Moderate Resolution Imaging Spectroradiometer (MODIS)

With the launch of the **Mod**erate Resolution **I**maging **S**pectroradiometer (MODIS) in December 1999, a new era in hyperspectral satellite remote sensing began. MODIS makes possible continuous monitoring of the environment by measuring atmospheric trace gases and aerosol density, and mapping the surface of clouds, land and sea in a variety of spectral ranges from the blue to the thermal infra-red.

The first **Mod**erate Resolution **I**maging **S**pectroradiometer (MODIS) sensor (http://modis.gsfc.nasa.gov/) went into orbit with the launch of the TERRA (EOS AM-1) satellite on December 18, 1999 (http://terra.nasa.gov/). With the successful launch of AQUA (EOS PM-1) from Vandenberg Air Force Base, CA, on May 4, 2002, a second MODIS sensor was put into orbit for studying the Earth's water cycle and our environment (http://aqua.nasa.gov/). TERRA and AQUA (both with a 705km orbit) have a sun-synchronous, near polar, circular orbit. AQUA will cross the equator daily at 1:30 p.m. as it heads north (ascending mode) in contrast to TERRA, which crosses the equator at 10:30 a.m. daily (descending mode). With this formation it is expected that AQUA's afternoon observations combined with TERRA's morning observations will provide important insights into the daily cycling of global precipitation and ocean circulation.

MODIS is a 36 band spectrometer providing a global data set every 1-2 days with a 16-day repeat cycle. The spatial resolution of MODIS (pixel size at nadir) is 250m for channel 1 and 2 (0.6μm - 0.9μm), 500m for channel 3 to 7 (0.4μm - 2.1μm) and 1000m for channel 8 to 36 (0.4μm - 14.4μm), respectively. A detailed overview for the 36 spectral channels of MODIS is given in Table 1. The MODIS instrument consists of a cross-track scan mirror, collecting optics and individual detector elements. The swath dimensions of MODIS are 2330km (across track) by 10km (along track at nadir). The along track swath dimension is due to the optical set-up as well as the scanning mechanism of MODIS. In contrast to other scanning sensors like e.g. AVHRR, MODIS is observing within one scan ten lines of 1km spatial resolution (40 lines of 250m resolution and 20 lines of 500m resolution, respectively). Due to this unique feature, the so called panoramic "bow tie" -effect occurs at the border of each scene. In figure 1, a schematic layout of the "bow tie" effect is presented.

All MODIS data are digitised in 12 bits. Detailed technical specifications are provided on NASA's MODIS Web pages (http://modis.gsfc.nasa.gov/about/specs.html).

