MODIS/Terra Sea Ice Extent 5-Min L2 Swath 1km, Version 5

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Hall, D. K., V. V. Salomonson, and G. A. Riggs. 2006. *MODIS/Terra Sea Ice Extent 5-Min L2 Swath 1km, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/3YC57WMDK2C8. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/MOD29

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

The MODIS science team continually seeks to improve the algorithms used to generate MODIS data sets. Whenever new algorithms become available, the MODIS Adaptive Processing System (MODAPS) reprocesses the entire MODIS collection—atmosphere, land, cryosphere, and ocean data sets—and a new version is released. NSIDC strongly encourages users to work with the most recent version.

Consult the following resources for more information about MODIS Version 5 data, including known problems, production schedules, and future plans:

- MODIS Sea Ice Products User Guide to Collection 5
- The MODIS Snow and Sea Ice Global Mapping Project
- NASA Goddard Space Flight Center | MODIS Land Quality Assessment
- MODIS Land Team Validation | Status for Snow Cover/Sea Ice (MOD10/29)

This data set is retired and no longer available for download. The most up-to-date version of this data can be accessed on the NSIDC website here.

1.1 Format

MODIS sea ice products are archived in compressed HDF-EOS format, which employs point, swath, and grid structures to geolocate the data fill fields to geographic coordinates. This data compression should be transparent to most users since HDF capable software tools automatically uncompress the data. See the Hierarchical Data Format - Earth Observing System (HDF-EOS) Web site for more information about the HDF-EOS data format.

Data can also be obtained in GeoTIFF format from Reverb | ECHO, NASA's Next Generation Earth Science Discovery Tool.

Data are produced in five minute segments of the orbital swath, which corresponds to approximately 203 scans. With 10 lines per scan, individual products have approximately 2030 pixels in the along-track direction and 1354 pixels in the cross track direction. At the Earth's surface, the coverage of a single granule is approximately 2030 km along track by 2330 km cross track.

The data are split into three different files:

- swaths acquired during daylight
- swaths acquired during night
- swaths that were acquired in both day and night.

The DayNightFlag object, which is a CoreMetadata.0 Global Attribute, specifies what input was used for a given MOD29/MYD29 granule. The content of sea ice data products is different between day and night because MODIS visible data are not acquired when the sensor is observing the surface in darkness. Thermal data are acquired day and night. Swaths acquired during the day, or those observed as a combination of day and night, contain fields based on reflective and thermal data. In swaths that were acquired in night mode, only data fields based on thermal data are included; Sea Ice by Relectance and Sea Ice by Relectance Pixel QA fields are not included. Each data file contains a mix of data fields depending on whether the data were acquired at night or during the day. And each data file contains the following HDF-EOS local attribute fields, which are stored with their associated Scientific Data Set (SDS):

1. Sea Ice by Reflectance (day only)
2. Sea Ice by Reflectance Pixel QA (day only)
3. Ice Surface Temperature (day and night)
4. Ice Surface Temperature Pixel QA (day and night)
5. Latitude (day and night)
6. Longitude (day and night)

Each data granule also contains metadata either stored as global attributes or as HDF-predefined fields, which are stored with each Scientific Data Set (SDS).

1.1.1 Description of Data Fields

IST = scale_factor * (data value - add_offset)

Where:

scale_factor = 0.01

data value = ice surface temperature

add_offset = 0

The valid range for IST is 243 to 271.5 K.

- **Sea Ice by Relectance** - the sea ice algorithm identifies pixels as being sea ice, ocean, cloud, land, inland water, or other condition. Sea ice is distinguished from open water based on reflective properties. Results are stored as coded integer values.
- **Ice Surface Temperature** - these data are expressed in kelvins and are stored as scaled integer data in HDF-EOS calibrated form. Data must be converted to kelvins using the calibration data in the HDF predefined local attributes:
- **Sea Ice by Relectance Pixel QA and Ice Surface Temperature Pixel QA** - these fields store the quality of the algorithm on a pixel-by-pixel basis. QA information tells if the algorithm results were good quality or not, or if other defined conditions were encountered for a pixel. If all the input data and calculations in the algorithm were nominal for a pixel, the QA value is set to good quality. If data show abnormal values, for example, out of range, the algorithm proceeds and outputs a value but flags it as other quality. See the

MOD29 and MYD29 Local Sea Ice Attributes document for more information about QA values in sea ice products.

