(5)

REPORT

ON

FACILITY INSTRUMENT

-"SILVER BULLETS"
-RESPONSE TO CES PRIORITIES
-DATA PRODUCTS AND ACCURACIES

PRESENTED TO

Eos IWG PAYLOAD ADVISORY PANEL
SCIENCE PRIORITIES AND PAYLOAD STRATEGIES MEETING

AT

UNIVERSITY OF NEW HAMPSHIRE
NOVEMBER 30, 1989

VINCENT V. SALOMONSON
NASA/GODDARD

INTRODUCTION

-THE ENCLOSED CHARTS CONCERN THE FOLLOWING FACILITY INSTRUMENTS

- -AIRS W/AMSU
- -MODIS
- -HIRIS
- -TIGER/ITIR
- -SAR
- -ALT
- -GLRS
- -LAWS

-THE CHARTS ARE AS RECEIVED FROM THE FACILITY TEAM LEADERS

-MATERIAL FOR EACH FACILITY INSTRUMENT INCLUDES:

-"SILVER BULLETS" PROVIDING STATEMENTS OF THE INSTRUMENT CONTRIBUTIONS TO QUESTIONS OF GLOBAL CHANGE;

-INDICATIONS ON THE COMMITTEE ON EARTH SCIENCES PRIORITIES CHART WHERE EACH INSTRUMENT MAKES WHAT ARE PERCEIVED TO BE "ESSENTIAL" OR "CONTRIBUTING" OBSERVATIONS;

-A LISTING OF DATA PRODUCTS AND THE EXPECTED ACCURACIES TO BE EXPECTED FROM EACH INSTRUMENT;

-IN GENERAL THE DATA PRODUCTS ARE THOSE THAT QUITE PROBABLY WILL BE PRODUCED.

- THE ACCURACIES VARY FROM THAT ASCRIBED TO A SINGLE PIXEL TO AN AGGREGATED RESULT USING SEVERAL PIXELS.

- EACH FACILITY INSTRUMENT TEAM IS CONTINUING TO STUDY THE PRODUCT PRODUCTION EXPECTATIONS SO, AT SOME LEVEL, THE ACCURACIES MUST BE REGARDED AS SUBJECT TO CONTINUED REFINEMENT AND DEFINITION.

- A LONG TABLE COMPILING THE DATA PRODUCTS FOR ALL FACILITY INSTRUMENTS AND THE ATTENDANT, EXPECTED ACCURACIES OF THE PRODUCTS.

AIRS/AMSU

GSFC Ext. 8601

IOM 14 November 1989

TO: V. V. Salomonson Code 600
GSFC FAX 301-286-9803

FROM: H. H. Aumann, AIRS Team

COPY: M. T. Chahine

SUBJECT: Silver bullets etc.

Following are the input from the AIRS team:

1. The five key AIRS/AMSU global change questions.

2. The AIRS/AMSU data products, and anticipated accuracies. These data refer to 3.3 degree spatial scales (i.e. 40 km from 705 km orbit altitude) and assume no supporting data from any other EOS instrument. Some products are only available for daylight scans, as indicated.

3. The global change research framework filled in with the following key (to make it through the FAX):
   P = primary supporting
   S = secondary supporting.

The originals are being mailed to you. In case of questions please contact me at 818-584-2934.

George Aumann

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5 pages total.

A I R S

Atmospheric Infrared Sounder

AIRS and AMSU will address the following questions in global change:

1. **Detection of the effects of increased greenhouse gases:**

   The ability to provide simultaneous observations of the Earth's atmospheric temperature, ocean surface temperature, and (for the first time) land surface temperature, as well as humidity, clouds, albedo, and the distribution of greenhouse gases, makes AIRS the primary space instrument to observe and study the effects of increased greenhouse gases.

2. **Determination of the factors which control the global energy and water cycles:**

   The study of the global hydrology cycle and its coupling to the energy cycle is key to understanding the major driving forces of the Earth's climate system. AIRS will measure the major components of these driving forces including the thermal structure of the surface and the atmosphere, the outgoing long wave infrared radiation, and the atmospheric water vapor.

3. Investigation of atmosphere-surface interactions:

   AIRS' super-window channels will be able to observe the surface with minimum spectral contamination by the atmosphere. In addition, AIRS' narrow spectral channels in the short wavelength infrared region will observe the atmospheric layers above the Earth's surface with the highest vertical resolution possible by passive remote sensing. The observations will enable investigations of the fluxes of energy and water vapor between the atmosphere and the surface, and study their effect on climate.

4. **Improving numerical weather prediction:**

   Numerical weather prediction models have now progressed to the point where they can predict atmospheric temperature profiles to an accuracy of 2^oC, which is equivalent to the accuracy of current satellite data. Further improvement in temperature profiles is therefore essential in order to improve forecasting accuracy. AIRS/AMSU temperature profiles with 1^oC accuracy will be an important step in improving weather prediction.

5. **Determination of the coupling between the troposphere and the stratosphere**

AIRS/AMSU will observe and define the mechanisms for coupling between the troposphere and the stratosphere through simultaneous determination of the vertical thermal structure of the atmosphere from the surface up to one mb together with the determination of the cloud amount, the cloud top height and temperature.

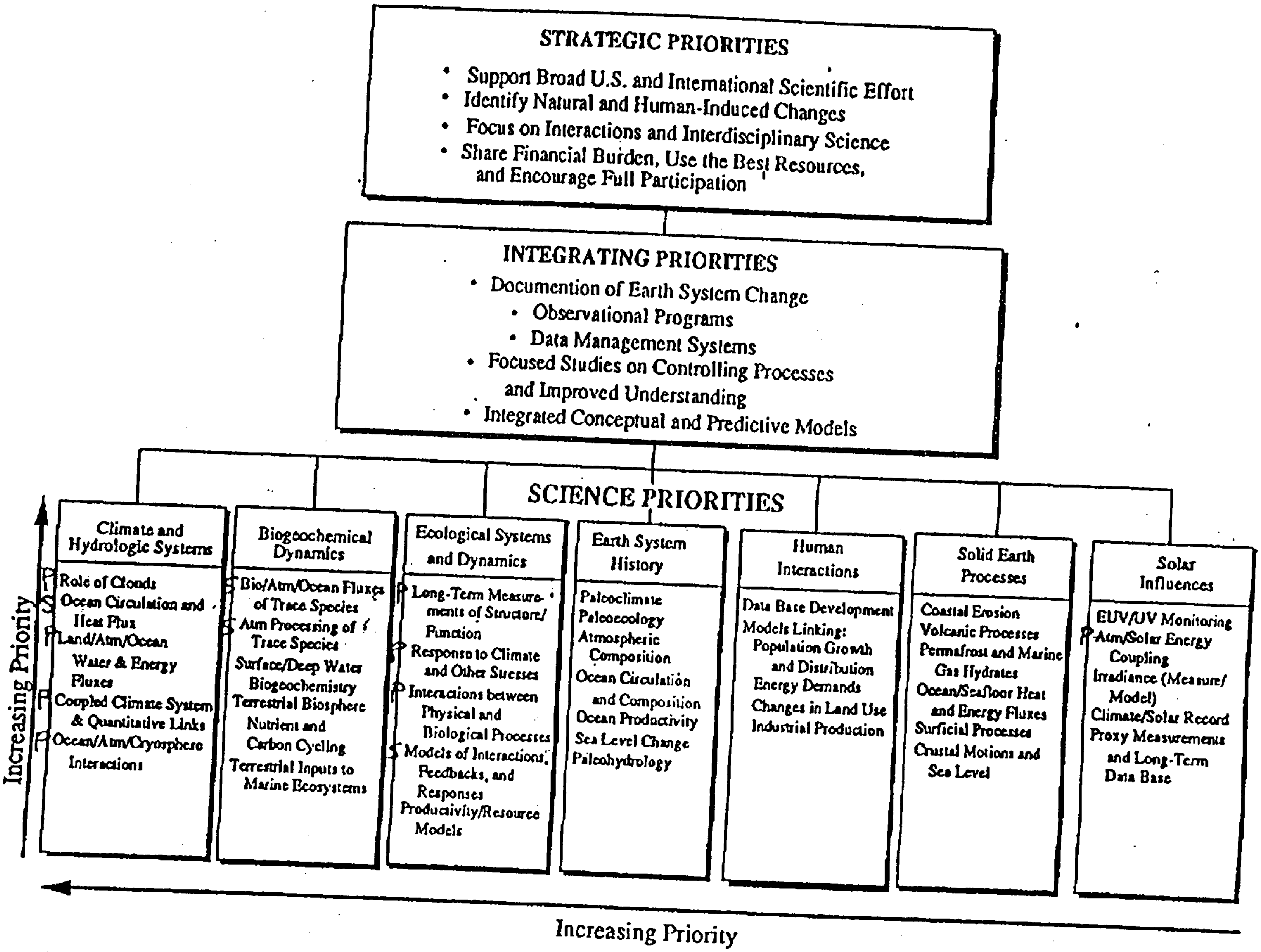

Figure 11. U.S. Global Change Research Program Priority Framework

AIRS/AMSU P = Primary Supporting
S = Secondary supporting

AIRS

Estimates of AIRS/AMSU Core Data Product Accuracies and their Support of Key Earth Science Issues	Type of observat-ion		Science Question Addressed					Accuracy	
								Now	Future
I. Atmosphere Data Products and Algorithm Analysis	Day	Night	1	2	3	4	5		
A. Temperature Profile (1 km vertical resolution)	x	x	P	P	S	P	P	2.5K	1.0 K
B. Humidity Profile	x	x	P	P	S	P	P	30 %	10 %
C. Total Precipitable Water	x	x	P	P	P	S	S	20 %	5 %
D. Precipitation estimate	x	x	P	P	S	S	S	3mm/day	2mm/day
E. Fractional Cloud Cover (0 - 1.0)	x	x	P	P	S	S	P	0.1	0.05
F. Cloud Top Pressure	x	x	S	S	P	S	S	2 km	0.5 km
G. Cloud Top Temperature	x	x	S	S	P	S	S	2 K	1 K
H. Cloud infrared spectral emissivity (3-17μm)	x	x	P	S	P	S	P	N / A	0.05
I. Cloud Optical Thickness	x		S	P	S	S	P	N / A	TBD
J. Cloud water thermodynamic Phase	x		P	P	S	S	S	N / A	ice/ liquid
K. Cloud Water Content	x	x	P	P	S	S	S	N / A	TBD
L. Total Ozone Burden	x	x	P		P	P	P	10 %	5 %
M. Mapping of Total Methane Burden	x	x	P		P		P	N / A	TBD
N. Mapping ofTotal Carbon Monoxide Burden	x	x	P		P		P	N / A	TBD
O. Mapping ofTotal Nitrous Oxide Burden	x	x	P		P		P	N / A	TBD
P. Carbon Dioxide Mixing Ratio	x	x	P	P			P	N / A	5 ppm
Q. Outgoing Longwave Spectral Radiation	x	x	P	P	S	P	P	N / A	TBD
R. Tropopause Height	x	x	S	S	S	S	P	3 km	0.5 km
S. Stratopause Height	x	x	S	S	S	S	P	5 km	1 km
T. Aerosols	x		P	S	S	S	P	0.05	TBD
II. Land Data Products and Algorithm Analysis									
A. Skin Surface Temperature	x	x	P	P	P	S	P	8 K	1 K
B. Day-Night Land Surface Temperature Difference	o	o	S	P	P	S	S	3 K	0.5 K
C. Land Surface Spectral Emissivity (3-17μm / Microwave)	x	x	P	P	P	S	P	N / A	0.05
D. Surface Albedo	x		S	P	P	S	S	N / A	TBD
E. Snow / Ice Cover	x	x	P	P	P	S	S	N / A	old / new
F. Downward Shortwave Flux	x		S	P	P	S	S	N / A	TBD
G. Upward Shortwave Flux	x		S	P	P	S	S	N / A	TBD
H. Downward Longward Flux	x	x	P	P	P	P	P	N / A	TBD
I. Upward Longwave Flux	x	x	P	P	P	P	P	N / A	TBD
III. Ocean Data Products and Algorithm Analysis									
A. Skin Surface Temperature	x	x	P	P	P	S	S	1.0 K	0.5 K
B. Sea Ice Cover (open water)	x	x	P	S	P	P	S	N / A	0.1
C. Surface Scalar Wind Speed (to 30 m/sec)	x	x		P	P	P		N / A	TBD
D. Downward Shortwave Flux	x		S	P	P	S	S	N / A	TBD
E. Upward Shortwave Flux	x		S	P	P	S	S	N / A	TBD
F. Downward Longward Flux	x	x	P	P	P	P	P	N / A	TBD
G. Upward Longwave Flux	x	x	P	P	P	P	P	N / A	TBD

x = yes
o = day + night

N / A = Not Available
TBD = Achievable, Accuracy to be determined
P = Primary support
S = Se :ondary support

