Comparison of surface freshwater fluxes from different climate hindcasts produced through different ensemble generation schemes.

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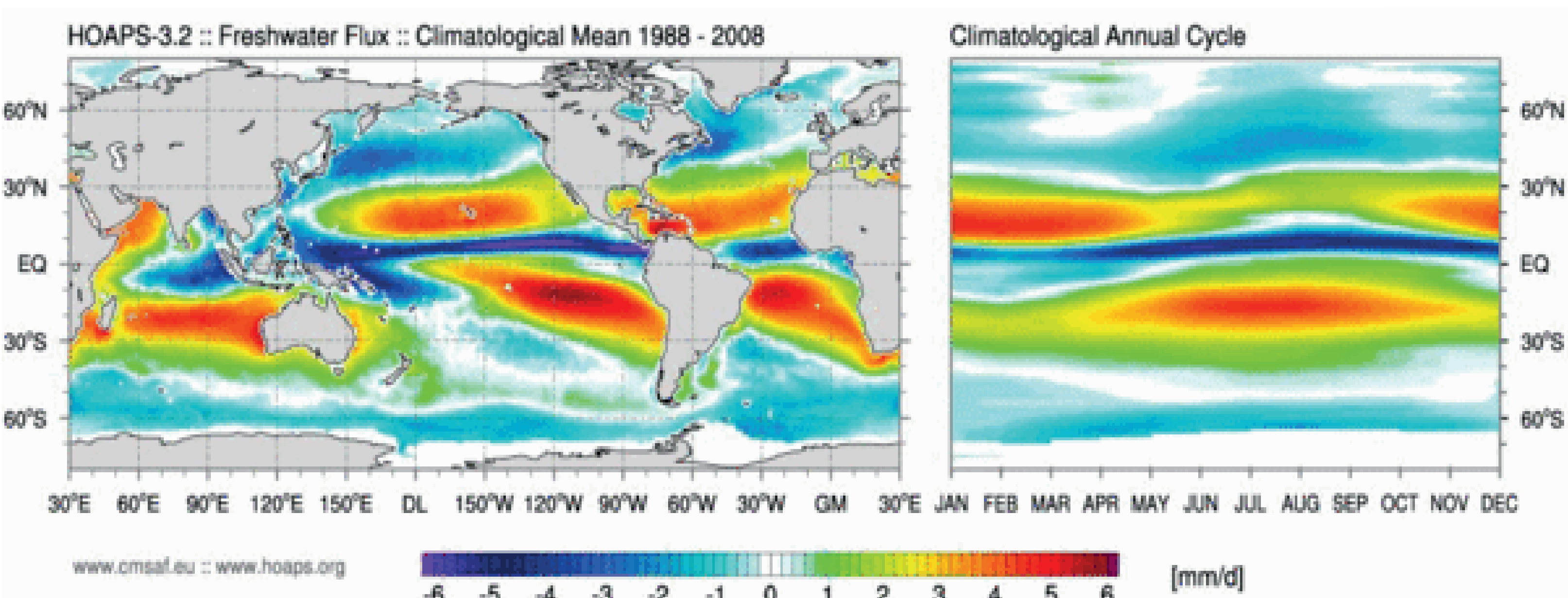
Freshwater fluxes from Reanalysis Data

- GFDL Ocean Data Assimilation Experiment;
- GECCO2 Ocean Reanalysis;
- NCEP R2;
- MERRA Modern-ERA Retrospective Analysis;

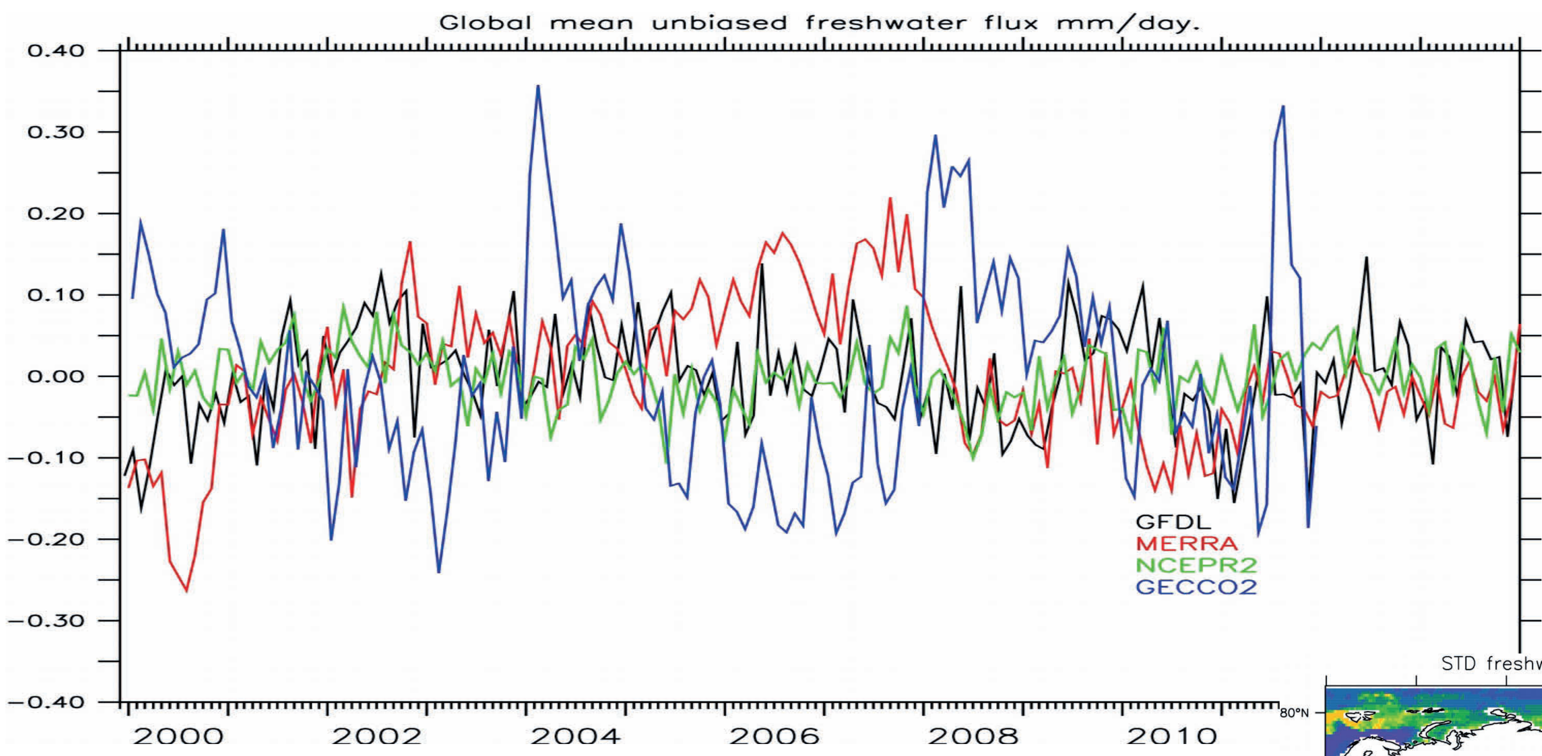
Removed annual mean, seasonal cycle, linear trends.

