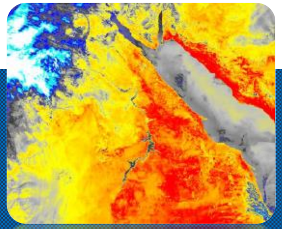

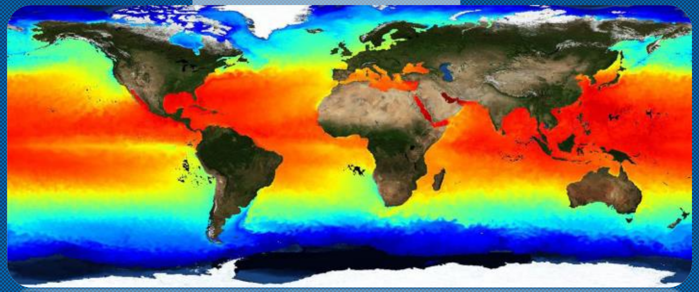

Infrared Radiative Simulated SSTskin Through Aerosol-Burdened Atmosphere

21st GHRSST Science Team Meeting

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IMSG, Inc. at NOAA/NESDIS/STAR

CONTENTS

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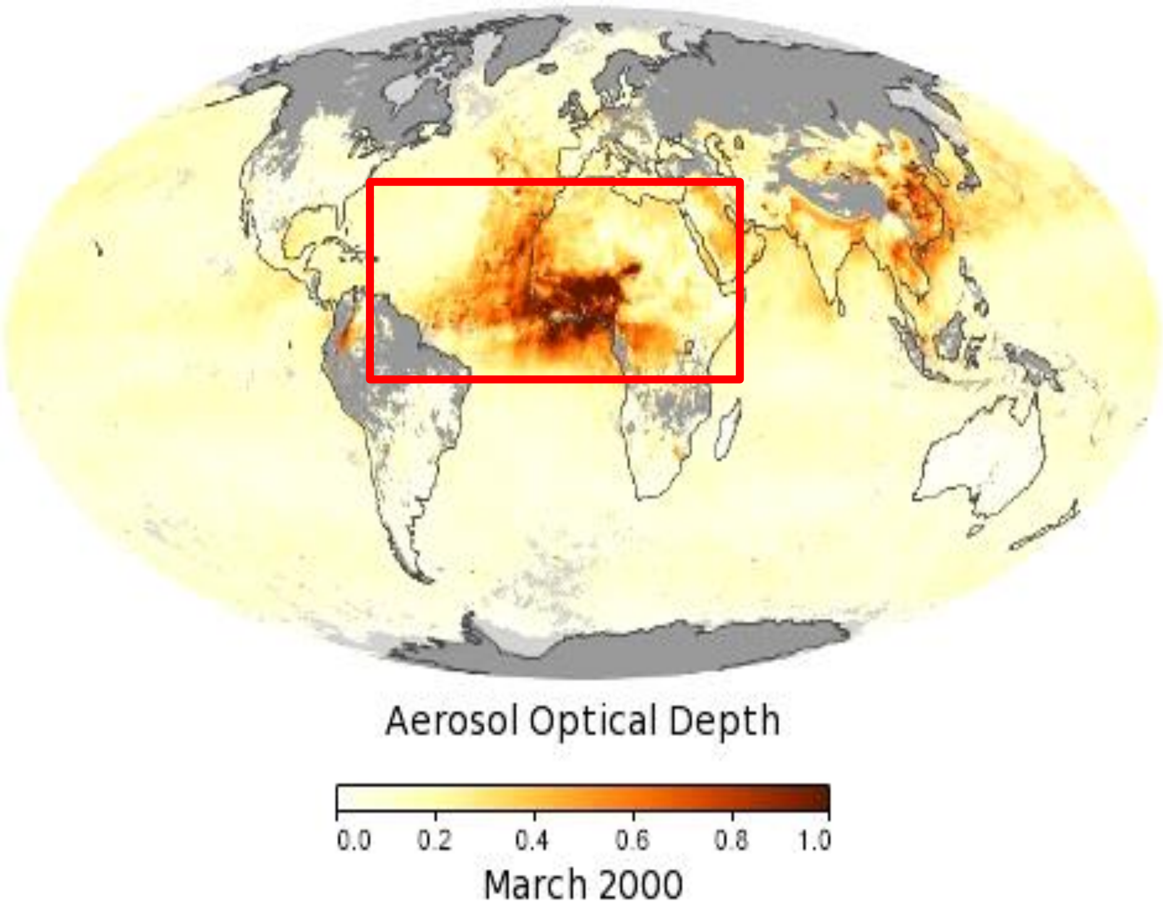
PART ONE

Introduction and Data

Significance of this study

- The accuracy of the Sea Surface Temperature (SST) derived from satellite measurements is one of the key factors of climate research and prediction.
- The SST accuracy requirements for climate research are very stringent: ~0.1K.
- But dense tropospheric aerosol concentrations in the atmosphere significantly increase infrared signal attenuation and prevent the retrieval of accurate satellite SSTs.
- Therefore, it is important to quantify the errors and uncertainties of SST and obtain accurate satellite derived SST.

