ATSR Arctic Surface Temperature (AAST) Dataset V2.1 Product User Guide

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Change log

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Applicable documents

Table 1: List of applicable documents

Reference Number	Document	Reference
[AD-1]	GlobTemperature Product User Guide	GlobTemp-WP3-DEL-11
[AD-2]	Satellite LST Validation Report	GlobTemp-WP4-DEL-12

Reference documents

Table 2: List of reference documents

Reference Number	Reference
[RD-1]	Merchant, C.J., Embury, O., Rayner, N.A., Berry, D.I., Corlett, G.K., Lean, K., Veal, K.L., Kent, E.C., Llewellyn-Jones, D.T., Remedios, J.J. and Saunders, R., 2012. A 20 year independent record of sea surface temperature for climate from Along-Track Scanning Radiometers. Journal of Geophysical Research: Oceans, 117(C12).
[RD-2]	Soria, G. and J.A. Sobrino, ENVISAT/AATSR derived land surface temperature over a heterogeneous region. Remote Sensing of Environment, 2007. 111(4): p. 409-422.
[RD-3]	IDEAS AATSR QC Team, User Note for the Third AATSR Reprocessing (DEAS-VEG-OQC-MEM-1158) https://earth.esa.int/web/guest/document-library. 2013.
[RD-4]	Ghent, D., et al., Advancing the AATSR land surface temperature retrieval with higher resolution auxiliary datasets: Part A – product specification. in preparation.
[RD-5]	Ghent, D., et al., Advancing the AATSR land surface temperature retrieval with higher resolution auxiliary datasets: Part B – validation. in preparation.
[RD-6]	Arino, O., et al., GlobCover: ESA service for Global land cover from MERIS. Igarss: 2007 Ieee International Geoscience and Remote Sensing Symposium, Vols 1-12: Sensing and Understanding Our Planet. 2007, New York: Ieee. 2412-2415.
[RD-7]	Baret, F., et al., GEOV1: LAI and FAPAR essential climate variables and FCOVER global time series capitalizing over existing products. Part1: Principles of development and production. Remote Sensing of Environment, 2013. 137: p. 299-309.
[RD-8]	National Ice Center, IMS daily Northern Hemisphere snow and ice analysis at 4 km and 24 km resolution, National Snow and Ice Data Center, Editor 2008, updated daily: Boulder, CO.

Reference Number	Reference
[RD-9]	Donlon, C.J., et al., The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system. Remote Sensing of Environment, 2012. 116(January 2012): p. 140-158.
[RD-10]	MyOcean, Ocean Monitoring and Forecasting http://www.myocean.eu/.
[RD-11]	Bulgin, C.E., et al., Cloud-clearing techniques over land for land-surface temperature retrieval from the Advanced Along-Track Scanning Radiometer. International Journal of Remote Sensing, 2014: p. 3594-3615.
[RD-12]	Comiso, J. C. 2003. "Warming trends in the Arctic from clear sky satellite observations." Journal of Climate 16 (21): 3498-3510.
[RD-13]	Rew, R., et al., The NetCDF Users Guide. 2011.
[RD-14]	Eaton, B., et al., NetCDF Climate and Forecast (CF) Metadata Conventions - Version 1.6. 2011.
[RD-15]	Cocevar, P., et al., Envisat AATSR Performance Report (IDEAS-VEG-OQC-REP-1143) https://earth.esa.int/web/guest/document-library. 2013.
[RD-16]	Prata, F., Land Surface Temperature Measurement from Space: AATSR Algorithm Theoretical Basis Document. 2002.
[RD-17]	Dee, D.P., et al., The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Quarterly Journal of the Royal Meteorological Society, 2011. 137(656): p. 553-597.
[RD-18]	Embury, O., Merchant, C. J., and Corlett, G. K (2012). A reprocessing for climate of sea surface temperature from the along-track scanning radiometers: initial validation, accounting for skin and diurnal variability. Remote Sensing of Environment, 116, 62-78. doi: 10.1016/j.rse.2011.02.028
[RD-19]	ATSR V3.0 Sea Surface Temperature Validation Report: Technical note for the ATSR QWG (UL-SST-P05 Issue 1B) https://earth.esa.int/documents/700255/702296/QC2_ATSR_V3_SST_Validation_Report_Issue1B_20160907. 2016.
[RD-20]	ARM (2015b). Sky and Ground Radiometers for Longwave Radiation. 1998–2015, 71° 19' 23.73" N, 156° 36' 56.70" W: North Slope of Alaska (NSA) Central Facility Barrow (C1). In T. ARM Data Archive: Oak Ridge, USA. (Ed.)
[RD-21]	ARM (2015c). Sky and Ground Radiometers for Longwave Radiation. 2000–2011, 70° 28' 19.11" N, 157° 24' 28.99" W: North Slope of Alaska (NSA) Central Facility Atqasuk (C2). In ARM (Ed.). ARM Data Archive: Oak Ridge, Tennessee, USA.
[RD-23]	BSRN (2015b). Sky and Ground Radiometers for Longwave Radiation. 2011–2014, 71° 35' 10.3" N 128° 55' 07.7" E: Station at Tiksi, Russia. In BSRN (Ed.

Reference Number	Reference
[RD-24]	ARM (2015a). Sky and Ground Radiometers for Longwave Radiation. 1997–1998, 77 ° 17' 24.0" N 158 ° 38' 24.0" W: Mobile site at SHEBA. In T. ARM Data Archive: Oak Ridge, USA. (Ed.)
[RD-25]	Dybkjaer, G., Hoyer, J.L., Tonboe, R., Olsen, S., Rodwell, S., & Wimmer, W. (2011). The Qaanaaq Sea Ice Thermal Emission EXperiment field and data report. In: Danish Meteorological Institute and Greenland Climate and Research Centre
[RD-26]	Hutchings, J.K. (2007). The Sea Ice Experiment: Dynamic Nature of the Arctic (SEDNA)-Applied Physics Laboratory Ice Station (APLIS) 2007-Field Report
[RD-27]	Van de Wal, R., Greuell, W., van den Broeke, M.R., Reijmer, C., & Oerlemans, J. (2005). Surface mass-balance observations and automatic weather station data along a transect near Kangerlussuaq, West Greenland. Annals of Glaciology, 42, 311-316
[RD-28]	Van den Broeke, M., Smeets, C., & Van de Wal, R. (2011). The seasonal cycle and interannual variability of surface energy balance and melt in the ablation zone of the west Greenland ice sheet. The Cryosphere, 5, 377-390
[RD-29]	Dodd et al (in preparation). Towards A Combined Surface Temperature Dataset for the Arctic from the Along-Track Scanning Radiometers (ATSRs).

Glossary

AAST-------------- ATSR Arctic combined Surface Temperature dataset
(A)ATSR --------- (Advanced) Along Track Scanning Radiometer
ALB-2------------ ATSR LST Biome version-2
AUX-------------- Auxiliary datafile
BT----------------- Brightness Temperature
CF----------------- Climate and Forecast Conventions
CST --------------- Combined Surface Temperature
ECMWF --------- European Centre for Medium Wave Forecasting
ESA--------------- European Space Agency
FCOVER---------- Fraction of Vegetation Cover
FV----------------- Fractional Vegetation
GCMD------------ NASA Global change Master Directory
GHRSST---------- The Group for High Resolution Sea Surface Temperature
IMS--------------- Northern Hemisphere Interactive Multisensor Snow and Ice Mapping System
IR------------------ InfraRed
IST ---------------- Ice Surface Temperature
LEO--------------- Low Earth Orbit
LSE---------------- Land Surface Emissivity
LST --------------- Land Surface Temperature
NASA------------- National Aeronautics and Space Administration
NetCDF---------- Network Common Data Format
NDVI ------------- Normalised Difference Vegetation Index
NIR---------------- Near InfraRed
OSTIA------------ Operational Sea Surface Temperature and Sea Ice Analysis
PUG-------------- Product User Guide
SLSTR------------- Sea and Land Surface Temperature Radiometer
SST---------------- Sea Surface Temperature
ST----------------- Surface Temperature
SW---------------- Split Window
TCWV------------ Total Column Water Vapour
TIR---------------- Thermal Infrared
UTC--------------- Coordinated Universal Time

0. Introduction

0.1. Purpose and Scope

The purpose of this document is to be a Product User Guide (PUG) for Along-Track Scanning Radiometer (ATSR) Arctic combined Surface Temperature (AAST) data products produced by the University of Leicester. This PUG has been developed to facilitate users in their exploitation of these products. It provides the technical specifications for this dataset, including the structure of the products, file naming conventions, metadata definitions and quality control information. A summary of how the data were produced and an overview of each satellite instrument used are also included for interested users. This work was funded by The UK Dept. for Business, Energy & Industrial Strategy.

0.2. Overview of the AAST Dataset

Surface Temperature (ST) changes in the Polar Regions are predicted to be more rapid than either global averages or responses in lower latitudes. It is, therefore, particularly important to monitor Arctic climate change. However, the Arctic consists of both land and ocean surfaces which may be permanently or transiently covered with snow and/or ice. In addition, in situ sampling of STs is sparse both temporally and spatially. These aspects make quantification of temperature changes over the Arctic a challenging problem, but an urgent one requiring progress which this dataset aims to help address.

The AAST dataset was first developed in 2010- 2012 and updated in 2012-2017 (V1.0). This document is the PUG for V2.1 of this dataset which was developed during 2017-2018. This dataset combines ocean, ice and land surface temperatures. Ice (and snow) Surface Temperatures (ISTs) and Land Surface Temperatures (LSTs) are sourced from the GlobTemperature Level 2 LST V2.1 product. Sea Surface Temperature (SSTs) are from the ATSR SST L2P V3.0 product. Pixel level ST uncertainty estimates are included in AAST V2.1.

0.3. Nomenclature

A variety of definitions exist for terms associated with the retrieval, validation and exploitation of satellite derived surface temperatures. For a consolidated resource of definitions for terminology associated with land, inland waters, and sea-ice surface temperatures please refer to the GlobTemperature Product User Guide [AD-1]. The AAST dataset also includes the surface temperature of open ocean, so SST is additionally defined here as “the surface temperature of open ocean including coastal, but not inland, waters”.