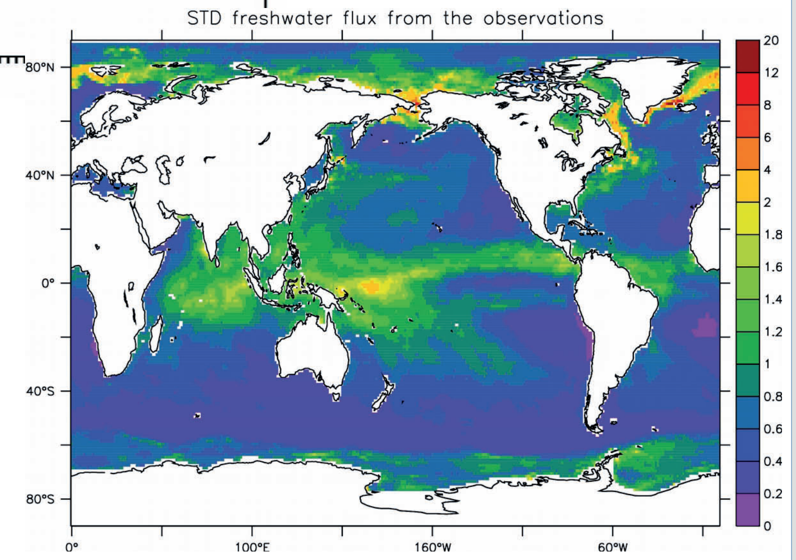
HOAPS climatology for the years 1988 - 2008



(A. Anderson et al. 2010)

Global mean unbiased freshwater flux from NCEP R2, MERRA, GECCO2 and GFDL Reanalysis



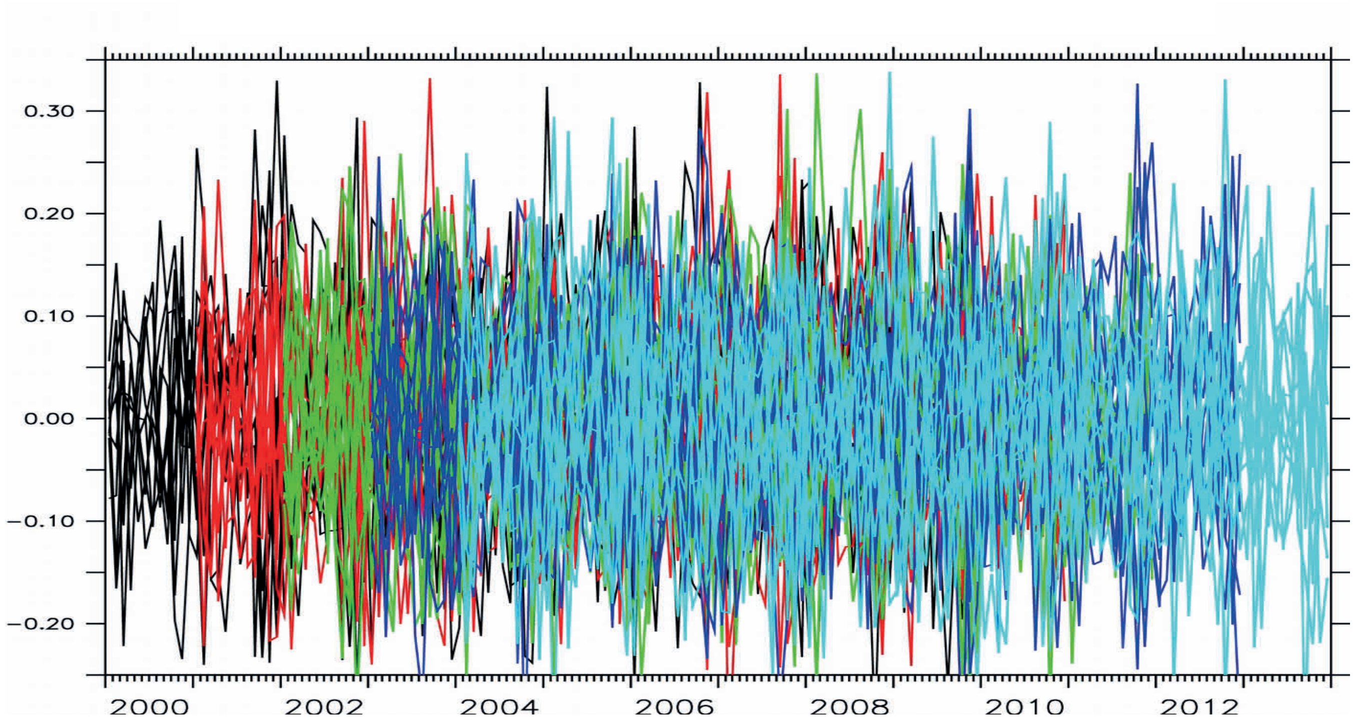


Freshwater variability from the reanalysis for the time period of 2000-2011 [mm/day]

Freshwater fluxes from the retrospective forecasts

Initialisation/Ensemble generation method:

- Anomaly Transform method – ocean perturbations
- Lagged Ocean – ocean perturbations
- Baseline 1
- ENKF filter

