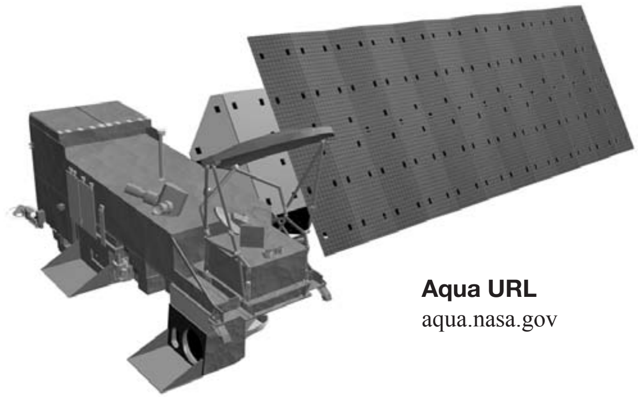
Aqua



Aqua URL
aqua.nasa.gov

Key Aqua Facts

Joint with Brazil and Japan

Orbit:
- Type: Near polar, sun-synchronous
- Altitude: 705 km
- Equatorial Crossings: 1:30 p.m. (south to north) and 1:30 a.m. (north to south)
- Inclination: 98.2°
- Period: 98.8 minutes
- Repeat Cycle: 16 days (233 revolutions)

Dimensions: 2.7 m × 2.5 m × 6.5 m stowed; 4.8 m × 16.7 m × 8.0 m deployed

Mass: 2,934 kg (1,750 kg spacecraft, 1,082 kg instruments, 102 kg propellants)

Power: 4,600 W silicon cell array and a NiH_2 battery

Design Life: 6 years

Average Data Rate: 89 Gbytes/day

Data Storage: 136-Gbit solid state recorder (SSR) for storage of up to two orbits of data

Data Relay Methods: Direct downlink from the SSR to polar ground stations; direct broadcast

Data Links: X-band

Telemetry: S-band

Summary

Aqua is a major international Earth Science satellite mission centered at NASA. Launched on May 4, 2002, the satellite has six different Earth-observing instruments on board and is named for the large amount of information being obtained about water in the Earth system from its stream of approximately 89 Gigabytes of data a day. The water variables being measured include almost all elements of the water cycle and involve water in its liquid, solid, and vapor forms. Additional variables being measured include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures.

Instruments

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

Points of Contact

- *Aqua Project Scientist:* Claire Parkinson, NASA Goddard Space Flight Center
- *Aqua Deputy Project Scientist:* Steven Platnick, NASA Goddard Space Flight Center

Other Key Personnel

- *Aqua Program Scientist:* Ramesh Kakar, NASA Headquarters
- *Aqua Program Executive:* Lou Schuster, NASA Headquarters
- *Aqua Mission Director:* William Guit, NASA Goddard Space Flight Center

Mission Type

Earth Observing System (EOS) Systematic Measurements

Launch

- *Date and Location:* May 4, 2002, from Vandenberg Air Force Base, California
- *Vehicle:* Delta II 7920-10L rocket, with a 10-ft diameter stretched fairing

Relevant Science Focus Areas
(see NASA's Earth Science Program section)

- Atmospheric Composition
- Carbon Cycle, Ecosystems and Biogeochemistry
- Climate Variability and Change
- Water and Energy Cycles
- Weather

Related Applications
(see Applied Sciences Program section)

- Agricultural Efficiency
- Air Quality
- Carbon Management
- Coastal Management
- Disaster Management
- Ecological Forecasting
- Homeland Security
- Water Management

Aqua Science Goals

- Enhanced understanding of water in the Earth's climate system and the global water cycle.
- Enhanced understanding of additional components of the Earth's climate system and their interactions.
- Improved weather forecasting.

Aqua Mission Background

The Aqua spacecraft takes its name from 'Aqua,' Latin for 'water,' in recognition of the large amount of data the Aqua instruments are collecting about the Earth's water and its water cycle. This includes data about ocean surface water, evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include radiative energy fluxes, atmospheric aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures.

Through its wide-ranging global measurements, the Aqua mission is assisting scientists in better quantifying the state of the highly interconnected Earth system and in addressing such key topics as whether the water cycle is accelerating, whether the Earth system is in radiative balance, and what the full role of clouds is in the climate system. Many of the topics of interest to Aqua scientists and others concern regional and global changes, with the most frequently highlighted one being global warming but others including Arctic sea ice decay, stratospheric ozone reductions, atmospheric carbon dioxide increases, tropical and mid-latitude deforestation, and degradation of water quality. All of these topics are being examined by Aqua scientists, but most of these variables have interannual variability that can overwhelm long-term trends. Hence an important aspect of maximizing the use of the Aqua data is linking it to earlier satellite data sets, even though some of those

Aqua Instruments

AIRS
Atmospheric Infrared Sounder

A high spectral resolution grating spectrometer containing 2378 infrared channels for obtaining atmospheric temperature profiles and a variety of additional Earth/atmosphere products. AIRS also has 4 visible/near-infrared channels, for characterizing cloud and surface properties and obtaining higher spatial resolution than the infrared measurements.

AMSR-E (Japan)
Advanced Microwave Scanning Radiometer for the Earth Observing System

A 12-channel microwave radiometer designed to monitor a broad range of hydrologic variables, including precipitation, cloud water, water vapor, sea surface winds, sea surface temperature, sea ice, snow, and soil moisture.

AMSU-A
Advanced Microwave Sounding Unit-A

A 15-channel microwave sounder designed to obtain temperature profiles in the upper atmosphere and to provide a cloud-filtering capability for the AIRS infrared measurements, for increased accuracy in tropospheric temperature profiles.

CERES
Clouds and the Earth's Radiant Energy System

A 3-channel, broadband radiometer (0.3 to > 100 μm, 0.3–5 μm, 8–12 μm) designed to measure major elements of the Earth's radiation budget.

HSB (Brazil)
Humidity Sounder for Brazil

A 4-channel microwave sounder designed to obtain humidity profiles under cloudy conditions and detect heavy precipitation.

MODIS
Moderate Resolution Imaging Spectroradiometer

A 36-band spectroradiometer measuring visible and infrared radiation, for derivation of products ranging from land vegetation and ocean chlorophyll fluorescence to cloud and aerosol properties, fire occurrence, snow cover on land, and sea ice in the oceans.

data sets might be of lesser quality. For instance, the Aqua radiation-budget data are being linked with earlier satellite Earth radiation-budget data going back to the early 1980s, the Aqua vegetation data are being linked with earlier satellite vegetation indices also going back to the early 1980s, and the Aqua sea ice data are being linked with satellite sea ice records going back to the 1970s.

To make its measurements, the Aqua spacecraft carries six Earth observing instruments: the AIRS, AMSU-A, HSB, AMSR-E, CERES, and MODIS, all described in more detail on the following pages. The AIRS, AMSU-A, and HSB are sounders, obtaining information at many levels in the atmosphere, while the AMSR-E, CERES, and MODIS are imagers. The AIRS, CERES, and MODIS measure in visible and infrared wavelengths, while the AMSR-E, AMSU-A, and HSB measure in microwave wavelengths. The combination greatly enhances the range of applications of the data, with, for instance, the microwave data enabling surface observations under all lighting conditions and most weather conditions and the visible data enabling detailed cloud studies as well as greater spatial detail in the surface and atmospheric measurements.

