Natural Resources and Environmental Issues

Volume 2 *Mapping Tomorrow's Resources* Article 3

1993

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Recommended Citation
Salomonson, Vincent V. (1993) "Global resources and mission to planet earth," *Natural Resources and Environmental Issues*: Vol. 2 , Article 3.
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Global Resources and Mission to Planet Earth

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Abstract

The NASA contribution to the U.S. Global Change Research Program is termed the Mission to Planet Earth. Components of the Mission to Planet Earth, such as the Upper Atmosphere Research Satellite (UARS), have already been flown; and several other satellites will be flown in the next few years. The major component of the Mission to Planet Earth is the Earth Observing System (EOS) scheduled for initial launch in 1998. Considerable volumes of valuable data will be stored and made accessible through the EOS Data and Information System (EOSDIS). These data will not only be useful for earth-science research but also for resource monitoring efforts and environmental impact studies. The challenges in making these data available are to provide the technologies and infrastructure to make them accessible to scientists, resource managers, and decision-makers in a timely and cost-effective fashion. In addition, students must be trained and given the background to make optimal use of remotely sensed data, such as that forthcoming from spaceborne observing platforms.

INTRODUCTION

It has often been stated in various contexts that "the only thing that is constant is change itself." Certainly this is true about the distribution in space and time of processes occurring on the earth. In these times, it is becoming clear that besides the natural variability that occurs with increasing human population and the activities associated with this increasing population man has become a factor in changing earth processes such as climate. Because of the potential effect on life on this planet (Eagleson 1991, Lubchenco et al. 1991, Silver and DeFries 1990), international (International Council of Scientific Unions 1990, Houghton et al. 1990) and national efforts (Lashof and Tirpak 1990) have begun to understand global change, including anthropogenic effects. As an agency contribution to the U.S. Global Change Research Program (Committee on Earth and Environmental Sciences 1992), NASA has embarked on the Mission to Planet Earth (Wickland 1991). The characteristics of the U.S. Global Change Research Program are to be captured into three streams of activity. These are documenting global change (observations), enhancing understanding of key processes (process research), and predicting global and regional environmental change (integrated modeling and prediction). The intents and purposes of the Mission to Planet Earth are primarily scientific in nature and contribute substantially to the activities of the U.S. Global Change Research Program. The broad objective of Mission to Planet Earth is to determine the extent, causes, and regional consequences of global climate change.

The purpose of this paper is to describe briefly the components of the Mission to Planet Earth and to comment upon the applications, opportunities, and challenges associated with utilizing the data to be collected for environmental monitoring and resources management.

MISSION TO PLANET EARTH

Considerable data from spaceborne platforms have already been collected. These data comprise databases extending over a decade. In many instances, these databases offer a comprehensive and global view of vegetation dynamics, snow and ice cover, sea surface temperature change, variability in cloud cover and attendant properties, and the composition of the upper and lower atmosphere of the earth. These databases have come from such U.S. satellite missions and sensors as the Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) with high spatial resolution; multispectral scanner data extending from 1972 to the present; and the NOAA operational satellite missions and such sensors as the Advanced Very High Resolution Radiometer (AVHRR) and the Tiros Operational Vertical Sounding (TOVS) unit, with comprehensive and relatively complete and consistent databases extending from as early as 1966 (snow cover) to the present. Data have also been gathered from the Nimbus Coastal Zone Color Scanner (CZCS) and the Scanning Multichannel Microwave Radiometer (SMMR) and the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSMI). Other nations or international organizations, such as the European Space Agency (ESA), France, and Japan, are also operating satellites that provide comprehensive and valuable observations of the earth on global and large regional scales. Most recently and notably, both ESA and Japan have succeeded in orbiting on free-flyer spacecraft Synthetic Aperture Radar (SAR) systems that provide high-spatial resolution, microwave (nearly all weather) views of the earth's surface.