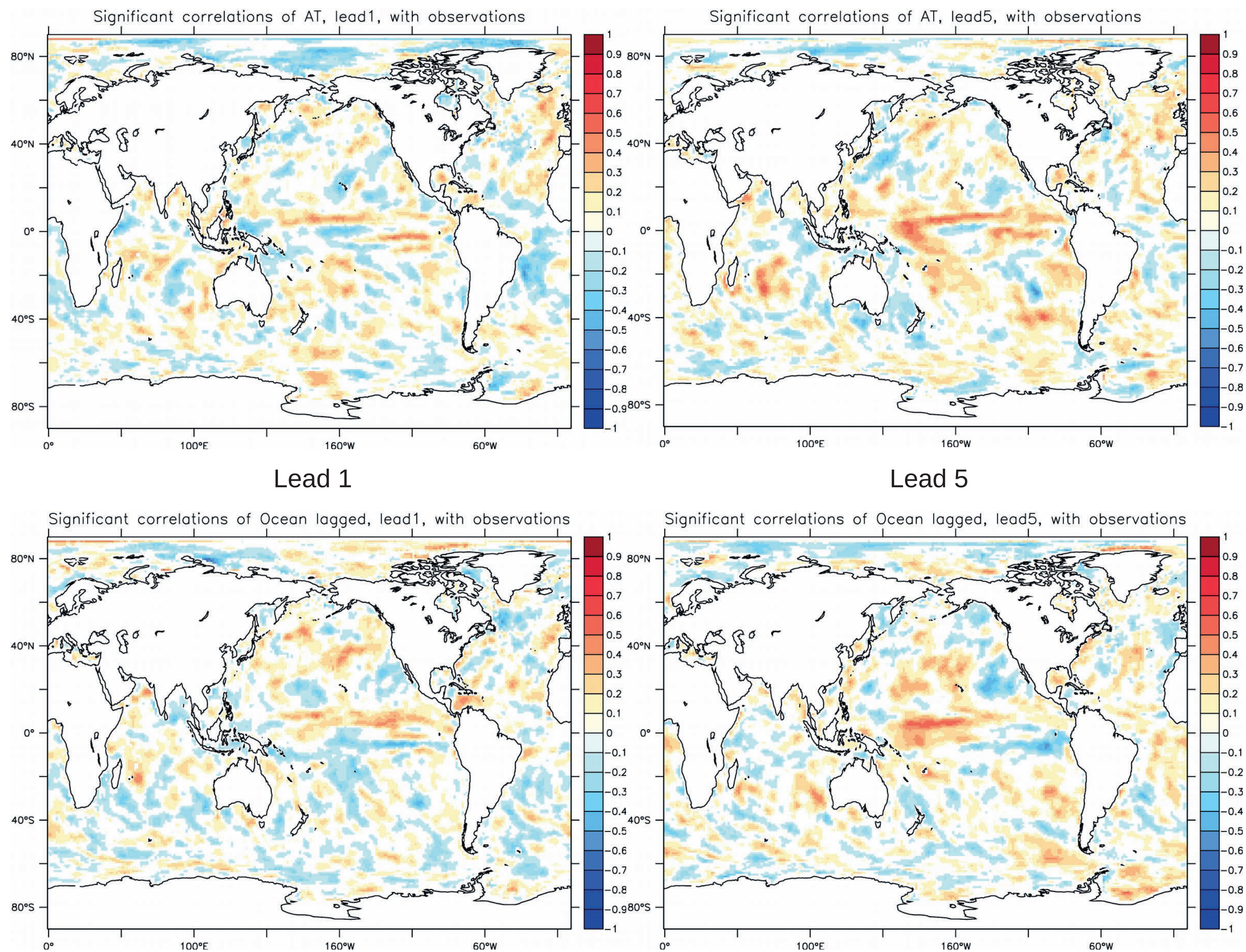


8 members, starting from 1-jan-2000 until 31-dec-2004, removed annual mean, seasonal cycle, linear trend, all leads are prepared for analysis on monthly mean values

Evaluation Score: Correlation between mean of observations and ensemble mean of hindcasts in 95% confidence level

AT

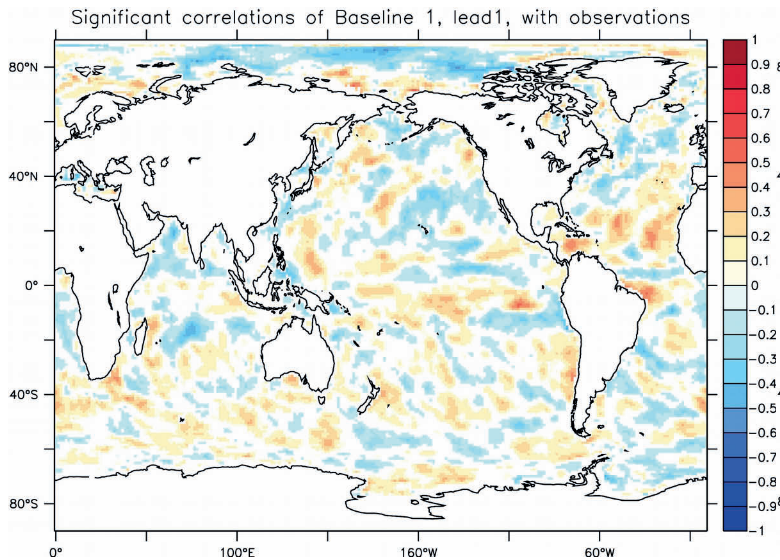
Lagged Ocean

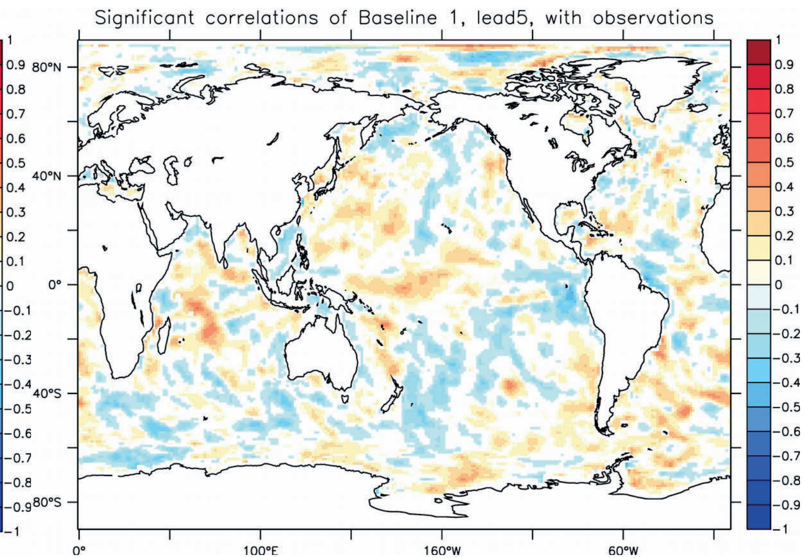


Perturbations applied on the **ocean** component

Evaluation Score: Correlation between mean of observations and ensemble mean of hindcasts in 95% confidence level

