MODIS Sea Surface Temperature (SST) Products

Summary:

Sea surface temperature (SST) products have been derived from the MODIS (MODerate Resolution Imaging Spectroradiometer) sensors onboard the NASA Terra and Aqua platforms since November 2000. These SST products are derived from the MODIS mid-infrared (IR) and thermal IR channels and are available in various spatial and temporal resolutions.

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1. Data Set Overview:

Data Set Identification:

This guide refers to PO.DAAC products 162, 163, 184 and 185 under the names Aqua/Terra MODIS Global Level 3 Mapped Thermal IR SST and MODIS Global Level 3 Mapped mid-IR SST respectively.

Data Set Introduction:

SST is derived from the MODIS IR channels using two channels in either the thermal IR (11-12 um) or channels in the mid-IR region (3.8-4.1 um). The approach is similar to the multi-channel sea surface temperature (MCSST) method used to generate AVHRR-based SST.

The MODIS data are available in a variety of spatial resolutions and temporal periods. The Level 3 mapped products are global gridded data sets with all points filled even over land. The Level 3 mapped files are derived from the Level 3 binned files.

Objective/Purpose:

The purpose of MODIS SST is to provide high quality global measurements of this parameter. MODIS SST is superior to AVHRR SST due to the higher sensitivity and lower signal-to-noise characteristics of the MODIS instrument. The mid-IR channels are especially useful in the high water vapor, low-latitude regions compared with previous radiometers. They are also less suspectible to aerosol contamination compared to the 11-12 um channels.

Summary of Parameters:

Sea Surface Temperature

Discussion:

In order to understand the processes involved in global climate change many different scientific measurements are needed. One of the parameters critical to understanding how the oceans affect climate on a global scale is sea surface temperature (SST). An example of the importance of this measurement for climate studies is their use in the study of the Western Boundary Currents of the world's oceans. The Western Boundary Currents play an important role in the Earth's heat balance. They carry a tremendous amount of heat poleward from low-latitude regions. Because the currents exhibit strong SST gradients, the SST measurements can be used to determine their displacements. Knowledge of the displacements, in turn, allows us to improve our understanding of ocean circulation and heat transport. SST measurements are also critical parameters in coupled atmospheric-ocean global circulation models (GCMs) for determining air-sea interaction, atmospheric convection, and model boundary conditions.

Related Data Sets:

AVHRR Pathfinder SST, AVHRR MCSST, and ATSR SST products. Also GHRSST products.

2. Investigator(s):

Investigator(s) Name and Title:

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3. Theory of Measurements:

Briefly, radiative transfer theory is used to correct for the effects of the atmosphere on the observations by utilizing "windows" of the electromagnetic spectrum where little or no atmospheric absorption occurs. Channel radiances are transformed (through the use of the Planck function) to units of temperature, then compared to a-priori (in situ) temperatures for algorithm development. Adjustments to skin temperature are made through comparisons with in situ radiometer measurements.

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

MODIS instrument. More information on MODIS can be found here.

Source/Platform:

NASA Terra and Aqua satellites

Source/Platform Mission Objectives:

The Terra and Aqua platforms contain a number of instruments whose purpose is to observe the Earth's oceans, land and atmosphere to study global climate.

Key Variables:

Terra/Aqua is in a sun-synchronous near polar orbit at an altitude of 705 km with a descending node of 10:30 a.m. The MODIS sensor detects emitted and reflected radiance in 36 channels (windows) spanning the visible to IR spectrum (0.4 - 14.4 um). Quantization is 12 bit. More information can be found here.

Principles of Operation:

MODIS is a scanning radiometer whereby the viewing optics scan side-to-side with respect to the ground track via a rotating mirror. The scan rate is 20.3 rpm. Specifically (from http://ltpwww.gsfc.nasa.gov/MODIS/MODIS.html):

"The Scan Mirror Assembly uses a continuously rotating double-sided scan mirror to scan +/- 55-degree driven by a motor encoder built to operate at 100 percent duty cycle throughout the 6-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 for each of the VIS, NIR, SWIR/MWIR and LWIR spectral regions covering a total spectral range of 0.4 to 14.4 um. "

Sensor/Instrument Measurement Geometry:

A +/- 55-degree scanning pattern at the Terra/Aqua orbit of 705 km altitude achieves a 2330 km ground swath providing global coverage every one to two days.

