Accuracy assessment of ERA5 Sea Surface Skin Temperature and Near-surface Air Temperature using M-AERI observations

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Introduction

Satellite-derived and in situ measurements of sea-surface temperature (SST) and atmospheric profiles are limited in duration, lack consistent global coverage, often have inadequate sampling and not all atmospheric properties are accurately observed. Reanalysis output is extensively used in atmospheric and oceanic research to complement the satellite and in situ data, and ERA5 is the latest climate reanalysis produced of ECMWF. ERA5 provides hourly data of many atmospheric and sea-surface parameters and aims to fill the gaps through the assimilation of as many observations as possible. But, the ERA5 data must be rigorously and continuously evaluated to understand their strengths and weaknesses. This study evaluates the Skin SST (SST_{skin}) and near-surface air temperatures in ERA5 through comparisons with independent Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) measurements. The results of the comparisons reveal that SST_{skin} and near-surface air temperature values in ERA5 are in very good agreement with the in-situ measurements. For the SST_{skin}, the comparison between the reanalysis and measurements show that the ERA5 SST_{skin} has a warm bias of ~0.15K and a standard deviation of ~0.31K between M-AERI. The ERA5 shows a larger bias near Saharan dust regions. The ERA5 near-surface air temperature over the tropical and sub-tropical ocean are found to have good accuracy based on in-situ M-AERI data. These results support the use of ERA5 fields in a variety of research applications, including those directed at improving the accuracies of satellite-derived SST_{skin}.

1. Data

➢ **ERA5 datasets:**

▪ERA-Interim is now 10 years old and has been replaced by ERA5, which is the latest climate reanalysis produced by ECMWF, providing hourly data with estimates of uncertainty.

▪ERA5 data are available in the Copernicus Climate Data Store on a 30km grid and resolve the atmosphere at 137 levels from the surface up to a height of 80km.

▪ERA5 covers the earth from 1979 to present.

▪ERA5 SST_{skin} is derived from the surface energy balance.

▪Details of the algorithms are available from ECMWF IFS Documentation (Cy43r1) Part IV: Physical Processes at: *https://www.ecmwf.int/en/elibrary/17117-part-iv-physical-processes*

➢ **Independent M-AERI in-situ data:**

•The M-AERI is a very well-calibrated and stable sea-going Fourier Transform Infrared Interferometer. It is well suited for independent validation of the ERA5 SST_{skin} retrieval.

Figure: M-AERI at Fiducial Measurements for Surface Temperatures Workshop – NPL, June 2016.

•At sea calibration by two internal blackbody cavities with thermometers with NIST-traceable calibration. Calibration sequence before and after each cycle of measurements.

