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Copernicus Climate Change Service

Product User Guide and Specification

Sea Surface Temperature

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History of modifications

Version	Date	Description of modification	Chapters / Sections
1	31/01/2018	First version	All
1.1	28/02/2018	Updated file example	Appendix A
1.2	19/04/2018	Added creation_date attribute	Appendix A
1.3	30/04/2018	Added CDR information	All
2	02/05/2018	Version number updated to reflect major change; no content change cf. v1.2	n/a
2.1	01/06/2018	Update following feedback	Summary, §2.2, §4.3.3
3.0	30/09/2018	Added Level 4 information	Summary, §1, §5
4.0	24/03/2019	Added early CDR information	Summary, §1, §2, §3, §5, §6
5.0	24/06/2019	Update for 312b service contract	n/a
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6.0	23/06/2020	Add full resolution MetOp and SLSTR issue	§2.1, §4.3.4

List of datasets covered by this document

Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
D3.SST.3	SST ICDR L3 v2	ICDR	2	10/2018 - present
D3.SST.4	SST ICDR L4 v2	ICDR	2	10/2018 - present
D312a_Lot3.3.2.6	ATSR L2P CDR v2	CDR	2	30/04/2018
D312a_Lot3.3.2.7	ATSR L3U CDR v2	CDR	2	30/04/2018
D312a_Lot3.3.2.2	AVHRR L2P CDR v2	CDR	2	30/04/2018

D312a_Lot3.3.2.3	AVHRR L2P CDR v2 (early)	CDR	2	31/03/2019
D312a_Lot3.3.2.4	AVHRR L3U CDR v2	CDR	2	30/04/2018
D312a_Lot3.3.2.5	AVHRR L3U CDR v2 (early)	CDR	2	31/03/2019
D312a_Lot3.3.2.8	Analysis L4 CDR v2	CDR	2	30/09/2018
D312a_Lot3.3.2.9	Analysis L4 CDR v2 (early)	CDR	2	31/03/2019

Related documents

Reference ID	Document
D1	GHRSST data specification; https://www.ghrsst.org/wp-content/uploads/2016/10/GDS20r5.pdf
D2	ESA SST CCI Product Specification Document (PSD); http://www.esa-sst-cci.org/PUG/pdf/SST_CCI-PSD-UKMO-201-Issue-1-signed.pdf
D3	ESA SST CCI Product User Guide (PUG); http://www.esa-sst-cci.org/PUG/pdf/SST_CCI-PUG-UKMO-201-Issue_1-signed.pdf
D4	Climate and Forecast (CF) Conventions and Metadata; http://cfconventions.org

Acronyms

Acronym	Definition
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	Climate Data Store
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS	EUMETSAT Polar System
ERS	European Remote Sensing
ESA	European Space Agency
GAC	Global Area Coverage
GDS	GHRSST Data Specification
GHRSST	Group for High Resolution SST
ICDR	Interim Climate Data Record
L2	Level-2 data product
L2P	Level-2 Pre-processed data product
L3	Level-3 data product
L3C	Level-3 Collated data product
L3U	Level-3 Uncollated data product
L4	Level-4 data product
NOAA	National Oceanographic and Atmospheric Administration
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice Satellite Application Facility
POES	Polar Operational Environmental Satellites
RDAC	Regional Data Assembly Centre
SLSTR	Sea and Land Surface Temperature Radiometer

SST	Sea Surface Temperature

General definitions

L2P – Geophysical variables derived from Level 1 source data on the Level 1 grid (typically the satellite swath projection). Ancillary data and metadata added following GHRSST Data Specification.
L3U – L2 data granules remapped to a regular latitude/longitude grid without combining observations from multiple source files. L3U files will typically be “sparse”, corresponding to a single satellite orbit.
L3C – SST observations from a single instrument combined into a space-time grid. In this project, a typical L3C file may contain all the observations from a single instrument in a 24-hour period.
L4 – SST observations from multiple instruments using an analysis system (e.g. optimal interpolation) to produce a gridded, gap-free product.

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Scope of the document

This document is the user guide for the Level 2, 3, and 4 SST products. This version describes the v2.0 CDR produced by ESA SST CCI project and v2.0 ICDR produced within the Copernicus Climate Change Service.

The main aim of the document is to aid users in selecting the data product they require (including understanding its features and limitations) and then enable them to read and use the data. Details of the data format are provided including: data and flag variables, metadata, and naming conventions.

Executive summary

This document is the user guide for the Sea Surface Temperature CDR/ICDR products. The C3S ICDR is intended to be used in combination with the corresponding SST-CCI CDR. Both ICDR and CDR datasets are generated using the same software and algorithms originally developed within the ESA SST CCI project. The version 2 SST-CCI CDR will provide a baseline record from 1980s through end-2016; and the version 2 C3S ICDR provides an ongoing extension in time of the record from Jan-2017 onwards. Unlike the CCI CDR which is a reprocessing of historical data, the C3S ICDR will provide short-delay access to current SST data.

The data files are in netCDF-4 format and follow the standard specification defined by the Group for High Resolution Sea Surface Temperature (GHRSST) [D1] and are also compatible with the SST-CCI product specification [D2]. The Level 2 and Level 3 CDR/ICDR provide two single-sensor SST fields: one provides a measure of the temperature of the skin of the water at the time it was observed; the second is an estimate of the temperature at 20 cm depth in the daily mean. They have uncertainty estimates that have been broken down into different components and a total uncertainty for each SST value.

A summary of the key data fields within the files is given below.

Variable name	**Units**	**Description**
lat	degrees	The latitudes of the grid points
lon	degrees	The longitudes of the grid points
sea_surface_temperature	K	The skin SST at each location in the grid
sses_standard_deviation	K	Uncertainty in the SST at each location
sea_surface_temperature_depth	K	The 20 cm depth SST at each location in the grid
sst_depth_total_uncertainty	K	Uncertainty in the 20 cm depth SST at each location in the grid
quality_level	N/A	Quality level of the SST: 0 for no data; 1 for bad data; 2 for worst usable data; 3 for low quality; 4 for good quality; 5 for best quality

The Level 4 CDR/ICDR products provide a global, spatially complete, daily analysis of SST and sea ice concentration from multiple sensors. The SST fields are designed to represent the daily average SST at 20 cm depth. A summary of the key data fields within the files is given below.

Variable name	Description
lat	The latitudes of the grid points
lon	The longitudes of the grid points
analysed_sst	The SST at each location in the grid
analysis_uncertainty	Uncertainty in the SST at each location
sea_ice_fraction	Sea ice fraction at each location in the grid
mask	Information on whether the grid cell is ocean, land, or sea ice

L2P files are supplied on the original satellite image grid. Level 3 and level 4 data are provided on a 0.05° regular latitude-longitude grid and hence the dimension of the data fields is 7200 in longitude and 3600 in latitude. The fields also have a time dimension, which always has a length of one.

Current data availability for different processing levels is shown in Figure 1 below.

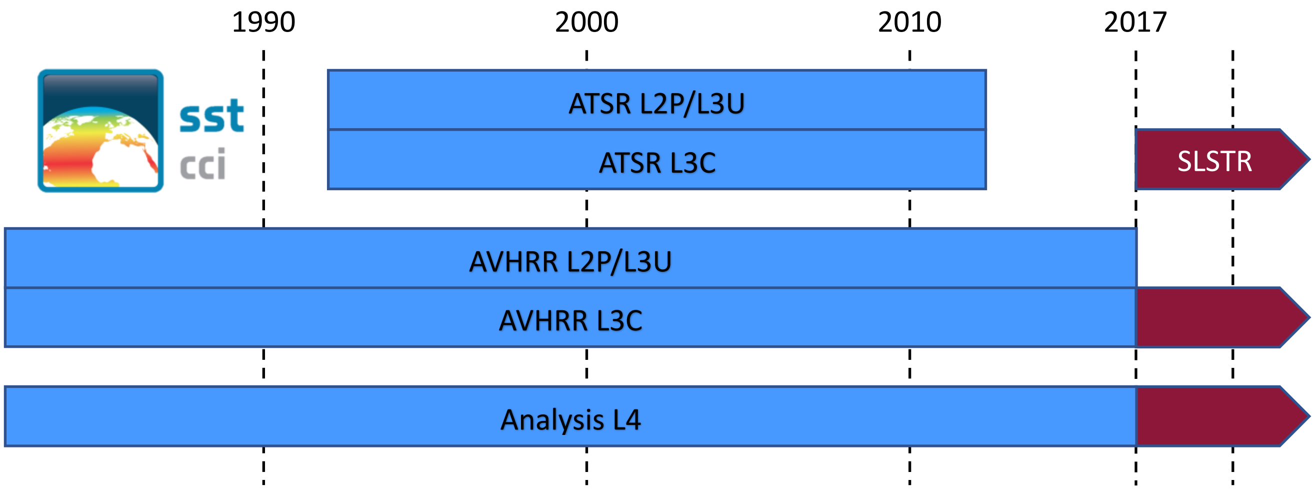

Figure 1 – CDR (dark blue) / ICDR (dark red) datasets: temporal coverage and availability. C3S ICDR provides an ongoing extension of the SST daily products (L3C and L4) from 2017 onwards.

1. General Information

1.1 Product description

The Sea Surface Temperature (SST) products are available in two main datasets: a Climate Data Record (CDR) produced by the European Space Agency (ESA) Climate Change Initiative (CCI) for SST; and an Interim Climate Data Record (ICDR) produced by the Copernicus Climate Change Service (C3S). The C3S ICDR is intended to be used in combination with the corresponding SST-CCI CDR. Both ICDR and CDR datasets are generated using the same scientific algorithms and a fully compatible implementation of the software originally developed within the ESA SST CCI project. The version 2 SST-CCI CDR will provide a baseline record from 1980s through end-2016; and the version 2 C3S ICDR provides an ongoing extension in time of the record from Jan-2017 onwards. Unlike the CCI CDR, which is a reprocessing of historical data, the C3S ICDR will provide short-delay access to current SST data.

Each Level 2 and Level 3 file contains two sets of SSTs. The first set provides a measure of the temperature of the skin of the water at the time it was observed; the second set are estimates of the temperature at 20 cm depth as a daily mean. Since SSTs at 1030 h or 2230 h local time are close to the mean SST across the diurnal cycle (see Figure 2), this daily mean is estimated by adjusting observations to the nearest of these times by use of a model of the sub-daily variations of SST. Both SSTs have uncertainty estimates that have been broken down into different components and a total uncertainty for each SST value.

The two SSTs are relevant for different purposes. The skin temperature is the primary measurement, controls the outgoing long-wave radiation emitted by the ocean, and controls the turbulent heat and moisture fluxes across the air-sea interface. However, many of the satellites used to build the CDR are in different (and in some cases, drifting) orbits, so the local time of observation is not constant, thereby aliasing the SST diurnal cycle into the record. Therefore, the skin temperature is not usually recommended for long-term trend analysis.

The daily mean 20 cm SST provides an estimate comparable to drifting buoys and the longer historical *in situ* records of SST. The adjustment to daily mean is intended to ensure it is stable with respect to the satellite overpass time, and 20 cm SST is recommended for applications where long-term average changes are important.

In addition to the source satellite data, the product also uses auxiliary data from the ECMWF NWP analysis: atmospheric and surface fields are used in the cloud detection, and these are auxiliary to the SST retrieval algorithm, although with low sensitivity to these prior data in both steps; surface fluxes are used to calculate the diurnal adjustment to standard depth and daily mean; and finally the 10 m surface windspeed is included in the SST product as an indicator of the turbulent state of the air-sea interface.

The Level 4 products merge data from the level 3 SSTs from all available sensors to create spatially complete, daily SST fields of average SST at 20 cm depth. The method for combining the SST data is a variational data assimilation scheme. More details can be found in Donlon et al. (2012) and Merchant et al. (2014) (although note that these refer to earlier versions of the processing scheme). Uncertainty information is provided with the SSTs.

Also included with the SST analyses are sea ice concentrations. These were produced by analysing input data sourced from the OSI SAF (EUMETSAT Ocean and Sea Ice Satellite Application Facility. Global sea ice concentration continuous reprocessing offline product (2017 onwards), [Online]. Norwegian and Danish Meteorological Institutes. Available from the CDS).

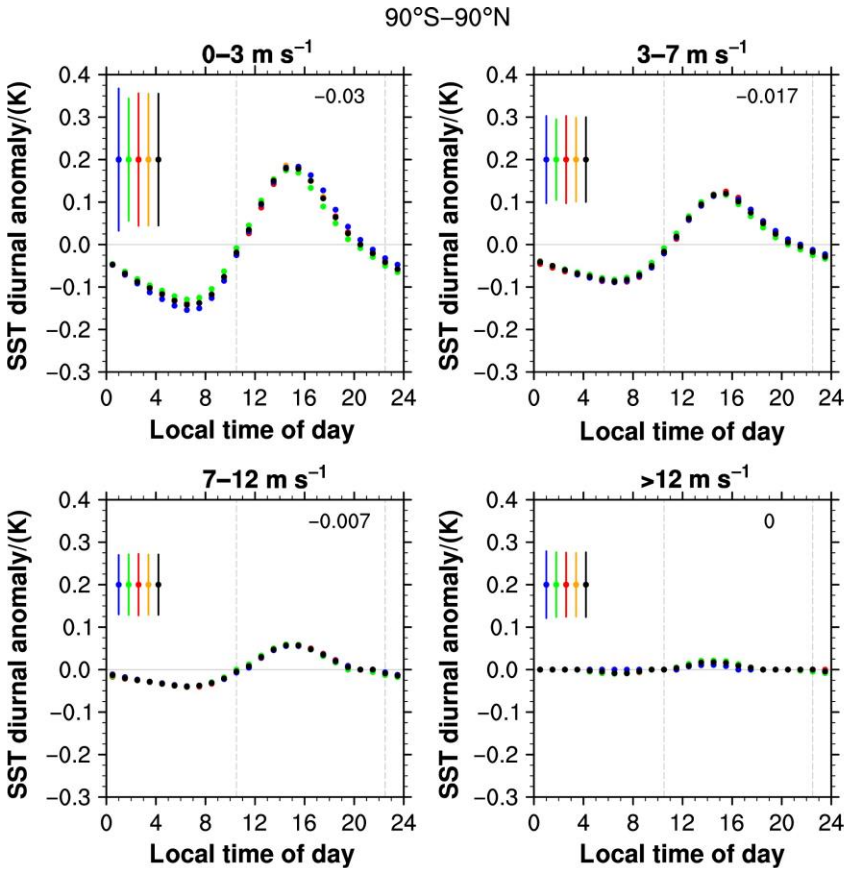

Figure 2 – Global mean diurnal cycle of daily SST anomalies from drifting buoys for different wind speeds. The annual mean diurnal cycle is displayed in black, Northern Hemisphere winter (DJF) in blue, spring (MAM) in green, summer (JJA) in red and autumn (SON) in orange. The bars in the top left corner show the associated uncertainties. Reproduced from Morak-Bozzo et al. 2016.