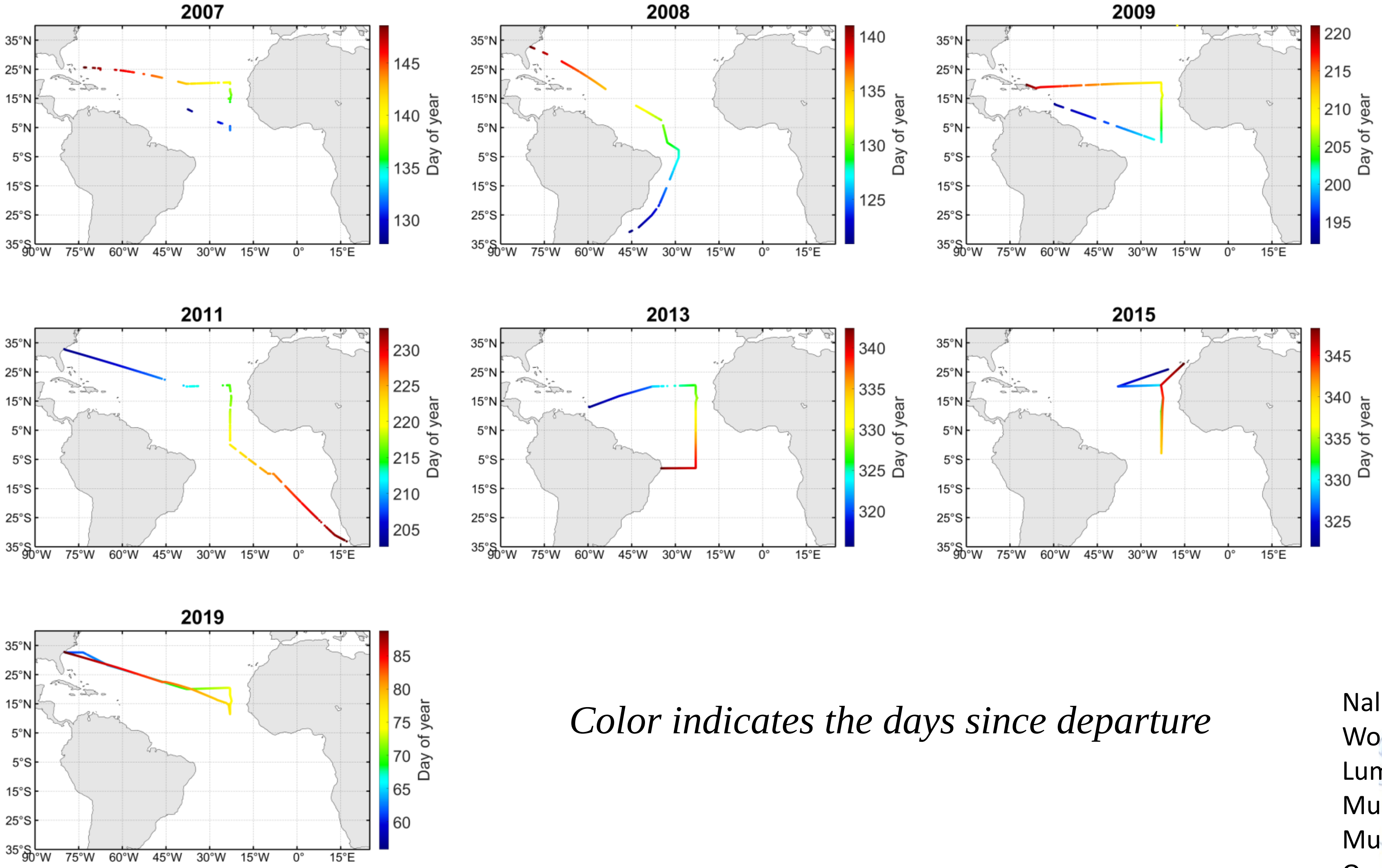
Aerosol fields



Areas of Interest:
Latitude: 20°S to 35°N
Longitude : 100°E to 100.0°W
Period: From 2006 to 2015

From NASA Earth Observations (NEO):
https://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD

Aerosols and Ocean Science Expeditions (AEROSE) tracks



Color indicates the days since departure

Nalli, N.R., Joseph, E., Morris, V.R., Barnet, C.D., Wolf, W.W., Wolfe, D., Minnett, P.J., Szczodrak, M., Izaguirre, M.A., Lumpkin, R., Xie, H., Smirnov, A., King, T.S., & Wei, J. (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

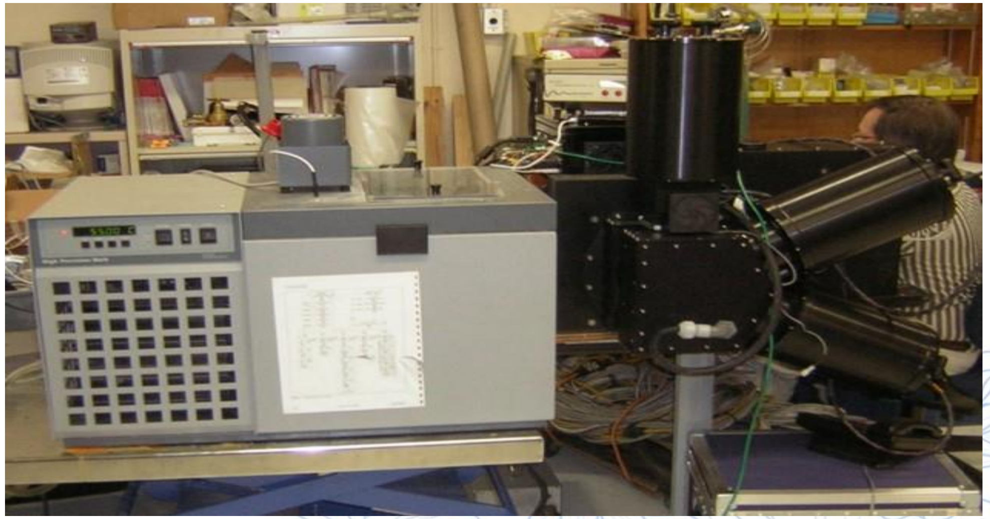
UNIVERSITY OF MIAMI

Shipboard SST dataset

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

M-AERI onboard the Ronald H. Brown.

NOAA Ship R.H.B at Florida. Mar 2 2018



M-AERI is calibrated in the laboratory before and after each deployment using an external validation procedure.

Shipboard Radiosonde dataset

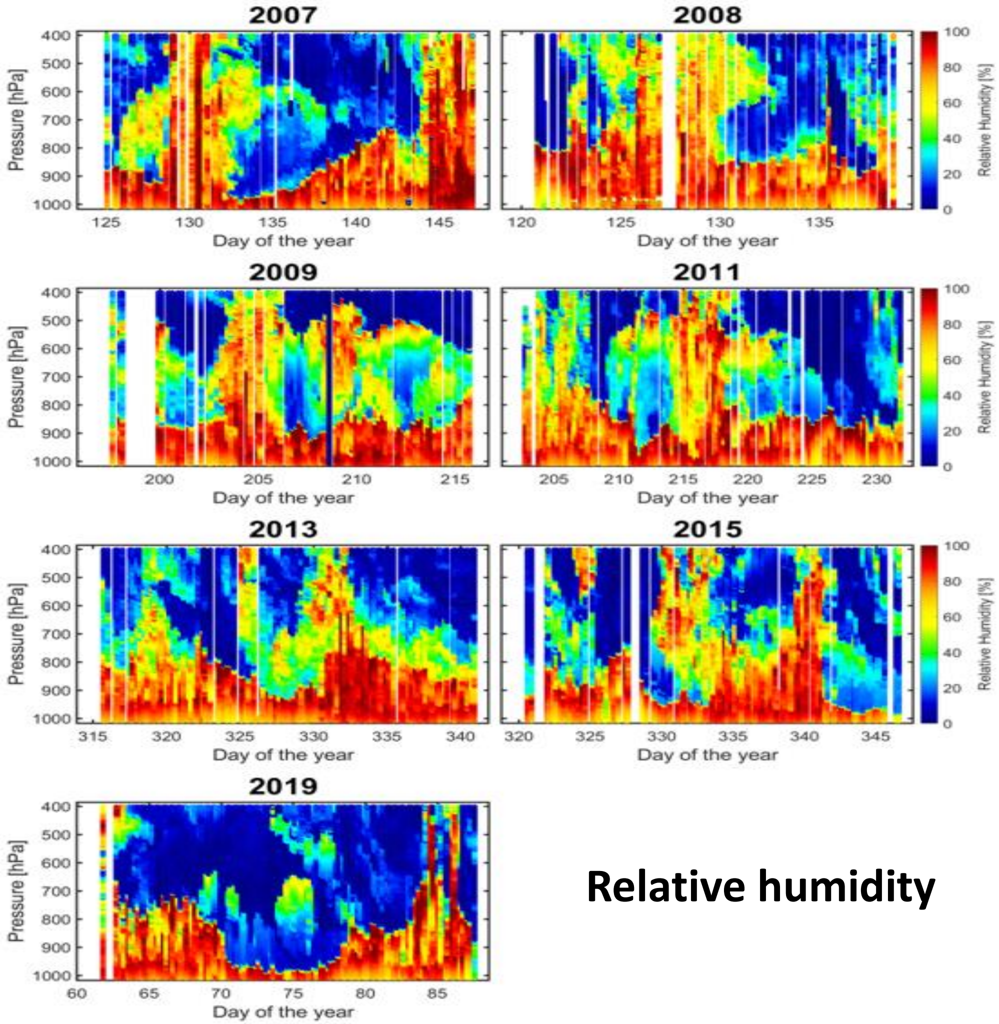
Table 1. Details of the AEROSE cruises used in this study.