0.4. Satellite Dataset Processing Levels

Here a description of the processing levels typically defined for satellite datasets is provided. The AAST dataset consists of Level 3 super collated products produced from two Level 2 datasets.

0.4.1. Level 0

Level 0 refers to unprocessed instrument and payload data on the orbit swath at native resolution.

0.4.2. Level 1 (L1b)

Level 1 data (L1b) are radiometrically calibrated and geometrically corrected radiances or brightness temperatures presented on the orbit swath at native resolution and geolocated to latitude and longitude of centres (and/or corners) of pixels or to tie-points.

0.4.3. Level 2 (L2 or L2P)

Level 2 data are geophysical variables (e.g. LST) derived from a single orbit of Level 1 data from one sensor and is provided at the same resolution and geolocation. These are usually delivered with geographic information, and form the basis for higher-level products. Level 2 pre-processed (L2P) datasets contain additional fields, for example confidence flags and uncertainty information.

0.4.4. Level 3 (L3, L3U, L3C, L3S)

Level 3 datasets are provided on a spatio-temporal grid e.g. daily LST on a 0.05° equal angle global grid. They can be categorised as: "uncollated" (L3U) whereby the Level 2 data from a single sensor have been regridded and/or spatially averaged onto a spatio-temporal grid without combination of observations from overlapping orbits; "collated" (L3C) whereby the Level 2 data for multiple orbits from a single sensor have been combined; and "super collated" (L3S) which is L3 data produced from L2 data from multiple instruments or sensor datasets. Modification from the input LST data, such as the removal of cloud contaminated pixels, may have been applied.

0.4.5. Level 4 (L4)

Level 4 can typically be defined as datasets constructed from multiple orbits and sensors, which have been combined in such a way as to apply statistical techniques to the combination and/or gap-filling of the data onto a spatio-temporal grid. These datasets may, or may not be, gap-free.

0.5. The (Advanced) Along Track Scanning Radiometers (A)ATSR

The Along Track Scanning Radiometer (ATSR) series of instruments consists of ATSR-1, ATSR-2 and AATSR (Advanced Along-Track Scanning Radiometer) on board the European Space Agency (ESA) sun-synchronous, polar orbiting satellites ERS-1, ERS-2 and Envisat which were launched in July 1991, April 1995, and March 2002, respectively. The third of these instruments – AATSR – provided its last data on 8th April 2012. All these instruments are global Low-Earth Orbit (LEO) infrared instruments with similar orbits and equator crossing times ensuring a high level of consistency - thus providing approximately 20 years of data. Continuation of this data, although with a gap of around 4 years, has been achieved with the launch of the Sea and Land Surface Temperature Radiometer (SLSTR) on board Sentinel-3 in February 2016.

AATSR has good radiometric accuracy (less than 0.1 K) in the mid-range of surface temperatures, based on two blackbodies scanned on each scan cycle for calibration and using Stirling Cycle coolers to maintain the infrared detectors at low noise. For AATSR, corrections of order 0.2 K to 12 µm brightness temperatures are necessary to achieve this accuracy. All three ATSRs have similar specifications with near-infrared (NIR) / infrared (IR) channels at 1.6, 3.7, 11 and 12 µm. Both ATSR-2 and AATSR however have three additional visible channels at 0.55, 0.66 and 0.87 µm for extending the application of ATSR data into the land domain (Table 3).

A distinguishing feature of the ATSRs was the dual-angle capability (nadir, and forward at an angle of ~55° to nadir) as illustrated in Figure 1. Both views are employed for the SST retrieval used for AAST, which is from the ATSR version 3.0 L2P SSTs and produced using methods based on those employed in the ARC SST L2P dataset [RD-1]. The SST retrieval scheme is a linear combination of either 2 (11 and 12µm) or 3 (11, 12, and 3.7µm; nighttime only) channels [RD-1]. LST retrievals in AAST are from GlobTemperature Level 2 LST V2.1 product, which utilises only the nadir view of ATSR sensors. The rationale on the use of the nadir view only is provided in [RD-1] which assessed both single-view and dual-angle over topographically flat and homogeneous rice fields and found dual-angle algorithms to be less accurate. The LST retrieval uses a split-window (SW) algorithm in which 1 km ST is retrieved based on the infrared channels at 11 and 12µm.

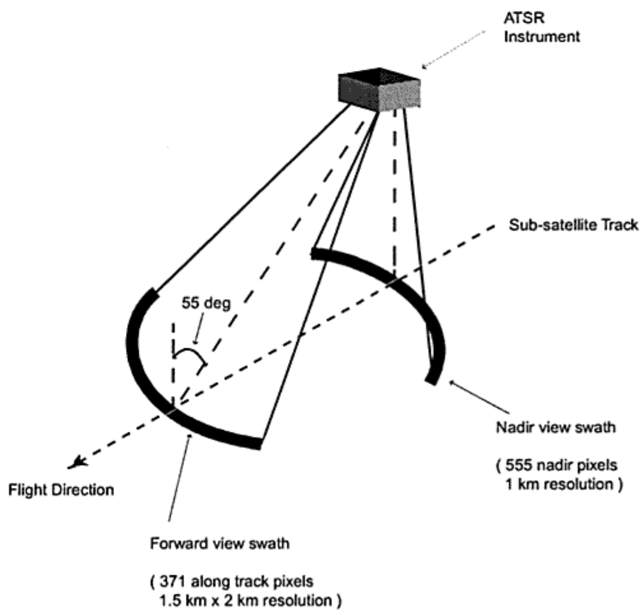

Figure 1: Viewing geometry of the AATSR instrument. Figure reproduced from [RD-2]

With a swath width of 512km, AATSR is able to provide approximately 3-day global LST coverage with a repeat cycle of 35 days. The overpass of AATSR is 10:00 in its descending node and 22:00 in its ascending node. For ATSR-1 and ATSR-2 the overpass times are 10:30 and 22:30 in their descending and ascending nodes respectively, with ATSR 24 hours ahead. All times given above are in local solar time.

Table 3: ATSR spectral channels; channels denoted with * are exclusive to ATSR-2 and AATSR and not present in ATSR-1. Table reproduced from [RD-3].

Channel (μm)	Central wavelength (μm)	Bandwidth (μm)	Application
0.55*	0.555	0.02	Chlorophyll
0.66*	0.659	0.02	Vegetation index
0.87*	0.865	0.02	Vegetation index
1.6	1.61	0.30	Cloud clearing
3.7	3.70	0.30	Surface temperature
11	10.85	1.00	Surface temperature
12	12.00	1.00	Surface temperature

1. AAST Product Description

1.1. Product Overview

Table 4: Overview information for the AAST AATSR Combined Surface Temperature (CST) products made available via the CEDA Archive

Information	Detail
Product(s) ID	UL_SSD-L3S
Latest version	2.1
Dataset coverage	20/05/2002 – 08/04/2012
Dataset availability	Combined Surface Temperature (CST) data for the entire AATSR mission is available from the CEDA Archive.
Dataset size	~4 Tb
Geographic coverage	Arctic (above 60°N)
Spatial resolution	0.05° equal angle latitude-longitude grid
Temporal resolution	Twice daily STs (descending / ascending overpass) from the observation nearest nadir (see Section 1.2 for more detail).
Lead investigator	Emma Dodd, University of Leicester
Contact information	Emma Dodd (emad2@le.ac.uk)
Key dataset strength	Highly accurate instrument; long time-series (when used in conjunction with other ATSRs); detailed uncertainty budget; sea-ice retrievals; combined land and ocean temperatures
Acknowledgement	The Advanced Along Track Scanning Radiometer (AATSR) CST products are made available through the CEDA Archive. This work was funded by The UK Dept. for Business, Energy & Industrial Strategy.
Instrument website	https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/aatsr
Product heritage	The products are consistent with the ATSR 3rd reprocessing (ATSR version 2.1), include enhancements on the latest ESA products (UOL_LST_2P v2.1 and UOL_LST_3P v2.1 respectively): • 12µm non-linearity correction • Sea-ice retrievals • Improved cloud masking at higher latitudes

Table 5: Overview information for the AAST ATSR-2 CST products made available via the CEDA Archive

Information	Detail
Product(s) ID	UL_SSD-L3S
Latest version	2.1
Dataset coverage	01/08/1995 – 22/06/2003
Dataset availability	LST data for the entire ATSR-2 mission is available from the CEDA Archive.
Dataset size	~4 Tb
Geographic coverage	Arctic (above 60°N)
Spatial resolution	0.05° equal angle latitude-longitude grid
Temporal resolution	Twice daily STs (descending / ascending overpass) from the observation nearest nadir (see Section 1.2 for more detail).
Lead investigator	Emma Dodd, University of Leicester
Contact information	Emma Dodd (emad2@le.ac.uk)
Key dataset strength	Highly accurate instrument; long time-series (when used in conjunction with other ATSRs); detailed uncertainty budget; sea-ice retrievals; combined land and ocean temperatures
Acknowledgement	The Along Track Scanning Radiometer -2 (ATSR-2) CST products are made available through the CEDA Archive. This work was funded by The UK Dept. for Business, Energy & Industrial Strategy.
Instrument website	https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/ers/instruments/atsr
Product heritage	The products are consistent with the ATSR 3rd reprocessing (ATSR version 2.1), include enhancements on the latest ESA products (UOL_LST_2P v2.1 and UOL_LST_3P v2.1 respectively): • 12µm non-linearity correction • Sea-ice retrievals • Improved cloud masking at higher latitudes

1.2. Product Description

The AAST L3S Combined Surface Temperature (CST) products produced from AATSR and ATSR-2 primarily provide data on STs in the Arctic, across all surfaces, with associated uncertainties. It further provides auxiliary information such as land cover type, fractional vegetation (FV) cover, total column water vapour (TCWV), normalized difference vegetation index (NDVI), and SST retrieval flags.

