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# NEW SEA-SURFACE TEMPERATURE ANALYSIS IMPLEMENTED AT NCEP[1]

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## 1. Introduction

A new Real-Time Global Sea Surface Temperature analysis (RTG_SST) has been developed specifically for use by the NCEP weather forecasting models. Each daily analysis uses the most recent 24-hours of *in situ* and satellite-derived surface temperature data and provides a global SST field on a 0.5-degree (latitude, longitude) grid. The RTG_SST, implemented in NCEP's operational job stream on 30 January 2001, currently provides the sea surface temperature fields for the regional Meso Eta Model, replacing the previously used NESDIS 50 km SST analysis.

This presentation describes the sequence of events in the development and implementation of the RTG_SST, compares its properties with those of the Reynolds-Smith analysis and the NESDIS 50 KM (satellite-only) analysis.

## 2. Background of the RTG_SST

Until recently, two different analyses were employed by the NOAA/NCEP/ Environmental Modeling Center, to provide ocean surface temperatures in EMC's short- and medium-range atmospheric forecast models. The Global Analysis/Forecast Systems used the 1-degree (latitude, longitude) Reynolds-Smith analysis (RS), run daily with the most recent 7-days data. The Meso-Eta used the NESDIS 50 KM analysis of satellite-retrieved SST's from NOAA AVHRR.

The RTG_SST, using both satellite and *in situ* data, had been under development specifically to meet the requirements of EMC's increased-resolution weather forecast models. A prototype RTG_SST was initially developed by the EMC Climate Modeling Branch; was modified by the EMC Ocean Modeling Branch; and final evaluations of its performance were carried out late in the fall of 2000.

During mid-December 2000, the Eta SST field, provided by the NESDIS 50 KM SST analysis, developed unrealistically warm areas in the NW Atlantic. Concern for the impact of these unusually warm areas on Eta model forecasts led to comparisons with the RS SST fields, which were significantly cooler in forecast-critical areas. Figure 1 shows the difference plot for 19 December 2000, where the NESDIS 50 KM was warmer than the RS by as much as 7 – 9°C in some areas[3]. On 20 December, the lower resolution RS was temporarily substituted for the NESDIS 50 KM analysis on an emergency basis.

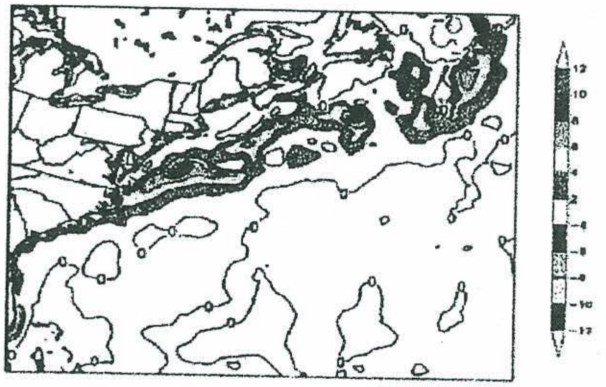

Figure 1. Difference between the NESDIS 50 KM and the RS SST analyses, for the Northwest Atlantic, 19 December 2000, with temperature in degrees Celsius.

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[3] The NESDIS analysis is a bi-weekly analysis, ingesting only SST retrievals from the AVHRR instrument, and cannot be updated under persistent cloud cover. While these characteristics do not, *per se,* account for unrealistically warm areas, the analysis will have whatever bias there is in AVHRR retrievals and, in some areas, it may not have been updated for many days. During winter, intervals longer than 10 days when the satellite cannot "see" the ocean surface are not uncommon.

Subsequently, on 30 December 2000, the Eta model misforecast significant snowfall for the DC/Baltimore area. Figure 2 shows the corresponding 12-hour accumulated precipitation predicted for the east coast, from the 24-hour Eta forecast valid 1200 UTC 30 December. The actions taken following this event, when only a dusting of snow followed a forecast of 4-to-6 inches, included parallel model runs with the RTG_SST and its subsequent preparation for rapid operational implementation.

