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Assessment of the impact of SLSTR L2P SST data in OSTIA

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Abstract

The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system was developed at the Met Office and produces daily, globally complete, near real time (NRT) analyses on a 1/20 degree (~6 km) grid. In this study, the impact of SLSTR L2P SST data is assessed in a pre-operational OSTIA trial, which assimilated dual view SST and included a skin-to-bulk SST adjustment before date assimilation. Global and regional statistics between the analysis and independent Argo floats are used to examine the impact of SLSTR data. These statistics are compared to those calculated from current operational OSTIA. Statistical assessments were conducted over two time periods: January – March and June – August 2018. The first period used SLSTR data prior to the implementation of Bayesian cloud screening. The data quality of SLSTR from winter 2018 is high enough to be assimilated in the operational OSTIA system and SLSTR data have neutral impact in both periods with the summer period showing slightly better statistics. Further study involves investigating the possibility of using SLSTR data as reference data in OSTIA system, as well as more sophisticated method for skin-to-bulk SST adjustment.

INTRODUCTION

OSTIA is the Met Office Operational SST and Ice Analysis, which produces L4, globally complete, daily products. OSTIA foundation SST is produced by using all nighttime observations and daytime observations when wind speed is larger than 6 m/s to remove diurnal warming signals. The system uses the NEMOVAR data assimilation scheme to generate the SST and ice concentration analyses. The scheme is also used successfully in the Met Office Forecasting Ocean Assimilation Model (FOAM) and it has proved to improve the reproduction of SST features in OSTIA (Waters et al., 2015; Fielder et al., 2018). OSTIA products are freely available from the CMEMS (Copernicus Marine Environment Monitoring Service) website: http://marine.copernicus.eu/. Table 1 shows the SST observation types used in the current operational OSTIA system. All satellite SST observations are bias corrected against a reference dataset. The current reference dataset consists of nighttime quality level (QL) 5 ACSPO VIIRS L3U data and in situ data from drifting and moored buoys.

SLSTR SST data have been assimilated in a pre-operational OSTIA run since September 2016. From July 2017 onwards, the Single Sensor Error Statistics (SSES) were obtained from the data instead of fixed values. The skin-to-bulk (s2b) SST adjustment, by adding 0.17 K, was applied in July 2018. Prior to the data assimilation, SLSTR data are pre-processed by applying SSES bias and subsampled to the OSTIA grid (~6 km). A satellite zenith angle was also in place to reject any data from the edge of the swaths. Only SLSTR observations from D2 and D3 channels with QL 5 were assimilated in the trials. The analysis produced by the pre-operational OSTIA system with the latest configuration is assessed in the study.

Observation Data	Data Provider
NAVO AVHRR-19[1]	NAVO
MetOp-B AVHRR	OSI SAF
SEVIRI	OSI SAF
ACSPO VIIRS L3U	STAR NOAA
AMSR2	RSS
In situ (ships, drifting and moored buoys)	GTS

***Table 1**.* **SST observations used in operational OSTIA system.**

The assessment of assimilating SLSTR in OSTIA is presented in the next section, followed by conclusions and future work.

ASSESSMENT OF THE IMPACT OF SLSTR IN OSTIA

The impact of assimilating SLSTR SST data in OSTIA (referred to as +SLSTR_s2b) are assessed in three ways: first by statistically comparing the +SLSTR_s2b run to a re-run equivalent to the operational OSTIA (control, the same configuration but run at a later time in parallel to the experiment run) using independent Argo observations as reference. Secondly, the bias field, which represents the differences between a satellite and the reference dataset, for SLSTR was assessed. Thirdly, the outputs from +SLSTR_s2b and control were assessed in numeric weather prediction (NWP) trials, which use the OSTIA outputs as boundary condition.

Argo Matchups

Argo observations have been a valuable source of independent data for the validation of OSTIA. Previous study has shown that OSTIA validates well against near-surface Argo data (Fiedler et al., 2018). In this study, Argo observations were sourced from Met Office Hadley Centre EN4 database (Good et al., 2013). Observations from the shallowest level between 3-5 m were used to validate the control and +SLSTR_s2b runs. All statistics were calculated for Argo minus analysis matchups; details of the methods can be found in Fiedler et al. (2018). The statistics over winter (January – March 2018) and summer (June – August 2018) periods are investigated in this section.

