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JV	Collected on-going updates with input from GHRSST Science Team	Resulting in Version 8.3	1st September 2011
AKW	Included references and removed duplication to other documents. GODAE description shortened. Format description updated according to GDS2.0 version 3. Updated Fig. 1, inserted Fig 2, updated Fig 3. Included MyOcean, Ourocean and JAXA portals. Shortened Australian portal. SST Definitions updated according to web-page. Cleaned up URLs	All (general updating) resulting in version 9.0	6th October 2011

Acronyms and abbreviation list

AATSR	Advanced Along Track Scanning Radiometer
AC	Advisory Council
AD	Applicable document
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
AUS	Australia NCAMERICA North-Central Eastern Pacific and Western Atlantic
Auxiliary data	Dynamic data that are used in the preparation of GHRSST L2P data products including wind speed, surface solar irradiance, aerosol optical depth and sea ice.
AVHRR	Advanced Very High Resolution Radiometer
CF	Climate Forecast (convention of netCDF)
CNES	Centre National d'Etudes Spatiales
CTD	Conductivity, temperature, depth (in situ ocean measurements)
DAS-TAG	Data Assembly and Systems Technical Advisory group
DB	Data Base
DD	Description Document
DDS	Diagnostic data set
DM	Data Management
DODS	Distributed Oceanographic Data System
DV	Diurnal Variation
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GAL	Galapagos Islands (Pacific)
GCOS	Global Climate Observing System
GDAC	Global data analysis centre
GDIP	GHRSST development and implementation plan
GDS	GHRSST Data processing Specification
GHRSST	Group for High Resolution SST
GHRSST-PO	International GHRSST Project Office
GHRSST-PP	The GODAE High Resolution Sea Surface Temperature Pilot Project
GI	Global integration
GLOB	Global Ocean
GMES	Global Monitoring for Environment and Security
GMPE	GHRSST Multi Product Ensemble
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary operational environmental satellite
GOOS	Global ocean observing system
GTS	Global telemetry system
HR-DDS	High Resolution Diagnostic Data Set
IR	Infra Red
ISO	International Organization for Standardization
JPL	Jet Propulsion Laboratory
L2	Level-2 data products
L2P	Level-2 data with added confidence flags after checking for gross errors, consistency and timelines. This family of data products provides the highest quality data obtained from a single sensor for a given processing window.
L3	Level 3 data products

L3C	Level 3 collated data product
L3S	Level 3 super-collated product
L3U	Level 3 un-collated data product
L4	Level-4
LTSRF	Long Term Stewardship and Reanalysis Facility
MDB	Match up database
MED	Mediterranean Sea
MMR	Master Metadata Repository
MODIS	Moderate Resolution Imaging Spectrometer
MSG	Meteosat Second Generation
MW	Micro Wave
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCOF	National Center for Ocean Forecasting
NERC	Natural Environment Research Council
NIR	Near Infra Red
NOAA	National Ocean and Atmosphere Administration
NODC	National Oceanographic Data Center
NSEABALTIC	North Sea and Baltic Sea
NWE	Northwest Europe (Atlantic)
NWP	Numerical Weather Prediction
OBPG	Ocean Biology Processing Group
OI	Optimal Interpolation
OM	Operation Manual
PO.DAAC	Physical Oceanography Data Active Archive Centre (U.S.)
POET	The PO.DAAC Ocean ESIP Tool
R/GTS	Regional/Global Task Sharing framework of GHRSST
RAN	Re-analysis
RD	Reference document (see section 1.5)
RDAC	Regional data assembly centre
REP	Report
RSMAS	Rosenstiel School of Marine and Atmospheric Science
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SSES	Single Sensor Error Statistics
SST	Sea Surface Temperature
TAG	Technical advisory group
TBC	To Be Confirmed
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Mapping Mission
U	surface wind speed at 10m height
UM	User Manual
UNFCCC	United Nations Framework Convention on Climate Change
URL	Universal Resource Locator
WG	Working Group
WMO	World Meteorological Organisation
XML	Extensible Mark-up Language

Summary

A new generation of integrated sea surface temperature (SST) data products is being provided by the Group for High-Resolution Sea Surface Temperature (GHRSST). These combine in near-real time various SST data products from several different satellite sensors and in situ observations and maintain fine spatial and temporal resolution needed by SST inputs to a variety of ocean and atmosphere applications in the operational and scientific communities. All GHRSST products have a standard format, include uncertainty estimates for each measurement and, are served to the international user community free of charge through a variety of data transport mechanisms and access points.

For a brief summary of ways to access, and how to display GHRSST data, a quick start guide is available and can be found in the appendix section of the User Manual.

This document serves as an overview and introduction for users to GHRSST products and services. Users seeking more detailed information may consult the relevant chapters of the GHRSST Data Specification (GDS) 2.0. For a complete discussion and access to the documentation, data products and services see https://www.ghrsst.org.

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1 Overview of the GHRSST Project

GHRSST originated from the Global Ocean Data Assimilation Experiment (GODAE), an international collaboration for ocean forecasting activities, which in 1997 acknowledged the need for better ocean observations and forecasts. In 2002, the GODAE High Resolution SST Pilot Project (GHRSST-PP) was initiated to address an emerging need for accurate high-resolution sea surface temperature (SST) products derived from satellite data. High quality SST data is required by operational ocean and atmospheric forecasting systems to constrain the modeled upper ocean circulation thermal structure and for studies of the exchange of energy between the ocean and atmosphere. However, due to the natural shortcomings of individual satellites and their sensors, no one platform alone is able to provide global, high resolution coverage of the SST of the world's oceans. GODAE ended in 2008; and GHRSST-PP continued as the **Group for High Resolution Sea Surface Temperature (GHRSST)**.

The primary aim of GHRSST is "to provide the best quality sea surface temperature data for applications in short, medium and decadal time scales in the most cost effective and efficient manner through international collaboration and scientific innovation". This is done through the development and operation of a system that delivers high-resolution (better than 10 km and ~6 hours), global coverage, SST data products for the diverse needs of GHRSST users and the wider scientific community. A new generation of SST data products is being derived and served to the user community by combining complementary satellite and in situ SST observations in near real-time. Significantly, GHRSST SST data products are global in scope, combining data received from multiple sensors and multiple satellite platforms. An overview for the project can be found in the GHRSST brochure: https://www.ghrsst.org/documents/q/category/brochure-2011/.

1.1 Sea Surface Temperature Definition

The Sea Surface Temperature (SST) is a difficult parameter to define exactly because the upper ocean (~10 m) has a complex and variable vertical temperature structure that is related to ocean turbulence and the air-sea fluxes of heat, moisture and momentum. A theoretical framework is required to understand the information content and the relationships between SST measurements made by different instruments, especially if these are to be merged together. The definitions of SST developed by the GHRSST-PP SST Science Team (agreed at the 2nd and 3rd GHRSST-PP workshops) achieve the closest possible coincidence between what is defined and what can be measured operationally, bearing in mind current scientific knowledge and understanding of how the near surface thermal structure of the ocean behaves in nature.

The GHRSST definitions were adopted in NetCDF Climate and Forecast (CF) community, within CF-1.3, and the current version (CF-1.4) of the standard name table can be found at: http://cf-pcmdi.llnl.gov/documents/cf-standard-names/standard-name-table/11/standard-name-table.

In addition, the Science Team agreed to use the CF Naming Convention, for variable names that do not already exist as part of the CF Convention:

http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.4/cf-conventions-multi.html ,

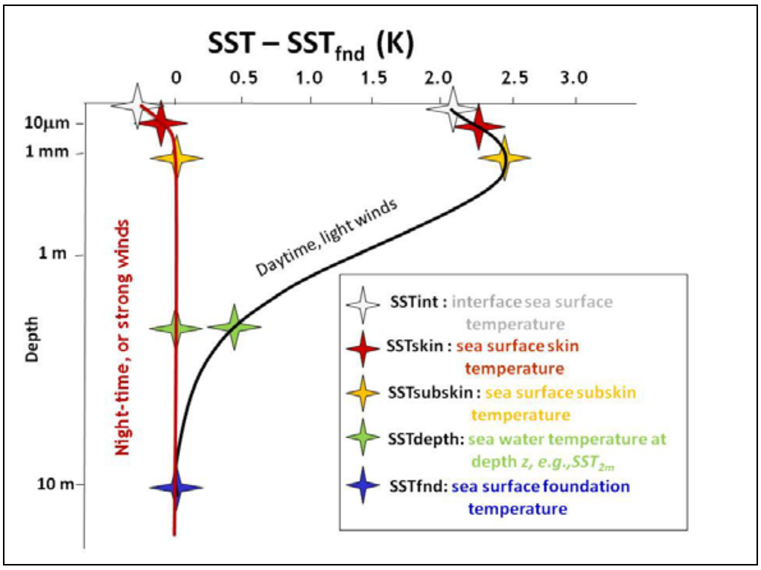


Figure 1: Overview of SST measurement types used within GHRSST.

At the exact air-sea interface a hypothetical temperature called the **interface temperature (SSTint)** is defined although this is of no practical use because it cannot be measured using current technology.

The skin temperature (SSTskin) is defined as the temperature measured by an infrared radiometer typically operating at wavelengths 3.7-12 µm (chosen for consistency with the majority of infrared satellite measurements) that represents the temperature within the conductive diffusion-dominated sub-layer at a depth of ~10-20 µm. SSTskin measurements are subject to a large potential diurnal cycle including cool skin layer effects (especially at night under clear skies and low wind speed conditions) and warm layer effects in the daytime.

The subskin temperature (SSTsubskin) represents the temperature at the base of the **conductive laminar sub-layer of the ocean surface**. For practical purposes, SSTsubskin can be well approximated to the measurement of surface temperature by a microwave radiometer operating in the 6-11 GHz frequency range, but the relationship is neither direct nor invariant to changing physical conditions or to the specific geometry of the microwave measurements.

All measurements of water temperature beneath the SSTsubskin are referred to as depth temperatures (SSTdepth) measured using a wide variety of platforms and sensors such as drifting buoys, vertical profiling floats, or deep thermistor chains at depths ranging from 10^{-2} - 10^{3}m. These temperature observations are distinct from those obtained using remote sensing techniques (SSTskin and SSTsubskin) and must be qualified by a measurement depth in meters (e.g., or SST(z) e.g. SST5m).

The foundation SST, SSTfnd, is the temperature free of diurnal temperature variability, i.e., **SSTfnd is defined as the temperature at the first time of the day when the heat gain from the solar radiation absorption exceeds the heat loss at the sea surface.** For conditions, when the SST increases or decreases monotonically over several days, the Tfnd occurs on a given day when the time rate of change of temperature is at a minimum (increasing SST), or a maximum (decreasing SST). If such a point in the daily time series cannot be identified, the SSTfnd should be set to a clearly stated time. SSTfnd is named to indicate that it is the foundation temperature upon which the growth and decay of the diurnal heating develops each day. Only in situ contact thermometry is able to measure SSTfnd and analysis procedures must be used to estimate the SSTfnd from radiometric retrievals of SSTskin and SSTsubskin taken at other times of the day.

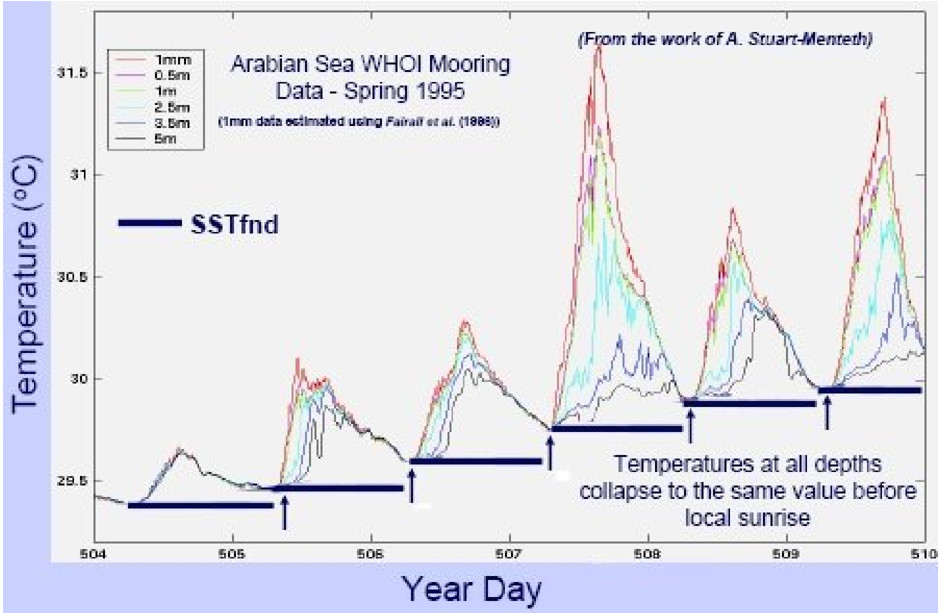


Figure 2: Example of SST find.

Blended SST (GHRSST code: SSTblend):

In addition to the CF standard names defined above, GHRSST also uses the term "Blended SST" for ambiguous cases when the depth or type of SST is not well known. This ambiguity in depth may arise in some L4 analysis products that merge multiple types of SST from satellite and in situ observations. Note, however, that many L4 analysis systems do attempt to specifically create a sea surface foundation temperature, SSTfnd.

The SST codes and CF standard names defined above and used within GHRSST are summarized along with their key characteristics in the table below.

Table 1: SST type code and summary table.

GHRSST Code	CF Standard Name	Approximate Depth	Typically Observed by…
SSTint	Sea_surface_temperature	0 meters	Not presently measurable
SSTskin	Sea_surface_skin_temperature	10 – 20 micrometers	Infrared radiometers operating in a range of wavelengths form 3.7 to 12 micrometers
SSTsubskin	Sea_surface_subskin_temperature	1 – 1.5 millimeters	Microwave radiometers operating in a range of frequencies from 6-11 gigahertz

GHRSST Code	CF Standard Name	Approximate Depth	Typically Observed by…
SSTdepth	Sea_water_temperature	Specified by vertical coordinate (e.g., SST_{5m})	In situ observing systems
SSTfnd	Sea_surface_foundation_temperature	1-5 meters pre-dawn	In situ observing systems
SSTblend	None	Unknown	Blend of satellite and in situ observations

1.2 GHRSST Data Processing System

GHRSST utilizes a distributed data system whereby the necessary data processing operations used to generate and distribute global high resolution SST data sets are shared by an international group of Regional Data Assembly Centers (RDACs). RDACs ingest, quality control and merge existing satellite and in situ SST data sources that are then used together to generate quality-controlled SST data products to the same specification (called L2P products), in real-time. The RDACs may also generate Level 3 (L3) and Level 4 (L4) products. RDAC data products are collected and assembled together at the Global Data Analysis Center (GDAC) where they are integrated, catalogued, and served to users for 30 days. After 30 days, the data are all sent to the Long Term Stewardship and Reanalysis Facility (LTSRF), where they are archived, documented, and served in perpetuity. For a schematic diagram showing the relationship between the RDACs, GDAC, and LTSRF, see Figure 3.

