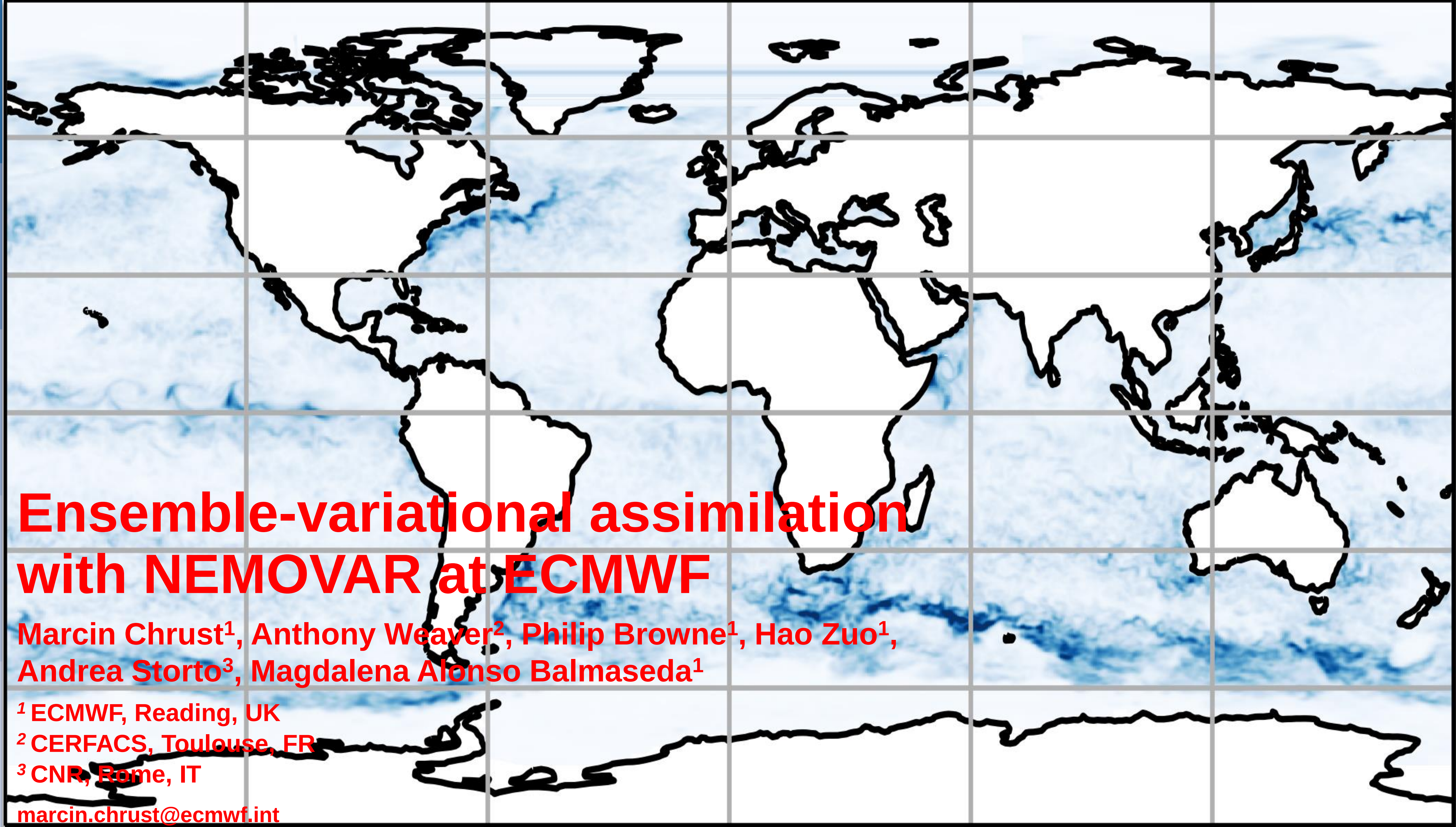

Ensemble-variational assimilation with NEMOVAR at ECMWF

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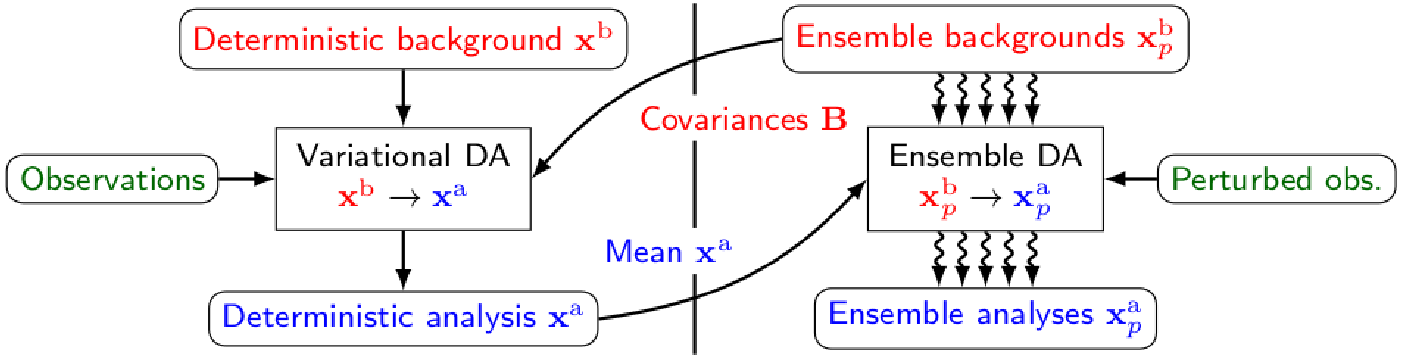
Ensemble of Ocean Data Assimilations

Climate Change Service
climate.copernicus.eu

- Development of an Ensemble of Data Assimilations (EDA) is supported by an EU Copernicus C3S contract: Technical preparation for C3S Seasonal Initialization and Global Reanalysis: Enabling of Ensemble of Data Assimilations for the Ocean;