Table 2 shows the averaged statistics for Argo-analysis matchups over the winter period in geographical regions defined by CMEMS (While et al., 2017). The mean bias and RMS of Argo-analysis matchups for +SLSTR_s2b and control are comparable, with differences between the two runs less than 0.02 K across all regions. Small degradation (red numbers in Table 2) was seen in the tropical Atlantic and Southern Ocean, whilst small improvement (green numbers) is seen in the North Pacific for +SLSTR_s2b run. In both cases, the differences are small and considered negligible. This suggest assimilating SLSTR dual view SST has neutral impact in OSTIA compared to the control in winter.

The same statistics for Argo-analysis matchups over summer are shown in Table 3. Similar to winter, the mean bias and RMS for the matchups are comparable when using +SLSTR_s2b and control. Small improvements (green numbers in Table 3) are seen in the tropical Atlantic, South Atlantic, Tropical Pacific and Southern Ocean for +SLSTR_s2b compared to the control. The differences are less than

0.02 K hence considered negligible. It is worth noting that Bayesian cloud screening was implemented in the SLSTR SST processing chain in April 2018, which may contribute to the slightly more positive impact of SLSTR in OSTIA in summer than in winter.

Regions (CMEMS definitions)	Mean bias to Argo (K)		Mean RMS difference to Argo (K)	
	Control	+SLSTR_s2b	Control	+SLSTR_s2b
Global	0.04	0.04	0.37	0.37
North Atlantic	0.05	0.05	0.55	0.55
Tropical Atlantic	0.14	0.15	0.33	0.33
South Atlantic	0.03	0.03	0.36	0.36
North Pacific	0.05	0.05	0.35	0.34
Tropical Pacific	0.03	0.03	0.23	0.23
South Pacific	0.03	0.03	0.31	0.31
Indian Ocean	0.06	0.06	0.28	0.28
Southern Ocean	0.02	0.03	0.38	0.38

Table 2**. Argo-analysis matchups statistics for January – March 2018 when using operational OSTIA and +SLSTR_s2b as the analysis.**

Regions (CMEMS definitions)	Mean bias to Argo (K)		Mean RMS difference to Argo (K)	
	Control	+SLSTR_s2b	Control	+SLSTR_s2b
Global	0.04	0.04	0.40	0.40
North Atlantic	0.01	0.01	0.54	0.54
Tropical Atlantic	0.10	0.10	0.32	0.31
South Atlantic	0.04	0.04	0.46	0.45
North Pacific	0.03	0.03	0.41	0.41
Tropical Pacific	0.03	0.03	0.23	0.22
South Pacific	0.03	0.03	0.29	0.29
Indian Ocean	0.13	0.13	0.42	0.42
Southern Ocean	0.04	0.04	0.42	0.41

Table 3. **Argo-analysis matchups statistics for June – August 2018 when using operational OSTIA and +SLSTR_s2b as the analysis.**

Bias Field

The bias fields show the magnitude of the correction applied to the satellite observations by the OSTIA system. Larger bias indicate larger deviation of one satellite type from the reference dataset and hence larger correction applied before data assimilation. In this subsection, the averaged bias fields for SLSTR from +SLSTR_s2b run during two seasons (winter, January – March 2018 and summer, June – August 2018) are investigated. Bias fields from two other satellite types in the same run are also compared to SLSTR for both seasons.

Figure 1 shows the seasonally averaged bias field for SLSTR in +SLSTR_s2b run during winter (Figure 1a) and summer (Figure 1b). For both season, cold biases are seen in the high latitudes north of ~60° N in the Northern Hemisphere (NH), whilst warm biases are seen in the lower and mid-latitudes NH. In the Southern Hemisphere (SH), warm biases are seen in the lower and mid-latitudes during winter but are replaced by cold bias during summer. Opposite signs are seen for the biases at higher latitudes in the SH. The SLSTR biases are generally within ±0.4 K range, although the biases are larger in some regions. The warm biases in the tropical Atlantic, where the aerosols from Saharan dust have strongest impact, could be an indication of VIIRS L3U SSTs being too cold in this region. This is because the dual view feature of SLSTR instrument has the advantage of reducing the cold bias introduced by aerosols during SST retrieval, compared to the single view VIIRS data. However, further investigation is required to confirm this hypothesis.

