The global FOAM system

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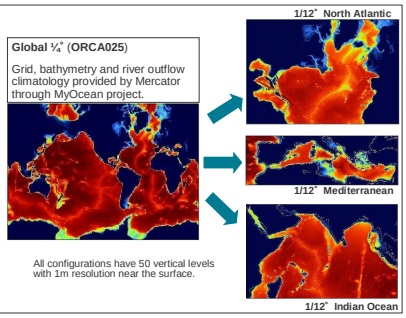
Summary

The FOAM (Forecast Ocean Assimilation Model) system run at the UK Met Office is a well-established ocean analysis and forecasting system, and provides the main UK contribution to GODAE. Daily analyses and 5-day forecasts of 3D temperature, salinity, currents and sea-ice are produced. Coverage is global at 1/4˚ resolution with nested models at 1/12˚ resolution in the North Atlantic, Mediterranean and Indian Ocean. The data assimilation system has been developed from the Analysis Correction scheme which deals efficiently with multiple observation types and with large numbers of observations to calculate multivariate increments to the model fields. The FOAM implementation of the scheme includes numerous significant developments, most notably: a two-component background error covariance model; a bias correction scheme for controlling biases in the tropics; a scheme to correct for bias in satellite SST observations; and a scheme to correct biases in the mean dynamic topography (MDT).

The model component of FOAM has recently been changed to use the NEMO modelling framework. During the transition to the new model a number of other changes have been made, including a new set of model configurations and improvements to the data assimilation. The global FOAM-NEMO system has been running in a trial operational suite since May 2008, and will be made fully operational before the end of 2008. The new system is presented below, with some validation results from a 2-year hindcast integration of the global configuration.

Model

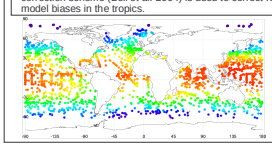
- The model component of FOAM has recently been changed to use the Nucleus for European Modelling of the Oceans (NEMO) modelling framework.
- The model has partial cells, a free surface, and TKE vertical mixing.
- The sea ice model is currently LIM2 but will be changed to use the CICE model.
- The model is forced by 6 hourly surface fluxes from the Met Office NWP system.
- For information on the regional configurations see poster by Ed Blockley (S2.2-086).

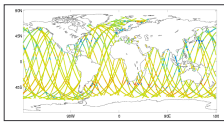


Data assimilation

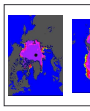
- 1/4˚ global and 1/12˚ regional FOAM configurations assimilate a range of data into the NEMO model on a daily cycle (Martin *et al*. 2007).
- The assimilation scheme used in FOAM is based on the Analysis Correction (AC) method introduced by Lorenc *et al.* (1991), which provides an efficient means of calculating the solution to the Optimal Interpolation analysis equation using an iterative procedure.
- A first-guess-at-appropriate-time (FGAT) scheme is used to calculate the model counterpart of the observations.
- Background error covariances are split into two components with different length scales and spatially varying variances. Balance relationships are used to calculate multivariate increments.
- Increments are added to the model using Incremental Analysis Updates (IAU) over 24 hours.
- Automatic quality control is performed on all data types (Ingleby and Huddleston, 2007).
- Bias correction schemes are used to correct for biases in the mean dynamic topography (MDT) (see poster by Dan Lea, S2.12-026), to correct for biases in the satellite SST data, and to correct for model biases in the tropics (Bell *et al.* 2004).

Temperature and salinity profiles from the Global Telecommunication System (GTS) including Argo floats, XBTs, CTDs and buoys are assimilated. A pressure correction scheme (Bell *et al.* 2004) is used to correct for model biases in the tropics.



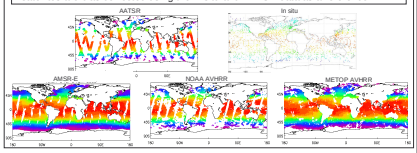


Along-track satellite altimeter SLA data processed by CLS are assimilated, with bias correction of the Rio05 MDT (see poster by Dan Lea, S2.12-026). The Cooper & Haines (1996) scheme is used to project the surface height information onto the sub-surface density field.



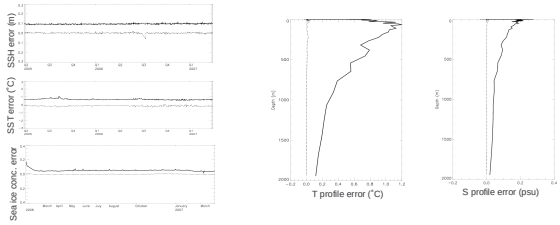
Sea ice concentration data produced by the EUMETSAT OSI-SAF are assimilated using the scheme of Stark *et al.* 2008.

