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**Document for VIIRS Land Surface Temperature (LST) Environmental Data Records (EDR) Software**

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**Goddard Space Flight Center**

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National Aeronautics and

Space Administration

**Joint Polar Satellite System (JPSS)**

**Operational Algorithm Description (OAD) Document for VIIRS Land Surface Temperature (LST) Environmental Data Records (EDR) Software**

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#### 2.1.1.1 Inputs

Refer to the CDFCB-X, 474-00001, for a detailed description of the inputs. For the AOT parameter format, refer directly to Volume III of the IDFCB, 474-00020. All temperatures are expressed in Kelvin (K) units. Table 3 shows the LST main inputs and Table 4 shows the LST EDR Auxiliary / Ancillary data inputs.

Table 3. LST Main Inputs

| Input | Type | Description | Units/Valid Range |
| --- | --- | --- | --- |
| BT\_M12 | Float32 | Brightness Temperature  of Band M12 | K /  Please refer to VIIRS Radiometric Calibration ATBD, 474-00027 |
| BT\_M13 | Float32 | Brightness Temperature  of Band M13 | K /  Please refer to VIIRS Radiometric Calibration ATBD, 474-00027 |
| BT\_M15 | Float32 | Brightness Temperature  of Band M15 | K /  Please refer to VIIRS Radiometric Calibration ATBD, 474-00027 |
| BT\_M16 | Float32 | Brightness Temperature  of Band M16 | K /  Please refer to VIIRS Radiometric Calibration ATBD, 474-00027 |
| VIIRS SDR MOD geolocation Data | Float32 | VIIRS SDR MOD  geolocation structure /  -Sensor Zenith Angle  -Solar Zenith Angle | Sensor Zenith Angle  degree /  0o ≤ SenZenAngle ≤ 71.62o |
| Solar Zenith Angle  degree /  0o ≤ SolZenAngle ≤ 180o |
| Latitude  degree/  Used to determine ellipsoid fill |
| VIIRS Cloud Mask IP | Uint8 | VIIRS\_CLOUD\_MASK\_IP\_TYPE  Land/Water Background Flag | Unitless /  000 = Land & Desert  001 = Land no Desert  010 = Inland Water  011 = Sea Water  101 = Coastal |
| Day/Night Flag | Unitless /  0 = Night  1 = Day |
| Confidence Indicator | Unitless /  11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear  00 = Confident Clear |
| Sun Glint Flag | Unitless /  00 = None  01 = Geometry Based  10 = Wind Speed Based  11 = Geometry & Wind |
|  |  | Thin Cirrus | Unitless /  0 = No  1 = Yes |
| VIIRS Land Surface Type EDR | Uint8 | VIIRS\_Surface\_Type\_EDR\_Type  Surface Type Flag  Fire Flag  Snow Cover Flag | Unitless /  Valid Range: 1 to 17,  0 = Invalid  1 = Evergreen Needleleaf Forests  2 = Evergreen Broadleaf Forests  3 = Deciduous Needleleaf Forests  4 = Deciduous Broadleaf Forests  5 = Mixed Forests  6 = Closed Shrublands  7 = Open Shrublands  8 = Woody Savannas  9 = Savannas  10 = Grasslands  11 = Permanent Wetlands  12 = Croplands  13 = Urban and Built-Up Lands  14 = Cropland/Natural Vegetation Mosaics  15 = Snow and Ice  16 = Barren  17 = Water Bodies  18-31 = Invalid  Unitless /  0 = No Fire  1 = Active Fire  Unitless /  0 = No Snow  1 = Snow Cover |
| VIIRS Aerosol Optical Thickness | Float32 | VIIRS\_AOT\_IP\_TYPE  Aerosol Optical Thickness  at 550 nm (slant path) | Unitless  AOT ≥ 0 |
| VIIRS\_LST\_LUT | Float64 | viirs\_Lst\_Coeffs\_LUT  term: dual window[9], split –window[5]  Indices representing coefficients a0… a8 | Term  Unitless |
| daynight[2] Key to LUT daynight dimension | Unitless /  0 = night  1 = day |
| surfacetype[17]  IGBP Surface Types  Land Surface Type EDR | Unitless / 0 to 16 |
| algorithm[2]  Key to LUT algorithm dimension | Unitless / 0 = “dual”  1 = “split” |
| regime[1]  This is a placeholder only (not used) | Unitless / regime = 0 |
| VIIRS\_LST\_COEFFICIENTS | Float32 | Structure containing all configurable parameters for LST  min\_Bt\_M12\_M13 | 180 K |
| max\_Bt\_M12\_M13 | 350 K |
| min\_Bt\_M15 | 180 K |
| max\_Bt\_M15 | 350 K |
| min\_Bt\_M16 | 180 K |
| max\_Bt\_M16 | 350 K |
| day\_Sol\_Zen\_Ang\_Lim | 1.4835 Radians |
| min\_Hcs\_Sens\_Zen\_lim | 0.0 Radians |
| max\_Hcs\_Sens\_Zen\_lim | 0.925 Radians |
| min\_Term\_Lim | 1.4835 Radians |
| max\_Term\_Lim | 1.7453 Radians |
| lst\_Min\_Rept\_Range | 213K |
| lst\_Max\_Rept\_Range | 343K |
| max\_Sens\_Zen\_Lim | 0.6981 Radians |
| LST Data Quality Notification | Structure | Reports erroneous pixels through a DQN | -999.71 to  –999.69  Check for  –999.7 is needed |

