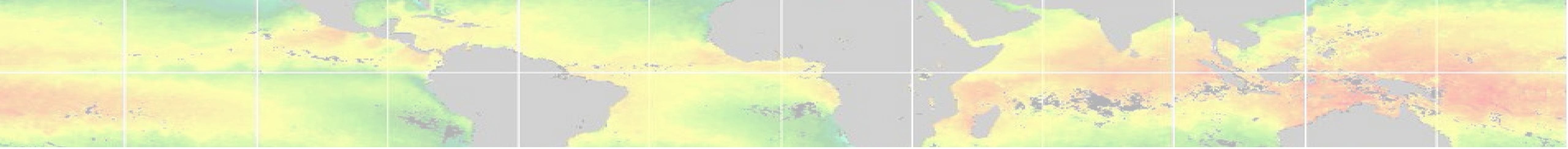


M-AERI validation of SLSTR, MODIS, VIIRS, ABI, and Reanalysis SST_{skin}

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

Chong Jia & Bingkun Luo*

Rosenstiel School of Marine, Atmospheric and Earth Science, University of Miami

*Now at Harvard Smithsonian Astrophysical Observatory, Harvard University

pminnett@rsmas.miami.edu pminnett@earth.miami.edu

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

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

- No new results for Sentinel 3a SLSTR, no comparisons with Sentinel 3b SLSTR.

Cruises	START	END	N	Mean	Med	STD	RMS	RSD
2017 Equinox	20170701	20171231	929	-0.274	-0.059	0.742	0.790	0.473
2017 Allure	20171002	20171126	205	-0.179	-0.023	0.780	0.799	0.313
2018 Equinox	20180111	20180415	532	-0.200	-0.106	0.691	0.719	0.326
2018 Adventure, Leg 1	20180212	20180527	451	-0.116	-0.029	0.529	0.541	0.291
2018 Adventure, Leg2	20180601	20181231	1344	0.038	0.033	0.385	0.386	0.242
2018 RHB	20180307	20181023	921	-0.001	0.044	0.415	0.415	0.275
2019 RHB	20190224	20190329	394	-0.143	-0.050	0.471	0.492	0.326
Total	20170701	20190329	5216	-0.098	-0.008	0.565	0.574	0.296

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

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

MODIS on *Terra* and *Aqua*

- *Terra* was launched on 18 December 1999; *Aqua* was launched on 4 May 2002.
- Both are in nominal operations. In January 2022 *Aqua* orbit began drifting later in the day, expected to exceed 1:45 in February 2023. *Terra* has been drifting to an earlier orbit since 2020, and a “Constellation Exit maneuver” (CEM) in October 2022. MODIS will be shut down Oct 8 - Oct 22 (TBC).
- Standard atmospheric correction algorithm is modified NLSST for day and night.
- Night-time algorithm uses measurements at λ = 3.96 and 4.05 μm.
- Entire missions reprocessed at end of 2019, called R2019. Prior version was R2014 (or C6).
- All SST_{skin} retrievals reprocessed, including R2019 MUDB.

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 atmospheric correction, for latitude >60^{o}.[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* - 251, 112094. https://doi.org/10.1016/j.rse.2020.112094

MODIS SST_{skin} Comparison with M-AERI

R2019 Residuals MODIS TERRA night LWIR SST_{skin} minus radiometer SST_{skin}.					
Quality	Mean	Median	SD	RSD	N
0	-0.102	-0.061	0.591	0.426	21725
1	-0.276	-0.295	0.658	0.475	7353

R2019 Residuals MODIS TERRA night MWIR SST_{skin} (SST4) minus radiometer SST_{skin}.					
Quality	Mean	Median	SD	RSD	N
0	-0.098	-0.047	0.449	0.324	22254
1	-0.165	-0.129	0.460	0.332	7133

LWIR retrievals use a modified NLSST algorithm applied to clear-sky measurements at λ= 11 and 12 µm.
MWIR retrievals use a modified NLSST algorithm applied to clear-sky measurements at λ = 3.96 and 4.05 µm

Quality = 0 is best, = 1 is good. $\Delta t \leq 30$ min. $\Delta r \leq 10$ km.

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

Suomi-NPP VIIRS (NASA algorithms)

- *Suomi-NPP* was launched on 28 October 2011.
- *S-NPP* had an anomalous shut-down on July 26, 2022. Brought back to operations on August 10, with science measurements resumed on August 11. Currently in nominal operations.
- VIIRS has fewer channels than MODIS, missing the SST4 pair.
- NASA VIIRS SST_{skin} atmospheric correction algorithm is comparable to MODIS NLSST.
- NASA night-time only algorithm is SST_{triple}, based on at λ = 3.70, 10.8 and 12.0 μm.
- Note, S-NPP SST_{skin} was an orphaned product for three years. New project started earlier this year.
- R2022 reprocessing includes high-latitude coefficients for > 60^{o}N
- Atmospheric correction coefficients based on a larger data set.

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

R2022.0

Period:
2 Jan 2012 –
7 Sept 2021

$\Delta t \leq 30$ min.
$\Delta r \leq 10$ km.

Quality	Mean	Median	SD	RSD	N
SST_{skin} day					
0	0.043	0.062	0.453	0.327	6959
1	-0.180	-0.131	0.604	0.436	5600
SST_{skin} night					
0	-0.002	0.013	0.428	0.309	16928
1	-0.251	-0.211	0.662	0.448	7909
SST_{triple} night					
0	0.008	0.020	0.316	0.228	12713
1	-0.125	-0.097	0.432	0.311	9526