Baseline 1

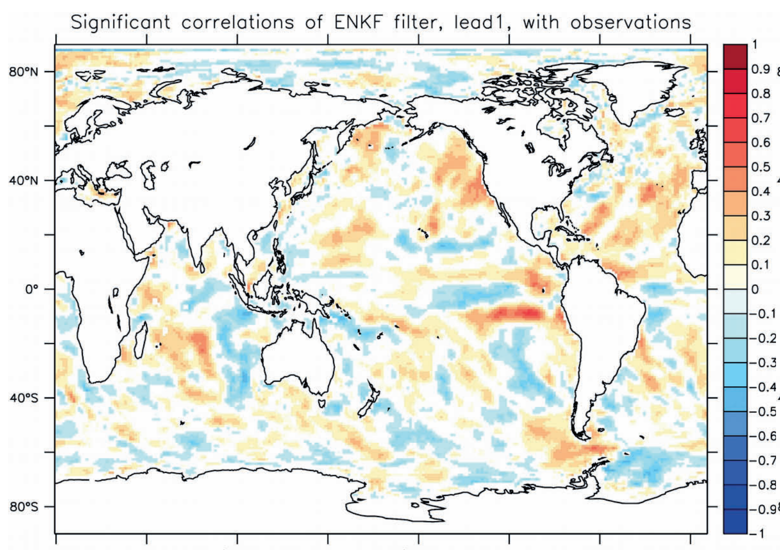


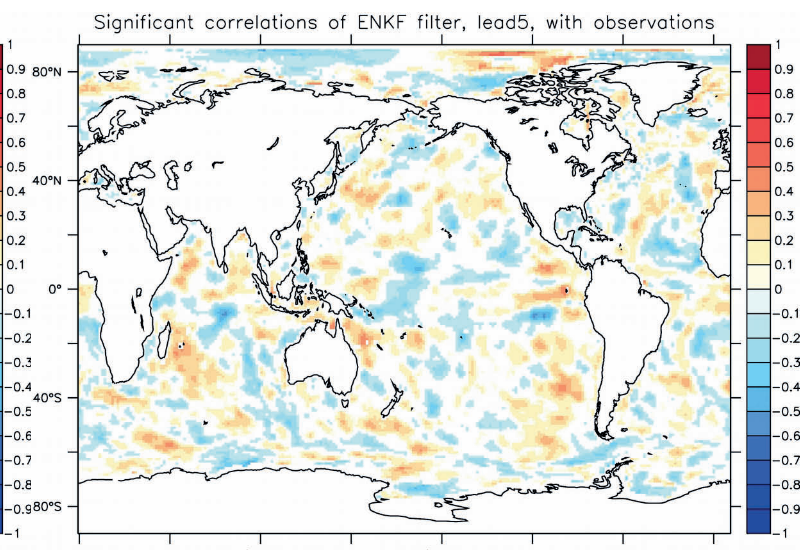


Lead 1

Lead 5

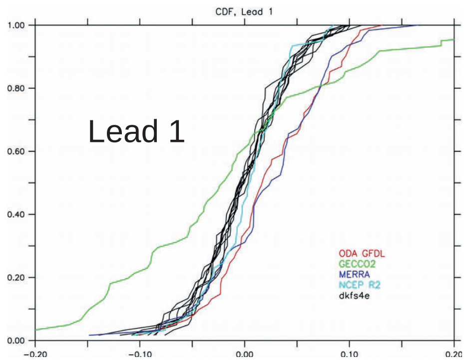
ENKF filter

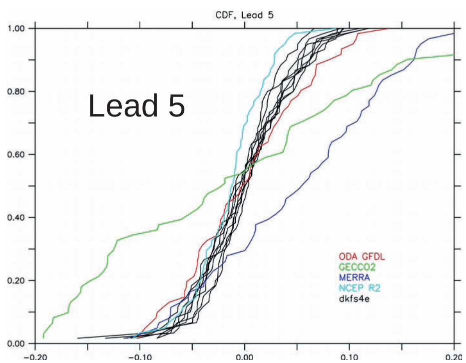




Perturbations applied on the **ocean+atmospheric** component

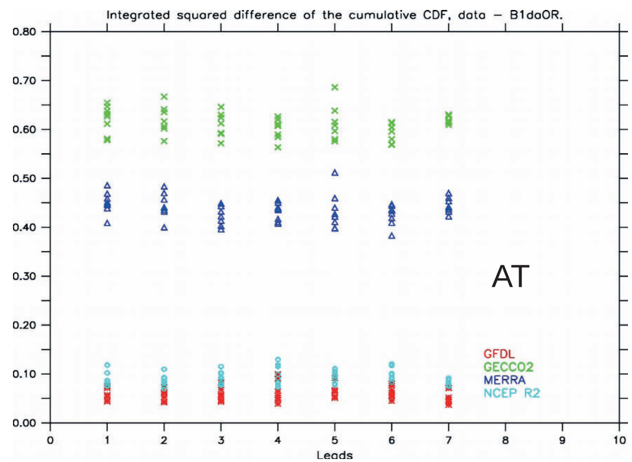
Evaluation Score: Cumulative frequency distribution (probability estimates), across all grid points for single hindcasts and single observation data set

