Use of ACSPO VIIRS L3U SST in the OSTIA system

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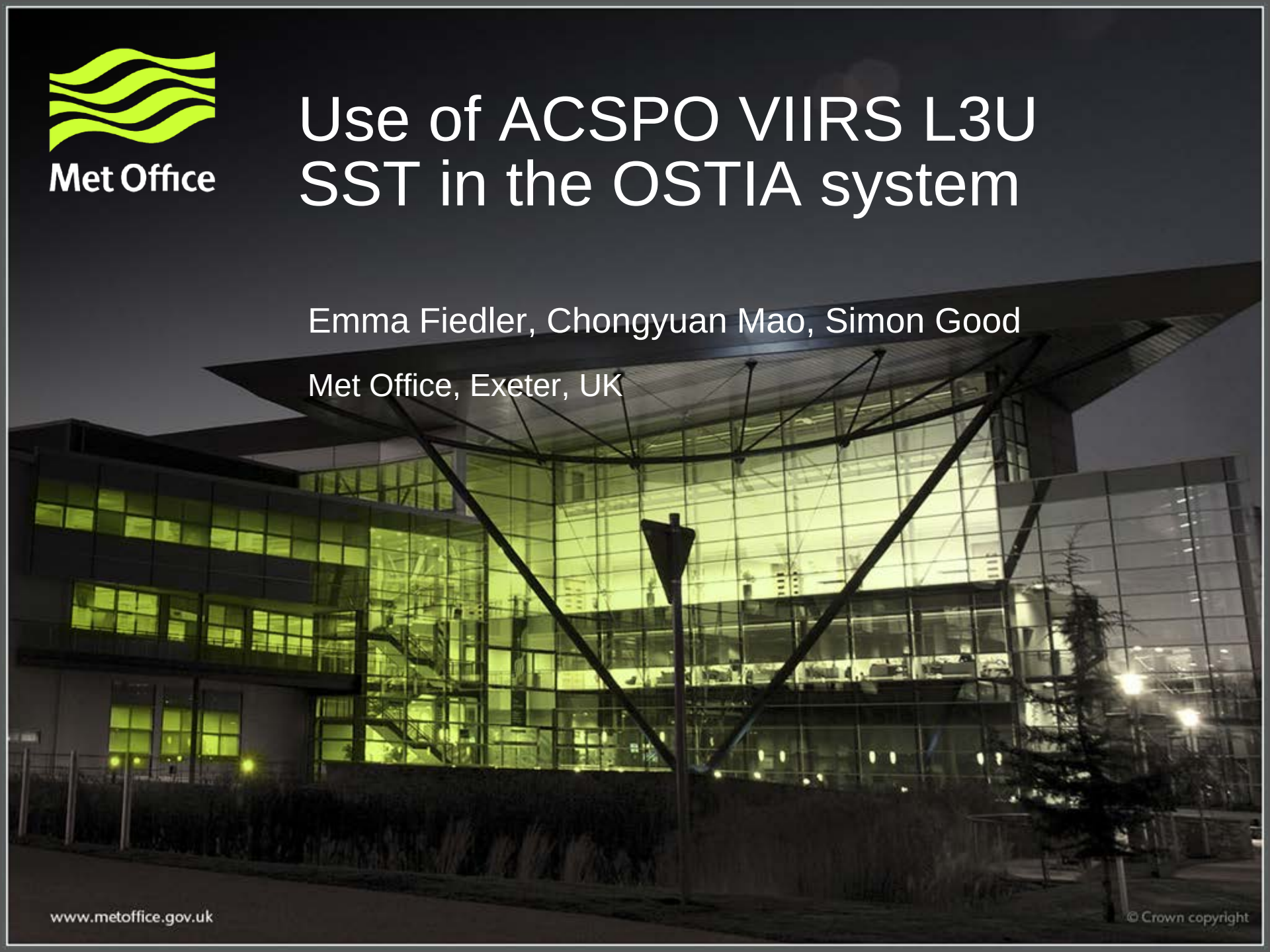


Introduction

OSTIA is the Met Office Operational SST and Ice Analysis system

- L4 (global, gap-free analysis), produced daily
- Foundation SST (uses all nighttime observations and daytime observations only when wind speed >6 m s^{-1} to remove diurnal warming effects)
- 1/20^{o} grid resolution
- Optimal Interpolation type assimilation scheme
- Validates well against other analyses (compared to independent near-surface Argo observations)

