ECMWF 6th generation of ocean and sea-ice reanalysis system (ORAS6)

Marcin Chrust, Hao Zuo, Philip Browne, Magdalena Alonso Balmaseda, Patricia de Rosnay, Eric de Boisseson, Beena Balan Sarojini

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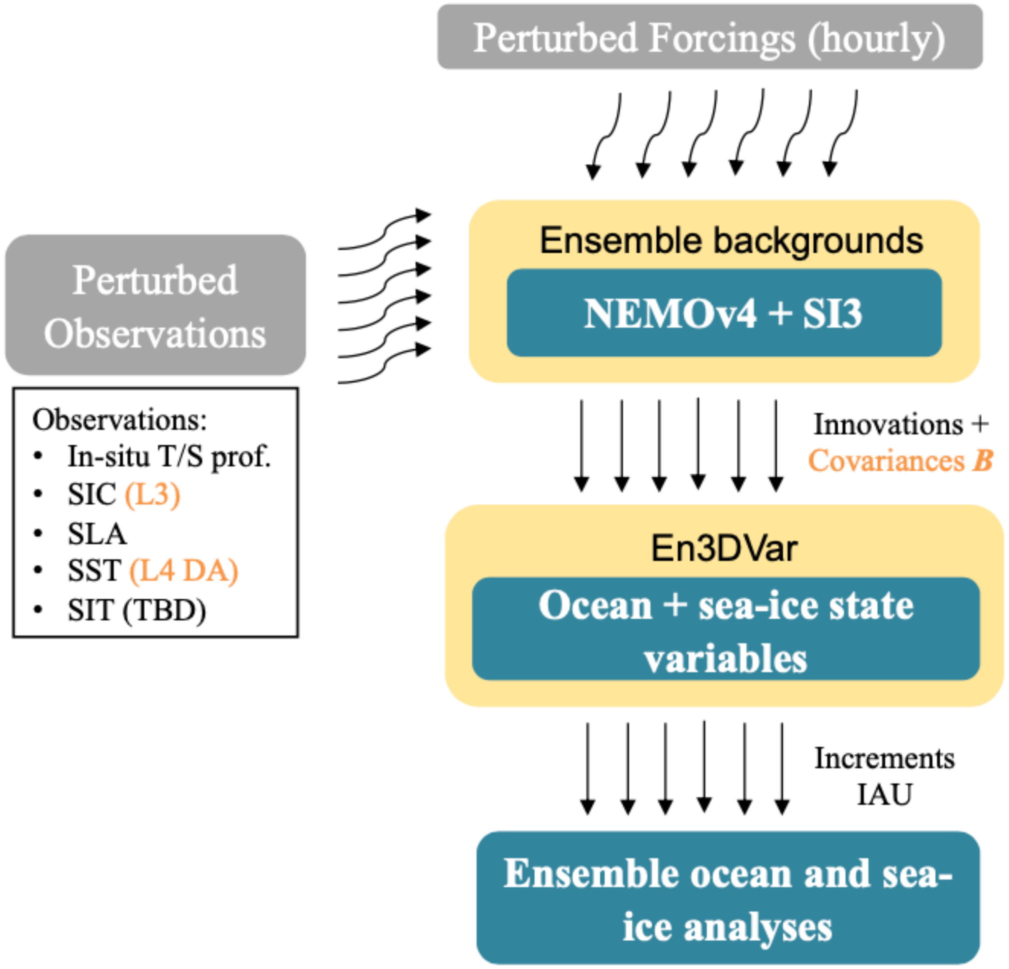
Overview of ORAS6

ORAS6 will be ECMWF 6th generation ocean and sea-ice reanalysis system:

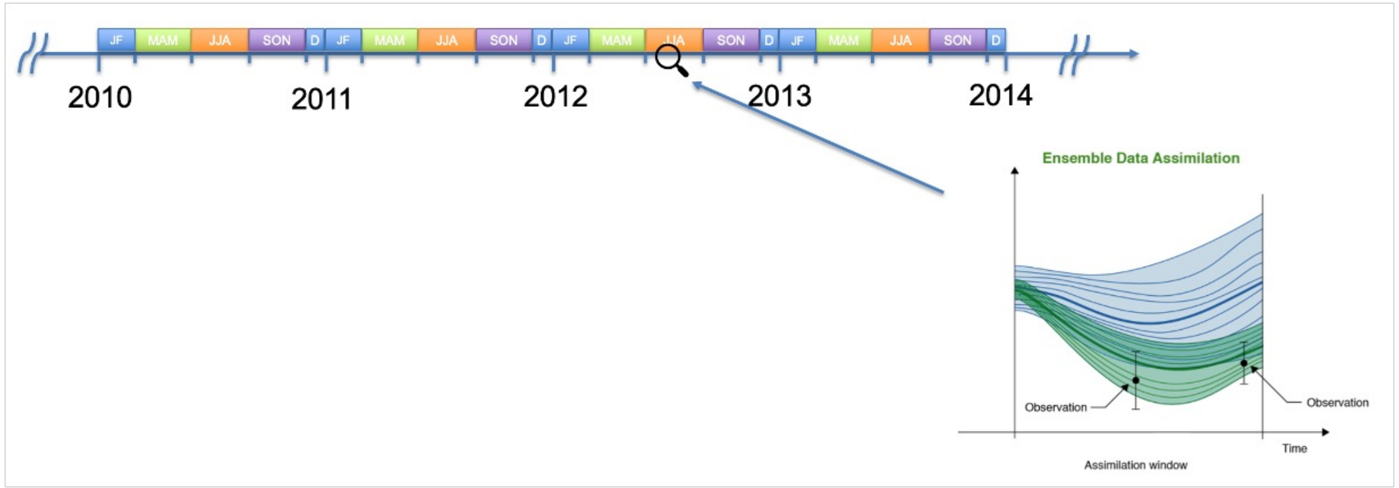
- Based on **NEMOv4 and SI3** ocean and multi-category sea ice framework forced by **hourly ERA5** boundary conditions
- Observations: In-situ T/S, SLA, **L4 SST** and **L3 SIC**
- Ensemble of ocean and sea-ice reanalysis (1 control + 10 members) generated with an **En3DVar** system
- The background error covariance matrix **B** is updated every cycle from ensemble background states generated by **perturbed forcings and observations**



