MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

WORLD METEOROLOGICAL ORGANIZATION

GSI based hybrid 3DVar data assimilation for the CPTEC-INPE BAM global model

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WMO Data Assimilation Symposium 2017

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Outline

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2. Applications of GSI at CPTEC
3. GSI based hybrid 3DVar DA
4. Results
5. Closing remarks
6. Further work

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Summary of CPTEC DA Activities

CPTEC is the Center for Weather Forecasts and Climate Studies, a research and operational branch from the Brazilian National Institute for Space Research (INPE).

Atmospheric Data Analysis (Research and Op.):

- **c. 1990's**: Optimum Interpolation (global);
- **c. 2000's**: Upgrade to DAO's PSAS (global/regional);
- **c. 2008 til 2011**: Research activities with LETKF (UMD);
- **2012 onward**: 3DVar with GSI (GMAO/NCEP) (global);
- **2015**: Regional data assimilation with WRF/GSI and other models (including ensembles).
- **Current**: GSI upgrade; development of observational processing routines (eg., PrepBUFR generation, quality control, verification of observation impact etc);

CPTEC/INPE campus at Cachoeira Paulista/SP

Applications of GSI at CPTEC

Short-Mid term goals

- Update CPTEC with the current generation of analysis/observational systems;
- Application of an updated background error covariance matrix within the DA framework;
- Update background error covariances using ensembles ("errors of the day");

Long term goal

- Provide CPTEC with its own analysis draw from a framework embracing NWP for 7-days forecasts and the global EPS for 15-days forecasts.

GSI based hybrid 3DVar DA

The Brazilian Atmospheric Model (BAM, Figueroa et al., 2016)

- CPTEC's general circulation model;
- Spectral model with global domain;
- Horizontal movement is given in terms of vorticity and divergence;
- Normal model initialization;
- Pure σ vertical coordinate (hybrid is under testing);
- Model physics is parameterized.
- GSI atmospheric analysis, spectral coefficient of $ln(ps)$, T_v, D, ζ, q .

GSI based hybrid 3DVar DA

GSI 3DVar

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mathbf{x}^b)^T \mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}^b) + \frac{1}{2}[\mathbf{y}^o - H(\mathbf{x})]^T \mathbf{R}^{-1}[\mathbf{y}^o - H(\mathbf{x})]$$

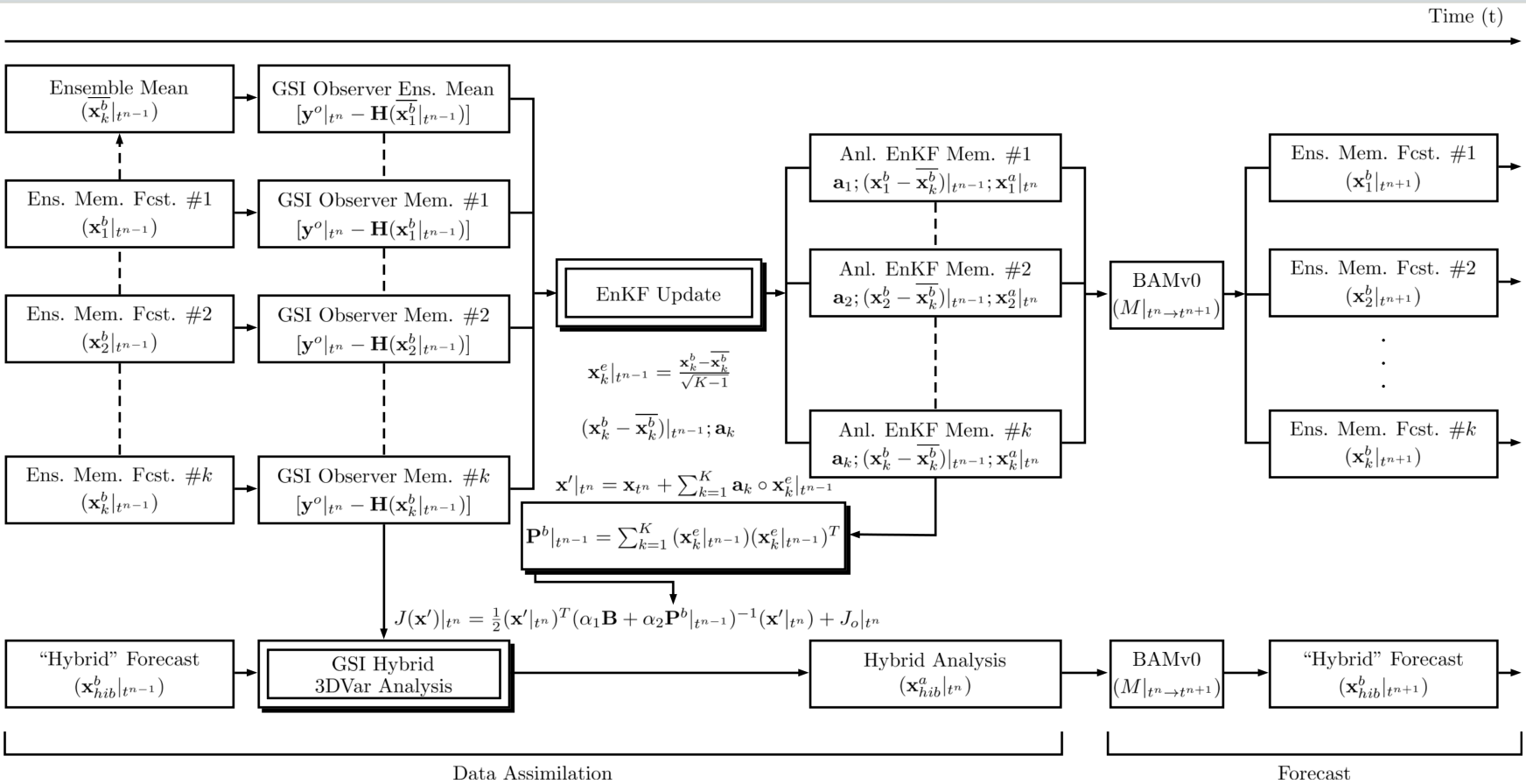
Ensemble Covariances

- Extended control variable (eg., Lorenc, 2003; Wang et al., 2008)