Introduction

SST observation types used in OSTIA (prior to update 15 March 2016):

- NOAA-18 and -19 AVHRR (from NAVO)
- MetOp-A AVHRR (from OSI SAF)
- SEVIRI (from OSI SAF)
- GOES-E (from OSI SAF)
- In situ (ships, drifters, moored buoys) (from GTS)

OSTIA performs a bias-correction of satellite data to a reference dataset of all in situ data and a high-quality subset of MetOp-A AVHRR (nighttime, max satellite zenith angle 48 degrees, Q4+)

Assimilation of ACSPO VIIRS in OSTIA

Methods

The effect of assimilating ACSPO VIIRS L3U SST into OSTIA was tested against a control run using the operational configuration.

Similar to the other satellite data types, the observation error variance for the new data type was taken from the SSES standard deviation estimate.

The SSES bias estimate was removed from the observations before any bias correction using the OSTIA reference dataset was applied.

The data were subsampled to the OSTIA grid size ($1/20^{o}$; ~6 km)

Methods

Validation was conducted against near-surface Argo observations.

- Used shallowest observation between 3-5 m depth (shown to be good representation of foundation temperature)
- Independent from the analysis
- Sourced from Met Office Hadley Centre EN4 database (includes QC; available with ~2 month delay)

Results are given for January 2016. The runs had a 2 week spin-up period prior to this (ample for OSTIA).

Results

Near-surface Argo minus OSTIA SST analysis for the operational system (control), and a run adding VIIRS (January 2016)

Region (CMEMS definitions)	Mean diff to Argo (K)		RMS diff to Argo (K)	
	control	+VIIRS	control	+VIIRS
Global	0.12	0.10	0.50	0.44
North Atlantic	0.23	0.22	0.59	0.53
Tropical Atlantic	0.14	0.14	0.30	0.28
South Atlantic	0.02	0.02	0.56	0.50
North Pacific	0.20	0.16	0.50	0.45
Tropical Pacific	0.08	0.05	0.33	0.29
South Pacific	0.03	0.01	0.39	0.36
Indian Ocean	0.04	0.03	0.34	0.30
Southern Ocean	0.07	0.07	0.52	0.47

Results

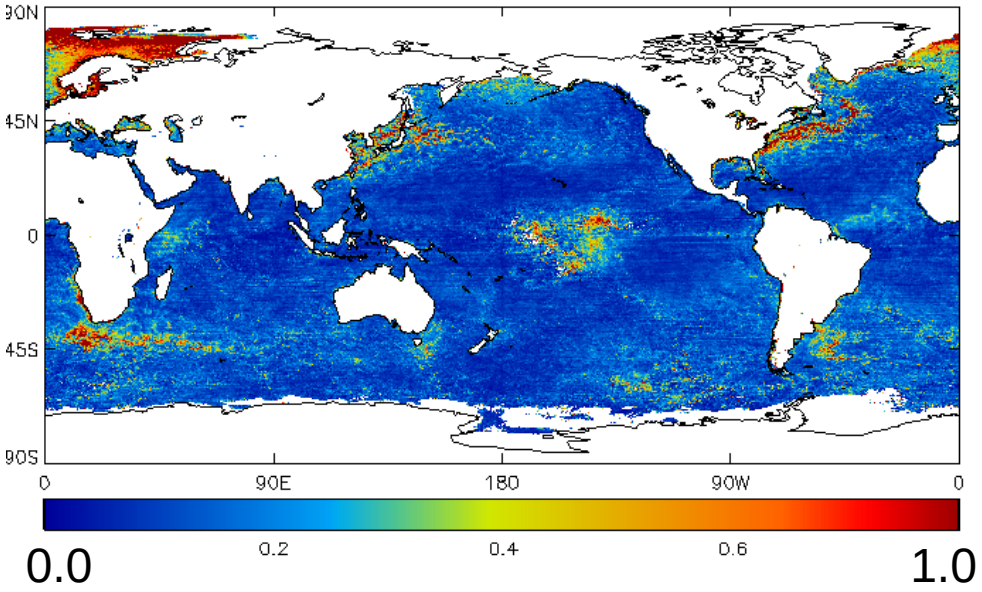
- Assimilation of VIIRS into OSTIA leads to sizable improvement of 0.06 K in the global RMS difference of the analysis to Argo
- RMS improvement consistent across all regions
- Improvement in mean difference seen in all regions, of up to 0.04 K in the North Pacific

