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Subject: The Real-Time, Global Sea Surface Temperature Analysis: RTG_SST

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This is a new product

This bulletin, prepared by Dr. H. Jean Thiébaux, Mr. Bert Katz, Dr. Wanqiu Wang, and Mr. Lawrence D. Burroughs of the National Centers for Environmental Prediction, describes a new, real-time, global sea surface temperature analysis (RTG_SST). This product has been developed specifically for use by the NCEP Weather Analysis and Forecasting suite of models. Each daily product uses the most recent 24-hours of *in situ* and satellite-derived surface temperature data and provides a global SST on a 0.5° x 0.5° longitude/latitude (lon/lat) grid.

The RTG_SST was implemented on 30 January 2001 in a crisis mode, and now provides the sea surface temperature fields for the Meso Eta Model, formerly provided by the NESDIS 50 km satellite-only sea surface temperature analysis.

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The Real-Time, Global Sea Surface Temperature Analysis: RTG_SST[1]

by

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1. Introduction

During early to mid December 2000, the Meso Eta forecast model (Eta, Black 1994) produced solutions with more and deeper cyclogenesis and more frontal activity and precipitation along Atlantic Coast than either the Nested Grid Model (NGM, National Weather Service 1985) or the Aviation runs of the Global Atmospheric Model (AVN, Kanamitsu *et al* 1991; Caplan *et al* 1997). Both the NGM and the AVN use the Reynolds-Smith SST analysis (1994) which is on a 1^o x 1^o longitude/latitude(lon/lat) grid, while the Meso Eta used the NESDIS multi-channel SST (MCSST) analysis (McClain *et al* 1985) on a 50 km grid. With help from EMC's Ocean Modeling Branch (OMB), the sea surface temperature (SST) fields used in the models were compared. (See Fig. 1)

OMB verified that the NESDIS 50 km analysis of the Gulf Stream was warmer than either the Reynolds-Smith analysis or buoy data. Several small areas were 5 or more degrees too warm, compared to buoy reports. Problems with NOAA-14 satellite-derived SST's were implicated by NESDIS. On 20 December 2000, use of the NESDIS 50 km SST analysis in the Eta was turned off, and replaced with the Reynolds-Smith SST analysis.

The Eta produced poor guidance for the Washington, DC, and Baltimore areas for the winter storm of 30 December 2000. Figure 2 depicts the Eta 24-h forecast of 12-h accumulated precipitation (water equivalent) valid at 1200 UTC on December 30. It shows enough precipitation to have resulted in 5 to 6 inches of snow, which never materialized. A Tiger Team (an *ad hoc* committee of experts) was constituted to examine the Eta's poor prediction of precipitation for the 30th. Prior to the events above, OMB had been testing a new, real-time, global sea surface temperature analysis (RTG_SST). After study by the Tiger Team and discussions with NESDIS and EMC on 12 January 2001, it was decided that the RTG_SST with an inhomogeneous (variable) covariance function provided the best possible solution. The decision was made to replace the Reynolds-Smith SST analysis with the RTG_SST analysis for use in the Eta, in a crisis mode, on 30 January 2001. It is anticipated that it will also soon replace the Reynolds-Smith global SST analysis in the Operational Global Analysis/Forecast Systems.

2. Description of RTG_SST

The first version of the RTG_SST was developed by EMC's Climate Modeling Branch. Its code was modified and adapted to run on the IBM-SP computer by OMB. The new global sea surface temperature analysis is produced daily on a 0.5^o x 0.5^o lon/lat grid. The algorithm (Purser and Wang 2000):

- Uses as a first guess, the previous analysis, with one-day's climate adjustment (Smith and Reynolds 1998) added;
- Ingests only the last 24-h of in-situ observations and high-resolution (4 km) satellite SST

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retrievals with
  - SST reports from moored buoys averaged over 24-h intervals;
  - Satellite-retrieved SST values averaged within 0.5^o x 0.5^o grid boxes, separately for day- and night-retrievals;
  - SST reports from ships and drifting buoys not averaged;

- Calculates surface temperature for those grid-boxes where the satellite-observed ice cover exceeds 50% with salinity climatology (Levitus 1982) used in Millero's (1978) formula;

- Uses a variable length scale parameter (?) for the analysis correlation function: $\exp(-d^2/?^2)$, where d is the distance between data and analysis gridpoint locations, and d and ? are in km.
  - The length scale varies within 100 to 450 km, based on the climatological temperature gradient: ? = min(450, max(225/|?T|, 100), where ?T is the temperature gradient;
  - Where the gradient is high (in the Gulf Stream and Kuroshio regions, for example) the length scale is on the order of 100 km;
  - Where the gradient is low (*e.g.,* in the Sargasso Sea) the length scale is on the order of 450 km.