Prior to launch, five Aqua science teams developed algorithms to convert the radiative data from each of the six instruments into meaningful geophysical parameters. After launch, each of these teams has been enhanced with new members and has analyzed the Aqua data, refined the algorithms, and carried out validation activities. The five teams are:

- The AIRS/AMSU-A/HSB Science Team (generally abbreviated as the AIRS Science Team), covering the full Aqua sounding suite. This team is centered at NASA's Jet Propulsion Laboratory and is led by Moustafa Chahine.
- The Japanese AMSR-E Science Team, centered in Japan and led by Akira Shibata.
- The U.S. AMSR-E Science Team, centered at NASA Marshall Space Flight Center and the University of Alabama and led by Roy Spencer.
- The CERES Science Team, centered at NASA Langley Research Center and led by Bruce Wielicki.
- The MODIS Science Team, centered at NASA Goddard Space Flight Center and led by Vince Salomonson.

Aqua data are transmitted from the spacecraft through two processes: direct downlink and direct broadcast. The direct downlink transmits the data from an on-board solid state recorder (SSR) to polar ground stations in Alaska and Svalbard, Norway. Direct downlink is routinely done each orbit, although the SSR has the capacity to hold up to two orbits of data. When direct downlink is not taking place, the direct broadcast system is generally in operation, allowing anyone with a direct broadcast receiver to receive the raw Aqua data.

From the polar ground stations, the downlinked data are transmitted to Goddard Space Flight Center, where the data processing is done for the MODIS, AIRS, AMSU-A, and HSB data. The CERES data are sent to Langley Research Center for processing, and the AMSR-E data are sent to Japan's Earth Observation Center (EOC) for initial processing, followed by further processing at Remote Sensing Systems and at Marshall Space Flight Center. After processing, the Aqua data and the derived products are made available through several NASA Distributed Active Archive Centers (DAACs). In particular: the AMSR-E data and the MODIS snow and ice products are available from the National Snow and Ice Data Center (NSIDC) DAAC; the AIRS/AMSU-A/HSB data and the MODIS ocean and atmosphere products are available from the NASA Goddard Space Flight Center DAAC; the CERES data are available from the NASA Langley Research Center DAAC; and the MODIS land products are available from the Earth Resources Observation System (EROS) Data Center DAAC.

The Aqua data are proving useful in several direct applications as well as for scientific advances. Most notably, the MODIS data on forest fires have been valuable in fire fighting efforts, the MODIS data on dust have been valuable in observing and tracking dust storms in Iraq and its vicinity, and AIRS/AMSU-A, MODIS, CERES, and AMSR-E data are all proving potentially useful in weather forecasting.

Aqua Partners

Aqua is a joint project involving many countries, with the primary ones being the United States, Japan, and Brazil. The spacecraft and the AIRS, AMSU-A, CERES, and MODIS instruments were all provided by the U.S., as was the launch vehicle, while the AMSR-E instrument was provided by Japan, and the HSB instrument was provided by Brazil. More specifically, NASA Goddard Space Flight Center provided the MODIS and AMSU-A instruments; NASA's Jet Propulsion Laboratory provided the AIRS instrument; NASA Langley Research Center provided the two CERES instruments; the National Space Development Agency of Japan (NASDA) provided the AMSR-E instrument; and Brazil's Instituto Nacional de Pesquisas Espaciais (INPE, the Brazilian Institute for Space Research) provided the HSB instrument. Subsequent to the delivery of the AMSR-E, NASDA was merged into the new Japan Aerospace Exploration Agency (JAXA) on October 1, 2003.

TRW (now Northrop Grumman) constructed and tested both the spacecraft and the two CERES instruments. AIRS was built by BAE Systems, AMSR-E by Mitsubishi Electronics, AMSU-A by Aerojet, HSB by Matra-Marconi, and MODIS by Raytheon Santa Barbara Remote Sensing. TRW contracted out the construction of Aqua's solar array, which was built in the Netherlands by Fokker. Boeing built the Delta launch vehicle, while NASA Kennedy Space Center was responsible for the launch operations and the U.S. Air Force was responsible for all range-related matters at the Vandenberg launch site.

Overall management of the Aqua mission is centered at NASA Goddard Space Flight Center. This included management of the integration and testing of the spacecraft prior to launch and continues to include operation of the spacecraft and initial receipt, processing, and dissemination of the data. Further processing of the data takes place within the individual science teams and at the following NASA DAACs: NSIDC in Boulder, Colorado; the NASA Goddard Space Flight Center DAAC in Greenbelt, Maryland; the NASA Langley Research Center DAAC in Hampton, Virginia; and the EROS Data Center DAAC in Sioux Falls, South Dakota.

Many additional countries, universities, and agencies are also involved in the Aqua mission through science team membership and validation activities. The Aqua science teams include scientists from Japan, Brazil, Australia, Belgium, Canada, France, Italy, Nigeria, Saudi Arabia, South Africa, and the United Kingdom, as well as from the U.S. Validation activities are taking place at ocean and land sites around the globe.

AIRS/AMSU-A/HSB

- **Atmospheric Infrared Sounder (AIRS)**
- **Advanced Microwave Sounding Unit (AMSU-A)**
- **Humidity Sounder for Brazil (HSB)**

Summary

AIRS, the Atmospheric Infrared Sounder, and two operational microwave sounders, AMSU-A and HSB, form the AIRS (or AIRS/AMSU-A/HSB) sounding system. AIRS, AMSU-A, and HSB measurements are analyzed jointly to filter out the effects of clouds from the infrared data, in order to derive clear-column air temperature profiles with high vertical resolution and accuracy, as well as high accuracy surface temperatures. Together, these instruments constitute an advanced sounding system, surpassing the Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS)/Advanced TOVS (ATOVS) systems that currently operate on NOAA satellites, and serve as a pathfinder to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Cross-track Infrared Sounder (CrIS).

The data retrieved from the AIRS/AMSU-A/HSB instrument suite improve global circulation modeling efforts, numerical weather prediction, the study of the global energy and water cycles, detection of the effects of greenhouse gases, investigation of atmosphere-surface interactions, and monitoring of climate variations and trends. These objectives are met through improvements in the accuracy, stability, and yield of several weather and climate parameters, including atmospheric temperature and water vapor, land and ocean surface temperature, cloud properties, and outgoing longwave radiation. The AIRS/AMSU-A/HSB data are being used by scientists around the world to better understand weather and climate and by the U.S. National Weather Service and other forecasting agencies from around the world to improve weather prediction.

AIRS Data Products

AIRS, AMSU-A, and HSB together constitute a single facility instrument program, so data products labeled as "AIRS Products" are often the result of calculations involving AMSU-A and/or HSB data as well as AIRS data. The HSB ceased operating in February 2003. The data products provided from the AIRS, AMSU-A, and HSB measurements are:

Level 1B Products

Level 1B products include the calibrated and geolocated radiances from the AIRS, AMSU-A, and HSB. The AIRS Level 1B products are presented in separate files for the infrared AIRS data and the visible/near-infrared AIRS data.

