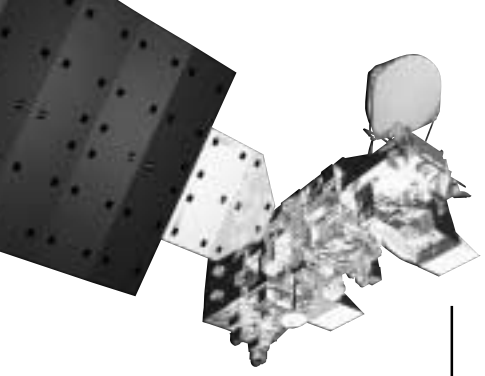
Science Writers' Guide To Aqua



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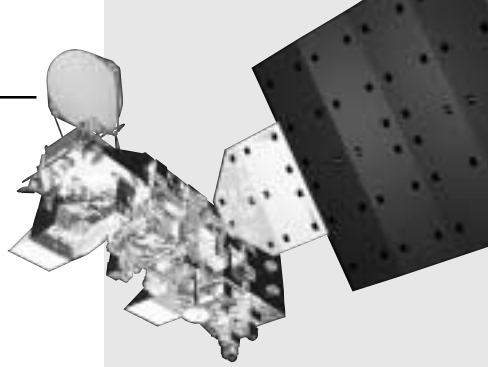


Aqua Science Objectives

The launch of NASA's Aqua spacecraft continues the Earth Observing System (EOS) series of comprehensive satellites to monitor the Earth from a space-based platform. Aqua was so named because it will obtain significant information about water in the Earth system including ocean surface water, humidity, precipitation infiltration, and runoff. Data from six Aqua instruments will provide continuous, long-term records of the hydrologic cycle around the world, which will be combined with data from other Earth-monitoring satellites launched by NASA and other countries.

The Earth Observing System (EOS) is the centerpiece of NASA's Earth Science Enterprise (ESE). It consists of a science component and a data system supporting a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans.

The science objectives of the EOS program are to provide global observations and improve the scientific understanding of the hydrologic cycle, land cover change and global productivity, climate variability and change, natural hazards, and atmospheric chemistry and dynamics.

Aqua's Instruments

The Aqua satellite has six instruments onboard to measure and monitor Earth's hydrologic cycle. These include:

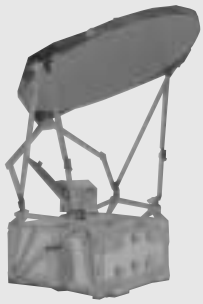
- **AIRS** (Atmospheric Infrared Sounder)
- **AMSR-E** (Advanced Microwave Scanning Radiometer - EOS)
- **AMSU** (Advanced Microwave Sounding Unit)
- **CERES** (Clouds and the Earth's Radiant Energy System)
- **HSB** (Humidity Sounder for Brazil)
- **MODIS** (Moderate-Resolution Imaging Spectroradiometer)

AIRS, AMSU, and **HSB** instruments will be used together to determine vertical profiles of water vapor, i.e., how much water vapor exists at different levels in the atmosphere from the Earth's surface to the stratosphere. This information will allow scientists to better estimate precipitation rates over land and water.

AIRS measures temperature profiles as well as precipitable water and cloud liquid water content. If cloud cover is too great, the microwave measurements alone will provide a coarse, low precision atmospheric temperature profile and surface characterization.

AMSR-E will monitor various atmospheric water processes that influence weather and climate. It will provide improved measurements of rain rates and extend the coverage of the Tropical Rainfall Measuring Mission (TRMM) satellite. It will also measure water vapor, sea ice, soil moisture, snow cover, and the amount of water in clouds.

AIRS



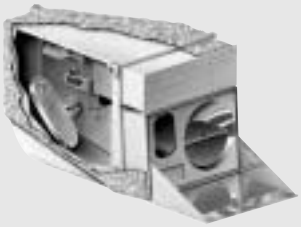
AMSR-E

AMSU-A1

AMSU-A2

CERES

HSB



MODIS

AMSU-A is made up of two separate sensor units, AMSU-A1 and AMSU-A2, but the observations from the two instruments are combined during data processing on the ground and treated as if they came from a single instrument. Together they provide measurements to derive temperature profiles from the surface to an altitude of about 25 miles (40 km). Some channels are used to provide cloud information.

CERES measures key elements of the energy balance of the Earth. Aqua contains two identical CERES instruments, each of which is a radiometer that measures reflected sunlight, Earth-emitted thermal radiation, and total radiation. Because clouds reflect sunlight, CERES can provide information about the amount of cloud cover over the globe. The CERES scanners operate continuously, obtaining a detailed representation of radiation from many directions by sampling the reflected and emitted radiation from multiple angles. A Two CERES instruments are also onboard the Terra satellite, Aqua's sister satellite launched in December 1999.

HSB provides measurements to derive water vapor profiles from the surface to an altitude of about 6.2 miles (10 km). HSB data will also provide some supplemental cloud information, and together with AMSU-A data, will be used to derive cloud liquid water profiles to check the accuracy of AIRS-derived profiles. Rain intensity can also be deduced from the HSB measurements.

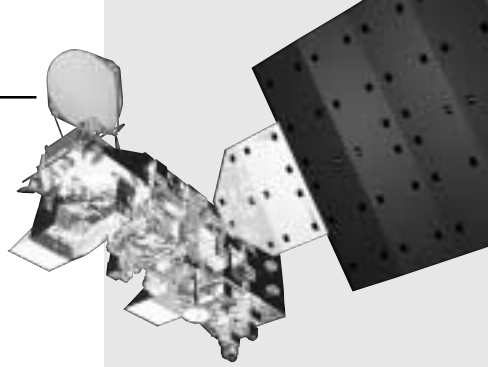
MODIS will comprehensively measure ocean, land and atmospheric processes. The MODIS instrument will observe the entire surface of the Earth every 1-2 days with a whisk-broom scanning imaging spectroradiometer that operates continuously. Its wide field of view over 1429 miles (2300 km), will provide images of daylight-reflected solar radiation and day/night thermal emissions over the entire globe. MODIS will be able to see features as small as 0.15 mile (250 meters) to 0.62 mile (1 km). A MODIS instrument is also onboard the Terra satellite.

Products Produced with Aqua's Data

Data from the six Aqua instruments will be used to produce dozens of data products on different aspects of the Earth's water cycle. These are described in the EOS Data Products Handbook, Volume 2, which can be found at aqua.nasa.gov.

These simultaneous, carefully registered data products will allow the EOS instrument teams to develop broad science approaches to specific problems.

For example, AMSR-E will provide improved rainfall data and estimates of the amount of latent heat released when clouds form. AIRS will provide profiles of a "column" of water vapor in the troposphere, total precipitable water, and cloud liquid water content data for a better understanding of water vapor's role in the Earth's radiation budget, and for improved weather prediction using computer models. Data from CERES and MODIS will complement and extend the measurements from identical instruments already flying on NASA's Terra satellite. The CERES instrument is used to observe the radiation budget and radiative forcing of Earth's climate. The MODIS instrument provides broad insight into many phenomena related to the Earth's surface, the atmosphere and the oceans.



What Aqua Will Measure

Region	Measurement	Instrument(s) Used
Atmosphere	Aerosol Properties (Composition, Size, Distribution)	MODIS, CERES
	Atmospheric Humidity	AIRS, AMSR-E, AMSU, HSB, MODIS
	Atmospheric Temperature	AIRS, AMSU, MODIS
	Cloud Properties	MODIS, CERES
	Greenhouse Gases	AIRS
	Precipitation	AIRS, AMSR-E, HSB
	Radiative Energy Fluxes (Emitted Thermal and Reflected Solar Radiation)	AIRS, AMSR-E, CERES, MODIS
Cryosphere	Sea Ice	AMSR-E, MODIS
	Snow Cover and Depth	AMSR-E, MODIS
Land	Fire Occurrence	MODIS
	Land Cover and Land Use Change	MODIS
	Surface Temperature	AIRS, AMSR-E, MODIS
	Surface Wetness	AMSR-E
	Volcanic Effects	MODIS
Ocean	Ocean Color	MODIS
	Phytoplankton and Dissolved Organic Matter	MODIS
	Sea Surface Temperature	AIRS, AMSR-E, MODIS
	Sea Surface Wind Speed	AMSR-E

Aqua Research Profiles

Improvements in Weather Forecasting

From initial knowledge of atmospheric winds, pressure and temperature, it is possible to compute projected changes in the circulation of the atmosphere, the development of storms, and even the next round of weather disturbances. However, since the beginning of worldwide forecasts in the 1970s, collecting accurate daily measurements of basic meteorological variables over the entire world has proven to be very difficult.

Over populated areas, observations can be obtained by launching balloon-borne instruments that measure air temperature, moisture, and wind at various levels of the atmosphere. Balloons, however, are not practical over the vast expanses of the oceans, and are too expensive to launch over many continental areas.