CRUISES	NUMBER OF RADIOSONDES	START	END	DAYS OF DATA
2007 RHB	96	2007-05-07	2007-05-28	22
2008 RHB	74	2008-04-29	2008-05-19	21
2009 RHB	78	2009-07-11	2009-08-11	31
2011 RHB	102	2011-07-21	2011-08-20	31
2013 RHB	111	2013-11-11	2013-12-08	28
2015 Alliance	92	2015-11-17	2015-12-14	28
2019 RHB	97	2019-02-24	2019-03-29	34
Total	**650**	**2007-05-07**	**2019-03-29**	**195**

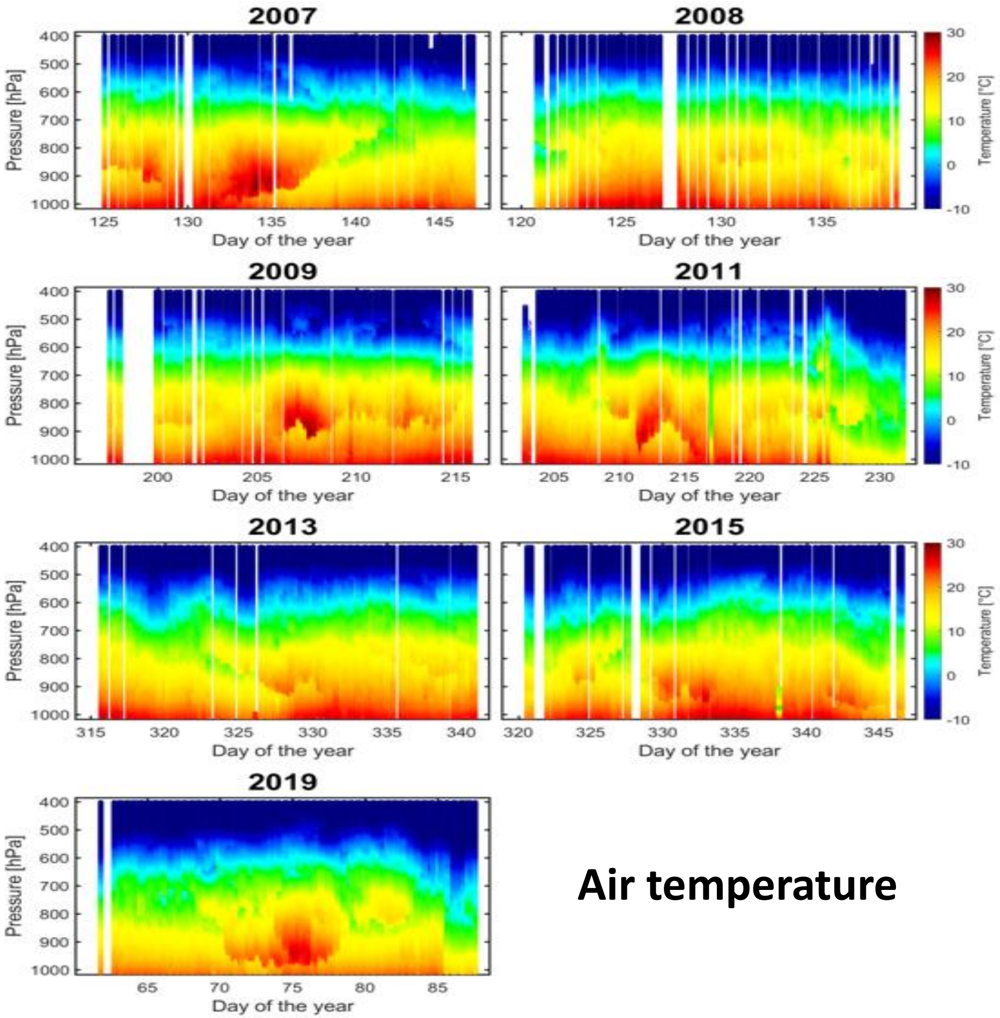
RHB: NOAA Ship *Ronald H. Brown*.
Alliance: North Atlantic Treaty Organization (NATO) R/V Alliance.

Launching RS92 radiosonde 30 min prior to satellite sounder overpass. (Nalli et al. 2011)

