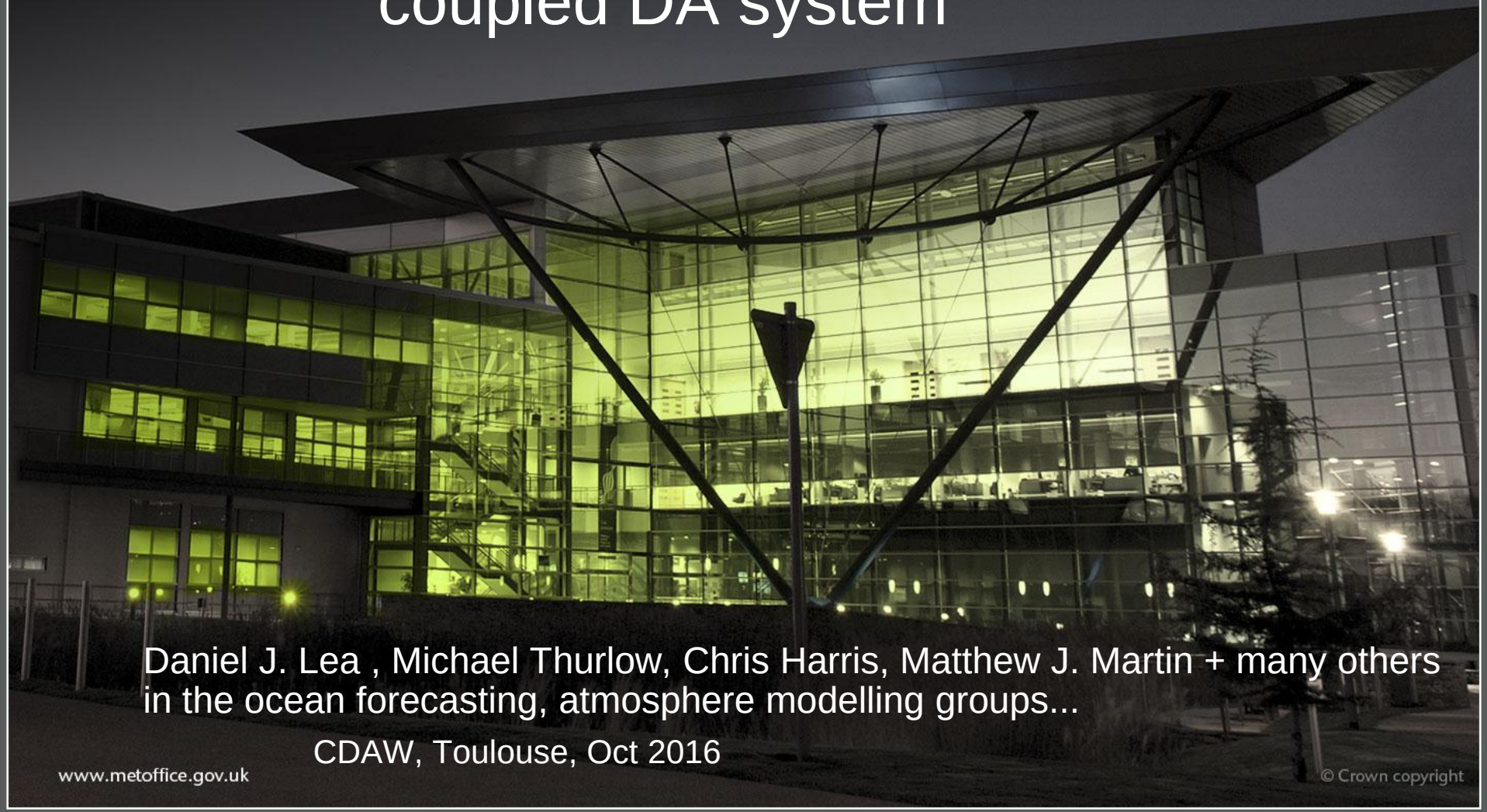
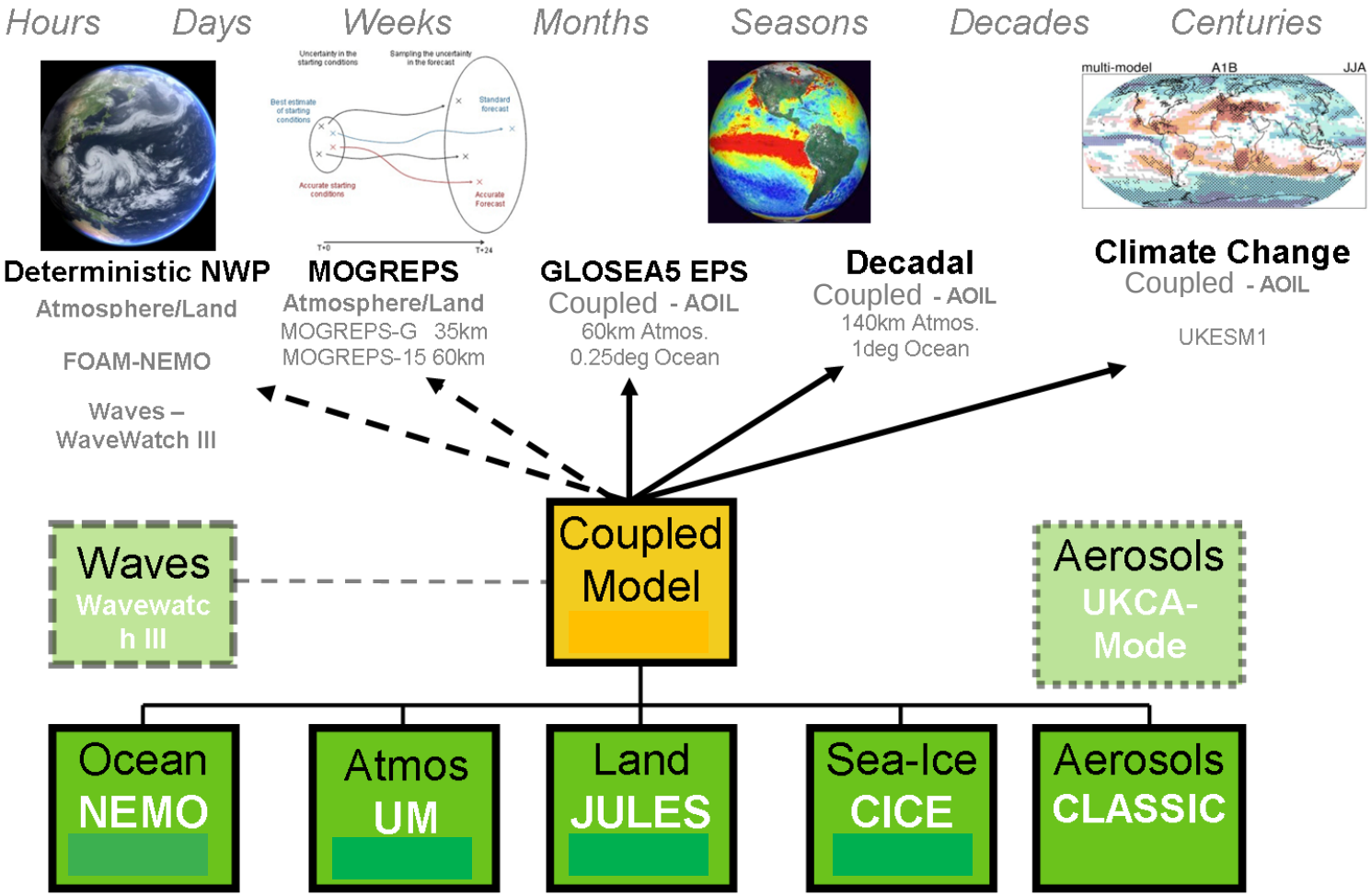
Met Office implementation of a demonstration operational weakly coupled DA system



Daniel J. Lea , Michael Thurlow, Chris Harris, Matthew J. Martin + many others in the ocean forecasting, atmosphere modelling groups...

