CEOS-ARD - Optical - Surface Temperature

Draft Version

This is a draft version. Please visit the CEOS-ARD website for the latest endorsed version of this document.

Document Status

Product Family Specification, Optical, Surface Temperature

Proposed revisions may be provided to: ard-contact@lists.ceos.org

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Version 6.0.0-draft (unreleased draft)
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CEOS Analysis Ready Data Definition

CEOS Analysis Ready Data (CEOS-ARD) are satellite data that 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 and interoperability both through time and with other datasets.

Description

Product Family Specification: Optical, Surface Temperature (ST)

Version: 6.0.0-draft

Applies to: Data collected with satellite sensors operating in the thermal infrared (TIR and MWIR) and microwave wavelengths. These typically operate with ground sample distance and resolution in the order 1 dm - 50 km however the specification is not inherently limited to these resolutions.

Background

Remotely sensed surface temperature measurements tend to be provided as surface brightness temperature (SBT), land surface temperature (LST), water surface temperature (WST), or ice surface temperature (IST), where LST, WST, and IST are derived from SBT accounting for the emissivity of the target. This specification identifies Surface Temperature (ST), including but not limited to LST, WST, and IST, as the minimum or threshold requirement for analysis ready surface data.

Definitions and Abbreviations

Auxiliary Data
: 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, e.g., DEM, aerosols.

CEOS-ARD
: Committee on Earth Observation Satellites - Analysis Ready Data

CEP
: Circular Error Probability, often provided with an additional percentage (e.g. CEP90 for 90% probability)

DOI
: Digital Object Identifier

GIS
: Geographic Information System

LST
: Land Surface Temperature

rRMSE
: Radial Root Mean Square Error

SBT
: Surface Brightness Temperature

SI
: International System of Units, internationally known by the abbreviation SI (from French Système international d'unités)

ST
: Surface Temperature

TIR
: Thermal Infrared

UTC
: Coordinated Universal Time

WGS84
: World Geodetic System 1984

Requirements

WARNING: The section numbers in front of the title (e.g. 1.1) are not stable and may change or may be removed at any time. Do **not** use the numbers to refer back to specific requirements! Instead, use the textual identifier that is provided below the title.

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 requirements listed below.

1.1. CEOS-ARD PFS Compliance Version

Identifier: `meta-ardver`

Threshold requirements:

Version of the CEOS-ARD PFS with which the product is complying is identified.

Goal requirements:

As threshold.

1.2. Metrological Traceability of the Measurand to SI

Identifier: `meta-trace-st`

Threshold requirements:

Not required.

Goal requirements:

Data must be traceable to SI reference standard, documented by URL or DOI.

Note:

1. SI Traceability requires an estimate of measurement uncertainty (see Radiometric and Atmospheric Corrections: Measurand Uncertainty).

1.3. Metadata Machine Readability

Identifier: `meta-memare-st`

Threshold requirements:

Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component/variable for further use.

Goal requirements:

As threshold, but metadata is provided in a community endorsed standard that facilitates machine-readability, such as CEOS-ARD Metadata Specifications, ISO 19115-2, STAC, the Climate and Forecast (CF) convention, or the Attribute Convention for Data Discovery (ACDD).

1.4. Data Collection Time

Identifier: `meta-time-st`

Threshold requirements:

The beginning and end of the data collection time is expressed in date/time and identified in the metadata consistent with ISO 8601. The time is expressed with the time offset from UTC unambiguously identified.

In the case of composite or mosaic products, the dates/times of the first and last data takes are provided with the product.

Goal requirements:

As threshold, but information required to determine, within a stated uncertainty, when the individual observations were taken is available.

1.5. Geographical Area

Identifier: `meta-geoarea-optical`

Threshold requirements:

The surface location to which the data relates is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g., WGS84).

Goal requirements:

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) with the projection sys-

tem (if any) and reference datum provided.

1.6. Coordinate Reference System

Identifier: `meta-crs-ar`

Threshold requirements:

The coordinate reference system that has been used is detailed.

Goal requirements:

As threshold.

