Recent development of the Met Office operational ocean forecasting system: an overview and assessment of the new Global FOAM forecasts

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Introduction and Overview

The Forecast Ocean Assimilation Model (FOAM) is an operational ocean analysis and forecast system run daily at the Met Office providing modelling capability in both deep ocean and coastal shelf seas regimes using the NEMO ocean model.

The Global FOAM configuration runs as part of the FOAM deep ocean suite producing daily analyses and 7 day forecasts of ocean tracers, currents and sea ice for the global ocean at 1/4º resolution. Satellite and in-situ observations of temperature, salinity, sea level anomaly and sea ice concentration are assimilated each day over a 48 hour observation window.

The Global FOAM configuration has recently undergone a major upgrade which has involved the implementation of a new data assimilation scheme, sea-ice model and surface boundary condition. The NEMO ocean model component has also been upgraded to use the UK's Joint Ocean Modelling Programme (JOMP) Global Ocean configuration version 1.0 (GO1.0) which is based on the DRAKKAR NEMO ORCA025 configuration of Barnier et al. 2006.

Table 1: Major components of the FOAM v12 upgrade.
Additional NEMO namelist and input files changes were made as part of the GO1.0 upgrade.
Further details can be found in Blockley et al. 2013.

	FOAM v12	FOAM v11
Data Assimilation scheme	NEMOVAR 3D-Var FGAT	OCNASM A/C FGAT
Sea ice model	CICE [5 thickness categories]	LIM2 [single category]
Surface Boundary Condition	CORE bulk formulae	Direct fluxes
Vertical resolution	75 levels	50 levels

Experiment Setup

To assess the quality of the new FOAM v12 system a series of reanalysis and hindcast trials have been performed using three separate FOAM configurations each run for the 2 year assessment period 1st December 2010 until 30th November 2012 :

- ***v12*** − the new FOAM v12 system
- ***v11*** − the old FOAM v11 system
- ***free*** − a FOAM v12 run with no data assimilation.

To assess the model forecast skill, a series of 31 5-day hindcasts were performed during the middle month of each season (January, April, July and October for both 2011 and 2012). These hindcasts were performed using SBC's generated from forecast NWP fields to reflect the true manner in which forecasts are run operationally.

Assessments

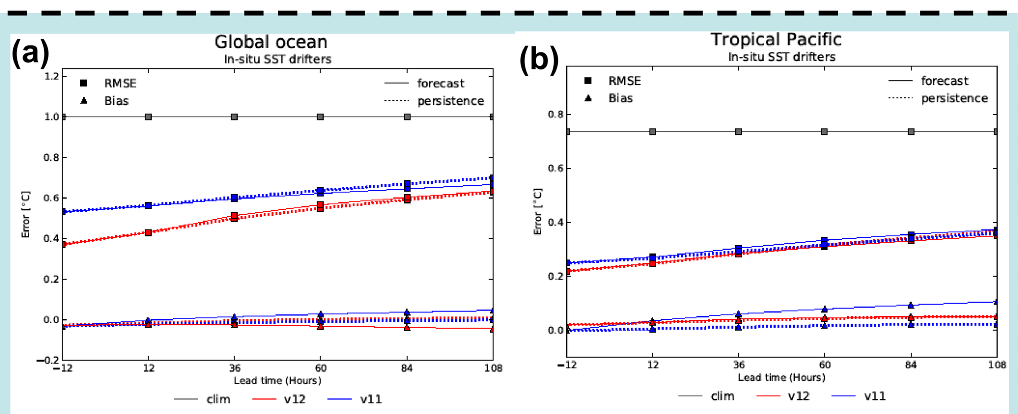
Results are shown in this section as a series of figures and will be discussed further in the *Summary and Discussion* section below. As well as the quantitative assessments of the reanalyses and hindcasts a qualitative assessment of surface fields is made by comparing 2D surface contours of monthly-mean reanalysis fields with gridded observational products.