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

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

Advanced Baseline Imager (ABI) on GOES-16

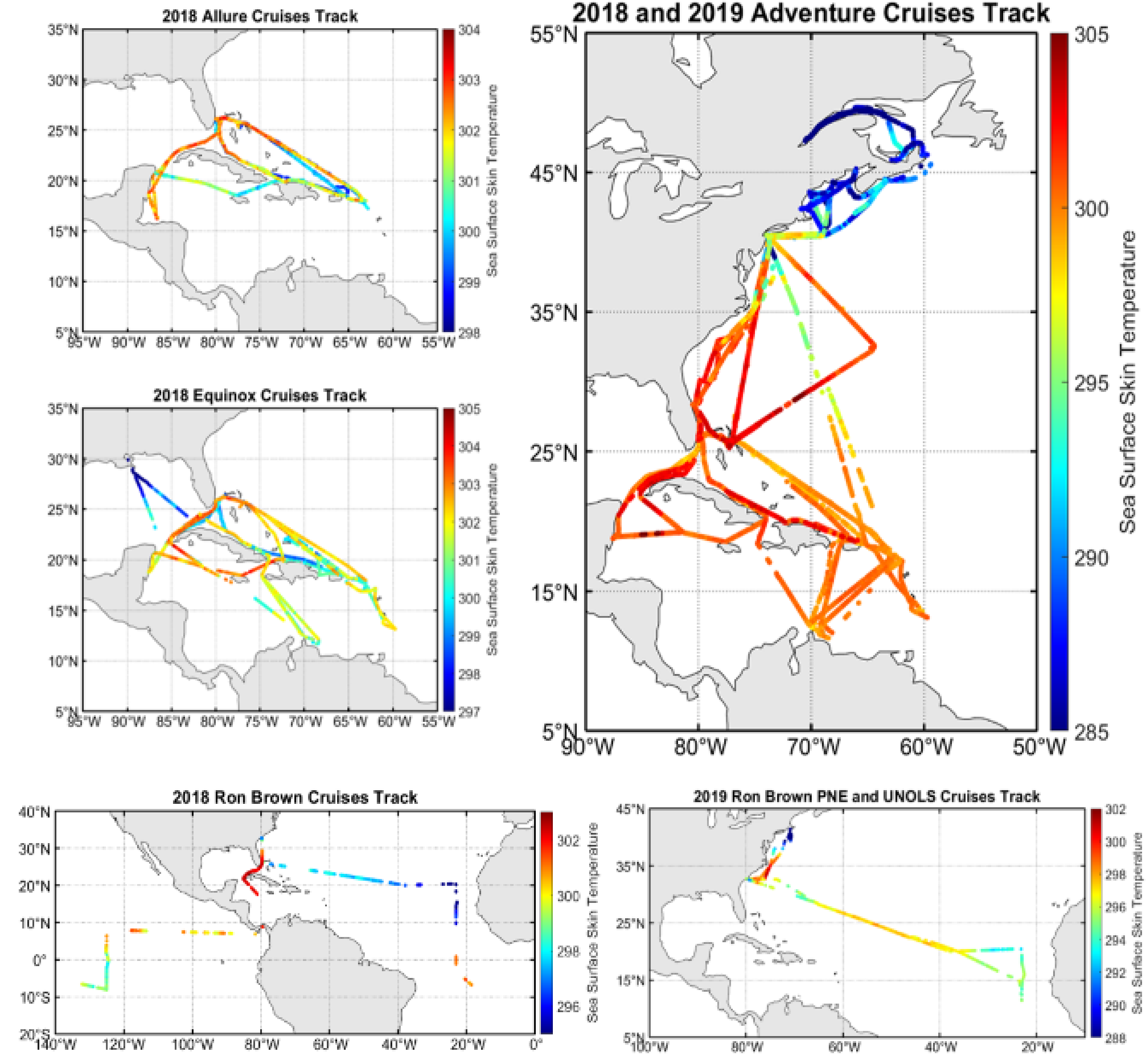
- GOES-16 is above 75.2^{o}W; became operational on 16th December 2017.
- SST_{skin} derived using NOAA ACSPO algorithm, using measurements at λ = 8.4 µm, 10.3 µm, 11.2 µm, and 12.3 µm.
- Hourly SST_{skin} data from https://podaac-tools.jpl.nasa.gov /drive/files/allData/ghrsst/dataGDS2/L2P/GOES16/STAR/ v2.70.
- Matchups with M-AERI within 30 minutes and 5 km.

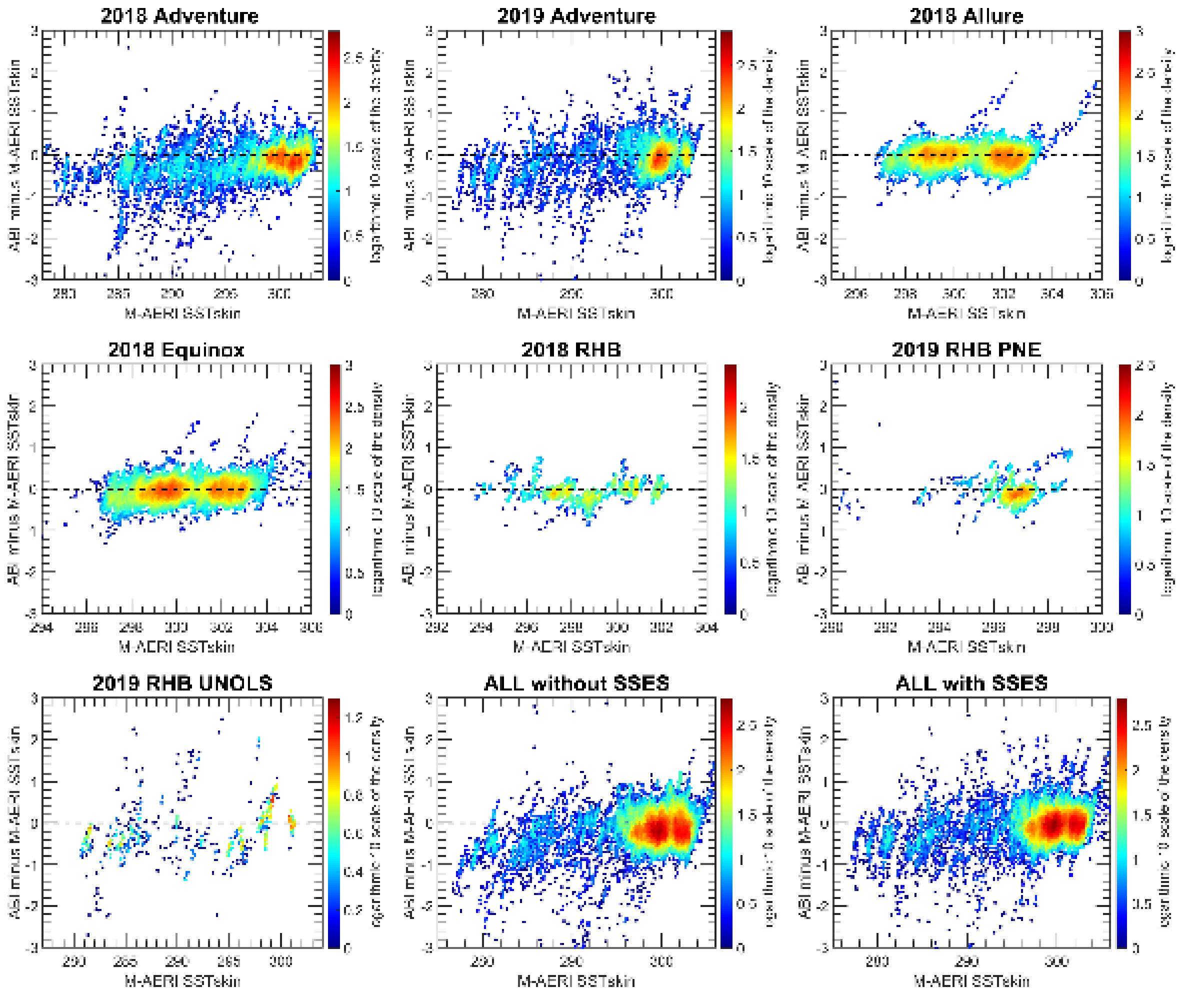
CRUISES	AREA	START	END	DAYS OF DATA
2018 Equinox	Caribbean Sea	2018-01-11	2018-09-23	255
2018 Allure	Caribbean Sea	2018-02-18	2018-10-14	238
2018 Adventure	Caribbean Sea and US East Coast	2018-02-12	2018-12-31	322
2019 Adventure	Caribbean Sea and US East Coast	2019-01-01	2019-10-30	302
2018 RHB	Global	2018-03-07	2018-10-23	230
2019 RHB PNE	North Atlantic Ocean	2019-02-24	2019-03-29	33
2019 RHB UNOLS	US East Coast	2019-05-07	2019-05-31	24
Total	**--**	**2018-02-12**	**2019-10-30**	**625**

