Multiscale Data Assimilation in Bluelink Reanalysis

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Multiscale DA Overview

- BRAN runs simulate the state of the global ocean at 0.1-degree resolution over the past decades.
- There is significant improvement in the fit of simulated ocean to observations using 2-stage, multiscale data assimilation process.
- Calculating corrections at coarse resolution is effective at reducing biases in the subsurface.
- Mean absolute errors in subsurface temperature are reduced by up to 30% and 20% for analysis and forecast (3-day) fields respectively.

"And now Edgar's gone . . . Something's going on around here."

Introduction

- Bluelink Project, a partnership since 2001 between CSIRO, BoM, and RAN; supporting development of operational ocean forecasting services for Australia.
- OFAM3 platform, near-global 0.1 deg resolution ocean model (Oke et al., GMD, 2013).
- Bluelink Reanalysis (BRAN) experiments, simulate the mesoscale ocean state over the past decades, assimilating SST, sea level, and subsurface T+S profiles; e.g. Oke et al. Ocean Modelling 2018. (~ OceanMAPS from BoM.)

- Output from OFAM spinups and reanalyses publicly available on NCI data catalogue.

Objective of this work

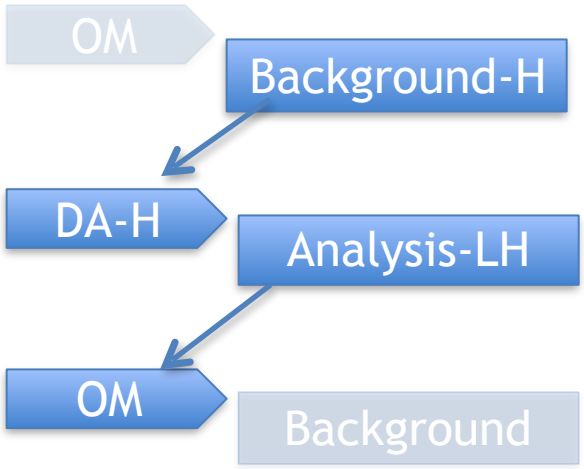
- Noted that large features (> mesoscale) in thermocline not being corrected for efficiently in current data assimilation system.
- Scope to improve the fit of simulated ocean state to observations. Could consider treatment of observational errors or spread of ensemble.
  Here, we take advantage of experience working at multiple resolutions.

Standard BRAN process

Cycle sequence

1. Background from previous ocean model cycle.
2. DA calculation of forecast and analysis (DA-H) and obtain new initial condition.
7. Run ocean model, generate initial background for next cycle.

