PRODUCT **USER MANUAL**

For SST_BAL_SST_L4_REP_OBSERVATIONS_010_016

Level 4 SST reprocessed products for the Baltic Sea

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CHANGE RECORD

Issue	Date	§	Description of Change	Author	Validated By
1.0	Aug 19, 2013	All	Creation of the document.	Jacob L. Høyer	L. Crosnier
1.1	May 1 2015	all	Change format to fit CMEMS graphical rules		L. Crosnier
1.2	2016.01.15	All	Rebranded for CMEMS	Jacob L. Høyer	B. Hackett
1.3	2017.09.07	All	Updated to include 2010+2011 results	Jacob L. Høyer	

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GLOSSARY AND ABBREVIATIONS

ARC	Artic Monitoring and Forecasting Centre
AVHRR	Advanced Very High Resolution Radiometer – Optical instrument onboard NOAA satellites
BAL	Baltic Monitoring and Forecasting Centre
BOOS	Baltic Operational Oceanographic System
BS	BlackSea Monitoring and Forecasting Centre
Calval	Calibration Validation
CIS	Central Information System
CMEMS	Copernicus Marine Environmental Monitoring System
CORIOLIS	In situ data system for operational oceanography
DGF	Direct Get File. It is a CMEMS download mean. "Direct download" directly transfers the file as stored on the server. It is able to deliver compressed data and should be used if you wish to download larger datasets.
DU	Dissemination Unit. A Dissemination Unit is a kind of Production Unit, with the ability to disseminate its own products or other Production Unit's products to the rest of CMEMS Production Centres and to external Users.
EC	European Commission
DT	Delayed Time
ECMWF	European Centre for Medium Range Weather Forecast
ECOOP	European Coastal Operational Oceanography Project
ECV	Essential Climate Variables
ENVISAT	ESA Environment Satellite
EO	Earth Observation
ERS	ESA Environment Remote Sensing satellite
ESA	European Space Agency
EU	European Union
EUMETSAT	European Meteorological Satellite agency

EuroGOOS	European Global Operational Oceanography System
FTP	File Transfer Protocol
GCOS	Global Climate Observing System
GDAC	Global Data Archiving Centre
GHRSST	GODAE High Resolution Sea Surface Temperature
GLO	Global Monitoring and Forecasting Centre
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
GTS	Meteorological data exchange network
I/F	Interfaces
IBI	Iberia – Biscay – Ireland Monitoring and Forecasting Centre
IBIROOS	EuroGOOS system for East Atlantic domain
ICES	International Council for the Exploitation of the Sea
INS	Insitu Thematic Assembly Centre
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
L1	Level 1 data : Raw data (telemetry) from instruments
L2	Level 2 data : (A and B) ground segment geophysical measures, interpreted, calibrated
L3	Level 1 data : Multi sensor data
L4	Level 4 data : Analysed data
MCS	Marine Core Service
MED	Mediterranean Sea Monitoring and Forecasting Centre
MedSea	Mediterranean Sea
METOP	EUMETSAT Polar Satellite
MFC	Monitoring and Forecasting Centre

MOON	Mediterranean Ocean Observing Network
MSSH	Mean Sea Surface Height
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration of the USA
NOOS	North East Atlantic Ocean Observing System
NRT	Near Real Time
NWP	Numerical Weather Prediction
NWS	North West Shelves Monitoring and Forecasting Centre
OC	Ocean Colour Thematic Assembly Centre
OSI-TAC	Ocean Sea Ice Thematic Assembly Centre
PUM	Product User Manual
QUID	Quality Information Document
R&D	Research and Development
REA	Reanalysis (for Models)
REP	Reprocessing (for Observations)
ROOS	Regional Operational Oceanography System
SAF	EUMETSAT Satellite Application Facility
SAR	Synthetic Aperture Radar
SEVIRI	Spinning Enhanced Visible and Infrared Imager – optical instrument onboard EUMETSAT MeteoSat Second Generation satellites
SIW	Former SeaIce and Wind Thematic Assembly Centre merged into OSI TAC
SLA	Service Level Agreement
SL	Sea Level Thematic Assembly Centre
SSS	Sea Surface Salinity
SST	Sea Surface Temperature Thematic Assembly Centre
SUBS	Subsetter Download mechanism : CMEMS service tool to download a NetCDF file of a selected geographical box using values of longitude an latitude, and time range

