Report for the Reanalysis Technical Advisory Group (RAN-TAG)

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Executive Summary
The GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP) has been established to provide international focus and coordination for the development of a new generation of global, multi-sensor, high-resolution (better than 10 km), sea surface temperature (SST) products provided in real time (6 hourly). Its primary aim is to oversee the development, timely delivery, assembly and processing of high-quality, global scale, SST products at a fine spatial and temporal resolution, for the diverse needs of GODAE and the wider scientific community.

The GHRSST-PP Reanalysis Technical Advisory Group (RAN-TAG) is the formal GHRSST-PP body that is responsible for the scientific and operational methods and algorithms used to generate delayed-mode GHRSST-PP data products suitable for use as climate data records. This document describes the working recommendations that have emerged from discussions of the RAN-TAG following the initial GHRSST-PP reanalysis data product specifications that arose from the first four GHRSST-PP Workshops. They constitute a "consensus opinion" of the GHRSST-PP community and form the basis of reanalysis procedures that will be implemented at GHRSST-PP Global Data Analysis Centres (GDAC) and Regional Data Assembly Centre (RDAC) facilities that exist within the global/regional task sharing model that forms the basis of the GHRSST-PP Implementation Plan.

Further information, including all reference material, can be found at the GHRSST-PP international Project Office web site: http://www.ghrsst-pp.org.

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1. Introduction

While the primary function of the GODAE High Resolution Sea Surface Temperature (SST) Pilot Project (GHRSST-PP) is the development of real-time SST products, it is widely appreciated that satellite datasets produced in such operational settings generally fail to provide the most highly accurate and consistent time series information possible. Experience with the Advanced Very High Resolution Radiometer (AVHRR) sensor on board the NOAA polar orbiters illustrates this problem. Although real-time SST products have been derived for years from the AVHRR, discrete changes to the processing algorithms result in inconsistent time series unsuitable for use in longer term or climate studies. These problems were addressed by the NOAA/NASA AVHRR Pathfinder Project, which is now on its fifth major reprocessing (Pathfinder v5.0, RSMAS/NODC). Other satellite sensors have similar reprocessing programs in place; SeaWiFS and MODIS/Terra have now completed several reprocessing cycles. Reprocessing efforts like these are required to attain the accuracies needed for climate and other long term applications. Target accuracies are on the order of 0.3 K absolute and 0.1 K relative, with a temporal stability requirement of 0.01 K/decade.

Based on these experiences, the GHRSST-PP Science Team initiated a Reanalysis (RAN) program whose goals are to produce delayed-mode products of higher accuracy and consistency than the real-time SSTs by taking advantage of additional delayed mode data streams that cannot be used by the operational real time system (e.g., MODIS), to link the RAN products to existing longer-term SST analyses, and to enable a reprocessing capability so that future users of the data can easily reprocess or utilize the data. As such, the RAN plan is as much about establishing a *data processing and management system* as it is about *creating SST products.* The GHRSST-PP RAN Technical Advisory Group (RAN-TAG) is the formal GHRSST-PP body that is responsible for the scientific and operational methods and algorithms used to generate delayed-mode GHRSST-PP data products. The delayed mode products will be suitable for use as climate data records, an emerging concept in environmental data management which dictates long-term accuracy and consistency (*e.g.* NRC, 2000)

This document describes the working recommendations and basic GHRSST-PP RAN strategy that has emerged from discussions of the RAN-TAG following the first four GHRSST-PP Workshops. They constitute a "consensus opinion" of the GHRSST-PP community and form the basis of the RAN procedures that will be implemented at GHRSST-PP Global Data Analysis Centres (GDAC) and Regional Data Assembly Centre (RDAC) facilities that exist within the global/regional task sharing model that forms the basis of the GHRSST-PP Implementation Plan. Following this introduction and the basic terms of reference in Section 2, the characteristics of the RAN products to be developed are identified in Section 3 and the RAN concept of operations is described in Section 4.