Remote sensing from space has already laid the basis for the Mission to Planet Earth. In fact, it has become clear that a comprehensive and forthcoming understanding of earth processes on a global scale can only be accomplished through spaceborne remote sensing as indicated in previously referenced publications. These spaceborne observing systems complement existing in situ networks primarily by providing relatively uniform, nearly synoptic, high-spatial density, frequent views over large regions.

The Mission to Planet Earth has several main components as illustrated in Figure 1. The space components are called Earth Probes, Polar Orbiting spacecraft, and Geostationary orbiting spacecraft. The key ground component is the Data and Information System (DIS). The information from the DIS will lead to improved process studies, better global interactive models of the land/ocean/atmosphere system, and, subsequently, as understanding improves and confidence in the models improves, better assessment and predictions of the consequences of global change brought about by natural and anthropogenic influences.

The Mission to Planet Earth is already under way, and several missions will be forthcoming in the next five to six years. Already launched are the Upper Atmosphere Research Satellite (UARS) and the Atmospheric Laboratory for Applications and Science (ATLAS) payload on the STS-45 mission, which will look at the composition and evolution of chemical compounds in the upper atmosphere. Following soon are the earth-probe missions, such as the SeaWiFS/Seastar mission to observe ocean color and biomass, scheduled to be launched in 1993; the Total Ozone Monitoring missions beginning in 1994; and the Tropical Rainfall Measuring Mission (TRMM)

