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AN IMPROVED IN SITU AND SATELLITE SST ANALYSIS

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1. INTRODUCTION

We will cover two interrelated topics here. The first is a brief discussion of the weekly optimum interpolation (OI) climate-scale in situ and satellite SST analyses produced at National Oceanic and Atmospheric Administration (NOAA, Reynolds and Smith, 1994, henceforth RS). We show that there are errors in this OI analysis (henceforth OI.v1, for OI version 1) due to an under correction of satellite bias and the choice of sea-ice to SST algorithm. We then present a new version of the OI analysis (henceforth OI.v2) that reduces these errors.

The second topic is an assessment of SST analysis errors for our period of interest. This is a necessary step in discussing errors in the OI.v1 and OI.v2. It is also important so that users have a better idea of the size of SST errors and the locations where they are larger and smaller than the average. Here, we focus on global differences in time and mean differences in space.

2. SST ANALYSES

Optimum interpolation or OI was developed by Gandin (1973) as an objective analysis method for irregularly spaced data. The OI.v1 SST analysis used here is described in RS and includes a discussion of how the error terms were estimated. The analysis is computed weekly on a 1° latitude by 1° longitude grid using satellite and in situ data. The specific algorithms used in the OI.v1 are based on the method by Lorenc (1983). Our analysis system is designed to balance the higher spatial resolution of the satellite data with the ground truth of the in situ data.

The OI method assumes that the data do not contain long-term biases. Because satellite biases occur in our period of interest, as discussed in detail in RS, a preliminary step is carried out to remove satellite biases relative to in situ data before the OI analysis is begun. In this method a spatially smoothed bias correction is determined and applied to the satellite data before they are used in the OI step.

The Oi.v2 analysis introduces two improvements. First additional in situ data are used to improve the bias correction. These data were obtained from a recently updated version of the Comprehensive Ocean-Atmosphere Data Set (COADS) (see Slutz et al., 1985 and Woodruff et al., 1998). The other improvement resulted from the use of a new sea-ice concentration to SST algorithm. The algorithm generates SSTs at the sea-ice margin where in situ observations tend to be sparse because of navigation hazards and satellite observations tend to be sparse due to cloud cover. The new algorithm was derived (see Rayner et al., 1996) from a quadratic fit of sea-ice concentration and SST. In the OI.v1, an SST value of -1.8°C was generated for sea-ice concentrations above 50%.

To better understand the accuracy of both versions of the OI, we will use three additional SST data summaries and two additional SST analyses. All data summaries are monthly averages of the observations on latitude by longitude boxes. These summaries are not referred to as analyses here because there are no assigned SST values in ocean boxes without data.

The first data summary is the UK Met Office Historical SST data set, version 6, of Parker et al. (1994), henceforth MOHSST, which is computed on a 5° grid using both ship and buoy data. The quality control (QC) for MOHSST is complex, as described in Appendix 1 of Parker et al. (1995).

The last two data summaries are COADS 2° gridded SST summaries. To QC COADS the actual distribution of the data is used instead of assuming a Gaussian distribution. As discussed in Slutz (1985), this method develops robust estimates of the mean and standard deviation that are statistically more stable when outliers are present. The main

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difference between the two summaries is that one product uses only surface marine observations from ships, while the other product adds data from buoys and other in situ sources to the ship data. Following the COADS definitions, we will refer to the two COADS summaries as standard (henceforth S-COADS) for the ship only product and enhanced (henceforth E-COADS) for the product using all in situ data. The COADS summaries end in 1997.

The two analyses are produced at the Met Office Hadley Centre for Climate Prediction and Research using variations on MOHSST as input data. These analyses also use AVHRR satellite data beginning in 1982. The first is the Global sea-Ice and SST data set, version 2.3b, (GISST) of Rayner et al. (1996). The second is the more recent Hadley Centre sea-Ice and SST data set, version 1, (HadISST), which is described in Parker et al. (1999). Both GISST and HadISST are computed monthly on a 1° grid.

3. INTERCOMPARISON OF SST ANALYSES

We selected E-COADS as our standard of comparison. We wanted to select one of the COADS summaries because they are not produced at a center doing SST analyses. E-COADS was selected over S-COADS because E-COADS includes the important contribution of buoy data. All intercomparisons are done on monthly time scales.