Reanalysis results shown here are calculated from the FGAT innovations output from all three FOAM runs for the entire 2-year assessment period. These model-observation differences are interpolated in space and valid at nearest model time-step to the observation time. Forecast assessments are performed by comparing daily-mean forecast fields with observations using the GODAE class4 validation methods described in the Ryan et al. poster [S3.3-11].

Fig. 1: Surface Temperature

Forecast lead-time plots of RMS (squares) and mean (triangles) errors against in-situ drifting buoy SST measurements (ºC): (a) globally and (b) in the Tropical Pacific (b).

Plots show model forecasts (solid lines) and persistence (dotted lines) averaged over all forecasts performed during the v12 (red) and v11 (blue) trials. The grey lines are corresponding errors for the EN3 climatology.



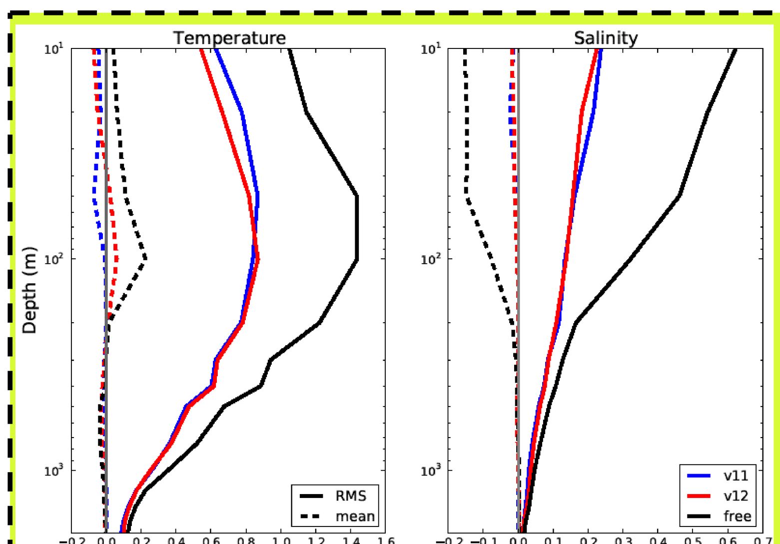


Fig. 2: Subsurface Profiles

Global mean temperature and salinity error profiles against model depth (m) on a log scale.

Mean errors are plotted as modelled-observed meaning that positive temperature (salinity) values indicate that the model is too warm (salty).

	FOAM v12	FOAM v11
SST (in-situ)	0.45 ºC	0.60 ºC
SLA	7.4 cm	7.7 cm
Temperature Profiles	0.61 ºC	0.63 ºC
Salinity Profiles	0.124	0.131
Zonal Velocity	20.8 cm/s	21.2 cm/s
Meridional Velocity	19.1 cm/s	19.7 cm/s

