Coupled Data Assimilation:

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Thanks also for correspondence from

Matt Martin, T. Awaji, Robin Wedd, Tony Rosati, Greg Smith, Jon Robson

Outline of Talk

- Why Coupled data assimilation?
- Challenges of coupled DA
  - Coupled phenomena
  - Coupled model (bias) errors
- Weak v Strong Coupling
- Review of DA plans for Coupled Systems
- Role of Ensemble and Var techniques
- Conclusions

Why Coupled Data Assimilation

- Seamless Prediction, days – decades
  - Desire to unify short-long range forecasting systems
  - Computing resources becoming sufficient
- Coupled ReAnalysis
  - Recover important surface exchange quantities, Heat, Freshwater, ...CO2. Heat fluxes critical for long-term ocean model simulations eg. CORE
  - Climate relevance of reanalysed: Ocean Heat/FW storage, Ocean/Atm. Transports, etc..
- Understand Coupled Error growth, including biases
  - Climate errors may depend on short timescale processes, eg. convection, mixing of heat, etc..
  - Reduce coupling shocks in coupled forecasts
- Improved use of near surface observational data
  - SST, Scatterometer-winds, Waves, Surface Salinity, Precipitation, Soil moisture
  - Often exhibit strong initial transients in these quantities
  - Improved forecasting of these quantities highly desirable on all timescales

Why Coupled Data Assimilation

- Representing the diurnal cycle
  - Near surface data often shows diurnal variability, eg SST, Mixed layer, Atmospheric winds, TKE
  - Need to model this diurnal variability to assimilate these data effectively
- Short term coupled phenomena eg. MJO
  - Longer term teleconnections may also respond, eg. NAO influenced by stronger MJO (Cassou 2008)
- Extreme air-sea flux events, eg. Trop cyclones
  - Fixed SSTs imply indefinite Upper ocean heat content
  - Coupled model SSTs may reduce hurricane intensity, eg. JMA, storm Morokot
- Coastal weather eg. Fogs
  - Strong air-sea interactions in boundary layer
- Coupled Atmosphere-Ice-Ocean processes
  - Polynyas, air-sea fluxes, winds, surface temperatures, water formation

Challenges of Coupled Data Assimilation

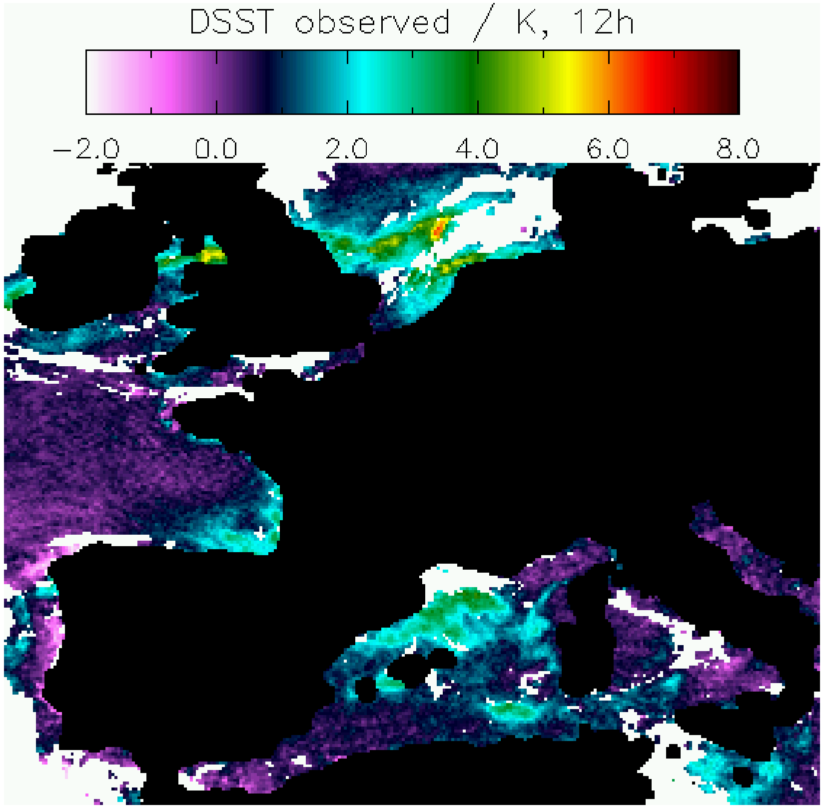
- In typical current systems Coupling takes place AFTER separate analyses
- Has allowed different mature assimilation schemes in Atm. and Oceans
- Different timescales
  - Atmospheric 4DVar 12 hours
  - Ocean 5-10 day windows typically 3DVar
- Timescales reflect; Data availability, Error growth rates, Linear-Nonlinear transitions
- Model coupling timescale may be infrequent, eg. OASIS sequential coupling 3 hourly
- Bias correction schemes in use in individual systems may need re-evaluation
  - Ocean bias schemes maintain realistic SST gradients for coupled forecasting
- Some coupled DA schemes very different eg. anomaly assimilation

Modelling Coupled Phenomena

- Short timescales
  - Diurnal cycles in Surface T, winds, Atm. Boundary layer, Ocean Mixed layer,
  - Inertial Wind-Wave-Current coupling
  - Tropics: Atm convection and MJO; Monsoon Onset
  - Tropics: Ocean mixed-layer cold wakes and Tropical Cyclones
  - Polar: Dynamic Ice, Heat fluxes and Surface T
- Longer timescales
  - Seasonal Forecasting (eg. ENSO,..)
  - Decadal forecasting (eg. AMOC,...)

Diurnal Sea Surface Temperatures

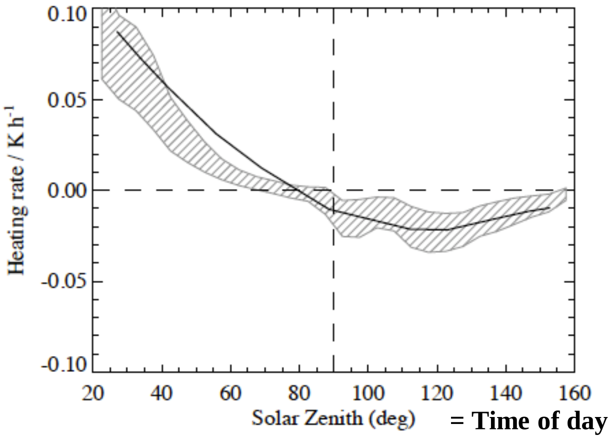
Diurnal Amplitude



ARC: Merchant et al 2008

Redefining SST validation

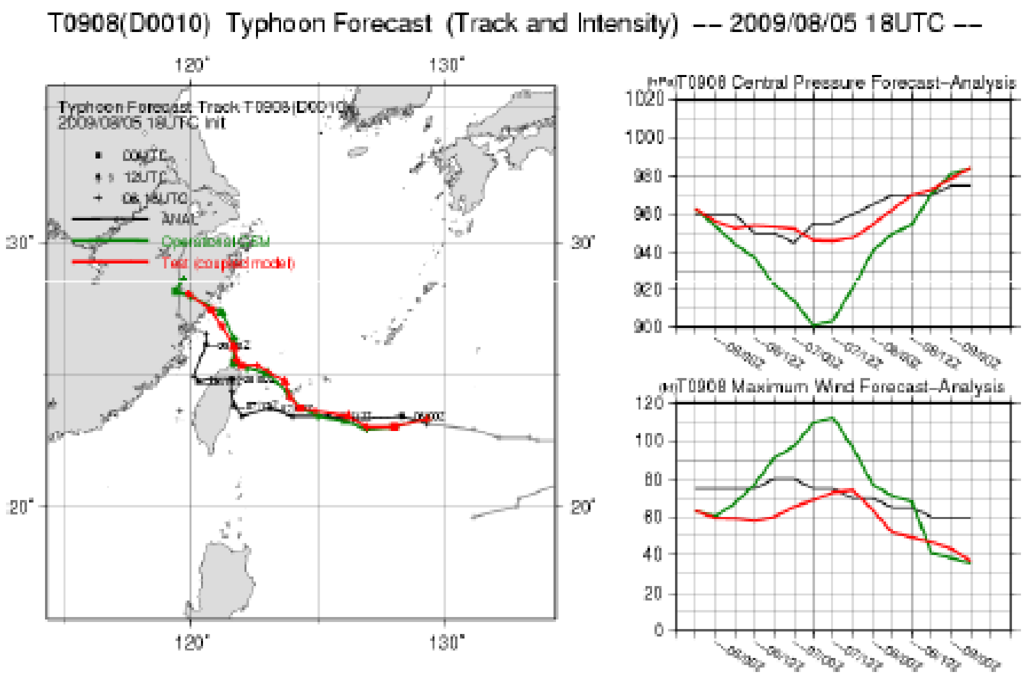
- Best satellite SSTs now more accurate than drifting buoys
- Sat-buoy time difference=> Ht rates



- Observed and NWP modelled SST Ht. rate (ATSR vs. drifting buoys)
- Model can correct time mis-matches

Impact of coupling

Typhoon intensity forecast for Typhoon Morakot

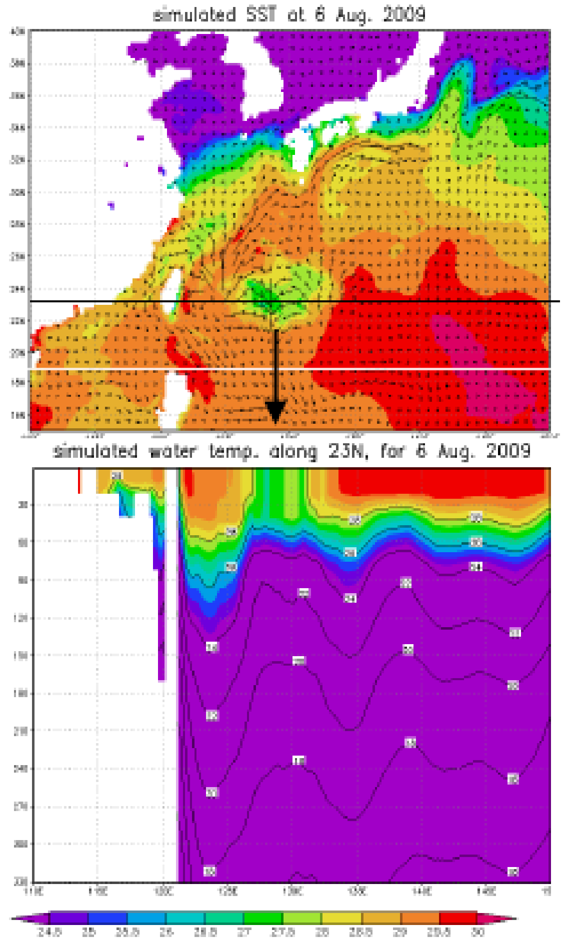


- Too strong in operational GSM (green)
- Coupling weaken the intensity (red)

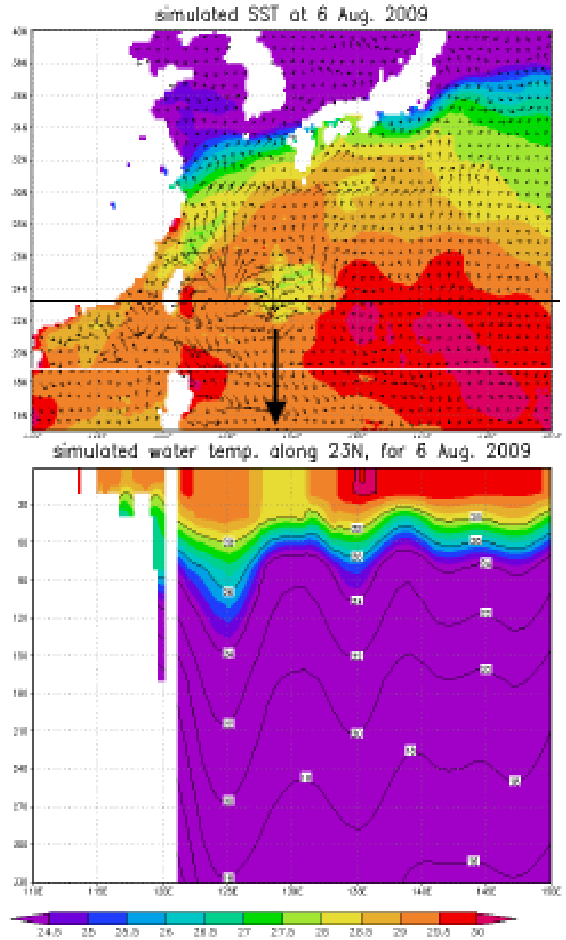
Higaki JMA

3D model or 1D mixed layer model?