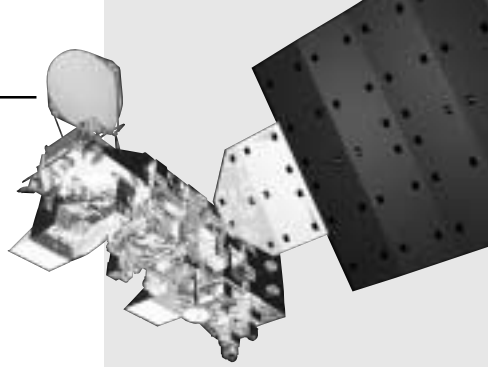
Satellites provide the key to obtaining worldwide observations of the Earth's atmosphere. The Atmospheric Infrared Sounder (AIRS), aboard the Aqua satellite will make global measurements of the atmosphere, providing new insights into Earth's weather and climate. Together with the Advanced Microwave Sounding Unit (AMSU) and the Humidity Sounder for Brazil (HSB), AIRS will provide basic meteorological observations of atmospheric temperature and moisture, day and night, over land and ocean areas where little or no data are available.

Accurate data are the key for computer-assisted weather forecasts. Any erroneous data (such as incorrect temperatures) will be amplified, and the error can double over forecasts for two or three days. The AIRS/AMSU/HSB instrument suite is designed to gather more accurate meteorological information about the Earth's atmosphere and its circulation than ever before, and will reduce the rate of error of initial data by a factor of two. Improving the accuracy of the initial state by a factor of two would be equivalent to increasing the useful range of weather forecasts by two or three days.

For the first time on a worldwide basis, a satellite remote sensing instrument is expected to achieve the same accuracy in temperature as is currently possible by direct balloon-borne sensors. The accuracy of the AIRS/AMSU/HSB in determining atmospheric moisture, moreover, will surpass that from balloon-borne sensors.

Accurate atmospheric moisture as input data to numerical weather prediction is also critical to forecasts. The AIRS/AMSU/HSB instrument suite represents a breakthrough in the ability to detect water vapor in the atmosphere, because it can discriminate between different layers of the atmosphere. Previously, it was very difficult to obtain the distribution of water vapor in the middle and upper troposphere.

It takes a tremendous amount of energy to vaporize liquid water. The condensation of water vapor in clouds and its eventual precipitation as rain or snow, release that energy in the form of heat, called latent heat. Latent heat is the principal energy source that fuels the development of strong weather systems, from tornadoes to hurricanes and severe storms outside the tropics. Latent heat can be calculated using the instruments aboard Aqua by measuring condensation or precipitation in the atmosphere.



Enhancing the quality of global weather observations can also yield considerable economic benefits through more reliable climate prediction. Improved weather forecasts, more accurate predictions of severe storm tracks, and better understanding of factors influencing air quality will reduce economic costs by giving advance warning time for storm preparations, and may save lives.

Moustafa Chahine, an atmospheric scientist at NASA's Jet Propulsion Laboratory in Pasadena, California and the Science Team of the AIRS/AMSU/HSB sounding system on Aqua are working with several Numerical Weather Prediction Centers around the world to demonstrate the impact of the new Aqua data on improving weather forecasting. Among the collaborating centers are: The National Weather Service (NOAA's National Centers for Environmental Prediction), NASA's Data Assimilation Office, the European Center for Medium-Range Weather Forecasts, the U.K. Meteorological Office, Meteorological Service of Canada, Japan Meteorological Agency, and Bureau of Meteorology Australia.

Insight Into Atmospheric Processes

Atmospheric temperature and humidity are key variables affecting local and global weather conditions. Accurate and frequent measurements of these parameters over the entire globe will greatly improve both short-term regional weather forecasts, and inter-seasonal and inter-annual climate predictions. In addition, aerosols (tiny particles of water and solid matter such as sea salt and volcanic ash) suspended in the atmosphere influence weather patterns by absorbing or scattering solar energy and by attracting condensation to form clouds.

Clouds are a major source of fresh water for the planet. They also impact our climate by reflecting solar energy into space (cooling) and by trapping heat emitted by the Earth (warming). Together, these and other parameters interact to produce an intricate and ever-changing atmosphere.

The atmospheric monitoring capabilities of the Aqua satellite offer unprecedented insight into many inter-related processes. Satellite remote sensing has already proven to be an invaluable tool for measuring specific atmospheric conditions, but the simultaneous measurement of several parameters from the same vantage point will enable scientists to more effectively study the complicated forcings and feedbacks of the atmosphere.

The MODIS instrument on both the Terra and Aqua satellites is designed to measure many biological and physical properties on a global basis every one to two days. The 36 wavelength bands (channels) on MODIS provide comprehensive long-term observations that enhance our understanding of global dynamics and processes occurring on the surface of the Earth and in the lower atmosphere.

EOS Senior Project Scientist Michael King at NASA's Goddard Space Flight Center is using the MODIS instrument to develop remote sensing algorithms for deriving time-series data products of cloud properties and distribution. King and his team are producing global maps of cloud optical thickness to measure how much solar radiation is not allowed to travel through a column of atmosphere. Similarly, cloud effective radius maps are generated to help determine the global extent of the size of water drops and ice crystals in optically thin clouds (such as cirrus clouds) as well as opaque clouds (cumulus clouds) and their role in our climate system. These data products are produced over time intervals ranging from daily to one week to one month or season, which reduces the data volume scientists must process, and are better suited for studying seasonal phenomenon.

Adding to King's research, the orbit characteristics of Terra and Aqua complement each other by crossing the equator in daylight in the morning and afternoon respectively. Together with extended observation duration, the mapping of atmospheric properties twice daily will provide valuable information on the Sun's daily influence on water vapor and clouds.

Precipitation and evaporation have extremely important roles in atmospheric dynamics. By providing water to the biosphere through precipitation, and removing excess heat from the surface by evaporation, these processes greatly contribute to the habitability of the Earth.

Roy Spencer, the AMSR-E U.S. Science Team Leader at NASA's Marshall Space Flight Center is using AMSR-E data to improve understanding of these processes by analyzing rain rates over both land and ocean.

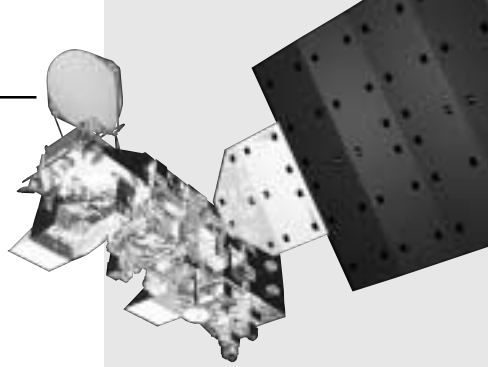
Over land, AMSR-E can measure the scattering effects of large ice particles, which later melt to form raindrops. These measurements, though a less direct measurement of rainfall intensity, are converted to rain rates with the help of cloud models. Over the ocean, the AMSR-E microwave frequencies can probe through smaller cloud particles to measure the microwave emission from the larger raindrops.

The total integrated water vapor of the atmosphere will also be measured over the ocean. This variable is important for the understanding of how water is cycled through the atmosphere. Since water vapor is the Earth's primary greenhouse gas, and it contributes the most to future projections of global warming, it is critical to understand how it varies naturally in the Earth system.

The high-resolution Atmospheric Infrared Sounder (AIRS) on Aqua operates in conjunction with two operational microwave sounders, the Advanced Microwave Sounding Unit (AMSU) and the Humidity Sounder for Brazil (HSB). AIRS Science Team Leader, Moustafa Chahine, at NASA's Jet Propulsion Laboratory in Pasadena, California is using measurements from these three instruments to filter out the effects of clouds from the IR data in order to derive column air temperature profiles with high vertical resolution and accuracy. Together, these three instruments constitute an advanced operational sounding system, which will improve global modeling efforts and numerical weather prediction.

Chahine and others are also using data from AIRS to advance studies of the global energy and water cycles, the effects of greenhouse gases, and atmosphere-surface interactions, and to facilitate monitoring of climate variations and trends. In addition, these microwave sounders provide sea ice concentration, snow cover, and additional temperature-profile information as well as precipitable water and cloud liquid-water content. If cloud cover is too great for infrared retrievals, the microwave measurements alone will provide a coarse, low-precision atmospheric-temperature profile and surface characterization.

Together, these instruments will provide unprecedented detail and accuracy in the global, all-weather measurement of atmospheric processes, and thereby allow a more-complete understanding of climate variability, ultimately enabling better prediction of climate and its impact on society.



Diurnal Cycles of Clouds & Solar Radiation

Our climate is strongly influenced by the radiation exchange between the Sun, the Earth and its atmosphere, and space. Clouds are a main factor in this exchange of energy.

All clouds can both absorb and reflect incoming short wave solar radiation, which cools the planet, as well as absorb and emit outgoing long wave radiation from the Earth's surface, which traps heat in the atmosphere and warms the planet. Since these cooling and heating effects compete with each other, and since cloud systems are extremely dynamic in time and space and closely tied to precipitation amounts and frequencies, it is difficult to determine the overall impact that clouds have on Earth's climate. According to the 2001 report of the Intergovernmental Panel on Climate Change, "probably the greatest uncertainty in future projections of climate arises from clouds and their interactions with radiation."