Level 2 Products

The Level 2 standard core products for AIRS, AMSU-A, and HSB include cloud-cleared infrared radiances, sea and land surface temperatures, temperature and humidity profiles, total precipitable water, fractional cloud cover, cloud top height, and cloud top temperature. All Level 2 products are contained in three files: the Level 2 Standard Retrieval Product, Level 2 Cloud-Cleared Radiance, and Level 2 Support Product. The Level 2 Support Product includes research products under development for which the feasibility, achievable accuracy, precision, and spatial and temporal coverage are not fully established. Research products include total-column carbon dioxide, total-column carbon monoxide, methane distribution, ozone vertical distribution, other trace gases (SO_2, etc.), surface air temperature, spectrally resolved outgoing radiation, a precipitation index, and cirrus cloud detection and characterization. A validation report accompanies each released version of the AIRS products, describing the extent and the level to which the products have been characterized.

Root-Mean-Square Uncertainties in AIRS, AMSU-A, and HSB Radiance and Standard Products

Radiance Products (Level 1B)	**RMS Uncertainty***
AIRS Infrared Radiance	0.1–0.5 K
AIRS Visible/Near-Infrared Radiance	20%
AMSU-A Radiance	0.25–1.2 K
HSB Radiance	1.0–1.2 K
Standard Core Products (Level 2)	**RMS Uncertainty***
Cloud-Cleared IR Radiance	1.0 K
Sea Surface Temperature	0.5 K
Land Surface Temperature	1.0 K
Temperature Profile (vertical resolution: 1 km below 700 Mb, 2 km 700–30 Mb)	1 K
Humidity Profile (vertical resolution: 2 km in troposphere)	15%
Total Precipitable Water	5%
Fractional Cloud Cover	5%
Cloud Top Height	0.5 km
Cloud Top Temperature	1.0 K

* Radiance error defined as the temperature error of a Planck blackbody at 250 K. The nominal horizontal resolution of the AIRS infrared and HSB radiance products is 15 km × 15 km, AIRS visible/near-infrared products 2.5 km × 2.5 km, and the remaining products 45 km × 45 km.

Level 3 Products

AIRS Level 3 products are composed of Level 2 geophysical data that have been spatially and/or temporally re-sampled to a uniform spatial grid. Level 3 data sets are substantially smaller than the lower level source products from which they are derived due to resampling and selecting a reduced set of reporting parameters. Level 3 products provide a global view of AIRS data in a record size that

Key AIRS Facts

Launch: May 4, 2002 on Aqua

Heritage: Advanced Moisture and Temperature Sounder (AMTS), High Resolution Infrared Radiation Sounder (HIRS)

Instrument Type: Temperature controlled (155 K) array grating spectrometer, plus a visible/near-infrared photometer

Aperture: 10 cm

Channels:
Infrared: 2378
Visible/near-infrared: 4

Spectral Range:
Infrared: 3.74–15.4 μm (3.74–4.61, 6.2–8.22, 8.8–15.4 μm);
Visible/near-infrared: 0.4–1.0 μm (0.4–0.44, 0.58–0.68, 0.71–0.92, 0.49–0.94 μm)

Spectral Resolution: $\lambda/\Delta\lambda$ 1200 nominal

Swath Width: 1650 km

Coverage: Global coverage every 1 to 2 days

Spatial Resolution:
Infared: 13.5 km at nadir
Visible/near-infrared: 2.3 km at nadir

Dimensions: 116.5 cm × 80 cm × 95.3 cm

Mass: 177 kg

Thermal Control:
Infrared detectors: 58 K by active cooling (pulse tube cryocoolers)

Spectrometer: 156 K by two-stage passive radiator, heater

Electronics: ~290 K by spacecraft heat rejection system

Blackbody: 308 K by heater

Power: 180/220 W (beginning/end of life)

Duty Cycle: 100%

Data Rate: 1.27 Mbps

Field of View (FOV): ± 49.5° cross-track from nadir

Instrument IFOV (track/scan):
Infrared: 1.1° × 0.6° (13.5 km × 7.4 km at nadir);
Visible/near-infrared: 0.149° × 0.190° (1.8 km × 2.3 km at nadir)

Calibration: Internal blackbody, space, parylene (spectral) views; 3 visible/near-infrared lamps

Pointing Accuracy: Infrared: 0.1° (2σ)

is manageable for long term or large scale studies. The uniform spatial gridding of the Level 3 products allows comparisons of data sets from different sources. AIRS Level 3 product development is driven by the need for global analysis of AIRS data for weather and climate studies and for an easy-to-use, quantitative gridded data set for interdisciplinary studies. A partial list of Level 3 products includes temperature and water vapor profiles, surface skin temperature, surface air temperature, column ozone, and column liquid water.

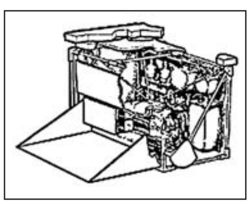
Product Validation

The Level 2 retrieval initially delivered to the GSFC DAAC (version 3.0.8.0 in August 2003) met AIRS Project requirements for nighttime, ocean fields of view within the latitude band 40°S – 40°N. Subsequent deliveries (approximately annually) include the activation and/or improvement of the validation status of subsets of the products, plus validation over a greater geographical and temporal extent. Phased activations are planned to expand the latitude range to include all non-polar nighttime ocean regions, non-polar daytime ocean retrievals, non-polar nighttime land retrievals, followed by non-polar daytime land retrievals. The final step will be to activate the polar retrievals.

AIRS

Atmospheric Infrared Sounder (AIRS)

Simultaneously measures the Earth's outgoing radiation in 2378 infrared channels from 3.7 to 15.4 μm and four visible/near-infrared channels from 0.4 to 1 μm. Used to obtain high resolution temperature and humidity profiles within the atmosphere, plus a variety of additional Earth/atmosphere products.



AIRS is designed to meet the NOAA requirement of a high-resolution infrared (IR) sounder to fly on future operational weather satellites.

The core of the AIRS instrument is a high-resolution infrared sounder, measuring simultaneously in 2378 spectral channels in the 3.74–15.4 μm spectral range. The spectral resolution ($\lambda/\Delta\lambda$) is nominally 1200. The high spectral resolution enables the separation of the contribution of unwanted spectral emissions and, in particular, provides radiometrically clear "super windows," ideal for surface observations. AIRS also provides four visible/near-infrared channels (0.4–1.0 μm) to characterize cloud and surface properties. The data from all channels are downlinked on a routine operational basis.

Temperature profiles from AIRS are derived even in the presence of multiple cloud layers, without requiring any field-of-view to be completely clear. Humidity profiles are derived from channels in the 6.3 μm water vapor band and the 11 μm windows, which are sensitive to the water vapor continuum. Determination of the surface temperature and surface spectral emissivity is essential for obtaining low-level water vapor distributions.

