

Handling of Position Errors in Variational and Hybrid Ensemble/Variational Data Assimilation Using Image Registration



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- Introduction
 - Handling of position errors in:
 - deterministic modeling system
 - probabilistic modeling system
 - Concluding remarks

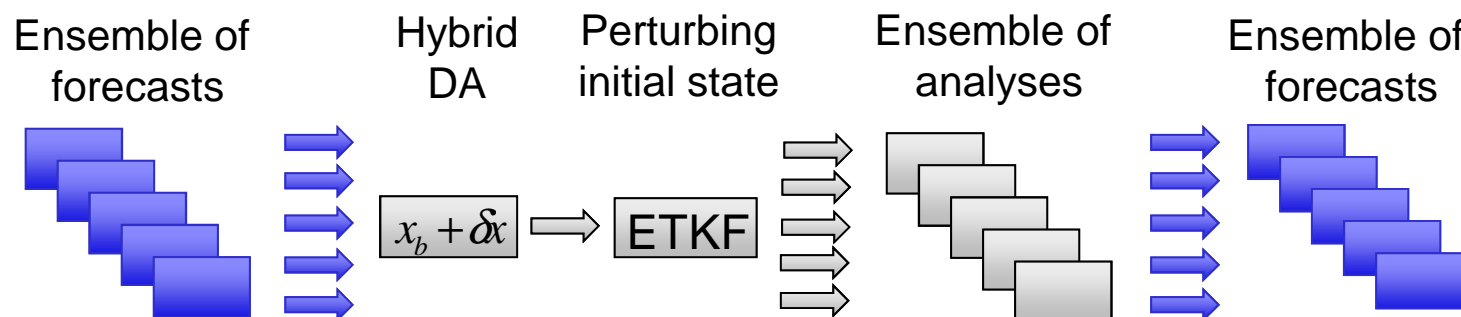
Data Assimilation in HIRLAM Modeling System

Variational data assimilation:

$$J = J_b + J_o = \frac{1}{2} \delta x^T B^{-1} \delta x + \frac{1}{2} (Hx^b + H_{tl} \delta x - y)^T R^{-1} (Hx^b + H_{tl} \delta x - y)$$

Hybrid Ensemble/Variational data assimilation (DA):

$$\delta x = \delta x_{var} + \sum_{k=1}^K (\alpha_k \circ \delta x_k^{ens})$$



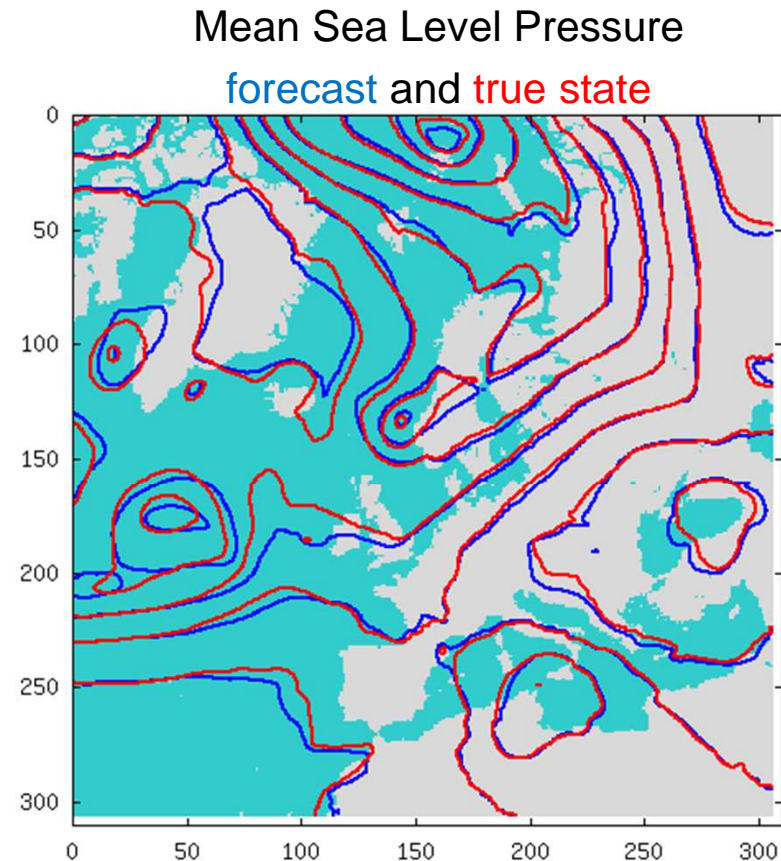
Position / Phase / Alignment / Displacement / Timing Errors

A mixed alignment (phase) and additive error model:

