

Terra and Aqua MODIS products available from NASA GES DAAC

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Abstract

The NASA Goddard Earth Sciences Distributed Active Archive Center (GES DAAC), known as GSFC-ECS in the Earth Observing System Data Gateway, distributes three major groups of MODIS products: Level 1 Radiometric and Geolocation data, and Level 2 and higher level of Atmosphere and Ocean products. The Atmosphere data types are aerosol, water vapor, cloud, temperature and moisture profiles, and cloud mask. The 107 (at present) Ocean data types include such parameters as normalized water-leaving radiances, chlorophyll and pigment concentrations (“ocean color”), total absorptions, sea surface temperatures, and ocean primary productivity. GES DAAC provides a broad spectrum of MODIS support, covering; data access, visualization tools, tools for search and order of the aforementioned data, documentation, data content, troubleshooting, and science and software support for the Earth Observing System Core System (ECS). The Web gateway for MODIS data products and services is <http://daac.gsfc.nasa.gov/MODIS/>.

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1. Introduction

Many global measurements over long time periods are required to improve computer models that can accurately predict the causes and effects of climate change. The goal of this data acquisition program is to develop models of Earth’s global dynamics (atmospheric, oceanic, and terrestrial) and predict changes in these systems. Consequently, these results will assist policymakers worldwide in making sound decisions concerning protection and management of Earth’s resources. With this goal in mind, NASA began a program for the study of planet Earth called the Earth Observing System (EOS), which is comprised of a series of satellites, a computer network for processing, storing and distributing data, and teams of scientists to analyze these data.

The Moderate Resolution Imaging Spectroradiometer (MODIS), a major NASA EOS instrument, was

launched aboard the Terra satellite on December 18, 1999 (10:30 AM equator crossing time, descending) for global monitoring of the atmosphere, terrestrial ecosystems, and oceans. On May 4, 2002, a similar instrument was launched on the EOS-Aqua satellite (1:30 PM equator crossing time, ascending). MODIS, flying on two satellites in orbits that complement each other by providing observations in the late morning and early afternoon will help scientists to study diurnal variation of the rapidly varying systems and will provide a long term data set with the same geophysical parameters for the study of climate and global change studies (Salomonson et al., 2001).

MODIS, with its 2330 km viewing swath width flying onboard Terra and Aqua, provides almost complete global coverage in one day. It acquires data in 36 high spectral resolution bands between 0.415 and 14.235 μm with spatial resolutions of 250 m (2 bands), 500 m (5 bands), and 1000 m (29 bands). The radiance measured by MODIS at high spatial resolution provides improved and valuable information about the physical structure of the Earth’s atmosphere and surface (Barnes et al., 1998).

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2. MODIS science data products

The GES DAAC is responsible for the distribution of the Level 1 data, and the higher levels of all Ocean and Atmosphere products (land products are distributed through the land processes (LP) DAAC, and Snow and Ice products are distributed through the National Snow and Ice Data Center (NSIDC) DAAC). Ocean products include SST, concentrations of chlorophyll, pigment and coccolithophores, fluorescence, absorptions, and primary productivity. Atmosphere products include aerosols, atmospheric water vapor, clouds, cloud masks, and atmospheric temperature and moisture profiles (King et al., 2003).

Most MODIS data from GES DAAC are provided as Hierarchical Data Format-Earth Observing System (HDF-EOS) files. MODIS Level 1 and 2 data are 5-min “Swath” granules, while Level 3 are global “Grid” maps. Only Ocean Level 3 binned and all Level 4 (primary productivity) data are in the native HDF4 format. Depending on the science product, the spatial resolutions of Level 2 data vary from 1 to 10 km. Correspondingly, Levels 3 and 4 products are available in various spatial and temporal resolutions, ranging from 4.63 km to 1°, and from one day to a year, respectively. Levels 1 and 2 Swath data must be projected by users to a projection of their choice. To do this, users can use either the attached geolocation arrays in the HDF-EOS files, or they may order MODIS Level 1A 1-km geolocation products (see next section) as separate HDF-EOS files. The geolocation file type is mandatory for Ocean Level 2 data. The Levels 3 and 4 Grid data are already mapped to a Cylindrical Equiangle projection and are very convenient for browsing. The Level 3 binned ocean products, however, are in 4.63-km bins that must be viewed on an Integerized Sinusoidal Equal Area projection.