3. Testing of the RTG_SST

The new RTG_SST analysis algorithm has been evaluated by OMB by running sequences of comparative analyses and verifying against observations from moored buoys in both the Atlantic and Pacific Oceans. Further, from 20 December 2000 to 29 January 2001, it was used as the lower boundary condition over the ocean in parallel tests for the Meso Eta Model (Etax).

3.1 Comparison of RTG_SST with NESDIS and Reynolds-Smith SST Analyses

a) Statistical evaluation with buoy data

Table 1 reports comparisons of the NESDIS, Reynolds-Smith, and RTG_SST analyses with SST observations from several Northern Hemispheric buoys at fixed positions in deep water (generally > 3,000 m). The results show the average biases for all analyses to be about -0.1^o C, but the analysis-minus-buoy root mean squared differences (RMSD) to be significantly different, with the average RMSD for the RTG_SST being half or less than the average for either of the other analyses.

b) Visual comparison with the NESDIS 50 km SST Analysis

The NESDIS 50 km SST analysis is done biweekly, uses satellite data only, and cannot be updated under persistent cloud cover. It has close to the same grid spacing as the RTG_SST. Figure 3 shows a comparison of the NESDIS 50 km SST analysis with the RTG_SST, valid for 1200 UTC 23 January 2001, and their difference. The most notable areas of difference are along the East Coast of the U.S. and south of Newfoundland, where there are significant negative anomalies which indicate that the NESDIS 50 km SST analysis is warmer than the RTG_SST.

c) Visual comparison with the Reynolds-Smith Analysis

The Reynolds-Smith daily analysis smooths the previous analysis for the first-guess, ingests 7-days of data, and "superobs" all the data over 1^o x 1^o lon/lat grid boxes. This results in a very smooth analysis with essentially no Gulf Stream or cool shelf water along the East Coast of the U.S. or Kuroshio in the western Pacific Ocean. Bias calculation and removal, for satellite retrieved SST observations, and all data quality control criteria are essentially the same as in the RTG_SST. Figure 4 depicts a comparison between the Reynolds-Smith analysis and the RTG_SST for the same day as Fig. 3, and their difference. The difference between Reynolds-Smith analysis and RTG_SST is greatest within the Gulf Stream, along the East coast, and over the Grand Banks south of Nova Scotia and Newfoundland.

3.2. Other Evaluations

a) Tiger Team evaluation

The Tiger Team that was put together to make recommendations, after the misforecast of the Eta for 30 December 2000, was composed of forecasters from various NCEP Centers and local WFOs, developers from EMC, researchers from two universities, and private meteorologists from two corporations. The group was co-chaired by Drs. Jeff McQueen and Ralph Peterson.

According to the Notice of Intent sent to the NWS Regions and field offices on 19 January 2001, the Eta is capable of providing the proper mesoscale response to ocean forcing, but only if it has the proper mesoscale structures depicted in the SST. The Tiger Team noted that the new RTG_SST had cooler waters near the coast and a warmer Gulf Stream with sharper gradients, which were considered critical to an accurate prediction of the December 30^{th} East Coast winter storm. The Etax had been running with a fixed (222 km), correlation length-scale version of the RTG_SST, and it predicted less than half the precipitation predicted by the Eta for DC and Baltimore.