In an effort to reduce this uncertainty, the CERES instrument on Aqua will measure both reflected and incoming solar energy and outgoing long wave energy. CERES also uses data from Aqua's MODIS instrument to derive parameters like cloud heights, atmospheric water vapor, water drops, ice particles, atmospheric aerosols and cloud thickness. These data can then be combined with similar observations from other satellites, such as Terra, to account for changes that occur over the course of the day and to get more complete readings of the Earth's energy budget.

Around the world on a daily basis, the amount and type of clouds change radically. Changing clouds can have very different properties with regard to their responses to energy. For example, many land areas are often clear in the morning, with increasingly thick and bright clouds in the afternoon. After storms dissipate, thin cirrus from a storm may linger in the area. Each of these situations reacts very differently to radiation. Thin cirrus clouds have an overall warming effect for the Earth's surface, while thick low clouds have a cooling effect. Thick cumulus clouds have an overall neutral effect. Also, in regions near a western coast of a continent, like the California coast, there is a strong diurnal cycle featuring thick low clouds in the morning that dissipate during the day. Since clouds are constantly changing, a single instrument passing over the Earth would not measure clouds frequently enough, and that would likely create large errors for climate modelers.

Fortunately, data gathered by the CERES and MODIS instruments on Aqua can now be combined with data from the same instruments on the Terra satellite. In this way, areas that may be obscured by clouds in the morning when Terra passes overhead, may be clear in the afternoon when Aqua flies by in the opposite direction.

In order for climate modelers to study climate change, they need to better understand the important relationship between clouds and radiation. To do this, scientists are trying to produce accurate global monthly mean estimates of both radiation and clouds. These estimates will provide modelers with the best data for testing the accuracy of their models, which should reduce uncertainty and lead to improved results in global climate models that predict the future.

David F. Young, a researcher at NASA's Langley Research Center in Hampton, Virginia, is responsible for using CERES and MODIS data to produce global maps of the earth's radiation budget. The addition of afternoon observations from the Aqua satellite to the morning observations from Terra will provide valuable information necessary for accurately modeling diurnal variability of clouds and

radiation. This, in turn, will lead to the most accurate global energy budget data set available for climate researchers.

Ocean Surface Heat Budget

The Earth's heat comes overwhelmingly from the Sun. Solar radiation is absorbed mostly by the tropical oceans and transported by ocean currents and atmospheric winds to colder regions. Figuring out how much heat, or energy, the ocean absorbs is important for understanding processes like evaporation, precipitation, and ocean circulation, which are all components needed for accurate climate prediction. The Clouds and the Earth's Radiant Energy System (CERES), Advanced Microwave Scanning Radiometer (AMSR) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard Aqua will provide the most comprehensive coverage yet on the total amount of heat that the oceans absorb from above, an important part of the ocean surface heat budget.

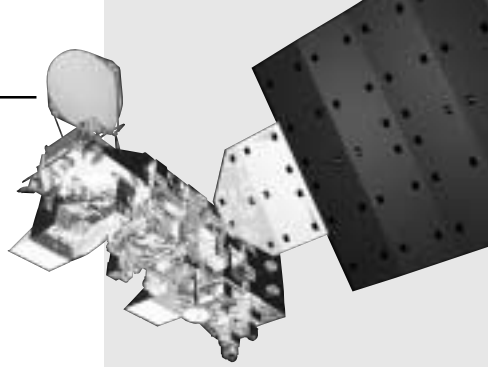
Until Aqua, measurements of the ocean surface heat budget have been incomplete. Cloud cover typically prevents satellite observations from reading radiative energy on the ocean's surface. The combination of CERES and MODIS instruments will allow scientists to 'see' both reflected solar and emitted thermal energy through the clouds. Through radiation measurements from CERES and the data from MODIS, researchers will be able to estimate the amount of total radiant energy flowing through the atmosphere and across the ocean's surface in both clear and cloudy conditions.

By obtaining data on the ocean surface heat budget, scientists can evaluate how heat is transported through the oceans from the tropics to the poles. If the data record continues for a long enough time period, they may also be able to measure the amount of heat transported from the surface into deep ocean water. Movements of heat through the water strongly affect ocean circulation, and create variations in climate through the exchange of heat between air and water.

The ocean's surface heat budget is also closely tied to the rate at which water evaporates from the ocean into the atmosphere. That's because when liquid water changes to vapor it absorbs energy, cooling the original surface. An example of this might be when we get out of a swimming pool, a breeze blows and we feel cold. At such times, the water over our skin is evaporating and taking heat from our body. In the ocean, the evaporation rate strongly depends on temperature, near-sea-surface wind speed and the dryness of the air, or water vapor mixing ratio. Higher temperatures, stronger winds and drier air all increase the evaporation rate. When evaporation increases, the ocean loses more heat.

Once in the atmosphere, water vapor gets redistributed globally by eventually raining or snowing out of the air back to land and ocean, after being transported in the air. This recycling of water provides an important supply of fresh water on land. Changes in evaporation rates indicate whether the Earth's water cycle is accelerating or decelerating, which is important for climate change. An increased global water cycle would likely change precipitation patterns, leading to increased rain, snow and floods in some regions.

The Aqua satellite will be invaluable for determining the ocean surface heat budget. MODIS data will be used to determine cloud amounts, cloud heights, cloud water/ice phase, cloud optical thickness, and cloud particle size. By combining CERES solar and thermal radiation measurements at the top of the atmosphere with these MODIS cloud properties, surface radiative fluxes will be estimated through a series of calculations and/or empirical methods.



Also, AMSR and MODIS both provide sea surface temperature observations, and AMSR will give near sea surface wind speed and water vapor mixing ratio. From these parameters, researchers can retrieve different kinds of heat, including the heat that is transferred when water turns to vapor, called latent heat. Latent heat is the same measure as evaporation.

With a complete set of data acquired from all of the above measurements, researchers like Bing Lin of NASA's Langley Research Center can better estimate the amount of heat moving from the atmosphere into the ocean, which will provide insights into climate variations.

The scientists at NASA's Langley Research Center will use the CERES and MODIS data to estimate shifts in surface radiation. The latent and sensible heats will be obtained from AMSR measurements. Sensible heat is a measure of surface heat loss caused by winds that mix warm air at the ocean's surface with cool air above. With all these important sea surface heat observations, the scientists will evaluate ocean and atmosphere heat transport and compare the results with those from models at NASA's Goddard Space Flight Center and the National Center for Atmospheric Research (NCAR). The comparisons will indicate how well model simulations do and will increase the accuracy of predicted climate change and fresh water redistribution.

Complete Ocean Color Coverage

Tiny marine phytoplankton are the basis of the food web in the ocean. These abundant organisms are also a vital part of the global carbon cycle as they collectively absorb close to half of all the atmospheric carbon dioxide that is absorbed by plants on Earth. The role of phytoplankton in the carbon cycle is especially relevant today because carbon dioxide acts as a heat trapping gas in the atmosphere and contributes to global warming.

By tracking the amount of phytoplankton in the ocean, researchers are able to better understand how these tiny plants might play a mitigating role in climate change. Also, monitoring shifts in marine ecosystems caused by natural cycles, environmental factors and climate change provides scientists with further information related to phytoplankton populations. The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on Aqua will let investigators measure the entire ocean rapidly enough to observe changes in phytoplankton in the ocean.

In a process called photosynthesis, phytoplankton harness the Sun's energy and use it to convert carbon dioxide and water into carbohydrates, oxygen and energy. A green pigment called chlorophyll absorbs the sunlight. The energy from the Sun's rays is either used for growth or the plants emit the excess as a faint, red fluorescence. Since the color of the water changes where phytoplankton are abundant, the MODIS instrument can allow detection of the presence of phytoplankton by measuring visible and near-infrared radiances. The instrument can scan close to 1429 miles (2300 kilometers) across the satellite's track over the globe.

Unfortunately, satellites cannot take readings fast enough to overcome difficulties that arise when measuring the entire ocean. Sunlight that reflects directly off the water's surface, along with clouds, interfere with instruments that detect light coming from within the ocean. As a result, a single instrument passing over the earth can only record about half of the total ocean area. Fortunately, data gathered by the MODIS instrument on Aqua can now be combined with MODIS data from the Terra satellite. In this way, areas that may be obscured by clouds in the late morning when Terra MODIS

passes overhead, may be clear in the early afternoon when Aqua flies by in the opposite direction. Likewise, the area of sun-glint shifts over the course of the day as the Sun rises and sets. Researchers will now be able to combine the Terra and Aqua observations to get a more complete view of the ocean on any single day or week.