MRI.COM (3D modeling)



MRI.COM (vertical mixing only)



- SST during the passage of Typhoon Morakat was simulated by (uncoupled) MRI.COM
- Surface fluxes were provided by GSM forecast products.
- Both models represent sea surface cooling around the TC track
- But SST by the 3D model is about 1K cooler than 1D

=>Ekman pumping

Understanding Coupled Model Errors

- Bias errors in coupled models not easy to attribute
  - Radiation, E-P, Wind stress
- Short timescale errors (vertical) eg. convection or mixing or air-sea fluxes => horizontal circulation and transport errors on longer timescales
- Study coupled forecast error growth (leadtime) to explore Coupled errors close to observations (Transpose AMIP => PRIMER)
- Study coupled model data assimilation increments
  - Increment attempting to prevent model drift
  - Patterns contain information about model process errors
  - Correlated error patterns, eg Atm-Ocean increments
- Compare with perturbed physics experiments (ERGODICS project)
  - Forecast drift from assimilated Observations due to unknown process errors
  - Perturbed physics drift from background due to known parameterisation changes
- Ensemble spread => Uncertainty in forecasts + Background Assim. errors
- How to initialise coupled ensemble spread?
  - Large ensembles?
  - Choose special/optimal (coupled?) perturbations to reduce ensemble size?
  - Ensemble choice depending on lead time of interest, days to decades?
  - Re-initialising spread on each assimilation cycle risks loosing uncertainty information especially in ocean

Weak v Strong Coupling in Assimilation

- No coupling => Atm. and Ocean boundary layers unbalanced
- Weak coupling: Always run coupled model so Background Atm. and Ocean fields in balance; Increments calculated separately so potentially unbalanced
  - Increments may be small (fn. of bias growth and data frequency)
- Strong coupling: Some balance between ocean and Atmos. Increments
  - Use of multivariate coupled covariances?
  - Or coupled adjoint in 4DVar
  - Physical constraints on coupled increments eg. reflecting air-sea exchanges; eg. wind or cloud cover errors, Pimentel et al (2008)
  - Tune coupling parameters for heat, momentum

Diurnal cycle SST assimilation adjusting cloud cover and windspeed

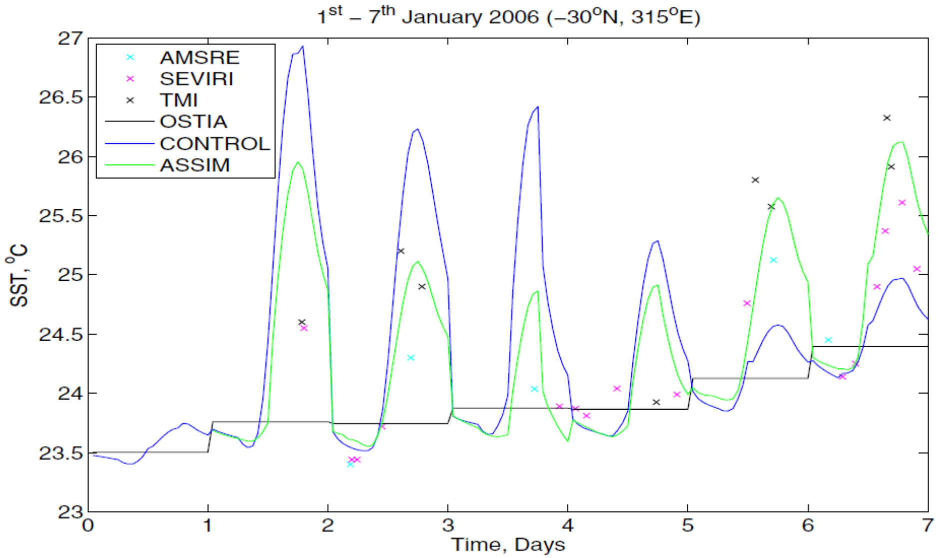


Figure 7.4: *A graph comparing the model SST before and after assimilation with the individual satellite observations and OSTIA at* $(-30\,^\circ N,\,315\,^\circ E)$ *for the* 1^{st}*–*7^{th} *January 2006*

	Mean	STD	RMS
control	0.07	0.79	0.79
cloud check	0.06	0.78	0.78
wind correction	0.10	0.52	0.53
wind then cloud correction	0.07	0.49	0.49

Table 1. *Results showing the mean, STD, and RMS of* $\theta_{model} - \theta_{obs}$*, in* $^\circ C$ *for the area* 45°S *to* 25°S *and* $300\,^\circ E$ *to* $330\,^\circ E$ *during* 1^{st}*–*7^{th} *January 2006.*

Existing/Planned CDA schemes

- NCEP CFSR
- Met Office (NWP-Seasonal)
- Canadian Met Service systems
- BMRC
- JAMSTEC
- GFDL Ensemble KF
- Met Office (Anomaly system: DePreSys)
- ECMWF

NCEP-CFSR (1979-present)
Climate Forecasting System Reanalysis

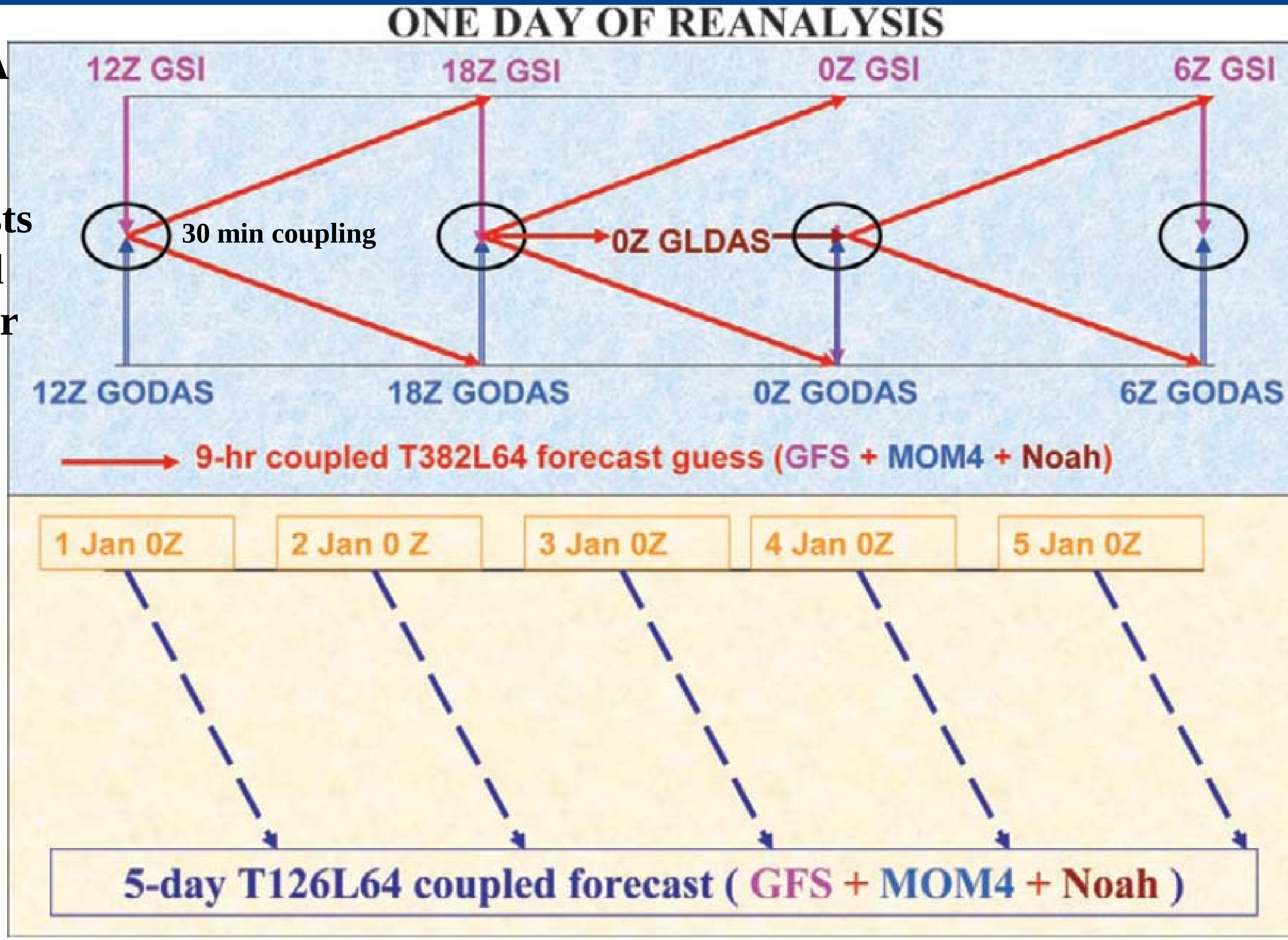
Weakly Coupled DA

Atmosphere Anal
9 hr coupled forecasts provide background tendencies for 3DVar every 6hrs

Ocean Anal
0.5° x 40 levels
Univariate 3DVar with pseudo S(T)

Noah Land Anal
at 0Z only

Saha et al (2010)



NCEP-CFSR

Not Ensemble system

Background error variances still flow dependent

Climatological variances scaled by 6hr tendencies

Assimilation of gridded surface products for
SST (daily), SSS(Clim),
Sea ice conc. (lin. interp. time)
Precip., Snow cover (daily)

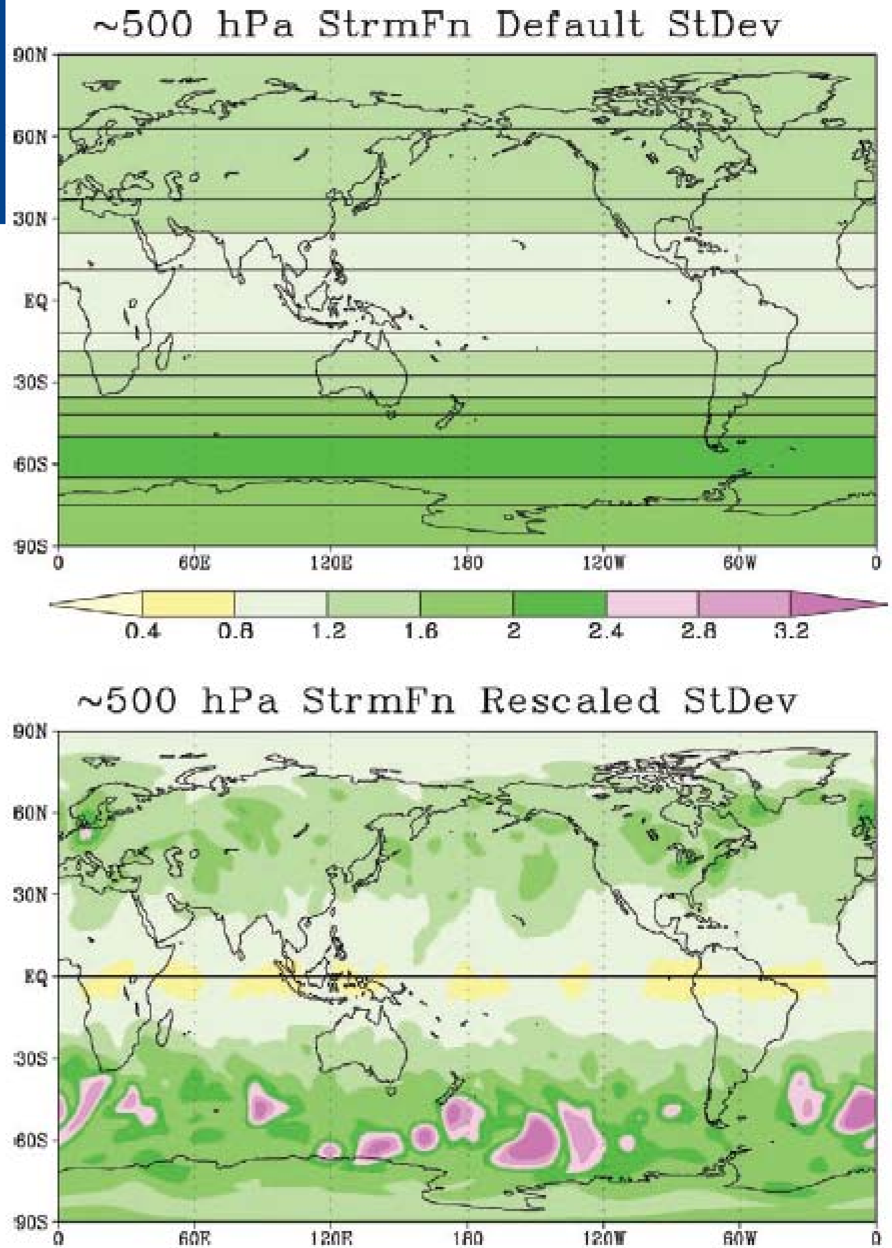


FIG. 5. (top) Static, zonally invariant, 500-hPa streamfunction (1e6/s) background error valid at 0000 GMT 06 Nov 2007; (bottom) flow-dependent adjusted background standard deviation.

