OSI-SAF SST Global applications

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ABSTRACT

The unique sea surface temperature (SST) data products provided by the OSI-SAF form a core input to the Global Ocean Data Assimilation Experiment (GODAE) High-resolution SST Pilot Project (GHRSSST-PP). The primary aim of the Global Ocean Data Assimilation Experiment (GODAE) High Resolution Sea Surface Temperature Pilot Project (GHRSSST-PP) is to develop and operate a demonstration system that will deliver high-resolution (better than 10 km and ~6 hourly) global coverage SST data products operationally in near real time for the diverse needs of GODAE and the wider scientific community. A new generation of global coverage SST data products will be derived and served to the international user community by combining complementary satellite and in situ observations in real time. There are obvious synergy benefits to such an approach but their practical realisation is complicated by characteristic differences that exist between measurements of SST obtained from subsurface situ sensors, satellite microwave radiometers and, infrared radiometer systems. Furthermore, diurnal variability of SST within a 24 hour period, manifest as both warm layer and cool skin deviations, introduces additional uncertainty for direct inter-comparison and the implementation of data merging strategies.

This presentation will quickly review the data products and services of the GHRSSST-PP that are now being implemented by regional projects in Europe, USA and Australia. The remainder of the presentation will discuss the present and future role of the OSI-SAF products within the framework of the GHRSSST-PP.

1 INTRODUCTION

It is only in recent times that nations have begun to recognise the size, diversity and complexity of the ocean industries and their importance. It is estimated that over 90% of world trade is carried over the ocean. Oceanographic research has grown significantly in response to developing concerns over the role of the oceans within the climate system and the growing demand for metocean data as more industries move offshore. Major growth in the marine industry is expected in the sectors of:

- marine transportation;
- the leisure industries;
- marine foods and services;
- mineral exploitation;
- underwater vehicles;
- renewable energy;
- the ports industries
- offshore oil & gas industry;
- submarine cables;
- marine biotechnology;
- marine information technology;
- Research and development.

The Global Ocean Data Assimilation Experiment (GODAE) is an international project to develop operational global ocean analysis and prediction systems to serve these industrial sectors, to save lives and property and to further oceanographic research and development. The vision behind GODAE is that these societal and economic advantages cannot be realized without implementing the concept of:

"A global system of observations, communications, modelling and assimilation, that will deliver regular, comprehensive information on the state of the oceans in a way that will promote and engender wide utility and availability of this resource for maximum benefit to society."
Through the period 2003-2007, through international co-operation, GODAE products, services and activities will demonstrate the benefits and utility of global ocean data and forecast products.

Within GODAE, one of the most important dependencies is on sea surface temperature (SST) products that are 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. In addition, they should properly address the difficult issue of SST at the sea ice edge. In 2000, no SST products could satisfy these requirements for the global domain.

As a direct response to this situation, the international GODAE steering team (IGST) initiated in 2000 a GODAE High Resolution SST Pilot Project (GHRSST-PP). The GHRSST-PP is based on a distributed system in which the data processing operations that are necessary to operationally generate and distribute high resolution SST data sets having global coverage are shared by Regional Data Assembly Centres (RDAC). RDAC ingest, quality control and merge existing satellite and in situ SST data sources that are then used together to generate regional coverage quality controlled SST data products to the same specification (called L2P products), in real-time. RDAC data products are then assembled together at Global Data Analysis Centres (GDAC) where they are integrated and analysed to provide L4 global coverage combined analysis products. Data products are served to the user community via dedicated applications and user services tailored to operational and scientific user requirements. Figure 1 shows the distributed system (called the Regional/Global Task Sharing (RTGS) approach) that is being implemented by the GHRSST-PP.

Figure 1. The Regional/Global Task sharing (RTGS) distributed implementation of the GHRSST-PP. Arrows indicate the flow of data.

Five RDAC projects now are at various stages of implementation in Europe, Australia, Tropical regions (French SEASNET program), USA and Japan. Each RDAC produces data products to the same specification in terms of quality control, auxiliary data and error estimates based on the GHRSST-PP Data Processing Specification (GDS, Donlon et al., 2004). Common format (netCDF based) observational data products (called L2P) are generated for SST data sets provided by data providers - including the OSI-SAF. GHRSST-PP L2P data products do not alter the provided SST data themselves but complement these observations by (a) providing a extensible common interface format data set that is internet ‘aware’ (appropriate for Live Access Server applications amongst others) and (b) adding value through metadata and
auxiliary fields that greatly aid the application and interpretation of the SST observations. A L2P data record, provided for every pixel in a L2P data product, includes the native (can be either swath or gridded) SST, an estimate of the bias error and standard deviation of error based on a large matchup database of co-located satellite and in situ data (see below), surface wind speed, aerosol optical depth (AOD), surface solar radiation (SSI), sea ice (SI) concentration, time of observation and a set of quality control flags. L2P data products provide the basic data product of the GHR SST-PP from which all others are generated including L4 analyses that capitalise on the synergy of complementary satellite observations to produce combined SST analysis product. Figure 2 shows in schematic form the basic passage of satellite SST data from satellite data products provided by agencies in a varied format with limited error estimates through to observation and analysis products in a common format.