AAST products comprise daily STs and their estimated uncertainties from descending and ascending ATSR overpasses (when the satellite is moving south or north respectively) on 0.05° equal angle grids for AATSR and ATSR-2 separately. AAST products are spatial averages of 1 km descending or ascending overpass STs from input ST products. Descending and ascending products allow the complete seasonal cycle to be represented in both products for the Arctic and provides more temporally consistent view times. L2 STs from descending and ascending overpasses are spatially averaged, weighted by the proportion of swath pixels included in the output pixel, and gridded onto separate 0.05° equal angle grids for each orbit type. Where STs from different surface types are present within a 0.05° pixel the output pixel will be a mixture of all available input L2 STs. If more than one descending or ascending overpass has ST data available during a day, the output pixel providing the observation nearest nadir (determined using the satellite zenith angle) is chosen. Uncertainty information is propagated from L2 STs to daily L3S STs.

For AAST the aim is to use the most appropriate retrieval for each pixel. Prior knowledge of the surface type is required in order to allow selection of the most suitable retrieval algorithm. The land-water mask provided in the GlobTemperature Level 2 LST V2.1 product is used to determine whether a surface is land or ocean. Over land, LSTs and ISTs from the GlobTemperature (A)ATSR L2 LST V2.1 product are utilised for AAST. ISTs are provided in areas where permanent snow and ice is identified in a variant of the 2006 GlobCover product, and where transient snow cover is identified in the 4km Northern Hemisphere Interactive Multisensor Snow and Ice Mapping System (IMS) snow map [RD-4]. When IMS 4 km data is not available (prior to start of dataset production) a daily climatology across all years of IMS 4 km data is used for snow detection. For ocean areas, AAST utilises either LST data or SST data depending on whether the pixel surface type is open ocean or sea ice. Information on sea ice presence is provided by Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) daily sea-ice analysis [RD-5] which is included in the GlobTemperature (A)ATSR L2 LST V2.1 product. If the OSTIA derived auxiliary information indicates the presence of sea ice, sea ice STs from the GlobTemperature LST product are used. If OSTIA information does not indicate sea ice, or the first bit of the flag is not set, and the SST data sourced from the ATSR SST L2P V3.0 product is of good quality then SST retrievals from the ATSR SST L2P V3.0 product are used. As the AAST dataset utilises L2 data from GlobTemperature ATSR L2 LST products and from the ATSR SST L2P V3.0 product, all ST data and associated fields are derived from the most recent L1b data following the 3rd ATSR reprocessing [RD-12].

For land and ice surfaces the detection of cloudy pixels in AAST is performed with the ULEIC_V3 cloud masking algorithm. This is a restricted Bayesian infrared cloud detection scheme which has improved skill compared to the cloud masks available in the (A)ATSR L1b data [RD-7]. For open ocean the cloud masking included in SST data from the ATSR SST L2P V3.0 product is used, which is based on the Bayesian cloud probability method used for ARC [RD-1].

The GlobTemperature L2 ATSR LST algorithm [RD-8] uses a nadir-only SW approach with classes of coefficients dependent on the biome (“lcc”), fractional vegetation cover (“fv”) and water vapour (“tcwv”) for each combination of biome-diurnal (day/night) condition. The FV cover and TCWV are seasonally dependent whereas the biome is invariant. Land surface emissivity (LSE) is implicitly handled within the fractional vegetation dependent retrieval coefficients.

A complete set of CST (and accompanying AUX (auxiliary datafiles)) datafiles is available covering each of the entire AATSR and ATSR-2 mission. CST files contain the ST data, total uncertainty estimate, number of clear and cloudy pixels and satellite angles. AUX files [RD-9, RD-10], which are derived from auxiliary data associated with the 2 LST and SST data, contain all additional auxiliary information, such as the uncertainty estimate components, land water mask, fractional vegetation and biome information. The files include data obtained during the commissioning period and known non-nominal data periods. During these periods L1b brightness temperatures (BTs) for the SW channels may not be available or optimum and this will impact the ST retrievals. This is not accounted for in the uncertainty estimates as the impact has not been quantified. More details on affected orbits can be found in [RD-11]. The purpose of making these data available is to give the user maximum flexibility in selecting data for their application.

The L2 biome auxiliary data contained in the AUX files is a variant of the Globcover classification [RD-13], with the original 1/360° spatial resolution product having been re-gridded to 1/120°. In addition, the original Globcover bare soil class has been divided into six separate classes, taking the total number of land and inland water classes to 27. To incorporate these changes the Globcover nomenclature has been replaced, with the new classification system known as the ATSR LST Biome version-2 (ALB-2). Although the biome classification is invariant, on any given orbit every pixel is assessed for snow and ice cover. Where snow or ice is identified the pixel is reclassified as either land ice (ALB-2 class 27) or sea ice (ALB-2 class 28). The sea ice biome is an addition to the standard GlobTemperature V2.1 product, produced specifically for this work. For AAST a biome of 0 is assumed where the land-water mask provided by the LST files is ocean and the biome is missing as biome information for open ocean is not provided in the input L2 LST files (in order to save space).

FV provided with the AUX files is based on the Copernicus FCOVER (Fraction of Vegetation Cover) dataset (formally the Geoland-2 FCOVER dataset), which is available globally at the desired near 1-km resolution of 1/112° every 10-days from 1999 and acquired from a moving temporal window of approximately 30-day composites of observations [RD-14]. For each pixel, FV is thus determined from the 10-day (A)ATSR FV cover which is created from the FCOVER dataset with missing values gap-filled from climatology. Prior to 1999 FV is determined from 10-day climatology AUX files created from the 1999 – 2012 period.

TCWV in the LST auxiliary information is derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis [RD-15]. This is derived from 6-hourly monthly climatology corresponding to the 4 synoptic times - 00UTC, 06UTC, 12UTC and 18UTC - covering the 11-year period 2002 – 2012 inclusive for AATSR and the 9-year period 1995 – 2003 inclusive for ATSR-2.

1.2.1. Uncertainties

The uncertainty analysis in AAST follows the 3-component model used by GlobTemperature, whereby uncertainties are categorised as random, locally correlated or systematic. Truly random uncertainties are uncorrelated; whereas uncertainties that appear randomly scattered spatially and temporally may in fact be correlated on synoptic scales, and are classified as locally correlated uncertainties. Large scale systematic uncertainties refer to the correlation of error components between distant pixels. The 3-component model is sensor-independent and applies equally to all satellite processing levels.

The random components ("cst_unc_ran") include the radiometric noise of the instrument and pixel-to-pixels variations in the emissivity not captured in the auxiliary data. AAST uncertainties include two locally-correlated components. The ("cst_unc_loc_sfc") is the surface component of the locally-correlated uncertainty and consists of the contribution due to uncertainty in the emissivity across each land cover class, due to uncertainty in the selection of retrieval coefficients, uncertainty in the classified biome (an addition to the standard GlobTemperature V2.1 product specifically for AAST), and uncertainty in the true geolocation which affects knowledge of the underlying biome. The atmospheric component ("cst_unc_loc_atm") consists of the contribution due to uncertainty in the atmospheric state, in this case the water vapour. The biome and atmospheric components are considered separately during processing as they are correlated on different length scales.

The large scale systematic uncertainty ("cst_unc_sys") applies to the uncertainty in the bias of the satellite surface temperatures relative to other data sources of temperature once all known residual biases have been corrected for.

The AAST primary (CST) datafiles contain the total propagated uncertainty ("cst_uncertainty") for each grid cell. This is derived by adding in quadrature the uncertainty components for each pixel. These components, available in the corresponding AUX datafiles are:

- Random uncertainty ("cst_unc_ran"), which is the averaged radiometric noise for *n* observations reduced by $1 / \sqrt{n}$ and the sampling uncertainty which relates to the grid-cell uncertainty as a result of sub-sampling only clear-sky pixels (based on an estimate of the grid-cell variance for clear-sky pixels).
- Locally correlated uncertainty ("cst_unc_loc-sfc" and "cst_unc_loc-atm"), which is a combination of the components that are assumed to be correlated over spatial and temporal distances related to surface and atmospheric and conditions respectively.
- Large scale systematic uncertainty ("cst_unc_sys"), which is the component relating to the errors that are strictly common to all the contributing pixels.

1.2.2. Validation

ISTs and LSTs from the GT LST V2.1 product used to produce AAST were validated against in situ data from stations located on Arctic land, the Greenland ice sheet and Arctic sea ice. This section provides a summary of the validation methods and results, which are described more fully in [RD-29]

Sites and sensors which were situated in the Arctic in areas observed by ATSR satellites (below 84°N), which provide thermal data in the time period of interest (August 1995 to April 2012) were selected for this validation. Sites where the area surrounding the site is relatively homogenous in terms of biome and topography, were chosen as the in situ STs are more likely to be representative of the instrument footprint and thus the impact of unresolved spatial and temporal representativeness on the validation is reduced. In situ data which fulfilled these requirements over land were sourced from Atmospheric Radiation Measurement (ARM) Climate Research Facility and Baseline Surface Radiation Network (BSRN) sites [RD-20, RD-21, RD-23]. In situ data over sea ice were from sensors deployed at several ice camps [RD-24, RD-25, RD-26]. Over the Greenland ice sheet, in situ ISTs from Automatic Weather Stations deployed by the

Institute for Marine and Atmospheric Research, Utrecht University (UU/IMAU) were used [RD-27, RD-28]. Arctic SSTs from SST L2P were compared against in situ SST data from Argo floats and drifting buoys. The location of these validation stations is shown in Figure 2.