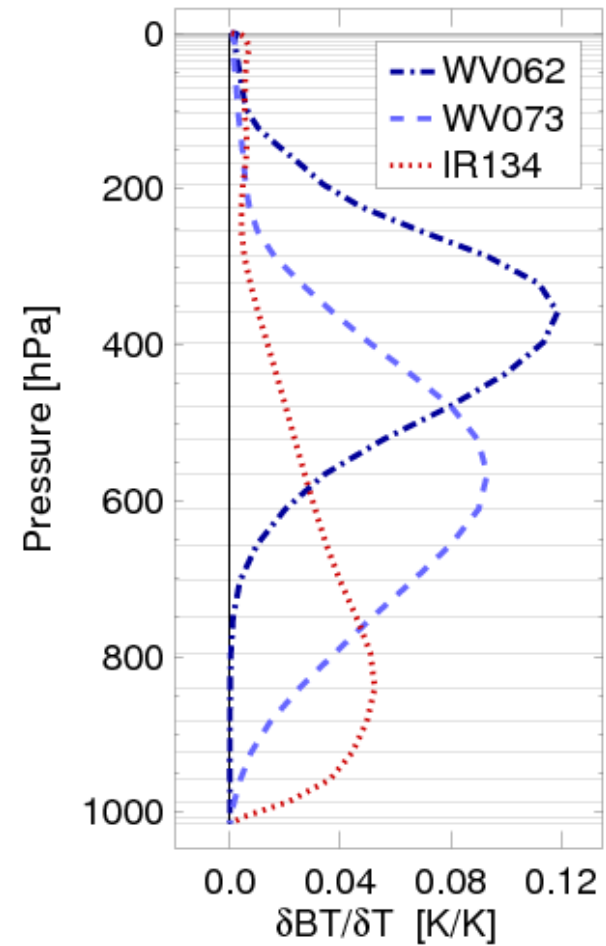
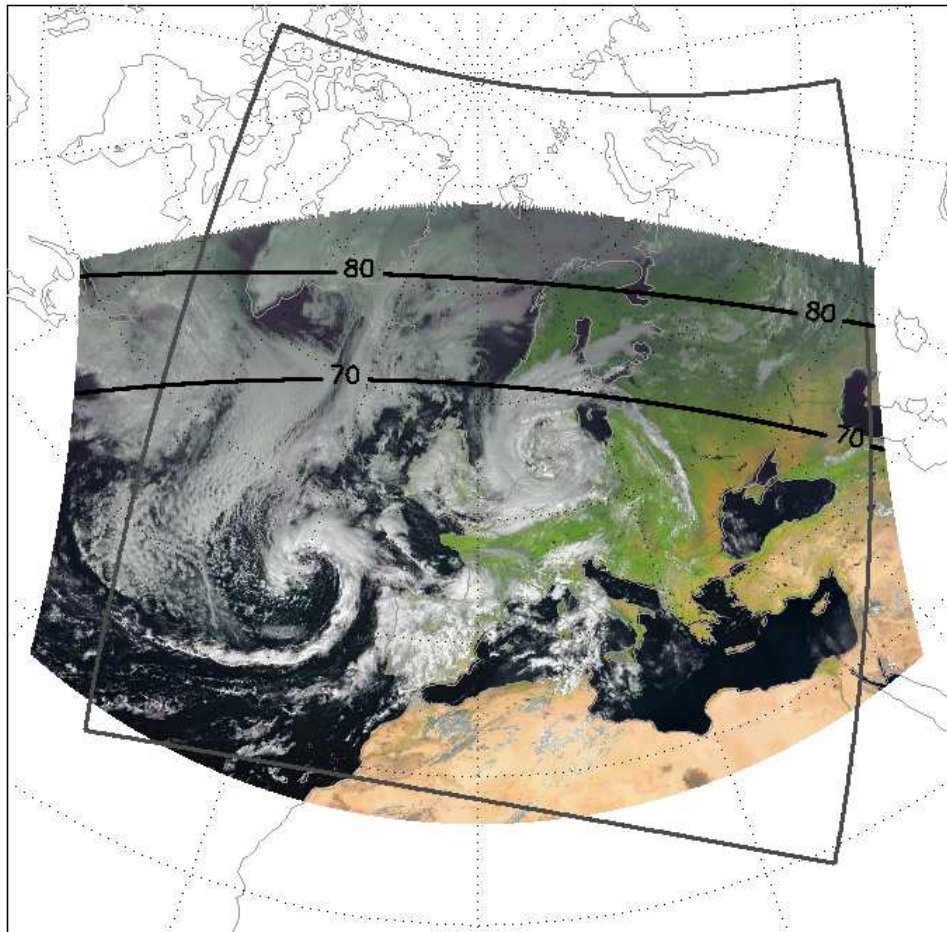
$$x_t(s) = x_b(s + \varepsilon_p(s)) + \varepsilon_a(s)$$

$$\begin{aligned}\varepsilon_t(s) &= x_t(s) - x_b(s) \\ &= x_b(s + \varepsilon_p(s)) - x_b(s) + \varepsilon_a(s)\end{aligned}$$

