The Met Office Coupled Atmosphere/Land/Ocean/Sea-Ice Data Assimilation System

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Outline

This presentation covers the following areas

- Why coupled NWP?
- Coupled data assimilation approaches
- Met Office weakly coupled DA
- Plans/future work

Why coupled NWP?

(see T. Johns' talk)

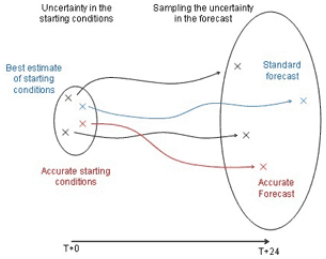
Potential benefits include:

- Improved modelling of lower boundary (diurnal cycle and mean fluxes, sea breezes, …)
- Improved modelling of strongly coupled phenomena (e.g. TCs, MJO)
- Better for "non-ocean" components that are difficult to model in atm-only (e.g. sea ice)
- Already running forced ocean forecast models (1 way coupling)

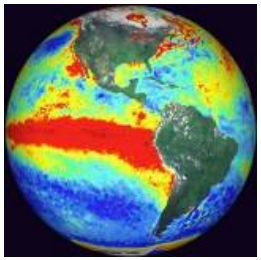
Coupled modelling with the UM

GC2.0 and its components

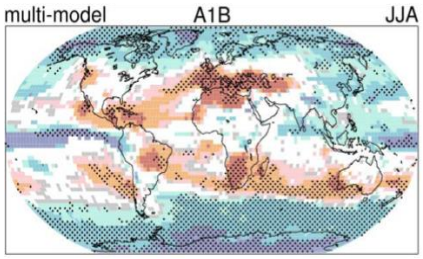
Coupled NWP



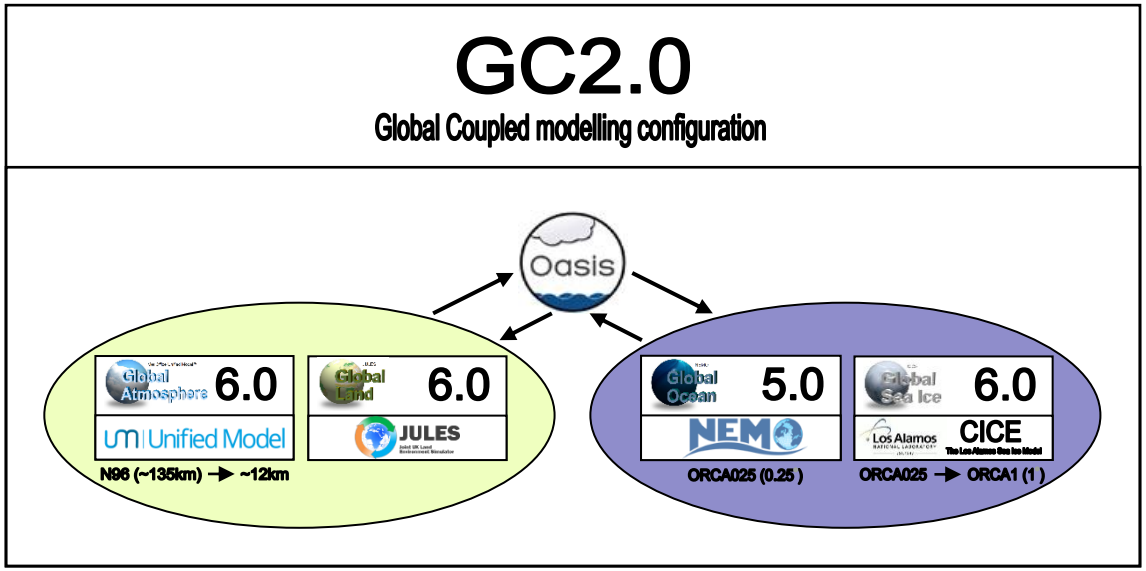
GloSea seamless EPS



Decadal Prediction

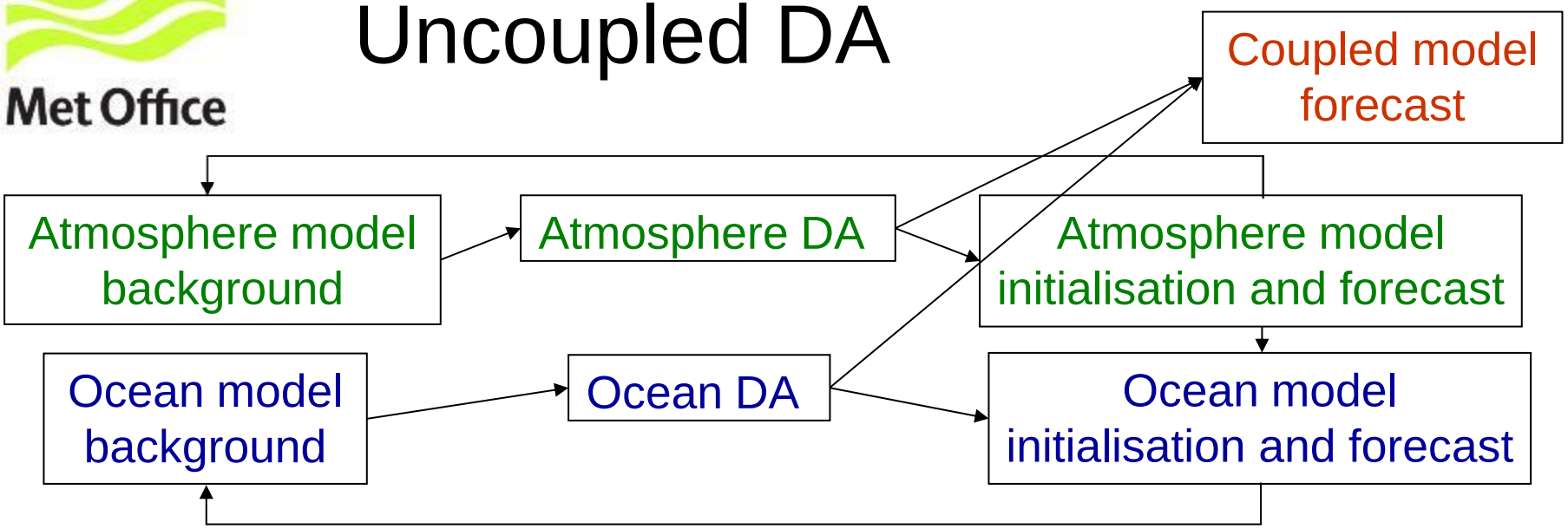


Climate Change studies



Coupled data assimilation

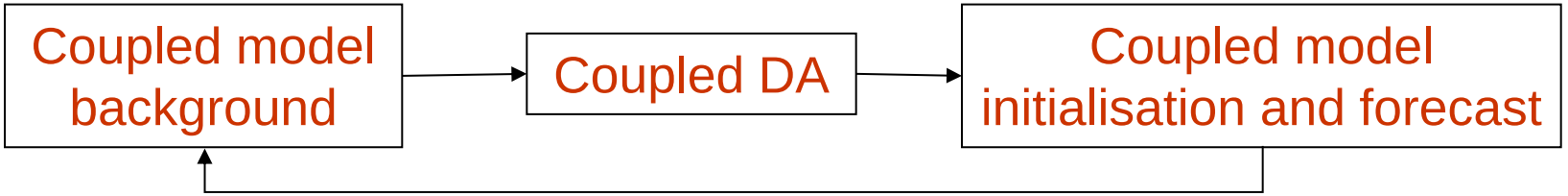