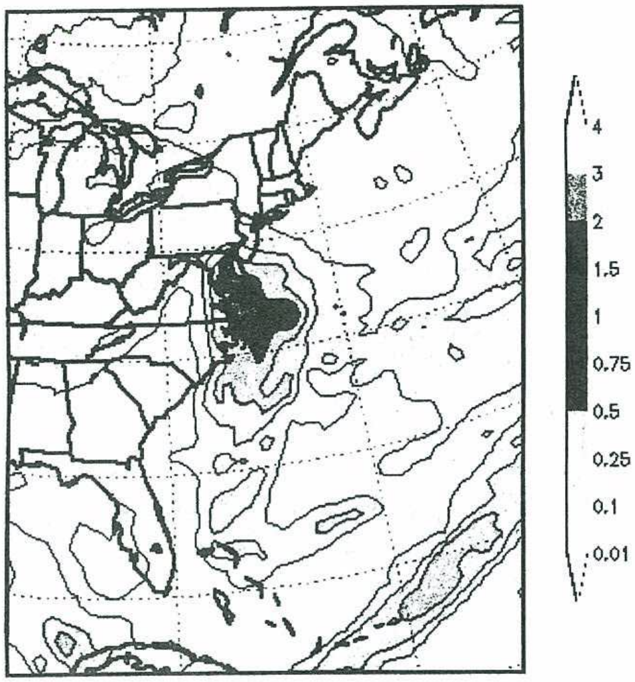

Figure 2. 24-hour Eta forecast of 12-hour accumulated precipitation, valid 1200 UTC 30
December 2000.

## 3. Important features of the RTG_SST

The most important features of the RTG_SST and the principal differences between it and the Reynolds-Smith analysis, are the following.

- 0.5 x 0.5 (longitude, latitude) grid spacing;

- Previous analysis as first-guess;

- Only 24-hours of *in situ* and satellite data;

- SST reports from moored buoys averaged within 24-h intervals;

- Satellite-retrieved SST values averaged within 0.5 degree grid boxes;

- Surface temperature for ice-covered water calculated using salinity climatology in Millero's (1978) formula, where the satellite-observed ice cover exceeds 50%;

- Correlation-length-scale-parameter $\gamma$, for the correlation function: $\exp(-d^2/\gamma^2)$ where d, the distance between data and analysis-gridpoint locations, is calculated from a climatological temperature gradient, as $\gamma = \min(450, \max(225/|\Delta T|, 100))$. $\gamma$ and d are in kilometers.

Data quality control criteria, and bias calculation and removal for satellite-retrieved SST, are the same as those of the RS SST.

The correlation-length-scale parameter, taking values between 111 km in the regions of highest climatological temperature gradient (Gulf Stream and Kuroshio), and 450 km where the gradient is low (Sargasso Sea), is a major change from the range of longer correlation scales employed by the Reynolds-Smith analysis and a critical element in the performance of the RTG_SST.

## 4. Analysis evaluations

Evaluations of the RTG_SST analyses have shown it to produce realistically tight gradients in the Gulf Stream region of the Atlantic and the Kuroshio region of the Pacific, and to be in close agreement with SST reports from moored buoys in both oceans. In contrast to the NESDIS and RS analyses, this new analysis properly depicts the colder shelf water -- a feature critical in accurate producing model prediction of the 29-30 December 2000, east coast winter storm.