Total error is generally non-Gaussian
(Lawson and Hansen 2005)

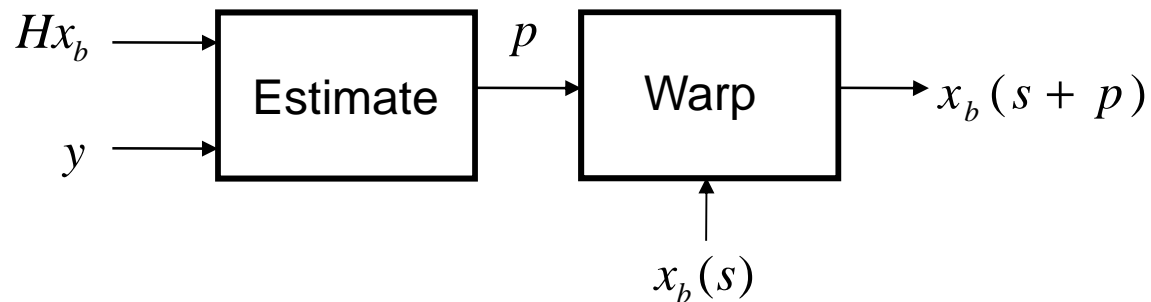


SEVIRI data



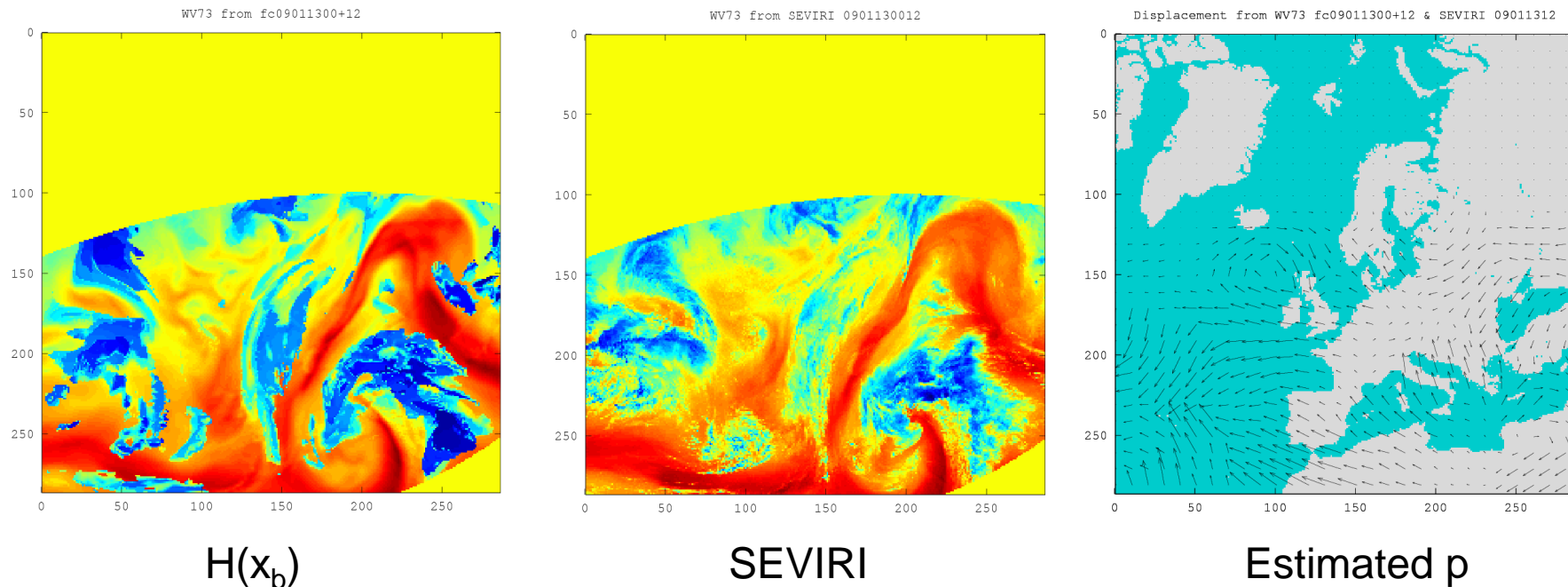
Handling of Phase Errors in Deterministic Variational Data Assimilation

- Use remote sensing image data to estimate the phase error (displacement field) and compensate for it by warping the background state.