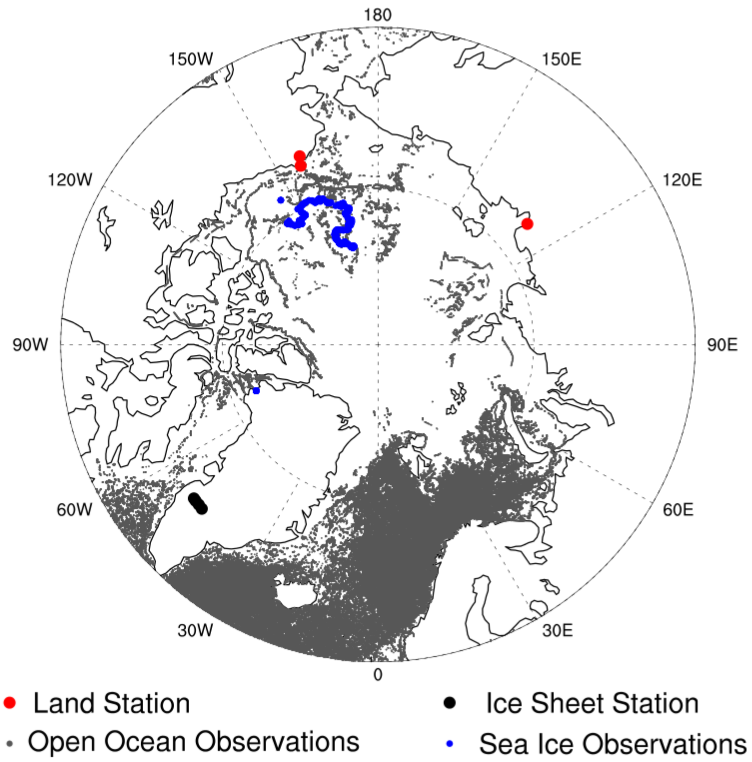

Figure 2: Location of in situ validation stations used for AAST validation.

Overall ISTs and LSTs from GT LST showed agreement with the in situ validation data, but there are noticeable outliers, particularly over Arctic land areas, which is likely due to cloud contamination (Figure 3). The daytime median differences across the whole time period are -1.48 K, -0.04 K and -1.39 K over ice and snow on land (excluding the Greenland Ice Sheet), the Greenland ice sheet and sea ice respectively. The nighttime median differences are -0.76 K, -1.74 K and -0.89 K. The robust standard deviations for both illumination conditions are up to 3.22 K. The validation results for LSTs in areas of snow-free Arctic land show larger differences between in situ and satellite data than noted for ISTs. The median differences are -3.21 K and -2.60 K for daytime and nighttime data respectively (Figure 3). The robust standard deviations are also higher.

The SSTs agree with a median difference of -0.19 K for daytime and -0.18 K for nighttime data (Figure 3). Much of the bias (around -0.17 K) between SST L2P and in situ data will be due to comparing skin SST (AAST) with subskin (Argo floats, measured between 3.5 and 5.5m, and drifting buoys, measured at around 20 m) when the wind speed is more than 6 m s^{-1} .

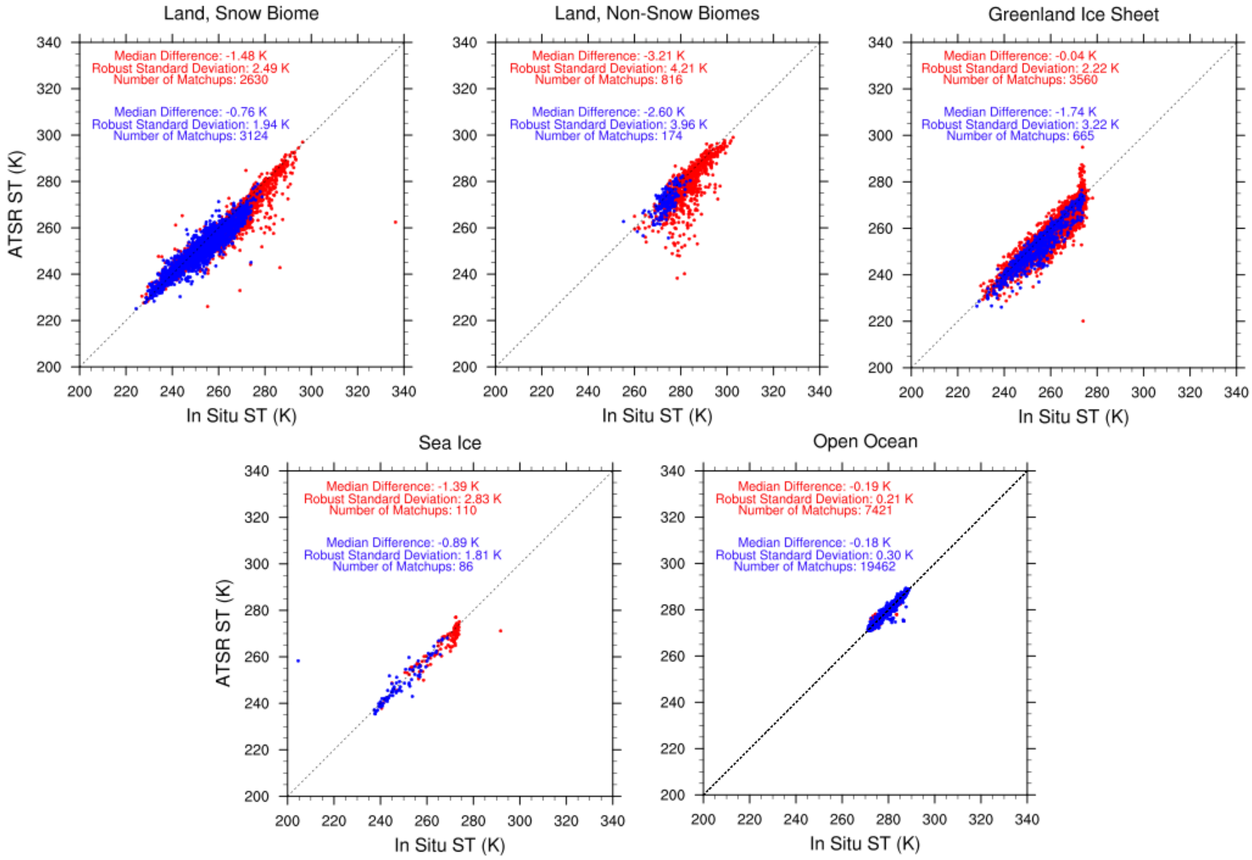

Figure 3: Density and scatter plots of validation results for ISTs and LSTs from the GlobTemperature Land Surface Temperature 1 km L2 V2.1 product, and SSTs from the ATSR Sea Surface Temperature L2P V3.0 product over Arctic land, the Greenland ice sheet, Arctic sea ice, and open ocean areas above 60°N across all years of ATSR-2 and AATSR data.

1.2.3. Known Deficiencies

There are some known deficiencies in the AAST dataset. Firstly, there are gaps in AAST data coverage. These may be due to a lack of observations: either because the instrument does not observe the whole Arctic region in the time frame of the product or due to maintenance of the satellite and/or instrument. Gaps will also occur due to cloud masking of ST data.

Secondly, users should be aware that even in a cloud cleared dataset such as AAST there will likely still be some cloud contamination. There may also be aerosol contamination.

The input datasets used to create AAST are not harmonised to understand differences and account for between sensors, even those of the same sensor series, primarily due to calibration differences

Finally, it should also be noted that the input datasets for AAST utilise different retrieval algorithms, cloud clearing algorithms and surface type identification datasets.

1.2.4. Format Specifics

The AAST dataset is provided in the latest version of the GlobTemperature Harmonised format for L3 and L4 LST data. There are small differences between AAST and the GlobTemperature format as described in [AD-1]: some additional variables are included in the AUX files.

All datasets provided by GlobTemperature is in netCDF-4 format [RD-16] using the CF-1.6 metadata convention [RD-17]. This is a self-describing, portable, scalable, appendable, sharable, archivable, and machine-independent data format. It is supported by all major data analysis and visualisation packages, and programming interfaces exist for a wide variety of other programming languages. The data is provided as individual variables in the netCDF files.

The GlobTemperature L3 and L4 format also only includes essential variables as mandatory. For the AAST dataset they are held in primary (CST) datafiles (Table 6) which ensure datafile size is at a minimum. These files are equivalent to the GlobTemperature LST datafiles.

Table 6: Harmonised format for Primary (CST) AAST L3 and L4 products in netCDF-4.

Dimensions	Name
	overpass
	lat
	lon

Variables	Name	Type	Dimensions	Units	Comment
	overpass	short	Overpass	unitless	Descending pass index is 0, Ascending pass index is 1.
	reftime	double	overpass	Julian	Reference time at start of day in julian date
	lat	float	lat	degrees_north	Grid cell centre latitude in decimal degrees north
	lon	float	lon	degrees_east	Grid cell centre longitude in decimal degrees east
	dtime	integer	overpass, lat, lon	seconds	Mean observation time in seconds since reference time.
	cst	short	overpass, lat, lon	K	Mean combined surface temperature of the grid cell from cloud cleared input pixels
	cst_uncertainty	short	overpass, lat, lon	K	Grid cell combined surface temperature uncertainty

	n	int	overpass, lat, lon	unitless	the total number of equivalent whole pixels assigned to the grid cell in the production of the averaged data (not including cloud contaminated, or non-valid pixels)
	ncld	int	overpass, lat, lon	unitless	the total number of equivalent whole pixels assigned to the grid cell in the production of the averaged data that are identified as cloud contaminated by the product's cloud clearing algorithm
	satze	short	overpass, lat, lon	degree	Mean satellite zenith viewing angle for the grid cell
	sataz	short	overpass, lat, lon	degree	Mean satellite azimuth angle for the grid cell

L3 and L4 optional fields are included in accompanying AUX datafiles (Table 7). AAST provides an expanded uncertainty budget and therefore provides uncertainty components in the AUX datafiles ("cst_unc_ran", "cst_unc_loc_atm", "cst_unc_loc_sfc" and "cst_unc_sys"). For each individual grid-cell within a dataset, the total uncertainty ("cst_uncertainty" in primary CST files) is obtained by summing each of these components in quadrature.