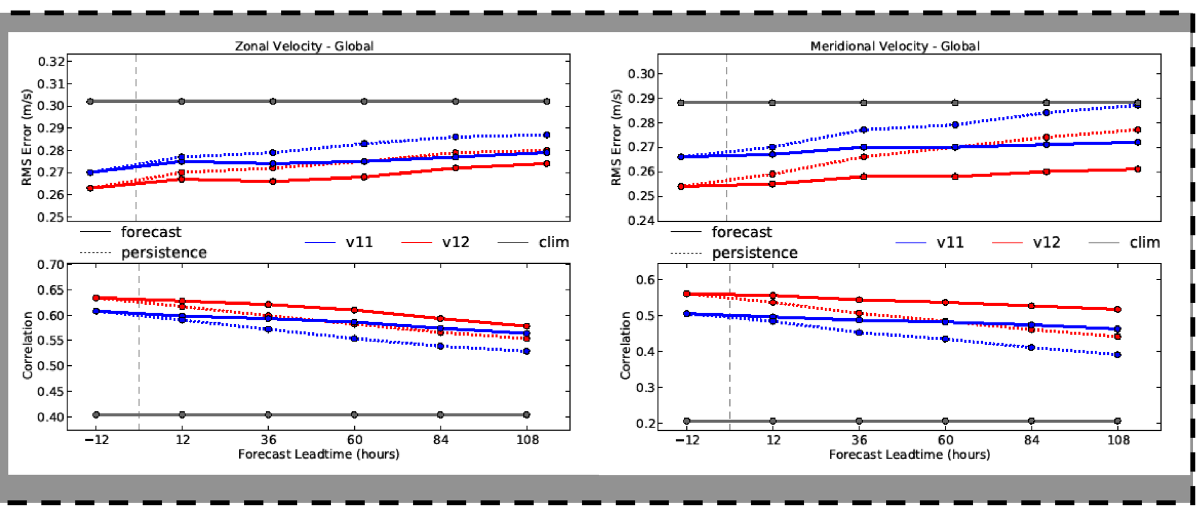
Table 2: RMS errors

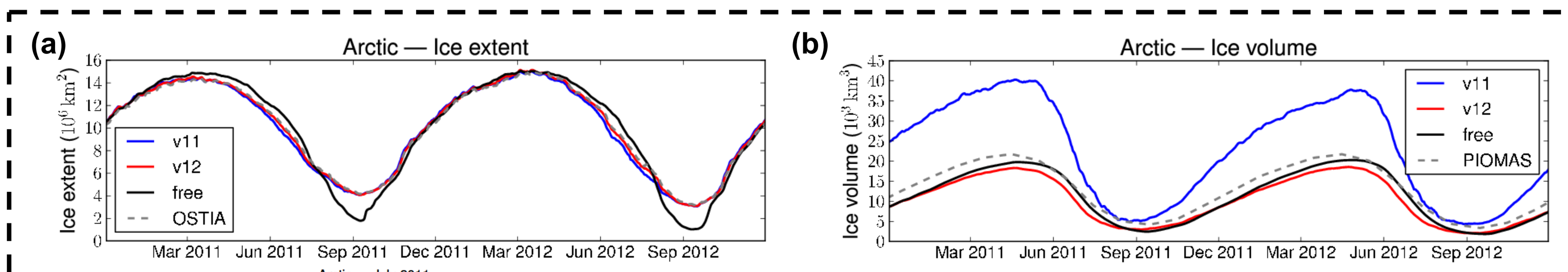
Global RMS errors calculated from model-observation differences for the full 2-year reanalysis period. For SST, SLA and subsurface temperature and salinity profiles, these are calculated from FGAT innovations. Velocity errors are calculated from daily-mean model fields using the methods of Blockley et al. 2012.

Fig. 3: Surface Velocities

Forecast lead-time plots of RMS error (upper) and correlation (lower) against zonal (left) and meridional (right) velocity observations (m/s) derived from drifter locations.

Lines plotted are forecasts (solid lines) and persistence (dotted lines) from the v12 (red) and v11 (blue) trials. Also shown are the corresponding results for climatological velocities (grey solid lines) from the GDP drifter climatology.





