Retrieval of MODIS SST with Optimal Estimation

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Objective:

To explore if it is possible to improve the accuracy of MODIS SSTs derived with Optimal Estimation (OE) compared to the routine approach that uses the Non-Linear SST (NLSST) algorithm.

Introduction

The current MODIS SST non-linear retrieval algorithm (**NLSST**) is based on a nearly linear combination of brightness temperature in two infrared channels with coefficients that are derived from match-ups with buoy measurements. The **NLSST** retrievals have global accuracy of about 0.5 to 0.4K (rms). However, they can be influenced by significant systematic bias when applied in conditions that depart significantly from the 'average' that is represented in the statistical coefficients. Intrusions of Saharan air layer (SAL), for example, over the eastern Atlantic are a seasonal phenomena and represent such a departure from average atmospheric conditions and lead to large errors in the NLSST.

We used the Optimal Estimation (**OE**) approach to explore if we can improve the accuracy of MODIS SST retrievals and eliminate at least some of the inherit **NLSST** bias errors.

Elements of the OE approach:

- Ocean-atmosphere system is represented by a reduced state vector is **x** = (SST, WV) where WV is total atmospheric column water vapor.
- A priori state vectors combine the SST and WV fields of the European Centre for Medium-Range Weather Forecast (ECMWF) reanalysis model.
- The forward model is the Line-By-Line Radiative Transfer Model (LBLRTM) of Clough, et al., 1995.
- The observation vector is the set of radiances in MODIS 11 and 12 µm channels or 3.94 and 4.05 µm.
- We treat the covariance matrix of forward modelling and observations, and covariance matrix of prior information as parameters of the model.

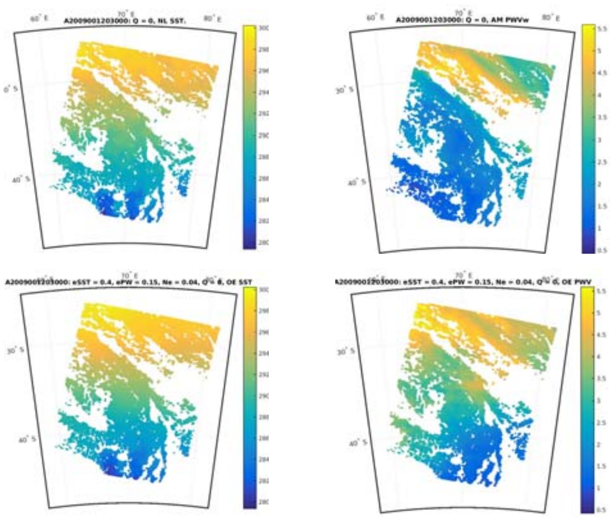

Figure 1. Comparison of SST retrieved with NLSST and OE and WV from AMSR-E and MODIS OE retrievals.

MODIS Dataset

We performed OE retrievals for a subset of AQUA MODIS data from 2009. We retrieved both SST and WV for:

1) Data in MODIS Match-up Data Base (MDB) for Jan, Apr, Jul and Oct of 2009. The MODIS MDB contains MODIS SST together with simultaneous and collocated values of in situ buoy measurements. Additionally the collocated AMSR-E microwave SST measurement are listed in the MODIS MDB.
2) Selected entire granules of MODIS level 1B data.

We compared the OE retrieval results with:

1) Buoy temperature measurements
2) NLSST retrievals
3) Simultaneous AMSR-E retrieval of SST and WV
4) ECMWF values of SST and WV
5) We tested the impact of covariance parameters the on the retrieved SST.

Difference between retrieved SST and buy measurements for data where MODIS quality flag QF=0, 1 or 2. Mean, standard deviation (std) and robust standard deviation (rstd).

11 µm

QF=0

e_{SST}	e_{wv}	$e_{11} = e_{12}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-0.1867	0.3454	-0.1485	0.4625	-0.1397	0.3488	0.0382	0.5253
0.4	0.05	0.04			-0.1515	0.4722			0.0352	0.5342
0.2	0.05	0.02			-0.1488	0.4620			0.0379	0.5246

QF=1

e_{SST}	e_{wv}	$e_{11} = e_{12}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-0.4027	0.5122	-0.2314	0.4900	-0.1448	0.3565	0.1714	0.6743
0.4	0.05	0.04			-0.2331	0.4950			0.1696	0.6755
0.2	0.05	0.02			-0.2293	0.4850			0.1734	0.6688

QF=2

e_{SST}	e_{wv}	$e_{11} = e_{12}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-0.9640	0.7887	-0.1446	0.4377	-0.1566	0.3376	0.8193	0.8288
0.4	0.05	0.04			-0.1483	0.4467			0.8157	0.832
0.2	0.05	0.02			-0.1404	0.4365			0.8239	0.8237

4 µm

QF=0

e_{SST}	e_{wv}	$e_{3.94} = e_{4.05}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-0.1943	0.2605	0.1007	0.4082	-0.1462	0.4125	0.2950	0.4529
0.4	0.05	0.04			0.0799	0.4096			0.2742	0.4568
0.2	0.05	0.02			0.071	0.4776			0.2657	0.5195

QF=1

e_{SST}	e_{wv}	$e_{3.94} = e_{4.05}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-0.4252	0.4934	0.0626	0.4082	-0.1582	0.4151	0.4878	0.6044
0.4	0.05	0.04			0.0462	0.4002			0.4715	0.6028
0.2	0.05	0.02			0.0285	0.4721			0.4539	0.6679

