SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Met Office

Theme 5

Recent developments in global ocean data assimilation at the Met Office

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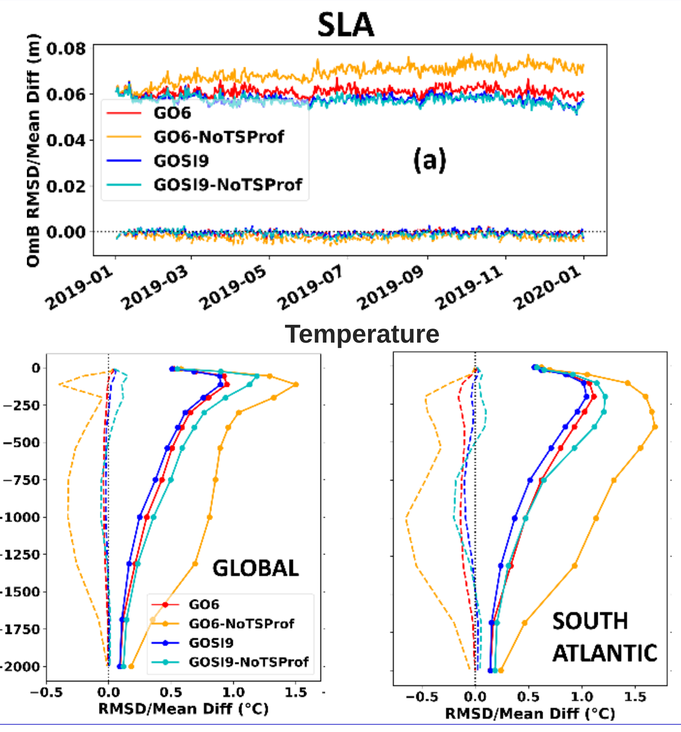
Introduction

Global ocean data assimilation at the Met Office is a crucial component of ocean reanalysis and ocean forecasting from short-range to seasonal time scales. We provide an overview of recent developments and areas of research in global ocean data assimilation at the Met Office. This includes a new version of the Forecasting Ocean Assimilation Model, FOAM-GOSI9, the application of the data assimilation on a 1/12th degree horizontal resolution grid and the development of a hybrid ensemble/variational data assimilation approach.

FOAM-GOSI9

We have updated from FOAM-GO6 to FOAM-GOSI9. FOAM-GOSI9 (Mignac et al; 2024) comprises an upgrade to a more recent version of the ocean model with a new equation of state, a new sea ice model and updates to the data assimilation.

Figure 1



	FOAM-GO6	FOAM-GOSI9
Model	NEMO 3.6 and CICE	NEMO 4.0.4 and SI3
Equation of state	EOS80	TEOS10
Data Assimilation	NEMOVAR 3DVAR FGAT	NEMOVAR 3DVAR FGAT
SST and SLA observation errors	Seasonally and spatially varying estimates produced using the Hollingsworth and Lönnberg method. This is treated as the total error.	Seasonally and spatially varying representation error due to unresolved scales in the model (Oke and Sakov, 2008) + observation-specific measurement error for SST and 4 cm measurement error for SLA.
Background error correlation length-scales	Short and long length-scales are used for both T and S.	Long length-scale is not applied for T but is used for S.
Inner loop iterations (ocean DA)	40	120
SSH balance	Applied below, but not in the mixed layer	Applied through the whole water column
Rejection criteria for T/S increments	None	Rejection of T/S increments based on water column instabilities diagnosed from Brunt-Väisälä buoyancy frequencies.

Good improvements to SLA and Temperature Obs minus bkg (OMB) RMSD in the FOAM-GOSI9 system (see Figure 1). The relative improvement is even larger when T and S profiles are with-held in the assimilation, indicating that FOAM-GOSI9 will produce an improved re-analysis.

Full Resolution DA

The ORCA12 version of FOAM currently performs the data assimilation at the lower ORCA025 resolution (mixedresDA). Recent developments to improve the efficiency of the data assimilation component, NEMOVAR, have allowed the implementation of data assimilation at the full, 1/12th degree, resolution (fullresDA). The main two efficiency improvements are a new approach to calculating normalisation factors (Weaver et al. (2020)) and multi-resolution assimilation which allows the diffusion calculation used to generate spatial correlation in the background error (BGE) to be applied on a coarser grid for longer correlation length-scales.
We have performed some preliminary tests to investigate the impact of applying the data assimilation at the same resolution as the model outer loop.

One potential benefit of fullresDA is that the Rossby radius can be better represented in the BGE correlations.

