The Version-2 Ocean Algorithm for TMI

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Introduction

The Version-1 ocean algorithm for TMI was developed shortly after launch. The algorithm was based on a brief 6-month calibration/validation activity and incorporated a hybrid of regression and model-versus-T_B matching algorithms, like those used for SSM/I. Subsequently, the Version-1 algorithm performance was carefully evaluated, and the following improvements were made:

1. A better technique was developed for error removal due to the TMI graphite antenna.
2. A more accurate sea-surface emissivity model was implemented.
3. The algorithm reliance on climatology SST was removed.
4. Changes were made to make the TMI code more similar to the AMSR Ocean Algorithm.

The new algorithm is called the Version-2 TMI Ocean Algorithm. This document describes the improvements that went into this algorithm.

1. Better Technique for Removing Errors Due to TMI Graphite Antenna

We are now fairly sure that the vapor-deposited aluminum on the TMI antenna was entirely oxidized by atomic oxygen shortly after launch. As a result, TMI has a graphite antenna, with a reflectivity of 96%. We developed an improved method of determining the temperature of the graphite antenna. Temperature variations in the antenna produce a unique spectral/polarization signature in the T_B's. As a result, the temperature of the antenna can be retrieved like any other parameter from the T_B's. The bad news is that the retrieval is very noisy for individual observations. The good new is that the temperature is fairly constant over 50 scans, and hence the retrievals can be averaged to reduce the noise. The retrievals can be averaged over 50 scans and also over 3 days since the same heating cycle occurs during each orbit. These very large averages reduce the noise considerably. We also use the on-board thermistors for additional information on the temperature of the antenna. Figure 1 shows the improvement that was realized with this new method. The green line shows the results from the original algorithm (version-1) and the blue line shows the results of the new algorithm (version-2). The annual signal in SST is clearly the dominant harmonic, but there are also high frequency peaks, due to yaw maneuvers, apparent in the green line (V01). For the Version-2 algorithm, these peaks are significantly reduced (blue line).

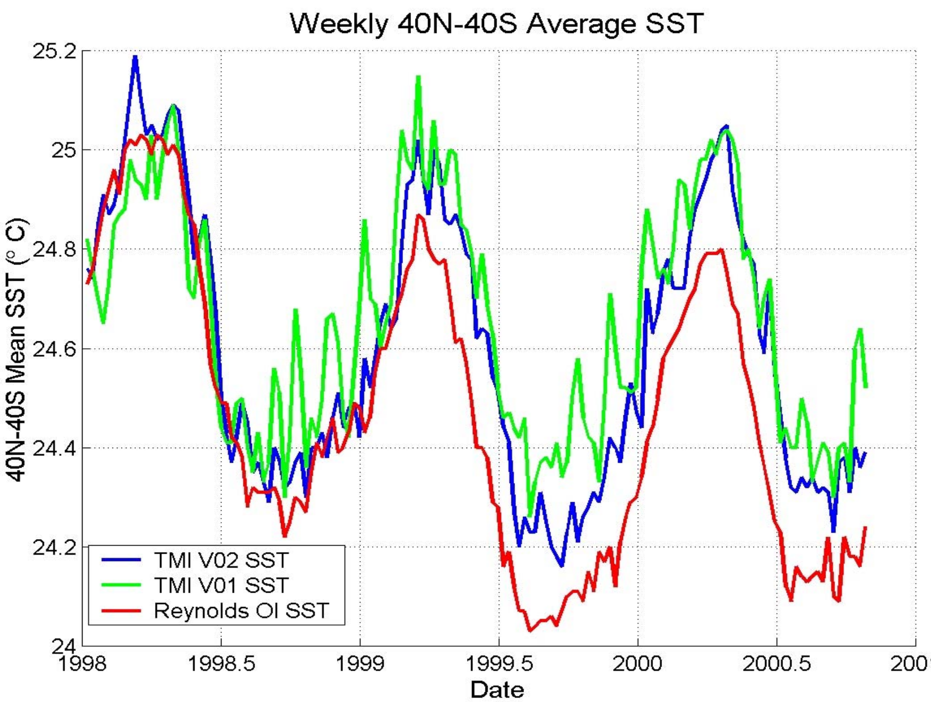

Figure 1. Weekly 40N - 40S average SST for TMI Version-1 algorithm, TMI Version-2 algorithm, and Reynolds OI SST.