The Notice of Intent also noted that, following the introduction of the variable-length-scale version of the RTG_SST in the Etax on 6 January 2001, the Etax showed major improvement over the Eta using the Reynolds-Smith analysis. Also, the RTG_SST compared favorably with the NESDIS 50 km SST analysis, and showed slight improvement over the fixed version of the RTG_SST studied by the Tiger Team. Overall, the new SST analysis provides a more accurate lower temperature boundary over water for the Eta; and this has improved the marine boundary layer evolution.

b) Field Evaluations

Field evaluations were made from mid-December through late January by the Scientific Operations Officers (SOO) of NCEP's Hydrometerological Prediction Center (HPC); Marine Prediction Center (MPC); WFO Sterling, Virginia (LWX); WFO State College, Pennsylvania (CTP); and the Chief of the Operations Division, Alaska Region. Comments from the evaluators were sent to the field on 25 January 2001, as a followup to the Notice of Intent.

i) HPC and WFOs

The SOO from HPC liked the performance of the Etax compared to the operational Eta,

applauded the use of the new RTG_SST analysis in the Etax, but cautioned that the new SST analysis is not the whole answer to the Meso Eta forecasting problems. Specific comments included:

- The Etax has either outperformed, or performed no worse than the operational Eta, for events involving East Coast cyclogenesis;

- For all other events, there has been no notable difference between the two models, for fields HPC typically utilizes;

- Forecasters at HPC who have used both models saw no reason not to make the Etax operational.

The SOOs at CTP and LWX concurred with these findings.

ii) MPC and Alaska Region

MPC's evaluation of Eta and Etax showed that the Etax, with the RTG_SST, was no worse than, or was better than the Eta, in almost all situations (Partain 2001). Specific comments included:

- Etax verified subjectively better in the Eastern Pacific than the Eta or AVN, when system intensity was $gale;

- Etax closed pressure centers tended to be on the order of 1 - 4 hPa deeper than in the Eta and much closer to the analyses, for both coasts;

- Etax had consistently better positioning, depth, and gradients of circulation centers, frontal features, and especially of complex lows;

- In several cases, the Etax had the gradient on the proper side of the low when compared to the Eta and AVN, for both coasts;

- Etax performed 'worse' than Eta in only one case: a SW Atlantic low (genesis just north of Cuba) that moved north into the Gulfstream. Interestingly, the Eta solution was better while the low was in southern waters, where the SST field was more homogeneous; however, the Etax solution was better for forecast projections beyond the 24-h projection, as the low moved up over Gulfstream.

The Alaska Region reported the performance of the Etax to be better, in their area, than the Eta.

4. Summary

Following the evaluations reported in Section 3, which ended on the 25th of January 2001, it was determined that the new RTG_SST would be implemented on 30 January, in a crisis mode, for use in the operational Eta (Thiébaux *et al* 2001). This was considered necessary because the greatest temperature differences between air and water along the East Coast of the U.S. occur during the winter season: the fluxes are greatest and, therefore, the bottom boundary condition has the most influence on storm development along the East Coast of the U.S.

The RTG_SST has been developed specifically for use by the NCEP weather forecasting

models. Each daily product is on a 0.5° x 0.5° lon/lat grid, uses the most recent 24-hours of *in situ* and satellite-derived surface temperature data, and gives a sharper depiction of the warm core of the Gulf Stream and associated gradients. The RTG_SST now provides the sea surface temperature fields for the Meso Eta Model, replacing the use of the daily Reynolds-Smith analysis. Output from the analysis can be found at

http://polar.wwb.noaa.gov/sst

5. Acknowledgments

We are grateful to Dr. Geoff DiMego for providing extensive documentation of the various evaluations of Eta and Etax models that took place during the period after the misforecast of the Eta on 30 December. We also thank Eric Rogers for creating the figures for us and the many others who participated along the way.

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Table 1. Root-mean-squared analysis-minus-buoy SST differences of the NESDIS, the Reynolds-Smith, and the RTG_SST analyses with reports from deep water, Northern Hemispheric buoys, from November through December 2000.

