSES								GEOPHYSICAL PROCESSES																				
																				ATMOSPHERIC PROCESSES					OCEANIC PROCESSES						SOLID EARTH PROCESSES									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
LASER ALTIMETRY	GLRS		●	●	●							●	●			●				●				●								●	●	●		●				
IMAGING SPECTROMETRY	MODIS-N	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●				●						
	MODIS-T						●	●	●	●	●	●		●	●	●	●		●	●	●				●	●		●	●	●				●						
	HIRIS	●	●		●	●	●	●	●		●		●	●	●	●	●	●		●	●								●		●	●	●		●					
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	TIGER	●	●		●	●	●	●							●		●														●	●	●		●					
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	EOSP					●					●	●	●	●		●				●	●			●																
SENSING WITH ACTIVE MICROWAVES	SAR	●	●	●	●	●	●	●							●	●	●	●								●	●				●	●	●	●						
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	GGI											●											●		●	●	●	●	●	●								●		●
MICROWAVE RADIOMETRY	AMSR	●									●	●			●				●							●	●													
	HIMSS	●	●								●	●			●	●			●					●		●	●													
TEMPERATURE & MOISTURE SOUNDING	AMSU	●										●		●	●	●			●	●	●			●																
	AIRS	●	●							●	●	●	●	●	●				●	●	●			●																
ATMOSPHERIC COMPOSITION	HIRRLS					●				●		●	●						●	●	●	●		●																
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	TRACER					●		●		●								●	●	●	●																			
	TES					●		●		●	●		●					●	●	●	●	●																		
ATMOSPHERIC WINDS	SWIRLS					●				●		●							●	●	●	●	●	●																
	LAWS					●				●	●	●		●					●	●	●			●																
RADIATION ENERGY BUDGET	LIS		●																				●																	
	CERES												●	●		●				●																				
SOLAR MONITORS	ACRIM												●																											
	SOLSTICE												●									●																		
PARTICLES AND FIELDS	GOS																						●														●	●	●	
	IPEI																						●																	
	XIE																						●																	
	SEM																						●															●	●	
SECONDARY SCIENCE	ENACEOS																						●																	
	POEMS																						●																	

The Importance of LAWS Wind Profiles for Earth System Science

W. E. Baker, LAWS Science Team Leader

Knowledge of the global wind field is widely recognized as fundamental to advancing our understanding and prediction of the total Earth system. Yet, because wind profiles are primarily measured by land-based rawinsondes, the oceanic areas (covering roughly three quarters of the Earth's surface) and many regions of the less-developed southern hemisphere land areas are poorly observed. The gap between our requirements for global wind data and their availability continues to widen. For example, as faster computers become available to model the atmosphere with ever increasing resolution and sophistication, our ability to do so will be hampered because of the lack of data, particularly wind profiles.

This article discusses the importance of global wind profiles for advancing our understanding and prediction of the total Earth system and outlines the probable characteristics of the space-based Laser Atmospheric Wind Sounder (LAWS) instrument envisioned to fly in polar orbit beginning in 1998. Some remaining issues, which are important for the final instrument design, are also briefly mentioned.

The members of the LAWS Science Team are working hard to help insure that the requirements of Earth system science for wind measurements will be met by the LAWS instrument. The members of the team and their affiliations are listed below:

John R. Anderson, University of Wisconsin
Robert M. Atlas, NASA/Goddard Space Flight Center
George Emmitt, Simpson Weather Associates, Inc.
R. Michael Hardesty, NOAA/ERL/Wave Propagation Laboratory
Robert W. Lee, Lassen Research
Andrew Lorenc, United Kingdom Meteorological Office
Robert Menzies, Jet Propulsion Laboratory
Timothy L. Miller, NASA/Marshall Space Flight Center
Madison Post, NOAA/Wave Propagation Laboratory
Robert A. Brown, University of Washington
John Molinari, State University of New York
Jan Paegle, University of Utah

Improved Numerical Weather Prediction

One of the most important applications of wind observations is in the field of numerical weather prediction (NWP). Significant progress has been made in this area in the last 10 years, especially with the development of accurate global NWP models, as well as with improved global coverage of the atmosphere provided by satellite observing systems. With the successful completion of the Global Weather Experiment in 1979, operational centers (e.g., the European Centre for Medium Range Weather Forecasts (ECMWF), the National Meteorological Center (NMC), and the research laboratories such as the Geophysical Fluid Dynamics Laboratory (GFDL) and the Goddard Laboratory for Atmospheres (GLA)) began producing forecasts that retained some useful skill beyond 5 days, much longer than was possible just a few years before.