1.1.1 SST Types

The term SST may be used to refer to the temperature of water anywhere from the interface with the atmosphere down to depths of 10 m or more. The distinction is important because the influence of the sun and atmosphere are largest near the surface. For example, the SST in a particular location at a depth of 20 cm might exhibit a large diurnal cycle, but not the SST in the same location at 10 m. Therefore, there are several types of SST that are sometimes referred to. The CDR/ICDR products use the definitions from the Group for High Resolution Sea Surface Temperature (GHRSST) Science Team:

- **The interface temperature (SSTint)** is a hypothetical temperature at the exact air-sea interface.

- **The skin sea surface temperature (SSTskin)** is defined as the temperature measured by an infrared radiometer, typically operating at wavelengths of 3.7-12 µm. This corresponds to a depth of ~10-20 µm. The skin temperature is typically ~0.2 K cooler than *in situ* SST measurements, though the exact value is strongly dependent on wind speed.
- **The sub-skin sea surface temperature (SSTsubskin)** represents the temperature at the base of the conductive laminar sub-layer of the ocean surface. For practical purposes the sub skin can be approximated as the temperature observed by a microwave radiometer.
- **The surface temperature at depth (SSTdepth)** is any measurement of the water temperature made below the surface. The majority of *in situ* measurements including drifting buoys, moorings, profiling floats, and ships are all SST depth measurements. All such measurements should be qualified by the measurement depth in meters e.g. $SST_{0.2m}$.

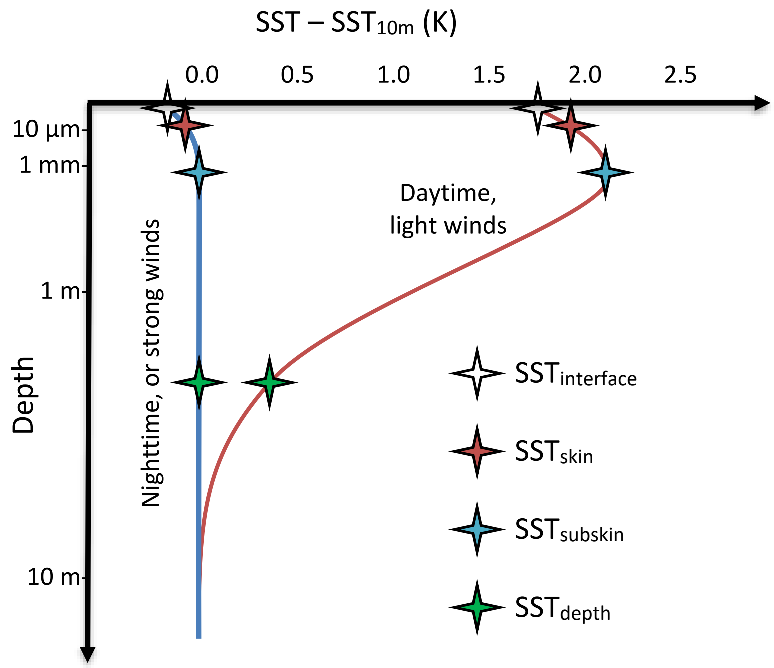

Figure 3 – GHRSST SST types and idealized upper ocean thermal structure for two simplified cases: night-time with a well-mixed surface layer, and a day-time case of near-surface warming under low wind speeds.

1.1.2 Data Levels

When dealing with satellite data it is common to encounter references to "data levels". The level of the data describes the amount of processing applied to the data, with higher levels corresponding to further processing. SST products follow the standards specified by the GHRSST Data Specification (GDS) [D1] and the following levels are relevant:

- **Level 2 Pre-processed (L2P)** – SSTs from a single input (level 1) file, still arranged in the way the satellite 'saw' them. Depending on the source instrument the file may correspond to a single orbit (approximately 100 minutes), or a shorter data granule (e.g. 3 minutes).
- **Level 3 Uncollated (L3U)** – contain the same data from a single L2P file remapped onto a regular latitude/longitude grid. L3U files will typically appear as a single narrow swath around the Earth with much of the surface unobserved.
- **Level 3 Collated (L3C)** – contain multiple L3U files from a single sensor combined into a longer time period. The L3C products described in this document cover a single UTC day. L3C files

contain data from multiple orbits giving more complete global coverage than lower level. However; coverage is still restricted to cloud free regions.
- **Level 4 (L4)** – SSTs from multiple orbits and sensors have been combined using a statistical analysis system to produce a global gap-free product.

The different data levels are illustrated in Figure 4 below. Many users prefer the Level 4 product due to its ease of use – the data are provided on a single daily, gap-free, global grid. However, as can been seen in the corresponding L3C image there are many areas of the ocean which could not be observed on that day due to clouds. These gaps have been filled using a prediction based on nearby observations (spatially and temporally) and historical climatology. Moreover, the gap-filling techniques also modify and blend the lower-level SST data in the observed areas, which tends to reduce feature resolution and is an additional source of error. The uncertainty information provided with the SSTs reflects this processing; for example the uncertainty is lower if there were observations contributing to the L4 product in a particular location than if there were none.

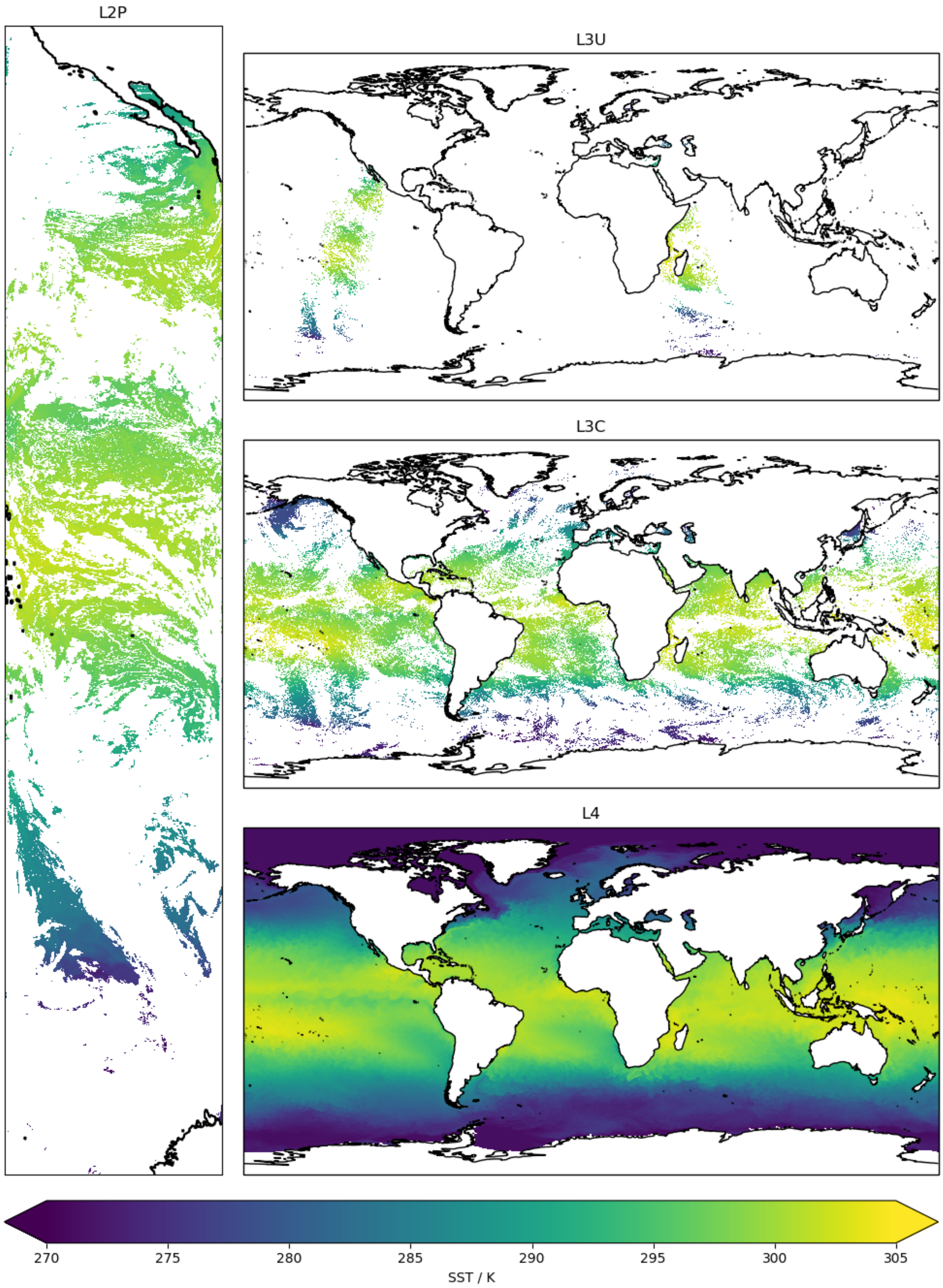

Figure 4 – Illustration of how data are stored according to the “level” of the product. White areas correspond to locations with no SSTs. These occur, for example, due to cloud preventing the SST retrieval or because the location corresponds to land or ice.

1.2 Data usage information

1.2.1 File naming convention

The data files are in netCDF-4 classic format and follow the GDS standard [D1] and are compatible with the SST-CCI products [D2, D3]. The file names have the format:

```
<Date><Time>-<RDAC>-<Level>_GHRSST-<SSTtype>-<Product>-<Dataset>_<Extra>-v02.0-fv01.0.nc
```

The variable components within braces: <*component*> are summarised in Table 1 and detailed in the following sections. Note that the fixed version string "v02.0_fv01.0" indicates that the file is a GDS 2.0 format file and that it is the first version of the file. The Climate Data Record version is indicated by the <*Dataset*> string.

1. Table – GDS 2.0 Filenaming convention components

Component	Definition	Description
<Date>	YYYYMMDD	The identifying date for this file in ISO8601 basic format
<Time>	HHMMSS	The identifying time for this file in ISO8601 basic format
<RDAC>	ESACCI or C3S	The creator of the file
<Level>	L2P, L3U, L3C, or L4	The data processing level
<SSTtype>	SSTskin or SSTdepth	The primary SST product type. See Section 1.1.1 for definitions
<Product>	GHRSST product string e.g. AATSR	Indicates the source data for this product. See table 2 for full list
<Dataset>	[GLOB_] CDR2.0 or ICDR2.0	Indicates if this file is CDR or ICDR and the version number; GLOB_ is only used if it is a L4 file
<Extra>	Optional text to distinguish between files with same <*Product*> string	Used for L3C files to indicate if the file corresponds to daytime or night-time observations.

1.2.1.1 Date

The identifying date for this file, using the ISO8601 basic format: YYYYMMDD.

1.2.1.2 Time

The identifying time for this file in UTC, using the ISO8601 basic format: HHMMSS. The time used depends on the processing level of the dataset:

- L2P: start time of granule
- L3U: start time of granule
- L3C: centre time of collation window (120000 for daily files)
- L4: nominal time of analysis (120000 for daily files)

1.2.1.3 RDAC

GHRSST Regional Data Assembly Centre (RDAC) where the dataset was generated. Two codes are used for C3S products:

- C3S: Copernicus Climate Change Service

ESACCI: ESA Climate Change Initiative

1.2.1.4 Level
GHRSST Processing level for this product. Will be one of L2P, L3U, L3C or L4.

1.2.1.5 SSTtype
GHRSST SST type as defined in Section 1.1.1. Two codes are used for C3S products:

SSTskin the skin sea surface temperature
SSTdepth the surface temperature at depth

1.2.1.6 Product
GHRSST Product string indicating the source sensor for this dataset:

2. Table – GDS 2.0 Product strings

Name	Description
AATSR	Advanced Along Track Scanning Radiometer (AATSR) on Envisat satellite
ATSR<X>	Along Track Scanning Radiometer (ATSR) on ERS-1 or -2
AVHRR<X>_G	Advanced Very High Resolution Radiometer (AVHRR) on NOAA-<X> satellite (reduced "GAC" resolution)
AVHRRMT<X>_G	Advanced Very High Resolution Radiometer (AVHRR) on MetOp-<X> satellite (reduced "GAC" resolution)
AVHRRMT<X>	Advanced Very High Resolution Radiometer (AVHRR) on MetOp-<X> satellite (full resolution)
SLSTR<X>	Sea and Land Surface Temperature Radiometer (SLSTR) on Sentinel 3<X> satellite
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA)

1.2.1.7 Dataset
Indicates which (Interim) Climate Data Record this file belongs to. Current strings in use are:

CDR2.0
ICDR2.0

L4 files include GLOB_ (i.e. GLOB_CDR2.0 or GLOB_ICDR2.0) to maintain the convention used for other files produced with the OSTIA system.

1.2.1.8 Extra
Optional extra text to distinguish between files with same <*Product*> string. Used for L3C files to indicate if the file contains collated day or night observations.

NOTE – the <*Dataset*> and <*Extra*> elements correspond to the GHRSST <Additional Segregator> component and are therefore separated by an underscore ("_") rather than a dash ("-").

1.2.2 Data format
The data files are in netCDF-4 format and are CF-compliant [D4], following the GDS [D1] SST-CCI [D2] standards. The SST-CCI Product User Guide [D3] is also applicable to CDR/ICDR products.

All L2P, L3U, and L3C files contain the same set of data variables, though on different coordinate grids. L2P files are supplied on the sensor image grid, whiles L3U/L3C are on a global regular latitude/longitude grid.

1.2.2.1 netCDF Variable Attributes

Variables in the netCDF files will include the standard metadata attributes listed in Table 3 below. These are recognised by most tools and utilities for working with netCDF files.

3. Table of standard variable attributes

Attribute name	Description
_FillValue	The number put into the data arrays where there are no valid data (before applying the scale_factor and add_offset attributes).
long_name	A descriptive name for the data
standard_name	A unique descriptive name for the data, taken from the CF conventions [D4]
units	The units of the data after applying the scale_factor and add_offset conversion
add_offset	After applying scale_factor below, add this to obtain the data in the units specified in the units attribute
scale_factor	Multiply the data stored in the netCDF file by this number
valid_min	The minimum valid value of the data (before applying scale_factor and add_offset).
valid_max	The maximum valid value of the data (before applying scale_factor and add_offset).
comment	Miscellaneous information
references	References that provide more information about the data
source	A list of data sources used for the data in this variable

1.2.2.2 Coordinate Grids

The coordinate variables are listed in Table 4 and discussed in the following sections.