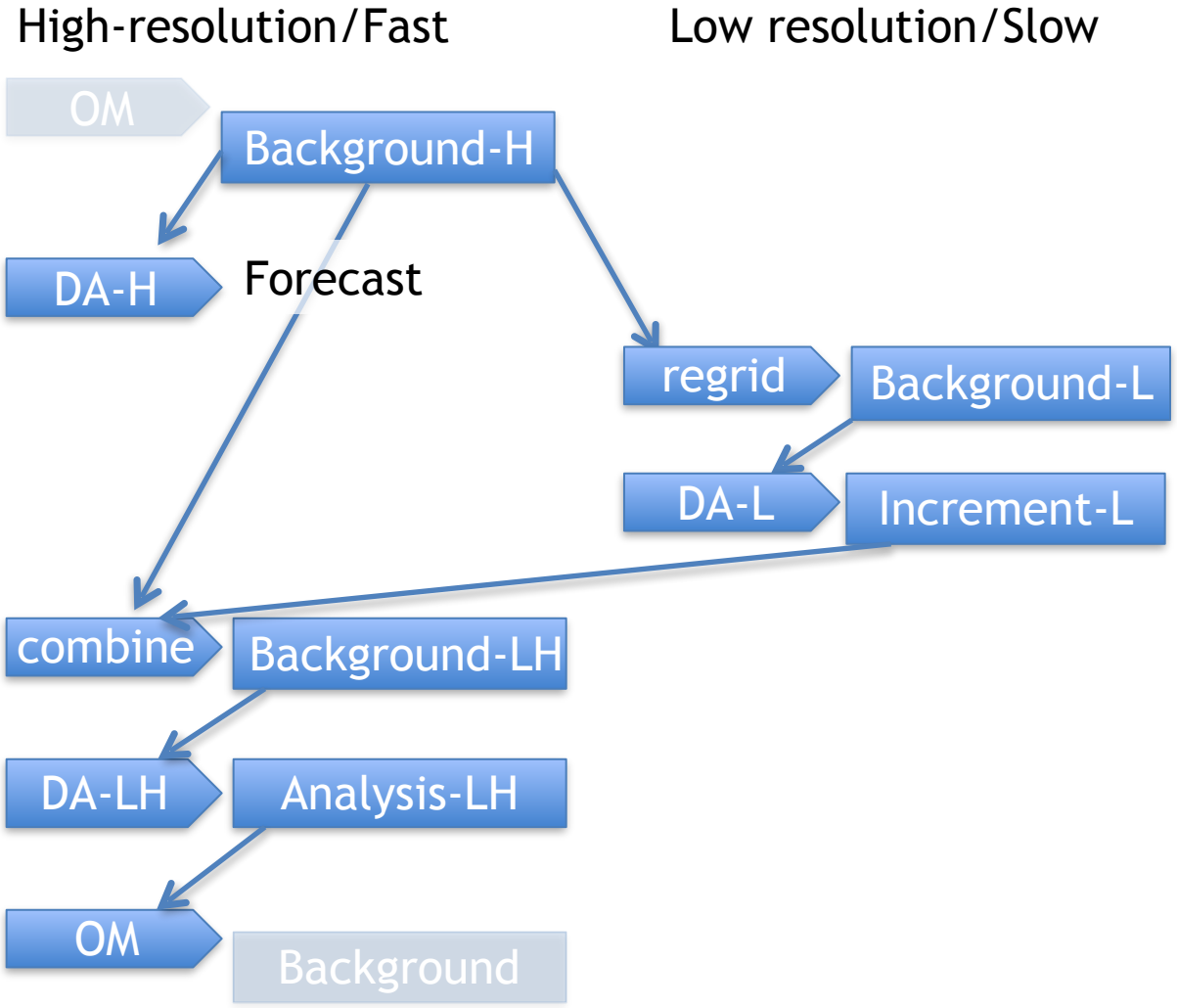
High-resolution/Fast



Multiscale DA schematic

Cycle sequence

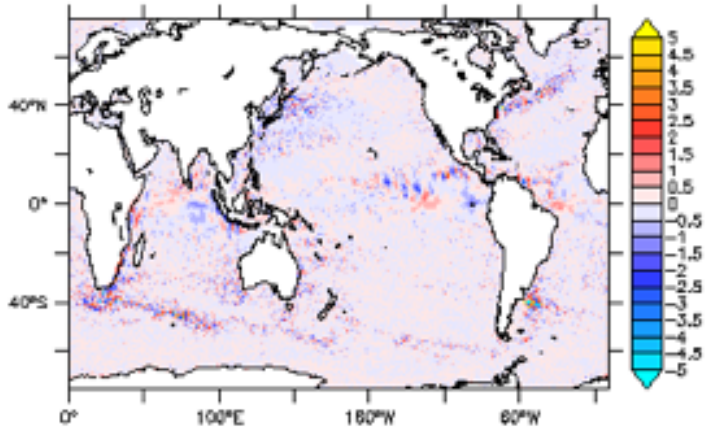
1. Background from previous ocean model cycle.
2. DA calculation of forecast statistics (DA-H)
3. Average background onto coarse grid.
4. DA calculation at low resolution (DA-L) for coarse increment.
5. Interpolate increment and add to original background.
6. DA calculation at high resolution (DA-LH) for analysis and new initial condition.
7. Run ocean model, generate initial background for next cycle.



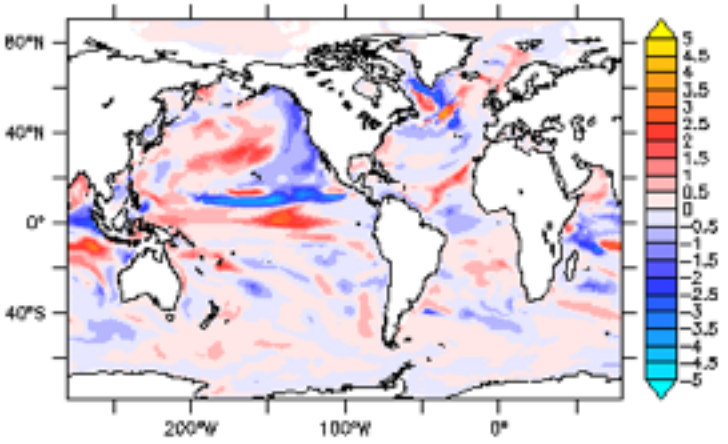
BRAN Multiscale DA - Ensembles

- BRAN ensemble “3-day minus 3-month average”; captures eddies and mesoscale variability.

- ACCESS 1-deg ensemble of 480 monthly anomalies (wrt. climatology of detrended time series) from 40-years of ocean-ice model with historical forcing (JRA-55); captures broad 1000-km scale variability.