However, we are still not close to the 2-week theoretical limit of dynamical predictability. It is clear that further improvements will be necessary in the observations that provide the initial data for the models as well as in the objective analysis techniques.

The first NWP models were designed to use only mass (height) data. Winds were derived from the mass observations using the geostrophic relationship. This relationship assumes that the latitudinally dependent Coriolis force is balanced by the pressure gradient force. This was a natural choice because pressure observations were more abundant and more accurate than wind observations. With the advent of global primitive equation models, however, the need for accurate wind profile data has become increasingly clear. There are two independent reasons for this (Kalnay et al., 1985).

The first reason is derived from the concept of geostrophic adjustment (Rossby, 1938; Washington, 1964; Daley, 1980). On the scales measured by a data swath of a low Earth-orbiting satellite, variations in mass data are quickly rejected by the model. This rejection process is consistent with atmospheric behavior. Specifically, small-scale pressure-height variations do not result in small-scale changes in the wind field; instead they are rapidly dispersed as gravity waves. Simply posed, models accept the wind data more readily than mass data for scales which can be observed. Pressure or height data are not retained as well unless they are forced a priori to be in geostrophic balance with the winds.

The second reason for the importance of wind data is that differentiation enhances the effect of noisy observations, whereas integration reduces the effect of noise. The geostrophic relationship relates the wind to the horizontal pressure gradient; at increasingly smaller scales, the geostrophic relationship is often invalid so that winds become an increasingly more important measure of the atmospheric state than pressure or height measurements.

Improved Understanding of Mesoscale Systems

Along with the increasing recognition of the importance of having global measurements for successful medium-range (3 to 10 days) and short-range (1 to 2 days) numerical weather forecasts, the importance of obtaining mesoscale observations for very shortterm forecasts (3 to 18 hours) and nowcasts (0 to 3 hours) is also becoming increasingly evident. The conventional sounding network has difficulty resolving these mesoscale features, and, as a consequence, the initial conditions for operational numerical models fail to capture important details necessary for an accurate forecast.

The ageostrophic nature of many mesoscale circulations (jet streaks, nocturnal jets, mountain waves, many cyclones) make them ideal candidates for LAWS observations since their wind fields cannot be derived from the mass fields -- particularly in the tropics. However, the spatial scale of the significant wind gradients can benefit from somewhat higher resolution than that expected from the present LAWS design.

The LAWS instrument, as currently envisioned, is configured to provide wind profiles with spatial (~100-300 km; ~0.5 to 1 km vertical spacing) and temporal (~12 hr) resolution consistent with the input requirements of global weather and climate models. While the design has been guided by this global and large scale perspective, smaller scale phenomena may not only impact the performance of LAWS (Emmitt, 1985) but may under certain conditions be resolvable (Houston and Emmitt, 1987).

LAWS will have the capability of providing 500 m to 1 km vertically resolved wind profiles from the top of the troposphere down to the first optically thick cloud or the ground. The spacing between shots will be on the order of 50-75 km with 4-6 shots being combined to produce single vector wind profiles on a 100-300 km grid. Any given grid area will be overflown once every 12 hours at the equator with increasing frequency as one goes poleward. When there are sufficient aerosols (including thin cirrus), it may be possible to use single shots and pairs of shots to achieve ~60 km resolution with temporal resolution remaining at 12 hours near the equator. With some form of shot management it may be possible to further increase the resolution to 25-30 km in regions of meso-α interest without impacting laser lifetime or jeopardizing the systems performance for global scale applications.

More Accurate Diagnostics of Large-Scale Circulation and Climate Dynamics

Fluctuations in the climate system over one part of the globe are capable of being communicated great distances to other parts. The remarkable weather experienced in many areas of the world during the tropical Pacific El Niño event of 1982-1983 (Rasmusson, 1984) is a dramatic case in point.

The degree to which behavior in one part of the globe can be communicated elsewhere by the atmosphere appears to depend subtly on the background atmospheric state (Branstator, 1983). For instance, one such teleconnection, namely the one between the tropical Pacific and northern hemisphere extratropics, may be sensitive to the structure of the wind field in the exit region of the subtropical east Asian jet that lies between two regions. Indications are, however, that the currently available data base is not able to depict the structure of the east Asian jet exit region sufficiently well. Thus, Rosen et al. (1985) found large differences between two different analyses of the zonal wind field in the area of the east Asian jet based on the data collected during the Global Weather Experiment despite the apparent extensive nature of these observations. Data from the LAWS instrument should significantly improve the quality of the wind analyses in such critical regions as the subtropical Pacific.

