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WP2 task 2.2 SST assimilation

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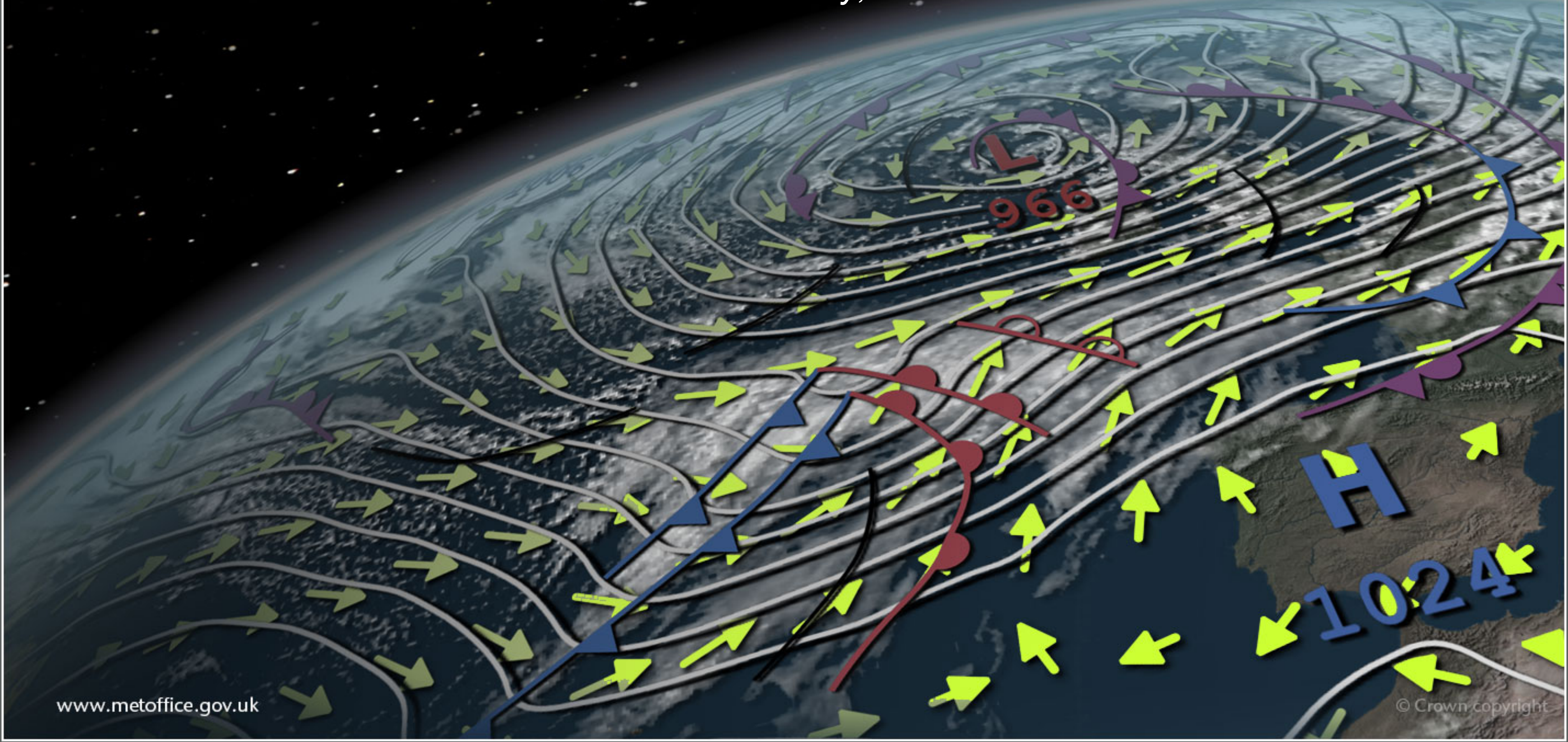

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Contents

- Impact of SST assimilation in coupled DA
- SST bias correction developments
- Assimilation using EOF-based error covariances

SST data assimilation in NEMOVAR (FOAM)