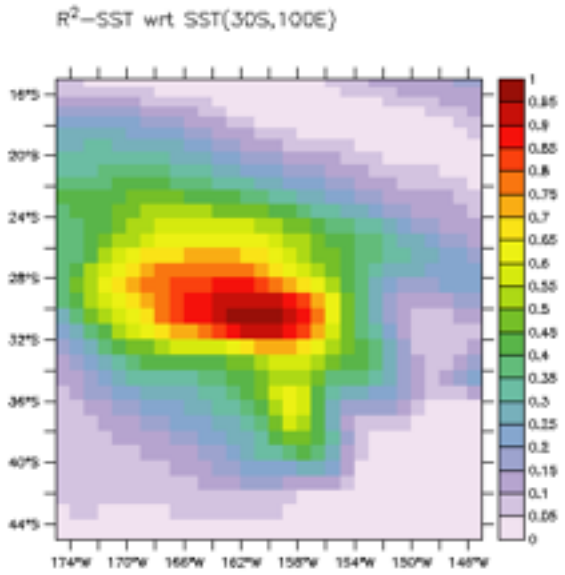
OFAM temp ens. member– 100m

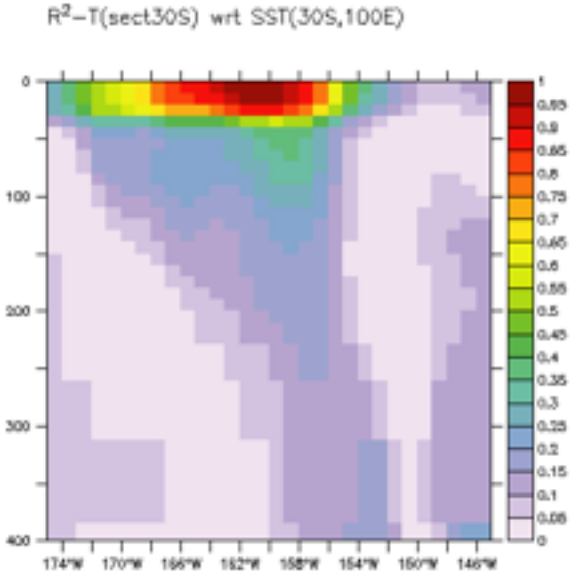


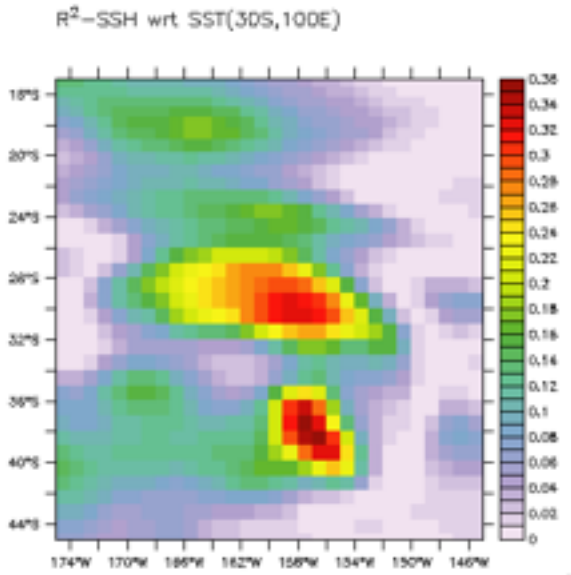
ACCESS 1–deg temp ens. member– 100m

BRAN Multiscale DA - ensemble correlation

1-deg







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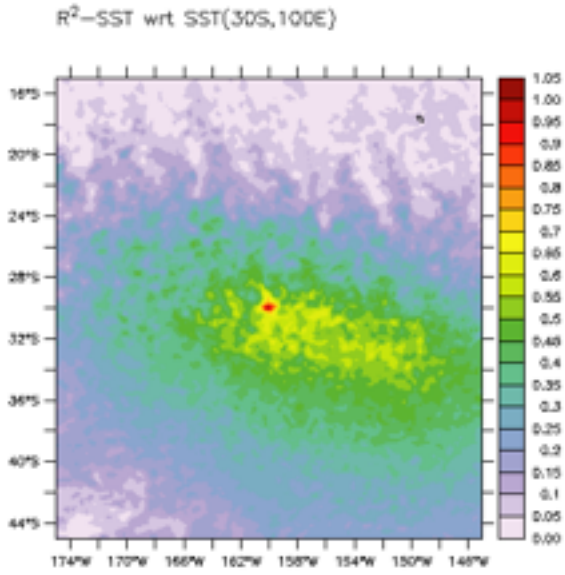
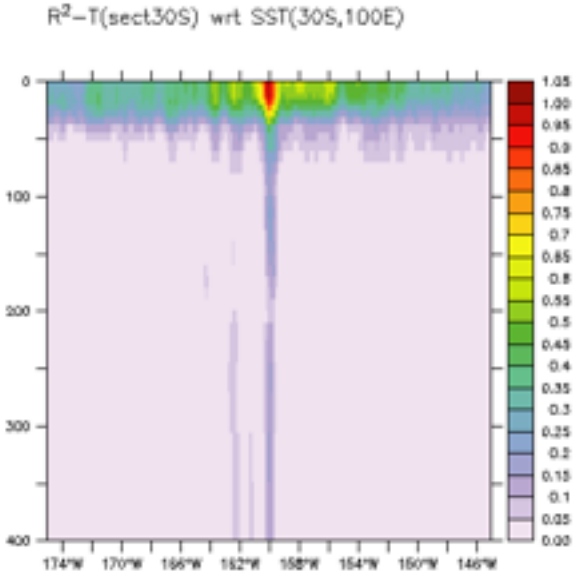
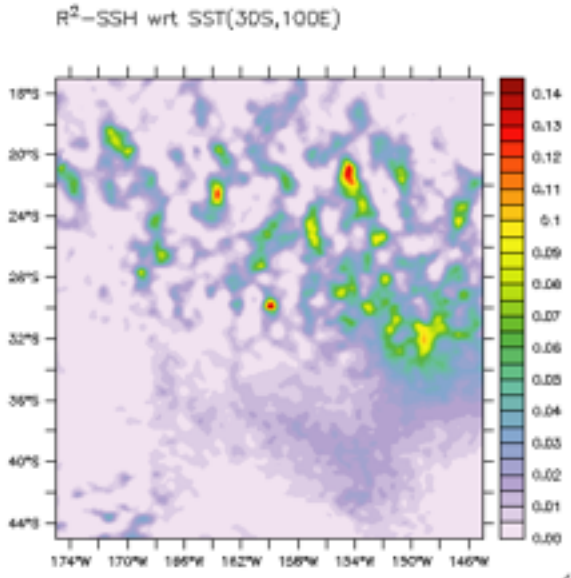
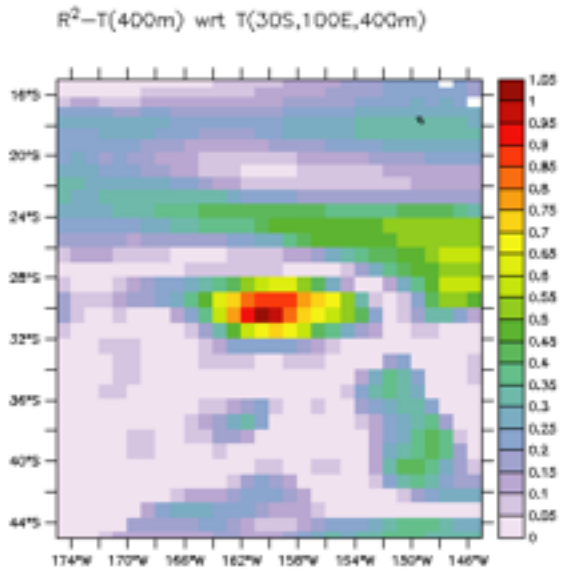