NCEP-CFSR

- Improved timing of SST and Tropical precipitation
- Improved MJO reproduction
- Uncoupled: Convection too early response to SSTs. Air-sea fluxes => SSTs damped
- Diurnal cycle in SST can be 2C from TOGA-COARE (Soloviev et al 1997)

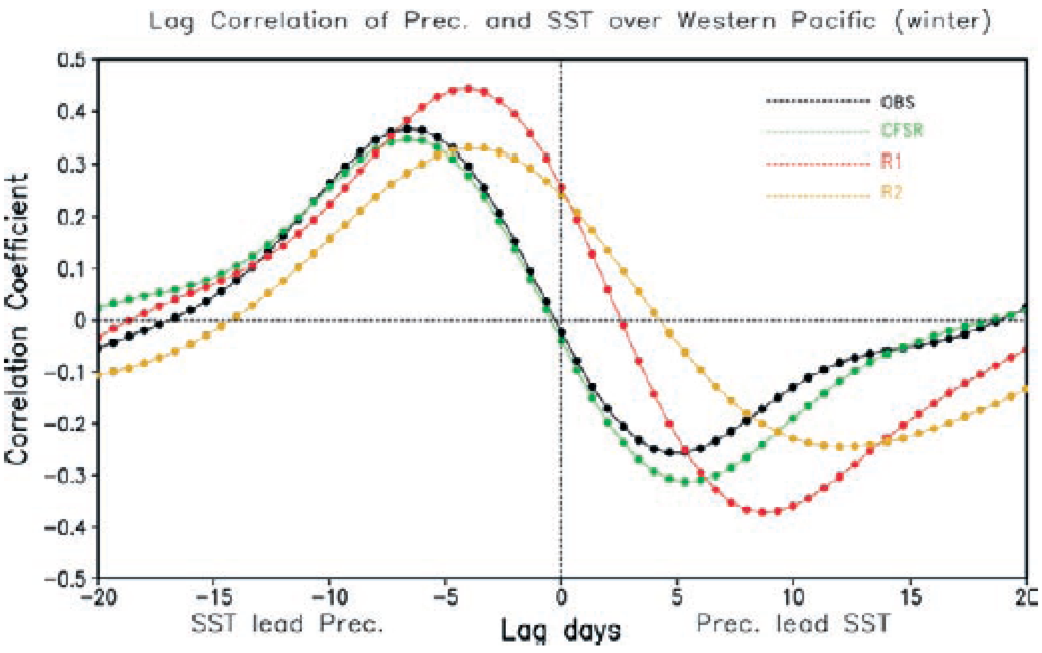


FIG. 27. Temporal lag correlation coefficient between precipitation and SST in the tropical western Pacific (averaged over 10°S–10°N, 130°–150°E) in R1 (red), R2 (brown), CFSR (green), and observation (black). GPCP daily precipitation and Reynolds ¼° daily SST are used as observational data. Negative (positive) lag in days on the x axis indicates the SST leads (lags) the precipitation. Data for the boreal winter (Nov–Apr) over the period 1979–2008 are bandpass filtered for 20–100 days after removing the climatological mean.

Met Office Coupled forecasting

- The next Met Office seasonal forecasting system (GloSea) is currently being developed:
    - N216 UM atmosphere L85
    - ORCA025 NEMO ocean (1/4 degree), L75
- Initial implementation: Atmospheric and Ocean assimilation within un-coupled models (NWP and FOAM).
    - Ocean component: NEMOVAR system (3DVar-FGAT)
    - Atm. Component : 6hr 4DVar
- Assessment in short- to medium-range coupled forecasts ongoing.

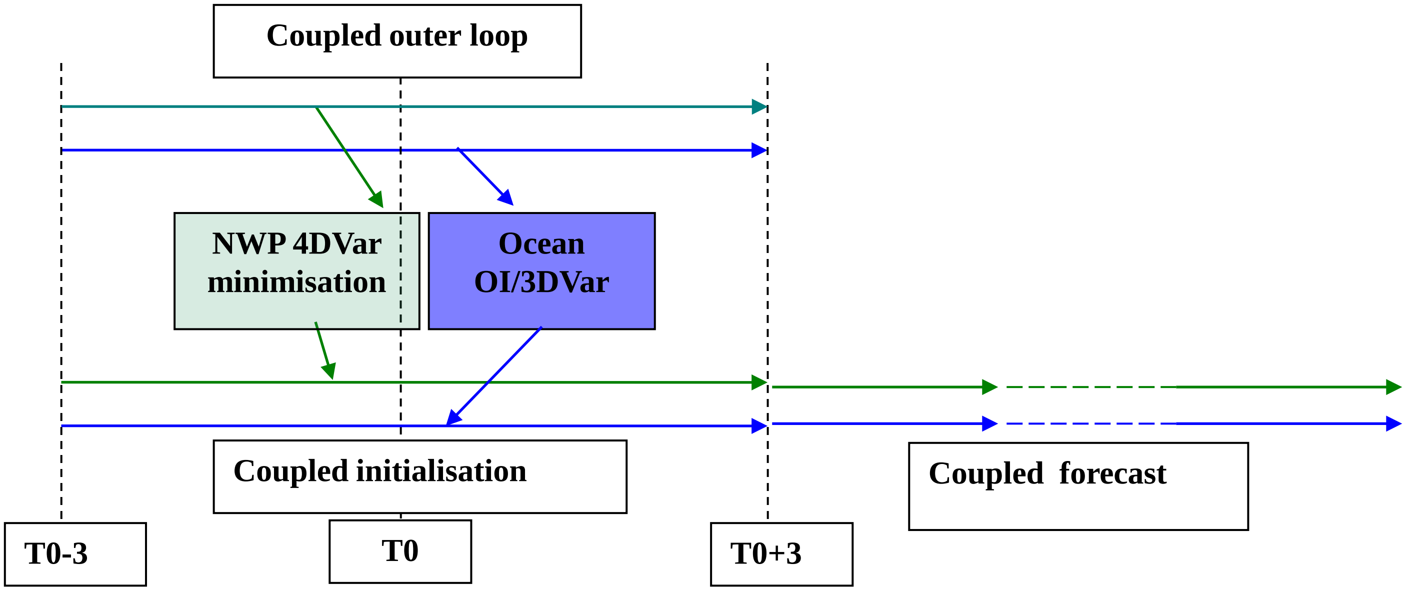
Met Office Coupled DA plans

R&D for coupled data assimilation carried out in parallel.

Plans include:

- **implement weakly coupled DA system: background state from coupled model, increments calculated separately no cross-covariances between the ocean and atmosphere.**
- **28 ensemble coupled runs initialised daily (15day-7mth)**
- **investigations including: time-windows, balance of the coupled system, bias correction, coupling frequency.**
- **longer-term: assess and implement cross-system error covariances.**

Met Office Weakly Coupled DA



Note initial timescale of 6 hours
Window limited by atmospheric error growth

Coupled 30day forecasts at MetO (Shelley et al 2011)

	Coupled	Atmosphere control	Ocean control
Components and resolution	**A** – MetUM N216L85 **O** – ORCA 0.25° L50 **I** – CICE 0.25°	**A** – MetUM N216L85	**O** – ORCA 0.25° L50 **I** – CICE 0.25°
Air-sea boundary conditions	*Interactively coupled every 3 hours (resolving diurnal cycle)*	Daily SST and sea ice from OSTIA analyses, time-interpolated to 3-hourly (but without a diurnal cycle)	3-hourly mean fluxes from corresponding atmosphere control
Initialisation	**A** - operational NWP analysis (N320L50), interpolated to N216L85 **O** - FOAM analysis (ORCA0.25L50) **I** - Monthly mean climatology from HadGEM3 pre-industrial control run	**A** - operational NWP analysis (N320L50), interpolated to N216L85	**O** - FOAM analysis (ORCA0.25L50) **I** - FOAM sea ice analysis

Winter	Summer
02.01.2007	01.06.2007
01.02.2007	01.07.2007
21.02.2007	10.08.2007
08.12.2007	25.06.2008
06.02.2008	25.07.2008
02.12.2008	03.09.2008

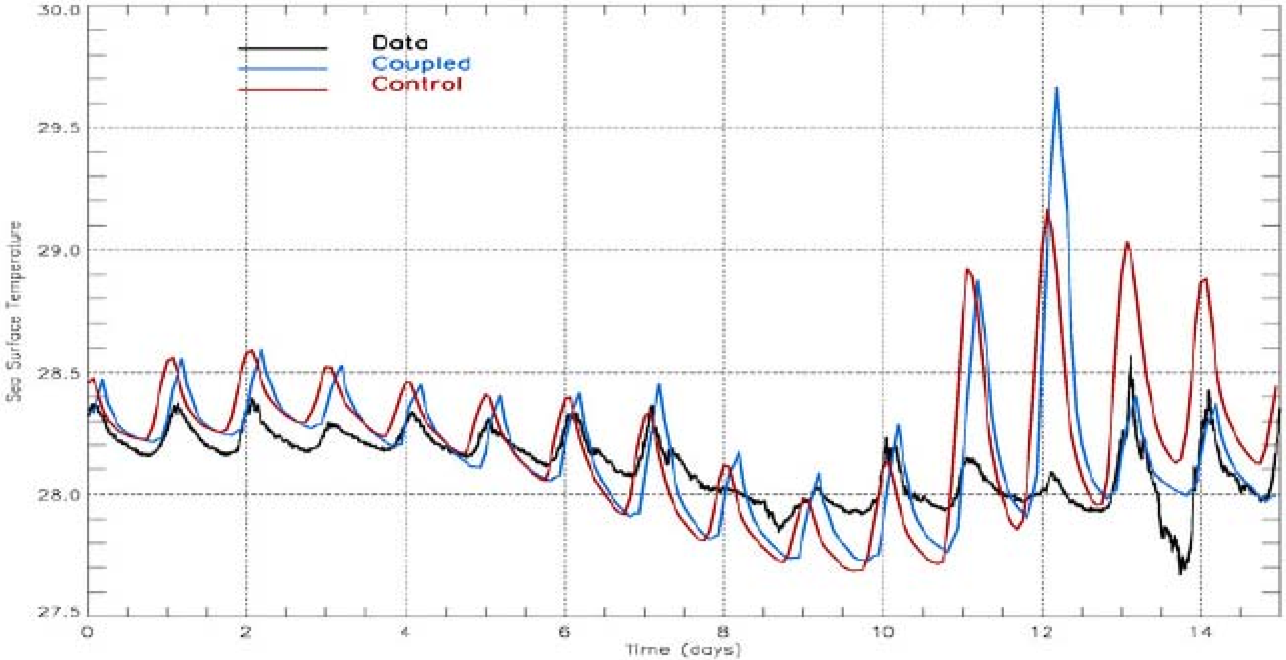
12 Single forecasts only
No Ensembles

*Table 1: Outline of experimental setup for the coupled, atmosphere and ocean forecasts. Model sub-components are denoted **A** – atmosphere, **O** – ocean and **I** – sea ice. See also Appendix A.*

Coupled 30day forecasts at MetO (Shelley et al 2011)

