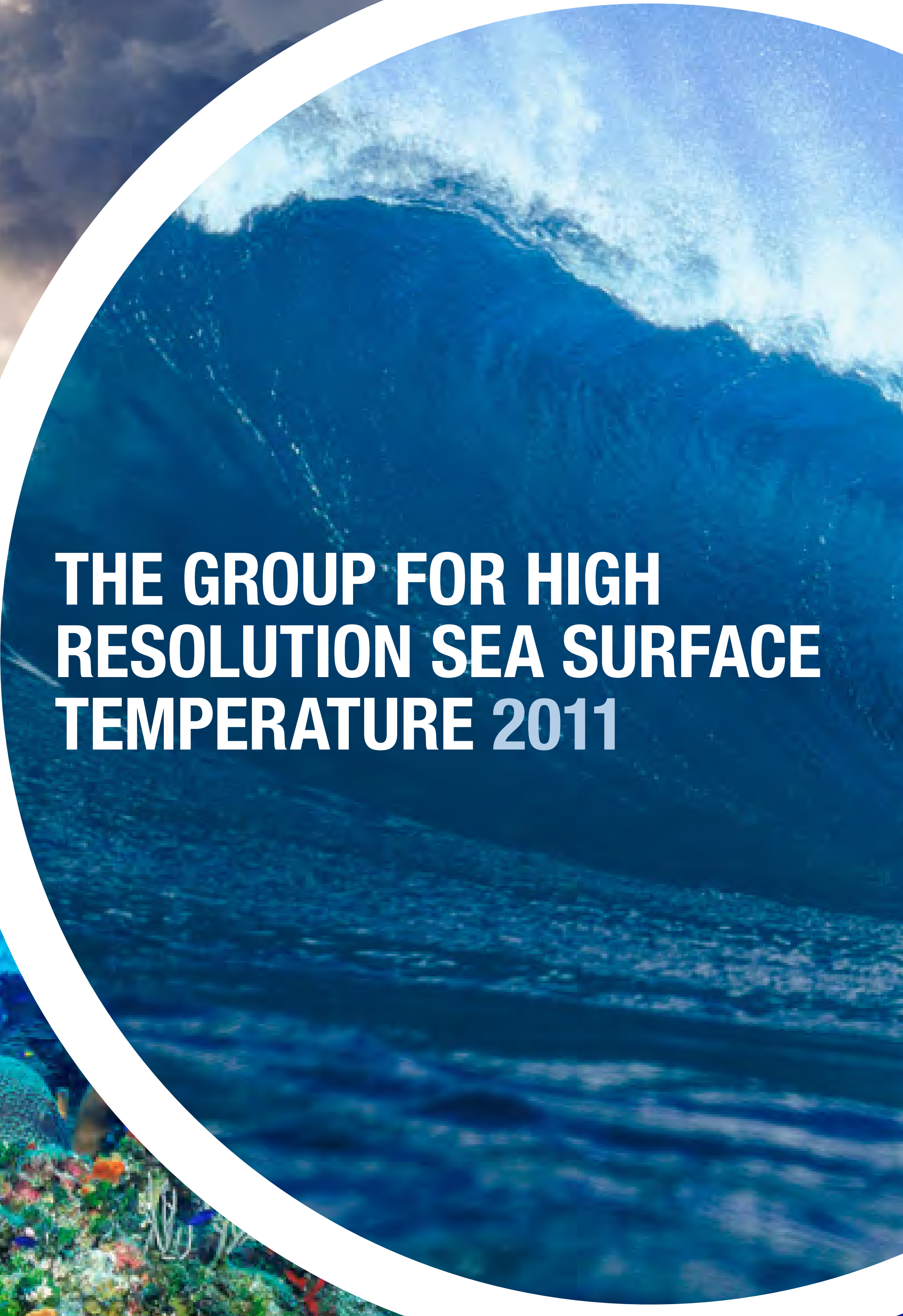
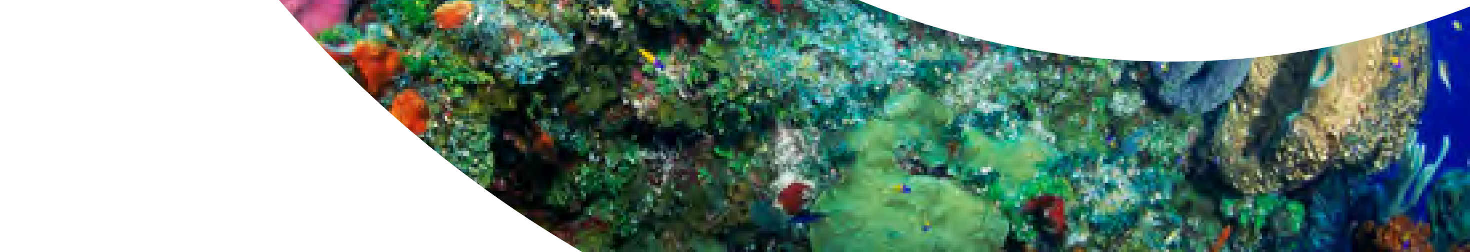


THE GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE 2011



THE GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE GHRSST

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WHY GHRSST?

The Group for High Resolution Sea Surface Temperature (GHRSST) is an open international science group that promotes the application of satellites for monitoring sea surface temperature (SST) by enabling SST data producers, users and scientists to collaborate within an agreed framework of best practice.

GHRSST serves its user community through the specification of operational SST data products, at a spatial resolution down to 1km, based on a consensus agreed by the GHRSST Science Team. Providers of SST data from particular satellites create and deliver GHRSST-compliant near-real time products that include error estimates and supporting data in a common netCDF format. While each data producer follows its own individual approach for generating SST values from satellite sensors, GHRSST provides the forum for close dialogue with SST users and the scientific community for evaluation, inter-comparison and improvement of SST products, facilitated by adoption of the GHRSST Data Specification (GDS). Every day, several agencies operate global or regional processing systems that combine the complementary data from various satellites and in situ SST data streams, to deliver several independent SST analysis products. These are passed from national or regional data producers to the GHRSST Global Data Assembly Center (GDAC) and finally to the Long Term Stewardship and Reanalysis Facility (LTSRF), which also handles subsequently reprocessed and reanalysed data. GHRSST SST data products are freely available, and can be accessed at **www.ghrsst.org**.

GHRSST is led by elected international experts: the GHRSST Science Team. The GHRSST Science Team monitors the data products and co-ordinates efforts to maintain and enhance data quality based on related research, with special focus on diurnal variability, validation and inter-comparison of GHRSST products. It also provides a discussion forum to support data producers with improving retrieval algorithms and reanalysis methods. Continuous efforts to refine the GHRSST data management infrastructures ensure a functional system that conforms to international directives and results in easy access to data and guidance for users.

Major stakeholders are represented in the GHRSST Advisory Council. The GHRSST Project Office supports the smooth day-to-day working of the group.

Sea Surface Temperature (SST) is of interest for many applications:

- Aquaculture
- Atmosphere research
- Climate variability and change
- Coastal users
- Commercial shipping
- Ecosystems
- Fisheries
- Habitats
- Hazardous spill mitigation
- Hurricane research
- Naval operations
- Ocean forecasting
- Ocean research
- Recreational boating
- Recreational fishing
- Search and rescue
- Seasonal forecasting
- Tourism
- Weather forecasting

UNDERSTANDING SEA SURFACE TEMPERATURE

SST is a key parameter for constraining the exchange of energy and moisture between the ocean and the atmosphere. However, one single parameter is not able to describe the complex and variable vertical temperature structure in the upper 10m of the ocean that is related to ocean turbulence and the air-sea fluxes of heat, moisture and momentum.

The definitions of Sea Surface Temperature (SST) have been developed by the GHRSST Science Team to achieve the closest possible coincidence between what is physically 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.

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. All measurements of water temperature beneath the SSTsubskin are referred to as depth temperatures (SSTdepth) and must be qualified by a measurement depth in meters. The foundation temperature (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. SSTfnd is named to indicate that it is the foundation temperature upon which the growth and decay of the diurnal heating develops each day.