QF=2

e_{SST}	e_{wv}	$e_{3.94} = e_{4.05}$	NL-Buoy mean	NL-Buoy rstd	OE-Buoy mean	OE-Buoy rstd	AMSRE-Buoy mean	AMSRE-Buoy rstd	NL-OE mean	NL-OE rstd
0.6	0.25	0.05	-1.2433	1.3884	-0.0306	0.4433	-0.1390	0.4328	1.2127	1.4315
0.4	0.05	0.04			-0.0382	0.4569			1.2051	1.444
0.2	0.05	0.02			-0.0307	0.5301			1.2151	1.4768

Results

For the MODIS MDB data during four months of 2009 we found 352,396 match-ups of which 22,808 were of the best quality (quality flag = 0), 15610 had QF=1, 7379 had QF=2, The remainder, with QF=3, are considered unusable. We compared SST retrievals for measurements with QF=0, 1 and 2. The statistics of these comparisons are given in Tables 1 to 3 for three combinations the covariance parameters. These parameters represent uncertainties of MODIS measurements in the two channels ($e_{11} = e_{12} = NE\Delta T$) and uncertainties of the a priori fields of SST and WV, e_{SST} and e_{WV}.
Figures 2 and 3 shows geographical distribution of SST-Buoy differences for MODIS **NLSST** and **OE SST**, for the three quality levels for 11 µm and 4 µm channel retrievals respectively.

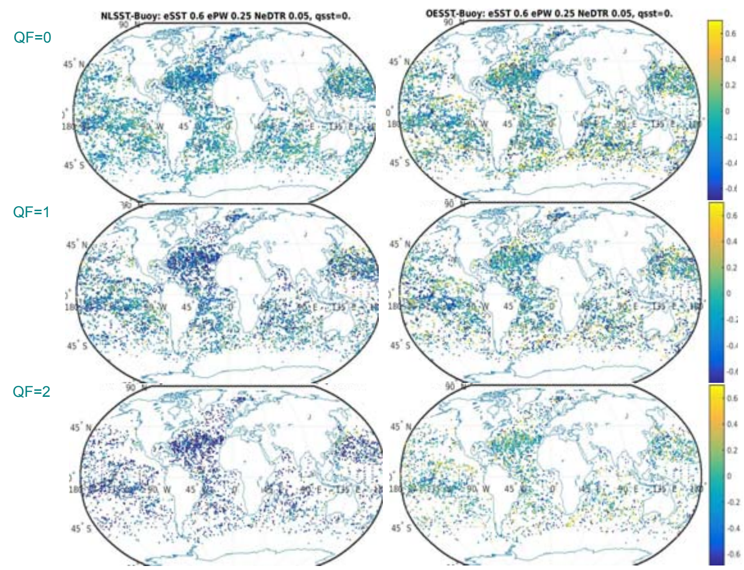

Figure 2. Difference MODIS SST – Buoy temperature: left column **NLSST**, right column **OE**. Rows correspond to quality flags from 0 to 2 for 11 µm channel retrievals (λ = 11, 12 µm).

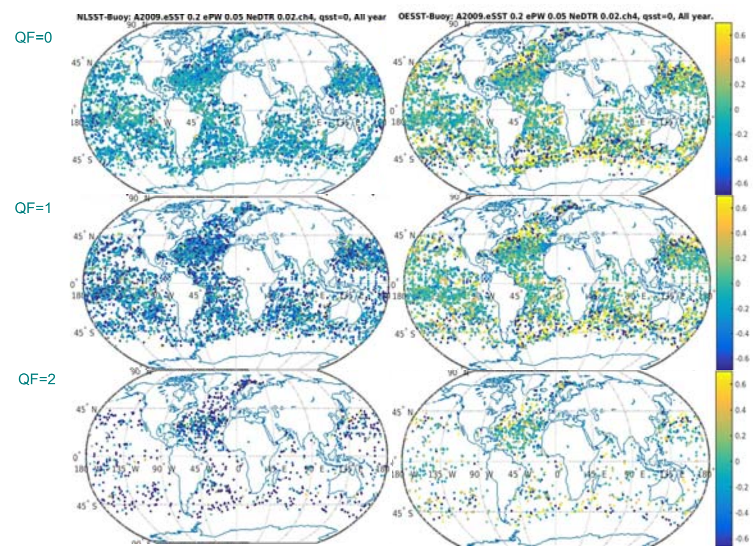

Figure 3. Difference night-time MODIS SST – Buoy temperature: left column **NLSST**, right column **OE**. Rows correspond to quality flags from 0 to 2 for 4 µm channel retrievals (λ = 3.96, 4.05 µm).

Summary, Conclusions and Future Work:

We found that for the set of MODIS data we examined:

- For the highest quality data the retrieval bias with respect to buoy measurements is slightly reduced for **OE** retrievals over the **NLSST**. But, standard deviation is increased in **OE**.
- For lower quality data **OE** outperforms **NLSST** in bias, scatter and robust standard deviation.
- Maps clearly show areas where SST bias is reduced in **OE** vs **NLSST**.
- OE is quite robust with respect to the choice of the covariance matrices parameters.
- MODIS OE WV retrievals appear more moist than AMSR-E. It is possible that a better understanding of the OE WV retrieval will help to further improve the SST retrievals.

In the future we plan to expand our comparisons with AMSR-E measurements to improve statistics and work on the refinement of the OE method.

Reference

Clough, S.A., & Iacono, M.J. (1995). Line-by-line calculations of atmospheric fluxes and cooling rates II: Application to carbon dioxide, ozone, methane, nitrous oxide, and the halocarbons. *J. Geophys. Res.* **100**, 16,519-516,535.

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