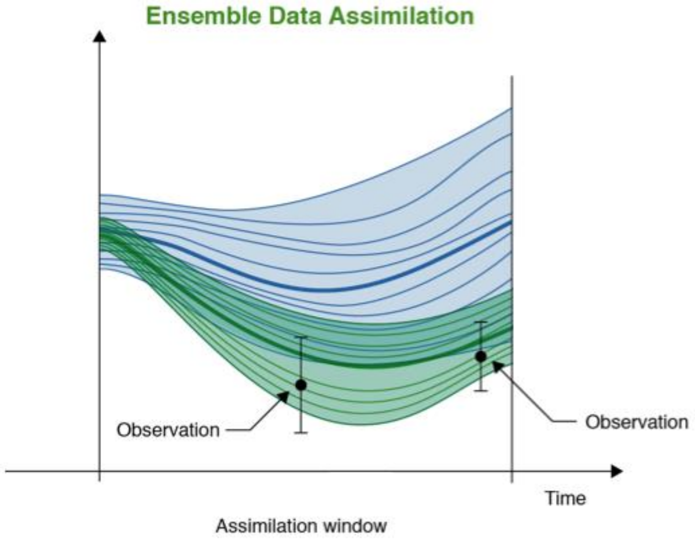
Generate an ensemble of analyses from an ensemble of background states and perturbed observations



- Ensemble DA perturbations simulate errors for the deterministic system;
- 3D-Var analysis for both deterministic and ensemble system;
- Observation and surface forcing perturbations as in ORAS5 (Zuo et al. 2017);
- Implementation of stochastic physics in NEMO (A. Storto, CMRE).

Climatological background error covariance parameters

- For each cycle, we compute filtered EDA standard deviations and estimate the diffusion tensor of the correlation model;
- These parameters are averaged to compute multi-year seasonal (DJF, MAM, JJA, SON) climatological background error standard deviations and correlation tensor;



Climatological background error covariance parameters

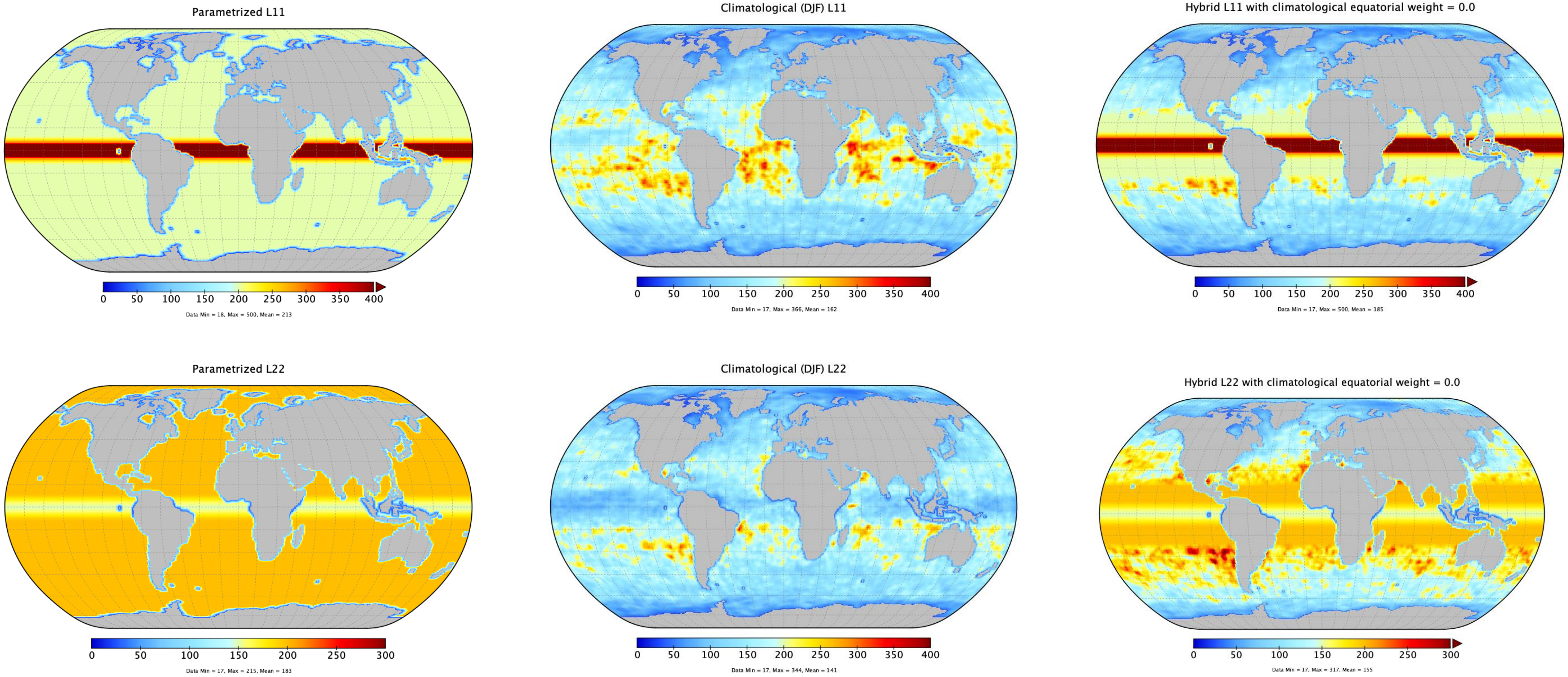
Lessons learned:

- We have used ORAS5 ensemble (4 perturbed members) to compute climatological parameters 2010-2014;
- ORAS5 ensemble is generated using perturbed observations and forcings;
- Diagnosed climatological correlation length scales are too short in the tropics, which leads to degradation of the performance of the system;
- Diagnosed climatological variances are small everywhere except eddy active regions;