Results

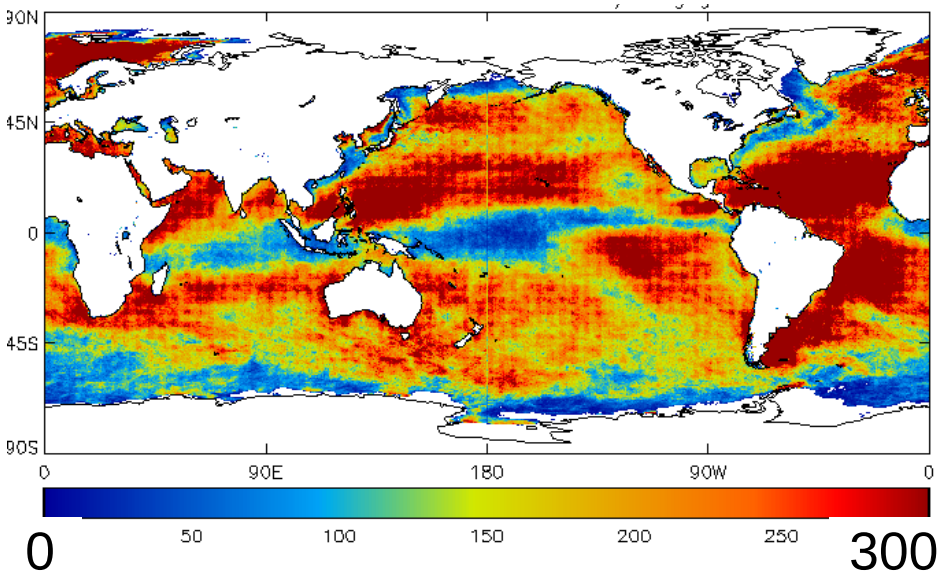
RMS difference to the analysis is generally small outside expected larger magnitude in high SST variability regions. This looks very good.

Exception is the Arctic (will be discussed in later slides) and region in Central Pacific. Is this related to reduced data volume?

VIIRS minus OSTIA RMS, Jan 2016 (K)



VIIRS total number observations in each 1/4deg grid box, Jan 2016

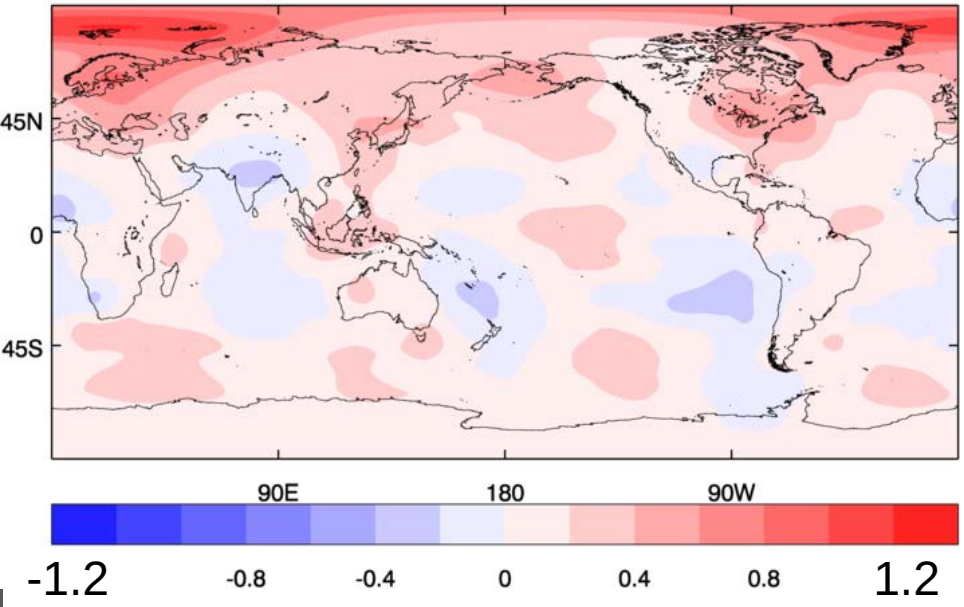


Conclusion

Results from assimilation experiments are very good so ACSPO VIIRS L3U (along with REMSS AMSR2 L2P) was added into OSTIA operationally on 15 March 2016.

Further results

Mean VIIRS bias to OSTIA reference, Jan 2016 (K)



Useful comparison as we don't have independent in situ observations for Arctic SST validation.