- **Latitude and Longitude** - the latitude and longitude data correspond to the center pixel of a 5 km by 5 km block of pixels in each of the data fields. Geolocation data are mapped to the sea ice data with an offset value of two and increment value of five. The offset indicates how far to move along a data dimension until reaching the first point with a corresponding entry along the geolocation dimension. The increment tells how many points to travel along the data dimension before the next point is found for which there is a corresponding entry along the geolocation dimension. In this case, the first element (0,0) in the latitude and longitude field corresponds to element (2,2) in the Sea Ice by Reflectance field. The algorithm then increments by five pixels in the cross track or along track direction to map geolocation data to the Sea Ice by Reflectance field elements. For more information on dimension maps and how geolocation field offsets work, please consult Section 5.1.4 Dimension Maps, page 27 of the HDF-EOS Library User's Guide, Volume 1 and see Geolocating HDF-EOS Data.

Figure 1 illustrates the relationship between the latitude and longitude fields and data fields in MOD29/MYD29.

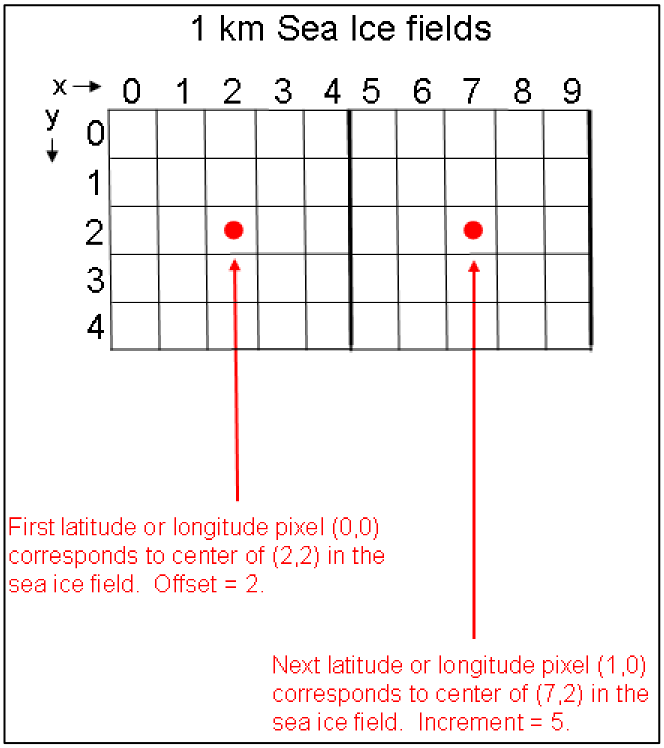

Figure 1. Illustration showing how MOD29/MYD29 data fields map to the latitude and longitude fields.

1.1.2 External Metadata File

A separate ASCII text file containing metadata with a .xml file extension accompanies the HDF-EOS file. The metadata file contains some of the same metadata as in the product file, but also includes other information regarding archiving, user support, and post-production QA relative to the granule ordered. The post-production QA metadata may or may not be present depending on whether or not the data granule has been investigated for quality assurance. The metadata file should be examined to determine if post-production QA has been applied to the granule.

1.2 File Naming Convention

The file naming convention common to all MODIS Level 2 data products is:

```
MOD29.A2000055.1630.005.2006251012020.hdf
```

Refer to Table 1 for an explanation of the variables used in the MODIS file naming convention.

Table 1. Variable Explanation for MODIS File Naming Convention

Variable	Explanation
MOD MYD	MODIS/Terra MODIS/Aqua
29	Type of product
A	Acquisition date
2000	Year of data acquisition
055	Day of year of data acquisition (day 55)
1630	Hour and minute of data acquisition in Greenwich Mean Time (GMT) (16:30)
005	Version number
2006	Year of production (2006)
251	Day of year of production (day 251)
012020	Hour/minute/second of production in GMT (01:20:20)
hdf	HDF-EOS data format

1.3 File Size

Data files are typically between 0.9 - 6.0 MB using HDF compression.

Note: New in V005, MOD20/MYD29 data files now use HDF data compression. The extent to which compression reduces the file size varies from image to image, but generally it is a factor of 10 or more.

