Implementation of a variational data assimilation system in the Met Office's ¼ degree global ocean model

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Introduction

An incremental 3DVAR FGAT (first guess at appropriate time) data assimilation scheme, NEMOVAR, has recently been implemented in the Met Office's operational 1/4 degree global ocean model, FOAM. NEMOVAR (Mogensen et al. 2012) is a multivariate data assimilation scheme where balances are specified through a balance operator. It also uses a diffusion operator (Mirouze and Weaver 2010) to model the background error correlations. The state vector in NEMOVAR consists of temperature (T), salinity (S), sea surface height (SSH), sea-ice concentration (C) and velocities (u,v).

We outline the Met Office's developments to the error covariance specification for NEMOVAR at the global configuration.

We validate the NEMOVAR systems performance against results from FOAM using the preceding Analysis Correction (AC) data assimilation scheme.

FOAM Model set-up

The FOAM system used in this study is described in detail in Blockley et al. (2013) and consists of the hydrodynamic model **NEMO**, the coupled sea ice model **CICE**, a data assimilation system (**NEMOVAR** or **AC**), a flux processing step (**BULK** formula fluxes), observation quality control, and a SST observation bias correction step

We have run 2 **re-analyses** with FOAM which cover the period from **December 2010 to November 2011**. The 2 versions of FOAM were identical apart from their data assimilation component; **FOAM-NEMOVAR** used NEMOVAR while **FOAM-AC** used the analysis correction method.

Both the FOAM experiments assimilated the following observations:

- Level 2 **satellite SST** data from AVHRR, AATSR and AMSRE.
- ***In-situ* SST** data from ships, moored and drifting buoys.
- Along-track altimeter sea level anomaly (**SLA**) data from Jason-1, Jason-2 and Envisat satellites
- *In-situ* temperature and salinity **profile data** from the EN3 data-set.
- Level 3 **sea-ice concentration** data from SSM/I satellites.

Summary of the Error Covariance specification in FOAM-NEMOVAR and FOAM-AC

	FOAM-NEMOVAR	FOAM-AC
Background error standard deviations	T and unbalanced S use a combination of statistical FOAM background error standard deviations and a vertical parameterisation. Sea ice concentration and unbalanced SSH use the statistical FOAM background error standard deviations.	Using the statistical FOAM background error standard deviations
Horizontal background error correlation length scales	T, unbalanced S and sea ice concentration: Rossby radius dependent scale (Figure 1). Unbalanced SSH - 400km (synoptic scale)	2 length scales: 400km (synoptic scale), 40km (mesoscale)
Vertical background error correlation length scales	T, S and SST: parameterised mixed layer dependent vertical length-scales	T and S : 2 length-scales (100m & 200m) SST: apply increments to the base of the mixed layer
Observation error standard deviations	Using the statistical FOAM observation error standard deviations	Using the statistical FOAM observation error standard deviations

Statistical FOAM error standard deviations – Calculated using the NMC method on 2 years worth of 24 and 48 hour model fields. Rescaled using errors calculated from the Hollingsworth and Lonnberg method (1986).

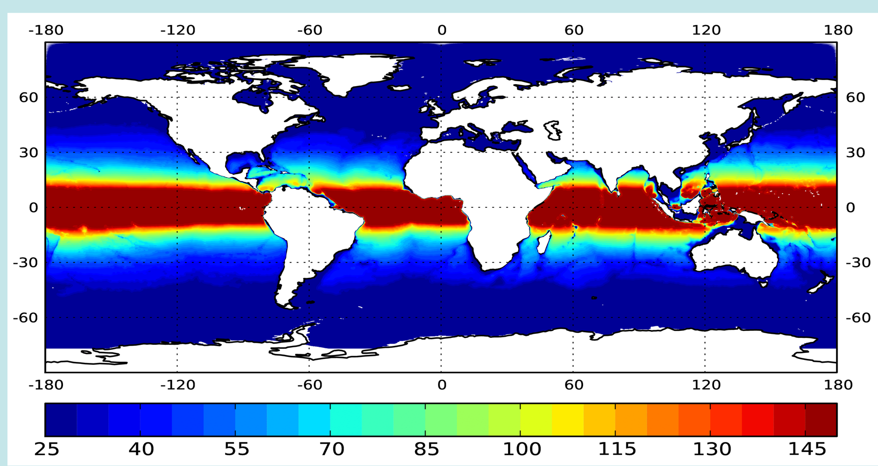

Figure 1: Rossby radius dependent length scales.

NEMOVAR vertical correlation length scales

A parameterisation is used which produces shorter length scales in the highly stratified region of the thermocline and longer length scales in the less stratified regions of the mixed layer and deep ocean (see Figure 2).