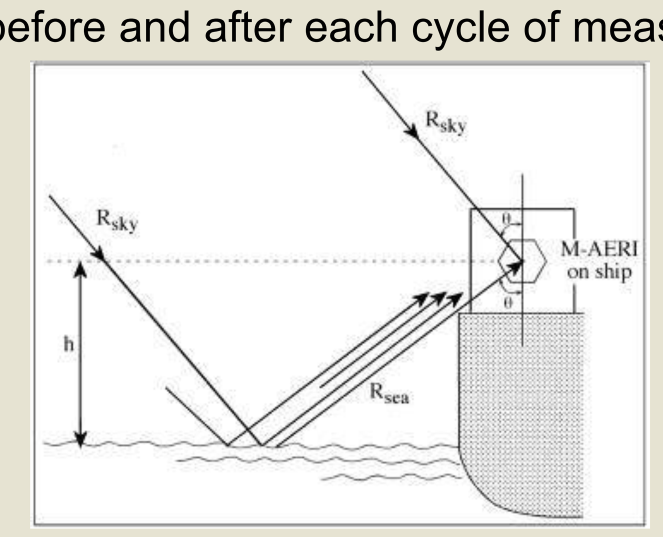
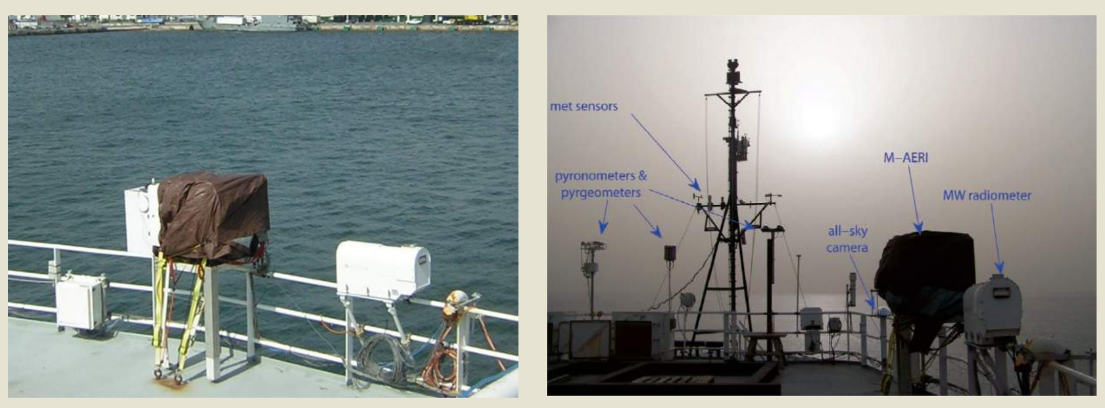
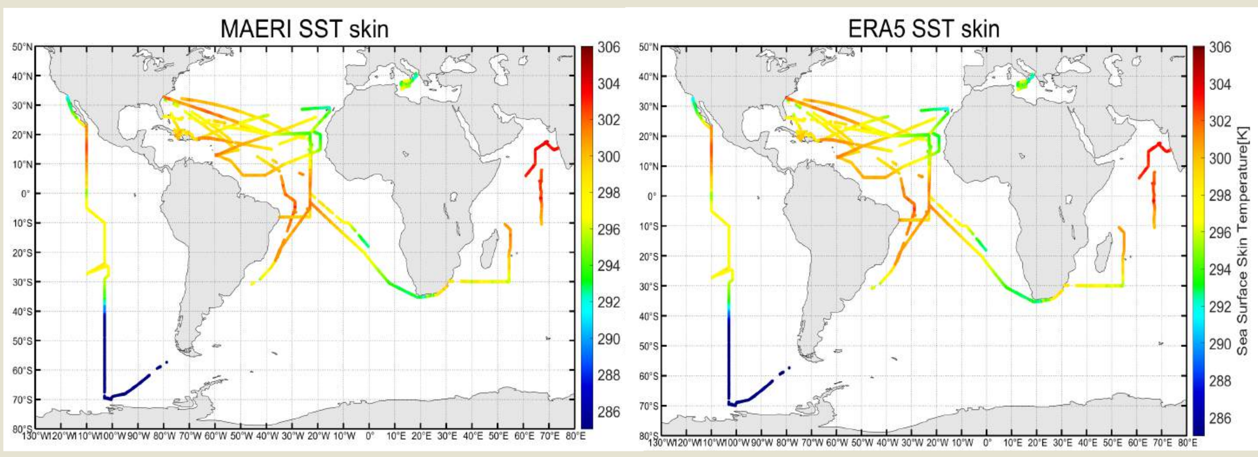