Knowledge of the means by which the atmosphere interacts with other components of the climate system, such as the oceans or the solid Earth, is important not only to meteorologists but also to scientists in other disciplines. For example, the geodynamics community is interested in accurate, global wind measurements. Recent studies of the angular momentum balance of the Earth-atmosphere system reveal that current geodetic and atmospheric data sets are capable of detecting day-to-day changes in this balance to good precision (Morgan et. al., 1985). Improvements in the accuracy and coverage of the atmospheric data are desired because the geodetic measurements of changes in the solid Earth's angular momentum are expected to become significantly more accurate in the next several years.

Improved Surface/Atmospheric Fluxes

Fluxes of momentum, heat, moisture, CO2, and other constituents are important to a majority of the Eos interdisciplinary studies. These fluxes are inevitably parameterized with respect to a mean horizontal wind in the boundary layer. The lowest level LAWS winds will provide complementary data to the scatterometer over water and to boundary layer wind measurements where no others exist in other locations.

Improved Understanding of Global Biogeochemical and Hydrologic Cycles

The global wind data set obtainable from the Eos LAWS system will form a significant component of the temporally continuous global data base required for studies of coupled climate systems. This data base is needed to: (1) describe atmospheric general circulation including annual and interannual changes and the transports of energy, momentum, moisture, trace gases, and aerosols; (2) quantify the cycles of atmospheric variables that are key ingredients of climate change; (3) test and verify existing coupled climate models and develop new and improved ones; and (4) advance theories of climate and its variations.

Hydrologic Cycle

The important components of the hydrologic cycle involve time scales ranging from hours to hundreds of years. An amount of water equal to the total global tropospheric reservoir is exchanged with the ocean and land surface every 10 days. Key components of the water cycle on this 10-day time scale include evaporation and precipitation over the land and oceans and large-scale horizontal transport of water vapor by the general circulation. Quantitative knowledge of these crucial processes over the ocean is inadequate for the comprehensive understanding of the global and regional hydrologic cycles largely because data on winds, water vapor, and precipitation are too sparse over the oceans for accurate three-dimensional analyses on daily, seasonal, and annual time scales.

The global wind observations obtained from LAWS will contribute in two very important ways toward an improved understanding of global and regional hydrologic cycles. First, they will provide a more accurate estimate of the horizontal transport of water vapor. Second, their use in global models in a data-assimilation cycle will contribute toward improved analysis and prediction of vertical motion (and vertical transport of water vapor) and precipitation. When global wind observations are used in conjunction with data from other observing systems (e.g., AIRS - the Atmospheric Infrared Sounder and MODIS - the Moderate Resolution Imaging Spectrometer) in numerical models, it will be possible to advance significantly our knowledge of the hydrologic cycle on time scales of days, seasons, and years.

Transport of Trace Gases and Aerosols

Next to water in importance to life on Earth are compounds involving carbon, nitrogen, and sulfur. There is abundant evidence that increases are occurring in the atmospheric composition of radiatively active trace gases composed of these elements, including carbon dioxide, methane, oxides of nitrogen and sulfur, as well as the chlorofluorocarbons. Many of these changes are thought to be a result of human activities superimposed on natural fluctuations, but the complex causes and relationships are not yet fully understood. Whatever the cause of these increases, the resulting changes in regional and global climates over the next 100 years could possibly exceed those experienced by human societies. Thus, there is an urgent need to understand the biogeochemical cycles of these elements.

Atmospheric aerosols, naturally and anthropogenically produced, are also potentially important in future climate changes. Some examples of possible aerosol impacts of the climate include: 1) the volcanic eruptions of Agung in 1963 and El Chichon in 1982 which were followed by reductions in solar radiation reaching the Earth's surface and increased longwave opacity in the stratosphere; 2) the transport of mineral dust from the deserts over adjoining regions, where radiatively active dust contributes to regional climate modification; 3) the dust transport to the open ocean, where water-soluble nutrients in the dust contribute to phytoplankton productivity, and dust mass contributes to ocean floor sediments; and 4) the transport of acidic aerosols over sensitive ecological regions, where acid rain can lead to serious environmental damage.