1.4 Spatial Coverage

Coverage is global; however, only ocean pixels are run through the sea ice algorithm. A ±55 degree scanning pattern at 705 km altitude achieves a 2330 km swath with global coverage every one to two days.

1.4.1 Latitude Crossing Times

The local equatorial crossing time of the Terra (Aqua) satellite is approximately 10:30 a.m. (1:30 p.m.), in a descending (ascending) node with a sun-synchronous, near-polar, circular orbit.

1.4.2 Spatial Resolution

Resolution at nadir is 1 km for the sea ice fields and 5 km for the latitude and longitude geolocation fields.

1.4.3 Swath Description

MOD29/MYD29 are produced in five-minute segments, which corresponds to approximately 203 scans. Visit the Space Science and Engineering Center (SSEC) Terra Orbit Tracks GLOBAL and Aqua Orbit Tracks GLOBAL Web sites to find appropriate swath data for your study.

1.5 Temporal Coverage

MODIS Terra data extend from 24 February 2000 to present.
MODIS Aqua data extend from 4 July 2002 to present.

Over the course of the Terra and Aqua missions, a number of anomalies have resulted in data gaps. If you are looking for data for a particular date or time and cannot find it, please visit the MODIS/Terra Data Outages and MODIS/Aqua Data Outages Web pages.

1.5.1 Temporal Resolution

Data are produced in five-minute segments. The time between repeat coverage of a given point on the earth depends on latitude with multiple pass coverage near the poles, and at least daily coverage of locations poleward of ±30 degrees latitude. The nominal repeat period of the satellite is 16 days.

1.6 Parameter or Variable

1.6.1 Parameter Description

The sea ice algorithm classifies pixels as sea ice, cloud, open ocean, inland water, or land. In the Sea Ice by Reflectance field, sea ice is distinguished from open water based on reflective properties. In the IST field, pixels contain an IST value in kelvins, scaled by 100 for all classes. The IST algorithm was designed for sea ice; however, IST values are provided for areas over open ocean.

1.6.2 Parameter Range

Refer to the MOD29 and MYD29 Local Sea Ice Attributes, Version 5 document for a key to the meaning of the coded integer values in the Sea Ice by Reflectance Field, the Sea Ice by Reflectance Pixel QA Field, the Ice Surface Temperature Field, the Ice Surface Temperature Pixel QA Field, the Latitude Field, and the Longitude Field.

2 SOFTWARE AND TOOLS

2.1 Data Access Aids

The following sites can help you select appropriate MODIS data for your study:

- MODIS Rapid Response System
- NASA Goddard Space Flight Center: MODIS Land Global Browse Images

2.2 Data Analysis Tools

The following software tools can help you analyze the data:

- Land Processes Distributive Active Archive Center: MODIS Swath Reprojection Tool Distribution Page: Software tools that read HDF-EOS files containing MODIS swath data and produce native binary HDF-EOS Grid or GeoTIFF files of gridded data in different map projections.
- HEG HDF-EOS to GeoTIFF Conversion Tool: This free tool converts many types of HDF-EOS data to GeoTIFF, native binary, or HDF-EOS grid format. It also has reprojection, resampling, subsetting, stitching (mosaicking), and metadata preservation and creation capabilities.
- NCSA HDFView: The HDFView is a visual tool for browsing and editing the National Center for Supercomputing Applications (NCSA) HDF4 and HDF5 files. Using HDFView, you can view a file hierarchy in a tree structure, create a new file, add or delete groups and

datasets, view and modify the content of a dataset, add, delete, and modify attributes, and replace I/O and GUI components such as table view, image view, and metadata view.

- Hierarchical Data Format - Earth Observing System (HDF-EOS): NSIDC provides more information about the HDF-EOS format, tools for extracting binary and ASCII objects from HDF, information about the hrepack tool for uncompressing HDF-EOS data files, and a list of other HDF-EOS resources.
- The MODIS Conversion Toolkit (MCTK): A free plugin for ENVI that can ingest, process, and georeference every known MODIS data product using either a graphical widget interface or a batch programmatic interface. This includes MODIS products distributed with EASE-Grid projections.

