The impact of assimilating altimeter SSH data from different numbers of satellites on FOAM surface currents

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  – FOAM system overview
  – Method used to assimilate the altimeter SSH data

• Observing system experiments
  – Description of experiments
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• Forecasting Ocean Assimilation Model (FOAM):
  
  • The Met Office’s operational deep ocean forecasting system. Produces daily analyses and 5-day forecasts.
  
  • Forced at the surface by 6 hourly heat, freshwater and momentum fluxes from the Met Office’s NWP system.
  
  • Various configurations are run. Focus here on the 1/9° resolution model of the North Atlantic.
  
  • Most of the results shown here are from the FOAM system running the ocean component of the Unified Model.
  
  • Currently transitioning to use the NEMO ocean model – will be operational in 2008.
Introduction

Data types assimilated

- Data assimilated using an OI type method.
  - In situ temperature profile data from Argo, moored buoys, XBTs, ships,…
  - In situ salinity profile data from Argo,…
  - In situ SST data from moored buoys, drifters, ships, rigs,…
  - Satellite SST data - 100km and 50km gridded products from NESDIS. Will start assimilating GHR SST data in 2008.
  - Sea-ice concentration data.
  - Altimeter SSH data – see next slide.

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Introduction
Data types assimilated

- Altimeter data used are along-track sea level anomalies (SLA) produced by CLS.
- Includes Jason, Envisat and Geosat Follow On (GFO) data.
- Altimeters provide the main source of information about the mesoscale ocean dynamics.

Jason data: 1/1/06 – 10/1/06
Envisat data: 1/1/06 – 10/1/06
GFO data: 1/1/06 – 10/1/06
Altimeter assimilation

- Mean dynamic topography (MDT) added to SLA data to produce SSH observations.
- Perform a 2D Optimal Interpolation type analysis based on observations and model to produce SSH increments.
- Altimeter data not assimilated in shallow seas or areas of weak stratification.
- SSH observation and forecast error covariances specified a priori using observed-forecast statistics (Hollingsworth and Lonnberg).

SSH observations for 1 day – SLA+MDT

Background model SSH

• Project the SSH analysis increments onto the subsurface temperature and salinity fields using the Cooper and Haines scheme, in which density profiles are lifted/lowered such that there is no change in the bottom pressure.

• The ocean is generally close to geostrophic balance so the density increments are used to calculate balancing velocity increments.

• The outcome of the analysis procedure is therefore a 2D field of SSH increments, and 3D fields of temperature, salinity, and both components of the velocity field.

• These increments are all applied using Incremental Analysis Updates (IAU, Bloom et al. 1995). The increments are slowly applied to the model throughout the 24 hours after the analysis.
Experiments

Experimental set-up

• Running the 1/9° North Atlantic FOAM configuration.

• Control run which assimilated just the in situ data from 1\textsuperscript{st} Dec 2005 – 31\textsuperscript{st} March 2006.

• Three runs which assimilated the in situ data together with altimeter SSH data from:
  – Jason
  – Jason and Envisat
  – Jason, Envisat and GFO

• Initial model state on 1\textsuperscript{st} December 2005 taken from a hindcast of the system from Jan 2001, which assimilated all available in situ data.

• Boundary data taken from the same run of the 1/3° FOAM configuration which assimilated only the in situ data.

• Surface fluxes taken from the Met Office NWP system — same for all runs.
Experiments

Assessing the impact of the assimilated data

• The last 3 months between January – March 2006 will be used for validation (to allow a one month spin-up of impact from altimeter).

• Various ways of assessing the performance of the assimilation:
  
  • *Comparison with the assimilated altimeter data* – (o-b) statistics.
  • Comparison with in situ data – also assimilated so not independent.
  • *Comparison with independent data*.

• Will show results of comparison of modelled SSH with altimeter data – (o-b) stats.