CDAW, Toulouse, Oct 2016

Global modelling at the Met Office



Introduction
Objectives and status

Ultimate aim is to produce operational global coupled NWP forecasts, i.e. weather forecasts and short-range ocean/sea-ice forecasts generated using a coupled model.

- Weakly coupled ocean/sea-ice/atmosphere/land data assimilation system was developed in N216/ORCA025 (60km/25km) configuration and reported in Lea *et al.* (2015).

- Demonstration operational system based on an updated version of the above (with increased atmospheric resolution to N320, 40km) is now being implemented.

    - Main objective of this implementation is to demonstrate that a coupled DA system can be run in an operational environment, dealing with issues to do with, for instance, late arrival of ocean observations.

- Future work, by ~2019, is to upgrade the resolution of the demonstration operational system so that the atmospheric resolution is the same as the global operational NWP system (i.e. N1280), and ocean resolution is 1/12 degree. A lower resolution coupled ensemble system will also be developed.

The weakly coupled DA system assessment of coupled DA

D. J. Lea, I. Mirouze, M. J. Martin, R. R. King, A. Hines, D. Walters, and M. Thurlow, Assessing a New Coupled Data Assimilation System Based on the Met Office Coupled Atmosphere–Land–Ocean–Sea Ice Model in Monthly Weather Review Nov 2015

Model components

	Models	Observations	Data assim system	Initialisation
Atmos	UM (N216) ~60km/L85	AIRS, IASI, ATOVS, GPSRO, SSMI, Aircraft, Sondes, Surf-Scat	4D-Var ~120km	Direct
Land	JULES horiz res as atmos / 4 layers	3D-Var Screen, ASCAT, NESDIS	Nudging Analysis	T/2 Direct
Ocean	NEMO (Orca025) ~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

Model components coupling frequency 1 hour

DA systems separate (ie. Weakly coupled DA)

Experimental setup

Already know that coupled model forecasts are superior to un-coupled ocean or atmosphere models on short to medium-range (to 15 day) forecasts (e.g. Johns et al., 2012).

Instead focus on the impact of the coupled initialisation strategy

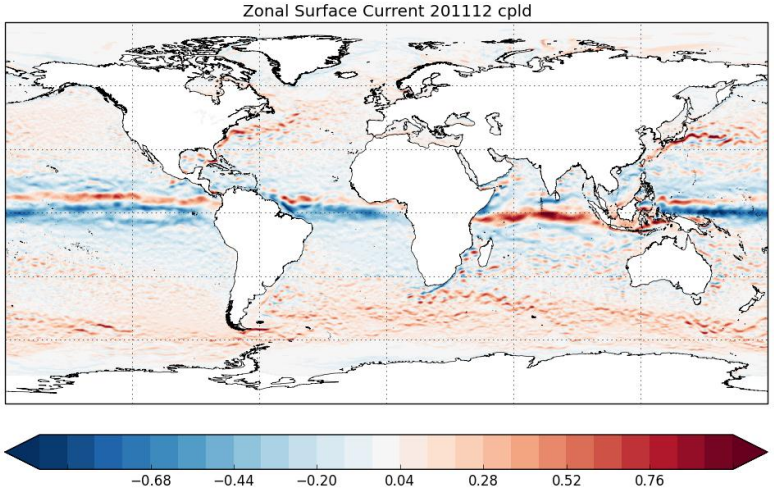
- on the performance of the data assimilation
- on the performance of short-range coupled forecasts.

13 month coupled DA run Dec 2011 to Dec 2012

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

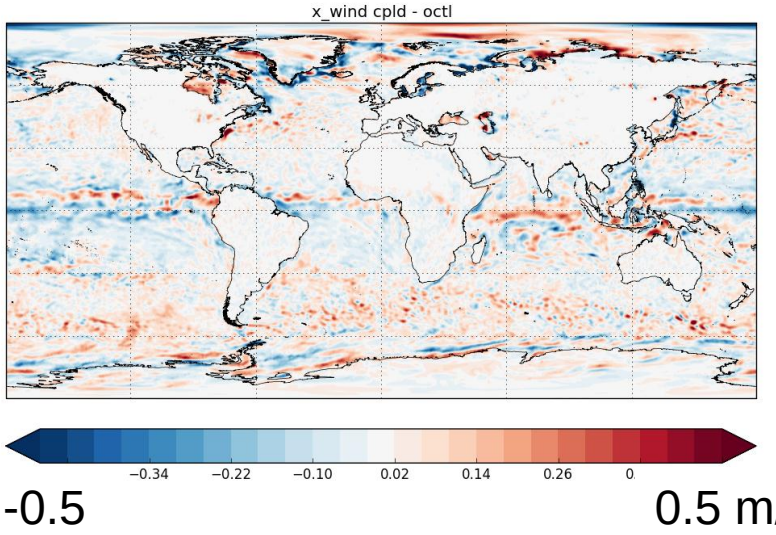
Ocean impact on atmosphere analysis (Dec 2011 average)

Ocean zonal current

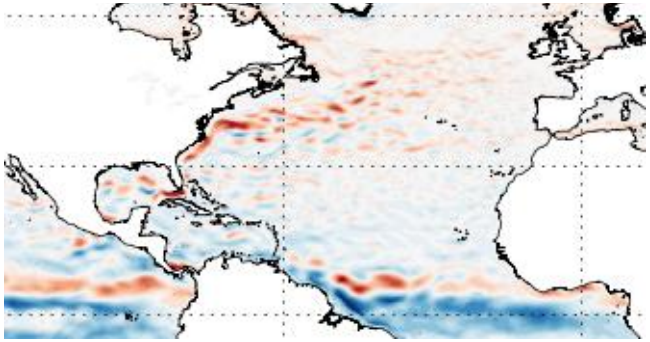


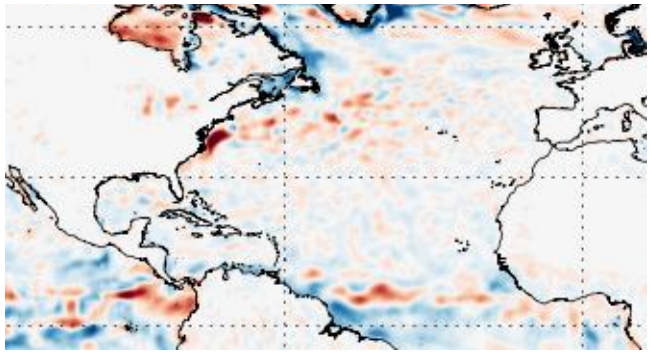
-1 1 m/s

Zonal wind: coupled control difference



-0.5 0.5 m/s





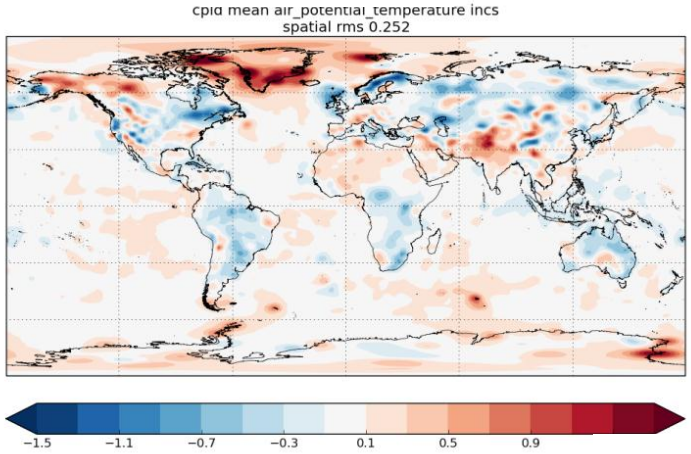
Monthly mean increments of surface air temperature (top) & ocean surface temperature (bottom) Dec 2011 – indication of model bias

