

Collection-5
MODIS Land Surface Temperature Products
Users' Guide

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ALERT ---

This document is a living document that describes the Collection-5 MODIS Land Surface Temperature (LST) products. It is revised as progress is made in the development and assessment of the LST products. Described is the current state of the MODIS LST products. The purpose of the document is to give the potential user of LST products an understanding of the MODIS LST products and the data in those products.

The MODIS LST products MOD11_L2, MOD11A1, and MOD11B1 have been validated at stage 1 with in situ measurements in more than 50 clear-sky cases in the temperature range from -10°C to 58°C and the column water vapor range of 0.4-4cm, most of them presented in published papers (Wan et al., 2002 and 2004; Coll et al., 2005; Wan, 2008; Wan and Li, 2008). More validation activities are under way.

Please use the Collection-4 Users' Guide for the descriptions of V4/V4.1 Terra MODIS LST products (named starting with MOD11) and V4/V4.1 Aqua MODIS LST products (named starting with MYD11).

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1. Introduction

The MODIS LST products are created as a sequence of products beginning with a swath (scene) and progressing, through spatial and temporal transformations, to daily, eight-day and monthly global gridded products. The algorithms and data content of these LST products are briefly described in this guide with the purpose of providing a user with sufficient information about the content and structure of the data files to enable the user to access and use the data. Overviews of the file format and sequence of MODIS LST products are given first. Descriptions of each algorithm and product content are given in following sections. Publications and documents related to the MODIS LST products are listed in the last two sections.

The major refinements implemented in the V5 daily LST Product Generation Executive (PGE) code are shown in Table 1 (Wan, 2007). This V5 PGE code has been used in the Collection-5 (C5) reprocessing of the MODIS LST product.

Table 1, major refinements implemented in the V5 daily LST code (PGE16).

| no. | Specification / Action | in V4 | in V5 |
|-----|-----------------------------------------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | clear-sky pixels defined by MODIS cloudmask | at 99% confidence over land at 66% confidence over lakes | at confidence of $\geq 95\%$ over land $\leq 2000\text{m}$ at confidence of $\geq 66\%$ over land $> 2000\text{m}$ at confidence of $\geq 66\%$ over lakes |
| 2 | temporal averaging in the 1km LST product (M*D11A1) | yes | no |
| 3 | grid size of LST/emissivities in M*D11B1 retrieved from day/night algorithm | 5km x 5km (exactly 4.63km) | 6km x 6km (exactly 5.56km) |
| 4 | number of sub-ranges of zenith view angles | 5 for the whole scan swath | 2x8 for the whole scan swath |
| 5 | effect of topographic slope in the M*D11B1 grid | not considered | considered in the QA |
| 6 | option of combined use of Terra and Aqua data in the day/night algorithm | no | yes |
| 7 | incorporate the split-window method into the day/night algorithm | partially with initial Ta & cwv, and variables of em31 & em32 | fully with em31, em32, Ta and cwv as variables in iterations |
| 8 | removing cloud-contaminated LSTs | not implemented | implemented for M*D11A1 and M*D11B1 |

1.1. File Format of LST Products

The MODIS LST products are archived in Hierarchical Data Format - Earth Observing System (HDF-EOS) format files. HDF, developed by the NSCA, is the standard archive format for EOS Data Information System (EOSDIS) products. The LST product files contain global attributes (metadata) and scientific data sets (SDSs) (arrays) with local

attributes. Unique in HDF-EOS data files is the use of HDF features to create point, swath, and grid structures to support geolocation of data. These structures (Vgroups and Vdata) provide geolocation relationships between data in an SDS and geographic coordinates (latitude and longitude or map projections) to support mapping the data. Attributes (metadata), global and local, provide various information about the data. Users unfamiliar with HDF and HDF-EOS formats may wish to consult Web sites listed in the Related Web Sites section for more information.

LST data product files contain three EOS Data Information System (EOSDIS) Core System (ECS) global attributes, which are also referred to as metadata by ECS. These ECS global attributes (*CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0*) contain information relevant to production, archiving, user services, geolocation and analysis of data. The ECS global attributes are written in parameter value language (PVL) and are stored as a character string. Metadata and values are stored as objects within the PVL string. Results of the LST algorithms are stored as SDSs with local attributes. Local attributes include summary statistics and other information about the data in an SDS or a key to data values. Detailed descriptions of each LST product are given in following sections.

Products may also contain product specific attributes (PSAs) defined by the product developers as part of the ECS *CoreMetadata.0* attribute. Geolocation and gridding relationships between HDF-EOS point, swath, and grid structures and the data are contained in the ECS global attribute, *StructuralMetadata.0*.

A separate file containing metadata will accompany data products ordered from a DAAC. That metadata file will have a .met extension and is written in PVL. The .met file contains some of the same metadata as in the product file but also has other information regarding archiving and user support services as well as some post production quality assurance (QA) information relevant to the product file ordered. The post production QA metadata may or may not be present depending on whether or not the data file has been investigated. The .met file should be examined to determine if post production QA has been applied to the product file. (The Quality Assurance sections of this guide provide information on post production QA.)

The data products were generated in the science data production system using the HDF-EOS toolkit, Science Data Processing (SDP) Toolkit, HDF API and the C programming language. Various software packages, commercial and public domain, are capable of accessing the HDF-EOS files.

1.2. Sequence of LST Products

LST data products are produced as a series of seven products. The sequence begins as a swath (scene) at a nominal pixel spatial resolution of 1km at nadir and a nominal swath coverage of 2030 or 2040 lines (along track, about five minutes of MODIS scans) by 1354 pixels per line. A summarized listing of the sequence of products is given in Table 2. Products in EOSDIS are labeled as Earth Science Data Type (ESDT). The ESDT label "shortname" is used to identify the LST data products. Each LST product in the sequence is built from the previous LST products. These LST products are identified, in part, by

product levels in EOSDIS which indicate what spatial and temporal processing has been applied to the data.

Data product levels briefly described: Level 1B (L1B) is a swath (scene) of MODIS data geolocated to latitude and longitude centers of 1 km resolution pixels. A level 2 (L2) product is a geophysical product that remains in latitude and longitude orientation; it has not been temporally or spatially manipulated. A level 3 (L3) product is a geophysical product that has been temporally and or spatially manipulated, and is usually in a gridded map projection format referred to as tiles. Each tile is a piece, e.g., about 1113km by 1113km in 1200 rows by 1200 columns, of a map projection.