Aqua's MODIS will greatly improve the frequency, accuracy and reliability of our estimates of phytoplankton net primary productivity, or the amount of energy these plants use to grow new cells. While we currently have a fairly good understanding of how much carbon dioxide humans put into the air each year, we can only make rough estimates of how much of that carbon is getting absorbed by marine plants. That means our understanding of the marine carbon cycle does not supply enough information to predict accurately the atmospheric carbon levels over time. The deficiencies of our data impact our ability to predict the effects of carbon dioxide on global climate change, and in turn, the ramifications of global climate change on marine ecosystems.

Scientists like NASA Goddard Space Flight Center researcher Wayne Esaias will use the new MODIS data to estimate the abundance and changes to marine phytoplankton. By knowing how much phytoplankton exist worldwide, Esaias can then calculate the amount of carbon these plankton remove from the atmosphere each year. Scientists can currently make full global estimates of how much total energy phytoplankton produce, an indicator of how much carbon these plants 'fix' or remove from the atmosphere and trap within their cells, but those estimates are not very accurate since they rely on weekly time intervals, and they don't include observations from a large part of the oceans. The data from the Aqua MODIS will help improve the database.

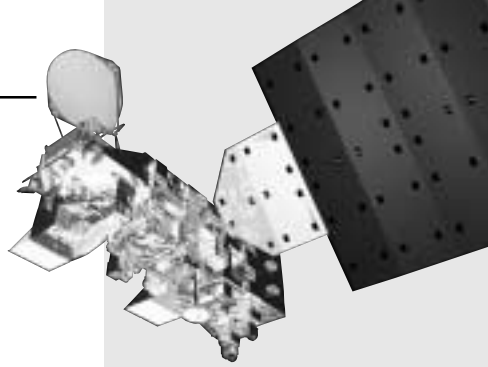
Sea Ice Can Foretell Climate Change

Scientists monitor changes in sea ice for several reasons. Sea ice is an important element of the Earth's climate system; it affects other elements of the climate system and changes in it can foretell additional changes in global climate, as well as being important for the polar ecosystem. The Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard the Aqua satellite will help researchers monitor sea ice changes.

Changes in sea ice have several impacts on the climate system and the polar ecosystem. For instance:

(1) The presence of sea ice in a region limits the amounts of heat, mass, and wind/wave energy that are exchanged between the ocean and the atmosphere. In winter in particular, sea ice helps oceans retain their thermal energy, by restricting evaporation and other heat transfers from the ocean surface. Snow cover over sea ice further limits heat loss from the ocean, acting as a blanket that traps heat.

(2) Sea ice has a high reflectivity or albedo, reflecting most of the Sun's radiation that reaches it back to space and thereby limiting the amount of solar radiation absorbed at the surface. In this respect, sea ice is similar to other white surfaces, including land ice and snow cover, the white color being indicative of a high reflectivity. This high albedo of ice surfaces contributes to making the polar regions colder than they would be if there were limited or no ice cover.



(3) Sea ice and changes in it also affect many polar life forms. For instance, sea ice serves as a habitat for organisms living within it, including algae and protozoa, and as a platform for seals and polar bears. It also limits the amount of light available for photosynthesis underneath it, reducing the growth of phytoplankton, which serves as food for larger organisms.

Both the AMSR-E and the MODIS will be used to derive information about the polar sea ice covers. In the case of AMSR-E, the measurements will be based on microwave radiation emitted from sea ice and other elements of the Earth/atmosphere system, whereas in the case of MODIS the measurements will be based on reflected solar radiation and on emitted thermal infrared radiation.

The data from the AMSR-E will be used to calculate sea ice concentration (the percentage of geographic area covered by sea ice) for each pixel (location) throughout the ice-covered oceans in a satellite-based image. Scientists can use the AMSR-E data to differentiate between sea ice and liquid water because at some of the microwave wavelengths being measured by the instrument, sea ice gives off considerably more radiation than water does.

Sea ice concentration will be used to determine sea ice extent (total area with ice concentrations of at least 15%) and sea ice area (total area of sea ice) in both the north and south polar regions as a whole and in many subregions. These extents and areas will be plotted versus time and compared with earlier sea ice records to determine changes in sea ice coverage. Scientists are particularly interested in determining whether the decreases in Arctic sea ice that occurred in the late twentieth century continue.

The AMSR-E data will also be used to calculate sea ice temperature and snow depth on sea ice. Snow depth can be determined from the difference between the measurements made by two of the AMSR-E channels. The deeper the snow, the more microwave scattering occurs within the snow layer for one channel relative to the other.

MODIS data will enable researchers to map sea ice in more spatial detail than AMSR-E data, because the MODIS data have a considerably higher resolution, at about 1 km (0.62 mile), than AMSR-E's best sea-ice resolution of about 12.5 km (7.76 miles). However, the MODIS surface data are restricted to periods when skies are clear or nearly clear, because significant cloud cover obscures the sea ice underneath. The AMSR-E data have the advantage of being obtainable under most weather conditions and during darkness as well as daylight. The two instruments complement each other well for sea ice studies, with the MODIS data showing greater detail but only under clear and sunlit conditions, and the AMSR-E data providing coarse-resolution information globally under almost all conditions.

Donald Cavalieri, Senior Research Scientist at NASA's Goddard Space Flight Center, is working with AMSR-E data to validate Arctic and Antarctic sea ice concentrations, sea ice temperatures, and snow depth on sea ice. After the validation effort is complete, he will use AMSR-E sea ice data to study global sea ice variability and the role of sea ice in global climate processes.

Josefino Comiso, Senior Research Scientist at NASA's Goddard Space Flight Center, specializes in product development for the southern hemisphere. He is developing sea ice algorithms to generate sea ice concentrations, ice temperature, and snow cover over sea ice. He is also studying variability and mass balance of the sea ice cover.

Dorothy Hall, Senior Scientist and Glaciologist at NASA's Goddard Space Flight Center, and George Riggs, Scientist at Science Systems and Applications, Inc., are working on algorithms for MODIS sea ice products. They will be mapping sea ice extent and ice surface temperature, two parameters that will be used by global climate modelers for energy balance studies. These scientists are mapping sea ice cover both in the daytime and at night using visible and infrared bands on MODIS.

Claire Parkinson, Senior Scientist and Aqua Project Scientist at NASA's Goddard Space Flight Center, specializes in sea ice/climate studies. She will be using AMSR-E data to extend the satellite record of the sea ice covers of both polar regions, analyzing sea ice variability and sea ice trends over the past three decades and placing these in the context of global climate and climate change.

By monitoring changes in sea ice and its associated snow cover with the instruments aboard Aqua, researchers will extend the record of changes in this important climate variable and may be able to predict changes in the ecosystem of the polar regions and the world's climate system.

Snow Cover Mapping & Runoff Estimates

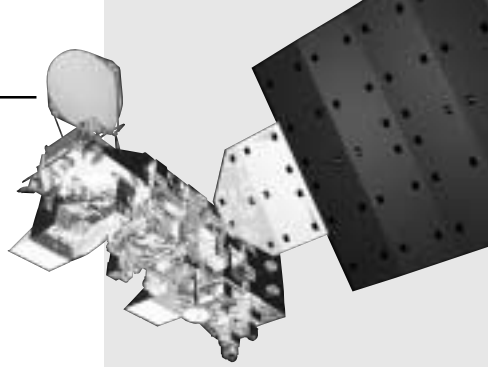
Snow cover and resulting snowmelt runoff have important agricultural, and socio-economic impacts. Using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and other satellite instruments, scientists can determine the extent of spring snow-cover, which can be a harbinger of flood or drought conditions. It is important to be able to accurately predict the amount of runoff in order to plan for flooding, drought, and the availability of water supplies.

MODIS, onboard the Aqua satellite, enables scientists to produce snow-cover maps depict the amount and extent of snow cover over land on a daily basis and as 8-day composite maps. The MODIS instrument has an improved ability over previous instruments to discriminate between snow and clouds. This ability to distinguish clouds from snow increases the accuracy of snow-cover maps.

These snow-cover maps are currently being produced from Terra satellite MODIS data, and are available on a daily basis. From these maps, researchers can estimate the amount of runoff to be expected, based on the amount of snow the maps show.

Up to 40 percent of the Earth's land surface in the Northern Hemisphere can be covered with snow during the winter months. The highly reflective nature of snow combined with its large surface coverage make snow an important factor in the Earth's radiation balance, which consists of incoming solar energy and energy reflected and emitted back into space. Because the Earth is in a steady-state balance of incoming and outgoing energy, its temperature undergoes only small changes, but the mean temperature stays nearly the same. According to the National Snow and Ice Data Center in Boulder, Colorado, snow may reflect up to 90 percent of the incoming solar energy reaching it, whereas a surface without snow would only reflect 10-20 percent. Retained solar energy means increased warmth near the Earth's surface.

Many areas of the world rely on snowmelt for irrigation and drinking water. In the western U.S., the mountain snow-pack contributes up to 75 percent of all year-round surface water supplies. Therefore, it is necessary to monitor snow-packs closely throughout the winter and spring for assessment of water supply and flooding potential, and MODIS data are proving useful in this capacity.