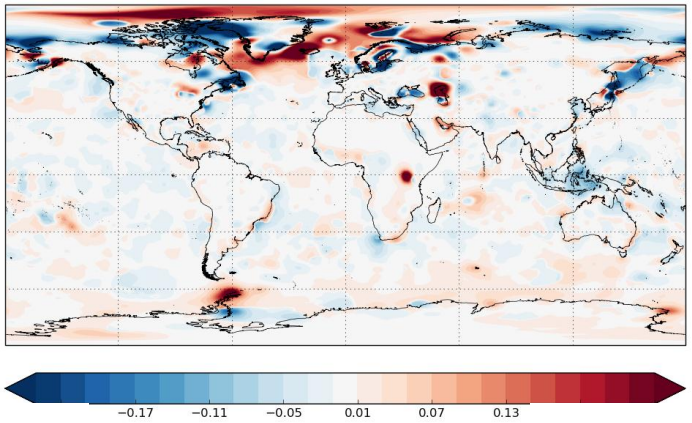
Coupled

Abs(coupled) minus abs(ctl)

Blue good for coupled

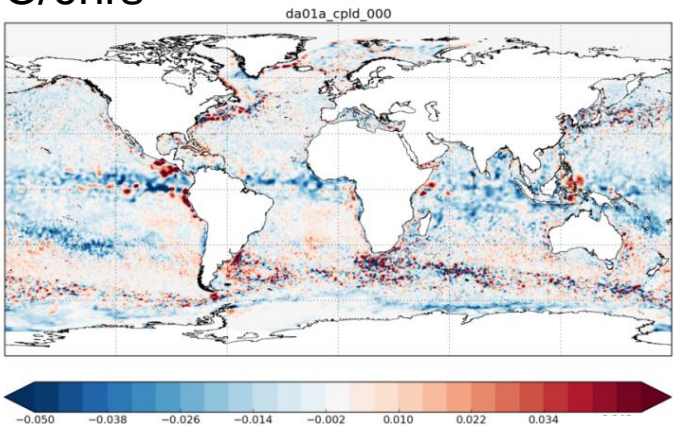
Air

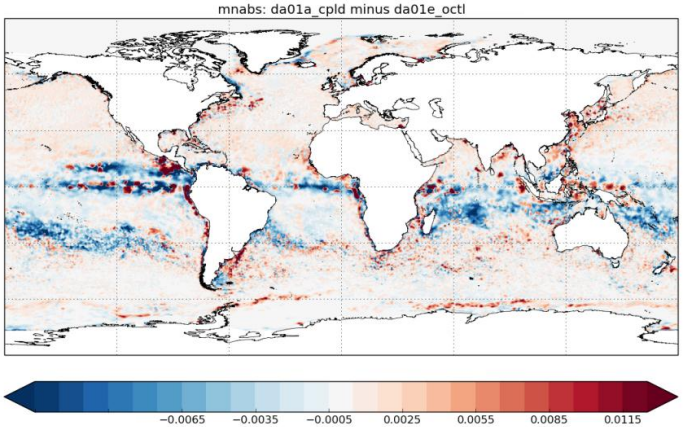




-1.5 ºC/6hrs -1.5 -0.25 0.25 ºC/6hrs

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**

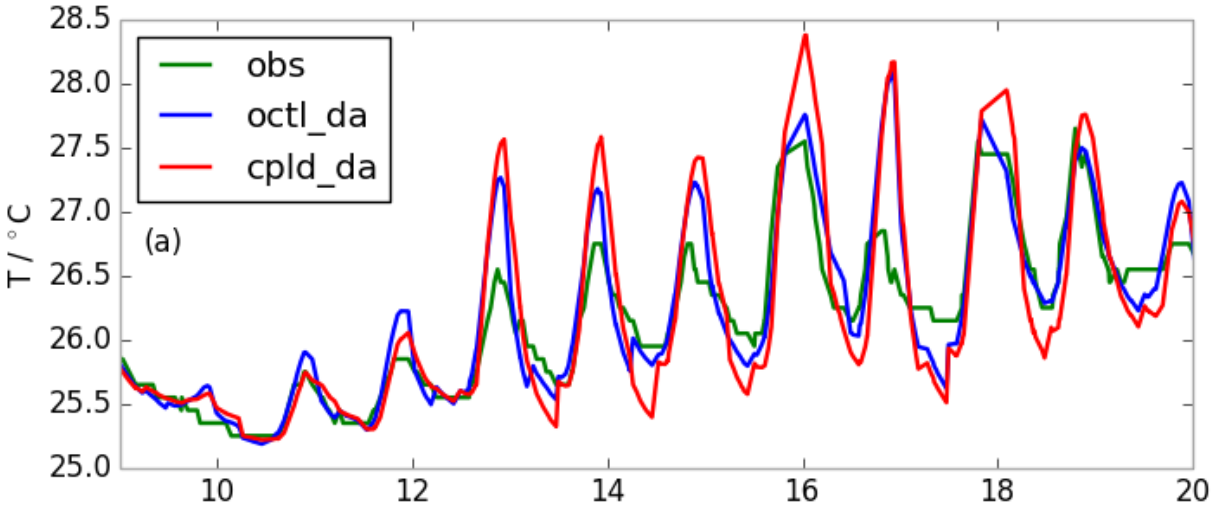
- Not too bad given the coupled model had not been used in ocean data assimilation previously
- Atmosphere statistics (not shown) similar for coupled vs atmosphere control
- Would like to understand the reasons for the (slightly) degraded SST and SSH statistics in particular

Why SST statistics are a bit worse in the coupled model?

Only really the case where the diurnal cycle is strong.

E.g. SST from a drifter (30cm depth) in the South Pacific

Observed SST
Control
Coupled DA

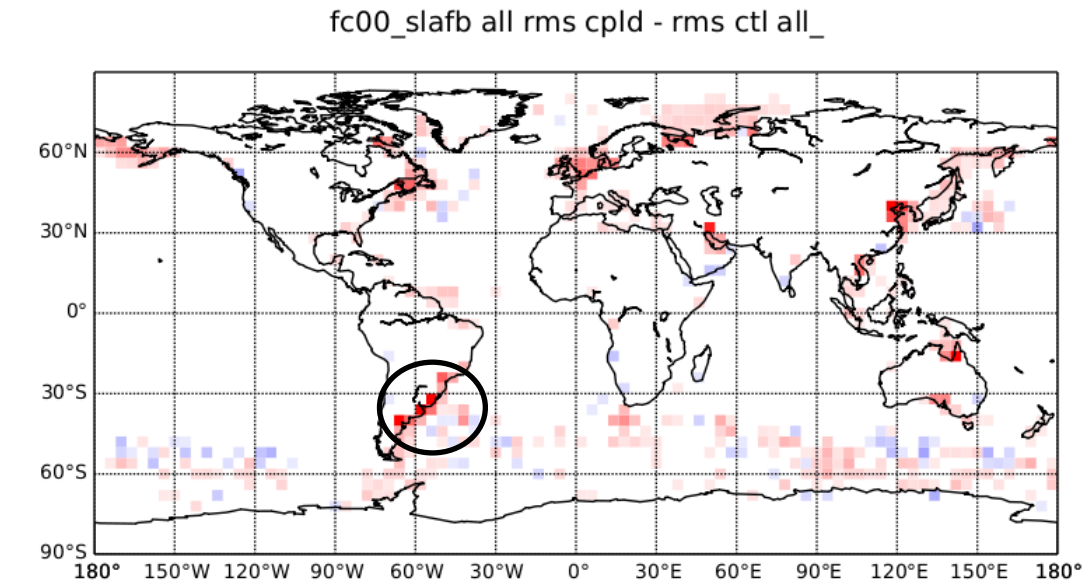


December 2011 day (UTC)