Table 2. Summary of the MODIS LST data products.

| Earth Science Data Type (ESDT) | Product Level | Nominal Data Array Dimensions | Spatial Resolution | Temporal Resolution | Map Projection |
|--------------------------------|---------------|--------------------------------------------|----------------------|---------------------|----------------------------|
| MOD11_L2 | L2 | 2030 or 2040 lines by 1354 pixels per line | 1km at nadir | swath (scene) | None. (lat,lon referenced) |
| MOD11A1 | L3 | 1200 rows by 1200 columns | 1km (actual 0.927km) | daily | Sinusoidal |
| MOD11B1 | L3 | 200 rows by 200 columns | 6km (actual 5.56km) | daily | Sinusoidal |
| MOD11A2 | L3 | 1200 rows by 1200 columns | 1km (actual 0.927km) | eight days | Sinusoidal |
| MOD11C1 | L3 | 360° by 180° (global) | 0.05° by 0.05° | daily | equal-angle geographic |
| MOD11C2 | L3 | 360° by 180° (global) | 0.05° by 0.05° | eight days | equal-angle geographic |
| MOD11C3 | L3 | 360° by 180° (global) | 0.05° by 0.05° | monthly | equal-angle geographic |

Brief descriptions of the LST data products are given here to give perspective to the sequence. Expanded descriptions of the LST products are given in following sections.

The first product, MOD11_L2, is a LST product at 1km spatial resolution for a swath. This product is the result of the generalized split-window LST algorithm (Wan and Dozier, 1996). Geolocation data (latitude and longitude) at a coarse resolution (5 lines by 5 samples) is also stored in the product. The second product, MOD11A1, is a tile of daily LST product at 1km spatial resolution. It is generated by mapping the pixels in the MOD11_L2 products for a day to the Earth locations on the sinusoidal projection. The third product, MOD11B1, is a tile of daily LST and emissivities at 6km spatial resolution. It is generated by the day/night LST algorithm (Wan and Li, 1997). The fourth product,

MOD11A2, is an eight-day LST product by averaging from two to eight days of the MOD11A1 product. The fifth product, MOD11C1, is a daily global LST product in a geographic projection. It is created by assembling the MOD11B1 daily tiles together and resampling the SDSs at 6km grids to the 0.05° spatial resolution of the Climate Modeling Grid (CMG) cells. The sixth product, MOD11C2, is an eight-day composite of LST at the same resolution as MOD11C1. The seventh product, MOD11C3, is a monthly composite of LST at the same resolution as MOD11C2.

The day/night LST algorithm needs a pair of daytime and nighttime L1B data in seven TIR bands, atmospheric temperature and water vapor in the MODIS atmospheric product MOD07_L2. BRDF parameters in the MODIS BRDF product MOD43B1C are also used since the V4 processing.

2. MOD11_L2 LST Product

This product is generated using the MODIS sensor radiance data product (MOD021KM), the geolocation product (MOD03), the atmospheric temperature and water profile product (MOD07_L2), the cloud mask product (MOD35_L2), the quarterly landcover (MOD12Q1), and snow product (MOD10_L2). The output file contains SDSs of LST, quality assurance (QA), error in LST, emissivities in bands 31 and 32, viewing zenith angle and time, latitude and longitude (each set of latitude and longitude for every 5 scan lines and 5 pixels), local attributes, and global attributes. This LST product is generated by the generalized split-window LST algorithm (Wan and Dozier, 1996). For complete global coverage a MOD11_L2 LST product would be generated for all swaths acquired in daytime and nighttime on the Earth including the polar regions.

The algorithm and data product contents for MOD11_L2 are described in the following sections.

2.1. Algorithm Description

A brief sketch of the LST algorithm for MOD11_L2 is described here for the purpose of aiding the user in understanding and interpreting the data product.

The LST retrieval in a MODIS swath is constrained to pixels that:

- (1). have nominal Level 1B radiance data in bands 31 and 32,
- (2). are on land or inland water,
- (3). are in clear-sky conditions at a confidence (defined in MOD35) of $\geq 95\%$ over land $\leq 2000\text{m}$ or $\geq 66\%$ over land $> 2000\text{m}$, and at a confidence of $\geq 66\%$ over lakes.

Data inputs to the LST algorithm are listed in Table 3.

Clouds are masked with the MODIS Cloud Mask data product (MOD35_L2). Because band 22 is used in the 4-11 micron test to determine the cloudiness of a pixel in the MODIS cloudmask algorithm, the noisy fourth channel in band 22 produced quite a lot of (cloud) strips in the cloudmask product based on the old A-side MODIS data (prior to October 30, 2000). To avoid the strips caused by the noisy channels, the cloudmask in all fourth channels of the scan cubes (one scan cube contains ten channels in each band) is refined with the adjacent pixels in the third and fifth channels.

Masking of oceans is done with the 1 km resolution land/water mask, contained in the MODIS geolocation product (MOD03).

Table 3. MODIS data product inputs to the MODIS LST algorithm for the MOD11_L2 product.

| ESDT | Long Name | Data Used |
|----------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| MOD021KM | MODIS Level 1B Calibrated and Geolocated Radiances | EV_1KM_Emissive for MODIS bands: 31 (11.03 μm) 32 (12.02 μm) Latitude (every 5 lines) Longitude (every 5 pixels) |
| MOD03 | MODIS Geolocation | Land/Water Mask Height Sensor Zenith Angles Solar Zenith Angles Latitude Longitude EV start time |
| MOD35_L2 | MODIS Cloud Mask | Cloud_Mask |
| MOD07_L2 | MODIS Atmospheric Profile | Retrieved_Temperature_Profile Water_Vapor |
| MOD12Q1 | Land Cover | Land_Cover_Type_1 |
| MOD10_L2 | MODIS Snow Cover | Snow Cover |

Emissivities in bands 31 and 32 are estimated by the classification-based emissivity method (Snyder and Wan, 1998) according to land cover types in the pixel determined by the input data in quarterly Land Cover (MOD12Q1) and daily Snow Cover (MOD10_L2). The land-cover product generated from MODIS data is used in the MODIS LST processing. A large uncertainty may exist in such estimated emissivities in semi-arid and arid areas. So the quality of the MOD11_L2 product may not be very good in these areas. Note that the cloud-contaminated LSTs in the MOD11_L2 product are not removed in the C5 processing.

2.2. Scientific Data Sets (SDS)

The MODIS L2 LST product contains nine scientific data sets (SDSs): LST, QC, Error_LST, Emis_31, Emis_32, View_angle, View_time, Latitude, and Longitude. The first seven DSDs are for 1km pixels. The last two DSDs are coarse resolution (five lines by five samples) latitude and longitude data. Each set of them correspond to a center pixel of a 5 lines by 5 pixels in the LST SDS. A mapping relationship of geolocation data to the first seven DSDs is specified in the global attribute *StructMetadata.0*. The mapping relationship was created by the HDF-EOS SDPTK toolkit during production. Geolocation data is mapped to the first seven DSDs data with an offset = 2 and increment = 5. The first element (0,0) in the geolocation SDSs corresponds to element (2,2) in LST SDS, then increments by 5 in the cross-track or along-track direction to map geolocation data to the LST SDS element. Details are shown in Table 4.