From Figure 2, Rossby radius scales are not resolved above 40N/S in mixedresDA.

FullresDA can produce smaller scale SST increments at high latitudes and near the coasts, see Figure 3.

Figure 2

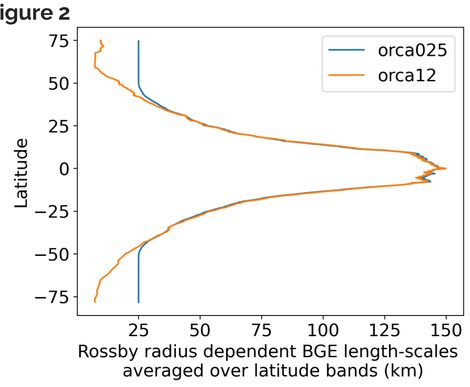
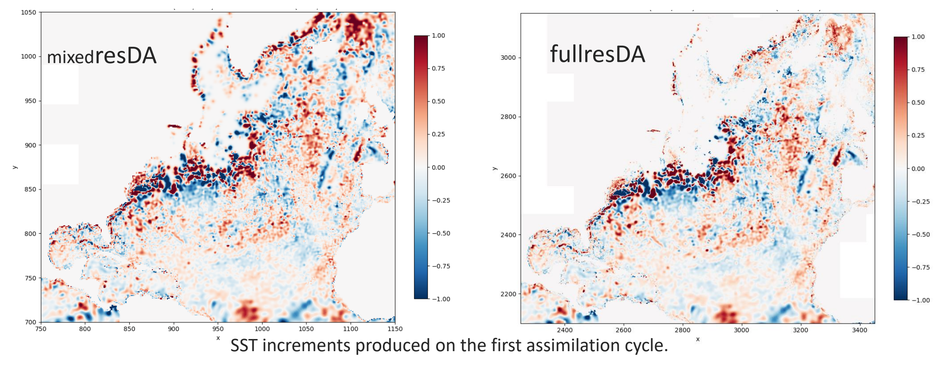


Figure 3



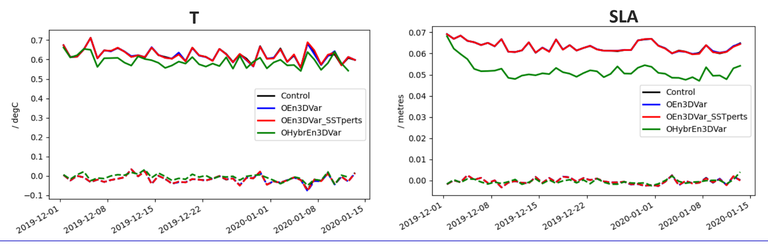
Initial 2 month tests of fullresDA in the FOAM system show very limited impacts on the innovation RMSD statistics when compared to mixedresDA. Some suggestions to better exploit the impact of increased DA resolution are:

- Using observations at higher spatial resolution e.g L2 SIC data, wide-swath altimeter and SST data with reduced thinning
- Development of a model bias correction scheme to better constrain large scale biases
- Refining background and observation error covariances for ORCA12 DA.

Hybrid 3D Ensemble Variational DA

An ensemble ocean forecasting system using a hybrid three-dimensional ensemble variational DA (hybrid-3DEnVar) approach with 36 members has been developed at the Met Office. Each member is forced by a different atmospheric realisation from the Met Office atmospheric ensemble and the system includes stochastic model perturbations and a relaxation to prior spread inflation scheme. In addition, observation perturbations are made in each member. The system has been tested with different weights for the ensemble component of the hybrid background-error covariance matrix and different inflation factors in the ocean only FOAM system (see Lea et al; 2022). Improvements to SLA RMSE of 20% and T and S RMSE of 5% were demonstrated with hybrid-3DEnVar in FOAM. More recently, hybrid-3DEnVar has been implemented in the ocean component of the coupled NWP system and gave similar results (see Figure 4).

Figure 4



Black – 3DVAR
Green – hybrid-3DEnVar (ensemble weight = 0.8)

Figure 5

The figures show temperature and salinity increments (colours) for one day/cycle 2018/09/01 against background density levels (contour lines). All are sections S-N in the Gulf Stream region at longitude 68W.

References:
Mignac et al; 2024. Updates to the Met Office's global ocean-sea ice forecasting system including model and data assimilation changes. *Submitted to GMD.*

Lea et al; 2022. A new global ocean ensemble system at the Met Office: Assessing the impact of hybrid data assimilation and inflation settings. *Quarterly Journal of the Royal Meteorological Society, 148(745), 1996–2030. https://doi.org/10.1002/qj.4292*

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