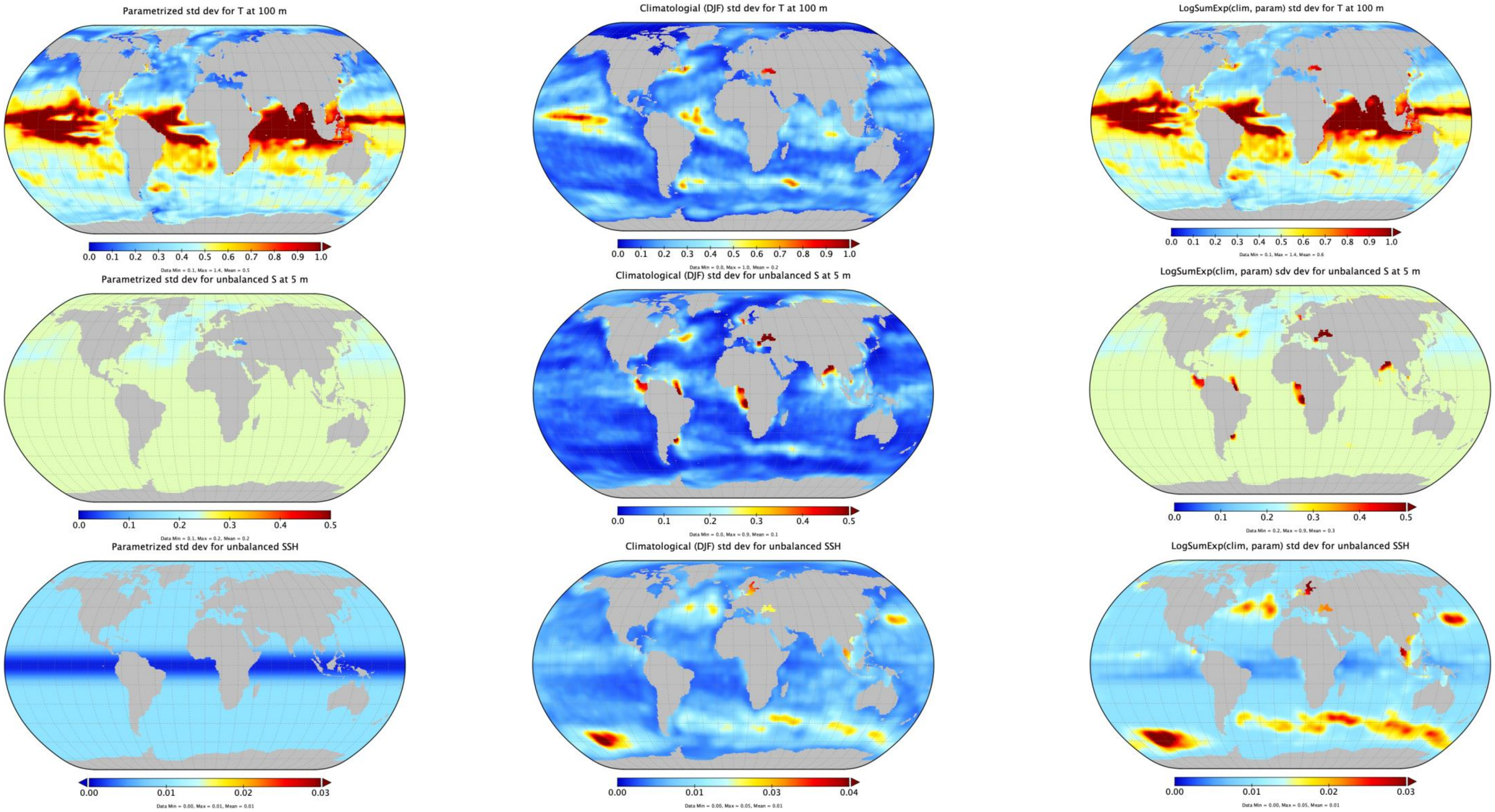
Practical approach:

- Combine parametrized and climatological tensor in the tropics;
- Combine parametrized and climatological variances using a smooth maximum function;

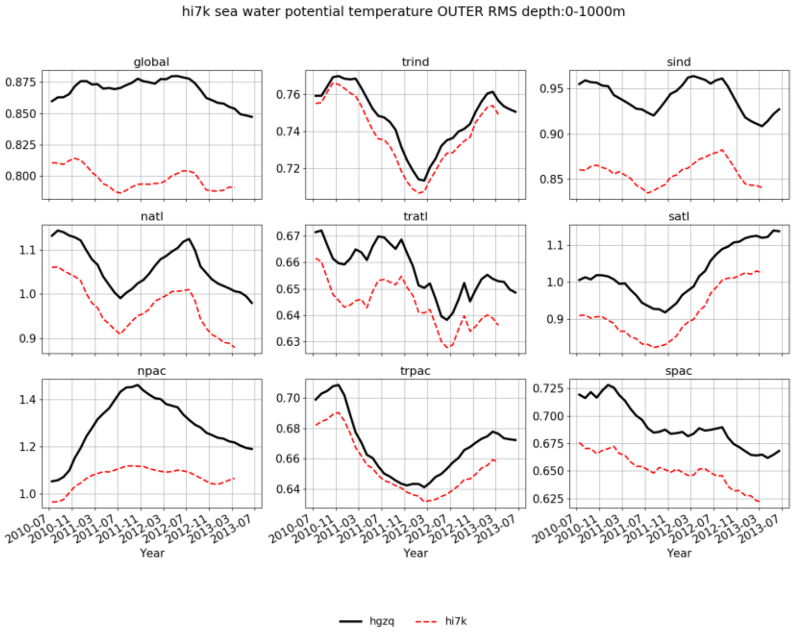
Climatological background error covariance parameters