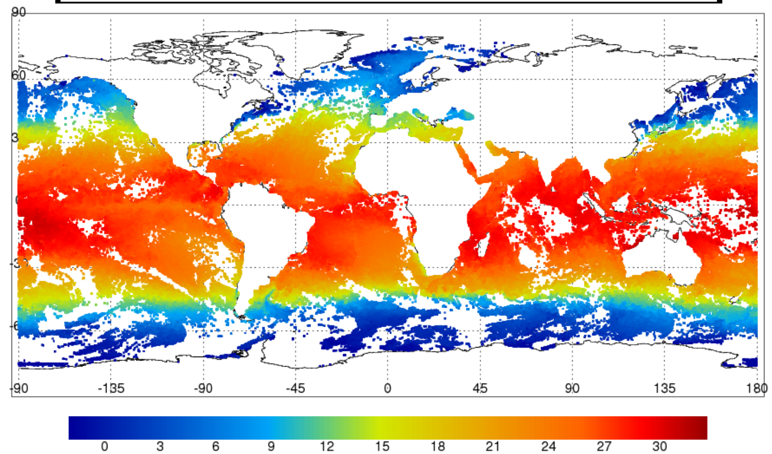
- SST observation bias correction is carried out by defining a set of un-biased observations

- Then for each biased satellite:
    - calculate match-ups within 24 hours and radius of 25km
    - produce a large-scale analysis of the bias for that satellite using a 2D set-up of NEMOVAR.
    - remove the bias estimate from each satellite observation

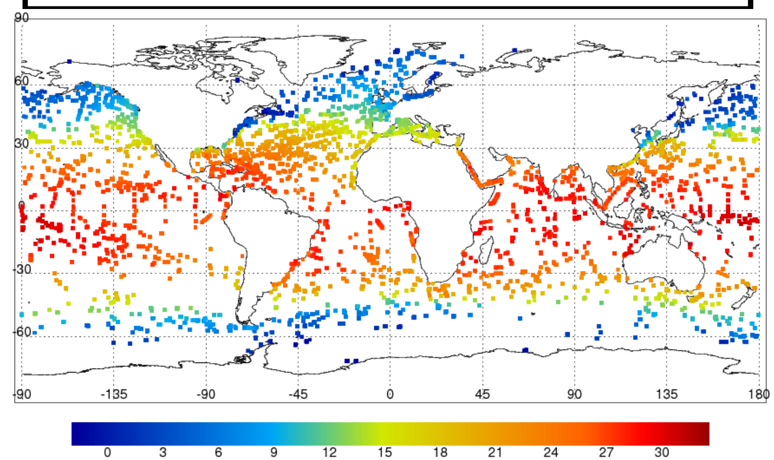
- The bias-corrected SST observations are then used in NEMOVAR in 3DVar-FGAT together with all other observation types (T&S profiles, altimeter SLA, sea-ice concentration).

- Vertical length-scales near the surface are defined based on the background mixed-layer depth, so that SST observations will affect the sub-surface ocean.

L2p Satellite SST data
(NOAA/AVHRR, MetOp/AVHRR)



Data for one day on 27th Feb 2015.



In situ SST data
(ships, moored and drifting buoys)