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### 2.1.2 Algorithm Processing

The objective of the LST algorithm is to calculate LST at each pixel in a moderate resolution (750 m) granule with all available input. Two similar regression algorithms are used to perform this retrieval:

1) The operational baseline algorithm is the 2-band split-window algorithm where only the thermal infrared (TIR) band pair M15 and M16 are used. The 2-band split-window algorithm is set as the baseline operational algorithm by a run time switch.

2) A 4-band dual-split window algorithm is available originally as an optional algorithm that uses brightness temperatures from two pair of VIIRS wavebands—one pair in the Medium-Wavelength Infrared (MWIR) atmospheric window (Bands M12 and M13) and the other pair in the TIR atmospheric window (Bands M15 and M16), and Quality assessment flags for each pixel are stored in the LST Flag output.

#### 2.1.2.2 LST Retrieval Logic….

The logic flow of the LST retrieval algorithm is provided in Figure 3. The core logic occurs in two functions, setLstQualFlags()and calculateLst(). In the current implementation, LST QFs additionally serve as decision flags. Their values are used in the decision of whether LST can be retrieved and, if so, which algorithm to use.



Figure 3. LST Retrieval Logic Flow

LST is not retrieved if any of the following conditions occur:

* The pixel is cloudy (i.e., Cloud Confidence Flag is “Confidently Cloudy”), or
* The pixel is an ocean pixel (i.e., LandWater Flag is “SeaWater”), or
* Band M15 brightness temperature is outside the LST defined range, or
* Band M16 brightness temperature is outside the LST defined range, or
* Land STYP is outside the LST defined range.

These pixels are marked with an LST QF of “No Retrieval” and are output with fill values.

For pixels that are processed, LST is retrieved by either the 2-band, split-window algorithm or an optional 4-band dual split window algorithm. The 2-band split-window algorithm is used as the operational baseline algorithm. The optional 4-band, dual split-window algorithm is available but may be used only under optimal conditions: no solar glint, no active fires, outside the terminator, and “in-range” brightness temperatures for the M12 and M13 bands. If the 4-band dual split-window algorithm is optionally invoked the algorithm will automatically revert to the split-window algorithm for non-optimal conditions. See Table 9, Section 2.1.2.3, for the logic to algorithm is used. The 2-band, split window algorithm is set as the operational baseline algorithm by a run time algorithm mode switch (*algmode*). A switch value of “1” specifies that the 2-band split window algorithm will be used as the baseline operational algorithm. A switch value of “0” specifies that the optional dual split-window algorithm is to be used. The run time algorithm mode switch should be set to 1 as the default run mode for initial operations at IDPS, corresponding to use of the 2-band split-window algorithm as the baseline algorithm. Determination of whether the 2-band split-window LST algorithm should remain as the baseline algorithm will be made during calibration/validation of the LST algorithm. If it is determined as a result of performance evaluated during calibration/validation that the 2-band split window algorithm should no longer be the baseline algorithm then the algorithm mode switch should be set to 0 resulting in the 4-band, dual split-window algorithm being used.

Core equations for the dual-band split-window and split-window fallback algorithms are specified in Table 10. The implementation is presented in calculateLst(). The daytime dual-band split-window algorithm varies slightly from its nighttime counterpart in that a solar zenith angle correction is made for the daytime retrieval.

For an off-nominal condition where a negative LST is retrieved, the LST field is filled and the LST quality bit field is set to “No Retrieval”.

Table 7 contains the list of configurable algorithm parameters.