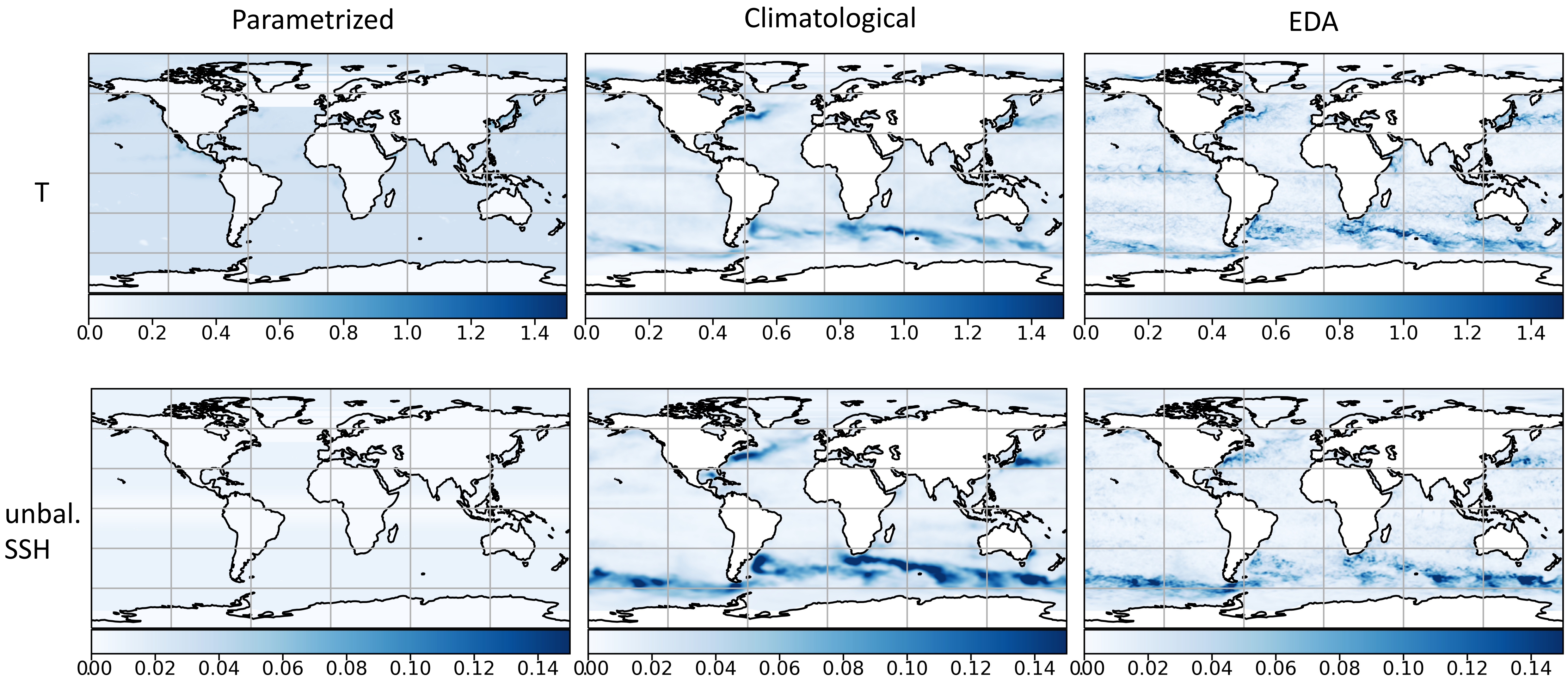
New B matrix

Being able to estimate flow dependent **variances** and the **local correlation tensor** using EDA allowed us to compute their climatology. To produce climatological estimates of parameters:

