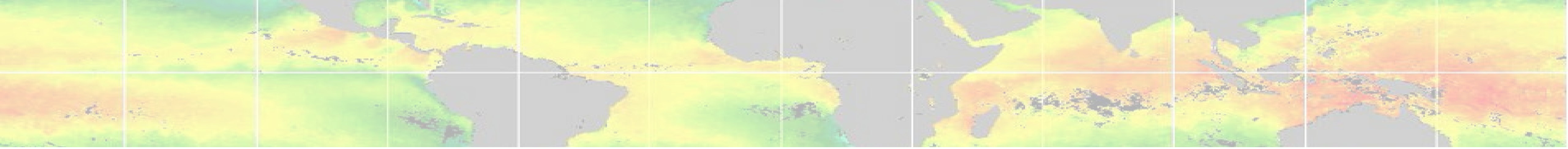


M-AERI validation of MODIS, VIIRS and SLSTR SST_{skin}

Peter J Minnett, Malgorzata Szczodrak, & Miguel Angel Izaguirre, Katherine Kilpatrick,

& Bingkun Luo.

Rosenstiel School of Marine and Atmospheric Science, University of Miami

pminnett@rsmas.miami.edu

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Validation by Comparison with Surface Measurements

Buoys

- Numerous, but not uniformly distributed in space or time.
- Long time series, starting in early 1980s.
- Subsurface measurement.
- Calibration issues.
- Not a comparison of like-with-like.

Radiometers

- Fewer, and not uniformly distributed in space or time.
- Began in mid-1990’s.
- Skin SST measurement.
- Very good calibration, repeatable and traceable to SI-standards.
- Is a comparison of like-with-like.

Best approach to use both, but here focus on radiometers.

RSMAS Ship Radiometers

M-AERI

- M-AERI is a very well-calibrated and stable sea-going Fourier Transform Infrared Interferometer.
- At sea calibration by two internal blackbody cavities with thermometers with NIST-traceable calibration.
- Calibration sequence before and after each cycle of measurements.
- Calibration before and after deployments using NIST-designed water-bath blackbody calibration target at RSMAS. Uses SI-traceable thermometers with mK accuracy.
- Periodic radiometric characterization of RSMAS water-bath blackbody calibration target by NIST TXR and NPL AMBER.

ISAR

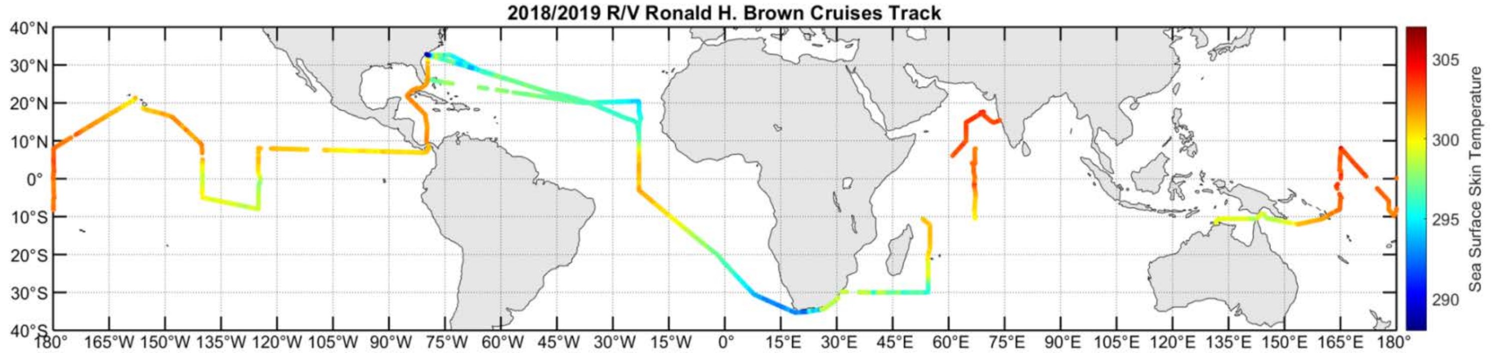
- ISAR is a very well-calibrated and stable sea-going filter radiometer.
- At sea calibration by two internal blackbody cavities with thermometers with SI-traceable calibration.
- Calibration sequence before and after each cycle of measurements.
- Calibration before and after deployments using NIST-designed water-bath blackbody calibration target at RSMAS or UW-APL. Use SI-traceable thermometers with mK accuracy.
- Periodic radiometric characterization of RSMAS water-bath blackbody calibration target by NIST TXR and NPL AMBER

