The impact of Argo on short-term coupled prediction

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Outline

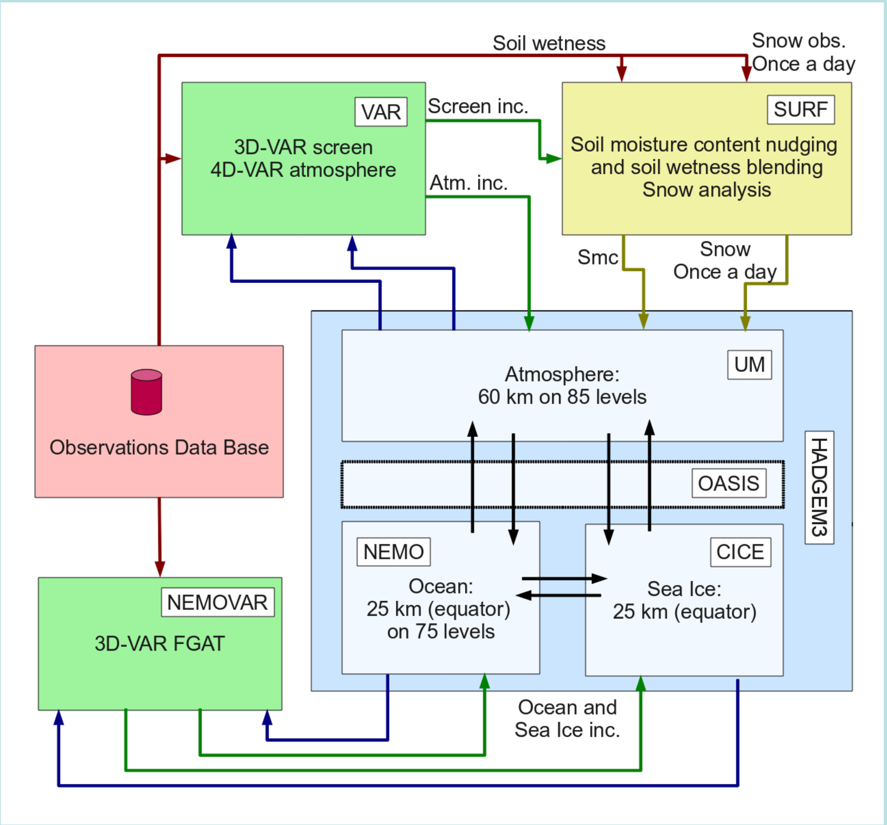
The necessity of coupling atmosphere and ocean models is accepted on seasonal to decadal prediction timescales, but the importance on shorter timescales has not been extensively addressed. The development of short-range coupled prediction systems at the UK Met Office, which assimilate data into both ocean and atmosphere components of a coupled model, provide the first opportunity to assess the potential for Argo to improve weather forecasts. We have used an Observing System Experiment (OSE) to investigate the effect of assimilating Argo profiles on coupled analyses and short-range forecasts. Observations of the upper ocean are clearly more important than the deep ocean for weather forecasting time-scales, but an important question is whether better sampling of the upper ocean brings a significant improvement over SST measurements alone. As with all OSEs, the impacts shown here are specific to the forecast model, data assimilation system and observations used, so cannot be generalised to other systems.

Coupled System & Observations Assimilated

Our OSE has been run using the Met Office weakly-coupled data assimilation system (Lea et al. 2015, submitted) which incorporates the Unified Model v8.0 and NEMO v3.2 as shown opposite.

Each analysis is created by two separate data assimilation systems, each run on a 6-hour cycle. The background is provided by a 6-hour forecast of the coupled model from the previous cycle and the component systems are coupled hourly.

In the atmosphere we assimilate satellite and in situ observations, including temperature, wind, pressure, humidity and satellite radiances. NEMOVAR is used to assimilate ocean observations including temperature and salinity profiles, SST, SLA and sea-ice concentration. The OSE was run over a 13 month period (Dec. 2011 – Dec. 2012) with two periods of 10-day forecasts to cover some extreme weather events.



Atmosphere Analysis Impact

In our system, the ocean and atmosphere exchange surface fluxes every hour and so sub-surface observations can in principle affect the atmosphere by altering the SST. The figure opposite demonstrates that even though both experiments are assimilating SST observations, the SST analyses still develop differences, particularly in the western boundary currents (WBCs) and near the equator. However, the atmosphere observation-minus-analysis statistics showed negligible systematic global impacts.