- For each cycle, we computed filtered EDA variances and estimated the local correlation tensor;
- These parameters were averaged to obtain multi-year seasonal statistics;
- We computed climatological parameters for four seasons DJF, MAM, JJA, SON from an 11-member ensemble using perturbations from 2010-2016;



Hybrid background error variances (σ_h^2)

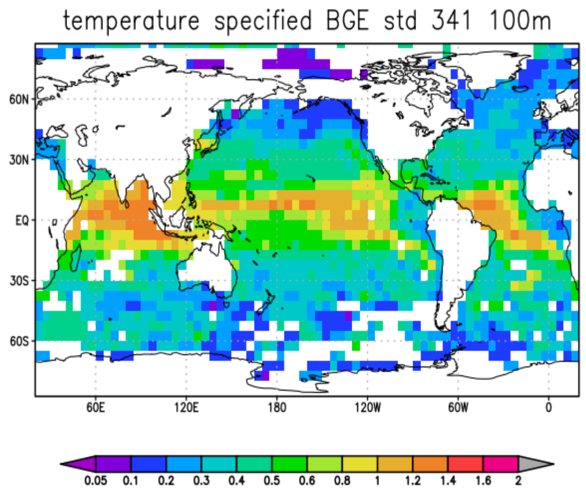


Hybrid background error variances (σ_h^2)

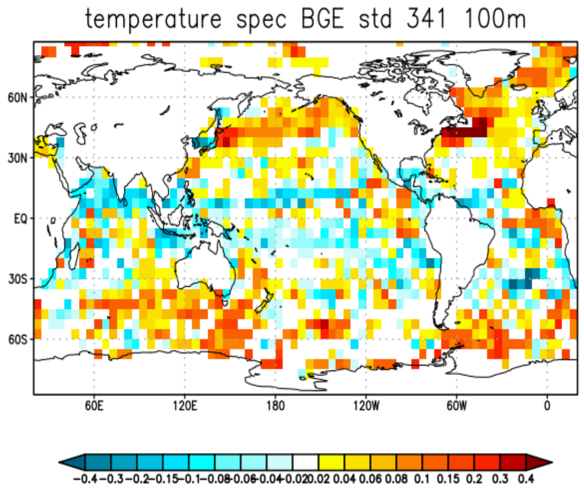
- Using hybrid variance in B reduces fit-to-obs RMSE in the WBCs and ACC, by giving more weight to observations.
- Performances in the tropics are not degraded despite using reduced BGE variances in Hybrid B.