As an instrument on NASA's Aqua satellite, MODIS, a scanning, imaging radiometer, continuously observes the Earth's surface in a sweeping motion, covering the Earth every 1-2 days. Its wide field of view (over 2,300 kilometers, or over 1,429 miles) provides images during the daytime from the visible and near-infrared sensors, as well as images from the thermal-infrared part of the spectrum both during the day and at night over the entire globe.

Dorothy K. Hall, a Glaciologist at NASA's Hydrological Sciences Branch at the Goddard Space Flight Center in Greenbelt, Maryland, has been working with Terra-generated MODIS snow maps since 2000, and will be working with MODIS snow maps from Aqua as well. There are other researchers in Europe and elsewhere in the United States that have also done work with the MODIS Terra snow maps.

Soil Moisture Content

By understanding how much moisture exists in the soil and how that soil moisture moves around over different periods of time, scientists will be able to make better predictions of weather, climate, and natural hazards such as floods and droughts.

The amount of moisture in the soil has a strong influence on the global water cycle. This cycle refers to the constant movement of water between the land, ocean and atmosphere. On land, the soil also acts as a reservoir for water that supports plant life and provides a water supply for human needs.

When rainfall hits the soil, some of it is absorbed, some runs off into rivers and other waterways, and some evaporates back into the atmosphere. In times of prolonged and intense precipitation, the soil may become saturated over large areas. In such instances, further rainfall can lead to floods.

The rate at which water evaporates from the land surface into the atmosphere depends in part on the amount of moisture that exists in the soil, including water in the root zone-i.e., the region accessed by the roots of plants. Water in the root zone travels through the plant roots, through the leaves, and into the atmosphere by the process of transpiration. Moisture entering the atmosphere in this manner, as well as moisture entering through evaporation, contributes to cloud formation, and can later be recycled back to the land as precipitation.

When scientists create computer simulations of water cycling for weather and climate forecasts they are aided by observational data, such as radiation, precipitation, and atmospheric and surface parameters, to initialize and update the models. Accurate observations of the amount of moisture in the soil can greatly aid and improve the models and provide early warnings of flood and drought conditions.

Until now, weather and climate forecasters have not had a reliable way of obtaining soil moisture levels on a large scale. An instrument aboard the Aqua satellite, the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), will provide the first opportunity to obtain that information. Changes in soil moisture are observable as changes in the intensity, or brightness temperature, of the microwave radiation emitted by the soil surface. AMSR-E is a microwave radiometer that measures radiation from the Earth's surface and atmosphere in six frequency bands. The lower frequency bands will be used to estimate soil moisture content.

The soil moisture estimates from AMSR-E will be available as maps with approximately 35 miles (approximately 56 kilometers) spatial resolution. The data will be limited to regions with low plant cover because vegetation obscures the soil emission that can be measured. Additionally, AMSR-E is sensitive to soil moisture in the top surface layer only (the top ~1 cm or approximately 4/10ths of an inch). Sensors operating at lower frequency bands than AMSR-E are necessary to probe deeper in the soil. Data assimilation techniques currently under development will be used as a method for combining the AMSR-E data with hydrologic models to provide estimates of soil moisture at greater depths in the soil.

Eni Njoku, a researcher at NASA's Jet Propulsion Laboratory in Pasadena, California, will use AMSR-E data to better understand the natural variability of soil moisture globally. Currently, there are no global space-borne measurements of soil moisture, and no clear global picture of seasonal and longer-term soil moisture cycles. As a result, little is known about whether or how these cycles may be changing. Njoku's research and that of his colleagues, will hopefully provide the first global views of soil moisture and its variability with time. Njoku believes this will lead to better understanding of global water distribution and the hydrologic processes involved in weather and climate.

Mapping Wildfire Hazards

More than 100,000 wildfires destroy millions of acres of forest each year in the United States. About 90% of wildfires result from lightning and the other ten percent are started by people. Though wildfires continue to threaten lives, property and forestlands, scientists can now assist firefighters and land managers in battling wildfires by using the satellite technology aboard the Aqua satellite.

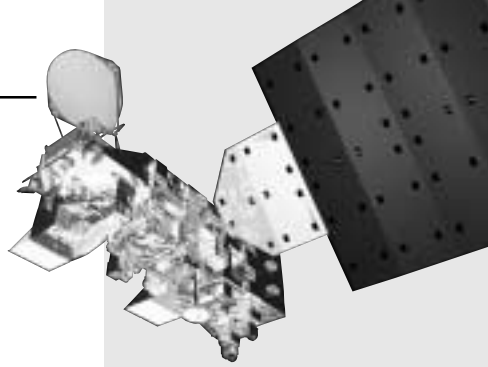
During the fire season in the United States, the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Aqua satellite, also aboard Terra, provides a detailed view of fires across the entire country. MODIS tracks location and movement of fires, from the time a fire ignites to after it has burned out.

These data help the experts strategize more effectively. The use of satellite data provides new capabilities that pinpoint where fires are, track smoke and aerosols, determine the type and intensity of a fire, and identify the potential for fires through soil moisture content.

The Aqua satellite beams daily images of wildfires to NASA within a few hours of the time that it passes over a region. These images, showing the locations of active fires, are transmitted to the U.S. Forest Service for distribution to planners and firefighters.

A complex communications network is maintained between NASA, the University of Maryland and the U.S. Forest Service to utilize and share the MODIS data. The three institutions are integrated under the Rapid Response Project. This program was created in response to the 2000 fire season, with its extensive wildfires in Idaho and Montana.

Among the products created from the satellite data are the Active Fire Maps. These maps can help firefighters see the 'big picture' when making decisions on where equipment and manpower could best be used. The maps can also help the public understand where the fires are located as they are occurring, and provide a look at the burned areas after the fire has ended.



The Forest Service's Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah, provides development, support and application of remote sensing technologies and techniques. To best determine where fires are occurring, the University of Maryland sends MODIS images and active fire location information daily to RSAC, where state boundaries and topographical features are overlaid on the images. These maps show current active fire areas in near-real-time on the Internet at http://www.nifc.gov/firemaps.html.

Satellite data from the MODIS instrument provide other benefits as well. Fires that produce heavy amounts of smoke prevent reconnaissance planes from mapping engulfed areas. However, MODIS can map the fires from space by measuring the heat of the fire and seeing through the smoke using infrared sensing.

The MODIS instrument can also help firefighters determine how hot a fire is by the amount of radiation the infrared sensor picks up from the fire. The intensity of the fire is then color coded on a fire map, to show where the hottest fires are burning. This is important because knowing how hot a wildfire is can help firefighters determine strategies for battling it.

There are two types of wildfires: ground fires and crown fires. Ground fires can be both hot and cool burning fires. They become hotter only if there is considerable fuel (underbrush), but may be cooler if they move slowly, burning up moderate amounts of fuel on a forest floor. The most variable factor with a ground fire is wind. Windy conditions can turn a slow moving fire into a raging fire forcing it rapidly through new fuels and feeding the fire with a lot of oxygen. Additional fuel and increased oxygen cause ground fires to “explode.”

A crown fire is generally a fast-moving fire in the upper canopy of a forest that burns branches, leaves and needles of a tree, and jumps from crown to crown. The rate at which canopy fires spread is controlled by high winds and terrain with steep slopes. The data that MODIS provides on the intensity of fires and how fast they move will help firefighters determine equipment needs for such actions as using bulldozers to plow dirt and redirect fires.

After a fire has burned out, MODIS data are used to generate a Burn Severity Map. These are maps of burned-out areas that help scientists identify critical wildlife habitats affected by a fire and facilitate reforesting an area. Each map is derived from satellite and ground measurements to help scientists take precautions against further erosion, soil loss and adverse impacts to water quality. The maps provide a quick look at burned areas, and are then refined by teams on the ground. Burned-Area Emergency Rehabilitation (BAER) teams that include soil scientists, hydrologists, and wildlife specialists use them.

Steven W. Running of the University of Montana will be using MODIS data to determine and quantify the dryness of Earth’s surface (by scaling the surface temperatures measured by MODIS and comparing them with vegetation indices). A dry surface is a good indicator of fire danger and the potential for a fire to ignite. Running will be developing these applications with the USDA Forest Service's Missoula, Montana Fire Science Lab.

Wei Min Hao, the Project Leader of the Fire Chemistry Project at the Forest Service’s Fire Science Laboratory in Montana, and Yoram Kaufman of NASA’s Goddard Space Flight Center are developing a MODIS aerosol product to track smoke dispersed by wildfires and to determine the impact that smoke has on regional air quality.

Is the Global Water Cycle Accelerating?

Water on Earth moves in a continuous cycle. It evaporates from the surface to the atmosphere where global-scale winds blow the water around before it rains and snows back to the planet's surface. Many scientists believe the Earth's water cycle may be turning over at a faster rate as a result of global warming. That's because warmer conditions can result in greater evaporation and warm air can hold more water than colder air. Also, water vapor acts as a greenhouse gas and adds to global warming by trapping the Sun's heat before it can radiate back out to space. Since the water cycle and global climate change are so closely related, better data regarding these processes are key to understanding our future climate.