4. Table of coordinate variables

Levels	Variable name	Description
2 3 4	lat	Central latitude of each grid cell
3	lat_bnds	Latitude cell boundaries
2 3 4	lon	Central longitude of each grid cell
3	lon_bnds	Longitude cell boundaries
2 3 4	time	Reference time of SST file
2 3	time_bnds	Time cell boundaries
2 3	sst_dtime	Time difference between the SST retrieval and the reference time for this file. The SST observation time is given by: `time + sst_dtime` and will be within the boundary defined by `time_bnds`.

		For a daily L3C file this will be in the range -43200 to +43200 seconds (12 hours).
2 3	sst_depth_dtime	Time difference between the adjusted SST retrieval and the reference time for this file. As the adjusted SST is to the nearest local 10:30 time it is possible for `time + sst_depth_dtime` to be outside boundary defined by `time_bnds`.

Time coordinate
All SST files include `time` as a dimension and coordinate variable to represent the reference time of the SST data array. The reference time used is dependent on the processing levels following GDS:

L2P: start time of granule
L3U: start time of granule
L3C: centre time of collation window (midday for daily files)
L4: nominal time of the analysis

In order to determine the exact time of a specific pixel or grid cell variables `sst_dtime` and `sst_depth_dtime` are provided (not applicable for L4). These provide the difference in seconds between the pixel observation time and the reference time for the file.

L2P image grid
L2P files are supplied on the sensor image grid and variables have the following dimensions:

time: 1
nj: Number of image rows (varies from file to file)
ni: Number of image columns (varies from sensor to sensor)

The locations of L2P pixels are irregular when viewed on a global grid and require separate two-dimensional arrays of longitude and latitude coordinates in order to geolocate the data. This can be seen in Figure 4 where the data in the L2P grid appears rectangular, but when projected onto the Earth's surface in the L3U product the data is seen to follow the orbital track of the satellite.

Following CF-conventions all the data variables have the attribute `coordinates = "lon lat"` indicating that the geographic coordinates of the pixel are stored in the variables lon and lat which are both 2D arrays.

Regular latitude/longitude grid (L3U / L3C / L4)
Level 3 and level 4 files are stored on a global regular latitude/longitude grid and variables have the following dimensions:

time: UNLIMITED (1)
lat: Number of latitude points (3600)
lon: Number of longitude points (7200)

The resolution used for the products is 0.05° hence the full size of the arrays is 7200x3600. In the L3 files, the time dimension is specified as **unlimited**, allowing standard netCDF tools to easily concatenate and manipulate multiple files, but each file will be distributed with a single time slice (corresponding to a day).

1.2.2.3 SST Data Variables

The data files contain two SST variables: the primary satellite measurement is the temperature of the skin at the time the satellite observes it; the adjusted SST is provided for a standard depth (0.2 m) and time representative of the daily mean to allow comparison with *in situ* measurements and prevent aliasing the diurnal cycle into the CDR/ICDR due to satellite drift.

5. Table of SST data variables

Variable name	Description
sea_surface_temperature	Best estimate of SST_{skin} as observed by the satellite
sea_surface_temperature_depth	Best estimate of $SST_{0.2m}$ at standard time representing daily mean
analysed_sst	In L4 files, the best estimate of $SST_{0.2m}$ at standard time representing daily mean

1.2.2.4 Quality Indicators

Each pixel or grid cell has an associated information field `l2p_flags` which indicates the type of pixel and what kind of SST retrieval was applied. Pixel type information includes: land, ice, lake, river. Pixels in the Level 2 products may have these flags set but will not contain any SST data (other than the Caspian Sea). Passive microwave data is not included in the current CDR/ICDR products. The dual-view bit (6) will be set for retrievals from one of the dual-view sensors (ATSR or SLSTR). The three-channel bit (7) indicates that the more accurate three-channel retrieval has been used. Although the three-channel retrieval can only be used at night, the use of the two-channel retrieval is not a guarantee that the pixel corresponds to a daytime observation (the retrieval may have switched to two-channel due to an instrument failure); therefore, there is a separate daytime flag which indicates if the solar zenith angle was < 90° when the pixel was observed.

Each pixel also has an associated `quality_level` which indicates the general quality of that pixel – higher values being better. Quantitative analyses should use the higher quality levels (4 or 5). Quality levels 2 and 3 may be useful for qualitative analyses, but the pixels have an increased change of being cloud contaminated.

6. Table of quality and flag indicators (level 2 and 3)

Variable name	Description
l2p_flags	Bit-field flags for interpreting data: 0 Passive microwave data 1 Land 2 Ice 3 Lake 4 River 5 Spare 6 Dual-view retrieval 7 Three-channel retrieval 8 Day time (solar zenith angle < 90°)
quality_level	Quality level of the SST: 0 no data

	1 bad data 2 worst usable data 3 low quality 4 good quality 5 best quality

7. Table of quality and flag indicators (level 4)

Variable name	Description
mask	Bit-field flags for interpreting data. The following values are used: 1 ocean 2 land 4 lake 8 sea ice

1.2.2.5 Auxiliary variables and uncertainties

There are several auxiliary variables and SST uncertainties listed in Table 8 below.

8. Table of auxiliary variables and uncertainties (level 2 and 3)

Variable name	Description
sses_standard_deviation	Total uncertainty in SST_{skin}
sst_depth_total_uncertainty	Total uncertainty in $SST_{0.2m}$
large_scale_correlated_uncertainty	Systematic uncertainty that is highly correlated between pixels over large scales
synoptically_correlated_uncertainty	Systematic uncertainty that is highly correlated between pixels over synoptic scales only
uncorrelated_uncertainty	Non-systematic uncertainty (uncorrelated or weakly correlated between pixels)
adjustment_uncertainty	Uncertainty in adjustment to standard depth and time (correlated between pixels over synoptic scales)
sensitivity	Estimated retrieval sensitivity to real changes in SST (this will be close to 1 for good quality retrievals)
wind_speed	An estimate of surface wind speed (from the ERA-Interim reanalysis)

9. Table of auxiliary variables and uncertainties (level 4)

Variable name	Description
analysis_uncertainty	Estimate of the uncertainty in the SST analysis

1.2.3 Product Contents

Detailed examples of product contents are given in the sensor specific sections below.

2. AVHRR SST

The information in this section applies to three AVHRR SST products:

- C3S AVHRR L3C ICDR v2
- ESACCI AVHRR L2P CDR v2
- ESACCI AVHRR L3U CDR v2
- ESACCI AVHRR L3C CDR v2

2.1 Product description

The AVHRRs are a series of multipurpose imaging instruments carried onboard the National Oceanic and Atmospheric Administration (NOAA) Polar Operational Environmental Satellites (POES) and EUMETSAT Polar System (EPS) MetOp satellites. The first AVHRR instrument was carried onboard the TIROS-N satellite launched in October 1978, as of 2018 there are four AVHRR instruments still in operation with the final AVHRR due to be launched onboard MetOp-C in late 2018. The equator crossing times of the various satellites as shown in Figure 5. The NOAA satellites are all in drifting orbits, meaning that the equator crossing times are slowly changing; which will affect the SST skin retrieval as discussed in section 1.1. The EUMETSAT MetOp satellites are in controlled orbits with equator crossing times of 9:30.

The AVHRR instruments were not designed for climate monitoring of SST and are not as well calibrated as the ATSR or SLSTR instruments. However; they have been operational and recording data for far longer, they have a wider swath and multiple satellites are in orbit meaning they produce much more complete coverage than the other instruments. The AVHRR swath is approximately 2800 km on the Earth's surface and the satellite completes approximately 14 orbits each day so a single satellite could potentially achieve global daily coverage. However, usable data is restricted to cloud-free regions and the data quality degrades towards the edge of the satellite swath due to the larger viewing angles.

The spatial resolution of the AVHRR instruments is approximately 1.1 km at nadir (directly below the satellite). However, due to hardware limitations on the NOAA platforms when the instruments were originally designed it was not possible to record a complete orbit of full resolution data for transmission to the ground station. Therefore, the onboard processor samples the real-time data to produce reduced resolution Global Area Coverage (GAC) data with a nominal resolution of ~4 km. This is achieved by averaging four pixels out of five in every third scanline as illustrated in Figure 6. Full resolution global AVHRR data is available from the MetOp platforms and has been processed in the ICDR product from 2019 onwards.

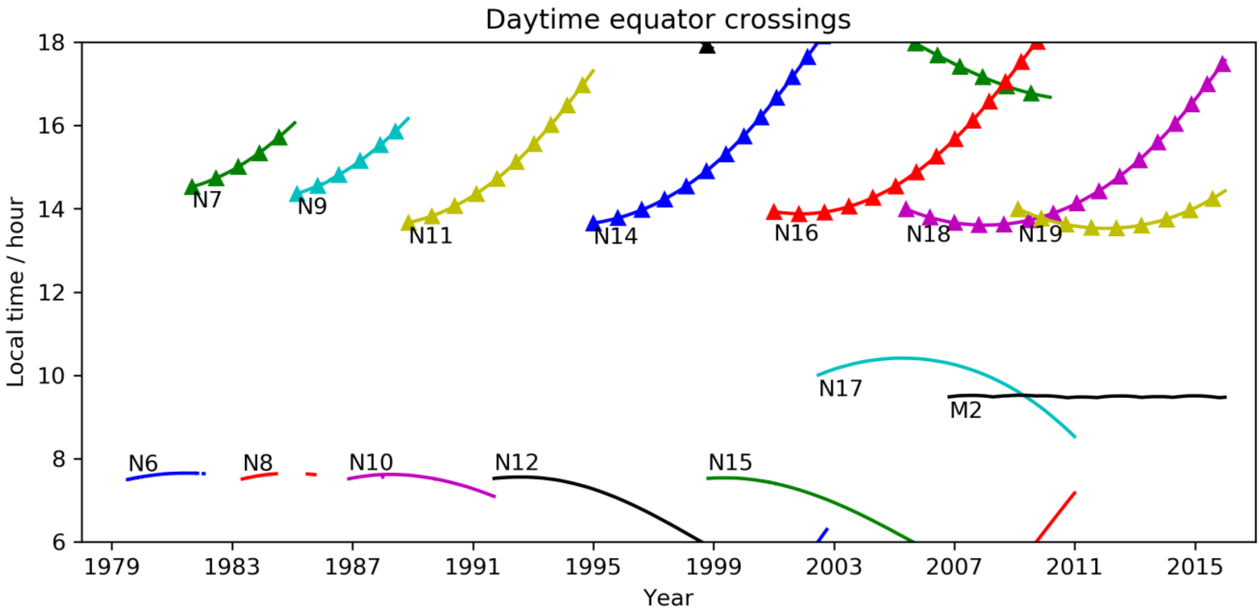

Figure 5 – AVHRR equator crossing times. Solid lines indicate descending node crossings, lines with triangles indicate ascending node crossings. NOTE – this diagram shows periods when AVHRR Level-1 data exists; it does not imply that the data is of sufficient quality to generate corresponding SST data.

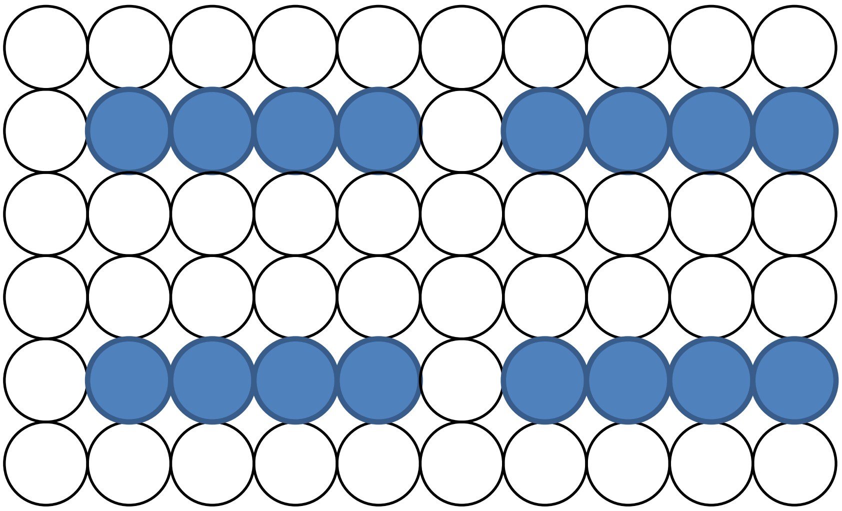

Figure 6 – schematic of GAC pixels (blue) which are the average of four full resolution pixels (circles). White circles indicate full resolutions pixels which are not included in the averaging, so data is not available.

2.2 Target requirements

10.Table showing target requirements for the product and the corresponding levels achieved by the product.

Characteristic	Target requirement	Level achieved (estimated by mean difference to validation data)
Bias (day)	0.1 K	AVHRR07: -0.17 K AVHRR09: -0.10 K AVHRR11: -0.09 K AVHRR12: -0.03 K

		AVHRR14: -0.05 K AVHRR15: -0.04 K AVHRR16: -0.01 K AVHRR17: -0.02 K AVHRR18: -0.11 K AVHRR19: -0.00 K AVHRRMTA: -0.02 K
Bias (night)	0.1 K	AVHRR07: -0.06 K AVHRR09: -0.02 K AVHRR11: +0.01 K AVHRR12: -0.00 K AVHRR14: +0.01 K AVHRR15: -0.02 K AVHRR16: -0.02 K AVHRR17: +0.00 K AVHRR18: -0.17 K AVHRR19: -0.00 K AVHRRMTA: +0.02 K
Stability (day)	30 mK / year	3.6 – 15.5 mK / year
Stability (night)	10 mK / year	-2.1 – 9.8 mK / year

2.3 Data usage information

2.3.1 File naming convention

Filenames follow the GDS/CCI conventions from section 1.2.1:

2.3.1.1 L3C ICDR

Format:

<Date>120000-C3S-L3C_GHRSST-SSTskin-AVHRR<X>_G-ICDR2.0_<Extra>-v02.0-fv01.0.nc

Example:

20170107120000-C3S-L3C_GHRSST-SSTskin-AVHRR19_G-ICDR2.0_day-v02.0-fv01.0.nc

2.3.1.2 L2P CDR

Format:

<Date><Time>-ESACCI-L2P_GHRSST-SSTskin-AVHRR<X>_G-CDR2.0-v02.0-fv01.0.nc

Example:

20100202103602-ESACCI-L2P_GHRSST-SSTskin-AVHRRMTA_G-CDR2.0-v02.0-fv01.0.nc

2.3.1.3 L3U CDR

Format:

<Date><Time>-ESACCI-L3U_GHRSST-SSTskin-AVHRR<X>_G-CDR2.0-v02.0-fv01.0.nc

Example:

20100202103602-ESACCI-L3U_GHRSST-SSTskin-AVHRRMTA_G-CDR2.0-v02.0-fv01.0.nc

2.3.2 Data format

See section 1.2.2

2.3.3 Product Contents

Examples of the data contained in one L3C product are shown below in Figure 7 (daytime) and Figure 8 (night-time). Each file contains observations from a single sensor during a 24 hour period split into either day or night conditions. These data come from polar-orbiting satellites which complete 14-15 orbits each day resulting in the swaths visible in the Figures below. Level-3 Collated (L3C) contain the "best" observation made in each grid cell during that day without any gap filling or data interpolation. Therefore, persistently cloud regions may contain no data during a given day. (For a gap-free product see the Level 4 Analysis product [Section 5]).