RHB: NOAA Ship Ronald H. Brown.
PNE: PIRATA (Prediction and Research Moored Array in the Tropical Atlantic) - North East extension moorings
UNOLS: University-National Oceanographic Laboratory System

Luo, B., & Minnett, P.J. (2021). Skin Sea Surface Temperatures From the GOES-16 ABI Validated With Those of the Shipborne M-AERI. *IEEE Transactions on Geoscience and Remote Sensing 59*, 9902-9913. 10.1109/TGRS.2021.3054895

M-AERI tracks and ABI SST_{skin} comparisons





Luo, … e
GOE…
Transactions on Geoscience and Remote Sensing 59, 9902-9913.
10.1109/TGRS.2021.3054895

SSES – Sensor Specific Error Statistics

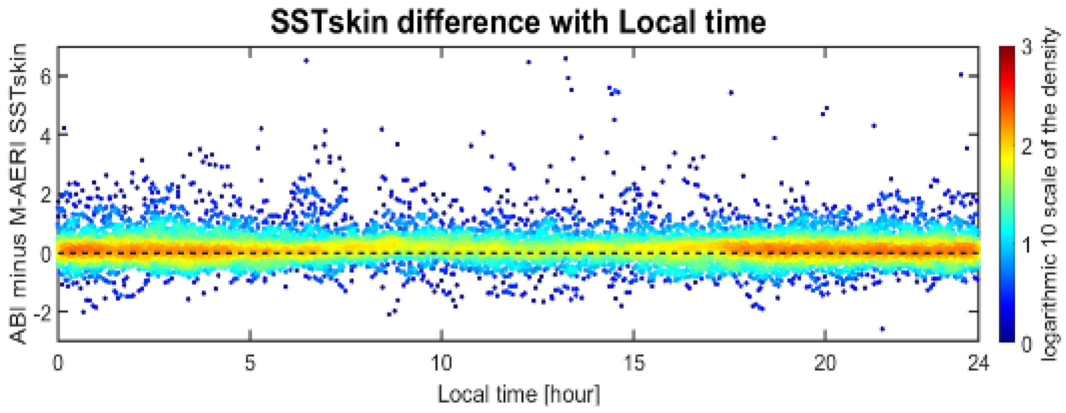
UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

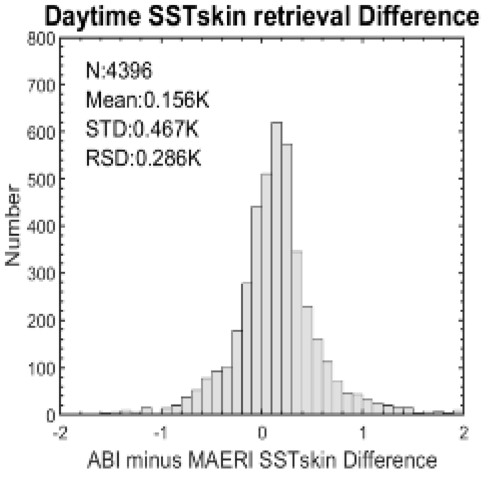
ABI – M-AERI SST_{skin} Statistics

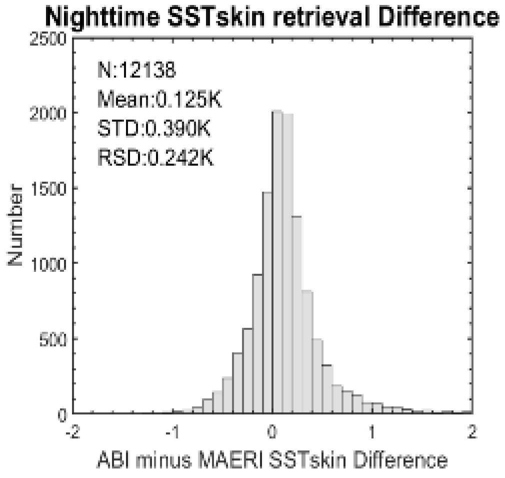
CRUISES	N	MEAN	MED	STD	RMS	RSD
2018 Equinox	10869	0.036	0.035	0.302	0.304	0.19
2018 Allure	8948	0.035	0.031	0.231	0.233	0.20
2018 Adventure	11840	0.171	0.136	0.394	0.430	0.24
2019 Adventure	10081	0.089	0.081	0.420	0.430	0.26
2018 RHB	1188	0.060	0.069	0.234	0.242	0.19
2019 RHB PNE	1003	0.069	0.101	0.291	0.299	0.16
2019 RHB UNOLS	519	0.174	0.259	0.744	0.764	0.49
Total	**44448**	**0.086**	**0.072**	**0.356**	**0.367**	**0.22**