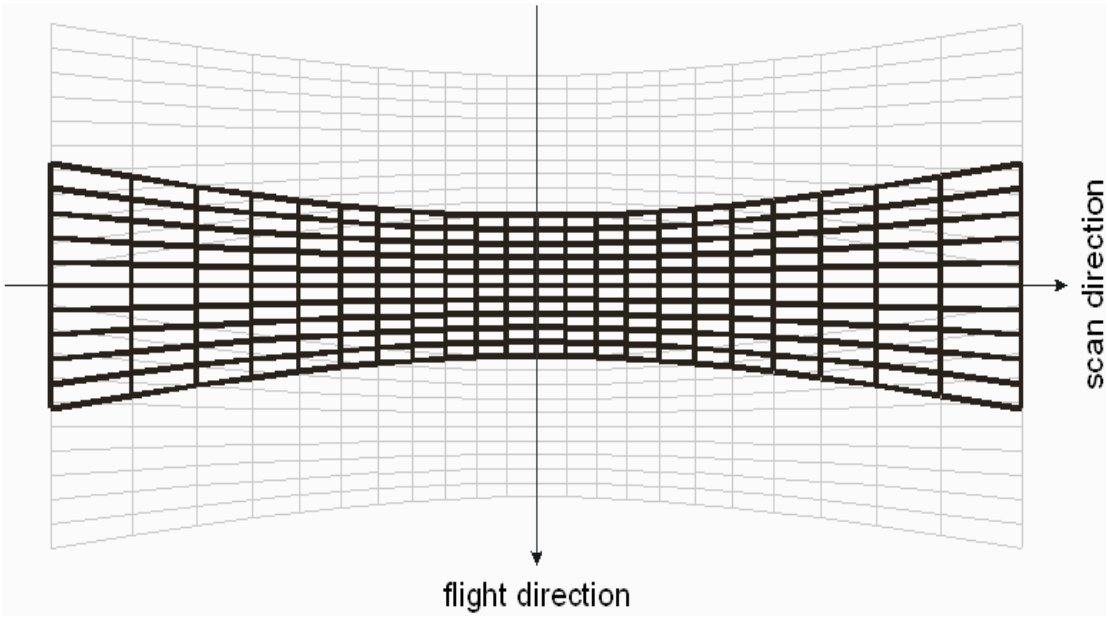

Figure 1: Three consecutive MODIS scans each consisting of ten 1km lines. Due to the panoramic "bow tie" effect, the scans are partially overlapping at off nadir angles. The first and third scan are represented by the light grey grids, while the second scan is shown in black.

Primary Use	Band number	Central wavelength [nm]	Bandwidth [nm]	Spatial resolution [m]
Land / Cloud / Aerosols / Boundaries	1	645	620 - 670	250
	2	858.5	841 - 876	
Land / Cloud / Aerosols Properties	3	469	459 - 479	500
	4	555	545 - 565	
	5	1240	1230 - 1250	
	6	1640	1628 - 1652	
	7	2130	2105 - 2155	
Ocean Colour / Phytoplankton / Biogeochemistry	8	421.5	405 - 420	1000
	9	443	438 - 448	
	10	488	483 - 493	
	11	531	526 - 536	
	12	551	546 - 556	
	13	667	662 - 672	
	14	678	673 - 683	

	15	748	743 - 753
	16	869.5	862 - 877
Atmospheric Water Vapour	17	905	890 - 920
	18	936	931 - 941
	19	940	915 - 965
Surface / Cloud Temperature	20	3750	3660 - 3840
	21	3959	3929 - 3989
	22	3959	3929 - 3989
	23	4050	4020 - 4080
Atmospheric Temperature	24	4465.5	4433 - 4498
	25	4515.5	4482 - 4549
Cirrus Clouds / Water Vapour	26	1375	1360 - 1390
	27	6715	6535 - 6895
	28	7325	7175 - 7475
Cloud Properties	29	8550	8400 - 8700
Ozone	30	9730	9580 - 9880
Surface / Cloud Temperature	31	11030	10780 - 11280
	32	12020	11770 - 12270
Cloud Top Altitude	33	13335	13185 - 13485
	34	13635	13485 - 13785
	35	13935	13785 - 14085
	36	14235	14085 - 14385

Table 1: Specification of the 36 MODIS channels, including primary use, central wavelength, bandwidth and spatial resolution.

Geographical and temporal coverage from DLR station at Oberpfaffenhofen

The German Remote Sensing Data Centre (DFD) is receiving MODIS data since January 2001 using the **D**irect **B**roadcast (DB) facility. On January 16, 2001 an antenna was installed on the roof of the DFD's building in Oberpfaffenhofen for the purpose of receiving data from the MODIS sensor (Fig. 2).

Figure 2: MODIS antenna on the roof of DFD's building in Oberpfaffenhofen

MODIS on board the Terra and Aqua spacecraft have the feature of Direct Broadcast (DB, http://rsd.gsfc.nasa.gov/eosdb/) capability together with an on board data storage and a transmission capability initiated by a ground command. Direct Broadcast means that all raw data collected on board are immediately transmitted to ground. The idea of this concept is that everybody on the world can listen to the downloaded data whenever the satellite is above their horizon assuming appropriate hard- and software equipment. An Overpass Predictor delivered by NASA can be used to determine when there will be a TERRA / AQUA spacecraft overpass. More than 50 stations world-wide are now in operation for receiving MODIS data by Direct Broadcast.

Hardware requirement for Direct Broadcast is an X-band receiving system with a 3m or larger antenna, coupled with appropriate hardware and software. At DFD a 3.60m dish for X-band reception is housed in a radome of 4.20m diameter to protect it from the weather. The antenna system can be adjusted along three axes (azimuth 360 degrees, elevation +/- 90 degrees, tilt +/- 20 degrees). It was sold by the SeaSpace Corporation (Fig.3).