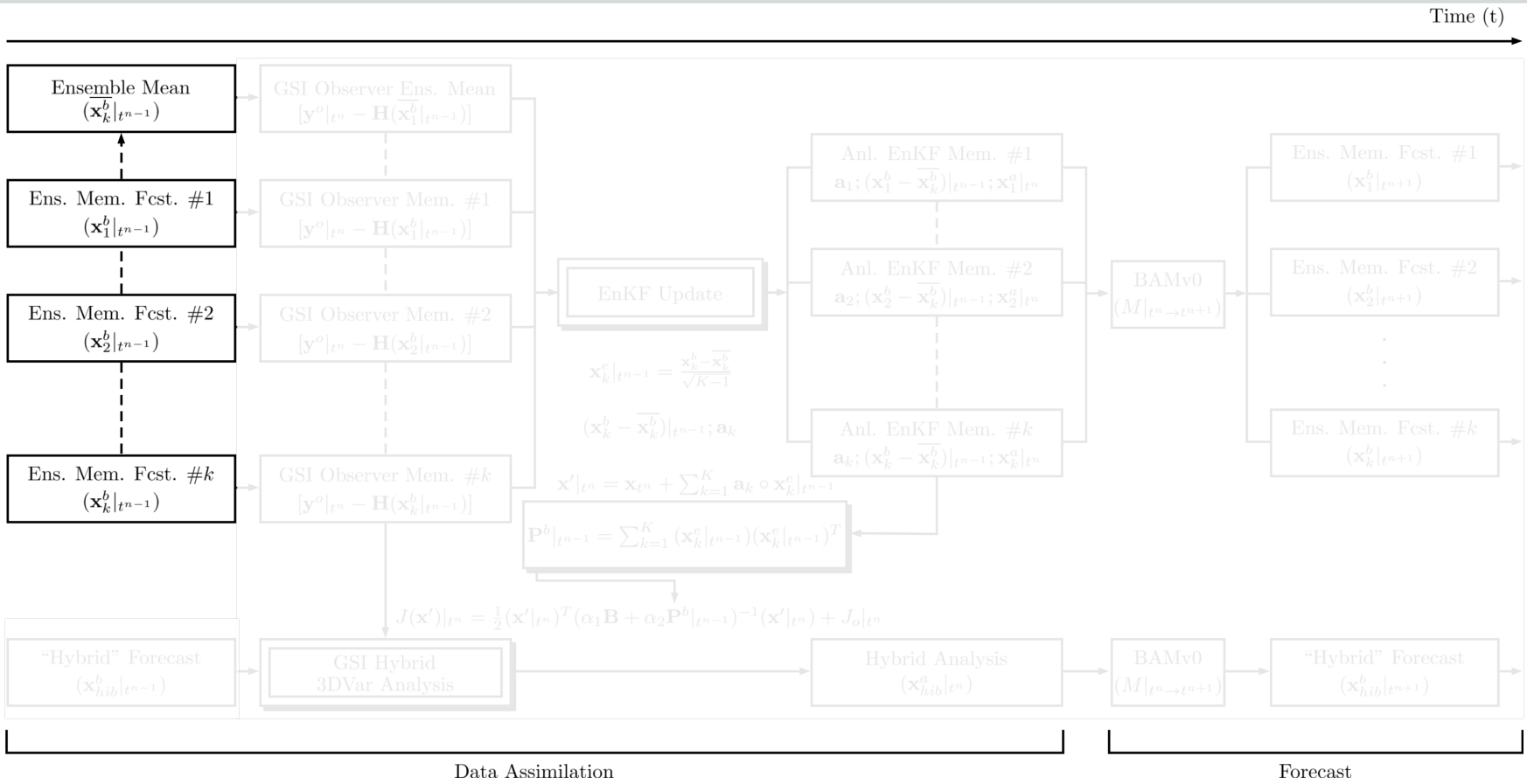
$$\delta\mathbf{x}' = \delta\mathbf{x} + \sum_{k=1}^{K}(\mathbf{x}_k^e \circ \mathbf{a}_k) \qquad \mathbf{x}_k^e = \frac{(\mathbf{x}_k^b - \bar{\mathbf{x}}^b)}{\sqrt{K-1}} \qquad \mathbf{P}_e^b = \frac{1}{K-1}\sum_{k=1}^{K}(\mathbf{x}_k^b - \bar{\mathbf{x}}^b)(\mathbf{x}_k^b - \bar{\mathbf{x}}^b)^T$$

$$J(\delta\mathbf{x}') = \frac{1}{2}(\delta\mathbf{x}')^T(\alpha_1\mathbf{B} + \alpha_2\mathbf{P}^b \circ \mathbf{A})^{-1}(\delta\mathbf{x}') + \frac{1}{2}[\mathbf{y}'^o - \mathbf{H}(\delta\mathbf{x}')]^T\mathbf{R}^{-1}[\mathbf{y}'^o - \mathbf{H}(\delta\mathbf{x}')]$$