Key AIRS Facts *(cont.)*

Scan Period: 2.667 s

Scan Sampling (scan/track): Infrared: 90 × 1 (1.1° spacing), in 2 s; visible/near-infrared: 720 × 9 (0.138° × 0.185° spacing), in 2 s

Sensitivity (NEΔT): 0.09–0.45 K, depending on spectral region

Design Life: 5 years

Direct Broadcast: Yes

Prime Contractor: BAE SYSTEMS (formerly Lockheed-Martin)

Responsible Center: NASA Jet Propulsion Laboratory

Land skin surface temperature and the corresponding infrared emissivity are determined simultaneously with the retrieval of the atmospheric temperature and water profiles. Shortwave window channels are used to derive the surface temperature and corresponding spectral emissivity and to account for reflected solar radiation. Once the surface temperature is determined, the longwave surface emissivity for the 11 µm region is determined and then is used to retrieve the water vapor distribution near the surface.

Cloud-top heights and effective cloud amount are determined based on the calculated atmospheric temperature, humidity, and surface temperature, combined with the calculated clear-column radiance and measured radiance. The spectral dependence of the opacity of the clouds will distinguish various cloud types (including cirrus clouds). Ozone retrieval is performed simultaneously with the retrievals of the other parameters, using the 9.6 µm ozone band.

AIRS visible and near-IR channels between 0.4 and 1.0 µm are used primarily to discriminate between low-level clouds and different terrain and surface covers, including snow and ice. In addition, the visible channels allow the determination of cloud, land, and ocean surface parameters simultaneously with atmospheric corrections. One broadband channel from 0.4 to 1.0 µm is used for the estimation of reflected shortwave radiation, i.e., albedo. The other three channels are used for surface properties such as ice and snow amount and vegetation index.

AIRS URL

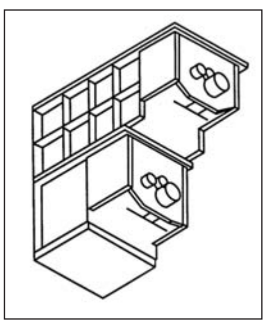
airs.jpl.nasa.gov/

AMSU-A1 and AMSU-A2

Advanced Microwave Sounding Unit (AMSU-A)

Provides atmospheric temperature measurements from the surface up to 40 km. Onboard NOAA 15/16/17/18 as well as Aqua.

AMSU-A is a 15-channel microwave sounder that obtains temperature profiles in the upper atmosphere and provides a cloud-filtering capability for the AIRS infrared channels for increased accuracy of tropospheric temperature observations. The fifteen AMSU-A channels have a 3.3° beam width, resulting in a nominal horizontal spatial resolution of 40.5 km at nadir.



Channels 3 to 14 on AMSU-A are situated on the low-frequency side of the oxygen resonance band (50–60 GHz) and are used for temperature sounding. Successive channels in this band are situated at frequencies with increasing opacity and therefore respond to radiation from increasing altitudes. Channel 1, located on the first (weak) water vapor resonance line, is used to obtain estimates of total column water vapor in the atmosphere. Channel 2 (at 31 GHz) is used to indicate the presence of rain. Channel 15 on AMSU-A,

Key AMSU-A Facts

Launches: May 13, 1998 on NOAA 15; September 21, 2000 on NOAA 16; May 4, 2002 on Aqua; May 21, 2002 on NOAA 17; May 20, 2005 on NOAA 18

Heritage: Microwave Sounding Unit (MSU)

Instrument Type: Microwave radiometer

Aperture: 13.2 cm on AMSU-A1 (two apertures); 27.4 cm on AMSU-A2 (one aperture)

Channels: 15 (13 for AMSU-A1, 2 for AMSU-A2)

Spectral Range: 23–90 GHz (50–90 GHz for AMSU-A1, 23–32 GHz for AMSU-A2)

Swath Width: 1690 km

Coverage: Global coverage every 1–2 days

Spatial Resolution: 40.5 km at nadir

Dimensions: 72 cm × 34 cm × 59 cm for AMSU-A1; 73 cm × 61 cm × 86 cm for AMSU-A2

Mass: 91 kg (49 kg for AMSU-A1, 42 kg for AMSU-A2)

Thermal Control: None (ambient)

Power: 101 W (77 W for AMSU-A1, 24 W for AMSU-A2)

Duty Cycle: 100%

Data Rate: 2.0 kbps (1.5 kbps for AMSU-A1, 0.5 kbps for AMSU-A2)

FOV: ± 49.5° cross-track from nadir

Instrument IFOV: 3.3° (40.5 km at nadir) for both units

Calibration: Internal blackbody, space view

Pointing Accuracy: 0.2°

Scan Period: 8 s

Scan Sampling: 30 × 3.3°, in 6 s

Sensitivity: 0.14–0.81 K, depending on spectral region

Design Life: 3 years

Direct Broadcast: Yes

Prime Contractor: Northrop Grumman (formerly Aerojet)

Responsible Center: NASA Goddard Space Flight Center at 89 GHz, is used as an indicator for precipitation, using the fact that at 89 GHz ice more strongly scatters radiation than it absorbs or emits radiation.

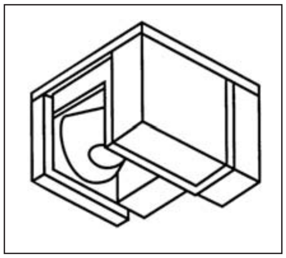
AMSU-A URL

airs.jpl.nasa.gov/

HSB

Humidity Sounder for Brazil

Provided atmospheric water vapor profile measurements until February 2003. (HSB has been non-operational since February 2003 due to an apparent electrical component failure in the scan drive system. Periodic attempts have been made to restart it.)



HSB is a 4-channel microwave sounder designed to obtain atmospheric humidity profiles under cloudy conditions and to detect heavy precipitation under clouds. The four HSB channels have a 1.1° beam width, resulting in a nominal horizontal spatial resolution of 13.5 km.

Three of the HSB channels make measurements on the wings of the strongly opaque water vapor resonance line at 183.3 GHz; the fourth makes measurements at 150 GHz. Successive channels have decreasing opacity and consequently their data correspond to humidities at decreasing altitudes. The four HSB channels improve the humidity profiles from AIRS/AMSU-A in the presence of liquid water.

AIRS/AMSU/HSB Science Team Leader

Moustafa Chahine, NASA Jet Propulsion Laboratory/California Institute of Technology

Key HSB Facts

Launch: May 4, 2002 on Aqua

Heritage: AMSU-B

Instrument Type: Microwave radiometer

Aperture: 18.8 cm

Channels: 4

Spectral Range: 150–190 GHz

Swath Width: 1650 km

Coverage: Global every 1 to 2 days

Spatial Resolution: 13.5 km at nadir

Dimensions: 70 cm × 65 cm × 46 cm

Mass: 51 kg

Thermal Control: None (ambient)

Power: 56 W

Duty Cycle: 100%

Data Rate: 4.2 kbps

FOV: ± 49.5° cross-track from nadir

Instrument IFOV: 1.1° (13.5 km at nadir)

Calibration: Internal blackbody, space view

Pointing Accuracy: 0.1°

Scan Period: 2.667 s

Scan Sampling: 90 × 1.1°, in 1.71 s

Sensitivity: 0.3–0.68 K, depending on spectral region

Design Life: 3 years

Direct Broadcast: Yes, until February 2003

Prime Contractor: Astrium (formerly Matra Marconi Space, United Kingdom)

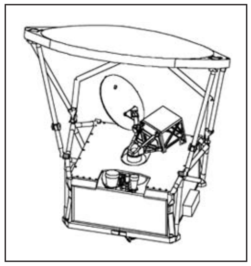
Provider: Instituto Nacional de Pesquisas Espaciais (INPE, the Brazilian Institute for Space Research)

AMSR-E

Advanced Microwave Scanning Radiometer-EOS

Provides daily, global all-weather measurements of geophysical parameters, supporting several global change science and monitoring efforts. (One day's data cover most of the globe; the full globe is covered within two days.)