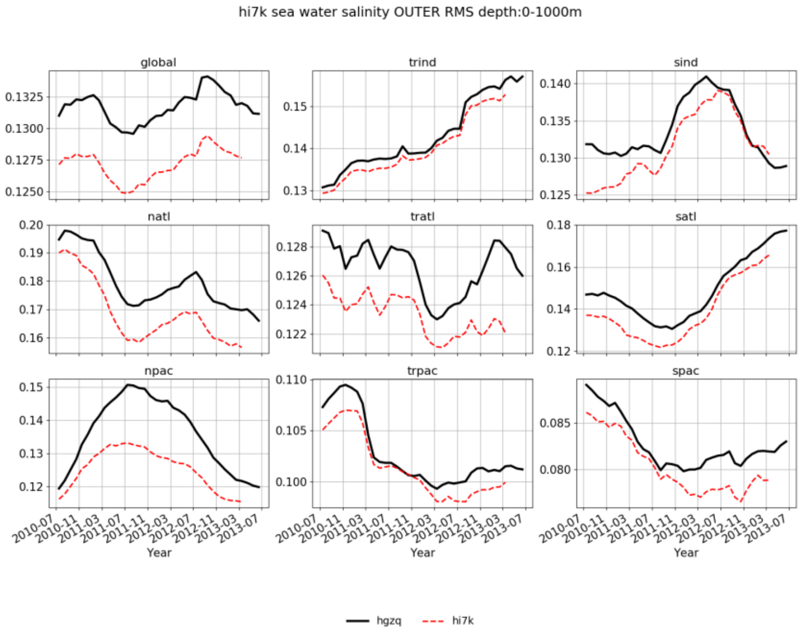


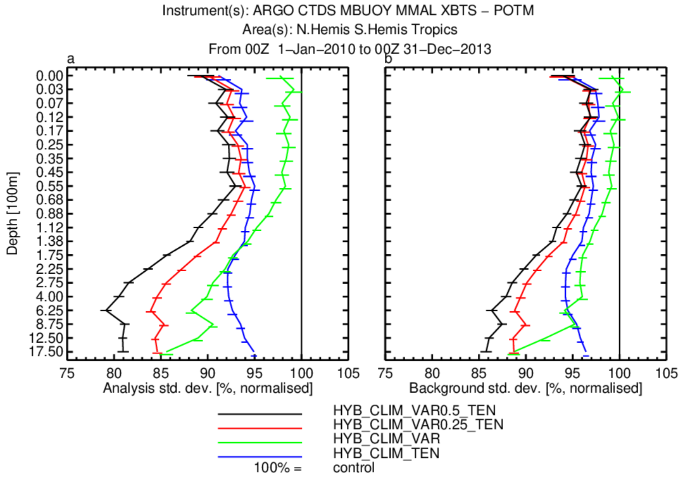
Climatological background error covariance parameters

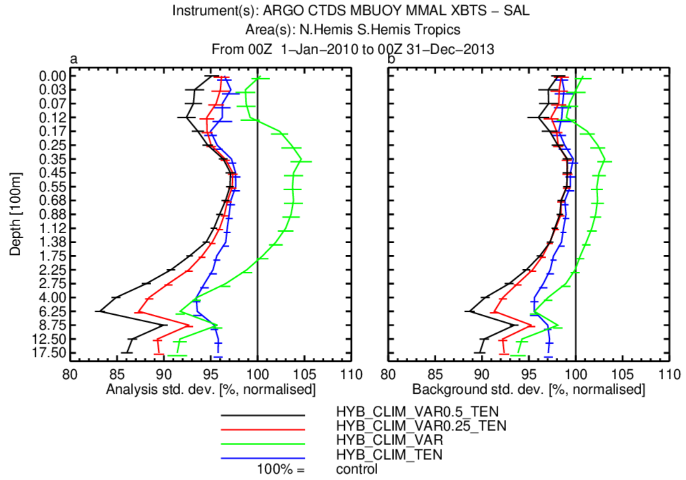


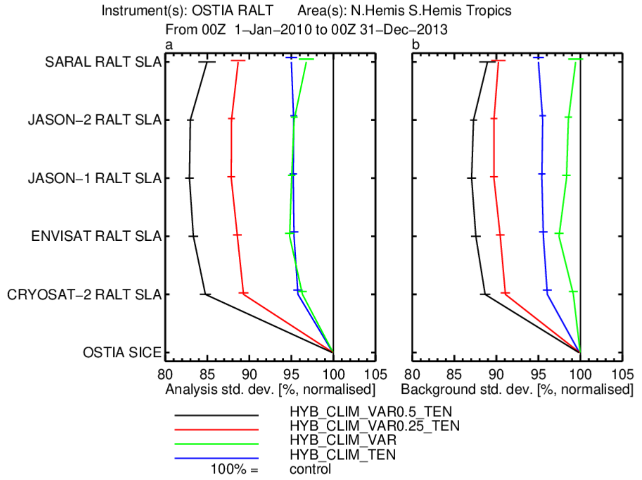
Climatological background error parameters