- Minimize the remaining additive error using a standard VAR-method.

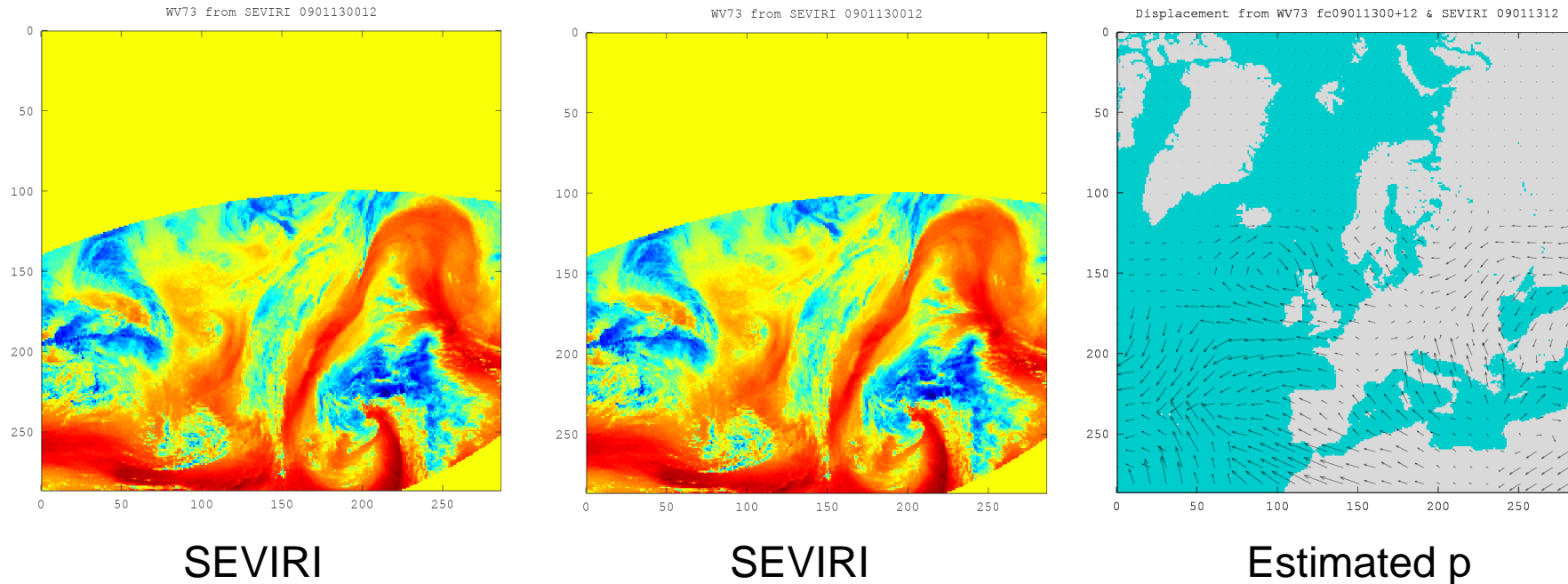
Registration using SEVIRI WV073



Estimate the displacement field with an image registration method, e.g.

Sun, D.; Roth, S. & Black, M. J. "Secrets of Optical Flow Estimation and Their Principles", IEEE Int. Conf. on Comp. Vision & Pattern Recognition, 2010.