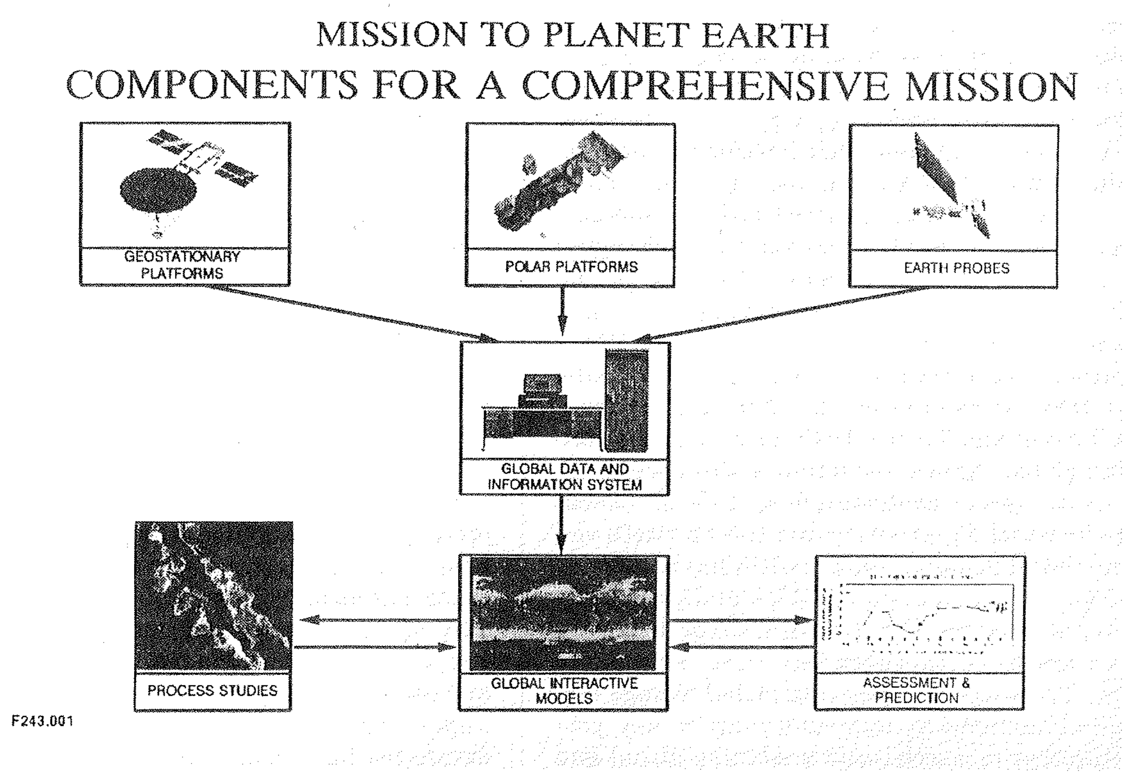

Figure 1

Salomonson: Global resources and mission to planet earth

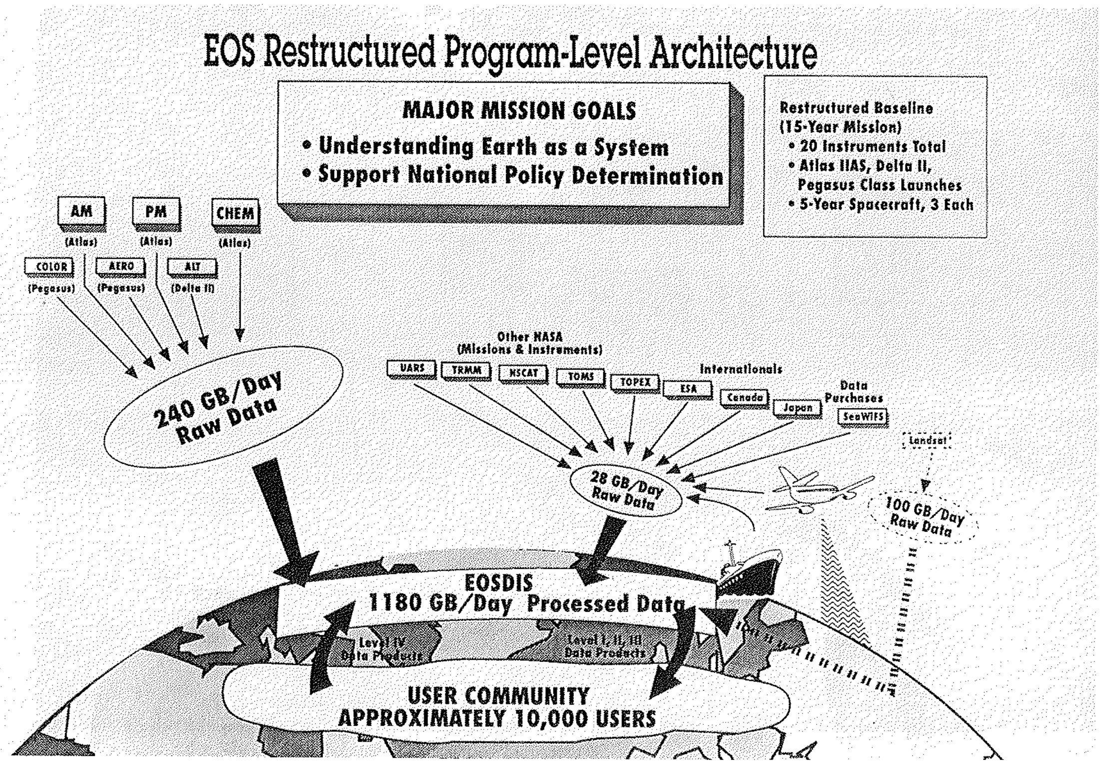

Figure 2. Schematic diagram depicting the extent of the EOS program including the amounts of data involved.