Regional Data Assembly Centres (RDACs) implement data processing procedures that account for specific aspects of regional coverage input data products (e.g., geostationary imagers). RDACs also provide additional data products and services to satisfy regional user requirements (e.g., regionally specific analyzed data products or ultra-high resolution data products) that will require research and development of new analysis, quality control, and data provision procedures. GHRSST global and regional coverage SST data products are now produced by GHRSST RDACs in Australia, Japan, the USA and Europe.

The Global Data Assembly Centre (GDAC) is maintained at the NASA Jet Propulsion Laboratory's Physical Oceanography Distributed Active Archive Center (PO.DAAC). RDAC SST Products are passed in near real-time to the operational GHRSST Global Data Assembly Center (GDAC) where the RDAC products are integrated together and served to the global application community. The GDAC play an essential role in quality control and data management. See Figure 3 for the relationship between the RDACs and the GDAC.

The Long Term Stewardship and Reanalysis Facility (LTSRF) is maintained at NOAA's National Oceanographic Data Center (NODC) in Silver Spring, Maryland, USA. The LTSRF receives all data produced by GHRSST and submitted to the GDAC. After 30 days, the data are sent from the GDAC to the NODC LTSRF. LTSRF completes the final metadata records and maintains the permanent archive. See Figure 3 for the relationship between the RDACs, the GDAC and the LTSRF. All data is permanently archived at the LTSRF.

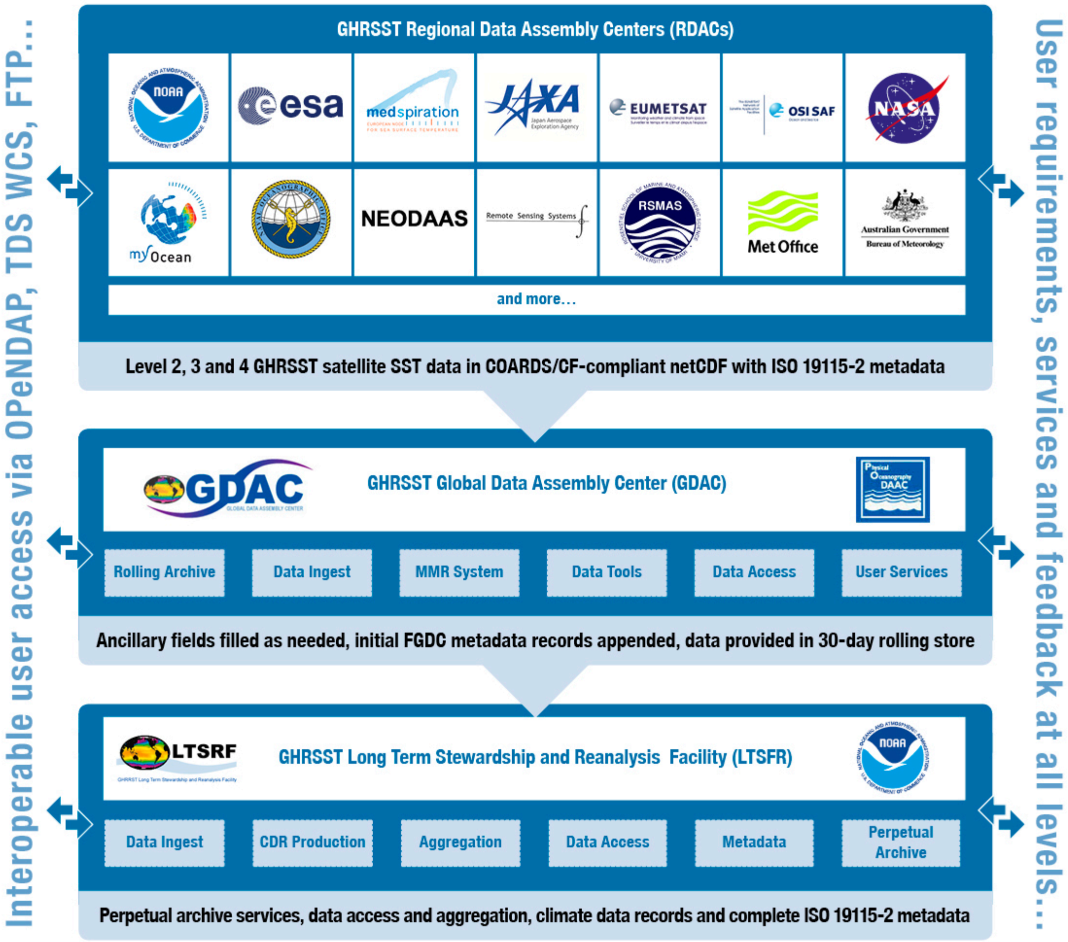


Figure 3: The relationship between Regional Data Assembly Centers (RDACs), the Global Data Assembly Center (GDAC), and the Long Term Stewardship and Reanalysis Facility (LTSRF).

2 GHRSST Data Products

GHRSST L2, L3 and L4 data products can are described here:
https://www.ghrsst.org/data/data-descriptions/
The format is documented in the GHRSST Data Specification:
https://www.ghrsst.org/files/download.php?m=documents&f=GDS2.0_TechnicalSpecifications_v2.0.pdf
The table below provides a summary of GHRSST GDS-2.0 data products and their basic characteristics.

Table 2: GHRSST data products produced by the GDS 2.0.

SST Product	L2 Pre-Processed	L3 Uncollated	L3 Collated	L3 Super-collated	Analysed SST	Multi-product analysed SST
Acronym	L2P	L3U	L3C	L3S	L4	GMPE
Description	Geophysical variables derived from Level 1 source data at the same resolution and location as the Level 1 data, typically in a satellite projection with geographic information. These data form the fundamental basis for higher-level GHRSST products and require ancillary data and uncertainty estimates. No adjustments to input SST have been made.	L2 data granules remapped to a space grid without combining any observations from overlapping orbits.	SST measurements combined from a single instrument into a space-time grid. Multiple passes/scenes of data can be combined. Adjustments may be made to input SST data.	SST measurements combined from multiple instruments into a space-time grid. Multiple passes/scenes of data are combined. Adjustments may be made to input SST data.	Data sets created from the analysis of lower level data those results in gridded, gap-free products. SST data generated from multiple sources of satellite data using optimal interpolation are an example of L4 GHRSST products	GMPE provides ensemble information about various L4 data products. It provides gridded, gap-free SST information as well as information about the spread in the various L4 products.
		L3 GHRSST products do not use analysis or interpolation procedures to fill gaps where no observations are available				
Grid specification	Native to SST data format	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider
Temporal resolution	Native to SST data stream	Native to data stream	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider
Delivery timescale	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	As available, Ideally within 3 hours from acquisition at satellite	Analysed product processing window as defined by data provider.	As available, ideally within 24 hours of the input L4 products being available.

SST Product	L2 Pre-Processed	L3 Uncollated	L3 Collated	L3 Super-collated	Analysed SST	Multi-product analysed SST
Target accuracy	Native to data stream	Native to data stream	<0.4 K	<0.4 K	< 0.4 K absolute) 0.1 K relative	< 0.4 K
Error statistics	Native to data stream if available, Sensor Specific error statistics otherwise	Native to data stream if available, Sensor Specific error statistics otherwise	Derived from input data for each output grid point.	Derived from input data for each output grid point.	Analysis error defined by data provider for each output grid point (no input data statistics are retained)	The standard deviation of the input L4 analyses is provided. This is not an error estimate, but provides some idea of uncertainty.
Coverage	Native to data stream	Native to data stream	Defined by data provider	Defined by data provider	Defined by data provider	Defined by data provider

2.1 Level-2 Pre-processed (L2P) data products

L2P files are the basic building blocks from which all other GHRSST SST data products can be derived. They include SST data as delivered by a data provider in their native format (swath, grid, or vector), together with a number of ancillary fields that simplify interpretation an application of the SST data. The common format of L2P products allows data users to rely on the fact that as new satellite derived SST data sets are brought on-line very minimal code changes will be required to make full use of new L2P data.

The main difference between input L2 SST data file and the output GHRSST L2P data file is that additional confidence data and sensor specific error estimates are included for each pixel and that the original SST data files are reformatted into the L2P specification. No adjustments to the input L2 SST measurements are allowed but instead, single sensor error statistics are used to provide bias error and standard deviation estimates that can be applied to the SST by a user. Full orbit input data files may be split into ascending and descending files or smaller granules and a unique L2P output may be generated for each file.

For every L2P file that is generated, a L2P GHRSST Master Metadata record (MMR) is created. The MMR system is maintained by the GDAC. Details on the specification of the MMR file can be found in the GHRSST GDS2.0. The current GDS2.0 specifications (and amendments) may be found at: https://www.ghrsst.org/documents/q/category/gds-documents/.

The GHRSST Science Team agreed upon mandatory fields that form the core data content of a GHRSST L2P data file. These fields will be known as L2P 'core' (L2Pcore) fields. In addition to metadata records, global attributes and geo-location information, an L2P file must contain:

Sea Surface temperature data (SST)
Time differences of SST measurements from a reference time
SST Single Sensor Error Statistic (SSES) measurement bias estimate
SSES measurement standard deviation estimate
Flags specific to each L2P data set that help users to specify data
A quality level for each measurement
An overall quality level for the L2P file.

In addition there are a number of requested auxiliary fields (L2Paux):

dt_ analysis – the difference between satellite SST measurements and a defined reference climatology of SST
An estimate of surface wind speed
An estimate of sea ice fraction
An estimate of atmospheric aerosol (as an aerosol dynamic indicator).

Optional fields may be provided by the data provider. It may be necessary to use an additional netCDF coordinate variable when including experimental fields. Only full L2P data files which contain all L2Pcore and L2Paux fields, together with full L2P MMR metadata, should be registered and ingested at the GHRSST GDAC and LTSRF system.

Note that within GHRSST, all L2P files require a full set of extensive ancillary data such as wind speeds and times of observation. These L2P files form the basis of higher-level products and are often the best level for data assimilation, so the requirement for extensive ancillary data or "dynamic flags" is important. For a full description of GHRSST L2P data products please consult the GDS 2.0.

Single Sensor Error Statistics

A key feature of the GHRSST L2P data product is the provision of Single Sensor Error Statistics (SSES). The SSES provide a bias and standard deviation in comparison to a reference dataset that allows a user to make an assessment as to the suitability of a particular satellite SST estimate for their specific application. The bias and standard deviation calculated from the comparison to the reference dataset are derived from a database of match-up coincidences produced within predefined spatial and temporal limits; the current GHRSST match-up limits are ±25 km, and ±6 hours and work is ongoing within the ST-VAL group to refine these limits.

Important: The SSES bias provided in the L2P product is the bias of the satellite measurement relative to the reference dataset. Consequently the user should subtract the bias value before using the data if the user wishes to adjust the satellite SST to the reference dataset.

All SSES provided in a GDS-2.0 L2P product are generated by the L2P data provider. When considering possible reference sources, consideration must be given to the nature of the SST being assessed. For satellite SST retrievals produced from infrared radiances, the SST is equivalent to the temperature at a depth of ~10 μm and is referred to as the skin SST; for satellite SSTs produced from microwave radiances, the SST is equivalent to the temperature at a depth of >100 μm and is a weighted average of the temperatures through the skin layer and into the sub-skin region beneath.

The current reference dataset used in GHRSST is that provided by surface drifting buoys. Although the uncertainty of this dataset is not traceable to an SI temperature standard, it has been chosen due to its significantly improved global coverage compared to all other potential reference datasets. Also, under certain conditions it is representative of the SST provided by the satellite after the application of a simple adjustment for the thermal skin effect.

Important: The application of the SSES bias provided in the L2P product maintains the depth of the satellite SST observation. So, if the satellite SST is SST-skin then the application of the SSES bias will provide an improved SST-skin relative to the reference dataset.

There are a number of different methods for determining SSES as they depend on a detailed understanding of the uncertainties associated with the in-flight performance of an individual satellite instrument and the retrieval of SST from the measured radiances. Consequently, all SSES provided in a GDS-2.0 L2P product are generated by the original L2P data provider as they use a scheme tailored to their specific dataset. However, the SSES scheme must conform to a set of agreed SSES common principles to facilitate commonality across all L2P products and allow the user to make their own judgment as to the fitness for purpose of each L2P dataset to a common reference.

The SSES common principles are maintained on the GHRSST website at https://www.ghrsst.org/ghrsst-science/science-team-groups/stval-wg/sses-common-principles/ and have been approved by the GHRSST Science Team. The L2P provider must provide documentation that summarizes the theoretical basis of their SSES scheme, its implementation, any recommendations for users, and its conformance to the agreed SSES common principles.

Important: While the SSES process is not able to account for all limitations in each L2P dataset it provides a method that is functional in a real time environment.

The derivation of SSES is an active area of research within GHRSST and methods are being refined all the time through activities coordinated by the ST-VAL group. Should you wish to participate in this group or should you find any issues with the SSES information in any GDS-2.0 L2P product then please contact https://www.ghrsst.org/ghrsst-science/science-team-groups/stval-wg/stval-membership/.

2.2 Level-3 data products

L3 data have been introduced to provide users with re-gridded, synthetic and potentially adjusted SST products, bringing added value with respect to the original L2P, but still allowing traceability to the original dataset.

The L3 GHRSST products include:

- Un-collated data that represent a simple remapping of L2P GHRSST data granules to a space grid without combining any observations from overlapping orbits or times. Although in principle these data can be adjusted or not to a reference sensor, in practice the un-collated L3 will be a remapped L2P.
- Collated data that grid observations from a single instrument and a single platform into space and/or time bins (adjusted or not to a reference sensor such as AATSR). Several adjusted collated data sets have been delivered in the frame of MERSEA

and MyOcean; a typical not-adjusted product is the OSI-SAF NAR product that consists in a mosaic of METOP or NOAA AVHRR orbits over the European Seas. Multi-sensor super-collated data that combine observations from a multiple instruments into a space-time grid. In this case, the adjustment to a common reference is necessary to avoid heterogeneities in the resulting field.

The L3 products do not use analysis or interpolation procedure to fill gaps where no observations are available.

In order to allow for the various cases presented above, an L3 file contains the following components:

1) A mandatory section containing the original L2P information remapped onto the grid point: the original sea surface temperature, quality indicator and SSES information.
2) A (non-mandatory) section including the remapping condition information
3) In case the L3 is a re-mapped L2P, all variables of the L2P must be present (see GDS2.0 version 3 https://www.ghrsst.org/files/download.php?m=documents&f=110930142852-GDS20r3.pdf).
4) In case the L3 is adjusted to a reference, the adjusted SST value must be provided, together with the local bias to the reference, the error generated by the adjustment processing, and the overall error resulting from the combination of the SSES and the adjustment processing error.
5) In case the L3 is supercollated, the source of SST at each pixel is mandatory

L3 products are often intended for general use or created for input to Level 4 analysis systems so the requirement for extensive ancillary data is reduced. However, since some GHRSST RDACs only process data natively on grids (especially in the case of geostationary platform observations), the GDS 2.0 L3 specification is flexible enough to allow for the creation of L3 files which meet all of the content requirements of a L2P file. In other words, these L3 products will have no available underlying L2P data. In all L2P and L3 cases, bias and standard deviation uncertainty estimates are required.