GSI based hybrid 3DVar DA



GSI based hybrid 3DVar DA



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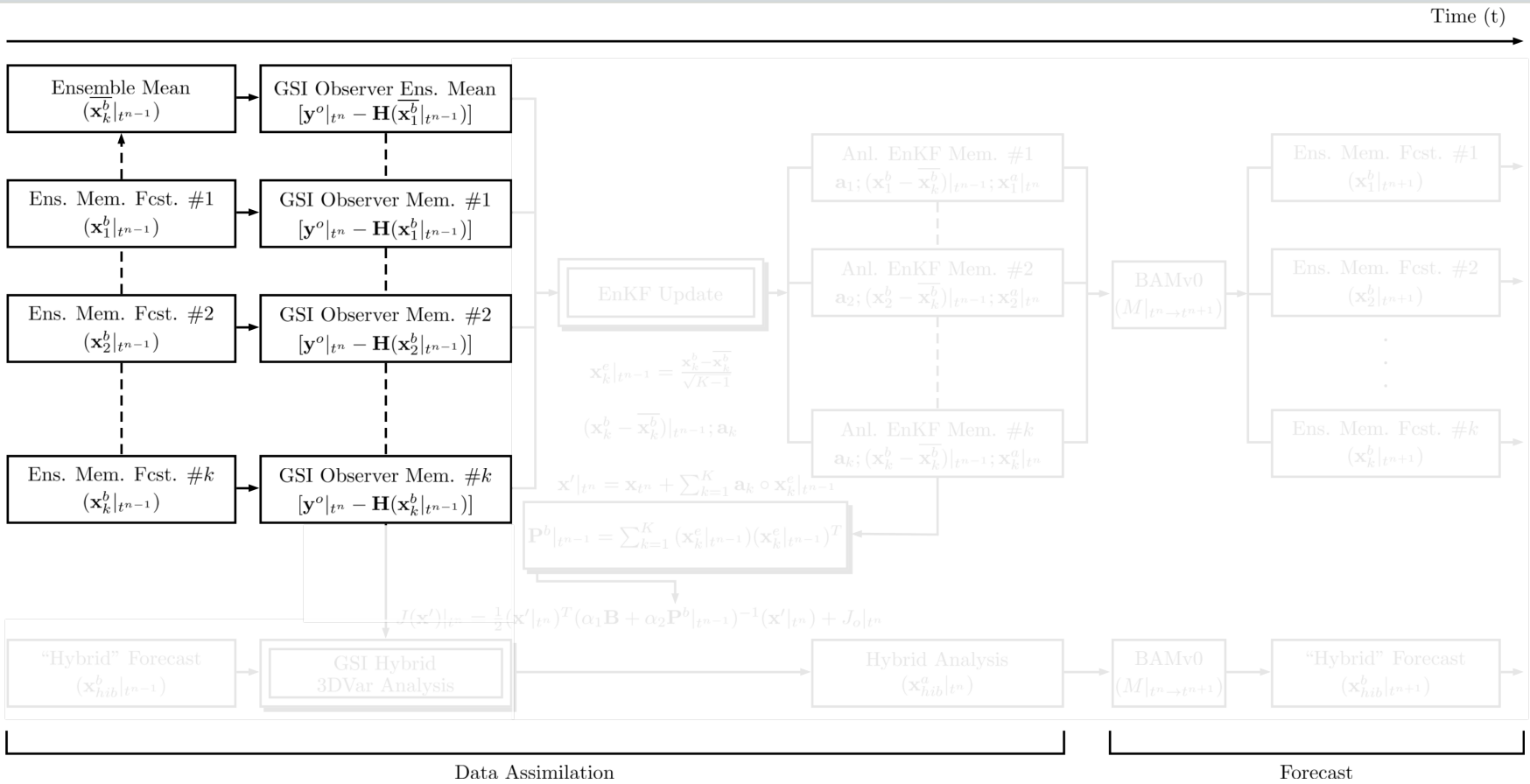
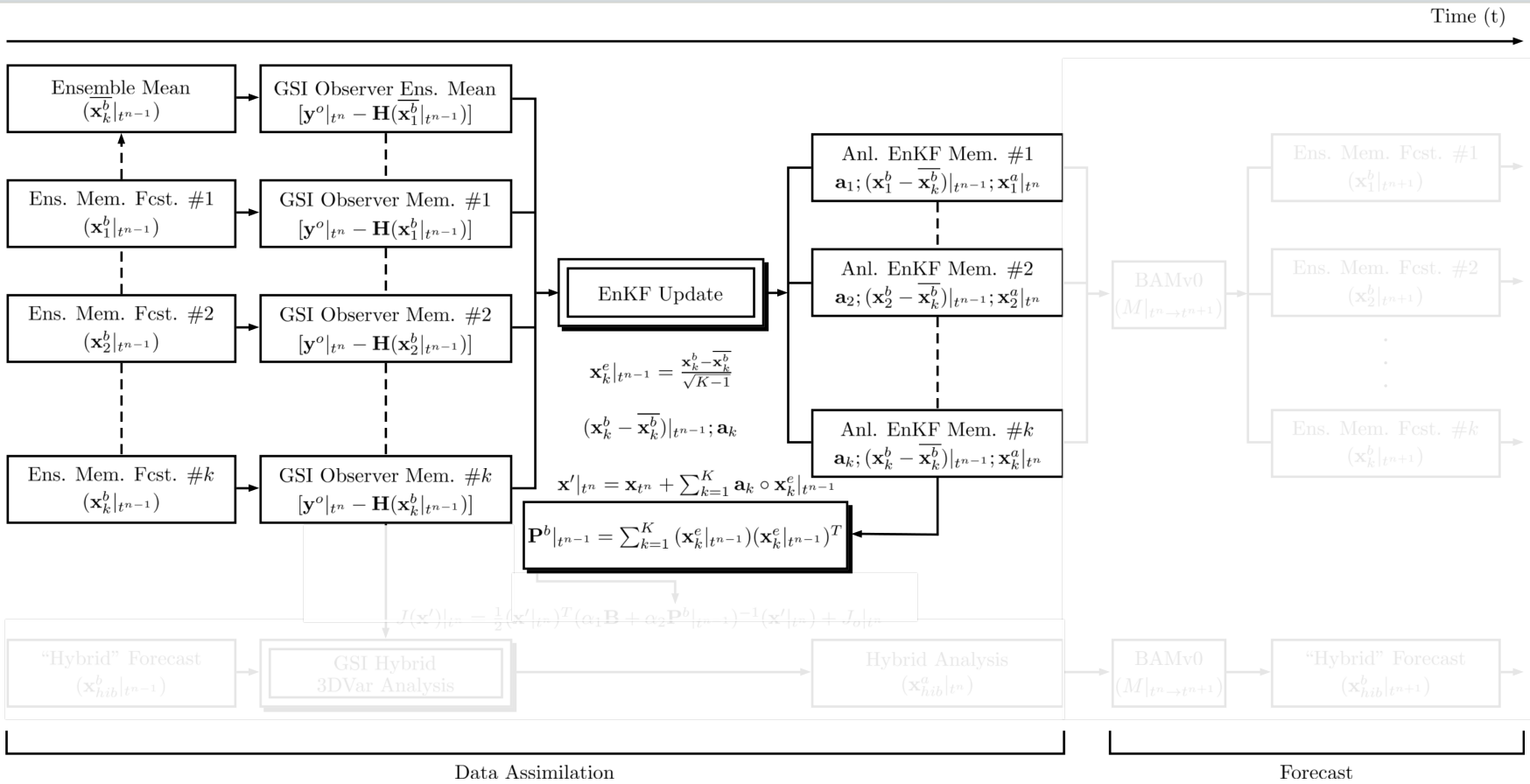


