The use of Argo data in the FOAM operational ocean forecasting system

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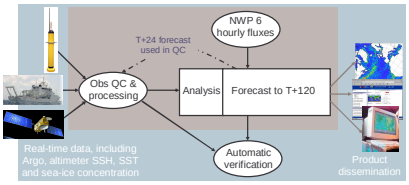
The FOAM (Forecast Ocean Assimilation Model) system is a well-established ocean analysis and forecasting system. Daily analyses and 5-day forecasts of 3D temperature, salinity, currents and sea-ice are produced. Coverage is global at 1 degree resolution with nested models up to 1/9 degree resolution in areas of interest. Selected output, for research purposes, is available in real time at http://www.nerc-essc.ac.uk/godiva. Results from a set of 5-year hindcast runs of this system are shown, with and without assimilation of Argo data, to show the impact of Argo on the errors in the analyses.

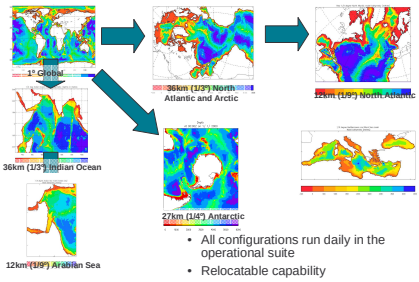
The ocean model component of the FOAM system is being changed from the Unified Model ocean to the NEMO (Nucleus for European Modelling of the Ocean) model at 0.25 degree globally. Models at 1/12 degree will be nested into the global model. The optimal interpolation assimilation system has been developed to assimilate observations compared to the model at the exact observation time. Various other improvements have also been made to the assimilation system. Initial results and comparisons to the previous system are shown. Future work will involve running some data withholding experiments with the new system in order to show the impact of Argo (and other data types) on the accuracy of the system.

Existing FOAM operational system

Every day the FOAM system takes observations, including Argo profiles, from the GTS (Global Telecommunication System) which are then processed using an in house QC (Quality Control) system (Ingleby and Huddleston 2007). An analysis using the QC'd data and 5 day forecast is then produced. Data is then served to the various users.



The nested series of models



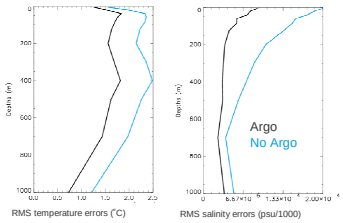
- All configurations run daily in the operational suite
- Relocatable capability

Output from the models is used by nested shelf seas models

Main features

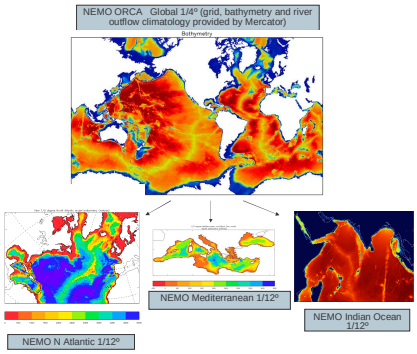
- 20 level UM ocean model (10 m surface level thickness).
- 6 hourly Met Office Numerical Weather Prediction fluxes.
- Optimal Interpolation type data assimilation scheme (Analysis Correction). More detail on the system is in Martin et al. (2007).
- Features:
  - Sea surface temperature (SST) bias correction for satellite data.
  - Pressure correction which corrects for wind stress errors in the tropics (Bell et al. 2004).
- Quality control system to remove bad data
- Assimilates:
  - NESDIS SST 50/100 km.
  - In-situ SST.
  - In-situ temperature and salinity profile data, including Argo profiles.
  - Satellite altimeter sea surface height.
  - Sea ice concentration is relaxed to an analysed product from the Canadian Met Centre.
- Output made available to:
  - The UK Royal Navy.
  - Commercial companies via Met Office's Data and Products Distribution System (DPDS) at *http://www.metoffice.gov.uk/research/ncof/foam/dpds.html*
  - Research community at *http://www.nerc-essc.ac.uk/godiva*
- Online coupling to HadOCC (Hadley Centre Ocean Carbon Cycle Model) (Hemmings et al. 2008)
  - NPZD ecosystem model coupled to carbon and alkalinity
  - Includes a novel ocean colour assimilation scheme

North Atlantic 1/9° model RMS errors



RMS error statistics comparing assimilation of all data to that without Argo data, averaged over a 5 year hindcast (2001-2005). This shows a dramatic improvement particularly in salinity in the top 400 m when Argo data is assimilated.