Shipboard Radiosonde measurements



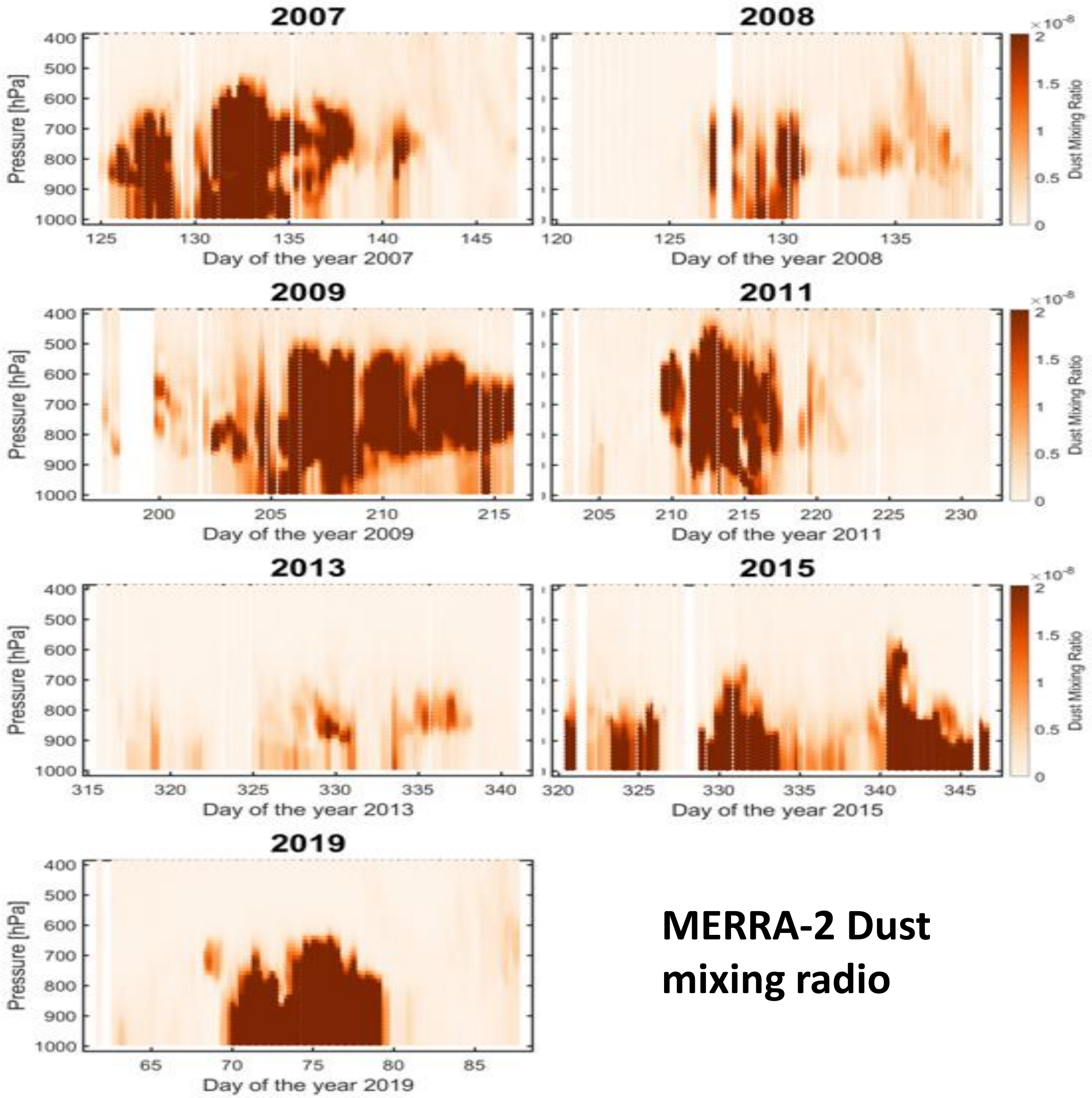
Relative humidity



Air temperature

MERRA-2 reanalysis value

NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) three-dimensional aerosol dust concentrations



MERRA-2 Dust mixing radio

Gelaro, Ronald, et al. "The modern-era retrospective analysis for research and applications, version 2 (MERRA-2)." Journal of Climate 30.14 (2017): 5419-5454.

RTTOV

- RTTOV (Radiative Transfer for TOVS) is a very fast radiative transfer model for measurements of satellite radiometers (Saunders et al. 2018).
- Brightness temperature simulations for TERRA MODIS infrared channels 20 (λ=3.8 µm), 29 (λ=8.9 µm), 31 (λ=11 µm) and 32 (λ=12 µm) have been performed with the RTTOV.
- The brightness temperatures are converted to SST_{skin} according to MODIS modified nonlinear SST algorithm (NLSST; Walton et al. (1998); Kilpatrick et al. (2015)).
- The aerosol dust-induced SST_{skin} error described in this study is defined as the aerosol-contaminated SSTskin minus the clear-sky derived SST_{skin}.
- Input: M-AERI SST_{skin}, MERRA-2 aerosol dust concentration, Radiosonde Air temperature and Relative humidity

Walton, C. C., et al. "The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites." Journal of Geophysical Research: Oceans 103.C12 (1998): 27999-28012.
Kilpatrick, K. A., et al. "A decade of sea surface temperature from MODIS." Remote Sensing of Environment 165 (2015): 27-41.

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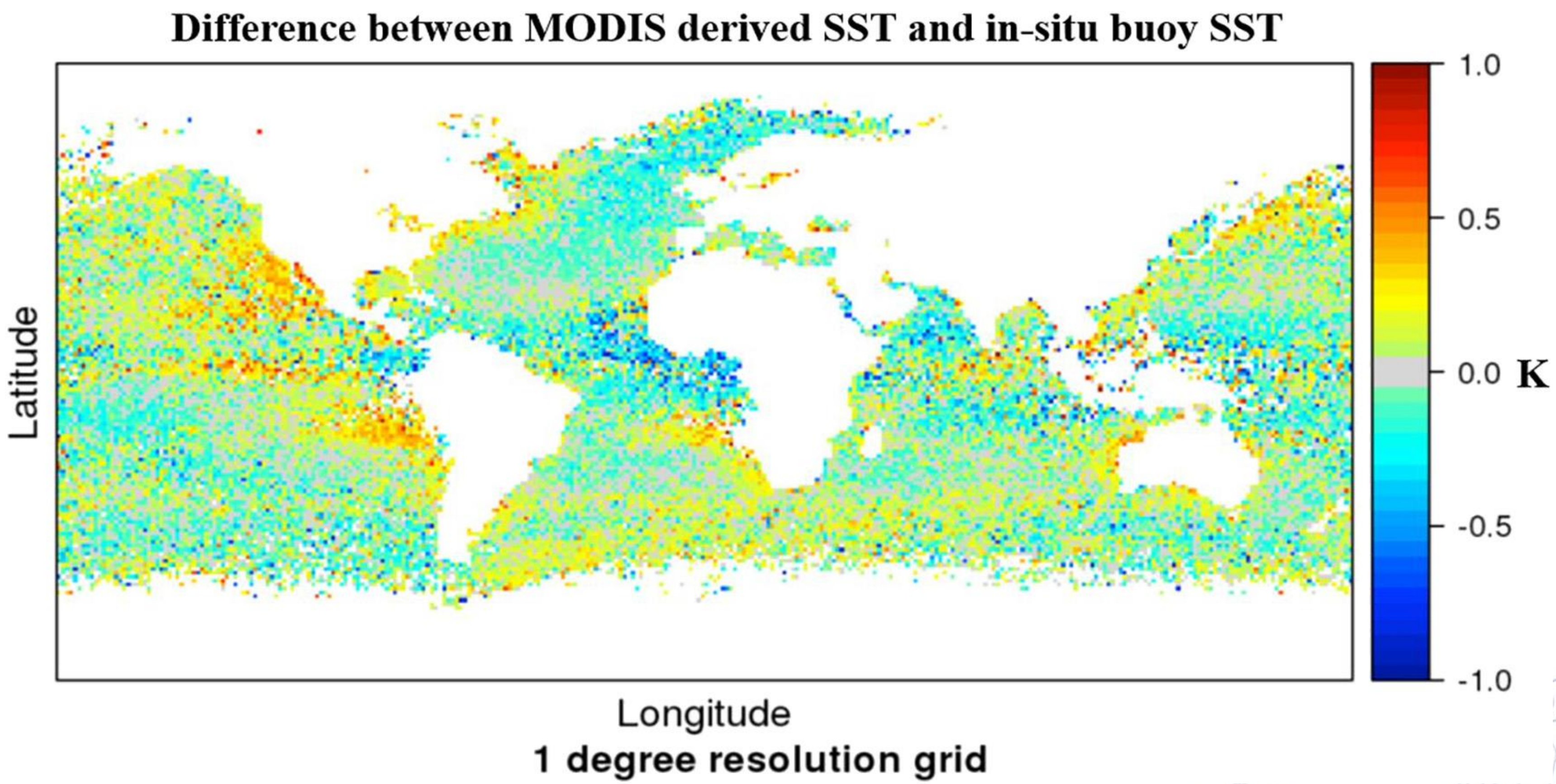
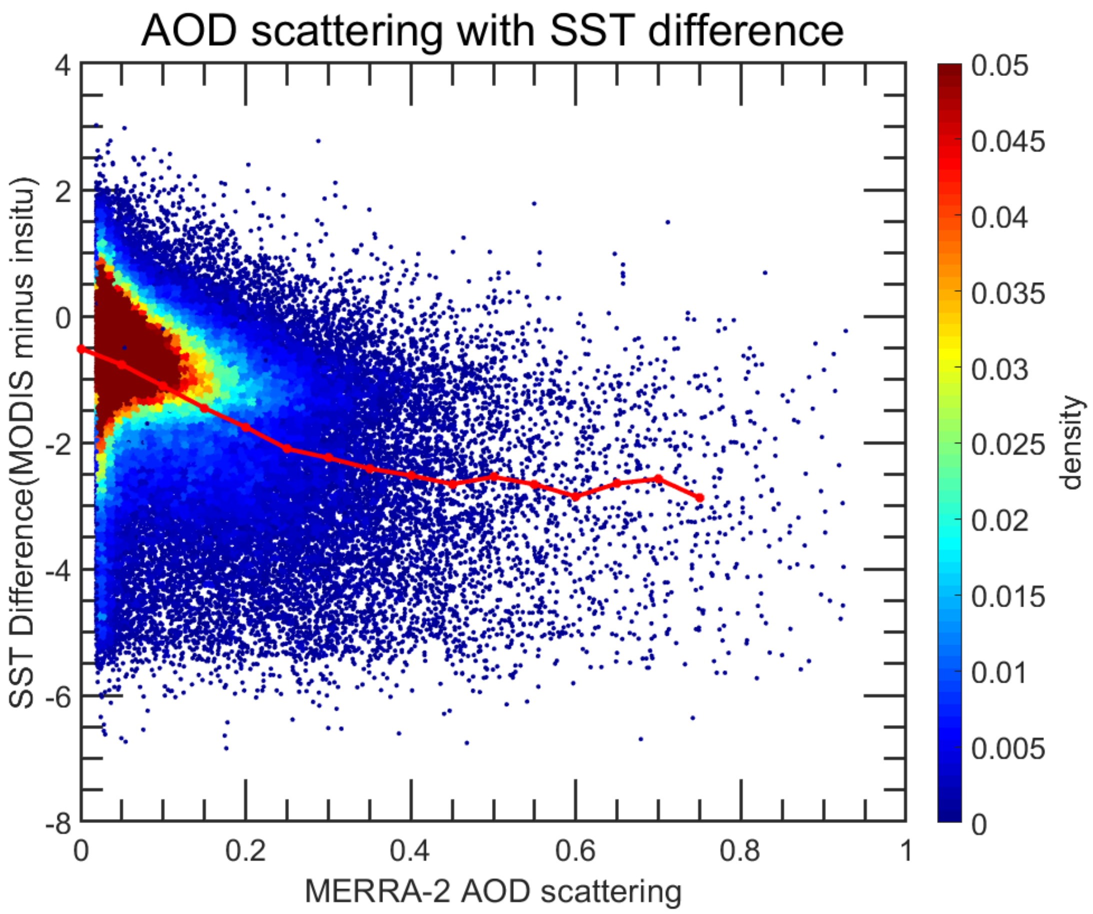
PART TWO