2.3 Merging SST data from different sources

In order to provide frequently sampled SST maps with the dense spatial resolution and global coverage required for input into ocean forecasting models, in situ measurements from buoys, ships of opportunity and voluntary observing ships are inadequate. Only Earth-observing satellite instruments provide the following necessary sampling capabilities: Instruments in geostationary and low-Earth orbits provide high temporal resolution but with only regional coverage, and those in near-polar orbits provide global coverage with repeat times from 12 hr to several days. Table 3 shows the different types of sensors and platforms used for measuring SST, and the typical sampling characteristics and absolute accuracy of the SST data produced from each, after applying atmospheric corrections.

No single source by itself can meet the user requirements (see https://www.ghrsst.org/users-partners/user-requirements/), but products can which exploit the synergy from combining several sources of SST data and are validated against in situ measurements. For example, microwave sensors can measure SST through cloud, although at poorer spatial resolution than infrared radiometers. Geostationary sensors compliment other types with their rapid sampling frequency, giving more opportunity for cloud-free views, but only within the field of view limited by the satellite's horizon. Although a dual-view radiometer with its narrow swath has a poor resampling interval, its high absolute accuracy can be used to standardize the bias errors of other sensors.

Table 3: Typical sampling capabilities of different types of satellite SST sensors.

Sensor type	Satellite type	Spatial resolution	Resampling interval	Absolute accuracy	Effect of cloud	Depth penetration
Infrared wide swath radiometer	Polar orbit	1-4 km, large off-nadir angles reduce resolution	12 hr, global	0.4-0.6 K	Fails over cloud and in the presence of atmospheric aerosol	Skin (~10-20 µm)
Infrared dual-view radiometer	Polar orbit	1-2 km	3 days, global	0.2-0.3 K	Fails over cloud	Skin (~10-20 µm)
Infrared Earth disc radiometer	Geostationary orbit	3-10 km, large off-nadir angles reduce resolution	30 min limited field of view	0.5-0.8	Fails over cloud	Skin (~10-20 µm)
Microwave radiometer	Polar orbit	25-50 km	1-2, global	0.5-1 K	Affected by non-precipitating cloud	Subskin (~1-1.5 mm)

2.4 Analysed SST (L4) data products

GHRSST L4 data are combined analysis products that capitalize on the synergy benefits of complementary satellite and in situ data. These products may have global or regional coverage. L4 data products are designed for user communities requiring full-field gridded SST products on a daily basis.

The distinction between L3 GHRSST and L4 GHRSST products is made primarily on whether or not any gap-filling techniques are employed, not on whether data from multiple instruments are used. If no gap filling procedure such as optimal interpolation is used then the product remains a L3 GHRSST product. GHRSST defines three kinds of L3 files: un-collated (L3U), collated (L3C), and super-collated (L3S). If gap filling is used to fill all observations gaps then the resulting gap-free product is a considered L4 GHRSST product.

L4 data products are derived from an analysis procedure performed at regular (daily, six-hourly or other) time periods. L4 data products include SST, error statistics, sea ice fraction, land/sea/ice mask, and other optional data sets for each grid-cell.

3 GHRSST Data Access and Discovery

GHRSST data products are available from the RDACs, the GDAC, and the LTSRF. Users looking for long term records should visit the Long Term Stewardship and Reanalysis Facility (LSTRF) via http, ftp, OPeNDAP, and THREDDS.

Real-time (30 days or less) SST from GDAC:	Historical SST (older than 30 days) from LTSRF:
http://podaac.jpl.nasa.gov/ ftp://podaac.jpl.nasa.gov/allData/ http://opendap.jpl.nasa.gov/opendap/ http://podaac.jpl.nasa.gov/podaac_thredds	http://data.nodc.noaa.gov/ghrsst/ ftp://ftp.nodc.noaa.gov/pub/data.nodc/ghrsst/ http://data.nodc.noaa.gov/opendap/ghrsst/ http://data.nodc.noaa.gov/thredds/catalog/ghrsst/

3.1 POET Viewer

Interactive data discovery can be performed using the POET data viewer: http://poet.jpl.nasa.gov

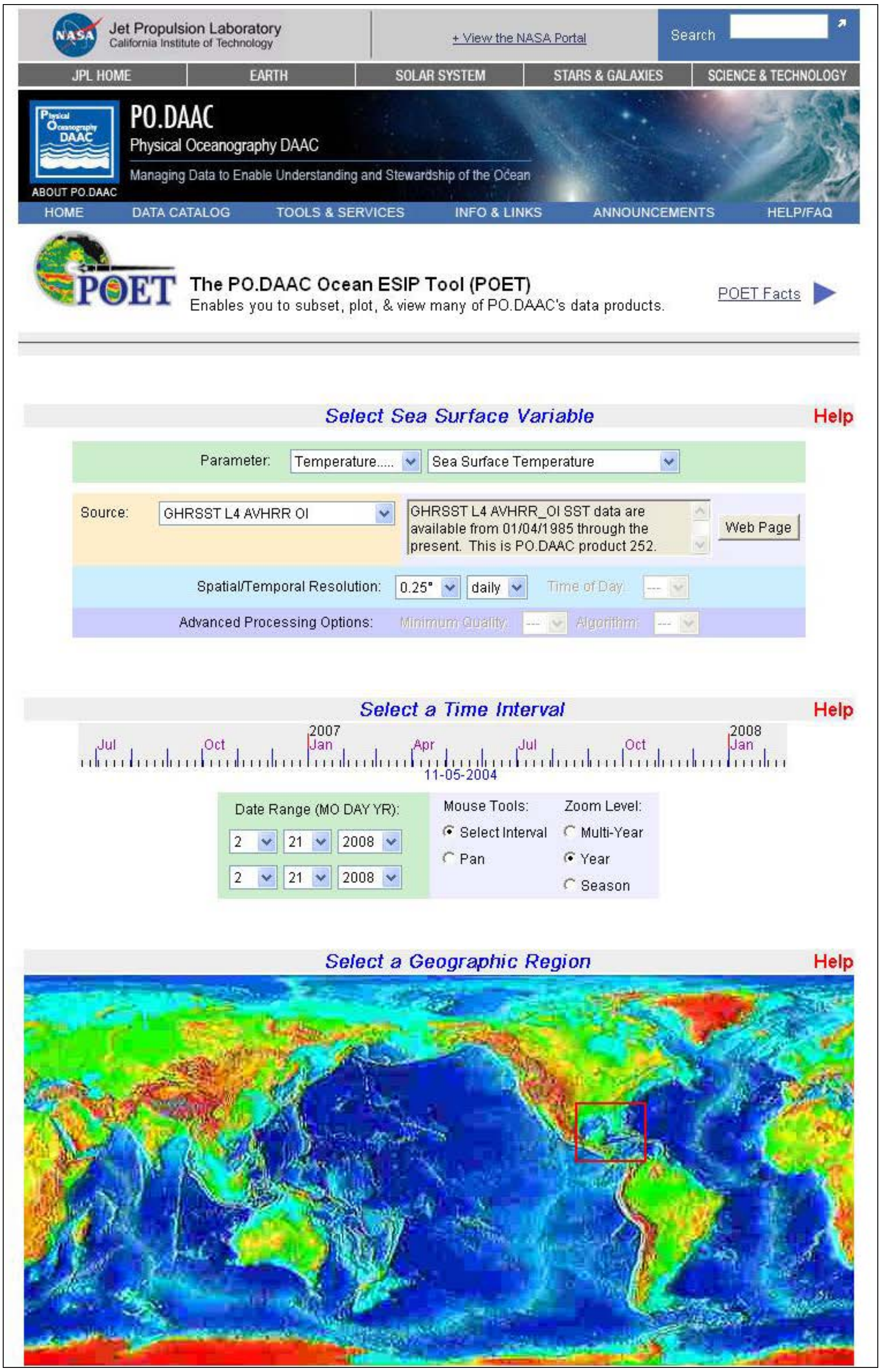


Figure 4: NASA JPL POET data visualization portal.

3.2 NAIAD Data Miner

The Data Miner is part of the tools and services provided by the GDAC in collaboration with IFREMER. It allows for subsetting of GHRSST L2P data. The list of currents data sets subsettable through the dataminer may be accessed at the web site. The tool may be accessed at the GDAC through: http://podaac-tools.jpl.nasa.gov/dataminer/ and at the French IFREMER through http://www.naiad.fr/. It is anticipated that the list of GHRSST L2P data sets subsettable through the dataminer tool will be dynamic and users are encouraged to access the tool for the latest results.

3.3 Long Term Stewardship and Reanalysis Facility (LTSRF)

Data access from the LTSRF is provided via HTTP, FTP and OPeNDAP. Access to these various servers can be found at http://ghrsst.nodc.noaa.gov. The GDAC and LTSRF maintain near identical FTP directory structures making access between the two nodes consistent. The NODC LTSRF also provides Web Mapping Service (WMS) and Web Coverage Service (WCS) to the archive of GHRSST datasets, through the use of a THREDDS Data Server (TDS).

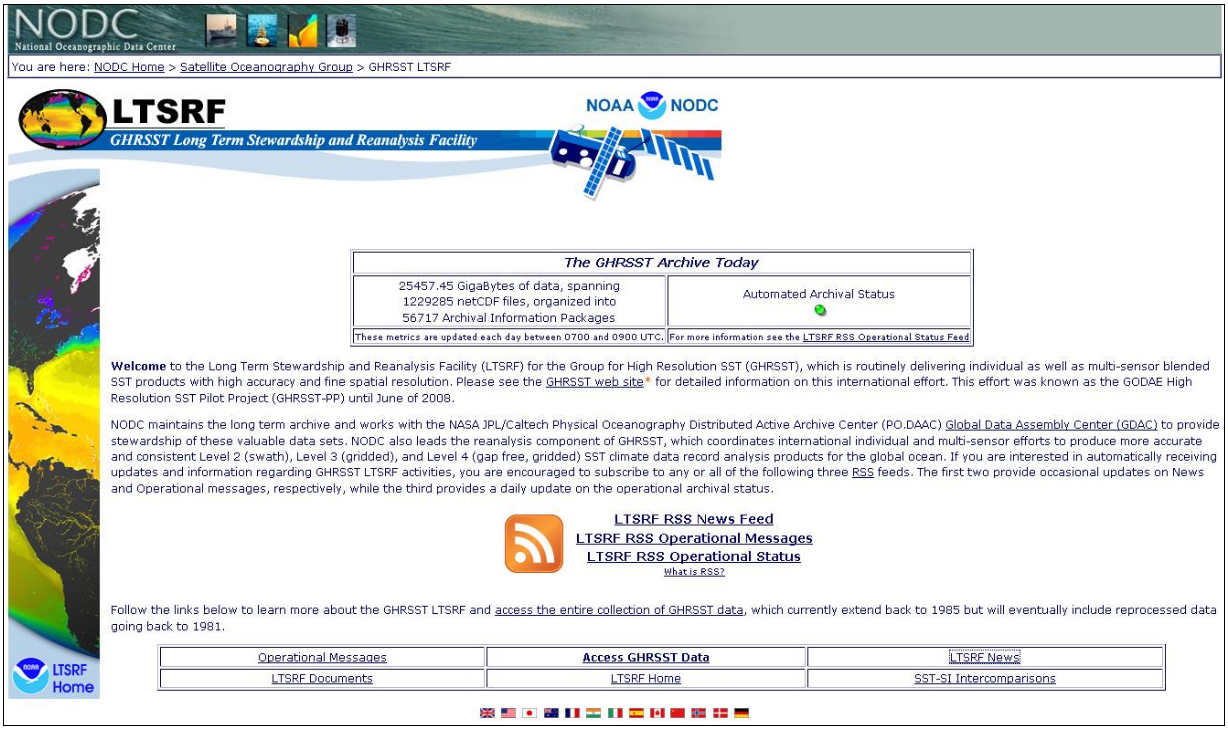


Figure 5: Long Term Stewardship and Reanalysis Facility maintained at NOAA National Oceanographic Data Center.

Individual images files and kml files for Google Earth are available at the LTSRF

3.4 Master Metadata Repository

A metadata master repository search capability is available at the GDAC for retrieving data files within specific time and space windows: MMR: http://ghrsst.jpl.nasa.gov/data_search.html

Each data file or granule consists of two different data files, a satellite data in netCDF, and a XML-based metadata file. The granule metadata record, known as the File Record (FR) contains XML tags that adhere broadly to the NASA Directory Interchange Format (DIF) format and describe relevant information such as time and geolocation. An additional XML metadata record known as the Data Set Descriptor (DSD) contains product summary information that is created once and updated on an as need basis. Together these metadata records reside in a relational database known as the Master Metadata Repository (MMR) that allows for search and discovery of all GHRSST products including those that do not immediately reside at the GDAC. A search capability, based on the MMR has been developed and is accessible through the GDAC interface. The MMR can also be accessed from the GDAC at home page at http://ghrsst.jpl.nasa.gov

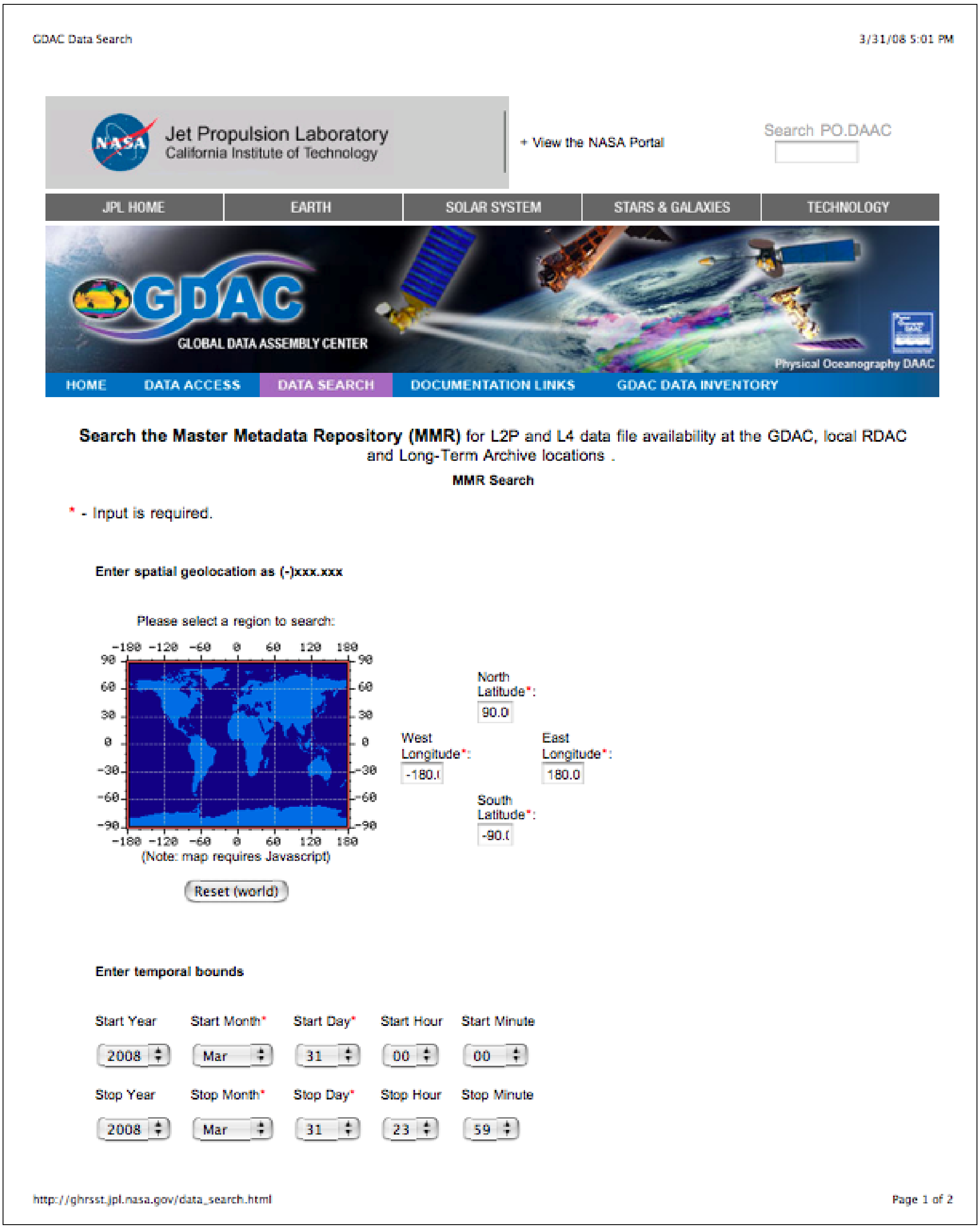


Figure 6: Master Metadata Repository (MMR) online access for GHRSST data is available at the GDAC.