1.7. Map Projection

Identifier: `meta-mapproj-ar`

Threshold requirements:

The map projection that has been used and any relevant parameters required in relation to use of data in that map projection is detailed.

Goal requirements:

As threshold.

1.8. Geometric Correction Methods

Identifier: `meta-geocorm-st`

Threshold requirements:

Not required.

Goal requirements:

Information on geometric correction source and methods are provided, including reference database and auxiliary data such as elevation model(s) and reference chipsets, documented by URL or DOI.

1.9. Geometric Uncertainty of the Data

Identifier: `meta-geounc-st`

Threshold requirements:

Not required.

Goal requirements:

Inclusion of metrics describing the assessed geodetic uncertainty of the data, expressed in units of the coordinate system of the data. Uncertainty is assessed by independent verification (as well as internal model-fit where applicable). Uncertainties are expressed quantitatively and documented by URL or DOI.

1.10. Instrument

Identifier: `meta-instru-st`

Threshold requirements:

The instrument used to collect the data is identified.

- Satellite name
- Instrument name

Goal requirements:

As threshold, with references to the relevant “CEOS Missions, Instruments and Measurements” (MIM) database record (database.eohandbook.com).

1.11. Spectral Bands

Identifier: `meta-specband-st`

Threshold requirements:

Spectral response function and method of assessment is provided.

Goal requirements:

As threshold, but information on spectral bands is documented by URL or DOI.

1.12. Sensor Calibration

Identifier: `meta-sencal-st`

Threshold requirements:

Binary description of calibrated/not calibrated only.

Goal requirements:

Sensor calibration parameters are identified or can be accessed using details included in the metadata, documented by URL or DOI.

Ideally this would support machine-to-machine access.

1.13. Measurand Uncertainty

Identifier: `meta-measurunc`

Threshold requirements:

Methods of determining the assessed measurand uncertainty of the version of the data are specified, documented by URL or DOI.

Goal requirements:

As threshold, but the absolute measurand uncertainty of the data is provided.

1.14. Measurand Encoding

Identifier: `meta-measurenc`

Threshold requirements:

Range and bit depth are provided.

Goal requirements:

As threshold.

1.15. Algorithms

Identifier: `meta-malgos-st`

Threshold requirements:

Not required.

Goal requirements:

All algorithms and the sequence in which they were applied in the generation process are identified and documented by URL or DOI.

Algorithms must be published and validated, and a description of the validation process is included.

1.16. Auxiliary Data

Identifier: `meta-auxdat-st`

Threshold requirements:

Lists the sources of auxiliary data used in the generation process, documented by URL or DOI.

Note:

1. Auxiliary data includes DEMs, aerosols, water vapor, Climate Modeling Grids, and any other data sources used in product generation.

Goal requirements:

As threshold, but information on auxiliary data should be available for free online download, contemporaneously with the product or through a link to the source.

1.17. Processing Chain Provenance

Identifier: `meta-proprov-st`

Threshold requirements:

The provider attaches to each delivered dataset (delivery unit) information which allows the provider to reconstruct the exact processing environment (software versions, calibration files, parameter settings) in which this particular output was produced.

Goal requirements:

As threshold, but the provider is required to reproduce the exact same output.

1.18. Data Access

Identifier: `meta-daccess-st`

Threshold requirements:

The location from where the data can be retrieved is identified, expressed as a URL or DOI.

Note:

1. Manual and offline interaction action (e.g., login) may be required.

Goal requirements:

An online location is identified from where the data can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required.

1.19. Valid Pixels

Identifier: `meta-valpix`

Threshold requirements:

Percentage of valid pixels in a specified area based on the applied flags from Per-Pixel Metadata.

Goal requirements:

As threshold.

2. Per-Pixel Metadata

The following minimum metadata specifications apply to each pixel. Whether the metadata is provided in a single record relevant to all pixels or separately for each pixel is at the discretion of the data provider. Per-pixel metadata should allow users to **discriminate between** (choose) observations on the basis of their individual suitability for application.

2.1. No Data

Identifier: `pxl-pinodat-st`

Threshold requirements:

Pixels that do not correspond to an observation (No Data / Invalid / Falsified / Valid / Modelled) are flagged.