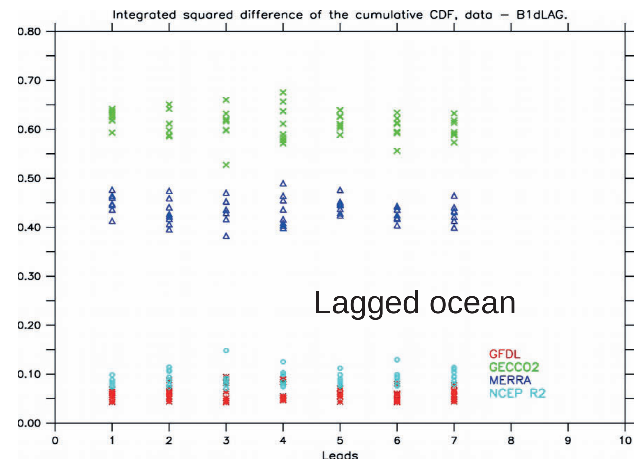


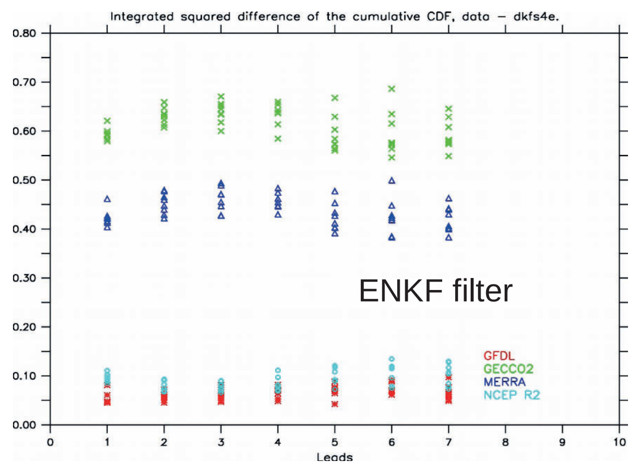


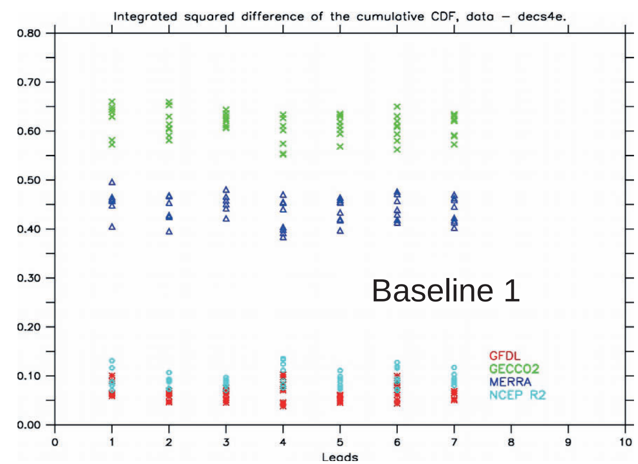
Cumulative frequency distribution (relative frequency of occurrence of an event in each interval)

Evaluation Score: Integrated squared difference of the cumulative frequency distribution

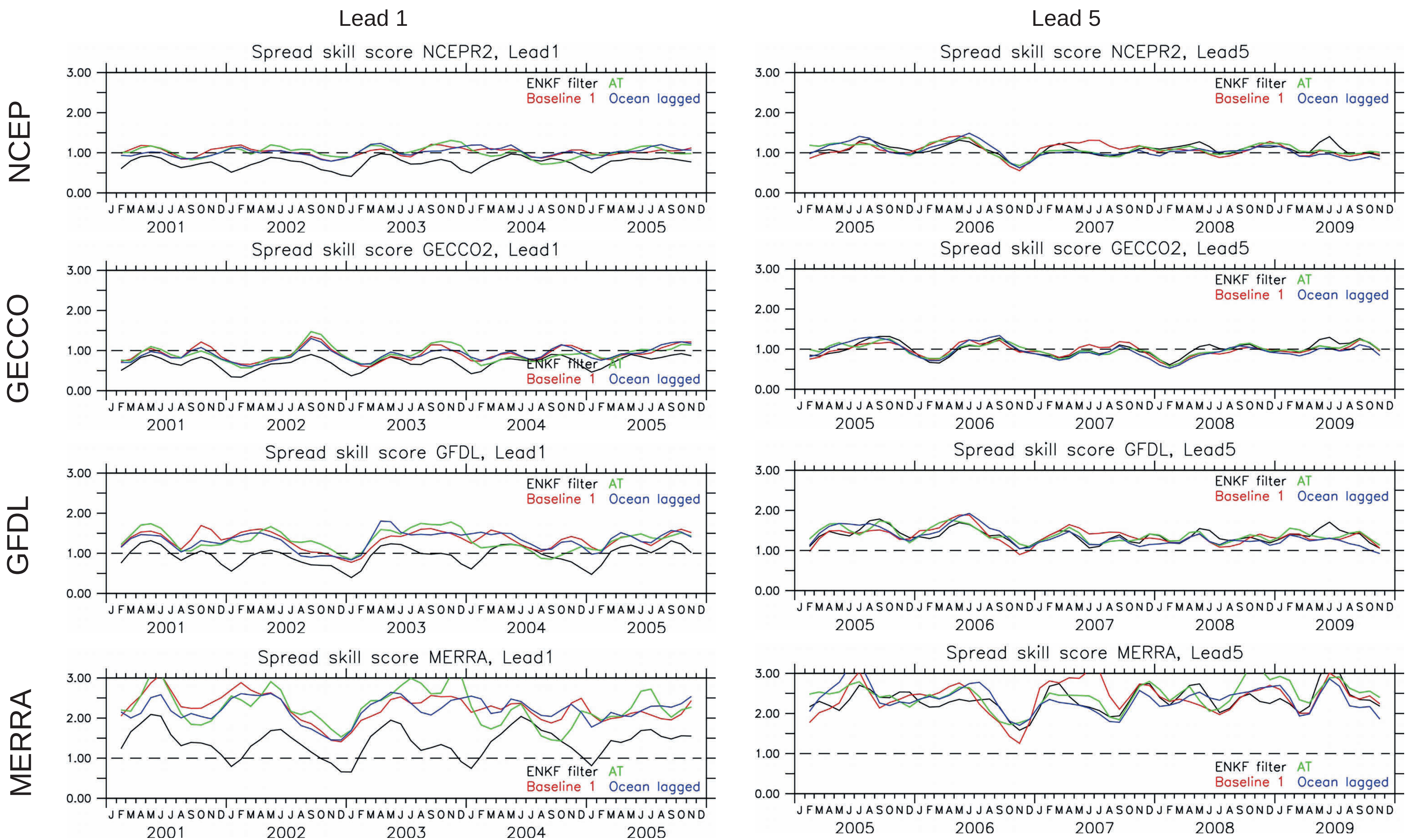








Evaluation Scores: Ensemble Spread Skill Score, between hindcast ensemble and each observational data set