Uncoupled DA



- Straightforward ... use existing ocean and atmosphere analysis systems to initialise coupled forecasts
- No guaranteed consistency between initial states

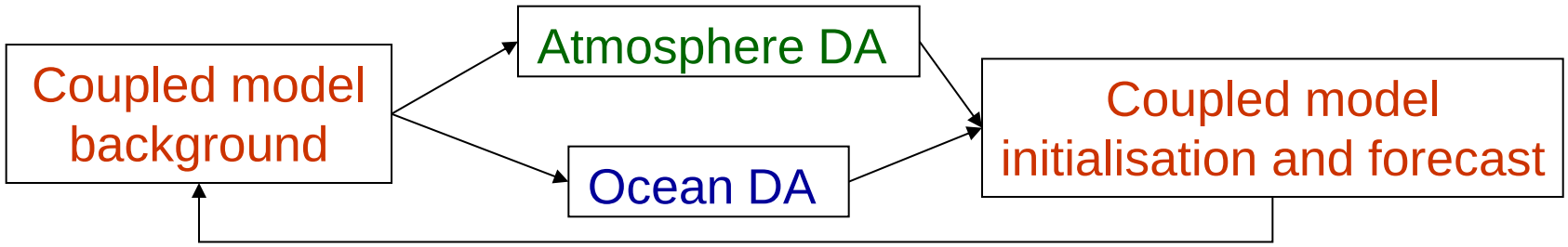
Johns, T.C., Shelly, A., Rodriguez, J.M., Copsey, D., Guiavarc'h, C., and Sykes, P., 2012. Report on extensive coupled ocean-atmosphere trials on NWP (1-15 day) timescales. (PMS key deliverable report, Feb 2012)
[Shelly, A., Johns, T.C., Copsey, D., and Guiavarc'h, C., 2011. Preliminary case-study experiments with a global ocean-atmosphere coupled model configuration on 1-15 day timescale. (PMS key deliverable report, Jan 2011)]

Fully (strongly) coupled DA



- Should give improved analysis and forecast because of more consistent initial conditions
  - Potentially less initialisation shock
- Less compartmentalised – have to understand the atmosphere and ocean if there are problems
- Work required to develop coupled DA compt

Weakly coupled DA



- Build system with existing components
- Still gives a more consistent initial state