The right-hand plots in Figure 7 (daytime) and Figure 8 show the estimated retrieval uncertainties. It is clear that the daytime uncertainties are much higher than the night-time estimates – especially towards the edge of the satellite swath and in the tropics. Under night-time conditions the retrieval can use three of the sensor channels: 3.7, 11, and 12 µm; which allows the most accurate and sensitive SST estimate to be produced. However, during the day the 3.7 µm channel is affected by reflected solar radiance and cannot be used for the retrieval. With only the 11 and 12 µm channels (both of which are much more sensitive to atmospheric water vapour) in use, the daytime estimate is generally less accurate.

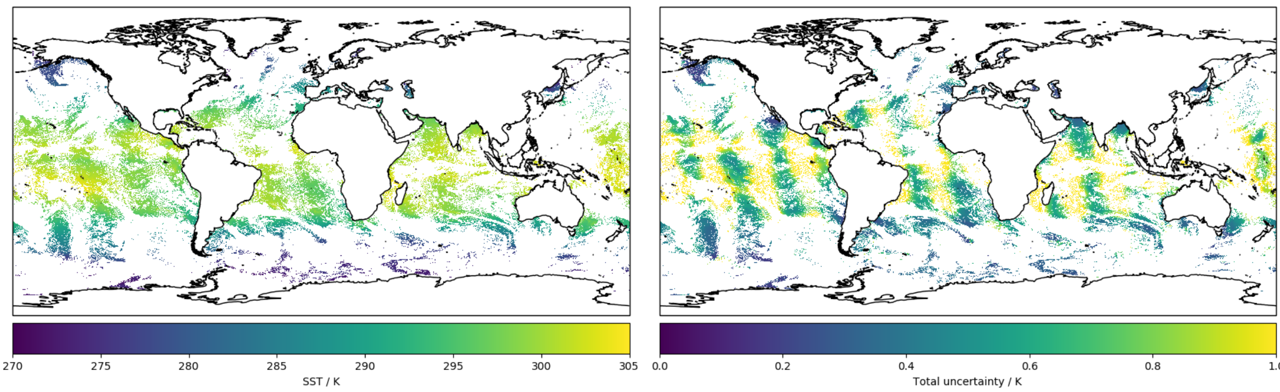

Figure 7 – example plot of NOAA-19 AVHRR daytime data. (left) sea surface temperature (right) estimated retrieval uncertainty.

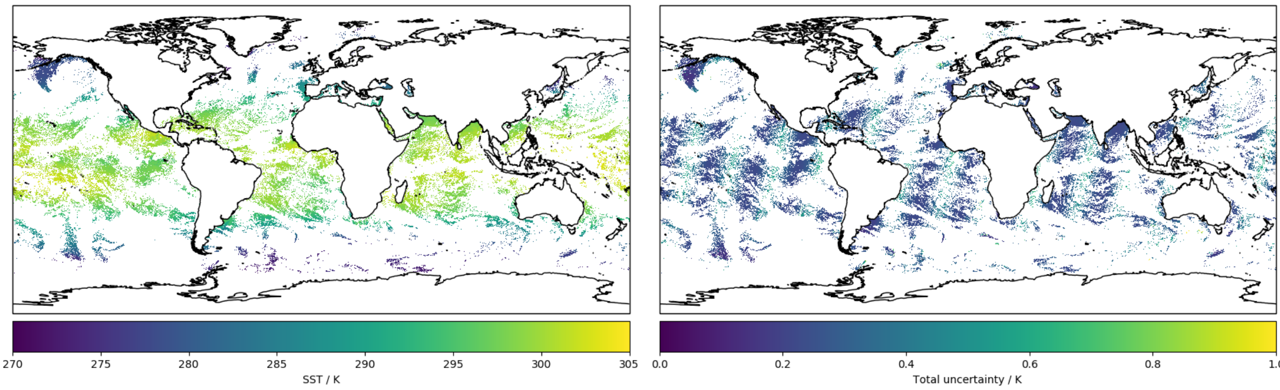

Figure 8 – example plot of NOAA-19 AVHRR night time data. (left) sea surface temperature (right) estimated retrieval uncertainty.

2.3.4 Known Issues

- AVHRR18 SSTs have a cold bias ~-0.1 K
- Day-time SSTs show seasonal cycle of up to 0.2 K which is not thought to be attributable to seasonal artefacts the in situ data – see Figure 9
- Trend visible in daytime AVHRR14 data – see Figure 9
- Daytime uncertainty estimates are too large – see Figure 10

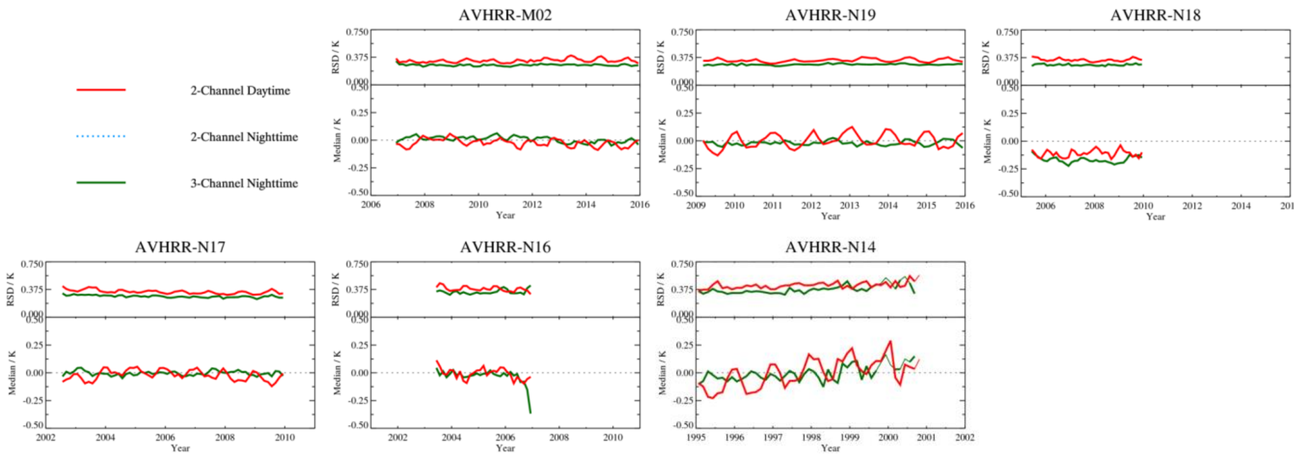

Figure 9 – Dependence of the median and robust standard deviation between AVHRR L3 $SST_{0.2m}$ and drifter SST discrepancies as a function of date. Day time results are shown in red and night time 3-channel results are shown in green.

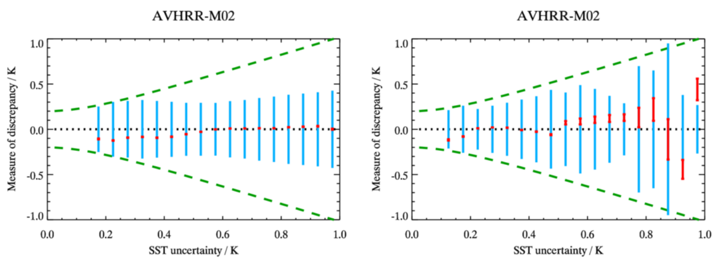

Figure 10 – Dependence of the median (red) and robust standard deviation (cyan) between AVHRR L3 $SST_{0.2m}$ and drifter SST discrepancies as a function of total uncertainty estimate. Dashed green line shows expected envelope based on *in situ* drifter uncertainty. Left: daytime. Right: nighttime.

3. ATSR SST

The information in this section applies to two ATSR SST products:

- ESACCI ATSR L2P CDR v2
- ESACCI ATSR L3U CDR v2
- ESACCI ATSR L3C CDR v2

3.1 Product description

The ATSRs instruments are well calibrated, dual-view radiometers intended to produce long-term, consistent SST observations. Three ATSR instruments have flown on board ESA's two European Remote Sensing (ERS) satellites and Envisat satellite. All three satellites were in stable sun-synchronous orbits with near-constant equatorial crossing times – the ERS-1 and ERS-2 platforms crossed at 10:30 and Envisat had a crossing time of 10:00 all of which were maintained within a few minutes.

Unlike the AVHRR instruments, the ATSRs were designed specifically for climate applications with significant improvements to calibration, characterization and stability. One feature unique to the ATSRs was the introduction of the dual-view capability using a single telescope with a conical scanning pattern. Having two views of the Earth's surface allows the instrument to gather more information and more effectively separate surface and atmospheric effects; i.e. the SST retrieval can be made more robust to atmospheric conditions, including water vapour and stratospheric aerosol. However, it also means the ATSR instruments have a much narrower swath – only 512 km wide compared to the 2800 km for AVHRRs. As a result it takes ~3 days for an ATSR instrument to collect global observations.

3.2 Target requirements

11. Table showing target requirements for the product and the corresponding levels achieved by the product.

Characteristic	Target requirement	Level achieved (estimated by mean difference to validation data)
Bias (day)	0.1 K	ATSR1: +0.02 K ATSR2: -0.00 K AATSR: +0.01 K
Bias (night)	0.1 K	ATSR1: -0.00 K ATSR2: +0.02 K AATSR: +0.01 K
Stability (day)	10 mK / year	-2.1 – 2.3 mK / year
Stability (night)	10 mK / year	-2.6 – 0.4 mK / year

3.3 Data usage information

3.3.1 File naming convention

Filenames follow the GDS/CCI conventions from section 1.2.1:

3.3.1.1 L2P CDR

Format:

`<Date><Time>-ESACCI-L2P_GHRSST-SSTskin-<Product>-CDR2.0-v02.0-fv01.0.nc`

Example:

`20031018011506-ESACCI-L2P_GHRSST-SSTskin-AATSR-CDR2.0-v02.0-fv01.0.nc`

3.3.1.2 L3U CDR

Format:

`<Date><Time>-ESACCI-L3U_GHRSST-SSTskin-<Product>-CDR2.0-v02.0-fv01.0.nc`

Example:

`20031018011506-ESACCI-L3U_GHRSST-SSTskin-AATSR-CDR2.0-v02.0-fv01.0.nc`

3.3.2 Data format

See section 1.2.2

3.3.3 Known Issues

- ATSR1 3.7 µm channel failed in May 1992 so subsequent night-time data are produced using 2-channel retrieval (lessening consistency with the night-time data of later ATSRs)
- ATSR2 scan mirror failed between December 1995 and July 1996 resulting in no ATSR2 data during a period when ATSR1 was degrading
- ATSR2 gyroscope failure in January 2001 means that locational accuracy is reduced until corrective measures were implemented in June 2001

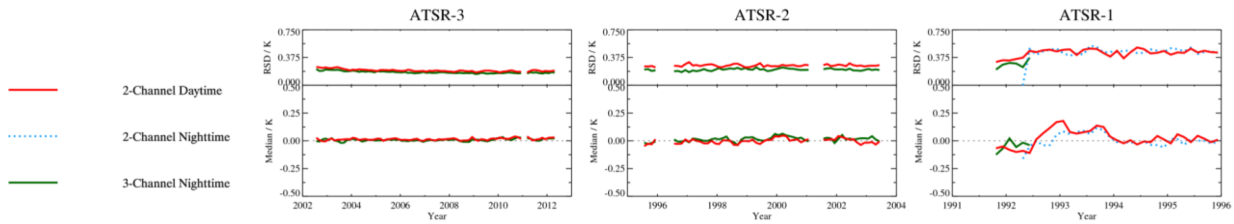

Figure 11 – Dependence of the median and robust standard deviation between ATSR L3 $SST_{0.2m}$ and drifter SST discrepancies as a function of date. Day time results are shown in red, night time 2-channel are shown in cyan, and night time 3-channel results are shown in green.

4. SLSTR SST

The information in this section applies to the SLSTR SST product:

- C3S SLSTR L3C ICDR v2

4.1 Product description

The SLSTR instrument is a well calibrated, dual-view radiometer intended to produce long-term, consistent SST observations. The design of the SLSTR instrument builds on the heritage of the earlier (A)ATSR instruments adding more spectral bands and a wider swath. The first SLSTR instrument is carried onboard the Sentinel-3A satellite launched in February 2016, with the second Sentinel-3B launched in April 2018.

The SLSTR dual-view swath is ~740 km wide (about 50 % wider than ATSR), meaning it can acquire global coverage in ~1.9 days. Once Sentinel-3B has completed commissioning and moved to its final orbit the constellation of two satellites will acquire global coverage in ~0.9 days.

4.2 Target requirements

12. Table showing target requirements for the product and the corresponding levels achieved by the product.

Characteristic	Target requirement	Level achieved
Bias (day)	0.1 K	Expected performance based on preliminary S3-MPC results is global bias < 0.1 K
Bias (night)	0.1 K	Expected performance based on preliminary S3-MPC results is global bias < 0.1 K
Stability (day)	10 mK / year	Not yet assessed
Stability (night)	10 mK / year	Not yet assessed

4.3 Data usage information

4.3.1 File naming convention

Filenames follow the GDS/CCI conventions from section 1.2.1:

4.3.1.1 L3C ICDR

Format:

`<Date>120000-C3S-L3C_GHRSST-SSTskin-SLSTR<X>-ICDR2.0_<Extra>-v02.0-fv01.0.nc`

Example:

`20170202120000-C3S-L3C_GHRSST-SSTskin-SLSTRA-ICDR2.0_night-v02.0-fv01.0.nc`

4.3.2 Data format

See section 1.2.2

4.3.3 Product Contents

Examples of the data contained in one L3C product are shown below in Figure 7 (daytime) and Figure 8 (night-time). Each file contains observations from a single sensor during a 24 hour period split into either day or night conditions. These data come from polar-orbiting satellites which complete 14-15 orbits each day resulting in the swaths visible in the Figures below. Level-3 Collated (L3C) contain the “best” observation made in each grid cell during that day without any gap filling or data interpolation.