Mean of VIIRS bias to the OSTIA reference dataset (in situ and high quality subset of MetOp-A AVHRR) demonstrates a lack of agreement between the VIIRS observations and the reference dataset in the Arctic.

Similar results are found for other datasets, e.g. AMSR2, and a weaker warm bias for combined NOAA-18 and -19 AVHRR.

The agreement of independent datasets (IR and MW) suggests it is the MetOp-A AVHRR reference data which is too cold in the Arctic.

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Using ACSPO VIIRS as a reference dataset in OSTIA

Introduction

- MetOp-A AVHRR is a satisfactory reference dataset for OSTIA, as the analysis compares well against independent Argo observations.
- However, we have seen there is room for improvement, particularly in the high latitudes.
- We also need to move away from MetOp-A AVHRR due to data availability (we can't use MetOp-B for our bias correction due to OSTIA being used in the processing chain).
- We have therefore investigated using VIIRS as a reference dataset for OSTIA, with a plan to use it at least until SLSTR becomes available.

Methods

The impact of using nighttime-only ACSPO VIIRS L3U in the OSTIA reference dataset (along with in situ data: drifters, moored buoys, ships) for bias correction of the remaining satellite data was assessed.

Two runs were conducted for the period 09 Dec 2015 – 11 Jan 2016:

- **Control**: Updated operational configuration (includes VIIRS +AMSR2) with subset of MetOp-A AVHRR (nighttime, max satellite zenith angle 48 degrees, Q4+) as a reference dataset
- **VIIRSG_ref:** As control, but using nighttime VIIRS as a reference dataset instead of MetOp.

Only Q5 VIIRS data were available. Similar to the data being assimilated, the SSES bias was first removed from the reference data. The reference data were also subsampled to ~6 km.

Results

Near-surface Argo minus OSTIA analysis for the updated operational system (control) and a run using VIIRS as a reference dataset (9 Dec 2015 – 11 Jan 2016)

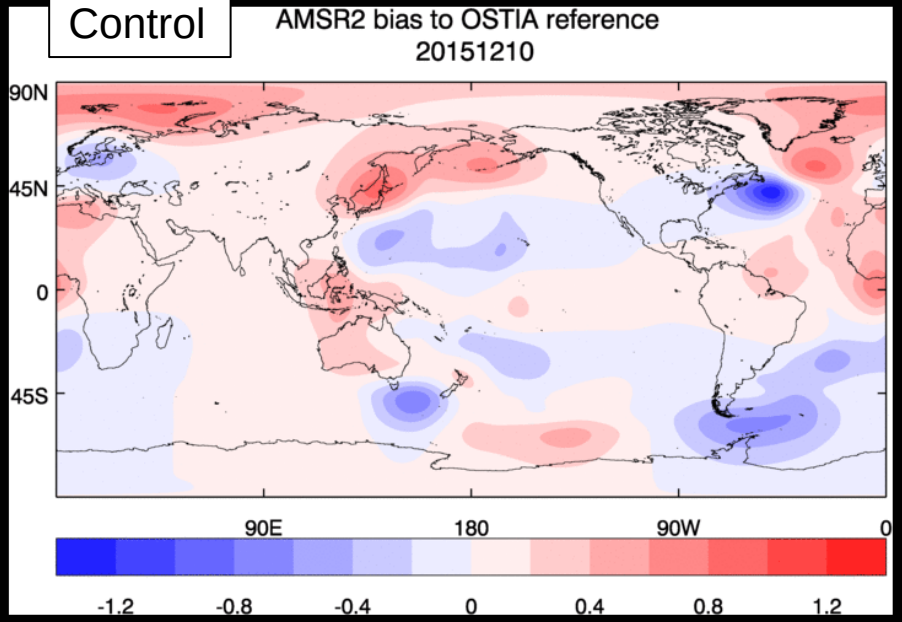
Region (CMEMS definitions)	Mean diff to Argo (K)		RMS diff to Argo (K)	
	control	VIIRSG_ref	control	VIIRSG_ref
Global	0.12	0.06	0.45	0.40
North Atlantic	0.22	0.05	0.48	0.42
Tropical Atlantic	0.17	0.11	0.28	0.24
South Atlantic	0.08	0.08	0.46	0.44
North Pacific	0.20	0.09	0.51	0.45
Tropical Pacific	0.08	0.07	0.26	0.22
South Pacific	0.03	0.07	0.32	0.30
Indian Ocean	0.03	0.09	0.29	0.28
Southern Ocean	0.07	0.04	0.45	0.42