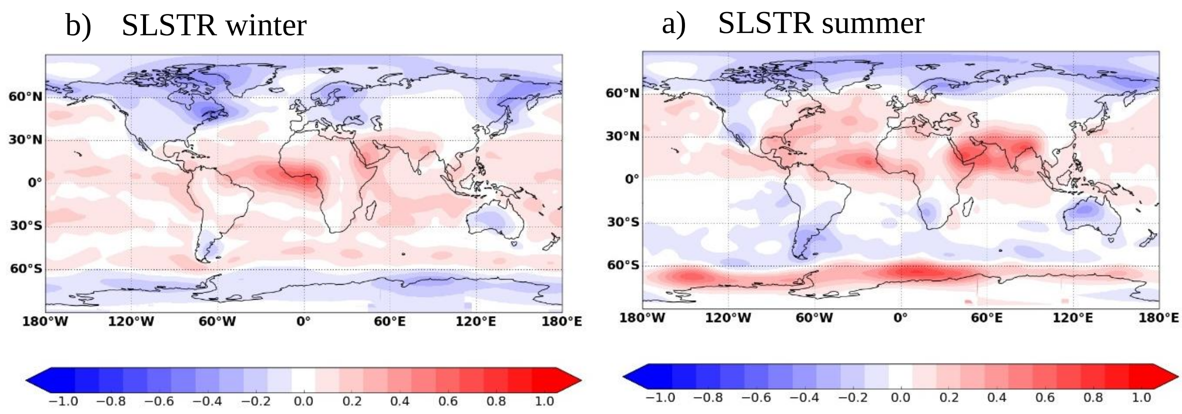

***Figure 1*. Bias fields for SLSTR in +SLSTR_s2b run during a) winter and b) summer.**

Figure 2 shows the bias fields for AMSR2 (Figure 2a and 2b) and MetOp-B AVHRR (Figure 2c and 2d) during winter (Figure 2a and 2c) and summer (Figure 2b and 2d). The AMSR2 bias field also present warm biases in the tropical Atlantic for both seasons, potentially support the hypothesis that VIIRS data are too cold in this region as satellite microwave observations tend to experience less influences from aerosols and clouds than Infrared observations (Chelton and Wentz, 2005). The magnitude of MetOp-B AVHRR biases is smaller than the magnitudes for AMSR2 and SLSTR, roughly ±0.2 K for MetOp-B AVHRR and ±0.4 K for the latter two satellites. It is worth noting that the bias fields were calculated using NEMOVAR scheme but without land-sea mask as the biases are expected to be on synoptic scales and reflect atmospheric variabilities. However, in regions with sparse observations, e.g. Southern Ocean, the bias information from a single observation could be spread too widely by the scheme. Therefore, the bias field should be used with caution and some detailed feature may not be entirely realistic.

Numeric Weather Prediction Trial

The OSTIA SST analysis is used in the Met Office NWP system as the boundary condition for atmospheric weather predictions. Hence it is important to assure the changes in OSTIA do not degrade the performance of the NWP system. NWP trials using +SLSTR run and operational OSTIA as boundary conditions were conducted to test the impact of assimilating SLSTR dual view observations in the context of NWP. Note that NWP trials generally need to run for at least 6 weeks to generate robust assessment, so results shown here are from a run without the skin-to-depth adjustment (referred to as +SLSTR) as this has the required length.

