Department of the Interior
U.S. Geological Survey

README

PROVISIONAL LAND SURFACE TEMPERATURE (LST) PRODUCT

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Contents

Contents 1
List of Tables 1
Section 1 Background 2
Section 2 Product Packaging 2
Section 3 Sample Product Collection 3
Section 4 Product Characteristics 3
Section 5 Limitations and Known Issues 4
Section 6 References 5
Appendix A Default File Characteristics 5
Appendix B Metadata Fields 6
Appendix C NARR Grid Spatial Extent 8

List of Tables

Table 4-A 4

Section 1 Background

A Land Surface Temperature (LST) algorithm has been implemented and is being tested by the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center for Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data. The methodologies used in this algorithm are derived directly from work performed by: Hulley, Hughes, and Hook (2012), Cook (2014), Cook and others (2014), and Cook and Schott (2014). After initial algorithm validation is completed at EROS, it will be installed in an on-demand generation system designed for higher level Landsat data processing. EROS is currently seeking feedback regarding product formatting, documentation, accuracy and interoperability with other data sets before proceeding with a public release of the data product.

The source code for this algorithm is written in C and executed with Python wrapper scripts. The code is hosted online at https://github.com/USGS-EROS/espa-land-surface-temperature.

Section 2 Product Packaging

Land Surface Temperature (LST) and associated products are supplied in a gzip file (.tar.gz). Unzipping this file produces a tarball (.tar), which will "untar" to a Georeferenced Tagged Image File Format (GeoTIFF; .tif) file. Upon request, files can be generated as ENVI binary (.img/.hdr) or HDF-EOS version 2 (.hdf/.hdr) file format. The filenames are structured as the original scene ID appended with the product name suffix. The following are the components of a typical file:

LXXPPPRRRYYYYDDDSTNVR_lst.ext – for final LST product
LXXPPPRRRYYYYDDDSTNVR_lst_prod.ext – for intermediate products
(e.g., LE71820342003126ASN00_lst_emis.tif)

LXX	LE7 for Landsat 7 ETM+; LT5 for Landsat 5 TM
PPP	Path
RRR	Row
YYYY	Year of Acquisition
DDD	Julian Date of Acquisition
STN	Receiving Station
VR	Version Number
prod	Product, such as "_atmospheric_transmittance", or "_thermal_radiance"
ext	File format extension, such as "tif", "xml", "img", or "hdr"

Section 3 Sample Product Collection

The following products are included within each archive:

- Brightness Temperature (_toa_band6) + QA band*
- CFmask + CFmask confidence band*
- Emissivity
- LST
- Atmospheric Transmittance
- Thermal Radiance
- Downwelled Radiance
- Upwelled Radiance
- XML metadata

Details of the output products are in **Table 4-A** and **Appendix A Default File Characteristics**.

*Additional details about the Landsat Brightness Temperature and CFmask products are in the Land Surface Reflectance Product Guide: http://landsat.usgs.gov/documents/cdr_sr_product_guide.pdf.

Section 4 Product Characteristics

The LST product is generated by default at 30-meter spatial resolution on a Universal Transverse Mercator (UTM) or Polar Stereographic (PS) mapping grid. The delivered file format is in GeoTIFF (.tif) by default.

LST is delivered as a final product – “lst” – and as separate components. Specifications of each output file is described in **Table 4-A**.

More information about the algorithm and general product characteristics can be found in **Section 6 References**.

Table 4-A Land Surface Temperature Product Specifications

CFmask C version of Function of Mask, UINT8 8-bit unsigned integer, LST Land Surface Temperature, NA not applicable, INT16 16-bit signed integer, FLT32 32-bit floating point

Band Name	Description	Data Type	Units	Range	Valid Range	Fill Value	Saturate Value	Scale Factor
lst	LST – final product	INT16	Kelvin	1500-3730	1500-3730	-9999	NA	0.1
atmospheric_transmittance	Atmospheric transmittance	INT16	Radiance	0-8091	0-8091	-9999	NA	0.1
downwelled_radiance	Downwelled radiance	FLT32	Radiance	0-8091	0-8091	-9999	NA	NA
upwelled_radiance	Upwelled radiance	FLT32	Radiance	0-8091	0-8091	-9999	NA	NA
thermal_radiance	Thermal band converted to radiance	FLT32	Radiance	0-8091	0-8091	-9999	NA	NA
emis	Landsat emissivity estimated from ASTER GED data	FLT32	Emissivity coefficient	0-1	0-1	-9999	NA	NA

Section 5 Limitations and Known Issues

- Geographic limits of the climate data used to estimate atmospheric contamination (North American Regional Reanalysis (NARR) grid), LST can only be generated for limited areas. Please see **Appendix C NARR Grid Spatial Extent** for more details.