MODIS

Fundamental Questions in Earth Science to be Addressed by MODIS:

1. Through global observations of ocean color, solar-stimulated fluorescence, and thermal emission MODIS will provide greatly improved estimates of phytoplankton biomass, oceanic photosynthetic potential, and sea surface temperature. These will provide improved understanding of the magnitude and variability of oceanic primary production (and the ability of the oceans to sequester carbon), ocean physical variability (related to ocean and ocean-atmosphere heat and mass flux), and the coupling between ocean biological and physical phenomena. MODIS data will lead to better understanding of the transformation of inorganic carbon into organic forms and their eventual burial in deep marine sediments (a key process of the carbon cycle), and the planetary heat and moisture cycles, and how variations in these cycles are affected by, and in turn affect, global climate change. MODIS will provide oceanic observations important for addressing oceanic components of global biogeochemical cycles, the hydrologic cycle, and the energy budget of the Earth.

2. Through the acquisition of daily and global observations at spatial resolutions of 214-856 meters, MODIS will provide improved global scale estimates of the areal extent and community composition of major terrestrial biomes. MODIS will assist in the estimation of photosynthetic potential, biomass, evapotranspiration and net primary productivity within these biomes and will monitor their phenology and changes in state through repetitive coverage. MODIS will play an integral role in monitoring hydrologic processes and fluxes within major biome types. MODIS will also provide regional monitoring of vegetation structure, growth stage, leaf area index, surface temperature, albedo changes, and spatial changes in land cover and land use with particular emphasis on forest alteration, agricultural expansion, and land degradation in semi-arid environments. MODIS-derived information on the nature and rates of change, including those brought about through anthropogenic activities, will be used to understand their contribution to regional and global climate change.

3. Through daily and global, relatively high spatial resolution (214-856 m.), and long-term measurements of cloud properties including cloud type, temperature, altitude, size distribution, cloud optical thickness, thermodynamic phase and effective particle radius, MODIS will provide information leading to a better understanding of the effects of clouds on the radiation budget of the Earth and the role of clouds in the so-called greenhouse warming of the Earth including feedback mechanisms associated with the dynamics of the atmosphere. MODIS will provide global data sets of surface temperature and albedo which will be used to provide improved information for modelling the energy balance of the planet. Additionally, these observations will provide improved estimates of surface-incident photosynthetically active solar radiation for use in studies of oceanic and terrestrial primary productivity on a global scale.

4. MODIS will provide estimates of the spatial extent of global snow and ice cover along with its temporal variation. Additionally, through measurements of snow and ice extent along with concurrent observations of surface temperature, outgoing longwave radiation, cloud cover and bidirectional reflectance obtained from MODIS, better understanding of the dynamics of snow and ice melt processes over large (greater than several thousands of square kilometers, for example) watersheds, continents and the globe will be derived with subsequent better quantification of the role of these processes in the hydrological cycle.

5. Through observations of marine and continental aerosol properties on a global basis, MODIS will provide information as to the spatial and temporal variability of aerosols and their relationship to sources and sinks associated with natural phenomena (e.g. volcanic activity, aeolian transport and sea salt) and anthropogenic activity (e.g., biomass and fossil fuel burning). Measurement of fire size and temperature, and land cover when combined with ground and airborne measurements will provide regional and global estimates of trace gas emissions from biomass burning. The interaction between aerosols and water vapor will also be studied in the context of cloud evolution.

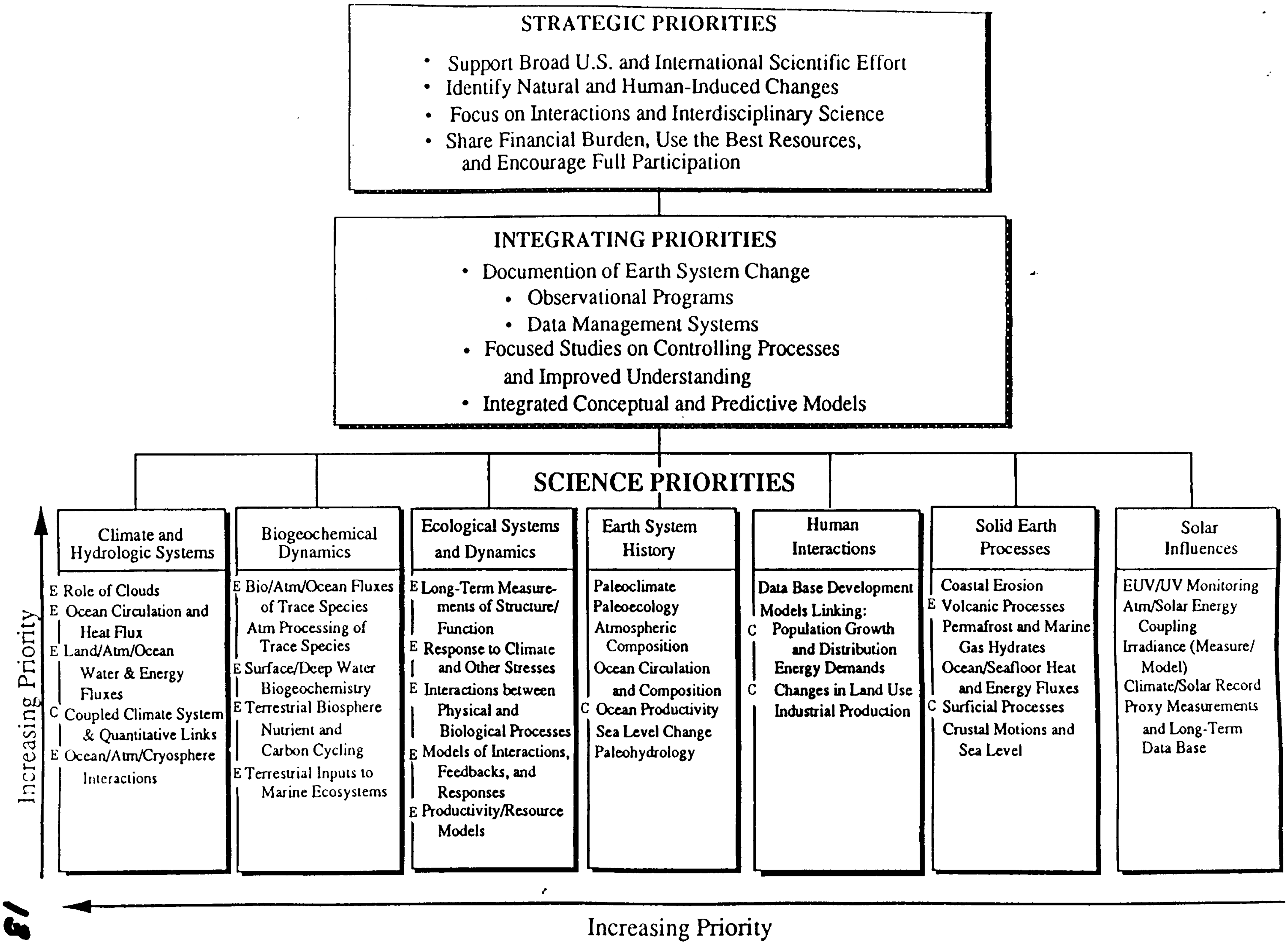

Figure 11. U.S. Global Change Research Program Priority Framework

SUPPORT COMMENTS FOR CES PRIORITIES CHART
18 November 1989

Climate and Hydrologic Systems

MODIS makes essential and strong contributions in this whole general area. MODIS makes contributions through its observations of cloud properties over the globe.' With relatively high spatial resolution, MODIS can provide data on the extent of the major terrestrial and marine biomes, plus the extent of snow and ice. Furthermore, it observes state variables such as solar reflectance and thermal emission that relate to radiative processes occurring at the ocean/atmosphere and land/atmosphere interfaces. MODIS will make essential contributions in estimating air/sea flux of energy through sea surface temperature measurements.

MODIS makes an essential contribution to the study of clouds through a determination of the global distribution of cloud optical thickness, effective particle radius, cloud top altitude, thermodynamic phase, and areal extent at a resolution of 4 km or better on a daily basis. MODIS also monitors water vapor and aerosol particles that interact to form clouds, and therefore determine the cloud characteristics.

The observations of ocean color and thermal emission including sea surface temperature contribute to synoptic, large area observations of the patterns of flow dynamics along with providing information pertaining to the latent and sensible heat flux at the ocean/atmosphere boundary.

Similarly over land, MODIS will monitor the extent (large regions, continental and hemispheric) of hydrologically significant land covers such as vegetation, snow and ice, and cloudiness, as well as the bidirectional reflectance and surface temperature leading to estimates of key components of the surface radiation balance within various land cover categories. MODIS-T, in combination with MISR, will help to better understand how to make better estimates of albedo using bidirectional reflectance observations. MODIS will be used to parameterize global biosphere dynamics into the global circulation models for exploring feedbacks between terrestrial conditions and climate responses.

Modis will be used to parameterize global biosphere dynamics into the global circulation models for exploring feedbacks between terrestrial conditions and climatic responses.

Biogeochemical Dynamics

MODIS data on leaf area index, absorbed photosynthetically active radiation, surface temperatures, and vegetation stress will contribute directly to this priority by determining global carbon fluxes from photosynthesis, respiration, and decomposition for all terrestrial biomes using complex simulation models.

MODIS will make essential contributions to biosphere/atmosphere/ocean fluxes of trace species. MODIS will allow much improved estimates of ocean color, and other important parameters such as attenuation coefficients and dissolved organics, especially in shelf areas which are important sites of carbon burial in sediment. The estimates of aerosols may also be significant, given current theories of limitation of marine primary production by aeolian trace metals. Specifically, it will allow synoptic estimates of primary production in the ocean, which is crucial for understanding carbon dioxide uptake by the ocean.

MODIS will be the only sensor with the high temporal/spatial resolutions necessary to follow terrestrial-aquatic transport of materials.

MODIS, through remote sensing of aerosol emission, fire frequency, size and temperature, will improve the trace gases and particulate emission inventories by monitoring biomass burning in tropical forests and savannah regions, as well as aerosol concentrations in industrial regions. MODIS has the capability to monitor active fronts of deforestation and, through the use of HIRIS (high spatial) in conjunction with MODIS (high temporal/moderate spatial) will provide the necessary multi-level data to monitor tropical deforestation components.

In summary, MODIS will permit improved estimates of marine and terrestrial production, by providing measurements of physiological indicators, such as chlorophyll fluorescence in the oceans, and driving variables such as surface illumination and surface temperature.

Ecological Systems and Dynamics

MODIS allows global monitoring of terrestrial and marine ecosystems at course spatial but fine temporal resolution. The MODIS data will complement high spatial resolution data from instruments like HIRIS, SAR, and TIGER/ITIR.

MODIS contributes directly to these priorities by daily, global estimation of key terrestrial variables such as leaf area index, absorbed photosynthetically active radiation, surface temperatures and vegetation stress. At annual time scales, MODIS is the only sensor that will document changes in global land use/land cover that will influence agro-forestry resource models.