- Coupled model skill similar to Atmosphere only most regions out to 15 days
- Cooling SST drift in both summer and winter
  - Due to upper ocean mixing bias?
- Diurnal SSTs reasonably well captured from Atmospheric fluxes alone
- Cyclone tracks similar
- Caveats : Very few cases studied, Model not yet weakly coupled, no ensemble forecasting yet

Coupled 30day forecasts at MetO (Shelley et al 2011)



2N 170W from 01/02/2007

3 hour coupling frequency

Control run uses Atm fluxes forced by daily SST

Coupled 30day forecasts at MetO (Shelley et al 2011)

Day 1 **Day 15**

Ocean Mixed Layer Depths

FOAM analysis

Coupled model

Ocean Control

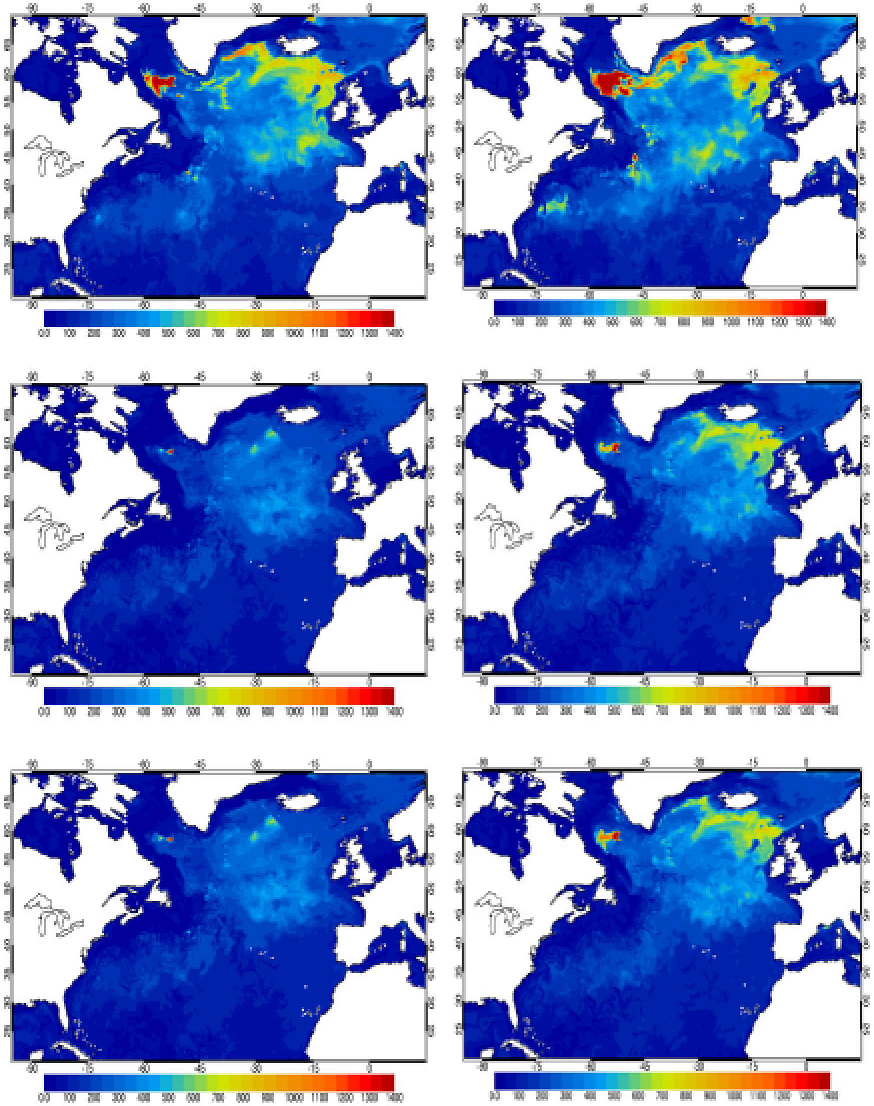


Figure 21: Mixed layer depth in North Atlantic for case initialised on 01/02/2007 for the analysis at day 1 (top left) and day 15 (top right), coupled model day 1 (middle left) and day 15 (middle right) and ocean control day 1 (bottom left) and day 15 (bottom right).

Coupled Atmosphere-Ice-Ocean Forecasting Activities in Canada: CONCEPTS

- **Aims:**
  - Development of Regional and Global Coupled Atmosphere-Ice-Ocean Forecasting Systems
  - Global coupled medium-to-monthly forecasting system:
    - Initially: produce 10 day operational forecasts
    - GEM atmospheric model and CMC analysis system (4DVAR/EnKF)
    - Coupled to 1/4° resolution (ORCA025) NEMO ice-ocean model
    - Initialized with Mercator SAM2 (PSY3V2) ocean analyses
  - Regional short-term forecasting system
    - Based on subdomain of ORCA12 for NW Atlantic + Arctic
    - Coupled to CMC regional forecasting system
    - Build on developments made by CNOOFS
  - Coupled DA will follow thorough testing of 10day coupled forecasts

Environment Canada

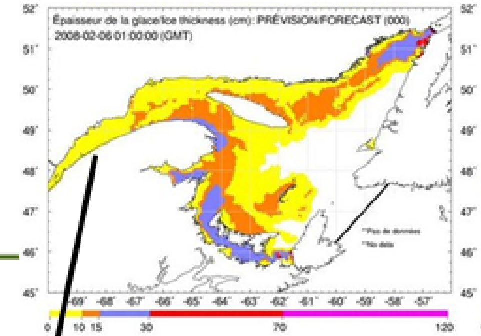
Fisheries and Oceans Canada

MERCATOR

Canada

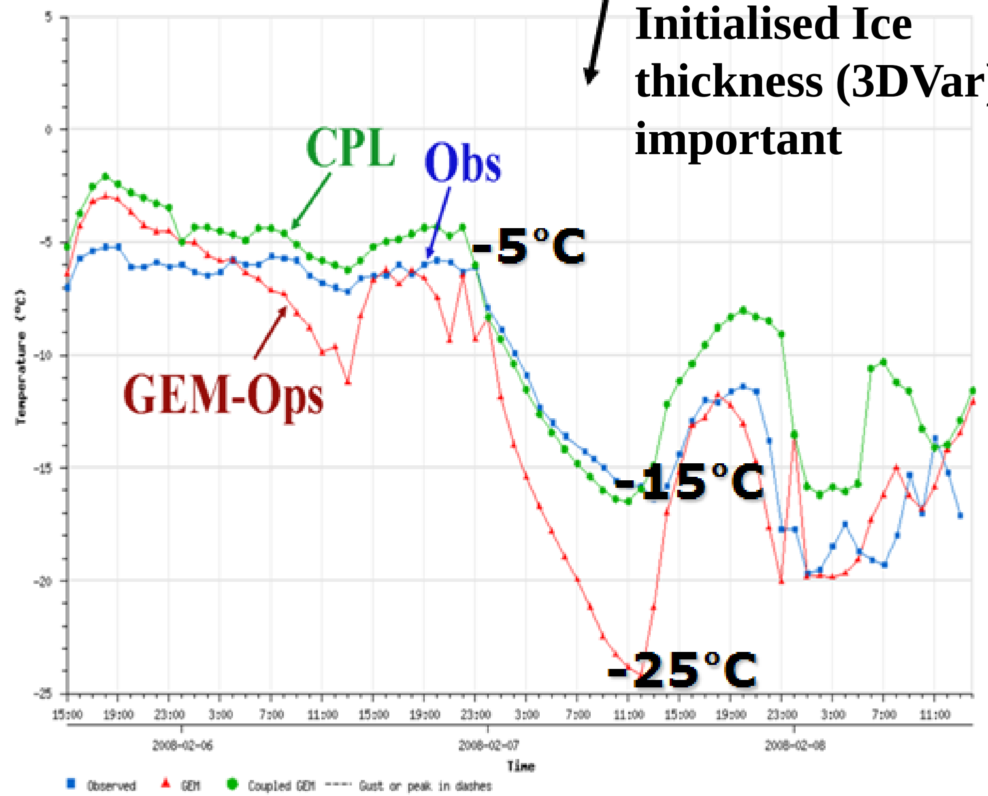
The Gulf of St. Lawrence (GSL) Coupled System

S. Desjardins



- A dynamic representation of sea surface conditions improves the meteorological forecast locally
  - Operational regional forecasting system (GEM-Ops) has tendency to overestimate cold events in winter.
  - Dynamic ice cover in coupled model allows vast stretches of ice-free water to open up, buffering atmospheric temperatures
- Use of coupled model results in significantly improved forecasts all around the GSL
- Demonstrates importance of air-sea-ice coupling even for short-range weather forecasts

Initialised Ice thickness (3DVar) important



Greg Smith

48hr forecasts

Environment Canada

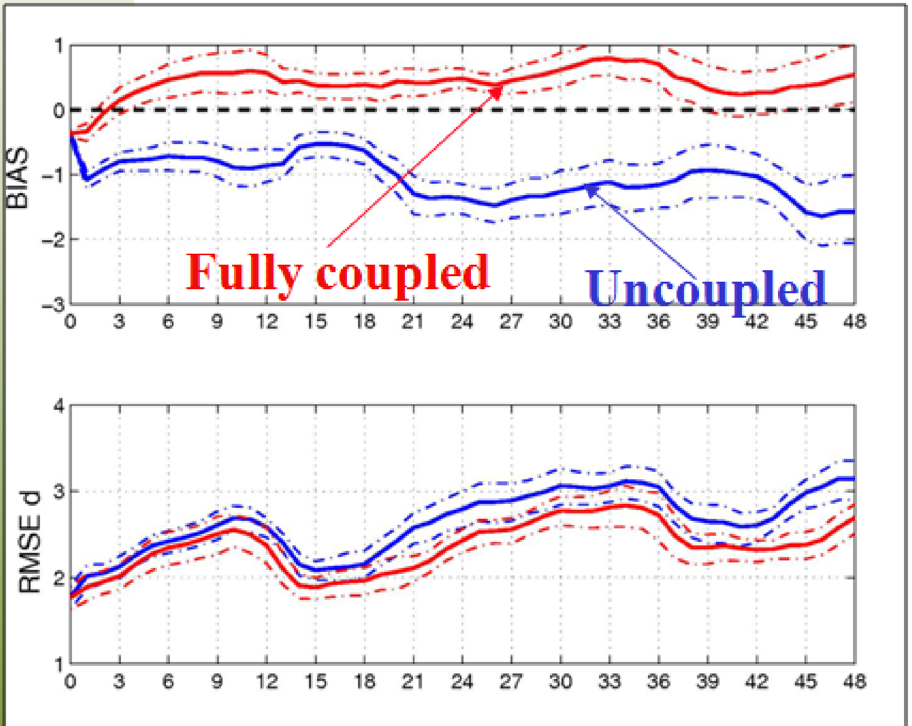
Fisheries and Oceans Canada

MERCATOR

Canada

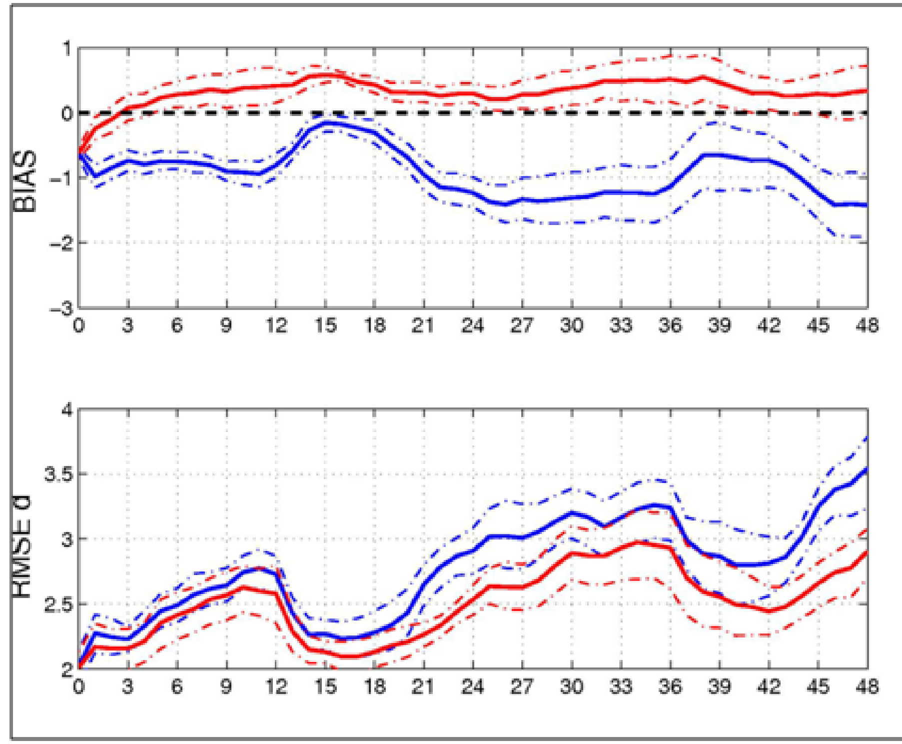
Statistics for February 2008

Surface temperature (TT)