MODIS SST_{skin} Validation



Distribution of Terra MODIS SST matchups with in situ drifting buoy measurements (Minnett, 2016).

Part 2 MODIS SST_{skin} Validation



Scatter plot of SST difference with MERRA-2 Dust Scattering AOD, the red line is the average difference of specific intervals. The SST difference is increasing with AOD.

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PART THREE

RTTOV simulation with AEROSE data

Part 3 RTTOV simulation with AEROSE data

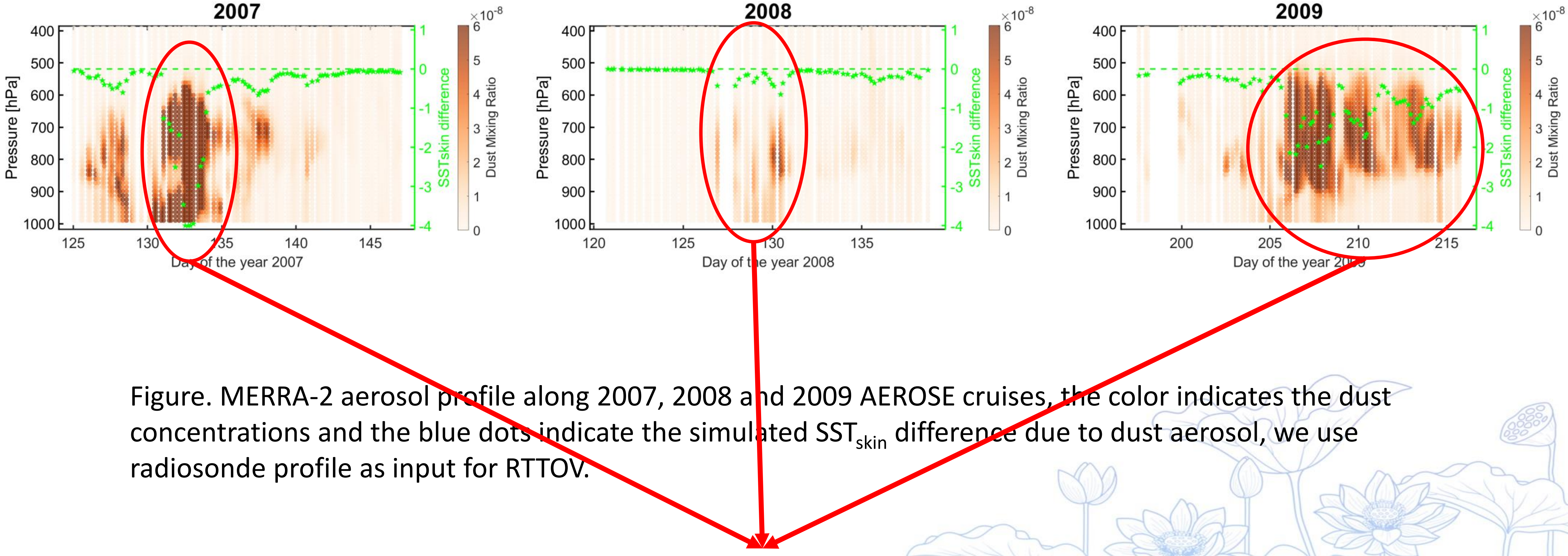


Figure. MERRA-2 aerosol profile along 2007, 2008 and 2009 AEROSE cruises, the color indicates the dust concentrations and the blue dots indicate the simulated SST_{skin} difference due to dust aerosol, we use radiosonde profile as input for RTTOV.

SST error is related to dust aerosol concentration and altitude.

