

 Committee on Earth Observation Satellites	Analysis Ready Data For Land	Product Family Specification Surface Temperature (CARD4L-ST)
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Document status

For Adoption as: **Product Family Specification, Surface Temperature**

This Specification should next be reviewed at: September 2018.

Proposed revisions may be provided to: lsi@lists.ceos.org

Document history

Version	Date	Description of change	Author
0.0.2	23-03-2017	Zero Draft based on materials provided by Geoscience Australia and the USGS in particular.	Jono Ross
1.0.0	16-04-2017 18-04-2017	Included document history; Revised to: - Formatting and structure - Included guidance section -	Adam Lewis
1.0.1	18-04-2017	Merged 'geometric source' and 'geometric method' elements	Adam Lewis
2.0	25-08-2017	Incorporated first round of revisions following feedback from the UK and others	Lewis
2.1	06-09-2017	Feedback from ESA; removed reference to bands (1.10) as these are not relevant to LST; Feedback on 1.13 included to the effect that LST algorithm may not be supplied at Threshold level. Added qualifying notes to 2.7,2.8	Lewis
3.0	05-12-2017	Feedback during the teleconference	Lewis
3.1	22-12-2018	Feedback from the teleconference (05/12/2018) and post teleconf (emails) included	Siqueira

Description

Product family title: **Surface Temperature (CARD4L-ST)**

Applies to:

Data collected with multispectral sensors operating in the thermal infra-red (TIR) wavelengths. These typically operate with ground sample distance and resolution in the order 10-100m however the Specification is not inherently limited to this resolution.

At present, surface temperature measurements tend to be provided as either surface brightness temperature (SBT), or, as land surface temperatures (LST) requiring the SBT to be modified according to the emissivity of the target.

This specification identifies the Surface Brightness Temperature (SBT) as being the minimum or Threshold requirement for analysis ready land surface data, and the Land Surface Temperature (LST) as being the desired or Target level of analysis ready data.

User experience and the ability of providers to undertake the necessary corrections will determine if this approach is the right balance, or whether future revisions of this Product Family Specification see changes in approach. For example, surface brightness temperature may be determined to be less than analysis-ready, or to be a separate product to land surface temperature. However, both SBT and LST are *land* measurements, requiring atmospheric corrections.

Definitions

LST	Land Surface Temperature
SBT	Surface Brightness Temperature
Ancillary Data	Ancillary data is data other than instrument measurements, originating in the instrument itself or from the satellite, required to perform processing of the data. They include orbit data, attitude data, time information, spacecraft engineering data, calibration data, data quality information and data from other instruments.
Auxiliary Data	Auxiliary data is the data required for instrument processing, which does not originate in the instrument itself or from the satellite. Some auxiliary data will be generated in the ground segment, whilst other data will be provided from external sources.
MTF	Modulation Transfer Function
Spectral Resolution	The spectral resolution defines the narrowest spectral feature that can be resolved by a spectrometer.
Spatial Resolution	The highest magnification of the sensor at the ground surface
Spectral Sampling Distance	Spectral sampling is the interval, in wavelength units, between discrete data points in the measured spectrum.
Spatial Sampling Distance	Spatial sampling distance is the barycentre-to-barycentre distance between adjacent spatial samples on the Earth's surface.

Requirements

1. General Metadata

These are metadata records describing a distributed collection of pixels. The collection of pixels referred to must be contiguous in space and time. General metadata should allow the user to assess the overall suitability of the dataset, and must meet the following requirements:

	Item	Threshold (minimum) requirements	Target (desired) requirements
1.1	Traceability	Not applicable	Data must be traceable to SI reference standard. For further information see, for example, http://l-a-b.com/information/traceability/ <i>Note 1. SI Traceability requires an estimate of measurement uncertainty</i>
1.2	Metadata machine readability	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold, but metadata is formatted in accordance with ISO 19115-2.
1.3	Data collection time	The start and stop time of data collection is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified.	Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second.
1.4	Geographical area	The surface location to which the data relate is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g., WGS84 coordinates).	The geographic area covered by the observations is identified specifically, such as through a set of coordinates of a closely bounding polygon. The location to which each pixel refers is identified (or can be reliably determined) expressed in projection coordinates with reference datum.
1.5	Coordinate reference system	The metadata lists the coordinate reference system that has been used.	As threshold
1.6	Map projection	The metadata lists the map projection that has been used, if any, and any relevant parameters required in relation to use of data in that map projection.	As threshold