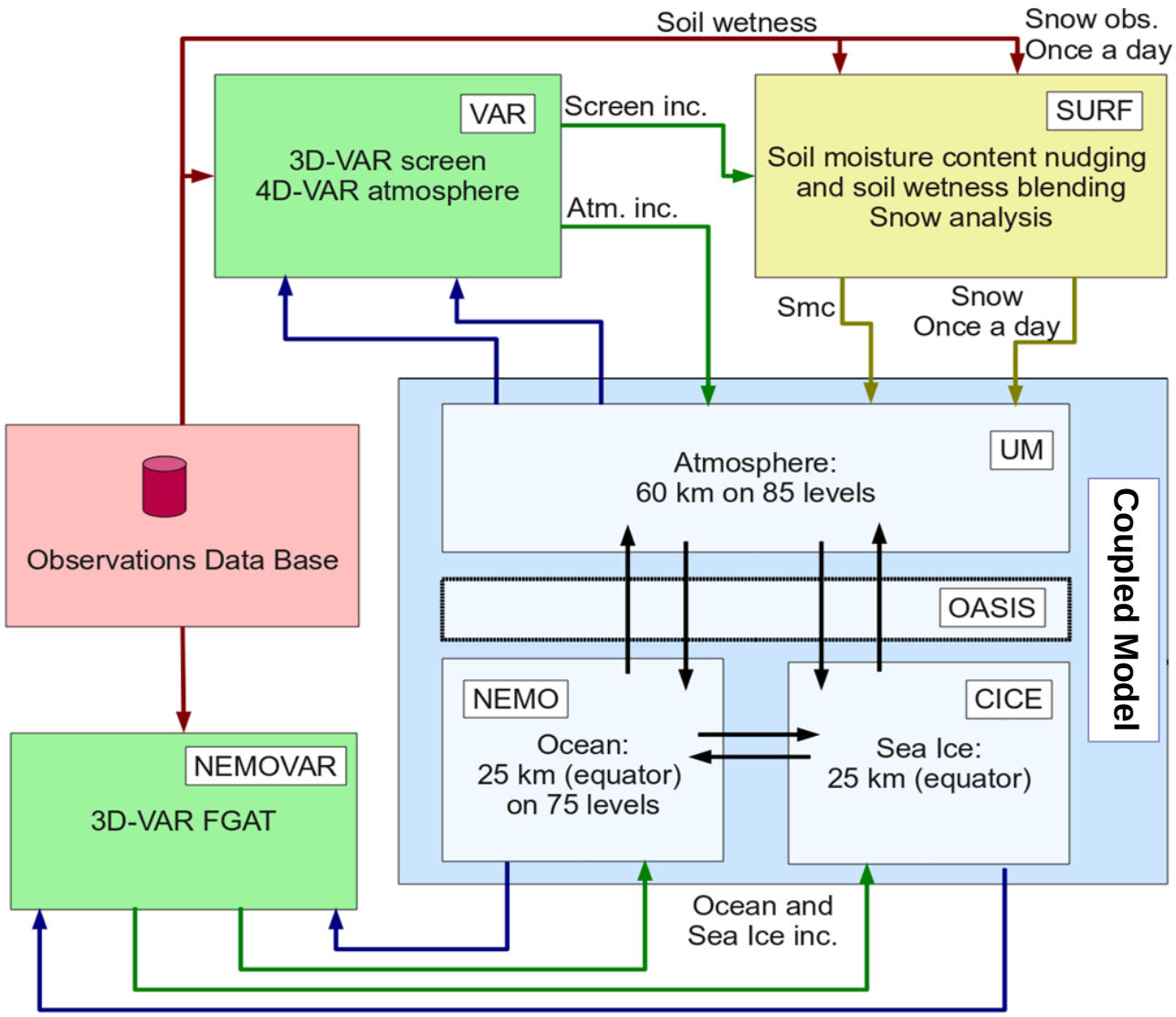
The weakly coupled DA system

Model components

	Models	Observations	Data assim system	Initialisation
Atmos	UM (N216) ~60km/L85 GA4.0	AIRS, IASI, ATOVS, GPSRO, SSMI, Aircraft, Sondes, Surf-Scat	4D-Var ~120km	Instantaneous (T-3)
Land	JULES ~60km/4 layers GL4.0	3D-Var Screen, ASCAT, NESDIS	Nudging Analysis	Instantaneous (T+3)
Ocean	NEMO ~25km/L75	In situ SST, T/S profiles, AATSR, AVHRR, AMSRE, Jason 1+2, ENVISAT	3D-Var FGAT	IAU
Sea Ice	CICE ~25km 5 categories	SSMI	3D-Var FGAT	IAU

Increased coupling frequency to 1 hour

Coupled DA components



Experimental setup

13 month coupled DA run Dec 2011 to Dec 2012

Focus on the impact of the coupled initialisation strategy

- on the performance of the data assimilation
- on the performance of short-range coupled forecasts.