Ensemble Spread Skill Score equal to 1 is for a perfect ensemble hindcast

Evaluation Score: Reliability Diagrams

RD – relative observed frequency against the estimated probabilities

Ensemble Reliability: ensemble members and observations should behave like samples from the same underlying probability distribution;

The event is considered to be the mean of the WFO anomalies;

The reliability needs large sample size – 10 year time series does not provide enough data for calculating the score. **Geographical boxes** are considered instead.

Reliability is shown by the proximity of the plotted curve to the diagonal. **If the curve lies below the line, this indicates over forecasting** (probabilities too high)**; points above the line indicate underforecasting** (probabilities too low).

The unobserved probability is fitted with Beta-Binominal model and the is assumes that P=(y=1/i)=(i+alpha)/(K+alpha+beta) instead of i/K;

Reliability definition in 2D:

$$\tan(\theta)=\frac{m_1-m_2}{1+m_1*m_2},$$

$$when\,,5°>\theta>-5°,reliable(hindcast)$$

(functions from SPECS, author Stefan Sieger)

Examples of Reliability Diagrams

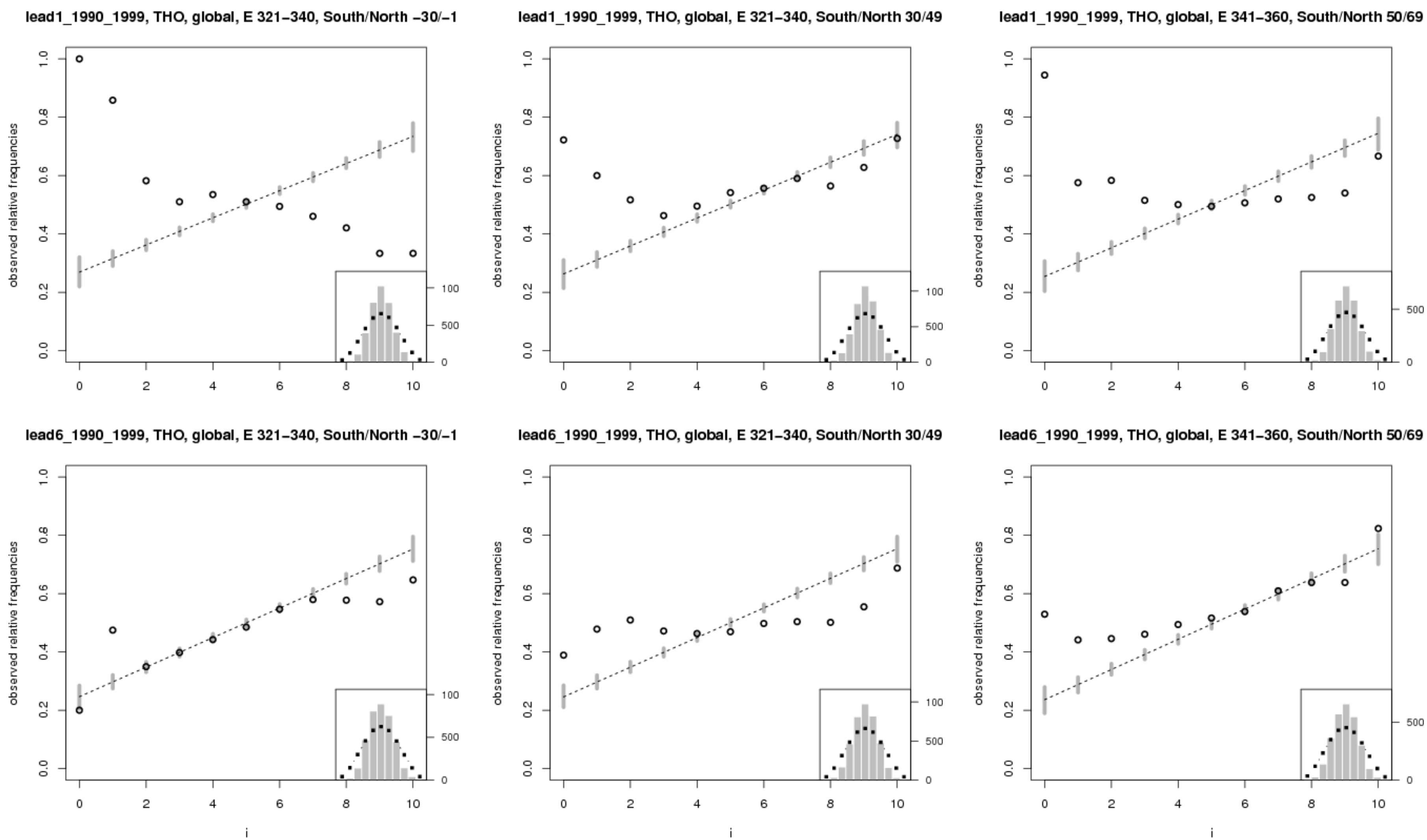
South Atlantic/Brazil Current

North Atlantic/Gulf Stream

North Atlantic/Faroe Channel

Lead 1

Lead 6



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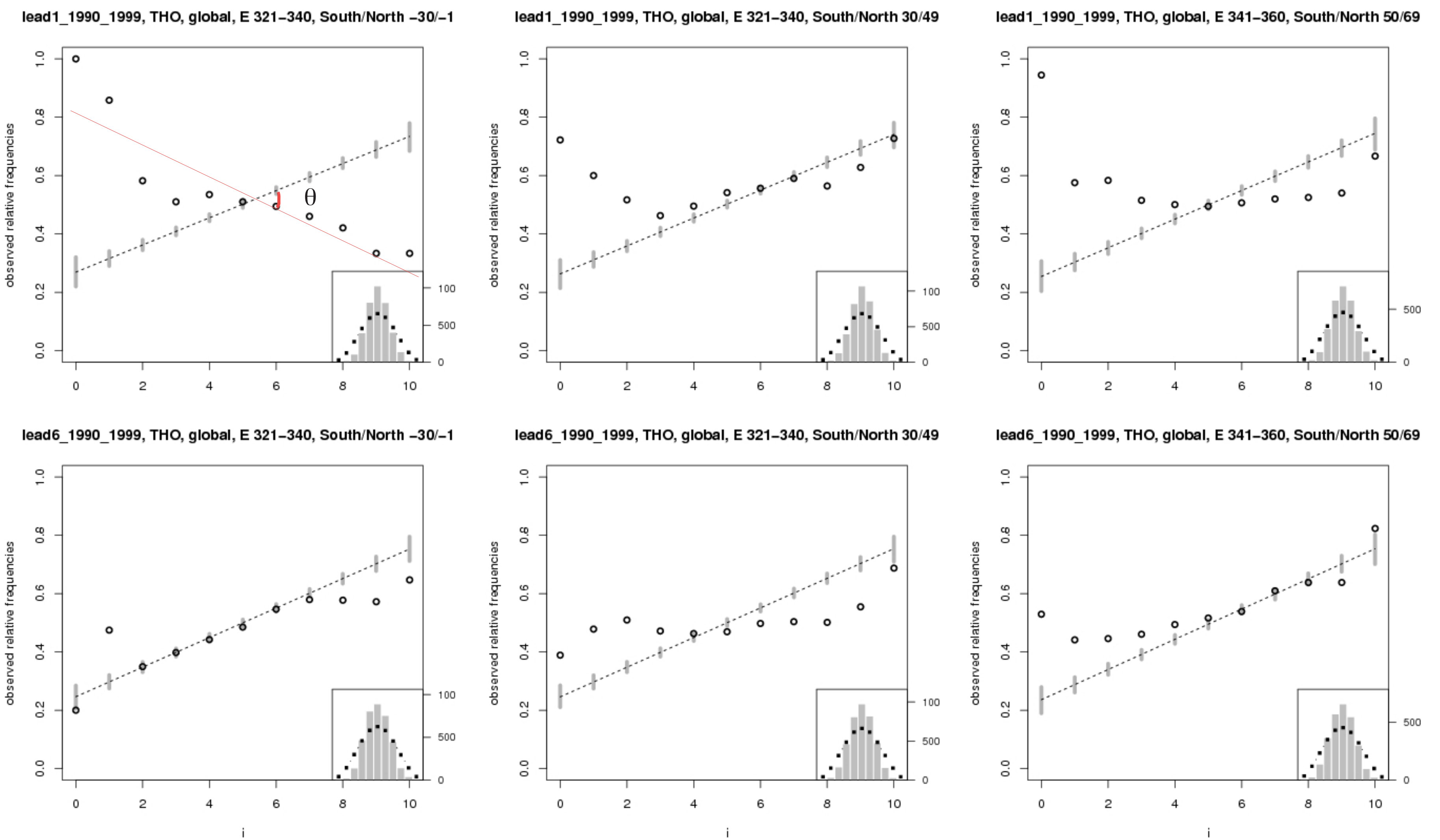
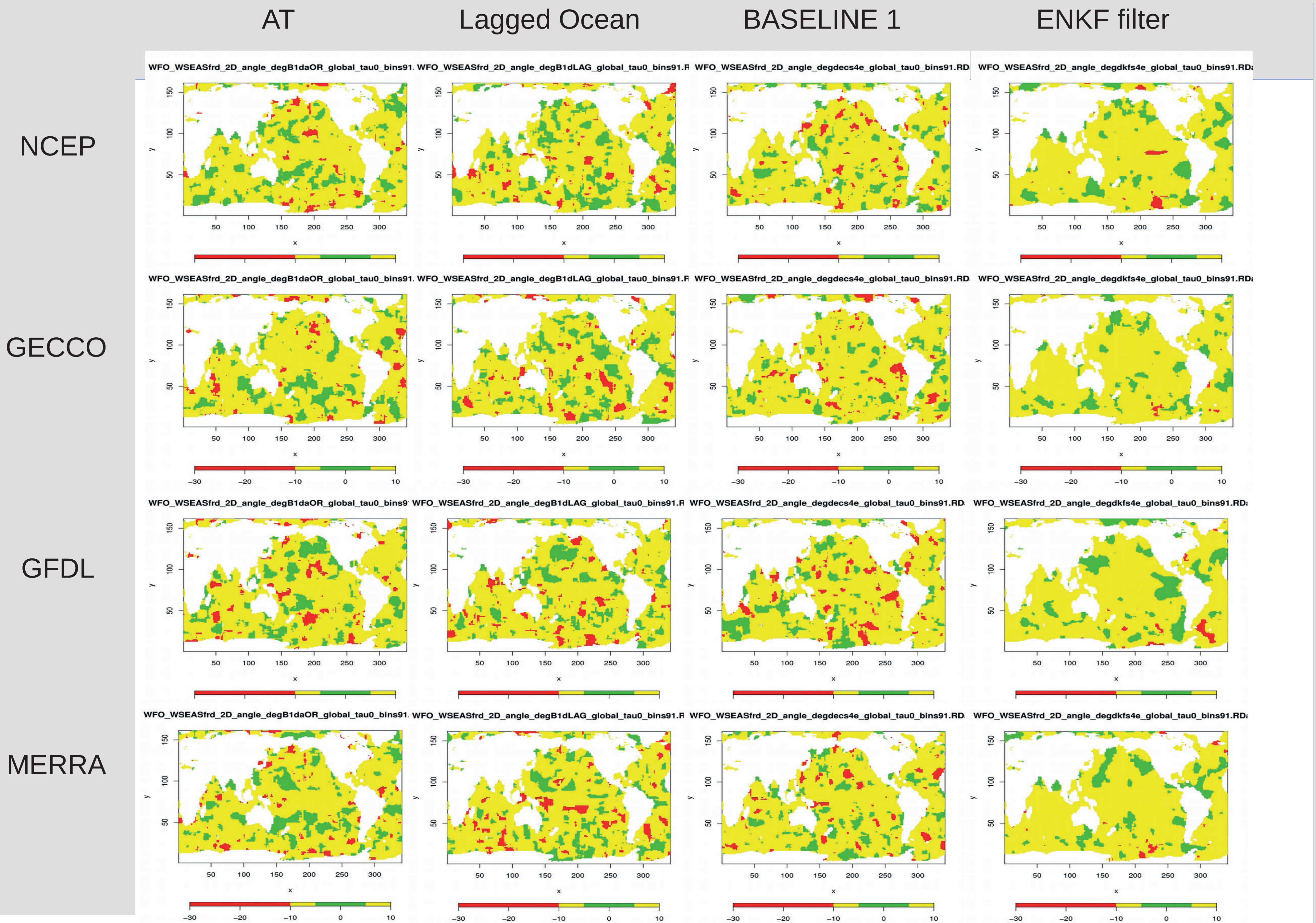


