MODIS Collection 6.1 (C61) Product User Guide

The C61 MOD11 product is identical in format to the C6 product. This (C61) reprocessing does not contain any change to the science algorithm used to make this product. Any improvement or change in the C61 product compared to the product from the prior major collection reprocessing (C6) is from changes and enhancements to the calibration approach used in generation of the Terra and Aqua MODIS L1B products and changes to the polarization correction used in this collection reprocessing. For further details on C61 calibration changes and other changes user is encouraged to refer to the Collection 6.1 specific changes that have been summarized here: https://landweb.modaps.eosdis.nasa.gov/QA_WWW/forPage/MODIS_C61_Land_Proposed_Changes.pdf

Collection-6

MODIS Land Surface Temperature Products

Users' Guide

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Table of Contents

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 V6 daily LST Product Generation Executive (PGE) code are given in (Wan, 2014). This V6 PGE code has been used in the Collection-6 (C6) reprocessing and forward processing of the MODIS LST product.

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. Global and local attributes (metadata) 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

C6 MODIS LST data products are produced as a series of nine products. The sequence begins as a swath (scene) at a nominal pixel spatial resolution of 1 km 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 in the daily LST product. There are two algorithms used in the daily MODIS LST processing: (1) the generalized split-window LST algorithm (Wan and Dozier, 1996), and (2) the day/night LST algorithm, which uses 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 LST processing. Wan (2014) described new refinements made in these two algorithms for the C6 MODIS LST product.

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 1113 km by 1113 km in 1200 rows by 1200 columns, of a map projection.

A summarized listing of the sequence of products is given in Table 1. 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.

Table 1. Summary of the C6 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 0.928km)	daily	Sinusoidal
MOD11B1	L3	200 rows by 200 columns	6km (actual 5.568km)	daily	Sinusoidal
MOD11B2				eight days	
MOD11B3				monthly	
MOD11A2	L3	1200 rows by 1200 columns	1km (actual 0.928km)	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 1 km 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 1 km 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 6 km spatial resolution. It is generated by the day/night LST algorithm (Wan and Li, 1997). The fourth product, MOD11B2, is an eight-day LST product by averaging from two to eight days of the MOD11B1 product. The fifth product, MOD11B3, is a monthly LST product generated from the daily MOD11B1 product. The sixth product, MOD11A2, is an eight-day LST product by averaging from two to eight days of the MOD11A1 product. The seventh 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 6 km grids to the 0.05° spatial resolution of the Climate Modeling Grid (CMG) cells. The eighth product, MOD11C2, is an eight-day composite of LST at the same resolution as MOD11C1. The ninth product, MOD11C3, is a monthly composite of LST at the same resolution as MOD11C2. Similarly, there are nine C6 LST products starting with MYD11 for the Aqua MODIS.

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 landcover (MCDLC1KM), 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 region.

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 condition at a confidence (defined in MOD35) of >=95% over land or lakes.

Note that the above clear-sky condition for the LST values in the C6 level-2 MOD11_L2 product is stricter than the clear-sky conditions for the LST values in the C6 level-3 MOD11A1 product (at a confidence >=95% over land <= 2000 m or >= 66% over land > 2000 m, and at a confidence of >= 66% over lakes). For the C6 level-3 LST products, cloud-contaminated LSTs in the 1 km product (MOD11A1 & MYD11A1) and the 6 km product (MOD11B1 & MYD11B1) will be removed by using constraints on the temporal variations in clear-sky LSTs in a period of 32 days by the refinement implemented in the PGE16 (Wan, 2008). However, there is no easy way to implement such a post-processing to remove the cloud-contaminated LSTs in the C6 level-2 products (MOD11_L2 & MYD11_L2).

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 cub 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).

Data inputs to the LST algorithm are listed in Table 2.

Table 2. 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
MCDLC1KM	Land Cover	Land_Cover_Type_1
MOD10_L2	MODIS Snow Cover	Snow Cover Fraction

Emissivity values 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 Land Cover (MCDLC1KM) and daily Snow Cover (MOD10_L2). The land-cover product generated from MODIS data is used in the MODIS LST processing. Because the range of diurnal variation in LSTs over the seasons at the bare soil sites is very wide it is necessary to use two separate sets of split-window algorithm coefficients for the type of bare soil in the hot and warm bare soil zone (HAWBSZ) within latitude range from −38° to 49.5°, one set for daytime LSTs and another for nighttime LSTs. Atmospheric radiative transfer simulations were made with MODTRAN4 code (Berk et al., 1999) in wide atmospheric and LST conditions: the range of the atmospheric surface temperature (Ts-air) is set as 280–325 K for the daytime and 275–305 K for the nighttime; the atmospheric column water vapor varies from nearly zero to 5.5 cm; and the range of (LST – Ts-air) is set as from 8–29 K for daytime LSTs and from −10–4 K for nighttime LSTs. A quadratic term of the difference between brightness temperatures in bands 31 and 32 was added into the original viewing angle dependent split-window algorithm in order to improve the LST retrieval accuracy slightly (Wan, 2014).