4 Using GHRSST Data Products

4.1 NetCDF

All GHRSST data are stored in NetCDF format data files that provide a convenient, standard, self-describing, and platform independent format for data transport. NetCDF (network Common Data Form) is an interface for array-oriented data sets and a freely-distributed collection of software libraries that provide implementations of the interface. The NetCDF software was developed by Glenn Davis, Russ Rew, Steve Emmerson, John Caron, and Harvey Davies at the UNIDATA Program Center in Boulder, Colorado, and augmented by contributions from other NetCDF users. The netCDF libraries define a machine-independent format for representing scientific data. Together, the interface, libraries, and format support the creation, access, and sharing of scientific data.

The British Atmospheric Data Centre (BADC) carries a short introduction to NetCDF data that provides an excellent introduction to NetCDF at:

http://badc.nerc.ac.uk/help/formats/netcdf/index_cf.html.

The complete NetCDF documentation can be found at the UNIDATA web site:

http://www.unidata.ucar.edu/packages/netcdf/index.html.

Note that all GHRSST NetCDF data files are compressed using either the gunzip or bzip2 compression utility. For up to date information on NetCDF version used please see documentation at the GHRSST project web site at: http://www.ghrsst.org. Current data sets are in NetCDF3.0, with implementation of GDSV2.0 requiring that attempts be made to process data in NetCDF4.0. The primary difference will be that NetCDF4.0 will allow for internal compression and tiling.

4.2 Reading GHRSST Products

Example read software in Fortran, Matlab, C and IDL can be accessed through https://www.ghrsst.org/data/ghrsst-data-tools/.

4.3 Filename convention for GHRSST data products

The filenaming convention for the GDS 2.0 is shown below.

<Indicative Date><Indicative Time>-<RDAC>-<Processing Level>_GHRSST-<SST Type>-<Product String>-<Additional Segregator>-v<GDS Version>-fv<File Version>.<File Type>

The variable components within braces ("< >") are summarized in Table 4 below and detailed in the following sections. Note that dashes ("-") are reserved to separate elements of the file name and should not be used in any GHRSST code or the <Additional Segregator> element. Example filenames are given later in this section. While no strict limit to filename length is mandated, RDACs are encouraged to keep the length to less than 240 characters to increase readability and usability.

Table 4: GDS 2.0 Filenaming convention components.

Name	Definition	Description
<Indicative Date>	YYYYMMDD	The identifying date for this data set.
<Indicative Time>	HHMMSS	The identifying time for this data set. The time used is dependent on the <Processing Level> of the data set: L2P: start time of granule L3U: start time of granule L3C and L3S: centre time of the collation window L4 and GMPE: nominal time of analysis All times should be given in UTC.
<RDAC>	The RDAC where the file was created	The Regional Data Assembly Centre (RDAC) code.
<Processing Level>	The data processing level code (L2P, L3U, L3C, L3S, or L4)	The data processing level code.
<SST Type>	The type of SST data included in the file.	Conforms to the GHRSST definitions for SST.
<Product String>	A character string identifying the SST product set. The string is used uniquely within an RDAC but may be shared across RDACs.	The unique "name" within an RDAC of the product line. For the product string lists, one each for L2P, L3, L4, and GMPE products.
<Additional Segregator>	Optional text to distinguish between files with the same <Product String>. Dashes are not allowed within this element.	This text is used since the other filename components are sometimes insufficient to uniquely identify a file. For example, in L2P or L3U (un-collated) products this is often the original file name or processing algorithm. Note, underscores should be used, not dashes. For L4 files, this element should begin with the appropriate regional code. This component is optional but must be used in those cases were non-unique filenames would otherwise result.
<GDS Version>	nn.n	Version number of the GDS used to process the file. For example, GDS 2.0 = "02.0".
<File Version>	xx.x	Version number for the file, for example, "01.0".
<File Type>	netCDF data file suffix (nc) or ISO metadata file suffix (xml)	Indicates this is a netCDF file containing data or its corresponding ISO-19115 metadata record in XML.

L2_GHRSST Filename Example
20070503132300-NAVO-L2P_GHRSST-SSTblend-AVHRR17_L-SST_s0123_e0135-v02.0-fv01.0.nc. This file contains GHRSST L2P blended SST data for 03 May 2007, from AVHRR LAC data collected from the NOAA-17 platform. The granule begins at 13:23:00 hours. It is version 1.0 of the file and was produced by the NAVO RDAC in accordance with the GDS 2.0. The <Additional Segregator> text is "SST_s0123_e0135".

L3_GHRSST Filename Example
20070503110153-REMSS-L3C_GHRSST-SSTsubskin-TMI-tmi_20070503rt-v02.0-fv01.0.nc. This file was produced by the REMSS RDAC and contains collated L3 sub-skin SST data from the TMI instrument for 03 May 2007. The collated file has a centre time of at 11:01:53 hours. It is version 1.0 of the file and was produced according to GDS 2.0 specifications. Its <Additional Segregator> text is "tmi_20070503rt".

L4_GHRSST Filename Example
20070503120000-UKMO-L4_GHRSST-SSTfnd-OSTIA-GLOB-v02.0-fv01.0.nc. This file contains L4 foundation SST data produced at the UKMO RDAC using the OSTIA system. It is global coverage, contains data for 03 May 2007, was produced to GDS 2.0 specifications and is version 1.0 of the file. The nominal time of the OSTIA analysis is 12:00:00 hours.

Example: opening a GHRSST L2P netCDF file
In most cases users will simply want to read the SST value and apply the appropriate confidence flag. Confidence flags of 4-5 should be applied to extract the highest quality data. Additionally a scale and offset need to be applied to the SST integer value to convert to degrees Kelvin. The scale, offset and confidence flags can be directly read from the netCDF file.

To convert to SST:
SST=sst*scale_factor+add_offset where SST is in degrees Kelvin. For degrees Celsius the user would just not apply the add_offset.

5 GHRSST Data Services

In addition to providing SST data products, GHRSST also supports a number of services which allow producers and users to examine the quality of the data via intercomparisons, match-ups and ensemble statistics.

5.1 High Resolution Diagnostic Data Sets (HRDDS) System

The HR-DDS system is currently undergoing a significant upgrade to enable full MyOcean capabilities by the end of October 2011. Unfortunately, during the upgrade process, the existing system is unable to be maintained, and will on temporary suspension until the upgrade is complete. The upgrade will restore the currently unavailable features of the system and bring a significant performance increase. The system will be placed on newer hardware bringing an order of magnitude improvement in capability. The system will be maintained for the duration of the MyOcean project, until early 2012, and on a best effort basis afterwards.

The GHRSST High Resolution Diagnostic Data Set (HR-DDS) is an online interactive archive and database system designed to allow fast and easy inter-comparison of all types of SST products. An interactive web portal is accessible at the URL http://www.hrdds.net and currently under development.

The dedicated web portal, hosted at the National Oceanography Centre, Southampton (United Kingdom), allows users to perform a host of interactive analyses of SST data through the HR-DDS database to which it is connected. In addition, a large archive of GHRSST and other SST subsets are made available via FTP and OPeNDAP.

The HR-DDS ingests nearly all GHRSST SST products and many additional SST products from outside the project. Every data file provided is analysed to find SST observations at all of approximately 250 HR-DDS sites (see Figure 7). These HR-DDS sites are geographic regions typically 2° by 2° is size, located over regions of interesting oceanographic or atmospheric conditions, areas with known in situ observations or regions representative of typical oceanic conditions. Additionally, many sites are located in polar regions to aid validation of SST products in the difficult conditions prevalent at those latitudes.

Every time an SST product contains an observation at one of these HR-DDS sites a new HR-DDS granule is produced. This is a subset of the original file with only the data for that location. This data is always interpolated onto a 0.01° by 0.01° degree regular grid through the nearest neighbour technique. Any absence of observation is maintained in the new grid. These files maintain the format of the source file, other than the grid specification as described.

Each of these granules is also analysed to create a statistical representation of each field that is then entered into the HR-DDS database. These statistics include the mean, median, skew, kurtosis, standard deviation, maximum and minimum values for the field. The statistics are calculated for the entire field, and for a smaller 0.05° by 0.05° region known as the centre area (although this region is not always exactly in the centre for each HR-DDS site, especially when that area may be land). All of these statistics are then recomputed only for those pixels with the highest quality level.

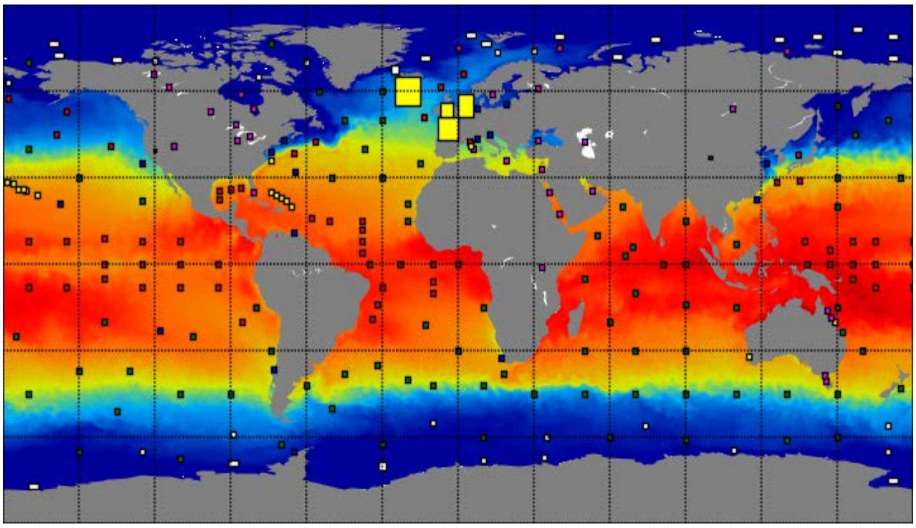


Figure 7: The location of the HR-DDS sites. This image is taken from the HR-DDS web portal front page. Red sites indicate the likely presence of in situ observations; white and yellow sites have been added by special request; purple sites indicate coasts or lakes; blue sites have been added for the ocean colour communities.

For each HR-DDS site a user may view dynamically generated time series data. By default the user is presented with a graph of the mean SST of every HR-DDS granule over that site for the last 14 days. The time series plots are user-configurable, and a number of options exist to modify their appearance and to control the data that is included.

In addition a user may either elect to produce a spatial inter-comparison of the data for a specific day or produce a multivariate scatter plot. Users can also view a quick look image of the field containing the data for which a statistic has been derived, and also view detailed comparisons of the image to all the other data available at the site for that day. To view an image of the data used to produce the point on the plot the user need only to click on that point. An image of the data is produced in real time form the HR-DDS granule used to generate the statistics

From the time series analysis pages, a user may select to download the data from which the plot was generated by clicking on 'Data Access' in the left hand menu and then clicking on 'CSV Data Access'. The user will then view a page containing in CSV format the data used to generate the plot. This is useful as CSV data may easily be imported into scientific analysis applications. FTP and OPeNDAP access to the HR-DDS archive is also provided. Note that all HR-DDS granules are compressed with the bzip2 compression utility.

Users may also register for additional services by selecting 'Users' and then 'register' from the menu on the left side of the web site. Registered users have access to many additional features on the HR-DDS website. The registered user homepage is similar to the normal front page of the HR-DDS website, but with a number of configurable options and additional links.

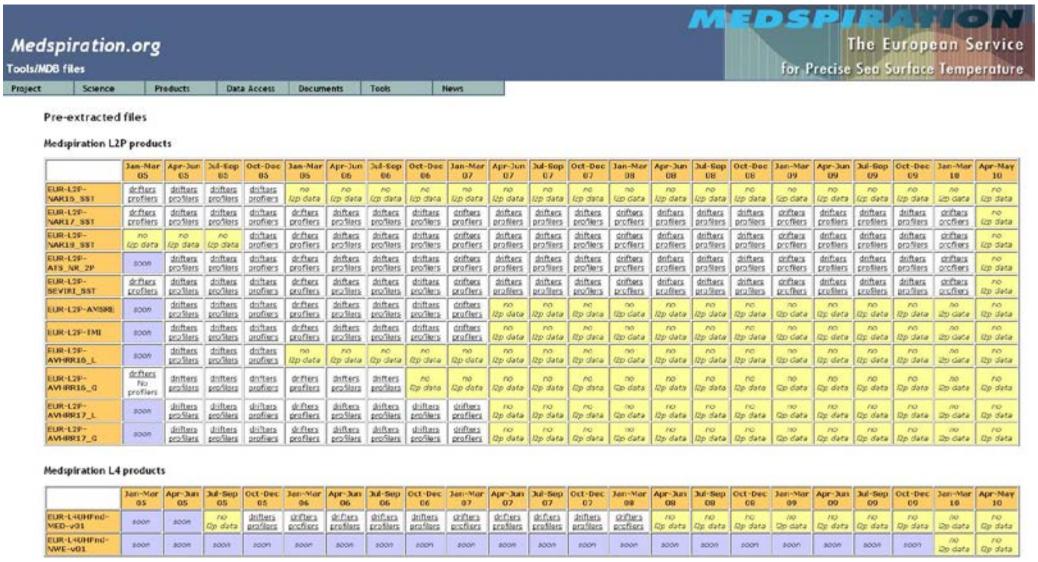
5.2 Match-up Database (MDB)

The address of the new GHRSST matchup database Ifremer/MyOcean is:
http://www.ifremer.fr/matchupdb. For further description, see
http://projets.ifremer.fr/cersat/Data/Quality-control/GHRSST-Match-up-Database.