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

Sea ice is a highly dynamic feature that requires satellite-based remote sensing to better understand its behavior. A strong insulator, sea ice restricts the exchange of heat, mass, and momentum between the ocean and atmosphere; influences circulation patterns; and reduces the amount of solar radiation absorbed by the ocean (Riggs, Hall, and Ackerman 1999). Newly formed, smooth, thin sea ice is changed by temperature fluctuations, compressive and shear forces, surface currents, and winds. Sea ice usually becomes snow-covered only a few days after formation. As snow melts on sea ice, albedo decreases across all wavelengths. Sea ice has a much higher albedo compared to open ocean. Specific reflective characteristics of sea ice depend on the age of the ice. Snow-covered, opaque, white sea ice, thick first-year ice, and multiyear ice typically show maximum reflectance between 0.4 μm and 0.8 μm, and again at 1.9 μm. Young sea ice has a lower spectral albedo, 10-40 percent, than older sea ice when measured in this spectral range. Sea ice in the process of ablation and formation of melt ponds shows a decrease in reflectance from 0.6 μm to 0.8 μm, followed by a consistent decrease to approximately 1.6 μm. Sea ice reflectance criteria are used to identify snow-covered sea ice and the age of the ice (Hall and Martinec 1985 and Hall et al. 1998).

Measurement of IST is useful for determining ice type and estimating radiative and turbulent heat fluxes for large-scale climate studies. IST estimates can be used as an additional discriminatory variable for the identification of sea ice cover. Studies of MODIS Airborne Spectrometer (MAS) images in the Beaufort Sea, near St. Lawrence Island, Alaska, show that the surface temperature of water is typically greater than 271.4 kelvins, while the surface temperature of saline ice is less than 271.4 kelvins (Hall et al. 1998). These thresholds take into account the emissivity of sea ice. First-year ice has an emissivity of about 0.92, and multiyear ice has an emissivity of about 0.84. The difference in ice emissivities results in a difference in recorded surface temperatures, allowing a researcher to distinguish the relative age of ice and infer relative ice thickness (Hall and Martinec 1985).

3.2 Data Acquisition Methods

3.2.1 Source or Platform Mission Objectives

MODIS is a key instrument aboard Terra and Aqua, the flagship satellites of NASA's Earth Observing System (EOS). The EOS includes a series of satellites, a data system, and the world-wide community of scientists 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 that together enable an improved understanding of the Earth as an integrated system. MODIS is playing a vital role in the development of validated, global, and interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment. (NASA's MODIS Web Site; NASA's Terra Web Site), and (NASA's EOS Web Site)

3.2.2 MODIS Snow and Sea Ice Global Mapping Project Objectives

Within this overall context, the objectives of the MODIS snow and ice team are to develop and implement algorithms that map snow and ice on a daily basis, and provide statistics of the extent and persistence of snow and ice over eight-day periods. Data at 500 m resolution enables sub-pixel snow mapping for use in regional and global climate models. A study of sub grid-scale snow-cover variability is expected to improve features of a model that simulates Earth radiation balance and land-surface hydrology (Hall et al. 1998).

3.2.3 Data Collection System

The MODIS sensor contains a system whereby visible light from the earth passes through a scan aperture and into a scan cavity to a scan mirror. The double-sided scan mirror reflects incoming light onto an internal telescope, which in turn focuses the light onto four different detector assemblies. Before the light reaches the detector assemblies, it passes through beam splitters and spectral filters that divide the light into four broad wavelength ranges. Each time a photon strikes a detector assembly, an electron is created. Electrons are collected in a capacitor where they are eventually transferred into the preamplifier. Electrons are converted from an analog signal to digital data, and down linked to ground receiving stations.

3.2.4 Data Acquisition and Processing

The EOS Ground System (EGS) consists of facilities, networks, and systems that archive, process, and distribute EOS and other NASA earth science data to the science and user community. For example, ground stations provide space to ground communication. The EOS Data and Operations System (EDOS) processes telemetry from EOS spacecraft and instruments to generate Level-0 products, and maintains a backup archive of Level-0 products. The NASA Goddard Space Flight Center MODIS Adaptive Processing System (MODAPS) is currently responsible for generation of Level-1A data from Level-0 instrument packet data. These data are then used to generate higher level MODIS data products, including MOD10_L2. MODIS snow and ice products are archived at the NSIDC Distributed Active Archive Center (DAAC) and distributed to EOS investigators and other users via external networks and interfaces. Data are available to the public through a variety of interfaces.

