

**DAILY REAL-TIME, GLOBAL SEA SURFACE TEMPERATURE -
High-Resolution Analysis: RTG_SST_HR**

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ABSTRACT

This note describes changes to the daily real-time, global sea surface temperature analysis (RTG_SST) on a $\frac{1}{2}$ degree latitude, longitude analysis, which was originally implemented on 30 January 2001. The new analysis, designated as RTG_SST_HR, was implemented into operations on 27 September 2005 with an increased horizontal resolution at $\frac{1}{12}$ degree. The original RTG_SST analysis continues to run in operations to allow for comparisons by users. Each daily product uses the most recent 24-hours of *in situ* and satellite-derived AVHRR ocean surface temperature data and provides a global SST analysis. The new SST's are further based on the new physical retrievals system developed with the Joint Center for Satellite Data Assimilation (JCSDA). The final part of the analysis system is to run a separate evaluation program that follows the completion of each analysis. The new RTG_SST_HR shows a small consistent improvement over the original RTG_SST in the RMS errors against in-situ data. And there is a reduction of the day to day noise in the analyses, especially in the tropics. But, it is evident that the depiction of smaller scales of the analyses are limited because of the obstruction of clouds.

1. Introduction

The daily Real-time Global Sea Surface Temperature analysis (RTG_SST) was implemented on January 30, 2001 (Thiebaux *et al* 2003). The RTG_SST was developed as a daily blended analysis using in-situ and infrared measurement from one NOAA satellite (currently its NOAA-17) from the Advanced Very High Resolution Radiometer (AVHRR) SST data on a ½ degree (latitude, longitude) grid. At that time, atmospheric and ocean forecast modeling systems were being developed at higher-horizontal resolutions, so it was desirable that the sea surface temperature (SST) analyses used as surface boundary conditions should have higher-horizontal resolution. But initially, many of the existing SST analyses were based on coarse horizontal resolution (i.e., on a 1 X 1 degree latitude and longitude rectangular grid) with large time averages (1 week). The present RTG_SST has run reliably over the past six years, and has been used by the regional North American Model (NAM; Black 1994) at the National Centers for Environmental Prediction (NCEP) and by the global forecast model at the European Center for Medium Weather Forecasting (ECMWF).

Several studies have examined the RTG_SST and the results indicate that the higher resolution contributes to a positive improvement over lower resolution analyses. Chelton & Wentz (2005) have shown the RTG_SST depicts gradients of ocean features better than the lower resolution (time & space) Reynolds-Smith SST. In-situ data contributes a slight improvement when compared to another SST analysis at an even higher horizontal resolution, but ingesting only satellite SST. . Kara and Barron (2007) compared the RTG_SST to a similar analysis, the 1/8 Degree Modular Ocean Data Analysis System (MODAS) of the Naval Research Laboratory, using only AVHRR SST data. Their results showed the two SST analyses to be comparable. Unfortunately a common concern in these studies is the limitation of the accuracy of analyses based on AVHRR data because the AVHRR sensor can not see through clouds. So good cloud detection is critical for accurate retrievals, which is not always the case. In addition, the persistence of large areas of cloudiness is common property of weather systems (storms, fronts and hurricanes) over the ocean. The result is that many ocean areas can go long periods without being observed with AVHRR satellite data.

But the RTG_SST analysis has other limitations, due to its resolution (1/2 degree), in resolving the detailed

temperature structure of ocean features (i.e. Gulf Stream), coastal zones bays and inland lakes. The NCEP's Global Forecast System (GFS) still uses the Reynolds-Smith SST (1994). Tests of the GFS using the RTG_SST showed that its forecast skill was slightly degraded, when compared to the GFS using the Reynolds-Smith SST. It was found that the RTG_SST day to day difference fields are noisy (as much as 0.5°C–1.0°C) which is likely due to degraded accuracy, inadequate cloud detection and irregular distribution of the various data sets. Satellite SST retrievals are processed by the U. S. Navy SST Shared Processing Center (SPC) at the Naval Oceanographic Office (May *et al*, 1998) and distributed to NCEP in near-real time. Those SST retrievals are based on regression equations which relate satellite brightness temperature to SST values by using drifting buoys (McClain *et al* 1985, Walton *et al* 1997).

But, because of the RTG_SST day to day noise, an alternative SST retrieval method was developed at NCEP through collaboration with the Joint Center for Satellite Data Assimilation (JCSDA). This SST retrieval algorithm is based on variational principles with a radiative transfer model(physical algorithm) which determines the SST increment to the SST first guess of the control variables using the previous day's SST analysis, the GFS model air temperature and mixing ratio (appendix 1). A cost function is defined to include: (1) control variables from the GFS and their first guess differences and (2) observed AVHRR radiances and the analyzed radiances. A derivation of the SST physical retrieval system is presented in the appendix by Li. The JCSDA physical retrievals show small positive improvements and a reduction of noise over the Navy regression derived SST.