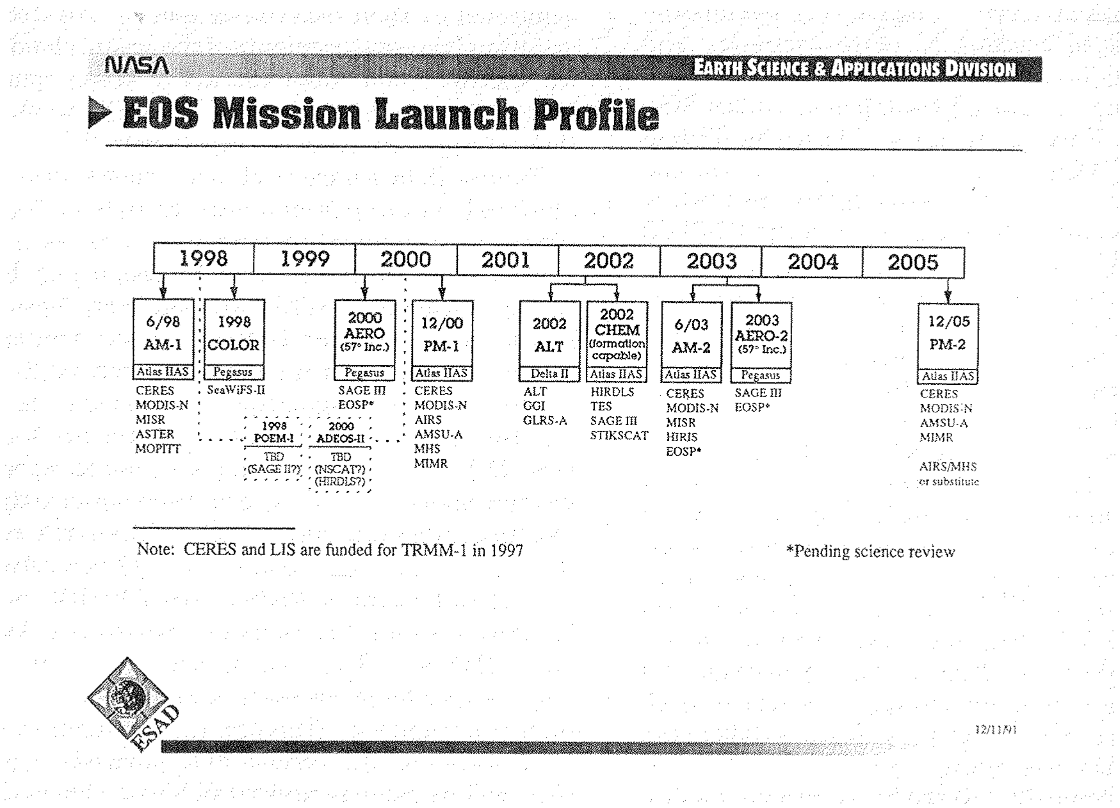

Figure 3. The launch sequence for the various EOS platforms.