Goal requirements:

As threshold.

2.2. Incomplete Testing

Identifier: `pxl-pincot-st`

Threshold requirements:

Identifies pixels for which the per-pixel tests (Per-Pixel Metadata: Saturation, Per-Pixel Metadata: Cloud, Per-Pixel Metadata: Cloud Shadow, Per-Pixel Metadata: Surface, Per-Pixel Metadata: Terrain Occlusion) have not all been successfully

completed.

Note:

1. This may be the result of missing ancillary data for a subset of the pixels.

Goal requirements:

Identifies which tests (Per-Pixel Metadata: Saturation, Per-Pixel Metadata: Cloud, Per-Pixel Metadata: Cloud Shadow, Per-Pixel Metadata: Surface, Per-Pixel Metadata: Terrain Occlusion) have and have not been successfully completed for each pixel.

2.3. Saturation

Identifier: `pxl-pisatur-ar`

Threshold requirements:

Specification of whether there is pixel radiometric saturation at Level 1 in one or more spectral bands.

Goal requirements:

As threshold, with specification of which pixels are radiometrically saturated for each spectral band.

2.4. Cloud

Identifier: `pxl-picloud-st`

Threshold requirements:

Specification of whether a pixel is cloud-affected.

Goal requirements:

As threshold, but information on cloud type or confidence is included, documented by URL or DOI.

2.5. Cloud Shadow

Identifier: `pxl-picloudsh-st`

Threshold requirements:

Not required.

Goal requirements:

Specification of whether a pixel is cloud shadow-affected. Information on cloud shadow detection is documented by URL or DOI.

2.6. Surface

Identifier: `pxl-surf-st`

Threshold requirements:

Specification of whether a pixel is assessed as being land or water, including the information source and other relevant surface characteristic information.

Note:

1. External data sources are listed in General Metadata: Auxiliary Data.

Goal requirements:

As threshold, but pixels are identified as being snow or ice.

2.7. Solar and Viewing Geometry

Identifier: `pxl-vigeso-ar`

Threshold requirements:

Specification of the solar and sensor viewing azimuth and zenith angles.

Goal requirements:

As threshold.

2.8. Terrain Occlusion

Identifier: `pxl-terrain-st`

Threshold requirements:

Not required.

Goal requirements:

Specification of whether pixels are not visible to the sensor due to terrain occlusion during off-nadir viewing.

3. Radiometric and Atmospheric Corrections

The following requirements must be met for all pixels in a collection. The requirements indicate both the necessary outcomes and the minimum steps necessary to be deemed to have achieved those outcomes.

3.1. Measurand

Identifier: `rac-measur-st`

Threshold requirements:

Pixel values are a measurement of the Surface Temperature expressed in kelvin.

Note:

1. See General Metadata: Spectral Bands

Goal requirements:

Surface temperature measurements are SI traceable (see also General Metadata: Metrological Traceability of the Measurand to SI).

3.2. Corrections for Atmosphere

Identifier: `rac-catmos`

Threshold requirements:

Retrieval methods for estimating surface temperature are provided.

Goal requirements:

As threshold.

3.3. Adjustments for Emissivity and Anisotropy

Identifier: `rac-emiani`

Threshold requirements:

Retrieval methods for estimating surface emissivity per channel are provided.

Goal requirements:

As threshold, but the retrieval method for estimating the total directional emissivity is provided.

3.4. Measurand Uncertainty

Identifier: `rac-muncer-st`

Threshold requirements:

A self-assessed declaration of per-pixel measurement uncertainty, following Section 3.2.4 (Uncertainty Characterization) of the Joint Earth Observation Mission Quality Assessment Framework - Optical Guidelines is provided, meeting the Basic or Good criteria.

Goal requirements:

A self-assessed declaration of per-pixel measurement uncertainty, following Section 3.2.4 (Uncertainty Characterization) of the Joint Earth Observation Mission Quality Assessment Framework - Optical Guidelines is provided, meeting the Excellent or Ideal criteria.