GSI based hybrid 3DVar DA



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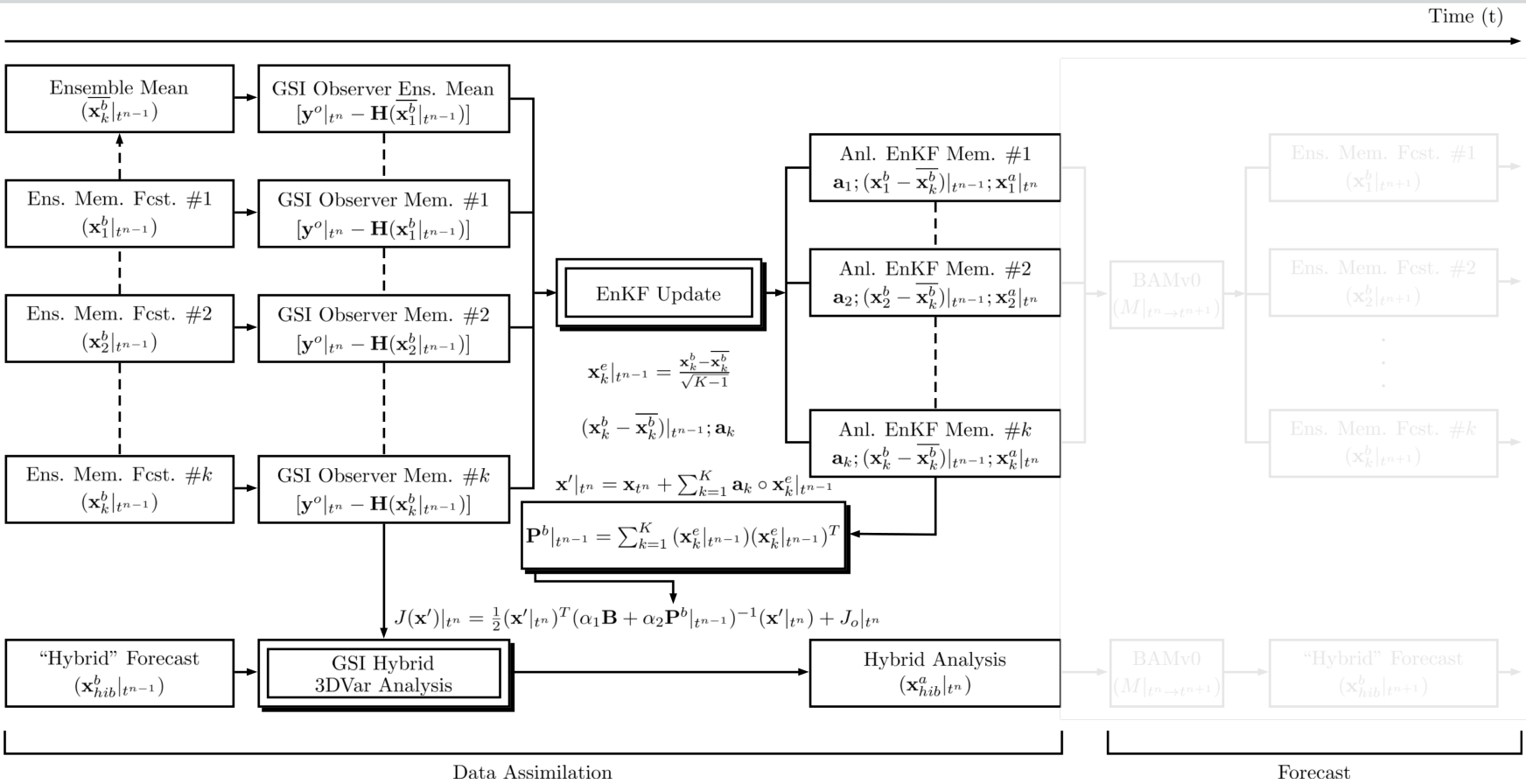
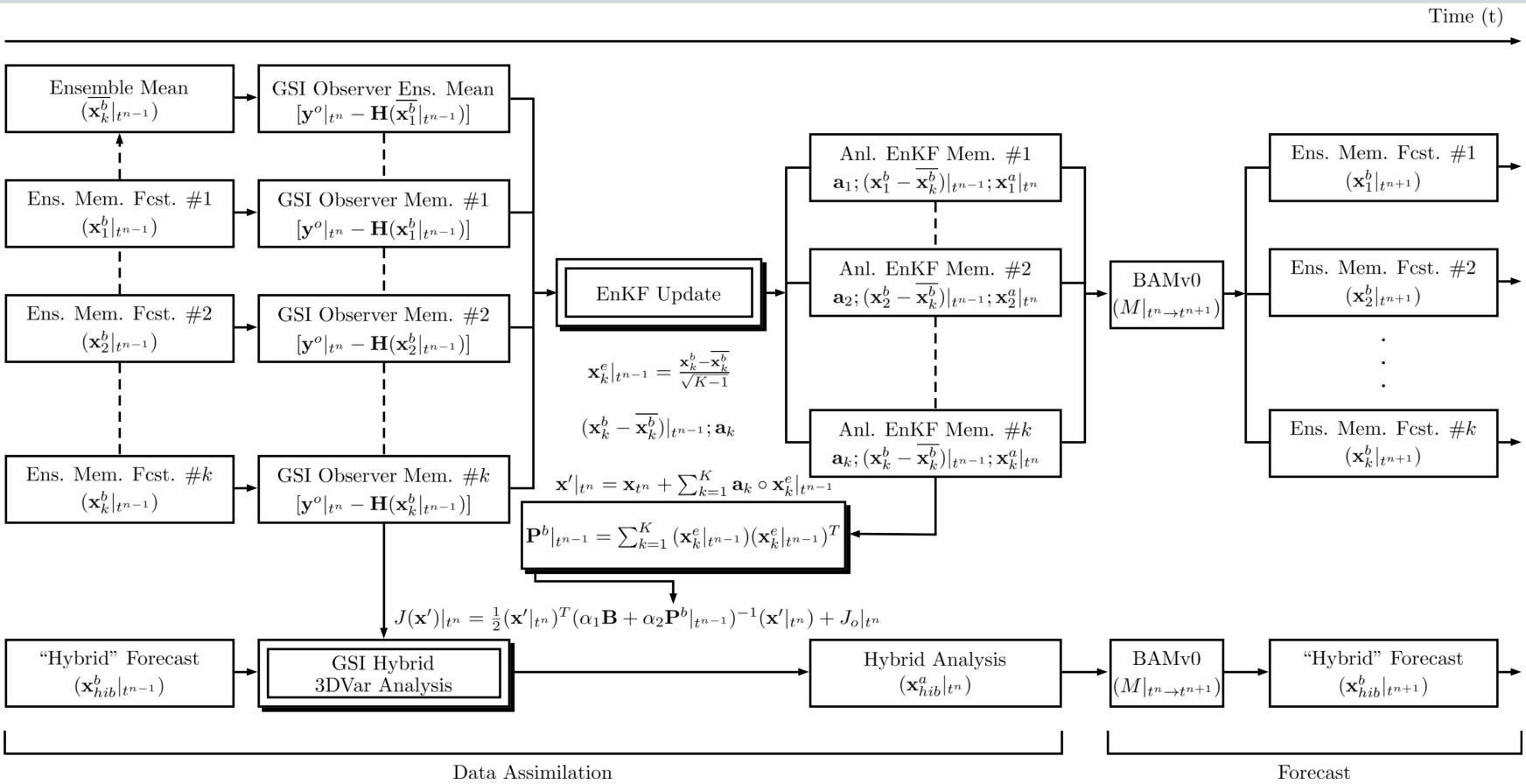