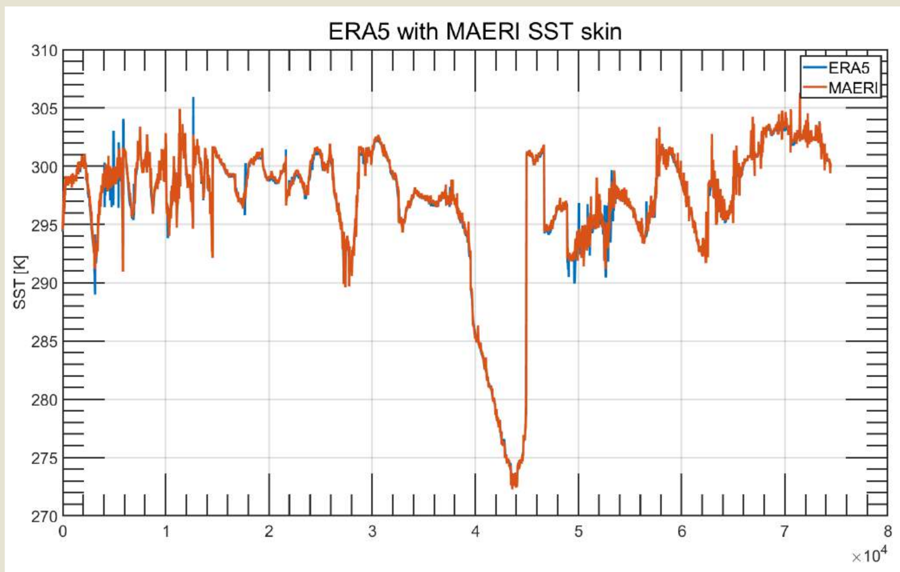
Figure: The viewing geometry of a ship-board radiometer measuring the SST_{skin}. The sky view is necessary to provide a correction for the small component in the sea-view measurements that is reflected infrared emission from the sky. The intersection of the radiometer field of view and the sea surface should be ahead of the bow wave to minimize the local influence of the ship.



Left: M-AERI at Deck. Right: Unenhanced photograph of the forward Deck02 of the NOAA ship Ronald H. Brown, taken during AEROSE-III, on the 13 May 2007, during the major Saharan dust outflow pulse. (Nalli et al. 2011)

2. SST_{skin} Validation





Upper: M-AERI cruise tracks with Geo-located ERA5 profile, color indicates the SST_{skin}.
Bottom: Time series of M-AERI (blue) and ERA5 (orange) SST_{skin}

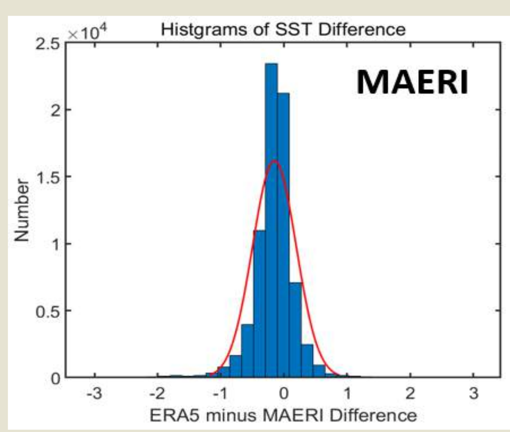
3. SST_{skin} Error Statistics

Year	START	END	N	Mean	Median	STD	RMS	RSD
2004	2004-02-13	2004-04-13	5809	0.173	0.139	0.350	0.390	0.270
2006	2006-05-27	2006-07-14	3924	0.140	0.120	0.300	0.331	0.294
2007	2007-05-01	2007-05-31	1257	-0.018	-0.010	0.381	0.381	0.396
2008	2008-04-29	2008-05-19	1591	0.022	0.019	0.347	0.346	0.285
2009	2009-07-17	2009-08-04	**	**	**	**	**	**
2011	2011-07-21	2011-08-20	1901	0.038	0.015	0.257	0.260	0.271
2013	2013-01-09	2013-02-13	7099	0.095	0.089	0.179	0.203	0.146
2015	2015-11-17	2015-12-14	5583	0.187	0.207	0.207	0.279	0.196
2016	2016-11-07	2017-02-01	17705	0.130	0.151	0.260	0.294	0.178
2017	2017-02-24	2017-03-19	3763	0.176	0.183	0.136	0.230	0.160
2018	2018-03-08	2018-07-04	20968	0.169	0.138	0.273	0.321	0.187
Total	2004-02-13	2018-07-04	69600	0.1506	0.1358	0.3109	0.3454	0.215

Table: Error Statistics of ERA5 minus M-AERI SST_{skin} (Unit: K)

The ERA5 SST_{skin} matchup co-location criteria:
Nearest 4*4 Point Interpolation and 1 hours time interpolation.

Difference	ERA5 – M-AERI
DAY	Mean:0.151 K Median:0.134 K STD:0.298 K RMS:0.335 K RSD:0.208 K
NIGHT	Mean:0.148 K Median:0.135 K STD:0.319 K RMS:0.352 K RSD:0.209 K



Left: Error Statistics of day and night. Right: Histograms of SST_{skin} difference.