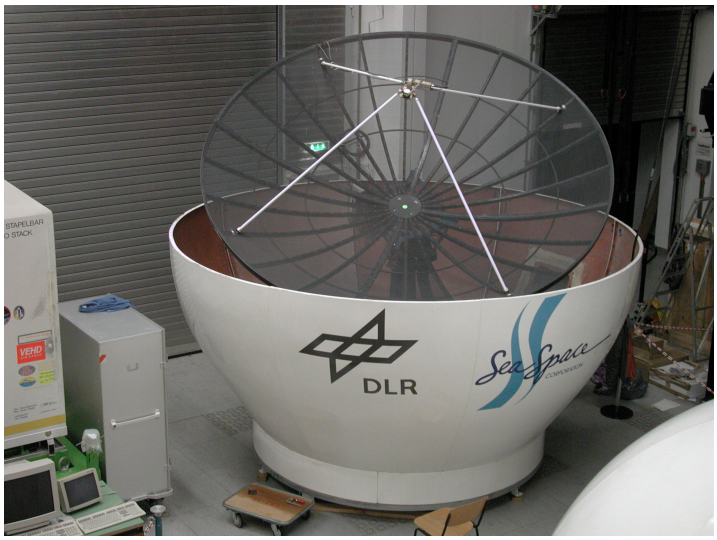

Figure 3: X-band antenna

The TERRA and AQUA platform have a sun-synchronous, near polar, circular orbit crossing the equator at

10:30 a.m. daily (descending mode forTERRA) and crossing the equator daily at 1:30 p.m. as it heads north (ascending mode for AQUA). Both satellites have a typical flight height of 705km. The ground station at Oberpfaffenhofen receives data from 3 passes per day, typically. Depending on the actual track, the scenes cover areas reaching from the Barents Sea in the north to the northern part of Africa in the south and from the Caspian Sea in the east to the Mid Atlantic in the west.

The real-time data stream carries the data from all 36 spectral bands for the entire MODIS field of view (2330km) whenever MODIS can be seen from the ground station at Oberpfaffenhofen.

DFD is receiving and archiving about 6 Gbytes of MODIS data daily. It is converting the raw data to Level 1b data according to NASA specification MOD01 (Barbieri, 1997) and MOD28 (Nishihama et al., 1997).