Summary



AMSR-E monitors various atmospheric and surface water processes that influence weather and climate. It provides improved measurements of rain rates and greatly extends the spatial coverage of the Tropical Rainfall Measuring Mission (TRMM) satellite, while also measuring water vapor, sea surface winds, sea surface temperature, sea ice, soil moisture, snow cover, and the amount of water in clouds.

Background

The Aqua AMSR-E measures geophysical parameters supporting several global change science and monitoring efforts. Of particular importance to its success is an external calibration design, which has proved suitable in other satellite microwave instrumentation for long-term monitoring of subtle changes in temperature and other variables.

Precipitation and evaporation have extremely important roles in the Earth system, through provision of water to the biosphere via precipitation and as an air conditioning agent that removes excess heat from the surface (via evaporation), thereby contributing toward making Earth habitable. AMSR-E measurements are used to calculate rain rates over both land and ocean. Over the ocean, radiation at the AMSR-E microwave frequencies passes through smaller cloud particles, allowing measurement of the microwave emission from the larger raindrops. The AMSR-E provides sensitivity to oceanic rain rates as high as 50 mm/hr (about 2 inches per hour). Over land, AMSR-E measures the scattering effects of large ice particles, which later melt to form raindrops. These measurements, though less direct a measure of rainfall intensity, are converted to rain rates with the help of cloud models.

Over the ocean, in addition to rain rates, AMSR-E provides sea surface temperatures (SST) through most types of cloud cover, supplementing infrared-based measurements of SST that are restricted to cloud-free areas. SST fluctuations are known to have a profound impact on weather patterns across the globe, and AMSR-E's all-weather capability could provide a significant improvement in our ability to monitor SSTs and the processes controlling them.

The total integrated water vapor of the atmosphere is also 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.

Key AMSR-E Facts

Launch: May 4, 2002 on Aqua (a similar instrument, AMSR, was launched on December 14, 2002 on ADEOS II)

Heritage: SMMR (on Nimbus-7 and Seasat), SSM/I (on DMSP), AMSR (on ADEOS II)

Instrument type: Passive microwave radiometer, twelve channels, six frequencies, dual polarization (vertical and horizontal); offset parabolic reflector, 1.6 m in diameter and drum rotating at 40 rpm; six feedhorns to cover six bands from 6.9–89 GHz with 0.3–1.1 K radiometric sensitivity.

Channels: 12

Spectral Range: 0.34–4.35 cm

Frequency Range: 6.9–89.0 GHz

Swath Width: 1445 km

Coverage: Global coverage every 1 to 2 days

Spatial Resolution: 6 km × 4 km (89.0 GHz), 14 km × 8 km (36.5 GHz), 32 km × 18 km (23.8 GHz), 27 km × 16 km (18.7 GHz), 51 km × 29 km (10.65 GHz), 74 km × 43 km (6.925 GHz)

Dimensions:
Sensor Unit: 1.95 m × 1.7 m × 2.4 m (deployed)
Control Unit: 0.8 m × 1.0 m × 0.6 m

Mass: 314 kg

Thermal Control: Passive radiator, thermostatically controlled heaters

Thermal Operating Range: -5° – 40°C (receiver qualification temperature)

Power: 350 W

Duty Cycle: 100%

Data Rate: 87.4 kbps average, 125 kbps peak

View: Forward-looking conical scan

Incidence Angle: 55°

Instrument IFOV at Nadir: Ranges from 74 km × 43 km for 6.9 GHz to 6 km × 4 km for 89.0 GHz

Sampling Interval: 10 km for 6–36 GHz channel

Calibration: External cold load reflector and a warm load for calibration

Accuracy: 1 K or better

Design Life: 3 years

Direct Broadcast: Yes

Prime Contractor: Mitsubishi Electric Company (MELCO)

Responsible Agency: Originally the National Space Development Agency of Japan (NASDA); as of October 1, 2003, the Japan Aerospace Exploration Agency (JAXA)

Measurements by AMSR-E of ocean surface roughness can be converted into estimated near-surface wind speeds. These winds are an important determinant of how much water is evaporated from the surface of the ocean. The winds help to maintain the water vapor content of the atmosphere, while precipitation continually removes it.

AMSR-E cloud-water estimates over the ocean help determine whether clouds, with their ability to reflect sunlight, increase or decrease under various conditions. This could be an important feedback mechanism that either enhances or mitigates global warming, depending on whether clouds increase or decrease with warming.

Monitoring of sea ice parameters, such as ice concentration and extent, is necessary to understand how this frozen blanket over the ocean affects the larger climate system. In winter, sea ice insulates the water against heat loss to the frigid atmosphere above it, whereas in summer sea ice reflects sunlight that would otherwise warm the ocean. AMSR-E measurements allow the derivation of sea ice concentrations in both polar regions, through taking advantage of the marked contrast in microwave emissions of sea ice and liquid water.

In much the same way as AMSR-E can 'see' large ice particles in the upper reaches of rain systems, it also measures the scattering effects of snow cover. These measurements are empirically related to snow-cover depth and water content based upon field measurements. Like sea ice, snow cover has a large influence on how much sunlight is reflected from the Earth. It also acts as a blanket, keeping heat from escaping from the underlying soil and allowing deep cold air masses to develop during the winter. It further provides an important storage mechanism for water during the winter months, and this affects how much surface wetness is available for vegetation and crops in the spring. AMSR-E monitoring of snow cover allows studies on how snow-cover variations interplay with other climate fluctuations.

Wet soil can be identified in the AMSR-E observations if not too much vegetation is present. AMSR-E provides the most useful satellite data yet for determination of how well low-frequency (6.9 and 10.65 GHz) microwave observations can be used to monitor surface wetness. Surface wetness is important for maintaining crop and vegetation health, and its monitoring on a global basis would allow drought-prone areas to be checked for signs of ongoing drought.

AMSR-E URLs

sharaku.eorc.jaxa.jp/AMSR/index_e.htm

wwwghcc.msfc.nasa.gov/AMSR/

AMSR-E Science Teams

There are two science teams involved in the production of AMSR-E (and AMSR) products for the science community: a U.S. AMSR-E team organized by NASA, and a Japan AMSR/AMSR-E team organized by the Japan Aerospace Exploration Agency (JAXA). Members from each team constitute a Joint AMSR Team that works together to share findings and unify procedures for analysis of the data. Both teams are also involved in field campaigns to help validate the products. AMSR flew on ADEOS II, launched on December 14, 2002, and operated until October 2003.

