Improving Satellite Retrieved Infrared Sea Surface Temperatures in the Aerosol Contaminated Regions

UNIVERSITY OF MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Bingkun Luo, Peter Minnett, Goshka Szczodrak, Katherine Kilpatrick

Rosenstiel School of Marine and Atmospheric Science, University of Miami

4600 Rickenbacker Causeway, Miami, Florida-33149, USA

Abstract

Infrared satellite observations of sea surface temperature (SST) have become essential for many applications in meteorology, climatology and oceanography. Users usually demand high accuracy SST data: for climate research and monitoring an absolute temperature uncertainty of 0.1K and stability of better than 0.04K per decade are required. Tropospheric aerosol concentrations increase infrared signal attenuation and prevent the retrieval of accurate satellite SST. We compare satellite-derived skin SST with measurements from the ship-based Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) deployed on ships during the Aerosols and Ocean Science Expeditions (AEROSE) and with quality-controlled drifter temperatures. After match-up with in-situ SST and filtering of cloud contaminated data, the results indicate that SST retrieved from MODIS (Moderate Resolution Imaging Spectroradiometer) aboard the Terra and Aqua satellites have negative (cool) biases compared to shipboard radiometric measurements. There is also a pronounced negative bias in the Saharan outflow area that can introduce SST errors >1 K at AOD>0.5. In this study we present a new method to derive night-time Saharan Dust Index (SDI) algorithms based on 3.9, 10.8 and 12.0 μm RTTOV simulated brightness temperatures. Then we derived correction coefficients by regression of the SST errors against the SDI. This method has been applied to MODIS AQUA data. The biases and standard deviations are reduced by 0.25K and 0.19K after SDI correction. The goal of this study is to understand the characteristics and physical mechanisms of the aerosol layer effect on satellite retrieved infrared SST, as well as to derive empirical formulae that better correct for aerosol-related effects.

1. Data

➢**In-situ SST datasets:**

▪M-AERI: The M-AERI is an accurate, self-calibrating, Fourier transform IR spectro-radiometer that measures emission spectra from the sea and atmosphere (Minnett et al. 2001).

▪Drifters: NOAA established the in situ sea surface temperature (SST) Quality Monitor (iQuam) to support the validation (Cal/Val) of satellite and blended SST products. IQuam consists of quality-controlled measurements from drifters, moored buoys and ships.