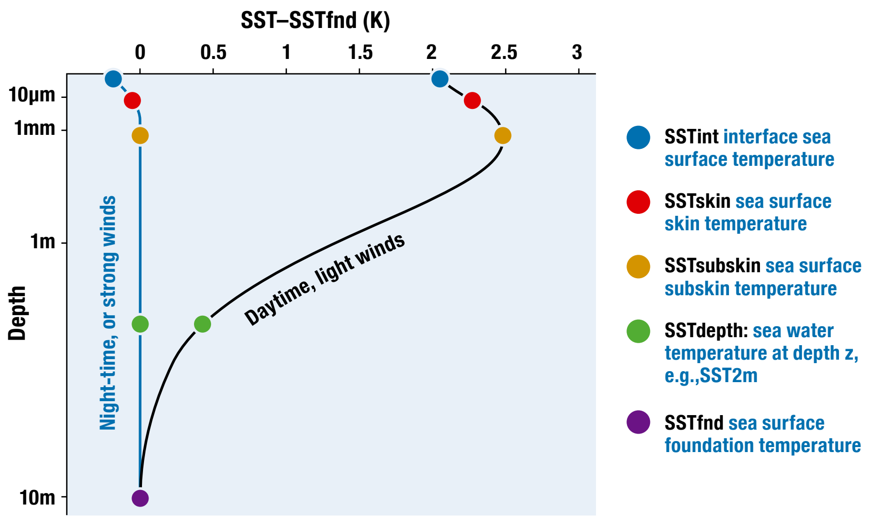


Figure 1: The hypothetical vertical profiles of temperature for the upper 10m of the ocean surface in high wind speed conditions or during the night (blue) and for low wind speed during the day (black).

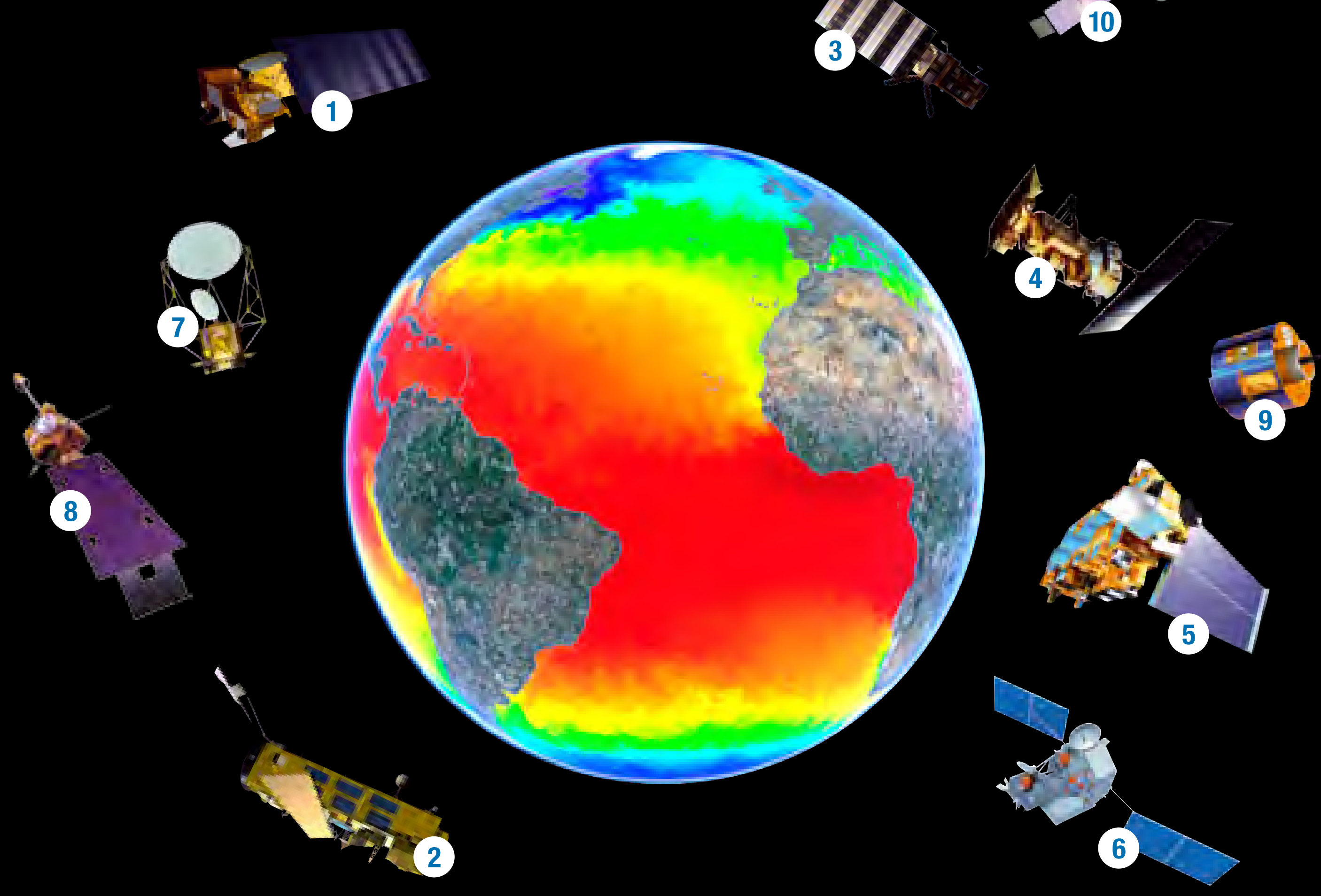
SATELLITES CARRYING SST INSTRUMENTS

Low Orbiting Satellites, their SST Sensors and Space Agencies:

1. AQUA MODIS NASA & AMSR-E JAXA, image credit: NASA
2. ENVISAT AATSR ESA, image credit: ESA
3. METOP-A AVHRR AND IASI EUMETSAT, image credit: ESA-AOES Medialab
4. NOAA-18 and NOAA-19 AVHRR NOAA, image credit: NOAA
5. Terra MODIS NASA, image credit: NASA
6. TRMM TMI & VIRS NASA, image credit: NASA
7. Coriolis WindSat NRL, image credit: US Navy

Geostationary Satellites, their SST Sensors and Space Agencies:

8. GOES-E and GOES-W GOES NOAA, image credit: NOAA
9. MSG SEVIRI EUMETSAT, image credit: ESA-D.DUCROS
10. MTSAT-2 MTSAT JMA, image credit: JMA



Although there are a number of satellites with sensors capable of measuring SST, the in-flight constellation is fragile. Four of the satellites are geostationary (GOES-E, GOES-W, MTSAT, MSG) and measure the earth disk beneath their orbit location (and with limited coverage at high latitudes); five are required for a full coverage of the lower latitudes. TRMM TMI and VIRS operate in a low inclination orbit tuned to measurements of the tropical regions (40 degrees north and south). Of the remaining satellites, only the NOAA-19 and METOP are within their expected design lifetime. The other satellites are past their expected lifespan and are at various degrees of health.

There are currently two operational polar orbiting microwave sensors (WindSAT on Coriolis and AMSR-E on AQUA) and seven infrared sensors (AVHRR on NOAA-18, NOAA-19 and METOP, IASI on METOP, MODIS on AQUA and TERRA, and AATSR on ENVISAT). The ENVISAT AATSR has an extremely narrow swath but provides highly accurate SST measurements. The AVHRRs and MODISs are complementary: when clouds block measurements of SST in the infrared waveband, the next overpass may be able to view the blocked region. Although ten sensors on eight satellites may seem quite a generous provision, because of gaps between successive orbits, clouds and rain occluding measurements, it is rare to obtain complete global coverage in less than 2–3 days. Producing an accurate daily SST requires these numerous measurements to be used in a complementary manner.

Satellite-based SST data sets have spatial resolutions which differ drastically from each other. For example, the infrared (IR) sensors can resolve down to 1 km in horizontal distance but the microwave (MW) sensor datasets are gridded at about 25 km resolution although their inherent resolution is coarser than this. In addition, there are numerous data-voids (holes in data coverage) due to contamination by clouds, aerosols and land (depending on the sensor). Sophisticated techniques have been developed to deal with these sampling issues objectively when combining the various complementary satellite measurements to create merged SST analysis products capitalising on the inherent synergy between each complimentary data set.

GHRSST PRODUCTS

L2P products are the GHRSST version of the level 2 satellite SST data.

These data are sampled on the grid or swath of the sensor, typically aligned with the satellite track, and represent the highest spatial resolution possible from the particular sensor. The L2P products contain the satellite SST observations together with a measure of uncertainty for each observation in a common GHRSST netCDF format. Auxiliary fields are also provided for each pixel to help interpreting the SST data. These data are ideal for data assimilation systems or as input to analysis systems.

A key feature of a GHRSST L2P data product is the provision of uncertainty information in the form of the Sensor Specific Error Statistics (SSES). These SSES are derived from a set of coincident satellite and reference observations taken at the surface.

The inclusion of SSES in L2P products allows a user to make an assessment of the suitability of a particular L2P product for their specific application, a step that can be incorporated automatically if data are being assimilated into forecasting models or ingested into an optimal interpolation procedure.

L3 gridded products are produced by combining, but not interpolating, the data contained in GHRSST L2P files.