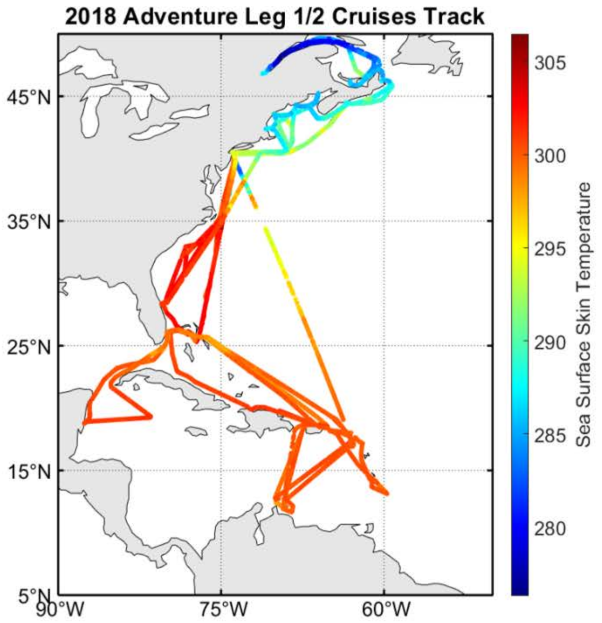
Sequence of Presentation

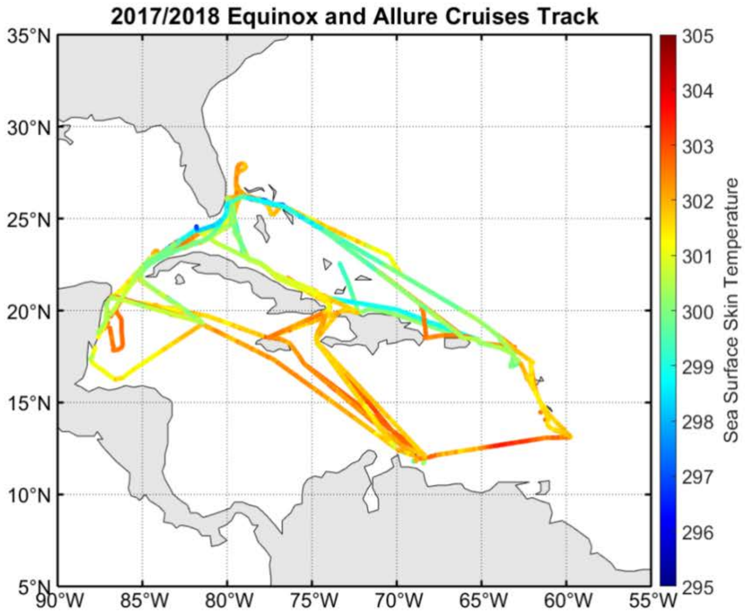
1. Sentinel-3a SLSTR
2. MODIS on *Terra* and *Aqua*
3. Suomi-NPP VIIRS

M-AERI SST_{skin} for Sentinal-3a SLSTR

Cruises	Area	START	END	Days of data
2017 Equinox	Caribbean Sea	2017-07-01	2017-12-31	183
2017 Allure	Caribbean Sea	2017-10-02	2017-11-26	55
2018 Equinox	Caribbean Sea	2018-01-11	2018-04-15	94
2018 - 1 Adventure	Caribbean Sea and US East Coast	2018-02-12	2018-05-27	104
2018 - 2 Adventure	Caribbean Sea and US East Coast	2018-06-01	2018-12-31	213
2018 RHB	Global	2018-03-07	2018-10-23	230
2019 RHB	North Atlantic	2019-02-24	2019-03-29	33
Total	--	2017-07-01	2019-03-29	636
RHB: NOAA Ship *Ronald H. Brown.*				