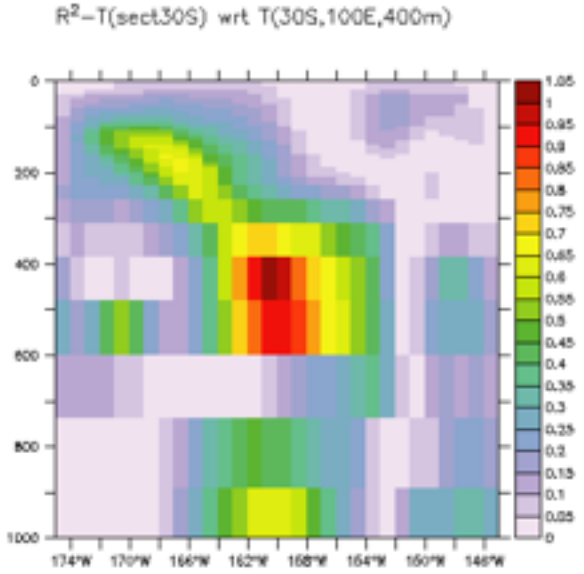


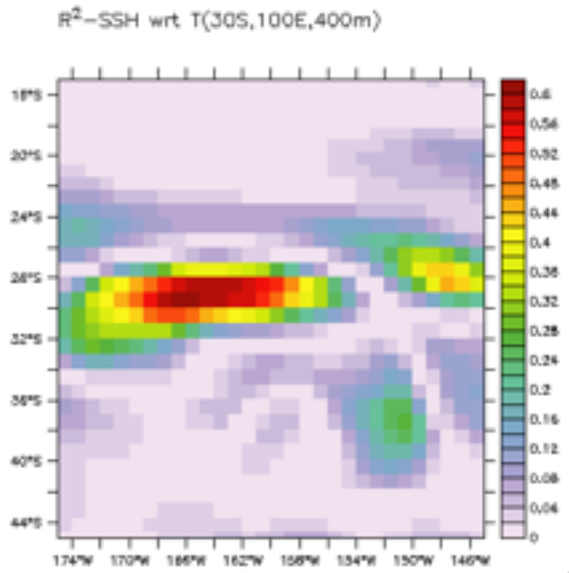


BRAN Multiscale DA - ensemble correlation

1-deg







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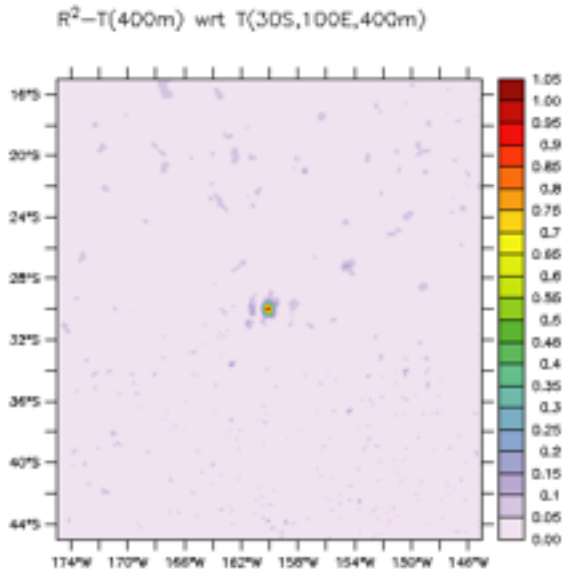
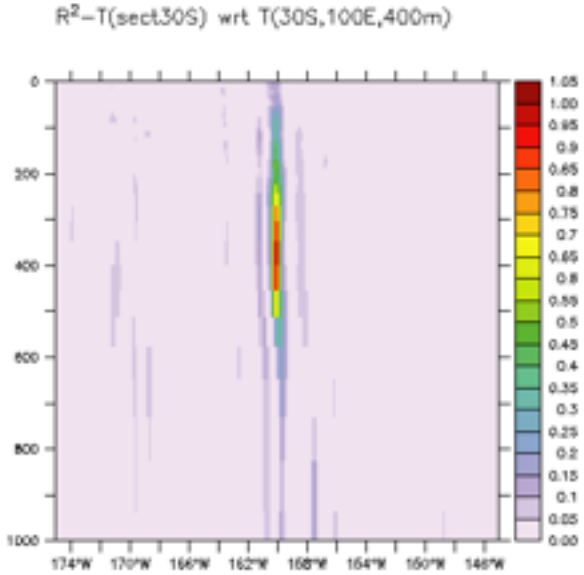
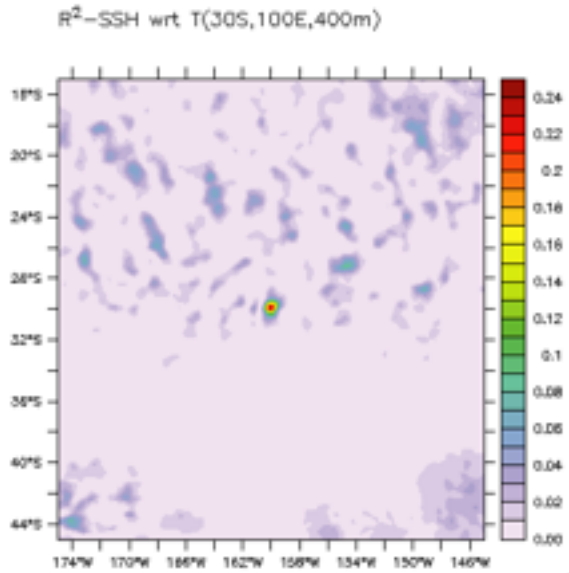
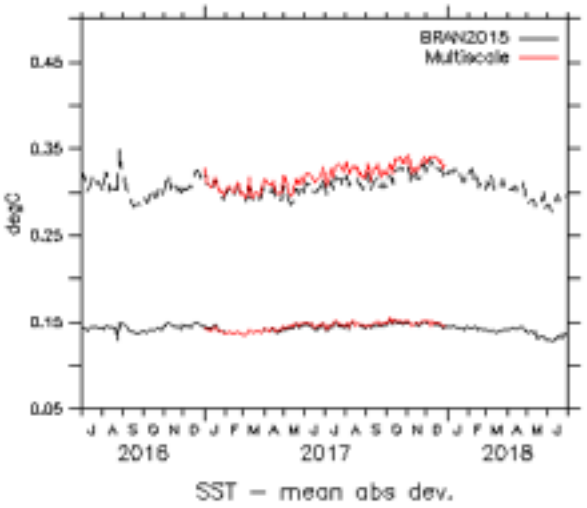


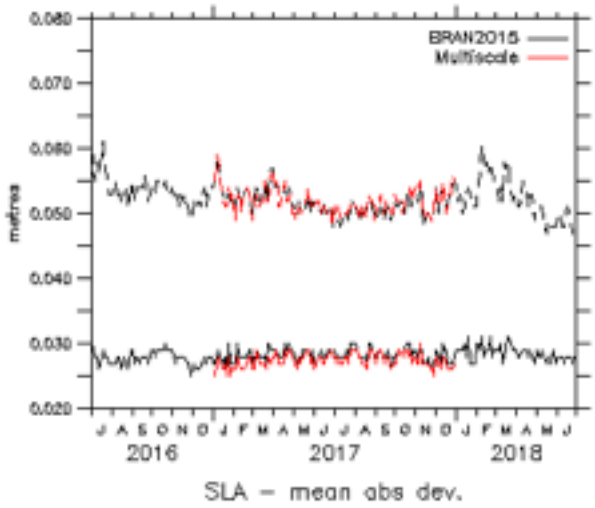




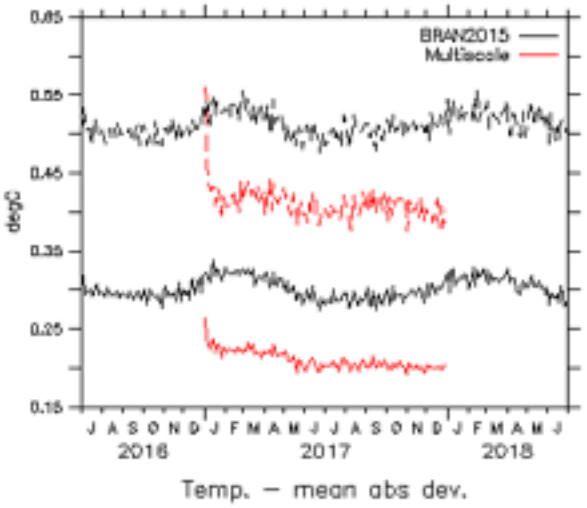
Global Mean Absolute Deviations - forecast and analysis



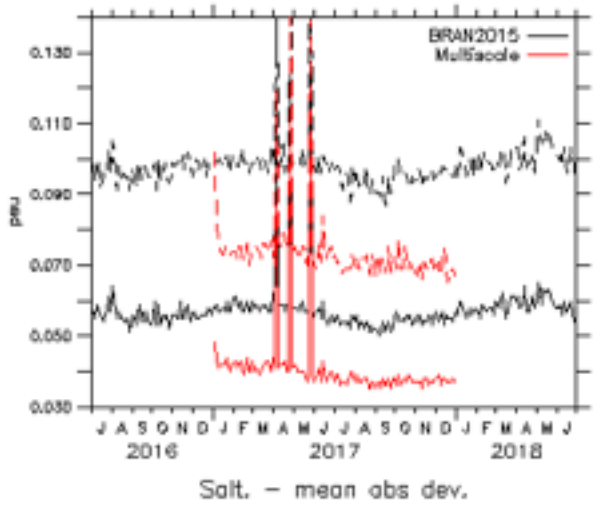
SST – mean abs dev.



SLA – mean abs dev.



Temp. – mean abs dev.