This requires re-sampling on a longitude-latitude grid, commonly referred to as gridding. Careful consideration must be given to the gridding algorithm, for optimal preservation of information, especially if multiple data sources are combined at a later stage. Gridding a single L2P file produces an "uncollated" L3 file (L3U). Multiple L2P files are gridded to produce either a "collated" L3 file from a single satellite sensor (L3C) or a "super-collated" L3 file from multiple sensors (L3S). These L3U, L3C and L3S files are of similar netCDF format to the L2P files and contain the same auxiliary fields such as SSES error estimates and quality level flags for each SST value. GHRSST L3 products are useful for applications that require gridded SST at the highest possible resolution, as the L3 SST values have not been "smoothed" by spatial or temporal interpolation to fill in data gaps. Applications include coastal weather forecasting and coastal marine biological studies such as forecasting coral bleaching.

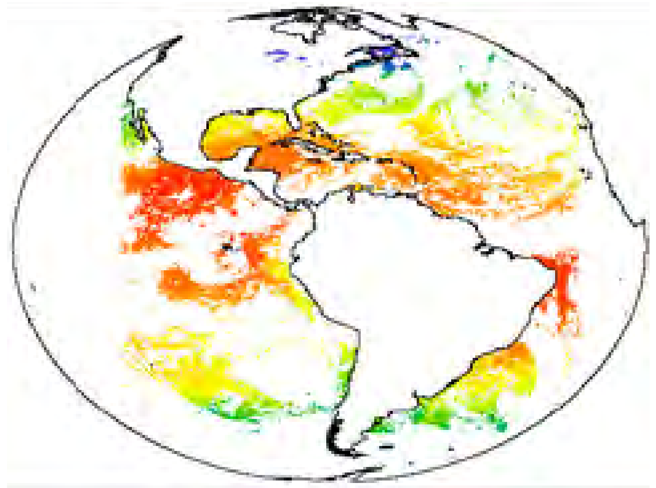


Figure 2: Example of L2P from geostationary GOES for 7 April 2011 (Figure courtesy of OSI-SAF).

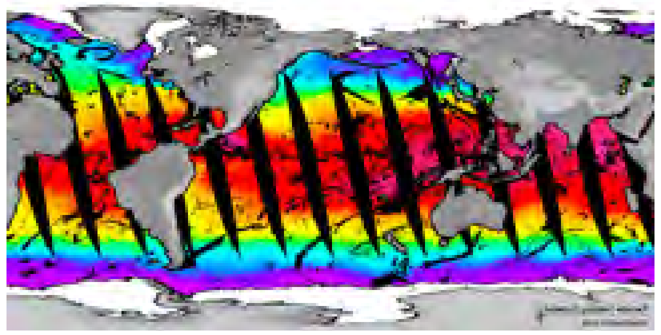


Figure 3: Example of a daily SST map composed from polar orbiting AMSR-E for 17 May 2011 (Figure courtesy of Remote Sensing Systems).

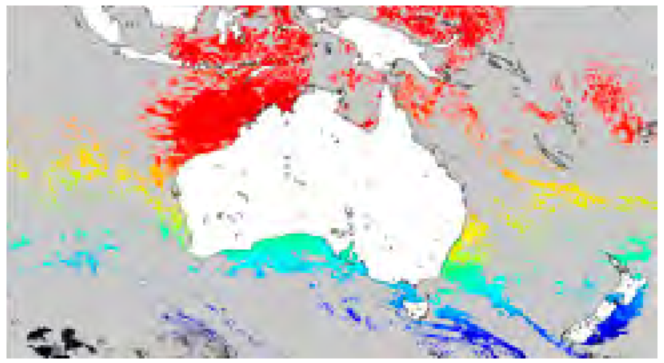


Figure 4: Example of nighttime 0.02° x 0.02° L3C composite from locally received NOAA-18 AVHRR SST data for 10 April 2009. SST is plotted for cloud-free pixels (quality level = 3 to 5). Figure courtesy Leon Majewski, Bureau of Meteorology.

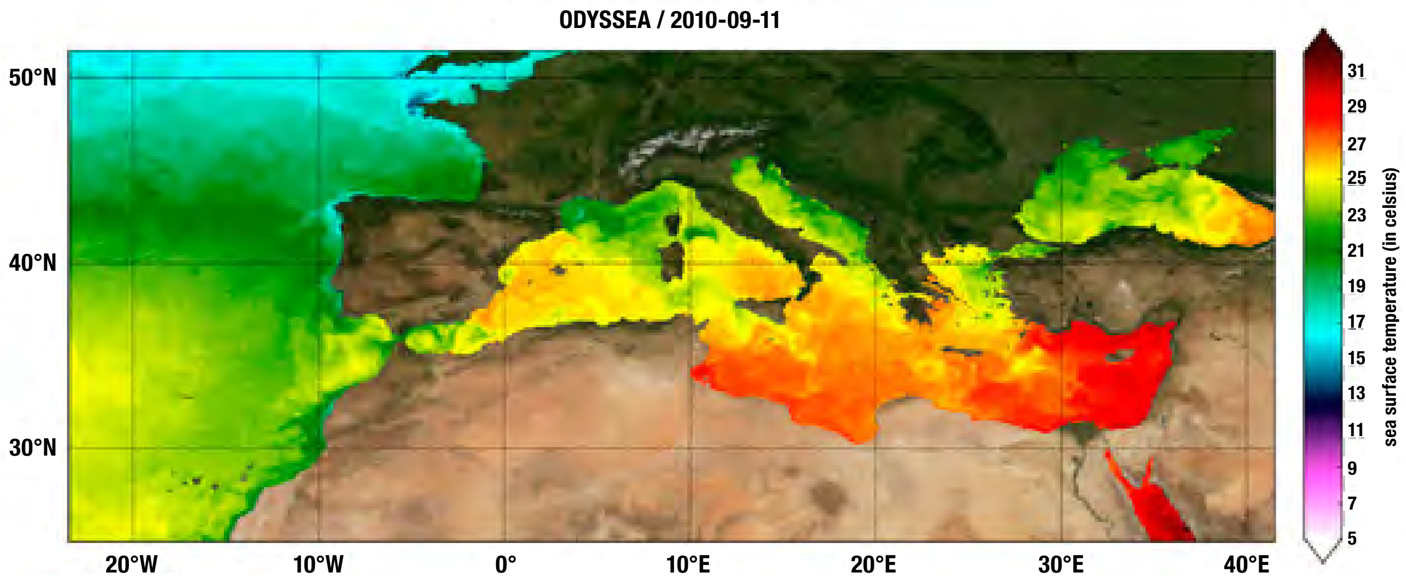


Figure 5: Medspiration is releasing in 2011 a new line of high resolution regional SST maps, for instance for the Mediterranean Sea.

Common format L4 gridded products are generated by combining complementary satellite and in situ observations to provide gap-free analyses of SST in the GHRSST format.

These L4 products are ideal for model diagnostic studies, model boundary condition specification, and model initialisation and are used by a number of groups including numerical weather prediction centres, operational ocean forecasting groups, seasonal forecasting systems, climate monitoring and research groups.

A large number of L4 SST analyses are produced by various institutes around the world, making use of the L2P and other data available through the GHRSST project. Each L4 product has a unique blend of SST data, resolution, time integration, regional surface covered, and interpolation technique, to cater for a variety of applications.

Matchup database

The GHRSST systems match satellite SST products to in situ observations and store these matchup pairs in a relational database. The GHRSST Matchup Data Base (MDB, see **http://projets.ifremer.fr/cersat/Data/Quality-control/GHRSST-Match-up-Database**) is then used to validate data products and to generate the Sensor Specific Error Statistics (SSES) required by L2P data products.

Diagnostic Data Sets

Diagnostic Data Sets are produced from satellite data every day for a number of globally distributed sites as part of the GHRSST data product monitoring system. In some cases, satellite winds, ocean colour, operational Numerical Weather Predictions (NWP) and ocean forecast model outputs are also available. These data products and associated analysis tools (**http://mydds.hrdds.net**) are aimed at groups interested in verification of satellite data sets (including L2P and L4 GHRSST products).

Metadata Records

The GHRSST-Master Metadata Repository (MMR, see **http://ghrsst.jpl.nasa.gov/data_search.html**) provides an on-line catalogue, compliant with international standards (ISO19115), of all GHRSST data holdings. It is searchable through ftp and OPeNDAP access via http links.

SST DATA PRODUCTION

Having evolved originally as a Pilot Project of the Global Ocean Data Assimilation Experiment (GODAE) to address an emerging need of the operational ocean forecasting community for accurate high resolution sea surface temperature (SST) products, GHRSST today collects all the data streams provided by the national or regional data producers, the so-called Regional Data Assembly Centers (RDACs).