Therefore, persistently cloud regions may contain no data during a given day. (For a gap-free product see the Level 4 Analysis product [Section 5]).

The right-hand plots in Figure 12 (daytime) and Figure 13 show the estimated retrieval uncertainties. It is clear that the daytime uncertainties are much higher than the night-time estimates – especially towards the edge of the satellite swath and in the tropics. Under night-time conditions the retrieval can use three of the sensor channels: 3.7, 11, and 12 µm; which allows the most accurate and sensitive SST estimate to be produced. However, during the day the 3.7 µm channel is affected by reflected solar radiance and cannot be used for the retrieval. With only the 11 and 12 µm channels (both of which are much more sensitive to atmospheric water vapour) in use, the daytime estimate is generally less accurate.

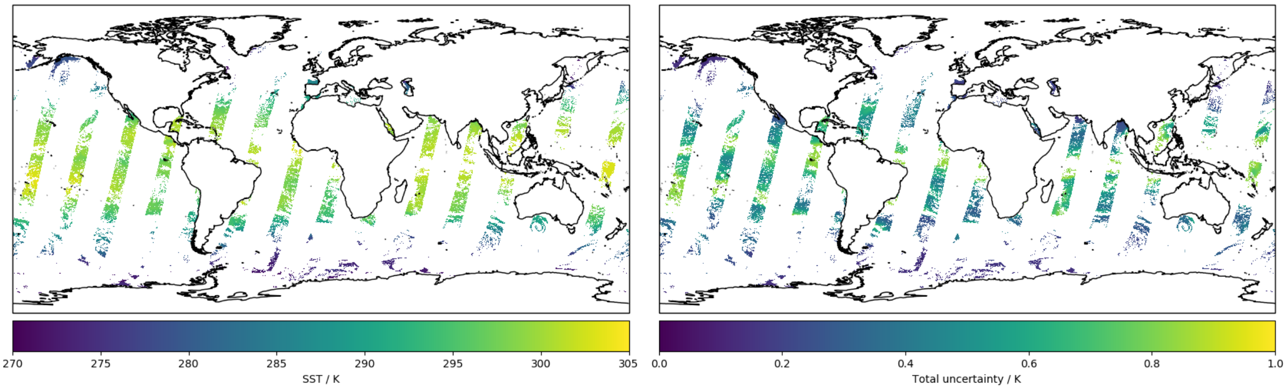

Figure 12 – example plot of Sentinel-3A SLSTR daytime data. (left) sea surface temperature (right) estimated retrieval uncertainty.

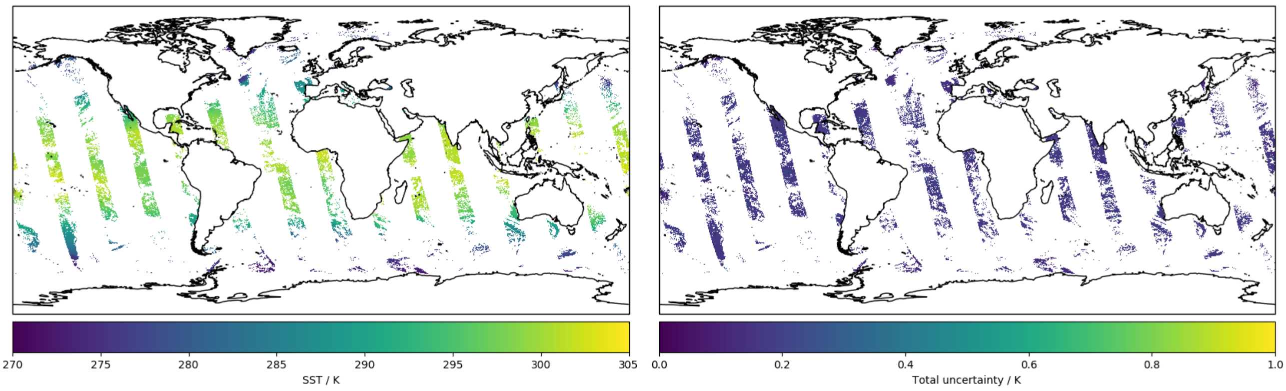

Figure 13 – example plot of Sentinel-3A SLSTR night time data. (left) sea surface temperature (right) estimated retrieval uncertainty.

4.3.4 Known Issues

- Daytime uncertainty estimates are too large to end 2018. Estimates are improved from 2019 onwards – see Figure 14

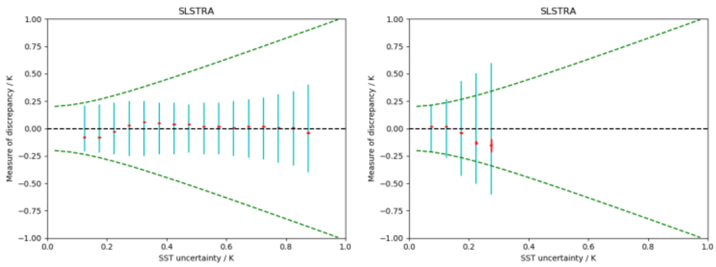

Figure 14 – Dependence of the median (red) and robust standard deviation (cyan) between SLSTR-A L3 $SST_{0.2m}$ and drifter SST discrepancies as a function of total uncertainty estimate. Dashed green line shows expected envelope based on *in situ* drifter uncertainty. Left: 2017-2018. Right: 2019 onwards.

5. Analysis SST

The information in this section applies to two Analysis SST products:

- ESACCI Analysis L4 CDR v2
- C3S Analysis L4 ICDR v2

5.1 Product description

The level 4 analysis system uses level 3 SSTs from the ATSR, AVHRR, and SLSTR series of sensors to create spatially complete, daily SST fields of the average SST at 20 cm depth. The input SSTs are those produced by the CCI/C3S projects. The method for combining the SST data is a variational data assimilation scheme. More details can be found in Donlon et al. (2012) and Merchant et al. (2014) (although note that these refer to earlier versions of the processing scheme). Uncertainty information is provided with the SSTs.

Also included with the SST analyses are sea ice concentrations. These were produced by analysing input data sourced from the OSI SAF (EUMETSAT Ocean and Sea Ice Satellite Application Facility. Global sea ice concentration climate data record 1979-2015 (v2.0, 2017) and Global sea ice concentration continuous reprocessing offline product (2017 onwards), [Online; available from the CDS)]. Norwegian and Danish Meteorological Institutes).

5.2 Target requirements

13. Table showing target requirements for the product and the corresponding levels achieved by the product.

Characteristic	Target requirement	Level achieved
Bias	0.1 K	~-0.05 K against night-time drifter data
Stability	10 mK / year	-1.51 – -0.05 mK / Year

5.3 Data usage information

5.3.1 File naming convention

Filenames follow the GDS/CCI conventions from section 1.2.1:

5.3.1.1 L4 CDR

Format:

`<Date>120000-ESACCI-L4_GHRSST-SSTdepth-OSTIA-GLOB_CDR2.0-v02.0-fv01.0.nc`

Example:

`20150202120000-ESACCI-L4_GHRSST-SSTdepth-OSTIA-GLOB_CDR2.0-v02.0-fv01.0.nc`

5.3.1.2 L4 ICDR

Format:

`<Date>120000-C3S-L4_GHRSST-SSTdepth-OSTIA-GLOB_ICDR2.0-v02.0-fv01.0.nc`

Example:

`20170202120000-C3S-L4_GHRSST-SSTdepth-OSTIA-GLOB_ICDR2.0-v02.0-fv01.0.nc`

5.3.2 Data format

See section 1.2.2 for information on coordinates and variable attributes.

5.3.2.1 Data Variables

The analysis files contain both daily average SST and 0.2m and sea ice fraction.

14. Table of analysis data variables

Variable name	Description
analysed_sst	Daily average $SST_{0.2m}$ in the grid cell
analysis_uncertainty	Analysis uncertainty (one error standard deviation)
sea_ice_fraction	Sea ice fraction in the grid cell

5.3.2.2 Mask Variable

Each grid cell has a bit mask to indicate if the cell corresponds to ocean, land, sea ice.

15. Table of quality and flag indicators

Variable name	Description
mask	Bit-field flags for interpreting data. The following values are used: 1 – ocean 2 – land 4 – lake 8 – sea ice

5.3.3 Product Contents

Examples of the data contained in one L4 product are shown below in Figure 15. Please note that the products do not include lakes (apart from the Caspian Sea); the mask variable can be used to identify only the ocean grid points.

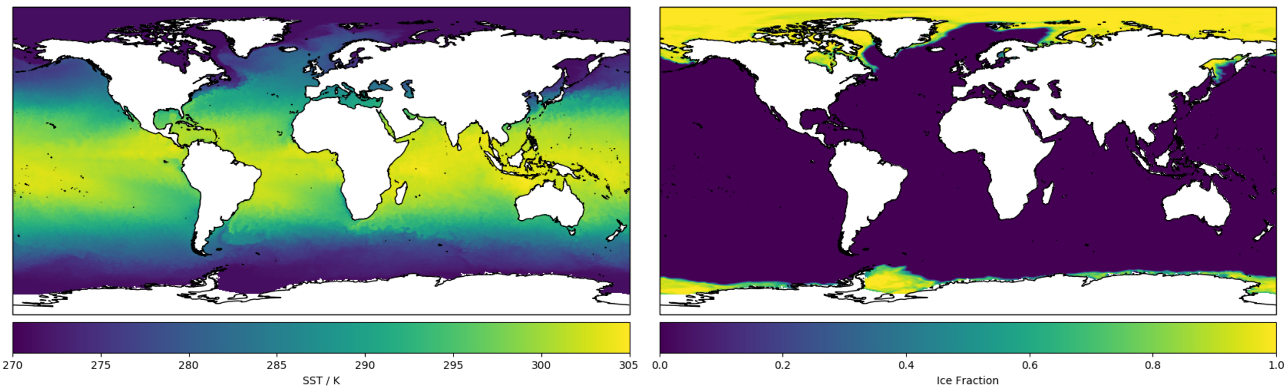

Figure 15 – example plot of level 4 analysis data. (left) sea surface temperature (right) sea ice fraction.

6. Data access information

6.1 Data visualization tools

The CDS Toolbox is an online C3S service for working with data in the CDS:

https://cds.climate.copernicus.eu

The CCI Toolbox is a desktop application for analysis and visualisation of CCI climate data sets and provides easy access to data from the CCI Open Data Portal:

http://climatetoolbox.io/

ESA is developing Science Toolbox Exploitation Platform (STEP) – a free open source toolbox for scientific exploitation of Earth Observation data. It includes direct support for data from ERS-ENVISAT missions, then Sentinel 1 / 2 / 3 missions, and a range of other satellites. It can also read and visualize the SST products. STEP is available from:

http://step.esa.int/main/

6.2 Data analysis / programming languages

Numerous programming languages exist that can be used for reading and analyzing netCDF files. These include both compiled languages such as Java, Fortran and C, and languages that allow interactive analysis and plotting of data. Some examples of the latter are:

- Python http://www.python.org/ with add on modules such as:
    - netCDF4 http://unidata.github.io/netcdf4-python/
    - NumPy http://www.numpy.org/
    - matplotlib http://matplotlib.org/
    - Iris and Cartopy http://scitools.org.uk/iris/
- IDL http://www.harrisgeospatial.com/SoftwareTechnology/IDL.aspx
- MATLAB https://www.mathworks.com/products/matlab.html
- Grid Analysis and Display System (GrADS) http://cola.gmu.edu/grads/
- NCAR Command Language (NCL) https://www.ncl.ucar.edu/

Acknowledgments

The SST CDR data are provided by ESA SST CCI under the Creative Commons by Attribution license (https://creativecommons.org/licenses/by/2.0/uk/). Please reference Merchant et al. (2019) if using the data.

References

Donlon, C. J., Martin, M., Stark, J. D., Roberts-Jones, J., Fiedler, E., and Wimmer, W. (**2012**) The Operational Sea Surface Temperature and Sea Ice analysis (OSTIA) system. *Rem. Sens. Env.*, 116, 140-158. doi:10.1016/j.rse.2010.10.017

Merchant, C. J., Embury, O., Roberts-Jones, J., Fiedler, E., Bulgin, C. E., Corlett, G. K., Good, S., McLaren, A., Rayner, N., Morak-Bozzo, S. and Donlon, C. (**2014**) Sea surface temperature datasets for climate applications from Phase 1 of the European Space Agency Climate Change Initiative (SST CCI). *Geosci. Data J.,* **1**: 179-191. doi:10.1002/gdj3.20

Morak-Bozzo, S., Merchant, C. J., Kent, E. C., Berry, D. I. and Carella, G. (**2016**) Climatological diurnal variability in sea surface temperature characterized from drifting buoy data. *Geosci. Data J.*, **3**: 20-28. doi:10.1002/gdj3.35