Manufacturer of Sensor/Instrument:

Raytheon Santa Barbara Remote Sensing, Goleta, California

Calibration:

Specifications:

For the IR channels onboard calibration consists of a v-groove Blackbody as well as a view to space. Additional onboard calibrators consist of a Solar Diffuser, a Spectroradiometric calibration assembly and a Solar Diffuser Stability Monitor.

Tolerance:

The noise equivalent temperature difference (NET) for the IR channels are:

MODIS Channel	Bandwidth (um)	NET (degK)
20	3.66-3.84	0.05
22	3.929-3.989	0.07
23	4.02-4.08	0.07
31	10.78-11.28	0.05
32	11.77-12.27	0.05

Frequency of Calibration:

A blackbody measurement is taken for each scan.

5. Data Acquisition Methods:

Terra and Aqua capture data on onboard tape recorders for later retransmission. MODIS data (along with data from other sensors on Terra and Aqua) are then transferred to ground stations in White Sands, New Mexico, via the Tracking and Data Relay Satellite System (TDRSS).

The data are then sent to the EOS Data and Operations System (EDOS) at the Goddard Space Flight Center. After Level 0 processing at EDOS, the Ocean Biology Processing Group (OBPG) produces the Level 1A, Level 1B, geolocation and cloud mask products. Higher-level geophysical products are also produced by the OBPG. The JPL PO.DAAC is acting as a mirror site for MODIS Level 3 SST products distributed by the OBPG.

6. Observations:

Data Notes:

Currently the MODIS SST algorithm coefficients are derived by regressing MODIS brightness temperature against buoy SST matchups.

Field Notes:

Not Applicable

7. Data Description:

Spatial Characteristics:

The MODIS SST products are distributed at various resolutions separated in ascending and descending orbits. The highest resolution for the Level 3 mapped products is 4.63 km. All Level 3 mapped products are derived from gridding the 4.63 km Level 3 binned data. The 4.63 km observations are themselves derived from binning and averaging (not subsampling) the nominal 1 km observations.

Spatial Coverage:

Global

Spatial Coverage Map:

Not available

Spatial Resolution:

4.63 km, and 9.26 km (mapped products)

Projection:

Cylindrical equal angle projection for the mapped products.

Grid Description:

The 4.63 km mapped product has 4320 rows and 8640 columns The 9.26 km mapped product has 2160 rows and 4320 columns

Temporal Characteristics:

Temporal Coverage:

Data are available from November 2000 to present for Terra products, and December 2002 to present for Aqua.

Temporal Coverage Map:

Not applicable

Temporal Resolution:

Daily, weekly (8 day), monthly and annual.

Data Characteristics:

Parameter/Variable:

Sea surface temperature

Variable Description/Definition:

The temperature of the sea surface

Unit of Measurement:

degrees Celsius

Data Source:

MODIS

Data Range:

-2 to 32 degrees Celsius

Sample Data Record:

Not available.

8. Data Organization:

Data Granularity:

Each Level 3 mapped product for each spatial and temporal resolution are stored in separate files for daytime and nighttime mid-IR and thermal IR data. The mapped products contain an SST array (scaled integers) and a quality flag array. File format is HDF version 4. A description of the Level 3 mapped filename format can be found here.

Data Format:

All data are stored in HDF4 format files.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

The original SST derivation paradigm was designed to use a radiative transfer model in conjunction with atmospheric profile data from radiosonde or atmospheric models (to determine the atmospheric transmittance) to propagate the SST signal to the satellite accounting for absorption and scattering effects and derive the empirical SST algorithm coefficients (Brown and Minnett, 1999). This approach apparently has deficiencies due to improper radiometer characterization. Instead, the SST derivation is similar to the NLSST approach (Walton, 1988)

used in AVHRR processing whereby the coefficients are determined by regressing MODIS brightness temperature to known measured surface temperatures. In this case, drifting and moored buoys are used as the reference. Measurements from the M-AERI (Marine-Atmosphere Emitted Radiance Interferometer) in situ radiometer are then used to convert the regressed SST to a skin SST measurement.

Data Processing Sequence:

Processing Steps:

Processed from level 1A at OBPG to geophsyical products.

Processing Changes:

Most recent version is 5.x for Terra products and 5.x for Aqua products.