ERA-CLIM2 Observing System Experiment

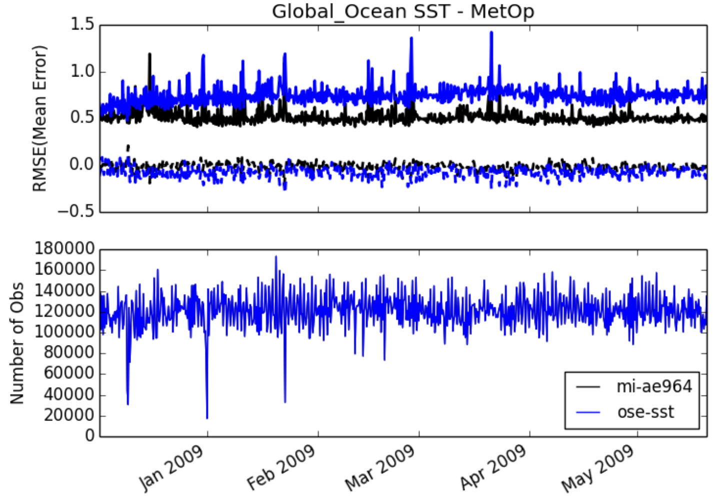
Rob King

- Aims:
  - to investigate the impact of assimilating SST observations in coupled prediction systems on weather-forecasting timescales.
  - to assess the impact of the SST assimilation improvements planned as part of this WP.
- Coupled DA run Dec 2008 – May 2009 complete
  - Control run assimilated all standard atmosphere and ocean observations in weakly-coupled DA system.
  - OSE with-held all satellite SST observations from the same weakly-coupled DA.
  - Atmosphere observations - standard set of in situ/satellite data for NWP
  - T/S profiles and in situ SST - HadIODv1.1.0
  - Altimeter SLA - AVISOv4.0 delayed mode SLA
  - Sea-ice concentration – EUMETSAT OSI-SAF.
  - Satellite SST: AMSRE from GHRSST; AATSR, NOAA-AVHRR, Metop-AVHRR from ESA CCI

ERA-CLIM2 Observing System Experiment

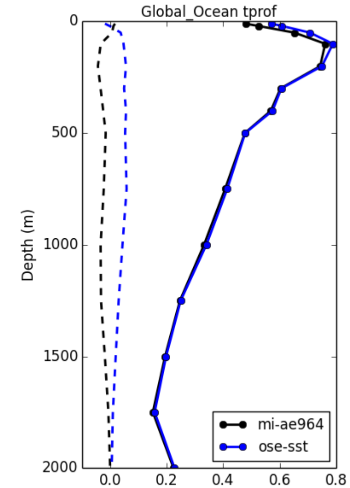
Status/results

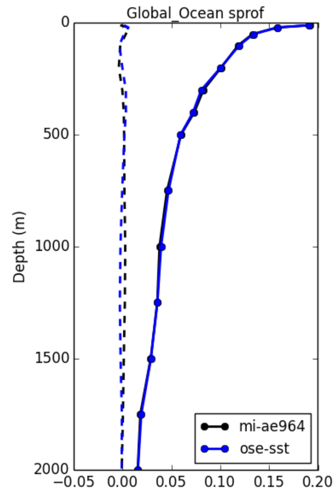
- Atmosphere/ocean innovations archived for further coupled error covariance investigations.
- Assessment still to be carried out, but initial ocean innovations statistics show expected degradation in the OSE when comparing satellite SST observations.
- An impact is also seen in the RMS temperature error in the upper ocean and in the bias down to almost 2000m.
- Plan to investigate impact on ocean in more detail, and also look at impact on the atmosphere.



Time-series of global MetOp SST innovation statistics and the corresponding number of observations.

Global temperature and salinity profile innovation statistics – RMS shown as solid line, mean error shown as dashed line.





SST bias correction development
Overview

James While

•As part of the ERA-Clim2 project we are developing an improved system of bias correction for satellite SST observations.

•Currently bias correction is done 'offline' by corr observations towards an 'unbiased' data set.

Correction for Obs bias

•We plan to replace this system with a variational methodology, but one that includes 'observations of bias' in the cost function:

$$J = 0.5(\mathbf{x}-\mathbf{x}^{\mathbf{f}})^{\mathrm{T}}\hat{\mathbf{B}}^{-1}(\mathbf{x}-\mathbf{x}^{\mathbf{f}}) + 0.5(\mathbf{y}-(\mathbf{H_y x}+\mathbf{H_b b}))^{\mathrm{T}}\hat{\mathbf{R}}^{-1}(\mathbf{y}-(\mathbf{H_y x}+\mathbf{H_b b}))$$

$$+0.5(\mathbf{b}-\mathbf{b}^{f})^{\mathrm{T}}\hat{\mathbf{O}}^{-1}(\mathbf{b}-\mathbf{b}^{\mathbf{f}}) + 0.5(\mathbf{z}-\mathbf{H_z b})^{\mathrm{T}}\hat{\mathbf{L}}^{-1}(\mathbf{z}-\mathbf{H_z b})$$

•Model SST bias will also be considered, but this will be corrected offline.