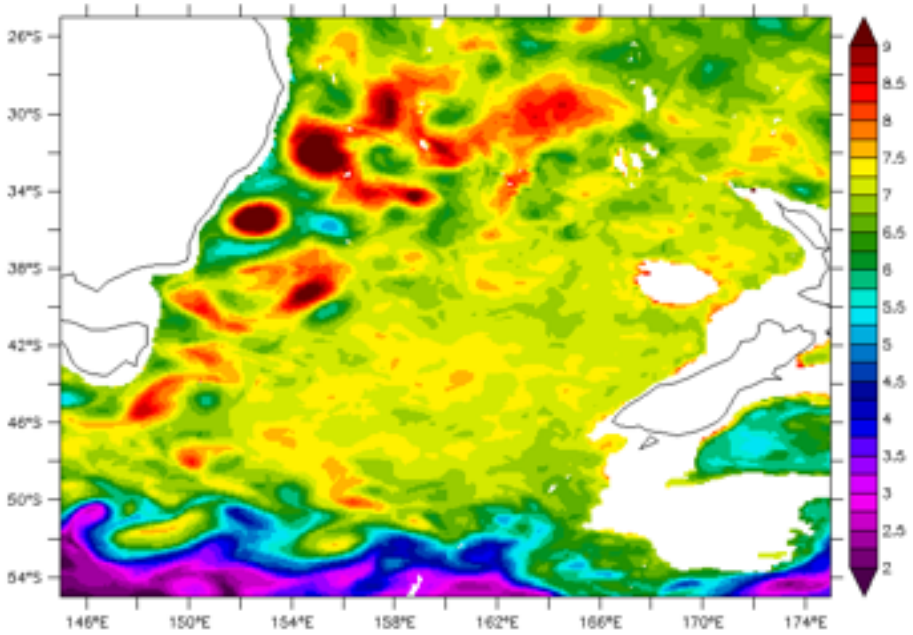
Salt. – mean abs dev.

Global Mean Absolute Deviations - forecast and analysis

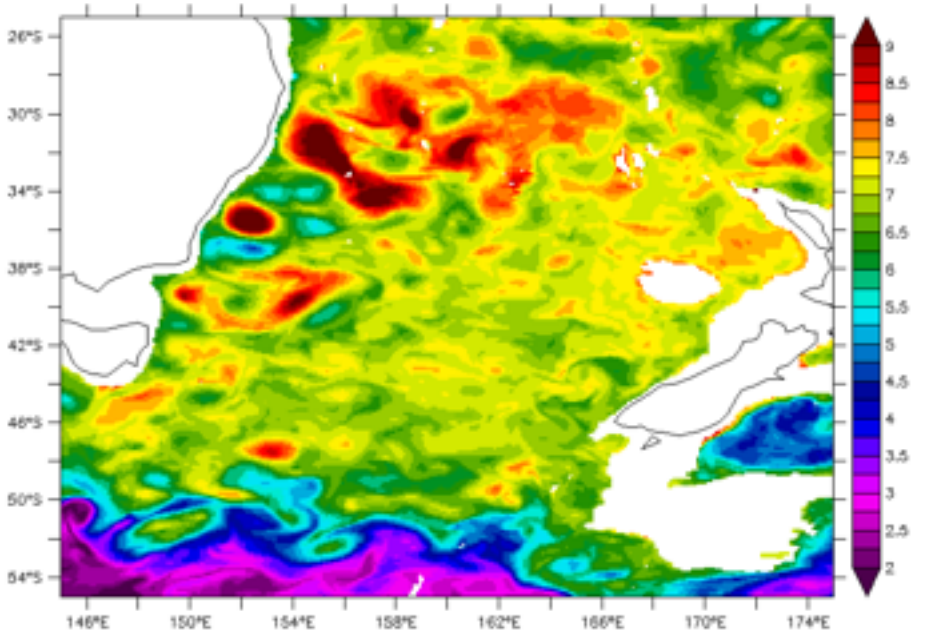
	BRAN2015		Multi scale	
	Forecast	Analysis	Forecast	Analysis
SST (C)	0.323	0.148	0.333	0.149
Sea height (cm)	5.16	2.82	5.22	2.74
Subsurface temperature (C)	0.510	0.297	0.402	0.201
Subsurface salinity (psu)	0.0958	0.0549	0.0698	0.0373

Improvements to ocean state

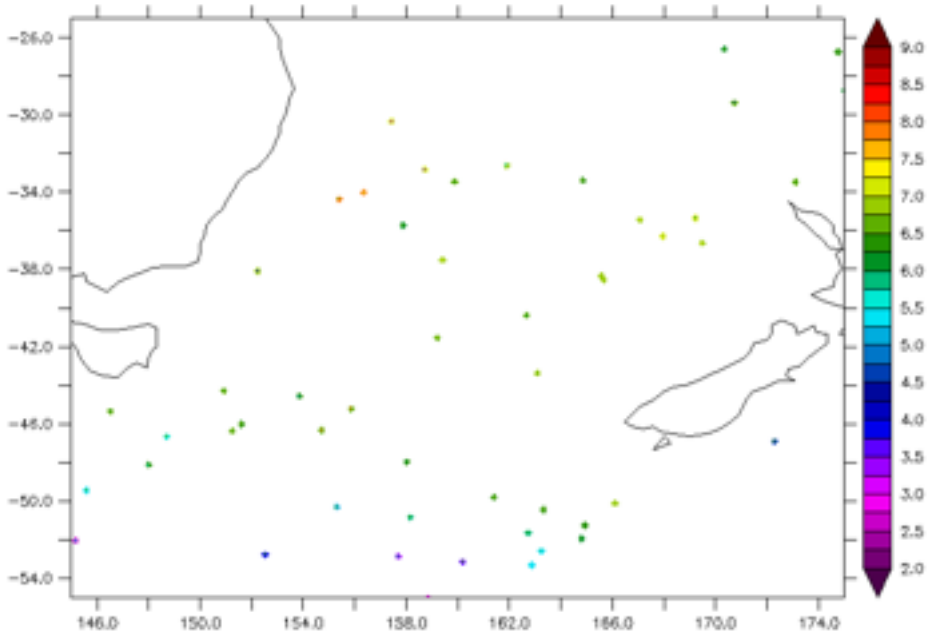
- Compare the simulated temperatures at depth (800m) from BRAN2015 and new multiscale DA experiment with temperature observations at same depth for the next day.
- Most improvement in areas away from eddy fields; improvement along fronts of Southern Ocean.