GSI based hybrid 3DVar DA



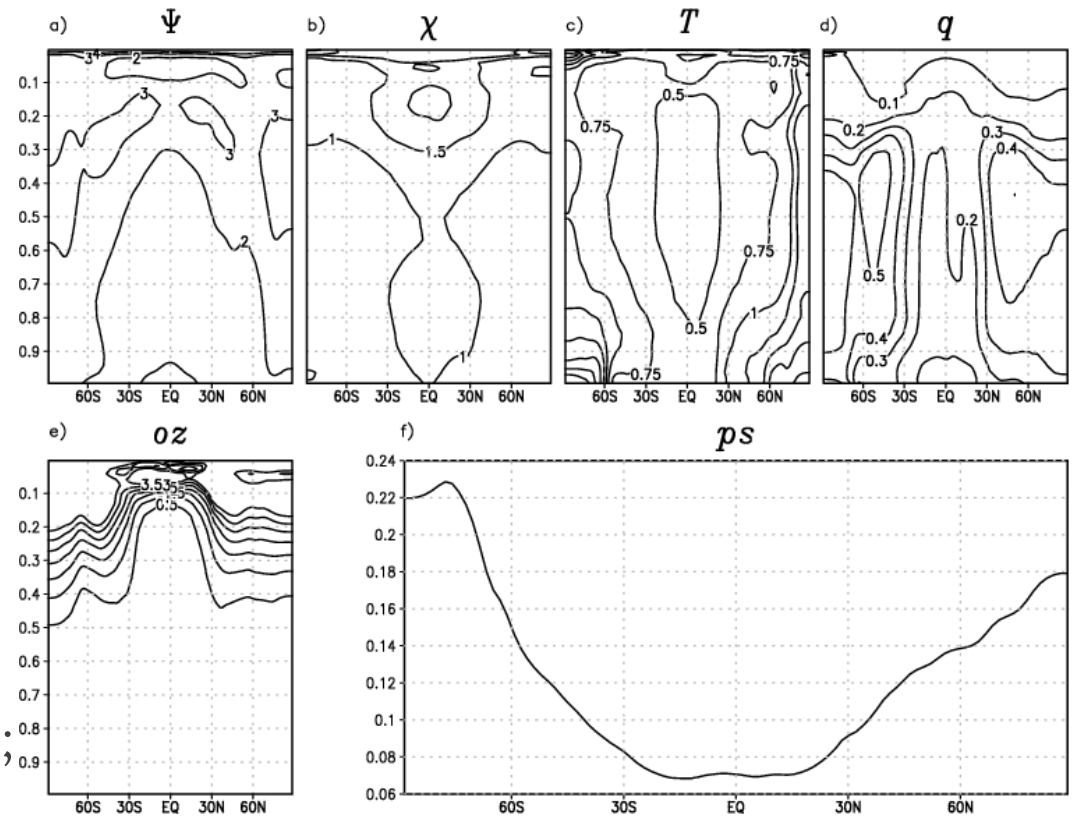
GSI based hybrid 3DVar DA

Static B

- NMC method;
- 730 pairs (48-24 hr fct);

Forecast and Analysis

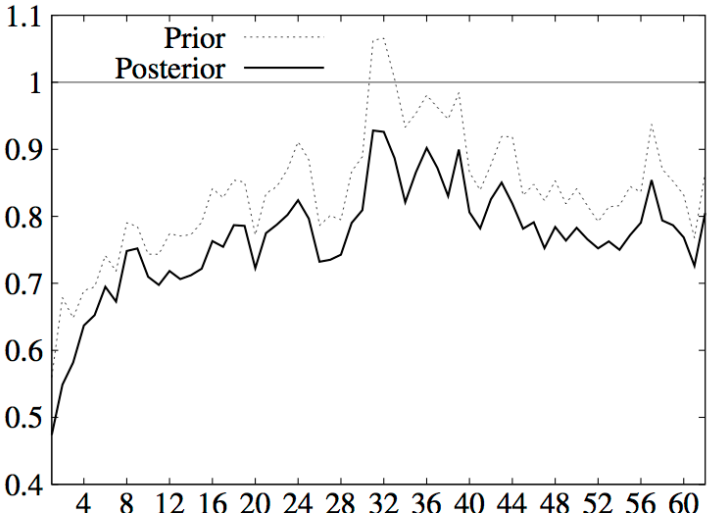
- TQ0062L028 (~200 Km);
- Single res. and no recenter;
- EnKF/EnSRF 40 members;
- Assimilation of conventional observations and satellite radiances (eg., AMSU, AIRS etc).



Results

Ensemble Innovation Statistics

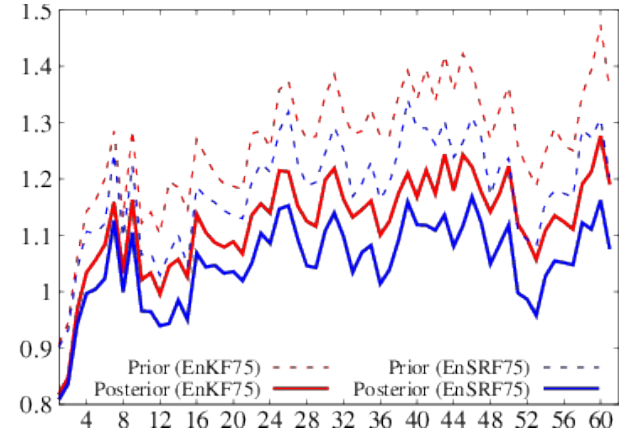
$$IC = \frac{\sigma(\mathbf{y}^o - \mathbf{H}\mathbf{x}_k^b)}{\sqrt{S+R}}$$



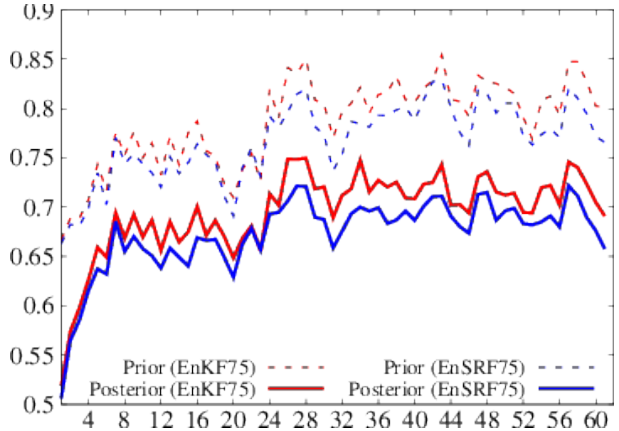
- Ensemble evaluation looking at the reduction of the error of the priors to posteriors, due to the observation innovation;
- Values must converge to 1 (unit);
- Greater values may indicate deficiencies in the ensemble spread.