1.7	Geometric correction source	Not required. The user is not explicitly advised of the geometric correction source and methods.	The metadata describes the geodetic correction methods used, including reference database and ancillary data such as elevation model(s) and reference chip-sets. DOIs are used.
1.8	Geodetic accuracy	Not required. The user is not provided with results of geometric correction processes pertaining to the dataset	The metadata includes metrics describing the assessed geodetic accuracy of the data, expressed units of the coordinate system of the data. Accuracy is assessed by independent verification (as well as internal model-fit where applicable). Uncertainties are expressed as root mean square error (RMSE) or Circular Error 90% Probability (CEP90).
1.9	Instrument	The instrument used to collect the data is identified in the metadata.	As threshold, but including a reference to the relevant CEOS Missions, Instruments and Measurements Database record.
1.10	Sensor calibration	Sensor calibration parameters are identified in the metadata, or can be accessed using details included in the metadata. Note 1: for example, a calibration parameter file located through a DOI.	Sensor calibration parameters are identified in the metadata, or can be accessed using details included in the metadata. Note 1: for example, a calibration parameter file located through a DOI.
1.11	Radiometric accuracy	Not required. The general metadata does not include information on the radiometric accuracy of the data.	The metadata includes metrics describing the assessed absolute radiometric accuracy of the data, expressed as absolute radiometric uncertainty relative to a known reference standard. <i>Note 1: for example, this may come from comparison with routine and rigorously collected in situ measurements</i>
1.12	Algorithms	All algorithms and versions, and the sequence in which they were applied in the generation process, are identified in the metadata.	As threshold, but only algorithms that have been published in a peer-reviewed journal. <i>Note: It is possible that high quality corrections are applied through non-disclosed processes. CARD4L does not per-se require full and open data and methods.</i> DOIs for each algorithm are identified in the metadata. The versions of the algorithms are identified.
1.13	Ancillary data	The metadata identifies the sources of ancillary data used in the generation process. The ancillary data can be requested from the owner.	As threshold, but the ancillary data are, expressed as DOIs and are also available for free online download, contemporaneously with the product.

		<i>Note 1: ancillary data includes DEMs, aerosols etc. and any additional data sources used in the generation of the product (auxiliary information location link).</i>	
1.14	Processing chain provenance	Not applicable	The metadata includes a description of the processing chain used to generate the product, including the versions of the software used.
1.15	Data access	The metadata identifies the location from where the product can be retrieved, expressed as a DOI. <i>Note 1: Manual and offline interaction action (e.g. log in) may be required.</i>	The metadata identifies an online location from where the data (including any available new records) can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required. <i>Note 1: Some manual interaction action may be required <u>in the first instance</u> ('one off' basis) to establish ongoing access to the data.</i>
1.16	Overall data quality	Not applicable	TBA. Further consideration is needed to confidently specify the overall metadata.

2. Per-pixel metadata (including, for example, quality flags and data-masks)

Per-pixel metadata should allow users to discriminate between (choose) observations on the basis of their individual suitability for application, and includes ‘quality flags’ The following minimum metadata specifications apply to each pixel. Whether the metadata are provided in a single record relevant to all pixels, or separately for each pixel, is at the discretion of the data provider. Similarly, the mechanism or form of the per-pixel metadata (additional data bands, mask layers, etc.) is open to the provider.

	Item	Threshold (minimum) requirements	Target (desired) requirements
2.1	Metadata machine readability	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold, but metadata is formatted in accordance with ISO 19115-2.
2.2	No data	Pixels that do not correspond to an observation (‘empty pixels’) are flagged.	As threshold.
2.3	Incomplete testing	The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed. <i>Note 1: e.g., due to missing ancillary data for some pixels.</i>	The metadata identifies which tests have, and have not, been successfully completed for each pixel.
2.4	Saturation	Metadata indicates where one or more spectral bands are saturated.	Metadata indicates which pixels are saturated for each spectral band.
2.5	Cloud	Metadata indicates whether a pixel is assessed as being cloud.	As threshold, with the metadata referencing (DOI) to a peer-reviewed algorithm for cloud detection.
2.6	Cloud shadow	Metadata indicates whether a pixel is assessed as being cloud shadow.	As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud shadow detection.
2.7	Illumination and viewing geometry	Not required	The solar incidence and sensor viewing angles are identified for each pixel, including coefficients used for terrain illumination correction.
2.8	Snow/ice mask	Not required	The metadata indicates whether a pixel is assessed as being snow/ice or not. The metadata references a citable peer-reviewed algorithm, as a DOI.

3. Radiometric and atmospheric corrections

The following requirements must be met for all pixels in a collection. Radiometric corrections must lead to a valid measurement of surface temperature.

	Item	Threshold (minimum) requirements	Target (desired) requirements
3.1	Measurement	Pixel values are expressed as a measurement of the Surface Temperature of the land, expressed as Kelvin	Surface temperature measurements are SI traceable (see also 1.1).
3.2	Corrections for atmosphere (and emissivity in the case of LST)	Atmospheric corrections are applied to derive Surface <u>Brightness</u> Temperature. The metadata references (as a DOI) a citable peer-reviewed algorithm.	The algorithms/ auxiliary information to derive emissivity used to estimate Surface Temperature is provided. The metadata references (as a DOI) a citable peer-reviewed algorithm.
3.3	Measurement Uncertainty	Not required.	Uncertainty, in Kelvin, of the surface temperature measurement for each pixel is provided. <i>Note: some of the intent of the initial wording (below) which refers to atmospheric windows may have been lost: Uncertainty, in units Kelvin, of the surface temperature for each pixel is also accompanied by distance from cloud (above) and atmospheric transmission (intervals, i.e. .4 - .55, .55 - .7 etc).</i>

4. Geometric corrections

Geometric corrections must place the measurement accurately on the surface of the Earth (that is, geolocate the measurement) allowing measurements taken through time to be compared.

