Treatment of flow-dependency in data assimilatoion

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Treatment of the background forecast error covariance

climatology

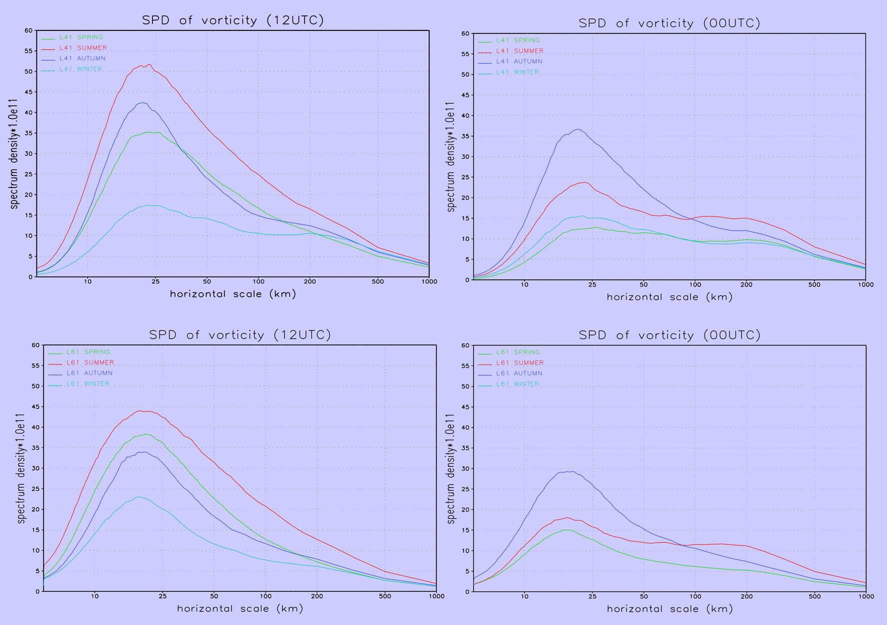
Diurnal dependency

Horizontal spectra more energy in meso-scale at day than at night during spring/summer/winter; less energy day/night variation during autumn.

Vertical correlation Slightly wider at daytime than at night for all season.

Humidity standard deviation not much diurnal change.

Moisture balances especially during summer (lower level) – coupling between unbalanced temperature and humidity at daytime is larger than at night.