For example, in Europe, Medspiration (an ESA DUE project) pioneered the implementation of an operational service delivering GHRSST-compliant SST products. L2P products are now produced by the agencies delivering the SST data, which are ESA and EUMETSAT through its Ocean and Sea Ice Satellite Application Facility (OSI-SAF).

Follow-up EU projects MERSEA and MyOcean extended the developments of new L4 and other products in collaboration with national weather services.

The Japanese GHRSST server is hosted by the Earth Observation Research Center of JAXA, the products are developed by JAXA, JMA, and Japanese universities, with a focus on application for fisheries.

The Australian contribution to GHRSST grew to meet the needs of operational ocean and weather forecasting in the ocean around Australia. It now has its research focus on improving satellite SST products over the Southern Ocean and the Tropical Warm Pool to the north of Australia.

Academic, government, military and industry researchers from the US (NASA, NOAA, Naval Research Laboratory, Naval Oceanographic Office, Remote Sensing Systems, and collaborating universities) have been involved in GHRSST directly as well as through the project USGODAE, the MISST project, and through the NASA-SST Science Team.

GHRSST is in the process of developing links with Brazil, Canada, China, India, Peru, and South Korea, and any national teams are warmly invited to join or collaborate.

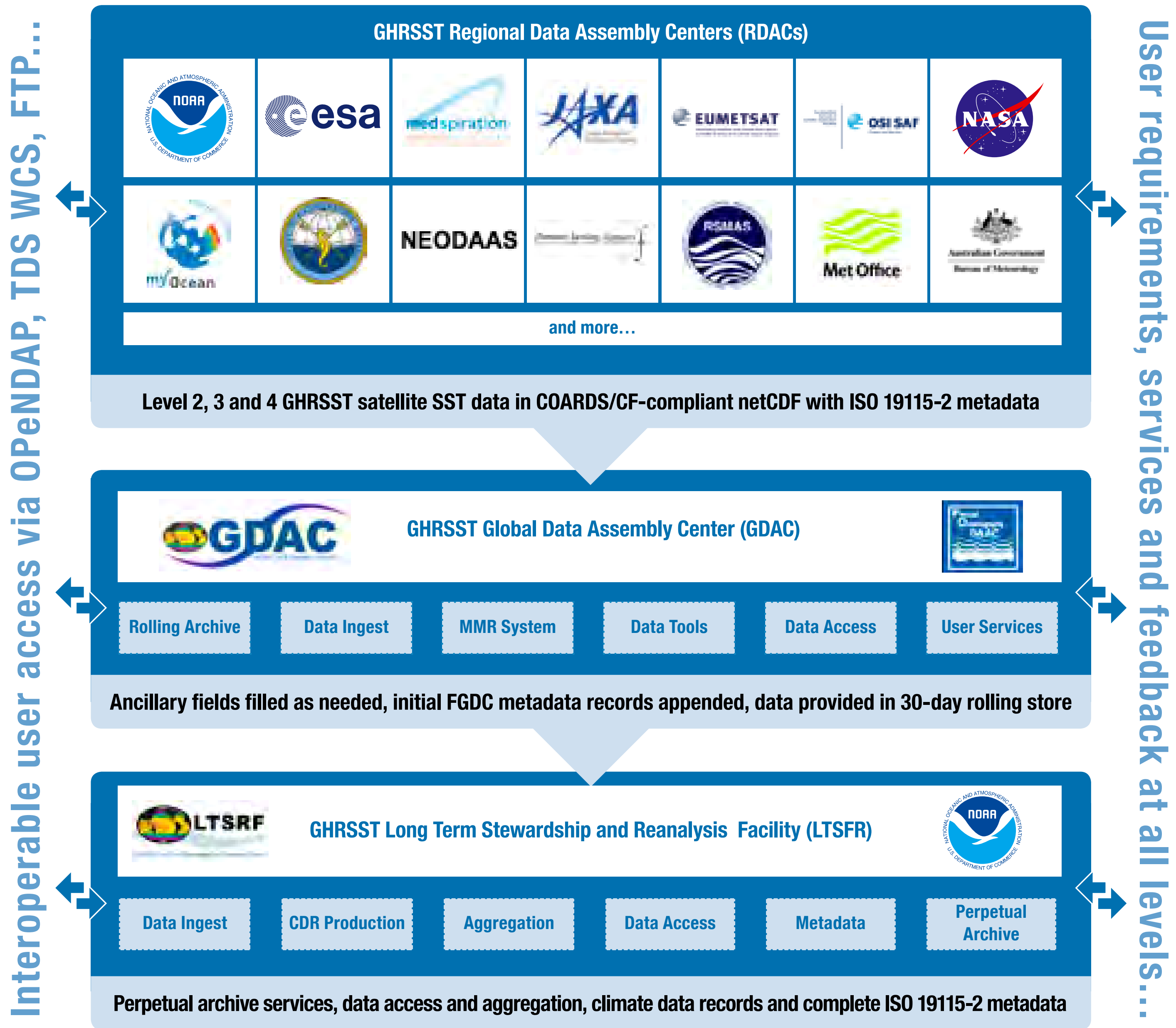


Figure 6: Overview of GHRSST Regional/Global Task Sharing Framework.

GHRSST DATA PROVISION

GHRSST provides its products through the Global Data Assembly Center (GDAC) and Long Term Stewardship and Reanalysis Facility (LTSRF).

The GDAC (**http://ghrsst.jpl.nasa.gov**), located at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC), serves as the near-real time clearinghouse for all GHRSST data sets. Here all near real time data can be accessed. The GDAC provides services and tools for accessing all data products, including FTP, HTTP, and OPeNDAP. Sub-setting of L4 products is available through **http://poet.jpl.nasa.gov**. All data products can be accessed via FTP through **ftp://podaac.jpl.nasa.gov/GHRSST/**

L2 sub-setting for specific products is available at **http://podaac-tools.jpl.nasa.gov/dataminer/aegina/src/dataminer.php**.

After 30 days, the data are sent to the GHRSST Long Term Stewardship and Reanalysis Facility (LTSRF) at the NOAA National Oceanographic Data Center (NODC) for permanent archive. The LTSRF routinely ingests, formally archives, and provides access to, all GHRSST products (**http://ghrsst.nodc.noaa.gov**). A large metadata transformation process to international standards is also completed at the LTSRF, where robust FGDC and ISO 19115-2 geospatial metadata records are maintained and provided to users. The LTSRF provides both the GHRSST long term archive and forms the central hub of the distributed GHRSST reanalysis (RAN) system. Additional access mechanisms include a THREDDS Data Server providing OGC Web Mapping Service (WMS) and Web Coverage Service (WCS), and a developing online analysis, visualisation, and sub-setting service based on the Live Access Server (LAS).

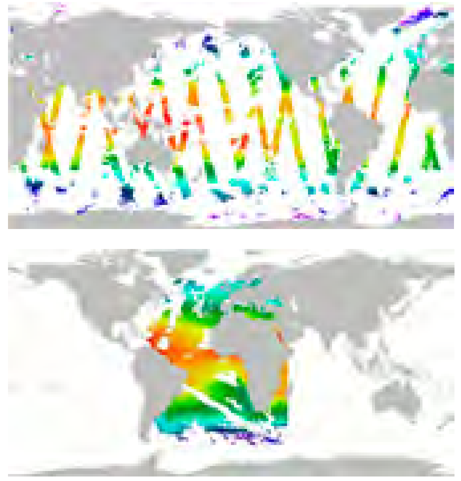


Figure 9: SST from polar orbiting (above) and from geostationary satellites (below).

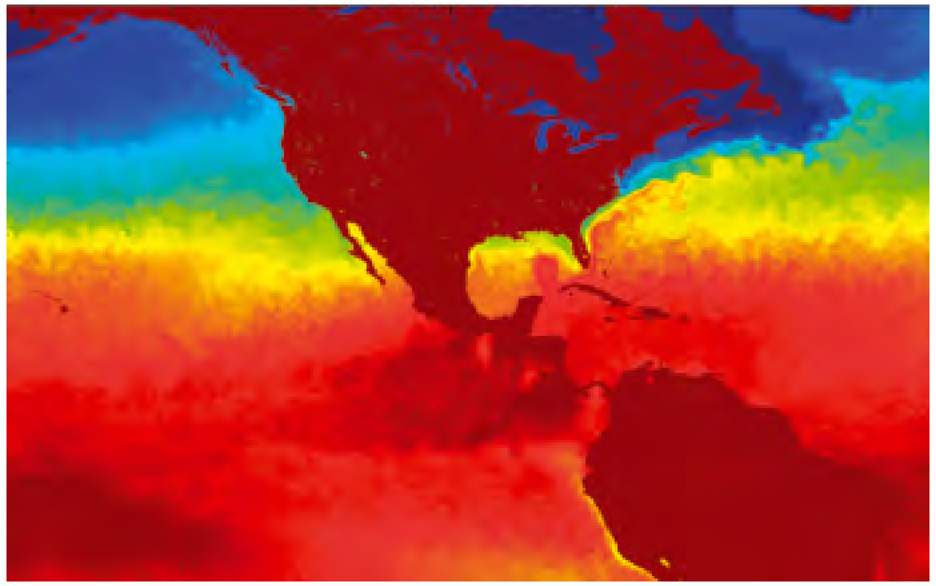


Figure 8: Example of an ultra-high resolution reanalysis product provided by the GDAC: A map of foundation temperature SST generated with multi-Resolution Variational Analysis, a statistical method for controlling smoothness (spectral contents) of the SST map without degrading local representativeness. Figure courtesy of NASA JPL PO.DAAC.