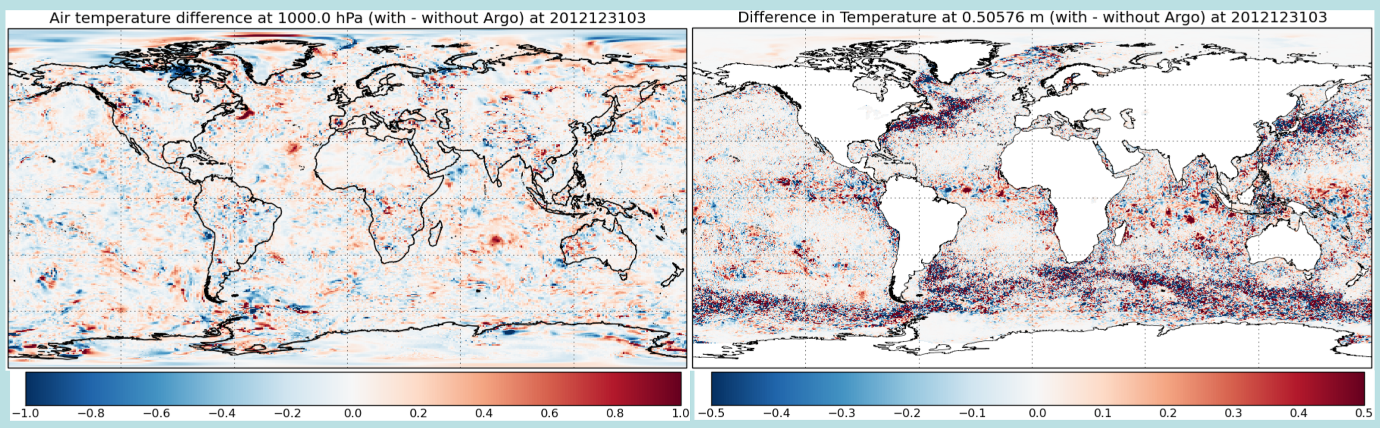
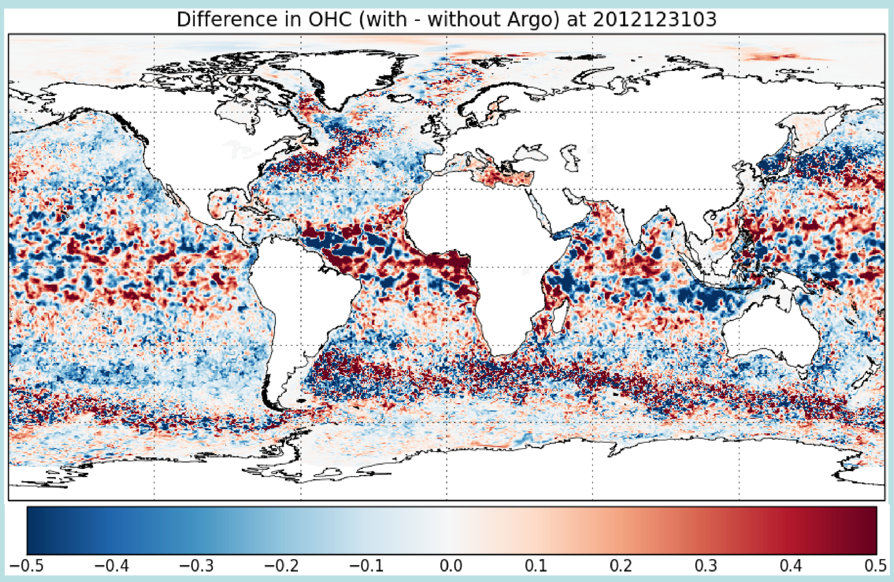


Figure: Air and sea surface temperature difference (°C) between the control and the no-Argo analyses at the end of the OSE run (control – no-Argo). Note the larger-scale differences near equatorial regions with persistent cloud cover which inhibits satellite SST observations.

