# Infrared satellite-derived sea-surface skin temperature sensitivity to aerosol vertical distribution–Field data analysis and model simulations

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## Abstract

Sea-surface temperature is an Essential Climate Variable. The radiative impact of mineral dust is one of the major contributors to inaccuracies in the satellite-retrieved sea-surface skin temperature ($SST_{skin}$). Different aerosol dust vertical distributions have varying effects on the satellite-derived $SST_{skin}$. To further investigate the physical mechanisms of aerosol effects on Terra MODerate-resolution Imaging Spectroradiometers (MODIS) derived $SST_{skin}$, the aerosol radiative effects were studied with a field-data match-up analysis and radiative transfer simulations. The field data are measurements of the $SST_{skin}$ derived from highly accurate ship-based infrared spectrometers vertical atmospheric temperature and water vapor radiosonde profiles. The aerosol dust concentrations in three-dimensions from the NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 have been used as input to radiative transfer simulations. Based on the analysis of field data and simulations, we have empirically determined that the sensitivity of the Terra MODIS retrieved $SST_{skin}$ accuracies is related to 1) dust concentration in the atmosphere, 2) the dust layer altitude, and 3) the dust layer temperature. As the aerosol altitude increases, the effect on the $SST_{skin}$ retrievals becomes more negative in proportion to the temperature contrast with the sea surface. $SST_{skin}$ differences, satellite-derived - surface measurements, for a given aerosol layer optical depth vary between -3 K and 1 K according to our match-up comparisons and radiative transfer simulations.

## 1. Motivation

- Knowledge of the accuracy of the SST derived from satellite measurements and models is one of the key factors of climate research and prediction.
- The SST accuracy requirements for climate research are very stringent: ~0.1K.
- But high tropospheric aerosol concentrations in the atmosphere significantly increase infrared signal attenuation and prevent the accurate retrieval of SSTs.
- To assess the impact of aerosols we compare SSTs from multiple sources under varying aerosol conditions..

## 2. Data & $SST_{skin}$ Validation

**Shipboard SST dataset: M-AERI**

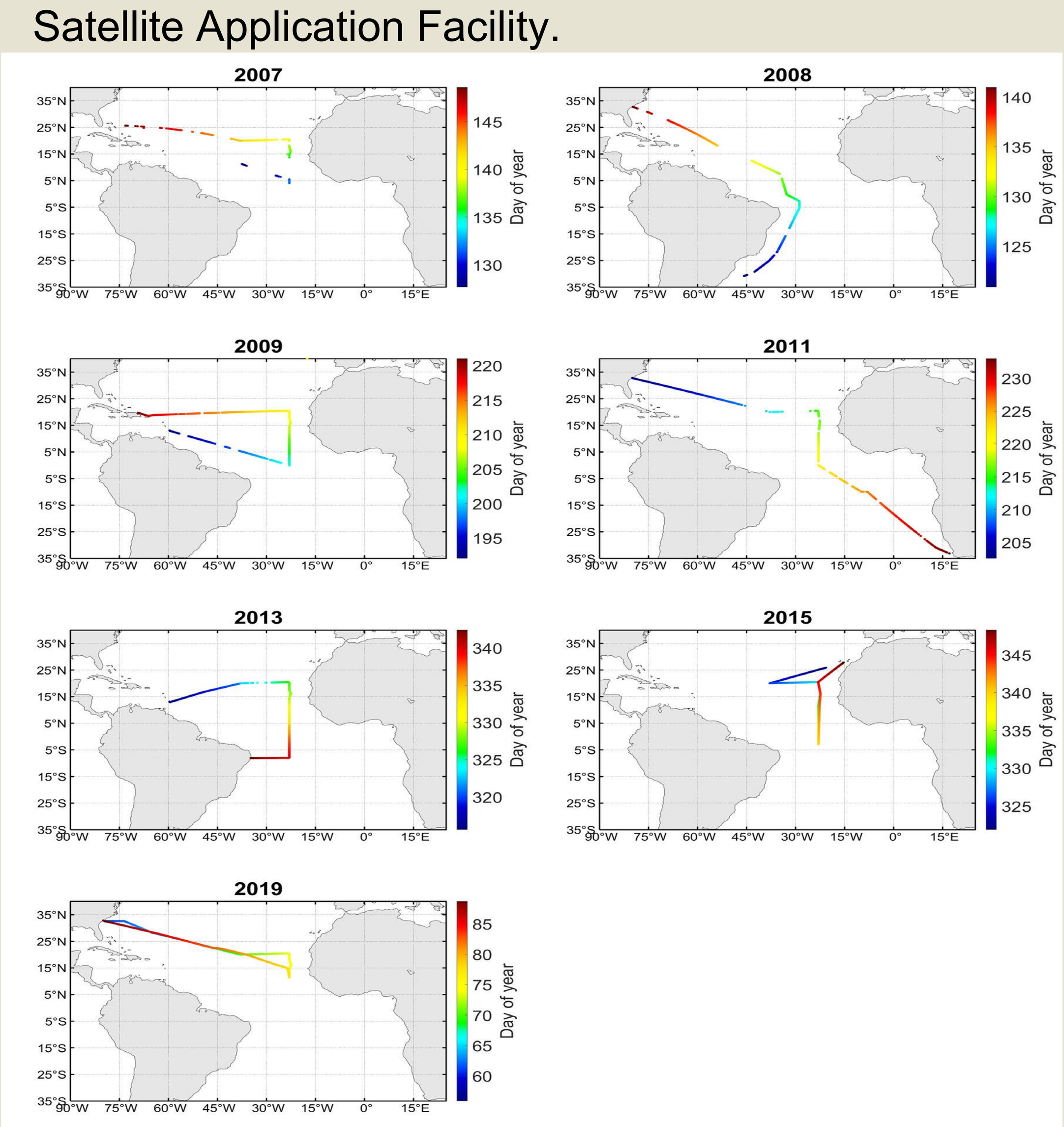
- The M-AERI is an accurate, self-calibrating, Fourier transform IR spectro-radiometer that measures emission spectra from the sea and atmosphere (Minnett et al. 2001).
- RSMAS Match-Up Data Base from NASA SEABASS
- All of the M-AERI and radiosonde data used here are from a series of AERosols and Ocean Science Expeditions (AEROSE) cruises in the tropical and subtropical Atlantic Ocean.