- The Modern-Era Retrospective Analysis for Research and Applications (MERRA) grid is being tested by RIT for implementation as a global product, thus allowing LST to be produced globally. More information about their progress is in the latest Landsat Science Team meeting briefing: http://landsat.usgs.gov//documents/science_LST_january2016/Laraby12_2015to_science_team.pdf.

- There is known error of LST retrievals relative to clouds and possibly cloud shadows. The characterization of this issue is documented in the briefing above.

- Most preliminary validations performed by RIT have been over water sites to determine the variance inherent to the algorithm. There has not been extensive validation performed over land. See the above link for more details on validation efforts.

Section 6 References

Hulley, G. C., Hughes, C. G., & Hook, S. J. (2012). Quantifying uncertainties in land surface temperature and emissivity retrievals from ASTER and MODIS thermal infrared data. *Journal of Geophysical Research: Atmospheres (1984–2012)*, 117(D23). http://dx.doi.org/10.1029/2012JD018506.

Cook, Monica J., "Atmospheric Compensation for a Landsat Land Surface Temperature Product" (2014). Thesis. *Rochester Institute of Technology*. Accessed from http://scholarworks.rit.edu/theses/8513.

Cook, M., Schott, J. R., Mandel, J., & Raqueno, N. (2014). Development of an operational calibration methodology for the Landsat thermal data archive and initial testing of the atmospheric compensation component of a Land Surface Temperature (LST) Product from the archive. *Remote Sensing*, *6*(11), 11244-11266. http://dx.doi.org/10.3390/rs61111244.

Cook, M., & Schott, J. R. (2014). Atmospheric Compensation for a Landsat Land Surface Temperature Product. *Landsat Science Team Meeting, July 22-24, 2014; Corvallis, Oregon, USA.* Accessed from https://landsat.usgs.gov/documents/science_LST_July_22_24_2014/Schott_LST_LLST.pdf.

Appendix A Default File Characteristics

CFmask C version of Function of Mask, DSWE Dynamic Surface Water Extent, TIF Tagged Image File Format, HDR header, SC shadow/cloud, PS percent slope

Description	Example File Size (bytes)	Example File Name
CFmask	54,968,000	LE70150422000036EDC00_cfmask.tif
CFmask	54,968,000	LE70150422000036EDC00_cfmask_conf.tif
Percent slope	126,715,862	LE70150422000036EDC00_percent_slope.tif
Dynamic Surface Water Extent – Diagnostic Tests	126,715,862	LE70150422000036EDC00 _dswe_diag.tif
Dynamic Surface Water Extent - Raw	54,968,000	LE70150422000036EDC00_dswe_raw.tif
Dynamic Surface Water Extent - cloud shadow and cloud filtered	54,968,000	LE70150422000036EDC00_dswe_ccs.tif
Dynamic Surface Water Extent - percent-slope, cloud shadow, and cloud filtered	54,968,000	LE70150422000036EDC00_dswe_psccs.tif
Metadata	33,185	LE70150422000036EDC00.xml