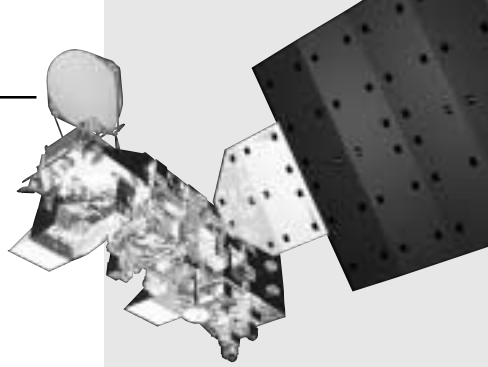
The Atmospheric Infrared Sounder (AIRS), Advanced Microwave Sounding Unit (AMSU), and Humidity Sounder for Brazil (HSB) instruments on Aqua will provide the most accurate measurements of water vapor in the atmosphere. AIRS, AMSU and HSB will very accurately gauge the infrared radiation and microwave energy coming from the Earth's surface, from clouds, and from carbon dioxide and water molecules in the atmosphere. From these measurements, scientists will be able to tell the water vapor content in 31-mile-wide (50 kilometer) air columns. In the past, for many satellite instruments clouds posed problems for scientists because they blocked a satellite's view to the lower atmosphere and the Earth's surface. But now, the instruments on Aqua can see the Earth's surface even when cloud cover obscures 80 percent of the view.

When water vapor condenses in the air, clouds are formed. When clouds get heavy enough, they eventually release water in the form of rain or snow. This precipitation feeds the flow of rivers and replenishes freshwater reservoirs. By knowing how atmospheric water vapor gets distributed back to Earth, scientists may be able to forecast when, where, and how much precipitation will occur. Scientists hope to measure how active the planetary water cycle is, how much heat is released in the atmosphere when water vapor condenses, and how much energy is available to fuel weather processes. This is important because precipitation, driven by the presence of moist, unstable air, is the most dominant manifestation of the Earth's weather and climate.

Current estimates, which are far less accurate than those from Aqua data, suggest that the atmosphere rains out all of its water about once every 10 days. Existing water vapor sensors, carried aloft by balloons, called radiosondes, can quickly travel and take readings all the way from the Earth's surface to the upper stratosphere. In their short flights, these balloon radiosondes show rapid shifts in atmospheric temperatures and water vapor amounts that change by four orders of magnitude per unit volume from the surface to the higher regions. Until now, no widely available sensor could span such diverse conditions and still take accurate readings.

Climate models predict that with rising temperatures, the rate of the global water cycle will increase, leading to faster evaporation of surface and greater global precipitation. While some regions may dry out, others will experience more frequent and severe floods. With the new data provided by Aqua instruments, scientists hope to predict such climate changes and project their regional impacts.

Atmospheric scientist and AIRS Team leader Moustafa Chahine of NASA's Jet Propulsion Laboratory in Pasadena, California, will use Aqua data to further investigate the dynamics of the global water cycle and the consequences that an accelerating hydrologic system may have on regional water resources, floods and droughts. AIRS and HSB measurements of atmospheric water content with additional data



from Aqua, the Tropical Rainfall Measuring Mission (TRMM), operational weather satellites, and ground measurements, will allow Chahine to track Earth's water cycle more accurately than ever before.

NASA's Earth Observing System

The purpose of NASA's Earth Science Enterprise is to improve our understanding the total Earth system and the effects of natural and human-induced changes on the global environment.

The NASA Office of Earth Science is pioneering the new interdisciplinary field of research called Earth system science, born of the recognition that the Earth's land surface, oceans, atmosphere, ice cover, and biota are dynamic and highly interactive.

The Earth Science Enterprise is comprised of an integrated slate of spacecraft and in situ measurement capabilities; data and information management systems to acquire, process, archive, and distribute global data sets; and research to convert data into new knowledge of the Earth system. It is NASA's contribution to the U.S. Global Change Research Program, an interagency effort to understand the processes and patterns of global change.

The centerpiece of the Earth Science Enterprise - the Earth Observing System (EOS), conceived in the 1980s, is a program of multiple spacecraft and interdisciplinary science investigations to provide key information needed to understand global climate change. The Terra satellite, launched in December 1999, was the flagship of EOS, and Aqua is one of several additional spacecraft that are scheduled to fly as part of the EOS program over the next few years.

The overall goal of the EOS program is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions among them, and how the Earth system is changing. Specific EOS program mission goals are to: (1) create an integrated, scientific observing system emphasizing climate change that enables multi-disciplinary study of the Earth's critical, interrelated processes; (2) develop a comprehensive data and information system, including a data retrieval and processing system; (3) serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth; and (4) acquire and assemble a global database of remote-sensing measurements from space over a decade or more to enable definitive and conclusive studies of the Earth system.

Terra, Aqua, and Aura are the three main EOS spacecraft that will support a broad range of scientific investigations. Each of these satellites is designed to operate for a period of at least six years. Additional observations are provided by Landsat-7, launched in April 1999, and several other more specialized missions. Some of these satellites will be flown in formation to simultaneously or sequentially monitor the same areas, and complement the measurements of the others.

Nearly all U.S.-led EOS missions include international contributions. For example,Terra includes the Canadian instrument Measurements of Pollution in the Troposphere (MOPITT) and the Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The Aqua mission includes the Japanese Advanced Microwave Scanning Radiometer (AMSR-E) and the Humidity Sounder for Brazil (HSB). Several U.S. instruments are part of the payloads aboard satellites launched by other countries, including the Russian Meteor 3M, Japanese ADEOS II, and French Jason-1

spacecraft. In addition, numerous agreements have been signed for joint data exchange and distribution, including integration with the EOS Data and Information System (EOSDIS).

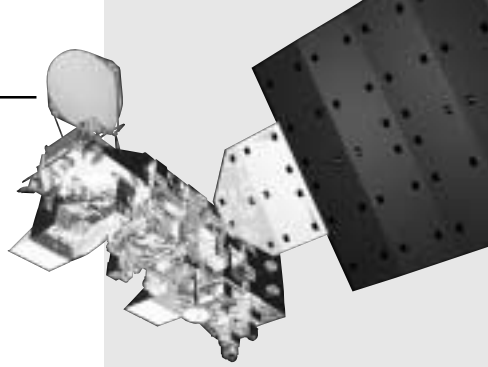
EOS sponsors many interdisciplinary research investigations that use specific Earth science data sets for a broader investigation into the function of Earth systems. Current EOS research spans a wide range of sciences, including atmospheric chemistry, hydrology, land use, and marine ecosystems.

The EOS Project Science Office at Goddard Space Flight Center consists of the Senior Project Scientist as well as Project Scientists associated with the various EOS missions and the EOS Data and Information System. This office serves as the primary day-to-day interface between the Earth science community and the EOS projects at all NASA centers.

Complementing the EOS missions are a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The New Millennium Program (NMP) is designed to identify, develop, and validate key instrument and spacecraft technologies that can enable new or more cost-effective approaches to conducting science missions in the 21st century.

Data from past and current Earth science missions are captured, processed into useful information, and broadly distributed by the EOSDIS. In addition to EOSDIS, NASA is engaged in a variety of activities to extend the usefulness of Earth science data through a broad range of users such as Regional Earth Science Applications Centers, and the Federation of Earth Science Information Partners.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. The Earth Science Research and Analysis program funds more than 1,500 scientific research tasks.



Other Earth Science Spacecraft and Instruments

ACRIMSAT
http://acrim.jpl.nasa.gov/

A series of U.S. Active Cavity Radiometer Irradiance Monitors (ACRIMs), the latest launched in 1999, provides long-term, precise measurements of the total amount of the Sun's energy that falls on our planet's surface, oceans, and atmosphere.

ADEOS II
http://winds.jpl.nasa.gov/missions/seawinds/seaindex.html

The Advanced Earth Observing Satellite II (ADEOS II), the successor to the Advanced Earth Observing Satellite (ADEOS) mission, is a joint mission with the National Space Development Agency (NASDA) of Japan. The mission will take an active part in the research of global climate changes and their effect on weather phenomena. It is scheduled for launch no earlier than November 2002.

Aura *(formerly EOS Chemistry)*
http://aura.gsfc.nasa.gov/

The Aura satellite will focus on measurements of atmospheric trace gases and their transformations. The primary objective of the mission is to study the chemistry and dynamics of the Earth's atmosphere from the ground through the mesosphere. It is scheduled for launch in July 2003.

CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations)
http://www-essp3.larc.nasa.gov/picasso.html or http://essp.gsfc.nasa.gov/calipso/index.html

CALIPSO will provide key measurements of aerosol and cloud properties needed to improve climate predictions. CALIPSO will fly in formation with Aqua and CloudSat to obtain coincident observations of radiative fluxes and atmospheric states. This comprehensive set of measurements is essential for accurate quantification of global aerosol and cloud radiative effects. It is scheduled for launch in April 2004.