The development of the GHRSST system has strengthened the need for the inter-comparison of the available satellite sea surface temperature products and the estimation of the various sensor error statistics, especially when addressing issues such as sensor merging into analysis systems. In situ data have proved to be a reliable independent source for such inter-comparisons. Satellite and in situ measurements coincident in time (typically less than 6 hours time difference) and space (typically less than 25 km distance) are referred to as match-ups and can be extracted in real or near-real time on a systematic basis to perform continuous control of the sensors and retrieval algorithms.

To serve that purpose, a match-up database (MDB) providing satellite-to-in situ match-ups was set up in the frame of the ESA-funded Medspiration project, relying within an integrated framework on the CORIOLIS system and the Medspiration data archive (the European node to GHRSST system, http://www.medspiration.org), both hosted at Ifremer in Brest, France. The strength of having a single source for in situ data is to ensure that all match-ups are consistent since they have been processed in the same manner with the same in situ data, level of quality and consistent control procedures. Respective satellite sensor error statistics can then be estimated with better confidence.

The MDB service currently offers users periodic match-up data files for each Medspiration GHRSST dataset in netCDF format, as well as an online extraction interface to perform more constrained queries. It can be accessed at: http://www.medspiration.org/tools/mdb/



Medspiration.org
Tools/MDB files
MEDSPIRATION The European Service for Precise Sea Surface Temperature
Project | Science | Products | Data Access | Documents | Tools | News

Pre-extracted files

Medspiration L2P products

	Jan-Mar 05	Apr-Jun 05	Jul-Sep 05	Oct-Dec 05	Jan-Mar 06	Apr-Jun 06	Jul-Sep 06	Oct-Dec 06	Jan-Mar 07	Apr-Jun 07	Jul-Sep 07	Oct-Dec 07	Jan-Mar 08	Apr-Jun 08	Jul-Sep 08	Oct-Dec 08	Jan-Mar 09	Apr-Jun 09	Jul-Sep 09	Oct-Dec 09	Jan-Mar 10	Apr-May 10
EUR-L2P-NAR16_SST	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-NAR17_SST	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data
EUR-L2P-NAR18_SST	no l2p data	no l2p data	no l2p data	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data
EUR-L2P-ATS_NR_2P	soon	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data
EUR-L2P-SEVIRI_SST	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data
EUR-L2P-AMSRE	soon	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-TMI	soon	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-AVHRR16_L	soon	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-AVHRR16_G	drifters No profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-AVHRR17_L	soon	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L2P-AVHRR17_G	soon	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data

Medspiration L4 products

	Jan-Mar 05	Apr-Jun 05	Jul-Sep 05	Oct-Dec 05	Jan-Mar 06	Apr-Jun 06	Jul-Sep 06	Oct-Dec 06	Jan-Mar 07	Apr-Jun 07	Jul-Sep 07	Oct-Dec 07	Jan-Mar 08	Apr-Jun 08	Jul-Sep 08	Oct-Dec 08	Jan-Mar 09	Apr-Jun 09	Jul-Sep 09	Oct-Dec 09	Jan-Mar 10	Apr-May 10
EUR-L4UHFnd-MED-v01	soon	soon	no l2p data	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	drifters profilers	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data	no l2p data
EUR-L4UHFnd-NWE-v01	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	soon	no l2p data	no l2p data

Figure 8: Pre-extracted match-up files for L2P and L4 products available from the Medspiration Match-up Database.

The scope of the match-up database has been limited so far to the GHRSST products delivered by the European DAC (Medspiration project). Future plans mostly focus on extending this scope to all other data sources (both satellite and in situ) and adding new high-level functionalities to the service:

- Processing and delivering match-ups for all other GHRSST datasets
- Including new sources of in situ measurements, e.g. in situ radiometer data
- Complementing the database with historical match-ups or additional ancillary information (for better quality control or stratification of the MDB)
- Implementing automatic procedures to trigger alarms when anomalies or drifting of the satellite sensors are detected by comparison with in situ data
- Implementing automatic and independent computation of SSES and providing periodically updated values

For more information on MDB content, processing details or data format, please refer to the MDB user manual appendices.

5.3 GHRSST Multi Product Ensemble (GMPE)

The National Centre for Ocean Forecasting (NCOF) produces SST ensemble inter-comparison statistics. These include differences between daily sea surface temperature (SST) analyses as well as differences between the median SST and multiyear means for the same time of year (climatology).

The analyses used in the statistics are OSTIA, RTG, K10, MGDSST, RSS MW, RSS MW+IR, FNMOC, NOAA AVHRR OI, CMC, ODYSSEA and GAMSSA (see Appendix for GHRSST product code tables). Where an analysis indicates sea ice, with no other SST value, a value of -1.8°C has been substituted. The analysis grids have been homogenised by area averaging onto a 0.25° lat/lon grid prior to comparison. The data have been restricted to the OSTIA ocean mask, although several analyses provide greater coverage (such as large lakes).

See http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html

GMPE is now available through MyOcean (access through the web-site www.myocean.eu.org).

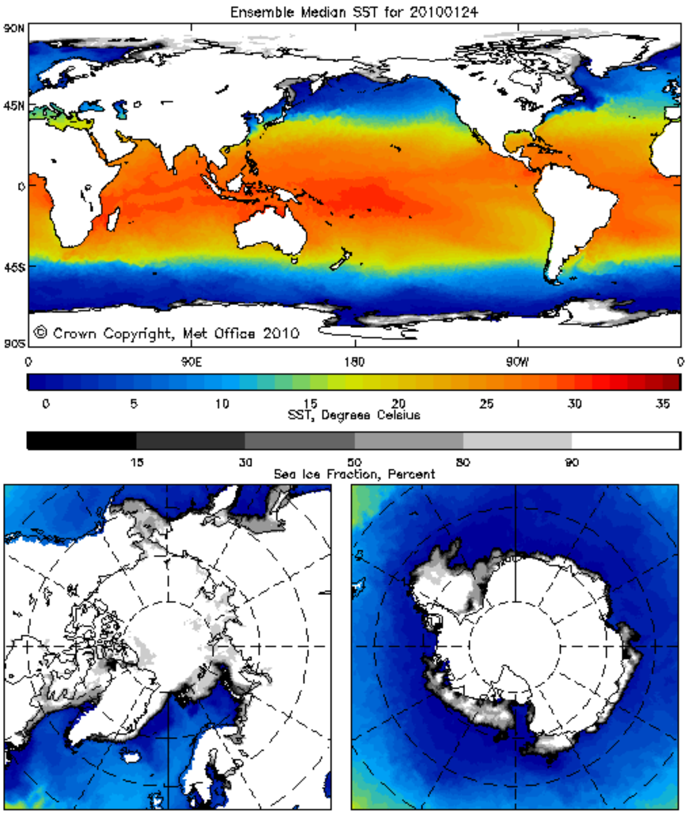


Figure 9: Example of the median SST analysis produced by NCOF. The sea ice data shown is derived from OSTIA.

5.4 SST Quality Monitor (SQUAM)

The SST Quality Monitor (SQUAM; http://www.star.nesdis.noaa.gov/sod/sst/squam/) is a near-real time web-based tool developed at NESDIS as a contribution to GHRSST STVAL and IC-TAG activities. SQUAM monitors various Level 2, 3, and 4 SST products, for self- and cross-consistency.

- Level 2: all major AVHRR Level 2 SST products are included in SQUAM: NAVO (2000-pr), NESDIS heritage (Main Unit Task, MUT; 2001-pr), NESDIS new (Advanced Clear-Sky Processor for Oceans, ACSPO) (2008-pr) and O&SI SAF (2008-pr). Work is underway to include complete time series of MODIS and (A)ATSR L2 products. VIIRS L2 product will be added in SQUAM with NPP launch.
- Level 3: Pathfinder v5 product is included in SQUAM (1985-pr).
- Level 4: as of this writing, eleven Level 4 daily products are monitored in SQUAM (two Reynolds; two RTG; NAVO K10; POES-GOES blended; G1SST; OSTIA; CMC 0.2; ODYSSEA; and GMPE). Adding missing L4 products (GAMSSA, MUR, NCODA; MGDSST; RSS blended) is underway. Comparisons with in situ SSTs (validation) is available for all L4 products.

Inter-comparisons are presented in the form of maps and histograms of differences. Time series and Hovmoller diagrams of the mean and STD differences are also available. Time series of double-differences emphasize cross-platform and day-night consistency. Dependencies of the differences on some environmental (wind speed, air-sea temperature difference, etc) and retrieval conditions (view zenith angle, water vapor) are also monitored.

SST data producers and users can monitor in near-real time how various SST products perform and compare, and how their differences evolve as a function of time (with product upgrade, for instance). Future work will include adding uniform validation against in situ data for Level 2 and 3 SST products; adding MODIS and (A)ATSR; and missing L4 products. Next stage will be using SQUAM to reconcile various SST products, based on their comparisons in SQUAM.

References:

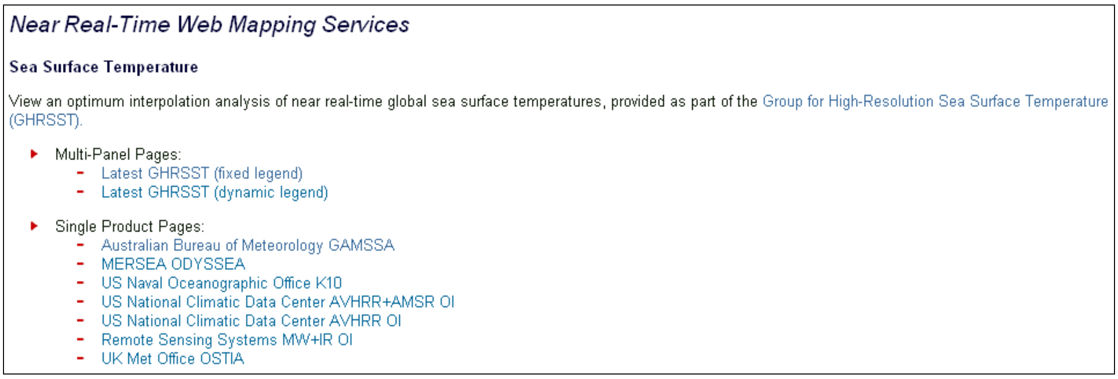
Dash, P., A.Ignatov, Y.Kihai, and J.Sapper, 2010: The SST Quality Monitor (SQUAM). JTech, 27, DOI: 10.1175/2010JTECHO756.1, 1899-1917.

Dash, P., A.Ignatov, M.Martin, C.Donlon, R.Grumbine, B.Brasnett, D.May, B.McKenzie, J.-F.Cayula, Y.Chao, H.Beggs, E.Maturi, A.Harris, J.Sapper, T.M.Chin, J.Vazquez, E.M.Armstrong, 2011: Group for High Resolution SST (GHRSST) Analysis Fields Inter Comparisons: Part 2. Near real-time web-based Level 4 SST Quality Monitor (L4-SQUAM), Deep Sea Res.-II, (in preparation).

5.5 Australian Navy (hydro metoc) Global High Resolution Sea Surface Temperature Web Map Services

The Royal Australian Navy Hydrography Meteorology and Oceanography Branch (HM Branch) have developed a number of web map services and viewing applications based on a selection of GHRSST L4 SST analysis products sourced from the GDAC. The L4 global sub-folders are within the GHRSST GDAC ftp site. They are checked every 30 minutes for new data and the latest netCDF file more recent than the currently displayed product is downloaded and processed into features and rasters within an ESRI Geodatabase via python scripts. The ESRI grid file raster matches the scale and resolution of the downloaded netCDF file and an ESRI Focal Statistics geo-processing algorithm is applied to obtain a feature class of sea surface temperature contours. These are loaded into raster catalogues and feature datasets within the Geodatabase where Oracle Views are applied to select only the latest data which become the layers in the published document.

A browser based viewing application has been developed using OpenLayers, a pure JavaScript library for displaying map data with simple navigation such as zooming and panning as well as layer switching enabled. The services can be viewed at: http://www.metoc.gov.au/products.php and GHRSST products are towards the top of the page under 'Near Real-Time Web Mapping Services'.



Near Real-Time Web Mapping Services

Sea Surface Temperature

View an optimum interpolation analysis of near real-time global sea surface temperatures, provided as part of the Group for High-Resolution Sea Surface Temperature (GHRSST).

- Multi-Panel Pages:
  - Latest GHRSST (fixed legend)
  - Latest GHRSST (dynamic legend)
- Single Product Pages:
  - Australian Bureau of Meteorology GAMSSA
  - MERSEA ODYSSEA
  - US Naval Oceanographic Office K10
  - US National Climatic Data Center AVHRR+AMSR OI
  - US National Climatic Data Center AVHRR OI
  - Remote Sensing Systems MW+IR OI
  - UK Met Office OSTIA

Figure 10: List of GHRSST browser products.

As displayed in Figure 11, GHRSST products may be viewed through selecting either of the multi-panel pages (fixed or dynamic legend) or through the 'single product pages'. In the former, all (currently) seven global L4 products are displayed together and are synchronised so that the navigation (pan or zoom) on any single panel applies to all panels.