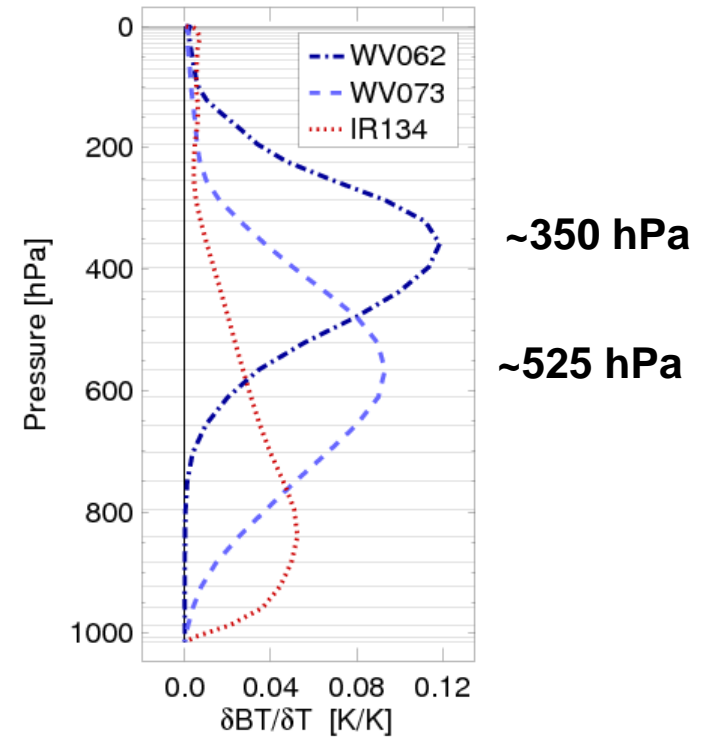
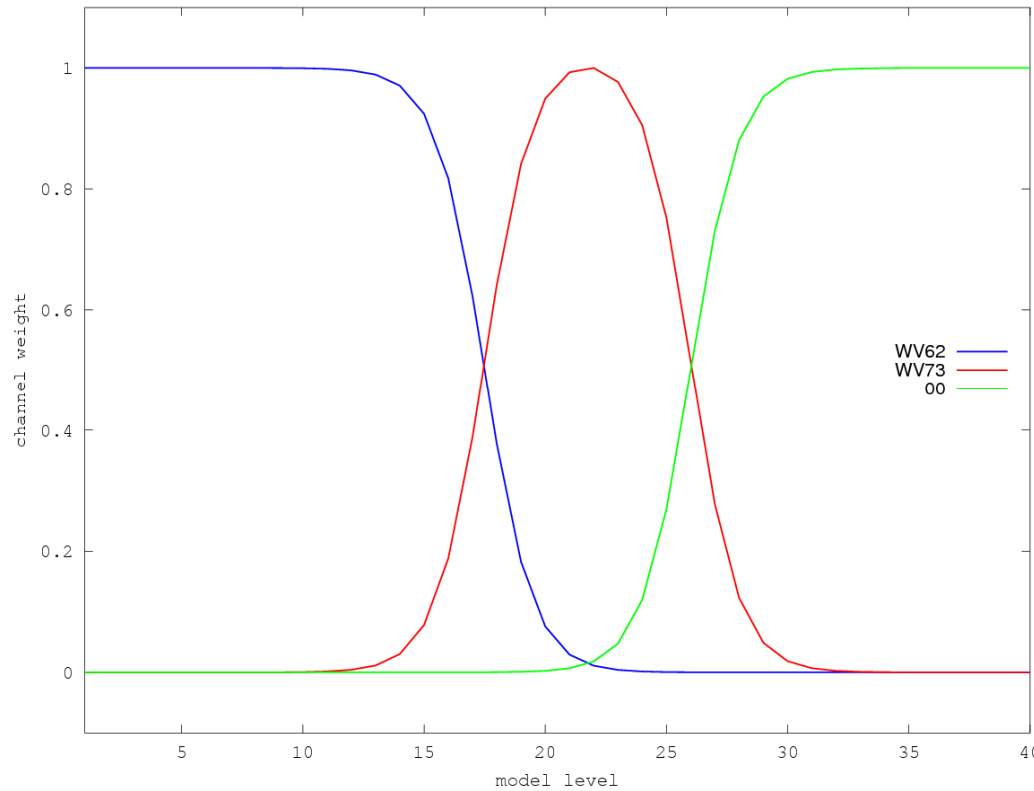
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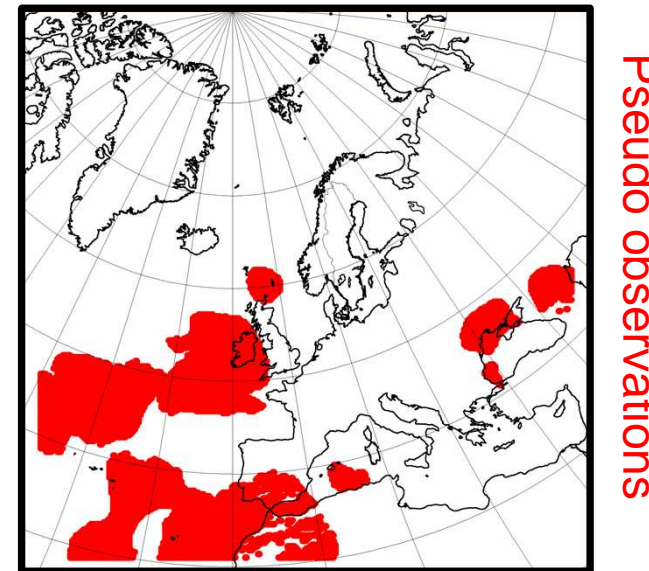
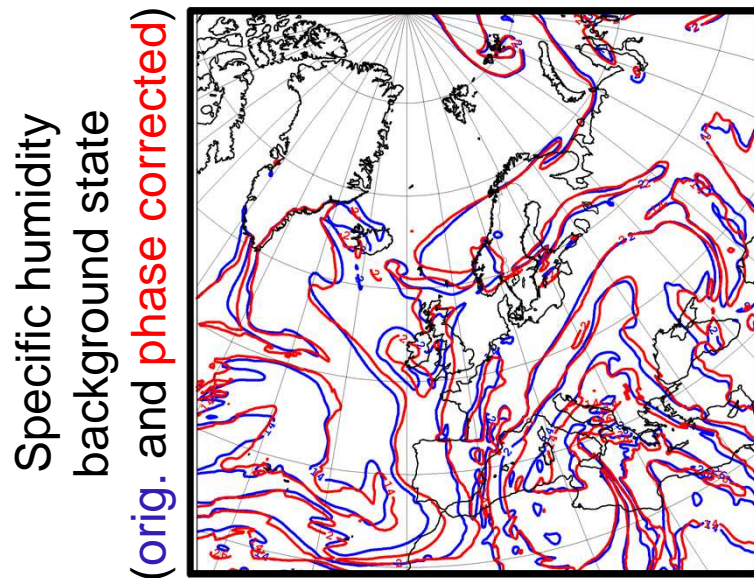
Vertical interpolation of displacement