CloudSat
http://cloudsat.atmos.colostate.edu/ or http://essp.gsfc.nasa.gov/cloudsat/index.html

CloudSat's primary goal is to furnish data needed to evaluate and improve the way clouds are parameterized in global models thereby contributing to better predictions of clouds. The new data will increase current understanding of the role that clouds play in climate change, referred to as cloud-climate feedback. It is scheduled for launch in April 2004.

EO-1 (Earth Observing 1)
http://eo1.gsfc.nasa.gov/

One of the key responsibilities of NASA's Earth Science Enterprise is to ensure the continuity of future Landsat data. The New Millennium Program's (NMP) first flight, Earth Observing-1 (EO-1) is validating technologies contributing to the reduction in cost of follow-on Landsat missions. The Hyperion instrument is aboard this spacecraft. It was launched November 21, 2001.

GRACE (Gravity Recovery and Climate Experiment)
http://www.csr.utexas.edu/grace/ or
http://essp.gsfc.nasa.gov/grace/index.html

The first of the Pathfinder missions, GRACE will employ a satellite-to-satellite microwave tracking system to measure the Earth's gravity field and its time variability over five years. Such measurements are directly coupled to long-wavelength ocean circulation processes and to the transport of ocean heat to the Earth's poles. It was launched March 17, 2002.

ICESat
http://icesat.gsfc.nasa.gov/

The Ice, Cloud, and Land Elevation Satellite (ICESat) is a small U.S. satellite mission to fly the Geoscience Laser Altimeter System (GLAS) in a near-polar orbit. GLAS will accurately measure the elevation of the Earth's ice sheets, clouds, and land. It is scheduled for launch in October 2002.

Jason-1
http://topex-www.jpl.nasa.gov/mission/jason-1.html

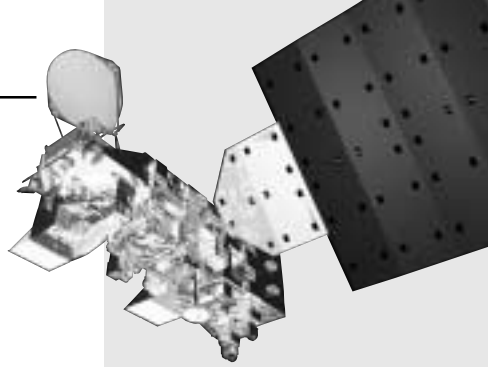
Jason-1 is a joint U.S.-France (Centre National d' Etudes Spatiales) oceanography mission designed to monitor global ocean circulation, quantify the tie between the oceans and atmosphere, improve global climate predictions, and monitor events such as El Niño and La Niña and ocean eddies. Jason-1 was launched on December 7, 2001.

Landsat 7
http://landsat.gsfc.nasa.gov/

Landsat 7 is a U.S. satellite used to acquire remotely sensed images of the Earth's land surface and surrounding coastal regions. The Landsat Program is the longest running enterprise for acquisition of imagery of the Earth from space. The first Landsat satellite was launched in 1972. Landsat 7 was launched on April 15, 1999.

Meteor 3M/SAGE III (Stratospheric Aerosol and Gas Experiment 3)
http://www-sage3.larc.nasa.gov/

SAGE III is a fourth generation, satellite-borne instrument and a crucial element in NASA's Earth Observing System (EOS). Its mission is to enhance our understanding of natural and human-derived atmospheric processes by providing accurate long-term measurements of the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere. It was launched December 10, 2001.



QuikSCAT
http://winds.jpl.nasa.gov/missions/quikscat/quikindex.html

The SeaWinds instrument on the QuikSCAT mission is a "quick recovery" mission to fill the gap created by the loss of data from the NASA Scatterometer (NSCAT) in June 1997. The SeaWinds instrument is a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over the Earth's oceans. QuikSCAT was launched on June 19, 1999.

SORCE (Solar Radiation and Climate Experiment)
http://lasp.colorado.edu/sorce/

The SOLar STellar Irradiance Comparison Experiment (SOLSTICE) and Total Irradiance Monitor (TIM) onboard the Solar Radiation and Climate Experiment (SORCE) provide the scientific community with long-term, accurate measurements of the solar ultraviolet (UV), far ultraviolet (FUV), and total irradiance from the Sun. It is scheduled for launch in July 2002.

Terra
http://terra.nasa.gov/

The Terra satellite, launched in December 1999, is the flagship of EOS. It is providing global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another.

VCL (Vegetation Canopy Lidar)
http://essp.gsfc.nasa.gov/vcl/index.html

The second of the Pathfinder missions, VCL seeks to provide the first global inventory of the vertical structure of forests across Earth using a multibeam laser-ranging device. The mission will enable direct measurement of tree heights, forest canopy structure, and derived parameters such as global biomass with at least ten times better accuracy than existing assessments. Launch date is to be determined.

Information Resources

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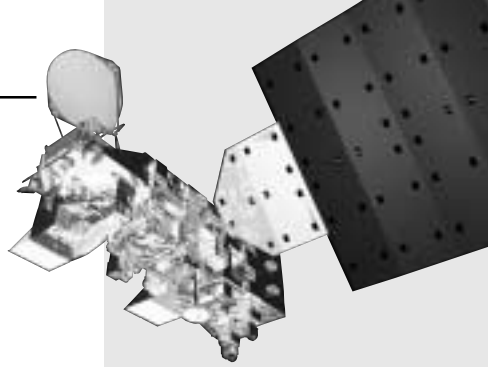

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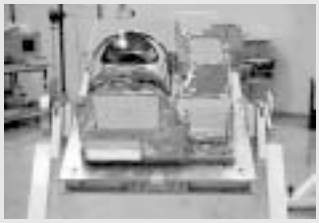
AIRS

AMSU-A1

AMSU-A2



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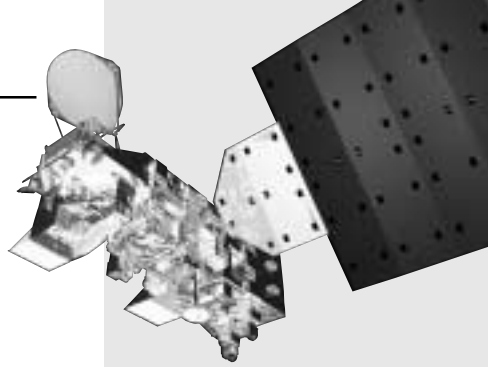

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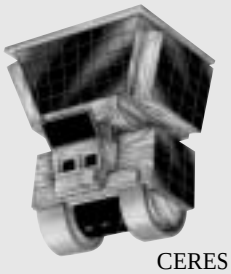

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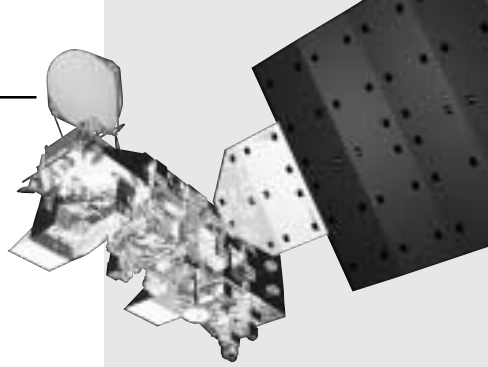

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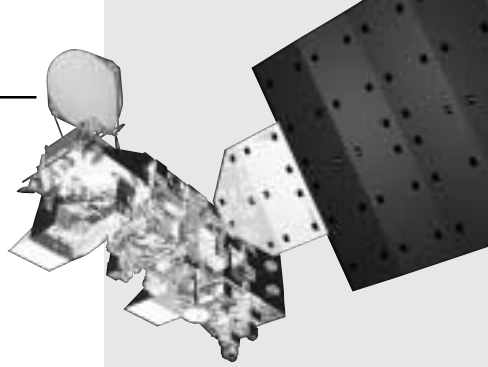

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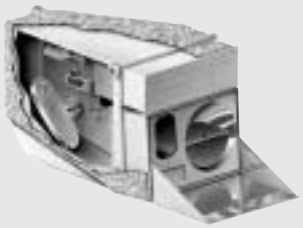

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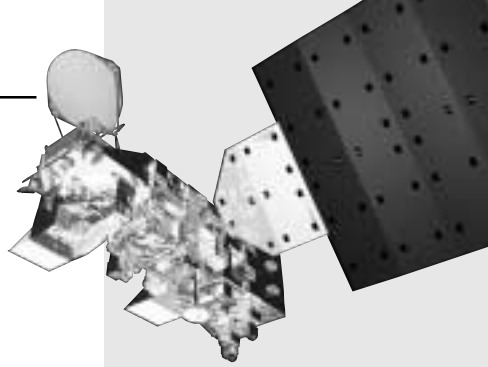

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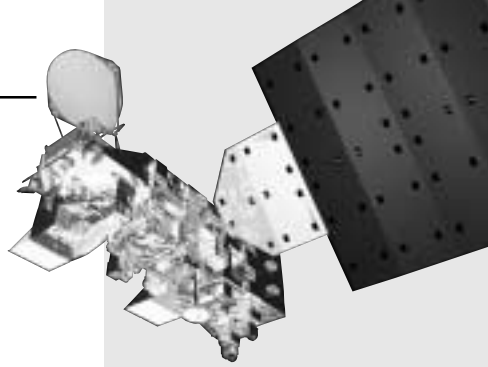

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AQUA Related Publications

* AIRS/AMSU/HSB Brochure, publication #NP-2001-5-248-GSFC
* AMSR-E Brochure, publication #NP-2000-10-126-GSFC
* Aqua Brochure, publication #NP-2002-1-422-GSFC
* Aqua Lithograph, publication #LG-2001-6-031-GSFC
* CERES Brochure, publication #CP2001-05-267-GSFC
* MODIS Brochure, publication #NP-2002-1-423-GSFC

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Aqua Web Sites

http://aqua.nasa.gov/ or
http://aqua.gsfc.nasa.gov/

The Aqua mission is part of the NASA-centered international Earth Observing System (EOS). Aqua was formerly named EOS PM, signifying its afternoon equatorial crossing time.