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

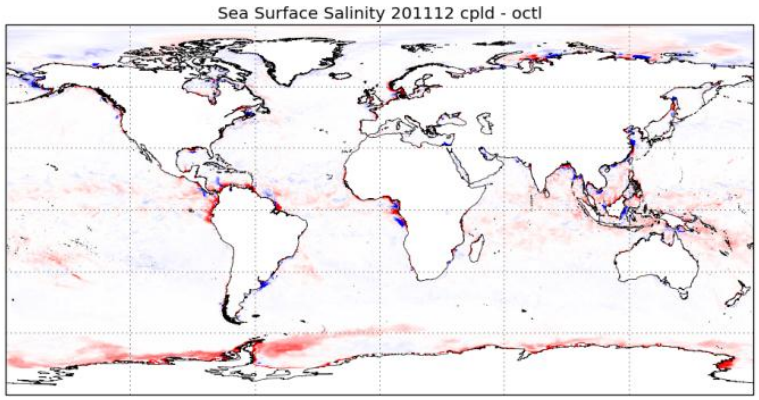
Where does the SSH error increase in coupled model

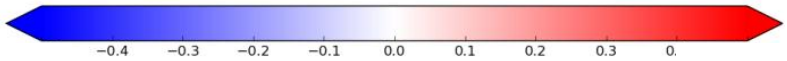
Binned SSH RMS obs model differences over the 13 months of the analysis. Coupled minus control



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

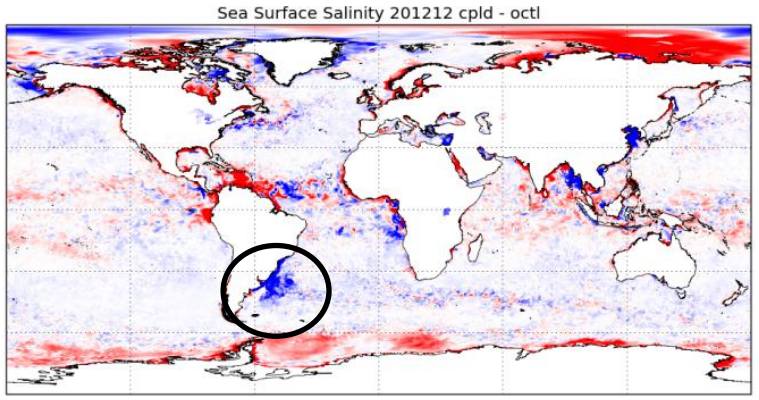
Month 1

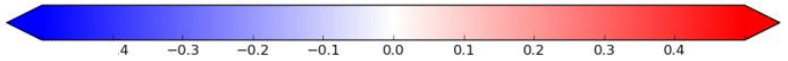




-0.5 0.5 psu

Month 13





-0.5 0.5 psu

Increasing differences in surface salinity between the coupled and control.

Comparison to salinity obs suggests the control may be closer to truth (but note limited sampling)

Demonstration operational coupled DA system

Demonstration operational coupled DA system

Intended as a technical demonstration to see how the system can work in an operational setting

The atmosphere resolution is too low to give comparable weather forecast results to the existing (non-coupled) NWP system

Resolution increased for the atmosphere to 40km (N320) from 60km.

This brings the atmosphere closer to the ocean resolution ~25km which may improve the two way feedback.

Demonstration operational coupled DA system

Running 6 hour cycles (to match atmosphere) but we're used to running the ocean on longer cycles. In the Met Office we receive

Profile: 20% data in 6 hours, 96% data within 24 hours

Altimeter: 0% data in 6 hours, 99% data within 24 hours

In-situ and satellite SST: 20%/40% data in 6 hours, 100% data within 24 hours

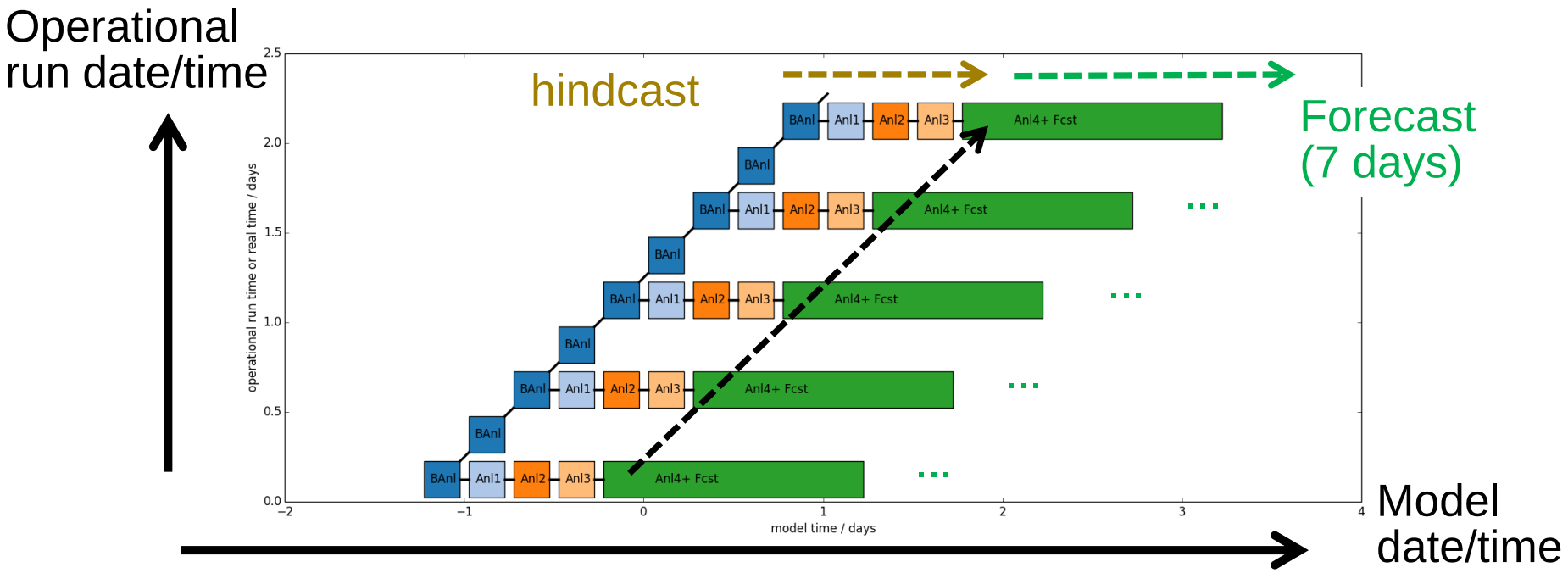
Seaice: 0% data in 6 hours, 100% in 24 hours

Note our internal processing chain adds delays on top of the those from the data providers. E.g. Jason-3 Altimeter

Demonstration operational coupled DA system

Dealing the data delays

Using sub-cycles



In future we may be able to reduce the number of sub-cycles as ocean observation latency is reduced

Changes for the demonstration system

Switched to climatological river runoff in the ocean to fix the salinity drift in the ocean

Now assimilating SST over the large lakes/inland seas which may fix some atmospheric biases seen on and near the large lakes.