Part 3 RTTOV simulation with AEROSE data

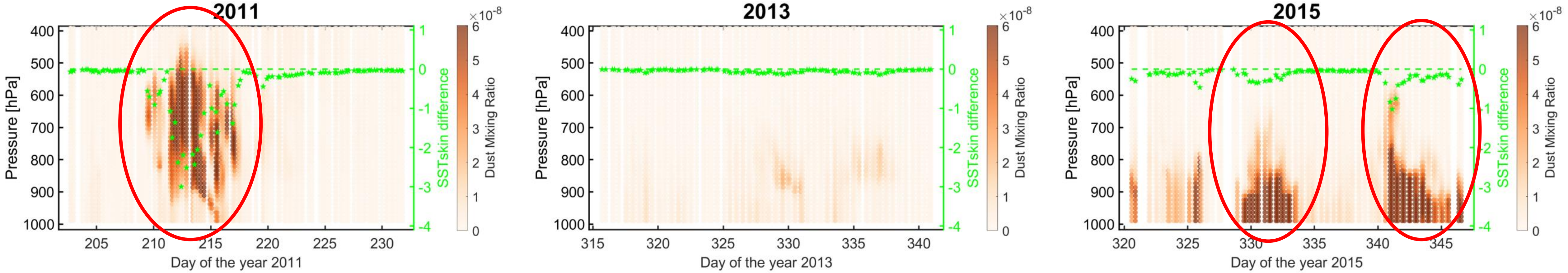
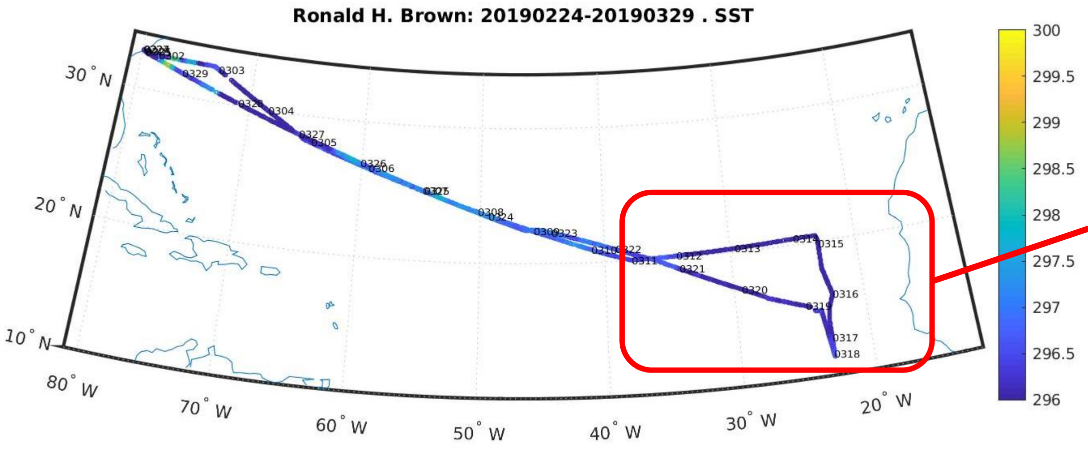
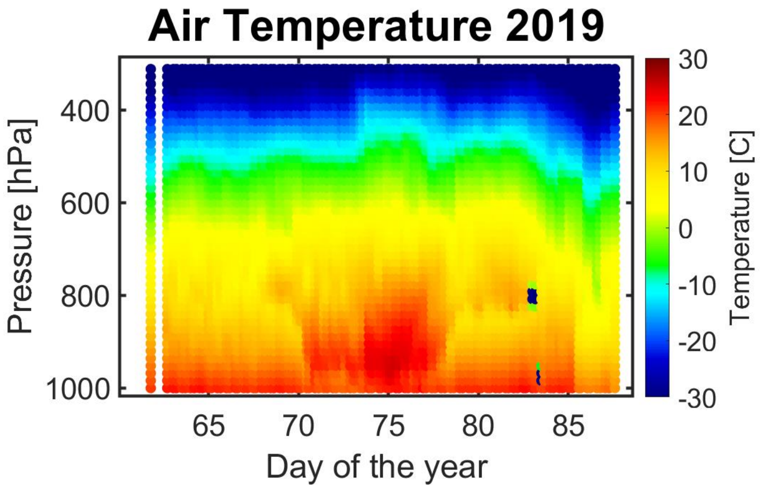


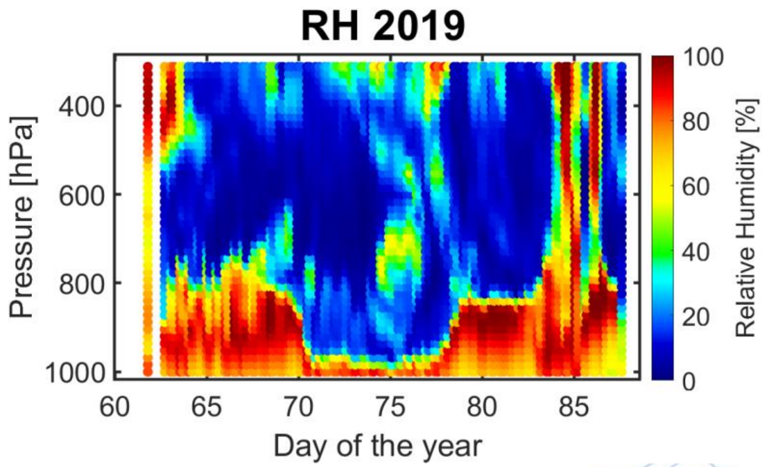
Figure. MERRA-2 aerosol profile along 2011, 2013 and 2015 AEROSE cruises, the color indicates the dust concentrations and the blue dots indicate the simulated SST_{skin} difference due to dust aerosol, we use radiosonde profile as input for RTTOV.

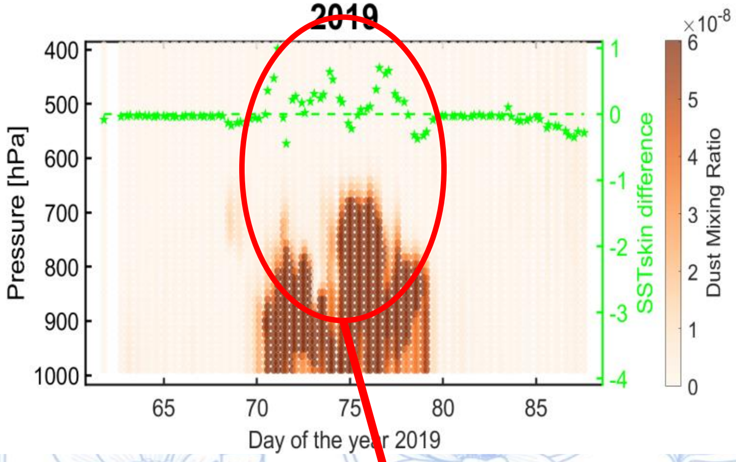
Part 4 Aerosol vertical distribution effect



Dust present at days 71-78 of 2019







It is interesting that 2019 has positive error!

RTTOV with TERRA MODIS coefficients.

Radiosonde as Atmospheric data input, MERRA-2 as dust input.