Appendix A - Specifications for Level 3 AVHRR ICDR

Example file structure (ncdump output):

```
netcdf \20170103120000-C3S-L3C_GHRSST-SSTskin-AVHRRMTA_G-ICDR2.0_night-v02.0-
fv01.0 {
dimensions:
	lat = 3600 ;
	lon = 7200 ;
	time = UNLIMITED ; // (1 currently)
	bnds = 2 ;
variables:
	float lat(lat) ;
		lat:long_name = "Latitude" ;
		lat:standard_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:valid_min = -90.f ;
		lat:valid_max = 90.f ;
		lat:reference_datum = "geographical coordinates, WGS84 projection" ;
		lat:axis = "Y" ;
		lat:bounds = "lat_bnds" ;
	float lat_bnds(lat, bnds) ;
		lat_bnds:long_name = "Latitude cell boundaries" ;
		lat_bnds:units = "degrees_north" ;
		lat_bnds:valid_min = -90.f ;
		lat_bnds:valid_max = 90.f ;
		lat_bnds:comment = "Contains the northern and southern boundaries of
the grid cells." ;
		lat_bnds:reference_datum = "geographical coordinates, WGS84
projection" ;
	float lon(lon) ;
		lon:long_name = "Longitude" ;
		lon:standard_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:valid_min = -180.f ;
		lon:valid_max = 180.f ;
		lon:reference_datum = "geographical coordinates, WGS84 projection" ;
		lon:axis = "X" ;
		lon:bounds = "lon_bnds" ;
	float lon_bnds(lon, bnds) ;
		lon_bnds:long_name = "Longitude cell boundaries" ;
		lon_bnds:units = "degrees_east" ;
		lon_bnds:valid_min = -180.f ;
		lon_bnds:valid_max = 180.f ;
		lon_bnds:comment = "Contains the eastern and western boundaries of
the grid cells." ;
		lon_bnds:reference_datum = "geographical coordinates, WGS84
projection" ;
	int time(time) ;
		time:long_name = "reference time of sst file" ;
```

```
            time:standard_name = "time" ;
            time:units = "seconds since 1981-01-01 00:00:00" ;
            time:calendar = "gregorian" ;
            time:axis = "T" ;
            time:bounds = "time_bnds" ;
      int time_bnds(time, bnds) ;
            time_bnds:long_name = "Time cell boundaries" ;
            time_bnds:units = "seconds since 1981-01-01 00:00:00" ;
            time_bnds:comment = "Contains the start and end times for the time
period the data represent." ;
      short sea_surface_temperature(time, lat, lon) ;
            sea_surface_temperature:_FillValue = -32768s ;
            sea_surface_temperature:long_name = "sea surface skin temperature" ;
            sea_surface_temperature:standard_name =
"sea_surface_skin_temperature" ;
            sea_surface_temperature:units = "kelvin" ;
            sea_surface_temperature:add_offset = 273.15f ;
            sea_surface_temperature:scale_factor = 0.01f ;
            sea_surface_temperature:valid_min = -200s ;
            sea_surface_temperature:valid_max = 5000s ;
            sea_surface_temperature:comment = "Temperature of the skin of the
ocean; total uncertainty =
sqrt(large_scale_correlated_uncertainty^2+synoptically_correlated_uncertainty^2+
uncorrelated_uncertainty^2)" ;
            sea_surface_temperature:references = "http://www.esa-sst-cci.org" ;
            sea_surface_temperature:source = "AVHRRMTA_G-ESACCI-L1C-v1" ;
            sea_surface_temperature:depth = "10 micrometres" ;
      short sea_surface_temperature_depth(time, lat, lon) ;
            sea_surface_temperature_depth:_FillValue = -32768s ;
            sea_surface_temperature_depth:long_name = "sea surface temperature
at 0.2 m" ;
            sea_surface_temperature_depth:standard_name =
"sea_water_temperature" ;
            sea_surface_temperature_depth:units = "kelvin" ;
            sea_surface_temperature_depth:add_offset = 273.15f ;
            sea_surface_temperature_depth:scale_factor = 0.01f ;
            sea_surface_temperature_depth:valid_min = -200s ;
            sea_surface_temperature_depth:valid_max = 5000s ;
            sea_surface_temperature_depth:comment = "Temperature of the ocean at
20 cm depth; total uncertainty =
sqrt(large_scale_correlated_uncertainty^2+synoptically_correlated_uncertainty^2+
uncorrelated_uncertainty^2+adjustment_uncertainty^2)" ;
            sea_surface_temperature_depth:references = "http://www.esa-sst-
cci.org" ;
            sea_surface_temperature_depth:source = "AVHRRMTA_G-ESACCI-L1C-v1" ;
            sea_surface_temperature_depth:depth = "0.2 metre" ;
      int sst_dtime(time, lat, lon) ;
            sst_dtime:_FillValue = -2147483648 ;
            sst_dtime:long_name = "time difference from reference time" ;
            sst_dtime:units = "seconds" ;
            sst_dtime:add_offset = 0.f ;
```

```
            sst_dtime:scale_factor = 1.f ;
            sst_dtime:valid_min = -43200 ;
            sst_dtime:valid_max = 43200 ;
            sst_dtime:comment = "time plus sst_dtime gives seconds after 1981-
01-01 00:00:00" ;
      int sst_depth_dtime(time, lat, lon) ;
            sst_depth_dtime:_FillValue = -2147483648 ;
            sst_depth_dtime:long_name = "time difference from reference time" ;
            sst_depth_dtime:units = "seconds" ;
            sst_depth_dtime:add_offset = 0.f ;
            sst_depth_dtime:scale_factor = 1.f ;
            sst_depth_dtime:valid_min = -43200 ;
            sst_depth_dtime:valid_max = 43200 ;
            sst_depth_dtime:comment = "time plus sst_depth_dtime gives seconds
after 1981-01-01 00:00:00" ;
      byte sses_bias(time, lat, lon) ;
            sses_bias:_FillValue = -128b ;
            sses_bias:long_name = "SSES bias estimate" ;
            sses_bias:units = "kelvin" ;
            sses_bias:add_offset = 0.f ;
            sses_bias:scale_factor = 0.01f ;
            sses_bias:valid_min = -127b ;
            sses_bias:valid_max = 127b ;
            sses_bias:comment = "Populated with zeroes" ;
      byte sses_standard_deviation(time, lat, lon) ;
            sses_standard_deviation:_FillValue = -128b ;
            sses_standard_deviation:long_name = "SSES standard deviation" ;
            sses_standard_deviation:units = "kelvin" ;
            sses_standard_deviation:add_offset = 1.27f ;
            sses_standard_deviation:scale_factor = 0.01f ;
            sses_standard_deviation:valid_min = -127b ;
            sses_standard_deviation:valid_max = 127b ;
            sses_standard_deviation:comment = "Uncertainty data are also
contained in the variables large_scale_correlated_uncertainty,
synoptically_correlated_uncertainty, uncorrelated_uncertainty and
adjustment_uncertainty" ;
      short sst_depth_total_uncertainty(time, lat, lon) ;
            sst_depth_total_uncertainty:_FillValue = -32768s ;
            sst_depth_total_uncertainty:long_name = "Total uncertainty in
sea_surface_temperature_depth" ;
            sst_depth_total_uncertainty:units = "kelvin" ;
            sst_depth_total_uncertainty:add_offset = 0.f ;
            sst_depth_total_uncertainty:scale_factor = 0.001f ;
            sst_depth_total_uncertainty:valid_min = 0s ;
            sst_depth_total_uncertainty:valid_max = 5000s ;
            sst_depth_total_uncertainty:comment = "Total uncertainty in each
sea_surface_temperature_depth data point" ;
      short l2p_flags(time, lat, lon) ;
            l2p_flags:_FillValue = -32768s ;
            l2p_flags:long_name = "L2P flags" ;
            l2p_flags:valid_min = 0s ;
```

```
            l2p_flags:valid_max = 511s ;
            l2p_flags:flag_meanings = "microwave land ice lake river spare views
channels day" ;
            l2p_flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s, 256s ;
            l2p_flags:comment = "These flags are important to properly use the
data" ;
      byte quality_level(time, lat, lon) ;
            quality_level:_FillValue = 0b ;
            quality_level:long_name = "quality level of SST pixel" ;
            quality_level:valid_min = 0b ;
            quality_level:valid_max = 5b ;
            quality_level:flag_meanings = "no_data bad_data worst_quality
low_quality acceptable_quality best_quality" ;
            quality_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
            quality_level:comment = "These are overall quality indicators and
are used for all GHRSST SSTs" ;
      byte wind_speed(time, lat, lon) ;
            wind_speed:_FillValue = -128b ;
            wind_speed:long_name = "10m wind speed" ;
            wind_speed:standard_name = "wind_speed" ;
            wind_speed:units = "m s-1" ;
            wind_speed:add_offset = 12.7f ;
            wind_speed:scale_factor = 0.1f ;
            wind_speed:valid_min = -127b ;
            wind_speed:valid_max = 127b ;
            wind_speed:comment = "Wind speeds sourced from ECMWF ERA Interim
Reanalysis; wind speeds greater than 25.4 m/s are set to 25.4." ;
            wind_speed:references = "http://www.esa-sst-cci.org" ;
            wind_speed:source = "ERA_INTERIM-ECMWF-WSP-v1.0" ;
            wind_speed:time_offset = 0.f ;
            wind_speed:height = "10 m" ;
      short large_scale_correlated_uncertainty(time, lat, lon) ;
            large_scale_correlated_uncertainty:_FillValue = -32768s ;
            large_scale_correlated_uncertainty:long_name = "Uncertainty from
errors likely to be correlated over large scales" ;
            large_scale_correlated_uncertainty:units = "kelvin" ;
            large_scale_correlated_uncertainty:add_offset = 0.f ;
            large_scale_correlated_uncertainty:scale_factor = 0.001f ;
            large_scale_correlated_uncertainty:valid_min = 0s ;
            large_scale_correlated_uncertainty:valid_max = 5000s ;
            large_scale_correlated_uncertainty:comment = "Component of
uncertainty that is correlated over large scales; can be combined with other
uncertainty estimates to form a total uncertainty" ;
            large_scale_correlated_uncertainty:references = "http://www.esa-sst-
cci.org" ;
      short synoptically_correlated_uncertainty(time, lat, lon) ;
            synoptically_correlated_uncertainty:_FillValue = -32768s ;
            synoptically_correlated_uncertainty:long_name = "Uncertainty from
errors likely to be correlated over synoptic scales" ;
            synoptically_correlated_uncertainty:units = "kelvin" ;
            synoptically_correlated_uncertainty:add_offset = 0.f ;
```

```
            synoptically_correlated_uncertainty:scale_factor = 0.001f ;
            synoptically_correlated_uncertainty:valid_min = 0s ;
            synoptically_correlated_uncertainty:valid_max = 5000s ;
            synoptically_correlated_uncertainty:comment = "Component of
uncertainty that is correlated over synoptic scales; can be combined with other
uncertainty estimates to form a total uncertainty" ;
            synoptically_correlated_uncertainty:references = "http://www.esa-
sst-cci.org" ;
            synoptically_correlated_uncertainty:correlation_length_scale = "100
km" ;
            synoptically_correlated_uncertainty:correlation_time_scale = "1 day"
;
      short uncorrelated_uncertainty(time, lat, lon) ;
            uncorrelated_uncertainty:_FillValue = -32768s ;
            uncorrelated_uncertainty:long_name = "Uncertainty from errors likely
to be uncorrelated between SSTs" ;
            uncorrelated_uncertainty:units = "kelvin" ;
            uncorrelated_uncertainty:add_offset = 0.f ;
            uncorrelated_uncertainty:scale_factor = 0.001f ;
            uncorrelated_uncertainty:valid_min = 0s ;
            uncorrelated_uncertainty:valid_max = 5000s ;
            uncorrelated_uncertainty:comment = "Component of uncertainty that is
uncorrelated between SSTs; can be combined with other uncertainty estimates to
form a total uncertainty" ;
            uncorrelated_uncertainty:references = "http://www.esa-sst-cci.org" ;
      short adjustment_uncertainty(time, lat, lon) ;
            adjustment_uncertainty:_FillValue = -32768s ;
            adjustment_uncertainty:long_name = "Time and depth adjustment
uncertainty" ;
            adjustment_uncertainty:units = "kelvin" ;
            adjustment_uncertainty:add_offset = 0.f ;
            adjustment_uncertainty:scale_factor = 0.001f ;
            adjustment_uncertainty:valid_min = 0s ;
            adjustment_uncertainty:valid_max = 5000s ;
            adjustment_uncertainty:comment = "Adjustment uncertainty; can be
combined with other uncertainty estimates to form a total uncertainty" ;
            adjustment_uncertainty:references = "http://www.esa-sst-cci.org" ;
            adjustment_uncertainty:correlation_length_scale = "100 km" ;
            adjustment_uncertainty:correlation_time_scale = "1 day" ;
      byte aerosol_dynamic_indicator(time, lat, lon) ;
            aerosol_dynamic_indicator:_FillValue = -128b ;
            aerosol_dynamic_indicator:long_name = "aerosol dynamic indicator" ;
            aerosol_dynamic_indicator:units = "" ;
            aerosol_dynamic_indicator:add_offset = 0.f ;
            aerosol_dynamic_indicator:scale_factor = 0.01f ;
            aerosol_dynamic_indicator:valid_min = -127b ;
            aerosol_dynamic_indicator:valid_max = 127b ;
            aerosol_dynamic_indicator:coordinates = "lon lat" ;
            aerosol_dynamic_indicator:time_offset = 0.f ;
            aerosol_dynamic_indicator:source = "ATSR SDI" ;
            aerosol_dynamic_indicator:comment = "ATSR Saharan Dust Index" ;
```

```
            aerosol_dynamic_indicator:references = "Good, E.J., Kong, X., 
Embury, O., Merchant, C.J., Remedios, J.J. (2012). An infrared desert dust index 
for the Along-Track Scanning Radiometers, Remote Sensing of Environment, 
116(15), DOI:10.1016/j.rse.2010.06.016" ;
      byte sensitivity(time, lat, lon) ;
            sensitivity:_FillValue = -128b ;
            sensitivity:long_name = "Sensitivity to SST" ;
            sensitivity:units = "K/K" ;
            sensitivity:add_offset = 1.f ;
            sensitivity:scale_factor = 0.01f ;
            sensitivity:valid_min = -100b ;
            sensitivity:valid_max = 100b ;
            sensitivity:coordinates = "lon lat" ;
            sensitivity:comment = "Sensitivity of retrieved SST to true changes 
in SST" ;

// global attributes:
            :Conventions = "CF-1.5, Unidata Observation Dataset v1.0" ;
            :title = "C3S AVHRRMTA_G SST product" ;
            :summary = "AVHRRMTA_G SST product from the Copernicus Climate 
Change Service (C3S), produced using smoothed OE algorithm." ;
            :references = "http://www.esa-sst-cci.org" ;
            :institution = "C3S" ;
            :history = "created with collate_l3.py" ;
            :license = "Creative Commons Licence by attribution 
(http://creativecommons.org/licenses/by/4.0/)" ;
            :id = "AVHRRMTA_G-C3S-L3C-ICDR-v2.0" ;
            :naming_authority = "org.ghrsst" ;
            :product_version = "2.0" ;
            :uuid = "cf1405a6-aece-4cc4-a666-dc41767aea59" ;
            :tracking_id = "cf1405a6-aece-4cc4-a666-dc41767aea59" ;
            :gds_version_id = "2.0" ;
            :netcdf_version_id = "4.4.1.1" ;
            :date_created = "20180219T105517Z" ;
            :file_quality_level = 3 ;
            :start_time = "20170103T000000Z" ;
            :time_coverage_start = "20170103T000000Z" ;
            :stop_time = "20170104T000000Z" ;
            :time_coverage_end = "20170104T000000Z" ;
            :time_coverage_duration = "P1DT0H00M00S" ;
            :time_coverage_resolution = "P1DT0H00M00S" ;
            :source = "AVHRRMTA_G-ESACCI-L1C-v1, ERA_INTERIM-ECMWF-WSP-v1.0" ;
            :platform = "MetOpA" ;
            :sensor = "AVHRR_GAC" ;
            :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
            :metadata_link = "" ;
            :keywords = "Oceans > Ocean Temperature > Sea Surface Temperature" ;
            :keywords_vocabulary = "NASA Global change Master Directory (GCMD) 
Science Keywords" ;
            :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) 
Metadata Convention" ;
```

```
            :geospatial_lat_units = "degrees_north" ;
            :geospatial_lat_resolution = 0.05f ;
            :geospatial_lon_units = "degrees_east" ;
            :geospatial_lon_resolution = 0.05f ;
            :geospatial_vertical_min = -0.2f ;
            :geospatial_vertical_max = -1.e-05f ;
            :acknowledgment = "Funded by the Copernicus Climate Change Service.
Use of these data should acknowledge the Copernicus Climate Change Service" ;
            :creator_name = "Copernicus Climate Change Service (C3S)" ;
            :creator_email = "science.leader@esa-sst-cci.org" ;
            :creator_url = "https://climate.copernicus.eu/" ;
            :creator_processing_institution = "These data were produced on the
JASMIN infrastructure at STFC as part of the C3S project" ;
            :project = "Copernicus Climate Change Service (C3S)" ;
            :publisher_name = "Copernicus Climate Data Store" ;
            :publisher_url = "https://climate.copernicus.eu/" ;
            :publisher_email = "copernicus-support@ecmwf.int" ;
            :comment = "For information about uncertainty estimates see the
comment attributes to the sea_surface_temperature and
sea_surface_temperature_depth variables" ;
            :northernmost_latitude = 90. ;
            :southernmost_latitude = -90. ;
            :easternmost_longitude = 180. ;
            :westernmost_longitude = -180. ;
            :geospatial_lat_min = -90.f ;
            :geospatial_lat_max = 90.f ;
            :geospatial_lon_min = -180.f ;
            :geospatial_lon_max = 180.f ;
            :processing_level = "L3C" ;
            :cdm_data_type = "grid" ;
            :source_file = "20170102225635-C3S-L3U_GHRSST-SSTskin-AVHRRMTA_G-
ICDR2.0-v02.0-fv01.0.nc, 20170103003850-C3S-L3U_GHRSST-SSTskin-AVHRRMTA_G-
ICDR2.0-v02.0-fv01.0.nc, 20170103022223-C3S-L3U_GHRSST-SSTskin-AVHRRMTA_G-
ICDR2.0-v02.0-fv01.0.nc, 20170103040438-C3S-L3U_GHRSST-SSTskin-AVHRRMTA_G-
ICDR2.0-v02.0-fv01.0.nc, 20170103054811-C3S-L3U_GHRSST-SSTskin-AVHRRMTA_G-
ICDR2.0-v02.0-fv01.0.nc,…
            :product_specification_version = "SST_CCI-PSD-UKMO-201-Issue-1-
signed" ;
            :spatial_resolution = "0.05 degree" ;
            :contact = "http://copernicus-support.ecmwf.int" ;
            :creation_date = "2018-02-19T10:55:17Z" ;
}
```