The same displacement field is applied to all model variables (T, u, v, q).

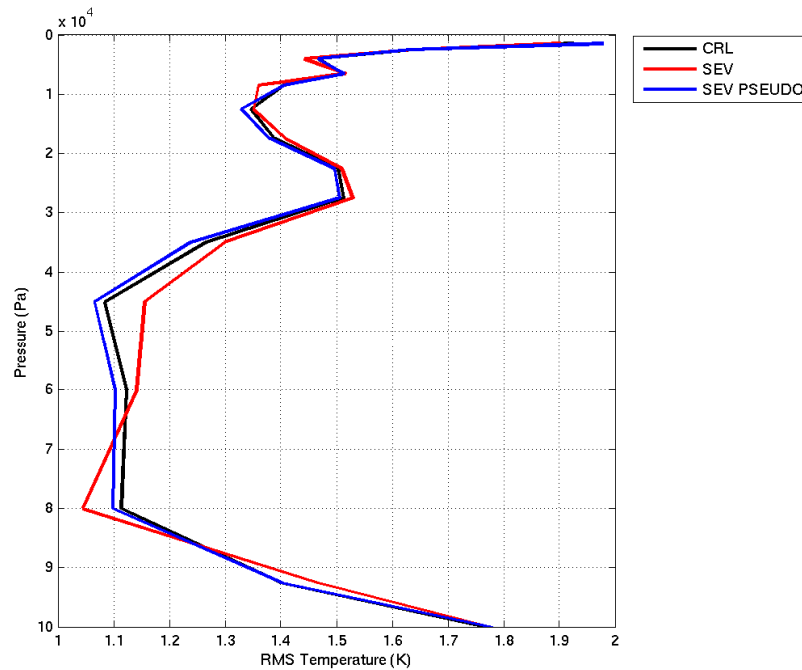
Impose Balance; Two Step Data Assimilation

- Generate pseudo observations from warped model state (q, T, u, v).
- Assimilate these in a first step to obtain a balanced and phase corrected background state.
- Use this modified background state to minimize the additive error using standard VAR-method and real observations in a second step.

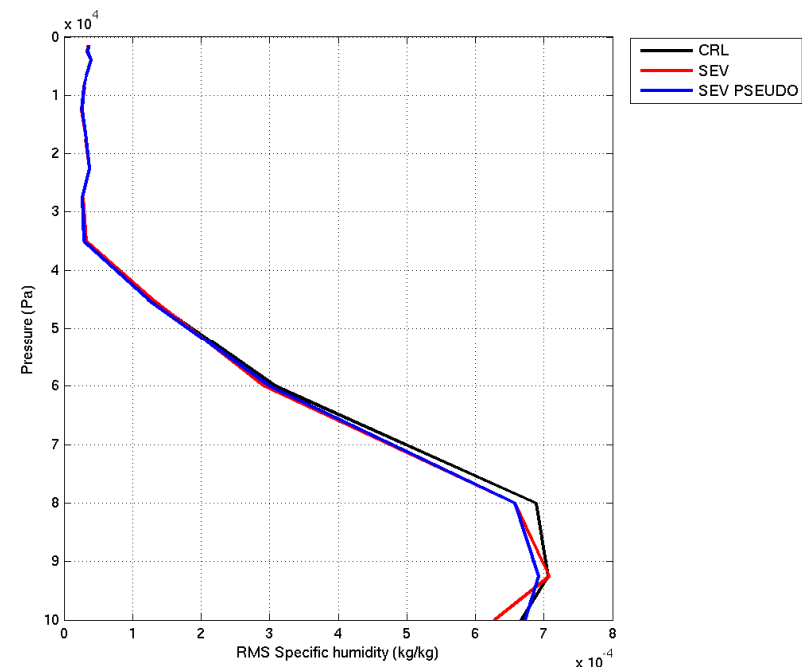


Verification of a +12 hour forecast against observations

- Traditional variational data assimilation
- Phase-correcting background state (without balance constraint)
- Phase-correcting background state (with balance constraint)