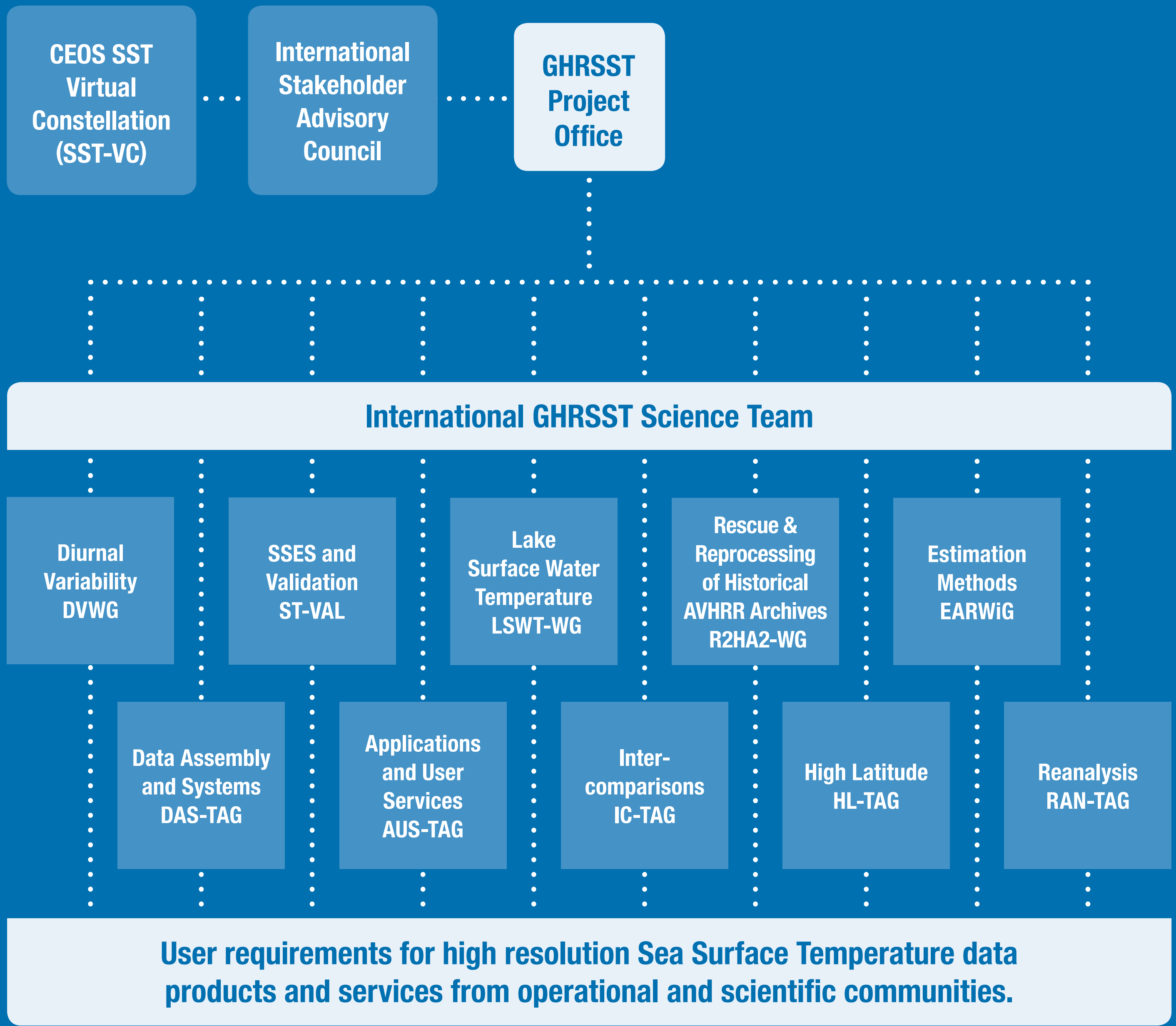
Figure 7: SST from AATSR measured near the African west coast. Figure courtesy of Rutherford Appleton Laboratory.

GHRSST ORGANISATION

User requirements drive the GHRSST data production. The GHRSST Science Team responds to those through steering dedicated Working Groups (WGs) and Technical Advisory Groups (TAGs). These groups concentrate on specific science issues or areas of interest. The diagram below lists the currently active GHRSST sub-groups.

With support of the GHRSST Project Office, the Science Team ensures the crosslinking of the sub-groups and encourages knowledge exchange with the users. The GHRSST Project Office maintains the formal communication within GHRSST, promotes GHRSST in the international landscape and takes advice given by the International Stakeholder Advisory Council.

GHRSST plans to serve in future as a Virtual Constellation for SST under the governance of the Commitee on Earth Observation Satellites (CEOS).



RESEARCH

GHRSST provides a forum for scientific interaction. GHRSST research is concerned with the scientific underpinning of SST data quality, and on how the measurements can be applied in a variety of contexts.

Several tools have been developed within GHRSST for inter-comparison between different GHRSST data products and for comparison to independent in situ data. Quality controlled drifting buoys, ship based temperature and radiometer measurements are used for validation. Recognising the need for high quality in situ observations, GHRSST has a pilot project with the Data Buoy Cooperation Panel (DBCP) and collaborates with the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM).

Satellite Sea Surface Temperature Validation Working Group (ST-VAL)

The development of the Sensor Specific Error Statistics (SSES) is one of the activities of ST-VAL. This group was established to look at all aspects of satellite SST validation: from the reference data itself, to the challenges which occur when comparing these locally representative reference observations to satellite data, to the ongoing refinement of the uncertainty estimates.

There are several sources of reference data used for satellite SST validation: drifting buoys, Argo profiling floats and ship-borne radiometers. The latter allow to trace satellite measurements to SI standards. Traceability to SI standards is necessary to generate a long-term Climate Data Record that is built on satellite measurements from many satellites.