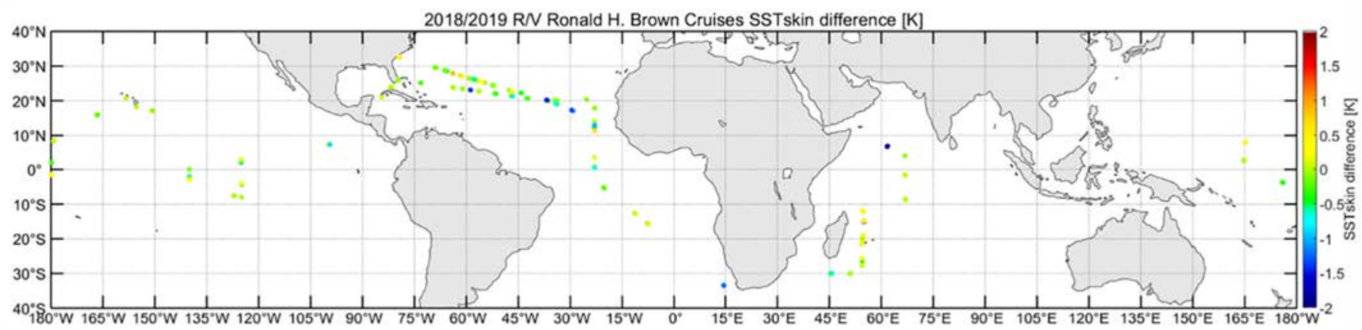
See: Luo, B., Minnett, P.J., Szczodrak, M., Kilpatrick, K., & Izaguirre, M. (2020). Validation of Sentinel-3A SLSTR derived Sea-Surface Skin Temperatures with those of the shipborne M-AERI. *Remote Sensing of Environment 244*, 111826. https://doi.org/10.1016/j.rse.2020.111826

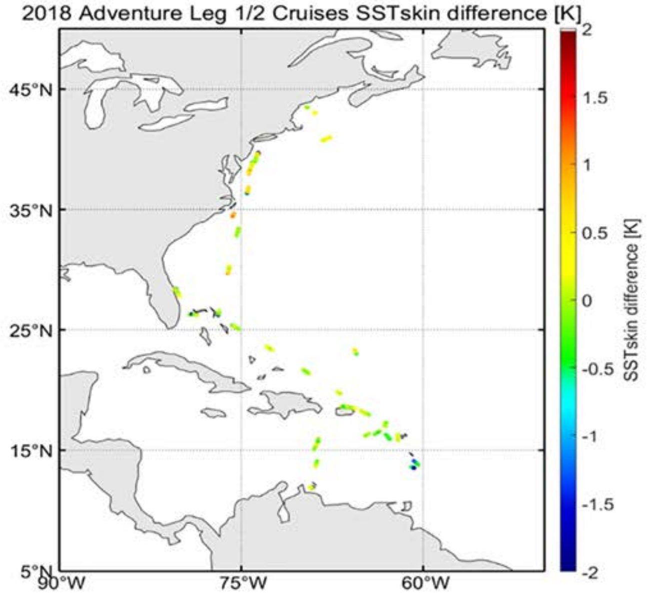
UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

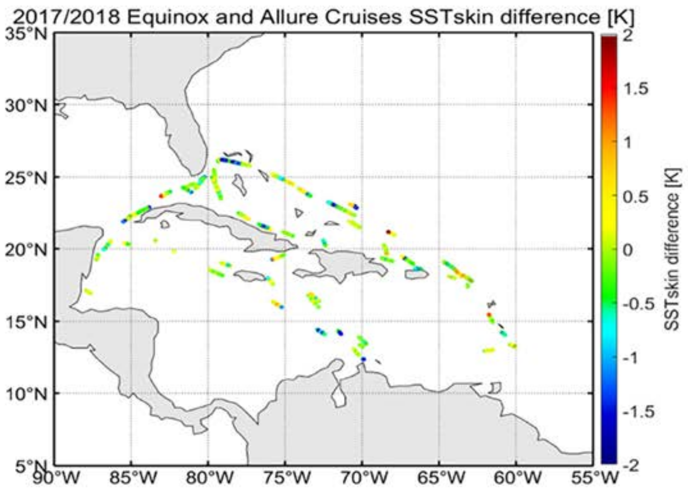
SLSTR SST_{skin} – M-AERI SST_{skin}

- Sentinel-3a SLSTR WCT L2P format data are used.
- Only QL = 5 (best quality) data used in this study.
- WCT files comprise “best” retrievals from the four possible algorithms.
- SLSTR data from EUMETSAT Copernicus Online Data Access server at https://codarep.eumetsat.int/