Forecast hour

Dew point temperature (TD)



Forecast hour

Environment Canada

Fisheries and Oceans Canada

MERCATOR

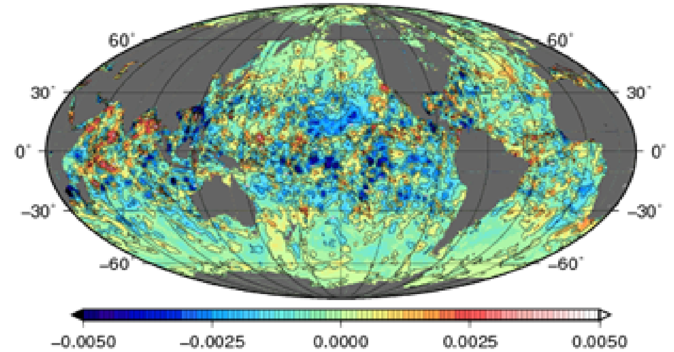
Canada

Parameter estimation for GEM-NEMO

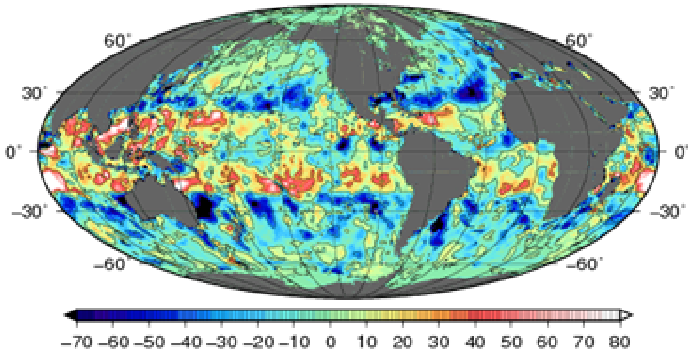
S. Skatchko, UQAM

- Augment atmospheric 4DVAR state vector to include bulk transfer coefficients
- Near-surface temperature will affect parameter estimation
- Preliminary results show improved forecast skill

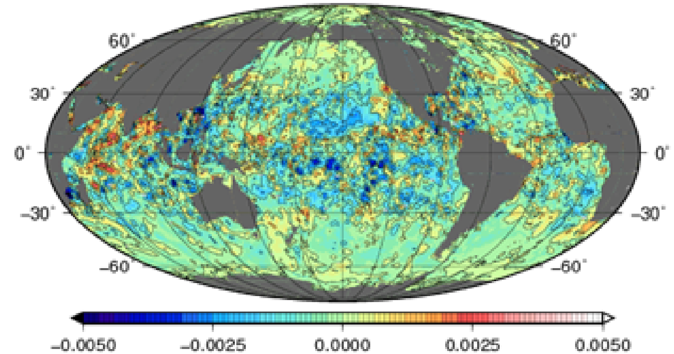
Humidity(10m)
Forecast - Analysis



Reference Run



Change in latent heat flux



Run with Parameter Estimation

Australian BMRC: POAMA-3/ACCESS

Model Features

- **Based on the New ACCESS coupled model**

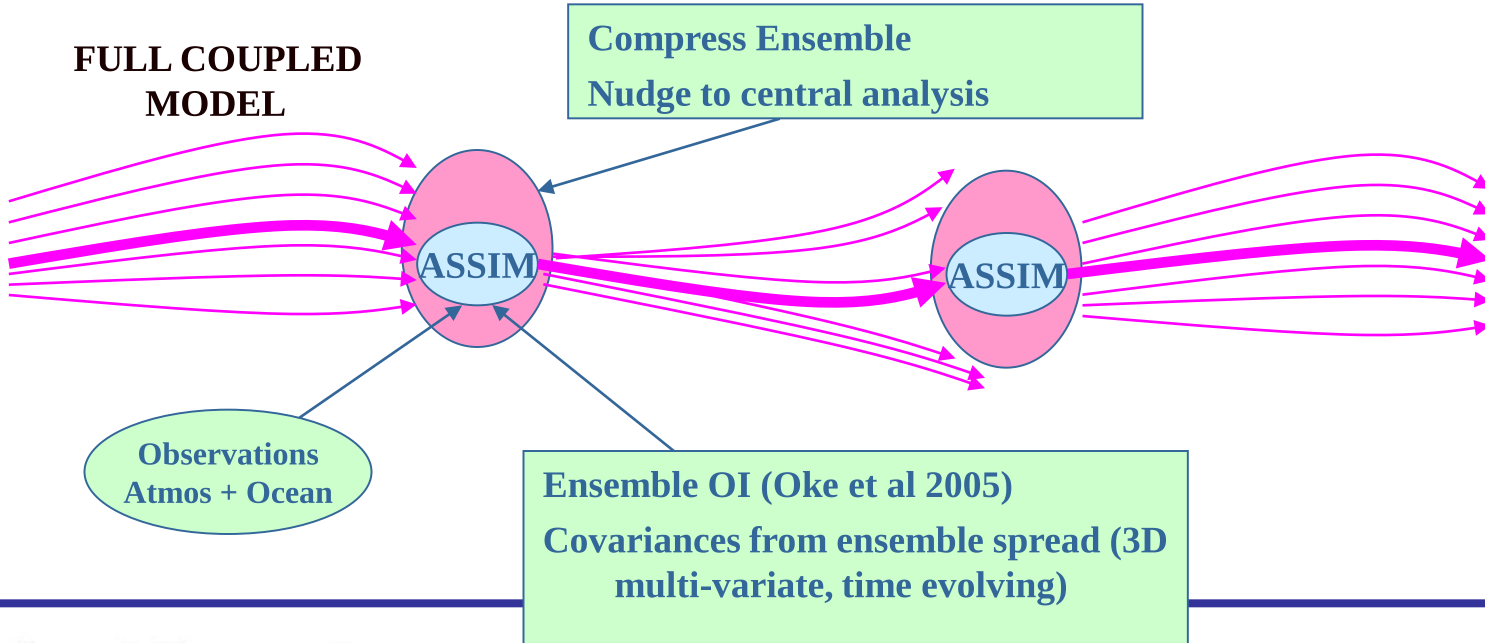
(UKMO UM + MOM4 + CICE + CABLE(Land))

- **Resolution tbd between N96 and N144, L~38-80, depending on supercomputing**
- **Preliminary version available now with limited hindcasts (N96L38, not CABLE, not tuned, simple initialisation eg. SST nudging)**

BMRC POAMA-3/ACCESS

Initialisation Plans

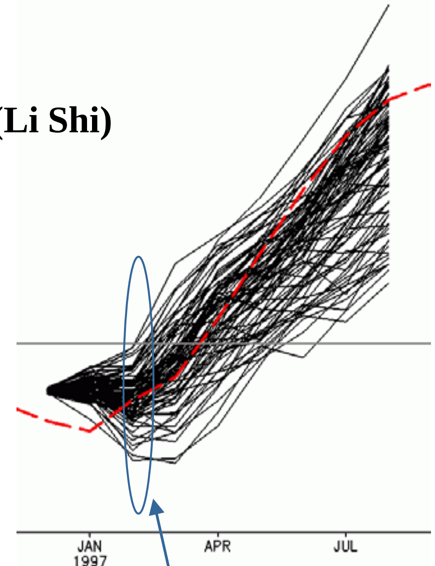
- **Full coupled initialisation (coupled PEODAS) with cross-covariances and implicit 'breeding'**
- **Progress through a series of incremental stages**

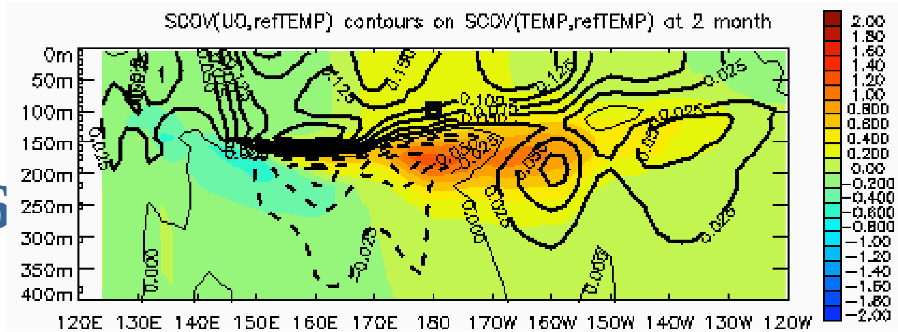


BMRC Coupled Covariances

Case study:
90 member ensemble forecast from Dec 1996

(Li Shi)

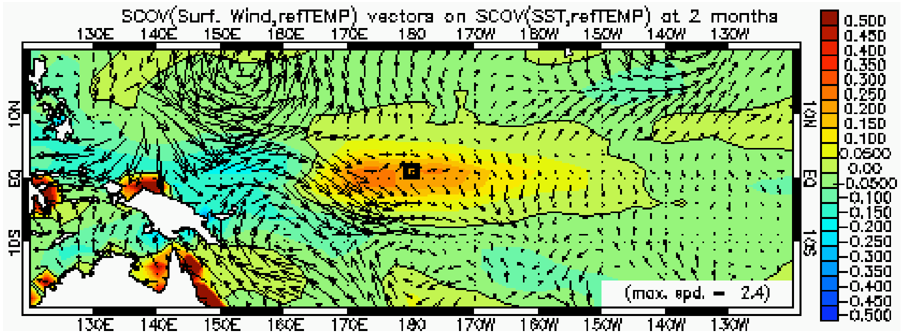




Ref.: Temp. 100m

Colour: Temp.

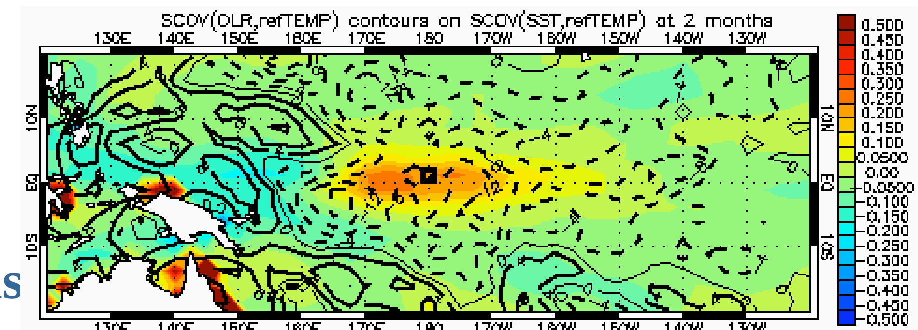
Cont.: Zon. Current



Ref.: Temp. 100m

Colour: SST

Vect.: Surf. Wind



Ref.: Temp. 100m

Colour: SST

Cont.: OLR

Estimate covariances from ensemble (eg. after 2 months

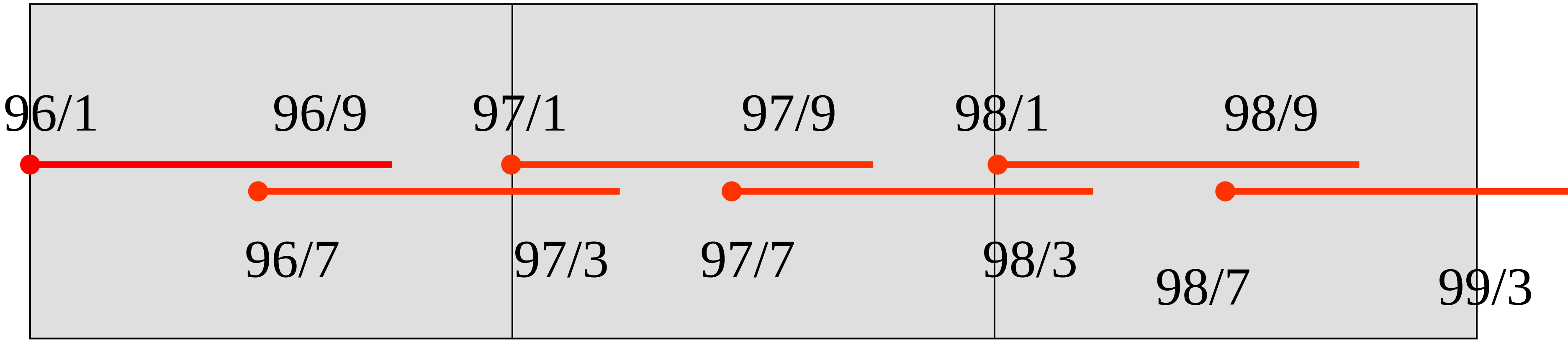
JAMSTEC Coupled Data Assimilation

thanks to Dr Sugiura and Prof. Awaji

- Assimilation into a fully coupled GCM
- By means of 4D-VAR
  - Long assimilation window (9 month)
  - Correction of model climatology by parameter estimation
  - Correction of seasonal to interannual trajectory by initialization
  - Atmospheric data are also assimilated
  - Weather mode is treated as noise

→To be suitable for Seasonal to Interannual state estimation and prediction

CDA Assimilation windows



9 mth windows overlap by 1.5 months each end!!

