

# **Analysis of Ultra High Resolution Sea Surface Temperature Level 4 Datasets**

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## Introduction

Sea surface temperature (SST) studies are often focused on improving accuracy, or understanding and quantifying uncertainties in the measurement, as SST is a leading indicator of climate change and represents the longest time series of any ocean variable observed from space. Over the past several decades SST has been studied with the use of satellite data. This allows a larger area to be studied with much more frequent measurements being taken than direct measurements collected aboard ship or buoys.

The Group for High Resolution Sea Surface Temperature (GHRSSST) is an international project that distributes satellite derived sea surface temperatures (SST) data from multiple platforms and sensors. The goal of the project is to distribute these SSTs for operational uses such as ocean model assimilation and decision support applications, as well as support fundamental SST research and climate studies. Examples of near real time applications include hurricane and fisheries studies and numerical weather forecasting. The JPL group has produced a new 1 km daily global Level 4 SST product, the Multiscale Ultrahigh Resolution (MUR), that blends SST data from 3 distinct NASA radiometers: the Moderate Resolution Imaging Spectroradiometer (MODIS), the Advanced Very High Resolution Radiometer (AVHRR), and the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSRE). This new product requires further validation and accuracy assessment, especially in coastal regions.

We examined the accuracy of the new MUR SST product by comparing the high resolution version and a lower resolution version that has been smoothed to 19 km (but still gridded to 1 km). Both versions were compared to the same data set of *in situ* buoy temperature measurements with a focus on study regions of the oceans surrounding North and Central America as well as two smaller regions around the Gulf Stream and California coast.



**Figure 1: North and Central America Region showing California Coast and Gulf Stream**

Ocean fronts exhibit high temperature gradients (Roden, 1976), and thus satellite data of SST can be used in the detection of these fronts. In this case, accuracy is less of a concern because the

primary focus is on the spatial derivative of SST. We calculated the gradients for both versions of the MUR data set and did statistical comparisons focusing on the same regions.

## Approach

To assess the accuracy of the two Level 4 datasets we co-located in time and space the buoy SST observations and satellite data using previously written software, and created maps showing the difference during the year 2009. The high resolution data set runs from April 2009 through May 2011

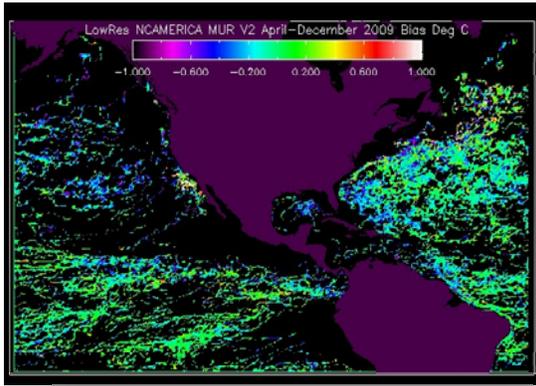


Figure 2: High Resolution satellite-buoy matchup

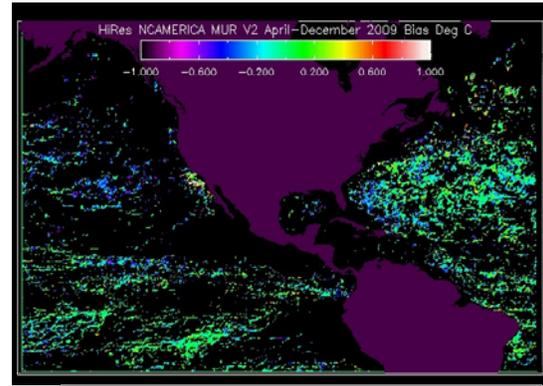


Figure 3: Low Resolution satellite-buoy matchup

and the low resolution product runs through 2009. The buoy data were taken from the US Navy FNMOC site. They collect *in situ* data globally from ships, drifting and moored buoys and other observations, quality control it and make it available in near realtime with one binary *in situ* observation file for each day. Separate comparisons were made to drifting and fixed buoys.

We then ran statistics on each matchup dataset to calculate the bias, standard deviation, and RMS for each region.