Table 7: Harmonised format for Auxiliary (AUX) AAST L3 and L4 products in netCDF-4

Dimensions	Name				
	overpass				
	lat				
	lon				
Variables	**Name**	**Type**	**Dimensions**	**Units**	**Comment**
	overpass	short	Overpass	unitless	Descending pass index is 0, Ascending pass index is 1.
	lat	float	lat	degrees_north	Grid cell centre latitude in decimal degrees north
	lon	float	lon	degrees_east	Grid cell centre longitude in decimal degrees east

	sst_retrieval_flag	short	overpass, lat, lon	unitless	SST retrieval information (see Table 8). This flag is to provide information about whether several different retrieval types are used in the production of L3S SSTs.
	lwm	short	lat, lon	unitless	land-water mask (proportion of land)
	lcc	short	overpass, lat, lon	unitless	Land cover classification (biome)
	fv	short	overpass, lat, lon	unitless	Mean grid cell fractional vegetation cover
	tcwv	short	overpass, lat, lon	kg m^{-2}	Mean grid cell total column water vapour
	ndvi	short	overpass, lat, lon	unitless	Mean grid cell normalised difference vegetation index
	Solze	short	overpass, lat, lon	degree	Mean grid cell solar zenith angle
	Solaz	short	overpass, lat, lon	degree	Mean grid cell solar azimuth angle
	cst_unc_ran	float	overpass, lat, lon	K	uncertainty due to random effects
	cst_unc_loc_atm	float	overpass, lat, lon	K	uncertainty due to locally correlated atmospheric effects
	cst_unc_loc_sfc	float	overpass, lat, lon	K	uncertainty due to locally correlated surface effects
	cst_unc_sys	float	overpass, lat, lon	K	uncertainty due to large scale systematic effects

For the "SST_retrieval_flag" variable a flag_meanings variable attribute is provided, which is additional metadata to describe the meaning behind any flags given in the variable.

Table 8: SST_retrieval_flag bits

Bit	Flag
0	SST flag • 0 = no SST data • 1 = SST data is present

1	Dual View flag • 0 = no dual view retrieval/s used • 1 = dual view retrieval/s have been included in the SST observation
2	Nadir Only flag • 0 = no nadir only retrieval/s used • 1 = nadir only retrieval/s have been included in the SST observation
3	3 channel flag • 0 = no 3 channel retrieval/s used • 1 = 3 channel retrieval/s have been included in the SST observation
4	2 channel flag • 0 = no 2 channel retrieval/s used • 1 = 2 channel retrieval/s have been included in the SST observation

1.2.5. Recommended Approach

CST data in the (A)ATSR L2 datafiles have been quality checked with regards to input L1b data, with only valid data stored. All invalid data is assigned with the _FillValue. For SST only data of GHRSST (The Group for High Resolution Sea Surface Temperature) acceptable quality or higher is employed from the SST datafiles. Cloud masks associated with the LST and SST data are applied to avoid cloud contamination of pixels. Furthermore, ST data where the corresponding "cst_uncertainty" is greater than 2.0 K should be treated with more caution. A final caveat is that the "NDVI" field in the AUX datafiles should be treated as supplementary information only, rather than as an accurate retrieval of NDVI, since no atmospheric correction has been applied in its derivation.

1.2.6. Example Plots

To complement the technical information contained within this PUG on the AAST product a few example images are included to better facilitate understanding of the product. Images from an example single standard daily AAST datafile are given in Figure 4 (CST data) and Figure 5 (AUX data). Figure 6 gives an example of the uncertainties from the same example AAST datafile.

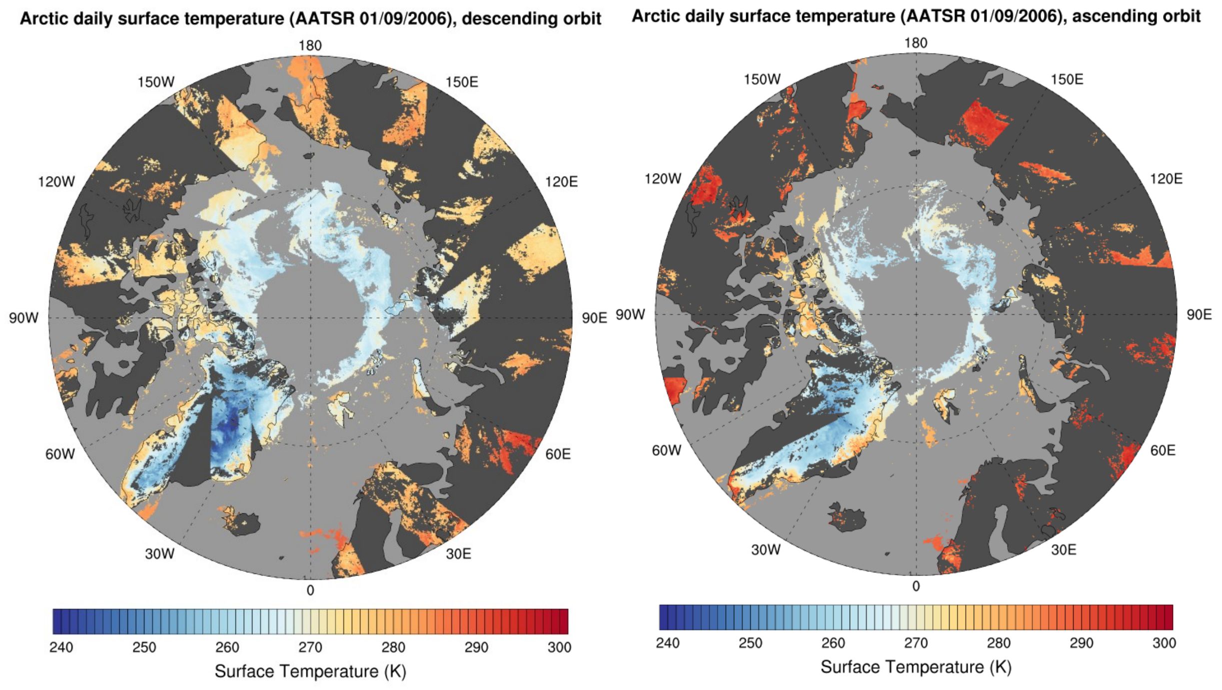

Figure 4: Example standard daily AAST Surface Temperatures.

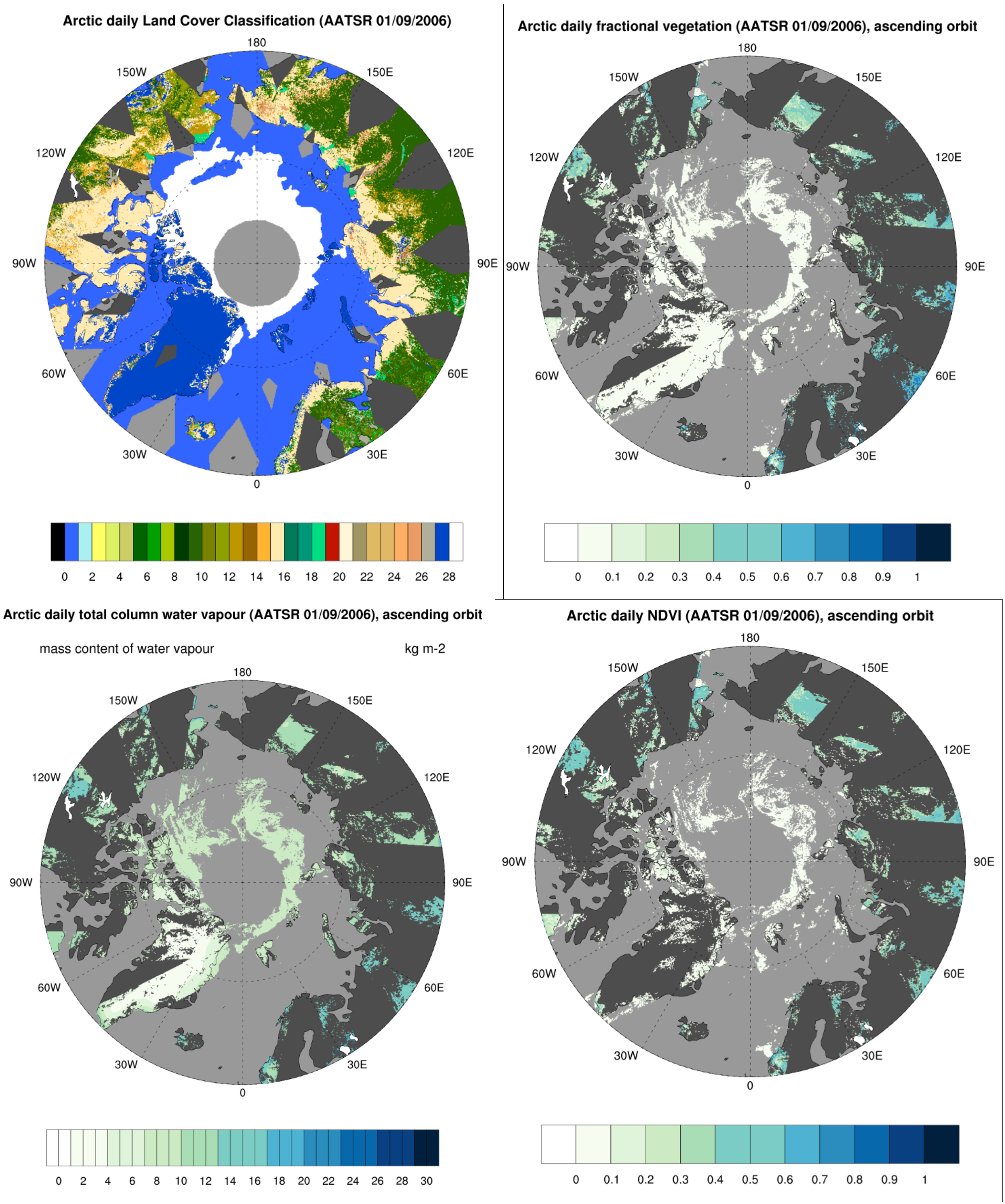

Figure 5: Example standard daily AAST auxiliary information (AUX datafile). From top left to right: lcc; fv. From bottom left to right: tcwv; NDVI.