TAC	Thematic Assembly Centres
WAM	Waves model
WMO	World Meteorological Organisation
WMS	Web Map Service

REFERENCE DOCUMENTS

Ref.	Document Name	Document Reference	Issue	Date
[RD.1]	FP7 call : WORK PROGRAMME 2007 COOPERATION **THEME 9 : SPACE**			
[RD.2]	**DRAFT GUIDE FOR APPLICANTS** *Theme 9: SPACE* COLLABORATIVE PROJECT *Call identifier: FP7-SPACE-2007-1*			
[RD.3]	**The Recommended GHRSST-PP Data Processing Specification** GDS (Version 1 revision 1.6) http://www.ghrsst.org/files/download.php?m=documents&f=GDS-v1.0-rev1.6.pdf	GHRSST/17	GDSv1 Revision 1.6	April 2005
[RD.4]	**The Recommended GHRSST Data Specification (GDS) Revision 2.0** GDS 2.0 Technical Specifications http://www.ghrsst.org/files/download.php?m=documents&f=GDS2.0_TechnicalSpecifications_v2.0.pdf	GDS2.0_TechnicalSpecifications_V2.0.doc	02.007	October 2010
[RD.5]	Høyer, J. L. and She, J., Optimal interpolation of sea surface temperature for the North Sea and Baltic Sea, J. Mar. Sys., Vol 65, 1-4, pp. 176-189, 2007.			2007
[RD.6]	Høyer, J. L., Le Borgne, P. and Eastwood, S., 2013. A bias correction method for Arctic satellite sea surface temperature observations, Remote Sensing of Environment, in press.			2013

Ref.	Document Name	Document Reference	Issue	Date
[RD.7]	Høyer, J. L., & Karagali, I. (2016). Sea surface temperature climate data record for the North Sea and Baltic Sea. *Journal of Climate*, *29*(7), 2529-2541.			2016

I EXECUTIVE SUMMARY

I.1 Description summary of the CMEMS product covered by this document

For the Baltic Sea, The Danish Meteorological Institute (DMI) Sea Surface Temperature reprocessing (Jan 1982- Dec 31st, 2011) provide daily gap-free maps of sea surface temperature and sea ice area fraction, referred as L4 product, at 0.03deg. x 0.03deg. horizontal resolution, using infra-red satellite observations from NOAA AVHRRs 7, 9, 11, 14, 16, 17, 18 19 and ERS/Envisat ATSR1, ATSR2 and AATSR. For more details on the product and validation, see [RD.7].

The CMEMS product name is: SST_BAL_SST_L4_REP_OBSERVATIONS_010_016.

II SST LEVEL 4 PROCESSING CHAIN AND ALGORITHMS

II.1 Reprocessing system

The reprocessing system running at DMI is shown in the figure below.