For the gradient analysis, we processed the daily global 1km MUR SST data into 10 day gradient averages for August and September 2010. The data was preconditioned using a 3x3 box-car filter over each image, and then processed for daily gradients by using a Sobel edge detection filter (Richards, 1986). The gradient (G) at each pixel is found by:

$$G_{jk} = |G_x| + |G_y|$$

$$G_x = F_{j+1,k+1} + 2F_{j+1,k} + F_{j+1,k-1} - (F_{j-1,k+1} + 2F_{j-1,k} + F_{j-1,k-1})$$

$$G_y = F_{j-1,k-1} + 2F_{j,k-1} + F_{j+1,k-1} - (F_{j-1,k+1} + 2F_{j,k+1} + F_{j+1,k+1})$$

where (j,k) are the coordinates of each pixel  $F_{j,k}$  in the original image. The daily gradients were used to calculate an average gradient over the 10 day period.

After calculating the gradients we created difference maps as well as calculated the correlation. The correlation was calculated in two ways. First we performed a correlation between each data set for the 10 day averages. We also performed a correlation between each pixel on a daily basis and created a correlation map to show where the highest and lowest correlations are.

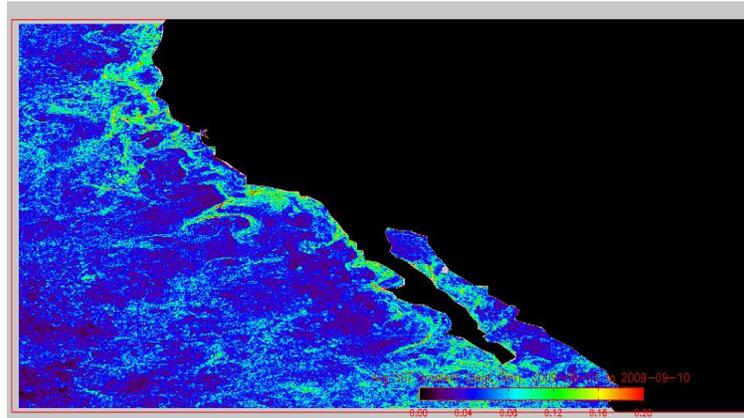


Figure 4: MUR High Resolution Average Gradient 9-1-2010 through 9-10-2010

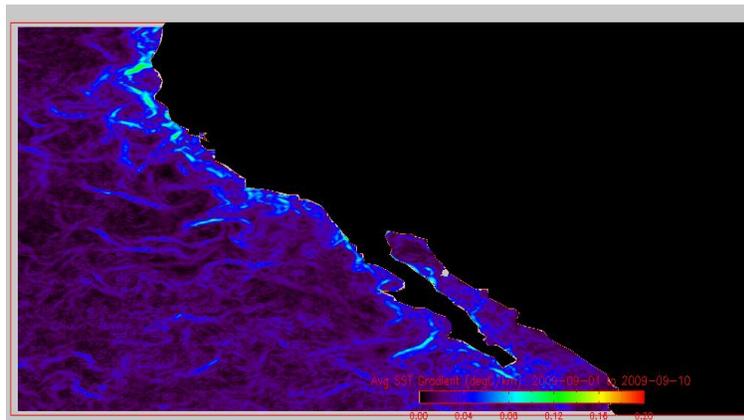


Figure 5: MUR Low Resolution Average Gradient 9-1-2010 through 9-10-2010

## Results

We analyzed the matchup data by computing the statistics of bias, standard deviation and RMS for each of the study regions. By comparing the standard deviation (and of lesser importance) the bias for each region we determined which data set showed larger differences from the buoy data.

Looking at figure 5, which shows the bias for the drifting buoys, we see close matchup between the bias for the low and high resolution data with small time periods where they differ. We calculated the average bias for the entire time period and also for each season to see which had the smaller average bias.