In situ and GHRSST satellite SST data are assimilated. Data from the various satellites are bias corrected using the in situ and AATSR data as a reference.

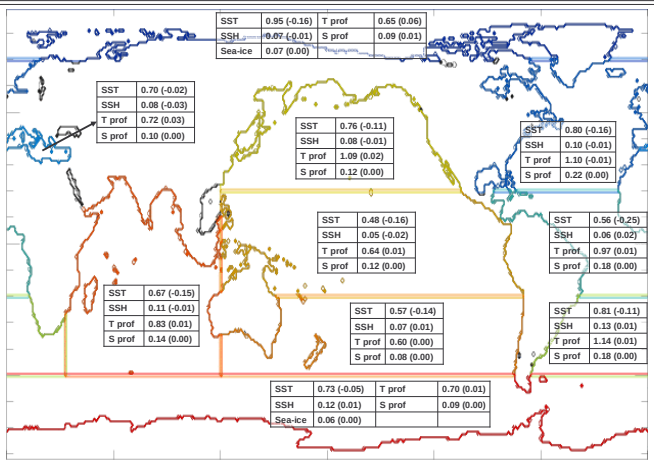


Validation

- A 2 year hindcast of the global 1/4˚ FOAM-NEMO system was run from April 2005 - April 2007.
- This assimilated all the data described in the opposite column. GHRSST data was not available before July 2006, so Pathfinder AVHRR data was used prior to that. The sea-ice concentration data was only available after January 2006.
- The following figures show error statistics of observation minus model forecast (background) from this hindcast for different variables, both globally and regionally.



Global RMS (solid lines) and mean (dotted lines) error statistics (observation – background) from the global ¼˚ FOAM system. Profile statistics are averaged over the 2 year hindcast.



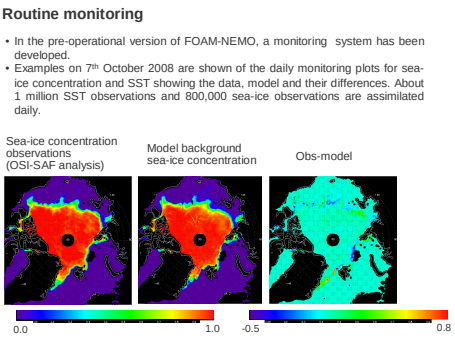
Regional RMS (mean) error statistics (observation – background) from the global ¼˚ FOAM system. Profile statistics are calculated over the top 2000m depth. Units are ˚C for SST and T profile, psu for salinity and metres for SSH.
The significant SST biases shown in this figure are because the verification is performed against all data (in situ and satellite) without bias correction, whereas a bias correction for the satellite SST data is performed within the assimilation.

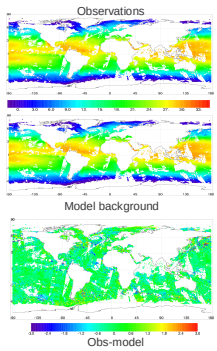
Operational aspects and data distribution

- The FOAM system runs daily in the operational suite of the Met Office and produces analyses and 5-day forecasts.
- All FOAM configurations have full operational support including 24/7 operator cover, on-call arrangements for response to problems by scientific staff, backup procedures, and use of resilient systems.
- Data is served to a number of customers through various routes:
  - Direct links to UK Royal Navy forecasters.
  - For commercial use, data is available from the Met Office's Data and Products Distribution System (DPDS) at http://www.metoffice.gov.uk/research/ncof/foam/dpds.html
  - Data is freely available for research use from the Live Access Server at http://www.nerc-essc.ac.uk/godiva/
  - To visualise and browse the data, see http://behemoth.nerc-essc.ac.uk/ncWMS/godiva2.html
  - In the MyOcean project, data will be freely available via sftp.

Routine monitoring

- In the pre-operational version of FOAM-NEMO, a monitoring system has been developed.
- Examples on 7th October 2008 are shown of the daily monitoring plots for sea-ice concentration and SST showing the data, model and their differences. About 1 million SST observations and 800,000 sea-ice observations are assimilated daily.





Future work

A number of improvements to the system are planned over the near future including:

- Implementation of the NEMOVAR data assimilation system.
- Improved specification of the error covariances.
- More in depth validation of the system leading to model improvements, e.g. tuning of TKE scheme.

References

Bell, M.J., M.J. Martin and N.K. Nichols (2004). Assimilation of data into an ocean model with systematic errors near the equator. *Q. J. R. Meteorol. Soc.*, **130**: 873-893.

Ingleby, N.B. and M. Huddleston (2007). Quality control of ocean temperature and salinity profiles – historical and real-time data. *J. Mar. Syst,*. **65**: 158-175.

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