Results (Innov. Statistics)

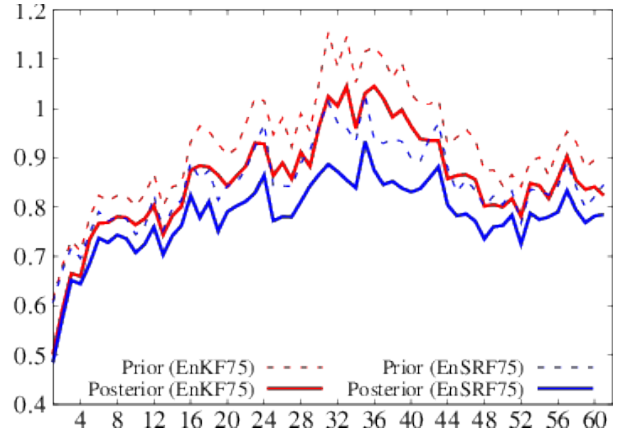
a) uv (NH)



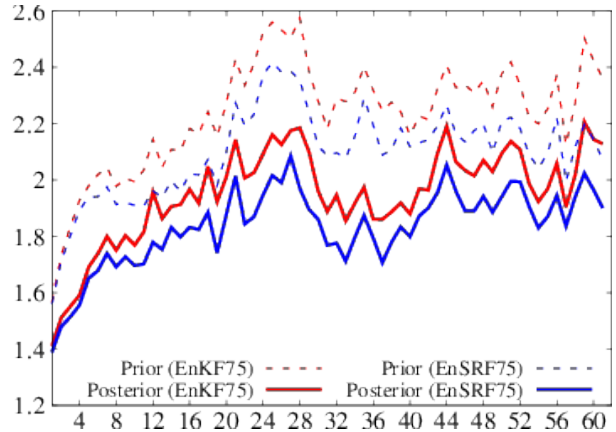
b) uv (TR)



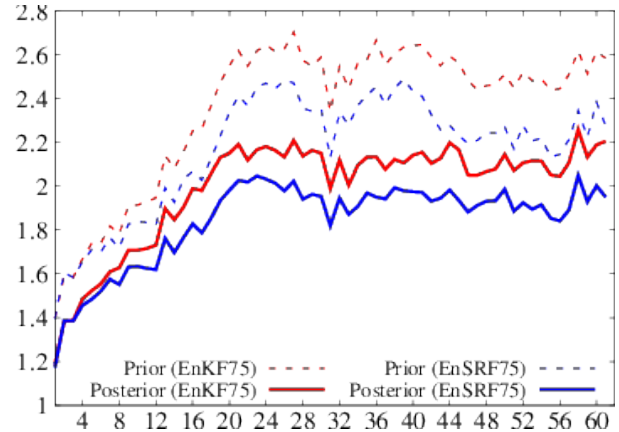
c) uv (SH)



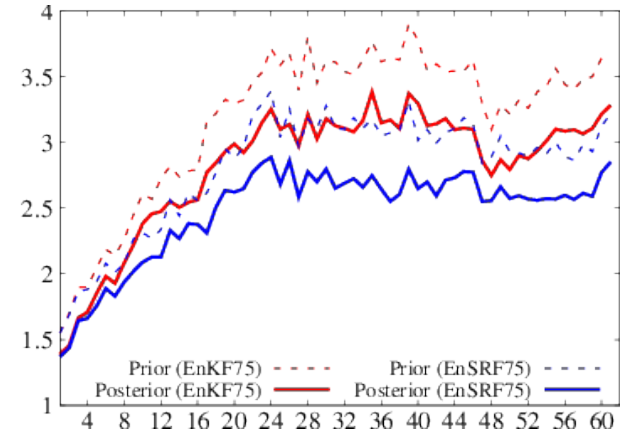
d) T (NH)



e) T (TR)

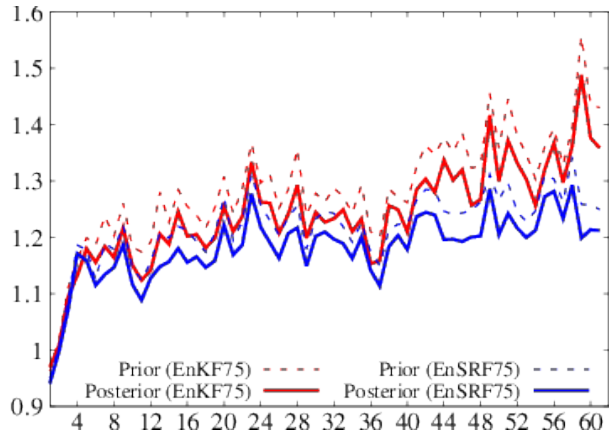


f) T (SH)

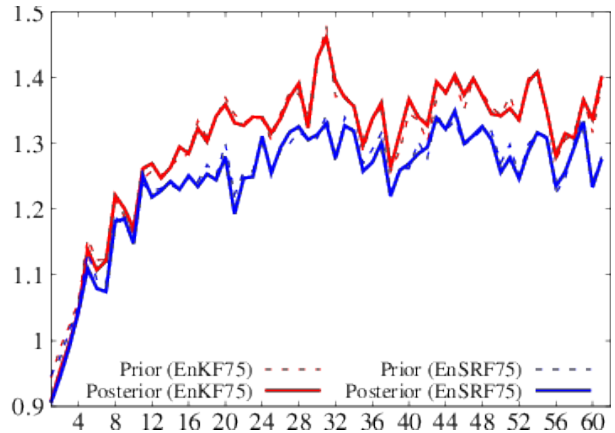


Results (Innov. Statistics)

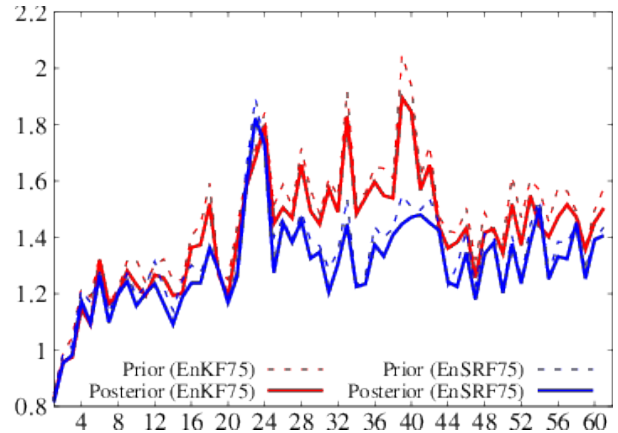
a) q (NH)



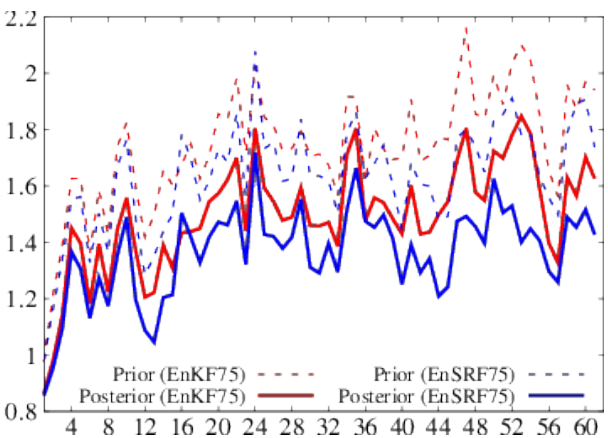
b) q (TR)