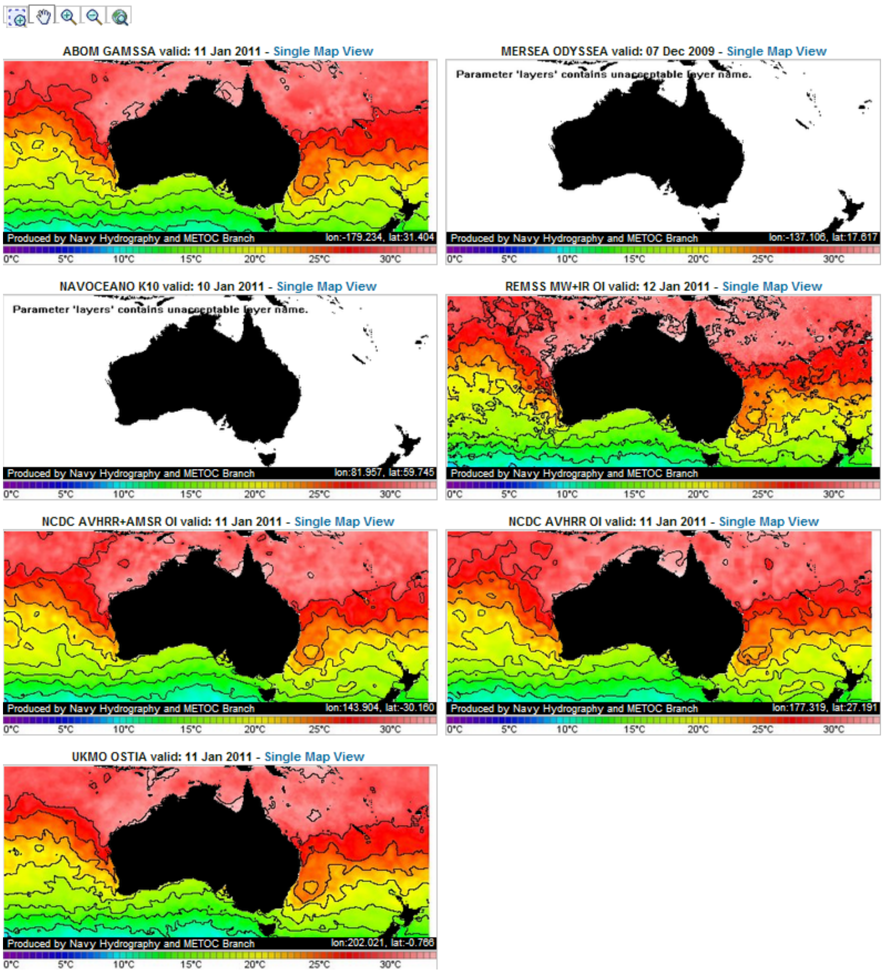


Figure 11: GHRSST (fixed legend) multi-panel page zoomed to area of interest.

The use of the fixed legend allows visual comparison using the same global palette, irrespective of the values within the view. Alternatively, use of the dynamic legend option modifies the palette for the range of values shown in the view extent. When using a dynamic palette, the scale is not shown on each panel and the user should refer to the contour values as part of the comparison.

All panels also include a link to the single product page, but do not carry the navigation information across to the single page view. Alternatively, single product pages can be accessed from the initial menu.

Single product pages use different navigation, this time through a widget on the top left of the display panel or using <Shift + Draw rectangle> to zoom, and are automatically set to a fixed legend. The single product pages also use the NASA Blue Marble Next Generation (courtesy of NASA's Earth Observatory) imagery as a background image. The background is sensitive to the date and changes with each month to the corresponding Blue Marble Next Generation monthly image. Spanning of longitude 180 is also available when displaying single product images.

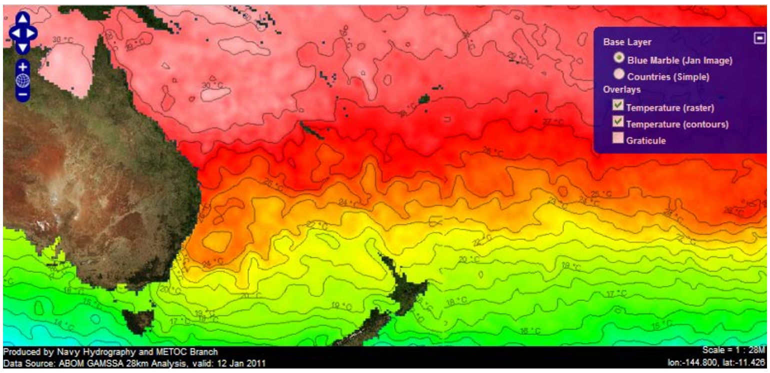


Figure 12: GHRSST single product page (zoomed across longitude 180).

Figure 12 also shows the layer menu available by clicking on the + button on the upper right side of the image. A plain country background may be substituted for the Blue Marble Next Generation image, contours switched on-off and a graticule added. The graticule is scale dependent and will automatically adjust to the view extent.

Direct GIS Access to GHRSST Map Services: The map services of sea surface temperature images and contours described earlier and viewable through the browser are being served as OGC compliant WMS (versions 1.0 to 1.3) from one published map document in ESRI's ArcGIS Server 9.3.1. The service can be also accessed independently by any OGC WMS capable application by accessing the GetCapabilities file of the service through the following URL:

http://www.metoc.gov.au/arcgis/services/near_real_time/ghrsst/MapServer/WMSServer?version=1.3&service=WMS&request=GetCapabilities

The service contains a number of layers grouped by the data provider and dataset name. Within each grouped layer there are two images of sea surface temperature; one with a fixed colour palette (i.e. light red is always around 30°C and dark purple is 0°C), the other a dynamic colour palette (the colour palette is stretched dynamically based on the maximum and minimum temperature values in the displayed extent), and two scale dependant layers representing sea surface temperature contours; one at two degree intervals, the other at one degree with the change over at a scale of 1:50,000,000. Naturally, each service can be accessed and displayed individually through its unique layer name found in the capabilities file.

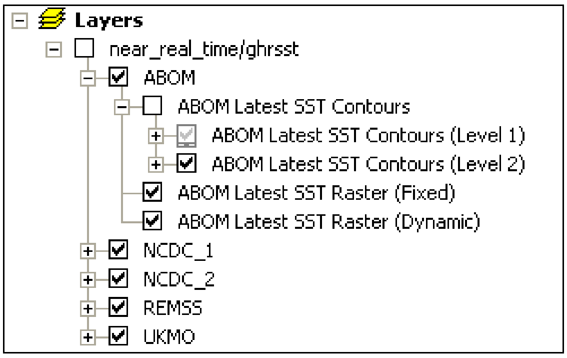


Figure 13: GHRSST Web Map Service layer list.

Future Plans are to migrate to service to the GHRSST2 ftp site and include other GHRSST products, notably the GHRSST Multi-Product Ensemble (GMPE). Other future developments include publishing map services directly from the native NetCDF via THREDDS and ncWMS applications.

The Royal Australian Navy welcomes all user comments, suggestions and queries via the feedback form at: http://www.metoc.gov.au/errors/feedback_form.php

5.6 G1SST and OurOcean portal (US)

The goal of the OurOcean portal web site http://ourocean.jpl.nasa.gov/ is to enable users to easily access ocean science data, run data assimilation models, and visualize both data and models. The concept of OurOcean is to allow users with minimal resource requirements to access data and interact with models. The data and model simulations can be viewed as still images in the Image Gallery and accessed through either a database with selected graphic capabilities or the Live Access Server (LAS), a highly configurable web interface designed to provide flexible access to geo-referenced scientific data. Users can display data in Google earth.
At http://ourocean.jpl.nasa.gov/SST/ an ultra-high resolution (1km) daily, global Sea Surface Temperature (SST) data set produced by the JPL ROMS (Regional Ocean Modeling System) group can be accessed, different satellite inputs can be chosen, data voids can be masked, and comparison to in-situ data is also an option.

5.7 MyOcean Data Portal (European)

MyOcean is a project funded by the European Commission. It is implementing and operating a system, which provides near real-time observed, analysed and forecast products, both for the global ocean and the regional seas around Europe. All MyOcean products are made available in a standardised way, through a single web data portal (http://www.myocean.eu.org/) and a central catalogue for products search and discovery. Once the user has registered, products can be downloaded free of charge from the MyOcean Data Portal, which is connected to OpenDAP/THREDDS servers in each MyOcean Dissemination Unit.

MyOcean has one Production Centre dedicated to satellite SST products, the SST Thematic Assembly Centre (SST TAC). The SST TAC is a GHRSST RDAC, providing near real-time L3S and L4 SST products for use both by MyOcean Monitoring and Forecast Centres, and by external users. These products are made available through the MyOcean Data Portal, and are also mirrored at GDAC. However, it is highly recommended that SST TAC products users get registered at MyOcean Service Desk level (email: servicedesk@myocean.eu.org) to benefit from MyOcean Services (user support, products documentation etc.).

5.8 Japanese GHRSST Portal

The Japanese GHRSST server http://sharaku.eorc.jaxa.jp/ADEOS2/ghrsst/ contains near-real-time SST retrieved from AMSR-E on board NASA's EOS-Aqua. These SSTs were produced at Earth Observation Research Center (EORC) of Japan Aerospace Exploration Agency (JAXA).

6 Example applications of GHRSST data products

Satellite SST measurements are used in many applications as they provide a synoptic view of the dynamic thermal character of the ocean surface. Measurements are fundamentally important to agencies and institutions tasked with the study of climate variability, operational weather and ocean forecasting, military operations, validation and forcing of ocean and atmospheric models, ecosystem assessment, tourism and, fisheries research, amongst many others. This section highlights some applications of GHRSST data products.

6.1 Ocean Forecasting

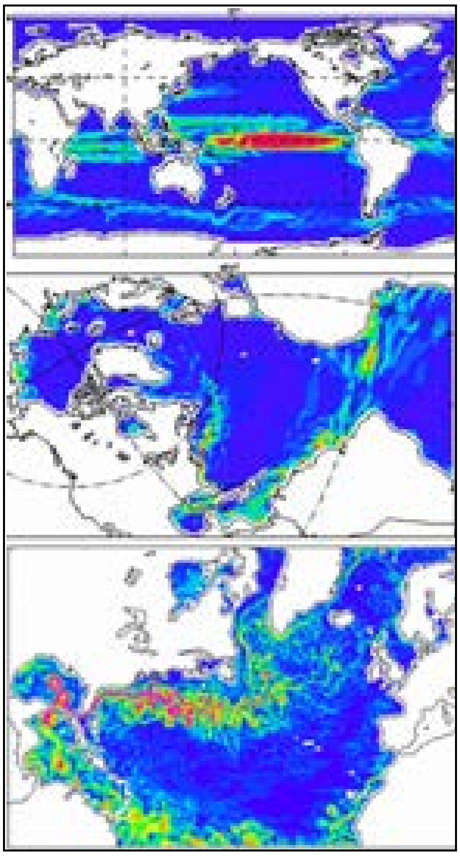


Figure 14: The image shown here depicts a series of surface current outputs from the Met Office Forecasting Ocean Assimilation Model (FOAM). The top panel shows global output, middle panel 1/3 degree North Atlantic and the lower panel 1/9th degree Atlantic model.

Ocean model systems provide forecasts of currents and other fields are required by a variety of Government and commercial groups in a variety of applications including environmental monitoring, Coral reef management, tide predictions, marine sanctuary and estuary management, diving operations, oil and chemical spill drift forecasts, search & rescue operations, offshore oil drilling operations, cable laying and ship-routing and operational wave forecasting to improve predictions of extreme waves. Recently, biogeochemical models are maturing rapidly and will soon provide unique information that will help monitoring the exchange of important greenhouse gasses (carbon dioxide) across the air-sea interface, to monitor the quality of near-surface waters and plankton distributions for input into management of fisheries. The primary Customer requirement is for near-shore forecasts of both physical and biological parameters several times per day.

Ocean models have long been used to support a variety of oceanographic research including in cruise planning and operations; for diagnostic studies; climate and seasonal-forecasting and to improve understanding the thermohaline circulation and how to monitor the system on a long- term basis. One of the most important ocean model dependencies is for SST which is required to properly constrain the upper ocean circulation and thermal structure. SST data products need to be accurate (better than 0.4K), be available in near real time and have high spatial (<10km) and temporal (6-12 hours) resolution.

GHRSST data products have been designed to meet these product requirements based on the user requirements first laid out by the International Global Ocean Data Assimilation Experiment (GODAE) Steering Team (IGST). In response, GHRSST was formed to deliver a new generation of SST data products and services that can satisfy the needs of operational ocean model systems. The links below point to several operational ocean forecast systems:

The UK National Centre for Ocean Forecasting (NCOF) provides a variety of operational ocean model services through the operational FOAM and shelf seas model systems and including operational wave forecasting. FOAM produces real-time daily analyses and forecasts of the temperature, salinity and currents of the deep ocean for up to five days ahead for the Royal Navy. FOAM is built around a physically based ocean model driven by surface fluxes from the Met Office NWP forecast system. See http://www.ncof.co.uk

The USA Naval Research Laboratory (NRL) provides real-time nowcast/forecast results from the global NRL Layered Ocean Model (NLOM), including snapshots, animations and forecast verification statistics for many zoom regions, mainly SSH, SST and surface currents. It also contains direct model-data comparisons. In addition this site contains the 1/8° global Modular Ocean Data Assimilation (MODAS) sea surface height (SSH) and sea surface temperature (SST) analyses, again with snapshots and animations for many zoom regions, plus a direct look at the real-time altimeter data available. See http://www7320.nrlssc.navy.mil/global_nlom

The Japan Meteorological Agency (JMA) provides operational marine meteorological forecasts and warnings for the safety and efficiency of shipping, fisheries and offshore activities. In the winter season, sea ice forecasts and bulletins are also issued (see http://www.jma.go.jp/jma/indexe.html).

6.2 SST and Long-range predictions

SST is one of the most important climate variables, with a history of measurement and analysis. The motivation for Climate Prediction Research and Climatology development is the continual improvement reliable climate prediction uncertainty in support to strategic development through input and advice to climate change assessments. In this context, SST is required for climate model initialization, diagnostics and fundamental climate monitoring. The most important requirement is that the observations are accurate and free of bias. Considering the best estimates of global warming trends, SST data sets should be exceptionally stable to better than 0.1K/decade with a mean zero bias.

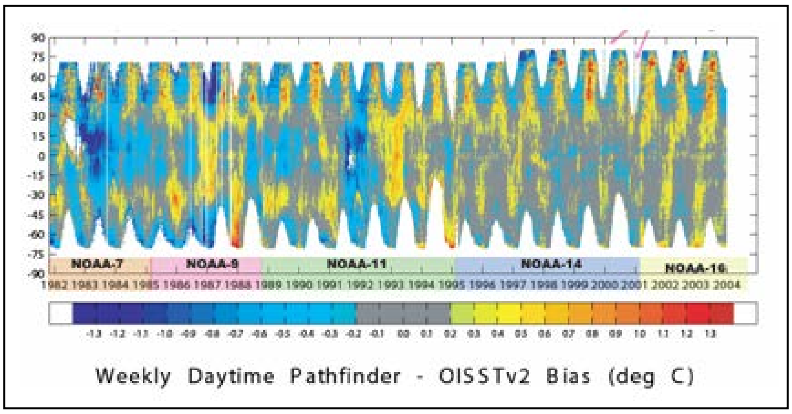


Figure 15: The Figure above shows bias differences between the NOAA Optimal Interpolated SST analysis Reynolds OIv2.0 SST and the NOAA/NODC Pathfinder daytime only SST. Clearly seen are different bias differences according to the particular NOAA AVHRR satellite instrument and other significant atmospheric events, such as the Mount Pinatubo volcanic eruption in 1991.