Figure 1 (for 60°S-60°N) shows time series of the difference of the OI.v1, OI.v2, GISST and HadISST analyses with respect to E-COADS. The figure shows that the OI.v2 analysis is closer to E-COADS than the OI.v1 in almost every month. Thus, a residual negative bias in the OI.v1 analysis relative to E-COADS has been reduced in the OI.v2 analysis by an improvement in the in situ data but not completely eliminated. The residual bias of GISST with respect to E-COADS is initially similar to both versions of the OI. However, the GISST difference gradually changes sign. It is influenced by differences in MOHSST, which are used as in situ input. HadISST incorporates a newer version of MOHSST and shows smaller differences relative to E-COADS than GISST. However, the HadISST differences seem to have a stronger seasonal cycle than the other analyses.

We now discuss the average spatial differences relative to E-COADS for OI.v1, OI.v2, GISST and HadISST (not shown). The most important difference occurs in the mid-latitude Southern Hemisphere (roughly 60°S-30°S). There HadISST has both warm and cool regions relative to E-COADS that tend to balance each other. However, the OI.v2 tends to be consistently cooler than E-COADS. This is the region that strongly contributes to the residual negative bias in the OI.v2 analysis as shown in the figure. The differences between the two analyses and E-COADS are similar at high latitudes as expected because they use the same sea ice and sea-ice to SST algorithms. The GISST differences with respect to E-COADS are very similar to those shown for HadISST including the high latitudes. The OI.v1 differences have a slightly larger negative bias. Otherwise they are very similar to the OI.v2 differences except at high latitudes where the change in the sea-ice to SST algorithm has a large impact.

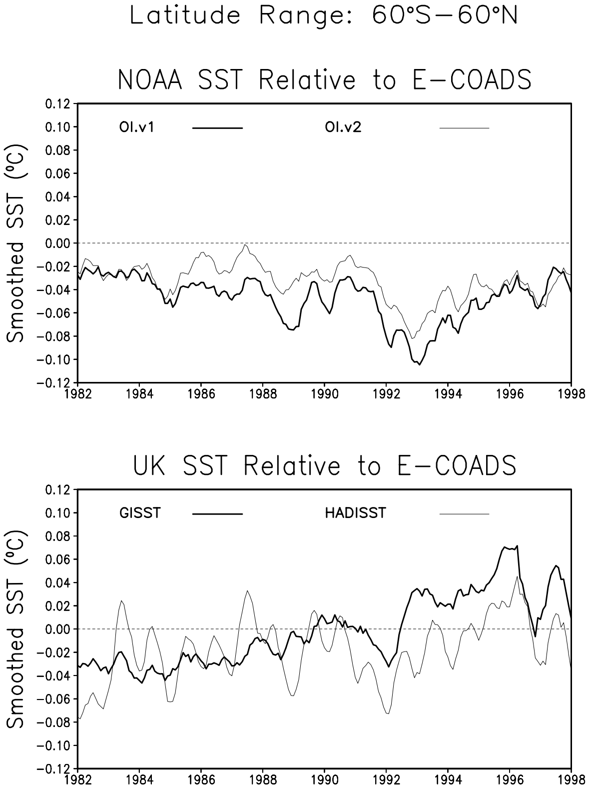

Figure 1. Monthly averaged SST differences for the OI.v1, OI.v2, GISST and HadISST analyses relative to E-COADS. Differences are computed only over grid boxes where E-COADS is defined. A seven-point running-mean filter was used to smooth the time series.

4. FINAL COMMENTS

As discussed in the preceding sections, the OI.v2 analysis is a replacement of RS OI.v1. The OI.v2 analysis has a modest improvement in the bias correction because of the addition of more in situ data. However, a small uncorrected residual bias remains. In addition, the OI.v2 uses an improved climatological sea-ice to SST algorithm that better fits the in situ data from E-COADS.

Our results also show that significant differences remain among analyses during the last two decades. In particular residual globally averaged differences of roughly 0.05°C occur on decadal scales. For climate change, monitoring and detection, these differences are, unfortunately, not negligible. The production of difference statistics such as those shown above is limited and is often not sufficient to determine the best analysis. We believe it would be very useful to do intercomparisons among analyses where buoy data are withheld. This would help quantify differences in data processing and analyses.

Even if the analysis were perfect, we would still need to improve the observations themselves. This would include improving both in situ and satellite observations. There are now new efforts to carefully monitor and improve the observations from selected ships. In addition, there are new efforts to produce high-resolution SST analyses that include careful examination of the satellite algorithms, the bulk and skin SST difference, and utilize multiple sensors. We believe that these efforts will lead to better analyses of SSTs in the future.

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