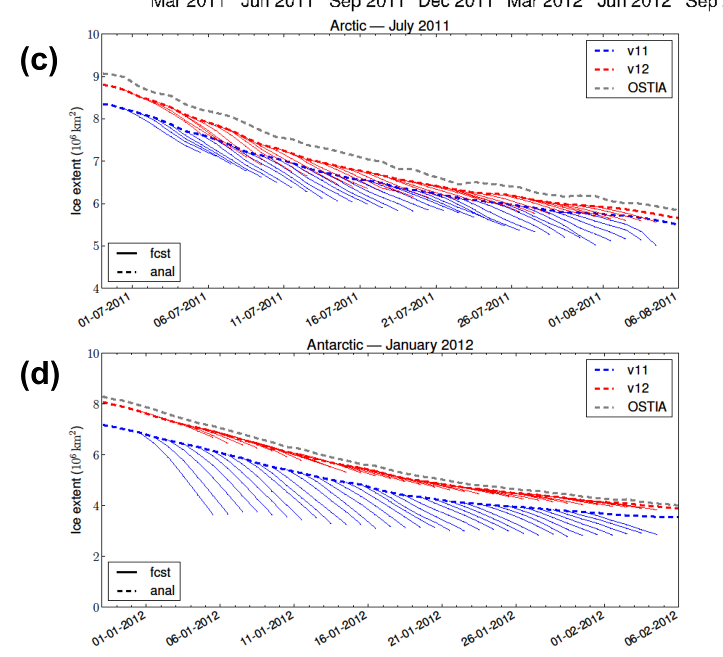


Fig. 4: Sea Ice Extent and Volume

(a), (b): 2-year time series of Arctic sea ice extent (a) and volume (b) derived from the v12 (red), v11 (blue) and free (black) trials.

(c), (d): Time series of Arctic sea ice extent for forecasts performed in July 2011 (c) and Antarctic sea ice extent for forecasts performed in January 2012 (d). Dashed lines show analysis ice extents whilst solid lines show the ice extent evolution over the 5-day hindcasts.

Grey dashed lines in (a), (c), (d) are daily OSTIA [Donlon et al., 2012] sea ice extent derived from OSI-SAF ice concentrations whilst those in (b) are monthly PIOMAS [Schweiger et al., 2011] ice volume data.