A large uncertainty may exist in such estimated emissivity values in semi-arid and arid areas. Therefore, a prototype emissivity adjustment model was developed by comparing the (T31–T32) values in MODIS data to simulation values estimated from column water vapor (cwv) and surface air temperature (Ta-surf), and correspondingly adjusting the emissivity in band 31 (em31 or $\varepsilon31$) with a value in range of ±0.0063 and the band 32 emissivity em32 ($\varepsilon32$) by the same amount in the opposite direction (Wan, 2014).

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 1 km 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 3.

Table 3. 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	NA	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	- 999.9	NA	NA
Longitude	Longitude of every 5 scan lines and 5 pixels	float32	degree	-180.0 to 180.0	- 999.9	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 4) describe characteristics of the data.

Table 4. 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 add_offset scale_factor_err add_offset_err calibrated_nt	scaling factor add offset scaling factor error add offset error calibrated nt	0.02 0. 0. 0. 5

* 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 = the SDS data in uint16 * 0.02, giving a value in the range of 150-1310.7 K.

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 5. 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	6	ECS Version
ReprocessingActual	"reprocessed"	
ReprocessingPlanned	"further update is anticipated"	Expect that products will be reprocessed one or more times.
LocalGranuleID	"MOD11_L2.A2000095.1915.006.20006208231007.hdf"	
DayNightFlag	"Day"	Day , Night or Both.
ProductionDateTime	"2006-07-27T23:10:07.000Z"	
LocalVersionID	"6.4.0A"	Version of algorithm delivered from the

		SCF.
PGEVersion	"6.4.0"	Version of production generation executable.
InputPointer	"MOD03.A2000095.1915.006.2006188045128.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
SciencelQualityFlagExplanation	"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.A2000095.1915.006.2006188045128.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 especially 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 6.

Table 6. 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	"6"	
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 7. 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 8.

Table 8. 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<= 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 1 km 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 1 km spatial resolution is 0.928 km by 0.928 km.

3.1. Algorithm Description

The C6 daily MOD11A1 LST product is constructed with the daily LST pixel values in each granules retrieved by the generalized split-window algorithm under clear-sky conditions defined in MOD35 (at a confidence >=95% over land <= 2000 m or >= 66% over land > 2000 m, and at a confidence >= 66% over lakes) through mapping all the valid clear-sky LST values 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 the C6 MOD11A1 product, LST values at all grids are from single clear-sky MODIS observations by selecting clear-sky LSTs at smaller viewing zenith angles or the LSTs at larger zenith angles but their values being larger by at least 2 K.

3.2. Scientific Data Sets (SDS)

The SDSs in the MOD11A1 product include LST_Day_1km, QC_Day, Day_view_time, Day_view_angl, 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 9. Note that the Day_view_time and Night_view_time are in local solar time, which is the UTC time plus grid's longitude in degrees / 15 degrees (in hours, +24 if local solar time < 0 or -24 if local solar time >= 24). The data day in the name of all the daily MOD11A1 files is in UTC so the data day in local solar time at each grid may be different from the data day in UTC by one day. The scale factor and offset for Day_view_angle and Night_view_angle in C6

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 9. 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	NA	NA	NA
Day_view_time	(local solar) Time of daytime Land-surface Temperature observation	uint8	hrs	0-240	255	0.1	0
Day_view_angl	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	NA	NA	NA
Night_view_time	(local solar) Time of nighttime Land-surface Temperature observation	uint8	hrs	0-240	255	0.1	0
Night_view_angl	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	1-65535	0	0.0005	0.
Clear_night_cov	night clear-sky coverage	uint16	none	1-65535	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 4.

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 10.

Table 10. *CoreMetadata.0* of the MOD11A1 data product.