Not yet implemented but a future version of the coupled model will include an explicit diurnal skin model and this should resolve some of the problems caused by not having this.

How is it going

The model has been running operationally for about a month and we've been working through various implementation issues. When it has run longer we will do more detailed assessment

We'll be comparing it to uncoupled systems again although the comparisons won't initially be clean due to some differences in the model resolutions

An uncoupled atmosphere only system at N320 is planned which will give a cleaner comparison

We also plan assess the impact of observation latency by comparing the difference between sub-cycles at the same actual time

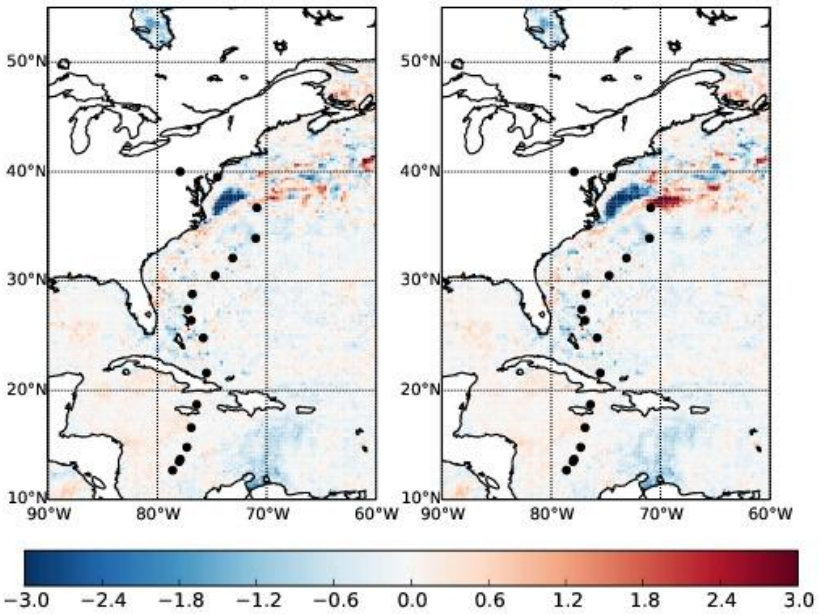
Other ongoing work

OSE (Coupled) impact of Argo withholding on Hurricane Sandy

Argo

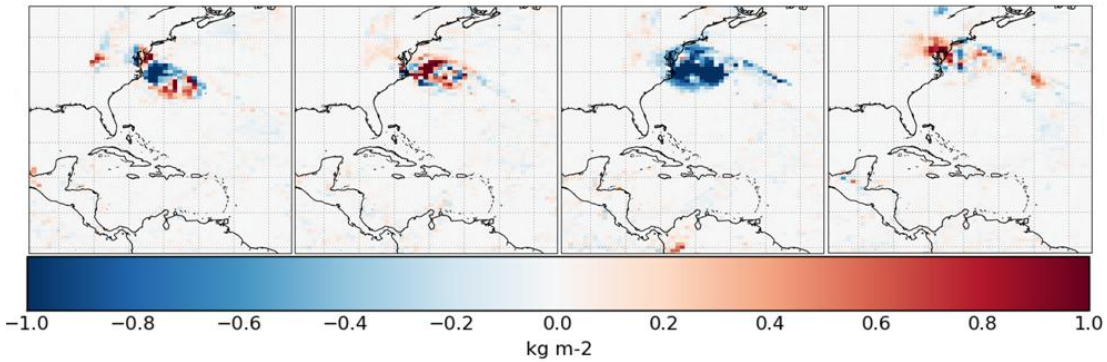
No Argo

SST obs – bkg



- 12 hour Hurricane positions

Rainfall diff (Argo – No Argo)



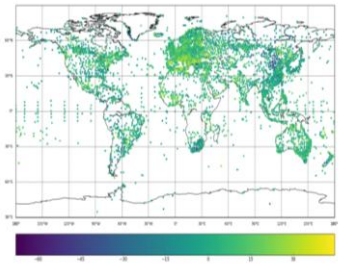
Towards development of fully coupled data assimilation

Techniques for calculating coupled error covariances from outputs of a weakly coupled data assimilation experiment

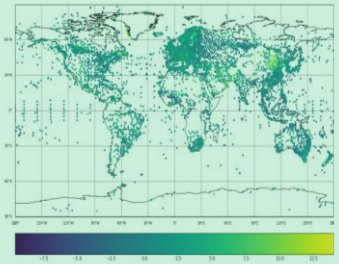
- Results from innovation-based method using METO coupled DA system for Jan-March 2009. Atmos/ocean innovations match-ups within 0.1 degrees and 6 hours.

Ocean & atmosphere innovations from coupled DA run every 6-h

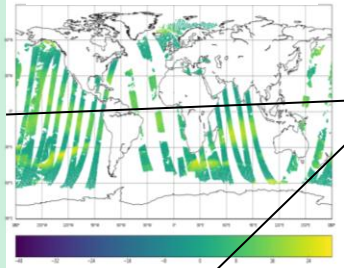
2m air humidity



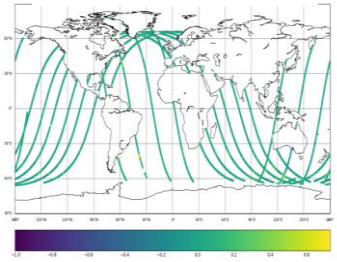
2m air temperature



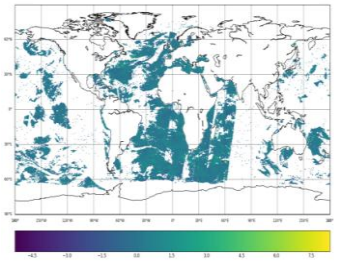
U10



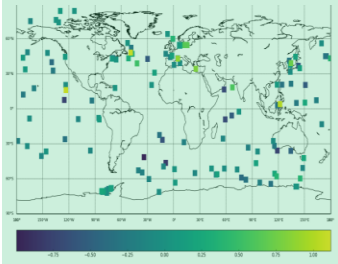
SLA



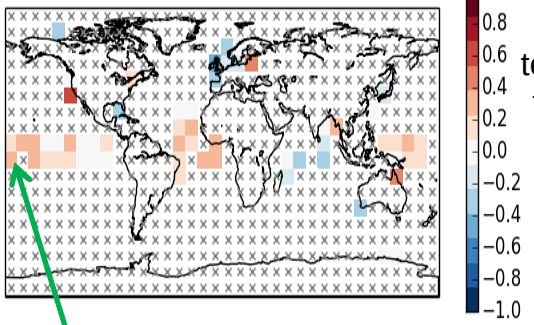
SST



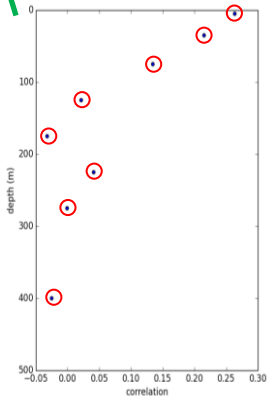
Temperature profiles



Background error correlations



2m air temperature and top 10m ocean temperature



2m air temperature and top sub-surface ocean temperature in selected 10 degree box

0.3 correlation

Summary / final comments

Summary 1/2

- Coupled NWP is the present and future for Met Office forecasting
- We saw reasonable results for the first coupled DA system given this was the first time these coupled model and data assimilation systems are put together
- Good enough to take the work forward with a demonstration operational coupled DA system which is now running
- With the operational coupled DA system we have addressed some of the main deficiencies in the first coupled DA runs in particular Lake atmosphere errors and river runoff errors.