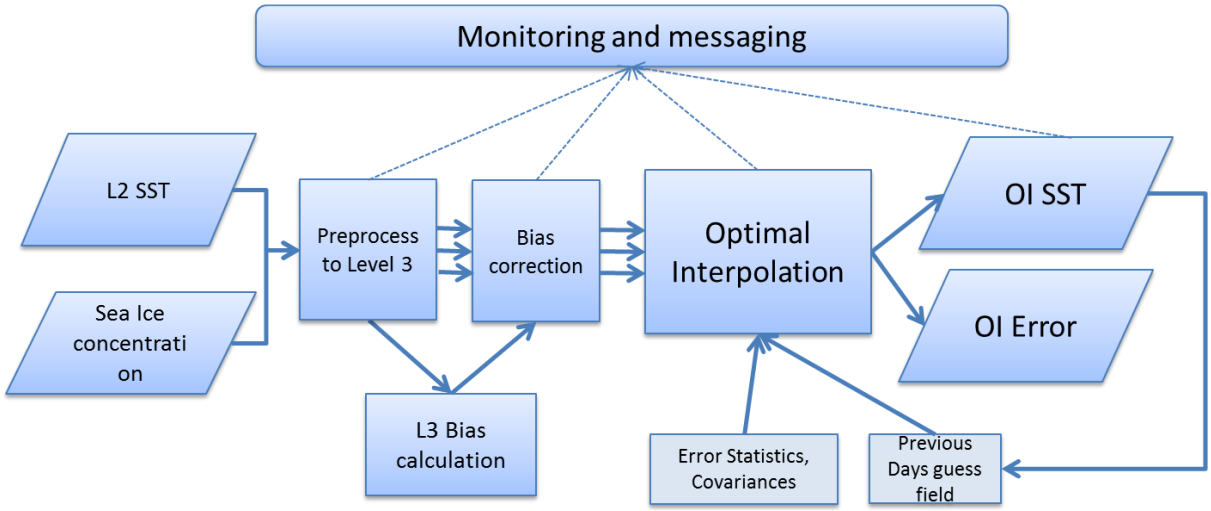

Figure II.1.1 Schematic diagram of the DMI-OI reprocessing chain at DMI

II.1.1 Input data

The following inputs are collected for input to the processing system, called DMI-OI:

(A)ATSR Reprocessing for Climate (ARC). The AATSR Reprocessing for Climate (ARC) SST level 3 dataset v1.0 and v1.1 is used, for the period Aug 1991 –December 31st, 2011. Data are obtained through the NERC Earth Observation Data Centre (http://www.neodc.rl.ac.uk/browse/neodc/arc). The selected file types are i) Day-time dual-view 2-channel and ii) Night-time dual-view 3-channel SST retrievals. The data series include observations from the ATSR 1 instrument on board the ERS-1 satellite, ATSR 2 on board the ERS-2, satellite and the AATSR on board ENVISAT.

Pathfinder SST: The 4 km AVHRR Pathfinder Version 5 SST Project (Pathfinder V5.1) is a reanalysis of the AVHRR data stream developed by the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) and the NOAA National Oceanographic Data Center (NODC). The L3 data series include observations from the AVHRR instruments on board NOAA 7, 9, 11, 14, 16, 17, 18 and 19.

In situ SST data from drifting buoys, moored buoys and ship observation are obtained from the ICOADS project and used for validation and bias correction of the Pathfinder observations. In addition, buoy observations from the German MARNET observational network are added to the in situ observations.

Sea-ice concentration data: High resolution sea ice data from Swedish Meteorological and Hydrological Institute (SMHI) are used in DMI-OI reprocessing.

A timeline with the input data is shown in the figure below

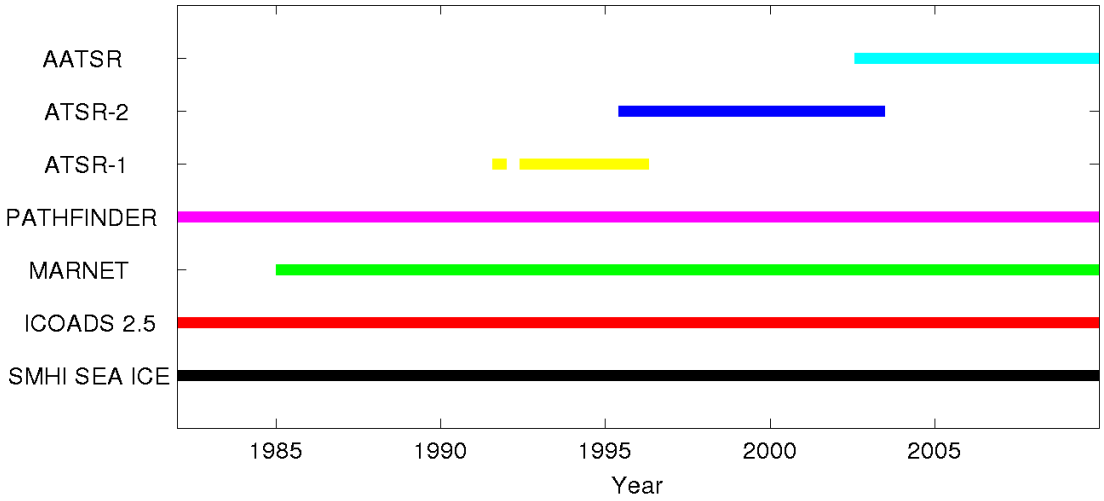

Figure II.1.2: Timeline of the data set included in the level 4 reprocessing.

II.1.2 Quality control and pre-processing of input data

All satellite data valid for a particular day, within 24 hours from the analysis are considered. The input L2/L3 SST data undergo various QC and processing steps to generate separate level 3 products:

- Only Pathfinder satellite data which have a quality flag of 4 and higher are accepted
- Only ARC observations with an estimated error less than 0.8 Deg C are accepted.
- Only In situ observations from the ICOADS data set passing all quality checks have been accepted.
- To avoid contamination from observations affected by diurnal warming, only local nighttime observations have been used for the Pathfinder data set.
- The ARC data have been adjusted to 1 meter, which minimizes the contamination from diurnal warming. Therefore both day and night time products have been used.