Aqua Instrument Team Sites

AIRS (Atmospheric Infrared Sounder)
http://www-airs.jpl.nasa.gov/

AMSR-E (Advanced Microwave Scanning Radiometer - EOS)
http://wwwghcc.msfc.nasa.gov/
http://www.eoc.nasda.go.jp/guide/satellite/sendata/amsr-e_e.html

AMSU (Advanced Microwave Sounding Unit)
http://www.aerojet.com/program/display.pl?program_ID=6

CERES (Clouds and the Earth's Radiant Energy System)
http://asd-www.larc.nasa.gov/ceres/ASDceres.html

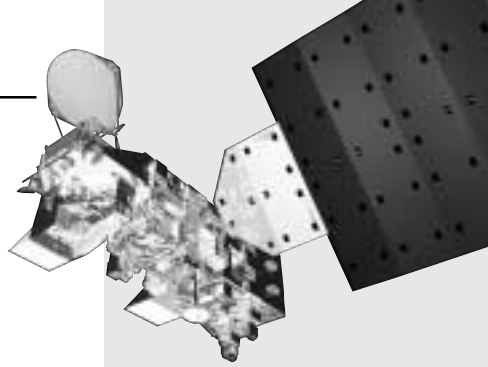
HSB (Humidity Sounder for Brazil)
Instituto Nacional de Pesquisas Espaciais
http://www.inpe.br/programas/hsb/default.htm

MODIS (Moderate-Resolution Imaging Spectrometer)
http://modis.gsfc.nasa.gov/

Aqua Science
http://aqua.nasa.gov

The Aqua Science web site summarizes the Aqua mission, contains electronic versions of many publications regarding Aqua, and archives videotaped segments of Aqua scientists as well as all the Aqua webcasts. It is also the site for live viewing of the webcasts.

Destination Earth
http://www.earth.nasa.gov/



The web site of NASA's Earth Science Enterprise in Washington, D.C., contains information about the Agency's entire Earth science program. The Science of the Earth System section of the site describes the Agency's major research themes: atmospheric chemistry, hydrological and energy cycle, land cover and land use, ozone, natural hazards and the solid Earth, and climate variability and change. The Missions section provides links to all major spacecraft missions and instruments as well as the Earth Probes program, the New Millennium missions, and commercial remote sensing.

Earth Observatory
http://www.earthobservatory.nasa.gov

The Earth Observatory presents articles, images, and animations that illustrate the complexities of Earth system science as well as NASA's use of satellite-based and other remote-sensing data to study change on global and regional scales. Updated daily, the Earth Observatory is an information resource for educators, interested lay persons, and media writers.

EOS Project Science Office
http://eospso.gsfc.nasa.gov/

The EOS Project Science Office (EOSPSO) web site presents program information and resources for the entire EOS program. It is appropriate for EOS program scientists and the general public alike.

Visible Earth
http://visibleearth.nasa.gov/

Visible Earth is a searchable directory of images, visualizations, and animations of the Earth. It features an extensive library of print and broadcast quality images in agriculture, atmosphere, biosphere, cryosphere, human dimensions, hydrosphere, land surface oceans, radiance or imagery, solid earth, and various locations.

Aqua Quick Reference Guide

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* AMSR-E Brochure, publication #NP-2000-10-126-GSFC
* Aqua Brochure, publication #NP-2002-1-422-GSFC
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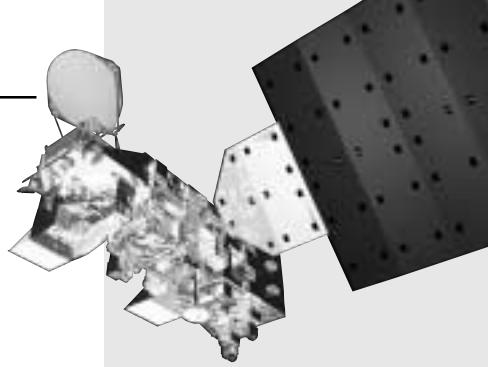

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Aqua Web Sites for More Information

http://aqua.nasa.gov/ or http://aqua.gsfc.nasa.gov/

Aqua is a NASA Earth Science satellite mission named for the large amount of information that the mission will be collecting about the Earth's water cycle.

Aqua instrument Web Sites

AIRS (Atmospheric Infrared Sounder)
http://www-airs.jpl.nasa.gov/

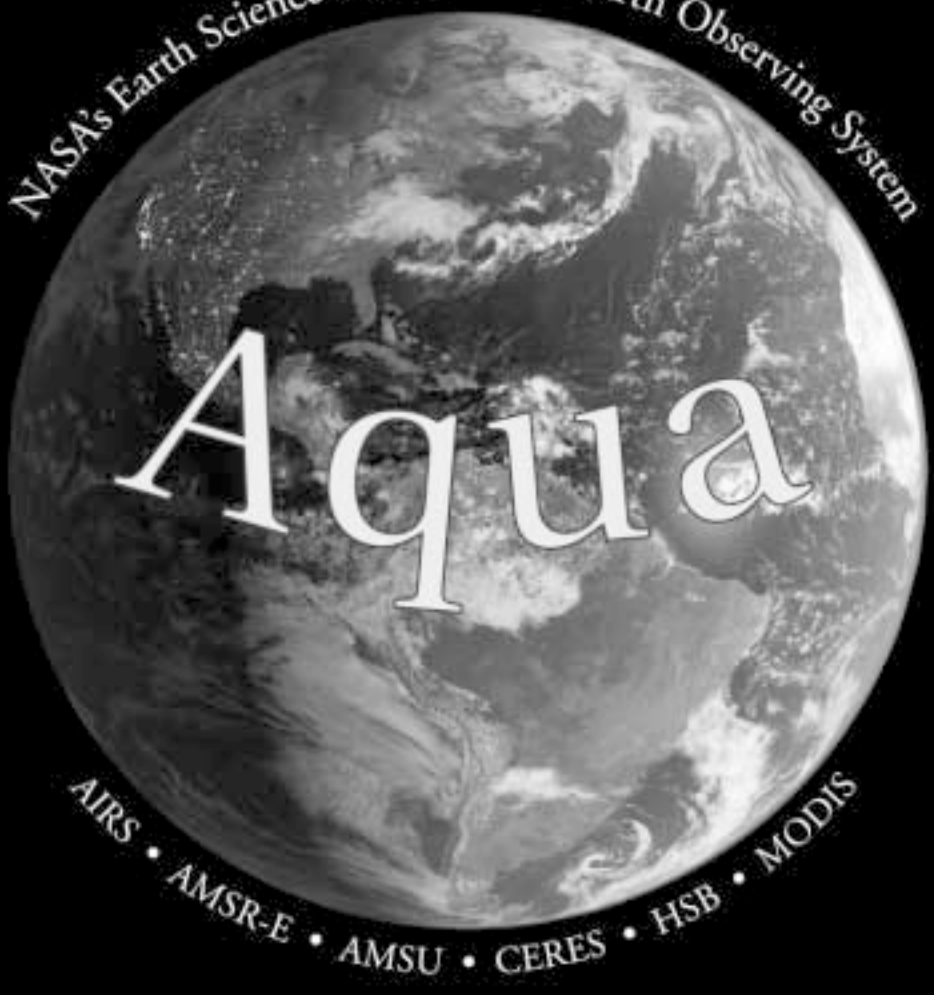
AMSR-E (Advanced Microwave Scanning Radiometer - EOS)
http://wwwghcc.msfc.nasa.gov/AMSR/
http://www.eoc.nasda.go.jp/guide/satellite/sendata/amsr-e_e.html

AMSU (Advanced Microwave Sounding Unit)
http://www.aerojet.com/program/display.pl?program_ID=6

CERES (Clouds and the Earth's Radiant Energy System)
http://asd-www.larc.nasa.gov/ceres/ASDceres.html

HSB (Humidity Sounder for Brazil)
Instituto Nacional de Pesquisas Espaciais
http://www.inpe.br/programas/hsb/default.htm

MODIS (Moderate-Resolution Imaging Spectroradiometer)
http://modis.gsfc.nasa.gov/



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