A new higher resolution (RTG_SST_HR) analysis was developed and implemented September 27, 2005 for operational use at NCEP. The RTG_SST_HR runs on a 1/12 degree grid, by using *in situ* data and physical retrievals from both NOAA-17 and NOAA-18 satellite data (Gemmill, 2005). The original analysis package was upgraded to execute efficiently on multiple processors, rather than on one processor as in the original. The upgrade uses an MPI anisotropic recursive filter code (Purser *et al*, 2003) taken from the NCEP Grid-point Statistical Interpolation (GSI) analysis (Treadon *et al*, 2005). Table 1 presents a comparison of the original SST analysis system with the new upgraded system.

Table 1. A summary of the of the original and new daily SST analysis systems.

	RTG_SST	RTG_SST_HR
Implementation Date	January 31, 2001	September 25, 2005
Horizontal resolution	½ Degree latitude/longitude grid	1/12 Degree latitude/longitude grid
Satellite Data	NOAA 17 AVHRR	NOAA 17 & 18 AVHRR
Satellite Processing	Navy – Regression Retrievals	JCSDA – Physical Retrievals
<i>In situ</i> Data	Fixed buoys, drifting buoys & ships	Fixed buoys, drifting buoys & ships
Correlation Length Scale	450 km to 100 km	450 km to 50 km.
AVHRR Limitations	Can not see through clouds	Can not see through clouds
IBM Code Configuration	Executes on one processor	Executes on multi-processors

In summary the major upgrades are:

- 1) Increased grid resolution to 1/12 degree,
- 2) Data from two satellites – NOAA 17 and 18,
- 3) SST generated by the JCSDA physical retrieval system.
- 4) Decrease in the minimum correlation length scale to 50km.
- 5) New 1/12 degree land-sea mask

2. Description of RTG_SST_HR

Examples of the RTG_SST and RTG_SST_HR analyses are presented in [Figure 1a & 1b](#), and their anomalies in [figures 2a & 2b](#). In general it is difficult to determine much in the way of differences between the two analyses, the influence of climatology dominates. . The SST patterns appear extremely similar. Differences are more apparent in the anomalies where the climatology is removed.

The algorithm (Parrish 2004) starts with a first-guess analysis, which is the previous day's SST analysis with a one day climate adjustment. *In-situ* observations for the last 24-h and high-resolution (8 km) satellite retrievals are ingested next. The SST data from moored buoys are averaged over the 24-h period; while SST reports from ships and drifting buoys are averaged separately within each 1/12° x 1/12° grid box over the last 24-h. The satellite SST retrievals are generated within NCEP by using the JCSDA physical retrieval algorithm (See

appendix by Li). Satellite SST retrievals are corrected for their biases, before ingest into the analysis. This is based on creating an SST analysis on a 4 x 4 latitude, longitude grid using the previous 7 days of *in situ* data only (Reynolds & Smith, 1994, appendix). The satellite data bias correction for both the NAVY and JCSDA SST retrievals are shown in the panels in figure 3 a & b. Further the bias corrections are sub-divided by satellite retrievals: as day-time and night-time plot for each satellite (NOAA-17 and NOAA-18). It can be seen there is little concern for biases in the AVHRR SST based retrievals from either systems.

Where the satellite observes an ice cover exceeding 50 percent, the satellite derived SST values are rejected. The in-situ SST values are then computed from Millero's (1978) formula using the Levitus (1982) salinity climatology. The determination for sea ice concentrations are determined by Grumbine (1996) by converting satellite data from the Special Sensor Microwave Imager (SSM/I) to sea ice concentrations.

The high-resolution SST analysis is an iterative minimum of a two dimensional variational interpolation analysis based on an SST first guess and SST observations (Thiebaut et al, 2003, Equation A1, appendix). The analysis error correlation function $R(d)$ is given by:

$$R(d) = \exp(-d^2/\ell^2),$$

where d is the distance between data and analysis grid-point locations, and ℓ the analysis error length scale. Both d and ℓ are in km. The length scale ℓ varies from 50 to 450 km depending on the climatological SST temperature gradient (Smith & Reynolds, 1998). It is determined from the relation

$$\ell = 225/|\text{gradT}|, \text{ and is within limits of } 50 \text{ km} < \ell < 450 \text{ km}$$

where gradT is the climatology temperature gradient.

From the above relations, ℓ is on the order of 50 km in high surface temperature gradient areas (i.e., Gulf Stream or Kuroshio) and on the order of 450 km in small gradient areas (i.e. Sargasso Sea).

Following the completion of the analysis, a separate verification program is run, which is described in the next section (3)

3. Evaluation of the RTG_SST_HR

The new RTG_SST_HR has been evaluated by comparing it with the RTG_SST. Since one of the problems of the original RTG_SST was there were large day to day differences "noise" in the analyses, the first concern was to compare the day to day SST analysis differences for each of the analyses (figures 4a & b). The