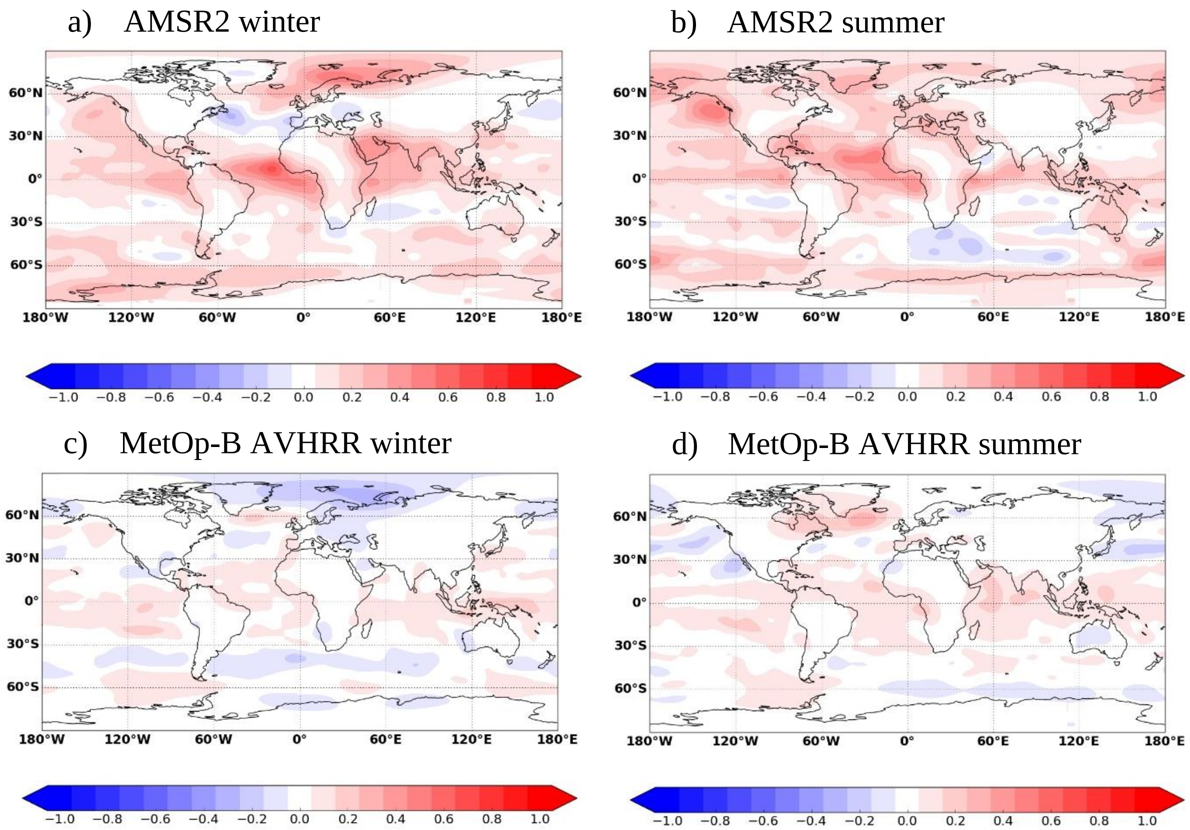

***Figure 2*. Bias fields for AMSR2 (a and b) and MetOp-B AVHRR (c and d) during winter (a and c) and summer (b and d).**

Global NWP index measures the performance of an experiment (e.g. +SLSTR) in reference to the control (operational OSTIA) in the trial. It is generated by comparing the atmospheric predictions from the trials to observations and analyses. Positive NWP index change (experiment minus control) indicates improvement in the experiment compared to the control. The results are sensitive to time periods, atmospheric observations/analyses included in the trial and grid resolution. Generally speaking, ±0.3 NWP index change is considered significant. The trials were run for winter (January – February 2018) and spring periods (14 April – 21 May 2018) and the averaged Global NWP index changes are shown in Table 4. Figure 3 and Figure 4 show the timeseries of the daily NWP index change over the two periods.

	Compared to observations (+SLSTR minus Control)	
	Winter	Spring
Global NWP Index	-0.14	-0.04
	Compared to analyses (+SLSTR minus Control)	
	Winter	Spring
	-0.17	-0.09

***Table 4*. Average Global NWP Index change (+SLSTR minus Control) during winter (January – February 2018) and spring (15 April – 21 May 2018).**

For both winter and spring, the Global NWP index changes between +SLSTR and control are negative, indicating that the +SLSTR run performs worse than the control in the NWP system. However, the index changes are less than 0.3 so the results indicate neutral impact from assimilating SLSTR observations. Spring results are better than winter results, suggesting possible positive impact from the Bayesian cloud screening. It is supported by the timeseries, as the spring trial timeseries show general positive index changes during the first half of the period (Figure 4), whilst the winter trial timeseries show generally negative index changes through the two months period (Figure 3). The NWP trials for +SLSTR_s2b runs are not long enough for robust comparison but the initial results (not shown) are more positive than the +SLSTR runs. Slight positive NWP index changes from the +SLSTR_s2b trials are expected, although the magnitude would be within ±0.3, hence neutral impact.