Comparisons had been made between analyses produced with the RTG_SST algorithm using different assignments of the correlation length scale ($\gamma$), during the early development phase. Figure 3.a illustrates the climatological temperature gradient from which $\gamma$ is calculated, for the Gulf Stream region: 20W – 80W and 30N – 60N; and 3.b provides a plot of the corresponding values of $\gamma$. In 3.c is the SST analysis using this variable correlation scale parameter; and comparative analyses with homogeneous correlation scale values: $\gamma$ = 111 km, $\gamma$ = 300 km, and $\gamma$ = 606 km, are shown in 3.d, e, and f, respectively. 3.c and d show nearly identical Gulf Stream detail; however, away from the strong temperature gradients, where the SST contours of 3.d are noisy, the larger correlations scales used to produce the analysis of 3.c give a more realistic looking temperature field. 3.e and f show the Gulf Stream with increasingly and unrealistically smooth temperature contours.

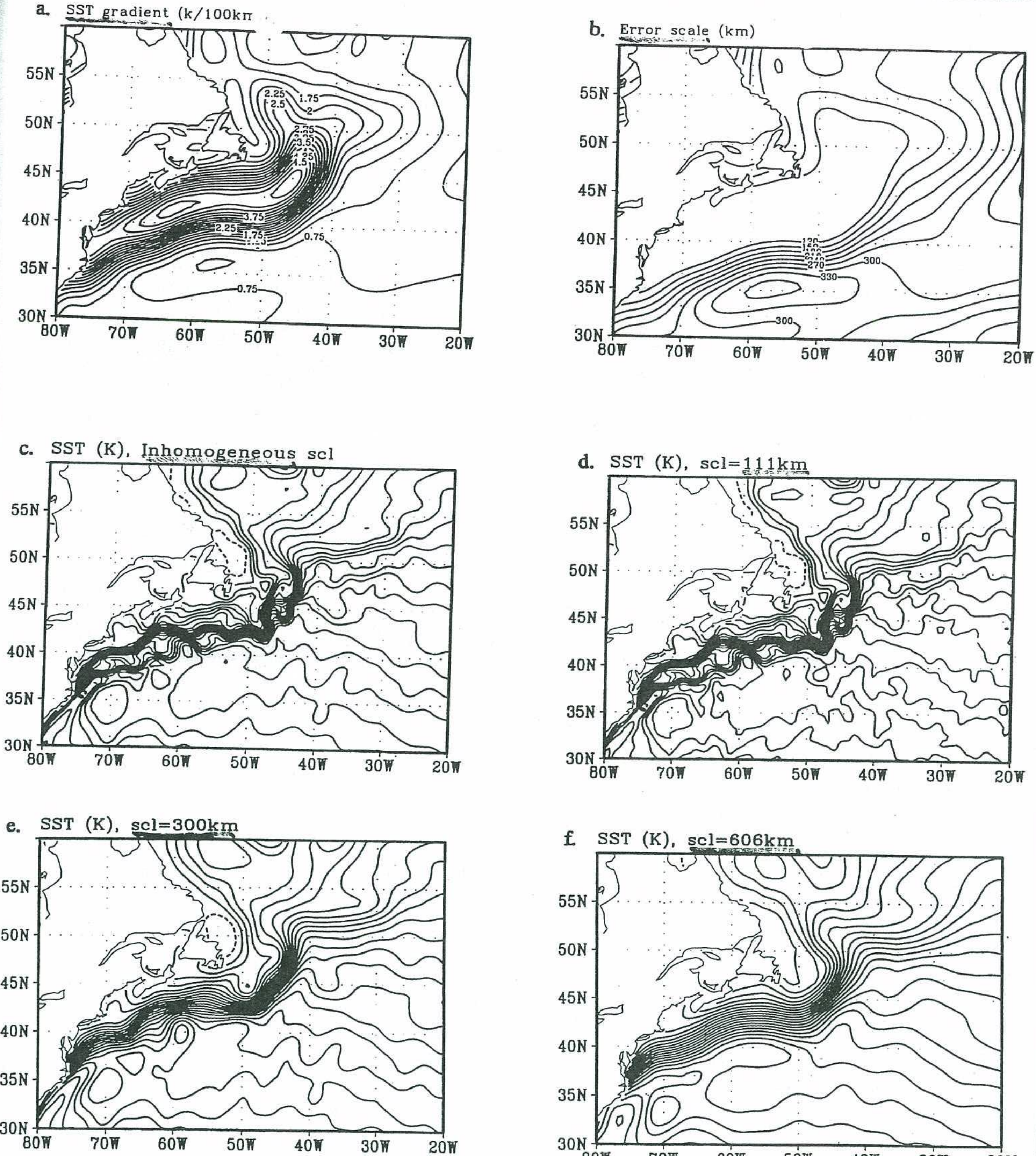

Figure 3.a. Climatological temperature gradients in the NW Atlantic; b. Correlation scale parameter γ calculated from gradients in first frame; c. NW Atlantic SST analysis for March 31, 2000, using inhomogeneous scale parameter γ; d. SST analysis using fixed, γ = 111 km; e. SST analysis using fixed, γ = 300km; f. SST analysis using fixed, γ = 606km.

Table 1 presents root-mean-square-difference statistics (RMSDs) of analysis-minus-buoy-observed SSTs, for all four correlations representations of Figure 3. The RMSDs were calculated using the analysis-independent reports of 12 moored buoys in the Northern Hemisphere, including one in the South China Sea and two near the U.K. Corresponding average biases of these analyses, for the 3-month spring period March – May 2000, were in the range 0.1 to 0.2°.