Summary 2/2

Ongoing work:

- OSEs in the coupled system to test the impact of ocean data on the coupled system including the atmosphere
- Looking at inter-fluid error covariances. (could be the first step to more strongly coupled DA)
- Assess the results of the operational coupled DA system

Next:

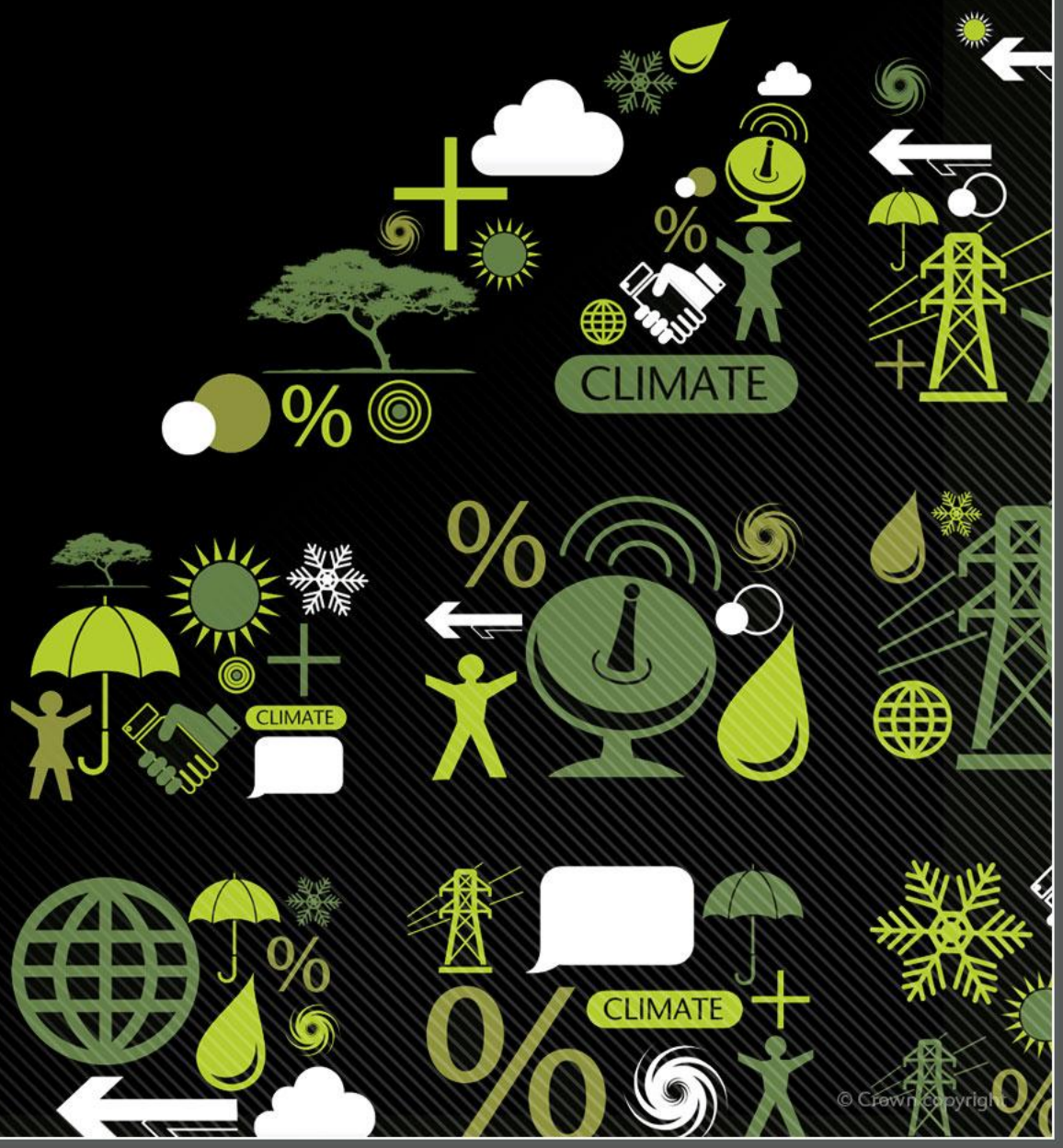
- Coupled DA with a coupled model with an explicit diurnal model
- Coupled model with waves
- Coupled weather forecasting/NWP which requires...
- Higher resolution ocean (1/12 degree ORCA12 ~10km) and atmosphere (N1280 ~10km) coupled NWP forecasts from ~2019 with a lower resolution coupled ensemble.
- Investigate more fully coupled DA.

Met Office

Thank you

Questions?

Met Office



www.metoffice.gov.uk

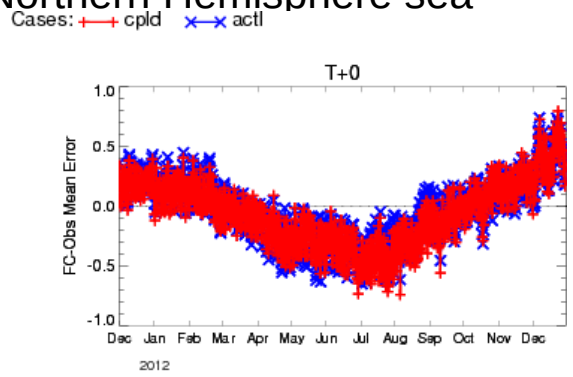
Atmosphere comparison to observations over 13 months

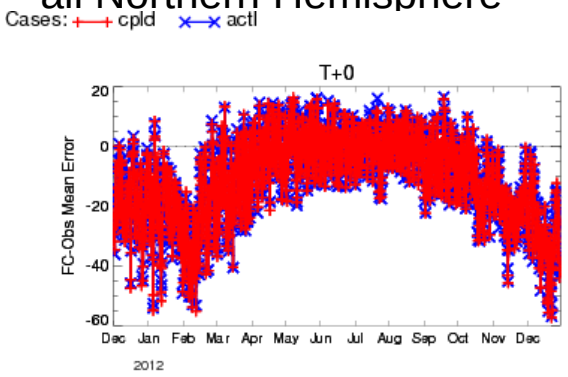
1.5m temperature over the Northern Hemisphere sea

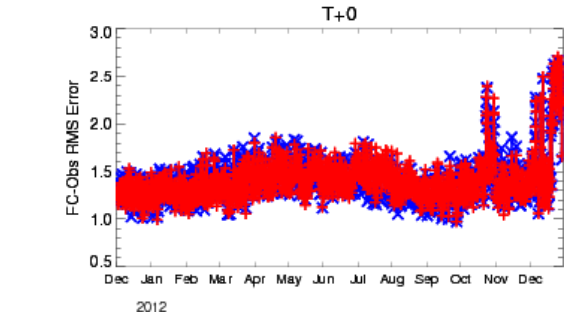
Mean sea level pressure over all Northern Hemisphere