Obs bias Variational term

Obs bias Obs-of-bias term

•Our work theoretical le 'toy' model, but we shortly plan to implement our ideas in the NEMOVAR system.

SST bias correction.
Test system

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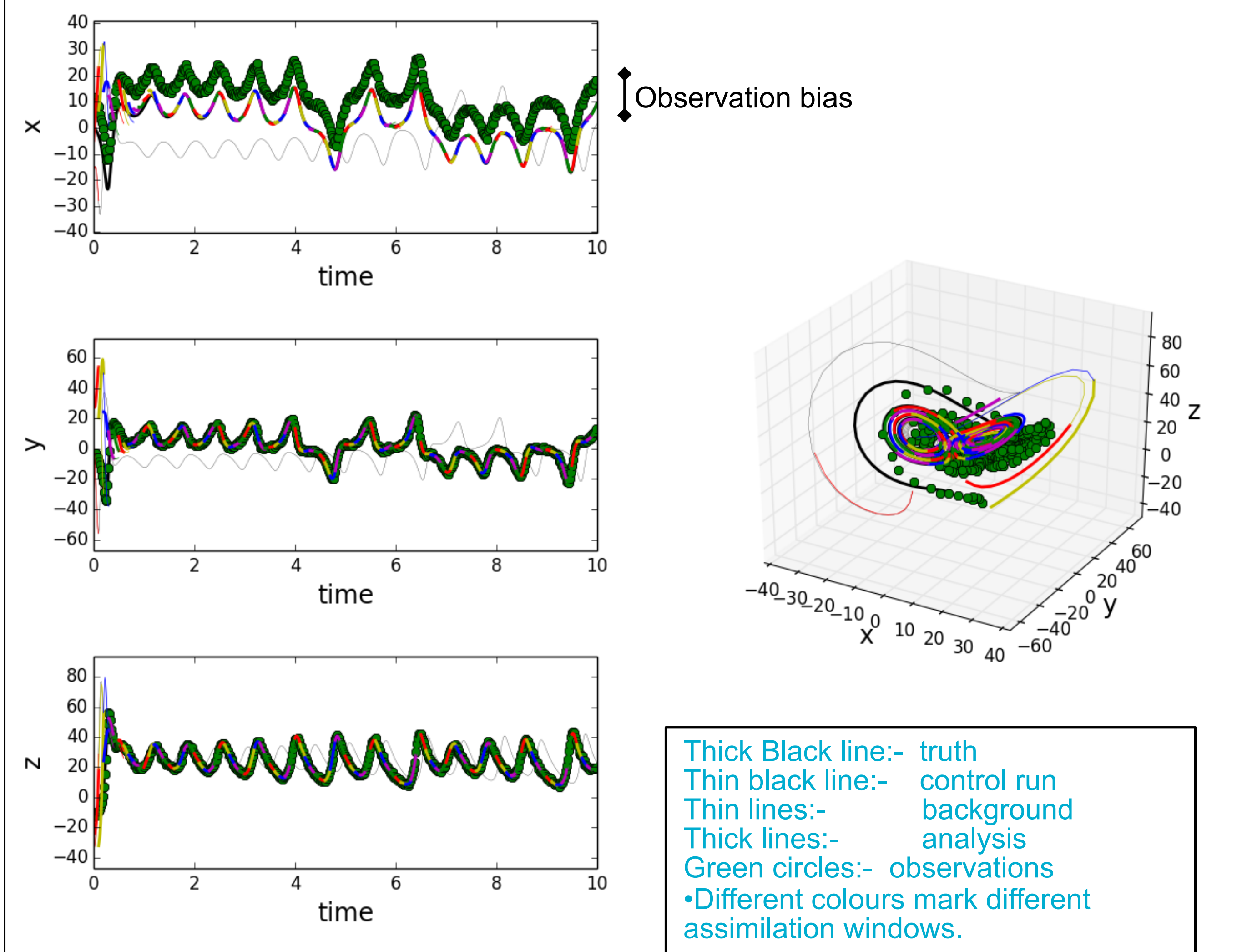
We are testing our ideas using the Lorenz 63 system.