Ocean Analysis Impact

Over the 13-month run, the most prominent SST differences were transient near-isotropic differences near the equator of approximately ±1º in addition to small-scale, chaotic differences in the Western Boundary Currents, and in the Antarctic Circumpolar Current. More significant differences between the experiments are seen in the near sub-surface where wide-spread, and in places large-scale, ocean heat content differences of ~5% are apparent. An analysis of the ocean innovation statistics has shown that removing the assimilation of Argo profiles from our system causes a large degradation in the temperature RMS error throughout the sub-surface water column and an increase in the bias, especially near the thermocline. A similar degradation in the salinity RMS error is seen throughout the water column. The greatest differences in the upper ocean seem to build over the first 6-months, but it is not clear if the full effects are realised by the end of the 13-month runs.



Above: Upper-ocean heat content difference (J, of top 300m) between the control and no-Argo analyses at the end of the OSE run.

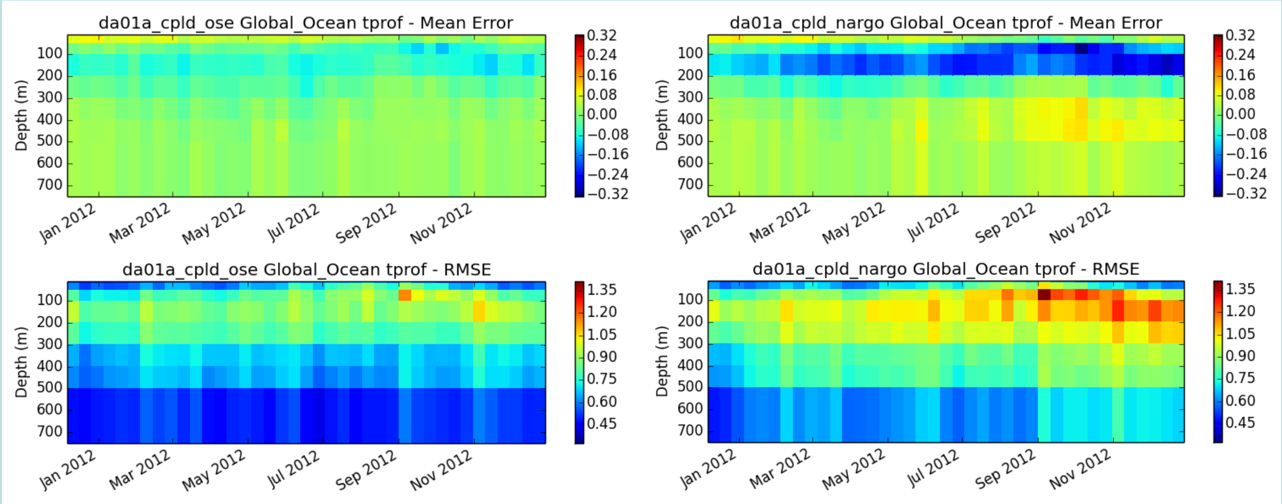
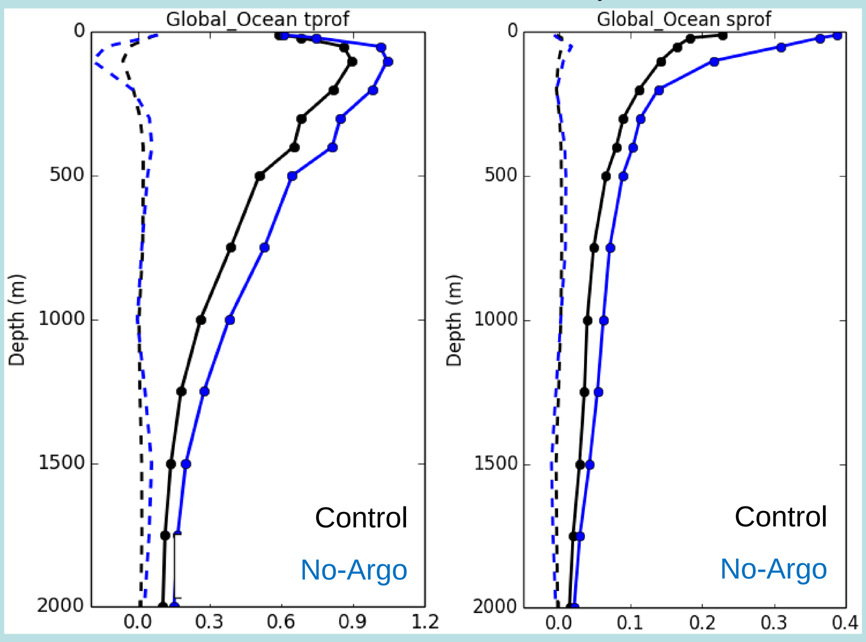