Results

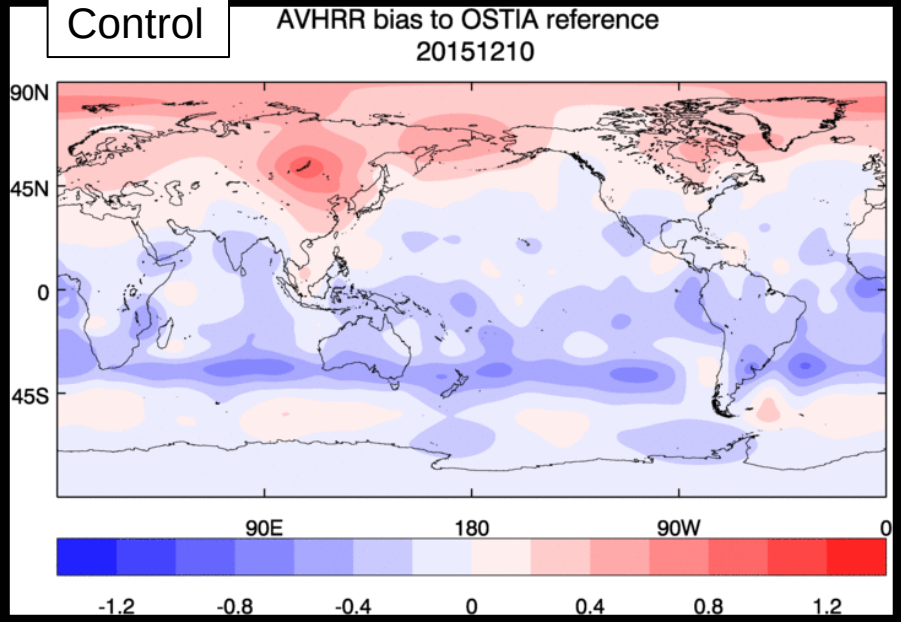
- Sizable improvement of 0.05 K global RMS difference to Argo using VIIRS as a reference
- Improvements in RMS consistent across all regions
- Similar results were seen for a second test period of 01 to 31 May 2016
- Improvements of mean difference to Argo in most ocean regions
  - Largest magnitude decrease of 0.16 K in North Atlantic
  - Smallest magnitude decrease of 0.01 K in Tropical Pacific
  - Detriments to mean difference seen in South Pacific (0.04 K) and Indian Ocean (0.06 K)

Next slide shows animations of daily bias fields: REMSS AMSR2 and NOAA -18 and -19 AVHRR minus the two reference datasets, control (MetOp-A AVHRR) and VIIRS. Observations have already been filtered to remove daytime measurements where wind speed < 6 m s^{-1}, and SSES biases have been removed.