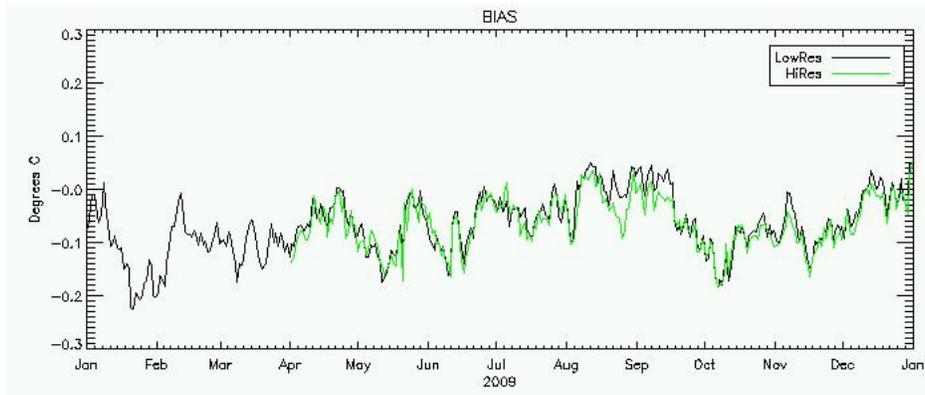


Figure 6: North and Central America bias for 2009

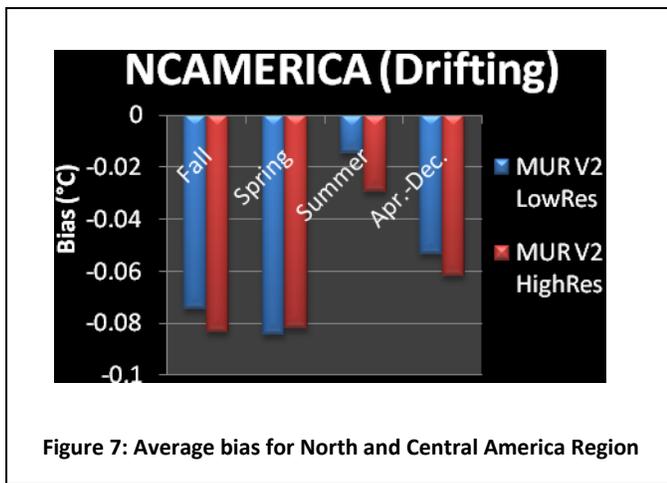


Figure 7: Average bias for North and Central America Region

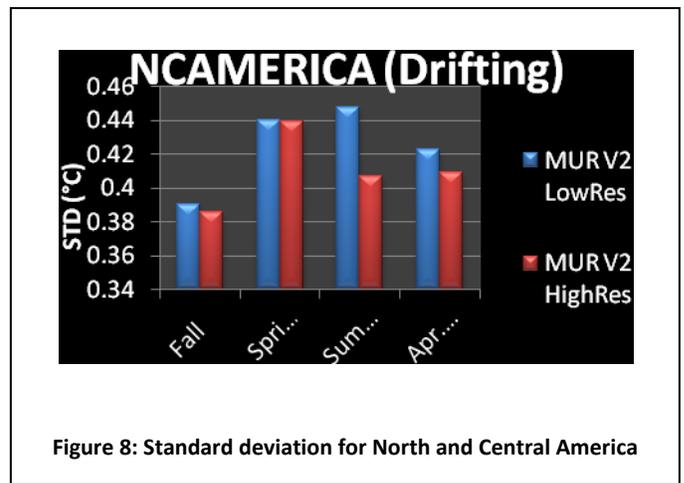


Figure 8: Standard deviation for North and Central America

We saw that the standard deviation was consistently smaller for the high resolution data than the low resolution. We have not yet determined if this difference is statistically significant. We plotted the other regions to see if they exhibited the same behavior.