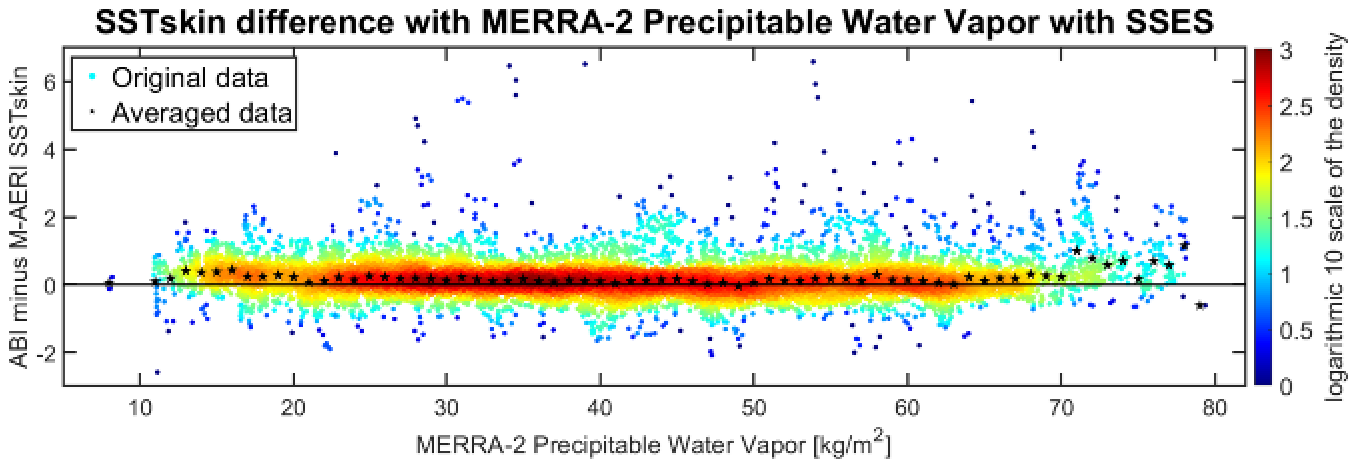
Luo, B., & Minnett, P.J. (2021). Skin Sea Surface Temperatures From the GOES-16 ABI Validated With Those of the Shipborne M-AERI. *IEEE Transactions on Geoscience and Remote Sensing 59*, 9902-9913. 10.1109/TGRS.2021.3054895

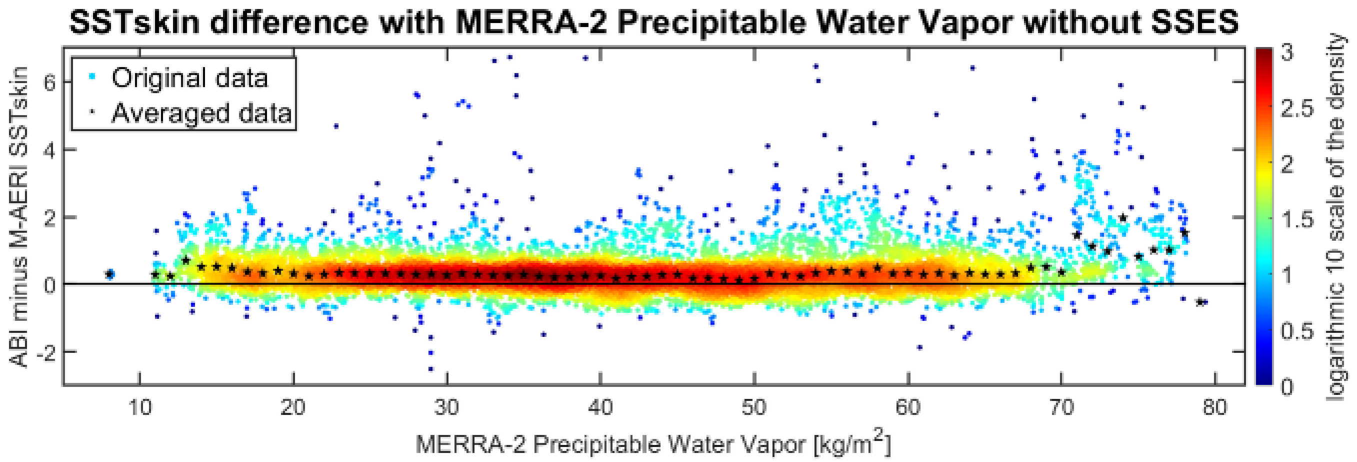
ABI – M-AERI SST$_{skin}$ Dependences





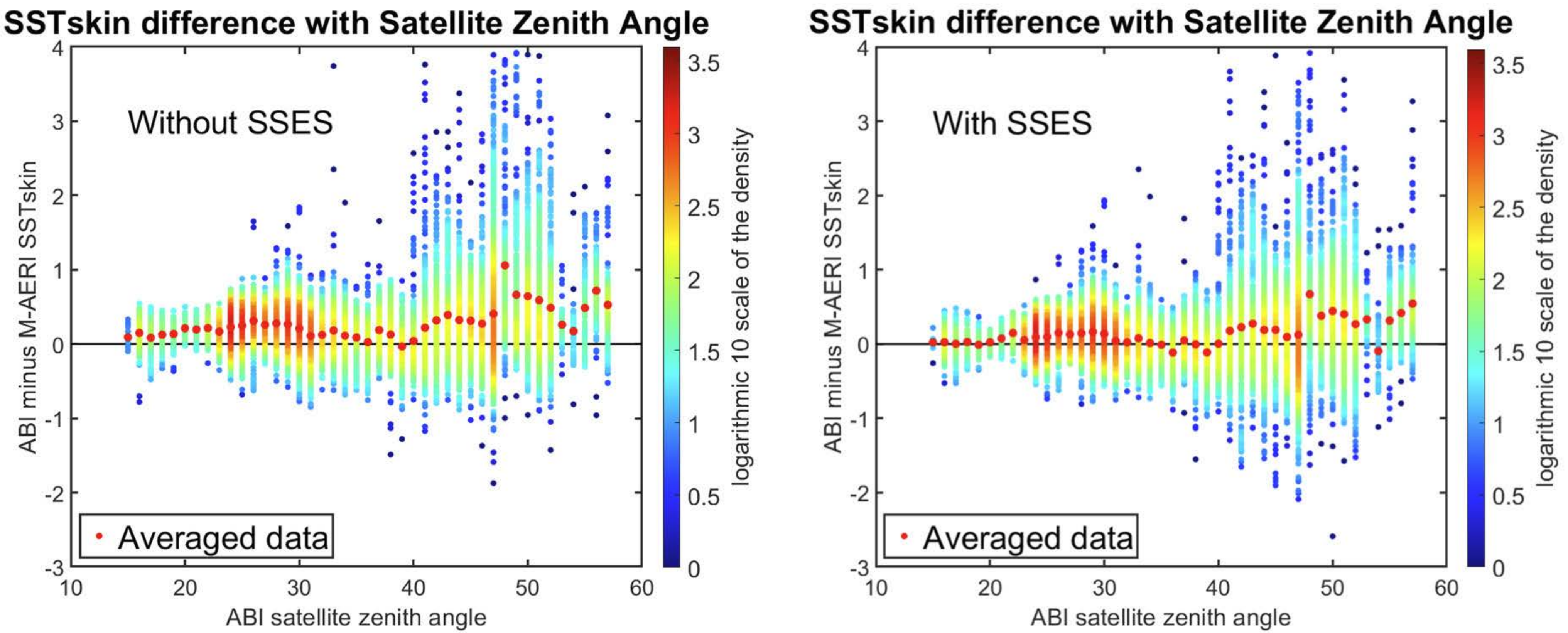






Luo, B., & Minnett, P.J. (2021). Skin Sea Surface Temperatures From the GOES-16 ABI Validated With Those of the Shipborne M-AERI. *IEEE Transactions on Geoscience and Remote Sensing 59*, 9902-9913. 10.1109/TGRS.2021.3054895