Calculations:

Special Corrections/Adjustments:

Currently the empirical coefficients in the MODIS SST algorithm are derived by regressing MODIS brightness temperatures to in situ observations from drifting and moored buoys. Measurements from the M-AERI in situ radiometer are then used to convert the regressed SST to a skin SST measurement (approximately -0.2 degC adjustment).

Calculated Variables:

Skin sea surface temperature.

Graphs and Plots:

Not applicable

10. Errors:

Sources of Error:

One of the greatest limitations is the obstruction by clouds in the field of view. Other sources of error include atmospheric gases and emissions, aerosols, as well as water surface characteristics. The daytime mid-IR SST suffer from reflected sunlight.

Quality Assessment:

Data Validation by Source:

All quality control occurs at OBPG during Level 1 to 2 processing using an extensive suite of tests for cloud contamination etc. In constructing the bins of 1 km observations at each resolution, only

observations of the same quality are binned. Different quality levels are never mixed. For example, a bin of quality level 0 only contains the highest quality 1 km observations that passed all quality control tests. No 1 km pixels of a lessor quality are used to determine the statistics of this bin.

Confidence Level/Accuracy Judgement:

Unknown

Measurement Error for Parameters:

The SST data can be considered accurate to +/- 0.4 degrees Celsius

Additional Quality Assessments:

None

Data Verification by Data Center:

More information can be found in Brown and Minnett (1999)

11. Notes:

Limitations of the Data:

Known Problems with the Data:

Daytime mid-IR SST products suffer from reflected sunlight contamination.

Usage Guidance:

It is highly recommended that the users filter the SST using the commensurate quality files. The flags are: 0 (good), 1 (questionable), 2 (clouds), 255 (land, gross clouds, and other errors). A quality flag of 0 is recommended. Flag 1 can be used under some circumstances.

Any Other Relevant Information about the Study:

Not applicable

12. Application of the Data Set:

Global climate studies, heat transport and ocean circulation.

13. Future Modifications and Plans:

None

14. Software:

Software Description:

The JPL PO.DAAC supplies IDL, C and FORTRAN read software for the MODIS HDF files. The C and FORTRAN read software require that the HDF v4 library be installed.

Software Access:

Read software can be found on the PO.DAAC FTP site.

15. Data Access:

Contact Information:

User Services Office
Physical Oceanography Distributed Active Archive Center (PO.DAAC)
Jet Propulsion Laboratory (JPL)
Phone: (626) 744-5508
Fax: (626) 744-5506
Email: podaac@podaac.jpl.nasa.gov
URL: http://podaac.jpl.nasa.gov

Data Center Identification:

Jet Propulsion Laboratory (JPL)
Physical Oceanography Archive Center (PO.DAAC)

Procedures for Obtaining Data:

Level 3 mapped data are available on the PO.DAAC FTP site.

Data Center Status/Plans:

Ongoing

16. Output Products and Availability:

Currently the Level 3 mapped products are only available via electronic FTP distribution. They are also available via POET, an interactive subsetting tool and also OPenDAP.

17. References:

Walton, C.C., W. G. Pichel, and J.F. Sapper, 1998, The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites, *Journal of Geophysical Research*, 103: (C12) 27999-28012.

Brown, O.B., and P.J. Minnett, 1999, MODIS Infrared Sea Surface Temperature Algorithm Theoretical Basis Document, Ver 2.0, http://modis.gsfc.nasa.gov/data/atbd/atbd_mod25.pdf

18. Glossary of Terms:

Sea Surface Temperature: the temperature of the layer of sea water nearest the atmosphere.

19. List of Acronyms:

AVHRR....Advanced Very High-Resolution Radiometer
EOS....Earth Observing System
FTP....File Transfer Protocol
GAC....Global Area Coverage
HDF....Hierarchical Data Format
IFOV....Internal Field of View
JPL....Jet Propulsion Laboratory
MCSST....Multichannel Sea Surface Temperatures
MODAPS ....MODIS Adaptive Processing System
NAVOCEANO....Naval Oceanographic Office
NASA....National Aeronautics and Space Administration
NOAA....National Oceanic and Atmospheric Administration
OBPG....Ocean Biology Processing Group
PO.DAAC....Physical Oceanography Distributed Active Archive Center
SST....Sea Surface Temperature

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