2. RAN-TAG Terms of Reference

The following Terms of Reference were agreed for the RAN-TAG (Annex I):

a) Based on the conclusions of the GHRSST-PP Workshops, develop a consensus methodology that can be implemented within GDAC facilities providing global coverage Level 4 (L4) SST_{fnd} RAN data products in delayed-mode;

b) Follow and conform whenever possible to the Recommended GHRSST-PP Data Processing Specification (GDS, GHRSST/17) and the GHRSST-PP Development and Implementation Plan (GDIP, GHRSST/15) definitions and policies;

c) Work with specific applications of RAN data products and act on any feedback;

d) Form and operate an international panel to develop and implement the RAN system, including its establishment at a GDAC. This panel should address (a) RAN product format and characteristics; (b) product validation protocols based on GHRSST-PP diagnostic data sets; (c) implementation of the RAN system at the GDAC data product computational facility (DPCF); (e) data archive of RAN products; and (d) suitable metrics to assess the performance of the RAN products and RAN system;

e) Review and assess proposals for improvements to the RAN methodology and decide if and how such improvements should be incorporated. It is assumed that a primary force in updating RAN methodology will be changes and improvements to the real-time GHRSST-PP products based on the GDS;

f) Work with GHRSST-PP RAN users and report on the progress of User Applications and Services (AUS) activities using GHRSST-PP RAN data products;

g) Provide scientific guidance to, and as appropriate, receive advice from, the GHRSST-PP Science Team, RDACs, and GDAC on the scientific and technical issues associated with the implementation and operation of the RAN system and on the use of GHRSST-PP RAN products by GODAE and other users;

h) Provide advice and guidance on scientific and technical innovations relevant to the GHRSST-PP;

i) Provide regular reports, through its interactions and metrics implemented by the AUS and GDAC, on progress to the GHRSST-PP Science Team.

3. Reanalysis SST Product Characteristics

The RAN product characteristics have been defined as follows:

a) Delivery timescale: Approximately one year lag time will be the delivery target. It is believed that shorter lag times (order days to weeks) will not provide sufficient improvements in associated data availability (*e.g.*, additional buoy measurements) or methodology to warrant reprocessing the GHRSST-PP data stream through the RAN system, so delivery time scales on the order of one year lag have been established.

b) Error statistics: Standard deviation and bias values will be determined for each output grid point. These statistics will be generated using GHRSST-PP diagnostic data sets, matchup databases (MDB), and comparisons with other SST data sets.

c) Spatial characteristics: Global coverage RAN L4 SST_{fnd} products will be produced on the same operational grid used in the real-time products. This grid is currently specified in the GDS, Work Package ID4 and Appendix A 1.3, to be 1/12° latitude x longitude. The RAN will not address regional 1/48° Ultra-High Resolution products during its initial implementation. The WGS84 datum will be assumed to facilitate GIS-use of RAN products, following the GDS specifications. The retrospective nature of the RAN system permits a greater use of computing resources and longer time requirements than may be suitable for real-time production, so higher resolution spatial grids may be pursued if they are determined by the RAN-TAG to be useful and feasible to create.

d) Temporal resolution: One output L4 product will be produced per Analysis Product Processing Window (APPW). The RAN APPW may differ from the real-time APPW established in Table 2.3.1 of the GDS if deemed necessary by the RAN-TAG, but is expected to remain at approximately 24 hours. Coarse temporal averages (*e.g.* monthly) may also be generated for comparisons to existing climate data sets.

e) Temporal Stability: Given a global surface temperature change signal of 0.1K/decade, global average temperature time series should be stable to much better than 0.1K/decade to be able to distinguish the signal from the instability of the time series. Assuming an error of 10% of the signal to be negligible, it is prudent to aim for a stability of 0.01K/decade in records of global mean temperature to enable the monitoring of evolving climate change.

f) SST product types: The RAN system will produce L4 SST_{fnd} along with offsets that can be applied at four discrete times of the day (currently established to be 00:00 , 06:00 , 12:00, and 18:00 UTC) to determine the SST_{skin} at each pixel. These offsets will be determined using the diurnal model specified in the GDS.

g) Data format: The netCDF format will be adopted following the L4 GDS product specifications. A variety of tools such as OPeNDAP and Live Access Server may be implemented to provide output in a wide array of formats suitable to many types of users.

h) Metadata: The CF metadata convention will be followed.