ABI – M-AERI SST_{skin} Satellite Zenith Angle Dependence



Luo, B., & Minnett, P.J. (2021). Skin Sea Surface Temperatures From the GOES-16 ABI Validated With Those of the Shipborne M-AERI. *IEEE Transactions on Geoscience and Remote Sensing 59,* 9902-9913. 10.1109/TGRS.2021.3054895

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Sequence of Presentation

1. SLSTR on *Sentinel-3a*
2. MODIS on *Terra* and *Aqua*
3. VIIRS on *Suomi-NPP*
4. ABI on *GOES-16*
5. ERA5

ERA5 Skin SST

- Reanalyses, including MERRA-2, ERA-Interim, and ERA5 include SST_{skin} fields. Here we focus on ERA5.
- The ERA5 SST_{skin} derived by model simulation with data from satellite-derived SSTs, being based on the foundation temperature taken from the OSTIA analysis.
- Spatial resolution: 0.25^{o} x 0.25^{o}. Temporal resolution is 1 hr, but OSTIA is daily. Thus, SST_{skin} is based on a) accuracy of OSTIA, b) a diurnal heating model, and c) a thermal skin layer model.
- ERA5 SST_{skin} accuracy determined by comparisons with M-AERI data. ERA5 fields bi-linearly interpolated to times and positions of the M-AERI measurements.

M-AERI Cruises

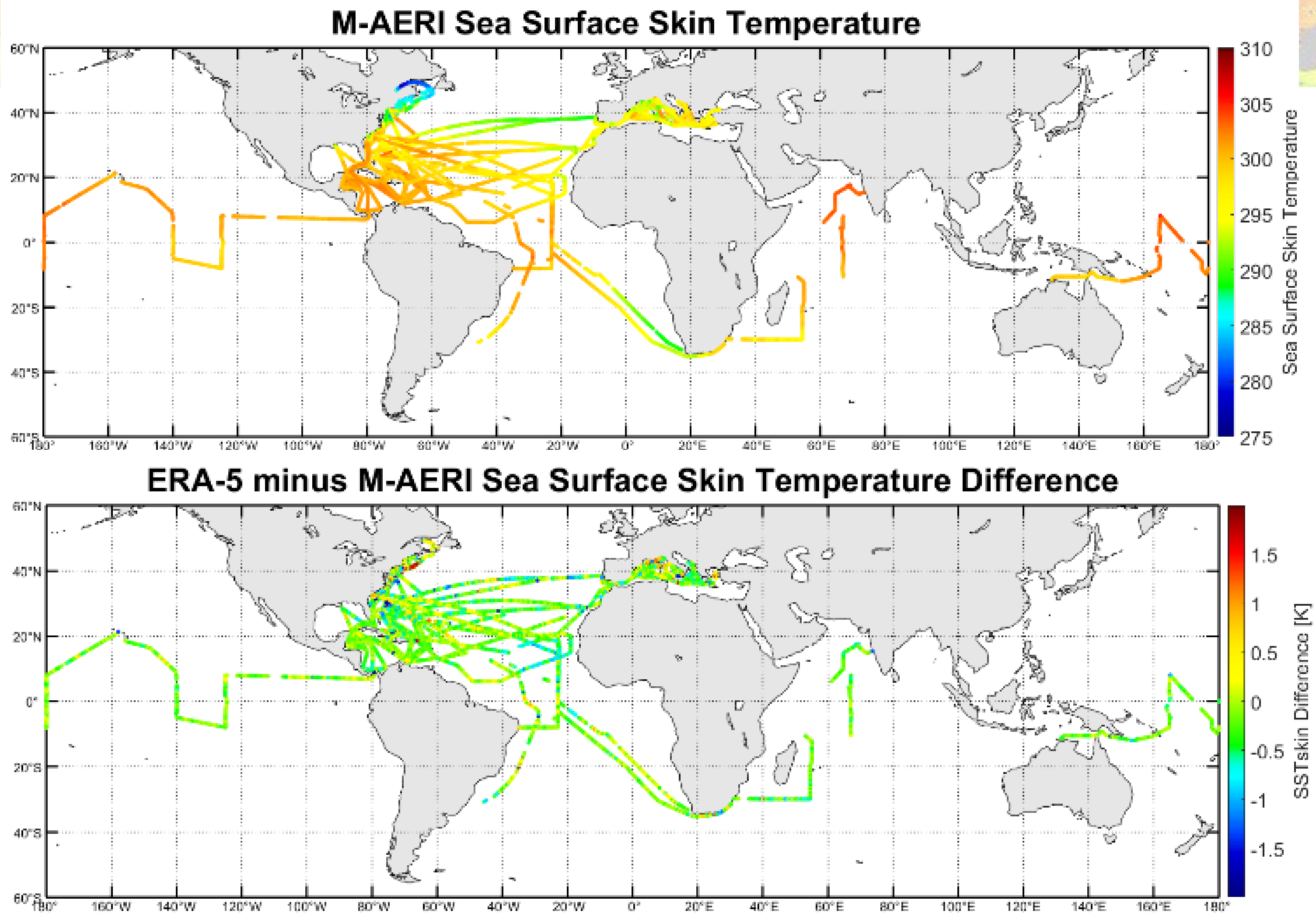
RCG CRUISES	AREA	START	END	DAYS OF DATA
2014 ALLURE	Caribbean Sea	2014-08-24	2014-12-31	130
2014 EQUINOX	Caribbean Sea	2014-11-16	2014-12-31	46
2015 ALLURE	Caribbean Sea, North Atlantic Ocean, and Mediterranean Sea	2015-01-01	2015-12-26	360
2016 EQUINOX	Caribbean Sea, North Atlantic Ocean, and Mediterranean Sea	2016-01-02	2016-12-31	365
2017 EQUINOX	Caribbean Sea	2017-01-01	2017-12-31	365
2017 ALLURE	Caribbean Sea	2017-10-02	2017-11-26	56
2018 EQUINOX	Caribbean Sea	2018-01-11	2018-09-23	255
2018 ADVENTURE	Caribbean Sea and US East Coast	2018-02-12	2018-12-31	322
2018 ALLURE	Caribbean Sea	2018-02-18	2018-10-14	238
2019 ADVENTURE	Caribbean Sea and US East Coast	2019-01-01	2019-10-30	302
TOTAL	--	2014-08-24	2019-10-30	**2439**