MODIS will make essential contributions to long-term measurements of structure/function. In particular, the long time series of phytoplankton biomass and primary production may be one of the most important legacies of MODIS. It provides frequent estimates of course biomass measures such as ocean color and NDVI, and more specific information such as coccolith or blue-green algal abundance in the oceans.

In the area of physical/biological interactions, MODIS will provide essential information for comparisons of biological patterns (both terrestrial and oceanic) with physical forcing. This cannot be done with any other sensor. MODIS can monitor both growth and decomposition processes within major biomes. The decomposition component is often regarded as the parameter in studying ecosystem health, function, and degradation.

MODIS data will be the preferred input source for complex global biome simulation models, predicting interactions and feedback responses of terrestrial biomes to climatic and other global changes.

MODIS also contributes to research on ecological processes by providing data on physical driving variables (solar illumination, temperature, cloud cover) on short time scales. Ecological processes cover a large range of space and time scales, and MODIS fills an important slot in this spectrum.

Earth System History

The long time scales in this general category do not suggest that MODIS will make any significant contributions in this particular area except as they are derived in activities that fall under the previous research areas discussed above.

Human Interactions

MODIS makes a strong contribution in this area by offering a direct approach to estimating the total extent of various land use practices associated with anthropogenic activities. Among these are such things are deforestation, extent of agricultural practices, urbanization, etc. The MODIS estimates must be refined through the use of high spatial resolution data to depict the fine detail and processes occurring at the boundaries and where there may be mixtures of land use within MODIS pixels. However, the high temporal resolution of MODIS makes it a key contributing sensor for more cloudy areas.

Solid Earth Processes

MODIS will contribute to this area through mapping the extent of permafrost and large glaciers or ice sheets. It will also serve a role as an early detection mechanism for volcanic eruptions in remote areas (i.e., the high temperature bands on MODIS-N are there, at least in part, to provide this capability.

Solar Influences

MODIS makes only very minor, if any, contributions in this area.

These are products that it is conservatively believed can be provided shortly after launch, based on prelaunch experience with precursor airborne and space-borne sensors. Many other products are expected to be developed as a result of postresearch. All accuracy numbers are on a pixel basis.

"D" indicates that science question is directly addressed; "I" indirectly addressed

PRELIMINARY ESTIMATES OF MODIS CORE DATA PRODUCTS ACCURACIES, AND THEIR RELEVANCE TO KEY EARTH SCIENCE ISSUES	SCIENCE QUESTION ADDRESSED					ESTIMATED ACCURACY OF MODIS CORE DATA PRODUCT		COMMENTS
I. ATMOSPHERE CORE DATA PRODUCT ANALYS	1	2	3	4	5	PRESENT DAY	MODIS ERA	
A. Total Column Ozone	I					±10 to 20%	±5 TO 10%	0.2μm present, 0.1μm MODIS
B. Aerosol Optical Depth	I	I				±0.05	±0.05	
C. Aerosol Size Distribution	I	I				±10%	±10%	
D. Aerosol Mass Loading	I	I				±40%	±30%	
E. Aerosol Single Scattering Albedo	I	I				±0.04	±0.04	
F. Temperature Profiles			I		I	±2.5°C	±2°C	
G. Total Precipitable Water					D	±25%	±15%	±5% MODIS possible
H. Cloud Fractional Area	D		D	D		±10%	±10%	
I. Cloud Area and Perimeter			D				TBD	
J. Cloud Optical Thickness	D		D	D		±50%	±20%	daytime
K. Cloud Effective Emissivity			D	D		±0.2	±0.2	
L. Cloud Top Pressure			D			±25 to 50mb	±25 to 50mb	
M. Cloud Top Temperature			D			±2°C	±1°C	
N. Cloud Water Thermodynamic Phase			D			N/A	TBD	
O. Cloud Droplet Effective Radius			D			N/A	±40%	
P. Tropospheric Water Vapor					D	TBD	TBD	
Q. Moisture Profile					D	±30%	±20%	
II. LAND CORE DATA PRODUCT ANALYSES	1	2	3	4	5	PRESENT DAY	MODIS ERA	COMMENTS
A. Vegetation Indices		D			D	±0.05	±0.04	
B. Leaf Area Index		D			D	±0.5	±0.25	
C. Vegetation Stress		D			D	±300 sec/m	±200 sec/m	
D. Surface Temperature		D		D	D	±5°C	±3°C	
E. Thermal Anomalies (volcanoes, fires)		D				±50°C	±5°C	
F. Spectral Surface Albedo				D		±0.01	±0.01	
G. Snowcover				D		±10%	±5% or less	
H. Level-2 Land-Leaving Radiances		I		I	I	±20%	±10%	
I. Level-1 Topographic Corrections		I		I	I	±1/2 km	±100m	
J. Surface Water Cover Mapping					D	TBD	TBD	
K. Biome Type and Area		D				TBD	TBD	
L. Primary Production		D				r sq.=.5 to .8		
M. Incident PAR		D					±20%	PAR: Photosynthetically Active Radiation
III. OCEAN CORE DATA PRODUCT ANALYSES	1	2	3	4	5	PRESENT DAY	MODIS ERA	COMMENTS
A. Sea Surface Temperatures	D		D	D		±0.8°K	±0.4°K	(Under favorable conditions)
B. Sea Ice (Maximum Total Extent)	I			D		Less than 4%	Less than 4%	
C. Water-Leaving Radiance, Visible Channels	D					±30%	±10%	Under typical conditions
D. Chlorophyll Fluorescence	D					N/A	±30%	Probably much larger at low concentrations
E. Chlorophyll-A Pigment Concent. (Case I)	D					±100%	±35%	Present and MODIS accuracies assume typical conditions
F. Chlorophyll-A Pigment Concent. (Case II)	D					±300%	±50%	Accuracy may be optimistic
G. Detached Coccolith Concentration	D					N/A	±35%	Accuracy may be optimistic
H. Surface Incident PAR	D					±40%	±25%	PAR: Photosynthetically Active Radiation
I. Attenuation at 490 nm (Case I Waters)	D					±100%	±35%	Present and MODIS accuracies assume typical conditions
J. Attenuation of PAR	D					N/A	±30%	
K. Primary Productivity, Case I Waters	D					±300%	±50%	
L. Angstrom Exponent	I						±15%	
M. Single Scattering Aerosol Radiance	I					±10%	±10%	MODIS: reasonable for Case I waters w/moderate concentrations
N. In-situ Validation Observations	I		I			Instr. Dep.	Instr. Dep.	
O. Dissolved Organic Material Concentration	D					N/A	±150%	
P. Phycoerythrin Pigment Concentration	D					N/A	±200%	
Q. Currents, Fronts, Eddies	D						214 - 856m	

"D" indicates that science question is directly addressed; "I" indirectly addressed

HIRIS

Note: On HIRIS Key Measurements pages they can be made into one large chart using the following layout:

X1	X2	X3
Y1	Y2	Y3
Z1	Z2	Z3

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HIRIS SILVER BULLETS

1. CHANGE DETECTION/SCALING. In the Earth sciences we investigate processes at a spectrum of scales, from individual plots to small watersheds to regional and global scales. Eos provides some instruments (MODIS) suitable for global mapping missions and other instruments (HIRIS) suitable for investigation of processes and mapping at scales compatible with field investigations. HIRIS can be used to examine the changes that occur in transport of nutrients, sediments, and other solutes to wetlands, rivers, lakes and oceans. HIRIS can detect changes in both processes and Earth surface characteristics at a fine spatial scale before the same changes would be seen with a coarser-resolution sensor. In addition, spatially-heterogeneous fluxes of radiatively important gases, including water vapor, can be inferred.

Corresponding CES Strategic Priorities:

A1,A2,A3,A4,A5
B1,B2,B3,B4,B5
C1,C2,C3,C5
D1
E2
F1,F2,F5

2. ENERGY FLUXES/CLOUDS. Clouds play a central role in the Earth's radiation budget and in the feedback mechanisms associated with atmospheric dynamics and polar processes and are currently a poorly understood aspect of climate change. HIRIS will provide, at high spatial resolution, measurements of bidirectional reflectance, cloud heights, thickness, type, three-dimensional structure, thermodynamic phase, and effective droplet and crystal size distributions, to help address these questions.

Corresponding CES Strategic Priorities:

A1,A3

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3. ENERGY FLUXES/SNOW AND ICE. HIRIS can measure energy fluxes over the snow cover and glaciers on Earth's mountain ranges and polar regions. It will thus contribute to the measurement of changes in the global energy budget, detect early signals of changing regional climates, and help measure the changes in the global distribution of snow and ice that contribute to changing sea levels.

Corresponding CES Strategic Priorities:
A3,A5

4. PRODUCTIVITY AND NUTRIENT CYCLING/OCEANS AND FRESHWATER. Understanding the productivity and nutrient cycling in the world's oceans and freshwater systems is essential for modelling the global carbon cycle. HIRIS can detect changes in processes and water surface characteristics long before they would be seen with a coarser resolution sensor. HIRIS will resolve phytoplankton patches on scales of tens to hundreds of meters; this small scale variability is an important determinant of food web structure and trophodynamics which ultimately control the flux of carbon in the ocean. HIRIS will be used to infer the flux of riverine nutrients, sediments and other solutes at the land-water interface (estuaries, bays, and beaches).

Corresponding CES Strategic Priorities:
B1,B3,B5
C3,C5

5. TERRESTRIAL ECOSYSTEM CHEMICAL COMPOSITION AND STRUCTURE. HIRIS will provide data on terrestrial ecosystem chemical composition and structure with sufficient spatial and spectral detail to enable quantification of mass and energy exchanges with the atmosphere and hydrosphere, such as the processes of primary productivity and nutrient cycling. HIRIS' high spectral resolution and multidirectional pointing can be used to estimate chemical composition of vegetation canopies, ecosystem structure, and hemispheric albedo.

Corresponding CES Strategic Priorities:
A3,A4
B4
C1,C2,C3,C4,C5
E2
G5

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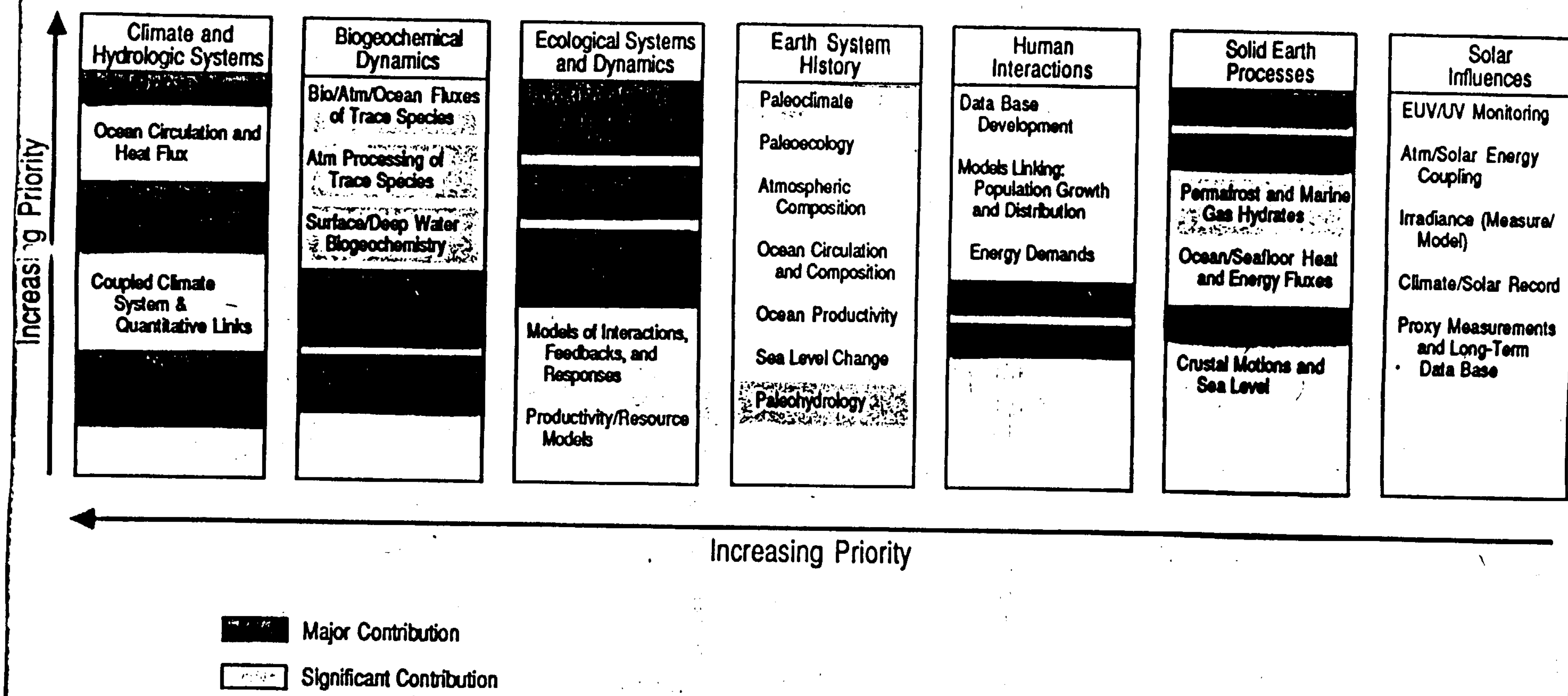
6. GEOLOGICAL PROCESSES. HIRIS is ideally suited to observe active geological processes as well as to provide insight into the Earth's history. HIRIS is uniquely designed to observe eolian processes that result in trace nutrients being added to the oceans, volcanic eruptions which affect atmospheric particle loading, and the source and extent of stabilized dune deposits that are important in understanding climates of the recent past. Present day Earth surface geology contains the record of past climate and can be used to validate global climate model predictions using "backward prediction".