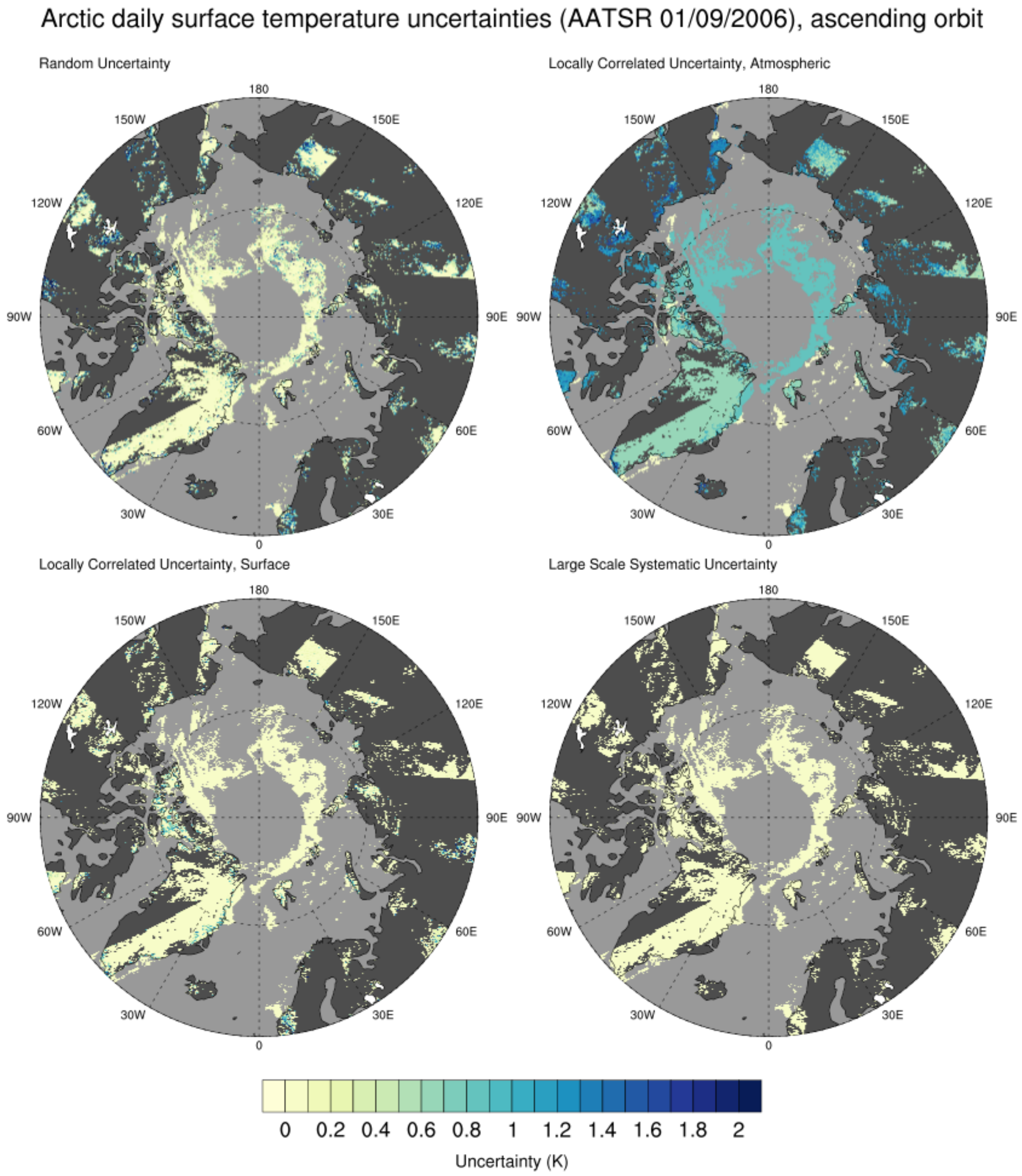

Figure 6: Example of pixel-level LST uncertainties in the Standard Daily AAST product.

1.3. Product Metadata

1.3.1. Global Metadata

AAST follows the GlobTemperature conventions for Global Metadata. The Global metadata describe the whole file with regard to general information about conventions, data producer, contact information etc. Table 9 describes the individual attributes, with specific examples from AAST detailed in the Appendices.

Table 9: Global metadata for GlobTemperature products in netCDF-4 harmonised format.

Name	Type	Comment
conventions	string	Refers to the metadata convention used in the file. For the harmonised format the Climate and Forecasting (CF) metadata convention version number (CF-1.6 is the latest version).
title	string	Title of the data product
summary	string	Summarizes the primary content of the data product
references	string	Provides a reference to cite for data users
institution	string	Name of Institution responsible for developing the dataset
history	string	Provides information about how the product was created
comment	string	Provides additional information that does not fit any of the other attributes
license	string	Provides guidance on the data use policy
Id	string	The identification name of the product
date_created	string	Gives the date on which the product was created. Given as DD-MM-YYYY HH:MM:SSZ±HHMM, where Z is the time zone relative to UTC and ±HHMM is any offset to this
product_version	string	Provides the version of the data product
netcdf_version_id	string	Gives the version of the used netCDF format and its creation date
spatial_resolution	string	Spatial resolution of data in datafile (e.g.: 1 km)
start_time	string	Provides the start time of the product; this relates to an orbit, start of a day or start of a month. Given as YYYY-MM-DD HH:MM:SSZ. Z is the time zone relative to UTC
time_coverage_start	string	Provides the start time of the total coverage of the data for the Product. Given as YYYY-MM-DD HH:MM:SSZ. Z is the time zone relative to UTC
stop_time	string	Provides the end time of the product; this relates to an orbit, end of a day or end of a month. Given as YYYY-MM-DD HH:MM:SSZ. Z is the time zone relative to UTC
time_coverage_end	string	Provides the end time of the total coverage of the data for the Product. Given as YYYY-MM-DD HH:MM:SSZ. Z is the time zone relative to UTC

northernmost_latitude	float	Provides the northernmost geographical extent of the data in the datafile. Given as decimal degrees, positive numbers are north of the equator
southernmost_latitude	float	Provides the southernmost geographical extent of the data in the datafile. Given as decimal degrees, positive numbers are north of the equator
easternmost_longitude	float	Provides the easternmost geographical extent of the data in the datafile. Given as decimal degrees, positive numbers are east of the Greenwich meridian
westernmost_longitude	float	Provides the westernmost geographical extent of the data in the datafile. Given as decimal degrees, positive numbers are east of the Greenwich meridian
source	string	Provides information about the source data on which the product is based on (eg: L1b identifier)
platform	string	Provides the name of the orbiting platform/satellite
sensor	string	Provides the name of the used sensor/instrument
processing_level	string	Product processing Level (e.g. L2, L3, L4)
keywords	string	Comma separated list of GCMD Science Keywords from http://gcmd.nasa.gov/learn/keyword_list.html
keywords_vocabulary	string	Provides vocabulary, typical form is "NASA Global change Master Directory (GCMD) Science Keywords"
geospatial_lat_units	string	Units of the latitudinal resolution. Typically “degrees_north”
geospatial_lat_resolution	float	Latitude Resolution in units matching geospatial_lat_units
geospatial_lon_units	string	Units of the longitudinal resolution. Typically “degrees_east”
geospatial_lon_resolution	float	Longitude Resolution in units matching geospatial_lon_units
acknowledgment	string	Acknowledgement of funding agency
creator_name	string	Name of Project Partner responsible for developing the dataset
creator_email	string	Email address of Project Partner responsible for developing the dataset
creator_url	string	(intentionally left blank, no creator_url)

1.3.2. Variable Metadata

Each individual variable in the GlobTemperature harmonised format has its own metadata. Table 10 details the attributes which are common for most variables.

Table 10: Variable metadata for GlobTemperature products in netCDF-4 harmonised format.

Name	Type	Comment
long_name	string	A free-text descriptive name for the variable
standard_name	string	The standard name for the variable as defined by CF conventions
units	string	Text description of the units the data is stored in.
_FillValue	same as variable type	A value used to indicate array elements which contain invalid or missing data. A proposed standard being -32768
scale_factor	float	Used to pack data into a smaller datatype. The original data can be recovered using: value = (scale_factor * packed_data) + add_offset
add_offset	float	
valid_min	same as variable type	The minimum valid value for the variable in its packed form
valid_max	same as variable type	The maximum valid value for the variable in its packed form
coordinates	string	Describes the coordinate system in which the data is given (for variables other than "lat" and "lon")
source	string	Published or web-based reference describing the origins of any third-party auxiliary data
Comment	string	Provides additional information that does not fit any of the other attributes

1.4. Product Naming Conventions

AAST follows the GlobTemperature naming convention, which has a single harmonised structure for all products:

<product_code> <"-"> <processing_level> <"-"> <primary_sensor_name> <"_"> <product_wildcard> <"-"> <start_day> <"_"> <position_wildcard> <"-"> <processing_centre> <originator_ID> <"-"> <geospatial_lat_resolution> <X> <geospatial_lon_resolution> <"-"> <product_version> <"."> <extension>

The filename length is thus consistent between AAST and GlobTemperature products.

Table 11 details the components of the AAST file naming conventions, which follow the GlobTemperature conventions outlined in [RD-1], using an example AAST filename.

- AAST Level 3S filename example:

  UL_SSD-L3S-AATSR_CST_3-20060701_XXXXXX_CUOL-0.05X0.05-V2.1.nc

Table 11: Description of output file naming conventions

Element	Example	Description
<product_code>	UL_SSD	6-character string identifying the developer and product: UL = University of Leicester SSD = single-sensor dataset
<processing_level>	L3S	3-character string identifying the processing level: L3S = Level 3S
<primary_sensor_name>	AATSR	5-character string identifying sensor name: AATSR, ATSR2
<product_wildcard>	CST_3	5-character wildcard string following the <product_type><"_"><processing_level> GlobTemperature convention: For LST or auxiliary (AUX) datafiles: CST_3, AUX_3

<start_day>	20060701	The start day of the product based on the start time of the first data set record. Given in YYYYMMDD. For aggregated datasets over a month for example then the DD element is replaced by 00.
<position_wildcard>	XXXXXX	6-character wildcard. For aggregated datasets, the appropriate elements will be replaced by X's
<processing_centre>	C	1-character string identifier of the production facility: C = UK-CEMS
<originator_ID>	UOL	3-character string identifier of the development facility: UOL = University of Leicester
<geospatial_lat_resolution>	0.05	Geospatial latitude resolution in the format F4.2
<geospatial_lon_resolution>	0.05	Geospatial longitude resolution in the format F4.2
<product_version>	V2.1	4-character string identifier of the product version number in the form of 1-character "V" followed by number in the format F3.1
<extension>	.nc	File name extension

2. Tools

The tools required for utilising AAST are the same as those required for GlobTemperature products. For information on reading the files, NetCDF operator tools, the BEAM toolbox and data programming languages please consult the GlobTemperature PUG [AD-1].