Two important components of biogeochemical cycles and budgets of aerosols are the horizontal and vertical transport of trace gases and aerosols, and their interactions with cloud and precipitation systems. The latter are important through their role in chemical transformations and in removal through wet scavenging. The same wind observations and models that will better define the hydrologic cycle will also be useful in estimating the long-range transport of trace gases and aerosols and in establishing better estimates of precipitation systems over the oceans.

Cirrus Impacts on the Earth's Radiation Budget

LAWS will be able to detect thin to sub-visible cirrus (optical thickness < .03) around the entire globe, day or night and in the presence of lower clouds. The effects of thin cirrus (including contrails) on the Earth's radiation budget has been recognized as significant. However, the low density cirrus has been difficult to detect with current passive remote sensing systems (e.g., infrared radiometers, spectrometers, visible imagery, Statospheric Aerosol and Gas Experiment, SAGE).

Because of its beam dimensions and the low spatial density of sampling, the LAWS will provide cirrus information in a different format than that available from passive systems. Techniques to integrate the cloud climatologies from different systems and perspectives will have to be developed to produce complete and reliable radiation budgets for use in global climate models.

LAWS Instrument Characteristics

The characteristics of the instrument most likely to be selected for the platform are summarized below:

Transmitter: Single-frequency, pulsed, transversely excited atmospheric CO2 laser operating at 9.11 μm
Pulse Energy: 10 J/Pulse
Pulse Length: 2 to 4 μsec (Optimized)
Pulse Repetition Frequency: 10 Hz
Receiver: Coherent detection
Telescope (Transmitting and Receiving): 1.5 M diameter; 6 rpm scan rate
Measurement Domain: Global, near surface to tropopause in cloud-free air (with sufficient aerosol)
Horizontal Resolution: ~100 km
Vertical Resolution: ~1 km in the free atmosphere, ~0.5 KM in the PBL
Line of Sight Accuracy: 1 to 5 m/s with quality indicators
Vector Wind Accuracy: 1 to 5 m/s with quality

indicators
Raw Data Rate: up to 40 Mbps
Expected Lifetime: 109 shots (3 year continuous usage)

Clarifications:
--Measurements may not be available at some points because of blockage by clouds or low aerosol levels.
--Vector wind accuracy will vary with horizontal resolution and shot management strategy.
--Data rate assumes an array detector with up to 20 elements. The rate drops to 1.5 Mbps for on-board processing (currently being investigated).

Some Remaining Design Issues

The required laser for the LAWS instrument is now considered to be technologically feasible. Some remaining science/hardware design issues which need to be addressed over the next several months include:

The extent to which the signal to noise ratio in marginal aerosol regions can be optimized through signal processing,

The science impact of proposed coverage changes to extend laser lifetime through laser shot management utilizing Observing System Simulation Experiments,

The level of background aerosol at the 9.11 μm wavelength (to be sampled by the field phase of the Global Backscatter Experiment (GLOBE) in the Fall of 1989 and Spring of 1990),

Anticipating that thin cirrus or sub-visible cirrus will provide excellent backscatter for LAWS, an effort is underway to assess the global cirrus distribution, and

Defining the best calibration and validation methodologies for LAWS velocity and backscatter measurements.

Identifying wind accuracy and discrimination in the PBL.

Summary

In summary, LAWS will provide a significant improvement in our ability to observe the global wind field. This will directly lead to an improvement in numerical weather forecasts and will fundamentally advance our understanding of the atmospheric circulation and dynamics and the biogeochemical and hydrological cycles.

Acknowledgements:

Much of the information in the first six sections of this article has been taken from the NASA Eos LAWS Instrument Panel Report, Volume IIg, Section II - Science Objectives. The report was one of the documents released as part of the NASA Eos Announcement of Opportunity in February 1988.

The contributions to the LAWS Instrument Panel Report by the Members of LAWS Instrument Panel are sincerely acknowledged. Members of the Panel included:

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James Bilbro
David Bowdle
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Robert Curran
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Milton Huffaker
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James Sparkman
Michael Vaughan
Christian Werner

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Eos Update

Schedule of Meetings

Date: July 5-7, 1989
Location: GSFC, Greenbelt, Maryland
Topic: MODIS Facility Team Instrument Meeting

Date: July 20, 1989
Location: GSFC, Greenbelt, Maryland *(note change)*
Topic: Science Executive Committee Meeting

Date: August 9-11, 1989
Location: MSFC, Huntsville, Alabama
Topic: LAWS Facility Instrument Team Meeting

Date: September 6-8, 1989
Location: Boulder, Colorado
Topic: HIRIS Facility Instrument Team Meeting