The parameterisation depends on the **mixed layer depth** of the background field and is therefore **flow dependent**.

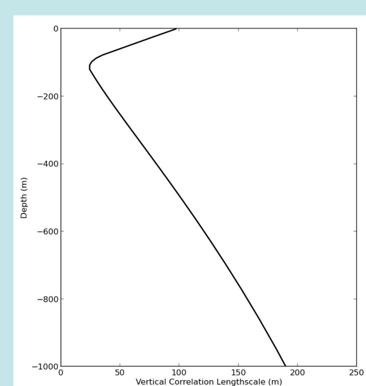

Figure 2: Vertical length scales for a mixed layer depth of 97m.

Errors in the normalisation look-up table at a number of sample locations

Location	Depth	Error in look up table
170W 0N	0m	2%
170W 30N	0m	4%
170W 30S	0m	2%
25W 0N	97m	1%
25W 30N	97m	4%
25W 30S	97m	2%
14W 52N	0m	5%

Using Flow dependent vertical correlation length scales requires that the normalisation factors, which are used to normalise the correlations from the diffusion operator, are calculated at each analysis step. This can be very expensive and therefore we have implemented a **normalisation look-up table method**.

Re-analysis Results

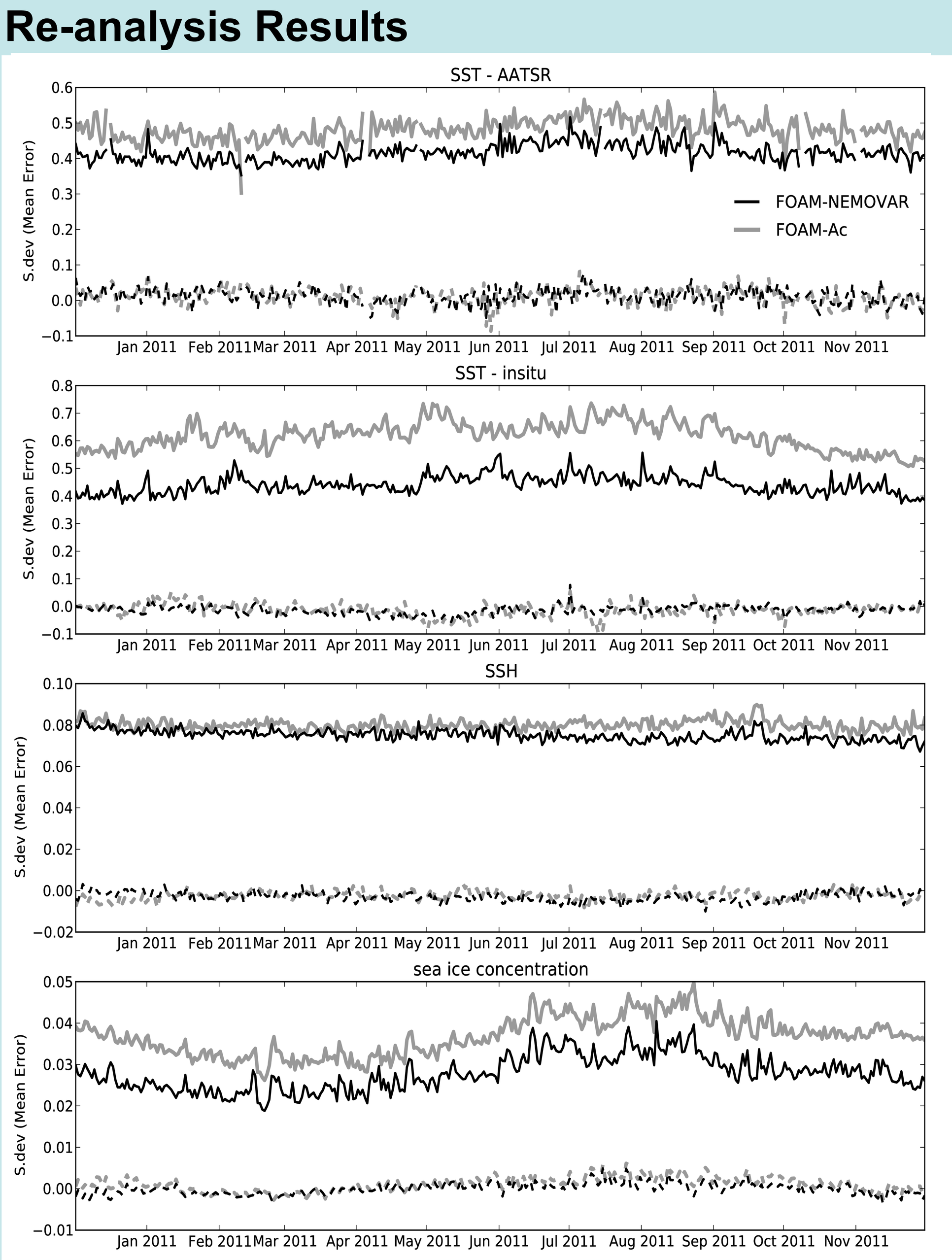

Figure 3: Global innovation statistics for surface variables. Solid line is the standard deviation, dashed line is the mean.