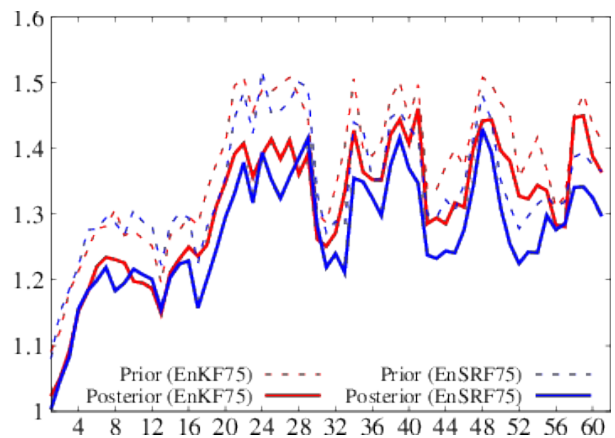
c) q (SH)



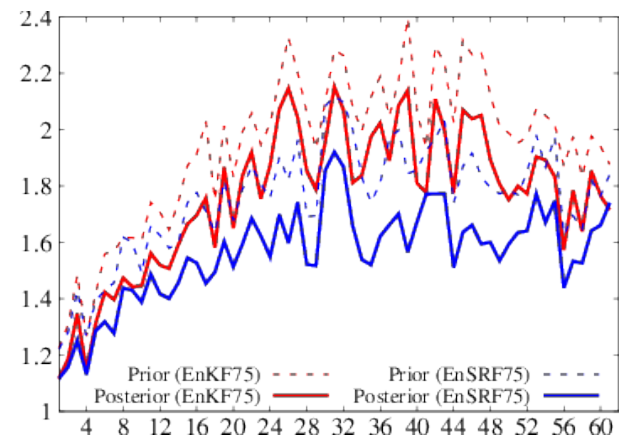
d) ps (NH)



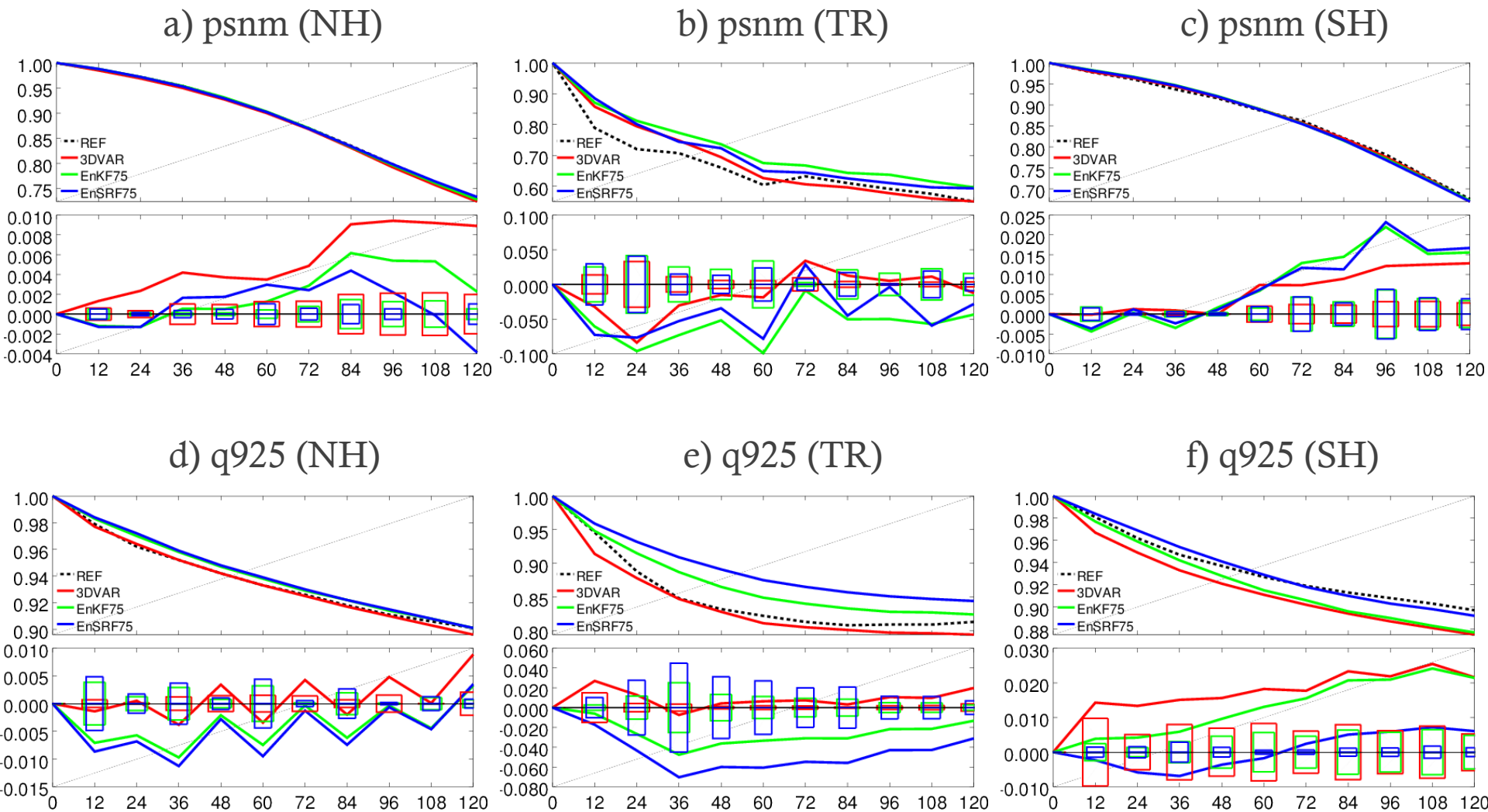
e) ps (TR)