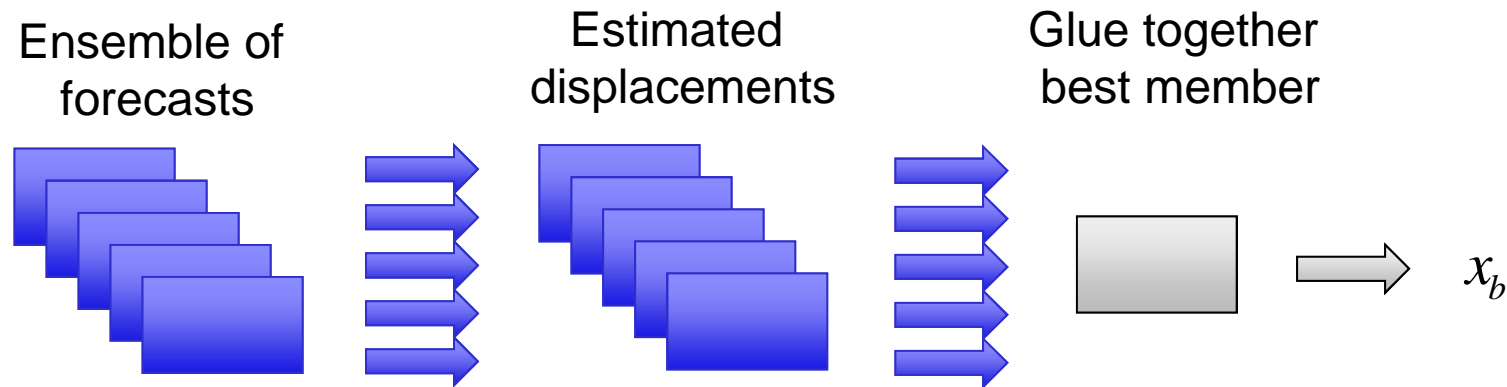


RMSE Temperature (K)



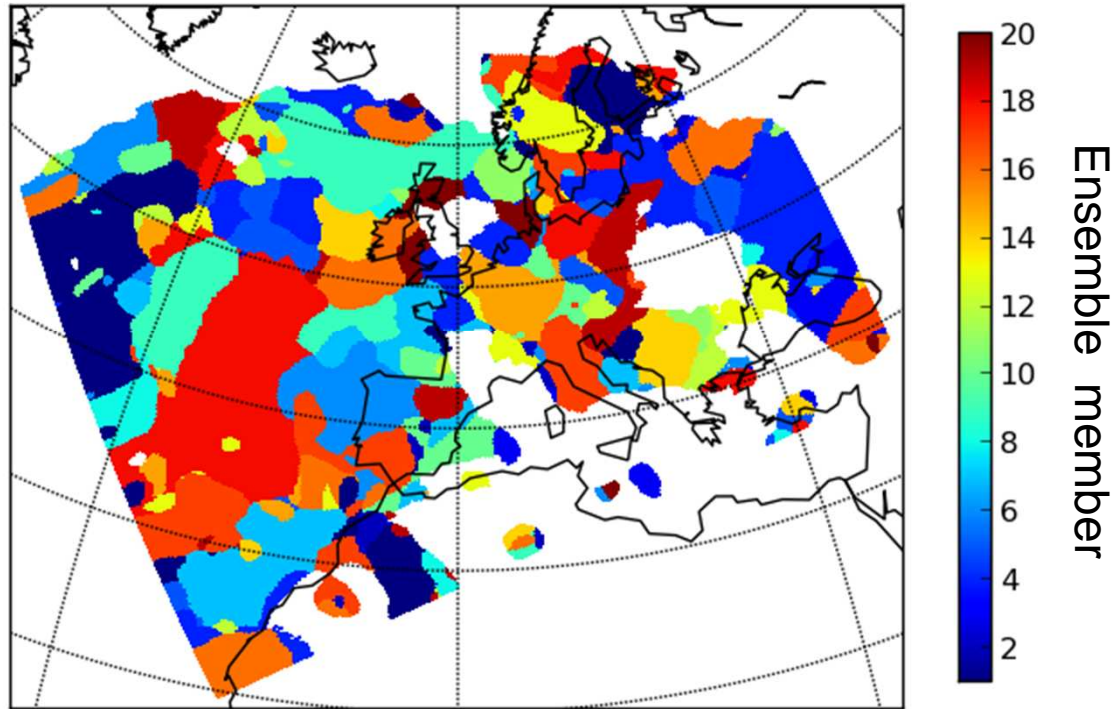
RMSE Spec. hum (kg/kg)