Effective Temperature BGE std at 100m

OCEAN5

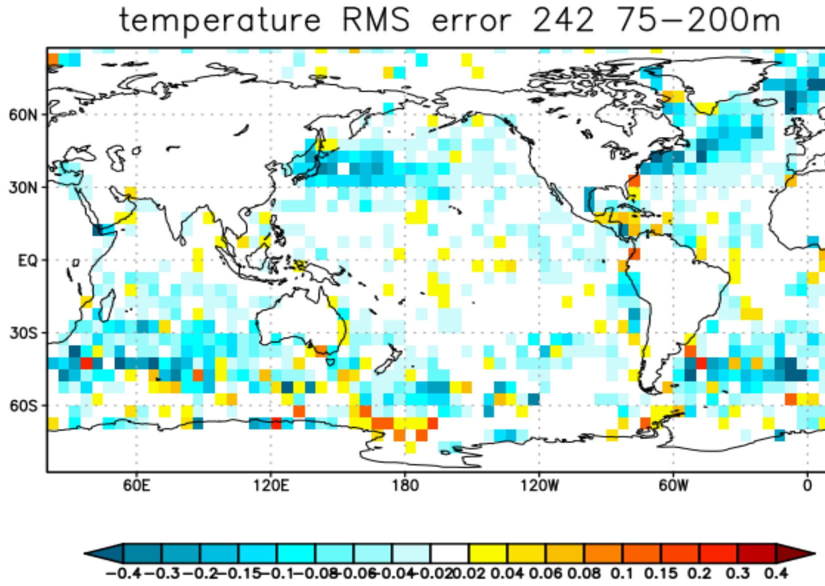


Hybrid – OCEAN5

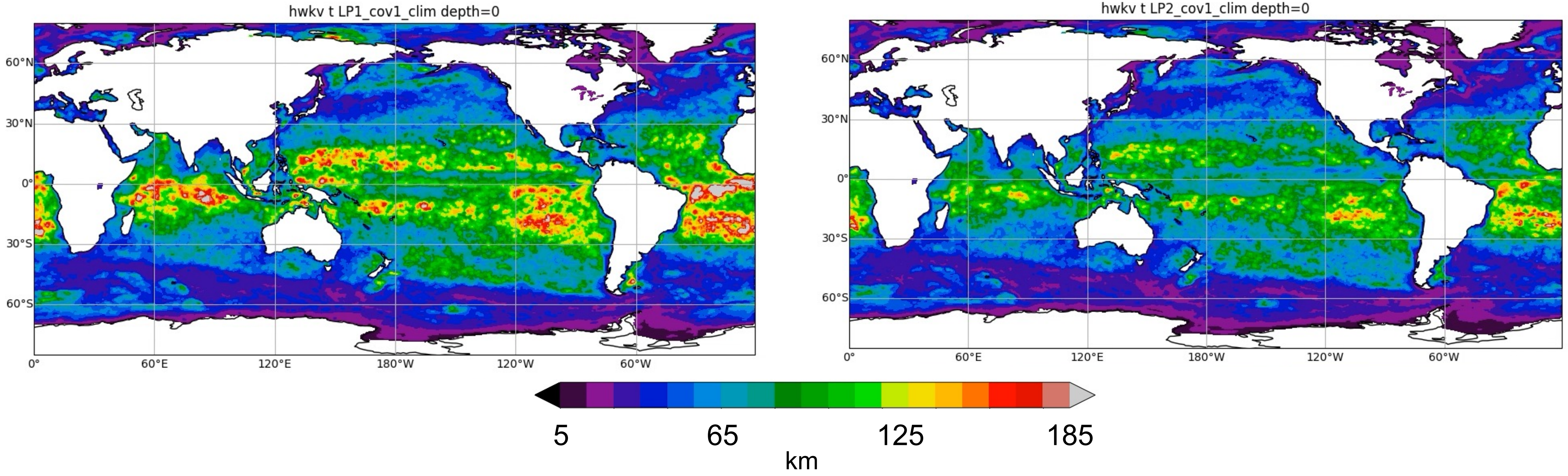


Changes in O-B RMSEs

Hybrid – OCEAN5



Hybrid climatological[2D]-flow dependent[1D] tensor



Climatological (left) zonal and (right) meridional de-correlation length-scales (in km) for temperature and salinity at 0 m, DJF season.

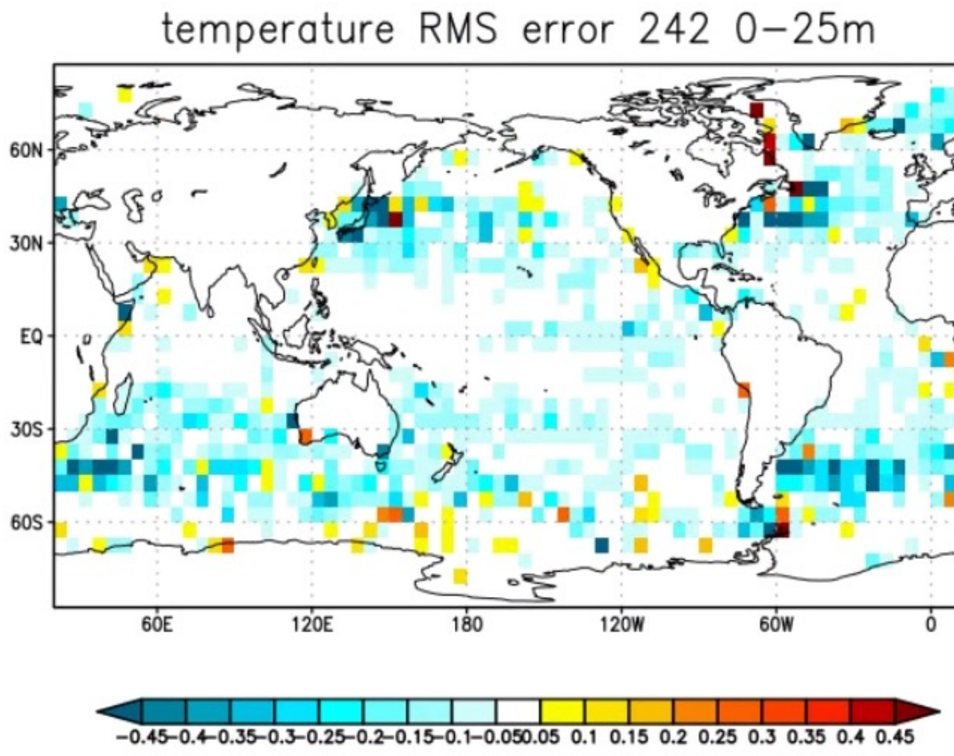
The 2Dx1D diffusion tensor formulation:

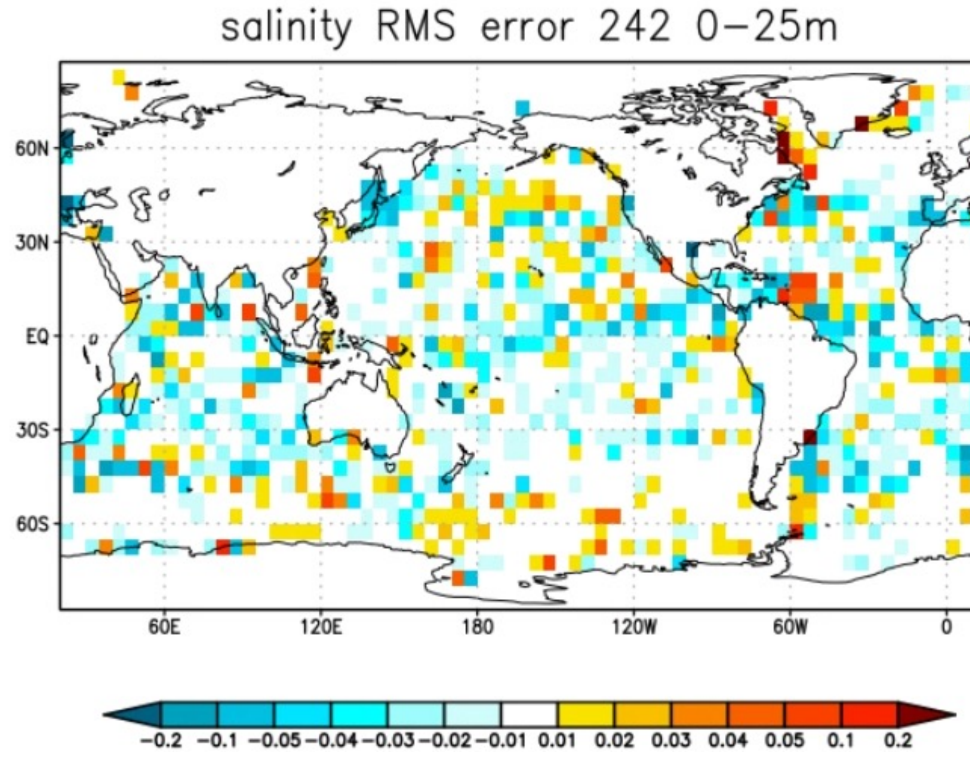
- a ***horizontal climatological diffusion tensor;***
- an ***ensemble-based vertical diffusion tensor*** that updates every cycle;

Hybrid climatological[2D]-flow dependent[1D] tensor

- Using Climatological horizontal diffusion tensor together with an ensemble-based vertical diffusion tensor results significant RMS error reductions compared to the parameterized tensor used in OCEAN5

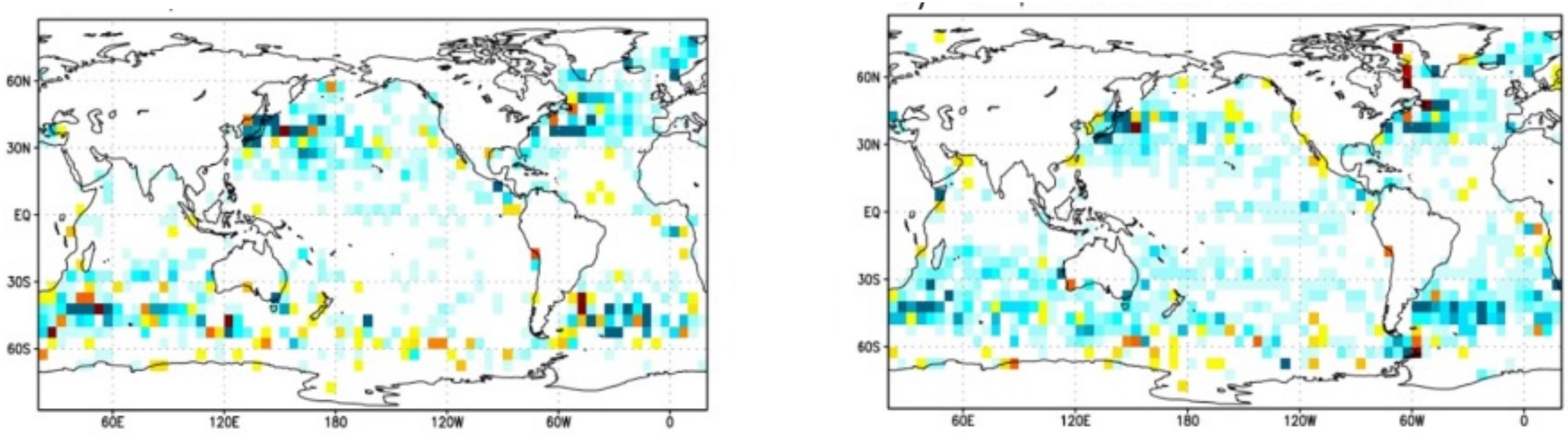
Hybrid Climatological-Flow dependent tensor vs parameterized tensor