Buoy id	Lat North	Lon East	NESDIS	Reynolds	RTG_SST
41001	34.7	287.8	1.0	1.4	0.1
42002	25.9	266.4	0.4	0.4	0.3
42003	25.9	274.1	0.7	0.8	0.2
44141	42.1	303.8	3.3	3.0	1.6
46001	56.3	211.8	0.5	0.3	0.2
46004	50.9	223.9	0.5	0.2	0.2
46005	46.0	229.0	0.5	0.6	0.2
46035	56.9	182.2	0.4	0.5	0.1
46059	38.0	230.0	0.4	0.3	0.2
51001	23.4	197.7	0.3	0.1	0.2
51004	17.4	207.5	0.5	0.3	0.2
51028	00.0	206.1	0.4	0.5	0.3
62029	48.7	347.6	0.6	0.2	0.1
62108	53.5	340.5	0.5	0.3	0.1
62132	56.4	002.0	0.4	0.3	0.3
63103	61.2	001.1	0.5	0.4	0.1
64045	59.1	348.6	1.1	0.9	0.3
Average			0.7	0.6	0.3

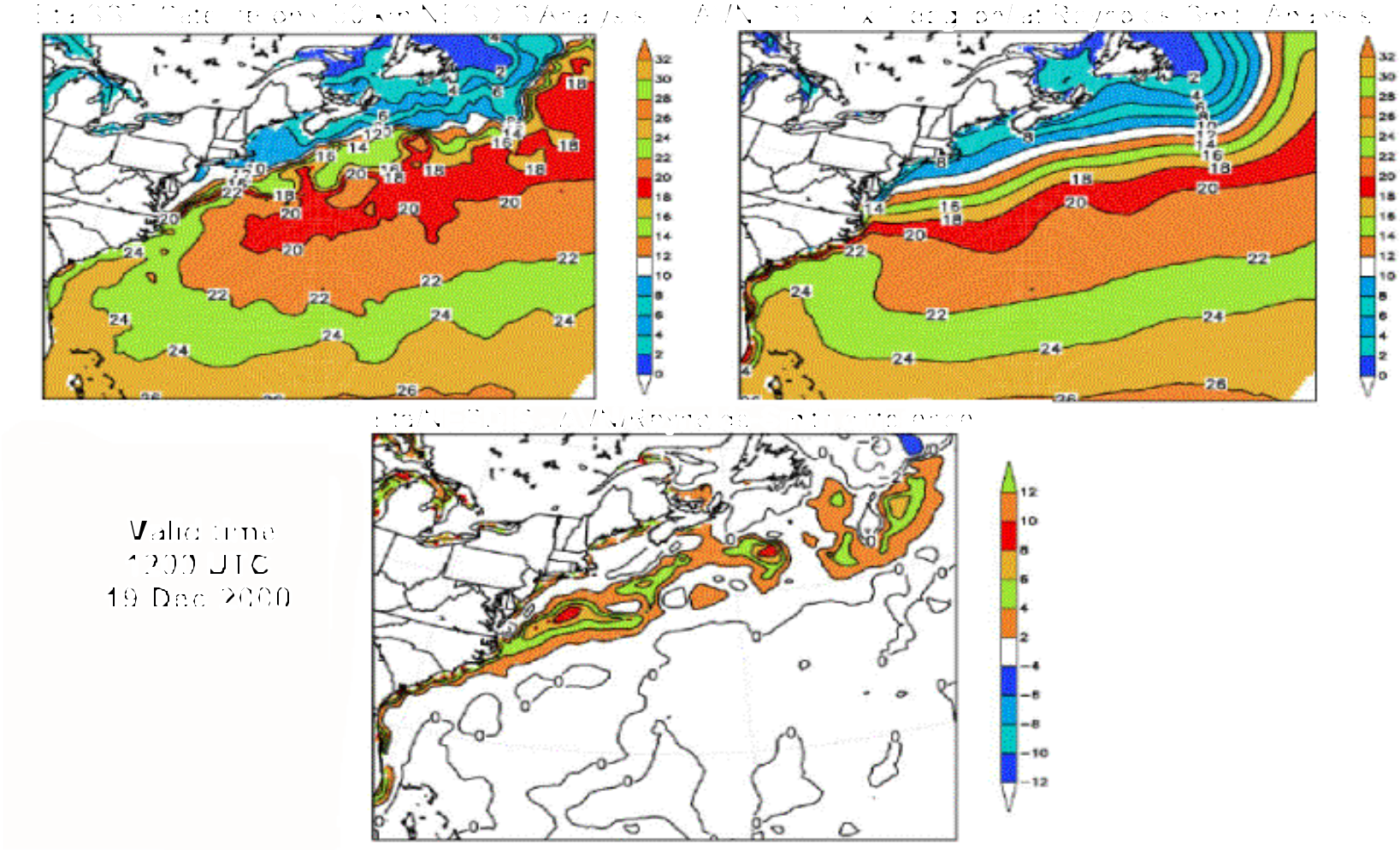

Figure 1. Comparison of Eta SST field derived from NESDIS 50 km SST analysis (top left) with AVN SST field derived from Reynolds-Smith