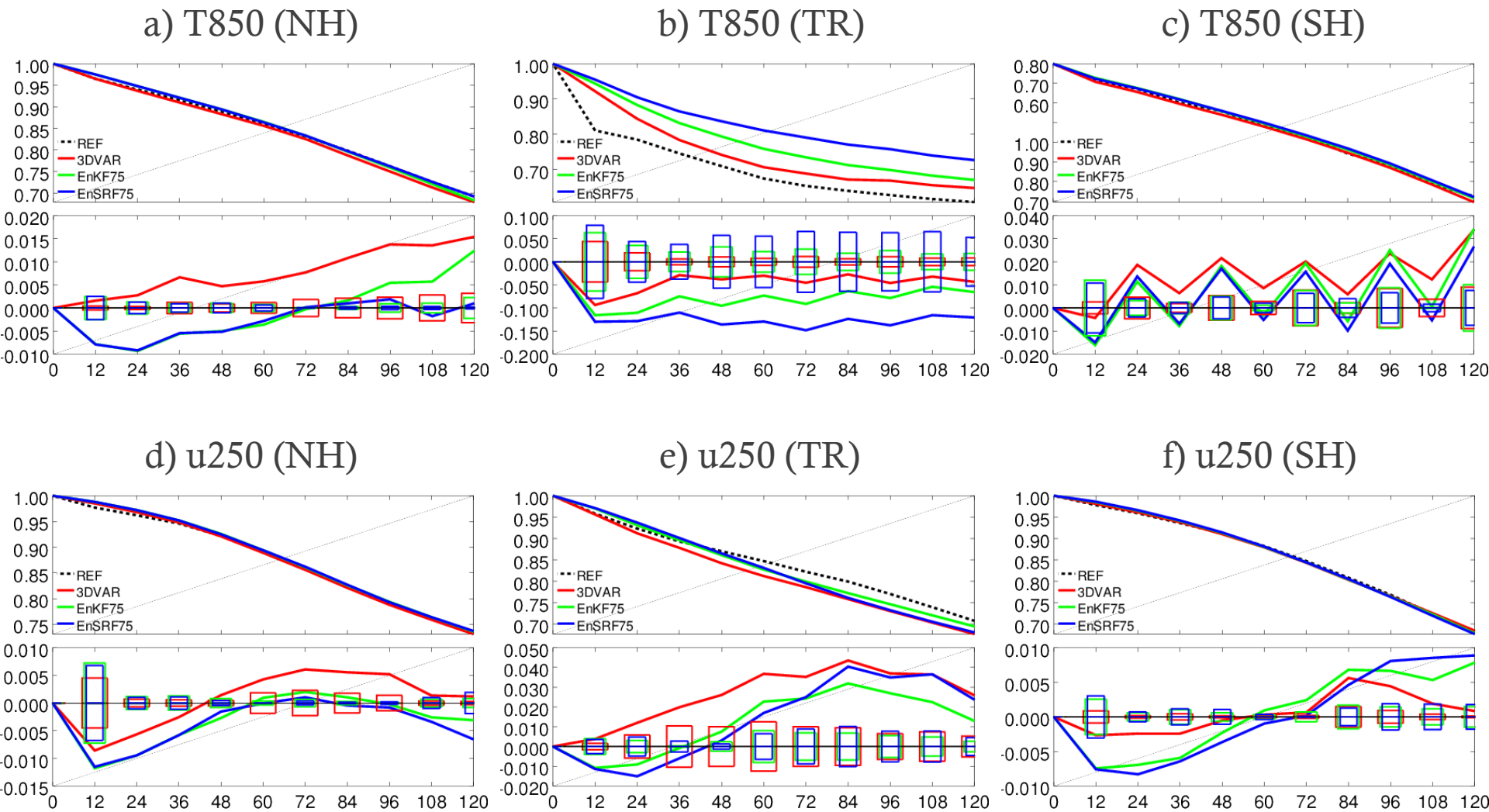
f) ps (SH)



Results (Anomaly Correlations)

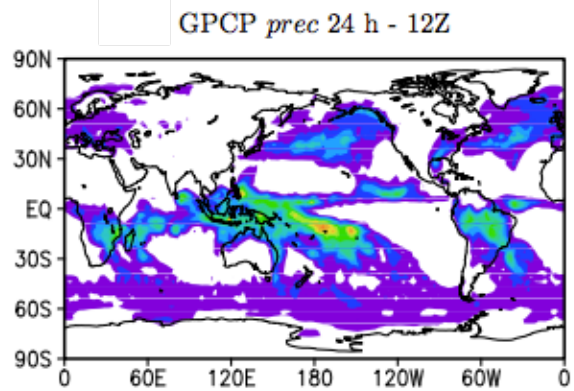


Results (Anomaly Correlations)

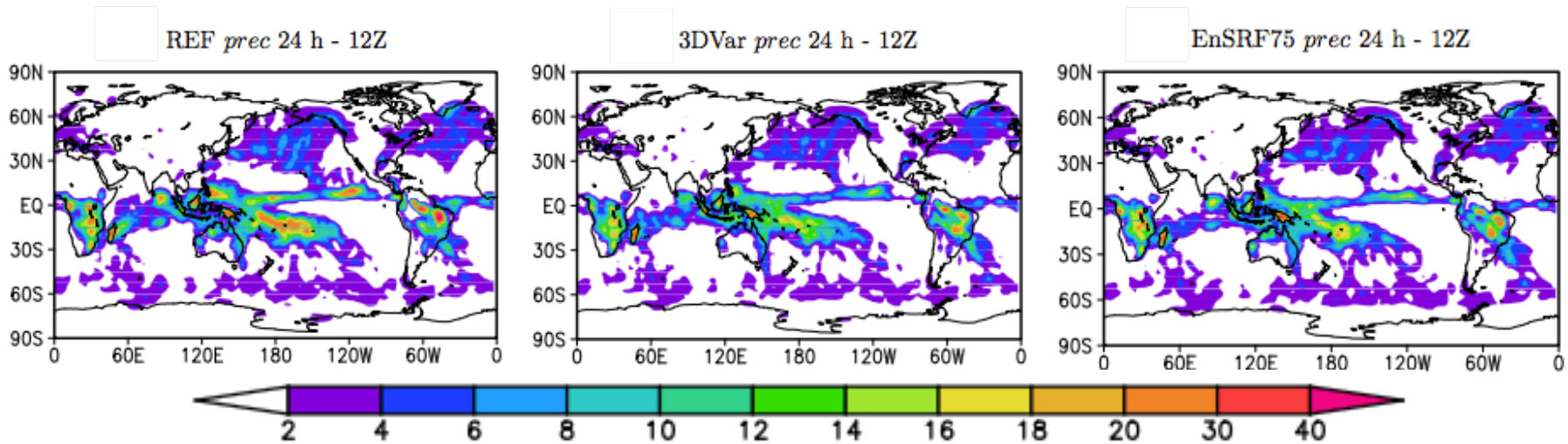


Results (Precip. Verification)

Precip. 24 hour forecast (monthly mean)



Precip. forecasts from the hybrid analysis show that the average patterns of the large and convective scale are relatively well represented, in comparison with the observed (GPCP), the BAM model with the NCEP anl, and also the BAM model with pure 3DVar analysis.



Closing Remarks

- Hybrid data assimilation is under development at CPTEC;
- We have tested both EnKF and EnSRF ensembles with 50 and 75% of contribution to static **B** (results with 50% not showed);
- Some caveats have to be addressed and several other evaluations remains to be made in order to truly access the hybrid analysis and forecasts, and the contribution of the day-to-day variations in the background error covariances;
- First results are encouraging and reinforces reported results by the community;
- Computational cost is high for CPTEC (even at TQ0062L028 resolution, but an upgrade to the supercomputer is on the way - supposedly);
  - Dual resolution maybe a viable option;

Further Work

- Verify the hybrid analysis for a longer period of time;
- Tune the ensemble covariance inflation and localization;
- Tune the static **B** application;
- Properly access the ensemble spread;
- What ensemble size best fits the computational resources available? Would it be suitable for forecasts between 5 and 15 days?
- So on…

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