3.3 Derivation Techniques and Algorithms

The MODIS science team is responsible for algorithm development. The MODIS Data Processing System (MODAPS) is responsible for product generation and transfer of products to NSIDC.

The sea ice algorithm identifies sea ice on the basis of reflectance characteristics in the visible and Near Infrared (IR) wavelengths (Riggs, Hall, and Ackerman 1999). The algorithm assumes that the sea ice is snow covered and that the NDSI can be used to detect sea ice. The NDSI is used to detect the high reflectance of sea ice at visible wavelengths, and the low reflectance at approximately 1.6 µm. NDSI is calculated using MODIS bands 4 (0.55 µm) and 6 (1.6 µm) radiances:

NDSI = (band 4 - band 6)/(band 4 + band 6)

3.3.1 Processing Steps

Analysis of sea ice in a MODIS swath is constrained to pixels that:

- have nominal Level-1B radiance data
- are over oceans
- are unobstructed by clouds

Constraints are applied in the order listed. After they are applied, only pixels having a 95 percent or greater probability of being unobstructed by cloud over an ocean surface are analyzed for sea ice. Clouds are masked with the MODIS Cloud Mask data product (MOD35_L2). Land and inland water bodies are masked with the MODIS 1 km mask contained within the MODIS geolocation product (MOD03).

3.3.1.1 Reflectance Criteria

Sea ice detection is achieved with a criteria test for sea ice reflectance characteristics in the visible and near-infrared regions. A pixel is identified as sea ice if all the following conditions are met: (Hall et al. 1998, Riggs, Hall, and Salomonson 2003)

- NDSI is greater than or equal to 0.4
- Band 2 reflectance is greater than 0.11
- Band 1 reflectance is greater than 0.10

Intermediate checks for theoretical bounding of reflectance data and the NDSI ratio are made in the algorithm. Reflectance values should be between 0 -100 percent, and the NDSI ratio should be within -1.0 to +1.0. Summary statistics are kept for pixels that exceed these theoretical limits; however, the test for sea ice is done regardless. A quality flag is set in the QA data array to indicate the occurrence of sea ice.

3.3.1.2 Ice Surface Temperature

A split-window technique is used to determine sea surface temperature and Ice Surface Temperature (IST). This technique allows for correction of atmospheric effects, primarily water vapor (Hall et al. 1998, Riggs, Hall, and Salomonson 2003).

Radiance data from MODIS Channels 31 and 32 (11 µm and 12 µm, respectively) are first converted to brightness temperatures with an inversion of Planck's equation (Key et al. 1994):

$$T = c_2 v / \ln(1 + ((e c_1 v^3)/E))$$

Table 2. Variables for Planck's Inversion Equation for Brightness Temperature

Variable	Description
T	brightness temperature in kelvins (K)
c1	1.1910659 * 10-5 mW m-2 sr cm-4
c2	1.438833 cm deg K
v	central wavelength in cm-1
E	radiance from sensor in mW m-2 sr cm-4
e	emissivity

The following equation, based on the technique of Key et al. (1997), is then used to estimate IST. Key's equation originally developed for the Advanced Very High Resolution Radiometer (AVHRR) was adapted for use with MODIS Channels 31 and 32.

$$IST = a + bT_{31} + c(T_{31} - T_{32}) + d\{[T_{31} - T_{32}][\sec(\theta) - 1]\}$$

Table 3. Variables for Key's Equation for IST

Variable	Description
a,b,c,d	coefficients determined from multilinear regression of brightness temperatures to estimated surface temperatures
T_{31}	brightness temperature of MODIS channel 31 (11 µm)
T_{32}	brightness temperature of MODIS channel 32 (12 µm)
θ	Sensor scan angle from nadir (radians)

Different coefficients are used for each of the three temperature ranges in the Northern and Southern hemispheres, a total of six coefficient sets.