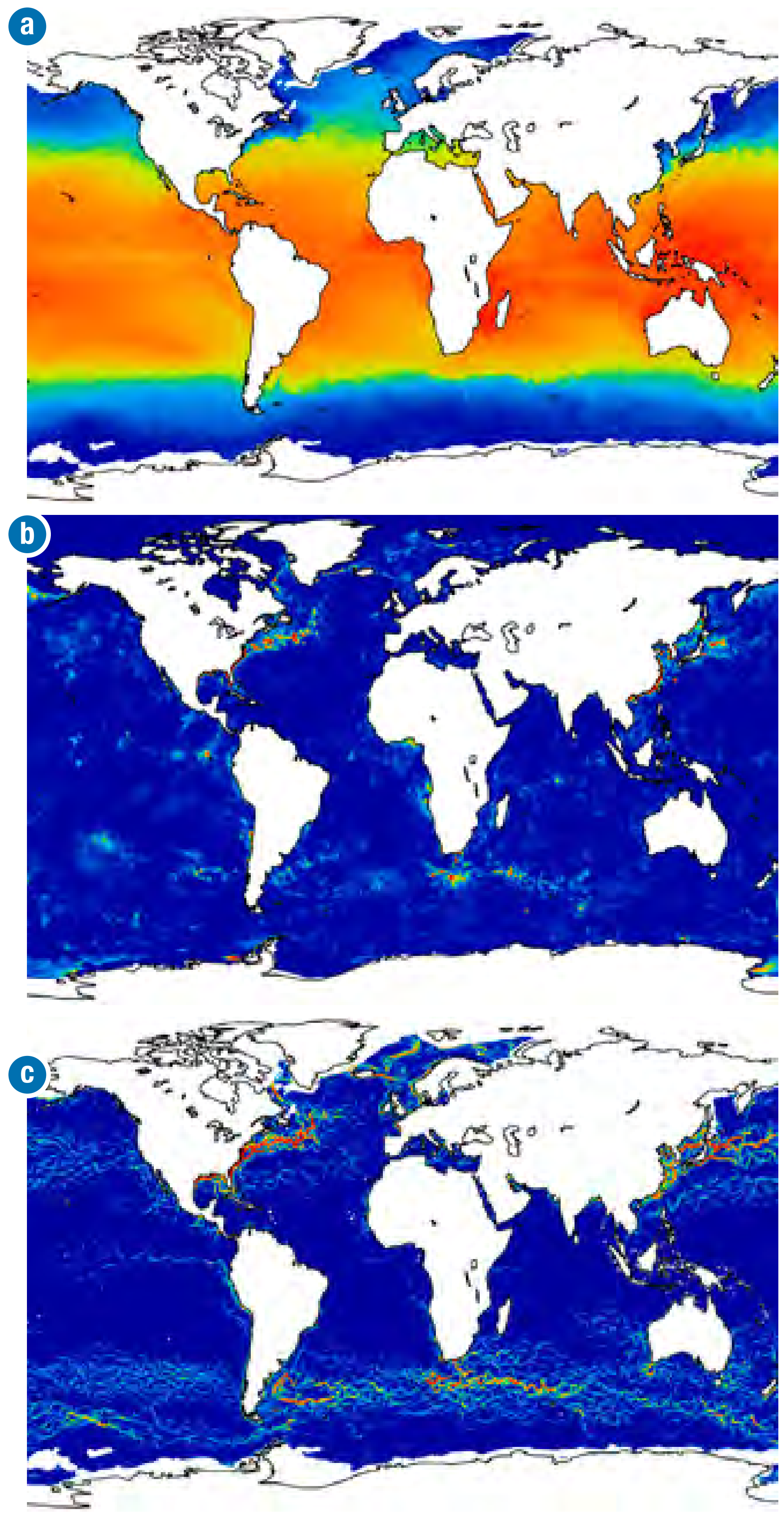
▲ **Figure 10: Ship-borne radiometers such as M-AERI, ISAR (a) and SISTeR (b) are providing essential long-term datasets to validate the accuracy and stability of SST measurements from space-borne sensors.**

The Inter-Comparison Technical Advisory Group (IC-TAG)

The aim of the IC-TAG is to develop international collaboration in this field in order to assess and inter-compare the different L4 SST analyses, and to provide uncertainty estimates on both the analyses and observational products, with appropriate guidance to users on the strengths and weakness of each analysis.

There are currently three systems used for inter-comparing the various L4 analyses within the IC-TAG:

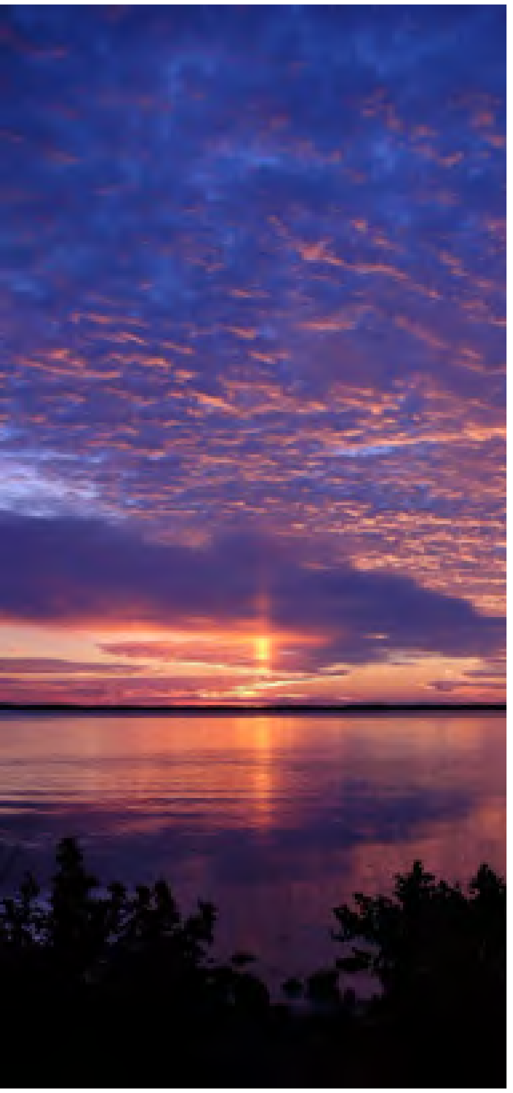
- The GHRSST Multi-Product Ensemble (GMPE) system (**http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html**) which is run on a daily basis at the UK Met Office. This produces global coverage ensemble median and standard deviation information, and provides an inter-comparison between the contributing analyses.
- The High Resolution Diagnostic Dataset (HRDDS) system (**www.hrdds.net**) run at the National Oceanography Centre, Southampton, which enables on-the-fly comparison of L4 analyses with both in situ and lower-level satellite SST data.
- The SST Quality Monitor (SQUAM) system (**www.star.nesdis.noaa.gov/sod/sst/squam**) which runs at NOAA NESDIS. This allows comparison between L4 analyses, and with other data, including the generation of difference maps, histograms, time-series and Hovmöller diagrams.



▶ **Figure 11:** GHRSST Multi-Product Ensemble (GMPE) outputs for 25th January 2011. Shown are the (a) median SST (K), (b) standard deviation SST (K) and (c) horizontal gradients of the median (km⁻¹).

Data Assembly and Systems Technical Advisory Group (DAS-TAG)

DAS-TAG is responsible for the day-to-day operational specification and management of GHRSST data products and services. In practice, this involves the specification and control of all aspects of data archiving, dissemination, file level and discovery metadata, international standards conformance, quality control and assurance issues, product content, amongst many others. DAS-TAG is a dynamic team drawing on the collective resources of an international membership that is actively involved in satellite and in situ data management issues.



Diurnal Variability Working Group (DVWG)

Diurnal variability of the SST results from the daily cycle of solar irradiance. While the variations are typically small due to mixing from the wind, under light winds and strong insolation, the surface temperature can warm by more than 5K in extreme cases. Diurnal variability matters to those who wish:

- to make optimum use of SST data captured at different times of day
- to make accurate estimates of ocean-atmosphere fluxes that are modified by any diurnal warming cycle
- to estimate the skin SST at a particular time of day

SST analyses frequently combine SST retrievals from multiple sensors collected at different times throughout the day. To provide a value representative of a specific depth or the heat content of the upper layer of the ocean, the observations should be adjusted as a function of depth and time. Neglecting these variations will lead to biases that can affect ocean forecasting models that assimilate SST observations. The instantaneous radiative and turbulent heat fluxes between ocean and atmosphere are fundamentally functions of skin SST. An analysis of the evolution of the skin temperature through the day is therefore both supportable by satellite observations and useful in improving ocean-atmosphere flux estimates. The air-sea flux of gas is likewise affected by SST if the gas solubility depends on temperature.

DVWG is attempting to understand better the factors influencing diurnal warming and to develop improved methods for predicting the amount of warming present at different times and depths.

Estimation and Retrievals Working Group (EARWiG)

Clouds are naturally an issue for satellite observations. Improving cloud detection, and understanding cloud-related biases is a research issue with high potential for improving our SST estimation. EARWiG is exploring the interaction of cloud detection and retrieval techniques, as well as other known issues such as geographical and aerosol related effects. These regionally varying aerosol and moisture contents add errors (biases) to the SST estimate.

EARWiG investigates methods of how to retrieve the SST from satellite IR measurements, with different potential for improvement. The classic approach is a multi-channel formula. The coefficients for the different channels can be found by a regression against a match-up database of in situ measurements (ships, moored or drifting buoys). Another possibility to obtain the coefficients is to calculate the radiative transfer in a model atmosphere.

More recently, a "physical retrieval" method is under development which abandons the multi-channel formula and inverts instead the radiative field resulting from modelling a NWP atmosphere.

EARWiG compares and develops these different retrieval methods, with the objective of assisting data production agencies to generate more accurate GHRSST L2P products.

High Latitude Technical Advisory Group (HL-TAG)

The high latitude regions are characterised by a lack of in situ observations, decreasing ice cover and strong sensitivity to climate changes. It is therefore important to secure the availability of accurate and reliable satellite SST observations in the high latitudes, which are the main objectives for HL-TAG.

The Polar Regions are challenging for several reasons. The dry atmosphere, presence of sea ice in the Marginal Ice Zone, the extended periods with cloud cover and the lack of in situ observations makes the retrieval of Sea Surface Temperature observations from satellites a challenging task, which requires special attention. The HL-TAG focuses upon validating and improving the satellite retrievals in the High Latitude region, with emphasis on the Marginal Ice Zone. In addition, the HL-TAG facilitates the use of existing in situ observations and encourages the community to deploy new drifting buoys and other in situ observations.