The generation of an international common format data product is extremely important as this enables user communities to invest in the generation of data access and manipulation tools that, through the GHR SST-PP, can make full use of all satellite data. This is especially true of operational National Meteorological Services (NMS) where even small code changes in an operational system constitute a significant investment. In summary, the GHR SST-PP processes SST data derived from several different satellite systems into a set of data products that represent the best measure of SST, presented in a form that can be assimilated into forecasting models.

Figure 2 The data processing strategy of the GHR SST-PP. Complementary satellite and in situ data of varied format and with limited error estimates, if any, are merged together to provide analysis products. Data are first quality controlled and error estimates added along with several other auxiliary fields to provide observational data products in a common netCDF data format.

2 APPLICATION OF OSI-SAF PRODUCTS WITHIN THE GHR SST-PP

The Medspiration Project is a European initiative funded by the European Space Agency (ESA) to provide a GHR SST-PP RDAC for Europe. It has implemented the GDS system for the Atlantic Ocean and European shelf seas providing L2P products to European users and the GHR SST-PP in an RDAC function. Full details of the Medspiration project can be found at http://medserve.soc.soton.ac.uk. A primary input to the European RDAC are OSI-SAF products including MSG-SEVIRI SST, AVHRR, MSG-SEVIRI Surface Solar Irradiance (SSI) and more recently OSI-SAF sea ice concentration. Until recently it was not possible to consider the OSI-SAF sea ice products due to the limited northern hemisphere coverage. However, now that global coverage data products are available, the OSI-SAF sea ice concentration will be used within the GHR SST-PP. LML and North Atlantic Regional (NAR) product SST form a core input to the European RDAC system and provide the baseline SST products for all European users. Figure 3 shows an example MSG-SEVIRI L2P SST product generated by the Medspiration project based on an OSI-SAF LML input. The excellent performance of the MSG-SEVIRI system means that SST data are potentially available every 15 minutes for the entire earth disk that could provide significant information describing diurnal variability. However, managing such a large volume of data is a challenge for most user communities and instead OSI-SAF products provide a 3 hourly observational data set. For the purpose of the GHR SST-PP this is
acceptable in the sense that SST data products are available in an operational context) but far from optimal for the important study of diurnal SST variability. Ideally, ½ hourly or hourly SST from MSG-SEVIRI should be the baseline for the OSI SAF SST products derived from the MSG SEVIRI so that diurnal variations of SST can be handled properly. For example, the World Aviation Forecast Centre (WAFC) team based at the Met Office, Exeter UK, are extremely interested in SST hot spot maps in the tropics and Mediterranean area that could trigger Cumulonimbus activity (M. Allwright, WAFC, Personal communication). In addition, the GHRSST-PP has a dedicated diurnal warming technical advisory group tasked with providing the best method to account for diurnal variations in satellite SST. This is necessary so that an estimate of the Foundation SST (the SST free of diurnal warming and similar to that of the Mixed Layer temperature generally required by ocean forecasting models and analysis systems) can be made. This is a complex issue and work within the GHRSST-PP would be considerably enhanced if high temporal resolution SST data products could be made available from the OSI-SAF.

Within the GHRSST-PP system, L2P SST uncertainty estimation is based on matching satellite retrieved SST with in situ observations co-located in space and time to within 25 km of the in situ measurement and 6 hours temporal separation. A large matchup database of co-located data is generated for each satellite instrument which is periodically analyzed to derive a mean bias and standard deviation. In order to provide a more realistic uncertainty estimate, a proximity confidence value is derived for every SST observation based on the most likely source of error for a given satellite instrument. In the generic case of an infrared satellite retrieval, the most likely source of error is cloud contamination. A confidence value (on a scale of 1-5 (value 6 is reserved for a ‘cool-skin’ effect)), is assigned based on the distance to the nearest cloud in a given scene and the magnitude of anomaly defined against a coldest SST climatology (currently derived from NASA Pathfinder SST). Every pixel in a scene is assigned a proximity confidence value and, using the matchup database, a bias and standard deviation (SD) uncertainty estimate is derived for each proximity confidence value. These time-bound bias and SD values derived from the matchup database can then be assigned to every pixel in a given scene based on the proximity confidence value. This process is referred to as a Single Sensor Error Statistic (SSES) and provides an uncertainty linked to in situ observations (taken as ‘truth’) allowing GHRSST-PP products to enter the climate record which is also referenced to in situ measurements.