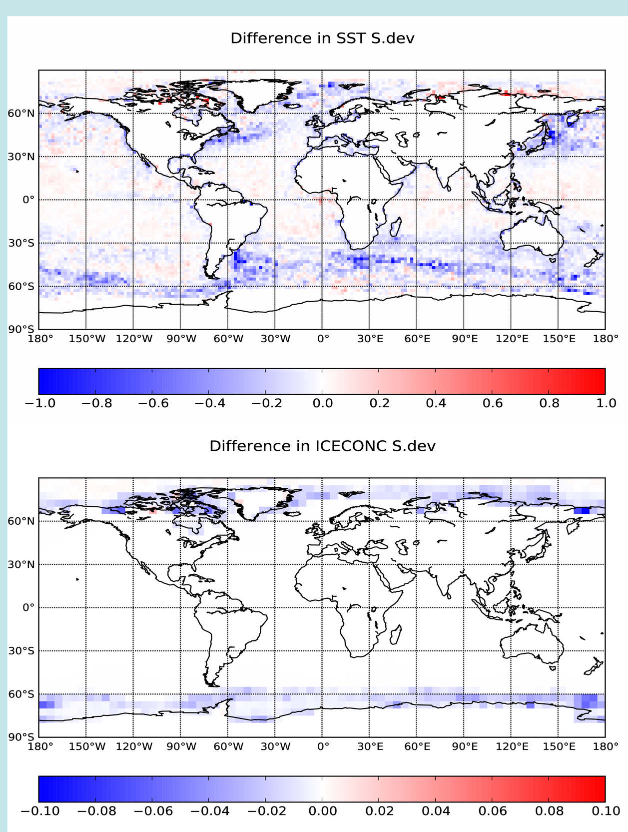

Figure 4: Binned innovation standard deviation from FOAM-NEMOVAR minus binned innovation standard deviation from FOAM-AC for June-July-August. Blue areas show regions where FOAM-NEMOVAR produces improved results.

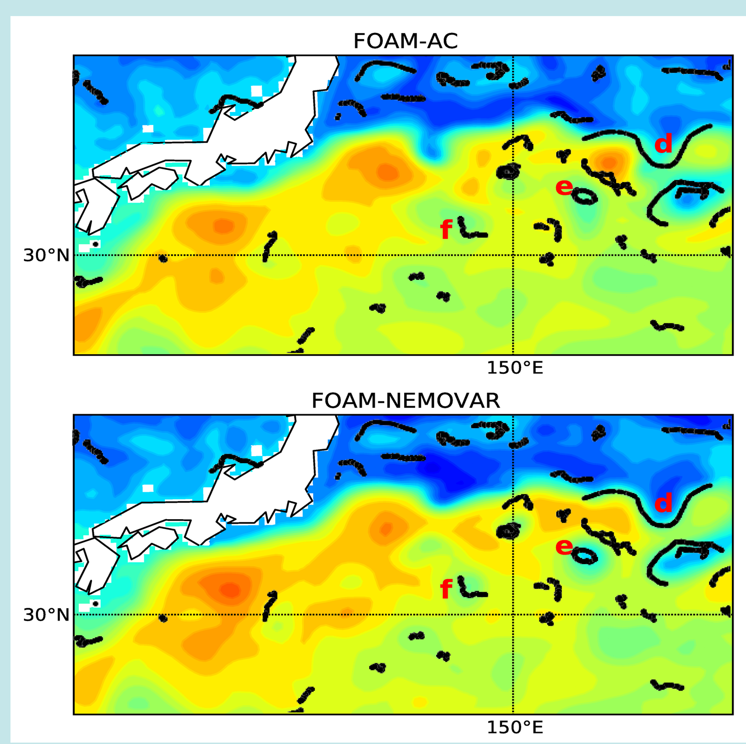

Figure 5: Model SSH fields in the Kuroshio region on 22/11/2011. Drifter positions for 19/11/2011 – 25/11/2011 are plotted over the SSH field in black.