Appendix B - Specifications for Level 3 SLSTR ICDR

Example file structure (ncdump output):

```
netcdf \20170103120000-C3S-L3C_GHRSST-SSTskin-SLSTRA-ICDR2.0_night-v02.0-fv01.0
{
dimensions:
	lat = 3600 ;
	lon = 7200 ;
	time = UNLIMITED ; // (1 currently)
	bnds = 2 ;
variables:
	float lat(lat) ;
		lat:long_name = "Latitude" ;
		lat:standard_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:valid_min = -90.f ;
		lat:valid_max = 90.f ;
		lat:reference_datum = "geographical coordinates, WGS84 projection" ;
		lat:axis = "Y" ;
		lat:bounds = "lat_bnds" ;
	float lat_bnds(lat, bnds) ;
		lat_bnds:long_name = "Latitude cell boundaries" ;
		lat_bnds:units = "degrees_north" ;
		lat_bnds:valid_min = -90.f ;
		lat_bnds:valid_max = 90.f ;
		lat_bnds:comment = "Contains the northern and southern boundaries of
the grid cells." ;
		lat_bnds:reference_datum = "geographical coordinates, WGS84
projection" ;
	float lon(lon) ;
		lon:long_name = "Longitude" ;
		lon:standard_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:valid_min = -180.f ;
		lon:valid_max = 180.f ;
		lon:reference_datum = "geographical coordinates, WGS84 projection" ;
		lon:axis = "X" ;
		lon:bounds = "lon_bnds" ;
	float lon_bnds(lon, bnds) ;
		lon_bnds:long_name = "Longitude cell boundaries" ;
		lon_bnds:units = "degrees_east" ;
		lon_bnds:valid_min = -180.f ;
		lon_bnds:valid_max = 180.f ;
		lon_bnds:comment = "Contains the eastern and western boundaries of
the grid cells." ;
		lon_bnds:reference_datum = "geographical coordinates, WGS84
projection" ;
	int time(time) ;
		time:long_name = "reference time of sst file" ;
```

```
            time:standard_name = "time" ;
            time:units = "seconds since 1981-01-01 00:00:00" ;
            time:calendar = "gregorian" ;
            time:axis = "T" ;
            time:bounds = "time_bnds" ;
      int time_bnds(time, bnds) ;
            time_bnds:long_name = "Time cell boundaries" ;
            time_bnds:units = "seconds since 1981-01-01 00:00:00" ;
            time_bnds:comment = "Contains the start and end times for the time
period the data represent." ;
      short sea_surface_temperature(time, lat, lon) ;
            sea_surface_temperature:_FillValue = -32768s ;
            sea_surface_temperature:long_name = "sea surface skin temperature" ;
            sea_surface_temperature:standard_name =
"sea_surface_skin_temperature" ;
            sea_surface_temperature:units = "kelvin" ;
            sea_surface_temperature:add_offset = 273.15f ;
            sea_surface_temperature:scale_factor = 0.01f ;
            sea_surface_temperature:valid_min = -200s ;
            sea_surface_temperature:valid_max = 5000s ;
            sea_surface_temperature:comment = "Temperature of the skin of the
ocean; total uncertainty =
sqrt(large_scale_correlated_uncertainty^2+synoptically_correlated_uncertainty^2+
uncorrelated_uncertainty^2)" ;
            sea_surface_temperature:references = "http://www.esa-sst-cci.org" ;
            sea_surface_temperature:source = "SLSTRA-SVL-L1-v1" ;
            sea_surface_temperature:depth = "10 micrometres" ;
      short sea_surface_temperature_depth(time, lat, lon) ;
            sea_surface_temperature_depth:_FillValue = -32768s ;
            sea_surface_temperature_depth:long_name = "sea surface temperature
at 0.2 m" ;
            sea_surface_temperature_depth:standard_name =
"sea_water_temperature" ;
            sea_surface_temperature_depth:units = "kelvin" ;
            sea_surface_temperature_depth:add_offset = 273.15f ;
            sea_surface_temperature_depth:scale_factor = 0.01f ;
            sea_surface_temperature_depth:valid_min = -200s ;
            sea_surface_temperature_depth:valid_max = 5000s ;
            sea_surface_temperature_depth:comment = "Temperature of the ocean at
20 cm depth; total uncertainty =
sqrt(large_scale_correlated_uncertainty^2+synoptically_correlated_uncertainty^2+
uncorrelated_uncertainty^2+adjustment_uncertainty^2)" ;
            sea_surface_temperature_depth:references = "http://www.esa-sst-
cci.org" ;
            sea_surface_temperature_depth:source = "SLSTRA-SVL-L1-v1" ;
            sea_surface_temperature_depth:depth = "0.2 metre" ;
      int sst_dtime(time, lat, lon) ;
            sst_dtime:_FillValue = -2147483648 ;
            sst_dtime:long_name = "time difference from reference time" ;
            sst_dtime:units = "seconds" ;
            sst_dtime:add_offset = 0.f ;
```

```
            sst_dtime:scale_factor = 1.f ;
            sst_dtime:valid_min = -43200 ;
            sst_dtime:valid_max = 43200 ;
            sst_dtime:comment = "time plus sst_dtime gives seconds after 1981-
01-01 00:00:00" ;
      int sst_depth_dtime(time, lat, lon) ;
            sst_depth_dtime:_FillValue = -2147483648 ;
            sst_depth_dtime:long_name = "time difference from reference time" ;
            sst_depth_dtime:units = "seconds" ;
            sst_depth_dtime:add_offset = 0.f ;
            sst_depth_dtime:scale_factor = 1.f ;
            sst_depth_dtime:valid_min = -43200 ;
            sst_depth_dtime:valid_max = 43200 ;
            sst_depth_dtime:comment = "time plus sst_depth_dtime gives seconds
after 1981-01-01 00:00:00" ;
      byte sses_bias(time, lat, lon) ;
            sses_bias:_FillValue = -128b ;
            sses_bias:long_name = "SSES bias estimate" ;
            sses_bias:units = "kelvin" ;
            sses_bias:add_offset = 0.f ;
            sses_bias:scale_factor = 0.01f ;
            sses_bias:valid_min = -127b ;
            sses_bias:valid_max = 127b ;
            sses_bias:comment = "Populated with zeroes" ;
      byte sses_standard_deviation(time, lat, lon) ;
            sses_standard_deviation:_FillValue = -128b ;
            sses_standard_deviation:long_name = "SSES standard deviation" ;
            sses_standard_deviation:units = "kelvin" ;
            sses_standard_deviation:add_offset = 1.27f ;
            sses_standard_deviation:scale_factor = 0.01f ;
            sses_standard_deviation:valid_min = -127b ;
            sses_standard_deviation:valid_max = 127b ;
            sses_standard_deviation:comment = "Uncertainty data are also
contained in the variables large_scale_correlated_uncertainty,
synoptically_correlated_uncertainty, uncorrelated_uncertainty and
adjustment_uncertainty" ;
      short sst_depth_total_uncertainty(time, lat, lon) ;
            sst_depth_total_uncertainty:_FillValue = -32768s ;
            sst_depth_total_uncertainty:long_name = "Total uncertainty in
sea_surface_temperature_depth" ;
            sst_depth_total_uncertainty:units = "kelvin" ;
            sst_depth_total_uncertainty:add_offset = 0.f ;
            sst_depth_total_uncertainty:scale_factor = 0.001f ;
            sst_depth_total_uncertainty:valid_min = 0s ;
            sst_depth_total_uncertainty:valid_max = 5000s ;
            sst_depth_total_uncertainty:comment = "Total uncertainty in each
sea_surface_temperature_depth data point" ;
      short l2p_flags(time, lat, lon) ;
            l2p_flags:_FillValue = -32768s ;
            l2p_flags:long_name = "L2P flags" ;
            l2p_flags:valid_min = 0s ;
```

```
            l2p_flags:valid_max = 511s ;
            l2p_flags:flag_meanings = "microwave land ice lake river spare views
channels day" ;
            l2p_flags:flag_masks = 1s, 2s, 4s, 8s, 16s, 32s, 64s, 128s, 256s ;
            l2p_flags:comment = "These flags are important to properly use the
data" ;
      byte quality_level(time, lat, lon) ;
            quality_level:_FillValue = 0b ;
            quality_level:long_name = "quality level of SST pixel" ;
            quality_level:valid_min = 0b ;
            quality_level:valid_max = 5b ;
            quality_level:flag_meanings = "no_data bad_data worst_quality
low_quality acceptable_quality best_quality" ;
            quality_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
            quality_level:comment = "These are overall quality indicators and
are used for all GHRSST SSTs" ;
      byte wind_speed(time, lat, lon) ;
            wind_speed:_FillValue = -128b ;
            wind_speed:long_name = "10m wind speed" ;
            wind_speed:standard_name = "wind_speed" ;
            wind_speed:units = "m s-1" ;
            wind_speed:add_offset = 12.7f ;
            wind_speed:scale_factor = 0.1f ;
            wind_speed:valid_min = -127b ;
            wind_speed:valid_max = 127b ;
            wind_speed:comment = "Wind speeds sourced from ECMWF ERA Interim
Reanalysis; wind speeds greater than 25.4 m/s are set to 25.4." ;
            wind_speed:references = "http://www.esa-sst-cci.org" ;
            wind_speed:source = "ERA_INTERIM-ECMWF-WSP-v1.0" ;
            wind_speed:time_offset = 0.f ;
            wind_speed:height = "10 m" ;
      short large_scale_correlated_uncertainty(time, lat, lon) ;
            large_scale_correlated_uncertainty:_FillValue = -32768s ;
            large_scale_correlated_uncertainty:long_name = "Uncertainty from
errors likely to be correlated over large scales" ;
            large_scale_correlated_uncertainty:units = "kelvin" ;
            large_scale_correlated_uncertainty:add_offset = 0.f ;
            large_scale_correlated_uncertainty:scale_factor = 0.001f ;
            large_scale_correlated_uncertainty:valid_min = 0s ;
            large_scale_correlated_uncertainty:valid_max = 5000s ;
            large_scale_correlated_uncertainty:comment = "Component of
uncertainty that is correlated over large scales; can be combined with other
uncertainty estimates to form a total uncertainty" ;
            large_scale_correlated_uncertainty:references = "http://www.esa-sst-
cci.org" ;
      short synoptically_correlated_uncertainty(time, lat, lon) ;
            synoptically_correlated_uncertainty:_FillValue = -32768s ;
            synoptically_correlated_uncertainty:long_name = "Uncertainty from
errors likely to be correlated over synoptic scales" ;
            synoptically_correlated_uncertainty:units = "kelvin" ;
            synoptically_correlated_uncertainty:add_offset = 0.f ;
```

```
            synoptically_correlated_uncertainty:scale_factor = 0.001f ;
            synoptically_correlated_uncertainty:valid_min = 0s ;
            synoptically_correlated_uncertainty:valid_max = 5000s ;
            synoptically_correlated_uncertainty:comment = "Component of
uncertainty that is correlated over synoptic scales; can be combined with other
uncertainty estimates to form a total uncertainty" ;
            synoptically_correlated_uncertainty:references = "http://www.esa-
sst-cci.org" ;
            synoptically_correlated_uncertainty:correlation_length_scale = "100
km" ;
            synoptically_correlated_uncertainty:correlation_time_scale = "1 day"
;
      short uncorrelated_uncertainty(time, lat, lon) ;
            uncorrelated_uncertainty:_FillValue = -32768s ;
            uncorrelated_uncertainty:long_name = "Uncertainty from errors likely
to be uncorrelated between SSTs" ;
            uncorrelated_uncertainty:units = "kelvin" ;
            uncorrelated_uncertainty:add_offset = 0.f ;
            uncorrelated_uncertainty:scale_factor = 0.001f ;
            uncorrelated_uncertainty:valid_min = 0s ;
            uncorrelated_uncertainty:valid_max = 5000s ;
            uncorrelated_uncertainty:comment = "Component of uncertainty that is
uncorrelated between SSTs; can be combined with other uncertainty estimates to
form a total uncertainty" ;
            uncorrelated_uncertainty:references = "http://www.esa-sst-cci.org" ;
      short adjustment_uncertainty(time, lat, lon) ;
            adjustment_uncertainty:_FillValue = -32768s ;
            adjustment_uncertainty:long_name = "Time and depth adjustment
uncertainty" ;
            adjustment_uncertainty:units = "kelvin" ;
            adjustment_uncertainty:add_offset = 0.f ;
            adjustment_uncertainty:scale_factor = 0.001f ;
            adjustment_uncertainty:valid_min = 0s ;
            adjustment_uncertainty:valid_max = 5000s ;
            adjustment_uncertainty:comment = "Adjustment uncertainty; can be
combined with other uncertainty estimates to form a total uncertainty" ;
            adjustment_uncertainty:references = "http://www.esa-sst-cci.org" ;
            adjustment_uncertainty:correlation_length_scale = "100 km" ;
            adjustment_uncertainty:correlation_time_scale = "1 day" ;
      byte aerosol_dynamic_indicator(time, lat, lon) ;
            aerosol_dynamic_indicator:_FillValue = -128b ;
            aerosol_dynamic_indicator:long_name = "aerosol dynamic indicator" ;
            aerosol_dynamic_indicator:units = "" ;
            aerosol_dynamic_indicator:add_offset = 0.f ;
            aerosol_dynamic_indicator:scale_factor = 0.01f ;
            aerosol_dynamic_indicator:valid_min = -127b ;
            aerosol_dynamic_indicator:valid_max = 127b ;
            aerosol_dynamic_indicator:coordinates = "lon lat" ;
            aerosol_dynamic_indicator:time_offset = 0.f ;
            aerosol_dynamic_indicator:source = "ATSR SDI" ;
            aerosol_dynamic_indicator:comment = "ATSR Saharan Dust Index" ;
```

```
            aerosol_dynamic_indicator:references = "Good, E.J., Kong, X.,
Embury, O., Merchant, C.J., Remedios, J.J. (2012). An infrared desert dust index
for the Along-Track Scanning Radiometers, Remote Sensing of Environment,
116(15), DOI:10.1016/j.rse.2010.06.016" ;
      byte sensitivity(time, lat, lon) ;
            sensitivity:_FillValue = -128b ;
            sensitivity:long_name = "Sensitivity to SST" ;
            sensitivity:units = "K/K" ;
            sensitivity:add_offset = 1.f ;
            sensitivity:scale_factor = 0.01f ;
            sensitivity:valid_min = -100b ;
            sensitivity:valid_max = 100b ;
            sensitivity:coordinates = "lon lat" ;
            sensitivity:comment = "Sensitivity of retrieved SST to true changes
in SST" ;

// global attributes:
            :Conventions = "CF-1.5, Unidata Observation Dataset v1.0" ;
            :title = "C3S SLSTRA SST product" ;
            :summary = "SLSTRA SST product from the Copernicus Climate Change
Service (C3S), produced using ARC algorithm." ;
            :references = "http://www.esa-sst-cci.org" ;
            :institution = "C3S" ;
            :history = "created with collate_l3.py" ;
            :license = "Creative Commons Licence by attribution
(http://creativecommons.org/licenses/by/4.0/)" ;
            :id = "SLSTRA-C3S-L3C-ICDR-v2.0" ;
            :naming_authority = "org.ghrsst" ;
            :product_version = "2.0" ;
            :uuid = "a321cda0-acd2-4f40-89e8-863b1aa3ff97" ;
            :tracking_id = "a321cda0-acd2-4f40-89e8-863b1aa3ff97" ;
            :gds_version_id = "2.0" ;
            :netcdf_version_id = "4.4.1.1" ;
            :date_created = "20180219T191337Z" ;
            :file_quality_level = 3 ;
            :start_time = "20170103T000000Z" ;
            :time_coverage_start = "20170103T000000Z" ;
            :stop_time = "20170104T000000Z" ;
            :time_coverage_end = "20170104T000000Z" ;
            :time_coverage_duration = "P1DT0H00M00S" ;
            :time_coverage_resolution = "P1DT0H00M00S" ;
            :source = "SLSTRA-SVL-L1-v1, ERA_INTERIM-ECMWF-WSP-v1.0" ;
            :platform = "Sentinel3A" ;
            :sensor = "SLSTR" ;
            :Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
            :metadata_link = "" ;
            :keywords = "Oceans > Ocean Temperature > Sea Surface Temperature" ;
            :keywords_vocabulary = "NASA Global change Master Directory (GCMD)
Science Keywords" ;
            :standard_name_vocabulary = "NetCDF Climate and Forecast (CF)
Metadata Convention" ;
```

```
            :geospatial_lat_units = "degrees_north" ;
            :geospatial_lat_resolution = 0.05f ;
            :geospatial_lon_units = "degrees_east" ;
            :geospatial_lon_resolution = 0.05f ;
            :geospatial_vertical_min = -0.2f ;
            :geospatial_vertical_max = -1.e-05f ;
            :acknowledgment = "Funded by the Copernicus Climate Change Service.
Use of these data should acknowledge the Copernicus Climate Change Service" ;
            :creator_name = "Copernicus Climate Change Service (C3S)" ;
            :creator_email = "science.leader@esa-sst-cci.org" ;
            :creator_url = "https://climate.copernicus.eu/" ;
            :creator_processing_institution = "These data were produced on the
JASMIN infrastructure at STFC as part of the C3S project" ;
            :project = "Copernicus Climate Change Service (C3S)" ;
            :publisher_name = "Copernicus Climate Data Store" ;
            :publisher_url = "https://climate.copernicus.eu/" ;
            :publisher_email = "copernicus-support@ecmwf.int" ;
            :comment = "For information about uncertainty estimates see the
comment attributes to the sea_surface_temperature and
sea_surface_temperature_depth variables" ;
            :northernmost_latitude = 90. ;
            :southernmost_latitude = -90. ;
            :easternmost_longitude = 180. ;
            :westernmost_longitude = -180. ;
            :geospatial_lat_min = -90.f ;
            :geospatial_lat_max = 90.f ;
            :geospatial_lon_min = -180.f ;
            :geospatial_lon_max = 180.f ;
            :processing_level = "L3C" ;
            :cdm_data_type = "grid" ;
            :source_file = "20170103235624-C3S-L3U_GHRSST-SSTskin-SLSTRA-
ICDR2.0-v02.0-fv01.0.nc, 20170103235324-C3S-L3U_GHRSST-SSTskin-SLSTRA-ICDR2.0-
v02.0-fv01.0.nc, 20170103235024-C3S-L3U_GHRSST-SSTskin-SLSTRA-ICDR2.0-v02.0-
fv01.0.nc,…
            :product_specification_version = "SST_CCI-PSD-UKMO-201-Issue-1-
signed" ;
            :spatial_resolution = "0.05 degree" ;
            :contact = "http://copernicus-support.ecmwf.int" ;
            :creation_date = "2018-02-19T19:13:37Z" ;
}
```