4. RAN Concept of Operations

The RAN concept of operations is designed to address the three key goals of the GHRSST-PP RAN. These goals will be achieved through a systematic leveraging of knowledge and experience gained during the course of real-time GHRSST-PP processing and through related satellite reprocessing efforts like those carried out at NASA/JPL and GSFC, the University of Miami, and NOAA/NESDIS/NODC. In priority order, these goals are to:

1) Produce delayed-mode products of higher accuracy and consistency than real-time SSTs by taking advantage of delayed mode data sets and techniques not implemented by the GHRSST-PP real time operational processor;

2) Link the RAN products to other climate data records and longer-term SST analyses (e.g., HadISST, ERSST);
3) Enable a reprocessing capability so that future users of the data can easily reprocess or utilize the data.

The first goal of creating an improved delayed mode suite of products will be achieved by applying techniques and data not available to real-time analyzed products. For example, the Pathfinder process calculates monthly algorithm coefficients using in situ matchup data from the present month, two months prior, and two months following the month in question to better account for fluctuating atmospheric interference. Clearly, this is a technique that cannot be applied in real-time production. Such techniques, however, may be applied in the RAN system. It is expected that the RDACs, while providing real time MDBs and L2P products, may also produce delayed-mode versions containing improvements such as more complete and consistent L2P data, more complete and better quality controlled MDBs, better Sensor Specific Error Statistics (SSES), and other improvements not possible in real time. Generating these improved, delayed mode L2P data streams is the responsibility of the individual RDACs, and it is expected they will strive to create them when possible. These delayed mode products will be utilized in the RAN system operated at the GDAC facilities. Additionally, any improvements made to the GHRSST-PP real-time analysis procedures needed to generate L4 products from L2P data will be evaluated and retrospectively applied on a regular basis to the entire record, thereby providing a consistently processed time series suitable for use in climate and trend analyses. Therefore, a fundamental driving force in improvements to the RAN products will come from changes made in the real-time analysis products. The reprocessing frequency as mentioned in the RAN product characteristics section is expected to be on the order of once per year, but analysis of expected improvements will be made before committing the extensive resources required. The GHRSST Diagnostic Data Sets (DDS, GHRSST/14) will provide critical information needed to evaluate any algorithm changes. A summary list of the key areas in which the RAN system is expected to make improvements over the real-time products is presented below:

1) Use of delayed-mode L2P products that do not make it into the real-time processor, such as MODIS data, for example. Other examples would include L2P files that did not arrive in a timely fashion to the real-time processing system due to occasional system failures such as network outages and disk failures.
2) Use of reprocessed L2P data steam provided by RDACs.
3) Use of improved MDBs with better quality control and more observations than were available in real-time.
4) Use of techniques which require data from future observations, such as the Pathfinder coefficient generation scheme described above.
5) Use of improved SSES, generated using new techniques or improved MDBs.
6) Use of new optimal analysis procedures for creating L4 products, or procedures which are computationally too demanding to be used in real-time environments.
7) Use of improved diurnal variability models or offset parameters for the calculation of SST_{skin} from $SST_{fnd.}$
8) Use of a consistent set of procedures on the entire time series.

The second goal of linking the RAN products to other existing longer-term satellite and historical SST analyses will be achieved through a careful accounting of biases between the various datasets. Overlapping records will be especially useful in this effort. Successful linking may require a processing of satellite data records collected before the GHRSST-PP period, but using GHRSST-PP techniques. Such an extension of the GHRSST-PP RAN record to include periods predating the GODAE Demonstration and Implementation Phases would serve to not only provide greater periods of overlap with other SST analyses but would also increase the usefulness of the RAN record itself. While extension backward in time is not a priority, it may be possible after demonstrating the RAN system on the GHRSST-PP period.

The final goal of enabling future reprocessing arises from past experience that shows these data sets will be used in many unforeseen ways by future generations and may be improved upon by methods and techniques not yet possible or imagined. This goal will be achieved by providing efficient archive and access capabilities to the original data streams through the GDAC and RDAC facilities, by developing standards compliant metadata as specified in the GDS, and through careful documentation of all analysis methods and changes.

5. References

GHRSST-PP/14. Draft GHRSST-PP High Resolution Diagnostic Data Set Implementation Plan, available at http://www.ghrsst-pp.org, 2004.

GHRSST-PP/15. The GHRSST-PP Development and Implementation Plan, available at http://www.ghrsst-pp.org, 2004.

GHRSST-PP/17. The GHRSST-PP Data Processing Specification v1.0, available at http://www.ghrsst-pp.org, 2004.

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