MODIS data have several levels of maturity. Many MODIS products were announced to be of validated maturity after the MODIS Science Teams had conducted rigorous testing. The following sections give short description of the MODIS data distributed from the GES DAAC. The MODIS product names start with “MO” and “MY” for Terra and Aqua products, respectively.

3. MODIS radiometric and geolocation data products

- *Raw Radiances in Counts, Daily L1A Swath (MOD01, MYD01)* data contain counts, raw instrument engineering, and spacecraft ancillary data for 36 MODIS channels. They serve as input for geolocation, calibration, and processing. Quality indicators are added to the data to indicate missing or bad pixels and instrument modes. This product includes all MODIS data

in digitized (counts) form for all bands, all spatial resolutions, all time tags (converted), all detector views (Earth, solar diffuser, solar diffuser stability monitor, Spectro-Radiometric Calibration Assembly (SRCA), black body and space view), and all engineering and ancillary data. Visible, shortwave infrared, and near infrared measurements (bands 1–19) are only made during the daytime, while radiances for the thermal infrared region (bands 20–25, 27–36) and shortwave infrared band 26 are measured continuously.

- *Calibrated Radiances Daily L1B Swath 250 m (MOD02QKM, MYD02QKM)* data contain calibrated Earth View observations from MODIS bands 1 and 2, at 250-m resolution in scientific units. These data are generated from the MODIS Level 1A scans of raw radiance. The entire channel data set is thus referenced to the same spatial and geolocation scales.
- *Calibrated Radiances, Daily L1B Swath 500 m (MOD02HKM, MYD02HKM)* data contain calibrated Earth View observations from MODIS bands 3–7, at 500-m resolution. In addition, data from MODIS bands 1 and 2 are each aggregated to appear at 500-m resolution in scientific units. These data are generated from the MODIS Level 1A scans of raw radiance. The entire channel data set is thus referenced to the same spatial and geolocation scales.
- *Calibrated Radiances, Daily L1B Swath 1 km (MOD021KM, MYD021KM)* data contain calibrated Earth View observations from MODIS bands 8–36, at 1-km resolution, in scientific units. It also contains calibrated data from MODIS bands 1–7, each aggregated to appear at 1-km resolution. These data are generated from MODIS Level 1A scans of raw radiance. The entire channel data set is thus referenced to the same spatial and geolocation scales.
- *On-Board Calibration and Engineering Data Daily L1B (MOD02OBC, MYD02OBC)* contain calibration sector data (solar diffuser, solar diffuser stability monitor, Spectro-Radiometric Calibration Assembly (SRCA), black body, and space view sectors) and additional engineering data. The three Earth View (science) products report calibrated data at the three spatial resolutions of 250 m, 500 m, and 1 km.
- *Geolocation Fields Daily L1A Swath 1 km (MOD03, MYD03)* data contain geodetic coordinates, ground elevation, solar and satellite zenith, and azimuth angles for each MODIS 1-km sample. These data are provided as a ‘companion’ data set to the Level 1B calibrated radiance and the Level 2 data sets to enable further processing. These geolocation fields are determined using the spacecraft attitude and orbit, the instrument telemetry, and a digital elevation model (Masuoka et al., 1998).
- *Subsampled L1B HDF-EOS Output 5 km (MOD02SSH, MYD02SSH)* data contain a 5 km subsample of the 36 bands as calibrated and geolocated

radiances at-aperture generated from MODIS Level 1B (MOD021KM for MOD02SSH, MYD021KM for MYD02SSH).

- *Subsampled L1B Binary Output 5 km (MOD02SSN, MYD02SSN)* data are binary versions of the Subsampled L1B HDF-EOS Output 5 km data. This data type is distributed as compressed tar file. A detailed description of the product is included in every tar file.

4. MODIS atmospheric data products

The MODIS Atmosphere parameters are grouped into the following data types: *aerosol properties, atmospheric water vapor, cloud properties, atmospheric profiles* and *cloud mask* (King et al., 1992, 2003). At Level 2, these constitute 5 separate data types for Terra and Aqua, and each data type is distributed as separate HDF-EOS files, or granules. Each granule covers 5 min of satellite time, i.e. about 2330×2030 km. At Level 3, all atmospheric parameters are joined into a single HDF-EOS file that contains daily, eight day, or monthly averages in a Global Cylindrical Equiangle 1° grid. The following is a short description of the MODIS Atmosphere data types as they appear at Level 2.