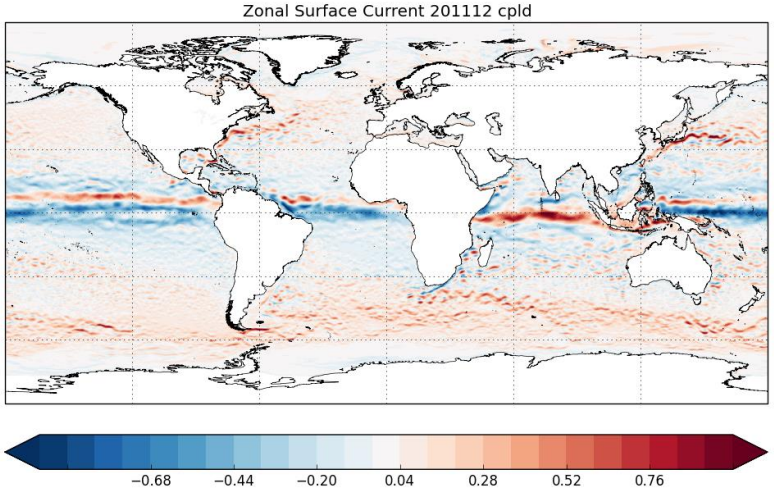
Compare to separate ocean and atmosphere DA runs with configurations the same as the coupled model equivalents

D. J. Lea, I. Mirouze, M. J. Martin, R. R. King, A. Hines, D. Walters, and M. Thurlow 2015, "Assessing a new coupled data assimilation system based on the Met Office coupled atmosphere, land, ocean, sea ice model", MWR early online:
http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-15-0174.1

Initial results – analysis runs

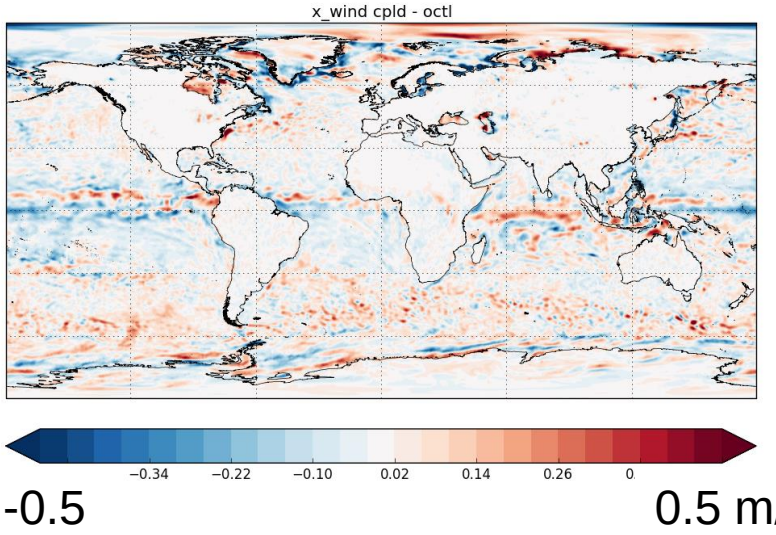
Ocean impact on atmosphere analysis (Dec 2011 average)

Ocean zonal current

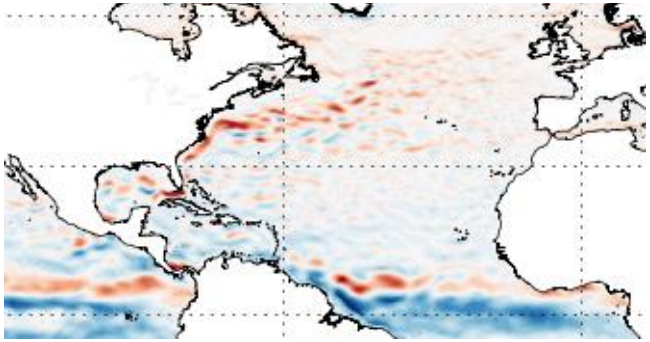


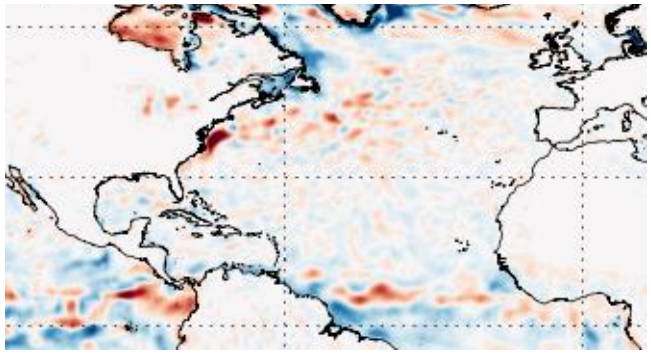
-1 1 m/s

Zonal wind: coupled control difference



-0.5 0.5 m/s





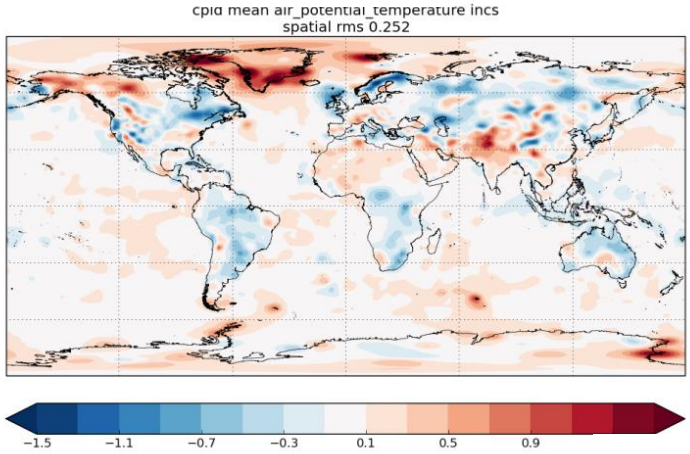
Monthly mean increments of surface air temperature (top) & ocean surface temperature (bottom) Dec 2011 – indication of model bias