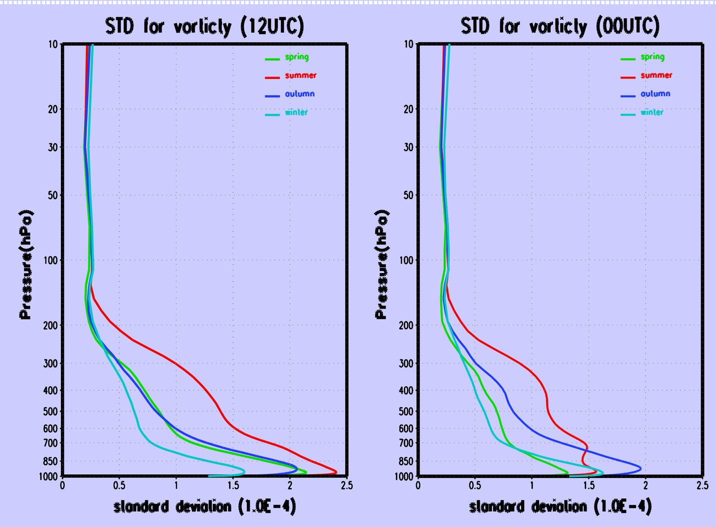
Seasonal dependency

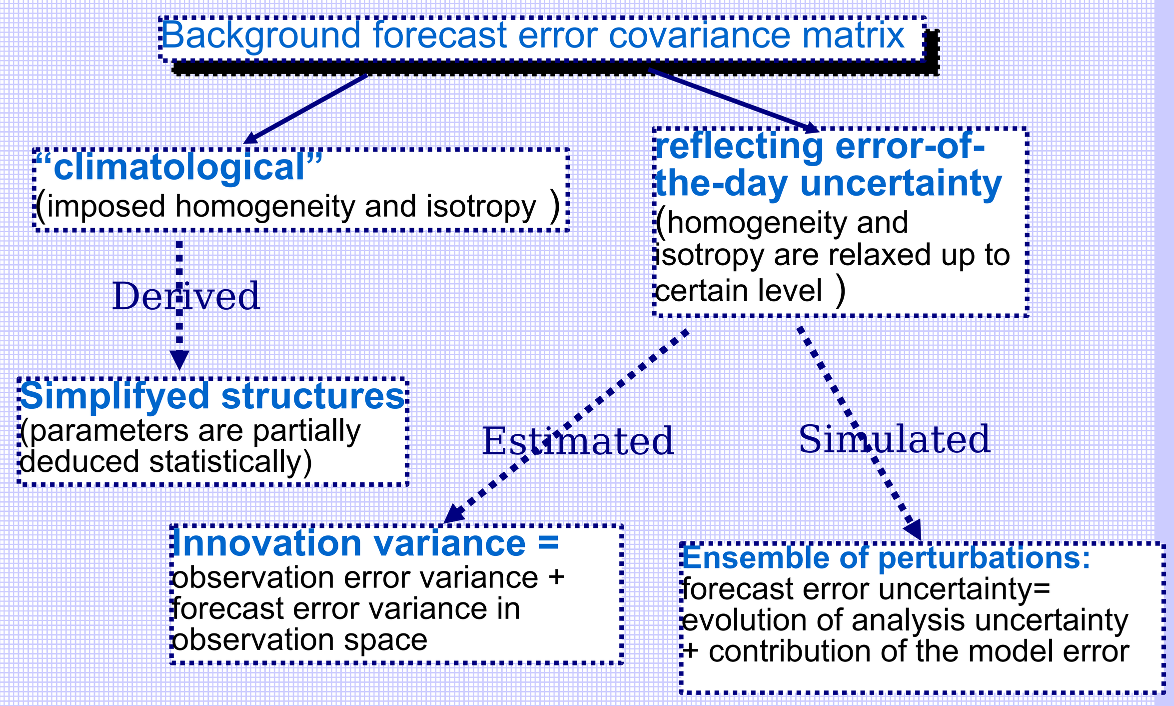
Horizontal spectra Winter - more energy in synoptical scales; Summer - more energy in meso scale

Vertical correlation Slightly wider in summer than in winter

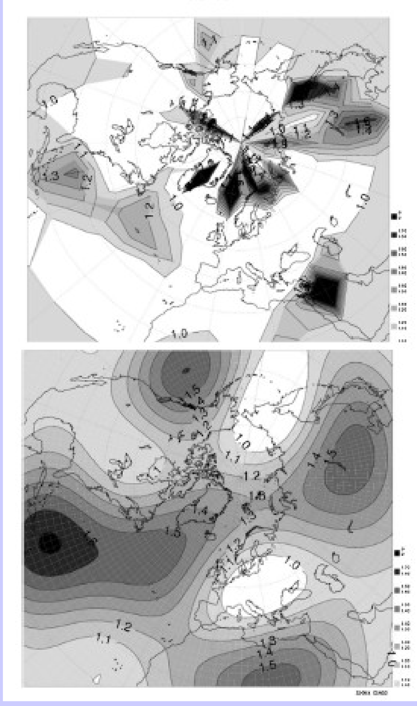
Humidity standard deviation Larger in summer than in winter

Moisture balances winter – coupling between vorticity and humidity is comparable to coupling between unbalanced temperature and humidity; summer – coupling between unbalanced temperature and humidity is dominate. (lower level)





Relaxed assumptions on in-isotropy and non-homogeneity



Geographical variation of the forecast error amplitude

One year average of the standard deviations of the surface pressure innovations (observation-minus-backround state) for HIRLAM (Lindskog et al, 2006)

Flow-dependent auto-correlation structures (estimated from the ensemble of 12 forecast differences using wavelets approach)