Observations are available for all 3 directions, but only x observations are biased.



SST bias correction.

Results with increasing bias

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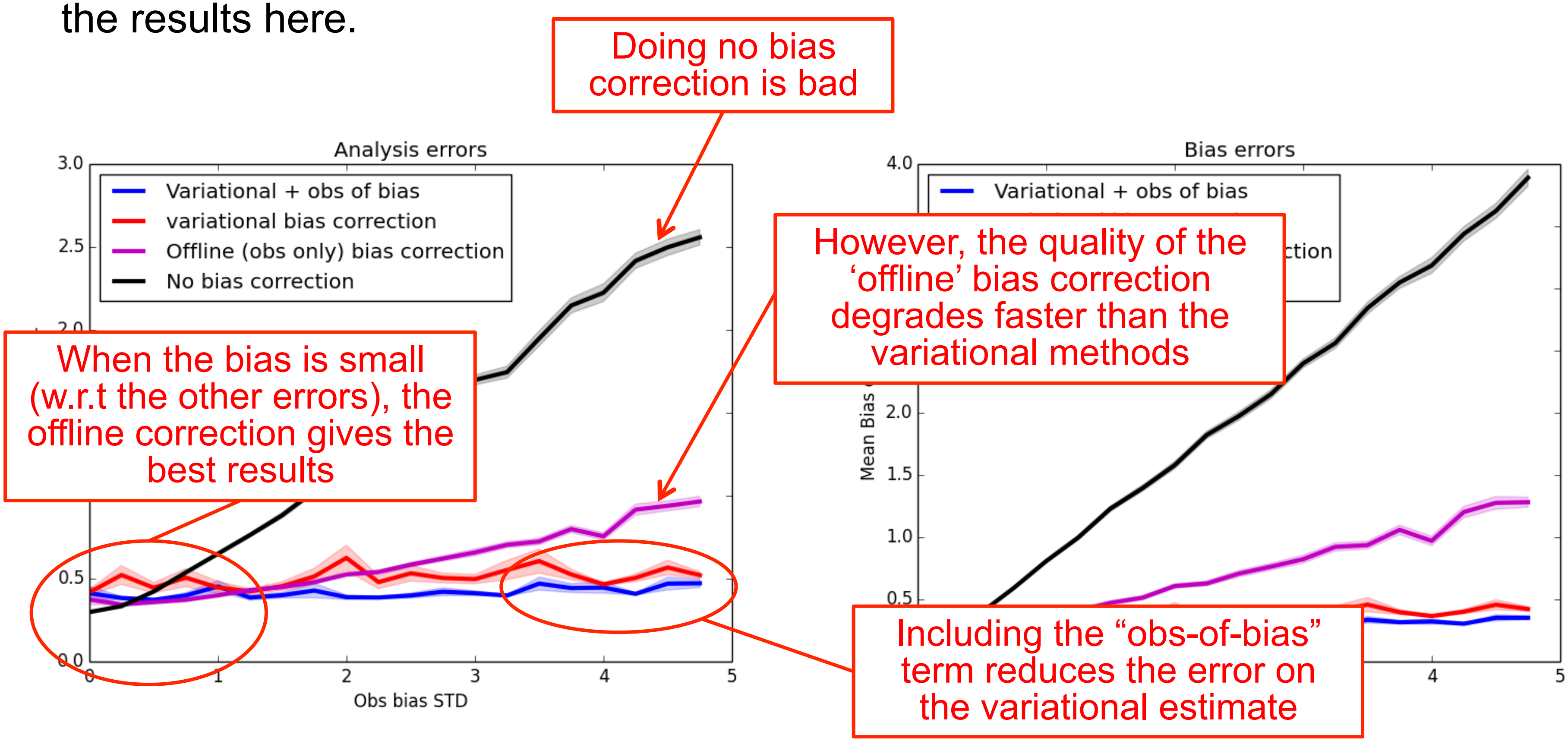
- These results are from the Lorenz 63 system.
- We have also looked at the theoretical errors from a linear system, which supports the results here.