Table 4. The SDSs in the MOD11_L2 product.

| SDS Name | Long Name | Number Type | Unit | Valid Range | Fill Value | scale factor | add offset |
|------------|-----------------------------------------------------------------------|-------------|--------|-----------------|------------|--------------|------------|
| LST | Land-surface temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC | Quality control for LST and emissivity | uint16 | none | 0-65535 | 0 | NA | NA |
| Error_LST | Land-surface temperature error | uint8 | K | 1-255 | 0 | 0.04 | 0. |
| Emis_31 | Band 31 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_32 | Band 32 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| View_angle | zenith angle of MODIS viewing at the pixel | uint8 | deg | 0-180 | 255 | 0.5 | 0 |
| View_time | Time* of Land-surface Temperature observation (* as local solar time) | uint8 | hrs | 0-240 | 255 | 0.1 | 0 |
| Latitude | Latitude of every 5 scan lines and 5 pixels | float32 | degree | -90.0 to 90.0 | -999.0 | NA | NA |
| Longitude | Longitude of every 5 scan lines and 5 pixels | float32 | degree | -180.0 to 180.0 | -999.0 | NA | NA |

Note that the Error_LST value is only an estimated value. It is quite conservative in real clear-sky conditions. However, the effect of cloud contaminations is not considered in the error estimation.

2.3. Local Attributes

Archived with the "LST" SDS are local attributes including the coefficients of the calibration which converts the SDS value to real LST value in K. HDF predefined local attributes (Table 5) describe characteristics of the data.

Table 5. HDF-predefined local attributes for SDS LST in the MOD11_L2 product.

| Attribute Name | Reserved Label(s) | Definition | Sample Value |
|----------------|-------------------|-------------------------------------------------|----------------------------------|
| Label | long_name | Long Name of the SDS | Land-surface Temperature |
| Unit | units | SI units of the data, if any | K |
| Format | Number Type | How the data are stored | uint16 (16-bit unsigned integer) |
| Range | valid_range | Max and min values within a selected data range | 7500-65535 * |
| Fill Value | _FillValue | Data used to fill gaps in the swath | 0 |
| Calibration | scale_factor | scaling factor | 0.02 |
| | add_offset | add offset | 0. |
| | scale_factor_err | scaling factor error | 0. |
| | add_offset_err | add offset error | 0. |
| | calibrated_nt | calibrated nt | 0. |

* The number 65535 in uint16 may be shown as -1s in 16-bit integer by some software toolkits, for example, by ncdump in the HDF toolkit.

The effective calibration formula for the "LST" SDS is

$LST = \text{the SDS data in uint16} * 0.02$, giving a value in the range of 150-1310.7K.

2.4. Global Attributes

There are three global ECS attributes, i.e., *CoreMetadata.0*, *ArchiveMetadata.0*, and *StructMetadata.0*, in the MOD11_L2 data product. Contents of these global attributes were determined and written during generation of the product and are used in archiving and populating the EOSDIS database to support user services. They are stored as very long character strings in parameter value language (PVL) format. Descriptions of the global attributes are given here to assist the user in understanding them.

CoreMetadata.0 is the global attribute in which information compiled about the product during product generation is archived and is used to populate the EOSDIS database to support user services. The content of the global attributes with sample values and comment of definition are listed in Table 6, Table 7, and Table 8, respectively. The user wanting detailed explanations of the global attributes and related information should query the EOSDIS related web sites.

Table 6. Listing of objects in the global attribute *CoreMetadata.0* in MOD11_L2.

| Object Name | Sample Value | Comment |
|---------------------|----------------------------------------------------|--------------------------------------------------------------------------|
| ShortName | "MOD11_L2" | ESDT name of product |
| VersionID | 5 | ECS Version |
| ReprocessingActual | "reprocessed" | |
| ReprocessingPlanned | "further update is anticipated" | Expect that products will be reprocessed one or more times. |
| LocalGranuleID | "MOD11_L2.A2000095.1915.005.20006208231007.hdf" | |
| DayNightFlag | "Day" | Day , Night or Both. |
| ProductionDateTime | "2006-07-27T23:10:07.000Z" | |
| LocalVersionID | "5.3.5A" | Version of algorithm delivered from the SCF. |
| PGEVersion | "5.3.6" | Version of production generation executable. |
| InputPointer | "MOD03.A2000095.1915.005.2006188045128.hdf", "..." | Location of input files in the production system. |
| RangeBeginningDate | "2000-04-04" | Beginning and ending times of the first and last scan line in the swath. |
| RangeBeginningTime | "19:15:00.000000" | |
| RangeEndingDate | "2000-04-04" | |
| RangeEndingTime | "19:20:00.000000" | |
| ExclusionGRingFlag | "N" | Geographic bounds of swath coverage. |
| GRingPointLatitude | [54.085346, 49.240036, 32.346612, 35.789540] | |
| GRingPointLongitude | [134.529204, 100.841011, 110.349156, | |

| | | |
|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| | -135.759611] | |
| GRingPointSequenceNo | [1,2,3,4] | |
| OrbitNumber | 1579 | |
| EquatorCrossingLongitude | -131.114787 | |
| EquatorCrossingDate | "2000-04-04" | |
| EquatorCrossingTime | "19:29:39.345204" | |
| ParameterName | "MODIS LST" | |
| AutomaticQualityFlag | "Passed" | Result of automated checks during the run of the algorithm that screen for significant amounts of anomalous data. |
| AutomaticQualityFlagExplanation | "No automatic quality assessment is performed in the PGE." | Explanation of result of automated QA checks made during execution. |
| ScienceQualityFlag | "Not Investigated" | Set by LST investigator after post-production investigation |
| ScienceQualityFlagExplanation | "See http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/qaFlagPage.cgi?sat=terra the product Science Quality status." | Explanation of Science Flag |
| QAPercentMissingData | 0 | 0-100 |
| QAPercentCloudCover | 60 | 0-100 |
| AncillaryInputPointer | "MOD03.A2000095.1915.005.2006188045128.hdf" | Location of geolocation input product in production system. |
| AncillaryInputType | "Geolocation" | Type of ancillary data referenced by pointer. |
| AssociatedSensorShortName | "MODIS" | |
| AssociatedPlatformShortName | "Terra" | |
| AssociatedInstrumentShortName | "MODIS" | |
| Product Specific Attributes (PSA) | | |
| QAPercentGoodQuality | 29 | Summary quality assurance statistic for data product. Range is from 0-100. |
| QAPercentOtherQuality | 8 | |
| QAPercentNotProducedCloud | 33 | |
| QAPercentNotProducedOther | 29 | |
| GranuleNumber | 233 | Unique granule identifier |
| QAFractionGoodQuality | 0.2947352 | Summary fraction of the LST product. Range is from 0.0 to 1.0. |
| QAFractionOtherQuality | 0.0831999 | |
| QAFractionNotProducedCloud | 0.3331286 | |
| QAFractionNotProducedOther | 0.2889363 | |

The four QAFraction PSAs are specially useful to granules in ocean regions where only a small number of island pixels exist. Because the total number of land and coastal pixels is highly variable in granules covering both land and ocean, the values of QAPercent and QAFraction PSAs are calculated on the base of the total number of all pixels in a granule. Therefore, we can always calculate how many pixels with LST in good quality and other quality from these PSA values, even for island pixels.