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PART FOUR

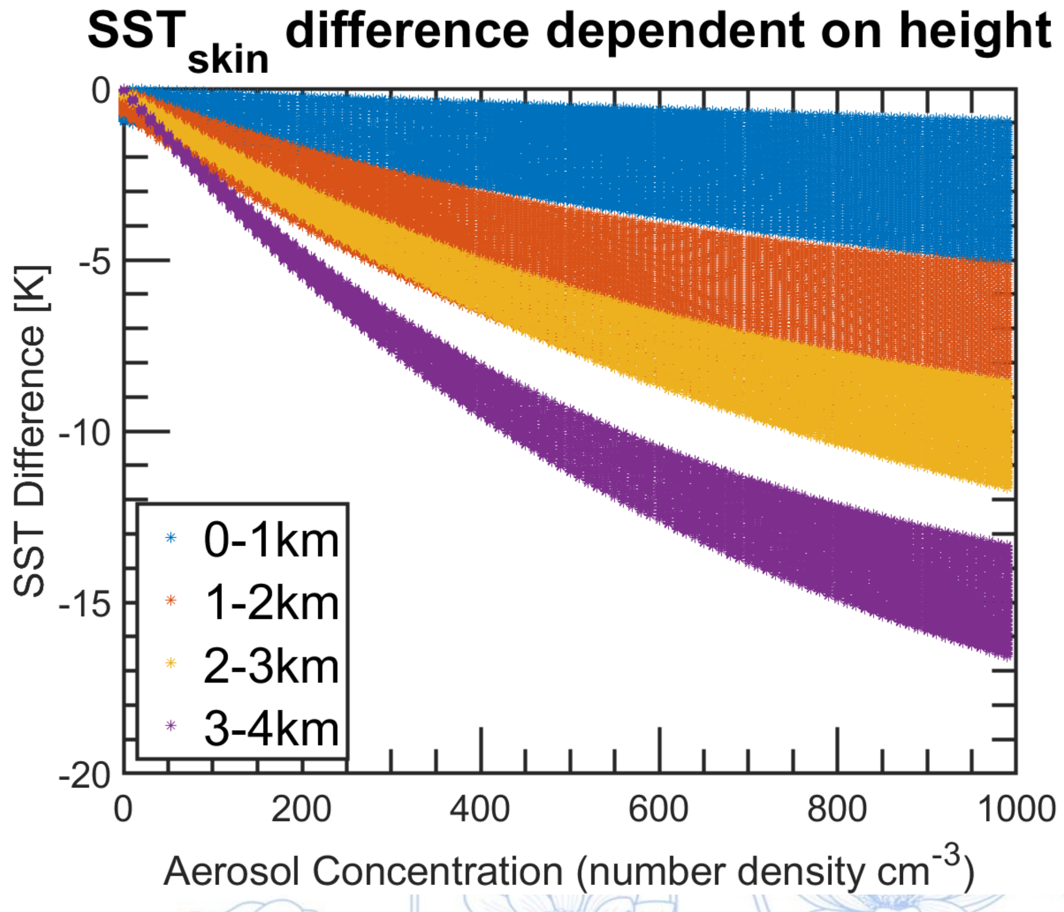
Aerosol vertical distribution effect

Part 4 Aerosol vertical distribution effect

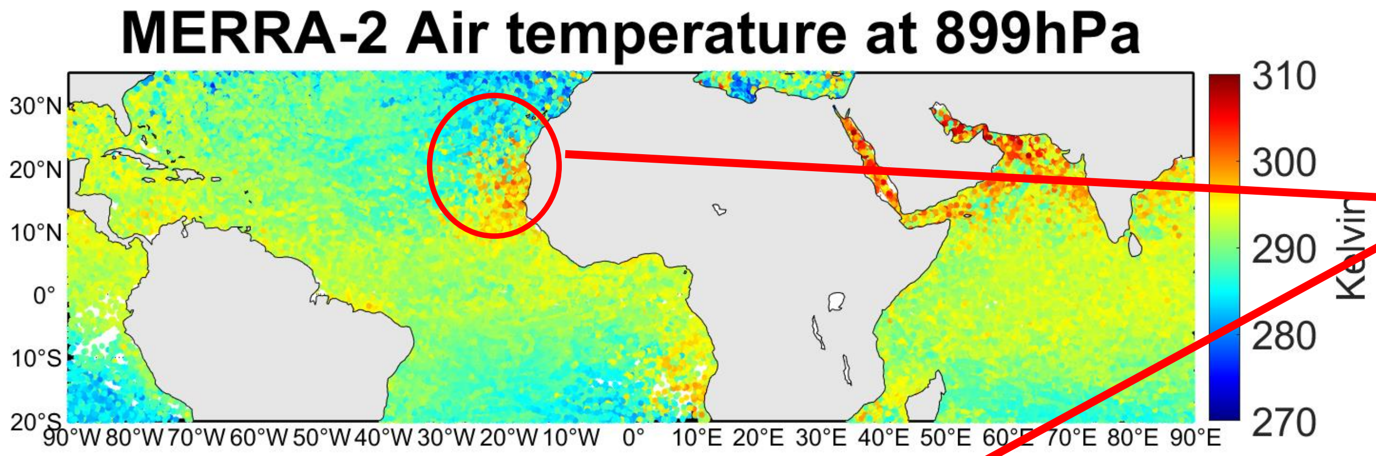
Dust layer altitude and corresponding RTTOV pressure layer

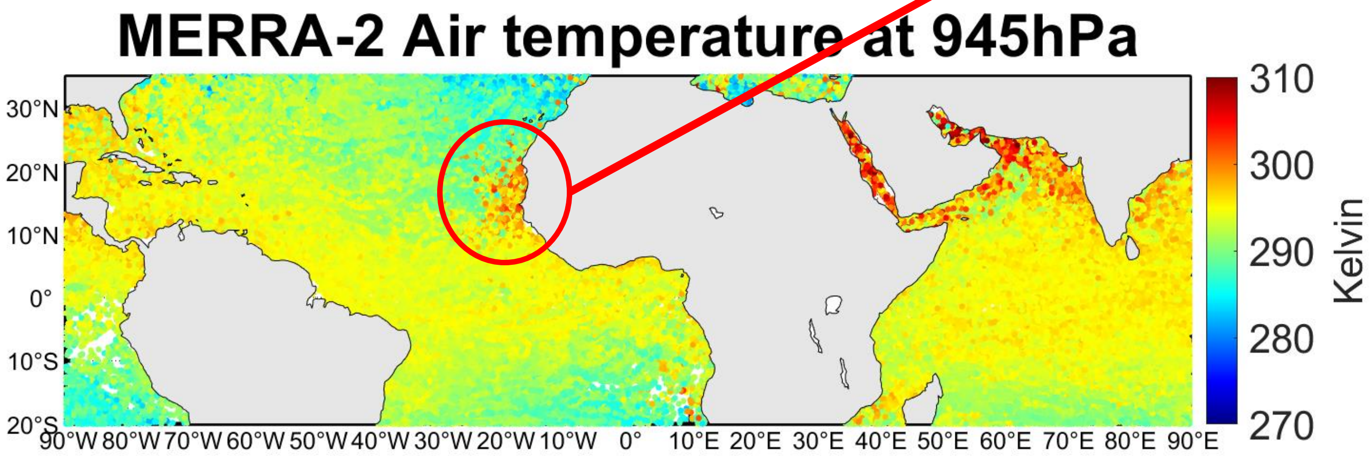
Altitude	Pressure
0 km - 1 km	922.46 hPa, 957.44 hPa, 985.88 hPa, 1005.43 hPa
1 km – 2 km	795.09 hPa, 839.95 hPa, 882.8 hPa
2 km – 3 km	702.73 hPa, 749.12 hPa
3 km – 4 km	610.60 hPa, 656.43 hPa

RTTOV simulation of MODIS onboard TERRA satellite



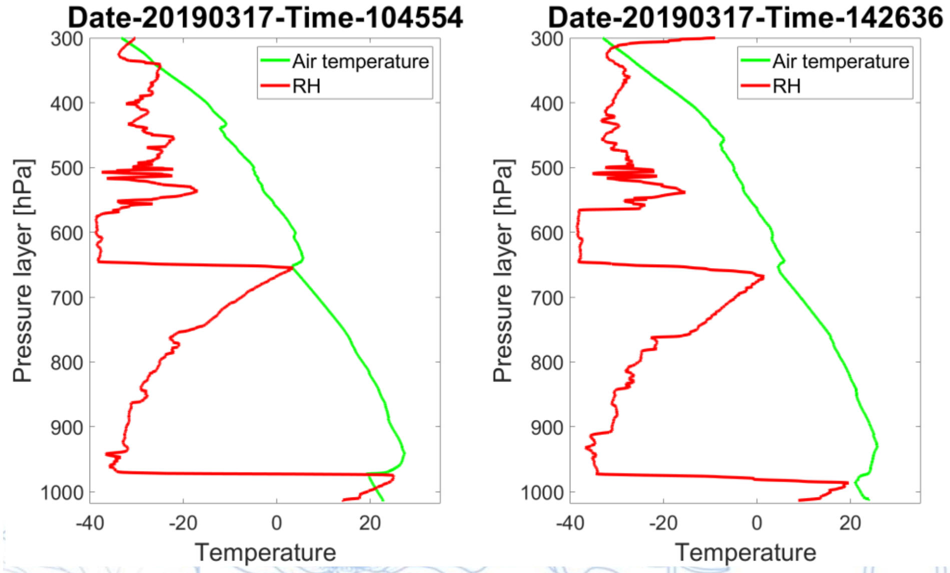
Part 4 Aerosol vertical distribution effect