- The results of the SST_{skin} comparison reveal that ERA5 are in good agreement with the in-situ measurement. ERA5 has a warm bias of ~0.15K and STD of ~0.3K.
- Part of bias due to the resolution of ERA5.
- There is negative bias near Saharan Dust region, due to the ERA5 surface energy balance retrieval method.

4. Air Temperature Validation

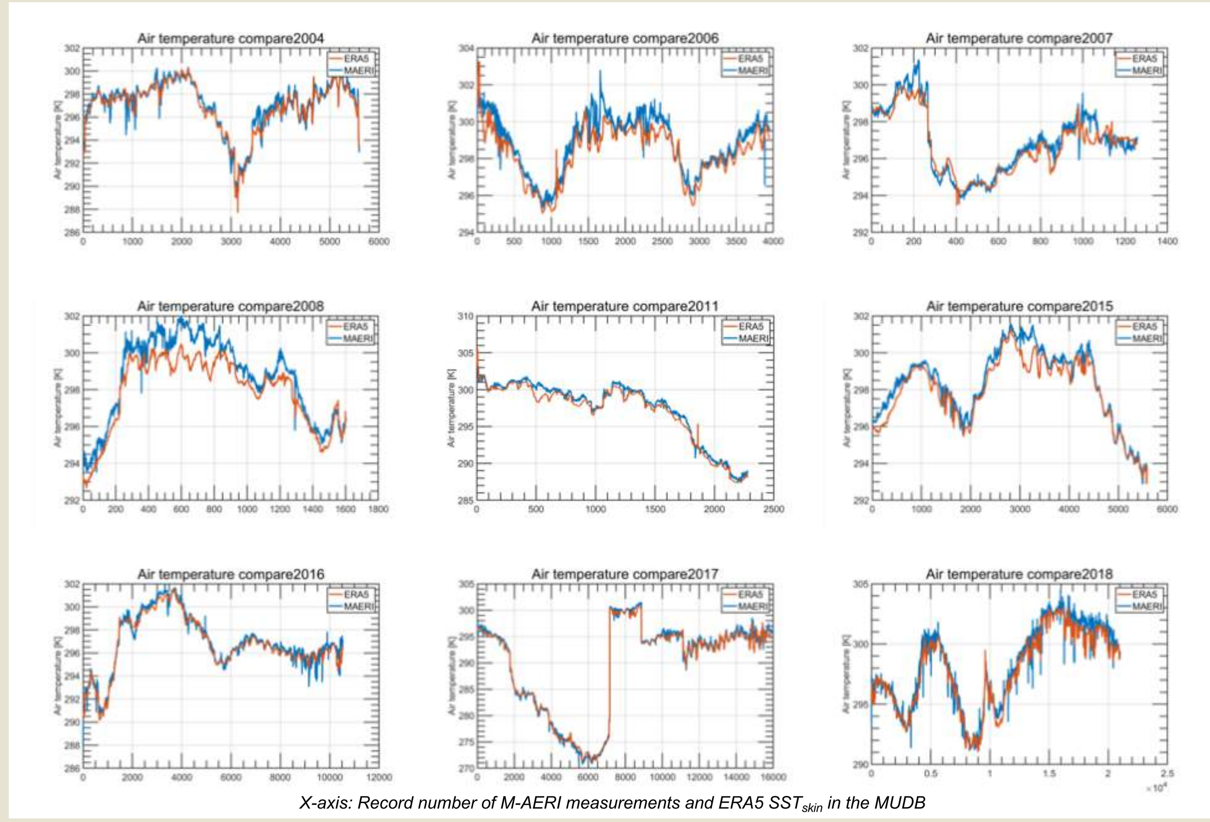
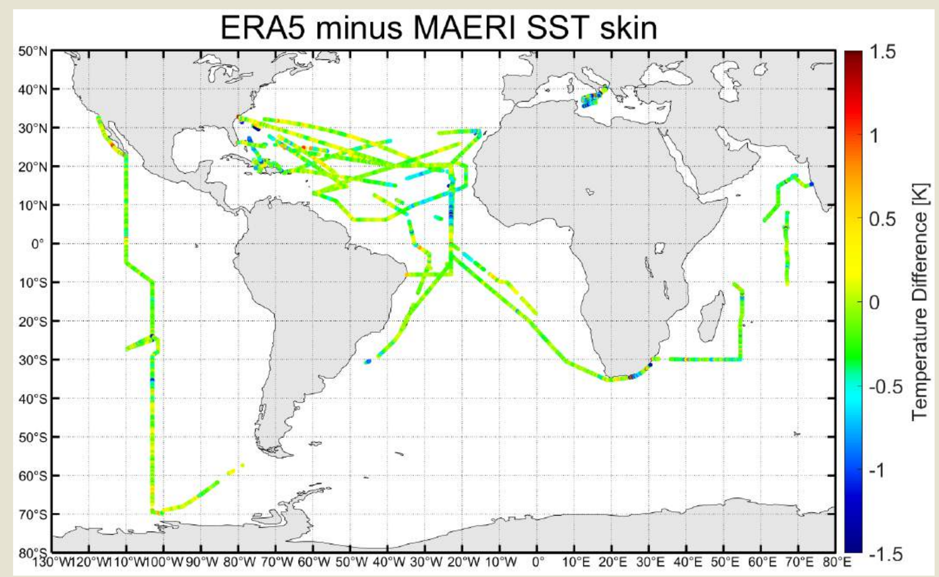
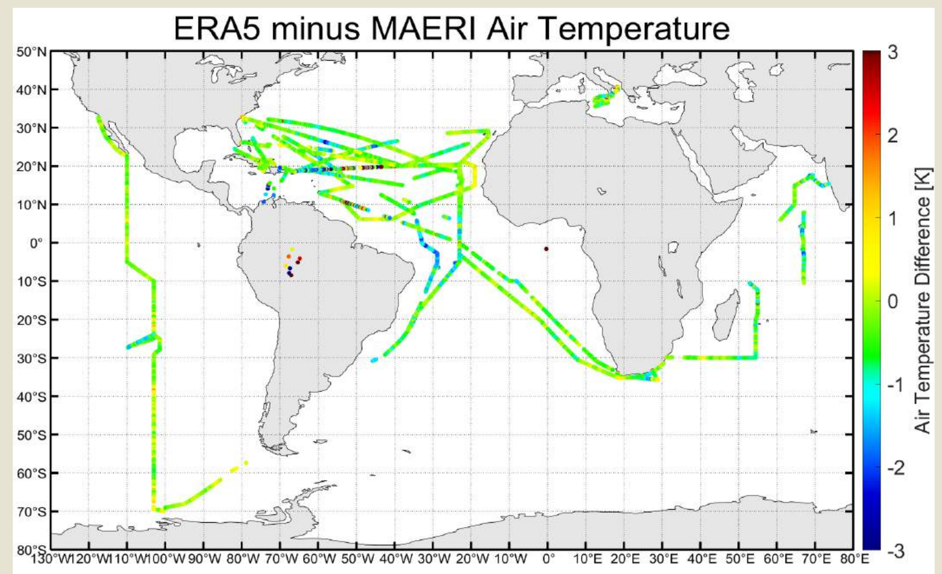


Figure: Near surface Air Temperature validation.

Conventional data have been recognized as being contaminated by direct solar heating and heat island effects of the ships. ERA5 includes air temperature at 2m, the M-AERI appears to be a more accurate in-situ air temperatures measurement than conventional measurements and can provide trustable data to validate ERA5 air temperature (Minnett et al. 2005).

5. Error Distribution





Locations of ERA5 minus M-AERI SST_{skin}(top) and Near surface air temperature(bottom) differences.

- SST_{skin}: Negative SST_{skin} difference near Sahara outflow region and Mediterranean Sea. Due to dust aerosol.
- Near surface air temperature: Positive (+1K) bias near Saharan dust outflow region. Negative bias (-2K) near equator. Large standard deviation when water vapor concentration is high and near the coast.

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7. References

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