2. More Accurate Sea-Surface Emissivity Model

When compared to the QuikScat wind speed, the wind speeds coming from the Version-1 TMI algorithm exhibited systematic regional biases. We have known for some time that regional biases exist between active and passive retrievals of wind speed. These were shown by earlier SSM/I versus QuikScat comparisons, as is shown in the top panel of Figure 2. A map of the Version-1 TMI-QuikScat wind speed difference (not shown) looks essentially the same as the SSM/I results. The appearance of these same biases in the TMI and SSM/I comparisons suggested that there was something fundamental in the radiative transfer model that was causing the problem.

To analyze the problem in greater detail, 2-dimensional (wind and SST) histograms of the wind differences were produced. These histograms revealed that the wind difference is jointly correlated with both wind and SST. Earlier analyses, which considered wind and SST separately, failed to show significant correlation. However, when working in terms of a joint SST-wind correlation, an appreciable correlation was obtained.

To correct the wind bias problem, we rederived the sea-surface emissivity model for TMI. The TMI T_B observations are first transformed to emissivity values, and then these emissivities are stratified into SST and wind speed bins. The SST used in the model comes from Reynolds weekly values, and the wind speed data come from collocated QuikScat observations. The new wind-induced emissivity model shows more dependence on SST than did the previous model. The coefficients for the retrieval algorithm were then recomputed, and we completely reprocessed all the TMI data. The

TMI versus QuikScat wind speed comparisons were then redone. The bottom panel of Figure 2 shows the Version-2 TMI-QuikScat wind speed difference using the new emissivity model. The regional wind biases are now much smaller: about ± 0.5 m/s rather than ±1.5 m/s with the old model. These results confirm that the long-standing difference between wind speed retrievals from active versus passive microwave sensors is mostly due to the sea-surface emissivity model being slightly incorrect.