II.1.3 Bias correction of input satellite data

Satellite data can be biased for several reasons, including: atmospheric water vapour; atmospheric aerosol (dust); surface changes (e.g. extreme roughness); instrument calibration problems. These biases can lead to biases in the analysis if they are not treated in some way. The DMI-OI uses a bias correction method for the reprocessing, which has been developed specifically for minimizing high latitude biases. The dynamical bias correction method is described in [RD.6] and is based upon aggregating observations within a temporal window and adjusting the satellite products to an accurate reference product. The method uses ICOADS (from 1982 to 1991) and (A)ATSR data (from

1991 to 2012) as to produce daily reference fields against which, the Pathfinder observations are corrected.

II.1.4 Processing Scheme

- The main SST analysis uses a persistence approach based on the use of the previous analysis field as a first guess. The SST observations from the current day are therefore interpreted as anomalies with respect to the first guess field. The errors on the guess field are derived from the data. They are shown in the figure below:

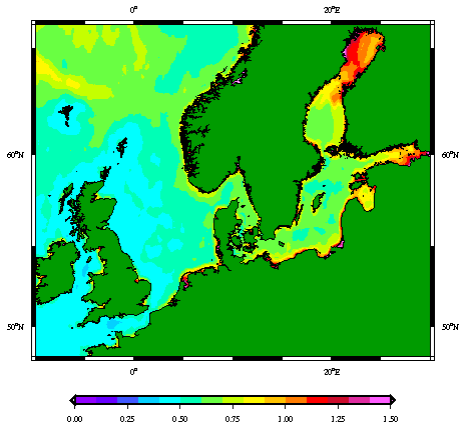

Figure II.1.4.1 Guess error variance in the OI estimation

- The **background error covariance matrix :** The correlation scales of the satellite anomalies have been derived empirically from observations. Spatially dependent error covariance functions have been fitted, based upon several years of analysis. The functions take the form of:

$$C_{ij} = \exp(-\lambda * dist_{i,j}^{\gamma})$$

Where $dist_{ij}$ is the distance between two observations and λ and γ are the two parameters that have been empirically determined. The figure below shows the spatial distribution of these parameters.

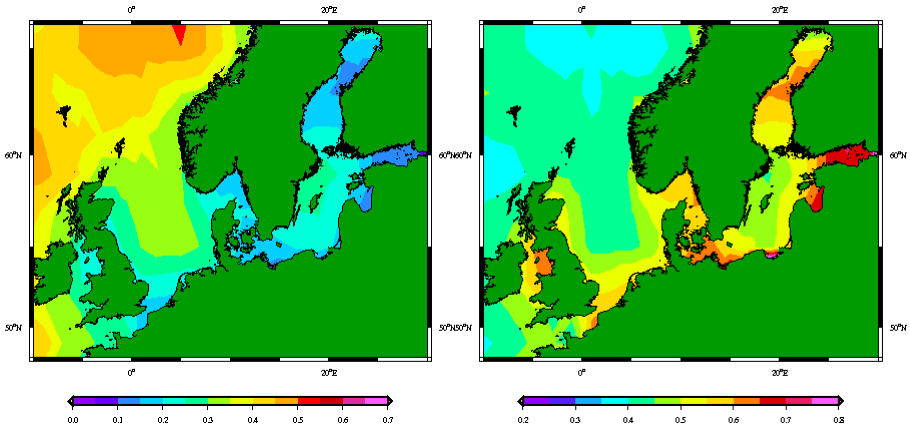

Figure II.1.4.2 The parameters (λ left and γ right) of the error correlation function used in the DMI-OI reprocessing.

- The **observation error covariance matrix** is assumed to be a diagonal matrix (observation errors are uncorrelated with each other). The diagonal elements are specified using the error obtained from validation against in situ observations and the reduced error estimate from the noise weighting procedure.
- The ice concentration mask is included in the analysis where all DMI-OI grid points with more than 30 percent sea ice concentration are considered as observations with temperature equal to -1. degree C The errors on the ice covered grid points are set to 1 degree C to account for errors in the sea ice mask.
- The error covariance functions, the first guess fields and the satellite observations are combined in an Optimal interpolation algorithm that inverts the covariance matrix and determines the optimal weights for the observations for each DMI-OI grid point. For more details on the DMI-OI algorithm, see **[RD.5]** for more details on the technical issues.
- Each SST analysis value is accompanied by an **uncertainty estimate** which is a result of the Optimal Interpolation algorithm. The errors in sea ice covered waters relates to the SST under ice estimate.