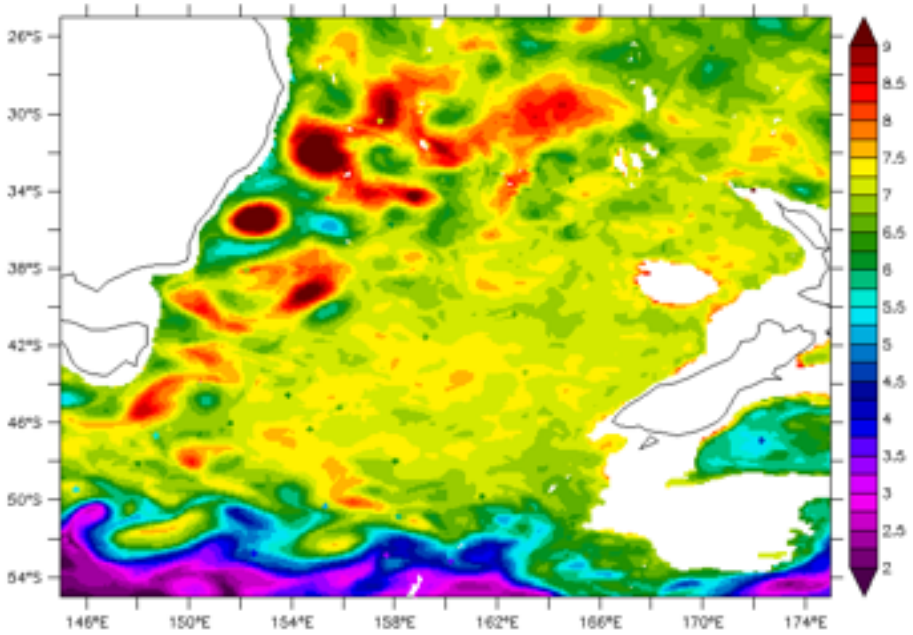


Temp(800m), BRAN2015

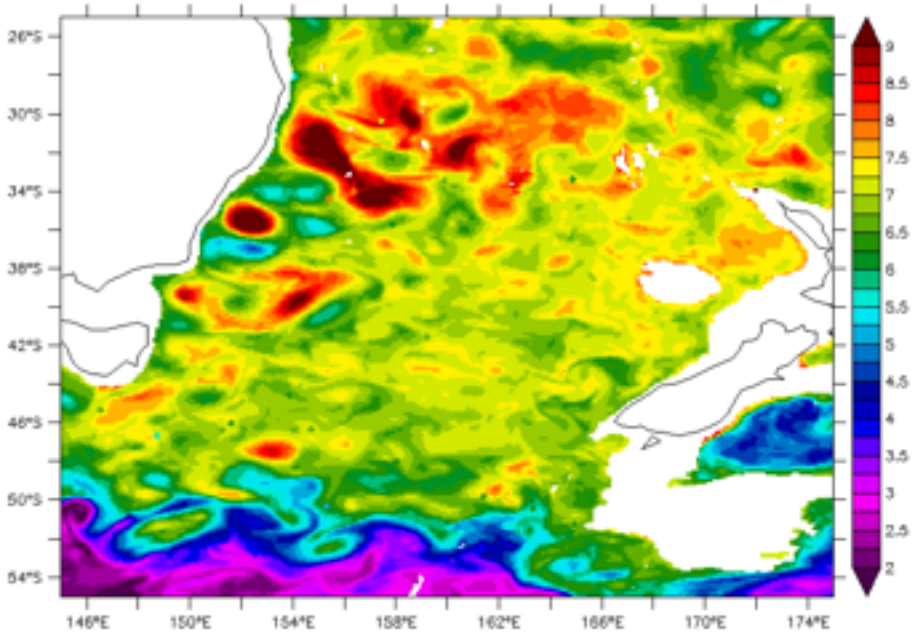


Temp(800m), multiscale

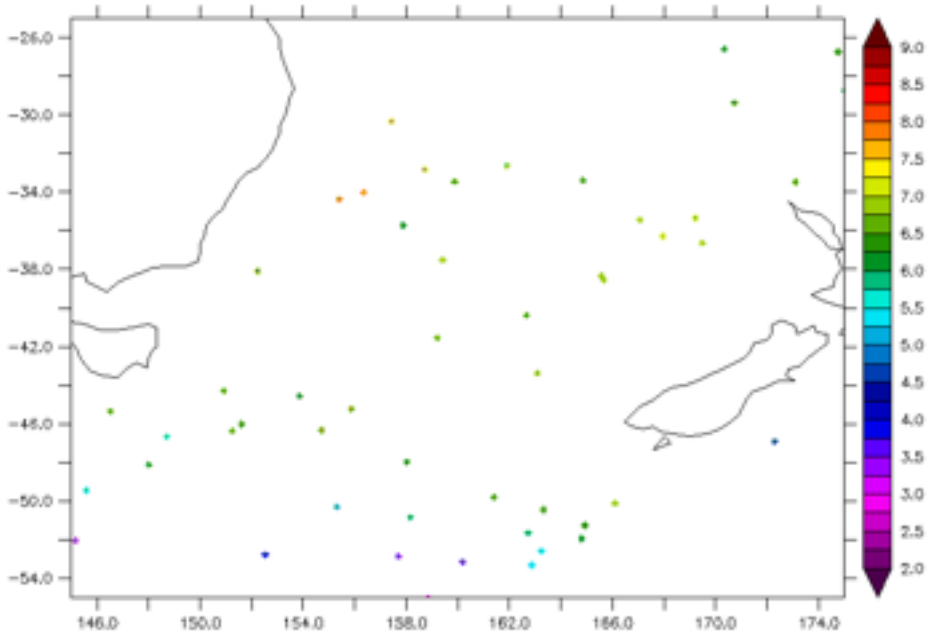




Temp(800m), BRAN2015, obs.



Temp(800m), multiscale, obs.



Discussion

- Improvements found in ocean state at depth; surface fields (SST, SLA) are already well observed/ constrained.
- Ideally, DA system would only have to correct for dynamics. In reality, it also corrects for model biases.
- Broader footprints of correlation in the coarse ensemble make the multiscale system more efficient at correcting for these biases.
- DA system is robust and able to use ensembles from different model platforms. It is advantageous to run a coarse model for longer control experiments and ‘cleaner’ climatological anomalies.

Summary

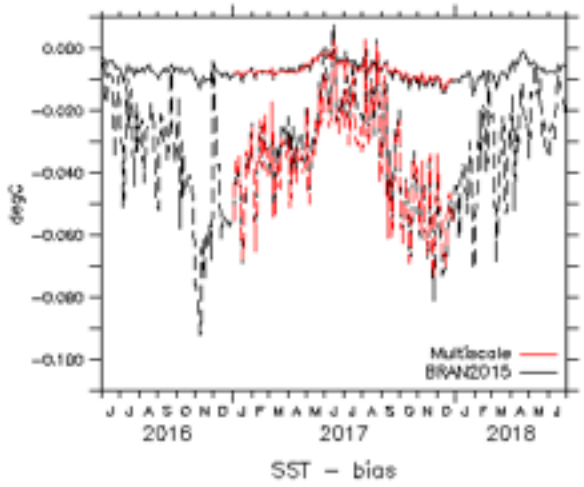
- There is significant improvement in BRAN simulations using 2-stage/ multiscale data assimilation process.
- Calculating corrections at coarse resolution is effective at reducing biases in the subsurface where observations are sparse.
- Mean absolute errors in subsurface temperature are reduced by up to 30% and 20% for analysis and forecast (3-day) fields respectively.