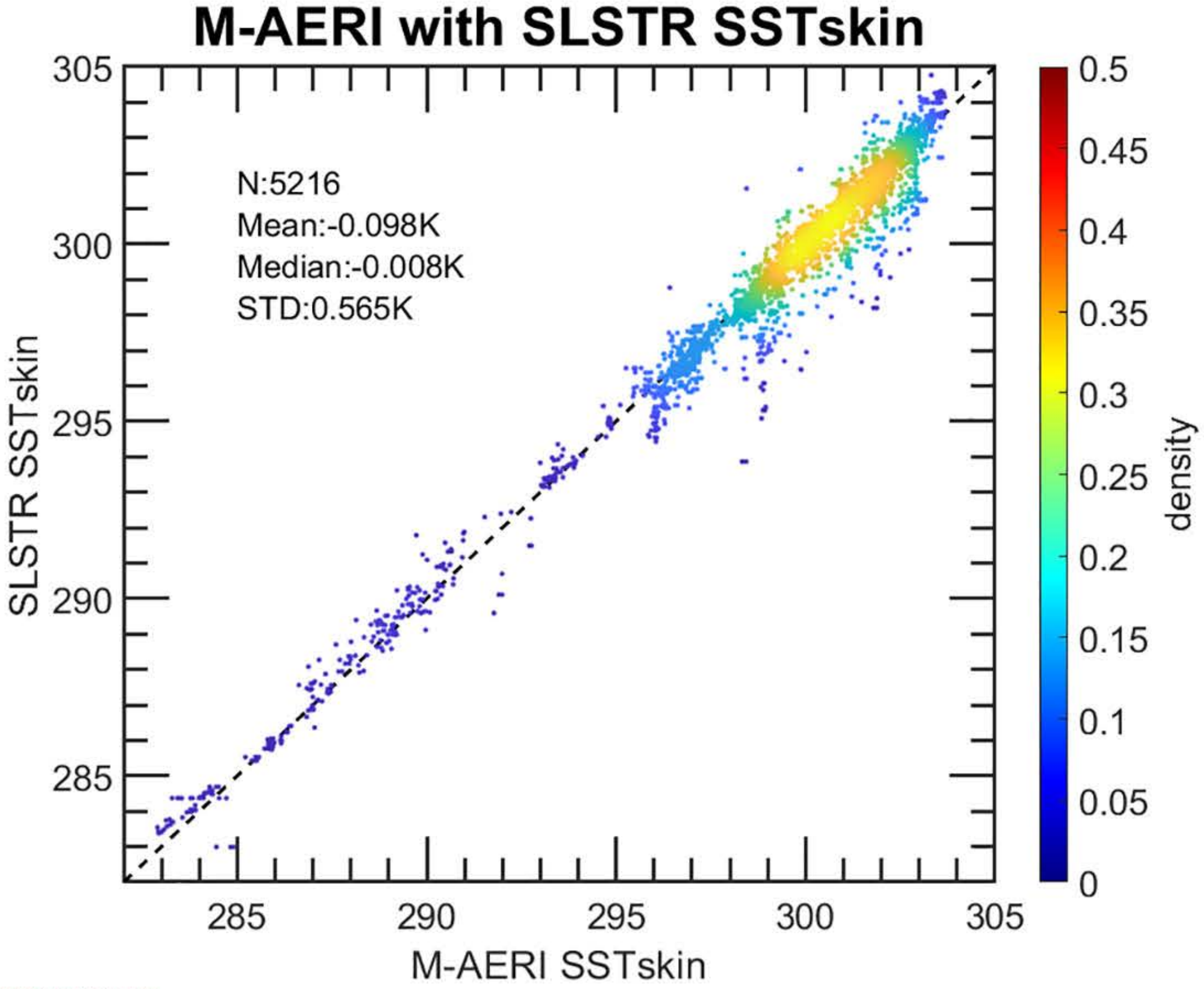
Type	Channel/view combinations
N2	Across-track single-view day-time retrieval (nadir swath only, 3.7 µm and along-track data are not used)
N3	Across-track single-view night-time (nadir swath only, along-track data are not used)
D2	Dual view day time (3.7 µm data are not used)
D3	Dual view night time (3 channels used)