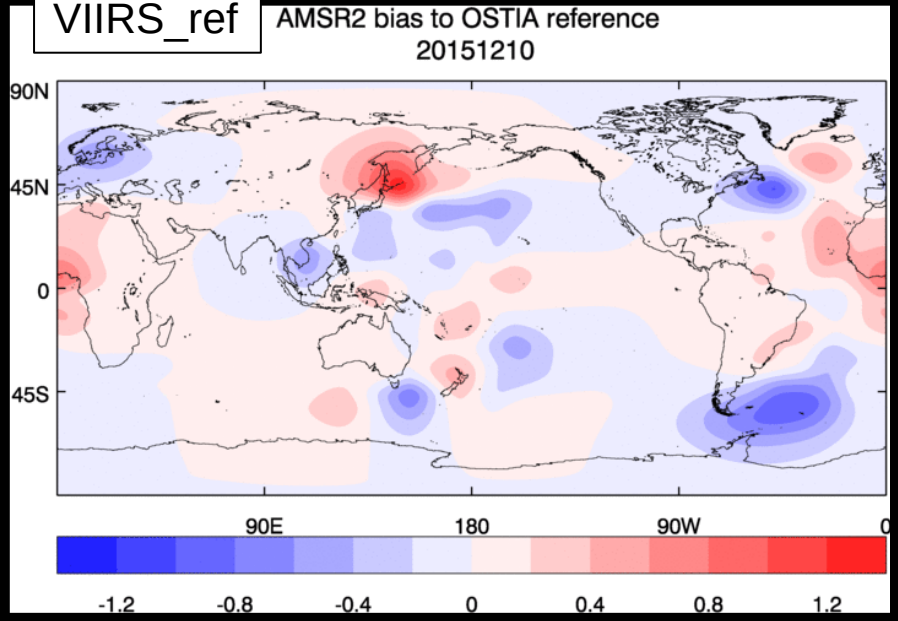
Control



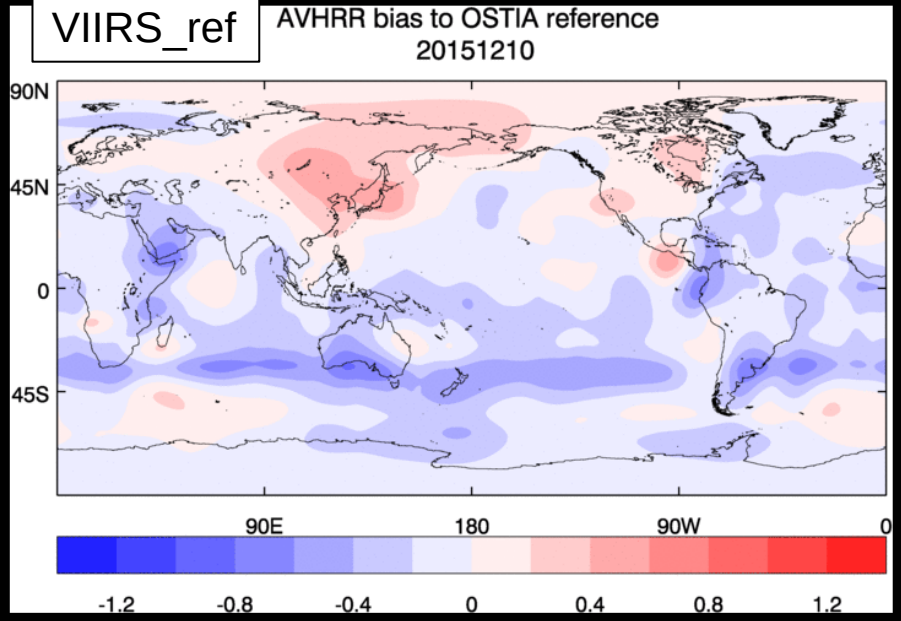
Control



VIIRS_ref



VIIRS_ref



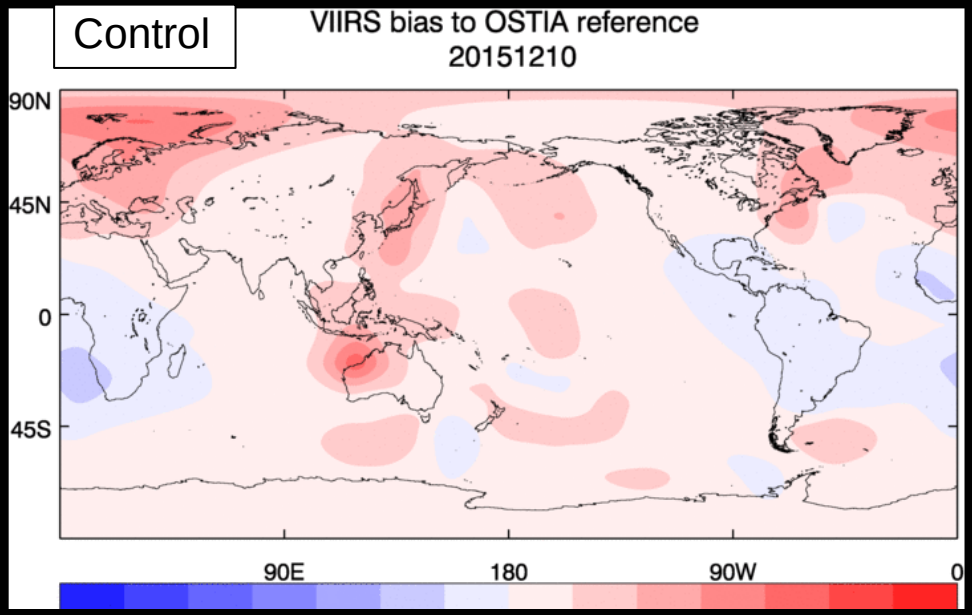
Results

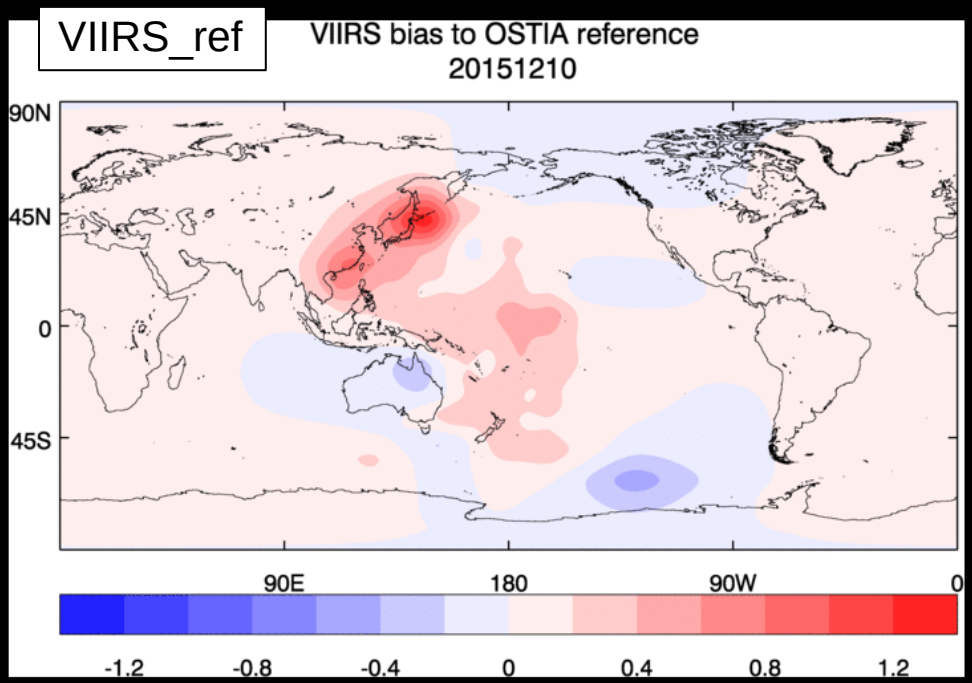
- The bias fields show the magnitude of the correction removed from the observations by the OSTIA system
- The run using VIIRS as a reference has eliminated the warm bias seen in the Arctic, so this “correction” is no longer being applied to the data
- The magnitude of the biases is generally smaller for the run using VIIRS as a reference, meaning the observations are in closer agreement with the reference data
- Note the unusual band of cold bias for combined NAVO AVHRR-18 and -19 along 30-40S compared to both reference datasets

Results

Control shows daily bias fields for all VIIRS compared to the MetOp-A AVHRR OSTIA reference dataset.