- Apply to future BRAN/OceanMAPS runs.
- OM2-0p1 => OFAM4

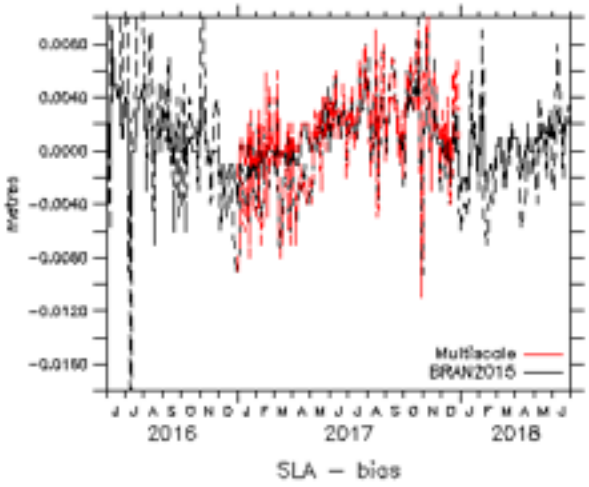
"Thanks for being my friend, Wayne."

- Done!

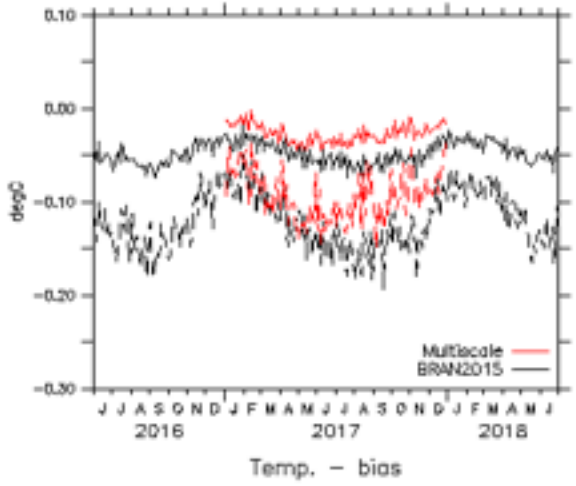
aug19a - global biases



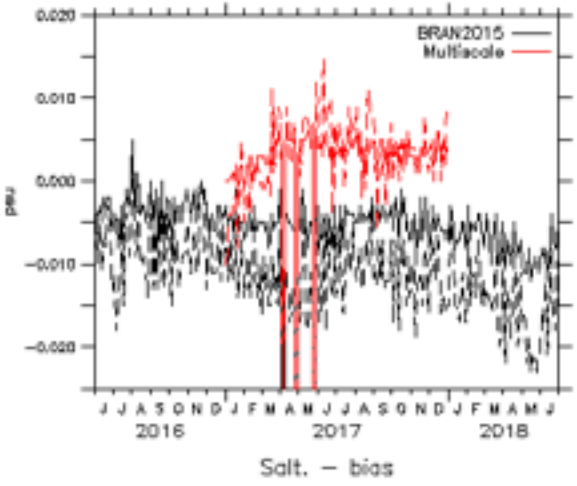
SST – bias



SLA – bias



Temp. – bias

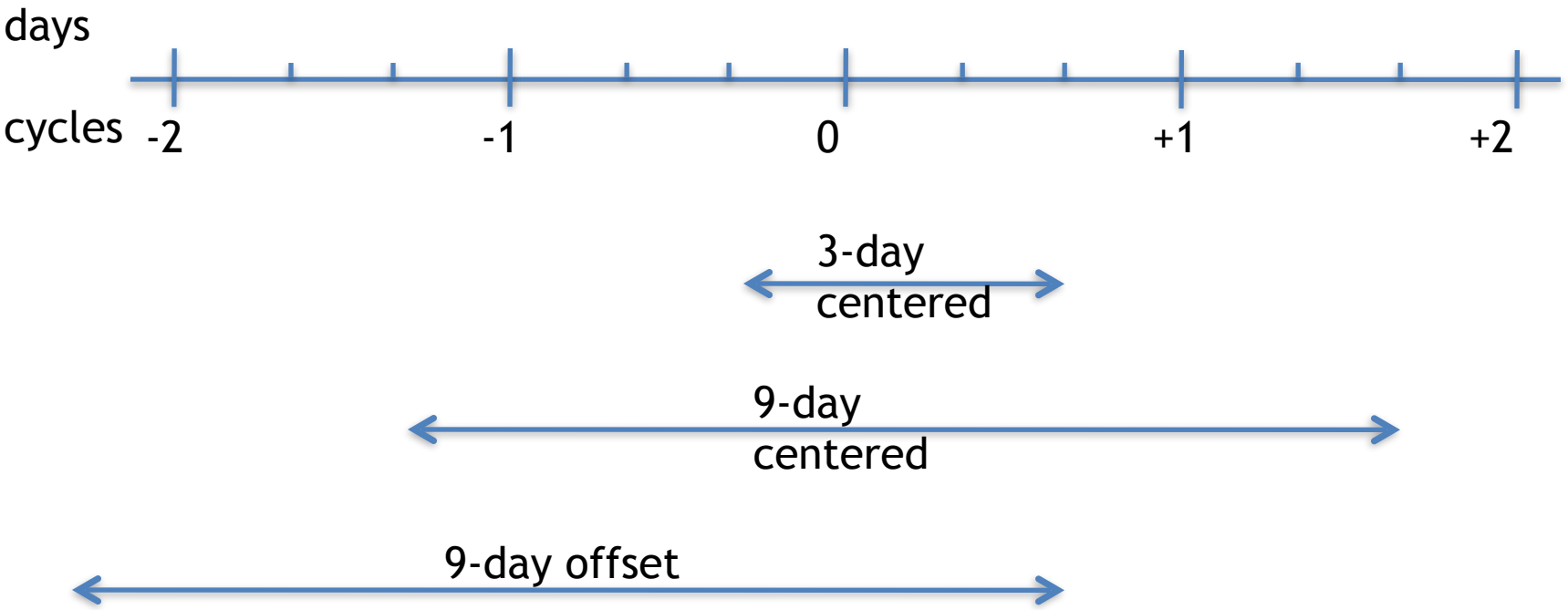


Salt. – bias

Global Mean Absolute Biases - forecast and analysis

	BRAN2015		Multi scale	
	Forecast	Analysis	Forecast	Analysis
SST (C)	-0.055	-0.011	-0.053	-0.010
Sea height (cm)	+0.18	+0.14	+0.30	+0.19
Subsurface temperature (C)	-0.125	-0.048	-0.084	-0.022
Subsurface salinity (psu)	-0.0118	-0.0053	+0.0032	+0.0037