➢**Satellite SST dataset: *MODIS Aqua L2***

▪ Spatial resolution:0.05°

▪ Area: *-20° S to 35° N , 100° W to 100° E*

▪ Temporal resolution: 5 min

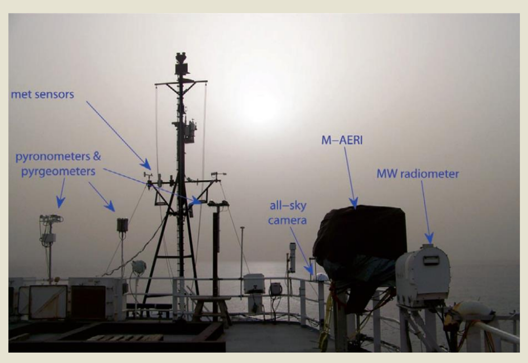
➢**Model SST dataset: *ECMWF***

• *European Centre for Medium-Range Weather Forecasts (ECMWF).*

▪Spatial resolution:0.75°

▪Area: Global

▪Temporal resolution: 6 h

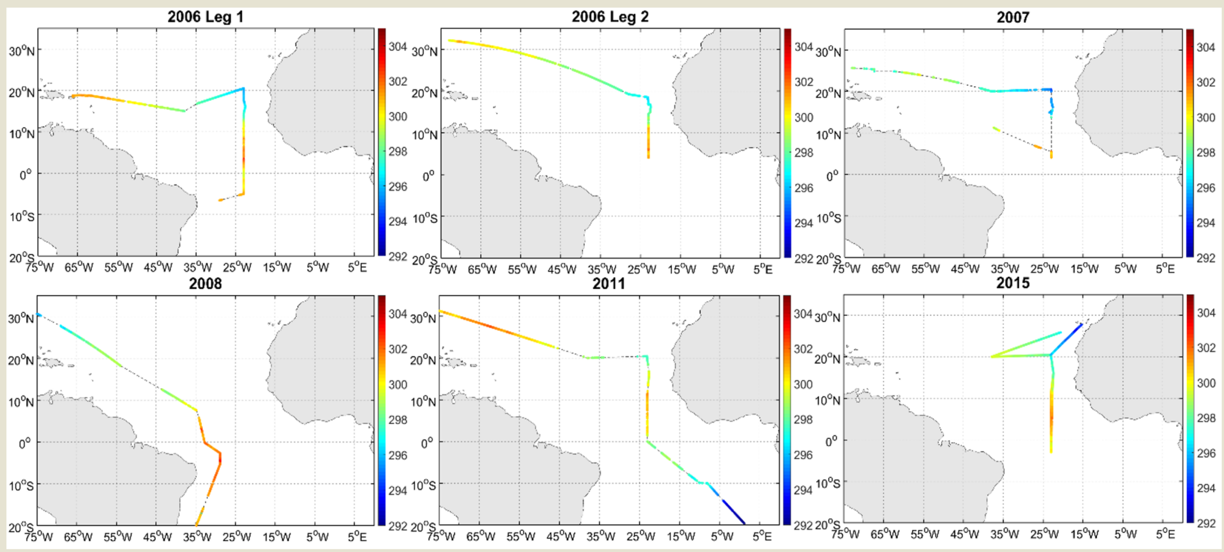


Left: The M-AERI is mounted on the port side railing of the ship. Right: Unenhanced digital color photograph of the forward deck-2 of the Ronald H. Brown, taken while holding station along 23° W longitude during PNE AEROSE-III, on the afternoon of 13 May 2007, during a major Saharan dust outflow pulse. (Nalli et al. 2011)

2. Method

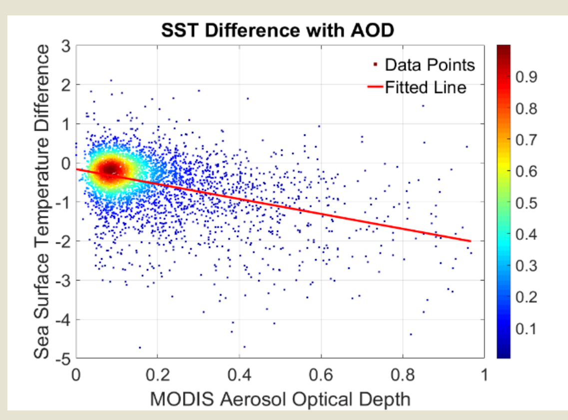
1. Preprocess the data: collocate satellite data and model data with the in-situ measurements.
2. Apply quality control and generate match-ups.
3. Evaluate the accuracy of the satellite SST data. Assess the impact of the Saharan Outflow on satellite retrieved SST.
4. Use Radiative transfer models (RTTOV) to simulate the SST differences with aerosol optical depth (AOD) and derive the Saharan Dust Index (SDI) based on ancillary data.
5. Use Match-up database to derive coefficients for an SDI correction algorithm.
6. Apply the new algorithm to this region, compare the new, aerosol corrected SST with in-situ SST.

3. Ship Tracks



The Aerosols and Ocean Science Expeditions (AEROSE) have collected atmospheric data from the tropical Atlantic Ocean, sampling important regional meteorological phenomena. Cruise track are in where large-scale Saharan dust outbreaks occur.

4. Match-ups and Comparisons



MODIS AOD	For the 2015 Match-up data (℃)					
	N	Min	Max	Med	Mean	STD
0-0.2	3079	-4.73	2.10	-0.28	-0.36	0.56
0.2-0.4	775	-4.33	1.83	-0.54	-0.70	0.80
0.4-0.6	253	-4.71	1.63	-0.98	-1.15	0.96
0.6-0.8	78	-3.47	0.66	-1.50	-1.48	0.89
>0.8	38	-4.39	1.44	-1.80	-1.71	1.24
Total	4223	-4.73	2.10	-0.36	-0.50	0.70

Left: SST differences (MODIS SST- in-situ SST) with MODIS Aerosol Optical Depth. This is a scatter plot colored by density of points. The red line is the fitted line of these points. Right: Statistics of errors of MODIS AQUA SST vs AOD