The HL-TAG also works with inter-sensor bias reference methods. Existing global methods that use the AATSR observations against which to reference the other sensors do not work in high latitudes due to the poor coverage and so there is a need for a multi-sensor based correction method.

The detection of sea ice and sea ice extent is important to many SST applications in the high latitudes, such as L4 products and climatologies, and is therefore followed closely in the HL-TAG.

Figure 12: A satellite image of the conditions in the high latitude regions off Greenland, with mixed sea ice and open waters. Image credit: NASA

Applications and User Services Technical Advisory Group (AUS-TAG)

The GHRSST project serves a broad community from operational users of Sea Surface Temperature products to researchers focusing on climate and modelling. The main goal of AUS-TAG is to facilitate usage of GHRSST products across this broad spectrum. Besides answering the user questions directly on an individual basis, AUS-TAG also maintains and develops the GHRSST Users' Manual and tools for data discovery. In collaboration with other GHRSST groups new technologies are implemented that can facilitate the usage and/or distribution of GHRSST products. The AUS-TAG collects all statistics related to the project, such as data transfer rates and unique user statistics. The AUS-TAG is promoting GHRSST to the different user communities.

Rescue & Reprocessing of Historical AVHRR Archives (R2HA2-WG) Working Group

Five-channel Advanced Very High Resolution Radiometers (AVHRR) have been flying on NOAA polar-orbiting satellites (and more recently the European polar-orbiting satellite, METOP) since 1981. Because there was no encryption of the down-linked data, anyone with a receiving station could acquire this 1km resolution data, but the data size was far too large to be held at the global data assembly centre. As a result, a number of organisations have set up HRPT receiving stations over the years and collected a subset of the passes seen by the station. These data have been archived in a variety of formats and on a variety of media ranging from 9 track tape to DVDs. Many of these receiving stations are situated in coastal areas, acquiring passes covering shelf and slope waters that are of general interest to the oceanographic community. The R2HA2 Working Group has been set up to locate these distributed data, re-process with a community-consensus algorithm and store in a consistent format on modern media, to rescue them for research on long-term SST changes.

Lake Surface Water Temperature Working Group (LSWT-WG)

Lakes strongly modify the structure and the transport properties of the atmospheric surface layer above.

LSWT-WG coordinates international activities related to the treatment of Lake Surface Water Temperature and lake/land masks in GHRSST data products. Although there are important differences between oceanographic and limnological processes, there is a strong overlap of interests between those who measure water surface temperatures in these different environments. This has led GHRSST to form a working group to foster collaboration in this field of study.

The impact of LSWT is an issue for NWP systems. The interaction of the atmosphere with the underlying surface is strongly dependent on the surface temperature and its time-rate-of-change. Most NWP systems assume that the water surface temperature can be kept constant over the forecast period. This assumption is doubtful for small-to-medium size relatively shallow lakes, where the diurnal variations of the surface temperature reach several degrees. A large number of such lakes will become resolved-scale features as the horizontal resolution is increased. Apart from forecasting the lake surface temperature, its initialisation is also an issue.

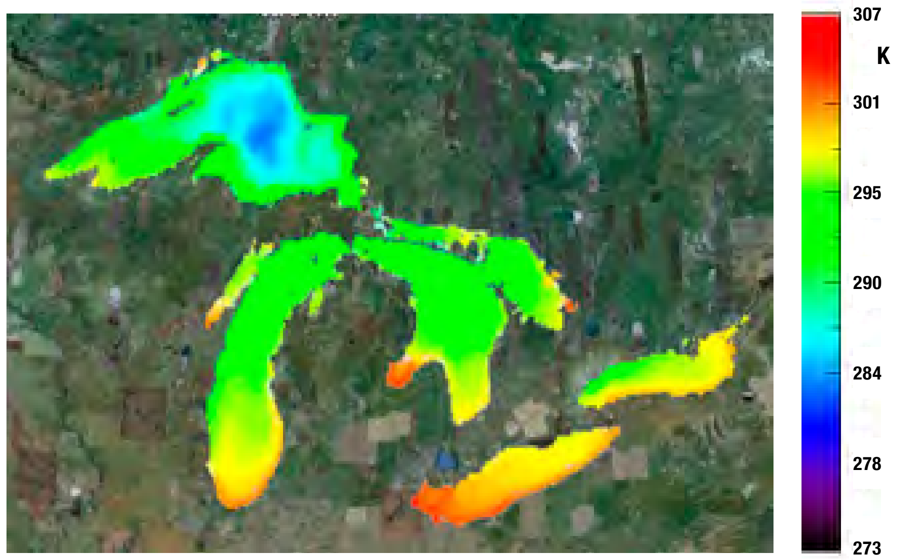


Figure 13: Example of ARC-Lake LSWT climatology for the Great Lakes: spatially resolved climatology for the period 1st July to 15th July. Figure courtesy of The University of Edinburgh/ESA.

Reanalysis Technical Advisory Group (RAN-TAG)

RAN-TAG coordinates the global production of SST Climate Data Records (CDR) extending back to 1981. Through interactions with the GCOS SST and Sea Ice Working Group, ESA's Climate Change Initiative, the NOAA CDR Program, and members of the global climate SST community, the RAN-TAG has developed a comprehensive SST Essential Climate Variable (ECV) Framework for SST (see figure below). This framework reflects the fact that no single SST CDR product can meet all user needs and illustrates the requirement for a coordinated suite of SST CDR products instead. The RAN-TAG works to ensure that all GHRSST operational and delayed mode data sets are archived and made available at the NODC LTSRF, and that the many groups developing CDRs around the world work together smoothly and efficiently, minimising unnecessary duplication of effort and sharing scientific advances and product development experience.

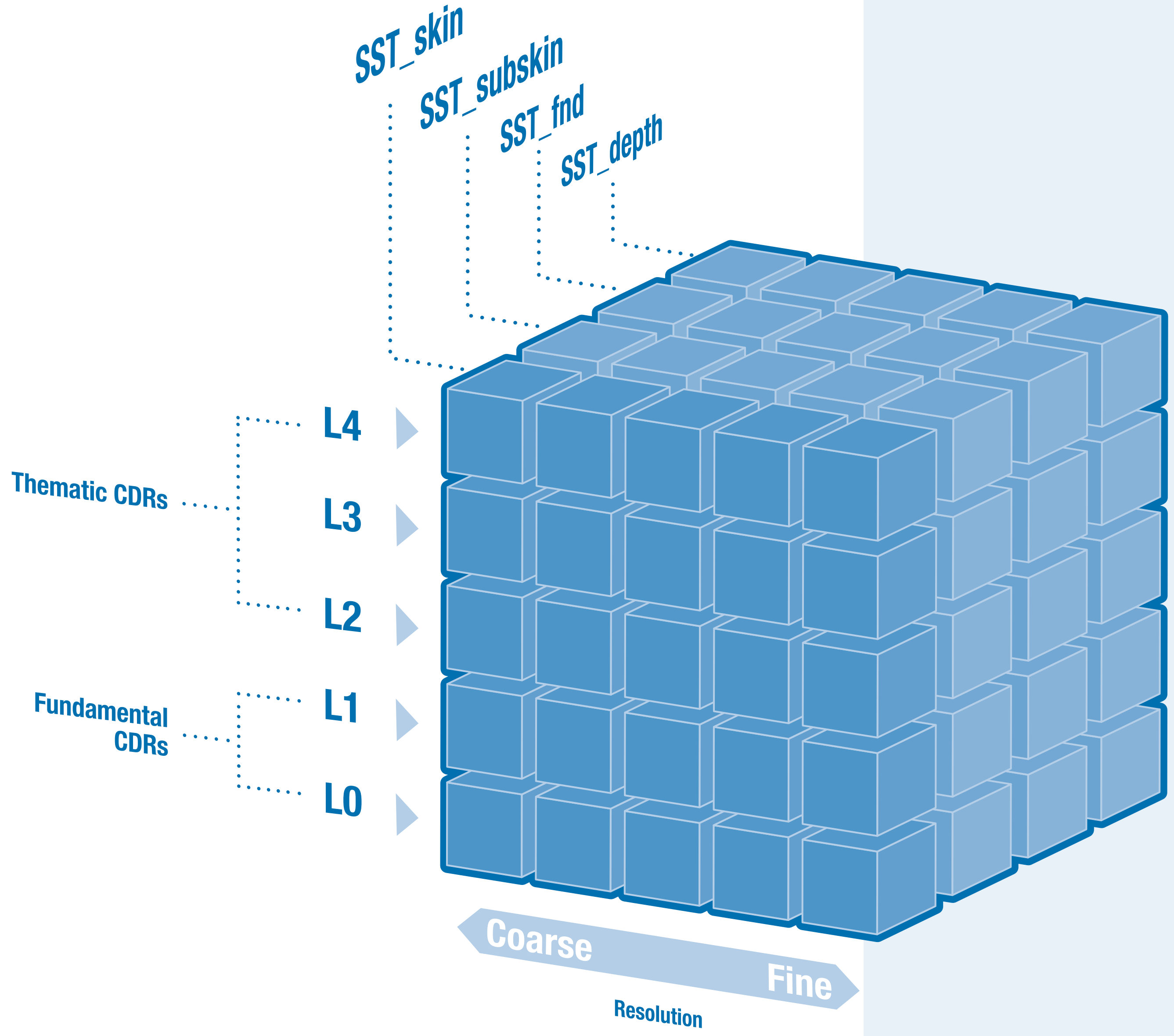


Figure 14: The SST - ECV Product Framework, with dimensions of SST type, processing level, and spatial-temporal resolution from coarse (25 km, daily) to fine (less than 1 km, sub-daily). User requirements, observing technologies, and the intricate SST structure of the surface ocean drive the need for multiple products. No single SST CDR can meet all user needs.