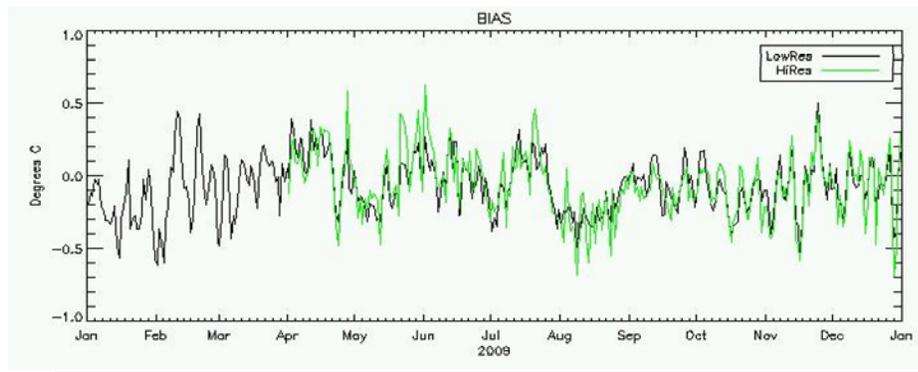


Figure 9: Gulf Stream bias for 2009

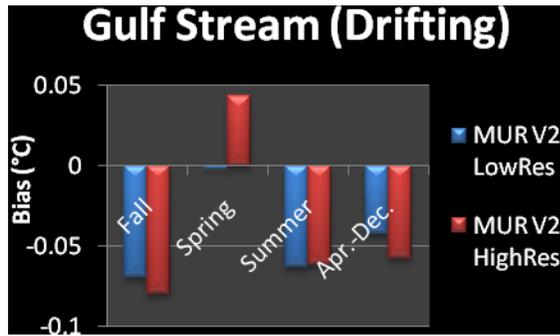


Figure 10: Average bias for Gulf Stream

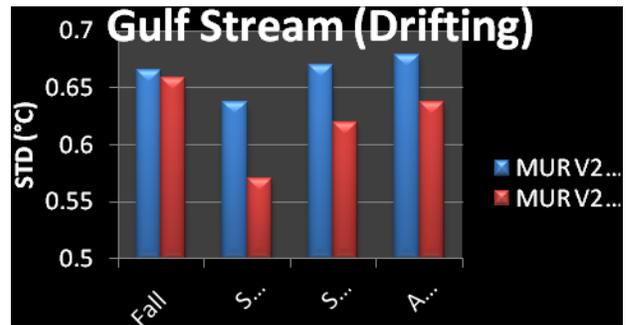


Figure 11: Standard deviation for Gulf Stream

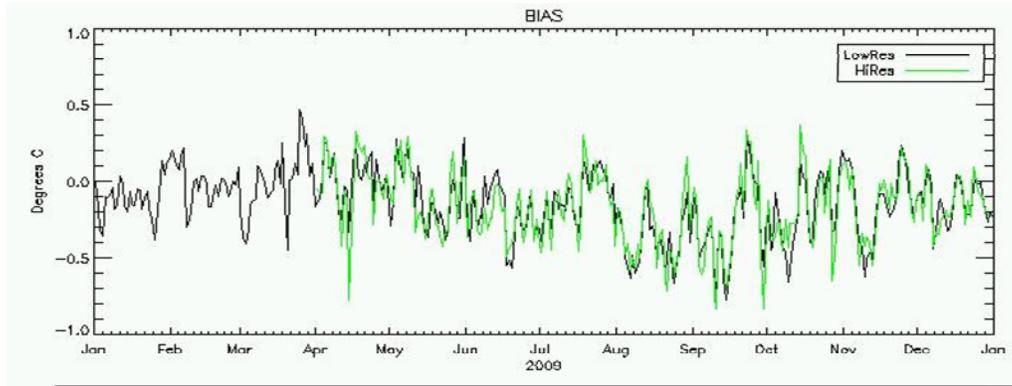


Figure 12: California Coast bias for 2009

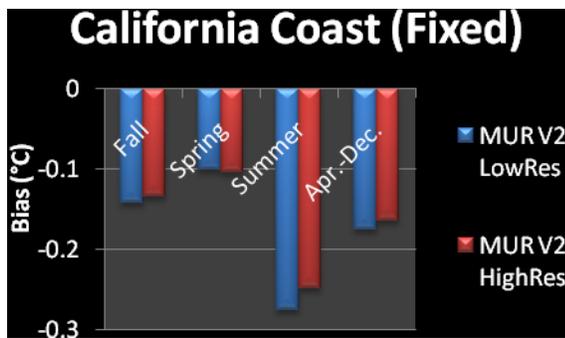


Figure 13: Average bias for California Coast

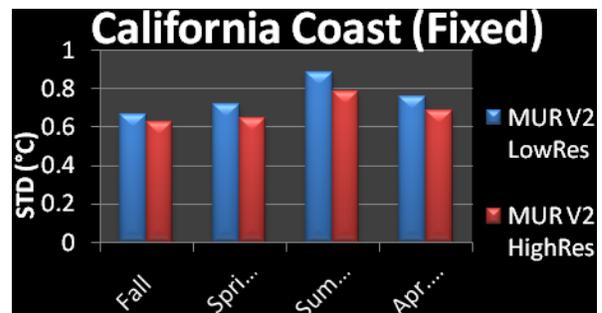


Figure 14: Standard deviation for California Coast

In all regions we saw that the standard deviation was consistently lower for the high resolution version. For the California Coast only the statistics from fixed (moored) buoys are shown because the sample size of drifting buoys was small.

To further analyze the gradient images and see where the differences are, we created maps of the value of high resolution minus low resolution gradient at each pixel (e.g., see Fig 14).