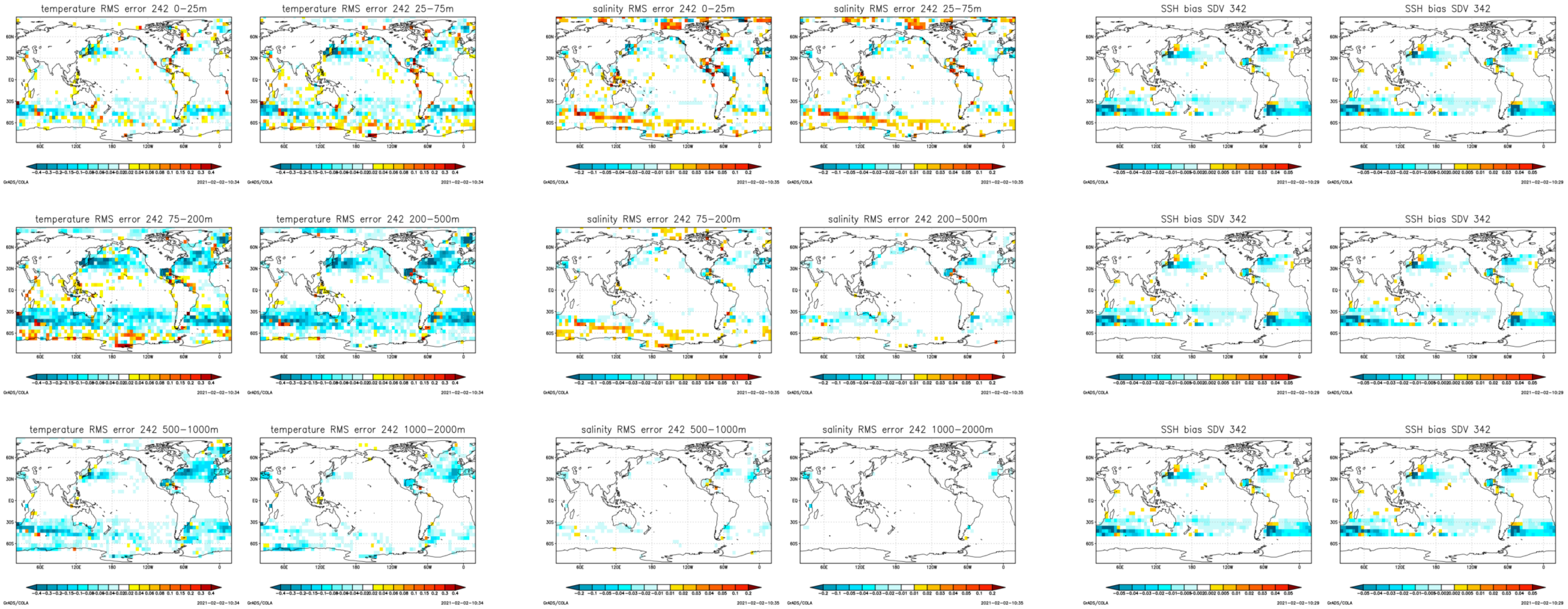








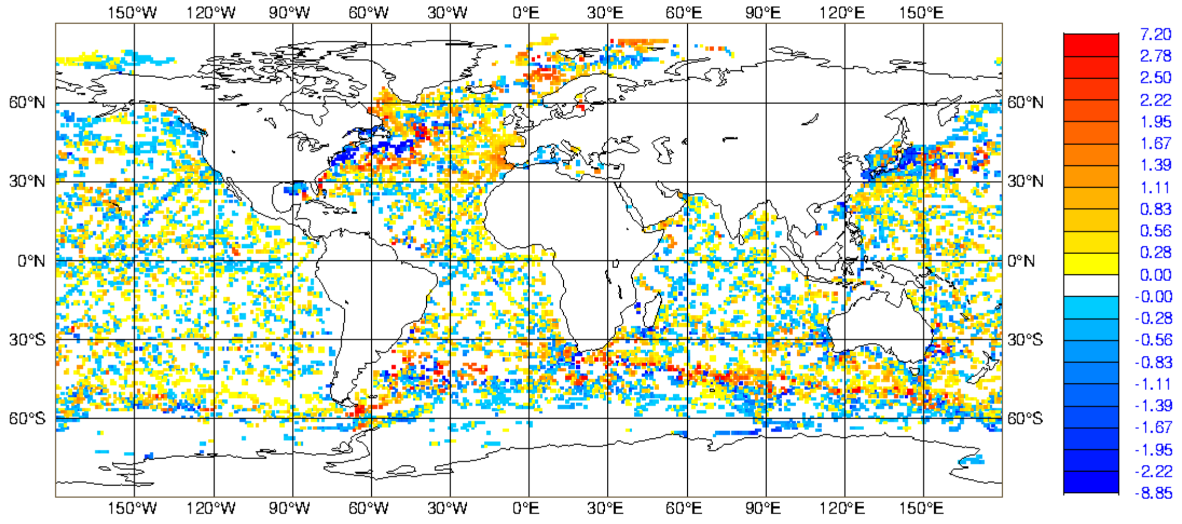
Climatological background error covariance parameters



Climatological background error covariance parameters

Can we do better and avoid having to use hybrid parameters?

- Hybrid tensor – recompute climatology with 15-member ensemble using improved ensemble generation scheme (+stochastic physics)
- Hybrid variances – retune observation errors (currently we define globally uniform observation errors following Ingleby, B. and M. Huddleston, 2005 with inflation close to coast) using observation space diagnostics;