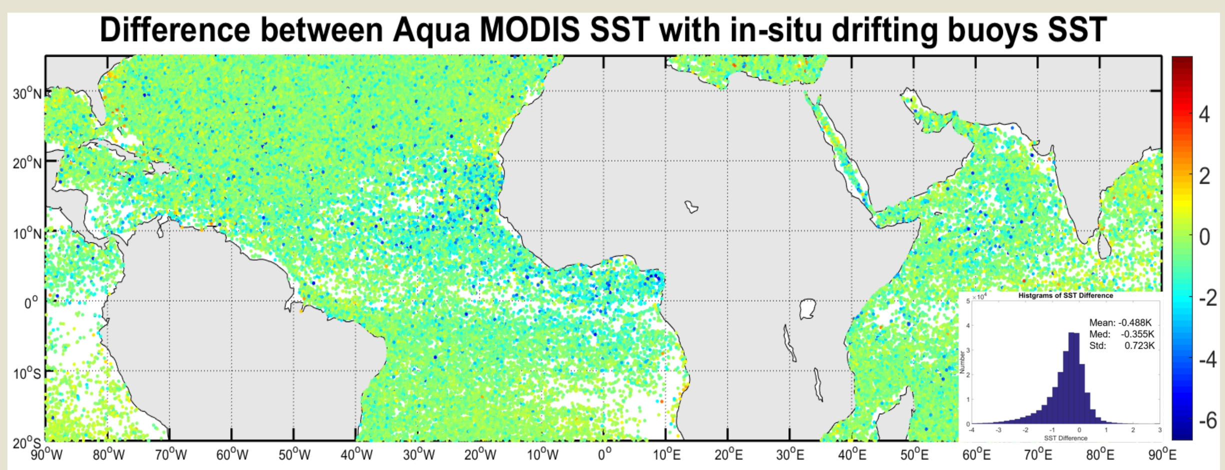
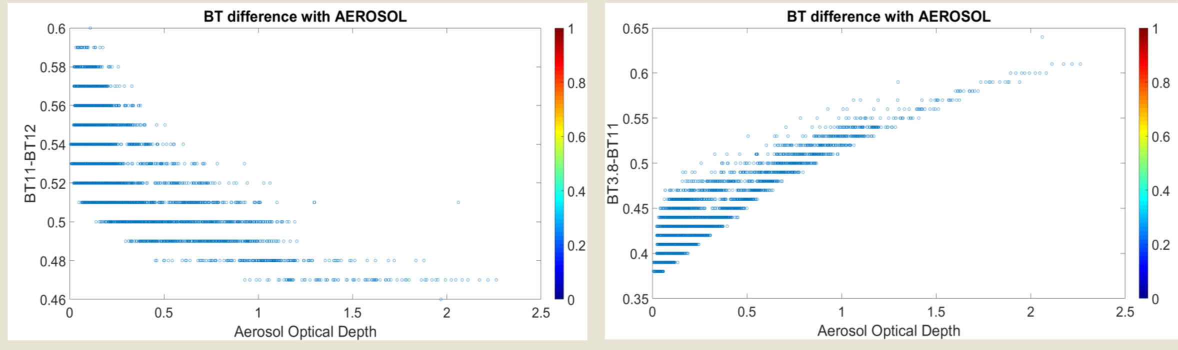


Figure: SST Difference Distribution

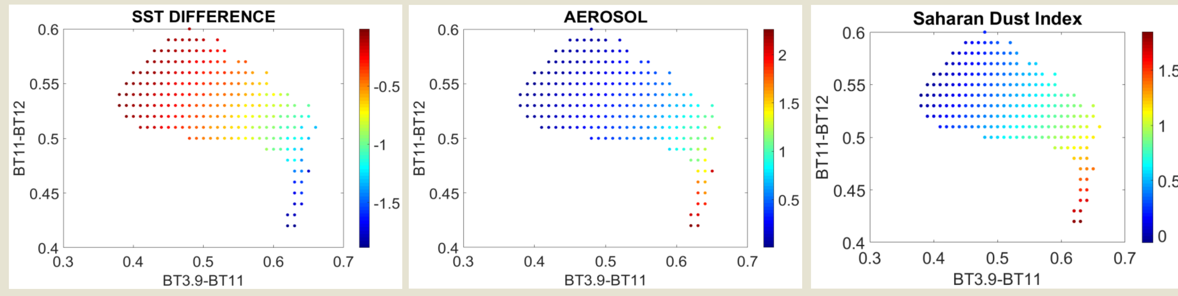
From the bias error distribution, there is a pronounced negative bias in the Saharan outflow area. High tropospheric aerosol concentrations significantly modify infrared atmospheric radiative transfer to prevent the retrieval of accurate satellite SST. The SST difference has a negative relationship with AOD as expected. From the statistics of errors, when the AOD is less than 0.4, the mean difference between satellite and in-situ SST is within 0.7℃. At larger AOD, the effect of aerosols is more obvious. We are fairly certain that the aerosol layers are a major sources of errors in this situation. A regression line fitted to the matchup data has a slope of -1.90 and an intercept of -0.17. There is a negative correlation between SST differences and AOD.