Coupled

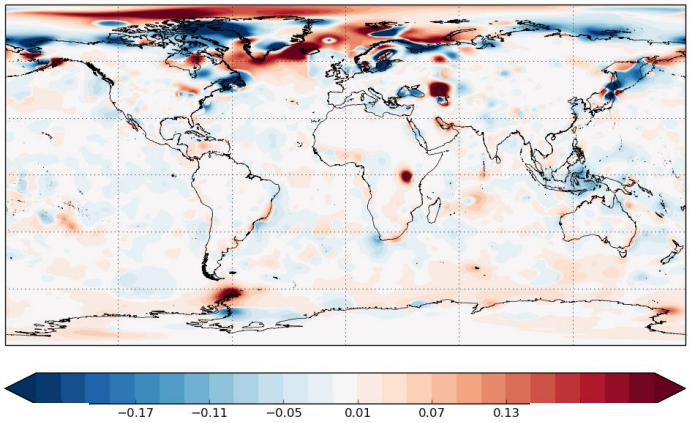
Abs(coupled) minus abs(ctl)

Blue good for coupled

Air

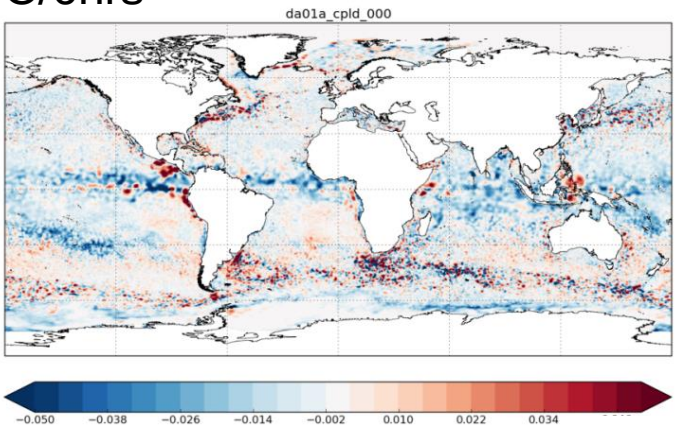


-1.5 ºC/6hrs -1.5

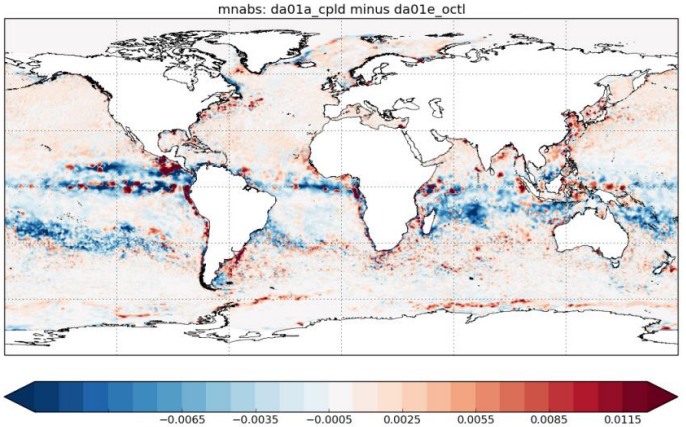


-0.25 0.25 ºC/6hrs

Ocean



-0.05 ºC/6hrs -0.05



0.0125 0.0125 ºC/6hrs

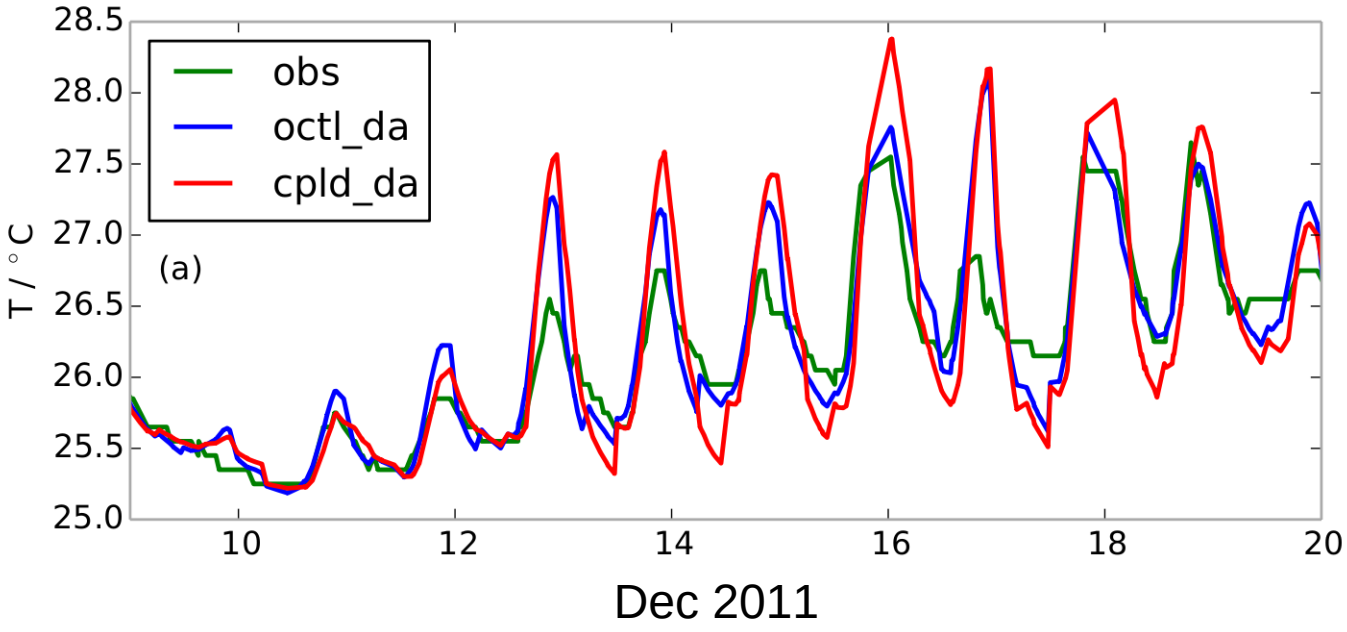
Ocean comparison to observations (obs-bkg RMS) coupled vs ocean control

	Coupled RMS	Ocean control RMS
SST in situ / deg C	0.4147	**0.3984**
SSH / m	0.0746	**0.0730**
Sea ice concentration	0.0296	**0.0295**
Profile T / deg C	0.6250	**0.6199**