Object Name	Sample Value	Comment
ShortName	"MOD11A1"	ESDT name of product
VersionID	6	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.h08v05.006.2006209..hdf"	Name of the granule.
DayNightFlag	"Both"	
ProductionDateTime	"2006-07-28T06:11:25.000Z"	Time granule was produced.
LocalVersionID	"6.4.0AS"	Version of algorithm delivered from the SCF
PGEVersion	"6.4.0"	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
GringPointLatitude	[39.995833, 39.995833, 30.004167, 30.004167]	longitude

GringPointLongitude	[-130.540731, -117.497536, -103.941403, -115.479755]	values of the corner grids in the tile
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"	
SciencelQualityFlagExplanation	"See http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/qaFlagPage.cgi?sat=terra for the product Science Quality status."	Explanation of Science 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

QAFractionOtherQuality	0.4461764	fraction of the LST product. Range is from 0.0 to 1.0.
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 11.

Table 11. *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	"6"	
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 12) is used by the HDF-EOS toolkit to create the mapping relationships between the defined grid and data (SDSs).

Table 12. 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 13.

Table 13. 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 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 C6 MOD11A2 product, the SDSs are described in Table 14.

Table 14. The SDSs in the MOD11A2 product.

SDS Name	Long Name	Number Type	Unit	Valid Range	Fill Value	scale factor	add offset

LST_Day_1km	8-day 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	NA	NA	NA
Day_view_time	Average time of daytime Land-surface Temperature observation	uint8	hrs	0-240	255	0.1	0
Day_view_angl	Average view zenith angle of daytime Land-surface Temperature	uint8	deg	0-130	255	1.0	-65.0
LST_Night_1km	8-day 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	NA	NA	NA
Night_view_time	Average view zenith angle of nighttime Land-surface Temperature	uint8	hrs	0-240	255	0.1	0
Night_view_angl	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_sky_days	the days in clear-sky conditions and with validate LSTs	uint8	none	1-255	0	NA	NA
Clear_sky_nights	the nights in clear-sky conditions and with validate LSTs	uint8	none	1-255	0	NA	NA

4.3. Local Attributes

Similar to MOD11A1.

4.4. 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 15.

Table 15. *CoreMetadata.0* of the MOD11A2 data product.

Object Name	Sample Value	Comment
ShortName	"MOD11A2"	ESDT name of product
VersionID	6	ESC Version
ReprocessingActual	"reprocessed"	Number of times processed.

ReprocessingPlanned	"further update is anticipated"	Expect that products will be reprocessed one or more times
LocalGranuleID	"MOD11A2.A2003001.h00v08.006.2019155161306.hdf"	Name of the granule.
DayNightFlag	"Both"	
ProductionDateTime	"2006-07-28T06:11:25.000Z"	Time granule was produced.
LocalVersionID	" 6.3.0"	Version of algorithm delivered from the SCF
PGEVersion	"6.4.2"	Version of PGE in MODAPS.
InputPointer	"MOD11A1.A2003001.h00v08.006.2019144130650.hdf", "MOD11A1.A2003003.h00v08.006.2019144130650.hdf",...	Location of input files in the production system
RangeBeginningDate	"2003-01-01"	Beginning and ending times of the first and last scan line in the swath
RangeBeginningTime	" 23:59:59"	
RangeEndingDate	" 2003-01-08"	
RangeEndingTime	"00:00:00"	
ExclusionGRingFlag	"N"	latitude and longitude values of the corner grids in the tile
GringPointLatitude	[0.554166666666666, 9.99583333333334, 0.00416666666666217, 0.00416666666666217]	
GringPointLongitude	-179.996035614598, -172.626768112332, -170.004180255674, -179.995830511716]	
GringPointSequenceNo	[1, 2, 3, 4]	
ParameterName	" MOD 8-DAY 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"	
SciencelQualityFlagExplanation	"See http://landweb.nascom/nasa.gov/cgi-bin/QA_WWW/qaFlagPage.cgi?sat=terra&ver=C6 the product Science Quality status.	Explanation of Science QualityFlag
QAPercentMissingData	0	0 - 100
QAPercentCloudCover	9	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	
HorizontalTileNumber	"00"	
VerticalTileNumber	"08"	
TileID	"51000008"	
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 16.

Table 16. *ArchiveMetadata.0* of the MOD11A2 data product.