APPLICATIONS

SST is a key parameter for ocean and atmosphere modelling, where especially weather forecasters rely on the timely delivery of high resolution SST.

Numerical Weather Prediction (NWP)

SST is an important boundary condition for the uptake of heat and moisture. SST provides the forcing for shower formation, affects the formation and subsequent evolution of tropical cyclones, convection and thunderstorms, sea fog and sea breezes. A high spatial and temporal resolution is required due to the nonlinearity of the physical processes involved. The high resolution GHRSST data allows better resolution of SST gradients and related wind stresses. GHRSST is working together with many meteorological services to ensure that their user requirements are met on an operational basis.

SST is also used to help upper air forecasters at the World Aviation Forecast Centre (WAFC).

Seasonal Forecasting

SST anomaly patterns change relatively slowly and can be reasonably well predicted up to 6 months ahead or longer in some regions of the world. The relationship between seasonal weather averages and SST anomaly patterns is strong over large parts of Africa. Strong signals are associated with the El Niño phenomenon in the tropical Pacific, and somewhat weaker links between SST anomalies and seasonal weather are found in many parts of the globe.

Ocean modelling and forecasting

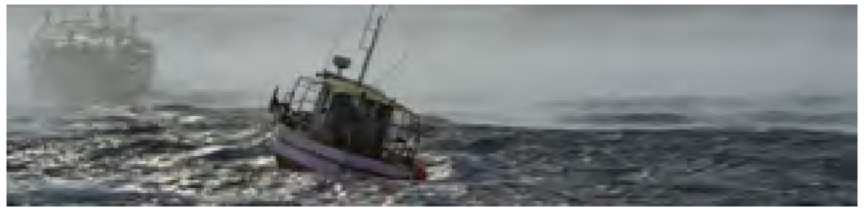
SST is required by marine ecological research and monitoring, as SST is a relevant parameter for habitats, from plankton distribution and algae blooms to fishing grounds and marine sanctuaries. Especially coral reefs can be sensitive to small (< 1K) variations in SST.

Ocean models use SST to constrain the upper ocean circulation and the thermal structure. Related commercial and operational applications include diving, search & rescue, offshore oil drilling operations, oil and chemical spill drift forecasts, cable laying, cruise planning and ship-routing, with implications for tide predictions and operational wave forecasting.

GHRSST collaborates with operational ocean forecasting centers as well as marine science and operations projects to meet their user requirements and to foster GHRSST research which might be of benefit to such applications.

Climate variability and change

SST is one of the most important climate variables, with a history of measurement and analysis. The historical SST data record based on in situ measurements extends from about 1870, although considerable effort is required to quality control biases in the observations. Today, satellite data provide a unique and extensive source of global coverage SST observations. Interpreting the current SST satellite data and merging with existing in situ SST climatologies require considerable effort to ensure that biases due to the change in the observing system (e.g., coverage change, instrument drifts, calibration) are properly accounted for. GHRSST follows the guidelines set by the Global Climate Observing system (GCOS) and the World Climate Research Program (WCRP) to ensure that accuracy and stability of the GHRSST time series are well defined. Currently, GHRSST data are reanalysed for the purpose of climate research. SST is required for climate model initialisation, diagnostics and fundamental climate monitoring. Several key processes, like energy, moisture and greenhouse gas exchange (carbon dioxide) across the sea-air interface are processes inherently dependent on SST.



GHRSST PARTICIPATING INSTITUTIONS, MAJOR PROJECTS, AND SPONSORS

GHRSST largely operates as a community of scientists seeking to co-ordinate their common endeavour to the benefit of all.

"GHRSST activities" referred to within this brochure are financed by national and international agencies who directly fund the activities, without any management role by GHRSST. The Science Team and GHRSST working group members are supported by diverse agencies.

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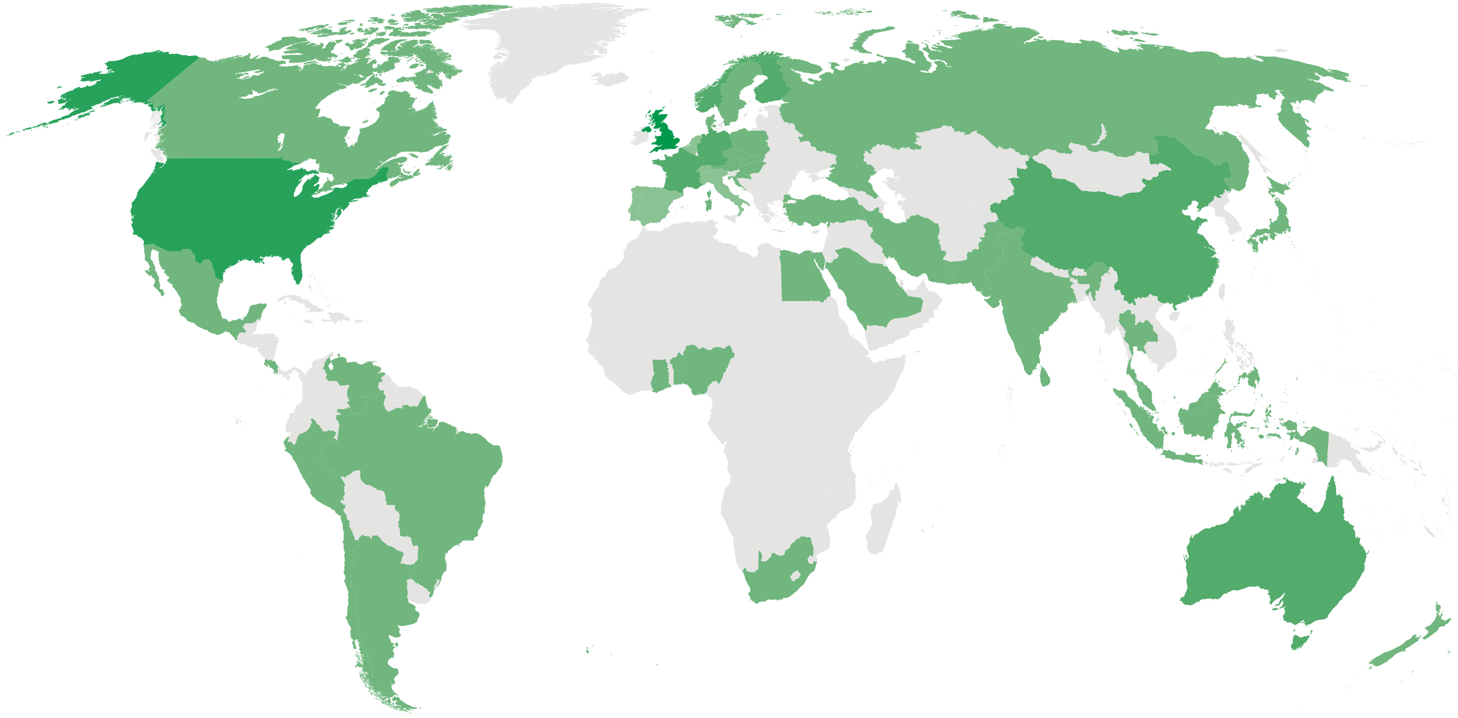

Figure 15: GHRSST related activities are distributed around the world (shades of green correspond to internet traffic at www.ghrsst.org in April 2011). Data provided by: Google Analytics.

Organizations associated with GHRSST:

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HL-TAG	High Latitude Technical Advisory Group **www.ghrsst.org/ghrsst-science/science-team-groups/hl-tag**	Dr Jacob Høyer Danish Meteorological Office	jlh@dmi.dk +1 45 391 5720
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