The ECS global attribute *ArchiveMetadata.0* contains information relevant to production of the data product. It also contains an alternate bounding of geographic coverage of the swath. These data may be useful in determining what version of the algorithm was used to generate the product. Contents are described in Table 7.

Table 7. Listing of objects in the global attribute *ArchiveMetadata.0* in MOD11_L2.

| Object Name | Typical Value | Comment |
|--------------------------------|----------------------------------------------------------------------|------------------------------------------------------|
| EastBoundingCoordinate | -100.843259 | Extent of swath coverage, in latitude and longitude. |
| WestBoundingCoordinate | -135.743222 | |
| NorthBoundingCoordinate | 54.070671 | |
| SouthBoundingCoordinate | 32.460855 | |
| AlgorithmPackageAcceptanceDate | "102004" | Algorithm Descriptors |
| AlgorithmPackageMaturityCode | "Normal" | |
| AlgorithmPackageName | "MOD_PR11A" | |
| AlgorithmPackageVersion | "5" | |
| InstrumentName | "Moderate-Resolution Imaging SpectroRadiometer" | |
| ProcessingDateTime | "2006-07-27T23:10:07.000Z" | |
| LongName | "MODIS/Terra Land Surface Temperature/Emissivity 5-Min L2 Swath 1km" | |
| ProcessingCenter | "MODAPS" | |
| SPSOParameters | "2484 and 3323" | |
| LocalInputGranuleID | "MOD021KM.A2000095.1915..." | input L1B HDF file. |

The *StructMetadata.0* global attribute is used by the HDF-EOS toolkit to specify the mapping relationships between the geolocation data and the LST data (SDSs). Mapping relationships are unique in HDF-EOS and are stored in the product using HDF structures. Description of the mapping relationships is not given here. Use of HDF-EOS toolkit, other EOSDIS supplied toolkits may be used to geolocate the data.

Table 8. Listing of objects in the global attribute *StructMetadata.0* in MOD11_L2.

| Object | Definition |
|-------------|----------------------------------------|
| DIMENSION_1 | along_swath_lines_1km (10*nscans) |
| DIMENSION_2 | Cross_swath_pixels_1km (Max_EV_frames) |

| | |
|----------------|-------------------------------------------------------------------------------------------------------|
| DIMENSION_3 | Coarse_swath_lines_5km (2*nscans) |
| DIMENSION_4 | Coarse_swath_pixels_5km (Max_EV_frames/5) |
| DIMENSIONMAP_1 | GeoDimension= Coarse_swath_lines_5km DataDimension= along_swath_lines_1km Offset=2 Increment=5 |
| DIMENSIONMAP_2 | GeoDimension= Cross_swath_pixels_1km DataDimension= Cross_swath_pixels_1km Offset=2 Increment=5 |
| GEOFIELD_1 | GeoFieldName=Latitude |
| GEOFIELD_2 | GeoFieldName=Longitude |
| DATAFIELD_1 | DataFieldName=LST |
| DATAFIELD_2 | DataFieldName=QC |
| DATAFIELD_3 | DataFieldName=Error_LST |
| DATAFIELD_4 | DataFieldName=Emis_31 |
| DATAFIELD_5 | DataFieldName=Emis_32 |
| DATAFIELD_6 | DataFieldName=View_angle |
| DATAFIELD_7 | DataFieldName=View_time |

2.5. Quality Assurance

Indicators of quality are given in metadata objects in the *CoreMetadata.0* global attribute QA and in a quality control (QC) SDS, generated during production, or in post-product scientific and quality checks of the data product. QA metadata objects in the *CoreMetadata.0* global attribute are the AutomaticQualityFlag and the ScienceQualityFlag and their corresponding explanations. The AutomaticQualityFlag is set according to rules based on data conditions encountered during a run of the LST algorithm. Setting of this QA flag is fully automated. The rules used to set it are liberal; nearly all of the data or intermediate calculations would have to be anomalous for it to be set to "Failed". Typically, it will be set to "Passed". The ScienceQualityFlag is set post production either after an automated QA program is run on the data product or after the data product is inspected by a qualified LST investigator. Content and explanation of this flag are dynamic so it should always be examined if present. A sampling of products will be inspected. Sampling may be random, in support of field campaigns, or event driven.

The QC SDS in the data product provides additional information on algorithm results for each pixel. The QC SDS unsigned 16-bit data are stored as bit flags in the SDS. This QC information can be extracted by reading the bits in the 16-bit unsigned integer. The purpose of the QC SDS is to give the user information on algorithm results for each pixel that can be viewed in a spatial context. The QC information tells if algorithm results were nominal, abnormal, or if other defined conditions were encountered for a pixel. The QC information should be used to help determine the usefulness of the LST data for a user's needs. The bit flags in the QC SDS are listed in Table 9.