Impact of ocean EDA and direct SST assimilation

a) Climatological B only **b) Hybrid-B with Ens V-tens**

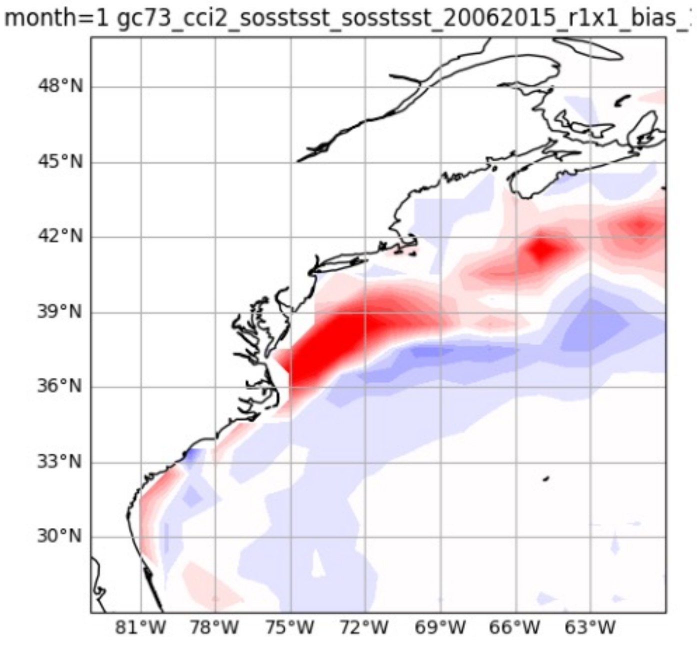


T RMSE changes (in K) wrt in situ T/S profiles (0-25m)

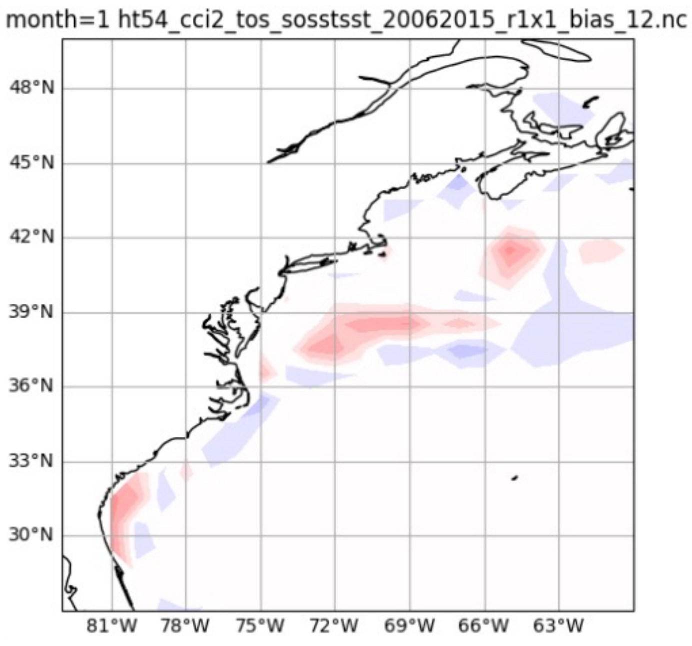
Changes in upper-ocean temperature RMSE between the parameterized B formulation and new B formulations show **best fit** to observations when using the **hybrid-B** formulation with **ensemble-based** vertical diffusion tensor

Impact of ocean EDA and direct SST assimilation

a) ORAS5 – SST nudging



b) ORAS6-prep – L4 SST DA



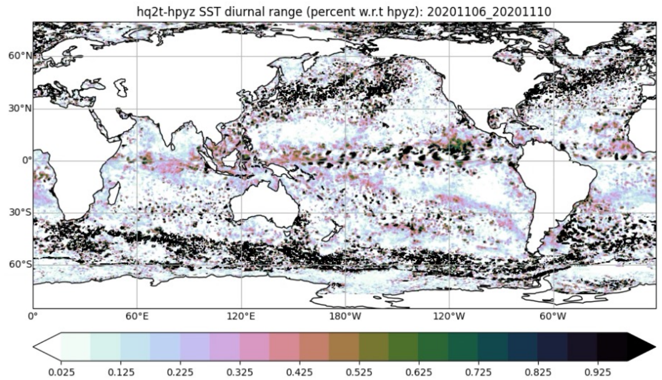
SST biases (in K) wrt ESA-CCI2 SST in the Gulf Stream region

- Assimilation of L4 SST with *parameterized* tensor increased SST biases in the Gulf Stream region
- SST DA with static (*climatological*) tensor in **B** reduced SST biases on the GS region
- Using a *ensemble-based* vertical diffusion tensor in **B** can improve SST performance in the GS even further

Impact of ocean EDA and direct SST assimilation

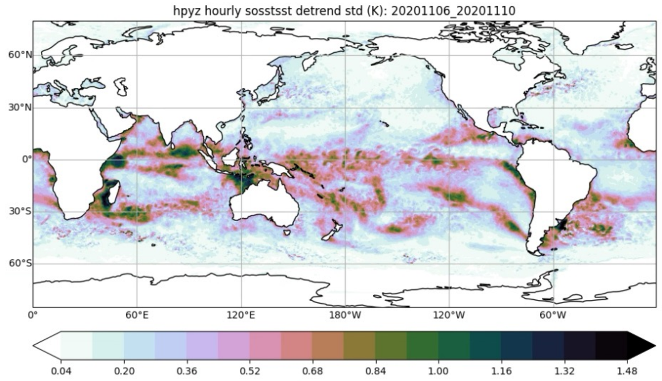
- Nudging to daily mean SST damps SST diurnal cycle (switched off in coupled DA)
- Direct assimilation of L4 SST with Ocean EDA system enhance the diurnal cycle (~15%) of analysis SST