Appendix C - Specifications for Level 4 Analysis ICDR

Example file structure (ncdump output):

```
netcdf \20170101120000-C3S-L4_GHRSST-SSTdepth-OSTIA-GLOB_ICDR2.0-v02.0-fv01.0 {
dimensions:
	time = 1 ;
	lat = 3600 ;
	lon = 7200 ;
variables:
	int time(time) ;
		time:long_name = "reference time of sst field" ;
		time:standard_name = "time" ;
		time:axis = "T" ;
		time:units = "seconds since 1981-01-01 00:00:00" ;
		time:comment =  ;
	float lat(lat) ;
		lat:standard_name = "latitude" ;
		lat:long_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:valid_min = -90.f ;
		lat:valid_max = 90.f ;
		lat:axis = "Y" ;
		lat:comment = " Latitude geographical coordinates,WGS84 projection"
;
	float lon(lon) ;
		lon:standard_name = "longitude" ;
		lon:long_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:valid_min = -180.f ;
		lon:valid_max = 180.f ;
		lon:axis = "X" ;
		lon:comment = " Longitude geographical coordinates,WGS84 projection"
;
	short analysed_sst(time, lat, lon) ;
		analysed_sst:long_name = "analysed sea surface temperature" ;
		analysed_sst:standard_name = "sea_water_temperature" ;
		analysed_sst:units = "kelvin" ;
		analysed_sst:coordinates = "lon lat" ;
		analysed_sst:_FillValue = -32768s ;
		analysed_sst:add_offset = 273.15f ;
		analysed_sst:scale_factor = 0.01f ;
		analysed_sst:valid_min = -300s ;
		analysed_sst:valid_max = 4500s ;
		analysed_sst:source = "AVHRR19_G-C3S-L3U-ICDR-v2.0 AVHRRMTA_G-C3S-
L3U-ICDR-v2.0 SLSTRA-C3S-L3U-ICDR-v2.0" ;
	short analysis_uncertainty(time, lat, lon) ;
		analysis_uncertainty:long_name = "estimated error standard deviation
of analysed_sst" ;
```

```
            analysis_uncertainty:standard_name = "sea_water_temperature
standard_error" ;
            analysis_uncertainty:units = "kelvin" ;
            analysis_uncertainty:coordinates = "lon lat" ;
            analysis_uncertainty:_FillValue = -32768s ;
            analysis_uncertainty:add_offset = 0.f ;
            analysis_uncertainty:scale_factor = 0.01f ;
            analysis_uncertainty:valid_min = 0s ;
            analysis_uncertainty:valid_max = 32767s ;
      byte sea_ice_fraction(time, lat, lon) ;
            sea_ice_fraction:long_name = "sea ice area fraction" ;
            sea_ice_fraction:standard_name = "sea_ice_area_fraction" ;
            sea_ice_fraction:units = "1" ;
            sea_ice_fraction:coordinates = "lon lat" ;
            sea_ice_fraction:_FillValue = -128b ;
            sea_ice_fraction:add_offset = 0.f ;
            sea_ice_fraction:scale_factor = 0.01f ;
            sea_ice_fraction:valid_min = 0b ;
            sea_ice_fraction:valid_max = 100b ;
            sea_ice_fraction:source = "EUMETSAT OSI SAF OSI-430" ;
            sea_ice_fraction:comment = " Sea ice area fraction" ;
      byte mask(time, lat, lon) ;
            mask:long_name = "land sea ice lake bit mask" ;
            mask:coordinates = "lon lat" ;
            mask:_FillValue = -128b ;
            mask:valid_min = 1b ;
            mask:valid_max = 31b ;
            mask:flag_masks = 1b, 2b, 4b, 8b, 16b ;
            mask:flag_meanings = "water land optional_lake_surface sea_ice
optional_river_surface" ;
            mask:source = "NAVOCEANO_landmask_v1.0 EUMETSAT_OSI-SAF_icemask
ARCLake_lakemask" ;
            mask:comment = " Land/ open ocean/ sea ice /lake mask" ;

// global attributes:
            :Conventions = "CF-1.5, Unidata Observation Dataset v1.0" ;
            :title = "C3S SST L4 product" ;
            :summary = "OSTIA L4 product from the C3S project, produced using
OSTIA reanalysis sytem v3.0" ;
            :references = "http://www.esa-sst-cci.org" ;
            :institution = "C3S" ;
            :history = "Created using OSTIA reanalysis system v3.0" ;
            :comment = "These data were produced by the Met Office as part of
the C3S project. WARNING Some applications are unable to properly handle signed
byte values. If values are encountered > 127, please subtract 256 from this
reported value" ;
            :license = "Creative Commons Licence by attribution
(https://creativecommons.org/licenses/by/4.0/)" ;
            :id = "OSTIA-C3S-L4-GLOB-v2.0" ;
            :naming_authority = "org.ghrsst" ;
            :product_version = "2.0" ;
```

```
		:uuid = "7fdf2639-26e5-4d4f-a60e-0bcfc9744204" ;
		:tracking_id = "7fdf2639-26e5-4d4f-a60e-0bcfc9744204" ;
		:gds_version_id = "2.0" ;
		:netcdf_version_id = "4.2.1.1 of Oct 19 2012 14:25:16" ;
		:date_created = "20180505T075534Z" ;
		:creation_date = "2018-05-05T07:55:34Z" ;
		:file_quality_level = 3 ;
		:spatial_resolution = "0.05 degree" ;
		:start_time = "20170101T000000Z" ;
		:time_coverage_start = "20170101T000000Z" ;
		:stop_time = "20170102T000000Z" ;
		:time_coverage_end = "20170102T000000Z" ;
		:time_coverage_duration = "P1D" ;
		:time_coverage_resolution = "P1D" ;
		:northernmost_latitude = 90.f ;
		:geospatial_lat_max = 90.f ;
		:southernmost_latitude = -90.f ;
		:gepspatial_lat_min = -90.f ;
		:easternmost_longitude = 180.f ;
		:geospatial_lon_max = 180.f ;
		:westernmost_longitude = -180.f ;
		:geospatial_lon_min = -180.f ;
		:geospatial_vertical_min = -0.2f ;
		:geospatial_vertical_max = -0.2f ;
		:source = "AVHRR19_G-C3S-L3U-ICDR-v2.0 AVHRRMTA_G-C3S-L3U-ICDR-v2.0
SLSTRA-C3S-L3U-ICDR-v2.0, OSI-430" ;
		:platform = "NOAA-19, MetOpA, Sentinel-3A" ;
		:sensor = "AVHRR_GAC, SLSTR" ;
		:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
		:metadata_link = "http://www.esa-cci.org" ;
		:keywords = "Oceans > Ocean Temperature > Sea Surface Temperature" ;
		:keywords_vocabulary = "NASA Global Change Master Directory (GCMD)
Science Keywords" ;
		:standard_name_vocabulary = "NetCDF Climate and Forecast (CF)
Metadata Convention" ;
		:geospatial_lat_units = "degrees_north" ;
		:geospatial_lat_resolution = 0.05f ;
		:geospatial_lon_units = "degrees_east" ;
		:geospatial_lon_resolution = 0.05f ;
		:acknowledgment = "Funded by the Copernicus Climate Change Service.
Use of these data should acknowledge the Copernicus Climate Change Service" ;
		:creator_name = "Copernicus Climate Change Service (C3S)" ;
		:creator_email = "science.leader@esa-sst-cci.org" ;
		:creator_processing_institution = "These data were produced on the
JASMIN infrastructure at STFC as part of the C3S project" ;
		:creator_url = "https://climate.copernicus.eu/" ;
		:project = "Copernicus Climate Change Service (C3S)" ;
		:publisher_name = "Copernicus Climate Data Store" ;
		:publisher_url = "https://climate.copernicus.eu/" ;
		:publisher_email = "copernicus-support@ecmwf.int" ;
		:processing_level = "L4" ;
```

```
            :cdm_data_type = "grid" ;
            :product_specification_version = "SST_CCI-PSD-UKMO-201-Issue-H" ;
            :contact = "http://copernicus-support.ecmwf.int" ;
}
```

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