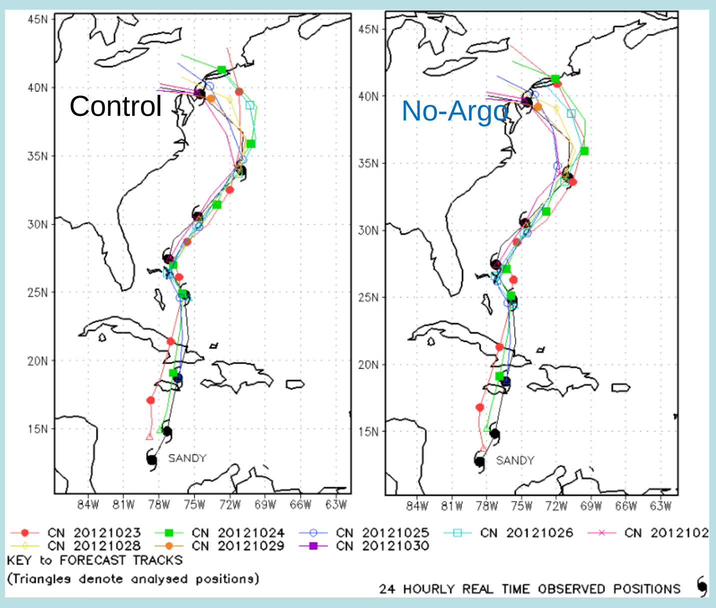
Figure: Time-series of the global temperature profile innovation statistics (mean error in the upper panels, RMS error in lower panels) for the control (left panels) and the no-Argo experiment (right panels).

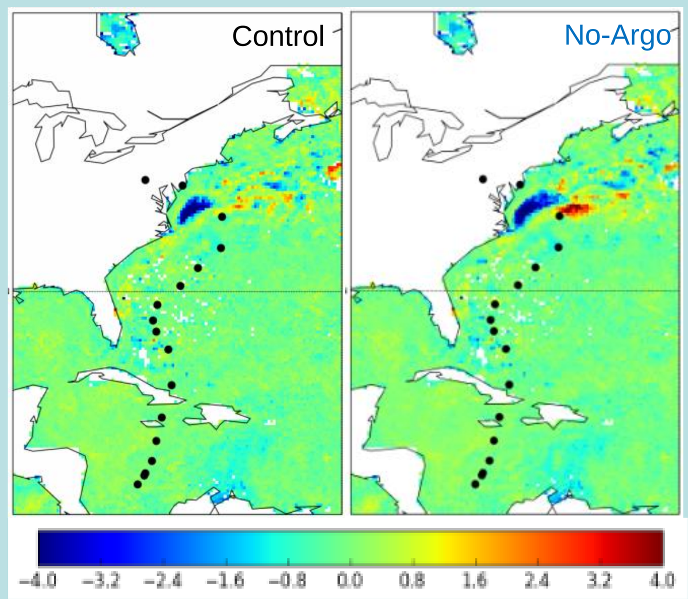
Below: Global temperature (left) and salinity (right) profile innovation statistics (RMS error shown as solid line, mean error shown as dashed line).



Case Study – Hurricane Sandy

Forecasts of Hurricane Sandy (initialised from analyses with and without Argo assimilation) showed no systematic improvements in the hurricane position (see below left) or intensity compared against the available observations. However, we found that assimilation of Argo profiles has an impact on the analysed position of the Gulf Stream with large-scale differences of up to 4°(see below right) and a consequent impact on surface fluxes.





Left: Forecast tracks for Hurricane Sandy for forecasts initialised at 00Z each day from 23-10-2012 to 30-10-2012 from the control (left) and no-Argo analysis (right).

Right: The mean SST observation-background differences binned to 0.25º for the control and no-Argo experiment over the period 22-30 October 2012. The best-track positions of the hurricane are show every 12 hours from 12Z on 22-10-2012.