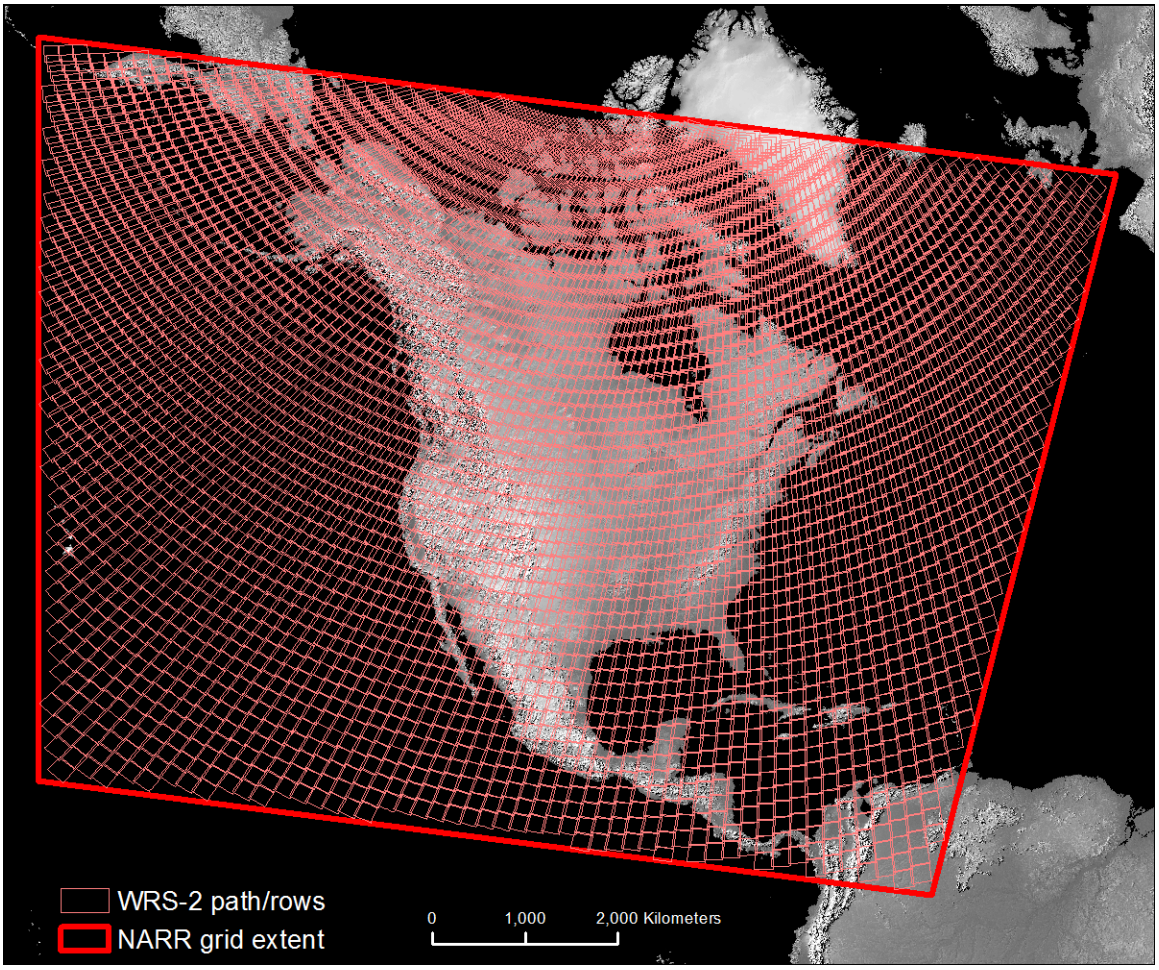
Appendix B Metadata Fields

Example of DSWE product XML metadata:


```
<band fill_value="255" nsamps="8091" nlines="7121" data_type="UINT8" category="qa" name="cfmask"
product="cfmask" source="toa_refl">
	<short_name>LE7CFMASK</short_name>
	<long_name>cfmask_band</long_name>
	<file_name>LE70290302014204EDC00_cfmask.img</file_name>
	<pixel_size units="meters" y="30.000000" x="30.000000"/>
	<resample_method>none</resample_method>
	<data_units>quality/feature classification</data_units>
	<valid_range max="4" min="0"/>
	<class_values>
		<class num="0">clear</class>
		<class num="1">water</class>
		<class num="2">cloud_shadow</class>
		<class num="3">snow</class>
		<class num="4">cloud</class>
		<class num="255">fill</class>
	</class_values>
	<app_version>cfmask_1.5.0</app_version>
	<production_date>2015-06-24T17:54:32Z</production_date>
</band>

<band fill_value="255" nsamps="8091" nlines="7121" data_type="UINT8" category="qa"
name="cfmask_conf" product="cfmask" source="toa_refl">
	<short_name>LE7CFMASK_CONF</short_name>
	<long_name>cfmask_conf_band</long_name>
	<file_name>LE70290302014204EDC00_cfmask_conf.img</file_name>
	<pixel_size units="meters" y="30.000000" x="30.000000"/>
	<resample_method>none</resample_method>
	<data_units>quality/feature classification</data_units>
	<valid_range max="3" min="0"/>
	<class_values>
		<class num="0">None</class>
		<class num="1">less than or equal to 12.5 Percent Cloud Confidence</class>
		<class num="2">greater than 12.5 and less than or equal to 22.5 Percent Cloud
		Confidence</class>
		<class num="3">greater than 22.5 Percent Cloud Confidence</class>
		<class num="255">fill</class>
	</class_values>
	<app_version>cfmask_1.5.0</app_version>
	<production_date>2015-06-24T17:54:32Z</production_date>
</band>

<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="FLOAT32" category="image"
name="lst_thermal_radiance" product="lst_temp" source="level1">
	<short_name>LE7LST_THERMAL_RADIANCE</short_name>
	<long_name>thermal band converted to radiance</long_name>
	<file_name>LE70290302014204EDC00_lst_thermal_radiance.img</file_name>
	<pixel_size units="meters" y="30.000000" x="30.000000"/>
	<resample_method>none</resample_method>
	<data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
```

```
        <valid_range max="8091" min="0"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T14:10:23Z</production_date>
</band>

<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="FLOAT32" category="image"
name="lst_atmospheric_transmittance" product="lst_temp" source="level1">
        <short_name>LE7LST_ATMOSPHERIC_TRANSMITTANCE</short_name>
        <long_name>atmospheric transmittance</long_name>
        <file_name>LE70290302014204EDC00_lst_atmospheric_transmittance.img</file_name>