Table 1. Root-mean-squared analysis-minus-buoy SST differences (degrees C), for the correlation representations of Figure 3, using independent data, March - May 2000

| buoy id | (lat,lon) | 100km | 300km | 606km | INHOM | γ (km) |
|---|---|---|---|---|---|---|
| 22001 | (28.1,126.3) | 1.2 | 1.4 | 1.8 | 1.3 | 175.59 |
| 41004 | (32.5,280.9) | 0.7 | 0.9 | 1.1 | 0.8 | 173.18 |
| 44007 | (43.5,289.9) | 1.0 | 1.1 | 1.1 | 1.0 | 107.50 |
| 44008 | (40.5,290.6) | 1.7 | 2.0 | 2.6 | 1.7 | 100.00 |
| 44138 | (44.3,306.4) | 0.9 | 1.4 | 1.7 | 0.9 | 100.00 |
| 46001 | (56.3,211.8) | 0.4 | 0.4 | 0.4 | 0.4 | 402.45 |
| 46053 | (34.2,240.2) | 0.7 | 0.7 | 0.8 | 0.7 | 200.41 |
| 46060 | (60.6,213.2) | 0.6 | 0.6 | 0.9 | 0.6 | 223.93 |
| 46204 | (51.4,231.2) | 0.3 | 0.3 | 0.3 | 0.3 | 249.26 |
| 51003 | (19.2,199.3) | 0.2 | 0.2 | 0.2 | 0.2 | 442.25 |
| 62103 | (49.9,357.1) | 0.5 | 0.4 | 0.5 | 0.5 | 205.60 |
| 62109 | (57.0, 0.0) | 0.4 | 0.4 | 0.4 | 0.4 | 283.95 |
| averages | | 0.7 | 0.8 | 1.0 | 0.7 | |

Comparisons of the RTG_SST with the NESDIS 50 KM analysis and with the 1-degree RS were made both visually for the NW Atlantic region of the Gulf Stream, and in comparisons of two-months of analyzed values with SST reports from moored buoys.

Figure 4 presents plots of the SST fields produced for 23 January 2001, by the NESDIS 50 KM analysis and the RTG_SST, and of their difference. Both analyses produced Gulf Stream temperature gradients that appear realistic; however the RTG_SST was significantly colder (by ~ 9°C) in the coastal waters of the southeastern US and south of the Grand Banks of Newfoundland. For the same January day, Eta-adaptations of the RTG_SST and the Reynolds-Smith analysis are compared in Figure 5. Again, the difference plot shows the RTG_SST to be significantly colder in the forecast-critical coastal waters and south of the Grand Banks. In this figure, the failure of the RS to depict the Gulf Stream is clearly evident.