U.S. AMSR-E Science Team Leader

Roy W. Spencer, University of Alabama in Huntsville

Japan AMSR-E Science Team Leader

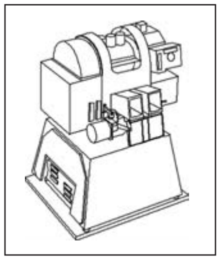
Akira Shibata, Earth Observation Research Center, JAXA

CERES

Clouds and the Earth's Radiant Energy System

Provides daily, global measurements in three broad radiation bands for details on the Earth's radiation budget.

Summary



CERES is a 3-channel radiometer aimed at collecting information about the Earth's radiative balance. Two CERES instruments are onboard Aqua and two are onboard Terra. For each satellite, one CERES instrument (while cross-track scanning) essentially continues the Earth Radiation Budget Experiment (ERBE) mission, while the second instrument (bi-axially scanning, in rotating azimuth plane scan mode) provides angular radiance information that will improve the accuracy of angular models used to derive the Earth's radiative balance. Each of the CERES instruments can operate in either of the two scanning modes.

Background

The CERES instruments provide accurate radiation flux measurements from the surface to the top of the atmosphere (TOA) that are fundamental inputs to models of oceanic and atmospheric energetics and that will also contribute to extended-range weather forecasting. These data have been requested for the Climate Change Science Program and for international efforts of the World Climate Research Program (WCRP), including the Tropical Ocean Global Atmosphere (TOGA) campaign, World Ocean Circulation Experiment (WOCE), Global Energy and Water Cycle Experiment (GEWEX), Global Climate Observing System (GCOS), and Indian Ocean Experiment (INDOEX). Understanding the role of clouds and radiation in the climate system is one of the highest priorities of the U.S. Global Change Research Program.

Clouds are regarded by many scientists as the largest source of uncertainty in understanding climate. Not only are clouds highly variable and difficult to measure, but they have competing heating and cooling effects on the Earth-atmosphere system. Clouds cool the Earth by reflecting part of the large flow of incoming radiative energy from the Sun but warm the Earth by enhancing the atmospheric greenhouse effect. CERES measures the radiative flows at the top of the atmosphere (TOA), and CERES scientists combine these data with data from higher resolution imagers (VIRS on TRMM, MODIS on Terra and Aqua) to calculate cloud properties and radiative fluxes through the atmosphere as well as the radiative energy budget at the Earth's surface. The imagers allow determination of cloud top height, fractional area, cloud liquid water path, droplet size, and other cloud properties that are consistent with the radiative fluxes. CERES is providing, for the first time, a critical tie between the measurements of the radiation budget and synchronous measurements of cloud properties. This capability is expected to be critical to uncovering cause and effect in cloud/climate feedback mechanisms.

Key CERES Facts

Launches: November 27, 1997 on the Tropical Rainfall Measuring Mission (TRMM; one CERES); December 18, 1999 on Terra (two CERES); and May 4, 2002 on Aqua (two CERES). A follow-on instrument will fly on NPOESS.

Heritage: ERBE

Instrument Type: Each CERES is a broadband, scanning radiometer capable of operating in either of two modes: cross-track or rotating plane (bi-axial scanning). On each of Aqua and Terra, typically one CERES operates in one mode and the second CERES operates in the other mode. The scan azimuth can be programmed for special science studies or validation operations.

Channels: 3 in each radiometer

Spectral Range: One channel each measuring total radiance (0.3 to >100 μm), shortwave radiance (0.3–5 μm), and the radiance in the atmospheric window at 8–12 μm

Swath Width: Limb to limb of the Earth view from each satellite

Coverage: Global coverage daily

Spatial Resolution: 10 km at nadir for TRMM, 20 km at nadir for Terra and Aqua

Dimensions: 60 cm × 60 cm × 57.6 cm/unit (stowed), 60 cm × 60 cm × 70 cm/unit (deployed)

Mass: 50 kg per scanner

Thermal Control: Heaters, radiators

Thermal Operating Range: 37–39°C (detectors)

Power: 47 W (average), 68 W (peak: biaxial mode) per scanner

Duty Cycle: 100%

Data Rate: 10 kbps per scanner

FOV: ±78° cross-track, 360° azimuth

Instrument IFOV: 14 mrad

Direct Broadcast: Yes (on Aqua)

Prime Contractor: NGST

Responsible Center: NASA Langley Research Center

The CERES instruments use a scanner very similar to the ERBE scanner to determine TOA fluxes. Key developments in meeting the CERES goal to double the accuracy of existing estimates of radiative fluxes include new models of the anisotropy of the Earth's reflected and emitted radiation (using the CERES bi-axial scanner) as well as improved time-sampling methods merging CERES data with high time resolution geostationary satellite data. CERES is also providing improved measurements of clear-sky radiative fluxes. Improvements in clear-sky fluxes require near-simultaneous measurements of both well-calibrated cloud-imager and broadband radiation measurements. Highly accurate clear-sky radiative fluxes are critical in assessing the land/ocean heat budget, as well as understanding the role of aerosols and clouds in the climate system.

Finally, the CERES Team produces Level 3 data products derived by time interpolation and integration of the Level 2 data into monthly averages. The time interpolation process is aided by data from geostationary imagers. Thus, CERES scientists are determining the structure of the atmospheric energy budget over the life of the CERES missions, with a time resolution of three hours in the synoptic data product. For long-term climate understanding, the CERES Team also produces data products that contain monthly averages of the cloud and radiation fields on a uniform spatial grid. During combined Terra, Aqua, and TRMM observations, the Level 3 CERES data products merge information from 11 instruments on 7 spacecraft.

CERES URLs

asd-www.larc.nasa.gov/ceres/ASDceres.html
(CERES Home Page, including CERES brochure, documentation, meetings, and links to activities)

eospso.gsfc.nasa.gov/eos_homepage/for_scientists/publications.php *(EOS Data Products Handbook, including CERES data product descriptions)*

asd-www.larc.nasa.gov/ATBD/ATBD.html
[CERES Algorithm Theoretical Basis Documents (ATBDs)]

asd-www.larc.nasa.gov/validation/valid_doc.html
(CERES Validation Plan)

CERES Principal Investigator

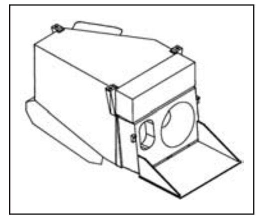
Bruce Wielicki, NASA Langley Research Center

MODIS

Moderate Resolution Imaging Spectroradiometer

Provides daily, global observations of biological and physical parameters on and near land and ocean surfaces and in the atmosphere. (One day's data cover most of the globe; the full globe is covered within two days.)