        <pixel_size units="meters" y="30.000000" x="30.000000"/>
        <resample_method>none</resample_method>
        <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
        <valid_range max="8091" min="0"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T14:10:23Z</production_date>
</band>

<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="FLOAT32" category="image"
name="lst_upwelled_radiance" product="lst_temp" source="level1">
        <short_name>LE7LST_UPWELLED_RADIANCE</short_name>
        <long_name>upwelled radiance</long_name>
        <file_name>LE70290302014204EDC00_lst_upwelled_radiance.img</file_name>
        <pixel_size units="meters" y="30.000000" x="30.000000"/>
        <resample_method>none</resample_method>
        <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
        <valid_range max="8091" min="0"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T14:10:23Z</production_date>
</band>

<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="FLOAT32" category="image"
name="lst_downwelled_radiance" product="lst_temp" source="level1">
        <short_name>LE7LST_DOWNWELLED_RADIANCE</short_name>
        <long_name>downwelled radiance</long_name>
        <file_name>LE70290302014204EDC00_lst_downwelled_radiance.img</file_name>
        <pixel_size units="meters" y="30.000000" x="30.000000"/>
        <resample_method>none</resample_method>
        <data_units>radiance (W m^(-2) sr^(-1) mu^(-1))</data_units>
        <valid_range max="8091" min="0"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T14:10:23Z</production_date>
</band>

<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="FLOAT32" category="image"
name="landsat_emis" product="lst_temp" source="toa_refl">
        <short_name>LE7EMIS</short_name>
        <long_name>Landsat emissivity estimated from ASTER GED data</long_name>
        <file_name>LE70290302014204EDC00_emis.img</file_name>
        <pixel_size units="meters" y="30.000000" x="30.000000"/>
        <data_units>Emissivity Coefficient</data_units>
        <valid_range max="1" min="0"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T09:11:14</production_date>
</band>
```

```
<band fill_value="-9999" nsamps="8091" nlines="7121" data_type="INT16" category="image"
name="land_surface_temperature" product="lst" add_offset="0.000000" scale_factor="0.100000"
source="toa_refl">
        <short_name>LE7LST</short_name>
        <long_name>Land Surface Temperature</long_name>
        <file_name>LE70290302014204EDC00_lst.img</file_name>
        <pixel_size units="meters" y="30.000000" x="30.000000"/>
        <data_units>temperature (kelvin)</data_units>
        <valid_range max="3730" min="1500"/>
        <app_version>l5-7_lst_0.0.1</app_version>
        <production_date>2015-07-07T09:11:29</production_date>
</band>
```


Appendix C NARR Grid Spatial Extent