Corresponding CES Strategic Priorities:

B5
D1
F1,F2,F5

HIRIS CONTRIBUTIONS TO CES SCIENCE PRIORITIES



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HIRIS KEY MEASUREMENTS

NOTES: These are all clear weather measurements (except for cloud measurements)
E = Essential Measurement
C = Contributing Measurement

Key Measurements	Silver Bullet #1	#2	#3	#4	#5	#6	Accuracy now	Accuracy fut	Application to CES priorities A1	A2	A3	A4	A5
Atmospheric Measurements													
√total column ozone	*						110%	110%					
cloud√type		*							E		E		
√fractional area	*	*						3%	E		E		
√optical thickness		*						3%	E		E		
√thickness		*						200m	E		E		
√top height		*						100m	E		E		
√base height								100m	E		E		
√water thermodynamic phase		*						10%	E		E		
√droplet effective radius		*						10% (!)	E		C		
√size distributions	*	*						5% (?)	E		E		
√BDRF as a function of the above parameters	*	*					5%	0.5%	E		E		
√total precipitable water	*	*					1mm	1mm	E		E		
Ice/Snow Measurements													
√snow covered area in selected mountainous regions	*		*					5%			E		C
√snow surface spectral albedo in selected mountainous regions	*		*				25% 25%	5% in vis 10% in IR			E		C
√grain size of snow surface	*		*					200%			C		C
√particulate content of snow	*		*					500%			C		C
√Ice type	*									E	E		E
√Floe ice fractional area	*							10%		E	E		E

X2

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11-21-89

HIRIS KEY MEASUREMENTS

NOTES: These are all clear weather measurements (except for cloud measurements)
E = Essential Measurement
C = Contributing Measurement

Key Measurements	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	D1	D2	D3	D4	D5	D6	D7
	Application to CES priorities																
Atmospheric measurements																	
√total column ozone		C															
cloud√type																	
√fractional area																	
√optical thickness																	
√thickness																	
√top height																	
√base height																	
√water thermodynamic phase																	
√droplet effective radius																	
√size distributions																	
√BDRF as a function of the above parameters																	
√total precipitable water																	
Ice/snow measurements																	
√snow covered area in selected mountainous regions																	
√snow surface spectral albedo in selected mountainous regions																	
√grain size of snow surface																	
√particulate content of snow																	
√Ice type																	
√Floe ice fractional area																	

X3

REV 1
11-21-89

HIRIS KEY MEASUREMENTS

NOTES: These are all clear weather measurements (except for cloud measurements)
E = Essential Measurement
C = Contributing Measurement

Key Measurements	E1	E2	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5
							Application to CES priorities						
Atmospheric Measurements													
√total column ozone													
cloud√type													
√fractional area													
√optical thickness													
√thickness													
√top height													
√base height													
√water thermodynamic phase													
√droplet effective radius													
√size distributions													
√BDRF as a function of the above parameters													
√total precipitable water													
Ice/snow measurements													
√snow covered area in selected mountainous regions													
√snow surface spectral albedo in selected mountainous regions													
√grain size of snow surface													
√particulate content of snow													
√Ice type													
√Floe ice fractional area													

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Key Measurements	Silver Bullet #1	#2	#3	#4	#5	#6	Accuracy now	fut	Application to CES priorities A1	A2	A3	A4	A5
√Floe ice area and perimeter	*							10%		E	E		E
√Floe ice size distributions	*							10%		E	E		E
√Broken ice fractional area	*							10%		E	E		E
√Meltpond fractional area	*							10%		E	E		E
√Meltpond:Onset of Melt/ Time of refreeze	*							n/a		E	E		E
√New ice/open water/lead fractional area	*							10%		E	E		E
√Sea ice crack density	*							n/a		C	C		C
√Sea ice BRDF as a function of the above ice parameters	*							10%		E	E		E
Ocean Measurements													
√Chlorophyll-a (concentration)	*			*			50-250%	20-50%					
√Accessory photosynthetic pigments (concentration)	*			*			n/a	20-50%					
√Suspended inorganic matter (concentration)	*			*			50-200%	20-50%					
√Suspended organic matter (concentration)	*			*			100-200%	20-50%					
√Dissolved organic matter (concentration)	*			*			100-300%	20-50%					
√Productivity of phyto-plankton (model result)	*			*			300%	50%					
√Gelbstoff abundance	*			*			n/a	50%					
Ocean/Land Measurements													
√Surface Photosynthetically Active Radiation (PAR)				*	*		40%	25%			E		
√Attenuation of PAR	*			*	*		n/a	30%			E		
Land measurements													
√Chlorophyll concentration (g/ha)	*				*		n/a	10%			C		
√Leaf area index	*				*		10%	5%			E		
√Leaf angle distribution	*				*		n/a	10%			E		

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REV 1
11-21-89

Key Measurements	Application to CES priorities																
	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	D1	D2	D3	D4	D5	D6	D7
√Floe ice area and perimeter																	
√Floe ice size distributions																	
√Broken ice fractional area																	
√Meltpond fractional area																	
√Meltpond:Onset of Melt/ Time of refreeze																	
√New ice/open water/lead fractional area																	
√Sea ice crack density																	
√Sea ice BRDF as a function of the above ice parameters																	
Ocean measurements																	
√Chlorophyll-a (concentration)	C		E		C			E		E					C		
√Accessory photosynthetic pigments (concentration)	C		E		C			E		E							
√Suspended inorganic matter (concentration)	E		C		E			E									
√Suspended organic matter (concentration)	C		E		E			E		E							
√Dissolved organic matter (concentration)	C		E		E			E		E							
√Productivity of phyto-plankton (model result)	C		E		C			E		E					C		
√Gelbstoff abundance	C		C		E			E		E							
Ocean/land measurements																	
√Surface Photosynthetically Active Radiation (PAR)	C		C	E		E	E	E	E/C	E			C				
√Attenuation of PAR	C		C	E		E	E	E	E/C	E			C				
Land measurements																	
√Chlorophyll concentration (g/ha)				E		E	E	E	E/C	C							
√Leaf area index				E		E	E	E	E/C	E							
√Leaf angle distribution				E		C	C	C	C	C							

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Key Measurements	E1	E2	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5
							Application to CES priorities						
√Floe ice area and perimeter													
√Floe ice size distributions													
√Broken ice fractional area													
√Meltpond fractional area													
√Meltpond:Onset of Melt/ Time of refreeze													
√New ice/open water/lead fractional area													
√Sea ice crack density													
√Sea ice BRDF as a function of the above ice parameters													
Ocean measurements													
√Chlorophyll-a (concentration)													
√Accessory photosynthetic pigments (concentration)													
√Suspended inorganic matter (concentration)													
√Suspended organic matter (concentration)													
√Dissolved organic matter (concentration)													
√Productivity of phyto-plankton (model result)													
√Gelbstoff abundance													
Ocean/land measurements													
√Surface Photosynthetically Active Radiation (PAR)		C											C
√Attenuation of PAR		C											C
Land measurements													
√Chlorophyll concentration (g/ha)		C											
√Leaf area index		C											
√Leaf angle distribution													

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REV 1
11-21-89

Key Measurements	Silver Bullet #1	#2	#3	#4	#5	#6	Accuracy now	fut	Application to CES priorities A1	A2	A3	A4	A5
√Stress indices	*				*		10%	5%			C		
√cellulose index	*				*		n/a	10%			C		
√Community stand structure	*				*		10%	5%			C		
√Landscape pattern	*				*		60m	60m			C		
√Canopy gap structure	*				*		10%	5%			E		
√Ecotone edge/structure	*				*		10%	5%			E		
√Ecosystem interfaces	*				*		60m	60m			E		
√Primary productivity	*				*		n/a	10%			E		
√Live/dead biomass	*				*		n/a	5%			E		
√Canopy lignin concentration	*				*		n/a	10%			E		
√Canopy BRDF's	*				*		n/a	10%			C		
√Land surface albedo maps	*				*		10%	5%			E		
√Land use change	*				*		n/a	30m			C		
√Soil mineralogy and organic content	*				*	*	n/a	n/a			C		
√Soil erosion rates	*				*	*	20%	10%			C		
√Aerosol concentration (optical depth)	*					*	5%	1%					
√SO4 Mineralization	*					*	n/a	n/a					
√Dust cloud iron content						*	n/a	120%					
√Surface aeolian mineralogy	*					*	n/a	n/a					

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11-21-89

Key Measurements	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	D1	D2	D3	D4	D5	D6	D7
											Application to CES priorities						
√Stress indices				C		E	E	C	E/C	E							
√cellulose index				E		E	E	C	C								
√Community stand structure				C		E	E	C	E/C								
√Landscape pattern				C		E	E	C	E/C								
√Canopy gap structure				C		E	E	C	E/C								
√Ecotone edge/structure				C		E	E	C	E/C								
√Ecosystem interfaces				C		E	E	C	E/C								
√Primary productivity		C		E		E	E	E	E/C				C				
√Live/dead biomass				C		E	E	C	E/C								
√Canopy lignin concentration		C		C		E	E	C	E/C				C				
√Canopy BRDF's				C		E	E	C	C								
√Land surface albedo maps				E		E	E	E	E				C				
√Land use change				C		E	E	C	E/C				C				
√Soil mineralogy and organic content				E	E			E		E	C						
√Soil erosion rates					E			C		C							
√Aerosol concentration (optical depth)					C												
√SO4 Mineralization					C												
√Dust cloud iron content					C												
√Surface aeolian mineralogy					C						E						

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REV 1
11-21-89

Key Measurements	E1	E2	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5
							Application to CES priorities						
√Stress indices		C											
√cellulose index		C											
√Community stand structure		C											
√Landscape pattern		C											
√Canopy gap structure		C											
√Ecotone edge/structure		C											
√Ecosystem interfaces		C											
√Primary productivity		C											C
√Live/dead biomass		C											
√Canopy lignin concentration		C											
√Canopy BRDF's		C											
√Land surface albedo maps		C											C
√Land use change		E											
√Soil mineralogy and organic content				C									
√Soil erosion rates			E				C						
√Aerosol concentration (optical depth)				E									
√SO4 Mineralization				C									
√Dust cloud iron content				C			C						
√Surface aeolian mineralogy							C						

TIGER/ITIR

TIGER/ITIR

This summary represents only the TIGER team view, taking into account what we know of the Japanese ITIR instrument. This summary has not been coordinated with the Japanese, but we will be meeting with them in Tokyo at the end of November. We cannot speak for the Japanese, as questions of data products and accuracies depend on their development process and resources.