3. Appendices

3.1. Appendix A – AAST Format Examples

Primary CST Product (CST)

```
netcdf UL_SSD-L3S-AATSR_CST_3-20060930_XXXXXX_CUOL-0.05X0.05-V2.1 {

dimensions:

    overpass = 2 ;

    lat = 600 ;

    lon = 7200 ;

variables:

    short overpass(overpass) ;

        overpass:long_name = "overpass index" ;

        overpass:standard_name = "overpass" ;

        overpass:units = "1" ;

        overpass:comment = "Overpass index: descending = 0, ascending = 1" ;

    double reftime(overpass) ;

        reftime:long_name = "reference time" ;

        reftime:units = "julian" ;

        reftime:comment = "reference time at start of day in julian date" ;

    float lat(lat) ;

        lat:long_name = "centre latitude" ;

        lat:standard_name = "latitude" ;

        lat:units = "degrees_north" ;

        lat:_FillValue = -32768.f ;

        lat:valid_min = -90.f ;
```

```
        lat:valid_max = 90.f ;
        lat:comment = "Grid cell centre latitude in decimal degrees north" ;
    float lon(lon) ;
        lon:long_name = "centre longitude" ;
        lon:standard_name = "longitude" ;
        lon:units = "degrees_east" ;
        lon:_FillValue = -32768.f ;
        lon:valid_min = -180.f ;
        lon:valid_max = 180.f ;
        lon:comment = "Grid cell centre longitude in decimal degrees east" ;
    int dtime(overpass, lat, lon) ;
        dtime:long_name = "time difference from reference time" ;
        dtime:units = "seconds since 2006-09-30 00:00:00" ;
        dtime:_FillValue = -32768 ;
        dtime:valid_min = 0 ;
        dtime:valid_max = 86400 ;
        dtime:coordinates = "lat lon" ;
        dtime:comment = "Mean observation time in seconds since reference time" ;
    short cst(overpass, lat, lon) ;
        cst:long_name = "combined surface temperature" ;
        cst:standard_name = "surface_temperature" ;
        cst:units = "K" ;
        cst:_FillValue = -32768s ;
        cst:add_offset = 273.15f ;
        cst:scale_factor = 0.01f ;
        cst:valid_min = -8315s ;
```

```
        cst:valid_max = 6685s ;

        cst:coordinates = "lat lon" ;

        cst:comment = "Mean combined surface temperature  of the grid cell from cloud cleared input pixels" ;

    short cst_uncertainty(overpass, lat, lon) ;

        cst_uncertainty:long_name = "combined surface temperature total uncertainty" ;

        cst_uncertainty:units = "K" ;

        cst_uncertainty:_FillValue = -32768s ;

        cst_uncertainty:add_offset = 0.f ;

        cst_uncertainty:scale_factor = 0.001f ;

        cst_uncertainty:valid_min = 0s ;

        cst_uncertainty:valid_max = 10000s ;

        cst_uncertainty:coordinates = "lat lon" ;

        cst_uncertainty:comment = "Grid cell combined surface temperature uncertainty" ;

    int n(overpass, lat, lon) ;

        n:long_name = "number of pixels averaged" ;

        n:standard_name = "number_of_observations" ;

        n:units = "1" ;

        n:_FillValue = -32768 ;

        n:valid_min = 0 ;

        n:valid_max = 75000 ;

        n:coordinates = "lat lon" ;

        n:comment = "The total number of equivalent whole pixels assigned to the grid cell in the production of
the averaged data" ;

    int ncld(overpass, lat, lon) ;

        ncld:long_name = "number of cloudy pixels" ;

        ncld:units = "1" ;
```

ncld:_FillValue = -32768 ;

ncld:valid_min = 0 ;

ncld:valid_max = 75000 ;

ncld:coordinates = "lat lon" ;

ncld:comment = "The total number of equivalent whole pixels assigned to the grid cell in the production of the averaged data that are identified as cloud contaminated by the product's cloud clearing algorithm" ;

short satze(overpass, lat, lon) ;

satze:long_name = "satellite zenith angle" ;

satze:standard_name = "platform_zenith_angle" ;

satze:units = "degree" ;

satze:_FillValue = -32768s ;

satze:add_offset = 0.f ;

satze:scale_factor = 0.01f ;

satze:valid_min = 0s ;

satze:valid_max = 18000s ;

satze:coordinates = "lat lon" ;

satze:comment = "Mean satellite zenith viewing angle for the grid cell" ;

short sataz(overpass, lat, lon) ;

sataz:long_name = "satellite azimuth angle" ;

sataz:standard_name = "platform_azimuth_angle" ;

sataz:units = "degree" ;

sataz:_FillValue = -32768s ;

sataz:add_offset = 0.f ;

sataz:scale_factor = 0.01f ;

sataz:valid_min = -18000s ;

sataz:valid_max = 18000s ;

sataz:coordinates = "lat lon" ;

sataz:comment = "Mean satellite azimuth angle for the grid cell" ;

// global attributes:

:Conventions = "CF-1.6" ;

:title = "Daily Arctic Surface Temperature from Advanced Along Track Scanning Radiometer" ;

:summary = "This file contains Daily Surface Temperature (ST) data for the Arctic in a harmonised format from operational Advanced Along Track Scanning Radiometer(AATSR) observations. By using these data, you agree to cite the papers given in the references metadata field in any publications derived from them" ;

:references = "Dodd E., A Combined Surface Temperature Dataset for the Arctic from the Along-Track Scanning Radiometers (ATSRs). In Preparation" ;

:institution = "University of Leicester" ;

:history = "Created using software developed at University of Leicester" ;

:comment = "These data were produced at the UK CEMS facility using software developed at The University of Leicester" ;

:license = "Data use is free and open" ;

:date_created = "05-06-2018 00:09:22Z+0100" ;

:product_version = "2.1" ;

:netcdf_version_id = "4.4.1.1 of Sep 25 2017 16:11:15 $" ;

:spatial_resolution = "0.05" ;

:start_time = "2006-09-30 00:00:00Z" ;

:time_coverage_start = "2006-09-30 00:00:00Z" ;

:stop_time = "2006-09-30 23:59:59Z" ;

:time_coverage_end = "2006-09-30 23:59:59Z" ;

:northernmost_latitude = 89.975f ;

:southernmost_latitude = 60.025f ;

:easternmost_longitude = 179.975f ;

:westernmost_longitude = -179.975f ;

:source = "UL_SSD-L2-AATSR" ;

:platform = "Envisat" ;

:sensor = "AATSR" ;

:keywords = "Earth Science, Surface Temperature, Arctic" ;

:keywords_vocabulary = "NASA Global change Master Directory (GCMD) Science Keywords" ;

:geospatial_lat_units = "degrees_north" ;

:geospatial_lat_resolution = 0.05f ;

:geospatial_lon_units = "degrees_east" ;

:geospatial_lon_resolution = 0.05f ;

:acknowledgment = "Development of the data was funded by the Department for Business, Energy and Industrial Strategy" ;

:creator_name = "Emma Dodd" ;

:creator_email = "emad2@le.ac.uk" ;

:creator_url = "" ;

:processing_level = "L3S" ;

:id = "UL_SSD-L3S-AATSR_CST_3" ;

}

Auxiliary LST Product (AUX)

netcdf UL_SSD-L3S-AATSR_AUX_3-20060930_XXXXXX_CUOL-0.05X0.05-V2.1 {

dimensions:

overpass = 2 ;

lat = 600 ;

lon = 7200 ;

variables:

short overpass(overpass) ;

overpass:long_name = "overpass index" ;

```
        overpass:standard_name = "overpass" ;
        overpass:units = "1" ;
        overpass:comment = "Overpass index: descending = 0, ascending = 1" ;
    float lat(lat) ;
        lat:long_name = "centre latitude" ;
        lat:standard_name = "latitude" ;
        lat:units = "degrees_north" ;
        lat:_FillValue = -32768.f ;
        lat:valid_min = -90.f ;
        lat:valid_max = 90.f ;
        lat:comment = "Grid cell centre latitude in decimal degrees north" ;
    float lon(lon) ;
        lon:long_name = "centre longitude" ;
        lon:standard_name = "longitude" ;
        lon:units = "degrees_east" ;
        lon:_FillValue = -32768.f ;
        lon:valid_min = -180.f ;
        lon:valid_max = 180.f ;
        lon:comment = "Grid cell centre longitude in decimal degrees east" ;
    short sst_retrieval_flag(overpass, lat, lon) ;
        sst_retrieval_flag:long_name = "SST retrieval flag" ;
        sst_retrieval_flag:units = "1" ;
        sst_retrieval_flag:_FillValue = -32768s ;
        sst_retrieval_flag:coordinates = "lat lon" ;
        sst_retrieval_flag:flag_meanings = "SST, Dual_View, Nadir_Only, 3_channel, 2_channel" ;
```

sst_retrieval_flag:flag_values = 1s, 2s, 4s, 8s, 16s ;

sst_retrieval_flag:comment = "Information on the SST retrieval algorithm/s contributing to this pixel" ;

short lwm(lat, lon) ;

lwm:long_name = "land area fraction" ;

lwm:standard_name = "land_area_fraction" ;

lwm:units = "1" ;

lwm:_FillValue = -32768s ;

lwm:add_offset = 0.f ;

lwm:scale_factor = 0.0001f ;

lwm:valid_min = 0s ;

lwm:valid_max = 10000s ;

lwm:coordinates = "lat lon" ;

lwm:comment = "Advanced Along Track Scanning Radiometer pixel land fraction" ;

short lcc(lat, lon) ;

lcc:long_name = "lcc land cover classification" ;

lcc:standard_name = "land_cover_lccs" ;

lcc:units = "1" ;

lcc:_FillValue = -32768s ;

lcc:valid_min = 0s ;

lcc:valid_max = 28s ;

lcc:coordinates = "lat lon" ;

lcc:flag_meanings = "Ocean, Post-flooding_OR_irrigated_croplands, Rainfed_croplands, Mosaic_Cropland_(50-70percent)_OR_Vegetation_(grassland_shrubland_forest)_(20-50%), Mosaic_Vegetation_(grassland_shrubland_forest)_(50-70percent)_OR_Cropland_(20-50percent), Closed_to_open_(more_than_15percent)_broadleaved_evergreen_AND_OR_semi-deciduous_forest_(more_than_5m), Closed_(more_than_40percent)_broadleaved_deciduous_forest_(more_than_5m), Open_(15-