The comparisons of analyzed values with buoy reports were made for a set of Northern Hemisphere buoys moored in deep water (generally > 3000 meters). The average biases for these analyses were all approximately -0.1°. However, as shown in Table 2, the RMSD results are significantly different, with the average RMSD for the RTG_SST half or less than that of the NESDIS or Reynolds-Smith analyses. In this comparison, the buoy data were included in both NCEP analyses, because they could not be excluded from the operational runs of the Reynolds-Smith analysis. (The NESDIS analysis is independent of buoy and ship data.)

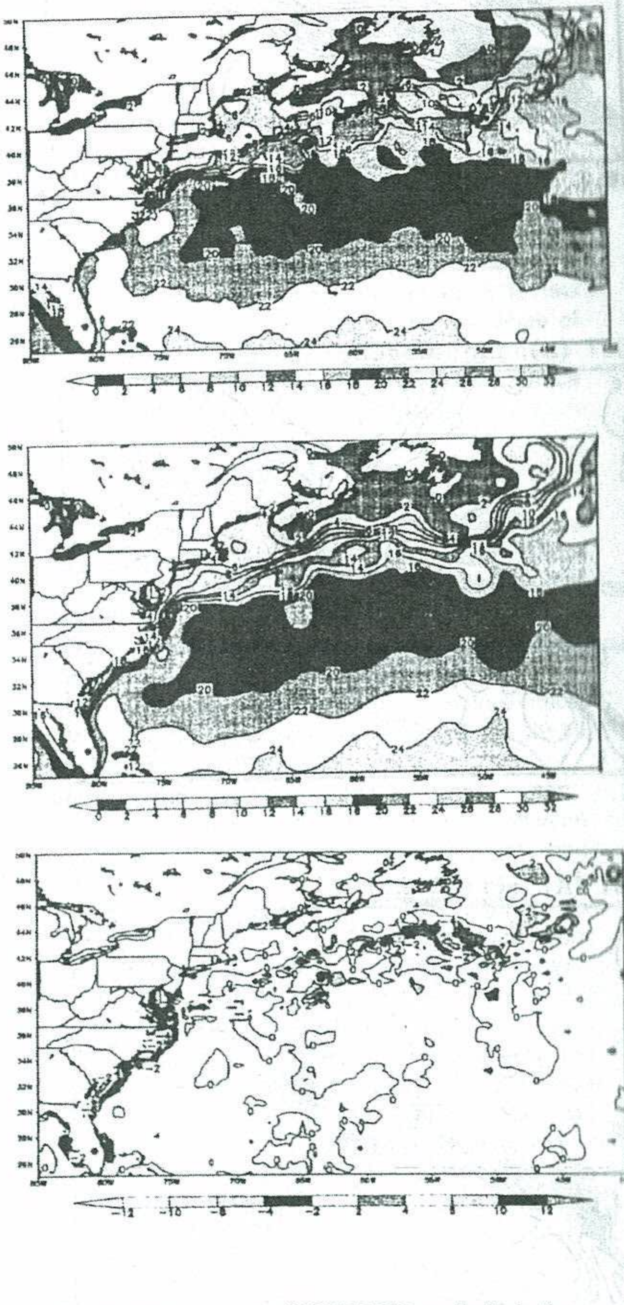

Figure 4.a. Satellite-only, 50 KM NESDIS analysis, b. the RTG_SST, and c. NESDIS-minus-RTG_SST, for the NW Atlantic, 23 January 2001, with temperatures in degrees Celsius