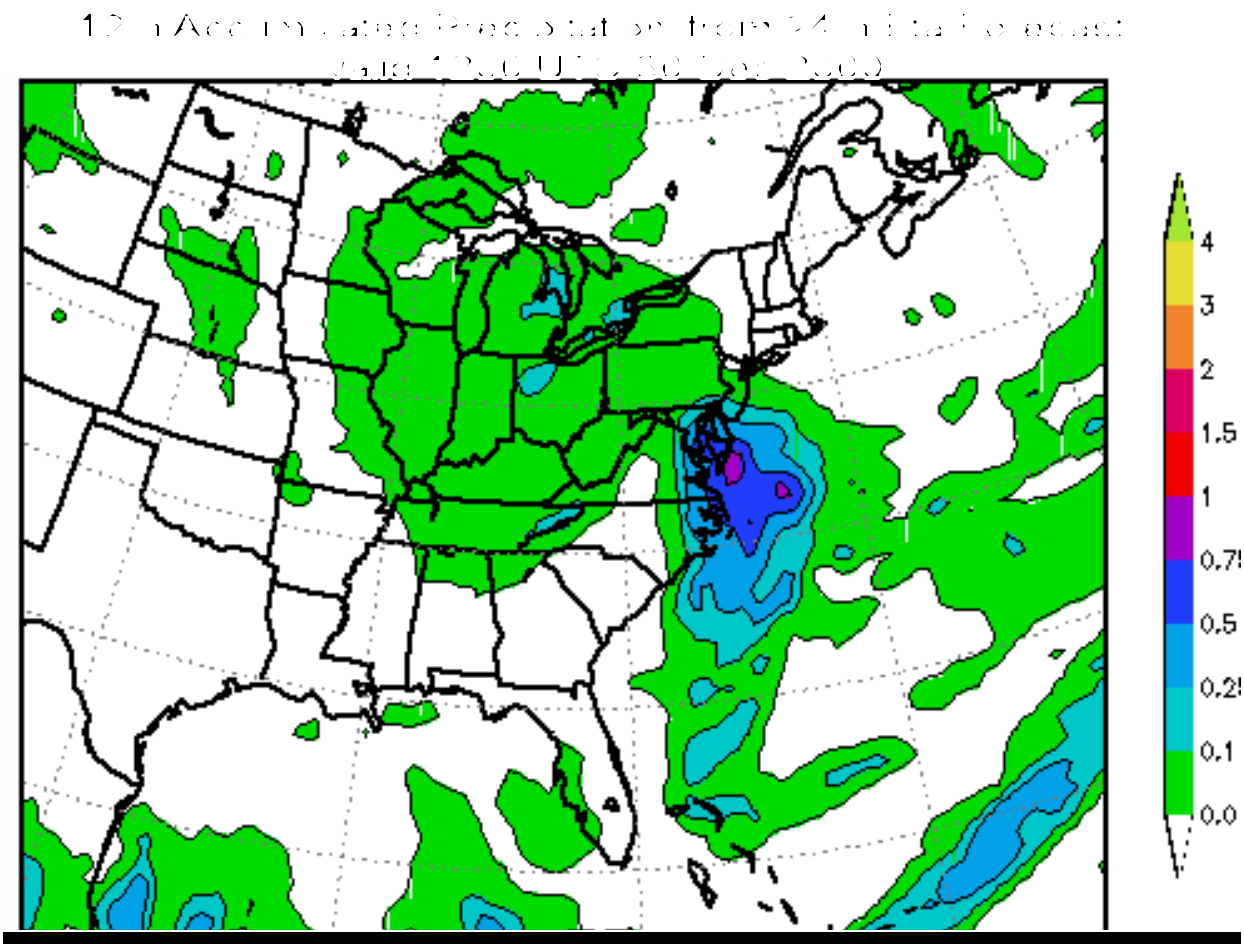

Figure 2. Eta misforecast of significant snowfall for the DC/Baltimore area on 30