Profile S / psu	**0.1243**	**0.1243**

- Not too bad given the coupled model has not been used in ocean data assimilation previously
- Would like to understand the reasons for the degraded statistics in particular:
- SST
- SSH

Why are SST stats degraded in coupled model?

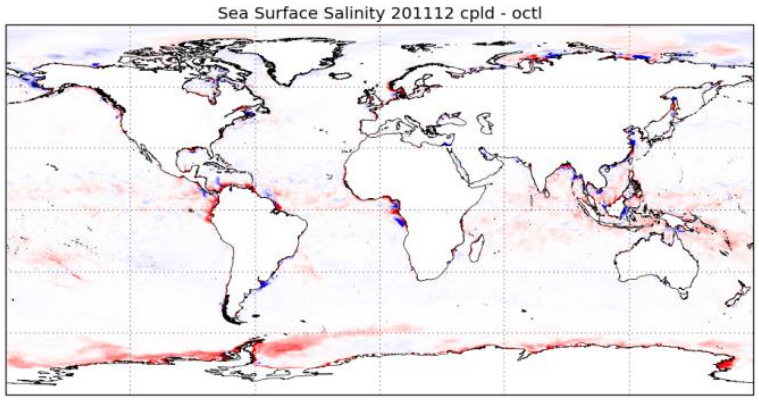
Diurnal cycle of a drifter (30cm depth) in the South Pacific

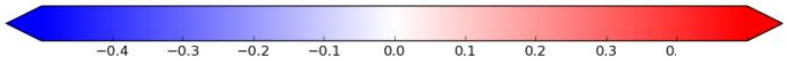


- Both coupled and uncoupled models lack an explicit diurnal model
- Ocean control errors lower but possibly compensating errors