SST DA – nudging (norm)

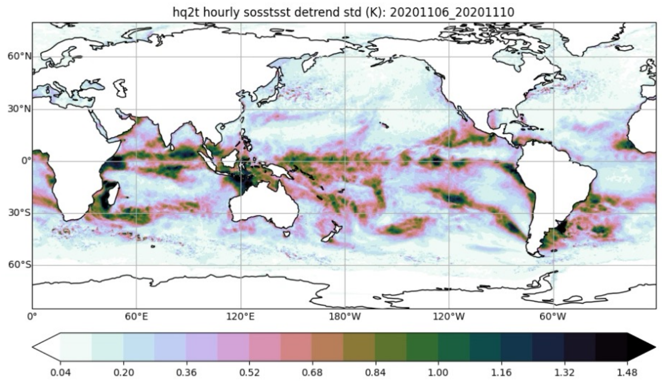


SST diurnal range (in K, 5-day mean)

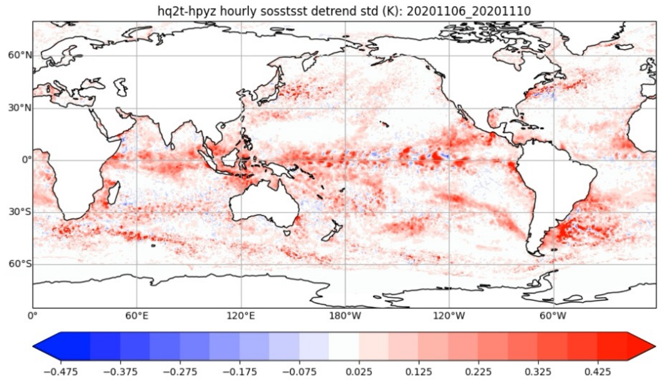
SST nudging



SST DA



SST DA - nudging

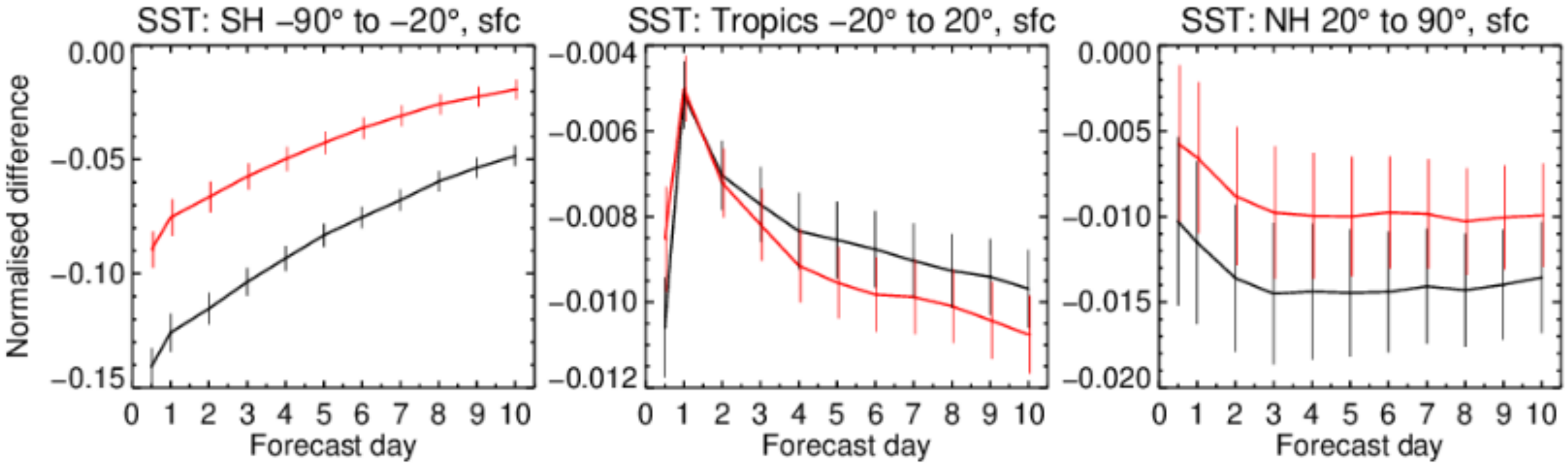


Potential impact on Numerical Weather Predictions

Outputs from preparation runs for ORAS6 were used as **ocean initial conditions** for ECMWF medium-range **coupled forecasts**:

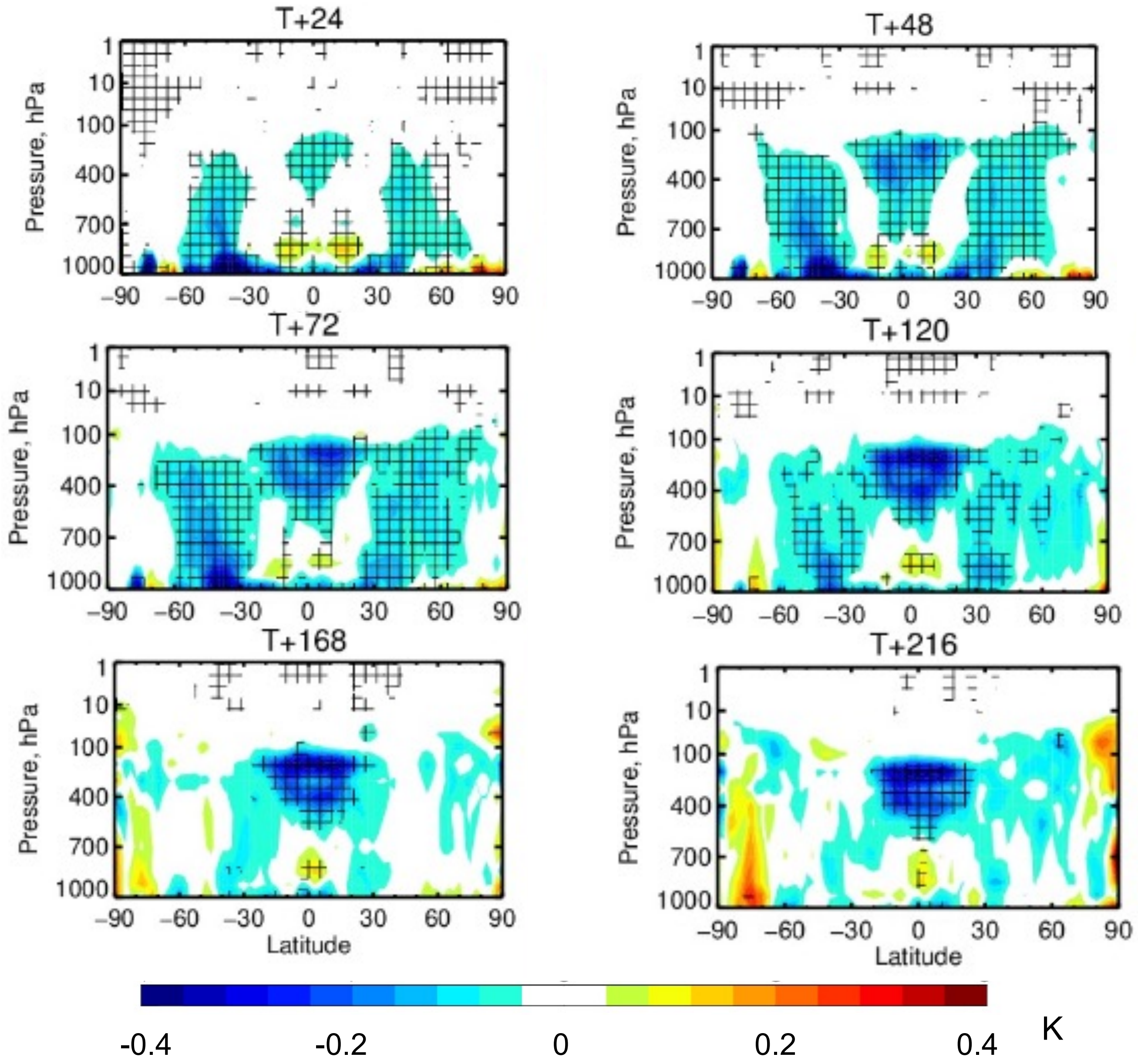
- **Improved SST forecast** at all latitudes
- Improvements are **transferred to the atmosphere** with significantly better temperature forecast at all latitudes in the troposphere (500-1000hPa)

Normalized SST RMSE changes for FC with ocean ICs from ORAS6 prep v2 and ORAS6 prep v1 wrt ORAS5 ICs



SST RMSE changes (in K) for forecast range 0-10 days when using ocean IC from ORAS6 preparation runs instead of ORAS5 ocean ICs for 2014-2019 starting dates. Verified against ECMWF operational analysis

Potential impact on Numerical Weather Predictions



T RMSE changes for FC with ocean ICs from ORAS6 prep v2 wrt ORAS5 ICs

Atmospheric T RMSE changes (in K) for forecast range 0-10 days when using ocean IC from ORAS6 preparation runs instead of ORAS5 ocean ICs for 2014-2019 starting dates. Verified against ECMWF operational analysis

Summary

- ECMWF is developing the 6th generation of ocean and sea-ice ensemble reanalysis-analysis system (ORAS6) based on NEMOv4 + SI3 ocean and sea-ice model and an ensemble based variational DA system

- The final version of ORAS6 will include 11 ensemble members from 1979 to Near Real Time. A backward extension of ORAS6 to cover the 1950-1978 period will also be produced

- ORAS6 outputs will eventually be used for both climate monitoring and as ocean initial conditions for ECMWF forecast activities

- Compared to SST nudging, direct assimilation of SST data improves the SST diurnal cycle. This approach also greatly reduces the SST biases in the Gulf Stream regions, in particular when ensemble based vertical diffusion tensor is used in the EDA system.