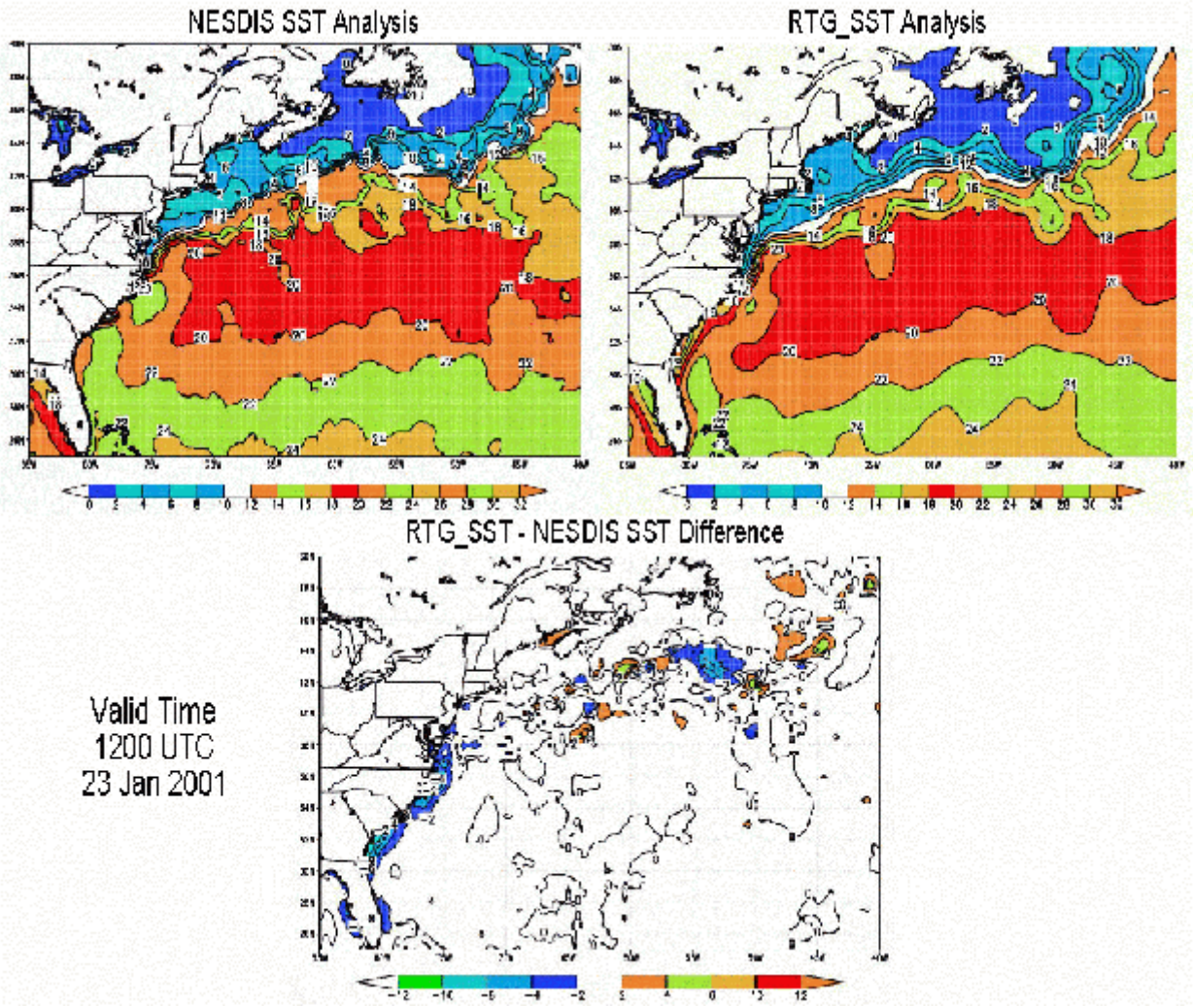

Figure 3. Comparison of Eta SST field based on NESDIS 50 km SST analysis (top left) with Etax SST field based on RTG_SST analysis (top right) with difference chart (bottom center) valid for 1200 UTC 23 January 2001.