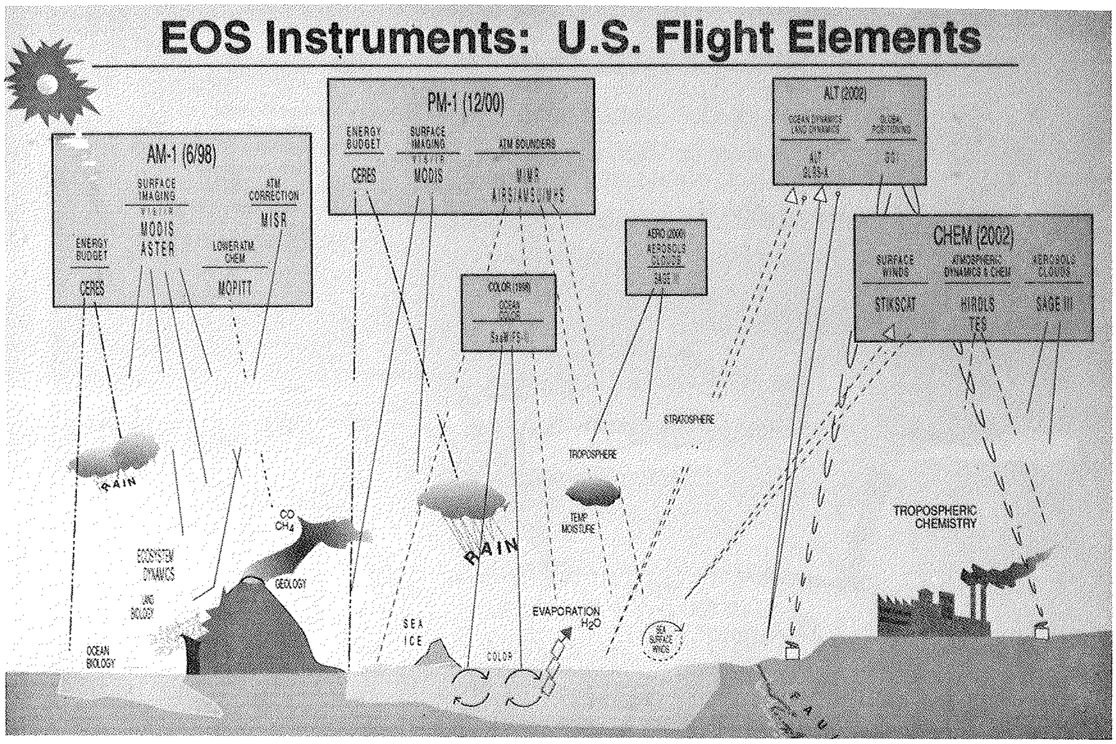

Figure 4. A diagram illustrating the broad observational intents of the EOS instruments.

scheduled for 1997. These missions will be complemented by Landsat 6 (1992), Landsat 7 (1997), and the Laser Geodynamics (LAGEOS 2) mission scheduled for launch in 1992, augmenting spaceborne contributions to studies of plate tectonics and macroscale motions of the earth itself.

The principal and largest component of the Mission to Planet Earth is the Earth Observing System (EOS) (Truly 1992). Figure 2 shows the various components of the EOS. This figure also offers insight to the data volumes going into the EOSDIS and eventually into the hands of the scientific and user communities. The challenge of acquiring, storing, and disseminating these data in a timely and user-friendly fashion is an imposing one. On the other hand, the richness of the data in terms of informational value promises to be very large.

Figure 3 shows the overall schedule for the launch of the EOS. The first component of the EOS is scheduled for launch beginning in 1998, with several payloads of varying size and composition to follow. The EOS components will eventually provide a fifteen-year data set of comprehensive and global remotely sensed data. The major platforms are the so-called A.M. and P.M. platforms. These platforms will cross the equator at approximately 1030 hours (local, solar time, descending daylight pass) and 1330 hours (local, solar time, ascending daylight pass). The A.M. platform is primarily devoted to observing surface cover dynamics, clouds, and radiation balance parameters. The P.M. platform will emphasize cloud cover, tropospheric temperature, and composition as well as land and ocean surface properties. The other platforms are more specialized in their contributions as suggested by their descriptive names: Alt (focusing on altimetric measurements of the ocean, clouds, and ice sheets); Color (observations of ocean color and biomass); and Chem (devoted primarily to observations of upper atmosphere constituents).

There will be a variety of instruments on the EOS platforms, ranging from relatively high-spatial resolution, multispectral instruments, such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the High Resolution Imaging Spectrometer (HIRIS), to lower spatial resolution, multispectral radiometers, such as the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Multispectral Imaging Microwave Radiometer (MIMR). Each of these instruments represents advancements over what has been previously successful in providing observations of the earth, such as the Landsat Thematic Mapper, the NOAA Advanced Very High Resolution Radiometer (AVHRR), and the Nimbus Scanning Multichannel Microwave Radiometer (SMMR). The instruments, of course, have various specific purposes that are schematically depicted in Figure 4. Through the applications of the instruments on the various EOS payloads, contributions will be made to understanding a wide variety of interconnecting processes on a global scale as depicted in Figure 5 (Earth System Sciences Committee 1988).