The reliable SST data record extends from about 1870 (see the International Comprehensive Ocean-Atmosphere Data Set (ICOADS)) although considerable effort is required to quality control biases in the observations caused by changing in the design of ships, observing practices and the geographical focus of shipping routes. Today, satellite data provide a unique and extensive source of global coverage SST observations. But in order to meld these together with existing SST climatologies based on in situ observations alone, considerable effort is required to ensure that biases due to satellite measurement techniques, instrument drifts, calibration etc. are properly accounted for. Due to the vast amounts of data that are provided by satellite instruments, even very small errors will have a significant impact. Cross calibration between follow-on instruments must be planned and executed and adherence to the ten GCOS climate monitoring principles is essential. Achieving such a small bias (and verifying that it is true) is a long process of verification and validation using in situ observations and other analysis The GHRSST Diagnostic Data Sets (DDS) are developed for this purpose. It can only be done through careful reference to a well documented and calibrated sub-set SST measurements derived from the in situ network of quality controlled buoys. Through community consensus, this is the most truthful measure of SST available today. But, there just simply are not enough buoys to measure all over the ocean.

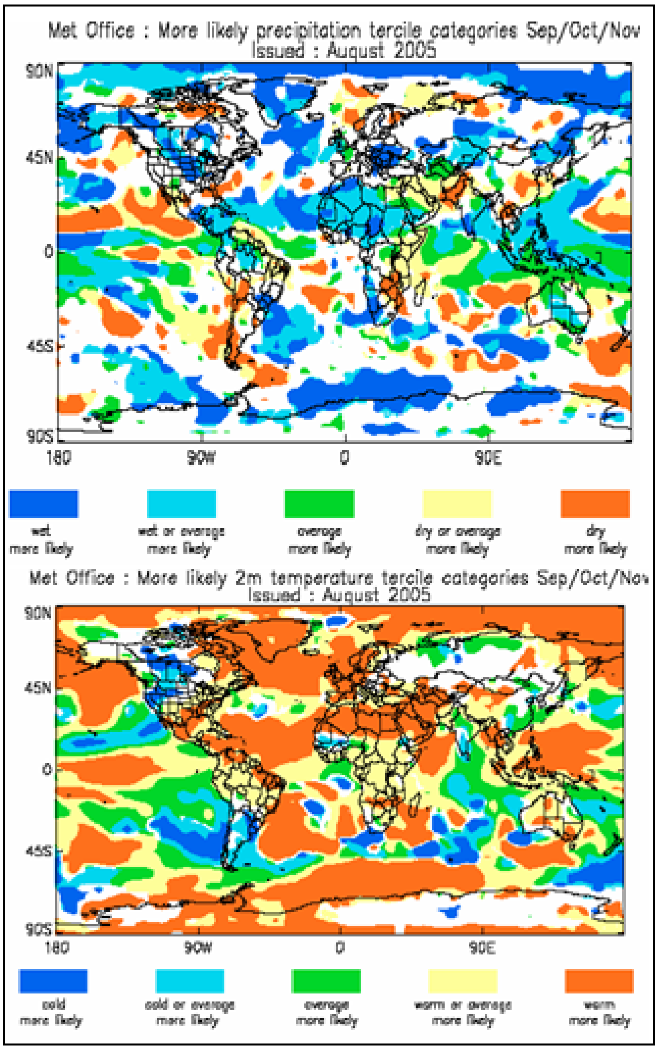


Figure 16: Seasonal forecasting with SST.

GHRSST is making an extremely valuable contribution to climate research through the GHRSST Re-analysis (RAN) program. The RAN is working to produce a new SST Climate Data Record (CDR) extending across the entire satellite record (from about 1984). The RAN has already established direct access to all GHRSST operational and delayed mode data which is archived at the National Oceanographic Data Centre (NODC), USA. Using the NASA Pathfinder program as an example of how to manage the production of a SST-CDR within GHRSST, the RAN will be conducting regular univariate reanalysis runs that consider different approaches to SST analysis, data preparation and quality control.

SST patterns change relatively slowly and can reasonably be well predicted up to 6 months ahead or longer in some regions of the world. The links between regional SST patterns and the atmosphere can be represented in computer models of the atmosphere and ocean or statistically related to SST observations or data-driven analysis. Dynamically coupled climate models increasingly form the basis of many seasonal prediction systems. The strongest relationship between SST patterns and seasonal weather trends are found in tropical regions. Strong signals are associated with the El Niño phenomenon in the tropical Pacific, roughly every three or four years, which can disrupt the global pattern of normal weather including large changes in seasonal rainfall patterns (droughts in some regions and floods in others). Weaker links between SST and seasonal weather are found in other parts of the globe.

Seasonal forecasts provide information about likely conditions averaged over the next few months based on long-term averages. The relationship between weather and SST is strongest when long-term weather averages are used and, because the uncertainty in forecasts generally rises as the forecast range increases, seasonal forecasts are different in format when compared to the familiar daily forecasts:

- Seasonal forecasts represent average conditions over several months
- Seasonal forecasts are given in terms of probability

The GHRSST project, as it builds up a global high-resolution SST CDR archive will provide a unique source of data for seasonal forecasting activities. In the short term, GHRSST-PP global analysis products can be used to initialize seasonal forecast models and verify seasonal forecasts in hindcast runs.

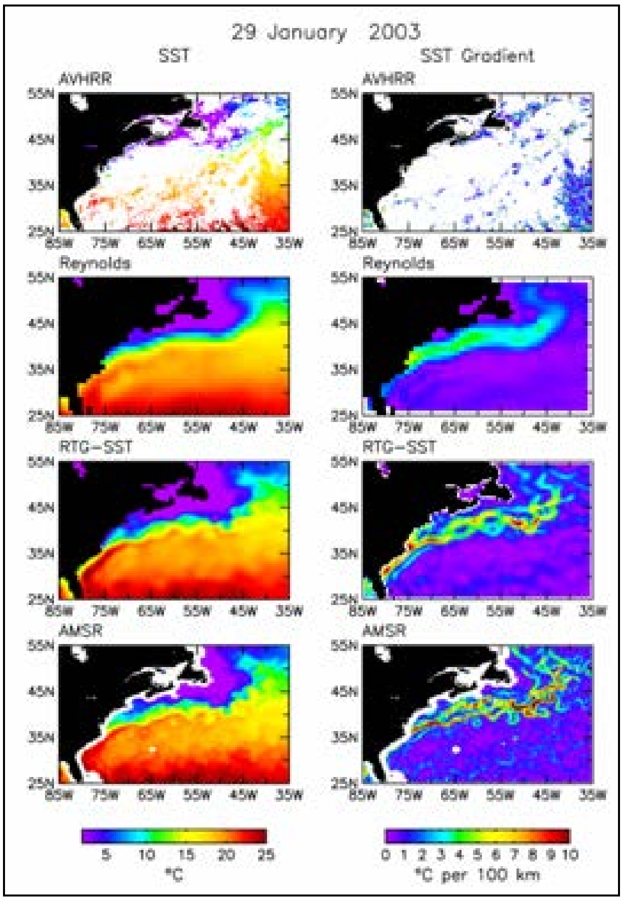


Figure 17: The figure to the left provides a useful overview of SST observations from the AVHRR and AMSR-E satellite systems compared to Reynolds OIv2 and the NCEP RTG_SST.

6.3 SST and Numerical Weather Prediction (NWP)

SST and sea-ice can have an important role in determining the behaviour of the overlying atmosphere. Consequently, NWP model systems need to be updated regularly to ensure an accurate forecast. Daily analyses of both the SST and sea-ice extent and concentration are required by many operational NWP systems. SST often provides the forcing for shower formation, affects the formation and subsequent evolution of tropical cyclones, convection and thunderstorms, cyclogenesis itself, sea fog and sea breezes. As the SST changes relatively slowly with respect to the atmosphere, it provides a good basis for seasonal forecasting techniques. SST is also used to help upper air forecasters at the World Aviation Forecast Centre (WAFC) monitor areas more likely to develop Culmulonimbus activity which can produce a significant threat to aircraft.

Sea-ice also has a significant impact on the exchange of energy between the atmosphere and the underlying surface, with a dramatic effect on the surface temperature. It is difficult to retrieve SST from space in the marginal ice zone due to the rapid development and retreat of sea ice depending on the season. Sea ice can also affect satellite radiance retrievals and an incorrect distribution of sea-ice may influence the model tropospheric state.

High resolution SST data products preserve SST gradients better and have been shown to significantly alter the surface wind stress field. In Figure 17 the near all-weather capability microwave SST observations preserve the gradient of SST compared to the analysis systems that rely on cloudy infrared and limited in situ sources. NWP model have been demonstrated to have a sensitivity to the spatial resolution of the SST fields used as the bottom boundary condition. A PDF of the paper is available from the BAMS pages at: http://www.ametsoc.org/pubs/bams DOI: 10.117/BAMS-86-81097.

GHRSST is working together with many National Meteorological services to ensure that GHRSST data products and services are tailored to requirements, provided on an operational basis and provide an improved service in terms of data quality and access. Never before have so many Satellite SST datasets been available to the community in this way. This frees up time to concentrate on applying the data rather than gaining access to it in the first place.

An important element of the GHRSST R/GTS is operational uptake of products. This can only take place if NWP systems are able to demonstrate a useful improvement to their forecast skill. This is a challenging and costly area, but one that is a pre-requisite for GHRSST.

7 Publications, Questions and Further Information

The following publication summaries the GHRSST product. For details on the individual products please refer to peer-reviewed articles for those products.

Donlon, C., I Robinson, K. S. Casey, J. Vazquez-Cuervo, E. Armstrong, O Arino, C. Gentermann, D. May, P. Le Borgne, J. Piolle, I Barton, H. Beggs, D. J. S. Poulter, C.J. Merchant, A. Bingham, S. Heinz, A. Harris, G. Wick, B. Emery, p. Minnett, R. Evans, D. Llewellyn-Jones, C. Mutlow, R. W. Reynolds, H. Kawamura, and N. Rayner, The Global Ocean Data Assimilation Experiment High-resolution Sea Surface Temperature Pilot Project, Bull. of the Amer. Metero, 88 (8), 1197-1213, Aug, 2007.

Updated information can be found at the GHRSST web-site http://www.ghrsst.org/ or by contacting the GHRSST Project office (mail to: ghrsst-po@nceo.reading.ac.uk)
General enquiries can be submitted via the GHRSST website site using a short on-line form at: https://www.ghrsst.org/contact/enquiry-form/.

A list of peer reviewed scientific papers and reports is maintained by the GHRSST Project Office: https://www.ghrsst.org/ghrsst-science/ghrsst-publications/

Questions can also be addressed directly to the Global Data Assembly Center (http://ghrsst.jpl.nasa.gov) or via the NASA's PO.DAAC user services at: podaac@podaac.jpl.nasa.gov or to the Long Term Stewardship and Reanalysis Facility

http://ghrsst.nodc.noaa.gov/ as well as directly to all the RDACs.

http://mailman.cgd.ucar.edu/mailman/listinfo/cf-metadata NetCDF Climate and Forecast (CF) community

APPENDICES

Appendix 1: GHRSST product tables

Because GHRSST is a dynamic project the tables are constantly changing. For the current list users are always encouraged to go the following links.
At the LTSRF: http://ghrsst.nodc.noaa.gov/ghrsst_product_table.html
At the GDAC: http://ghrsst.jpl.nasa.gov/GHRSST_product_table.html

Table 5: GHRSST Product table.

GHRSST Products in the LTSRF					
RDAC	Product	GHRSST Product Level	Start Date (YYYYMMDD)	Stop Date (YYYYMMDD)	Resolution
ABOM	GAMSSA_28km	L4	20080824	ongoing	28 km
	RAMSSA_09km	L4	20080401	ongoing	9 km
DMI	DMI_OI	L4	20070604	ongoing	3 km
EUMETSAT	AVHRR_METOP_A	L2P	20091101	ongoing	1 km
EUR	AMSRE	L2P	20050131	20070226	25 km
	ATS_NR_2P	L2P	20050315	20090929	1 km
	AVHRR16_G	L2P	20050131	20060814	8.8 km
	AVHRR16_L	L2P	20050201	20051026	2.2 km
	AVHRR17_G	L2P	20050131	20070226	8.8 km
	AVHRR17_L	L2P	20050131	20070226	2.2 km
	NAR16_SST	L2P	20050131	20051122	2 km
	NAR17_SST	L2P	20050131	ongoing	2 km
	NAR18_SST	L2P	20051124	ongoing	2 km
	SEVIRI_SST	L2P	20050131	ongoing	0.1 deg
	TMI	L2P	20050131	20070227	25 km
	ODYSSEA GAL	L4	20080123	20081215	2 km
	ODYSSEA GLOB	L4	20071001	20091207	6 km
	ODYSSEA MED	L4	20050426	ongoing	2 km
	ODYSSEA NEW	L4	20080123	ongoing	2 km
JPL	MUR	L4	20080911	ongoing	1km
JPL/RSMAS/OBPG	MODIS_A	L2P	20060630	ongoing	1 km
	MODIS_T	L2P	20061001	ongoing	1 km
JPL/OurOcean	G1SST	L4	20100609	ongoing	1 km
NAVO	AVHRR17_G	L2P	20060621	20090706	8.8 km
	AVHRR17_L	L2P	20060621	20080916	2.2 km
	AVHRR18_G	L2P	20060125	ongoing	8.8 km
	AVHRR18_L	L2P	20060125	20090909	2.2 km
	AVHRRMTA_G	L2P	20070926	ongoing	9 km
	K10_SST	L4	20080401	ongoing	10 km
NCDC	AVHRR_AMSR_OI	L4	20020601	ongoing	0.25 deg
	AVHRR_OI	L4	19810901	ongoing	0.25 deg
NEODAAS	AVHRR17_L	L2P	20080902	ongoing	1.1 km
	AVHRR18_L	L2P	20080726	20090818	1.1 km
	AVHRR19_L	L2P	20091003	ongoing	1.1 km
OSDPD	GOES11	L2P	20061222	ongoing	6 km
	GOES12	L2P	20061222	20100414	6 km
REMSS	AMSRE	L2P	20020601	ongoing	25 km
	TMI	L2P	19980101	ongoing	25 km
	AMSRE	L2P_GRIDDED	20020601	ongoing	25 km
	TMI	L2P_GRIDDED	19980101	ongoing	25 km
	mw_ir_OI	L4	20050821	ongoing	9 km
UKMO	OSTIA	L4	20060401	ongoing	6 km

GHRSST Products in the LTSRF					
RDAC	Product	GHRSST Product Level	Start Date (YYYYMMDD)	Stop Date (YYYYMMDD)	Resolution
UPA	ATS_NR_2P	L2P	20090324	ongoing	1 km

Table 6: GHRSST RDAC Codes.

RDAC Codes	
ABOM	Australian Bureau of Meteorology
DMI	Danish Meteorological Institute
EUR	European Medspiration Project
EUM	EUMETSAT
JPL	NASA Jet Propulsion Laboratory
MYO	MyOcean
NAVO	US Naval Oceanographic Office
NCDC	NOAA National Climatic Data Center
NEODAAS	NERC Earth Observation Data Acquisition and Analysis Service
OBPG	Ocean Biology Processing Group
OSDPD	NOAA Office of Satellite Data Processing and Distribution
OSI-SAF	Ocean and Sea Ice Satellite Application Facility
REMSS	Remote Sensing Systems, Inc.
RSMAS	Rosenstiel School of Marine and Atmospheric Science, University of Miami
UKMO	UK Meteorological Office
UPA	UK Multi-Mission Product Archive Facility

Table 7: Listing of current products at the GDAC (found at: http://ghrsst.jpl.nasa.gov/GHRSST_product_table.html).