Table 7. List of Configurable Algorithm Parameters

| Algorithm Parameter | Description | Assigned Values |
| --- | --- | --- |
| LST\_MIN\_M12\_M13\_BT | Minimum brightness temperatures for M12 and M13 | 180 K |
| LST\_MAX\_M12\_M13\_BT | Maximum brightness temperatures for M12 and M13 | 350 K |
| LST\_MIN\_M15\_BT | Minimum brightness temperature for M15 | 180 K |
| LST\_MAX\_M15\_BT | Maximum brightness temperature for M15 | 350 K |
| LST\_MIN\_M16\_BT | Minimum brightness temperature for M16 | 180 K |
| LST\_MAX\_M16\_BT | Maximum brightness temperature for M16 | 350 K |
| LST\_DAYNIGHT\_SOL\_ZEN\_LIMIT | Solar zenith angle defining day/night boundary | 1.4835 Radians |
| LST\_MIN\_HCS\_SENS\_ZEN\_LIMIT | Sensor zenith angle at Nadir \* PI/180 | 0.0 Radians |
| LST\_MAX\_HCS\_SENS\_ZEN\_LIMIT | Sensor zenith angle at the edge of scan | 0.925 Radians |
| LST\_MIN\_TERMINATOR\_LIMIT | Minimum solar zenith angle defines the terminator region | 1.4835 Radians |
| LST\_MAX\_TERMINATOR\_LIMIT | Maximum solar zenith angle defines the terminator region | 1.7453 Radians |
| lstMinTemp | Minimum reported temperature | 183.20K |
| lstMaxTemp | Maximum reported temperature | 350K |
| Algmode | 1. equals dual mode, 1 equals split mode | 0 |

#### 2.1.2.3 LST Quality Flag Logic…..

Table 8. LST QF Logic

| LST Flag | Input Source | Flag Setting |
| --- | --- | --- |
| Band M12 Brightness Temperature Quality | viirs\_mod\_SDR\_bt\_type | if (180 K < *BTM12* < 350 K) set to “within range” otherwise set to “out of range” end if |
| Band M13 Brightness Temperature Quality | viirs\_mod\_SDR\_bt\_type | if (180 K < *BTM13* < 350 K) set to “within range” otherwise set to “out of range” end if |
| Band M15 Brightness Temperature Quality | viirs\_mod\_SDR\_bt\_type | if (180 K < *BTM15* < 350 K) set to “within range” otherwise set to “out of range” end if |
| Band M16 Brightness Temperature Quality | viirs\_mod\_SDR\_bt\_type | if (180 K < *BTM16* < 350 K) set to “within range” otherwise set to “out of range” end if |
| AOT Condition | VIIRS\_AOT\_IP | if (AOT > 1.0) and (AOT < 0) set to “out of range” otherwise set to “within range” end if |
| Day/Night | SDR | if (0 deg <= Solar Zenith Angle <= 85deg) set to “Day” otherwise set to “Night” end if |
| Terminator | SDR | if (85 deg < Solar Zenith Angle <= 100 deg) set to “Inside Terminator” otherwise set to “Beyond Terminator” end if |
| Horizontal Reporting Interval | SDR | if (0 deg <= Sensor Zenith Angle <= 53 deg) set to “within range” otherwise set to “out of range” end if |
| Sun Glint | VIIRS\_CLOUD\_MASK\_IP\_TYPE | if (VCM Glint Flag == “No Glint”) set to “None” otherwise set to “Present” end if |
| Active Fire | VIIRS Surface Type EDR | LST Active Fire Flag = SurfaceType EDR Active Fire Flag |
| Cloud Confidence Indicator | VIIRS\_CLOUD\_MASK\_IP\_TYPE | LST Cloud Confidence Indicator = VCM Cloud Confidence Indicator |
| Land/Water | VIIRS\_CLOUD\_MASK\_IP\_TYPE | LST LandWater = VCM LandWater flag |
| Exclusion – Thin Cirrus | VIIRS\_CLOUD\_MASK\_IP\_TYPE | LST Thin Cirrus = VCM Thin Cirrus flag |
| SurfaceType | VIIRS Surface Type EDR | LST SurfaceType = SurfaceType EDR Surface Type (See note above in Section 2.1.2.3) |
| Algorithm | Logical combination of LST Flags | Originally, three algorithms were implemented: two for Dual Split window algorithms (day and night, respectively), one for Split Window Algorithm. The Split Window algorithm is used as baseline algorithm that is set (“Single Split) from a run time switch. |
| Degraded – Sensor Zenith Angle > 40 | viirs\_mod\_SDR\_bt\_type | If (Sensor Zenith Angle > 40) set to LST\_ZSEN\_DEGRAD |
| Quality | Logical combination of LST Flags | See Table 9 |

#### 2.1.2.4 LST LUT Coefficient Selection

A unique set of regression coefficients is derived offline for each land type. Each LST core equation (Table 10) uses a different set of coefficients for a given land STYP and day/night condition. Access to the coefficients is achieved by setting the values of the indices based on the given pixel viewing conditions and indicating the algorithm approach to be used. Once indices are specified, coefficients are retrieved for the desired LST algorithm by indexing on the “term” index. Currently, the “regime” index is set to “0” and has only one value. It is a placeholder for possible future improvement by further stratification of atmospheric conditions or geolocations. For the dual split-window algorithm, there are nine coefficients. For the split-window fallback algorithm, there are five coefficients. For the latter, four additional zero-valued coefficients are present as “fillers” in the LUT file.

Example:

LUTCoeffs[n][1][14][0][0], where n is indexed from 0 to 8, corresponds to the coefficients *a0* to *a8* of the dual split algorithm under daytime viewing conditions with no solar glint or active fire and with a pixel viewing surface type 15.