III SST LEVEL 4 PRODUCTS DESCRIPTION

III.1 Example of fields

The figures below show examples of the three variables delivered in each file:

- Analysed SST
- Analysis error
- Sea ice area fraction

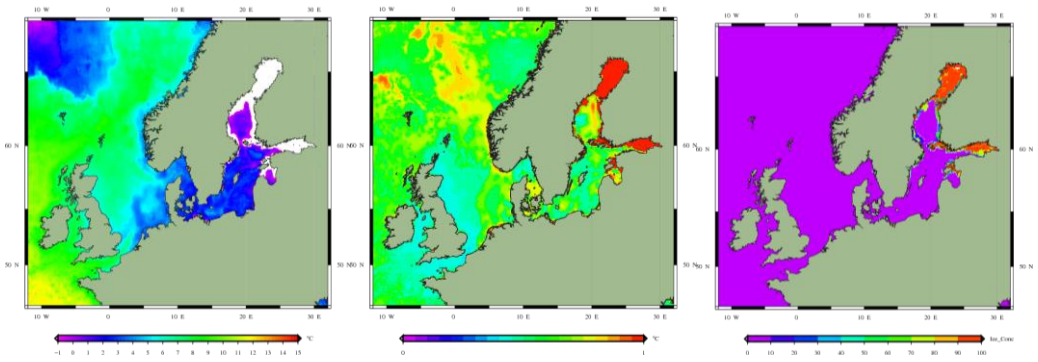

Figure IV.1.1 Examples of outputs from the L4 DMI-OI_REP product on March, 4th, 2009 (analysed SST (left), analysis error (middle) and ice concentration (right).

III.2 Common characteristics

The L4 fields are delivered on a regular lat/lon grid, from 12.0 °W to 32.0 °E and 46.0 °N to 67.99 °N at a 0.03° horizontal resolution for the high resolution product in netCDF format.

III.3 L4 products

The L4 product format specification is described in detail in the GHRSST format specification **[RD.3].** Section V.4 provides an example of the netCDF file header.

III.4 Details of variables and units

- Analysed sst (K)
- Analysis error (K)
- sea ice area fraction (value between [0;1])

III.5 Grid Characteristics and Geographical Projection

The L4 fields are delivered on a regular lat/lon grid, from 12.0°W to 32.0°E and 46.0°N to 67.99°N at a 0.03° horizontal resolution.

IV PRODUCT DISTRIBUTION

IV.1 Which Download mechanism is available for this product?

The download mechanisms available for this product are:

- Subsetter
- Authenticated FTP

IV.2 How to Download this product?

You first need to register. Please find below the registration steps:
http://marine.copernicus.eu/web/34-products-and-services-faq.php#1

Once registered, the CMEMS FAQ http://marine.copernicus.eu/web/34-products-and-services-faq.php will guide you on How to download a product through the CMEMS Web Portal Subsetter Service.

IV.3 Download a product through the CMEMS FTP Service

You first need to register. Please find below the registration steps:
http://marine.copernicus.eu/web/34-products-and-services-faq.php#1

The ftp site is accessed using your CMEMS user name and password and the files are located in the directory called SST_BAL_SST_L4_REP_OBSERVATIONS_010_016

V FILES NOMENCLATURE AND FORMAT

The nomenclature of the downloaded files differs on the basis of the chosen download mechanism Subsetter or CMEMS FTP services.

V.1 Nomenclature of files when downloaded through the Subsetter Service

SST_BAL_SST_L4_REP_OBSERVATIONS_010_016 files nomenclature when downloaded through the CMEMS Web Portal Subsetter is based as follows:

The scheme is: DMI-BAL-SST_REANALYSIS-OBS_FULL_TIME_SERIE**-nnnnnnnnnnnn.nc**
where :

- **nnnnnnnn**: 13 digit integer corresponding to the current time (download time) in milliseconds since January 1, 1970 midnight UTC.
- **.nc**: standard NetCDF filename extension.