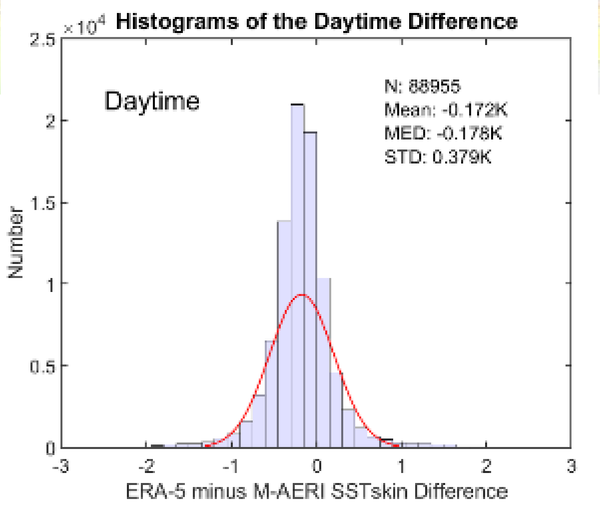
R/V CRUISES	AREA	START	END	DAYS OF DATA
2004 RHB	North Atlantic. South Atlantic, Indian and Pacific Oceans	2004-02-13	2004-04-13	61
2006 RHB		2006-05-27	2006-07-14	49
2007 RHB		2007-05-07	2007-05-28	22
2008 RHB		2008-04-29	2008-05-19	21
2011 RHB		2011-07-21	2011-08-20	31
2013 RHB		2013-11-11	2013-12-08	28
2015 ALLIANCE		2015-11-17	2015-12-14	28
2018 RHB		2018-03-07	2018-10-23	231
2019 RHB		2019-02-24	2019-03-29	34
TOTAL		2004-02-13	2019-03-29	**505**

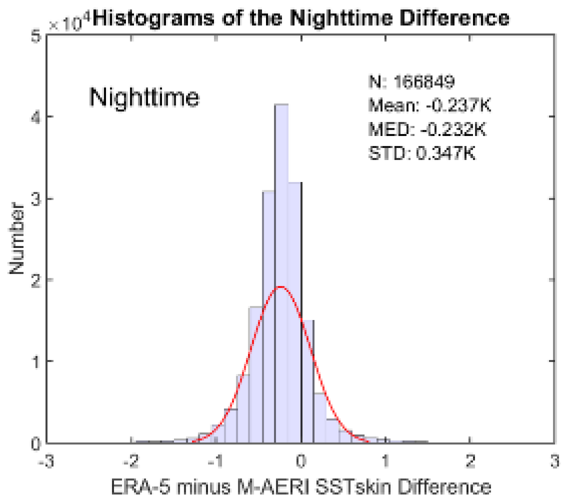
RHB: NOAA Ship *Ronald H. Brown.*

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Spatial Coverage & SST_{skin} Differences







UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

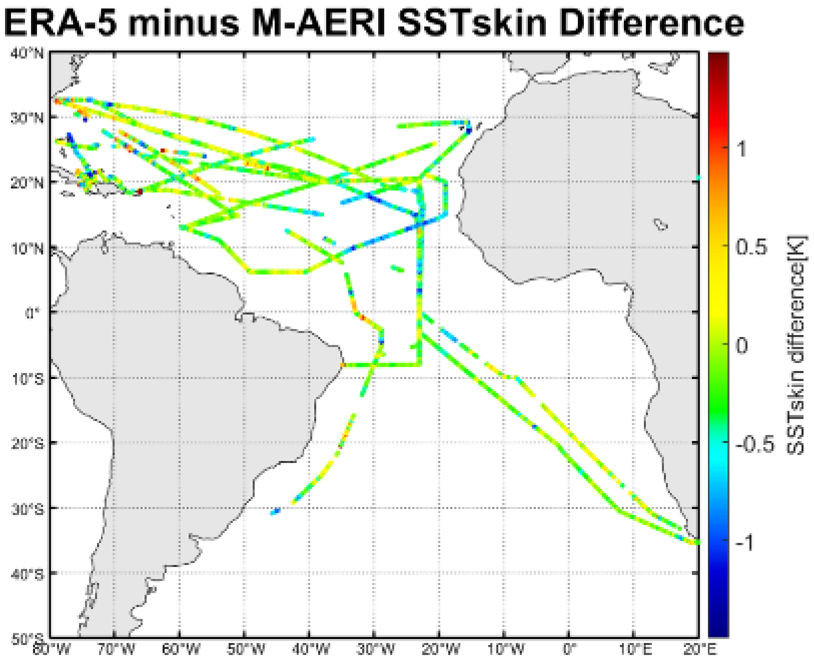
ERA5 Numbers: Big & Small

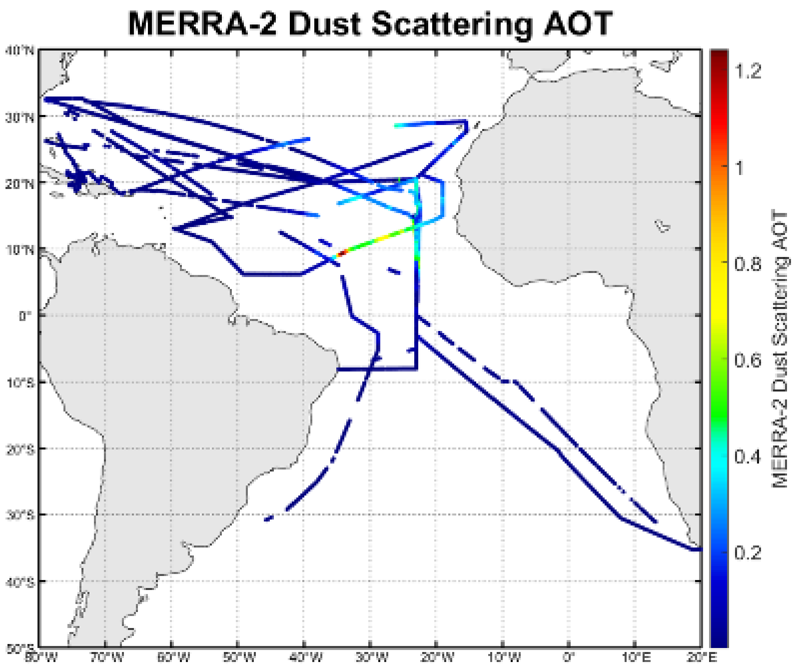
RCG CRUISES	N	MEAN	MED	STD	RMS	RSD
2014 ALLURE	9811	-0.196	-0.199	0.262	0.327	0.233
2014 EQUINOX	5421	-0.293	-0.288	0.247	0.383	0.219
2015 ALLURE	34,658	-0.208	-0.231	0.367	0.422	0.265
2016 EQUINOX	28,673	-0.188	-0.205	0.371	0.416	0.272
2017 EQUINOX	41,945	-0.244	-0.238	0.270	0.364	0.211
2017 ALLURE	5031	-0.145	-0.133	0.218	0.262	0.206
2018 EQUINOX	29,779	-0.266	-0.240	0.291	0.395	0.213
2018 ADVENTURE	7266	-0.170	-0.182	0.480	0.509	0.213
2018 ALLURE	27,215	-0.257	-0.252	0.274	0.376	0.238
2019 ADVENTURE	28,229	-0.169	-0.218	0.548	0.574	0.272
TOTAL	**218,028**	**-0.220**	**-0.228**	**0.358**	**0.420**	**0.239**