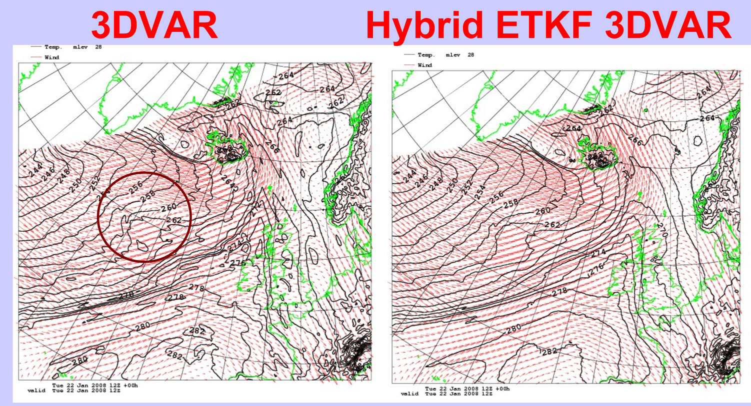
500 hPa geopotential height (Lindskog et al, 2007)

The hybrid ETKF 3D-Variational data assimilation

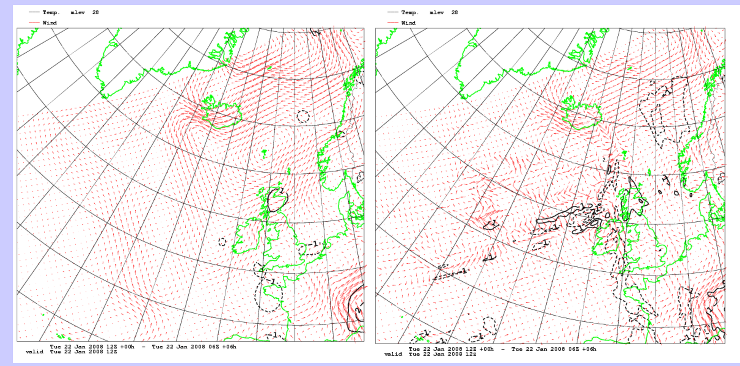
HIRLAM approach to use ensembles in 3D-Var

- **Sample (or Construct)** perturbations which reflect stuctures of the analysis error (*EuroTEPS*, *ETKF* or *EnsDA*)
- **Grow** flow-dependent structures by integrating analysis ensemble forward in time to obtain the 6h forecast perturbations.
- **Perform** the variational data assimilation blending the structures of the full-rank statically and analytically deduced $B_{3D\text{-}Var}$ and the flow- and observation-network dependent structures of the rank-deficient B^f_{ens}.
- ***Repeat*** Steps 1-3

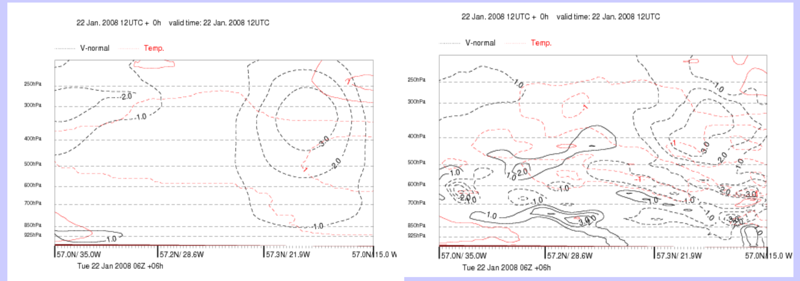
3DVAR **Hybrid ETKF 3DVAR**



Analysis mlen28 (front)

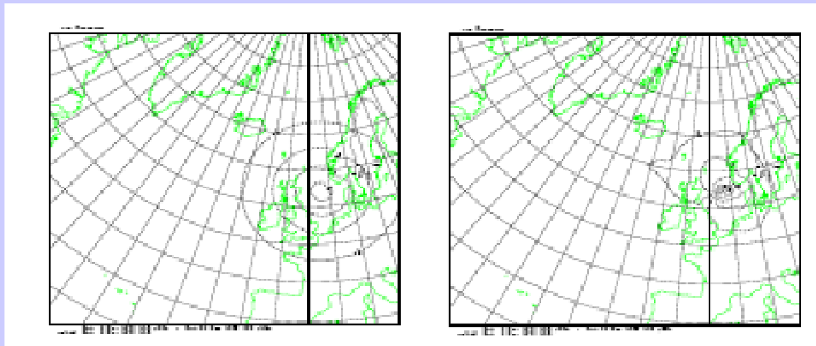


Analysis increment mlen28 (front)