Example:

DMI-BAL-SST_REANALYSIS-OBS_FULL_TIME_SERIE_1383233655122.nc

V.2 Nomenclature of files when downloaded through the CMEMS FTP Services

SST_BAL_SST_L4_REP_OBSERVATIONS files when downloaded through the CMEMS FTP services is named as the example below

19911231000000-DMI-L4_GHRSST-SSTfnd-DMI_OI_REP-NSEABALTIC-v02.0-fv01.0.nc

, where the first field is the validity day and time of the data in the file { YYYYMMDDHHmmSS}

and fvXX.Y is the file version number. Nc indicates it is a netcdf file format

V.3 File Format: Netcdf

The products are stored using the NetCDF-CF format version 3.6.

NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The netCDF libraries define a machine-independent format for representing scientific data.

Please see Unidata netCDF pages for more information, and to retrieve netCDF software package.

NetCDF data is:

* Self-Describing. A netCDF file includes information about the data it contains.

* Architecture-independent. A netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.

* Direct-access. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.

* Appendable. Data can be appended to a netCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a netCDF dataset can be changed, though this sometimes causes the dataset to be copied.

* Sharable. One writer and multiple readers may simultaneously access the same netCDF file.

V.4 Structure and semantic of NetCDF maps files

An example of the content of a netcdf file is shown below using ncdump:

ncdump -h 19910930000000-DMI-L4_GHRSST-SSTfnd-DMI_OI_REP-NSEABALTIC-v02.0-fv01.0.nc

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netcdf 19910930000000-DMI-L4_GHRSST-SSTfnd-DMI_OI_REP-NSEABALTIC-v02.0-fv01.0.nc {
dimensions:
        lon = 1468 ;
        lat = 734 ;
        time = 1 ;
variables:
        float lon(lon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:axis = "X" ;
                lon:valid_min = -180.f ;
                lon:valid_max = 180.f ;
                lon:comment = "geographical coordinates, WGS84 projection" ;
        float lat(lat) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:axis = "Y" ;
                lat:valid_min = -90.f ;
                lat:valid_max = 90.f ;
                lat:comment = "geographical coordinates, WGS84 projection" ;
        int time(time) ;
                time:standard_name = "time" ;
                time:long_name = "reference time of sst field" ;
                time:units = "seconds since 1981-01-01 00:00:00" ;
                time:axis = "T" ;
                time:comment = "Nominal time of Level 4 analysis" ;
        short analysed_sst(time, lat, lon) ;
```

```
        analysed_sst:standard_name = "sea_surface_foundation_temperature" ;
        analysed_sst:long_name = "analysed sea surface temperature" ;
        analysed_sst:units = "kelvin" ;
        analysed_sst:scale_factor = 0.01f ;
        analysed_sst:add_offset = 273.15f ;
        analysed_sst:_FillValue = -32768s ;
        analysed_sst:comment =  ;
        analysed_sst:source = "Pathfinder and ARC satellite SST products" ;
        analysed_sst:valid_min = -300s ;
        analysed_sst:valid_max = 4500s ;
    short analysis_error(time, lat, lon) ;
        analysis_error:standard_name = "sea_suface_temperature_error" ;
        analysis_error:long_name = "estimated error standard deviation of analysed_sst" ;
        analysis_error:units = "kelvin" ;
        analysis_error:scale_factor = 0.01f ;
        analysis_error:add_offset = 0.f ;
        analysis_error:_FillValue = -32768s ;
        analysis_error:comment =  ;
        analysis_error:valid_min = 0s ;
        analysis_error:valid_max = 32767s ;
    byte mask(time, lat, lon) ;
        mask:long_name = "land sea ice lake bit mask" ;
        mask:_FillValue = -128b ;
        mask:comment = "Mask can be used to further filter the data" ;
        mask:flag_meanings = "water land optional_lake_surface sea_ice optional_river_surface" ;
        mask:source = "NAVOCEANO_landmask_v1.0, SMHI HR ice" ;
        mask:flag_masks = 1b, 2b, 4b, 8b, 16b ;
        mask:valid_min = 1b ;
        mask:valid_max = 31b ;
    byte sea_ice_fraction(time, lat, lon) ;
        sea_ice_fraction:standard_name = "sea_ice_area_fraction" ;
        sea_ice_fraction:long_name = "sea ice area fraction" ;
        sea_ice_fraction:units = "1" ;
        sea_ice_fraction:scale_factor = 0.01f ;
        sea_ice_fraction:add_offset = 0.f ;
        sea_ice_fraction:_FillValue = -128b ;
        sea_ice_fraction:comment =  ;
        sea_ice_fraction:source = "SMHI HR icemask" ;
        sea_ice_fraction:valid_min = 0b ;
        sea_ice_fraction:valid_max = 100b ;