Object Name	Sample Value	Comment
GRIDTYPE	"Sinusoidal"	
HorizontalTileNumber	"08"	

VerticalTileNumber	"05"	
AlgorithmPackageMaturityCode	"Normal"	Algorithm Descriptors
AlgorithmPackageName	"MOD_PR11A2"	
AlgorithmPackageVersion	"6"	
InstrumentName	"Moderate-Resolution Imaging SpectroRadiometer"	
ProcessingDateTime	" 2019-06-04T16:13:06.000Z "	
LongName	" MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1km SIN Grid "	
ProcessingCenter	"MODAPS"	
SPSOParameters	"2484 and 3323"	
LocalInputGranuleID	"Reserved for future use. "	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 17) is used by the HDF-EOS toolkit to create the mapping relationships between the defined grid and data (SDSs).

Table 17. Listing of objects in the global attribute *StructMetadata.0* in MOD11A2.

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_sky_days
DataField_12	DataFieldName=Clear_sky_nights

4.5. Quality Assurance

The bit flags defined for the quality assurance SDSs QC_day and QC_Night are listed in Table 18.

Table 18. Bit flags defined for SDSs QC_day and QC_Night in MOD11A2. 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 LST Error flag	00=average LST error <= 1K 01=average LST error <= 2K 10=average LST error <= 3K 11=average LST error > 3K

5. MOD11B1 Daily LST

The C6 daily level 3 LST product at 6 km 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 6 km spatial resolution is 5.56 km by 5.56 km.

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 C6 LST processing include: (1) the new sets of split- window algorithm coefficients are also incorporated into the day/night algorithm in order to improve the LST and emissivity retrieval for bare soil grids in HAWBSZ within latitude range from −38° to 49.5°. (2) the retrieved emissivity values in the view angle bins for the current day's daytime and nighttime observations are separately outputted to the level-3 M*D11B1 product for bands 20, 22, 23 and 29, in order to preserve the viewing angle dependence in emissivity values in these bands. Usually the viewing angles of MODIS daytime and nighttime observations in the same day are quite different at a given location (Wan, 2014).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) >= 198 K and Tb31(nighttime) >= 195 K 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 region. 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, Emis_20_night, Emis_22_night, Emis_23_night, Emis_29_night, LST_Day_6km_Aggregated_from_1km and LST_Night_6km_Aggregated_from_1km, QC_Emis, QC_Emis_night, Percent_land_in_grid. The two SDSs Aggregated_from_1km 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 6 km grids. They can be used to supplement LST_Day_6km and LST_Night_6km, and for global browse imagery. The retrieved emissivity values in the view angle bins for the current day's daytime and nighttime observations are separately outputted to the daily MOD11B1 product for bands 20, 22, 23 and 29, in order to preserve the viewing angle dependence in emissivity values in these bands. Usually the viewing angles of MODIS daytime and nighttime observations in the same day are quite different at a given location (Wan, 2014). Their details are shown in Table 19.

Table 19. The SDSs in the MOD11B1 product.

SDS Name	Long Name	Number Type	Unit	Valid Range	Fill Value	scale factor	add offset
LST_Day_6km	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	NA	NA	NA
Day_view_time	(local solar) Time of daytime Land-surface Temperature observation	uint8	hrs	0-120	255	0.2	0
* Day_view_angl	View zenith angle of daytime Land-surface Temperature	uint8	deg	0-130	255	1.0	-65.0
LST_Night_6km	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	NA	NA	NA
Night_view_time	(local solar) Time of nighttime Land-surface Temperature observation	uint8	hrs	0-120	255	0.2	0

* Night_view_angl	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
Emis_20_night	Band 20 emissivity	uint8	none	1-255	0	0.002	0.49
Emis_22_night	Band 22 emissivity	uint8	none	1-255	0	0.002	0.49
Emis_23_night	Band 23 emissivity	uint8	none	1-255	0	0.002	0.49
LST_Day_6km_Agregated_from_1km	Daily daytime 6km LST aggregated from 1km	Uint16	K	7500-65535	0	0.02	0.0
LST_Night_6km_Agregated_from_1km	Daily nighttime 6km LST aggregated from 1km	Uint16	K	7500-65535	0	0.02	0.0
Emis_29_night	Band 29 emissivity	uint8	none	1-255	0	0.002	0.49
QC_Emis	Quality control Emis	uint8	none	0-255	NA	NA	NA
QC_Emis_night	Quality control Emis	uint8	none	0-255	NA	NA	NA
Percent_land_in_grid	Percentage of Land in the Grid	uint8	none	1-100	0	NA	NA

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 EOSDIS 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 20.