Table 9. Bit flags defined in the QC SDS in the MOD11_L2 product. Note that bit 0 is the least significant bit.

| bits | Long Name | Key |
|---------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 & 0 | Mandatory QA flags | 00=Pixel produced, good quality, not necessary to examine more detailed QA 01=Pixel produced, unreliable or unquantifiable quality, recommend examination of more detailed QA 10=Pixel not produced due to cloud effects 11=Pixel not produced primarily due to reasons other than cloud (such as ocean pixel, poor input data) |
| 3 & 2 | Data quality flag | 00=good data quality of L1B in bands 31 and 32 01=missing pixel 10=fairly calibrated 11=poorly calibrated, LST processing skipped |
| 5 & 4 | Cloud flag | 00=cloud free pixel 01=pixel only with thin cirrus 10=fraction of sub-pixel clouds $\leq 2/16$ 11=LST affected by nearby clouds |
| 7 & 6 | LST model number | 00=generalized split-window method 01=day/night method 10=high LST w/o atmospheric & emis corrections 11=cirrus effects corrected |
| 9 & 8 | LST quality flag | 00=no multi-method comparison 01=multi-method comparison done 10=fair consistency 11=good consistency |
| 11 & 10 | Emissivity flag | 00=inferred from land cover type 01=MODIS retrieved 10=TBD 11=default value used |
| 13 & 12 | Emis quality flag | 00=emis quality not checked 01=emis quality checked with land cover type 10=emis quality checked with NDVI 11=emis view-angle dependence checked |
| 15 & 14 | Emis error flag | 00=error in emis_31 emis_32 ≤ 0.01 01=error in emis_31 emis_32 ≤ 0.02 10=error in emis_31 emis_32 ≤ 0.04 11=error in emis_31 emis_32 > 0.04 |

It should be noted that fillvalue 0 listed for the SDS QC in Table 9 is valid for the bit flags only when a fillvalue 0 is present in the SDS LST pixels (so the 00-01 bits in the QC pxels have a value of 10 or 11). A value of 0 in the QC bit flags means good data quality, cloud free, or small error in emis_31 and emis_32, and etc, if a pixel has a valid LST value. We do not discriminate fillvalue 0 from valid value 0 for all bit flags in the QC in order to minimize the data volume. Users should read SDSs LST and QC at the same time in order to properly interpret their values in an easy way.

3. MOD11A1 Daily LST

The daily level 3 LST product at 1km spatial resolution is a tile of daily LST product gridded in the Sinusoidal projection. A tile contains 1200 x 1200 grids in 1200 rows and 1200 columns. The exact grid size at 1km spatial resolution is 0.928km by 0.928km.

3.1. Algorithm Description

The daily MOD11A1 LST product is constructed with the results in the MOD11_L2 products of a day through mapping the SDSs of all pixels in MOD11_L2 products onto grids in the sinusoidal projection and averaging the LST values of overlapping pixels in each grid with overlapping areas as weight.

As latitude increases beyond 30 degrees, there may be multiple MODIS observations in clear-sky conditions. In V5 MOD11A1 product, LST values at all grids are from single clear-sky MODIS observations by selecting LSTs in MOD11_L2 files at smaller viewing zenith angles or the LSTs at larger zenith angles but their values being larger by at least 2K.

3.2. Scientific Data Sets (SDS)

The SDSs in the MOD11A1 product include LST_Day_1km, QC_Day, Day_view_time, Day_view_angle, LST_Night_1km, QC_Night, Night_view_time, Night_view_angle, Emis_31, Emis_32, Clear_day_cov, Clear_night_cov, as shown in Table 10. **Note that the scale factor and offset for Day_view_angle and Night_view_angle in V5 Level-3 MODIS LST products have been changed so that a negative sign of the viewing angle means MODIS viewing the grid from east. The view zenith angle itself is always a positive number, the zenith angle from nadir.** The information of MODIS viewing the grid from east or west may be important in understanding the view angle effect in the temporal variations in LSTs, especially in rugged regions.

Table 10. The SDSs in the MOD11A1 product.

| SDS Name | Long Name | Number Type | Unit | Valid Range | Fill Value | scale factor | add offset |
|-----------------|----------------------------------------------------------------------|-------------|------|-------------|------------|--------------|------------|
| LST_Day_1km | Daily daytime 1km grid Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Day | Quality control for daytime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Day_view_time | (local solar) Time of daytime Land-surface Temperature observation | uint8 | hrs | 0-240 | 255 | 0.1 | 0 |
| Day_view_angle | View zenith angle of daytime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| LST_Night_1km | Daily nighttime 1km grid Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Night | Quality control for nighttime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Night_view_time | (local solar) Time of nighttime Land-surface Temperature observation | uint8 | hrs | 0-240 | 255 | 0.1 | 0 |

| | | | | | | | |
|------------------|------------------------------------------------------------|--------|------|-------------|-----|--------|-------|
| Night_view_angle | View zenith angle of nighttime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| Emis_31 | Band 31 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_32 | Band 32 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Clear_day_cov | day clear-sky coverage | uint16 | none | 0- 65535 | 0 | 0.0005 | 0. |
| Clear_night_cov | night clear-sky coverage | uint16 | none | 0- 65535 | 0 | 0.0005 | 0. |

3.3. Local Attributes

The local attributes for SDSs LST_Day_1km and LST_Night_1km are similar to those in Table 5.

3.4. Global Attributes

Three ECS global attributes and 12 product-specific global attributes are stored as metadata. The ECS global attributes, *CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0* are stored as very long character strings in PVL format.

CoreMetadata.0 contains information about the product during production and is used to populate the EOSDIS data base for user support. A listing of objects along with sample values is given in Table 11.

Table 11. *CoreMetadata.0* of the MOD11A1 data product.

| Object Name | Sample Value | Comment |
|---------------------|--------------------------------------------|------------------------------------------------------------|
| ShortName | "MOD11A1" | ESDT name of product |
| VersionID | 5 | ESC Version |
| ReprocessingActual | "reprocessed" | Number of times processed. |
| ReprocessingPlanned | "further update is anticipated" | Expect that products will be reprocessed one or more times |
| LocalGranuleID | "MOD11A1.A2000095.h08v05.005.2006209..hdf" | Name of the granule. |
| DayNightFlag | "Both" | |
| ProductionDateTime | "2006-07-28T06:11:25.000Z" | Time granule was produced. |
| LocalVersionID | "5.3.5AS" | Version of algorithm delivered |

| | | |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| | | from the SCF |
| PGEVersion | "5.3.6" | Version of PGE in MODAPS. |
| InputPointer | "MOD03.A2000095.1920...hdf", "MOD021KM.A2000095...hdf", ... | Location of input files in the production system |
| RangeBeginningDate | "2000-04-04" | Beginning and ending times of the first and last scan line in the swath |
| RangeBeginningTime | "00:00:00" | |
| RangeEndingDate | "2000-04-04" | |
| RangeEndingTime | "23:59:59" | |
| ExclusionGRingFlag | "N" | latitude and longitude values of the corner grids in the tile |
| GringPointLatitude | [39.995833, 39.995833, 30.004167, 30.004167] | |
| GringPointLongitude | [-130.540731, -117.497536, -103.941403, -115.479755] | |
| GringPointSequenceNo | [1, 2, 3, 4] | |
| ParameterName | "MOD 1KM L3 LST" | Parameter for which QA statistics are given in this metadata object. |
| AutomaticQualityFlag | "Passed" | Result of automated checks done on the data during a run of algorithm. |
| AutomaticQualityFlagExplanation | "No automatic quality assessment is performed in the PGE." | Explanation of result of automated QA checks made during execution. |
| ScienceQualityFlag | "Not Investigated" | |
| ScienceQualityFlagExplanation | "See http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/qaFlagPage.cgi?sat=terra for the | Explanation of Science |