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        :title = "DMI Sea Surface Temperature reanalysis" ;
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:summary = "DMI Sea Surface Temperature reanalysis created using multisensor satellite SST observations" ;

:references = "Høyer, J. L. and She, J., Optimal interpolation of sea surface temperature for the North Sea and Baltic Sea, J. Mar. Sys., Vol 65, 1-4, pp. 176-189, 2007" ;

:institution = "Danish Meteorological Institute, DMI" ;

:history = "Version 1.0" ;

:license = "these data are available free of charge under the GMES data policy" ;

:id = "DMI-L4UHfnd-NSEABALTIC-DMI_OI" ;

:naming_authority = "org.ghrsst" ;

:product_version = "Version 1.0" ;

:uuid = "68e2cd1a-7c2e-4ff2-a9cd-e2b6a2d59443" ;

:gds_version_id = "2.0" ;

:netcdf_version_id = "netcdf-3.6.2 of Sep 10 2008 10:39:34" ;

:date_created = "20130711T104608Z" ;

:file_quality_level = 3 ;

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:stop_time = "19911001T000000Z" ;

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:easternmost_longitude = 32.01f ;

:southernmost_latitude = 46.f ;

:northernmost_latitude = 67.99f ;

:source = " ARC SST version 1.0, 1.1, Pathfinder v 5.0, 5.1, SMHI High Resolution Sea Ice concentration" ;

:platform = "ERS-1, ERS-2, Envisat, NOAA" ;

:sensor = "AATSR, AVHRR," ;

:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;

:metadata_link = "http://data.nodc.noaa.gov/NESDIS_DataCenters/metadata/index.html" ;

: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_lon_units = "degrees east" ;

:geospatial_lat_resolution = 0.03f ;

:geospatial_lon_resolution = 0.03f ;

:acknowledgment = "Please acknowledge the use of these data with the following statement: These data were provided by GHRSST, DMI and the MyOcean regional data assembly centre" ;

:creator_name = "Jacob L. Hoeyer" ;

:creator_email = "jlh@dmi.dk" ;

:creator_url = "http://ocean.dmi.dk/satellite/" ;

:project = "MyOcean and Group for High Resolution Sea Surface Temperature" ;

:publisher_name = "MyOcean and GHRSST project office" ;

:publisher_url = "http://www.myocean.eu.org/ and http://www.ghrsst.org" ;

:publisher_email = "servicedesk@myocean.eu.org , ghrsst-po@nceo.ac.uk" ;

:processing_level = "L4" ;

:cdm_data_type = "grid" ;

:comment = "IN NO EVENT SHALL DMI OR ITS REPRESENTATIVES BE LIABLE FOR ANY DAMAGES WHATSOEVER INCLUDING, WITHOUT LIMITATION, SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR DAMAGES FOR LOSS OF BUSINESS PROFITS OR SAVINGS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION OR OTHER PECUNIARY LOSS ARISING OUT OF THE USE OF OR THE BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION OR OTHER PECUNIARY LOSS ARISING OUT OF THE USE OF OR THE INABILITY TO USE THIS DMI PRODUCT, EVEN IF DMI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION SHALL APPLY TO CLAIMS OF PERSONAL INJURY TO THE EXTENT PERMITTED BY LAW. SOME COUNTRIES OR STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF LIABILITY FOR CONSEQUENTIAL, SPECIAL, INDIRECT, INCIDENTAL DAMAGES AND, ACCORDINGLY, SOME PORTIONS OF THESE LIMITATIONS MAY NOT APPLY TO YOU. BY USING THIS PRODUCT, YOU HAVE ACCEPTED THAT THE ABOVE LIMITATIONS OR THE MAXIMUM LEGALLY APPLICABLE SUBSET OF THESE LIMITATIONS APPLY TO YOUR USE OF THIS PRODUCT. WARNING Some applications are unable to properly handle signed byte values. If values are encountered > 127, please subtract 256 from this reported value" ;