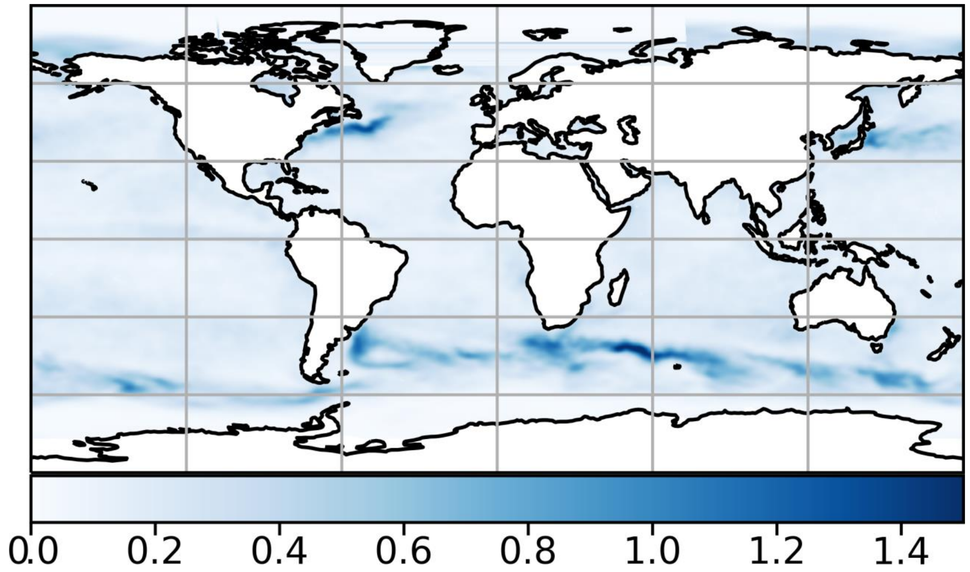
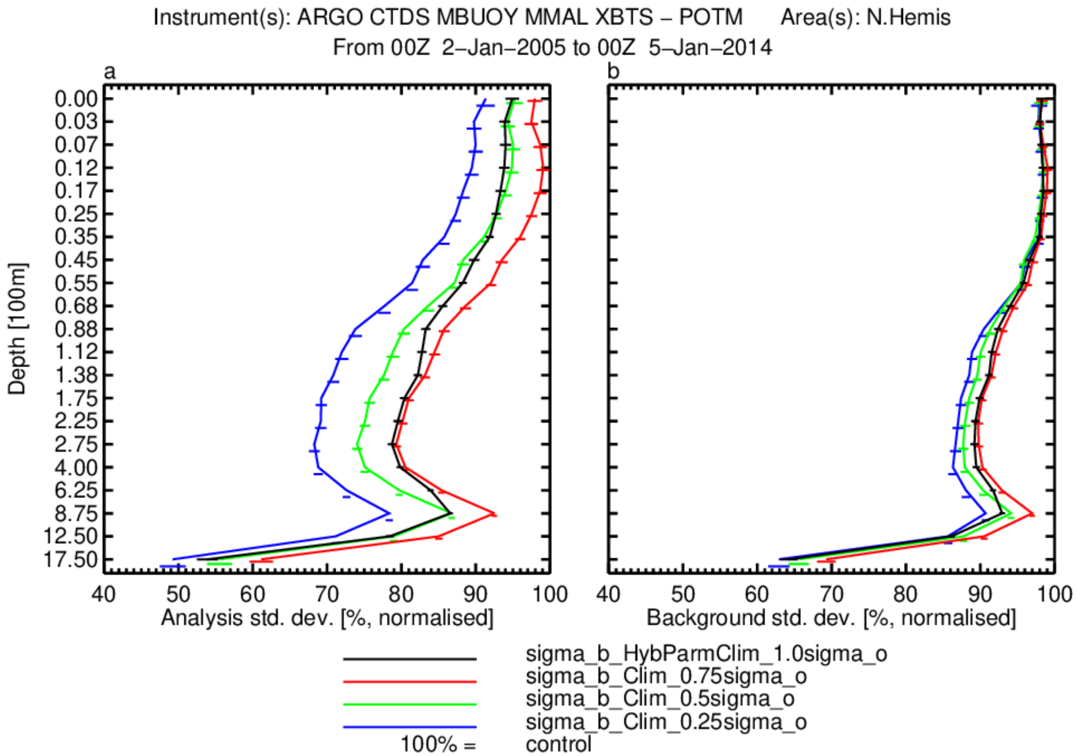
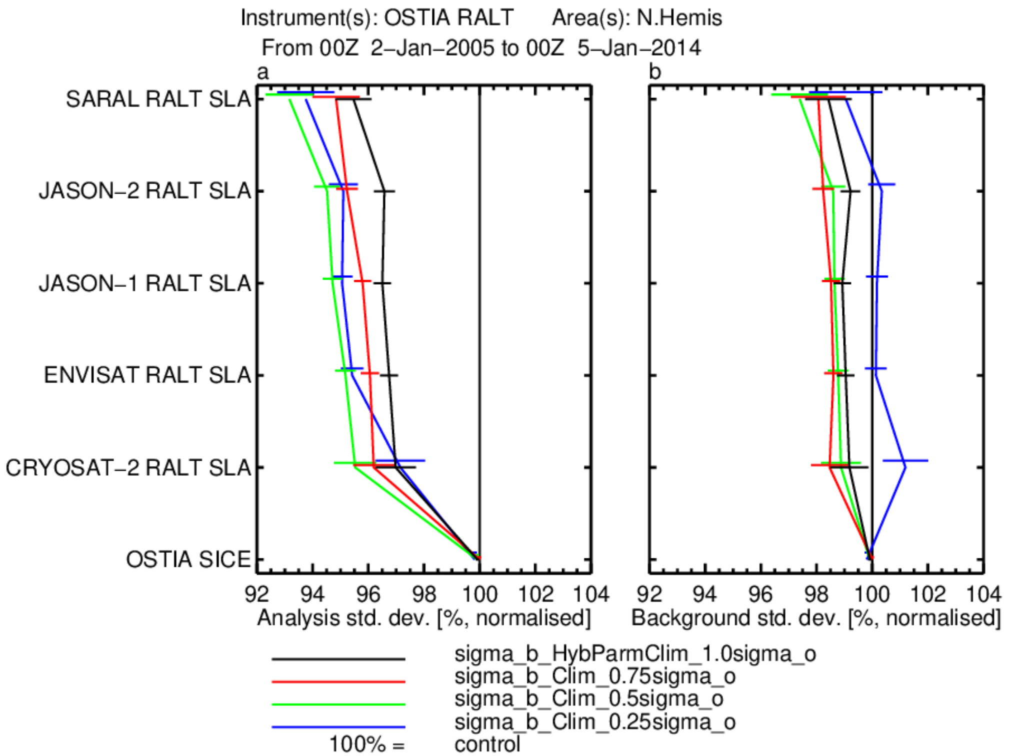


Fig. Left: Averaged first guess departures (SON); Right: Climatological background errors standard deviations; Representativeness error has spatial and temporal variability associated with unresolved spatial and temporal scales.