Summary



MODIS is a multi-disciplinary, keystone instrument on Aqua and Terra, providing a wide array of multispectral, daily observations of land, ocean, and atmosphere features at spatial resolutions between 250 m and 1000 m. Approximately 40 data products are produced from the MODIS data. Data are distributed not only through the EOS Data and Information Service (EOSDIS) Distributed Active Archive Centers (DAACs) at Goddard Space Flight Center, the EROS Data Center in Sioux Falls, South Dakota, and the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, but also via over 100 Direct Broadcast (DB) stations distributed world-wide.

Background

MODIS is an EOS facility instrument designed to measure biological and physical processes on a global basis every 1 to 2 days. Onboard both the Terra and Aqua satellites, the two multidisciplinary MODIS instruments are providing long-term observations from which an enhanced knowledge of global dynamics and processes occurring on the surface of the Earth and in the lower atmosphere can be derived. Each MODIS instrument is supplying simultaneous, congruent observations of high-priority atmospheric features (aerosol properties, cloud cover, cloud optical thickness, cloud phase, cloud top pressure, temperature and water vapor profiles), oceanic features (sea surface temperature, ocean color and related ocean surface water constituents such as chlorophyll concentration), and land-surface features (land-cover changes, atmospherically-corrected land surface reflectance, land-surface temperature, surface albedo, fire location and intensity, snow cover, and vegetation properties). These observations are expected to make major contributions to understanding the global Earth system, including interactions among land, ocean, and atmospheric processes.

The MODIS instrument employs a conventional imaging spectroradiometer concept, consisting of a cross-track scan mirror and collecting optics, and a set of linear arrays with spectral interference filters located in four focal planes. The optical arrangement provides imagery in 36 discrete bands between 0.4 and 14.5 μm selected for diagnostic significance in Earth science. The spectral bands have spatial resolutions of 250, 500, or 1,000 m at nadir. Signal-to-noise ratios are greater than 500 at 1-km resolution (at a solar zenith angle of 70°), and absolute irradiance accuracies are < ±5% from 0.4 to 3 μm (2% relative to the Sun) and 1% or better in the thermal infrared wavelengths (3.7–14.5 μm). MODIS provides daylight reflection and day/night emission spectral imaging of any point on the Earth at least every 2 days, operating continuously.

MODIS is included on both the Terra and Aqua satellites to increase cloud-free remote sensing of the Earth's surface and to exploit synergism with other EOS sensors.

MODIS URLs

modis.gsfc.nasa.gov/ *(general instrument status and related overall Science Team matters)*

modis-land.gsfc.nasa.gov *(MODIS land information)*

edcdaac.usgs.gov/dataproducts.asp *(MODIS land products)*

nsidc.org/daac/modis/index.html *(MODIS cryosphere products)*

modis-atmos.gsfc.nasa.gov *(MODIS atmosphere information)*

ladsweb.nascom.nasa.gov/MODIS/products.shtml *(MODIS Level 1 data, geolocation, cloud mask, and atmosphere products)*

oceancolor.gsfc.nasa.gov *(MODIS ocean color and sea surface temperature products)*

www.mcst.ssai.biz/mcstweb/index.html *(calibration and characterization details for the MODIS instrument and Level 1 product characteristics)*

modis.gsfc.nasa.gov/data/ and modis.gsfc.nasa.gov/data/dataprod/index.php *(MODIS data products, overview)*

MODIS Science Team Leader

Vincent V. Salomonson, University of Utah and NASA Goddard Space Flight Center, *emeritus*.

Key MODIS Facts

Launches: December 18, 1999 on Terra; May 4, 2002 on Aqua

Heritage: AVHRR, HIRS, Landsat TM, and Nimbus-7 CZCS

Instrument Type: Medium-resolution, multi-spectral, cross-track scanning radiometer; daylight reflection and day/night emission spectral imaging

Channels: 36 spectral bands

Spectral Range: 20 bands within 0.4–3.0 μm; 16 bands within 3–14.5 μm

Swath Width: 2,300 km at 110° (± 55°)

Coverage: Global coverage every 1 to 2 days

Spatial Resolution: 250 m, 500 m, 1 km

Dimensions: 1.04 m × 1.18 m × 1.63 m

Mass: 229 kg

Thermal Control: Passive radiators

Thermal Operating Range: 268 ± 5 K

Power: 162.5 W (average), 225 W (peak)

Duty Cycle: 100%

Data Rate: 6.2 Mbps (average), 10.5 Mbps (daytime), 3.2 Mbps (nighttime)

Instrument Nadir IFOV: 250 m (2 bands), 500 m (5 bands), 1,000 m (29 bands)

Polarization Sensitivity: 2% from 0.43 μm to 2.2 μm and ± 45° scan

Signal-to-Noise Ratios: From 500 to 1100 for 1-km ocean color bands at 70° solar zenith angle

NEΔt: Typically < 0.05 K at 300 K

Absolute Irradiance Accuracy: 5% for wavelengths < 3 μm and 1% for wavelengths > 3 μm

Direct Broadcast: Yes

Prime Contractor: Raytheon Santa Barbara Remote Sensing

Responsible Center: NASA Goddard Space Flight Center

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Aqua Data Products

Data from the six Aqua instruments are used to produce dozens of data products on different aspects of the Earth's water cycle. The pre-launch descriptions of these products are given in the *EOS Data Products Handbook*, Volume 2 (Parkinson and Greenstone, 2000), which can be found at: eos.nasa.gov/eos_homepage/for_scientists/data_products. The various data products are at different levels of maturity and validation, but the table here provides a brief overview. Additional information can be found in the individual instrument sections. Future updates regarding data products and data availability should be available through the URLs provided in the instrument sections.

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
AIRS/AMSU-A/HSB *Data Set Start Date: August 31, 2002; End Date for the HSB Data: February 5, 2003*			
Level 1B Calibrated, Geolocated Radiances	1B	Global	AIRS infrared (IR): 13.5 km resolution at nadir/twice daily (daytime and nighttime) AIRS visible/near-infrared (Vis): 2.3 km resolution at nadir/twice daily AMSU-A: 40.5 km resolution at nadir/twice daily HSB: 13.5 km resolution at nadir/twice daily
Cloud Cleared Radiances	2	Global	40.5 km resolution at nadir/twice daily
Flux Product (clear column radiance, outgoing longwave and shortwave radiation at the top of the atmosphere, net longwave and shortwave flux)	2	Global	40.5 km resolution at nadir/twice daily
Atmospheric Temperature Product (temperature profile)	2	Global	40.5 km at nadir; 28 vertical levels (1-km levels below 700 mb and 2-km levels between 700 and 30 mb)/twice daily (daytime and nighttime)
Humidity Product (water vapor profile in 2 km layers in the troposphere, total precipitable water, cloud liquid water content, precipitation flag, cloud-ice flag)	2	Global	40.5 km resolution at nadir/twice daily
Cloud Product (cloud top pressure and temperature, spectral properties, cloud fraction and variability index)	2	Global	40.5 km at nadir for cloud top pressure and temperature, spectral properties; 13.5 km at nadir for cloud fraction and variability index/once or twice daily (varies with parameter)
Ozone Product (ozone concentration profile and total)	2	Global	40.5 km resolution at nadir/twice daily (daytime and nighttime)
Trace Constituent Product (CO, CH_4, CO_2)	2	Global	40.5 km resolution at nadir/twice daily
Surface Analysis Product (sea and land surface skin temperature, infrared and microwave surface emissivity)	2	Global	40.5 km resolution at nadir/twice daily
Level 3 Products (temperature and water vapor profiles, surface skin temperature, surface air temperature, column ozone, and column liquid water)	3	Global	1° × 1° grid cells/1-day, 8-day, and monthly averages