Product [GHRSST product code]	Instrument / Type	Satellite / Orbit	Data Source Agency	Data producer [RDAC code]	Resolut-ion	Latitude range	Longitude range	Files per day	Time Series
L2P									
ATS_NR_2P	AATSR / Infrared	Envisat / Polar	ESA	EUR and UPA	1 km	90ºN - 90ºS	180ºW - 180ºE	15	Mar 2005 - present
SEVIRI_SST	SEVIRI / Infrared	MSG / Geostationary	EUMETSAT	EUR	0.1 deg	60ºN - 60ºS	100ºW - 45ºE	8 (1 file per 3 hours)	Feb 2005 - present
AMSRE	AMSRE / Microwave	Aqua / Polar	Remote Sensing Systems, Inc.	EUR	25 km	90ºN - 90ºS	180ºW - 180ºE	14	Feb 2005 – Feb 2007
AMSRE	AMSRE / Microwave	Aqua / Polar	Remote Sensing Systems, Inc.	REMSS	25 km	90ºN - 90ºS	180ºW - 180ºE	14 (& 14 realtime files) *	June 2002 - present
AVHRR16_G	AVHRR / Infrared	NOAA-16 / Polar	NAVOCEANO	EUR	8.8 km	90ºN - 90ºS	180ºW - 180ºE	14	Feb 2005 – Aug 2006
AVHRR16_L	AVHRR / Infrared	NOAA-16 / Polar	NAVOCEANO	EUR	2.2 km	90ºN - 70ºS	100ºW - 45ºE	1-5	Feb 2005 – Oct 2005
AVHRR17_G	AVHRR / Infrared	NOAA-17 / Polar	NAVOCEANO	EUR	8.8 km	90ºN - 90ºS	180ºW - 180ºE	14	Feb 2005 – Feb 2007

Product [GHRSST product code]	Instrument / Type	Satellite / Orbit	Data Source Agency	Data producer [RDAC code]	Resolut-ion	Latitude range	Longitude range	Files per day	Time Series
AVHRR17_L	AVHRR / Infrared	NOAA-17 / Polar	NAVOCEANO	EUR	2.2 km	90ºN - 70ºS	100ºW - 45ºE	~1-5	Feb 2005 – Feb 2007
AVHRR17_G	AVHRR / Infrared	NOAA-17 / Polar	NAVOCEANO	NAVO	8.8 km	90ºN - 90ºS	180ºW - 180ºE	14	Jun 2006 – Jul 2009
AVHRR17_L	AVHRR / Infrared	NOAA-17 / Polar	NAVOCEANO	NAVO	2.2 km	N America west and east coasts and various other		~30	Jun 2006 – Sep 2008
AVHRR17_L	AVHRR / Infrared	NOAA-17 / Polar	Plymouth Marine Laboratory	NEODAAS	1.1 km	Northeast Atlantic and Europe		8	Sept 2008 – May 2010
AVHRR18_L	AVHRR / Infrared	NOAA-18 / Polar	Plymouth Marine Laboratory	NEODAAS	1.1 km	Northeast Atlantic and Europe		8	Jul 2008 – Aug 2009
AVHRR19_L	AVHRR / Infrared	NOAA-19 / Polar	Plymouth Marine Laboratory	NEODAAS	1.1 km	Northeast Atlantic and Europe		8	Sept 2009 – present

* AMSRE L2P "realtime" products (contain "_rt_" in filename) from Remote Sensing Systems (REMSS) can have partial orbits. A "-po*X*-" will be found in the filename:

- "-po0-: the whole orbit
- -po1-: first section of orbit
- -po2-: second section of orbit

Product [GHRSST product code]	Instrument / Type	Satellite / Orbit	Data Source Agency	Data producer [RDAC code]	Resolution	Latitude range	Longitude range	Files per day	Time Series
L2P									
MTSAT_1R	MTSAT / Infrared	MTSAT / Geostationary	NOAA	OSDPD	4 km	55ºN - 55ºS	165ºW - 85ºE	~48	Nov 2009 – present
MSG	SEVIRI / Infrared	MSG-02 / Geostationary	NOAA	OSDPD	3 km	55ºN - 55ºS	55ºW - 55ºE	~48	Nov 2009 – present
AVHRR_METOP_A	AVHRR / Infrared	MetOP_A / Polar	EUMETSAT	EUM	1 km	90ºN - 90ºS	180ºW - 180ºE	~300	Nov 2009 – present
AVHRR18_G	AVHRR / Infrared	NOAA-18 / Polar	NAVOCEANO	NAVO	8.8 km	90ºN - 90ºS	180ºW - 180ºE	14	Jan 2006 – present
AVHRR18_L	AVHRR / Infrared	NOAA-18 / Polar	NAVOCEANO	NAVO	2.2 km	N America west and east coasts and various other		~30	Jan 2006 – Sept 2009
AVHRR18_L	AVHRR / Infrared	NOAA-18 / Polar	Plymouth Marine Laboratory	NEODAAS	1.1 km	Northeast Atlantic and Europe		8	Sept 2008 – Aug 2009
AVHRRMTA_G	AVHRR / Infrared	Envisat / Polar	ESA	NAVO	9 km	90ºN - 90ºS	180ºW - 180ºE	14	Sept 2007 – present
NAR16_SST	AVHRR / Infrared	NOAA-16 / Polar	NAVOCEANO	EUR	2 km	78ºN - 20ºS	45ºW - 45ºE	2	Feb 2005 – Nov 2005
NAR17_SST	AVHRR / Infrared	NOAA-17 / Polar	NAVOCEANO	EUR	2 km	78ºN - 20ºS	45ºW - 45ºE	2	Feb 2005 – Mar 2010

Product [GHRSST product code]	Instrument / Type	Satellite / Orbit	Data Source Agency	Data producer [RDAC code]	Resolution	Latitude range	Longitude range	Files per day	Time Series
NAR18_SST	AVHRR / Infrared	NOAA-18 / Polar	NAVOCEANO	EUR	2 km	78ºN - 20ºS	45ºW - 45ºE	2	Nov 2005 – present
MODIS_T	MODIS / Infrared	Terra / Polar	NASA OBPG/RSMAS/JPL	JPL	1 km	90ºN - 90ºS	180ºW - 180ºE	~288	Oct 2006 - present
MODIS_A	MODIS / Infrared	Aqua / Polar	NASA OBPG/RSMAS/JPL	JPL	1 km	90ºN - 90ºS	180ºW - 180ºE	~288	Jul 2006 - present
GOES11	GOES Imager / Infrared	GOES-11	NOAA	OSDPD	6 km	76ºN - 50ºS	146E - 59ºW	~48	Dec 2006 - present
GOES12	GOES Imager / Infrared	GOES-12	NOAA	OSDPD	6 km	72ºN - 55ºS	152W - 4ºE	~48	Dec 2006 - Jun 2010
GOES13	GOES Imager / Infrared	GOES-13	NOAA	OSDPD	6 km	65ºN - 50ºS	135W - 30ºW	~48	Jul 2010 - present
TMI	TMI / Microwave	TRMM / Equatorial	Remote Sensing Systems, Inc.	EUR	25 km	38ºN - 38ºS	180ºW - 180ºE	~16	Feb 2005 – Feb 2007
TMI	TMI / Microwave	TRMM / Equatorial	Remote Sensing Systems, Inc.	REMSS	25 km	38ºN - 38ºS	180ºW - 180ºE	14 (& 14 realtime files)	Jan 1998 – present

Product [GHRSST product code]	Instrument / Type	Satellite / Orbit	Data Source Agency	Data producer [RDAC code]	Resolution	Latitude range	Longitude range	Files per day	Time Series
L3/L2P_GRIDDED									
GLOB_AVHRR_METOP_A	AVHRR Infrared	MetOP_A / Polar	EUMETSAT	EUR	.05 deg	78ºN - 23ºN	76ºW - 73ºE	2	Sept 2009 – present
NAR_AVHRR_METOP_A	AVHRR Infrared	MetOP_A / Polar	EUMETSAT	EUR	.02 deg	78ºN - 23ºN	76ºW - 73ºE	2	Sept 2009 – present
AMSRE	AMSRE / Microwave	Aqua / Polar	Remote Sensing Systems, Inc.	EUR	25 km	90ºN - 90ºS	180ºW - 180ºE	1 (& 1 realtime file)	Jun 2002 – present
TMI	TMI / Microwave	TRMM / Equatorial	Remote Sensing Systems, Inc.	REMSS	25 km	38ºN - 38ºS	180ºW - 180ºE	1 (& 1 realtimefile)	Jan 1998 - present

Product [GHRSST product code]	Region	Source Data	Producer Agency	Data producer [RDAC code]	Resolution	Latitude range	Longitude range	Files per day	Time Series
L4									
MUR	NCAMERICA	AMSRE, MODIS	JPL	JPL	1 km	62ºN - 20ºS	165ºW - 30ºW	1	Apr 2008 – Jun 2010
G1SST	GLOB	AMSRE, MODIS, AATSR, SEVIRI, MTSAT, AVHRR, in situ	JPL_OUROCEAN	JPL	1 km	80ºN - 80ºS	180ºW - 180ºE	1	Jun 2010 – present
ODYSSEA	GLOB	AVHRR, AMSRE, TMI, AATSR, SEVIRI, GOES	CNES/Ifremere	EUR	6 km	90ºN - 90ºS	180ºW - 180ºE	1	Jan 2008 – present
AVHRR_OI	GLOB	AVHRR, in situ (buoys, ships)	NOAA	NCDC	0.25 deg	90ºN - 90ºS	180ºW - 180ºE	1	Sep 1981 - present
AVHRR_AMSR_OI	GLOB	AVHRR, AMSRE, in situ	NOAA	NCDC	0.25 deg	90ºN - 90ºS	180ºW - 180ºE	1	Jun 2002 – present
OSTIA	GLOB	AVHRR, AMSRE, TMI, AATSR, SEVIRI, in situ	UK Met Office	UKMO	6 km	90ºN - 90ºS	180ºW - 180ºE	1	Mar 2006 - present
mw_ir_OI	GLOB	AMSRE, TMI, MODIS	Remote Sensing Systems	REMSS	9 km	90ºN - 90ºS	180ºW - 180ºE	1	Aug 2005 – present
ODYSSEA	MED	AVHRR, AMSRE, TMI, AATSR, SEVIRI	CNES/Ifremer	EUR	2 km	46.5ºN - 30ºN	18.5ºW – 36.5ºE	1	Jan 2008 - present
ODYSSEA	GAL	AVHRR, AMSRE, TMI, AATSR, SEVIRI	CNES/Ifremere	EUR	2 km	20ºN - 20ºS	120ºW - 69ºE	1	Jan 2008 – present
ODYSSEA	NWE	AVHRR, AMSRE, TMI, AATSR, SEVIRI	CNES/Ifremer	EUR	2 km	60ºN - 43ºN	13ºW - 9ºE	1	Jan 2008 - present
MED*	MED	AVHRR, AMSRE, TMI, AATSR, SEVIRI	CNES/Ifremere	EUR	2 km	45.99ºN - 30.01ºN	5.99ºW – 36.49ºE	1	Jan 2005 – Jan 2008
DMI_OI	NSEABLATIC	AVHRR, AMSRE, AATSR, SEVIRI	Danish Met Inst	DMI	3 km	65.98ºN - 48.01ºS	9.99ºW - 30ºE	1	Jun 2007 - present
GAMSSA	GLOB	AVHRR, AATSR, in situ	Australian Bureau of Meteorology	ABOM	0.25 deg	90ºN - 90ºS	180ºW - 180ºE	1	Aug 2008 - present
RAMSSA	AUS	AVHRR, AATSR, in situ	Australian Bureau of Meteorology	ABOM	9 km	20ºN - 70ºS	60ºE - 190ºE	2	Apr 2008 - present
K10_SST	GLOB	AVHRR, GOES, AMSRE	NAVOCEANO	NAVO	10 km	90ºN - 90ºS	180ºW - 180ºE	1	Apr 2008 - present

* L4 MED product originally produced from 2005 to 2008 has been superseded by the ODYSSEA product for this region since Jan 2008

Appendix 2: In a hurry to use SST data? Quick Start

What does GHRSST offer?

GHRSST can supply Sea Surface Temperature (SST) data in satellite swath coordinates (L2P), gridded data (L3), and gap-free gridded products (L4). Descriptions of these data and more at: http://www.ghrsst.org/data/data-descriptions. See the GHRSST web-site or the GHRSST brochure for the project description.

Which data set should I use?

Before deciding on the data set users should be aware of the definitions of skin, sub-skin, and foundation temperatures (https://www.ghrsst.org/ghrsst-science/sst-definitions/) and other aspects that may be influences by the requirements of your application, such as sampling intervals and the length of the data sets.

Infra-red instruments measure SSTskin at high spatial resolution and high quality data.	Microwave instruments measure an approximation to the SSTsubskin, including through clouds and thus have fuller coverage but at a reduced spatial resolution

Geostationary satellites have high temporal resolution and constant spatial coverage.	Low orbiting satellites have higher spatial resolution and higher quality data.

Products blended from multiple satellites (L3S, L4) use different methods to combine the observations from several sensors and to preserve the resolution or gradients in SST.

Where can I download the data?

You can download from the respective data producers (RDACs), or as collected by the GHRSST Global Data Archiving Centre (GDAC) at NASA JPL are transferred after 30 days to the Long Term Stewardship and Reanalysis Facility (LTSRF) at NOAA NODC.

	Real-time (30 days or less) SST from GDAC:	**Historical SST (older than 30 days) from LTSRF:**
HTTP:	**http://podaac.jpl.nasa.gov/**	**http://data.nodc.noaa.gov/ghrsst/**
FTP:	**ftp://podaac.jpl.nasa.gov/allData/**	**ftp://ftp.nodc.noaa.gov/pub/data.nodc/ghrsst/**
OPeNDAP:	**http://opendap.jpl.nasa.gov/opendap/**	**http://data.nodc.noaa.gov/opendap/ghrsst/**
THREDDS:	**http://podaac.jpl.nasa.gov/podaac_thredds**	**http://data.nodc.noaa.gov/thredds/catalog/ghrsst/**

How do I read the data?

All data are in netCDF. It is important for users to familiarize themselves with the flags contained in the L2P files (see previous GDS1.5 and current GDS2 specifications in https://www.ghrsst.org/documents/q/category/gds-documents/operational/). In general using proximity confidence flags of 5 for the infrared and 4 for the microwave data result in the retrieval of highest quality pixels. Template codes in C, FORTRAN, MATLAB and IDL can be found in: https://www.ghrsst.org/data/ghrsst-data-tools/.

Questions?

Ask the GHRSST Project office ghrsst-po@nceo.ac.uk or go directly to the GDAC PO.DAAC user services podaac@podaac.jpl.nasa.gov.