Table 4. Northern and Southern Hemisphere Coefficients

Coefficients for the Northern Hemisphere
IST coefficients, <240 = -1.5711228087,1.0054774067,1.8532794923,-0.7905176303
IST coefficients, 240-260 = -2.3726968515,1.0086040702,1.6948238801,-0.2052523236
IST coefficients, >260 = -4.2953046345,1.0150179031,1.9495254583,0.197132579
Coefficients for the Southern Hemisphere
IST coefficients, <240 = -0.1594802497,0.9999256454,1.3903881106,-0.4135749071
IST coefficients, 240-260 = -3.3294560023,1.0129459037,1.2145725772,0.1310171301
IST coefficients, >260 = -5.207360416,1.0194285947,1.5102495616,0.2603553496

3.3.1.3 Cloud masks

The major caveat with the IST algorithm is that it is only applicable to clear-sky conditions. Inadequate cloud masking may result in significant error in estimating the IST. The MODIS cloud mask is used to identify clear sky conditions since only pixels with a 95 percent or greater probability of being unobstructed by cloud cover will be considered (Hall et al. 1998; Riggs, Hall, and Salomonson 2003).

3.3.1.4 Calculated Variables

The sea ice algorithm classifies pixels as sea ice, cloud, open ocean, inland water, or land. Sea ice extent and IST are the primary variables of interest in this data set.

3.3.2 Error Sources

As with any upper level product, the characteristics of or anomalies in input data may carry through to the output data product. The following products are input to MYD29:

- MOD021KM - MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 1km, Version 5 - This product is not available; however, a document describing the product titled the MODIS Level 1B Product User's Guide is available from the MODIS Characterization Support Team (MCST) Web site.
- MOD03 - MODIS/Terra Geolocation Fields 5-Min L1A Swath 1km, Version 5
- MOD35_L2 - MODIS/Terra Cloud Mask and Spectral Test Results 5-Min L2 Swath 250m and 1km, Version 5 (This product is not retained).

For example, the sea ice detection algorithm is sensitive to the presence of clouds within the field of view, and it will map clouds as sea ice if for some reason the cloud mask product fails to mask a cloud (Hall et al. 2004). The algorithm assumes that sea ice is snow covered and that snow dominates the reflectance characteristics. As a consequence, the presence of surface melt ponds, small ice floes, polynyas, and leads at subpixel resolution will contribute to errors in identification and mapping of sea ice (Hall et al. 1998).

Melt ponds and leads in the summer months affect the emissivity of the ice surface; therefore, affecting the calculation of ice surface temperature (Hall et al. 1998). The presence of even very thin clouds or fog within the field of view prevent obtaining an accurate IST (Hall et al. 2004). Recent studies in the arctic and Antarctic have shown that under clear sky conditions the IST are accurate to better than ± 1.5 over the 245-270 K range for all ice types (Hall et al. 2004) (Scambos, Haran, and Massom 2006).

3.4 Quality Assessment

All MODIS/Terra and MODIS/Aqua sea ice products are considered validated or at stage 2 meaning that accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation campaigns. Quality indicators for MODIS sea ice data can be found in the following three places:

- AutomaticQualityFlag and the ScienceQualityFlag metadata objects and their corresponding explanations: AutomaticQualityFlagExplanation and ScienceQualityFlagExplanation located in the CoreMetadata.0 global attributes

- Custom local attributes associated with each Scientific Data Set (SDS), for example Ice Surface Temperature
- The Pixel QA SDS that accompanies each data field, for example, Ice Surface Temperature Pixel QA.

These quality indicators are generated during production or in post-production scientific and quality checks of the data product. For more information on local and global attributes, go to one of the following links:

- MOD29 and MYD29 Local Sea Ice Attributes, Version 5
- MOD29 and MYD29 Global Sea Ice Attributes, Version 5

An AutomaticQualityFlag for each SDS is automatically set according to conditions for meeting data criteria in the algorithm. In most cases, the flag is set to either Passed or Suspect, and in rare instances, it may be set to Failed. Suspect means that a significant percentage of the data were anomalous and that further analysis should be done to determine the source of anomalies. The AutomaticQualityFlagExplanation contains a brief message explaining the reason for the setting of the AutomaticQualityFlag. The ScienceQualityFlag and the ScienceQualityFlagExplanation maybe updated after production, either after an automated QA program is run or after the data product is inspected by a qualified scientist. Content and explanation of this flag are dynamic so it should always be examined if present in the external metadata file. In the MYD29 data product, there are two instances of the ScienceQualityFlagExplanation, one for sea ice determined by reflectance data and one for IST written in the metadata

The sea ice algorithm identifies missing data and reports them in the output product. Certain expected anomalous conditions may exist with the input data such as a few missing lines or unusable data from the MODIS sensor. In these cases, the algorithm makes no decision for an affected pixel. Summary statistics are calculated for these conditions and reported as Valid EV Obs Band X percent and Saturated EV Obs Band X percent local attributes. Where X equals 2, 4, or 6 for Sea Ice by Reflectance and 31 or 32 for IST (Riggs, Hall, and Salomonson 2003).