Climatological background error covariance parameters

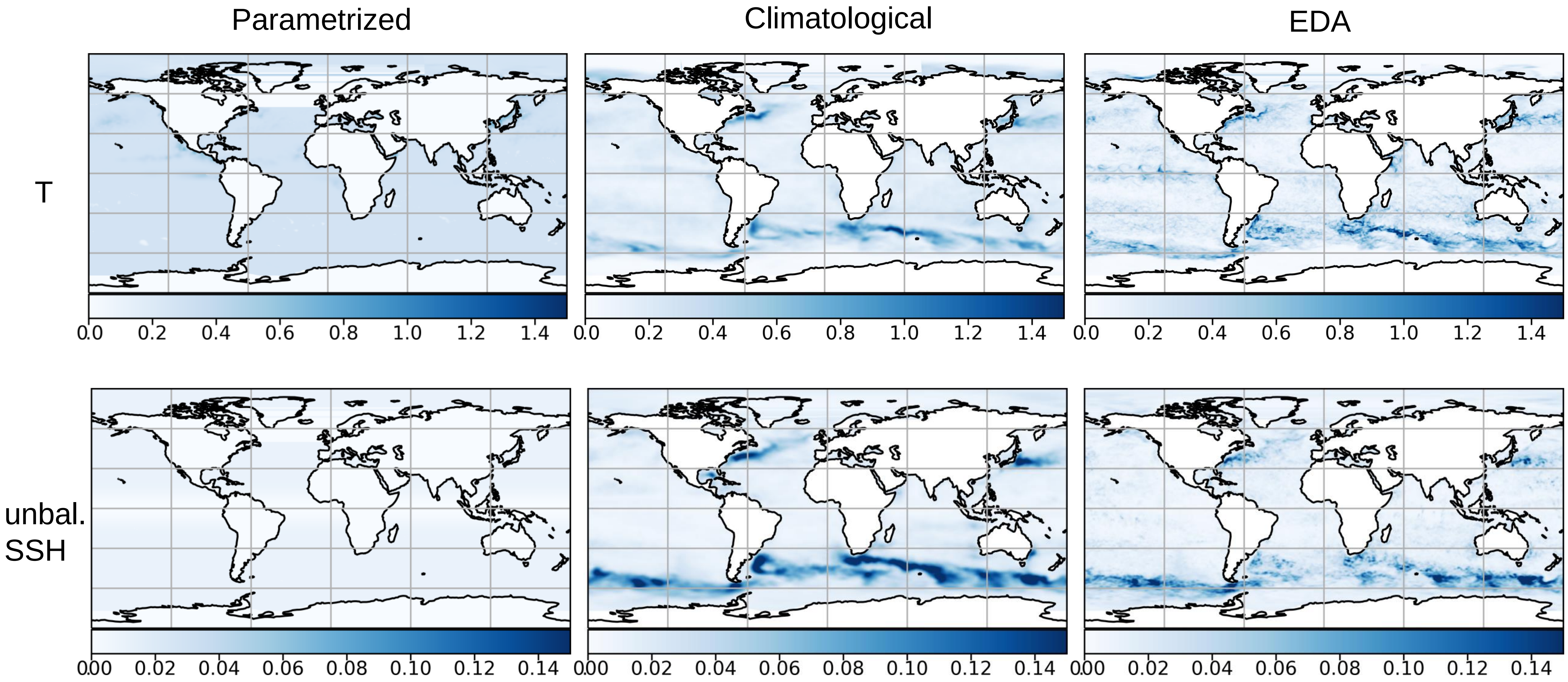




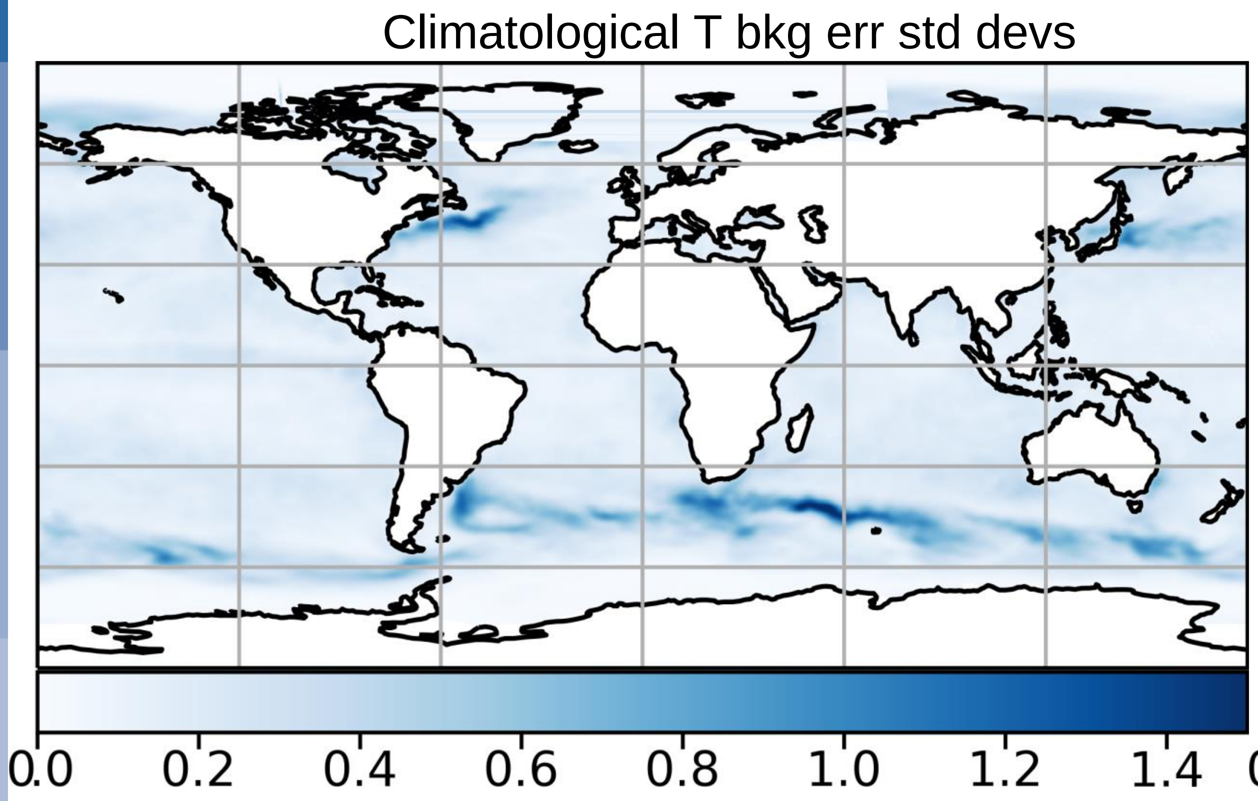
ORCA1_Z75:

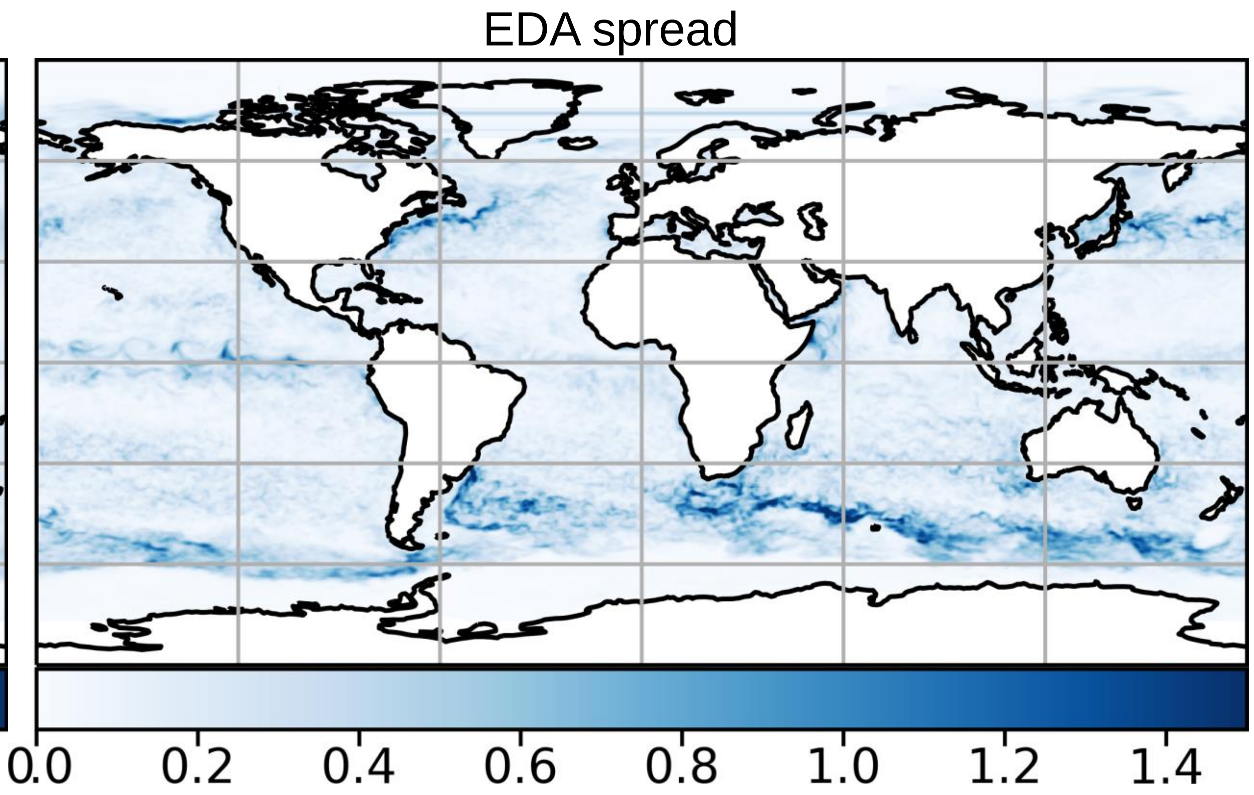
- Simple tuning of observation error standard deviations allows us to use pure climatological background error standard deviations while the system performance is not affected;
- Retuning observation errors using observation space diagnostics shall bring further benefits – under way;
- **Ability to use pure climatological background error standard deviations is key for accounting for the errors of the day;**

Hybrid background errors standard deviations – ORCA025 (15 member ensemble; +stochastic physics)



Hybrid background errors standard deviations – ORCA025 (15 member ensemble; +stochastic physics)





- Climatological bkg error variances should be combined using weighted sum to extract sharp features (errors of the day) while keeping the combined variances smooth (climatological component);
- Until we re-tune the observation errors, we have to rely on the smooth maximum – far from ideal;

Summary

- We have developed a methodology to compute climatological **B** matrix parameters using climatological ensembles;
- The quality of the parameters depends on the quality of climatological ensemble and its generation methodology – ensemble reliability diagnostics required;
- Using hybrid climatological-parametrized **B** matrix parameters results in a significant improvement of the performance of our DA system;
- We need to compute climatological observation errors corresponding to the new climatological **B** matrix using observation space diagnostics – work under way;
- Combining errors of the day with climatological bkg error variances will allow us to extract sharp features while keeping the combined errors smooth – we need to get rid of the requirement to combine climatological and parametrized bkg error variances first.