- *Aerosol Optical and Microphysical Properties (MOD04_L2, MYD04_L2)* data contains aerosol type, optical thickness, particle size parameters, mass concentration, cloud condensation nuclei (CCN), asymmetry factor, backscattering ratio and Angström exponents. The aerosol particle size distribution is provided only over the oceans, and the aerosol type is provided only over the continents (*10 km pixel resolution, level-2 swath product, day*).
- *Atmospheric Water Vapor (MOD05_L2, MYD05_L2)* data contains near-infrared estimates of total atmospheric column water vapor over clear land areas of the globe, over extended clear oceanic areas in the glint region, and above clouds over both land and ocean (*1 km pixel resolution, daytime*). The data also contains infrared-derived total precipitable water vapor, a component of another MODIS product, MOD07_L2 and MYD07_L2 (*5 km pixel resolution, day and night*).
- *Cloud Optical and Physical Properties (MOD06_L2, MYD06_L2)* data contains cloud top parameters (temperature, height, pressure, effective emissivity), cloud phase, cloud fraction, brightness temperature, cloud forcing, and surface temperature (*5 km pixel resolution, day and night*); cirrus and contrail reflectance, cloud water path, cloud optical thickness, effective radius (*1 km pixel resolution, day*).
- *Atmospheric Profiles and Stability Indices (MOD07_L2, MYD07_L2)* data contains temperature, moisture, and geopotential height values at 20 atmospheric pressure levels, total ozone, and three stability indices. The total ozone burden is an estimate

of the total-column tropospheric and stratospheric ozone content (*5 km pixel resolution, day and night*).

- *Cloud Mask (MOD35_L2, MYD35_L2)* data contains global cloud mask, clear-sky confidence level (high confident clear, probably clear, undecided, cloudy), and identifications of cirrus cloud, cloud shadow, sun-glint, land/water, snow/ice and day/night (*250 m and 1 km pixel resolution*).

5. MODIS ocean data products

MODIS Ocean data consist of 36 Ocean Color and 4 sea surface temperature (SST) science parameters. There are an additional 38 parameters, such as wind speed, surface pressure, brightness temperatures, etc., that are used for quality control (QC). At Level 2, the 40 Ocean science parameters are grouped into 3 Ocean Color data types and one SST data type: *ocean color radiance products, ocean color derived products group 1, ocean color derived products group 2*, and SST (Esaias et al., 1998). Each data type is distributed as a separate HDF-EOS file, or granule. Each granule covers 5 min of satellite time, i.e. about 2330×2030 km. Ocean Level 2 (swath) files do not contain geolocation arrays, except for MODOCQC (MYDOCQC). Either the latter, or the geolocation product MOD03 (MYD03) should be ordered so that Ocean swath data can be geolocated. At Level 3, each of the 40 parameters is space-binned and time-averaged to a separate HDF-EOS grid file. Thus each Level 3 Ocean parameter is available in daily, 8-day, monthly and yearly average, and at 4.63 km, 36 km and 1° spatial resolution. Each parameter's mean map has associated quality and statistics files where information for each pixel can be found. The quality files are of ultimate importance to assess the quality of each pixel and should be ordered together with the mean maps. The following is a description of the 40 Ocean parameters grouped at Level 2:

- *Ocean Color Radiance Product* contains 12 parameters: Normalized water leaving radiance at 412, 443, 488, 531, 551, 667 and 678 nm, Aerosol optical thickness at 865 nm, Epsilon of aerosol correction at 765 and 865 nm, Aerosol model identification number (1,2), and Epsilon of clear water aerosol correction at 531 and 667 nm.
- *Ocean Color Derived Products Group 1* contains 13 parameters: MODIS chlorophyll *a* concentration for Case 1 waters, two pigment concentrations (MODIS and CZCS), three chlorophyll fluorescence parameters, suspended solids concentration, three coccolithophore concentrations, a diffuse attenuation coefficient at 490 nm (K490), and phycoerythrobilin and phycoerythrobilin absorptions.
- *Ocean Color Derived Products Group 2* contains 11 parameters: an additional chlorophyll *a* concentra-

tion for Case 1 waters using SeaWiFS algorithm, a semi-analytic chlorophyll *a* concentration for Case 2 waters, instantaneous photosynthetically available radiation (IPAR), absorbed radiation by phytoplankton (ARP), total absorptions (412, 443, 488, 531 and 551 nm), and chlorophyll and Gelbstoff absorption coefficients.