| | | |
|----------------------------------------------|----------------------------------|-----------------------------------------------------------------|
| | product Science Quality status." | QualityFlag |
| QAPercentMissingData | 0 | 0 - 100 |
| QAPercentCloudCover | 2 | 0 - 100 |
| AssociatedPlatformShortName | "Terra" | |
| AssociatedInstrumentShortName | "MODIS" | |
| AssociatedSensorShortName | "MODIS" | |
| **Product Specific Attributes (PSA)** | | |
| QAPercentGoodQuality | 32 | Summary quality assurance statistic for data product. (0 - 100) |
| QAPercentOtherQuality | 45 | |
| QAPercentNotProducedCloud | 2 | |
| QAPercentNotproducedOther | 21 | |
| N_GRAN_POINTERS | "27" | the number of granules considered for the tile |
| HorizontalTileNumber | "08" | |
| VerticalTileNumber | "05" | |
| TileID | "11008005" | |
| QAFractionGoodQuality | 0.3172743 | Summary fraction of the LST product. Range is from 0.0 to 1.0. |
| QAFractionOtherQuality | 0.4461764 | |
| QAFractionNotProducedCloud | 0.0237937 | |
| QAFractionNotProducedOther | 0.2127556 | |

The ECS global attribute *ArchiveMetadata.0* contains information relevant to the input data, an alternate geographic coverage bounds, and information relevant to version of the algorithm and product. A listing of objects along with sample values is given in Table 12.

Table 12. *ArchiveMetadata.0* of the MOD11A1 data product.

| Object Name | Sample Value | Comment |
|--------------------------------|-------------------------------------------------|-----------------------|
| HorizontalTileNumber | "08" | |
| VerticalTileNumber | "05" | |
| AlgorithmPackageAcceptanceDate | "102004" | Algorithm Descriptors |
| AlgorithmPackageMaturityCode | "Normal" | |
| AlgorithmPackageName | "MOD_PR11A" | |
| AlgorithmPackageVersion | "5" | |
| InstrumentName | "Moderate-Resolution Imaging SpectroRadiometer" | |
| ProcessingDateTime | "2006-07-27T23:09:54.000Z" | |

| | | |
|-------------------------|-------------------------------------------------------------|------------------------------|
| LongName | "MODIS Level-3 1km Land Surface Temperature and Emissivity" | |
| ProcessingCenter | "MODAPS" | |
| SPSOParameters | "2484 and 3323" | |
| LocalInputGranuleID | "1920,0535,0540,0715,1740,1915" | only keep the time IDs |
| EastBoundingCoordinate | -103.941403 | Extent of the tile coverage. |
| WestBoundingCoordinate | -130.540731 | |
| NorthBoundingCoordinate | 39.995833 | |
| SouthBoundingCoordinate | 30.004167 | |

The *StructMetadata.0* global attribute (Table 13) is used by the HDF-EOS toolkit to create the mapping relationships between the defined grid and data (SDSs).

Table 13. Listing of objects in the global attribute *StructMetadata.0* in MOD11A1.

| Object | Definition |
|--------------|--------------------------------|
| DIMENSION_1 | XDim = 1200 |
| DIMENSION_2 | YDim = 1200 |
| DataField_1 | DataFieldName=LST_Day_1km |
| DataField_2 | DataFieldName=QC_Day |
| DataField_3 | DataFieldName=Day_view_time |
| DataField_4 | DataFieldName=Day_view_angle |
| DataField_5 | DataFieldName=LST_Night_1km |
| DataField_6 | DataFieldName=QC_Night |
| DataField_7 | DataFieldName=Night_view_time |
| DataField_8 | DataFieldName=Night_view_angle |
| DataField_9 | DataFieldName=Emis_31 |
| DataField_10 | DataFieldName=Emis_32 |
| DataField_11 | DataFieldName=Clear_day_cov |
| DataField_12 | DataFieldName=Clear_night_cov |

3.5. Quality Assurance

The bit flags defined for the quality assurance SDSs QC_day and QC_Night are listed in Table 14.

Table 14. Bit flags defined for SDSs QC_day and QC_Night in MOD11A1. Note that bit 0 is the least significant bit.

| bits | Long Name | Key |
|-------|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 & 0 | Mandatory QA flags | 00=LST produced, good quality, not necessary to examine more detailed QA 01=LST produced, other quality, recommend examination of more detailed QA 10=LST not produced due to cloud effects 11=LST not produced primarily due to reasons other than cloud |
| 3 & 2 | Data quality flag | 00=good data quality 01=other quality data 10=TBD 11=TBD |
| 5 & 4 | Emis Error flag | 00=average emissivity error <= 0.01 01=average emissivity error <= 0.02 10=average emissivity error <= 0.04 11=average emissivity error > 0.04 |
| 7 & 6 | LST Error flag | 00=average LST error <= 1K 01=average LST error <= 2K 10=average LST error <= 3K 11=average LST error > 3K |

4. MOD11A2 Eight-day LST

An eight-day compositing period was chosen because twice of such period is the exact ground track repeat period of the Terra platform. LST over eight days is the averaged LSTs of the MOD11A1 product over eight days.

4.1. Algorithm Description

A simple average method is used in the current algorithm for the MOD11A2 product.

4.2. Scientific Data Sets

In the V5 MOD11A2 product, the first ten SDSs are similar to those in the MOD11A1 product described in Table 10. The last two SDSs, Clear_sky_days and Clear_sky_nights, are similar to those in the 8-day CMG product described in Table 17.

4.3. Local Attributes

Similar to MOD11A1.

4.4. Global Attributes

Similar to MOD11A1.

4.5. Quality Assurance

Similar to MOD11A1.

5. MOD11B1 Daily LST

The daily level 3 LST product at 6km spatial resolution is a tile of daily LST product gridded in the Sinusoidal projection. A tile contains 200 x 200 grids in 200 rows and 200 columns. The exact grid size at the 6km spatial resolution is 5.56km by 5.56km.

5.1. Algorithm Description

The daily MOD11B1 LST product is constructed with the results produced by the day/night LST algorithm (Wan and Li, 1997) from pairs of daytime and nighttime observations in seven MODIS TIR bands (bands 20, 22, 23, 29, and 31-33). New refinements implemented in the V5 LST processing are listed in Table 1.