40percent)_broadleaved_deciduous_forest_(more_than_5m), Closed_(more_than_40percent)_needleleaved_evergreen_forest_(more_than_5m), Open_(15-40percent)_needleleaved_deciduous_or_evergreen_forest_(more_than_5m), Closed_to_open_(more_than_15percent)_mixed_broadleaved_and_needleleaved_forest_(more_than_5m), Mosaic_Forest_OR_Shrubland_(50-70percent)_OR_Grassland_(20-50percent), Mosaic_Grassland_(50-70percent)_OR_ForestORShrubland_(20-50percent), Closed_to_open_(more_than_15percent)_shrubland_(more_than_5m), Closed_to_open_(more_than_15percent)_grassland, Sparse_(more_than_15percent)_vegetation_(woody_vegetation_shrubs_grassland), Closed_(more_than_40percent)_broadleaved_forest_regularly_flooded_-Fresh_water, Closed_(more than_40percent)_broadleaved_semi-deciduous_AND_OR_evergreen_forest_regularly_flooded_-Saline_water, Closed_to_open_(more_than_15percent)_vegetation_(grassland_shrubland_woody_vegetation)_on_regularly_flooded_or_waterlogged_soil_-Fresh_brackish_or_saline_water, Artificial_surfaces_and_associated_areas_(urban_areas_more_than_50percent), Bare_areas_of_soil_types_not_contained_in_biomes_21_to_25, Bare_areas_of_soil_type_Entisols_-_Orthents, Bare_areas_of_soil_type_Shifting_sand, Bare_areas_of_soil_type_Aridisols_-_Calcids, Bare_areas_of_soil_type_Aridisols_-_Cambids, Bare_areas_of_soil_type_Gelisols_-_Orthels, Water_bodies_(inland_lakes_rivers_sea_maximum_10km_away_from_coast), Permanent_snow_and_ice, Sea_ice" ;

lcc:flag_values = 0s, 1s, 2s, 3s, 4s, 5s, 6s, 7s, 8s, 9s, 10s, 11s, 12s, 13s, 14s, 15s, 16s, 17s, 18s, 19s, 20s, 21s, 22s, 23s, 24s, 25s, 26s, 27s, 28s ;

lcc:source = "Globcover: http://due.esrin.esa.int/globcover/" ;

lcc:comment = "ALB3 land cover classification modified from the original Globcover classifcation for use with the Advanced Along Track Scanning Radiometer land surface temperature product" ;

short fv(overpass, lat, lon) ;

fv:long_name = "fractional vegetation cover" ;

fv:standard_name = "vegetation_area_fraction" ;

fv:units = "1" ;

fv:_FillValue = -32768s ;

fv:add_offset = 0.f ;

fv:scale_factor = 0.0001f ;

fv:valid_min = 0s ;

fv:valid_max = 10000s ;

fv:coordinates = "lat lon" ;

fv:source = "GEOLAND-2 FCOVER dataset: http://www.geoland2.eu/" ;

fv:comment = "Fractional vegetation cover from the GEOLAND-2 FCOVER dataset for use with the Advanced Along Track Scanning Radiometer land surface temperature product. The original 10-day datafiles are gap-filled from climatology" ;

short tcwv(overpass, lat, lon) ;

tcwv:long_name = "total column water vapour" ;

tcwv:standard_name = "atmosphere_mass_content_of_water_vapor" ;

tcwv:units = "kg m-2" ;

tcwv:_FillValue = -32768s ;

tcwv:add_offset = 0.f ;

tcwv:scale_factor = 0.004f ;

tcwv:valid_min = 0s ;

tcwv:valid_max = 20000s ;

tcwv:coordinates = "lat lon" ;

tcwv:source = "ECMWF ERA-Interim dataset: http://www.ecmwf.int/" ;

tcwv:comment = "Total column water vapour from the European Centre for Medium Weather Forecasting ERA-Interim dataset for use with the Advanced Along Track Scanning Radiometer land surface temperature product" ;

short ndvi(overpass, lat, lon) ;

ndvi:long_name = "normalised difference vegetation index" ;

ndvi:standard_name = "normalized_difference_vegetation_index" ;

ndvi:units = "1" ;

ndvi:_FillValue = -32768s ;

ndvi:add_offset = 0.f ;

ndvi:scale_factor = 0.0001f ;

ndvi:valid_min = 0s ;

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        ndvi:valid_max = 10000s ;
        ndvi:coordinates = "lat lon" ;
        ndvi:comment = "Normalised difference vegetation index derived from the Advanced Along Track Scanning Radiometer" ;
    short solze(overpass, lat, lon) ;
        solze:long_name = "solar zenith angle" ;
        solze:standard_name = "solar_zenith_angle" ;
        solze:units = "degree" ;
        solze:_FillValue = -32768s ;
        solze:add_offset = 0.f ;
        solze:scale_factor = 0.01f ;
        solze:valid_min = 0s ;
        solze:valid_max = 18000s ;
        solze:coordinates = "lat lon" ;
        solze:comment = "Advanced Along Track Scanning Radiometer pixel solar zenith angle" ;
    short solaz(overpass, lat, lon) ;
        solaz:long_name = "solar azimuth angle" ;
        solaz:standard_name = "solar_azimuth_angle" ;
        solaz:units = "degree" ;
        solaz:_FillValue = -32768s ;
        solaz:add_offset = 0.f ;
        solaz:scale_factor = 0.01f ;
        solaz:valid_min = -18000s ;
        solaz:valid_max = 18000s ;
        solaz:coordinates = "lat lon" ;
```

solaz:comment = "Advanced Along Track Scanning Radiometer pixel solar azimuth angle" ;

short cst_unc_ran(overpass, lat, lon) ;

cst_unc_ran:long_name = "combined surface temperature random uncertainties" ;

cst_unc_ran:units = "K" ;

cst_unc_ran:_FillValue = -32768s ;

cst_unc_ran:add_offset = 0.f ;

cst_unc_ran:scale_factor = 0.001f ;

cst_unc_ran:valid_min = 0s ;

cst_unc_ran:valid_max = 10000s ;

cst_unc_ran:coordinates = "lat lon" ;

cst_unc_ran:comment = "Advanced Along Track Scanning Radiometer combined surface temperature random uncertainty" ;

short cst_unc_loc_atm(overpass, lat, lon) ;

cst_unc_loc_atm:long_name = "combined surface temperature locally correlated atmospheric uncertainty" ;

cst_unc_loc_atm:units = "K" ;

cst_unc_loc_atm:_FillValue = -32768s ;

cst_unc_loc_atm:add_offset = 0.f ;

cst_unc_loc_atm:scale_factor = 0.001f ;

cst_unc_loc_atm:valid_min = 0s ;

cst_unc_loc_atm:valid_max = 10000s ;

cst_unc_loc_atm:coordinates = "lat lon" ;

cst_unc_loc_atm:comment = "Advanced Along Track Scanning Radiometer combined surface temperature locally correlated atmospheric uncertainty" ;

short cst_unc_loc_sfc(overpass, lat, lon) ;

cst_unc_loc_sfc:long_name = "combined surface temperature locally correlated surface uncertainty" ;

cst_unc_loc_sfc:units = "K" ;

cst_unc_loc_sfc:_FillValue = -32768s ;

cst_unc_loc_sfc:add_offset = 0.f ;

cst_unc_loc_sfc:scale_factor = 0.001f ;

cst_unc_loc_sfc:valid_min = 0s ;

cst_unc_loc_sfc:valid_max = 10000s ;

cst_unc_loc_sfc:coordinates = "lat lon" ;

cst_unc_loc_sfc:comment = "Advanced Along Track Scanning Radiometer combined surface temperature locally correlated surface uncertainty" ;

short cst_unc_sys(overpass, lat, lon) ;

cst_unc_sys:long_name = "combined surface temperature large scale correlated uncertainty" ;

cst_unc_sys:units = "K" ;

cst_unc_sys:_FillValue = -32768s ;

cst_unc_sys:add_offset = 0.f ;

cst_unc_sys:scale_factor = 0.001f ;

cst_unc_sys:valid_min = 0s ;

cst_unc_sys:valid_max = 10000s ;

cst_unc_sys:coordinates = "lat lon" ;

cst_unc_sys:comment = "Advanced Along Track Scanning Radiometer combined surface temperature large scale correlated uncertainty" ;

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:summary = "This file contains Daily Surface Temperature (ST) data for the Arctic in a harmonised format from operational Advanced Along Track Scanning Radiometer(AATSR) observations. By using these data, you agree to cite the papers given in the references metadata field in any publications derived from them" ;

:references = "Dodd E., A Combined Surface Temperature Dataset for the Arctic from the Along-Track Scanning Radiometers (ATSRs). In Preparation" ;

:institution = "University of Leicester" ;

:history = "Created using software developed at University of Leicester" ;

:comment = "These data were produced at the UK CEMS facility using software developed at The University of Leicester" ;

:license = "Data use is free and open" ;

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:southernmost_latitude = 60.025f ;

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:acknowledgment = "Development of the data was funded by the Department for Business, Energy and Industrial Strategy" ;

:creator_name = "Emma Dodd" ;

:creator_email = "emad2@le.ac.uk" ;

:creator_url = "" ;

:processing_level = "L3S" ;

:id = "UL_SSD-L3S-AATSR_AUX_3" ;

End of document