Date: October 10, 1989
Location: JPL, Pasadena, California
Topic: Hydrological Panel Meeting
(contact Eric Barron, Chairman)

Date: October 11-13, 1989
Location: CalTech, Pasadena, California
Topic: Second Meeting of the IWG

Date: October 17-20, 1989
Location: JPL, Pasadena, California
Topic: TOPEX Science Team

Acronyms

ADEOS = Advanced Earth Observing Satellite
DFVLR = Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt
Eos = Earth Observing System
Eos-A, C, E = first platform and replacements
Eos-B, D, F = second platform and replacements
EosDIS = Eos Data and Information System
EPOP = European Polar Orbiting Platform (Eos)
ERS-1 = Earth Remote-sensing Satellite (ESA)
ESA = European Space Agency
GREM = Geopotential Research Explorer Mission
GSFC = Goddard Space Flight Center
JERS-1 = Japanese Earth Remote-sensing Satellite
JPL = Jet Propulsion Laboratory
JPOP = Japanese Polar Orbiting Platform (Eos)
MSFC = Marshall Space Flight Center
NPOP = NASA Polar Orbiting Platform (Eos)
NSCAT = NASA Scatterometer
Radarsat = Radar Satellite
SIR-C = Spaceborne Imaging Radar-C
SSC = Eos Science Steering Committee
TOPEX/Poseidon = Topography Experiment
UARS = Upper Atmosphere Research Satellite
XSAR = X-band SAR (DFVLR)

Earth Observer Launch Schedule

ERS-1	October, 1990
UARS	September, 1991*
SIR-C/X-SAR ,1st flight	February, 1992
JERS-1	February, 1992
TOPEX/Poseidon	June, 1992
GREM	1992
SIR-C/X-SAR, 2nd flight	March, 1993
Radarsat	April, 1994
SIR-C/X-SAR, 3rd flight	1994
NSCAT/ADEOS	February, 1995
Eos-A	December, 1997
EPOP -1A	1996
Eos-B	December, 1999
JPOP	1998
Eos-C	2001
Eos-D	2003

* tight launch window due to desire to cover two northern hemisphere winters in the expected 18 month lifetime of UARS

LAWS

(Coninued from page 9)

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Letters to the Editors

The Earth Observer welcomes letters to the Editors on subjects relevant to Eos and the Earth science community. We reserve the right to edit letters when necessary in order to permit a greater number of views to be expressed. Questions of general interest may also be answered through this column. Letters should be mailed to the editor or sent via telemail (addresses below) by the tenth of the month in order to appear in the next newsletter. In the interest of fostering communication on the mission, we will give equal time (and space) to opposing opinions.

Note From the Editors:

If you would like to include anything in this newsletter, please send it to Marguerite Schier, the editor, preferably via telemail, by the 10th of the month. The newsletter will be released monthly, mailed approximately on the first of the month. The newsletter will also be available on the GSFCMAIL Eos bulletin board and on a JPL VAX. If you would like to receive a copy of the newsletter, please phone the Eos Support Office at Birch & Davis Associates, Inc. at (301) 589-6760 with your address and telemail address (*please do not phone the editor with addresses; you will be asked to call Birch & Davis directly*).

NOTE: The editor is still on the move -- watch this space for further updates on my whereabouts.

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The Earth Observer Logo: What does it mean?

The Earth Observer logo is more than just a pretty picture. The depiction of Earth in space signifies the study of the Earth as a planet, ala Mission to Planet Earth. Only a sliver of the Earth is shown to represent our limited understanding of Earth and its cycles/processes. As Eos progresses over the next decade, we will collect more data (through field studies and aircraft experiments), and the sliver will increase until, at launch, we will at last be able to see the whole Earth (via both the instruments and the logo). In the coming years, the logo may be changed periodically to show other views of the Earth, such as topographic views from altimetry, wind vector maps, and temperature maps, in order to respresent the full spectrum of instruments that make up Eos.

Publications

Please notify the editors of any new publications that may be of interest to the Eos community.

NASA TM 100718 -- MODIS-HIRIS Ground Data Systems Commonality Report

NASA TM 100719 -- MODIS Information, Data, and Control System (MIDACS) Level II Functional Requirements

NASA TM 100720 -- MODIS Information, Data, and Control System (MIDACS) Operations Concepts

NASA TM 100721 -- MODIS Information, Data, and Control System (MIDACS) System Specifications and Conceptual Design.

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