EOF-based assimilation
Motivation

Dan Lea

- Ocean observation network has changed markedly in the last 100 years or so.

- Observations were sparse and sampling inhomogeneous. Observations now much less sparse and more globally homogeneous, but we still have sparse sampling at depth.

- How can assimilation make best use of the sparse historical data while still doing a good job with today's data?

- The key thing which gives data assimilation its power is the background error covariance which allows us to spread information from the observation locations.

- Can we improve the error covariance structures to allow us to correctly spread sparse observation information over greater distances in order to fill in the gaps?

EOF-based assimilation
Initial tests with NEMOVAR

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• New version of NEMOVAR written by Anthony Weaver which does hybrid ensemble/variational DA.

• Hybrid EOF error covariances now added to a preliminary version of this new code.

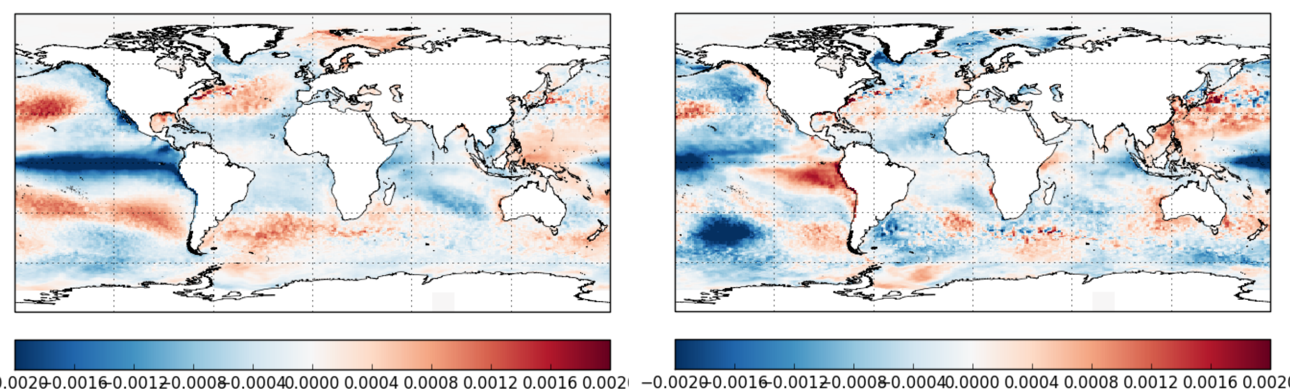
Hybrid EOF/variational

$$\delta \mathbf{x} = w_1 \, \mathbf{E} \, \mathbf{a} + w_2 \, \delta \, \mathbf{x}_{residual}$$

$$J = w_1 \, ½ \, \mathbf{a}^T \, \mathbf{\Lambda}^{-1} \, \mathbf{a} \; + \; w_2 \, ½ \, \delta \, \mathbf{x}_{res}{}^{T} \, \mathbf{B}^{-1} \, \delta \, \mathbf{x}_{res} + \text{[obs cost]}$$

• Initial estimates of EOFs generated from 20 year Glosea reanalysis.

•Top two EOFs:



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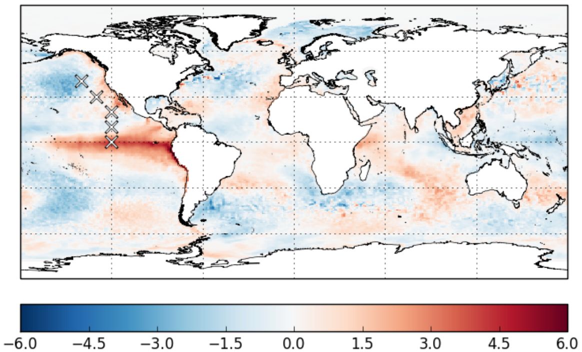
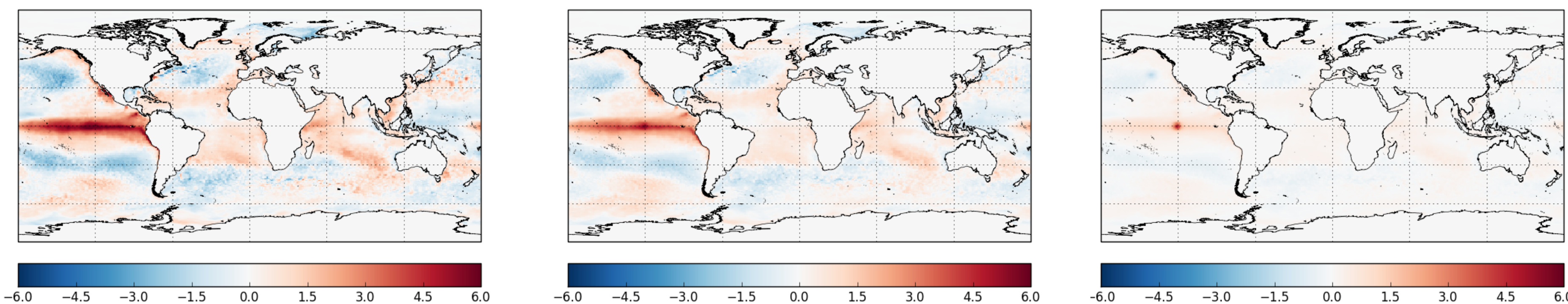
Idealised experiments in NEMOVAR



"True" increments and simulated obs locations

Increments generated from NEMOVAR with different hybrid weights



EOF only

Reducing weight to EOF part of B

SST assimilation development plans

- **Coupled DA SST OSEs:**
  - Assess impact of satellite SST data assimilation on ocean and atmosphere.
- **SST bias correction developments:**
  - Implement combined scheme in NEMOVAR and assess impact during periods with different satellite combinations.
- **EOF-based error covariances:**
  - Set-up a test framework:
    - Twin experiments and data withholding for various dates in 1960-2010 period
    - Model fields from coupled runs to estimate EOFs – investigate stability and compare to obs-based estimates.
  - Development work:
    - Multivariate aspects (use EOFs or local balance relationships)
    - Set-up cycling: with EOF increments applied to the NEMO ocean model
    - Improve error modelling: evolve errors in time in EOF space (using an AR model of the EOFs); adjust observation error to account for EOF truncation.
    - Hybrid DA development: run a present-day analysis system

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Thank you

EOF-based assimilation

Theory

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Working in model space

$$J(\delta \mathbf{x}) = \tfrac{1}{2}\, \delta \mathbf{x}^T \mathbf{B}^{-1} \delta \mathbf{x} + \tfrac{1}{2}\, (\mathbf{y}-H(\mathbf{x}_b+\delta \mathbf{x}))^T \mathbf{R}^{-1} (\mathbf{y}-H(\mathbf{x}_b+\delta \mathbf{x}))$$

$$\delta \mathbf{x} = \mathbf{E}\, \mathbf{a}$$

Working in EOF space

$$J(\mathbf{a}) = \tfrac{1}{2}\, \mathbf{a}^T \mathbf{\Lambda}^{-1} \mathbf{a} + \tfrac{1}{2}\, (\mathbf{y}-H(\mathbf{x}_b+\mathbf{E}\mathbf{a}))^T \mathbf{R}^{-1} (\mathbf{y}-H(\mathbf{x}_b+\mathbf{E}\mathbf{a}))$$

Hybrid

$$\delta\, \mathbf{x} = w_1\, \mathbf{E}\, \mathbf{a} + w_2\, \delta\, \mathbf{x}_{residual}$$

$$J = w_1\, \tfrac{1}{2}\, \mathbf{a}^T \mathbf{\Lambda}^{-1} \mathbf{a} + w_2\, \tfrac{1}{2}\, \delta\, \mathbf{x}_{res}{}^T \mathbf{B}^{-1} \delta\, \mathbf{x}_{res} + \text{[obs cost]}$$

(W_1+W_2=1)

a= vector of coefficients/ weights for each EOF (Temperature anomaly = **Ea**)

E= EOFs

Λ= diagonal matrix of eigenvalues (calculated with the EOFs) (squared)