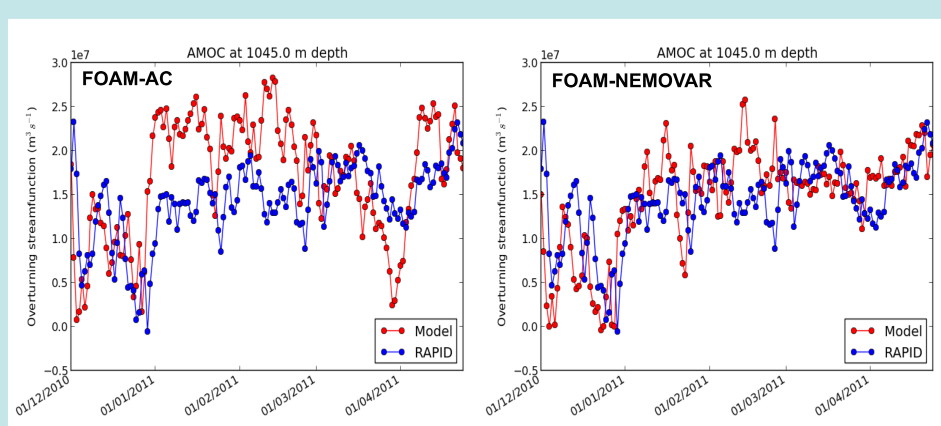

Figure 6: Comparison of model and RAPID observations of AMOC

The surface statistics results in Figure 3 are very good with a significant improvement in innovation standard deviation. Figure 4 shows that the largest improvements in FOAM-NEMOVAR are seen in the high variability reasons such as the frontal zones and marginal sea ice areas. While Figure 5 shows the **improvement** to the fit of **mesoscale features** in FOAM-NEMOVAR.

There is also an improvement in the modelling of the AMOC in FOAM-NEMOVAR in the reanalysis period (Figure 6).

The temperature profile innovation standard deviations in Figure 7 are improved near the surface in FOAM-NEMOVAR but slightly degraded in the thermocline. There is also a larger bias in FOAM-NEMOVAR. Salinity results are degraded in the top 100m.

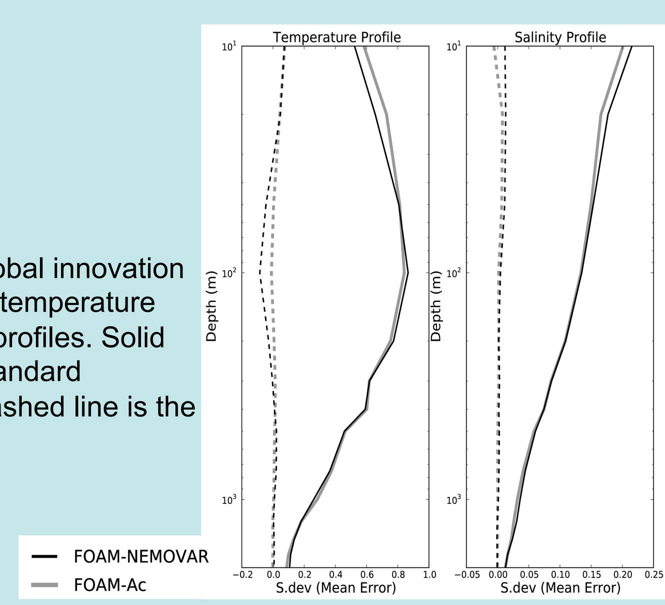

Figure 7: Global innovation statistics for temperature and salinity profiles. Solid line is the standard deviation, dashed line is the mean.

Summary

Results from the NEMOVAR data assimilation system in the Met Office's global ¼ degree model are presented here.

The results show that the FOAM-NEMOVAR system produces a significant improvement to surface variables. The largest improvements are shown to be in high variability regions where mesoscale features dominate. This is predominantly attributed to the horizontal correlation length scales in FOAM-NEMOVAR which are shorter than those in FOAM-AC at the higher latitudes.

The results for subsurface variable are more mixed with an increase in the temperature profile bias at 100m and a degradation in the salinity innovation statistics near the surface. The temperature bias in FOAM-NEMOVAR is in fact a warm model bias. This bias is quite well constrained in FOAM-AC but not so well constrained in FOAM-NEMOVAR. While the shorter correlation length scales improve the modelling of mesoscale features, it is likely that they are less able to constrain large scale biases or produces as good results when data networks are sparse (as is the case for salinity).

Future Work

-Improving the subsurface results. We will Investigate the use of 2 correlation length scales and a T and S bias correction scheme for high latitudes.

- Improving data assimilation in the equatorial region.

- Using ensembles in FOAM-NEMOVAR.

References

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