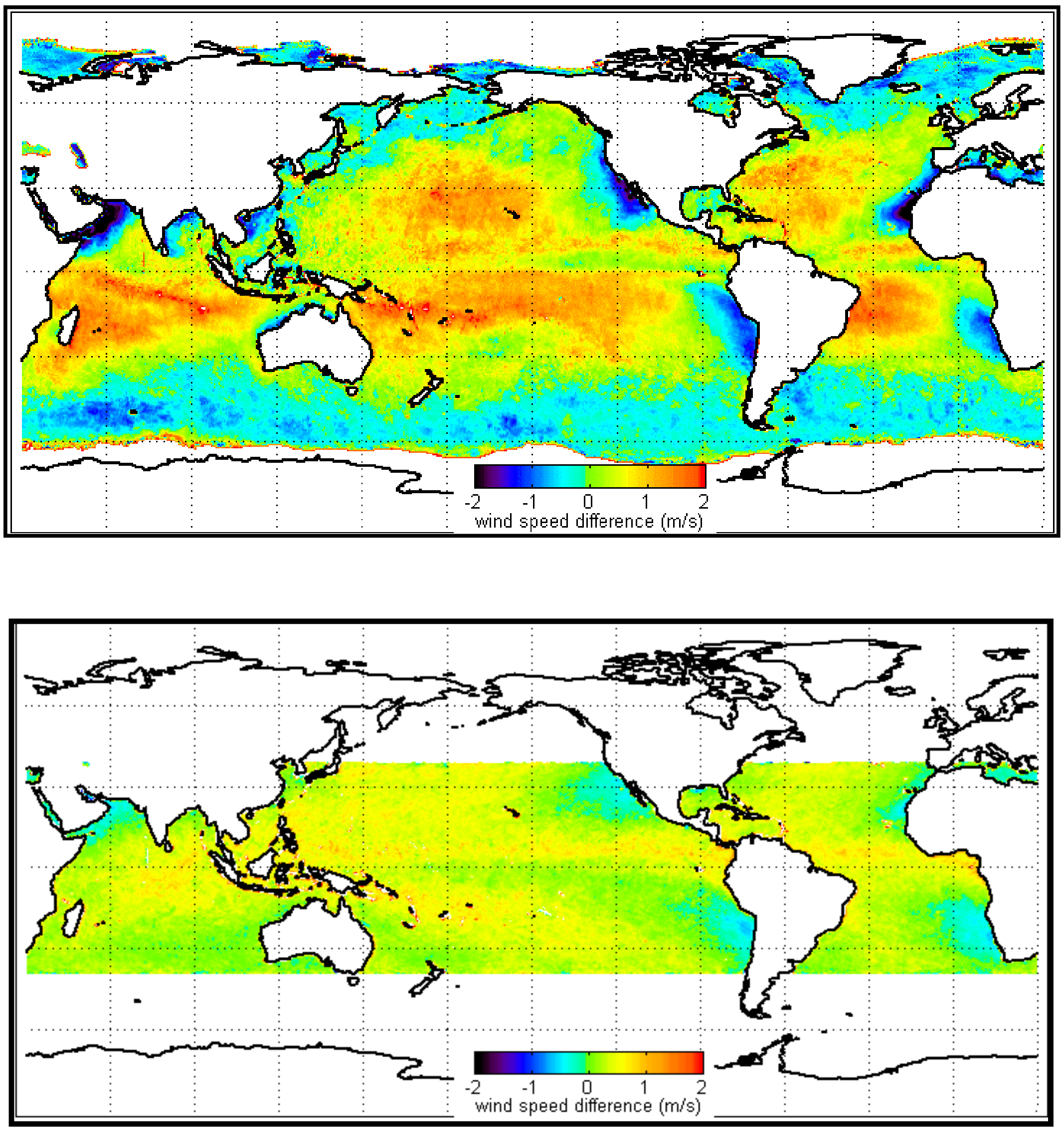

Figure 2. Wind speed differences between microwave radiometers and microwave scatterometers. The top panel shows the SSM/I minus QuikScat wind speed difference resulting from the old emissivity model. The bottom panel shows the TMI minus QuikScat wind speed difference resulting from the new emissivity model. The regional biases are now about ±0.5 m/s as compared to ±1.5 m/s for the old model. These figures are an averaged from July 1999 to September 2000.

3. Removal of the Algorithm's Reliance on Climatology SST

With nearly three years of TMI SST retrievals, we assessed TMI's capability to track small interannual variability in the SST. The TMI time series begins at the height of the 1997 El Nino, and then sees the rapid cooling that begins in the middle of 1998. We compared the TMI tropical time series from December 1997 through September 2000 with the TOGA-TAO equatorial buoy array. We found that the Version-1 TMI time series was not fully tracking the cooling event. TMI underestimated the cooling trend by about 10%. Upon checking, we found a small problem with the retrieval algorithm. The Version-1 algorithm used a climate SST to specify air temperature, and hence the SST retrievals have a small dependence on the value of the climate SST. A 1°C change in the climate SST produced about a 0.1°C change in the retrieved SST (i.e., a 10% effect). Thus the SST retrievals were, to a small degree, tied to a static climate value, and hence did not fully track the true climate signal.

The Version-2 algorithm does not require an SST climatology. As a consequence, the Version-2 SSTs accurately track the El Nino-to-La Nina cooling trend, and show nearly the same trend (within 0.1 C) as reported by the TAO array of buoys, as shown in Figure 3.

Figure 3. Time series of SST from TAO buoys, TMI, and Reynolds' OI product.

4. More Commonality with the AMSR Ocean Algorithm

The Version-1 TMI algorithm was a hybrid of regression algorithms and iterative algorithms that matched the T_B's to a simplified radiative transfer model (RTM), similar to the type used for SSM/I. Based on the results coming from our AMSR investigation, it appears that retrieval algorithms based on 2-stage regressions perform as good as (or possibly even better than) the RTM-T_B matching algorithms. Since we want the TMI ocean algorithm to be a surrogate for AMSR, we decided to revise the TMI algorithm, substituting the 2-stage regressions for the RTM-T_B matching algorithms.

The operation of the 2-stage regression algorithm is as follows. An initial set of regressions is used to obtain a first guess for SST and wind. A second-stage regression is then selected that locally corresponds to the first guess SST and wind. This two-stage approach effectively handles the non-linearities in the retrieval process. Note that both the first and second stage regressions are based on a physically based computer simulation that produces a massive array of brightness temperatures corresponding to millions of realistic environmental scenes. Hence we use the term "physically based regressions" as opposed to blind regressions.

There are several other common features of the TMI and AMSR algorithms. The Version-2 algorithm is the same in both structure and functionality as the AMSR algorithm. By having common data processing routines that can accommodate both AMSR and TMI, we can more fully test the AMSR algorithm using TMI observations. In addition, we have greater confidence that the AMSR algorithm will perform similarly to the TMI algorithm given that the new algorithms have nearly the same form.