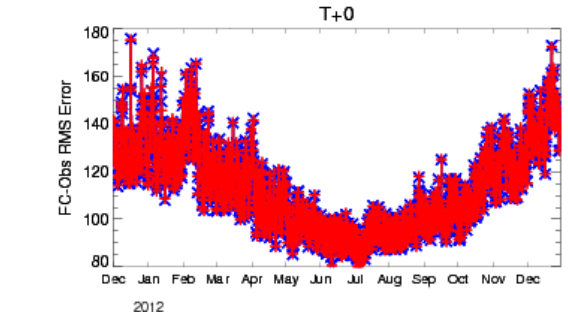
Bias

RMS



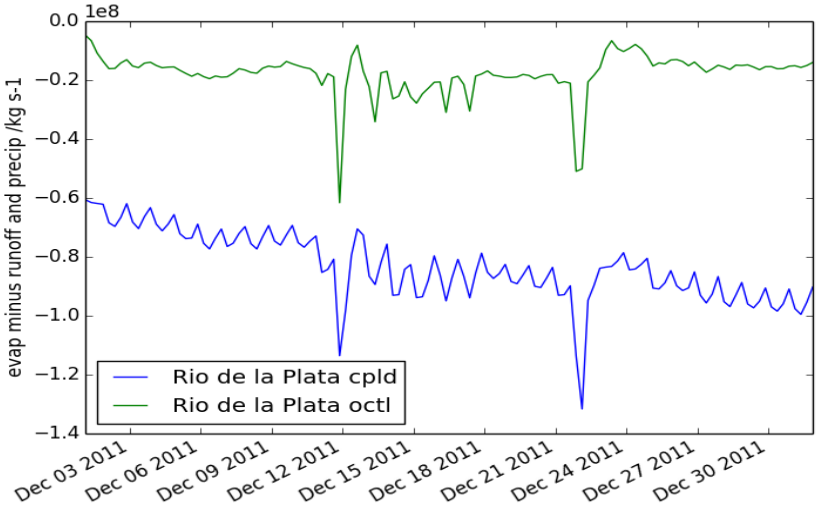






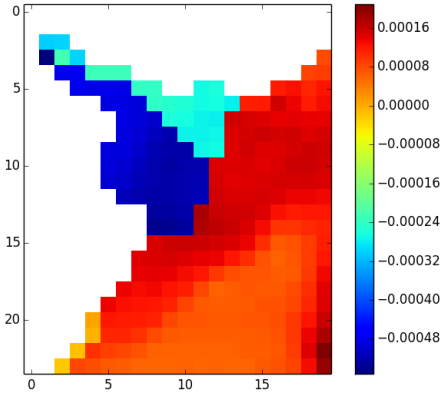
coupled vs atmosphere control (Table**)

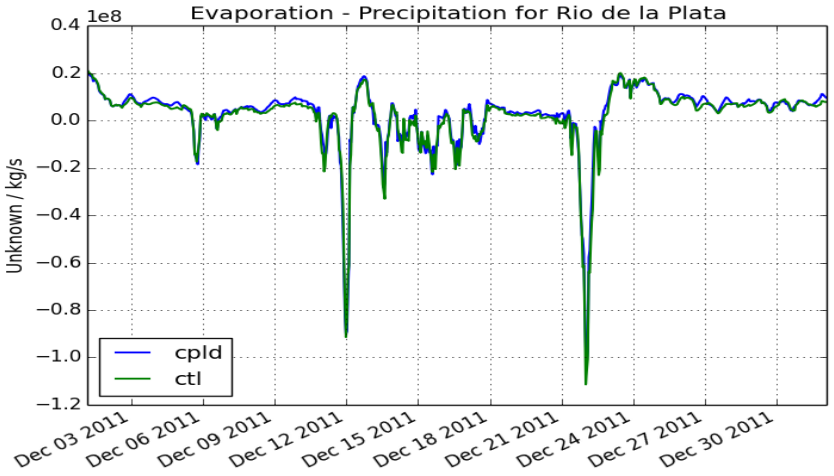
River Plate
Evaporation minus precip and runoff (freshwater flux out of the ocean)



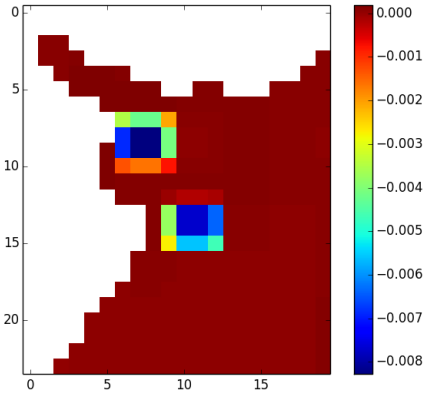
Runoff difference

Ocean control





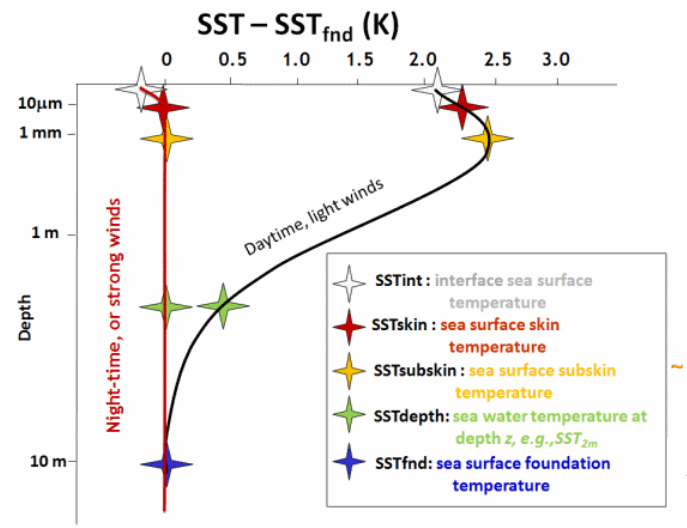
Coupled model



kg m-2 s-1

Diurnal cycle of SST: vertical thermal structure near the surface and definitions of SST

https://www.ghrsst.org/

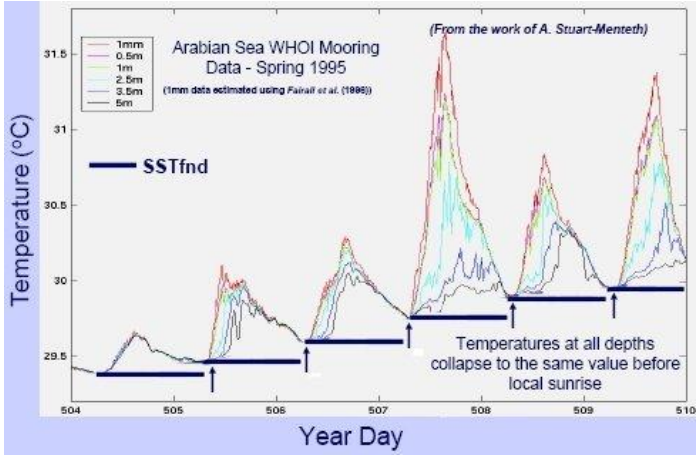


infrared radiometer

~ microwave radiometer

in situ

Foundation SST: temperature free of diurnal variability



Upper ocean (~10m) has a variable vertical structure, related to ocean turbulence and air-sea fluxes of heat, moisture and momentum .

Idealised picture: stratified warm layer that develops due to insolation.