Note:

1. https://science.nasa.gov/wp-content/uploads/2026/05/joint-optical-guidelines-jul2025-signed.pdf

4. Geometric Corrections

Geometric corrections are steps that are taken to place the measurement accurately on the surface of the Earth (that is, to geolocate the measurement) allowing measurements taken through time to be compared. This section specifies any geometric correction requirements that must be met in order for the data to be analysis ready.

4.1. Geometric Correction

Identifier: `gcor-geocorr-st`

Threshold requirements:

Sub-pixel uncertainty is achieved in relative geolocation, that is, the pixels from the same instrument and platform are consistently located, and in thus comparable, through time.

Sub-pixel uncertainty 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 used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur).

Relevant metadata must be provided under General Metadata: Geometric Uncertainty of the Data and General Metadata: Instrument.

Notes:

1. The threshold level will not necessarily enable interoperability between data from different sources as the geometric corrections for each of the sources may differ.
2. It is useful to note if the sensor is used at its native resolution before geometric correction or that some resampling must be done.

Goal requirements:

Sub-pixel uncertainty is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid).

Relevant metadata must be provided under General Metadata: Geometric Uncertainty of the Data and General Metadata: Instrument.

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.

Introduction

This section aims to provide background and specific information on the processing steps that can be used to achieve analysis ready data for a specific and well-developed Product Family Specification. This Guidance material does not replace or override the specifications.

What is CEOS Analysis Ready Data?

CEOS-ARD are products that 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. In general, 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.

CEOS-ARD 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 CEOS-ARD?

The CEOS-ARD branding is applied to a particular product once:

- that product has been assessed as meeting CEOS-ARD requirements by the agency responsible for production and distribution of the product, and
- that the assessment has been peer reviewed by the relevant CEOS team(s).

Agencies or other entities considering undertaking an assessment process should consult the CEOS-ARD Governance Framework.

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

What is the difference between Threshold and Goal?

Threshold (Minimum) requirements are the **minimum** that is needed for the data to be analysis ready. This must be practical and accepted by the data producers.

Goal (Desired) requirements (previously referred to as “Target”) are the ideal; where we would like to be. Some providers may already meet these.

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

Products that meet *goal* 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.

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

References

Cook, Monica, John R. Schott, John Mandel, and Nina Raqueno. 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): 11244–66. https://doi.org/10.3390/rs61111244.

International Organization for Standardization. 2009. *Geographic information — Metadata — Part 2: Extensions for imagery and gridded data*. Standard. International Organization for Standardization.

Li, Zhao-Liang, Bo-Hui Tang, Hua Wu, et al. 2013. "Satellite-Derived Land Surface Temperature: Current Status and Perspectives." *Remote Sensing of Environment* 131: 14–37. https://doi.org/https://doi.org/10.1016/j.rse.2012.12.008.

Document History

Editorial changes are not listed.

Version 6.0.0-draft (unreleased draft)

This version has not been released yet. Based on the recorded changes (highest level: major), the proposed next version number is **6.0.0**.

This version contains major changes. Products that comply with a previous version need to be reassessed to confirm their compliance with this version.

Editors: Harvey Jones

Building Block	Change	Level
Document	• Created separate requirements for ‘Corrections for Atmosphere’ and ‘Adjustments for Emissivity and Anisotropy’. Per-pixel emissivity information is now required at Threshold. • Introduced a Threshold requirement for ‘Measurement Uncertainty’. • Renamed ‘Measurement’ to ‘Measurand’ • Removed threshold requirement for ‘Algorithms’. • Introduced Per-pixel Goal requirement for ‘Terrain Occlusion’. • Replaced ‘Snow/Ice’ mask with ‘Surface’, covering Land/Water at Threshold and Snow/Ice at Goal. • Updated ‘Cloud’ and ‘Cloud Shadow’ requirements to align more closely with the AR PFS v2.0 and the suitability of cloud shadow for non-reflectance methods. • Updated ‘No Data’ requirement to address https://github.com/ceos-org/ceos-ard/issues/4. • Updated ‘Incomplete Testing’ requirement to aid machine readability / automated assessment. • Removed redundant ‘Metadata Machine Readability’ requirement from Per-pixel Metadata. • Replaced General Metadata Percentage of Valid Observations requirement with Valid Pixels • Introduced a new Processing Chain Provenance requirement, where Threshold = Reconstructibility, Goal = Reproducibility. • Removed ‘Radiometric Accuracy’ requirement. • Adopted AR PFS v2.0 requirements for ‘Auxiliary Data’, ‘Measurand Uncertainty’, ‘Encoding’, ‘Sensor Calibration’, ‘Spectral Bands’, ‘Instrument’, ‘Geometric Uncertainty of the Data’,	**major**