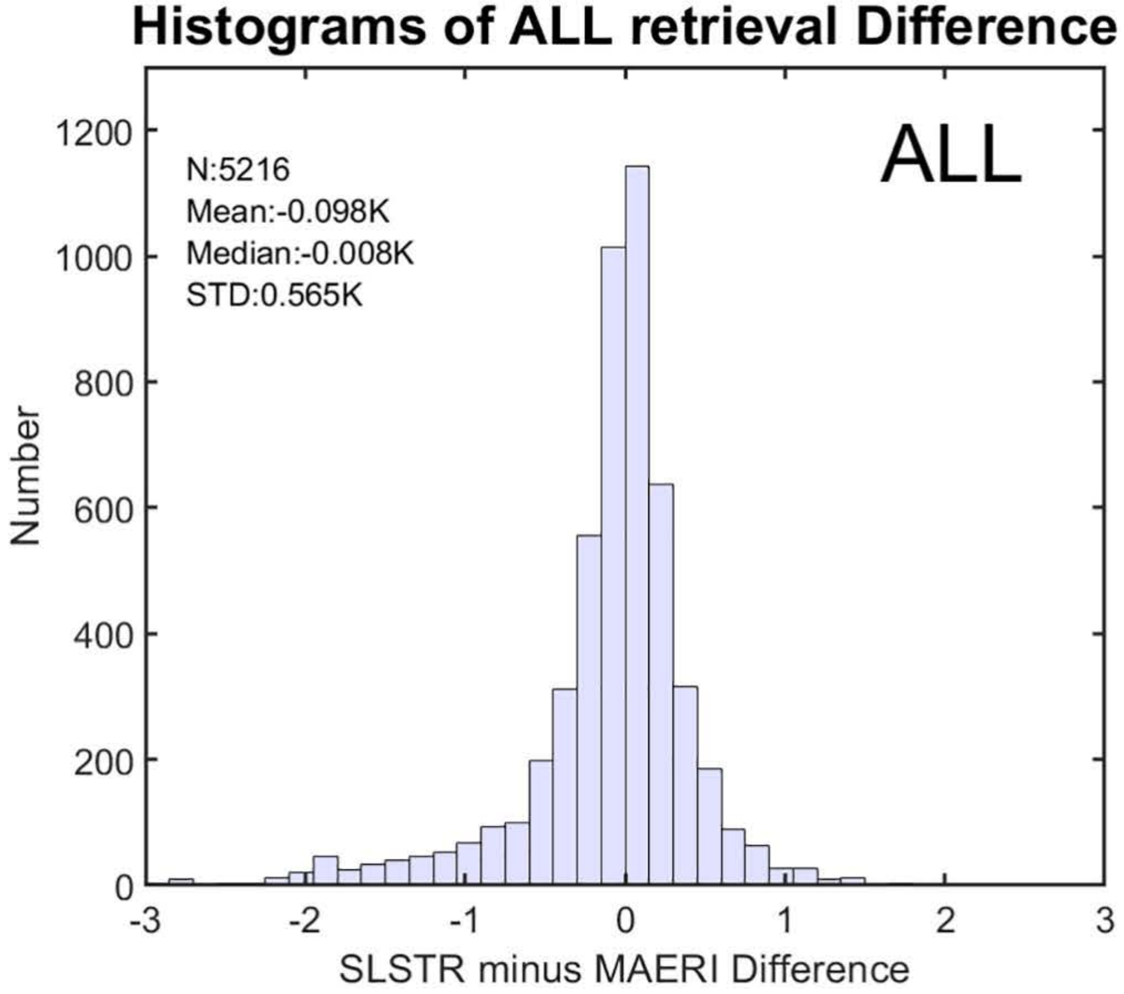






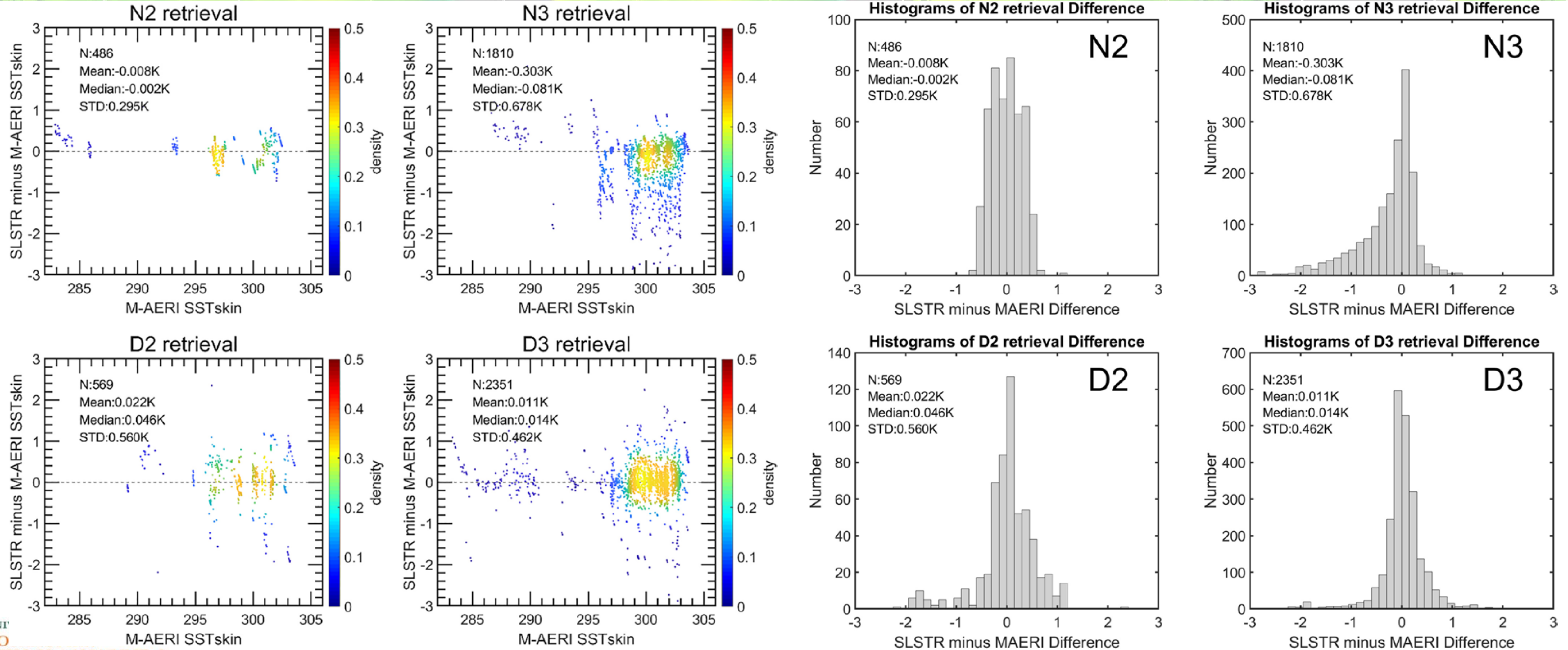
SLSTR SST_{skin} – M-AERI SST_{skin}





UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

SLSTR SST_{skin} by retrieval type – M-AERI SST_{skin}



Comparison Statistics

Cruises	START	END	N	N*	Mean	Med	STD	RMS	RSD
2017 Equinox	20170701	20171231	34439	929	-0.274	-0.059	0.742	0.790	0.473
2017 Allure	20171002	20171126	6713	205	-0.179	-0.023	0.780	0.799	0.313
2018 Equinox	20180111	20180415	15817	532	-0.200	-0.106	0.691	0.719	0.326
2018 Leg1 Adventure	20180212	20180527	11201	451	-0.116	-0.029	0.529	0.541	0.291
2018 Leg2 Adventure	20180601	20181231	35826	1344	0.038	0.033	0.385	0.386	0.242
2018 RHB	20180307	20181023	38354	921	-0.001	0.044	0.415	0.415	0.275
2019 RHB	20190224	20190329	8407	394	-0.143	-0.050	0.471	0.492	0.326
Total	20170701	20190329	150757	5216	-0.098	-0.008	0.565	0.574	0.296

MODIS on Terra and Aqua

- Terra was launched on 18 December, 1999; Aqua was launched on 4 May, 2002
- Both are in nominal operations. Aqua recently revitalized after a data formatter failure caused a shut-down.
- Standard atmospheric correction algorithm is modified NLSST for day and night.
- Night-time algorithm uses measurements at λ = 3.95 and 4.05 μm.
- Entire missions reprocessed at end of 2019, called R2019. Prior version was R2014 (or C6).
- All SST_{skin} retrievals reprocessed, but R2019 MUDB a casualty of Covid-19.