- *Sea Surface Temperature Product* contains one thermal- and one mid-infrared SST parameter. The former is retrieved from MODIS bands 31–32 (10.8–12.3 μm) whereas the latter from MODIS bands 22–23 (3.9–4.1 μm). Both are collected during day and night, thus providing total of 4 SST parameters.

Derived ocean parameters are used to calculate ocean primary productivity (OPP), which is distributed as Level 4 Global mapped or binned products. OPP has semi-analytical and statistical model outputs. The former has 8-day and yearly products, while the latter has only a yearly average product. The spatial resolution, though, is the same as at Level 3 for both models. The core parameters from the semi-analytical model are the Behrenfeld/Falkowski and the Howard/Yoder/Ryan primary production indices. The statistical model output yields new nitrogen production, export carbon production, and annual chlorophyll *a* pigment concentration for Case 2 water (3 band).

6. Highlights of MODIS products

6.1. MODIS/Terra and MODIS/Aqua radiance

The power of having MODIS on both Terra and Aqua satellite covering area on the Earth twice each day is demonstrated using this combined true color (bands 1, 4 and 3) MODIS image from September 16, 2002. MODIS/Terra passed over the Gulf of Oman at 06:50 UTC, and 3 h later MODIS/Aqua passed over the

Persian Gulf, making possible stitching of the two overpasses into a single product. Thus, both platforms allow for unprecedented daily coverage. In the near future, users will be able to create their own combined products, similar to the above, for higher level science parameters like SST, chlorophyll and aerosol concentrations, etc. (Fig. 1).

6.2. MODIS/Terra atmosphere and ocean level 2 science parameters

This series of MODIS/Terra images is a small sample of the large Atmosphere and Ocean collection of science parameters that are distributed by the GES DAAC. It depicts a monsoon event (Fig. 2a), where warm surface waters are pushed inside the Persian Gulf (Fig. 2b). Lower, colder layer waters that in the Gulf are typically nutrient-depleted replace them. This is reflected in the chlorophyll concentration (Fig. 2c) images. The dark area in the chlorophyll image is caused by the sun glint, visible in the true color image. Ocean color is among algorithms that do not produce values in sun glint affected areas. Users should be aware that the sun glint typically affects MODIS in the summer hemisphere. Higher level products provide a sun glint mask to filter affected pixels (Fig. 2). Events such as this can have a negative impact on local fisheries.

7. MODIS data support

The MODIS Data Support Team (MDST) continues the tradition of quality support at the GES DAAC for various satellite data by providing expert assistance to the users in accessing data products (Ouzounov et al., 2004) and information on the scientific content of data products and metadata. The official MDST web site at <http://daac.gsfc.nasa.gov/MODIS/> contains all the