• Also comparison of surface currents with independent data from surface drifters. These allow us to validate the accuracy of the modelled mesoscale dynamics.
Assessing the impact of the satellite altimeters: impact on model’s fit to SSH data

- Comparing each experiment to all altimeter data.
- Most impact from the first altimeter.
- Correlations seem to be improved more by addition of GFO than by Envisat, particularly in NE Atlantic.

SSH correlation coefficients

- Dark blue – No altimeter
- Light blue – Jason
- Yellow – Jason + Envisat
- Orange – Jason + Envisat + GFO
Assessing the impact of the satellite altimeters: *drifter data*

- Surface buoys with a drogue centred at ~15m depth.
- Positions reported every ~hour.
- Quality control performed on the floats by comparing the temperature reported by the floats with climatology, plus maximum threshold on daily mean velocity (2m/s).

Positions of drifters available on GTS between 1/1/06 – 31/3/06
Assessing the impact of the satellite altimeters:

*model comparison with drifter data*

- Observed daily mean value calculated from the positions of the first and last report on each day.
- Model equivalent taken from top model level (average over top 10m).
- Daily mean model value calculated by averaging the daily mean velocities at all float locations during the day.
- 232 accepted floats which provide ~16000 daily values.
Assessing the impact of the satellite altimeters: impact on model’s fit to surface current data

- RMS velocity errors reduced by the assimilation of Jason data.
- No subsequent improvement in RMS errors when more altimeters added.
- Correlations are improved by the addition of more altimeters.
- Overall correlations fairly low – can be significantly improved by model tuning (viscosity).

**Velocity RMS statistics**

<table>
<thead>
<tr>
<th>Region</th>
<th>No altimeter</th>
<th>Jason</th>
<th>Jason + Envisat</th>
<th>Jason + Envisat + GFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Atlantic</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
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<tr>
<td>NE Atlantic</td>
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<tr>
<td>NW Atlantic</td>
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**Velocity correlation coefficients**

<table>
<thead>
<tr>
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<th>Jason</th>
<th>Jason + Envisat</th>
<th>Jason + Envisat + GFO</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>NW Atlantic</td>
<td>0.15</td>
<td>0.08</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Impact of different numbers of altimeter satellites: example in the Gulf of Mexico

(a) No altimeter data
(b) Jason only
(c) Jason+Envisat
(d) Jason+Envisat +GFO
Assessing the impact of the altimeter assimilation: impact of the model used

Velocity RMS statistics

- NEMO model run with same set-up at 1/9° resolution (but more vertical levels) — has free-surface and partial bottom cells — assimilating same data with same scheme.
- Improvements in both RMS errors and correlations.
- Would be useful to re-run data impact experiments to see how the use of a different model affects the results.

Velocity correlation coefficients

Dark blue — Jason+Envisat+GFO
Yellow — NEMO - Jason+Envisat+GFO
Assessing the impact of the altimeter assimilation: *impact of the error covariances*

- Re-run of the NEMO integration with a different specification of the error covariances for SSH as a sensitivity study.
- Has a significant impact on the results in the NE Atlantic.

**Velocity RMS statistics**

- Yellow: NEMO - Jason+Envisat+GFO
- Red: NEMO - new error covariances

**Velocity correlation coefficients**

- Yellow: NEMO - Jason+Envisat+GFO
- Red: NEMO - new error covariances
Conclusions

• Described an OSE looking at the impact of different numbers of satellites on the FOAM surface currents.
  
  − Results show that the correlations with independent surface drifters are improved when adding in one, two and three altimeters.
  − The first altimeter seems to have the most impact.
  − Would be useful to try changing the order in which satellites are added to see the impact.

• Overall RMS errors and correlations are improved when moving to new NEMO model - the results from the OSE are likely to be dependent on the model used.

• Results also dependent on the data assimilation scheme and its error covariances.
Assessing the impact of the satellite altimeters: 
impact on model’s fit to SSH data

![SSH RMS statistics graph]

- **Dark blue** – No altimeter
- **Light blue** – Jason
- **Yellow** – Jason + Envisat
- **Orange** – Jason + Envisat + GFO