Measured Parameters

- Multispectral radiance 0.4-12.0 μm with high spatial resolution (15-90 m).
- Stereo viewing with 15 m resolution in the visible.

Level One and Higher Products

- Surface and cloudtop brightness temperatures at 90 m spatial resolution.
- Surface spectral emissivity (8-12 μm). (Relative emissivity if no apriori assumptions are made).
- Surface kinetic temperatures (derived from brightness temperature and relative spectral emissivity using various model assumptions).
- Surface and cloud spectral reflectance in bands from 0.4-2.5 μm at 15-30 m resolution.
- Stereo images with 15 m IFOV.

Derivation of first four products will require atmospheric data from AIRS and other sounders; variables needed as a function of altitude are atmospheric temperature, water vapor, and ozone.

TIGER/ITIR

Science Applications

- **Surface Process Modeling**

  High spatial resolution temperature, albedo, and spectral data will bridge the gap between in situ (point) measurements, aircraft measurements and MODIS scale measurements. These data will be used in determining and parameterizing sub-grid scale phenomena in process models. Included in these will be ocean, land, and icepack energy fluxes, evapotranspiration studies, and vegetation density studies.

- **Monitoring of Volcanic and Geothermal Processes**

  This will include (1) monitoring volcanic plumes and their atmospheric effects during eruptions, (2) monitoring active lava flows, (3) frequent monitoring of warm and hot spots in known and suspected volcanic and geothermal areas, and (4) mapping of recent (< 2000 year old) flows in isolated areas to determine eruptive potential of little-known volcanoes.

- **Lithospheric Research**

  Phanerozoic sea level and climate cycles and relationship to evolution of continental crust, global tectonics and sea floor spreading.

TIGER/ITIR

Science Applications (cont'd)

- **Soil Mapping**

  These maps will allow determination of long term and short term (man-made) changes in soil characteristics and quality, land use, and surficial processes.

- **Lithofacies Mapping and Stratigraphic Analysis**

  Mapping will contribute to knowledge of sea level change, coastal erosion, paleoclimate, paleohydrology and paleoecology.

- Resource Exploration

  Contributions will be made to evaluation of global resources. This will also have implications for potential global land-use changes.

- Compositional, Structural, and Geomorphological Mapping

  The preceding four applications are a subset of the general problem of surface mapping of the continents. The extensive wavelength coverage and same-orbit stereo will contribute to the major EOS compositional mapping objective which supports or provides a base for regional and global geologic studies.

SAR

Eos SAR
Silver Bullets
November 15, 1989

1. Through its unique capability to penetrate forest canopies and its sensitivity to the woody biomass, the Eos SAR is the only instrument with the capability to measure forest biomass, a key input to monitoring successional stage and carbon cycling for forests older than about 20 years. Along with its ability to penetrate clouds, the Eos SAR will play an important role in the measurement and monitoring of carbon storage and flux in the tropical rain forests and the contribution of deforestation to global warming.

2. With its ability to acquire data day and night, year round, and independent of cloud cover, combined with its sensitivity to the dielectric constant (which is tied to diurnal water potential and seasonal water state), the Eos SAR will play an important role in monitoring the structure, function, and stress of vegetation under all environmental and phenologic conditions: key parameters in understanding the relationship of the Earth's ecosystems to global warming, land use and the hydrologic cycle.

3. Through its sensitivity to dielectric constant, and therefore water content and state, the Eos SAR will play a primary role in monitoring seasonal and annual water storage in soil, snow and ice, and in determining the contribution of snow, glaciers, and soil moisture to the global hydrologic and climatic cycles.

4. Through its fine-scale measurement of sea ice motion, ice type and concentration, and ice edge configuration, the Eos SAR (in conjunction with MODIS surface temperature and ocean color data and ECMWF weather data) provides key measurements for determining ice dynamics, heat flux, bottom water formation and ice margin biological productivity: these are important for modeling of the global climate, energy balance, and ocean circulation, and for monitoring ocean/atmosphere/cryosphere/biosphere interactions. In addition, knowledge of the nature of thin sea ice as measured by the Eos SAR along with HIMMS will help determine the ice mass balance, important for assessing the magnitude of global warming. SAR observations of ice sheets will make measurements of ice discharge rates possible for Antarctica and Greenland.

5. With its sensitivity to surface structure and roughness, the Eos SAR will play a key role in the development of a global perspective of the Earth's crust and the processes that have influenced its development. The effects of both the internal forces of tectonism and volcanism and the externally driven erosional processes may be identified, mapped, and their rates determined. In particular, with the radar's ability to penetrate arid soils, it will be an essential tool in determining the Earth's paleoclimate and paleohydrologic history. Also, the Eos SAR will measure the extent, rates and geologic conditions indicative of desertification and soil erosion, both human- and climate-induced.

6. Through its ability to detect current boundaries, including eddies and rings, and the surface wave field, the Eos SAR will enable improved understanding of mesoscale ocean circulation, and therefore understanding of air-sea atmospheric forcing and global heat, mass, and momentum fluxes.

Eos SAR
Role in CES Priority Chart
Preliminary

Essential Role:

Climate and Hydrologic Systems:
Land/Atm/Ocean Water and Energy Fluxes
Ocean/Atm/Cryosphere Interactions

Biogeochemical Dynamics:
Terrestrial Biosphere Nutrient and Carbon Cycling

Ecological Systems and Dynamics:
Long-Term Measurements of Structure and Function
Response to Climate and Other Stresses
Interactions Between Physical and Biological Processes

Earth System History:
Paleoclimate
Paleohydrology

Human Interactions:
Changes in Land Use

Solid Earth Processes:
Coastal Erosion
Volcanic Processes
Surficial Processes

Contributing Role:

Climate and Hydrologic Systems:
Ocean Circulation and Heat Flux

Biogeochemical Dynamics:
Bio/Atm/Ocean Fluxes of Trace Species

Ecological Systems and Dynamics:
Productivity/Resource Models

Earth System History:
Ocean Circulation and Composition

Solid Earth Processes:
Permafrost

Eos SAR

Preliminary Geophysical and Biophysical Parameters

November 15, 1989

Parameter	Units	Estimated Accuracy	Bullet Number
Canopy water content	vol fraction	TBD	1,2,3
Canopy water potential	bars	TBD	2
Canopy geometry	linear, angular	TBD,45°	2
Biomass	mass/area (kg/km^2)	TBD	1,2
Surface cover state	extent (m^2)	$(60m)^2$	1,2
Seasonal growth pattern	extent (m^2)	$(60m)^2$	1,2
Forest boundaries/deforestation	extent (m^2)	$(60m)^2$	1,2
Leaf area index	areal fraction	TBD	1,2
Soil moisture	vol fraction	5%	2,3,5
Erosion	area (m^2)	$(60m)^2$	1,5
Landform patterns	area (m^2)	$(60m)^2$	1,5
Land-water boundaries/floods	extent (m^2)	$(60m)^2$	1,2,3
Snow extent	area (m^2)	$(60m)^2$	3,4
Snow water equivalent	height (cm)	30 cm	3,4
Snow wetness	fraction	20%	3,4
Snow state (wet or dry)	areal extent (m^2)	$(60m)^2$	3,4
Sea ice extent	area (km^2)	$(0.5km)^2$	4
Sea ice concentration	fraction	5% hi res/10% lo-res	4
Sea ice type	fraction	5% hi res/10% lo-res	4
Sea ice motion	velocity (km/day)	0.5km/day	4
Ice sheet, lake and river ice extent	area (m^2)	$(60m)^2$	3
Ice sheets and shelf dynamics	velocity (m/year)	TBD	3,4
Landforms	areal extent (m^2)	$(60m)^2$	5
Surface roughness	RMS height (cm)	2cm	5
Drainage patterns	linear extent (m)	60m	3,5
Surficial material boundaries	extent (m^2)	$(60m)^2$	5
Topography	height (m)	TBD	3,5
Currents, fronts, eddies	location (m)	60m	6
Currents, fronts, eddies	boundary velocity (m/s)	TBD	6
Internal waves	location (m)	60m	6
Bathymetric features	location (m)	60m	6
Surface wind field	velocity (m/s)	2m/s	6
Surface waves	wavelength (m), dir (deg)	60m,10°	6

ALT

A SUMMARY OF EOS ALTIMETER SCIENCE OBJECTIVES IN RELATION TO GLOBAL CHANGE STUDIES

INTRODUCTION

A radar altimeter measures the altitude of the satellite center of mass above the sea surface or smooth land/ice surface. With precise knowledge of the position of the satellite center of mass, one can calculate the height of the sea surface, called the sea level, relative to the center of the Earth. The shape and strength of the returned radar pulse allow us to measure ocean wave height and surface windspeed, respectively. The height of the continental ice sheet can also be measured by an altimeter.

The spatial and temporal variabilities of sea level can be directly related to the ocean surface geostrophic circulation, a key element for determining the ocean's role in global change processess. To make precise sea level measurement from an altimeter, one needs both precision altimetry and orbit determination. Achieving the former requires (1) two-frequency altimeter measurement for correcting the ionospheric range delay, and (2) water vapor measurement from an onboard microwave radiometer for correcting wet tropospheric range delay. Achieving the latter requires precision spacecraft tracking, which can be achieved by the EOS GPS Geoscience Instrument (GGI). The discussion below is based on the availability of these three critical capabilities to the EOS Mission.

THE "SILVER BULLETS"

Following are six key areas in the context of Global Change where the EOS Altimeter can make significant contributions (in order of importance):

1. Ocean Circulation

Altimetric measurement of sea surface topography allows us to calculate ocean surface geostrophic current velocity, which, when comined with ocean models, can lead to a 3-dimensional description of ocean circulation. The heat and biogeochemical fluxes resulting from ocean circulation hold the key to understanding the ocean's role in the PHYSICAL AND HYDROLOGIC SYSTEMS and BIOGEOCHEMICAL DYNAMICS, the two top priority CES objectives.

2. Sea Level Changes

The changes in global sea level measured by altimetry allow us to study the effects of global warming/cooling and hydrologic balance.

3. Ice Sheet Mapping

Altimetric measurement of ice sheet topography allows us to monitor the variation of global ice sheet volume in reponse to climatic changes. The chagne in ice sheet volume also affects the global hydrologic system.

4. Air-Sea Heat and Gas Fluxes

Altimetric windspeed measurement can complement scatterometer wind measurement in the study of air-sea heat and gas fluxes (e.g. in the scatterometer nadir gap).

5. Marine Geophysics

The shape of the mean sea surface mapped by altimetry provides information on the elastic thickness and the strength of the lithosphere that affect the tectonic movement as well as on the convection on various scales in the Earth's mantle.

6. Coastal Erosion and Sea-state Forcast

Atimetric measurement of waveheight provides useful information for the study of beach erosion processes. When assimilated into dynamical ocean wave models, altimetric waveheight also improves global sea-state forcast.