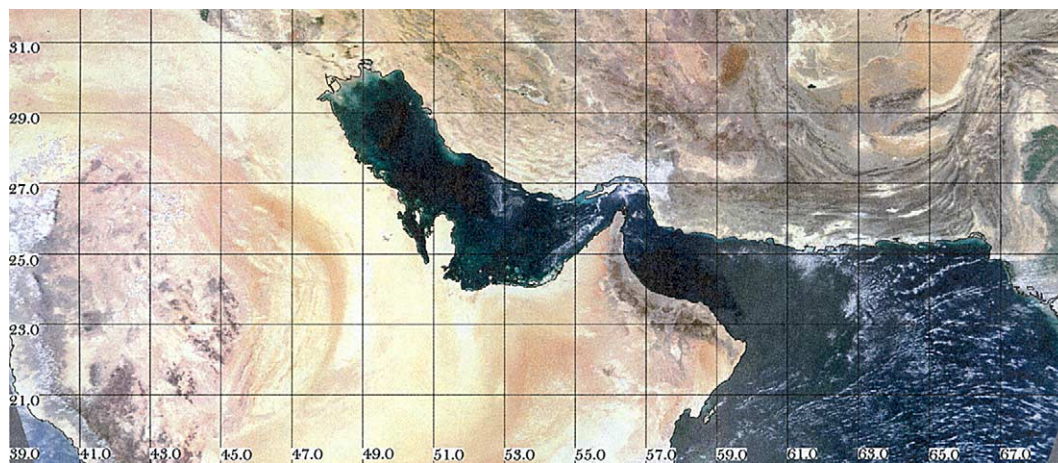


Fig. 1. MODIS Aqua and Terra combined true color image (bands 1, 4 and 3) from September 16, 2002. MODIS/Terra passed over the Gulf of Oman at 06:50 UTC, followed by MODIS/Aqua over the Persian Gulf at 09:50 UTC.

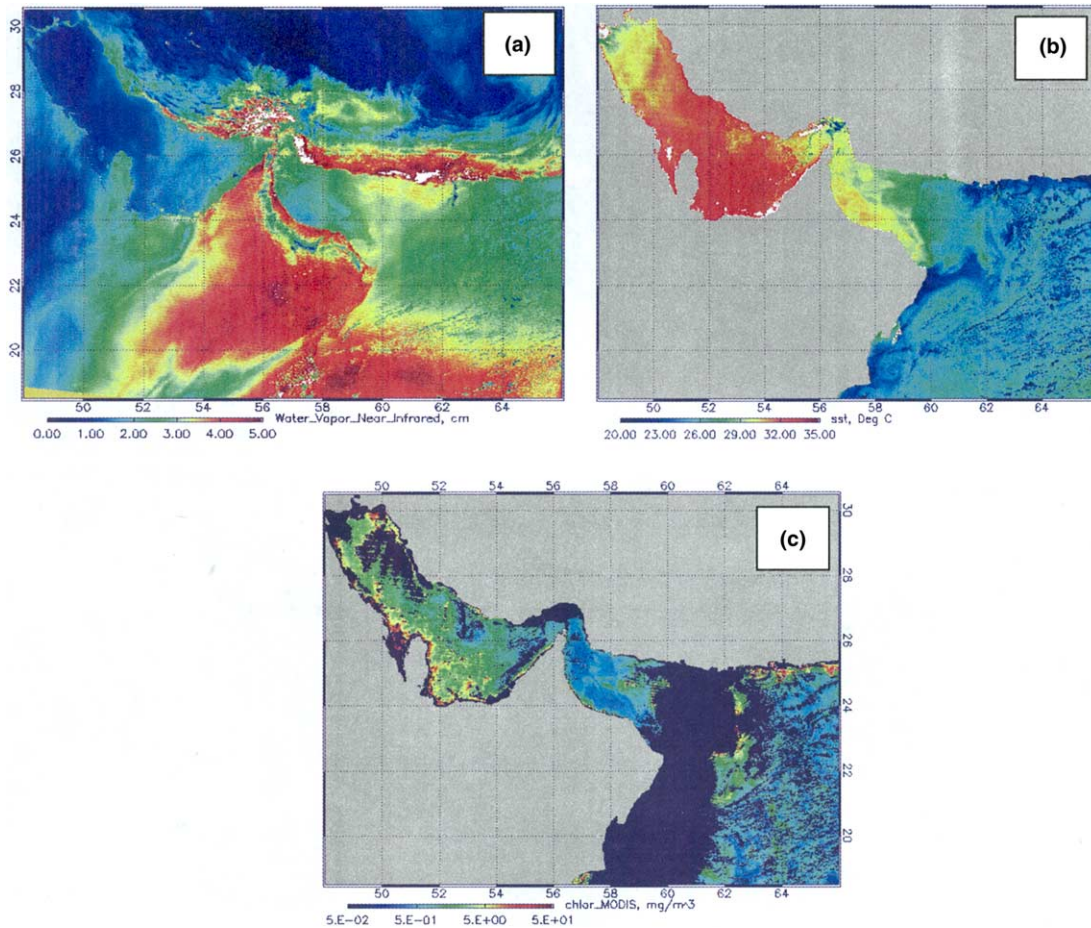


Fig. 2. MODIS/Terra Water Vapor near-infrared retrieval (a), 11 μm SST (b) and chlorophyll *a* concentration (c) from the high-pressure liquid chromatograph empirical algorithm, over the Persian Gulf from September 16, 2002.

MODIS products and documents available from GES DAAC.

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