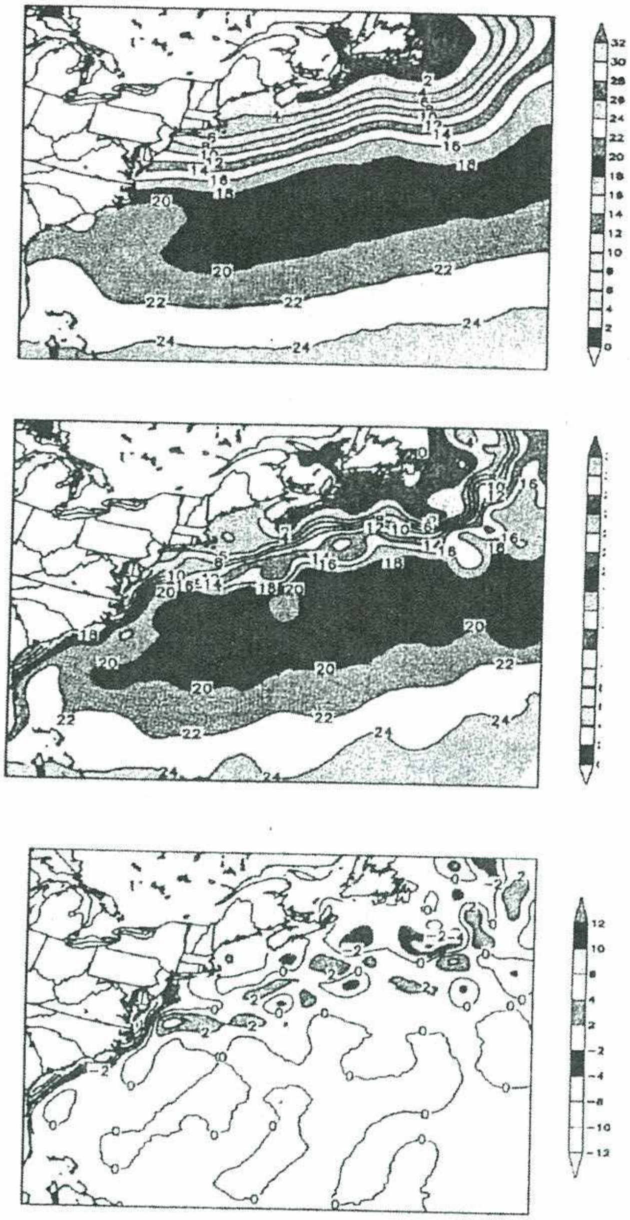

Figure 5.a. 1x1 degree RS analysis, b. RTG_SST analysis, and c. RS-minus RTG_SST difference, for the NW Atlantic, 23 January 2001, with temperatures in degrees Celsius

Table 2. Root-mean-squared analysis-minus-buoy differences, November through December 2000

| buoy id | (lat,lon) | NESDIS | OPER | INHOM |
|---|---|---|---|---|
| 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 | ( 0.0,206.1) | 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, 2.0) | 0.4 | 0.3 | 0.3 |
| 63103 | (61.2, 1.1) | 0.5 | 0.4 | 0.1 |
| 64045 | (59.1,348.6) | 1.1 | 0.9 | 0.3 |
| average | | 0.7 | 0.6 | 0.3 |

The foregoing comparisons and evaluation results formed the basis of the decision to implement the new RTG_SST analysis on 30 January 2001, and to use it to provide the sea surface temperature fields for the Meso Eta model and the Global Analysis/Forecast Systems. Subsequently, a daily analysis verification algorithm has been added to the run-suite. A parallel analysis is now run daily, with about 20% of the moored and drifting buoys withheld for independent-data evaluation.

Website http://polar.wwb.noaa.gov/sst provides a brief description of the RTG_SST algorithm, daily graphical products, and links to the data in grib format and to verification statistics for recent analysis products.

## 5. Acknowledgements

We are extremely grateful to Diane Stokes for her unending contributions to the project that has resulted in the RTG_SST becoming operational: to understanding the data flow and quality control, and the differences between this and the Reynolds-Smith analysis. We also wish to express our appreciation to Eric Rogers who kindly provided the graphics, and to Regina Green who formatted the tables and figures.