RELATIONSHIP TO CES PRIORITIES

Following are the CES Science Priorities where the EOS Altimeter measurement is either essential (indicated by E) or contributing (indicated by C):

1. CLIMATE AND HYDROLOGIC SYSTEMS

* ocean circulation and heat flux (E)

* land/atm/ocean water and energy fluxes (C)

* coupled climate system and quantitative links (E)

* ocean/atm/cryosphere interactions (C)

2. BIOGEOCHEMICAL DYNAMICS

* bio/atm/ocean fluxes of trace species (C)

3. ECOLOGICAL SYSTEMS AND DYNAMICS

* interaction between physical and biological processes (C)

4. SOLID EARTH PROCESSES

* coastal erosion (C)

* crustal motions and sea level (E)

DATA PRODUCTS AND ACCURACIES

Data Products	Res.(space)	Res.(time)	Accuracy (rms)
Along-track Sea Surface Height	7 km	1 sec	6 cm
Along-track Windspeed	7 km	1 sec	2 m/sec

Along-track Waveheight	7 km	1 sec	the greater of 0.5 m or 10%
Sea Surface Topography Maps	25 km	16 days	the greater of 3 cm or 10 % of standard deviation
Ice Sheet Topography Maps	15 km	1 year	30 cm (flat regions) 5 m (steep regions)

Figure 1
U.S. Global Change Research Program Priority Framework

Essential

Contributing

STRATEGIC PRIORITIES

- Support Broad U.S. and International Scientific Effort
- Identify Natural and Human-Induced Changes
- Focus on Interactions and Interdisciplinary Science
- Share Financial Burden, Use the Best Resources,

INTEGRATING PRIORITIES

- Documention of Earth System Change
  - Observational Programs
  - Data Management Systems
- Focused Studies on Controlling Processes and Improved Understanding
- Integrated Conceptual and Predictive Models

SCIENCE PRIORITIES

Increasing Priority ↑

Climate and Hydrologic Systems	Biogeochemical Dynamics	Ecological Systems and Dynamics	Earth System History	Human Interactions	Solid Earth Processes	Solar Influences
Role of Clouds E Ocean Circulation and Heat Flux C Land/Atm/Ocean Water & Energy Fluxes E Coupled Climate System & Quantitative Links C Ocean/Atm/ Cryosphere Interactions	C Bio/Atm/Ocean Fluxes of Trace Species Atm Processing of Trace Species Surface/Deep Water Biogeochemistry Terrestrial Biosphere Nutrient and Carbon Cycling Terrestrial Inputs to Marine Ecosystems	Long-Term Measurements of Structure/ Function Response to Climate and Other Stresses C Interactions between Physical and Biological Processes Models of Interactions, Feedbacks, and Responses Productivity/Resource Models	Paleoclimate Paleoecology Atmospheric Composition Ocean Circulation and Composition Ocean Productivity Sea Level Change Paleohydrology	Data Base Development Models Linking: Population Growth and Distribution Energy Demands Changes in Land Use Industrial Production	C Coastal Erosion Volcanic Processes Permafrost and Marine Gas Hydrates Ocean/Seafloor Heat and Energy Fluxes Surficial Processes E Crustal Motions and Sea Level	EUV/UV Monitoring Atm/Solar Energy Coupling Irradiance (Measure/ Model) Climate/Solar Record Proxy Measurements and Long-Term Data Base

GLRS

Key Questions of Global Change to be Addressed by GLRS

GLRS addresses critical scientific questions concerning geophysical processes, the hydrological cycle, climatological processes, and the biogeochemical cycle.

1. GLRS will monitor crustal deformation through repeated laser ranging to ground-emplaced retroreflector targets. These measurements will define the magnitude and spatial and temporal patterns of strain accumulation and release in seismic zones, the boundary interactions at diffuse tectonic plate boundaries, local and regional scale uplifts and block rotations, post-glacial rebound, subsidence induced by fluid withdrawal, and other naturally occurring and artificially induced motions. The observations will provide kinematic constraints on dynamical models of the rheological and structural processes that control crustal and lithospheric deformations and provide fundamental insight into both earthquake mechanisms and the internal workings of the earth.

2. GLRS altimeter measurements will provide direct, high accuracy, high resolution measurements of ice sheet and glacier topography and roughness. Repeated surveys will define ice sheet mass balance and permit studies of the hydrological and climatological coupling between ice sheets and critical global environmental factors such as temperature and precipitation. The contributions of ice sheet volume changes to sea level variations will be determined. Measurements of the slope and roughness characteristics of the ice sheets will contribute to understanding ice dynamics and evolution. Repeated range measurements to retroreflectors will determine ice-sheet flow and strain and thus provide important additional kinematic constraints on ice dynamics.

3. GLRS altimetric observations will directly determine the heights of cloud and aerosol layers, including multilayer cloud distribution and thin cirrus. GLRS will significantly aid the retrieval of the distribution and radiative properties of clouds and will define the structure of inversion-capped aerosol layers, type II polar stratospheric clouds and episodic haze events. GLRS measurements will define cloud-climate interactions, vertical and horizontal air mass transport, and thermal inversion height interactions with atmospheric dynamics. The measurement of the vertical and horizontal distribution of atmospheric particulates will aid in the determination of the Earth's biogeochemical cycle. GLRS will provide strong complementary measurements to Eos passive atmospheric sounding.

4. GLRS ranging observations to retroreflector targets located on volcanos will define the three dimensional kinematic patterns of inflation and deflation in the eruptive cycle and aid in the determination of the dynamic processes governing these deformations. In addition, GLRS will provide data for predictive models of eruptive processes for various classes of volcanoes (e.g., explosive, extrusive) which can be utilized in the development of strategies for multisensor observations of the volcanic input to the atmosphere and hydrosphere.

5. GLRS altimeter observations of targets of opportunity along the sub- nadir point of the Eos satellite will define the topography, roughness, and local slope characteristics of various geomorphic systems in order to provide constraints on models of their formational characteristics and on the dynamics and evolution of landforms in regions of deformation, uplift, volcanic construction, and erosion.

6. GLRS ranging observations of retroreflector targets located at tide guage sites will define the crustal deformation contribution of the apparent sea level change. Repeated range measurements to the retroreflectors will establish the short and long term temporal history of the ellipsoidal heights of the tide guages allowing the determination of sea level change. GLRS measurements are an essential component of the determination of sea level change which is a fundemental parameter for Global Change.

GLRS Contributions to U.S. Global Change Science Priorities

1 ESSENTIAL

2 CRITICAL

3 SUPPORTING

Strategic Priorities

- Support Broad U.S. and International Scientific Effort
- Identify Natural and Human-Induced Changes
- Focus on Interactions and Interdisciplinary Science
- Share Financial Burden, Use the Best Resources, and Encourage Full Participation

Integrating Priorities

- Documentation of Earth System Change
- Observational Programs
- Data Management Systems
- Focused Studies on Controlling Processes and Improved Understanding
- Integrated Conceptual and Predictive Models

SCIENCE PRIORITIES

Climate and Hydrologic Systems

1 Role of Clouds
1 Ocean Circulation and Heat Flux
1 Land/Atm/Ocean Water & Energy Fluxes
1 Coupled Climate System & Quantitative Links
1 Ocean/Atm/Cryosphere Interactions
1 Ice Sheet Dynamics

Biogeochemical Dynamics

1 Bio/Atm/Ocean Fluxes of Trace Species
1 Atm Processing of Trace Species
Surface/Deep/Water Biochemistry
1 Terrestrial Biosphere Nutrient and Carbon Cycling
2 Terrestrial Inputs to Marine Ecosystems

Ecological Systems and Dynamics

1 Present Sea Level Change
2 Long-Term Measurements of Structure/Function
2 Response to Climate and Other Stresses
Interactions between Physical and Biological Processes
Models of Interactions, Feedbacks, and Responses
Productivity/Resource Models

Earth System History

Paleoclimate
Paleoecology
Atmospheric Composition
Ocean Circulation and Composition
Ocean Productivity
Sea Level Change
Paleohydrology

Human Interactions

Data Base Development
Models Linking:
Population Growth and Distribution
Energy Demands
Changes in Land Use
Industrial Production

Solid Earth Processes

1 Crustal Motions and Sea Level
1 Crustal Deformation
1 Volcanic Processes
Coastal Erosion
Permafrost and Marine Gas Hydrates
Ocean/Seafloor Heat and Energy Fluxes
1 Surficial Processes
1 Tectonics

Solar Influences

EUV/UV Monitoring
3 Atm/Solar Energy Coupling
Irradiance (Measure/Model)
3 Climate/Solar Record
3 Proxy Measurements and Long-Term Data Base

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PRELIMINARY ESTIMATES OF GLRS CORE DATA PRODUCTS, AND THEIR RELEVANCE TO KEY EARTH SCIENCE ISSUES

GLRS DATA PRODUCTS	SCIENCE QUESTION ADDRESSED						ESTIMATED ACCURACY OF GLRS DATA PRODUCT	
LAND DATA PRODUCT	1	2	3	4	5	6	ACCURACY	
horizontal site positions	X			X		X	3 mm	
vertical site positions	X						5 mm	
three-dimensional site velocities	X			X				
secular	X						1 mm/yr	
episodic	X						5 mm/month	
post-seismic	X						10 mm/week	
crustal strain rates	X						10^{-7}/yr	
volcanic inflation and deflation rates	X			X			10 cm/day to 5 mm/yr	
intersite distance rates of change	X			X			10 mm/week to 1 mm/yr	
height rates	X			X		X	10 cm/day to 5 mm/yr	
geomorphic features					X		10 cm	
CRYOSPHERIC DATA PRODUCT	1	2	3	4	5	6	ACCURACY	
ice sheet height profiles		X					10 cm	
sea ice height profiles		X					10 cm	
ice sheet surface roughness profiles		X					10 cm	
sea ice surface roughness profiles		X					10 cm	
ice sheet height		X					10 cm	
ice sheet volume change		X					10 cm	
ice sheet displacement and velocity		X					10 cm/day to 1 mm/yr	
ice sheet strain rates		X					10^{-6}/yr	
ice sheet mass balance		X					TBD	
ATMOSPHERIC DATA PRODUCT	1	2	3	4	5	6	ACCURACY	HORIZONTAL RESOLUTION
cloud top height			X				75 m	200 m
cloud base height			X				75 m	200 m
cloud optical thickness			X				0.1	200 m
mixed layer height			X				75m	2 - 200 km
tropopause height (cirrus located)			X				300 m	10 km
tropopause height (aerosol located)			X				75 m	200 m
aerosol layer boundary heights			X				75 m	2 - 200 km
aerosol layer optical thickness			X				75 m	2 - 200 km
polar stratospheric cloud (PSC) heights			X				75 m	2-50 km
PSC optical thickness			X				0.1	200 m
OCEANIC DATA PRODUCT	1	2	3	4	5	6	ACCURACY	
crustal deformation contribution to tide gauge measurement of apparent sea level change	X					X	1 mm/yr	

LAWS

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
National Meteorological Center
Washington, DC 20233

November 15, 1989 W/NMC2x1:WEB

Dr. Vince Salomonson
Deputy Director for Earth Sciences
Code 600
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Dear Vince:

As per your request, here are five Global Change Science Objectives (Attachment 1), as defined in the AO (January 11, 1988) and enumerated in the July 1989 issue (No. 4) of "The Earth Observer", for which LAWS data are expected to contribute. Also enclosed is the CES priority chart with the expected LAWS contribution indicated as "essential" or "contributing" (Attachment 2), a table showing the expected LAWS data products, resolution, accuracy and science questions (objectives) addressed (Attachment 3), and a commmentary on the table (Attachment 4).

Sincerely,

Wayman

Wayman E. Baker
LAWS Science Team Leader
and Deputy Chief,
Development Division

cc:
R. Menzies, LAWS Science Team
Payload Panel Representative

Hydrologic Cycle

1. AO Objective #1

   - Determine what factors control the hydrologic cycle.

The global wind observations obtained from LAWS will contribute in two very important ways toward an improved understanding of the hydrologic cycle. 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.

Biogeochemical Cycles

2. AO Objective #9

   - Quantify the global distribution and transport of tropospheric gases and aerosols and determine the strengths of their sources and sinks in the ocean, land surface, coastal and inland waters, and upper atmosphere

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.

Climatological Processes

3. AO Objective #11

   o Determine the relationships between large-scale and low-frequency variability of meteorological observables and the variability of sea surface temperatures and current systems

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.

Geophysical Processes - Atmospheric

4. AO Objective #23

   o Improve the accuracy of deterministic weather forecasting and extend the useful forecast period.

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.

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; in the tropics and 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.