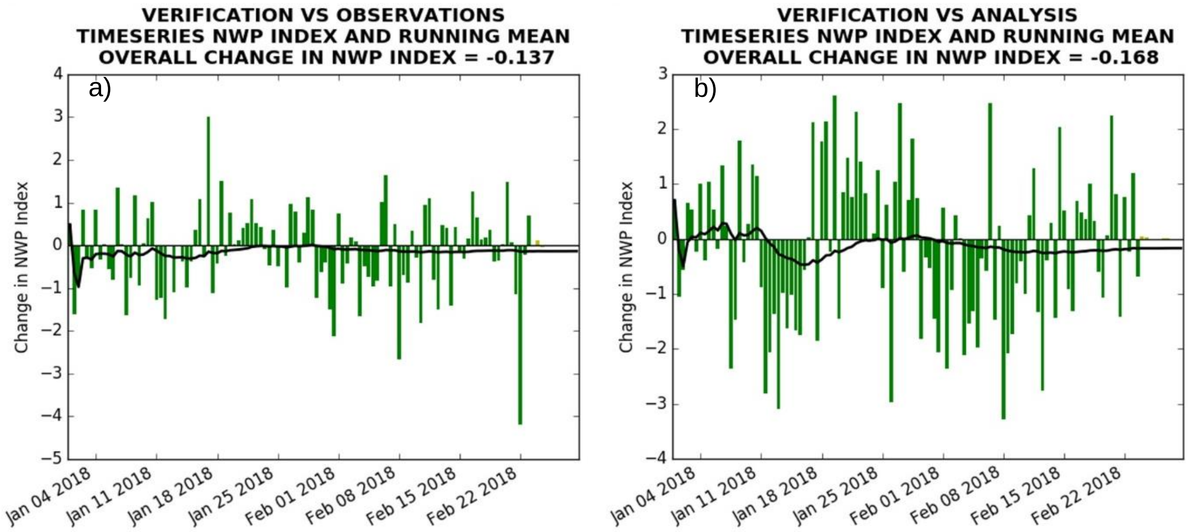

***Figure 3*. Global NWP index changes between +SLSTR and control (+SLSTR minus control) when compared against a) observations and b) analyses during January – February 2018.**

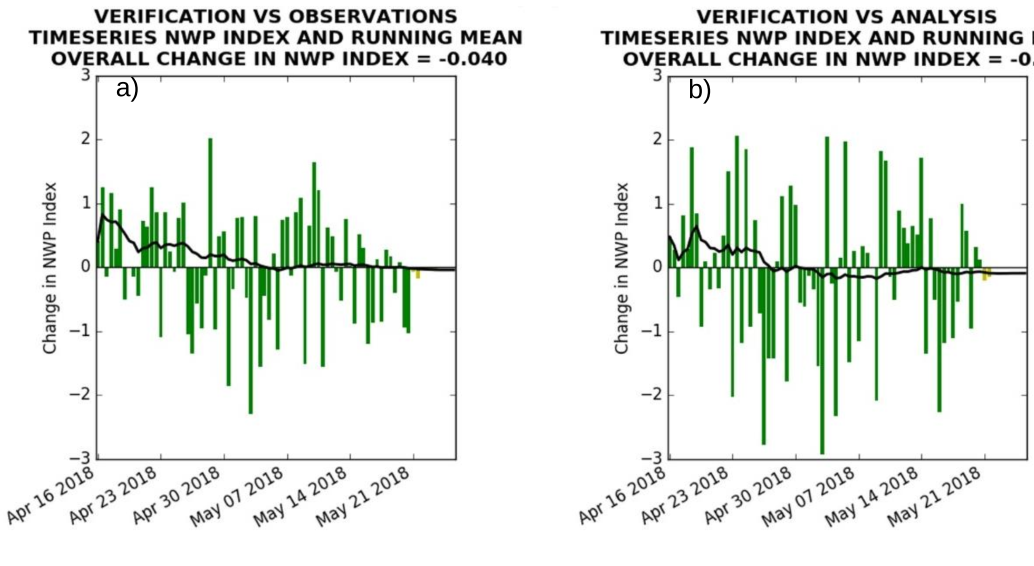

***Figure 4*. Global NWP index changes between +SLSTR and control (+SLSTR minus control) when compared against a) observations and b) analyses during 15 April – 21 May 2018.**

CONCLUSION AND FUTURE WORK

The impact of assimilating SLSTR L2P SST dual view observations are assessed in a pre-operational OSTIA system. The results were validated against independent Argo observations and were tested in the NWP trials. Both Argo matchups and NWP trials indicated neutral impact from assimilating SLSTR observations, compared to the current operational OSTIA. Bayesian cloud screening implemented in April 2018 may have led to slightly better statistics for +SLSTR_s2b in spring and summer than in winter. The +SLSTR_s2b configuration are scheduled to be implemented operationally at next system upgrade in early 2019.

Future work includes testing the impact of using SLSTR as part of the reference dataset. More noticeable impact from SLSTR observations is expected as reference dataset and a proper selection scheme will be investigated to balance the use of SLSTR and VIIRS observations in the reference dataset. In addition, a more statistically robust skin-to-bulk adjustment will be examined, potentially prior to the trial of using SLSTR as part of the reference dataset.

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[1] NAVO AVHRR-18 discontinued in May 2018