Monthly mean differences (coupled minus control) of sea surface salinity

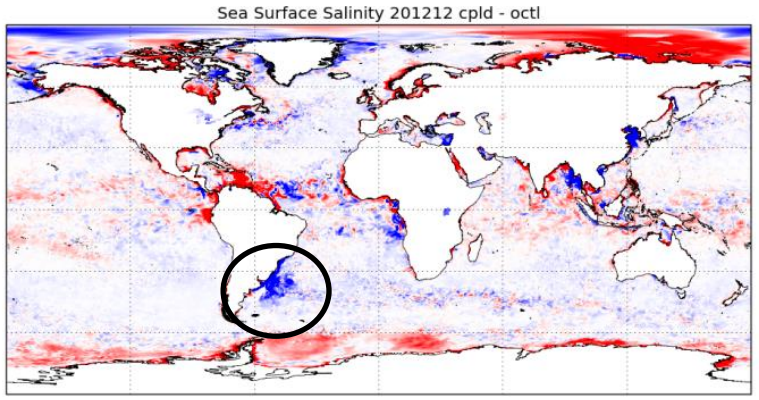
Month 1

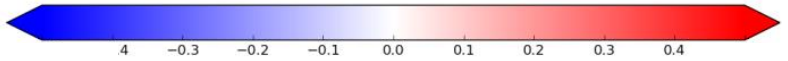




-0.5 0.5 psu

Month 13



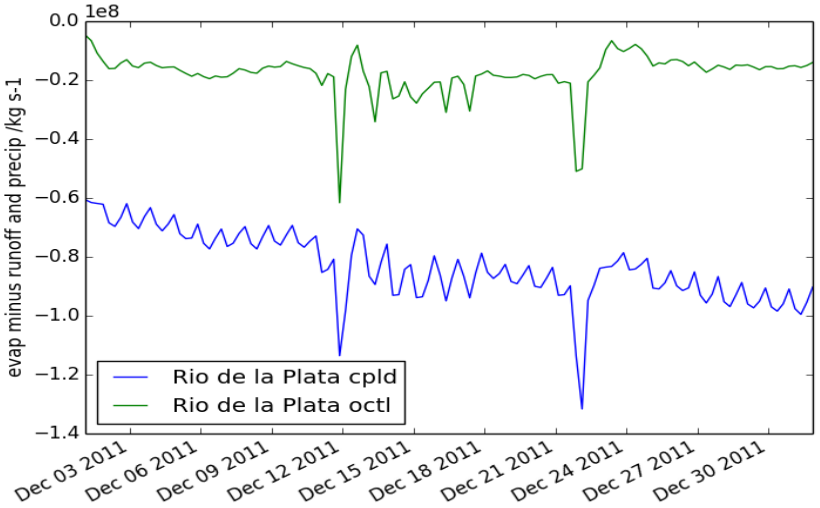


-0.5 0.5 psu

Increasing differences in surface salinity between the coupled and control.

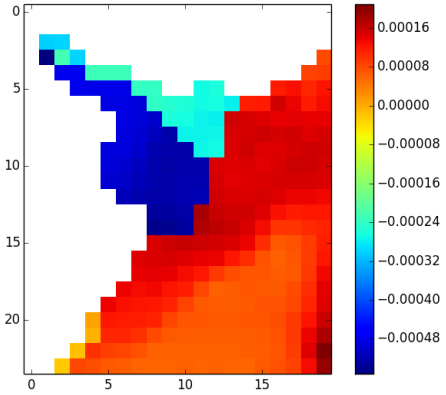
Not clear from comparison to salinity obs which is correct (sampling sparse)

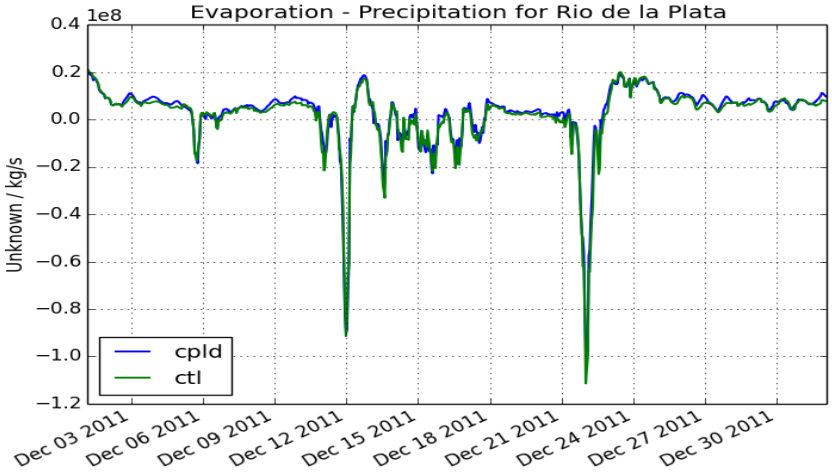
River Plate
Evaporation minus precip and runoff (freshwater flux out of the ocean)