VIIRS_ref shows daily bias fields for daytime VIIRS compared to the nighttime VIIRS reference dataset. The large Arctic warm bias is gone, but a clear latitudinal pattern seen, though the magnitude is small.





Numerical Weather Prediction (NWP) Trial

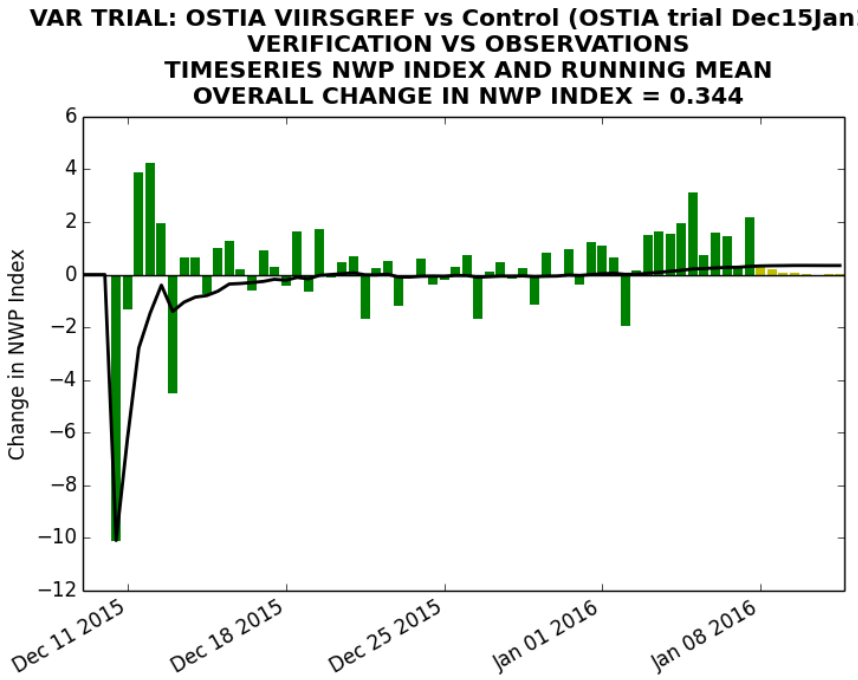
- OSTIA is used as the SST boundary in the Met Office's NWP system
- An NWP trial was run to compare the effect of changing the original OSTIA (control) to the latest version assimilating VIIRS and REMSS AMSR2 and using VIIRS as a reference dataset
- The Global NWP index is a weighted average of the improvement in RMS errors of model forecast fields compared to a persistence forecast
- A positive NWP index change indicates improvement in the experiment run compared to the control