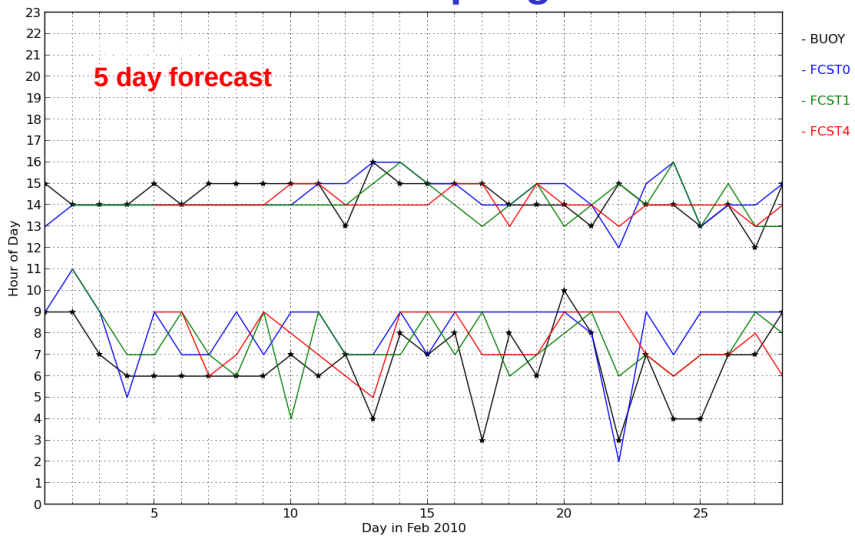
Daytime: solar radiation is absorbed below the surface and heat moves up through the ocean to the surface (heat transfer in the bulk by turbulence). As the interface is approached, heat transfer is carried out by conduction (viscous forces, molecular processes). In order for conductive process to happen a T drop is needed between top and bottom of that microscopic layer (atmosphere is usually a few degrees cooler than ocean surface)→skin effect, skin layer

Night time: Skin layer again. Ocean cools. Temperature below skin layer is basically isothermal (mixing, surface water cools, becomes denser than below and sinks).

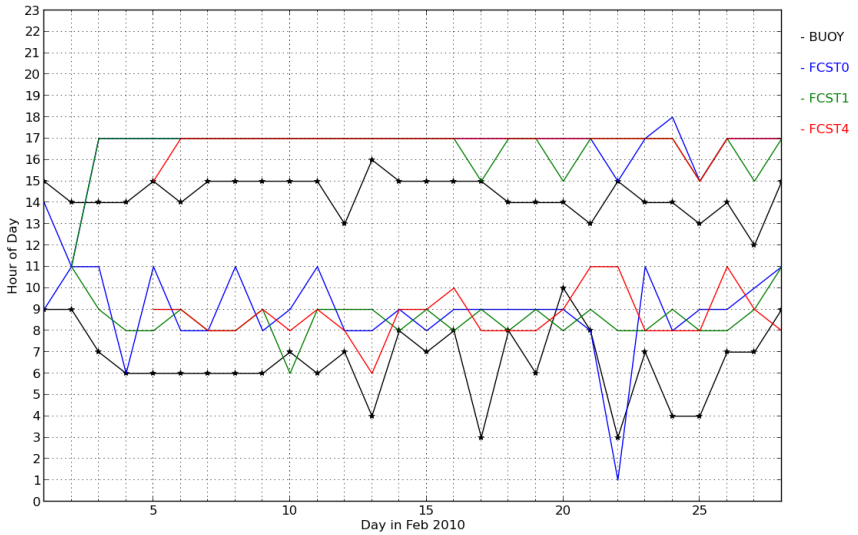
Diurnal SST in climate models: Sensitivity to air-sea coupling frequency

Peter Sykes, Livia Thorpe, José Rodríguez

1-hour coupling



3-hour coupling

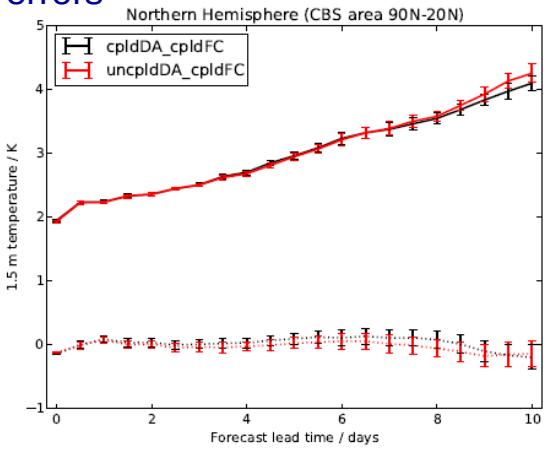


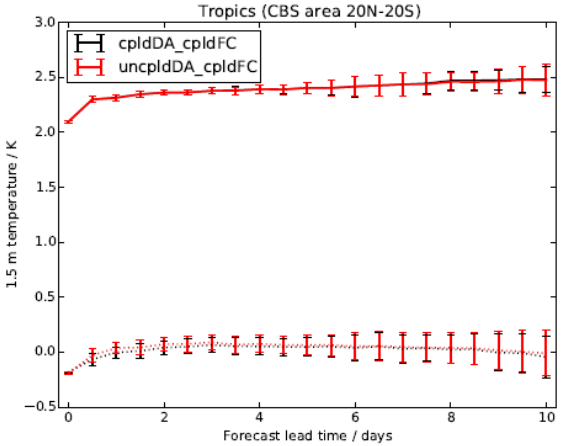
Daily time series of time of day at which maximum and minimum SST occurs according to buoy and coupled NWP model forecast.

- Until recently many CMIP models had air-sea coupling frequencies of 1 day.
- 3 hourly coupling: minimum frequency needed to represent diurnal cycle of SST.
- Increasing the coupling frequency does not change significantly the model diurnal amplitude (not shown). However, it improves the timing of maxima and minima events.

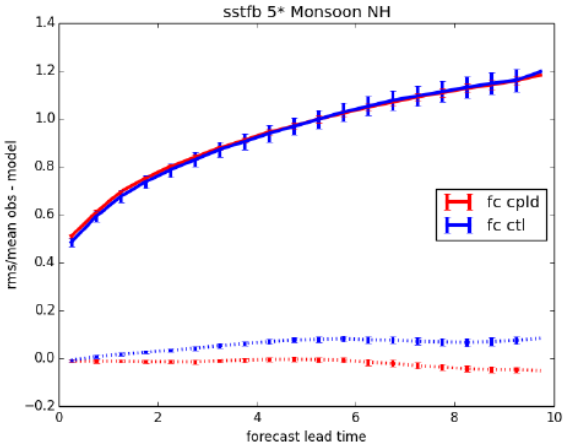
Coupled DA Forecasts versus Control DA Forecasts
Large scale regional bias and RMS errors

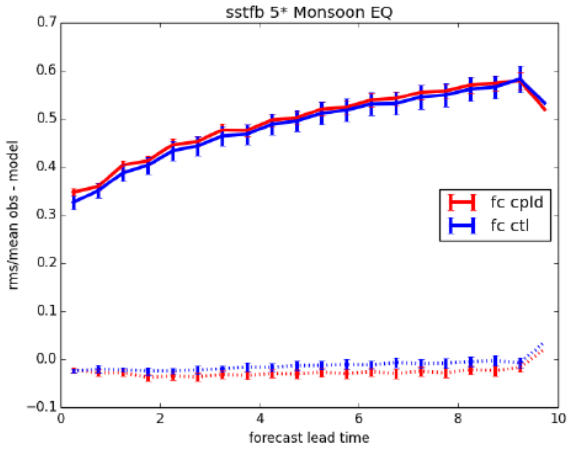
Surface air-temperature forecast errors





SST forecast errors





10-day forecasts for 26 August -15 September 2012

Two forecasts per day (00z and 12z)

- Generally only a small impact on f/c errors
- Positive impact on 9-10 day air-temperature f/c in NH in coupled DA fcsts (significant?)
- Impact on NH SST bias
- Small impact on SH RMS SST errors (not shown)