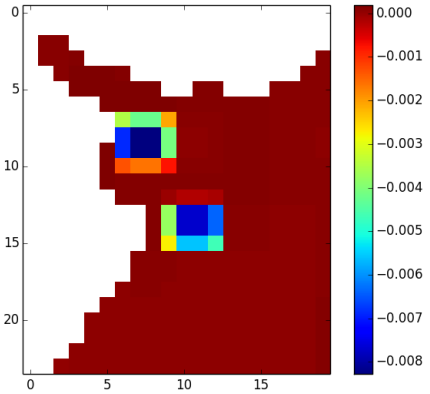
Runoff difference

Ocean control





Coupled model

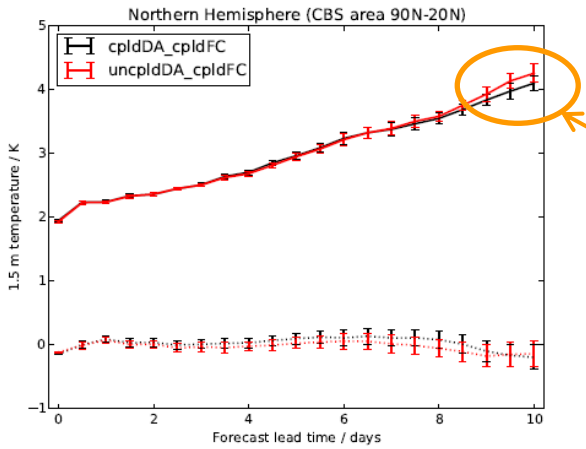


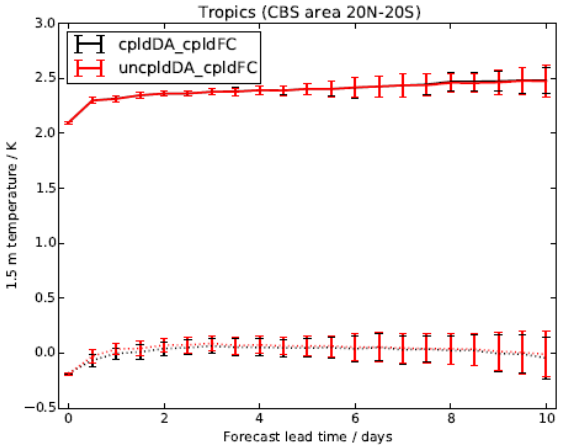
kg m-2 s-1

Forecast results

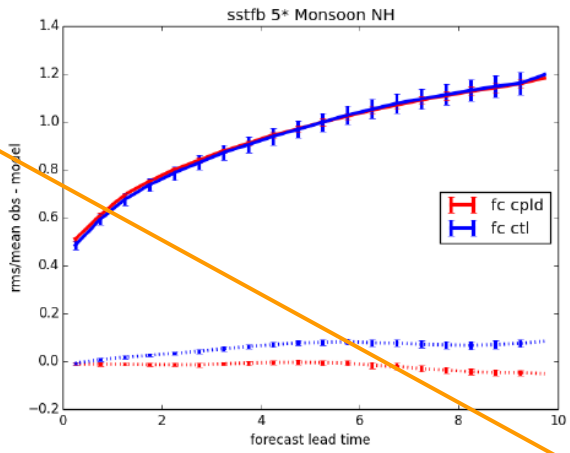
CPLD DA Forecasts versus Control DA Forecasts
Large scale regional bias and RMSE

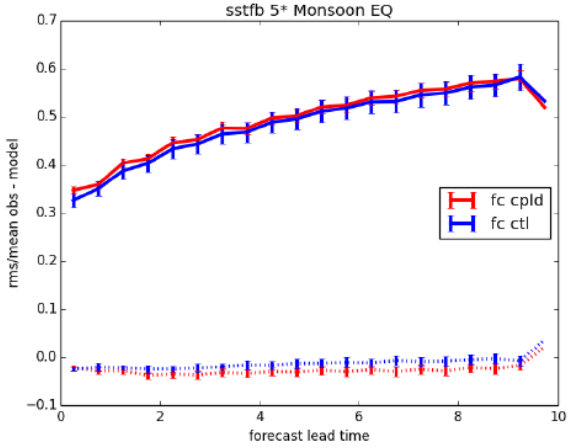
Surface air-temperature f/c errors





SST f/c errors





10-day forecasts for 26 August -15 September 2012

Two forecasts per day (00z and 12z)

- **<u>Generally only a small impact on f/c errors</u>**

- Positive impact on 9-10 day air-temperature f/c in NH in FC_CPLD_DA (significant?)

- Impact on NH SST bias

- Small impact on SH RMS SST errors (not shown)

Forecast results summary

5 day and 10 day forecasts run for selected periods (Dec 2011, Monsoon: 26 Aug-15 Sept 2012, Sandy: 20 Oct-31 Oct 2012)

Performance of the atmosphere forecasts is very similar in coupled and control DA

Performance of the ocean forecasts:

- Month 1 (Dec 2011) similar in coupled and control (SST diurnal error does not affect the forecasts)
- Later (e.g. Aug/Sep/Oct) the coupled forecast performance is hampered by the drift in the ocean analysis (described earlier).

Conclusions & future work

Conclusions

- Coupled and un-coupled DA compared in one-year trials.
- Reasonable results given this is the first time these coupled model and data assimilation systems are put together
- Impact of the ocean currents visible in the atmosphere.
- Some issues of the coupled model are highlighted by coupled DA:
  - The amplified diurnal cycle probably leads to the innovation statistics for SST and upper temperature profiles being slightly worse, although mean increments are smaller
  - Problem with the river run off. This may stem from P-E errors
- Demonstrates that the demands of coupled DA can highlight issues with the coupled model that might not be otherwise noticed. Such improvements should then feed back into improved climate modelling.

Ongoing and future work

- Implement a GC2 demonstration operational system for coupled DA in 2016
- Upgrade system in-line with operational NWP/FOAM
- Continue research on inter-fluid error covariances, modelling diurnal cycle and freshwater errors in DA
- Work towards operational coupled NWP (and retirement of uncoupled systems) on timescale of 2-4 years?

Met Office

Questions?