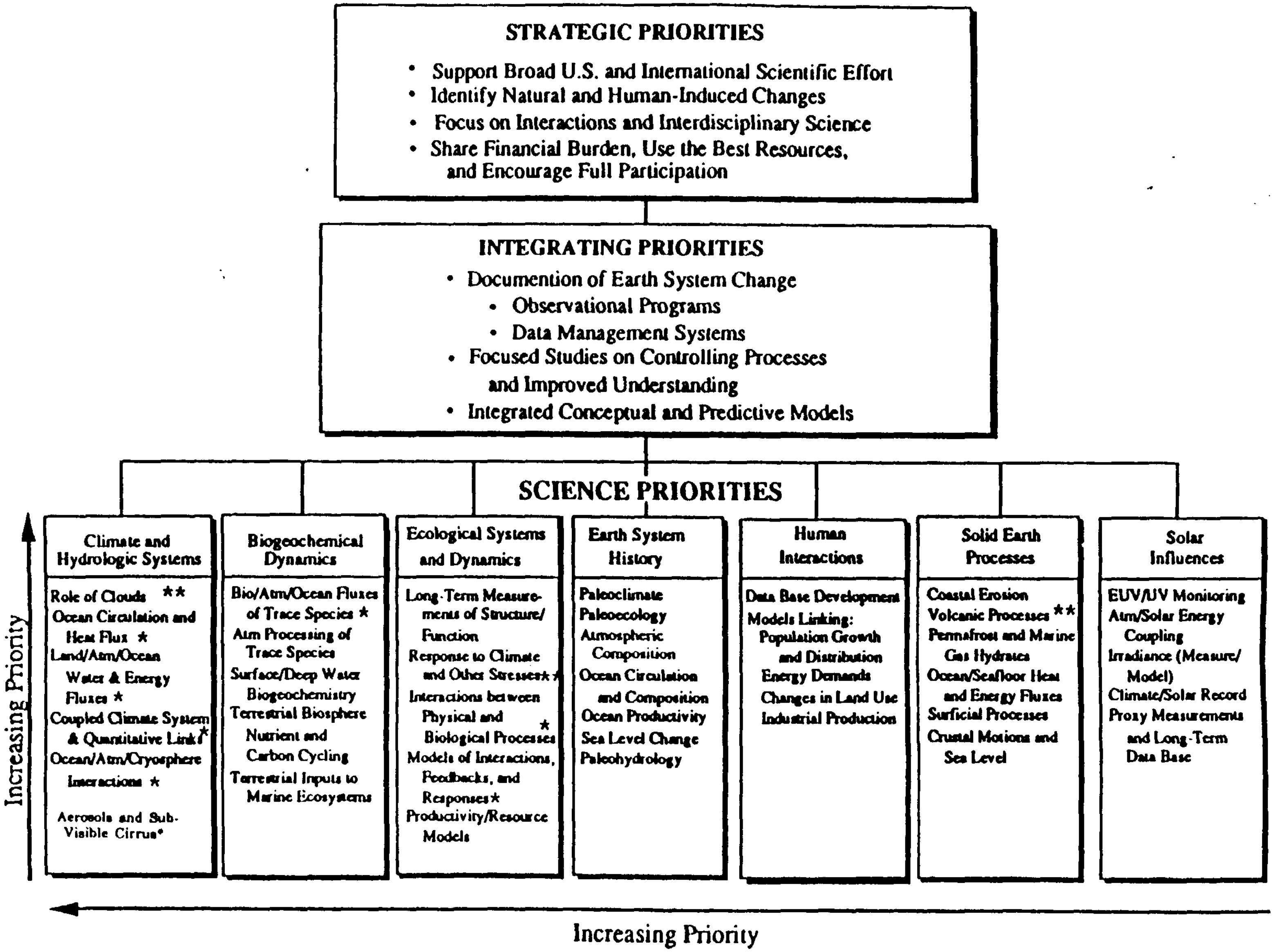
Geophysical Processes - Oceanic

5. AO Objective #25

   - Determine the global heat, mass, and momentum coupling between the ocean and atmosphere.

Fluxes of momentum, heat, moisture, CO_2, and other constituents are important to a majority of the Eos inderdisciplinary 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.

LAWS Contributions to U.S. Global Change Science Priorities



PRIORITIES

Figure 11. U.S. Global Change Research Program Priority Framework

* Essential
** Contributing

Attachment 2

Expected LAWS Core Data Products, Resolution, Accuracy, and Science Questions Addressed (see narrative in Attachment 1)

Product	Science Question Addressed					Expected Resolution	Accuracy	
	1	2	3	4	5		Current	LAWS
A. Horizontal Vector Wind Profiles	D	D	D	D	D	100 km - Horiz. 1 km - Vert. (0.5 km in high aerosol regions (e.g., PBL) or cirrus)	± 1 to 2 ms^{-1} (lower troposphere)[A] ± 4 to 5 ms^{-1} (upper troposphere)[A]	± 1 to 5 ms^{-1} depending on aerosol amount with quality flags
B. Aerosol* Distribution	I	D	I		I	100 km - Horiz. 1 km - Vert. (0.5 km in high aerosol regions (e.g., PBL). Temporally averaged (e.g., a few days)	N/A	TBD
C. Cirrus** Distribution	D	I	D	I	I	100 km - Horiz. 0.5 km - Vert. Temporally averaged (e.g., daily)	N/A	TBD
D. Cirrus Height	I	I	D	I	I	50 km - Horiz.	$\pm$0-10 mb[B]	$\pm$500 m
E. Stratoform Cloud Height	I	I	D	I	I	50 km - Horiz.	$\pm$10-20 mb[C]	$\pm$50 m

NOTES:
* Wavelength dependent (currently 9.11 μm)
** Cirrus not detectable by passive techniques (i.e., sub-visible)
D Indicates that a science question/issue is directly addressed
I Indicates that a science question/issue is indirectly addressed
A Rawinsondes
B Using IR channels for upper tropospheric cloud height determination
C Using the "window" technique for lower tropospheric cloud height determination

Commentary on LAWS Data Products
(Re: Products B, C, D, and E in Attachment 3;
Note: Product A, winds, is covered in Attachment 1)

While winds are its primary data product, for LAWS to operate, there must be aerosols or cloud particles to reflect the laser radiation. Combined with other sensor data (e.g., AIRS, MODIS, HIRIS), the LAWS return signal intensity (and perhaps depolarization ratio) will provide information on the extent and vertical distribution of aerosols and liquid water content above opaque clouds within each sample's field of view.

The sensitivity of LAWS to low concentrations of aerosols or ice particles exceeds that of any passive instrument being proposed for Eos. Information on the extent of these atmospheric constituents will be of use to those studying the global radiation budget; the global water budget and cycle; the removal and redistribution of gases and particles that interact with ice particles; injection and dispersion of volcanic material; and any other physical process that is involved with these particles that provide backscatter for LAWS.

A
LISTING
OF ALL
FACILITY INSTRUMENTS PRODUCTS
AND
ACCURACIES

(GROUPED BY LAND, OCEAN AND ATMOSPHERE AND WHERE PRODUCT GEOPHYSICAL PARAMETERS WERE SIMILAR. PARAMETER ACCURACIES ARE AS RECEIVED FROM FACILITY TEAM LEADERS)

Eos Facility Instruments Data Product Comparison

ATMOSPHERE - Cloud Measurements PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Fractional Area	HIRIS		3%	
Fractional Cloud Cover (0 - 1.0)	AIRS	0.1	0.05	
Cloud Fractional Area	MODIS	±10%	±10%	
Optical Thickness	HIRIS		3%	
Cloud Optical Thickness	AIRS	N/A	TBD	
Cloud Optical Thickness	MODIS	±50%	±20%	Daytime
Cloud Optical Thickness	GLRS		0.1	200m horizontal resolution
Polar Stratospheric Cloud Optical Thickne	GLRS		0.1	200m horizontal resolution
Thickness	HIRIS		200m	
Top Height	HIRIS		100m	
Cloud Top Height	GLRS		75m	200m horizontal resolution
Cloud Top Pressure	AIRS	2 km	500m	Same as height?
Cloud Top Pressure	MODIS	±25-50 mb	±25-50 mb	Will change mb to height eventually
Base Height	HIRIS		100m	
Cloud Base Height	GLRS		75m	200m horizontal resolution
Droplet Effective Radius	HIRIS		10%	
Cloud Droplet Effective Radius	MODIS	N/A	±40%	
Size Distributions	HIRIS		5%	
Cloud Area and Perimeter	MODIS	N/A	TBD	
Cirrus Distribution	LAWS	N/A	TBD	Resolution: 0.5km vert.; 100km horiz.
Tropopause Height	AIRS	3km	500m	
Tropopause Height (cirrus located)	GLRS		300m	Horizontal resolution 10km.
Cirrus Height	LAWS	±0 to 10mb	±500m	
Stratopause Height	AIRS	5km	1km	
Stratiform Cloud Height	LAWS	±10 to 20mb	±50m	
Polar Stratospheric Cloud Height	GLRS		75m	Horizontal resolution 2 - 50km
Mixed Layer Height	GLRS		75m	2 - 200km horizontal resolution

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

ATMOSPHERE - Cloud Physics PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Bidirectional Reflectance Distribution Funct.	HIRIS	5%	0.50%	
Water Thermodynamic Phase	HIRIS		10%	
Cloud Water Thermodynamic Phase	AIRS	N/A	Ice/liquid	Eos accuracy not understood
Cloud Water Thermodynamic Phase	MODIS	N/A	TBD	Ice/water/snow
Cloud Top Temperature	AIRS	2°K	1°K	
Cloud Top Temperature	MODIS	±2°C	±1°C	
Cloud Top Brightness Temperature	TIGER			ITIR. 90m spatial resolution
Cloud IR Spectral Emissivity (3 -17µm)	AIRS	N/A	0.05	
Cloud Effective Emissivity	MODIS	±0.2	±0.2	
Surface Spectral Emissivity (8 - 12µm)	TIGER			ITIR. Does not specifically address clouds.
Cloud Spectral Reflectance (0.4 - 2.5µm)	TIGER			ITIR. 15 - 30m resolution

ATMOSPHERE - Aerosols PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Aerosol Concentration (Optical Depth)	HIRIS	5%	1%	
Aerosols	AIRS	0.05	TBD	Concentration?
Aerosol Optical Thickness	MODIS	±0.05	±0.05	
Aerosol Layer Optical Thickness	GLRS		75m	Horizontal resolution 2 - 200km
Aerosol Size Distribution	MODIS	±10%	±10%	
Aerosol Mass Loading	MODIS	±40%	±30%	
Aerosol Single Scattering Albedo	MODIS	±0.04	±0.04	
Angstrom Exponent	MODIS		±15%	
Single Scattering Aerosol Radiance	MODIS	±10%	±10%	Eos: Case I waters w/moderate concentrations
Aerosol Layer Boundary Heights	GLRS		75m	Horizontal resolution 2 - 200km
Tropopause Height (Aerosol Related)	GLRS		75m	Horizontal resolution 200m
Aerosol Distribution	LAWS	N/A	TBD	Resolution 100km horizontal; 1km vertical
2				

Comparisons were based on nearest relationships among products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

ATMOSPHERE - Moisture PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Total Precipitable Water	HIRIS	1mm	1mm	
Total Precipitable Water	AIRS	20%	5%	
Total Precipitable Water	MODIS	±25%	±15%	±5% possible (Eos era)
Precipitation Estimate	AIRS	3mm/day	2mm/day	
Cloud Water Content	AIRS	N/A	TBD	
Tropospheric Water Vapor	MODIS	TBD	TBD	
Humidity Profile	AIRS	30%	10%	
Moisture Profile	MODIS	30%	20%	