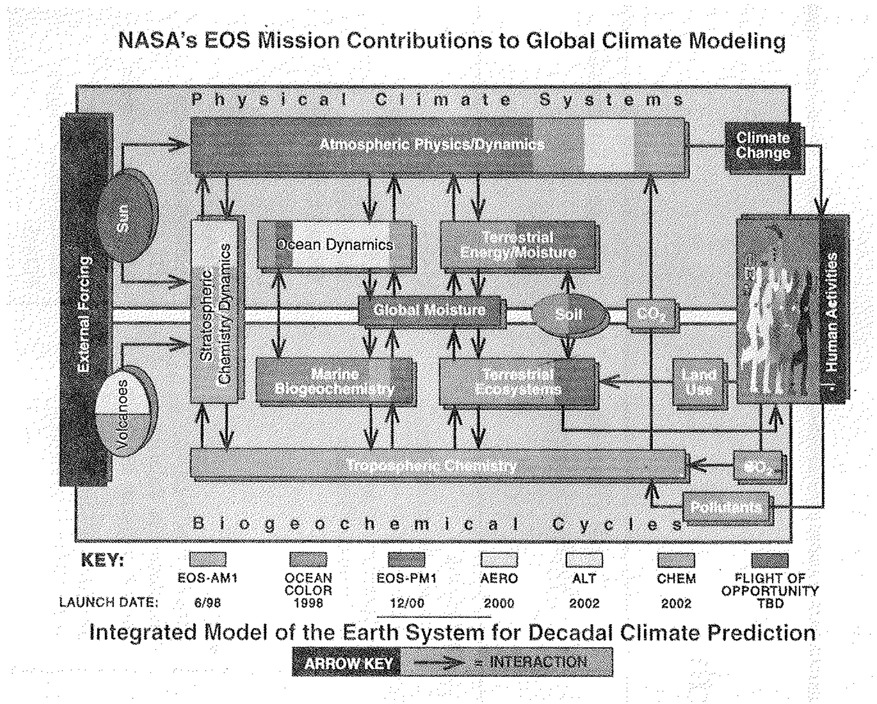

Figure 5. The contributions of the EOS platforms and attendant instruments to global climate monitoring.

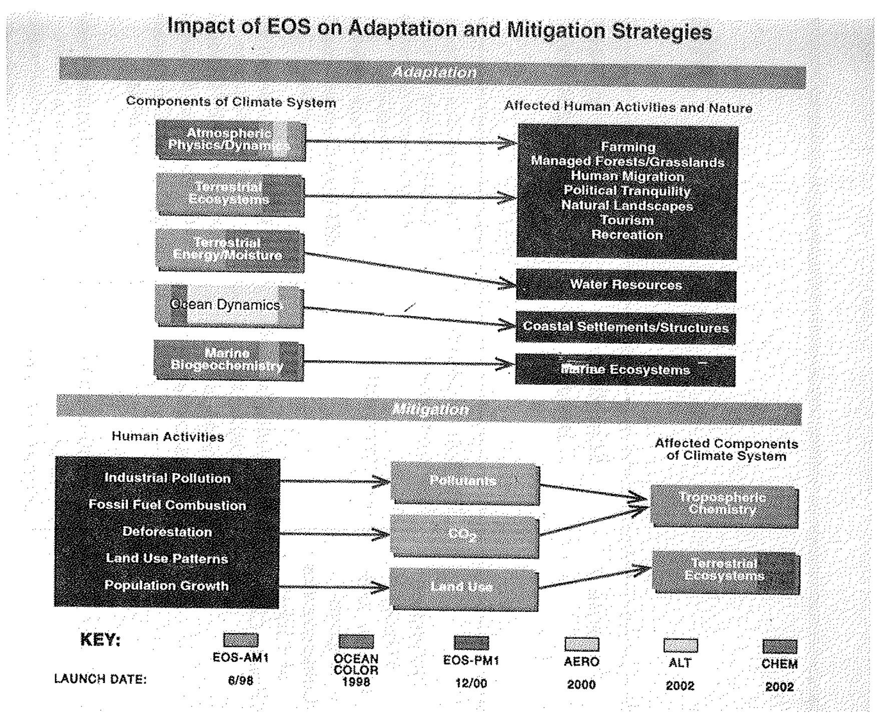

Figure 6. The relationship envisioned for EOS science as manifested on the various platforms and resource monitoring and environmental change activities.