Building Block	Change	Level
	'Geometric Correction Methods', 'Map Projection', and 'Data Collection Time'. • Aligned with other optical PFS where the ST PFS had minor editorial differences.	
Requirement: Metadata Machine Readability	Added more format examples to Goal description and replaced part for variable in the threshold description	minor
Requirement: Data Collection Time	Added clarification for mosaic products.	minor
Requirement: Geometric Uncertainty of the Data	Added reference to URL / DOI to Goal description	minor
Requirement: Instrument	Added requirement to include the satellite and instrument names in the metadata	**major**
Requirement: Spectral Bands	Added method of assessment and removed full from full spectral response function. Added reference to URL/DOI at Goal.	minor
Requirement: Sensor Calibration	updated goal description to reference DOI/URL access and support for machine-to-machine access	minor
Requirement: Measurand Uncertainty	Replaced requirement title and description from radiometric to measurand uncertainty	minor
Requirement: Measurand Encoding	Renamed Radiometric Encoding to Measurand Encoding	minor
Requirement: Algorithms	Removed threshold requirement, updated goal requirement	minor
Requirement: Auxiliary Data	Added URL/DOI reference and note of examples auxiliary data	minor

Building Block	Change	Level
Requirement: Processing Chain Provenance	introduced a threshold requirement requiring reconstructibility at Threshold and reworded the Goal requirement for reproducibility.	**major**
Requirement: Data Access	Added goal requirement to identify online data access location, and minor wording update to threshold description.	minor
Requirement: No Data	Added different no data classes	**major**
Requirement: Incomplete Testing	Specified the per-pixel tests that must be completed for threshold.	minor
Requirement: Cloud	Adopted AR PFS approach with an adjustment to the Goal requirement (broad cloud type/confidence over cirrus cloud identification) and requiring only ‘cloud-affected’ pixels to be identified.	minor
Requirement: Cloud Shadow	Adopted AR PFS approach but removed Threshold requirement and specified only ‘cloud-affected’ pixels	minor
Requirement: Surface	Replaced Snow/Ice requirement with a Surface requirement, which features a threshold requirement for pixels identified as land or water to be flagged.	**major**
Requirement: Terrain Occlusion	Added SR terrain occlusion requirement with minor grammar change	minor
Requirement: Measurand	Removed ‘of the land’ qualifier for ‘surface temperature,’ renamed requirement to ‘measurand’ and added a link to Spectral Bands requirement	minor

Version 5.0.1 (2026-05-27)

Editors: Matthias Mohr

Building Block	Change	Level
Document	• Renamed CARD4L to CEOS-ARD • Restructured the document; removed empty or unused parts • Split “Applies to” section into “Applies to” and “Background” sections • Document history has been reset. Check the previous versions for details • Numerical identifiers were rotated and are deprecated; new textual identifiers have been added • The requirement “Radiometric corrections must lead to a valid measurement […]” has been moved from the category description to the measurement requirement. • If no threshold requirement applies, the wording has been made consistent (e.g. former req. 1.7 and 1.8). • Former req. 1.9: Removed “on instrument” from “As threshold, but information on instrument should be available”. • Former req. 2.3: Replaced the wording “e.g., due to missing ancillary data for some pixels.” with “This may be the result of missing ancillary data for a subset of the pixels.” • Annex has been reformatted and updated	minor

The history of the versions before 5.0.1 is available in the older versions of this document, see the CEOS-ARD website or the GitHub releases.