The IST Pixel QA and the Sea Ice by Reflectance Pixel QA data fields provide additional information on algorithm results for each pixel within a MODIS scene, and are used as a measure of usefulness for sea ice data. The QA data are stored as coded integer values and tells if algorithm results were nominal, abnormal, or if other defined conditions were encountered for a pixel. For example, intermediate checks for theoretical bounding of reflectance data and the NDSI ratio are made in the algorithm. Reflectance values should lie within the 0-100 percent range, and the NDSI ratio should lie within the -1.0 to +1.0 range. If these limits are violated, the test for sea ice is still done, but the quality flag is set to Other quality in the Pixel QA field (Riggs, Hall, and Salomonson 2003).

The NASA Goddard Space Flight Center: MODIS Land Quality Assessment Web site provides updated quality information for each product.

3.5 Sensor or Instrument Description

The MODIS instrument provides 12-bit radiometric sensitivity in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm. Two bands are imaged at a nominal resolution of 250 m at nadir, five bands at 500 m, and the remaining bands at 1000 m. A ±55 degree scanning pattern at an altitude of 705 km achieves a 2330 km swath with global coverage every one to two days.

The scan mirror assembly uses a continuously rotating, double-sided scan mirror to scan ±55 degrees, and is driven by a motor encoder built to operate 100 percent of the time throughout the six year instrument design life. The optical system consists of a two-mirror, off-axis afocal telescope which directs energy to four refractive objective assemblies, one each for the visible, near-infrared, short- and mid-wavelength infrared, and long wavelength infrared spectral regions.

The MODIS instruments on the Terra and Aqua space vehicles were built to NASA specifications by Santa Barbara Remote Sensing, a division of Raytheon Electronics Systems. Table 1 contains the instruments' technical specifications:

Table 5. MODIS Technical Specifications

Variable	Description
Orbit	705 km altitude, sun-synchronous, near-polar, circular. Equatorial crossing times: Terra: 10:30 A.M., descending node Aqua: 1:30 P.M., ascending node
Scan Rate	20.3 rpm, cross track
Swath Dimensions	2330 km (cross track) by 10 km (along track at nadir)
Telescope	17.78 cm diameter off-axis, afocal (collimated) with intermediate field stop
Size	1.0 m x 1.6 m x 1.0 m
Weight	228.7 kg
Power	162.5 W (single orbit average)
Data Rate	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization	12 bits
Spatial Resolution	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands (8-36)
Design Life	6 years

3.5.1 Calibration

MODIS has a series of on-board calibrators that provide radiometric, spectral, and spatial calibration of the MODIS instrument. The blackbody calibrator is the primary calibration source for thermal bands between 3.5 µm and 14.4 µm, while the Solar Diffuser (SD) provides a diffuse, solar-illuminated calibration source for visible, near-infrared, and short wave infrared bands. The Solar Diffuser Stability Monitor tracks changes in the reflectance of the SD with reference to the sun so that potential instrument changes are not incorrectly attributed to changes in this calibration source. The Spectroradiometric Calibration Assembly provides additional spectral, radiometric, and spatial calibration.

MODIS uses the moon as an additional calibration technique and for tracking degradation of the SD by referencing the illumination of the moon since the moon's brightness is approximately the same as that of the Earth. Finally, MODIS deep space views provide a photon input signal of zero, which is used as a point of reference for calibration.

For additional details about the MODIS instruments, see NASA's MODIS | About Web page.

4 REFERENCES AND RELATED PUBLICATIONS

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4.2 Related Data Sets

See MODIS | Data Sets for all the MODIS snow cover and sea ice data sets available from NSIDC.

4.3 Related Websites

- MODIS @ NASA Goddard Space Flight Center
- The MODIS Snow and Sea Ice Global Mapping Project

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