2015-2019 MODIS Terra Matchup Database

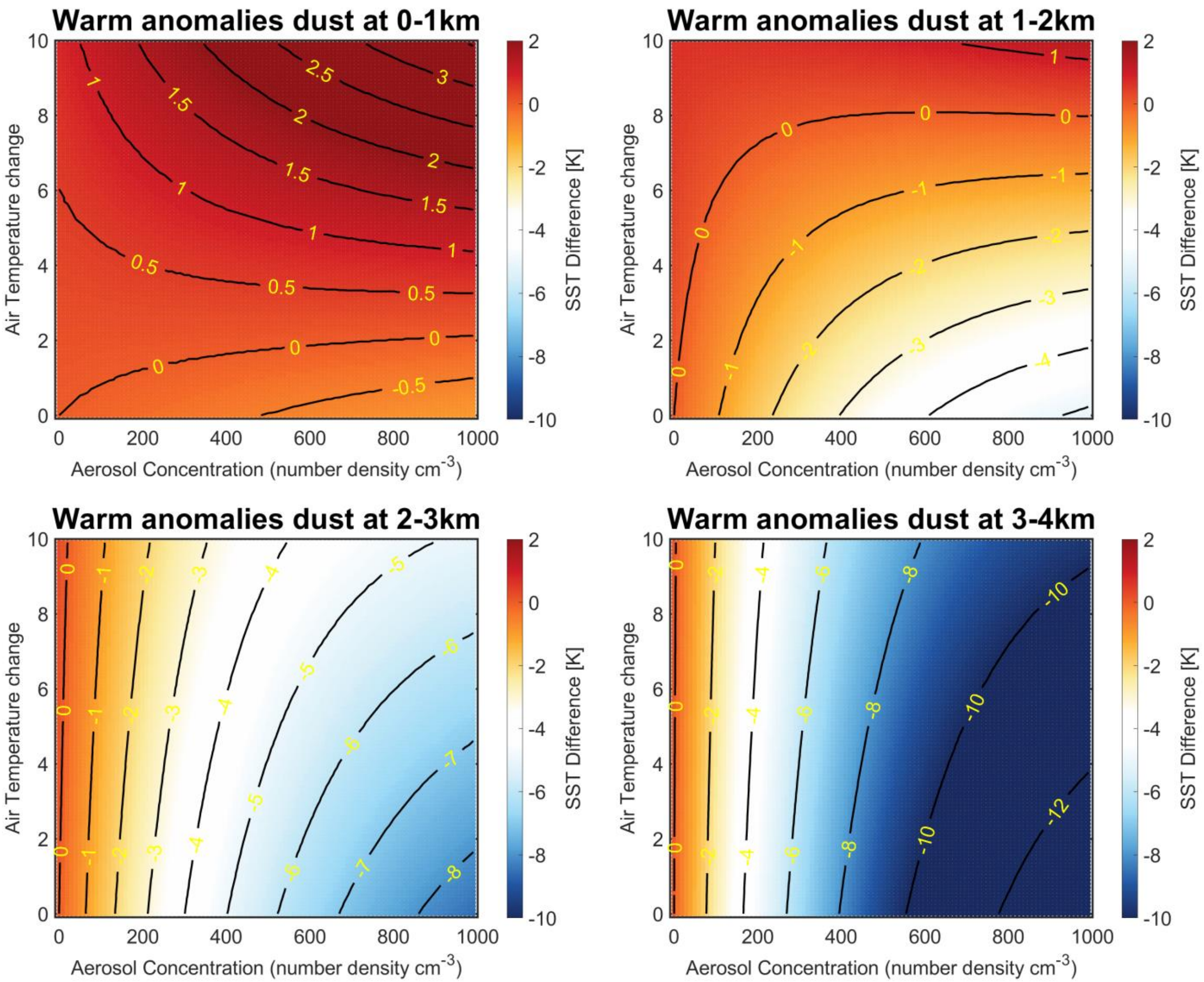
The IR channel brightness temperature is depended on δT_{sa}, which is the difference between the temperature of aerosol layer and surface.



Aerosol dust layer can warm Lower Air temperature!

And $T_{air} > T_{surface}$

Part 4 Aerosol vertical distribution effect



We use RTTOV to simulate the aerosol vertical distribution effects on SST_{skin}. Vertical distribution of aerosols has a significant impact on SST_{skin} retrieval. The temperature contrast between SST and the dust layer is related to the retrieved SST_{skin} error.

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PART FIVE

Conclusions & Future Work

Conclusions:

- AEROSE radiosondes and M-AERI provide useful input for RTTOV.
- Temperature changes caused by dust direct radiative effect may result in positive or negative SST_{skin} retrieval errors. High concentration dust aerosols in the lower atmosphere warm air temperature, and let the errors positive; dust aerosols in high altitude cause more negative error.
- Reanalysis data, such as those from MERRA-2 and ECMWF ERA-5 (not shown here), can provide vertical aerosol and air temperature data and be used to reduce the satellite retrieved SST_{skin} errors.

Future Work :

- The vertical distribution of aerosol influences the accuracy of infrared-derived SST_{skin}. RTTOV simulated dust layer effects at different heights have an impact on the satellite SST retrieval. CALIPSO provides information about the vertical distribution of aerosol layers, it can be used to derive different coefficients in the correction algorithms.
- The impact of different kinds of aerosol layers should be further explored.
- Such approaches as developed here can be applied to other well-calibrated infrared satellite radiometers such as Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi-NPP and NOAA-20, SLSTR on Copernicus Sentinel-3 A/B satellites, Advanced Baseline Imager (ABI) onboard GOES series satellite, and others in the future.

Acknowledgements

- Funding from NASA Earth Science Division & Physical Oceanography Program, Future Investigators in NASA Earth and Space Science and Technology (FINESST) Program, U. Miami, RSMAS travel funds.
- AEROSE works in collaboration with the NOAA PIRATA Northeast Extension (PNE) project and is supported by the NOAA Center for Atmospheric Sciences and Meteorology (NCAS-M) at Howard University (Prof. Vernon Morris, PI), the NOAA Educational Partnership Program grant NA17AE1625, NOAA grant NA17AE1623, the Joint Polar Satellite System (JPSS) and NOAA/NESDIS/STAR.
- Captains, officers and crews of many research vessels.
- Support from Ocean Biology Processing Group at Goddard, and PO.DAAC at JPL.

Thank you.

THANK YOU!

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