Figure 3 L2P SST derived from the OSI-SAF MSG LML product produced by the Medspiration RDAC (Medspiration Team).

Figure 4 shows the proximity confidence map generated for the MSG-SEVIRI SST data shown in Figure 3. Clearly seen in this example are high confidence values in cloud free regions and degraded confidence values in the proximity of clouds. Shown to the right are the SSES bias and SD estimates for each
confidence value (1-5 corresponding to cloudy through to excellent in the proximity confidence map legend) for the SEVIRI over a 6 month period showing how higher confidence values are associated with lower bias and reduced SD. While the SSES process is not able to account for all errors (particularly with microwave SST observations), it provides an optimised method for uncertainty estimation that is functional and far better than simply taking the latest published figures from ad hoc in situ validation studies. Furthermore, it is expected that as more experience is gained with the SSES process, better error estimates will be generated. This is a priority area of study for the USA RDAC project called Multi-instrument SST (MISST) sponsored by the US National Ocean Partnership Program (NOPP) and for the European MERSEA-IP EC integrated project tasked with defining the scope and content of operational oceanography within GMES.

Figure 4. L2P data proximity_confidence product produced from OSI-SAF SEVIRI LML product shown in Figure 3. To the right is the SST error plotted with the GHRSST-PP proximity_confidence values for the period 03/28/04 to 09/02/2004. (P. LeBorgne)

Figure 4 shows a global L4 SST analysis produced by the Met Office, UK in support of the GHRSST-PP based on Medspiration and in situ observations for the 28/02/2005 produced during a beta-test phase of the Medspiration system during February 2005. The analysis, called the Operational SST and Sea Ice Analysis (OSTIA) is a persistence based Optimal Interpolation scheme providing SST on a 1/20° global grid (~5km) and is produced each day. At present OSTIA uses fixed x and y correlation length scales (order 400km and 10km) in a two pass process that first computes synoptic scale innovations followed by mesoscale innovations (a future version of OSTIA will use dynamic correlation scales based on the approach adopted by the NOAA RTG_SST (Thiébaux et al, 2003) which provides a better approach to preserving SST gradients.
Figure 4. Operational SST and Sea Ice Analysis (OSTIA) prototype L4 product produced by the Met Office based on GHRSST-PP data products. Scale is in Degrees C. (M. Martin)

Figure 4 is the result of combined use of GHRSST-PP L2P data products generated for OSI-SAF LML and NAR SST products, TRMM TMI, EOS-AQUA AMSR-E and ENVISAT AATSR observations. The OSTIA system has been made possible as all of these products are provided in a common data format greatly enhancing their utility, requiring only a single read/archive software configuration. The impact of Medspiration L2P fields is shown in Figure 5 which maps the increments to the analysis computed from the Levitus SST climatology. Clearly seen is the region covered by the European RDAC (mainly dictated by the coverage of OSI-SAF SST LML products) where strong increments are seen – the large north-south bias is due to the slight seasonal mismatch between the monthly climatology and the observations. In all other areas of the global ocean, only in situ observations have been retained for comparison revealing the extremely limited data volume from this source of data. The benefit of satellite SST over limited in situ SST observations is clearly demonstrated by Figure 5 and in the coming 18 months the OSTIA system will be further developed to take full advantage of the common data format specification provided by GHRSST-PP RDAC and GDAC systems. It is hoped that EUMETSAT Polar System (EPS) data will be made available in GHRST-PP format so that EPS SST data can be used immediately within the OSTIA system.

Figure 5. SST Increments used by the Operational SST and Sea Ice Analysis (OSTIA) prototype on 1/02/2005. The Scale is in K and is the deviation from Levitus SST Climatology. The strong N-S impact in the Atlantic is due to the difference between climatology and the actual SST reported in Medspiration L2P
3 Future role of OSI-SAF products

The OSI-SAF currently provides a core input to the GHRSST-PP as a data provider of MSG-SEVIRI and AVHRR data products. Together these resources constitute baseline operational SST coverage of the Atlantic and European Seas. In addition, SSI and sea ice data products are also used as auxiliary fields within GHRSST-PP L2P products. In the future, the role of the OSI-SAF is expected to increase significantly following the launch and commissioning of the Initial Joint Polar System (IJPS) EUMETSAT Polar System (EPS). SST products derived from EPS Advanced Very High Resolution Radiometer (AVHRR/3) and the Infrared Atmospheric Sounding Interferometer (IASI) will provide global coverage products that will, for the first time, provide a European global coverage SST measurement capability. The activities of the GHRSST-PP are providing complementary user community application development (e.g., the Met Office OSTIA, MERSEA-IP, MISST) in anticipation of the new capability provided by the EPS. In this sense, the GHRSST-PP Science Team request that the L2P data format is considered as a basic output format for both EPS AVHRR and IASI SST measurements – ideally managed through the OSI-SAF.