**Satellite SST dataset: MODIS TERRA**

- Daily L2 SST products from the Long-Term Stewardship and Reanalysis Facility of Group for High Resolution Sea -Surface Temperature (GHRSST).
- The thermal-infrared $SST_{skin}$ was retrieved by nonlinear $SST_{skin}$ algorithms.
- Spatial resolution:0.01°
- Temporal resolution: Twice a day

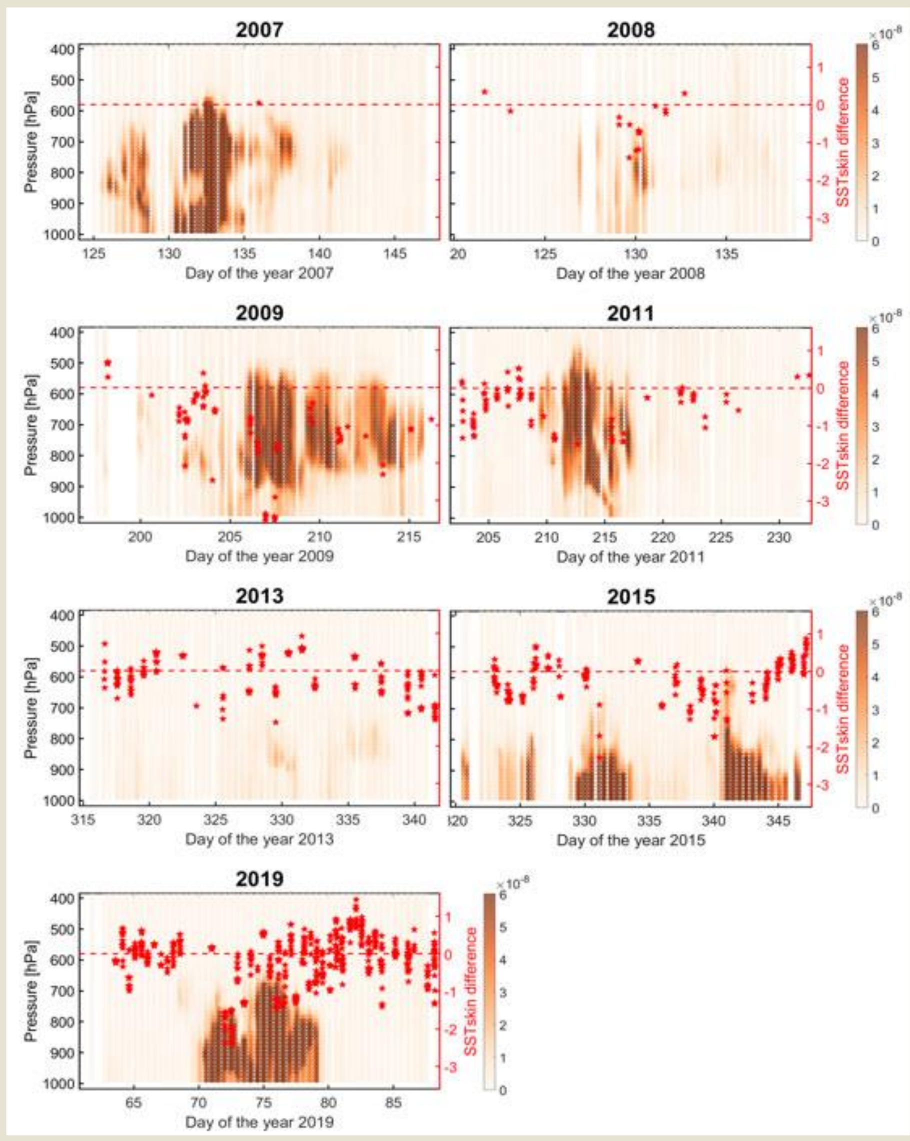
**Model simulation dataset: MERRA-2 and RTTOV**

- NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2).
- Radiative Transfer for TOVS (RTTOV) is a fast-radiative transfer model developed by the EUMETSAT NWP Satellite Application Facility.




- *Cruise tracks of each AEROSE campaign. The colors indicate the day of year*

## 3. $SST_{skin}$ Assessment

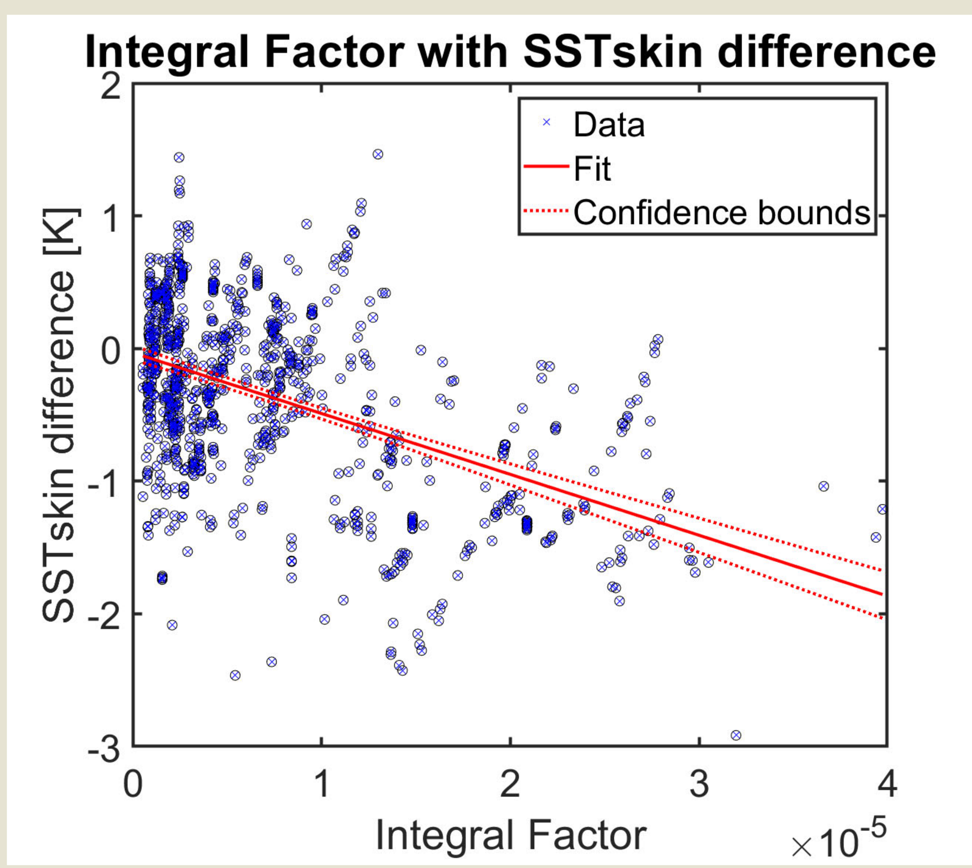



*$SST_{skin}$ difference from each of the ship tracks. Red stars indicate the difference with the right y-axis range. The operations of M-AERIs are suspended during rain thus causing some $SST_{skin}$ data gaps along the track. Comparisons in and close to ports are not used. The background color indicates the dust mixing ratio.*

By using the AEROSE match up database, this study revealed the impacts of the dust layer vertical distribution on the MODIS derived $SST_{skin}$. The comparison shows that the negative differences are mainly localized in the Saharan dust outflow region. The $SST_{skin}$ retrieval error is related to the concentrations, altitudes, and temperatures of dust layers. We define the following $SST_{skin}$ bias factor ($\Delta SST_{aer\_\delta T}$) as:

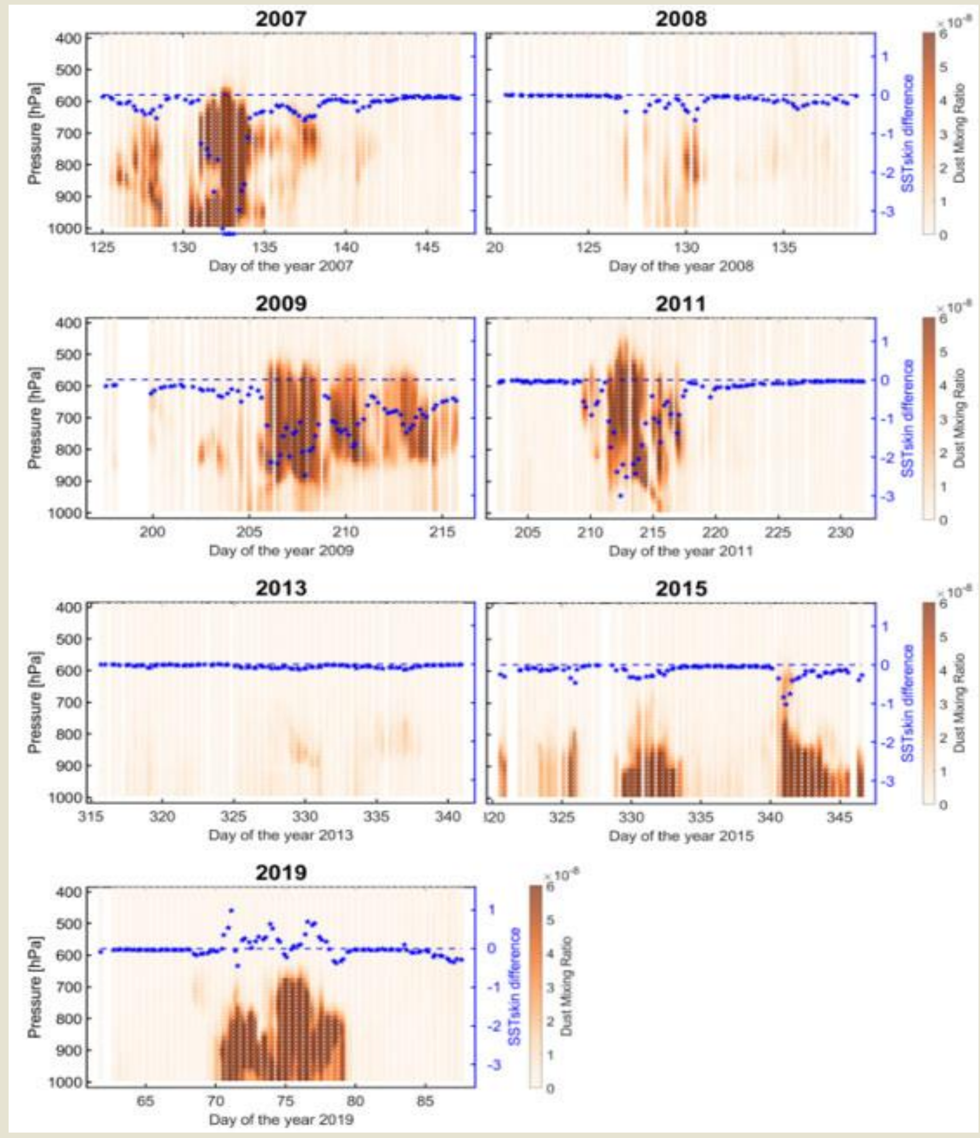
$$\Delta SST_{aer\_\delta T} = \sum_{p=surface}^{p=400hPa} \sum_{i=3}^{i=1} (SST_{skin} - T_{air}) \times x_i \times \beta_{ext,i}$$

Where $x_i$ is each layer's MERRA-2 dust mixing ratio, $\beta_{ext,i}$ is the sum of scattering and absorption coefficients, $T_{air}$ is the air temperature of the corresponding layer, $SST_{skin}$ is the M-AERI measured skin temperature.




*The relationship between MODIS $SST_{skin}$ retrieval bias and $\Delta SST_{aer\_\delta T}$.*

## 4. RTTOV Simulation Assessment




*$SST_{skin}$ differences from RTTOV simulations along the cruise tracks. The blue stars indicate the simulated $SST_{skin}$ error caused by the aerosol according to the y-axis scale at right.*

The results show that the negative $SST_{skin}$ difference can be marked when the ship entered significant, large-scale Saharan dust outflow regions. The uncertainties are also related to the dust layer thickness and altitude.

## 5. Summary

- $SST_{skin}$ differences vary between -3 K and 1 K according to our match-up comparisons and radiative transfer simulations.
- MODIS retrieved $SST_{skin}$ accuracies is related to:
  1) dust concentration in the atmosphere
  2) the dust layer altitude,
  3) the dust layer temperature.
- As the aerosol altitude increases, the effect on the $SST_{skin}$ retrievals becomes more negative in proportion to its temperature contrast to the sea surface.

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## 8. References

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