Table 20. 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 LST Error flag	00=average LST error <= 1K 01=average LST error <= 2K 10=average LST error <= 3K 11=average LST error > 3K

6. MOD11B2 8-Day LST

The C6 8-day level 3 LST product at 6 km spatial resolution is the average LST product of the daily LST product over the period of eight days.

6.1. Algorithm Description

The simple average and composite method is used to average the valid LST and emissivity values in the MOD11B1 product over the 8-day period. The 8-day period does not across the end of the data year.

6.2. Scientific Data Sets (SDS)

The SDSs in the MOD11B2 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,. Clear_sky_days, Clear_sky_nights, and Percent_land_in_grid. Their details are shown in Table 21.

Table 21. The SDSs in the MOD11B2 product.

SDS Name	Long Name	Number Type	Unit	Valid Range	Fill Value	scale factor	add offset
LST_Day_6km	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	NA	NA	NA
Day_view_time	(local solar) Time of daytime Land-surface Temperature observation	uint8	hrs	0-240	255	0.1	0
* Day_view_angl	View zenith angle of daytime Land-surface Temperature	uint8	deg	0-130	255	1.0	-65.0
LST_Night_6km	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	NA	NA	NA
Night_view_time	(local solar) Time of nighttime Land-surface Temperature observation	uint8	hrs	0-240	255	0.1	0
* Night_view_angl	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.
Clear_sky_days	Days in clear-sky conditions and with valid LSTs	uint8	None	1-255	0	NA	NA
Clear_sky_nights	Nights in clear-sky conditions and with valid LSTs	uint8	None	1-255	0	NA	NA
Percent_land_in_grid	Percentage of Land in the Grid	uint8	none	1-100	0	NA	NA

6.3. Local Attributes

Similar to those in MOD11B1.

6.4. Global Attributes

Similar to those in MOD11B1.

6.5. Quality Assurance

Similar to those in MOD11B1.

7. MOD11B3 MONTHLY LST

The C6 monthly level 3 LST product at 6 km spatial resolution is the average LST product of the daily LST product over one month.

7.1. Algorithm Description

The simple average and composite method is used to average the valid LST and emissivity values in the MOD11B1 product over one month.

7.2. Scientific Data Sets (SDS)

The SDSs in the MOD11B3 product are similar to those in Table 21.

7.3. Local Attributes

Similar to those in MOD11B1.

7.4. Global Attributes

Similar to those in MOD11B1.

7.5. Quality Assurance

Similar to those in MOD11B1.

8. **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 5.6 km by 5.6 km at the Equator.

8.1. 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 6 km equal area grids in the sinusoidal projection. The LST values aggregated to 6 km 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.

8.2. 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 19, 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.

8.3. Local Attributes

The local attributes for SDSs LST_Day_CMG and LST_Night_CMG are similar to those in Table 4.

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 20.

9. 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.

9.1. 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 validated LSTs are flagged in each bit of two 8-bit unsigned integers (one for daytime LSTs

and another for nighttime LSTs).

9.2. Scientific Data Sets (SDS)

There are 17 SDSs in the MOD11C2 product as shown in Table 22.

Table 22. 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	NA	NA	NA
Day_view_time	Averaged time of daytime LST observation (UTC)	uint8	hrs	0-120	255	0.2	0
Day_view_angl	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	1-255	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	NA	NA	NA
Night_view_time	Averaged time of nighttime LST observation (UTC)	uint8	hrs	0-120	255	0.2	0
Night_view_angl	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	1-255	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	1-100	0	NA	NA

* 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.

9.3. Local Attributes

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

9.4. 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.

9.5. Quality Assurance

The bit flags in the QC SDS are similar to those in Table 20.

10. 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.

10.1. 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 validated LSTs are flagged in each bit of two 32-bit unsigned integers (one for daytime LSTs and another for nighttime LSTs).

10.2. Scientific Data Sets (SDS)

There are 17 SDSs in the MOD11C3 product as shown in Table 23.

Table 23. 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	NA	NA	NA
Day_view_time	Averaged time of daytime LST observation (UTC)	uint8	hrs	0-120	255	0.2	0
Day_view_angl	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	NA	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	NA	NA	NA
Night_view_time	Averaged time of nighttime LST observation (UTC)	uint8	hrs	0-120	255	0.2	0
Night_view_angl	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	NA	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	1-100	0	NA	NA

10.3. Local Attributes

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

10.4. 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.

10.5. Quality Assurance

The bit flags in the QC SDS are similar to those in Table 13.

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