The constraints on the day/night LST algorithm include: (1) the day observations with solar zenith angle not larger than 75 degrees; (2) the night observations with solar zenith angle larger than 90 degrees (i.e., no solar radiation in the night observations); (3) the time difference between the day and night observations cannot be longer than 32 days; (4) brightness temperature Tb31 (daytime) \geq 198K and Tb31(nighttime) \geq 195K because the signal-to-noise of TIR data in MWIR band 20 (which is used in the day/night algorithm) becomes very small at low temperatures. These constraints significantly limit the LST/emissivity retrieval in the polar regions. Because a 12-bit linear quantization is used for all MODIS TIR bands, MWIR bands 20 and 22 may saturate at hot spots during the daytime in arid and semi-arid regions in the summer. The day/night LST algorithm cannot be used in saturation cases due to lack of valid daytime data in bands 20 or 22.

5.2. Scientific Data Sets (SDS)

The SDSs in the MOD11B1 product include LST_Day_6km, QC_Day, Day_view_time, Day_view_angl, LST_Night_6km, QC_Night, Night_view_time, Night_view_angl, Emis_20, Emis_22, Emis_23, Emis_29, Emis_31, Emis_32, Percent_land_in_grid, LST_Day_6km_Aggregated_from_1km and LST_Night_6km_Aggregated_from_1km. The last two SDSs are the daytime and nighttime LSTs generated from the level-2 MOD11_L2 product through the 1-km band 31 radiance values aggregated to the 6km grids. They can be used to supplement LST_Day_6km and LST_Night_6km, and for global browse imagery. Their details are shown in Table 15.

Table 15. The SDSs in the MOD11B1 product.

| SDS Name | Long Name | Number Type | Unit | Valid Range | Fill Value | scale factor | add offset |
|---------------|--------------------------------------------------------------------|-------------|------|-------------|------------|--------------|------------|
| LST_Day_5km | Daily daytime 6km grid Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Day | Quality control for daytime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Day_view_time | (local solar) Time of daytime Land-surface Temperature observation | uint8 | hrs | 0-120 | 255 | 0.2 | 0 |

| | | | | | | | |
|-----------------------------------|-----------------------------------------------------------------------------------|--------|------|----------------|-----|-------|-------|
| * Day_view_angle | View zenith angle of daytime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| LST_Night_5km | Daily nighttime 6km grid Land-surface Temperature | uint16 | K | 7500- 65535 | 0 | 0.02 | 0.0 |
| QC_Night | Quality control for nighttime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Night_view_time | (local solar) Time of nighttime Land- surface Temperature observation | uint8 | hrs | 0-120 | 255 | 0.2 | 0 |
| * Night_view_angle | View zenith angle of nighttime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| Emis_20 | Band 20 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_22 | Band 22 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_23 | Band 23 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_29 | Band 29 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_31 | Band 31 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_32 | Band 32 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| LST_Day_6km_Aggregated_from_1km | Daily daytime 6km grid LST aggregated from 1km | uint16 | K | 7500- 65535 | 0 | 0.02 | 0. |
| LST_Night_6km_Aggregated_from_1km | Daily nighttime 6km grid LST aggregated from 1km | uint16 | K | 7500- 65535 | 0 | 0.02 | 0. |
| ** QC_Emis | Quality control for retrieved emissivities | uint8 | none | 0-255 | 0 | na | na |
| Percent_land_in_grid | Percentage of Land in the Grid | uint8 | none | 0-100 | 0 | 1.0 | 0 |

Note: * a negative sign before the zenith view angle indicates that the MODIS views the Earth surface from east.

** The 03-00 four bits are for view angle flag of the companion observation (which is night observation if LST_Day_6km valid, or day observation otherwise), with key 0-15 as index of view angle sub-range of the companion observation: 0-7 if view from east (0 at the west end of scan line); 8-15 if view from west (15 at the east end of scan line). The 06-04 three bits are used for a flag of time difference between the day and night MODIS observations, with key 0-7 as couples of days, 7 representing the range from 7 to 16 (i.e., 14-32 days). Bit 07 is for DEM slope flag, with key 0=DEM slope not considered or 1=DEM slope considered in the day/night algorithm. There are eight view angle sub-ranges in the whole range of viewing zenith angle at the surface from 0-65° and they are 0-10, 10-20, 20-30, 30-39, 39-47, 47-54, 54-60, and 60-65 degrees.

5.3. Local Attributes

The local attributes for SDSs LST_Day_6km and LST_Night_6km are similar to those in Table 5.

5.4. Global Attributes

Three ECS global attributes and 16 product-specific global attributes are stored as metadata. The ECS global attributes, *CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0* are stored as very long character strings in PVL format.

CoreMetadata.0 contains information about the product during production and is used to populate the EOSSDIS data base for user support. They are similar to those of MOD11A1.

5.5. Quality Assurance

The bit flags defined for the quality assurance SDSs QC_day and QC_Night in MOD11B1 are listed in Table 16.

Table 16. Bit flags defined for SDSs QC_day and QC_Night in MOD11B1. Note that bit 0 is the least significant bit.

| bits | Long Name | Key |
|-------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 & 0 | Mandatory QA flags | 00=LST produced, good quality, not necessary to examine more detailed QA 01=LST produced, other quality, recommend examination of more detailed QA 10=LST not produced due to cloud effects 11=LST not produced primarily due to reasons other than cloud |
| 2 | Data quality flag | 0=good data quality 1=other quality data |
| 3 | Terra/Aqua Combined-use flag | 0=no 1=yes |
| 5 & 4 | Emis Error flag | 00=average emissivity error <= 0.01 01=average emissivity error <= 0.02 10=average emissivity error <= 0.04 11=average emissivity error > 0.04 |
| 7 & 6 | LST Error flag | 00=average LST error <= 1K 01=average LST error <= 2K 10=average LST error <= 3K 11=average LST error > 3K |

6. MOD11C1 Daily CMG LST

This daily global LST product provides temperature and emissivity values at 0.05 degree latitude/longitude climate model grids (CMG). The exact areal size of the equal angle grids varies with latitude, and it is 5.6km by 5.6km at the Equator.

6.1. Algorithm Description

The temperature and emissivity values in MOD11C1 are derived by reprojection and average of the values in the daily MODIS LST/E product (MOD11B1) at 6km equal area grids in the sinusoidal projection. The LST values aggregated to 6km grids from those retrieved by the generalized split-window algorithm are used to supplement the LSTs retrieved by the day/night LST algorithm at grids where there is no valid pair of day and night observations (usually in high-latitude regions). Due to this LST supplement, the spatial coverages of LSTs are larger than the spatial coverage of retrieved emissivities in the MOD11C products.