5. RTTOV Model Simulation

- Surface temperature: 1013hPa
- Mineral Transported aerosol type (1km layer depth)
  0-1km: 1013hPa 975hPa 937hPa 898hPa
  1-2km: 864hPa 830hPa 794hPa
  2-3km: 763hPa 732hPa 701hPa
  3-5km: 656hPa 610hPa
- ECMWF SST AOD as Input 12/07/2015 6:00AM

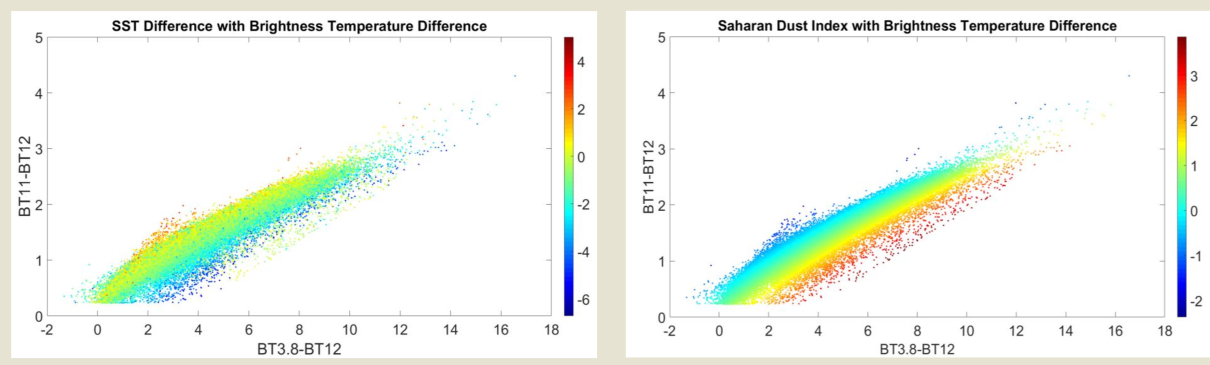


$$SDI=a_0+a_1*(BT_{3.8}-BT_{12})+a_2*(BT_{11}-BT_{12})+a_3*(BT_{11}-BT_{12})^2$$

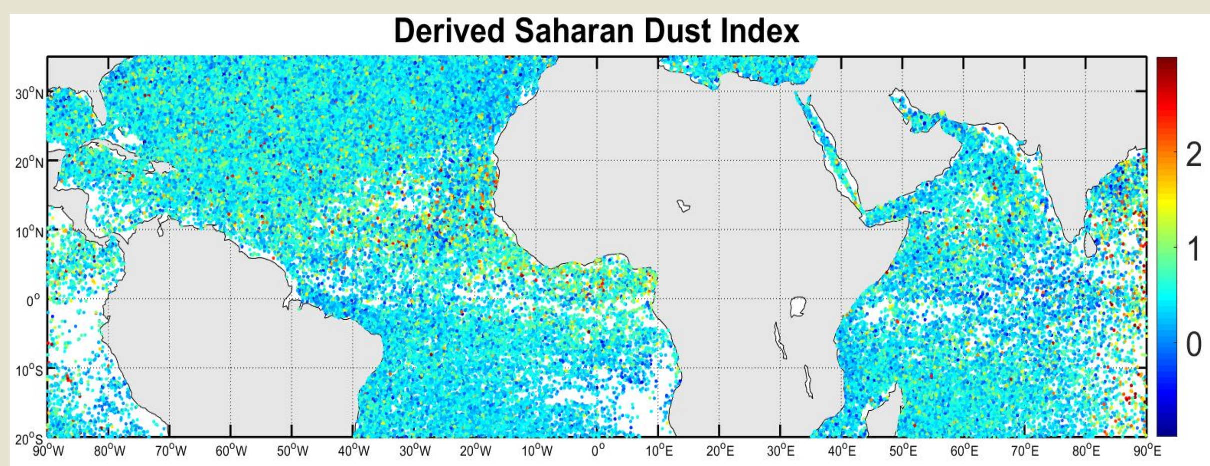


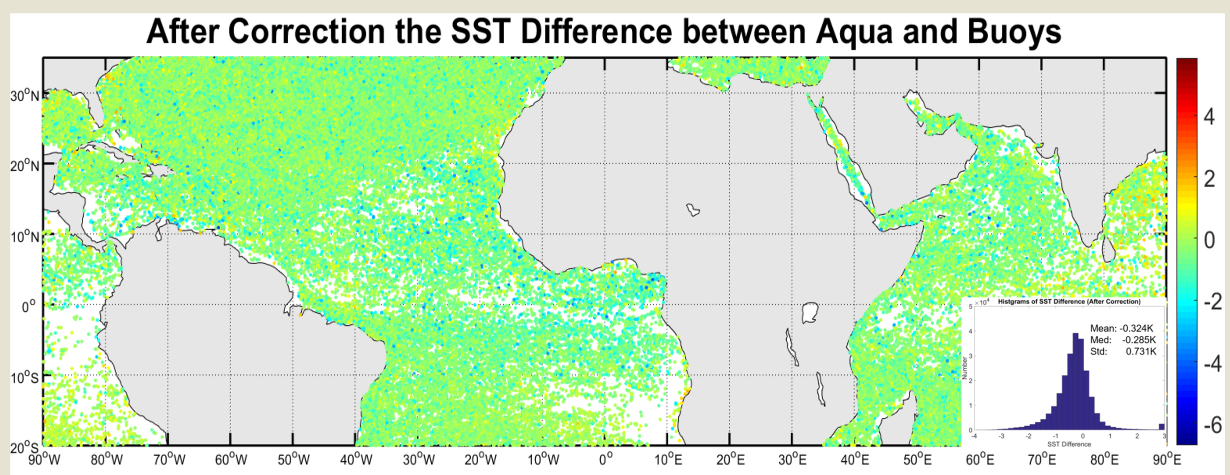
The top figures show the simulated change in BTs from the presence of a Saharan dust layer. The differences between channels can be used to derive a Saharan Dust Index (SDI) algorithm. After regressing MODIS Aqua simulated BTs against MUDB SST difference values we derived the SDI equation. It appears that increasing the AOD affects the accuracy of MODIS derived SST, and SDI is related to AOD.

6. MODIS SDI Correction Algorithm



Apply a_0 =0.9435 a_1 =0.8027 a_2 =-2.227 a_3 =-0.3039 to SDI equation we get this MODIS SDI.





Filter: BT11-BT12> 1.8*(BT3.8-BT12)-2.8 & SDI>1
SDI_Correction =2.053*SDI+1.013

7. Affiliations & Acknowledgement

Bingkun Luo: MPO/RSMAS, University of Miami Email: LBK@rsmas.miami.edu
Thanks to colleagues on the AEROSE cruises. Thanks for EUMETSAT Copernicus Student Travel Scholarships.
Funded through NASA Physical Oceanography Program.

8. References

Merchant, C. J., et al. (2006) Saharan dust in nighttime thermal imagery: Detection and reduction of related biases in retrieved sea surface temperature. Remote Sensing of Environment, 104(1), 15-30.

Minnett, P.J., et al. (2001) The Marine-Atmospheric Emitted Radiance Interferometer (M-AERI), a high-accuracy, sea-going infrared spectro-radiometer. Journal of Atmospheric and Oceanic Technology 18, 994-1013.

Nalli, N. R., et al. (2011) Multiyear observations of the tropical Atlantic atmosphere: Multidisciplinary applications of the NOAA Aerosols and Ocean Science Expeditions. Bulletin of the American Meteorological Society, 92, 765-789. doi: 10.1175/2011BAMS2997.1