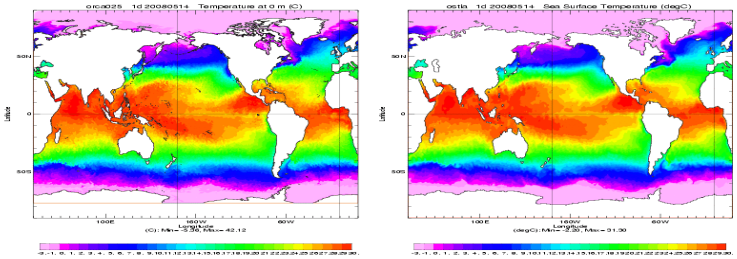
New NEMO FOAM system under development



New features improving on the existing FOAM system

- 50 level NEMO model (1 m surface level thickness).
- Higher resolution global model allowing a reduced number of nested models
- Model has partial cells, a free surface, higher global resolution and TKE vertical mixing.
- OI assim. with observation operator comparing data at the correct time (FGAT)
- Observation operator output can be examined in Google Earth or using IDL routines to easily identify problems with the data or the model or assimilation system.
- Improved sea ice assimilation uses OSI-SAF sea ice concentration data and uses the OI scheme as do all the other data types.
- Altimeter bias correction to correct any errors in the mean dynamic topography.
- Assimilating GHRSST data with improved satellite bias correction scheme (the same as is used in the OSTIA SST analysis system).
- Updated estimates of model and observation error covariances are currently being made.

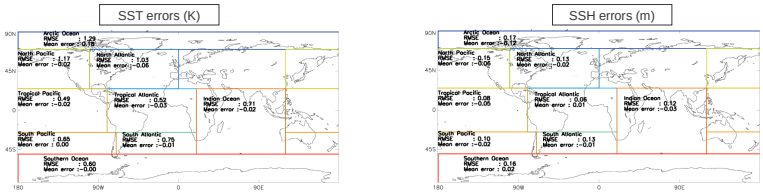
FOAM-NEMO SST on 14th May 2008 | OSTIA SST analysis on 14th May 2008



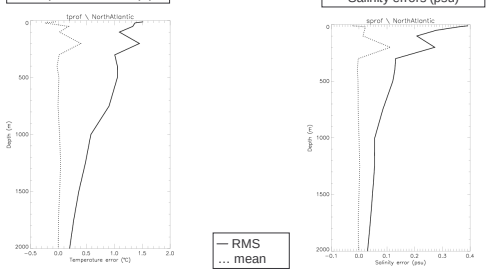
An example output field from ¼ degree NEMO, compared to the high resolution OSTIA SST analysis for the same day.

Model mean and RMS errors

SST errors (K) | SSH errors (m)



Temperature errors (K) | Salinity errors (psu)



Plotted are statistics of observation minus background (model values before assimilation). Shown are maps of regional average errors (comparing the model to SST and SSH) for the first six months of a hindcast experiment, and profile averages for the North Atlantic (compared to profile data) over the same time period.

We cannot make a detailed comparison between these results and those for the existing FOAM system because they are averaged over a different time period. However, generally, the results compare reasonably well with the existing FOAM system (salinity is somewhat worse, but temperature is somewhat better). This is particularly encouraging bearing in mind that the error covariances have not yet been updated for the new system.

The various improvements made to the data assimilation and model system will enable better use to be made of the Argo data. In the near future, a number of data withholding experiments will be performed with the new system aimed at demonstrating the impact of various observation types, including Argo data. These results will be compared with other GODAE (Global Ocean Data Assimilation Experiment) systems.

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