6.2. Scientific Data Sets (SDS)

There are 16 SDSs in the MOD11C1 product. They are similar to those in the MOD11B1 product as shown in Table 15, except changing LST_Day_6km to LST_Day_CMG and LST_Night_6km to LST_Night_CMG, and without LST_Day_6km_Aggregated_from_1km and LST_Night_6km_Aggregated_from_1km.

6.3. Local Attributes

The local attributes for SDSs LST_Day_CMG and LST_Night_CMG are similar to those in Table 5.

6.4. Global Attributes

Three ECS global attributes and 16 product-specific global attributes are stored as metadata. The ECS global attributes, *CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0* are stored as very long character strings in PVL format.

CoreMetadata.0 contains information about the product during production and is used to populate the EOSDIS data base for user support. They are similar to those of MOD11A1.

6.5. Quality Assurance

The bit flags in the QC SDS are similar to those in Table 16.

7. MOD11C2 8-Day CMG LST

This LST product provides 8-day composited and averaged temperature and emissivity values at 0.05 degree latitude/longitude grids (CMG), as well as the averaged observation times and viewing zenith angles for daytime and nighttime LSTs.

7.1. Algorithm Description

The temperature and emissivity values in the MOD11C1 product over a period of 8 days are simply composited and averaged. The days and nights in clear-sky conditions and

with valid LSTs are flagged in each bit of two 8-bit unsigned integers (one for daytime LSTs and another for nighttime LSTs).

7.2. Scientific Data Sets (SDS)

There are 17 SDSs in the MOD11C2 product as shown in Table 17.

Table 17. The SDSs in the MOD11C2 product.

| SDS Name | Long Name | Number Type | Unit | Valid Range | Fill Value | scale factor | add offset |
|----------------------|------------------------------------------------------------------|-------------|------|-------------|------------|--------------|------------|
| LST_Day_CMG | 8-day daytime 3min CMG Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Day | Quality control for daytime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Day_view_time | Averaged time of daytime LST observation (UTC) | uint8 | hrs | 0-120 | 255 | 0.2 | 0 |
| Day_view_angle | Averaged view zenith angle of daytime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| * Clear_sky_days | the days in clear-sky conditions and with validate LSTs | uint8 | none | 0-255 | 0 | na | na |
| LST_Night_CMG | 8-day nighttime 3min CMG Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Night | Quality control for nighttime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Night_view_time | Averaged time of nighttime LST observation (UTC) | uint8 | hrs | 0-120 | 255 | 0.2 | 0 |
| Night_view_angle | Averaged view zenith angle of nighttime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| * Clear_sky_nights | the nights in clear-sky conditions and with validate LSTs | uint8 | none | 0-255 | 0 | na | na |
| Emis_20 | Band 20 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_22 | Band 22 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_23 | Band 23 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_29 | Band 29 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_31 | Band 31 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_32 | Band 32 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Percent_land_in_grid | Percentage of Land in the Grid | uint8 | none | 0-100 | 0 | 1.0 | 0 |

* Each bit in the 8-bit unsigned integer indicates clear-sky (1) or not (0) in the corresponding day or night. Bit 00 is for the first day or night, and bit 07 is for the last day or night in the 8-day period.

7.3. Local Attributes

The local attributes for SDSs LST_Day_CMG and LST_Night_CMG are similar to those in Table 5.

7.4. Global Attributes

Three ECS global attributes and 16 product-specific global attributes are stored as metadata. The ECS global attributes, *CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0* are stored as very long character strings in PVL format.

CoreMetadata.0 contains information about the product during production and is used to populate the EOSDIS data base for user support. They are similar to those of MOD11A1.

7.5. Quality Assurance

The bit flags in the QC SDS are similar to those in Table 16.

8. MOD11C3 Monthly CMG LST

This LST product provides monthly composited and averaged temperature and emissivity values at 0.05 degree latitude/longitude grids (CMG), as well as the averaged observation times and viewing zenith angles for daytime and nighttime LSTs.

8.1. Algorithm Description

The temperature and emissivity values in the MOD11C1 product in a calendar month are simply composited and averaged. The days and nights in clear-sky conditions and with valid LSTs are flagged in each bit of two 32-bit unsigned integers (one for daytime LSTs and another for nighttime LSTs).

8.2. Scientific Data Sets (SDS)

There are 17 SDSs in the MOD11C3 product as shown in Table 18.

Table 18. The SDSs in the MOD11C3 product.

| SDS Name | Long Name | Number Type | Unit | Valid Range | Fill Value | scale factor | add offset |
|----------------|----------------------------------------------------------------|-------------|------|--------------|------------|--------------|------------|
| LST_Day_CMG | Monthly daytime 3min CMG Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Day | Quality control for daytime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Day_view_time | Averaged time of daytime LST observation (UTC) | uint8 | hrs | 0-120 | 0 | 0.2 | 0 |
| Day_view_angle | Averaged view zenith angle of daytime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| Clear_sky_days | the days in clear-sky conditions and with validate LSTs | uint32 | none | 0-4294967295 | 0 | na | na |

| | | | | | | | |
|----------------------|------------------------------------------------------------------------|--------|------|------------------|-----|-------|-------|
| LST_Night_CMG | Monthly nighttime 3min CMG Land-surface Temperature | uint16 | K | 7500-65535 | 0 | 0.02 | 0.0 |
| QC_Night | Quality control for nighttime LST and emissivity | uint8 | none | 0-255 | 0 | NA | NA |
| Night_view_time | Averaged time of nighttime LST observation (UTC) | uint8 | hrs | 0-120 | 0 | 0.2 | 0 |
| Night_view_angle | Averaged view zenith angle of nighttime Land-surface Temperature | uint8 | deg | 0-130 | 255 | 1.0 | -65.0 |
| Clear_sky_nights | the nights in clear-sky conditions and with validate LSTs | uint32 | none | 0- 4294967295 | 0 | na | na |
| Emis_20 | Band 20 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_22 | Band 22 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_23 | Band 23 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_29 | Band 29 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_31 | Band 31 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Emis_32 | Band 32 emissivity | uint8 | none | 1-255 | 0 | 0.002 | 0.49 |
| Percent_land_in_grid | Percentage of Land in the Grid | uint8 | none | 0-100 | 0 | 1.0 | 0 |

8.3. Local Attributes

The local attributes for SDSs LST_Day_CMG and LST_Night_CMG are similar to those in Table 5.

8.4. Global Attributes

Three ECS global attributes and 16 product-specific global attributes are stored as metadata. The ECS global attributes, *CoreMetadata.0*, *ArchiveMetadata.0* and *StructMetadata.0* are stored as very long character strings in PVL format.

CoreMetadata.0 contains information about the product during production and is used to populate the EOSDIS data base for user support. They are similar to those of MOD11A1.

8.5. Quality Assurance

The bit flags in the QC SDS are similar to those in Table 16.

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