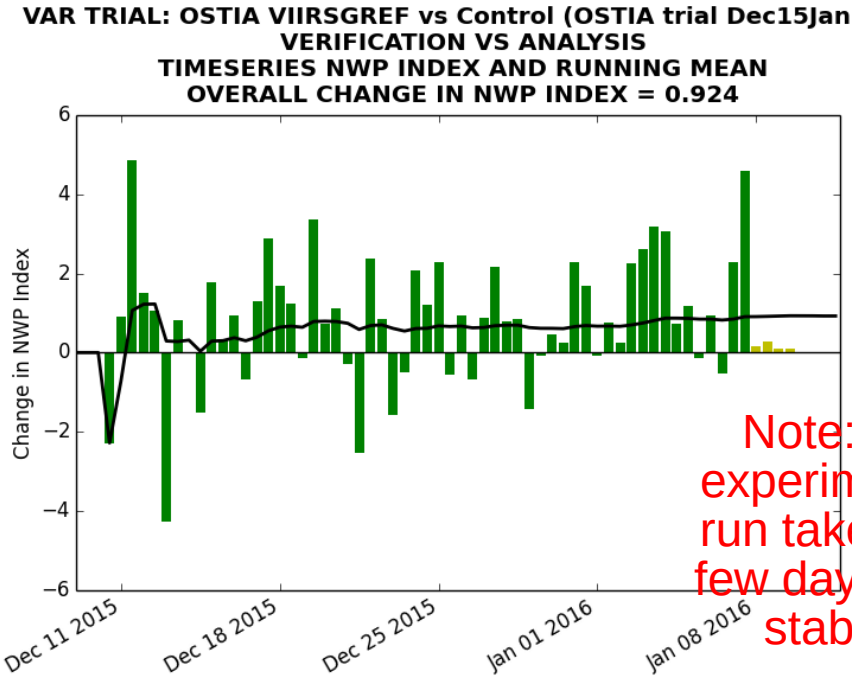
Numerical Weather Prediction (NWP) Trial

NWP Index	Compared to observations (VIIRSG_ref minus Control)	Compared to analyses (VIIRSG_ref minus Control)
Global NWP Index	0.334 (0.308%)	0.878 (0.661%)

✓ Global NWP index change is positive, so VIIRSG_ref run is better than control

✓ Figure in brackets is the improvement in RMS error





Note: the experiment run takes a few days to stabilise

Comparison to other SST analyses

Assimilating VIIRS (and REMSS AMSR2) substantially improves the accuracy of the OSTIA analysis compared to other L4 SST analyses.

The effect of using VIIRS as a reference dataset for OSTIA instead of MetOp-A AVHRR continues this improvement.

Analysis Name	Global standard deviation of diff to independent Argo (K)
OSTIA +VIIRS, AMSR2, and VIIRS bias correction	0.40
CMC	0.42
GMPE Median	0.43
OSTIA +VIIRS, AMSR2	0.44
FNMOC	0.48
K10_SST	0.52
OSTIA (original)	0.53
RSS mw	0.53
GAMSSA	0.54
MGDSST	0.57
Reynolds	0.59
RTG	0.69
RSS mw_ir	0.82

Statistics for 9 December 2015 to 11 January 2016, from the GMPE (GHRSST Multi-Product Ensemble) system

Summary

- Assimilation of ACSPO VIIRS L3U into OSTIA produces good results. This was included operationally on 15 March 2016.
- Using nighttime VIIRS as a reference dataset instead of MetOp-A AVHRR produces even better results.
  - Improvement to NWP
  - OSTIA at top of GMPE comparison table for Argo validation (for particular time period shown, this can fluctuate)

The update to use VIIRS as a reference in the OSTIA system instead of MetOp-A AVHRR is now running in a test mode alongside the operational system. This should go live on or after 20 September 2016.

Thanks for producing such a good product!

Met Office

Questions?

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