ATMOSPHERE - Physics PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Temperature Profile (1km vertical res.)	AIRS	2.5°K	1.0°K	
Temperature Profiles	MODIS	±2.5°C	±2°C	
Outgoing Longwave Spectral Radiation	AIRS	N/A	TBD	
Surface Scalar Wind Speed (to 30m/sec)	AIRS	N/A	TBD	
Surface Wind Field	SAR		2m/sec	
Horizontal Vector Wind Profiles	LAWS	±1 to 5m/sec	±1 to 5m/sec	100km horizontal res.; 1km vertical resolution
Along-track Wind Speed	ALTIMETER		2m/sec	7km and 1 sec resolutions

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

ATMOSPHERE - Chemistry PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Total Column Ozone	HIRIS	110%	110%	
Total Ozone Burden	AIRS	10%	5%	
Total Column Ozone	MODIS	±10 TO 20%	±5 to 10%	0.2µm present; 0.1µm MODIS acuracy
Dust Cloud Iron Content	HIRIS	N/A	120%	
Mapping of Total Methane Burden	AIRS	N/A	TBD	
Mapping of Total Carbon Monoxide Burden	AIRS	N/A	TBD	
Mapping of Total Nitrous Oxide Burden	AIRS	N/A	TBD	
Carbon Dioxide Mixing Ratio	AIRS	N/A	5ppm	

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

LAND - Vegetation PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Chlorophyll Concentration (g/ha)	HIRIS	N/A	10%	
Leaf Area Index	HIRIS	10%	5%	
Leaf Area Index	MODIS	±0.5	±0.25	
Leaf Area Index	SAR		TBD	Units: areal fraction
Cellulose Index	HIRIS	N/A 10%		
Vegetation Indices	MODIS	±0.05	±0.04	
Leaf Angle Distribution	HIRIS	N/A	10%	
Canopy Gap Structure	HIRIS	10%	5%	
Canopy Geometry	SAR		TBD, 45°	Units: linear, angular
Canopy BRDFs	HIRIS	N/A	10%	
Canopy Lignin Concentration	HIRIS	N/A	10%	
Stress Indices	HIRIS	10%	5%	
Vegetation Stress	MODIS	±300sec/m	±200sec/m	
Community Structure	HIRIS	10%	5%	
Landscape Pattern	HIRIS	60m	60m	
Landforms	SAR		60mX60m	
Landform Patterns	SAR		60mX60m	
Surface Cover State	SAR		60mX60m	
Ecotone Edge/Structure	HIRIS	10%	5%	
Ecosystem Interfaces	HIRIS	60m	60m	
Forest Boundaries/Deforestation	SAR		60mX60m	
Surficial Material Boundaries	SAR		60mX60m	
Biome Type and Area	MODIS	TBD	TBD	
Primary Productivity	HIRIS	N/A	10%	
Primary Production	MODIS	r sq. =0.5-0.8		
Live/Dead Biomass	HIRIS	N/A	5%	
Biomass	SAR		TBD	Units: kg/km sq.
Incident Photosynthetically Active Radiation	MODIS		±20%	
Seasonal Growth Patterns	SAR		60mX60m	

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

LAND - Soils

PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Soil Erosion Rates Erosion	HIRIS SAR	20%	10% 60mX60m	
Soil Mineralogy and Organic Content	HIRIS	N/A	N/A	
Soil Moisture	SAR		5%	Units: Volume fraction
SO4 Mineralization	HIRIS	N/A	N/A	
Surface Aeolian Mineralogy	HIRIS	N/A	N/A	

LAND - Use/Maps/Physics

PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Land Use Change	HIRIS	N/A	30m	
Land Surface Albedo Maps Surface Albedo Spectral Surface Albedo Surface Spectral Reflectance (0.4 - 2.5μm)	HIRIS AIRS MODIS TIGER	1% (I) N/A ±0.01	0.5% TBD ±0.01	ITIR. 15 to 30m resolution
Skin Surface Temperature Surface Temperature Thermal Anomalies (Volcanoes, Fires) Surface Kinetic Temperature	AIRS MODIS MODIS TIGER	8°K ±5°C ±50°C	1°K ±3°C ±5°C	ITIR. Derived fr. brightness temp. & emissivity
Day-Night Land Surface Temperature Diff.	AIRS	3°K	0.5°K	
Upward Longwave Flux Spectral Emissivity (3-17μm/microwave) Surface Spectral Emissivity	AIRS AIRS TIGER	N/A N/A	TBD 0.05	ITIR. 8 to 12 μm. Relative emissivity
Upward Shortwave Flux	AIRS	N/A	TBD	
Level 2 Land Leaving Radiances Multispectral Radiance	MODIS TIGER	±20%	±10%	0.4 TO 12.0μm. 15 - 90m spatial resolution
Downward Longwave Flux	AIRS	N/A	TBD	
Downward Shortwave Flux	AIRS	N/A	TBD	
Stereo Viewing	TIGER			ITIR. 15m resolution in the visible.

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

LAND - Water

PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Surface Water Cover Mapping	MODIS	TBD	TBD	
Land - Water Boundaries/Floods	SAR		60mX60m	
Ice Sheet, Lake and River Ice Extent	SAR		60mX60m	
Canopy Water Content	SAR		TBD	Units: volume fraction
Canopy Water Potential	SAR		TBD	Units: bars
Drainage Patterns	SAR		60m	
Meltpond Fractional Area	HIRIS		10%	
Meltpond: Onset of Melt/Time of Refreeze	HIRIS		N/A	

LAND - Snow

PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Snow Covered Area in Selected Mountains	HIRIS		5%	
Snow/Ice Cover	AIRS	N/A	Old/New	
Snow Cover	MODIS	±10%	±5% or less	
Snow Extent	SAR		60mX60m	
Snow Spectral Albedo in Selected Mountains	HIRIS	25%	5%viz,10%IR	
Grain Size of Snow Surface	HIRIS		200%	
Particulate Content of Snow	HIRIS		500%	
Snow Water Equivalent	SAR		30cm	Units: height in cm
Snow Wetness	SAR		20%	Units: in fraction
Snow State (Wet or Dry)	SAR		60mX60m	Units: areal extent in m sq.

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

LAND - Surface & Subsurface State PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Level 1 Topographic Corrections	MODIS	±1/2 km	±100m	
Vertical Site Positions	GLRS		5mm	
Topography	SAR		TBD	Units: height in meters
Geomorphic Features	GLRS		10cm	
Surface Roughness	SAR		2cm	Units: rms height in cm
Horizontal Site Positions	GLRS		3mm	
Secular Three-Dimensional Site Velocities	GLRS		1mm/year	
Episodic Three-Dimensional Site Velocities	GLRS		5mm/month	
Post Seismic 3-D Site Velocities	GLRS		10mm/week	
Crustal Strain Rates	GLRS		10E-7/year	
Volcanic Inflation and Deflation Rates	GLRS		10cm/day	Maximum accuracy 5mm/year
Intersite Distance Rates of Change	GLRS		10mm/week	Maximum accuracy 1mm/year
Height Rates	GLRS		10cm/day	Maximum accuracy 5mm/year

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

OCEAN - Ice

PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Ice Type	HIRIS			
Sea Ice Type	SAR		5% hi; 10% lo	
Floe Ice Fractional Area	HIRIS		10%	
Sea Ice Concentration	SAR		5% hi; 10% lo	Units: in fraction
Floe Ice Area and Perimeter	HIRIS		10%	
Sea Ice Cover (Open Water)	AIRS	N/A	O.1	
Sea Ice (Maximum Total Extent)	MODIS	<4%	<4%	
Sea Ice Extent	SAR		500mX500m	
Floe Ice Size Distributions	HIRIS		10%	
Broken Ice Fractional Area	HIRIS		10%	
New Ice/Open Water/Lead Fractional Area	HIRIS		10%	
Sea Ice Crack Density	HIRIS		N/A	
Sea Ice Bidirectional Reflectance Dist. Funct.	HIRIS		10%	
Ice Sheet Height Profiles	GLRS		10cm	
Ice Sheet Height	GLRS		10CM	
Sea Ice Height Profiles	GLRS		10cm	
Along-Track Sea Surface Height	ALTIMETER		6cm	Resolutions of 7km and 1 sec
Ice Sheet Topography Maps	ALTIMETER		30cm flat reg.	5m steep regions. Resolutions15km, 1year
Ice Sheet Surface Roughness Profiles	GLRS		10cm	
Sea Ice Surface Roughness Profiles	GLRS		10cm	
Ice Sheet Volume Change	GLRS		10cm	
Ice Sheet Displacement and Velocity	GLRS		10cm/day	1mm/year
Sea Ice Motion	SAR		0.5km/day	
Ice Sheets and Shelf Dynamics	SAR		TBD	
Ice Sheet Strain Rates	GLRS		10E-6/year	
Ice Sheet Mass Balance	GLRS		TBD	

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

OCEAN - Surface & Subsurface State PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Along-Track Wave Height	ALTIMETER		0.5m or 10%	Resolutions of 7km and 1sec
Surface Waves	SAR		60m, 10°	Units: wavelenth in meters, direction in degrees
Sea Surface Topography Maps	ALTIMETER		3cm or 10%	of standard Deviation. Resolution 25km, 16 days
Skin Surface Temperature	AIRS	1.0°K	0.5°K	
Sea Surface Temperatures	MODIS	±0.6°K	±0.4°K	Under favorable conditions
Surface Spectral Emissivity	TIGER			ITIR. 8 TO 12 µm. Relative emissivity
Apparent Sea Level Change	GLRS		1mm/year	
Currents, Fronts, Eddies	SAR		60m	Location in meters
Currents, Fronts, Eddies	MODIS		214 - 856m	
Currents, Fronts, Eddies	SAR		TBD	Boundary velocity in meters/second
Internal Waves	SAR		60m	
Bathymetric Features	SAR		60m	

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.

Eos Facility Instruments Data Product Comparison

OCEAN - Organics and Inorganics PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Chlorophyll-a (concentration)	HIRIS	50 to250%	20 to 50%	
Chlorophyll-a Pigment Concentratn (Case	MODIS	±100%	±35%	Present and MODIS accuracies typical cond.
Chlorophyll-a Pigment Concent. (CaseII)	MODIS	±300%	±50%	Accuracy may be optimistic
Chlorophyll Fluorescence	MODIS	N/A	30%	Probably much larger at low concentrations
Accessory Photosynthetic Pigments (Conc	HIRIS	N/A	20 to 50%	
Suspended Organic Matter (Concentration)	HIRIS	100 - 200%	20 - 50%	
Dissolved Organic Matter (Concentration)	HIRIS	100 - 300%	20 - 50%	
Productivity of Phytoplankton	HIRIS	300%	50%	Accuracy based on model result
Primary Productivity, Case I Waters	MODIS	±300%	50%	
Dissolved Organic Material Concentration	MODIS	N/A	±150%	
Gelbstoff Abundance	HIRIS	N/A	50%	
Surface Photosynthetically Active Radiati	HIRIS	40%	25%	
Surface Incident PAR	MODIS	±40%	±25%	PAR: Photosynthetically Active Radistion
Attenuation of PAR	HIRIS	N/A	30%	
Attenuation of PAR	MODIS	N/A	±30%	
Attenuation at 490 nm (Case I Waters)	MODIS	±100%	±35%	Present and MODIS accuracies typical cond.
Detached Coccolith Concentration	NODIS	N/A	±35%	Accuracy may be optimistic
Phycoerythrin Pigment Concentration	MODIS	N/A	±200%	
Suspended Inorganic Matter (Concentratio	HIRIS	50 - 200%	20 - 50%	

OCEAN - Physics PRODUCT	INSTRUMENT	PRESENT ACCURACY	Eos ACCURACY	COMMENTS
Downward Shortwave Flux	AIRS	N/A	TBD	
Downward Longwave Flux	AIRS	N/A	TBD	
Upward Shortwave Flux	AIRS	N/A	TBD	
Upward Longwave Flux	AIRS	N/A	TBD	
Water-Leaving Radiance, Visible Channels	MODIS	±30%	±10%	Typical conditions
In-Situ Validation Observations	MODIS	Inst. Dependnt	Inst. Dependnt	

Comparisons were based on nearest relationships between products. Where possible, similar products are grouped.