Reliable hindcast $(5° > \theta > -5°)$, lead1, green color



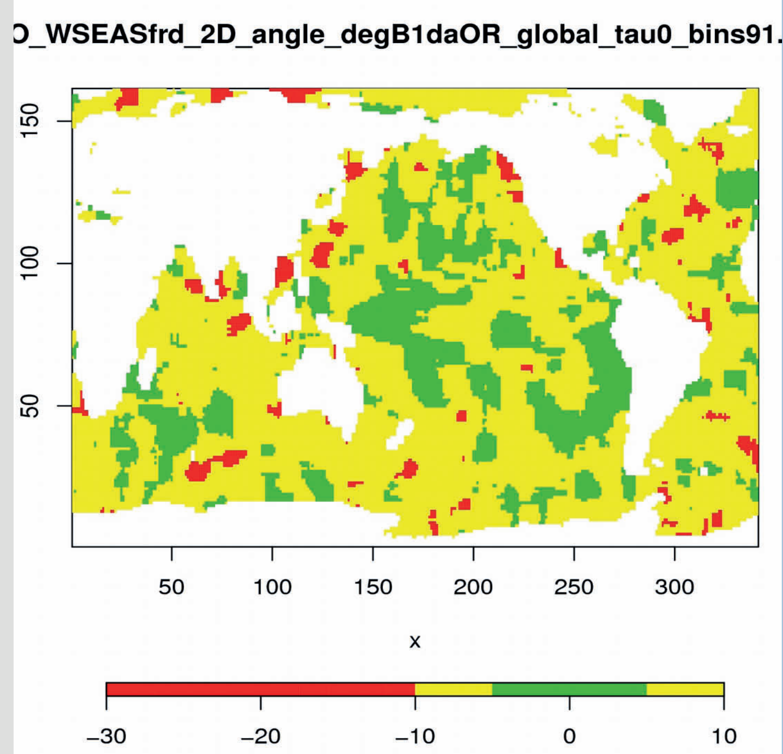
Percentage reliable hindcast for lead1 and lead5 different initialisations schemes

LEAD 1 (%)	NCEP	GECCO	GFDL	MERRA
ENKF filter	13.91	11.04	15.56	13.13
Baseline 1	12.23	11.35	13.46	12.51
Lagged	17.94	14.00	14.43	15.26
AT	15.68	14.59	15.69	17.37
LEAD 5 (%)	**NCEP**	**GECCO**	**GFDL**	**MERRA**
ENKF filter	13.12	13.19	10.69	14.37
Baseline 1	12.73	15.97	17.89	18.22
Lagged	16.44	14.63	19.36	16.26
AT	21.43	18.23	22.60	21.06

Table 1 Percentage reliable forecasts for different ensemble generation experiments compared to different reanalysis data sets.

LEAD 1 (%)	NCEP	GECCO	GFDL	MERRA
ENKF filter	1.58	0.55	1.74	1.11
Baseline 1	4.99	5.31	7.14	5.33
Lagged	4.94	6.02	6.40	7.21
AT	3.67	5.03	6.31	4.61
LEAD 5 (%)	**NCEP**	**GECCO**	**GFDL**	**MERRA**
ENKF filter	6.15	4.71	6.08	6.30
Baseline 1	9.53	6.86	5.72	6.67
Lagged	5.54	6.59	6.23	6.48
AT	5.57	5.53	4.57	5.23

Table 2 Percentage un-reliable forecasts for different ensemble generation experiments compared to different reanalysis data sets.



Conclusions

- Comparison of retrospective predictions created through different ensemble generation schemes was performed to asses the most reliable hindcast.
- Our results show adequate prediction using disturbances only in the ocean initial variables.
- The level of hindcast skill depends considerably on both the freshwater flux product used and the ensemble generation method.
- The ensembles show behavior closest to NCEP R2 and GFDL reanalysis.
- The Anomaly Transform ensemble generation scheme with orthogonal initial condition, and the ENKF filter prevail over the lagged initialisations.
- Hindcast skill in analysed initialisations is low, and tends to increase with lead years. Most of the scores show improvement of the prediction not at the first lead year but around the fifth lead year, due to adjusment of the ocean.

Thanks for the attention!

Anomaly Transform Method,
choice of the norm and constrains

1. *Total energy norm*

$$\|Z_f\| = \frac{w_u}{2}\int u'^2 dV + \frac{w_v}{2}\int v'^2 dV + \frac{w_\rho g}{2\rho_0}\int \frac{\rho'^2}{\rho_z} dV$$

2. *Constrains to observations*

$$(PG)^T w (PG)\vec{c} = (PG)^T w \vec{\Psi}_O$$

What we consider:

Orthogonal conditions on perturbation patterns;

Selection of a suitable norm;

Conserved fields;

Perturbation only in ocean;

where ,
$\vec{\Psi}$ − *model , represented as a linear combination of G andand coefficients c*
G − perturbation elements − salt , temp , velocity
$\vec{\Psi}_O$ − *observations*
P − linear combination fromfrom model space toto observation space
w − TE weighting coefficients

(Romanova and Hense, 2015)