Control Variables

1. Ocean initial condition
2. Bulk parameters controlling Air-sea fluxes of ;

* 97/1 = January of 1997

Momentum $$F_{\mathbf{v}} = -\rho\alpha_M C_M |\mathbf{v}|\mathbf{v}$$

Sensible heat $$F_\theta = \rho c_p \alpha_H C_H |\mathbf{v}|(\theta_g - \theta)$$

Latent heat $$F_q = \rho\alpha_E C_E |\mathbf{v}|(q_g - q)$$

adjustment factors (x,y,10daily)

Experimental Settings of Coupled DA

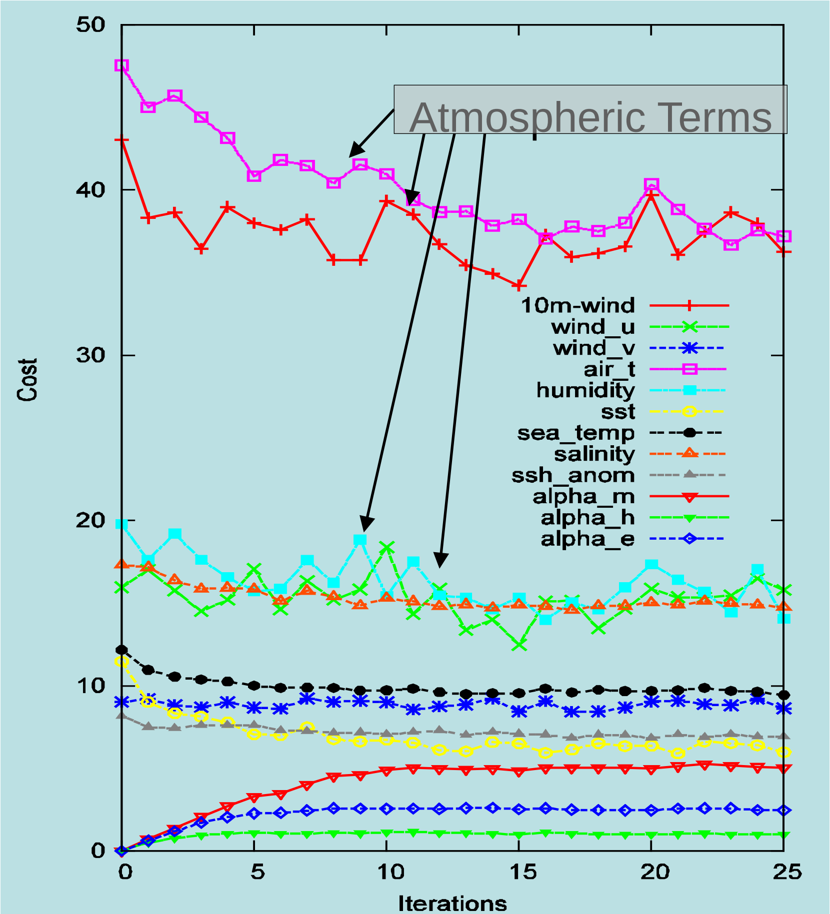
- Coupled Model (CFES):
  - T42L24 AFES for AGCM
  - 1x1deg L45 MOM3 for OGCM
  - IARC SeaIce model
  - MATSIRO Model for Land
- Observational Data
  - Atmosphere:
    - NCEP's BUFR data U,V,T,Q (10day averages)
    - SSM/I sea wind scalar x ERA40 wind direction (10day averages)
  - Ocean:
    - T/P altimeter data(10daily)
    - Reynolds SST (10daily)
    - WOA data T,S (monthly)
    - Ocean Data Assimilation Product T,S(monthly)
- Adjoint Code
  - Adjoint OGCM and adjoint AGCM are coupled [Line by line transformation by TAMC,TAF]
  - Temporal averaging of forward field for the adjoint integration is applied to smooth the basic field
  - Adjoint AGCM contains damping terms to suppress the strong adjoint sensitivity from weather fluctuations.

$$-\frac{\partial \boldsymbol{\lambda}}{\partial t} = \left(\frac{\partial \mathrm{M}}{\partial \mathbf{x}} \right)^T_{\mathbf{x}=\bar{\mathbf{x}}} \boldsymbol{\lambda} - \boldsymbol{\Gamma}\boldsymbol{\lambda} + \mathbf{H}^T \mathbf{R}^{-1} \left(\mathbf{H}\bar{\mathbf{x}} - \mathbf{y} \right)$$

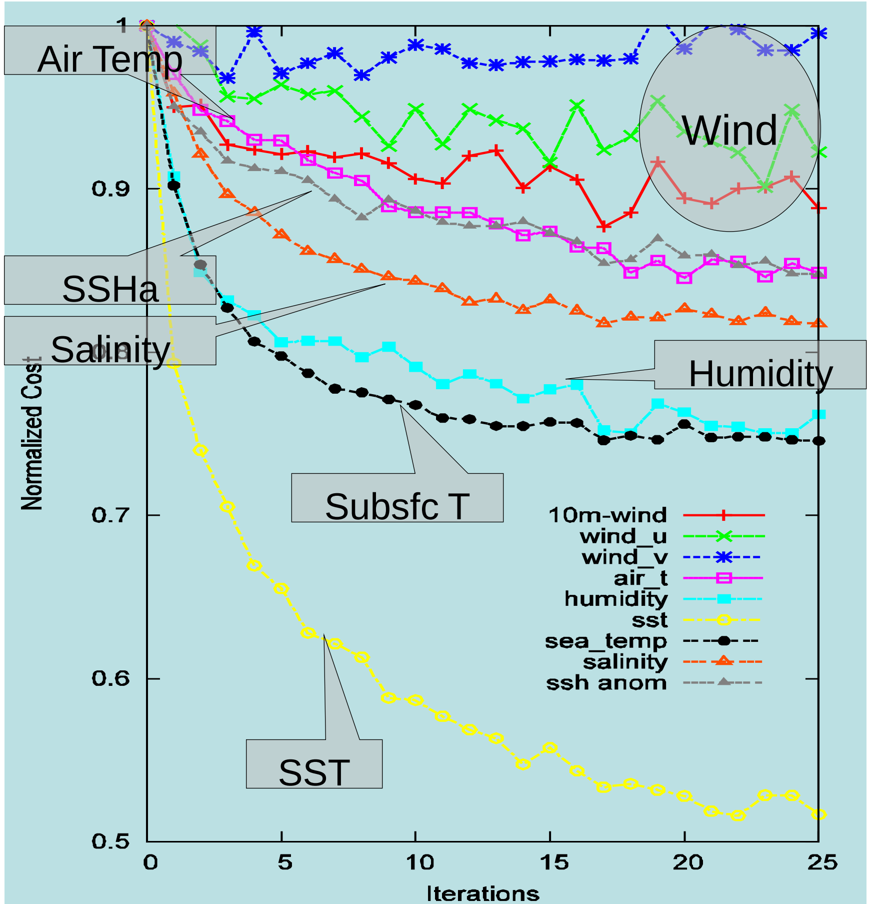
$$\boldsymbol{\lambda} : \text{adjoint variables}, \quad \bar{\mathbf{x}} : \text{temporal average}, \quad -\boldsymbol{\Gamma}\boldsymbol{\lambda} : \text{damping}.$$

The CDA cost function minimisation

Cost variation for the period from Jul1996

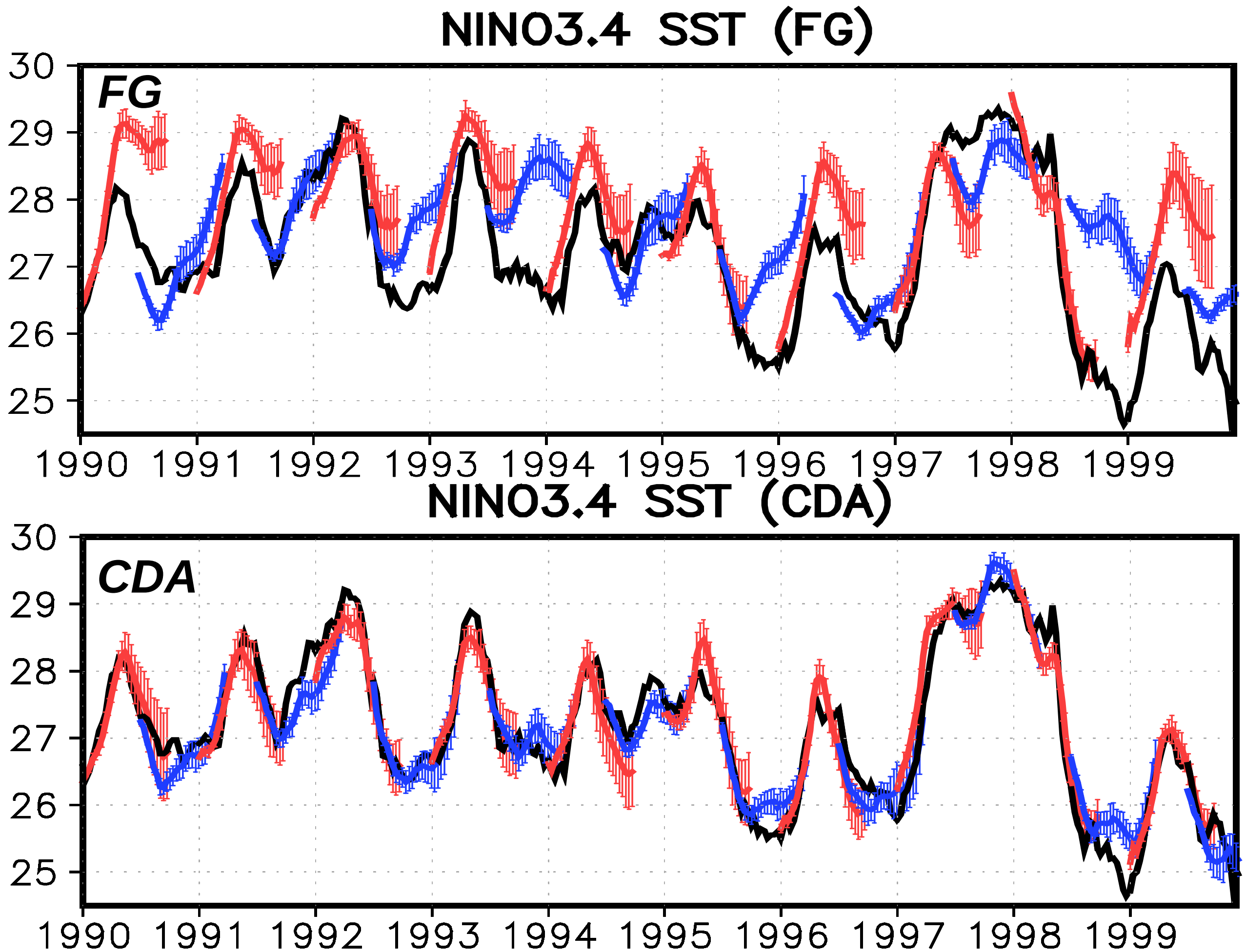


Normalized cost variation in the 1990s



Atmospheric cost terms show some fluctuations with iteration. SST cost significantly reduced.