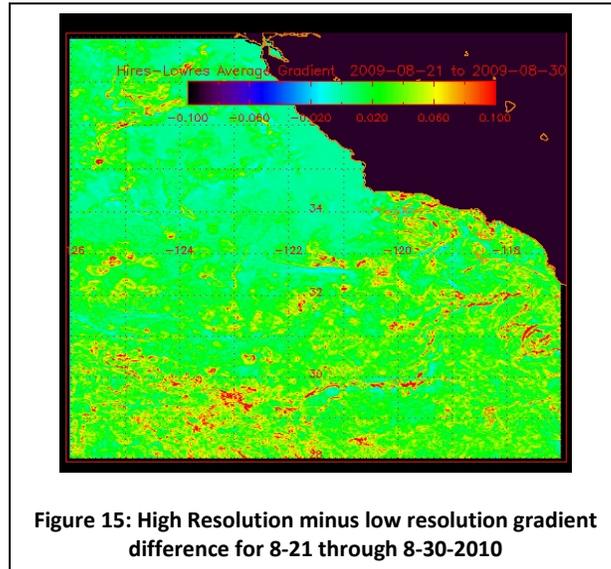
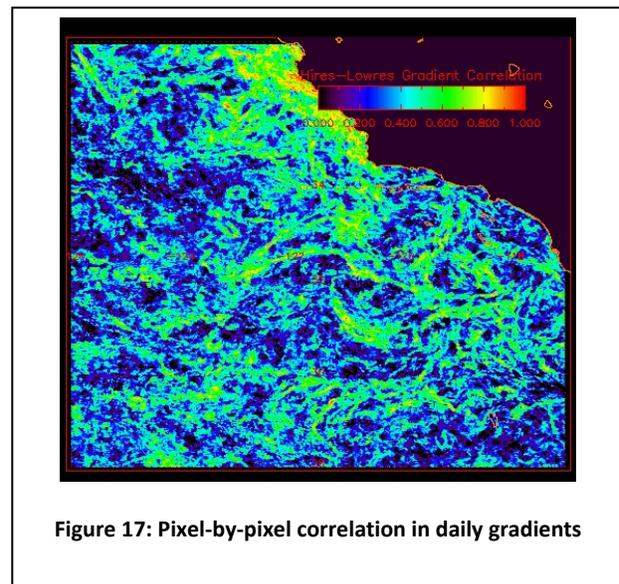
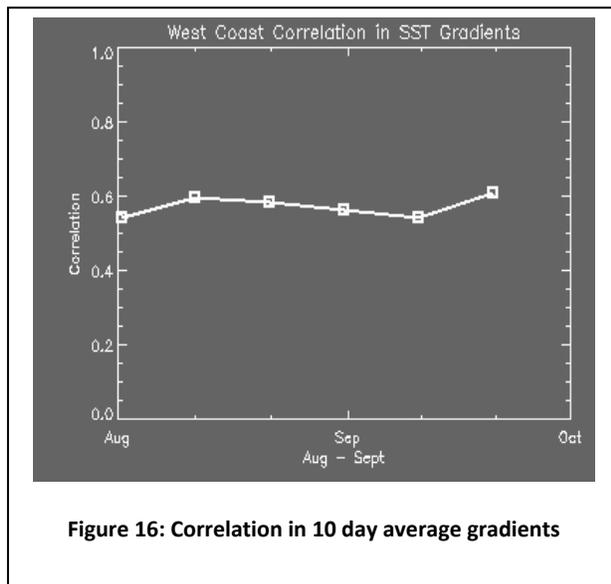


Figure 16 shows a high correlation in regions where there are high gradients and very low correlation in regions with small gradients and the region with high correlation matches up with the region in figure 14 where the differences are smallest. The largest differences are appearing in the open ocean where the high resolution product may be picking up gradients that the low resolution version doesn't.



## **Discussion and Conclusion**

Comparing the daily global 1km MUR High Resolution and low resolution data we were able to learn several interesting things about each case study region. In both the larger NCAMERICA and smaller sub-regions the high resolution MUR exhibited smaller standard deviations than the low resolution MUR when compared to buoy measurements, and in general the fixed buoys showed a larger bias than the drifting buoys. Also, the high resolution data product produced higher gradients than the low resolution product which would be expected. The good statistical performance of the high resolution product suggests that these gradients are real (and not noise) and therefore the differences are real as well.

Previous studies had shown a lower standard deviation in lower resolution products. The results of our study have consistently shown a lower standard deviation for the higher resolution product than the lower. More statistical tests need to be done to determine if this difference is statistically significant but the result is encouraging because it indicates that we can increase the resolution without decreasing the accuracy of the product with respect to noise. The low resolution product can still be useful for assimilating in atmospheric models or calculating air-sea fluxes and other applications where a smoother SST field is useful.

## **Acknowledgements**

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