The figure below shows a sequence of sea level pressure differences at different lead-times when the hurricane is passing across the Gulf Stream. In the analysis, no difference in position is apparent, but each of the forecasts show an offset position with a dipole, similar to the features seen in the SST and ocean heat content fields. This may indicate that, although the central pressures differ, the position of the hurricane in both experiments is well-constrained by the plethora of atmosphere observations in the analysis, but through the forecasts, when such observations are no longer available, the different upper ocean temperatures affect the development of the hurricane.

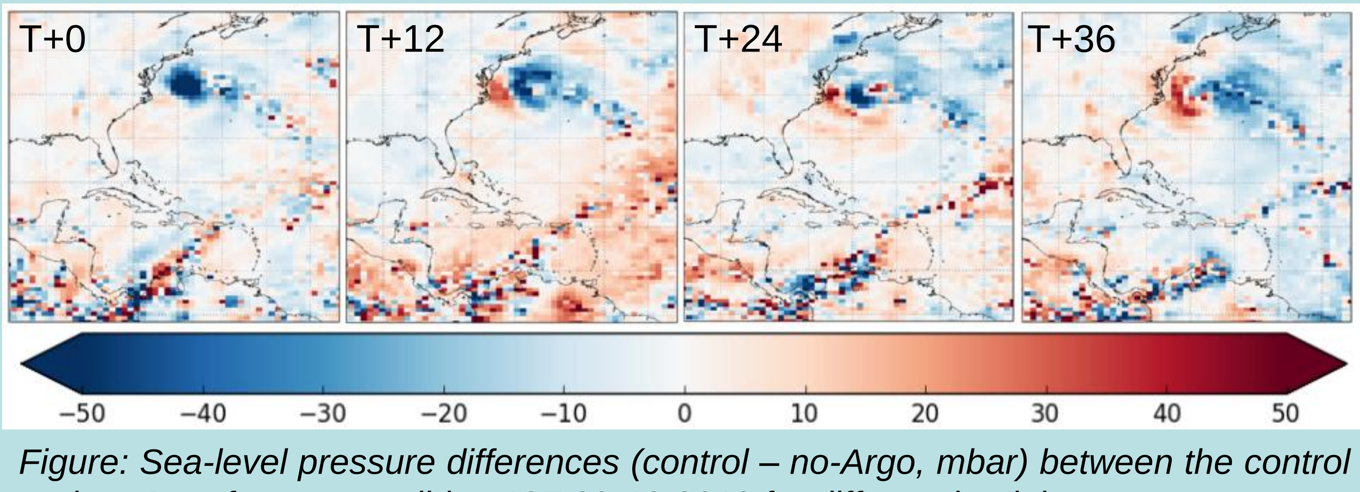


Figure: Sea-level pressure differences (control – no-Argo, mbar) between the control and no-Argo forecasts valid at 12Z 29-10-2012 for different lead times.

Conclusions

We have used a 13-month observing system experiment to investigate the effect of assimilating Argo profiles on coupled analyses and short-range forecasts using the Met Office weakly-coupled data assimilation system. An analysis of the ocean innovation statistics has shown that removing the assimilation of Argo profiles from our system causes a large degradation in the temperature RMS error throughout the sub-surface water column and an increase in the bias, especially near the thermocline. A similar degradation in the salinity RMS error is seen throughout the water column as there are no additional observations to constrain surface salinity. The greatest differences in the upper ocean seem to build over the first 6-months, but it is not clear that the full effects are realised even by the end of the 13-month run. Consequently, any OSE run over a shorter period is likely to under-estimate the impact of profile assimilation, especially for the deeper ocean.

Although the removal of Argo assimilation has some impact on the SST analysis, the atmosphere observation-analysis statistics showed negligible systematic global impacts on the atmospheric analyses. However, this was not unexpected due to the continued assimilation of all available atmosphere and SST observations in both experiments. On the other hand, forecasts of Hurricane Sandy highlighted the impact of Argo assimilation on the analysed position of the Gulf Stream, with possible impacts on forecasts after the hurricane passes over the Gulf Stream. Unfortunately, however, no systematic improvements in the position or intensity of the hurricane were found in a comparison against the available observations. Further work is ongoing to determine if there is an appreciable impact due to the sub-surface differences caused by the assimilation/denial of Argo observations. As part of the ERA-Clim2 project we will also be investigating the impact of SST assimilation within this coupled system.

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