Coupled DA Seasonal prediction



Top: Firstguess

Bottom: CDA

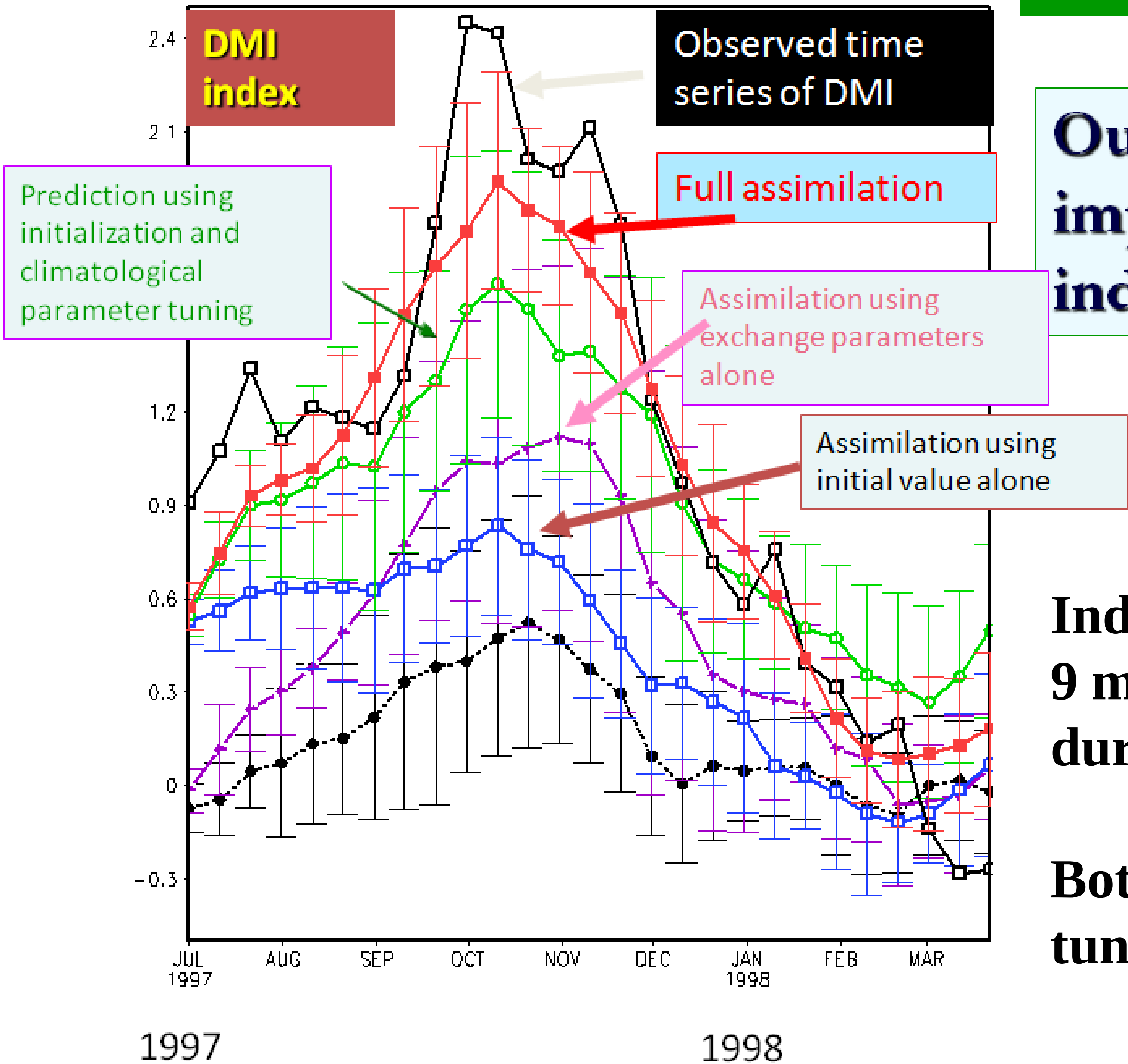
Red: from Jan.

Blue: from Jul.

Black: Obs.

Error bars are for the spread of **Ensemble runs with 11-different atmospheric initial conditions**. Nino3.4 SST is much more realistic in the CDA analysis field.

Indian Ocean Dipole



For IOD case,

Our 4DVAR CDA improved DMI index

Indian Ocean Dipole
9 month hindcasts
during 1998 ENSO

Both IC and Parameter tuning important

Coupled DA Summary

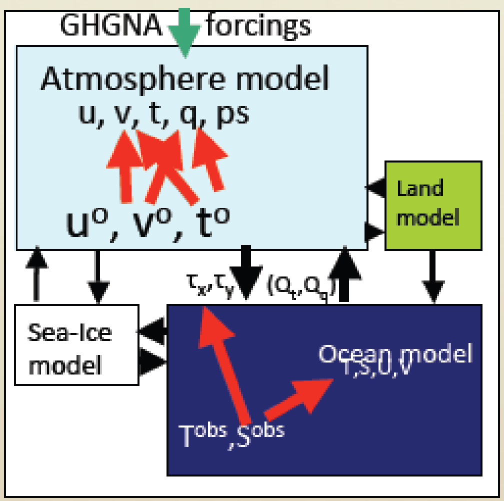
- The optimizations of ocean initial condition and of bulk parameters reproduce coupled field realistically.
  - Extraction of coupled/climate mode works to some extent by temporal averaging of forward fields and simple damping terms in adjoint code which is shown by the reduction of the cost values for coupled field.
  - For El Nino, the departures from observation do not grow in the 9-month assimilation windows which verifies that CDA works as a smoother.
- System is also useful for prediction.
  - Bulk parameter adjustment useful to represent properly the climatological mean state by the Coupled GCM.
  - Optimal ocean initial condition fit to the coupled model useful for Seasonal-Interannual prediction because it contains proper tendency information thanks to the 4dVar and hence Reduces Shocks.

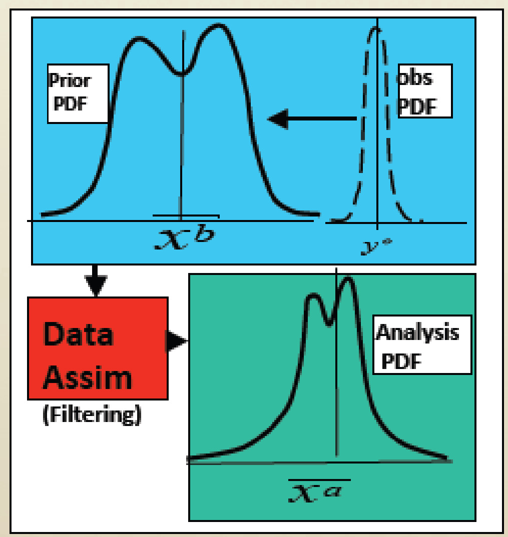
GFDL: Coupled Ensemble filter

Pioneering development of coupled data assimilation system

Ensemble Coupled Data Assimilation estimates the *temporally-evolving probability distribution* of climate states under observational data constraint:

- Multi-variate analysis maintains physical balances between state variables such as T-S relationship – primarily geostrophic balance
- Ensemble filter maintains the nonlinearity of climate evolution
- All coupled components adjusted by observed data through instantaneously-exchanged fluxes
- Optimal ensemble initialization of coupled model with minimum initialization shocks





S. Zhang, M. J. Harrison, A. Rosati, and A. Wittenberg MWR 2007

Geophysical Fluid Dynamics Laboratory

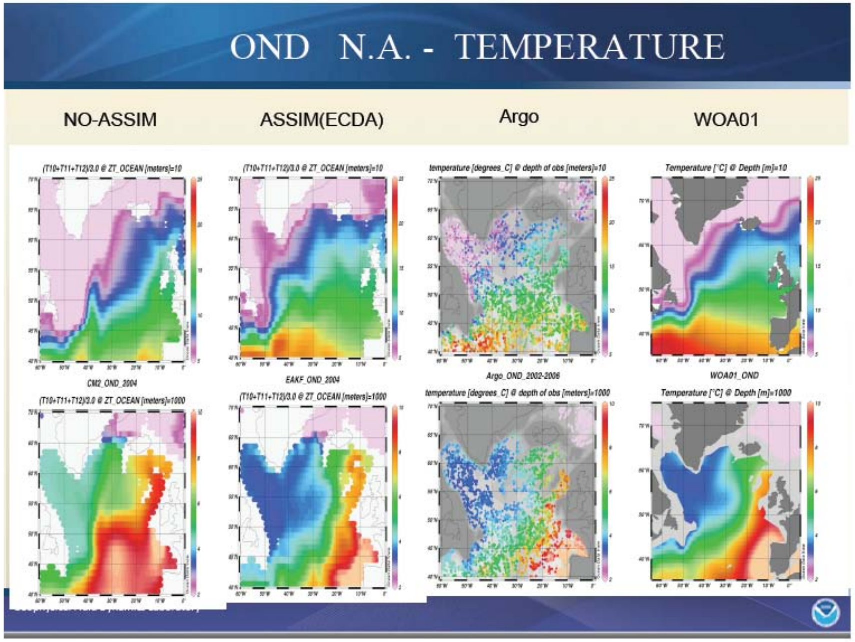
Ensemble Adjustment Kalman filter

GFDL: Coupled Ensemble filter

- Atmosphere CM2.0 ~2° 24lev Ocean MOM4 1° 22lev
- Main focus on ocean variables
  - Seasonal-decadal forecasting, eg. ENSO and AMOC variability
- Coupled ensemble EAKF(Anderson): 6-10 members
- Analysed PDF rather than single state
  - Members modified with ensemble covariances weighted by obs.
  - Covariances capture balances eg. Atm. geostrophy, Ocean T-S

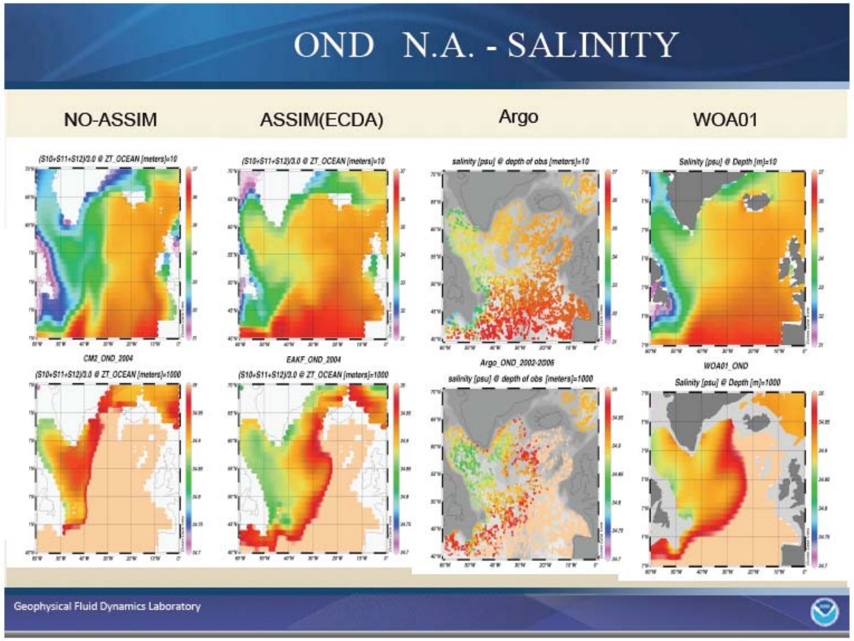
- “Assimilation” of NCEP Atmospheric reanalyses (winds v. T tested)
- Top 50m ocean T influences wind stress (through mom. transfer coeffs.?)