Handling of Phase Errors in Data Assimilation with Ensembles



- In each location use the member state with least displacement error.
- Assimilate pseudo observations from best member model state (q,T,u,v).
- Use this modified background state to minimize the additive error using normal ensemble DA method and real observations in a second step.

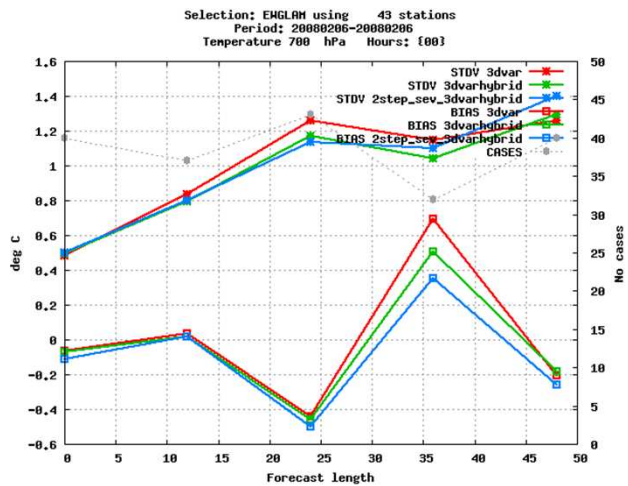
Best member calculation



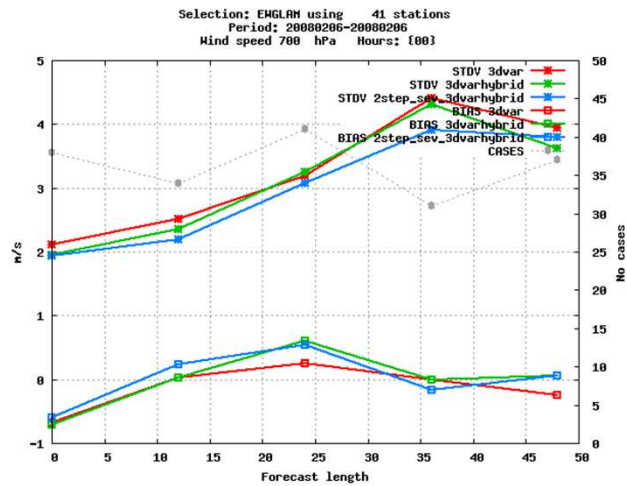
Best member map

Verification of a forecast against observations

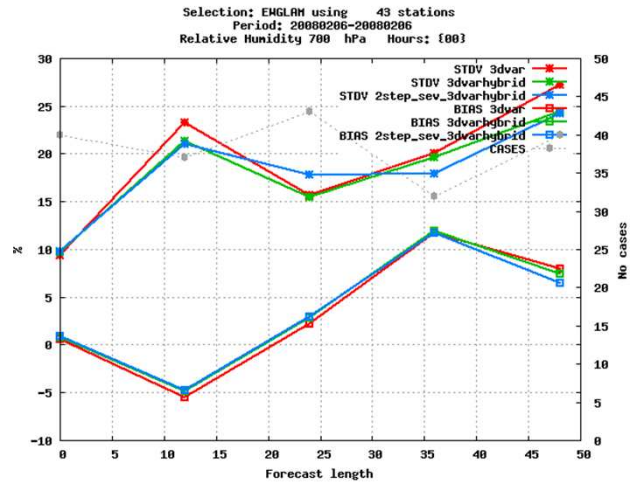
- 3D-Var
- 3D-Var/ETKF Hybrid Data Assimilation
- 3D-Var/ETKF Hybrid Data Assimilation with correction of phase errors in background state utilizing gluing approach



**Temperature (K)
at 700 hPa**



**Wind Speed (m/s)
at 700 hPa**



**Relative Humidity (%)
at 700 hPa**

- Image registration for phase error correction.
- Warp the background state or exploit different ensemble members in different areas.
- Impose balance by use of pseudo observations.
- Encouraging first results with real data but more experiments over extended periods needed.
- Idealized studies with a simple model in order to investigate the ability of different data assimilation techniques to handle phase errors.