Mission to Planet Earth

Purpose	Scientific Issues	Interdisciplinary Investigations	Distributed Active Archive Centers	Earth Observing System Spacecraft	Phase 1 Spacecraft
Determine Extent, Causes, and Regional Consequences of Global Climate Change	The Role of Clouds, Radiation, Water Vapor and Precipitation	LaRc-Radiation & Clouds Goddard Institute for Space Studies-Interannual Climate Variability NCAR-Climate Modeling MRI (Japan)-Atmos/Ocean/Land Interactions	•LaRC Radiation Budget, Aerosols, Tropospheric Chemistry	•EOS-AM -Clouds, Aerosols, and Radiative Balance -Characterization of Terrestrial Surface	**NASA** UARS Upper Atmosphere TOPEX/Poseidon (with France) Ocean Circulation
	The Productivity of the Oceans, their Circulation, and Air-Sea Exchange	GSFC-Atmos/Ocean/Land 4-D Data Animation Penn State U.MSFC-Water Cycle GSFC-Global Water & Energy Cycle BMRC (Australia)-Atmospheric Modeling	•MSFC Hydrology and Hydrodynamics	•EOS-PM -Clouds, Precipitation, and Radiative Balance -Terrestrial Snow & Sea Ice	LAGEOS Laser Geodynamics ATLAS Series Atmos/Solar Effects LITE Series Atmospheric Aerosols
	The Sources and Sinks of Greenhouse Gases, and their Atmospheric Transformations	U. of Washington-Physical Climate over Oceans U. of Texas-Geodynamics JPL-Air-Sea Interaction Woods Hole Ocean Inst-Biogeochemical Flume over Oceans CSIRO (Australia)-Physical & Biological Oceanography	•GSFC Upper Atmosphere, Dynamics, Global Biosphere, Geophysics	-Sea-Surface Temperature and Ocean Productivity •EOS-COLOR -Oceanic Biomass and Productivity	SRL Series Surface Radar Images TOMS Ozone Mapping Sea WiFs/SeaStar Ocean Color TRMM Clouds, Hydrology, Rain

Figure 7. The flow of activities in Mission to Planet Earth from the present to ultimate purposes.

	Changes in Land Use, Land Cover, Primary Productivity, and the Water Cycle	Chilworth Research (U.K.)-Oceans Oregon State U.-Physical & Biological Oceanography Cornell U.-Tectonic/Climatic Dynamics CCRS (Canada)-Northern Hemisphere U. of New Hampshire-Biogeochemical Cycles	●JPL Ocean Circulation, Air/Sea Interaction	●EOS-AERO -Atmospheric Aerosols	**Other U.S. (Data)** POES (NOAA) Global Environment GOES (NOAA) Global Environment DMSP (DoD) Hydrology and Sea Ice Geosat (Dod) Ocean Topography/Sea Ice
	The Role of the Polar Ice Sheets, and Sea Level	GSFC-Biosphere Atmosphere Interactions INPE (Brazil)-Amazonia U. of Cal at Santa Barbara-Snow Hydrology and Chemistry LERTS (France)-Climatic Processes in Arid/Semi-Arid Lands	●EROS Data Center Land Processes Imagery	●EOS-ALT -Ocean Circulation -Ice Sheet Mass Balance	Landsat-6 (EOSAT) Landsat-7 (NASA/DoD) Surface Images Earth Radiation Budget Measurement (DOE)
	The Coupling of Ozone Chemistry with Climate and the Biosphere	U. of Washington-Ocean-Ice-Atmosphere Interactions CCRS (Canada)-Cryospheric Monitoring in Canada GSFC-Middle Atmosphere Chemistry and Dynamics	●Alaska SAR Facility Sea Ice, Polar Processes Imagery	●EOS-CHEM -Atmospheric Chemical Species and their Transformations -Ocean Surface Stress	**International (Data)**Meteor-3 (Russia) Ozone/Radiation Budget ERS-1/2 (ESA) Global Environment JERS-1 (Japan) Sea Ice Characteristics
	The Role of Volcanoes in Climate Change	LaRC-Radiative/Chemical/ Dynamical Processes in the Atmosphere U. of Cambridge (UK)-Middle Atmosphere and Thermosphere U. of Hawaii-Volcanism and Climate	●National Snow and Ice Data Center Cryosphere, Snow and Ice Data Products of Level 2 and above		Radarsat (Canada) Sea Ice Characteristics ADEOS (Japan) Sea Surface/Atmosphere