GFDL: Coupled Ensemble filter



10m

1000m



National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

The University of Reading

Met Office DePreSys: Anomaly Assimilation

Observations ← Observations of ocean temperature, salinity (AMOC?) Atmosphere "observations" from ERA reanalyses

↓

Gridding ← Observations made into anomalies with respect to the observed climatology and put into monthly means and specific grid boxes

↓

Analysis ← Use model ocean covariances to spread information from observations to create complete ocean anomaly T&S fields. ERA used to define atmosphere anomalies

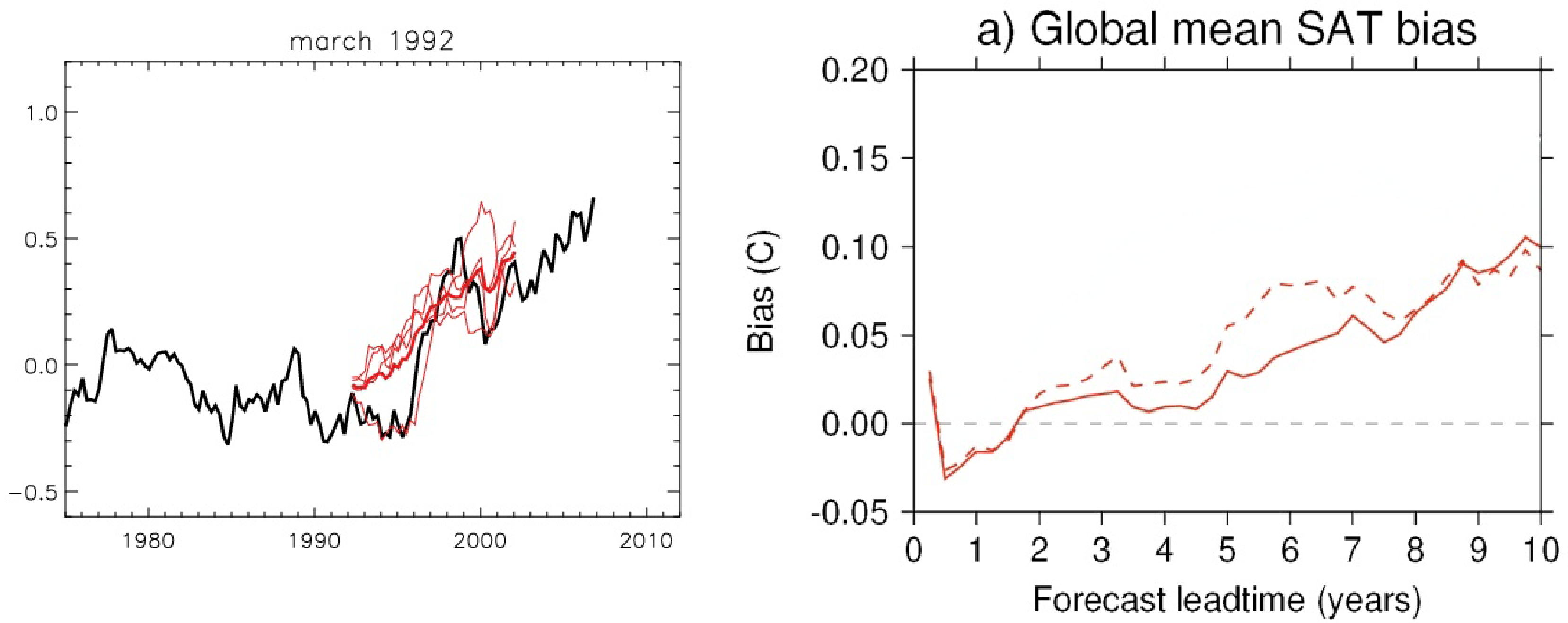
↓

Assimilation ← Nudge model T&S fields (+SLP) to analysed anomalies + model climatology to create complete ocean and atmosphere start dumps

↓

Forecast ← Start dumps (lagged atmosphere ensemble) provide initial conditions for forecast of future anomalies

DePreSys Decadal forecasting shocks?



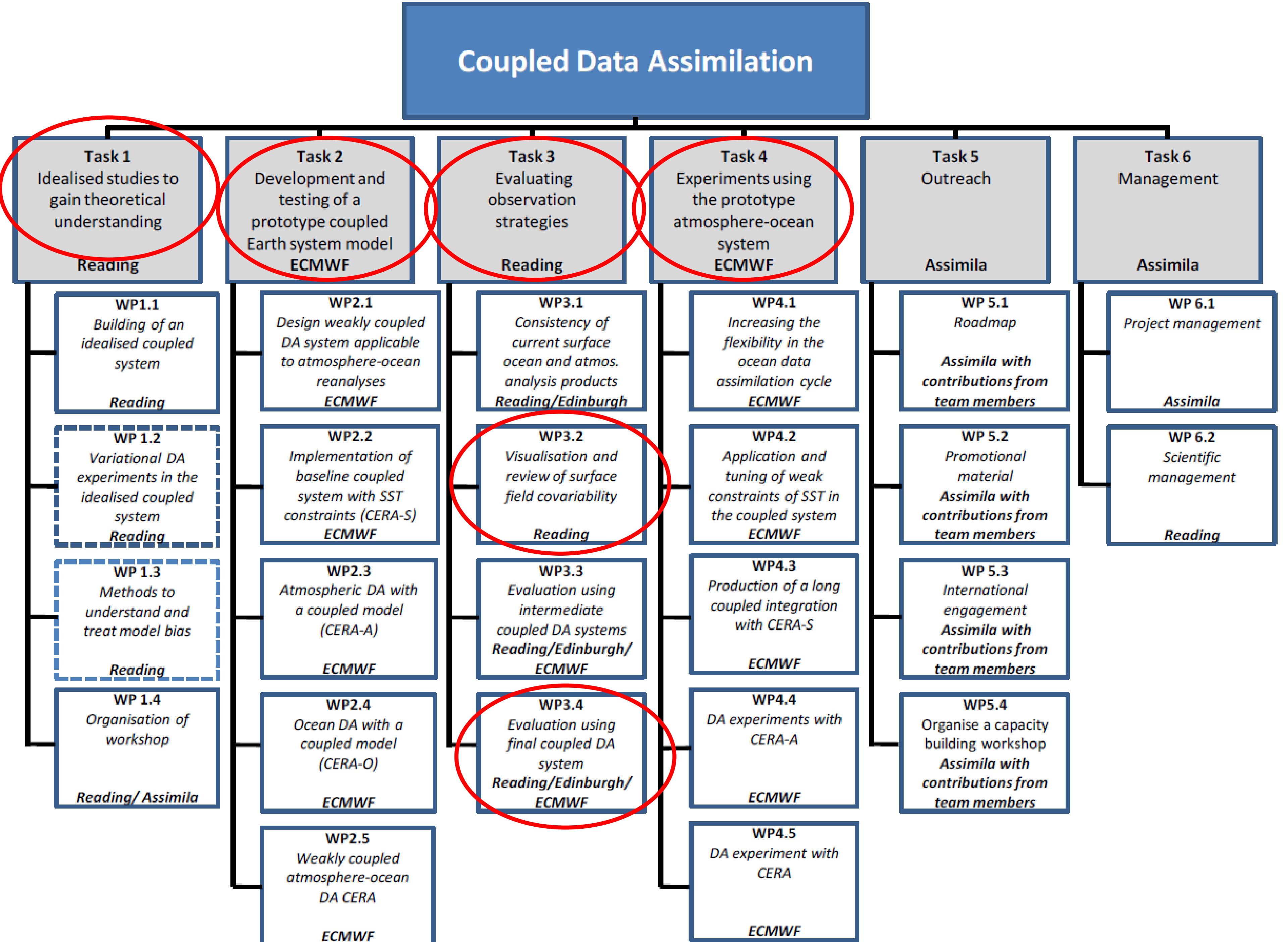
A **B**

Fig. 1: (A) Observations of N. Atlantic upper ocean heat content (black) and DePreSys predictions from March 1992 hindcast (red). Note that three ensemble members predict a rapid warming, and one follows the observations more closely. (B) Growth of surface air temperature bias in DePreSys hindcasts showing initialisation shock in the first two seasons. Both from Robson (2010, PhD thesis).

Robson PhD 2010

Coupled ECMWF ReAnalysis (CERA): Plans

- NCEO-ECMWF 2yr-proposal to ESA
- Build Weakly Coupled DA system and use to
  - Seek improvements in Surface Obs. Assim; SST, Scatt, Waves
  - Representation of short timescale phenomena, Diurnal cycle, MJO etc...
- Currently separate Atm. Ocean systems
  - IFS : 12 hr 4DVar cycle, fixed SST
  - NEMO : 10 day 3DVar FGAT IAU
- CERA-A : Atmospheric 4DVar over 24hr with Coupled IFS-NEMO using NEMO 3DVar Reanalysis to initialise ocean each cycle and No Ocean assimilation
- CERA : As CERA-A but cycling ocean model corrections based on coupled model: Full Weakly coupled system


Coupled Data Assimilation
Task 1 Idealised studies to gain theoretical understanding Reading
Task 2 Development and testing of a prototype coupled Earth system model ECMWF
Task 3 Evaluating observation strategies Reading
Task 4 Experiments using the prototype atmosphere-ocean system ECMWF
Task 5 Outreach Assimila
Task 6 Management Assimila
WP1.1 Building of an idealised coupled system Reading
WP 1.2 Variational DA experiments in the idealised coupled system Reading
WP 1.3 Methods to understand and treat model bias Reading
WP 1.4 Organisation of workshop Reading/ Assimila
WP2.1 Design weakly coupled DA system applicable to atmosphere-ocean reanalyses ECMWF
WP2.2 Implementation of baseline coupled system with SST constraints (CERA-S) ECMWF
WP2.3 Atmospheric DA with a coupled model (CERA-A) ECMWF
WP2.4 Ocean DA with a coupled model (CERA-O) ECMWF
WP2.5 Weakly coupled atmosphere-ocean DA CERA ECMWF
WP3.1 Consistency of current surface ocean and atmos. analysis products Reading/Edinburgh
WP3.2 Visualisation and review of surface field covariability Reading
WP3.3 Evaluation using intermediate coupled DA systems Reading/Edinburgh/ ECMWF
WP3.4 Evaluation using final coupled DA system Reading/Edinburgh/ ECMWF
WP4.1 Increasing the flexibility in the ocean data assimilation cycle ECMWF
WP4.2 Application and tuning of weak constraints of SST in the coupled system ECMWF
WP4.3 Production of a long coupled integration with CERA-S ECMWF
WP4.4 DA experiments with CERA-A ECMWF
WP4.5 DA experiment with CERA ECMWF
WP 5.1 Roadmap Assimila with contributions from team members
WP 5.2 Promotional material Assimila with contributions from team members
WP 5.3 International engagement Assimila with contributions from team members
WP5.4 Organise a capacity building workshop Assimila with contributions from team members
WP 6.1 Project management Assimila
WP 6.2 Scientific management Reading

Role of Coupled Ensembles

- Natural development of coupled error covariances
- Proper weighting of surface observation uncertainties
  - SSTs, Cloud cover, at appropriate spatial scales
- Atmospheric spread develops on short timescales, ocean spread on longer timescales
- Ocean spread less constrained by ocean Obs:- Need to maintain ocean ensemble spread through many assimilation cycles
- Assess impact of coupled bias corrections on ensemble spread
- Need better understanding of bias corrections in coupled models

Role of Coupled 4DVar

- Reduce initialisation shocks
- Confined to linear error growth timescales in Atm.
- OR use averaging methods eg. JAMSTEC (precludes better representation of short timescales eg. diurnal
- Overlapping time periods may be required for smooth reanalyses
- Possibility to tune coupling parameters
- Value of a coupled adjoint in short timescale OSE analyses

Final Thoughts

- Few Coupled DA GCM implementations
- Weakly coupled approach most popular
  - Move away from using pre-analysed surface fields eg. SST, ..
- Transition to strong coupling requires--
  - Coupled covariances and/or
  - Coupling parameter tuning
- JAMSTEC temporally filtered coupled 4DVar
  - Not favoured elsewhere, avoids short timescale coupling
- Future of Anomaly assimilation?
- Coupled bias studies
  - Process focussed studies; Growth of bias
  - Bias corrections <==> Anomaly assimilation

Thanks for Listening