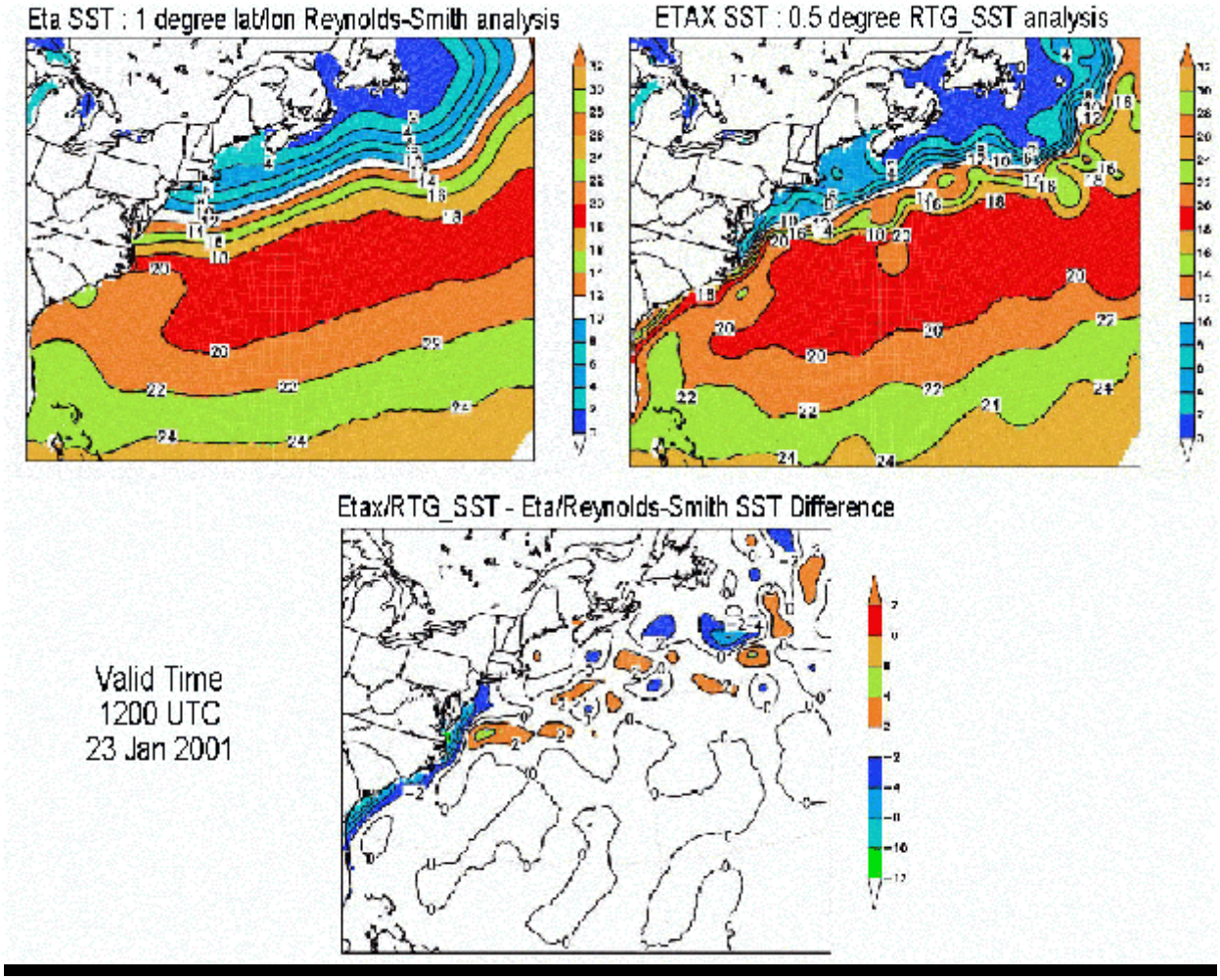

Figure 4. Same as Fig. 3 except Eta based on Reynolds-Smith analysis.