MODIS R2019 Improvements

The major changes in R2019 are:

a) Replacing the NOAA OI “Reynolds” SSTs, with the CMC as the reference field.
b) New cloud screening – Alternating Decision Trees.[1]
c) Night-time aerosol correction – additive term to atmospheric correction algorithm if an aerosol index threshold passed.[2]
d) High-Latitude coefficients.[3]
e) Improvement to cloud-ice discrimination.

[1] Kilpatrick, K.A., Podestá, G., Williams, E., Walsh, S., & Minnett, P.J. (2019). Alternating Decision Trees for Cloud Masking in MODIS and VIIRS NASA Sea Surface Temperature Products. *Journal of Atmospheric and Oceanic Technology 36*, 387-407. DOI: 10.1175/jtech-d-18-0103.1

[2] Luo, B., Minnett, P.J., Gentemann, C., & Szczodrak, G. (2019). Improving satellite retrieved night-time infrared sea surface temperatures in aerosol contaminated regions. Remote Sensing of Environment 223, 8-20. https://doi.org/10.1016/j.rse.2019.01.009

[3] Jia, C., & Minnett, P.J. (2020). High Latitude Sea Surface Temperatures Derived from MODIS Infrared Measurements. *Remote Sensing of Environment* - Accepted.

MODIS SSTs & Ship Radiometers

R2014 data

MODIS Skin SST vs M-AERI and ISAR Skin SST. **Temperatures in K**

Satellite and Algorithm	Mean	Median	Standard Deviation	Robust St. Deviation	Number
Terra SST Day	0.082	0.080	0.567	0.409	1025
Terra SST Night	0.048	0.034	0.467	0.337	2454
Terra SST4 Night	0.016	0.023	0.339	0.244	2467
Aqua SST Day	0.105	0.107	0.666	0.480	910
Aqua SST Night	0.020	0.027	0.489	0.353	1752
Aqua SST4 Night	-0.010	0.016	0.396	0.285	1858

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Partial R2019 Statistics – M-AERI

MODIS SST_{skin} - M-AERI SST_{skin} for quality level = 0 (best). Mean, median, Standard deviation, Robust standard deviation (IQR/1.836), and count.						
Sensor	QL	Mean	Median	SD	RSD	Count
Terra	0	-0.058	-0.052	0.481	0.347	3069
Aqua	0	0.042	0.040	0.494	0.347	2070

Suomi-NPP VIIRS (NASA algorithms)

- Suomi-NPP was launched on 28 October 2011.
- VIIRS has fewer channels than MODIS, missing the SST4 pair.
- NASA SST_{skin} atmospheric correction algorithm is comparable to MODIS NLSST.
- NASA night-time only algorithm is SSTtriple, based on at λ = 3.70, 10.8 and 12.0 μm.

S-NPP SST_{skin} vs M-AERI SST_{skin}

Quality Level	Mean	Median	Standard Deviation	Robust Standard Deviation	Count
SST_{skin} day					
0	0.077	0.066	0.260	0.193	7380
1	-0.035	-0.020	0.427	0.316	5878
SST_{skin} night					
0	0.029	0.043	0.411	0.305	10074
1	-0.205	-0.192	0.643	0.477	4906
SST_{triple} night					
0	0.053	0.090	0.468	0.347	4359
1	-0.162	-0.117	0.633	0.470	3792

Global statistics for VIIRS SST_{skin} retrievals compared to SST_{skin} derived from M-AERIs.

Summary

- Target accuracies and decadal stability requirements for SST are very demanding, and challenging to verify.
- Comparison with ship-board radiometers provides a primary mechanism for ensuring satellite SST_{skin} retrievals have an SI-traceable reference.
- SI-traceability permits the generation of SST_{skin} Climate Data Records.
- SLSTR, MODIS and VIIRS are producing very good SST_{skin}, but room for improvements.
- Continuing ship radiometer measurements in the post-Covid world?

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Outstanding issues

- Better cloud screening and atmospheric correction algorithms.
- Developing full error and uncertainty budgets for satellite-derived SST_{skin}.
- Assess sampling errors in ship radiometer measurements, (also for drifting buoy data)
- The SSES (Sensor Specific Error Statistics) for each SST_{skin} product should be revisited.
- Improved modeling of thermal skin effect is needed.
- And much more….