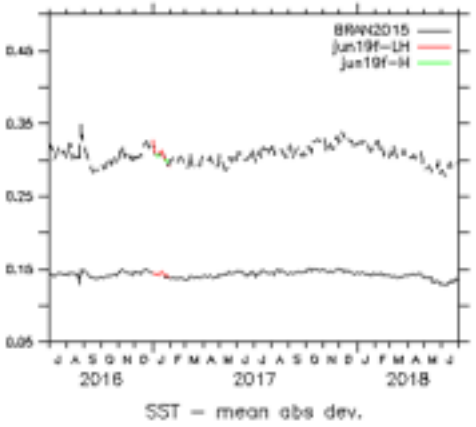
DA Cycles and Observation Windows



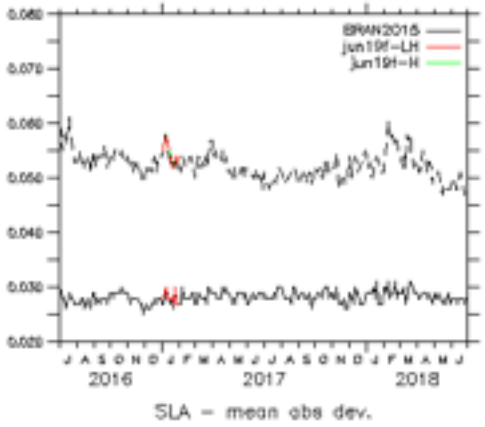
Offset such that no observations overlap with the forecast statistics (with 3-day window) in next cycle.

9-day Argo obs window, BRAN

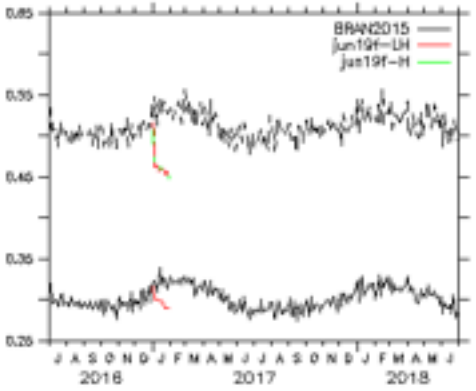
- Short test to investigate, “is the improvement just because of 9-day window?”
- Better TEM and SAL forecasts, but only marginal improvement in analyses -> need the larger correlation fields of DA-L (i.e. multiscale) for full benefit.



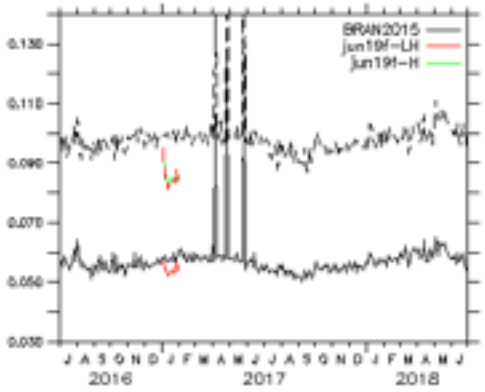
SST – mean abs dev.



SLA – mean abs dev.

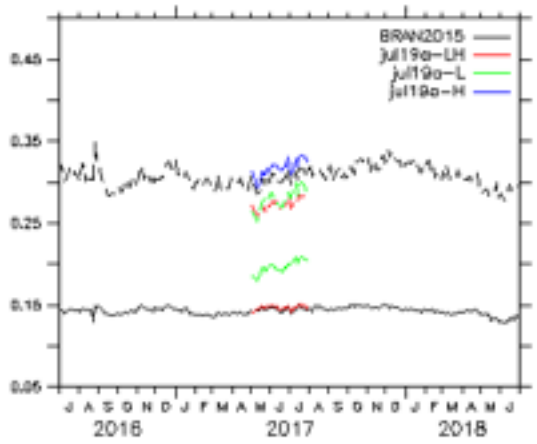


Temp. – mean abs dev.

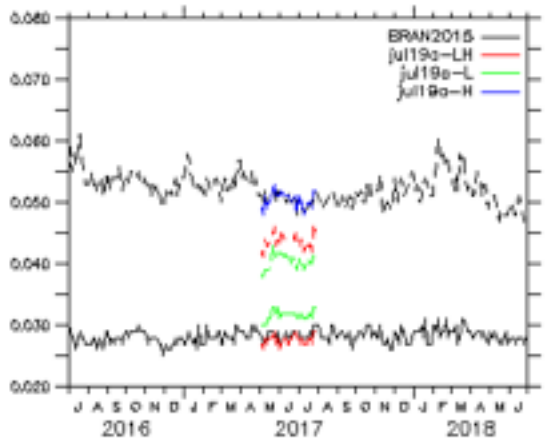


Salt. – mean abs dev.

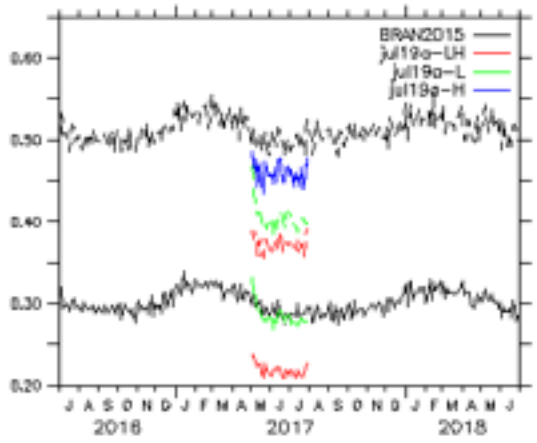
9-day-offset window, 3-day cycle for DA-L



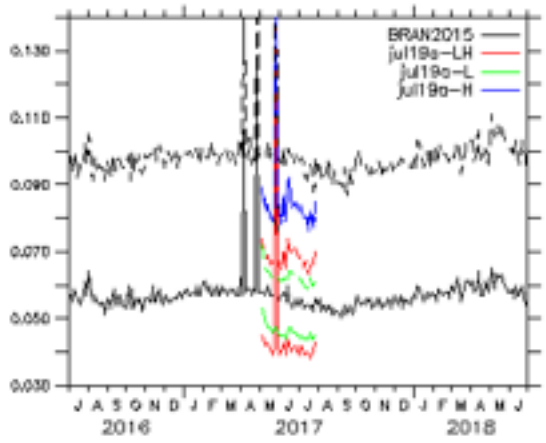
SST – mean abs dev.



SLA – mean abs dev.



Temp. – mean abs dev.



Salt. – mean abs dev.