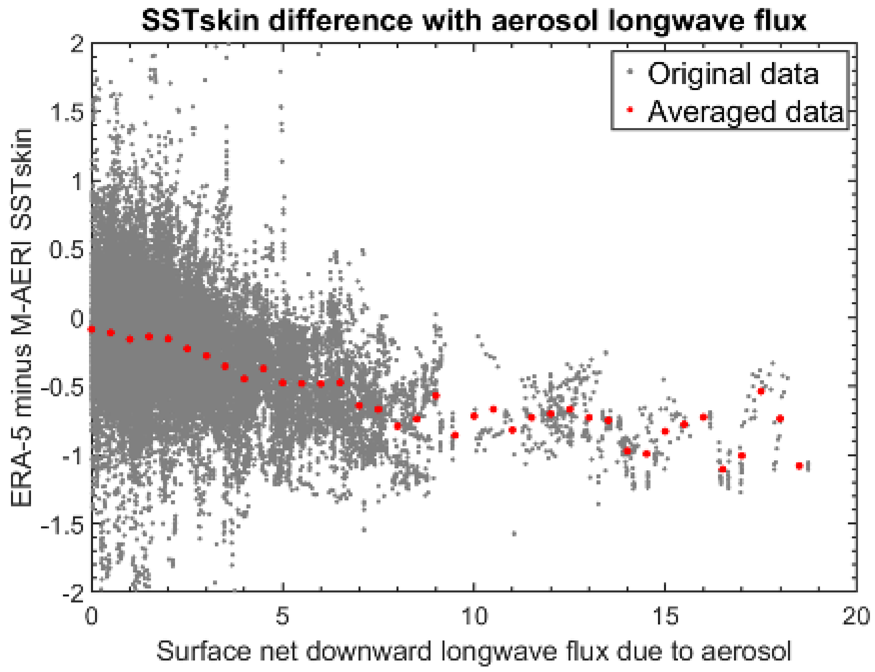
R/V CRUISES	N	MEAN	MED	STD	RMS	RSD
2004 RHB	5805	-0.212	-0.165	0.460	0.507	0.342
2006 RHB	3908	-0.152	-0.124	0.383	0.413	0.357
2007 RHB	1257	0.024	-0.029	0.441	0.442	0.415
2008 RHB	1592	0.020	-0.012	0.482	0.483	0.366
2011 RHB	2264	-0.038	-0.005	0.327	0.329	0.308
2013 RHB	7099	-0.201	-0.193	0.230	0.305	0.180
2015 ALLIANCE	5547	-0.299	-0.318	0.242	0.385	0.228
2018 RHB	38,108	-0.167	-0.148	0.282	0.328	0.206
2019 RHB	8378	-0.329	-0.299	0.502	0.601	0.380
TOTAL	**73,958**	**-0.190**	**-0.170**	**0.348**	**0.396**	**0.247**

CRUISES	N	MEAN	MED	STD	RMS	RSD
R/V	73,958	-0.190	-0.170	0.348	0.396	0.247
RCG	218,028	-0.220	-0.228	0.358	0.420	0.239
TOTAL	**291,986**	**-0.213**	**-0.214**	**0.356**	**0.415**	**0.243**

Sources of Error: Dust Aerosols

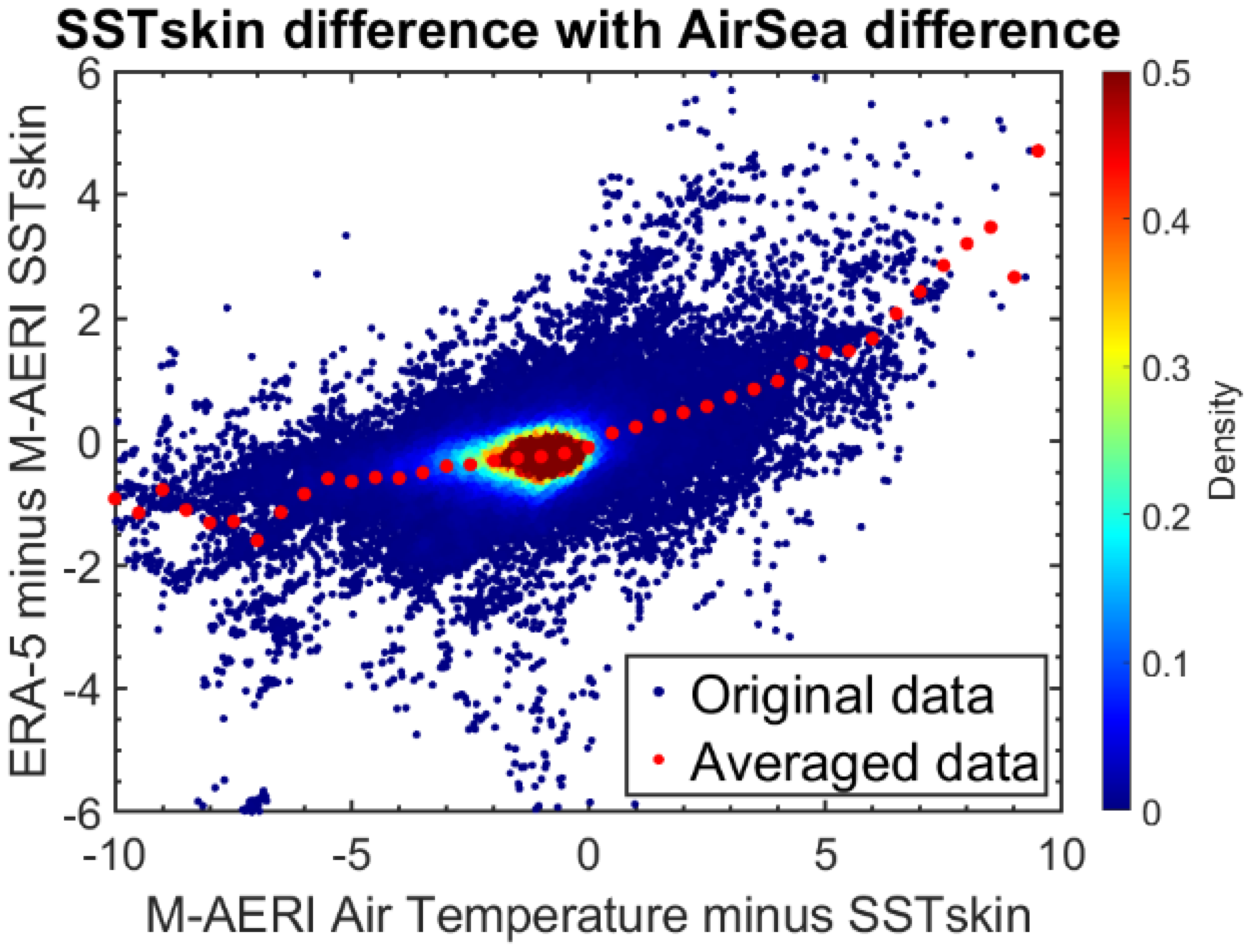






UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Sources of Error: Air-Sea Temperature Difference



UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Further details

- For more details, see Luo, B., & Minnett, P.J. (2020). Evaluation of the ERA5 Sea Surface Skin Temperature with Remotely-Sensed Shipborne Marine-Atmospheric Emitted Radiance Interferometer Data. *Remote Sensing* 12, 1873. doi:10.3390/rs12111873
- For ERA-Interim and MERRA-2 results, see Luo, B., Minnett, P.J., Szczodrak, M., Nalli, N.R., & Morris, V.R. (2020). Accuracy Assessment of MERRA-2 and ERA-Interim Sea Surface Temperature, Air Temperature, and Humidity Profiles over the Atlantic Ocean Using AEROSE Measurements. *Journal of Climate* 33, 6889-6909. doi: 10.1175/jcli-d-19-0955.1

Summary

- Target accuracies and decadal stability requirements for SST_{skin} 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,VIIRS, and ABI are producing very good SST_{skin}.
- ERA5 SST_{skin} is good, but room for improvement through better modelling of aerosol effects, diurnal heating and skin layer.

Current Priorities

- Monitor *Terra* and *Aqua* MODISs for effects of orbital drift.
- Come back up to speed with S-NPP VIIRS.
- Optimize cloud-screening algorithm for NOAA-20 VIIRSGenerate atmospheric correction algorithm coefficients for NOAA-20 VIIRS (launched November 18, 2017).
- Develop Saharan Dust correction for S-NPP and NOAA-20 VIIRS.
- Generate MatchUps between 2019 Saildrone SST_{skin} with MODIS and VIIRS retrievals.
- Improve high-latitude retrievals for MODIS and VIIRS.
- Explore Machine Learning approaches to the atmospheric correction.

Relevant Publications

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

1. Jia, C., & Minnett, P.J. (2020). High Latitude Sea Surface Temperatures Derived from MODIS Infrared Measurements. *Remote Sensing of Environment* 251, 112094. https://doi.org/10.1016/j.rse.2020.112094
2. 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
3. Minnett, P.J., Kilpatrick, K.A., Podestá, G.P., Evans, R.H., Szczodrak, M.D., Izaguirre, M.A., Williams, E.J., Walsh, S., Reynolds, R.M., Bailey, S.W., Armstrong, E.M., & Vazquez-Cuervo, J. (2020) Skin Sea-Surface Temperature from VIIRS on Suomi-NPP — NASA Continuity Retrievals. *Remote Sensing* 12, 3369. doi:10.3390/rs12203369
4. Luo, B., & Minnett, P.J. (2020) Evaluation of the ERA5 Sea Surface Skin Temperature with Remotely-Sensed Shipborne Marine-Atmospheric Emitted Radiance Interferometer Data. *Remote Sensing* 12, 1873. doi:10.3390/rs12111873
5. Luo, B., & Minnett, P.J. (2020) Comparison of SLSTR Thermal Emissive Bands Clear-Sky Measurements with those of Geostationary Imagers. *Remote Sensing* 12, 3279. doi:10.3390/rs12203279

Relevant Publications II

6. Luo, B., Minnett, P.J., & Nalli, N.R. (2021) Infrared satellite-derived sea surface skin temperature sensitivity to aerosol vertical distribution‒Field data analysis and model simulations. *Remote Sensing of Environment* 252, 112151. https://doi.org/10.1016/j.rse.2020.112151
7. Kumar, C., Podestá, G., Kilpatrick, K. & Minnett, P. (2021}. A machine learning approach to estimating the error in satellite sea surface temperature retrievals. *Remote Sensing of Environment*, https://doi.org/10.1016/j.rse.2020.112227
8. Luo, B., & Minnett, P.J (2021). Skin Sea Surface Temperatures From the GOES-16 ABI Validated With Those of the Shipborne M-AERI. *IEEE Transactions on Geoscience and Remote Sensing*, 59(12), 9902-9913. 10.1109/TGRS.2021.3054895
9. Luo, B., Minnett, P.J., Zuidema, P., Nalli, N.R., & Akella, S. (2021). Saharan Dust Effects on North Atlantic Sea-Surface Skin Temperatures. *Journal of Geophysical Research: Oceans* 126, e2021JC017282. https://doi.org/10.1029/2021JC017282
10. Luo, B., Minnett, P.J., Szczodrak, M., & Akella, S. (2022). Regional and Seasonal Variability of the Oceanic Thermal Skin Effect. Journal of Geophysical Research: Oceans 127, e2022JC018465. https://doi.org/10.1029/2022JC018465
11. Minnett, P.J., Knuteson, R.O., & Gero, J. (2022). Surface-based thermal infrared spectrometers. In N.R. Nalli (Ed.), Field Measurements for Passive Environmental Remote Sensing. To be published October 2022: Elsevier.
12. Jia, C., Minnett, P.J., Szczodrak, M., & Izaguirre, M.A. (2022). High Latitude Sea Surface Skin Temperatures Derived From Saildrone Infrared Measurements. *IEEE Transactions on Geoscience and Remote Sensing (in revision).*
13. Jia, C., Minnett, P.J.. and Luo B. (2022), Significant Diurnal Warming Events Observed by Saildrone at High Latitudes. In preparation.

Acknowledgements.

- NASA Physical Oceanography Program.
- NASA Participating Investigators Program.
- NASA Senior Review Support.
- NASA Future Investigators in NASA Earth and Space Science and Technology (FINESST) Program – Bingkun Luo.
- University of Miami Graduate School Fellowship – Chong Jia.
- Royal Caribbean Group.
- Officers and crew of the NOAA Ship *Ronald H. Brown*.

Thank you for your attention.

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE, ATMOSPHERIC & EARTH SCIENCE

Outstanding issues

- Better cloud screening and atmospheric correction algorithms.
- 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 – see Kumar, C., Podestá, G., Kilpatrick, K. & Minnett, P. 2021. A machine learning approach to estimating the error in satellite sea surface temperature retrievals. *Remote Sensing of Environment*, https://doi.org/10.1016/j.rse.2020.112227.
- Improved understanding of thermal skin effect is needed.
- And much more….

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

Quality	Mean	Median	SD	RSD	N
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.