Aqua Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
AMSR-E *Data Set Start Date: June 18, 2002*			
Columnar Cloud Water	2, 3	Global ocean surface, clear and cloudy skies and light rainfall	Level 2: swath pixels at 12 km resolution Level 3: 0.25° latitude-longitude grid/daily, weekly, and monthly
Columnar Water Vapor	2, 3	Global ocean surface, clear and cloudy skies and up-to-moderate rainfall rates	Level 2: swath pixels at 21-km resolution Level 3: 0.25° latitude-longitude grid/daily, weekly, and monthly
Level 2A Brightness Temperature	2A	Global	Swath pixels at resolutions from 5 to 56 km
Rainfall – Level 2	2	70° N – 70° S ice-free and snow-free land and ocean	Satellite orbit track, 5-km resolution
Rainfall – Level 3	3	70° N – 70° S	5° × 5°/monthly
Sea Ice Concentration	3	Global	12.5 and 25 km/ascending, descending, and daily averages
Sea Ice Temperature	3	Global	25 km/ascending, descending, and daily averages
Sea Surface Temperature	2, 3	Global ocean surface, clear and cloudy skies except in the presence of rainfall	Level 2: swath pixels at 38-km and 56-km resolution Level 3: 0.25° latitude-longitude grid/daily, weekly, and monthly
Sea Surface Wind Speed	2, 3	Ocean surface, clear and cloudy skies except in the presence of rainfall	Level 2: swath pixels at 24-km and 38-km resolution Level 3: 0.25° latitude-longitude grid/daily, weekly, and monthly
Snow Depth on Sea Ice	3	Southern Ocean and the Arctic seasonal sea ice zones	12.5 km/5-day average
Snow Water Equivalent and Snow Depth	3	Global land surface	EASE grid 25-km resolution/daily, 5-day, monthly
Surface Soil Moisture	2, 3	Global land surface, although only under snow-free and low-vegetation conditions	56-km spatial resolution on a nominal 25-km Earth-fixed grid; swath (Level 2) and daily (Level 3) ascending and descending

Note: The AMSR-E data products are being archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, where the corresponding products for the Japanese AMSR instrument on Midori II (formerly ADEOS II) will also be archived, for the seven months of Midori II operations, December 2002–October 2003.

Aqua Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
CERES *Data Set Start Date: June 18, 2002*			
Bi-Directional Scans Product	0, 1	Global	20 km at nadir/0.01 second
ERBE-like Instantaneous TOA Estimates	2	Global	20 km at nadir/0.01 second
ERBE-like Monthly Regional Averages (ES-9) and ERBE-like Monthly Geographical Averages (ES-4)	3	Global	2.5°, 5.0°, 10.0°, region and zone, global/ monthly (by day and hour)
Single Scanner TOA/Surface Fluxes and Clouds	2	Global	20 km at nadir/0.01 second
Clouds and Radiative Swath	2	Global	20 km at nadir/0.01 second
Monthly Gridded Radiative Fluxes and Clouds	3	Global	1° region/hourly
Synoptic Radiative Fluxes and Clouds	3	Global	1° region/3-hour, monthly
Average (AVG) (used for the CERES Monthly Regional Radiative Fluxes and Clouds data product); Zonal Average (ZAVG) (used for the CERES Monthly Zonal and Global Radiative Fluxes and Clouds data product)	3	Global	1° region, 1° zone, global/monthly
Monthly Gridded TOA/Surface Fluxes and Clouds	3	Global	1° region/hourly
Monthly TOA/Surface Averages	3	Global	1° region/monthly
MODIS *Data Set Start Date: June 25, 2002*			
Level 1B Calibrated, Geolocated Radiances	1B	Global	0.25, 0.5, and 1 km/daily (daytime and nighttime)
Geolocation Data Set	1B	Global	1 km /daily (daytime and nighttime)
Aerosol Product	2	Global over oceans, nearly global over land	10 km/daily daytime
Total Precipitable Water	2	Global	Varies with retrieval technique; 1 km near-infrared/daylight only, and 5 km infrared/ day and night
Cloud Product	2	Global	1 or 5 km/once or twice per day (varies with parameter)
Atmospheric Profiles	2	Global, clear-sky only	5 km/daily (daytime and nighttime)

Aqua Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
MODIS			
Atmosphere Level 2 Joint Product (select subset)	2	Global	5 or 10 km/once or twice per day (varies with parameter)
Atmosphere Level 3 Joint Product	3	Global	1.0° latitude-longitude equal-angle grid/daily, 8-day, and monthly
Cloud Mask	2	Global	250 m and 1 km/daily
Surface Reflectance; Atmospheric Correction Algorithm Products	2	Global land surface	500 m, 0.05°, and 0.25°/daily
Snow Cover	2, 3	Global, daytime	500 m and 0.05°/daily; 500 m and 0.05°/8-day; 0.05°/monthly
Land Surface Temperature (LST) and Emissivity	2, 3	Global land surface	1 km, 5 km/daily; 1 km/8-day
Land Cover/Land Cover Dynamics	3	Global, clear-sky only	1 km and 0.05°/yearly
Vegetation Indices	3	Global land surface	250 m, 500 m, 1 km/16-day; 1 km/monthly
BRDF/Albedo	3	Global land surface	1 km, 0.05°/16-day
Land Cover Change and Conversion	3, 4	Global, daytime	250 m, 500 m/96-day, yearly
Thermal Anomalies/Fire	2, 3	Global, daytime/ nighttime	Swath (nominally 1-km) (Level 2); 1 km/daily, 8-day (Level 3)
Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation (FPAR)	4	Global	1 km/8-day
Net Photosynthesis and Net Primary Production	4	Global	1 km/8-day, yearly
Normalized Water-Leaving Radiance (412, 443, 488, 531, 551, and 667 nm)	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, seasonal, yearly (Level 3)
Chlorophyll *a* Concentration	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, seasonal, yearly (Level 3)
Ocean Diffuse Attenuation Coefficient at 490 nm	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, seasonal, yearly (Level 3)
Sea Surface Temperature (11 μm, day and night; 4 μm, night)	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, yearly (Level 3)

Aqua Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
MODIS			
Sea Ice Cover and Ice-Surface Temperature	2, 3	Global, daytime and nighttime over nonequatorial ocean	1 km, 0.05°/daily
Epsilon of Aerosol Correction at 748 and 869 nm	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 36 km, 1°/daily, 8-day, monthly, yearly (Level 3)
Aerosol Optical Thickness (869 nm)	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, seasonal, yearly (Level 3)
Ångstrom Coefficient (531–869 nm)	2, 3	Global ocean surface, clear-sky only	1 km/daily (Level 2); 4 km, 9 km/daily, 8-day, monthly, seasonal, yearly (Level 3)

Aqua Data Products