In the near future global coverage OSI-SAF sea ice concentration data sets will become also become a core input to the GHRSST-PP. Sea ice observations from space demand careful quality control and data processing which requires both capability and experience. The OSI-SAF sea ice data products and scientific team provide one of the best sea ice data sets available in an operational context and are thus invaluable for the GHRSST-PP. Full use of OSI-SAF sea ice concentration fields will be made by the GHRSST-PP.

It is expected that the L2P netCDF format will be refined to definitive state based on 12 months of application and development at the next GHRSST-PP International Science Team meeting, Met Office, Exeter, UK 16-22nd May 2005. Given the large (~€10 million) investment already committed by agencies within the GHRSST-PP, the OSI-SAF is urged to consider the operational sustained production of SST data products in the GHRSST-PP L2P data format. This format has been developed by an international team of experts actively engaged in the generation and application of satellite SST data products and represents a format that is easy to use, self describing, extensible, and contains content that can satisfy the widest range of application scenarios. In return, EUMETSAT and the OSI-SAF can expect a larger and more diverse community using EUMETSAT SST data products. Furthermore, if the L2P format is adopted for EPS AVHRR and IASI SST products, it is obvious that the user application community will already be fully prepared to take advantage of these new data sets immediately.

The need for high temporal resolution observations from the MSG-SEVIRI instrument cannot be over emphasised. While there must be a good reason for the OSI-SAF to provide SST data from SEVIRI at a reduced spatial and temporal resolution compared to that generated by the satellite instrument itself (data overload for users), there is an acute need to provide full resolution (5km) SEVIRI observations capable of resolving diurnal variability (driven by a strong user requirement from both the operational meteorological forecasting community (WAFC) and ocean forecasting community). As user requirements develop and technology improves data transmission and storage solutions users can manage much larger data sets than ever before in a real time mode. The GHRSST-PP represents a large international community that requests hourly or (better still) ½ hourly SEVIRI SST products to be made available to the community as soon as possible.

The GHRSST-PP framework and data processing specification (Donlon et al., 2004) provide an ideal application of OSI-SAF products. A large scientific and operational user community is now building within the GHRSST-PP that is tuned to the data products provided. As OSI-SAF products already form a major input to the GHRSST-PP RDAC service, it would be extremely beneficial for the OSI-SAF, in a cross-SAF project, to consider production of complete GHRSST-PP L2P specification products. This would maximise the collaboration between SAF and at the same time provide an operational service within the international GHRSST-PP Regional/Global Task Sharing Framework (note that discussions are now in progress to develop L2P products from the recently launched Japanese MTSAT-1R imager within the GHRSST-PP framework). Such an activity at this time would allow full integration of EPS SST data sources.

4 Summary

The GHRSST-PP is a large international project that provides a framework for the exchange, processing and application of satellite SST. It has over €10 million invested by projects in Europe, Japan, Australia France.
and the USA. The GHRSST-PP is making full use of OSI-SAF outputs and recognises the importance of the operational service provided. OSI-SAF SST, sea ice, surface solar irradiance and potentially wind speeds are all operational inputs to the GHRSST-PP and constitute the core data sets for the European GHRSST-PP RDAC service. GHRSST-PP intends to make full use of OSI-SAF sea ice concentration products now that global coverage has been achieved. For studies of diurnal SST variability, hourly products of SST and SSI at full SEVIRI and AVHRR native resolution are requested in L2P format. Operational agencies are now engaging with GHRSST-PP as it transits to sustained operations as the user requirement is evolving rapidly (e.g., global 5km SST analysis at the Met Office). For the future, the GHRSST-PP International Science Team request that OSI-SAF consider GHRSST-PP L2P format and methods for the EPS SST products derived from IASI and AVHRR. This would allow users to be fully prepared for the application of these data using a standard set of well documented I/O utilities that are common to all satellite SST data sets with obvious benefits to EUMETSAT and the application community through a more flexible approach that will allow the OSI-SAF a more natural way to explore and work with new users.

At the OSI-SAF workshop Mr Schueller noted that ‘...cross linking of SAF operations need to have a better dialog, cross link based on user needs...’; GHRSST-PP L2P products arguably provide an ideal basis for a cross-SAF activity integrating SSI, AOD, sea ice, SST and surface ocean winds into a single products requested by a large international user community. The GHRSST-PP urge the OSI-SAF and EUMETSAT to consider these recommendations as part of the refinement required in the development phase prior to the Full Operations Phase in 2007.

References