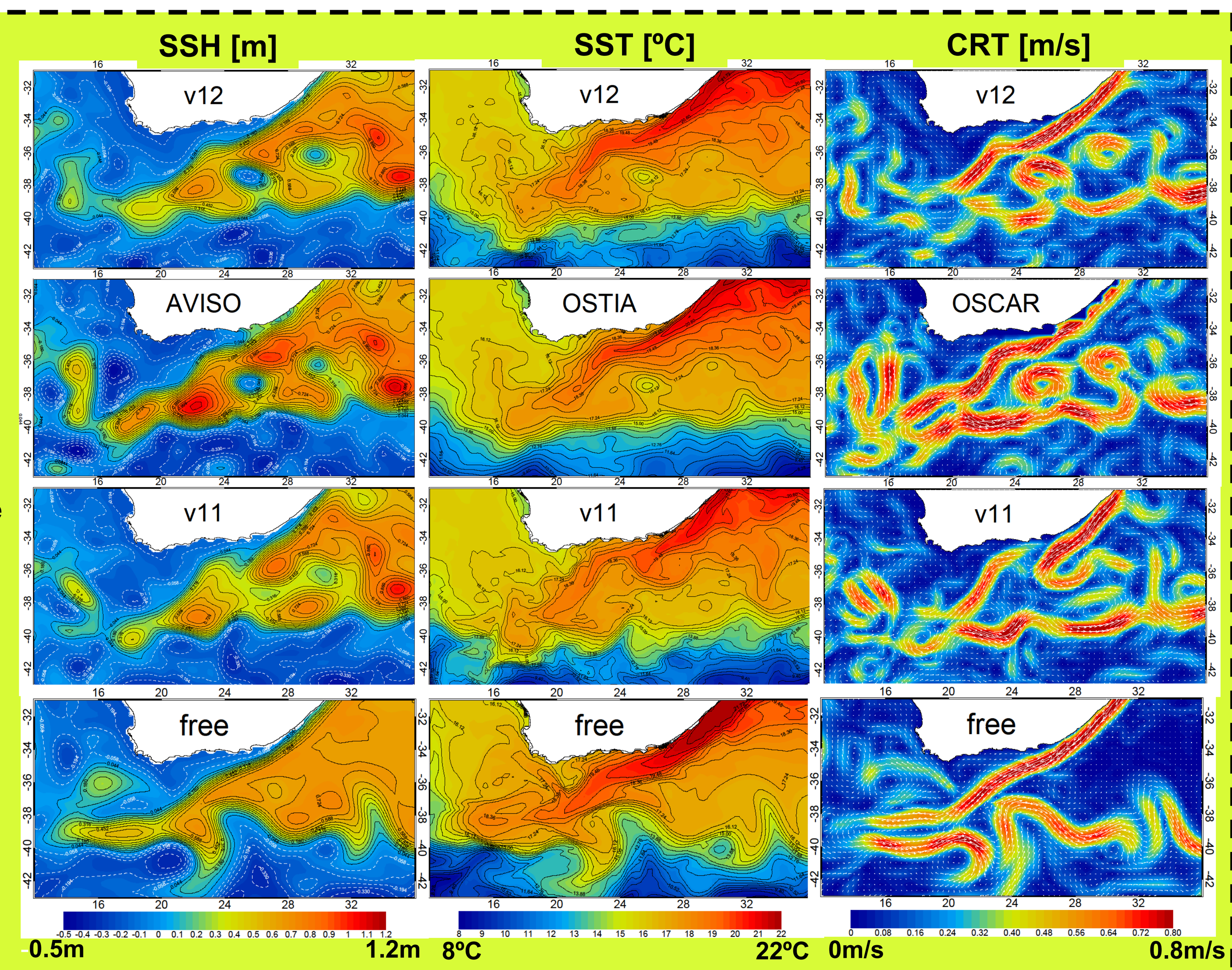
Fig. 5: Surface Fields

Monthly-mean contour plots over the Agulhas retroflection (2ºE – 36ºE; 31ºS – 43ºS) for September 2012.

SSH (left: m) and SST (centre: ºC) are plotted as coloured contours with black contour lines overlaid. For the SSH plots solid black lines denote positive contour values and broken white lines denote negative values.

Surface currents (right: m/s) are displayed as coloured contours of current intensity (speed) with white direction arrows overlaid. Model currents are total integrated velocity over the top 15m.

Output from the v12, v11 and free trials are plotted in the 1st, 3rd and 4th rows whilst the 2nd row plots are gridded observational products: AVISO SSH, OSTIA SST and OSCAR surface currents.



Summary and Discussion

Results show that surface fields are considerably improved in the new v12 system. In particular forecast SST assessments show that globally the RMS error for the new v12 3-day forecast is comparable to the 1-day forecast from the old v11 system (Fig. 1a). Comparisons with climatology also show a clear benefit to using the model particularly in the tropics (Fig. 1b, 3).

Comparisons with gridded observational products suggest that the v12 system provides a better representation of mesoscale features in the extra-tropics (Fig. 5) — an improvement caused primarily by the shorter horizontal correlation lengthscales used within NEMOVAR [Waters et al., 2013]. These surface improvements are particularly important as the future of FOAM short-range ocean forecasts lies within a fully coupled ocean-ice-atmosphere system with weakly coupled data assimilation (as introduced by the Lea et al. poster [S3.1-15]).

Although the quality of near-surface (< 80 m) temperature and salinity fields is improved in the new v12 system, temperature at 100 m is slightly degraded. This seems to be a result of the present version of the NEMOVAR assimilation scheme not being able to constrain a persistent model bias quite as well as the old OCNASM scheme did. Plans to extend NEMOVAR to use dual horizontal correlation lengthscales should allow the system to better constrain these subsurface fields.

There are clear improvements to the sea-ice fields in the v12 system with forecasts in particular performing better during melt periods (Fig. 4). This improvement is attributed partly to the CICE multi-category model and partly to the bulk formulae surface boundary conditions. Ice thickness is also better at v12 as, although the ice is thinner in the marginal ice zones, the total volume of ice in the v11/LIM2 system is too high − particularly in winter. It is hoped that these improvements can be further improved by tuning the CICE model to reduce excessive summer-time melting in the free run.

Barnier et al.: *"Impact of partial steps and momentum advection schemes in a global ocean circulation model at eddy-permitting resolution"*, Ocean Dynam., 56, 543–567, 2006.
Blockley et al.: *"Recent development of the Met Office operational ocean forecasting system: an overview and assessment of the new Global FOAM forecasts"*, in prep for Geosci. Model Dev., 2013.
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Schweiger et al.: *"Uncertainty in modeled Arctic sea ice volume"*, J. Geophys. Res., 116, C00D06, 2011.
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