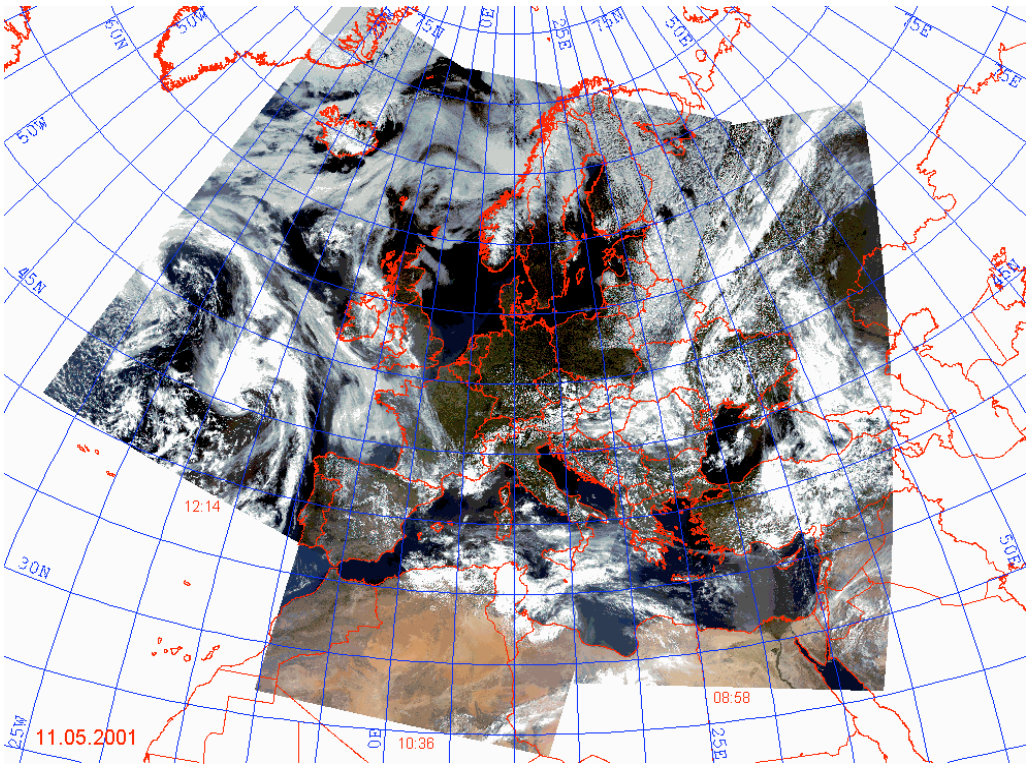

Figure 4: Typical daily coverage for the MODIS Direct Broadcast receiving station at Oberpfaffenhofen (DLR – DFD)

Data format and Products

MODIS digital quicklooks for Europe can be accessed via DFLR network (http://eoweb.dlr.de/). The quicklooks show a combination of the MODIS channels 1-2-31(inverted) representing a RGB image for daytime data and a gray value image (channel 31) for night-time data. The quicklook-images are magnifiyed and contrast enhanced.

The Level 0 or raw data are stored at DFD in a so called "pds" format (Production Data Set) which is the expected input format for the International MODIS/AIRS Processing Package (IMAPP). The IMAPP software

allows any user of TERRA or AQUA Level 0 data to produce calibrated and geolocated MODIS radiances (Level 1). IMAPP is derived from the current operational MODIS processing software developed at NASA GSFC, and is modified by the University of Wisconsin to be compatible with direct broadcast data (Level 0 data). IMAPP can be downloaded from http://cimss.ssec.wisc.edu/~gumley/IMAPP/IMAPP.html and is running on various UNIX platforms.

Level 0 data can be obtained from DFD's archive in the near future when the full processing chain for MODIS is implemented in the **D**ata **I**nformation and **M**anagement **S**ystem (**DIMS**) of DLR. In the moment, only registered user can get access to MODIS Level 0 and level 1b data via FTP.

In contrast to the Levelo data, the Level 1b output product consists of four HDF -files:

- **MOD02_250M**: Calibrated data of channel 1 and 2 only at 250m resolution.
- **MOD02_500M**: Calibrated data of channels 3 – 7 at 500m resolution. The file also contains the 250m bands resampled to 500m.
- **MOD02_1000M**: Calibrated data of channels 8 – 36 at 1km resolution,. The file is splitted into two 1km resolution categories: reflective channels (8 -19, 26) and emissive channels (20-36 except 26). This file also contains the 250m and 500m bands resampled to 1km.
- **GEOLOC**: Geolocation for every 1km pixel

The calibrated Level 1b data for the reflective channels are given in radiances ($W/(m^2*\mu m*sr)$) and reflectances, whereas the thermal bands are given in radiances. Therefore, for many applications the emissive channels must be converted to equivalent black body temperature according to the Planck's law.

All Level 1b data are in sensor projection and thus not "bow tie" corrected. It is important to note that the output files from IMAPP (HDF version 4) are not identical to the GSFC DAAC Level 1b output files (HDF-EOS; http://hdfeos.gsfc.nasa.gov/hdfeos/index.cfm).

All NRT – data produced at DLR - DFD are hold on disk for one week. The raw data as well as the Level 1b data will be available for external users via the graphical interface EOWEB (http://eoweb.dlr.de:8080/) in the near future.

Remarks

The size for a full pass of Level 0 data is typical 1,2 GB (daytime) and 300MB (night-time).

Information

For questions regarding MODIS data usage, please contact Dr. K. P. Günther, DLR – DFD, D-82234 Oberpfaffenhofen (kurt.guenther@dlr.de). For questions regarding data format and acquisition schedules, please contact Walter Ebke, DLR – DFD, D-82234 Oberpfaffenhofen (walter.ebke@dlr.de).