KEY
*Earth Probes Mission
[1]Includes U.S. TOMS Instrument
[2]Launch by NASA
[3]Includes U.S. TOMS and NSCAT (Sea Surface Winds) Instruments
[4]Proposed

RESOURCES MONITORING APPLICATIONS

Although the EOS and other missions have as the principal objectives those associated with atmospheric, biospheric, and hydrospheric scientific matters, the data produced will be continuous, well calibrated, and georeferenced so that it will also be quite useful in monitoring earth resources (see Figure 6). For example, data collected for hydrological science studies, besides providing a better understanding of hydrological processes and how they are involved or affected by climate change and geological change, will provide valuable data for water resources management efforts, such as reservoir design and stormwater-management planning. Observations made to determine ocean color and biomass are of interest and utility to agencies and to private industry involved with utilizing marine resources. Instruments that are capable of observing vegetation dynamics and land-cover change will be applicable to monitoring the extent and condition of food and fiber resources, such as crops, forested areas, and wetlands. Instruments useful for doing geological studies are also applicable to mineral and petroleum explorations. Finally, observations of atmospheric constituents are of direct interest in an environmental sense.

The Mission to Planet Earth instruments (Goddard Space Flight Center 1991) such as Landsat, ASTER, and HIRIS will continue and improve upon the use of high-spatial resolution, multispectral (e.g., 192 narrow bands in the case of HIRIS) observations for a wide suite of resource applications. MODIS and MIMR will allow improved observations over wide areas of land-use change, vegetation condition, snow- and ice-cover change, wetness and water content, coastal water surface temperature, and color useful for fisheries' interests, plus more spectrally rich information useful for locating mineral and petroleum resources. There are no proprietary restrictions on the use of these data, so fundamentally there are no restrictions in the access or use of the data in the EOSDIS.

CHALLENGES

The point to be made here is that residing within the EOSDIS will be large volumes of data that will not only be useful for earth-science research but also for the monitoring and management of earth resources and for making associated resource allocations and economic decisions. The major challenge is to make private industry, state and local agencies, and academia aware of this resource and to provide the mechanisms and other infrastructure to make these data available in a timely fashion and at costs compatible with available or accessible funding. Legislation is now reportedly being considered in the U.S. Congress that may contribute toward this end. Among the technical, as opposed to legislative, infrastructure items involved is the development of archival media that permits the compact and cost-effective storage of large volumes of data for use with microcomputers and workstations so that the data can be widely used and processed to derive information. Electronic access, e.g., networks, and accounting procedures also need to be developed or enhanced to facilitate access to the archival centers and associated archives that are part of EOSDIS (see Figure 7). The further development of geographic information systems (GIS) to combine remotely sensed data, such as that from EOS with that from other sources, is very important in order to facilitate resource management and economic decision-making. A further challenge is to train a body of individuals, not only those in colleges and universities but many who are now in elementary and secondary schools, to have the skills and background to make good use of these data and the tools necessary to analyze and develop the information contained therein.

CONCLUSIONS

The purpose of this paper has been to heighten awareness of the characteristics of the NASA Mission to Planet Earth, including the amount and extent of data that will be forthcoming from this mission. It seems apparent that within the EOSDIS globally acquired data will be of immense value not only for earth-science research, particularly relevant to climate change, but also for earth-resources monitoring and environmental studies of importance in a wide variety of economic prediction and decision-making situations. The challenges include the technical ones of storing and disseminating the data in a timely and cost-effective fashion to a wide variety of users, educating future generations to make optimum use of these data, and providing the legislative framework to allow these challenges to be met and the opportunities for maintaining and improving life on this earth to be realized.

ACKNOWLEDGMENTS

The author wishes to thank Kelly Pecnick for preparing the original manuscript for publication.