	Item	Threshold (minimum) requirements	Target (desired) requirements
4.1	Geometric correction	Sub-pixel accuracy is achieved in <u>relative</u> geolocation, that is, the pixels from the same instrument and platform are consistently located, and in thus comparable, through time. Sub-pixel accuracy is taken to be less than or equal to 0.5 pixel radial root mean square error (rRMSE) or equivalent in Circular Error Probability (CEP) relative to a defined reference image. A consistent gridding / sampling frame is necessary to meet this requirement. Relevant metadata must be provided under 1.8 and 1.9 <i>Note 1. The threshold level will not necessarily enable interoperability between data from <u>different</u> sources as the geometric corrections for each of the sources may differ. Therefore, this may be too low a bar to meet the objectives of CARD4L</i>	Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid). A consistent gridding / sampling frame is necessary to meet this requirement. Relevant metadata must be provided under 1.8 and 1.9 <i>Note 1: This requirement is intended to enable interoperability between imagery from different platforms that meet this level of correction, and with non-image spatial data such as GIS layers and terrain models.</i>

Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve analysis ready data. This Guidance material does not replace or over-ride the specifications.

Introduction to CARD4L

What is CEOS Analysis Ready Data for Land (CARD4L) products?

CARD4L products have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort. These products would be resampled onto a common geometric grid (for a given product) and would provide baseline data for further interoperability both through time and with other datasets.

CARD4L products are intended to be flexible and accessible products suitable for a wide range of users for a wide variety of applications, including particularly time series analysis and multi-sensor application development. They are also intended to support rapid ingestion and exploitation via high-performance computing, cloud computing and other future data architectures. They may not be suitable for all purposes, and are not intended as a 'replacement' for other types of satellite products.

When can a product be called CARD4L?

The CARD4L branding is applied to a particular product once:

- that product has been assessed as meeting CARD4L requirements by the agency responsible for production and distribution of the product.
- that assessment has been peer reviewed by the CEOS Land Surface Imaging Virtual Constellation in consultation with the CEOS Working Group on Calibration and Validation.

Agencies or other entities considering undertaking an assessment process should contact the co-leads of the Land Surface Imaging Virtual Constellation ([hyperlink](#)).

A product can continue to use CARD4L branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

What is the difference between Threshold and Target?

Products that meet all threshold requirements should be immediately useful for scientific analysis or decision-making.

Products that meet target requirements will reduce the overall product uncertainties and enhance broad-scale applications. For example, the products may enhance interoperability or provide increased accuracy through additional corrections that are not reasonable at the *threshold* level.

Target requirements anticipate continuous improvement of methods and evolution of community expectations which are both normal and inevitable in a developing field. Over time, *target* specifications may (and subject to due process) become accepted as *threshold* requirements.

Procedural examples

Processes to produce Threshold Surface (Brightness) Temperature CARD4L-ST

The following correction processes would typically be applied to produce CARD4L-ST Threshold

- Complete metadata would be provided on the methods used to calibrate the sensor, generate the data, and to derive the estimates of surface temperature. Any ancillary datasets used in the process, such as atmospheric data, would be referenced using a DOI and would, ideally, be accessible to the user. This general metadata would include the timing and extent of the dataset, the latter using a bounding box or bounding polygon.
- The data would be ortho-rectified to sub-pixel accuracy, at least compared to other data from the same sensor, and ideally relative to an accepted coordinate reference system.
- A set of layers would be produced indicating, for each pixel, the quality of the pixel by flagging saturated pixels and identifying clouds.
- An image of surface brightness temperature would be produced in Kelvin, based on the instrument values corrected for atmospheric transmission.

The following additional processes could be applied to produce CARD4L-ST Target

- An image of surface temperature in Kelvin would be produced by adjustment of the surface brightness temperature for the estimated emissivity of the target.
- The user would be provided with information on the uncertainty, in Kelvin, of the estimated surface temperature value at each pixel. This could, for example, be through a layer of pixels uncertainty values.

Specific examples

Processes to produce Threshold Surface Temperature CARD4L-ST

Reference papers

The following papers provide scientific and technical guidance:

Cook, M., Schott, J.R, Mandel, J., Raqueno, M. (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 (11244-11266). doi:10.3390/rs6111244 ISSN 2072-4292.
www.mdpi.com/journal/remotesensing

Li et al., (2013) Satellite-derived land surface temperature: Current status and perspectives ***Remote Sensing of Environment*** 131 (2013) 14–37.