Vertical cross-section (wind ,T)

4D-Variational data assimilation provide flow-dependent structure functions implicitly within the assimilation window. Thus 4D-VAR is equivalent with ***the extended Kalman smoother approach*** over the data assimilation window starting from the climatological background error covariance ***Hybrid Ensembe 4D-Variational data assimilation*** can be thought as a powerful synthesis and is now under investigation for ***the HIRLAM forecasting system***.

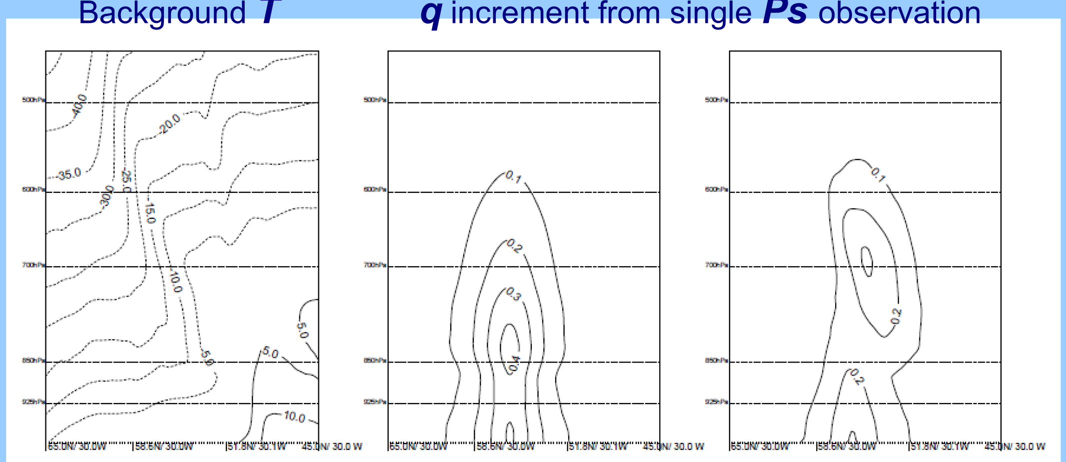


To improve Gaussianity and homogeneity by transform of variables

A non-linear pseudo-relative humidity control variable

The non-linear transform provides flow-dependency in specific humidity. Due to normalization with the background error standard-deviation, dependent on the background state, super-saturation and negative humidities are significantly reduced.

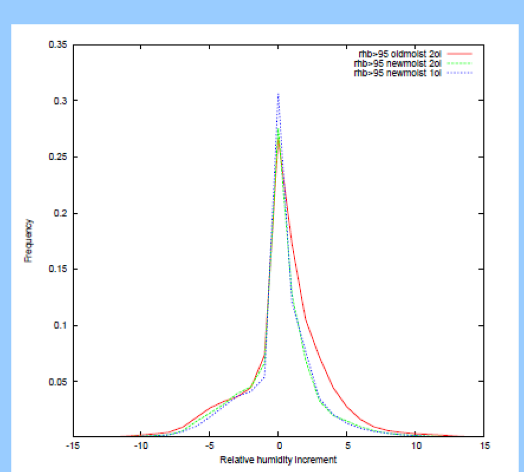
Background ***T*** ***q*** increment from single ***Ps*** observation



q control ***rh**** control

Frequency of assimilation increments close to saturation .

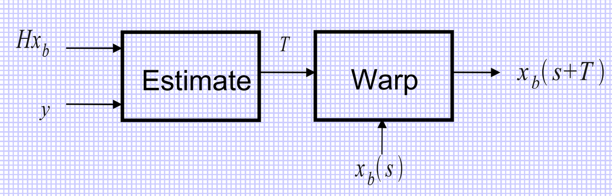
- q control (2 outer loops)
- rh* control (1 outer loop)
- **rh* control (2 outer loops)**



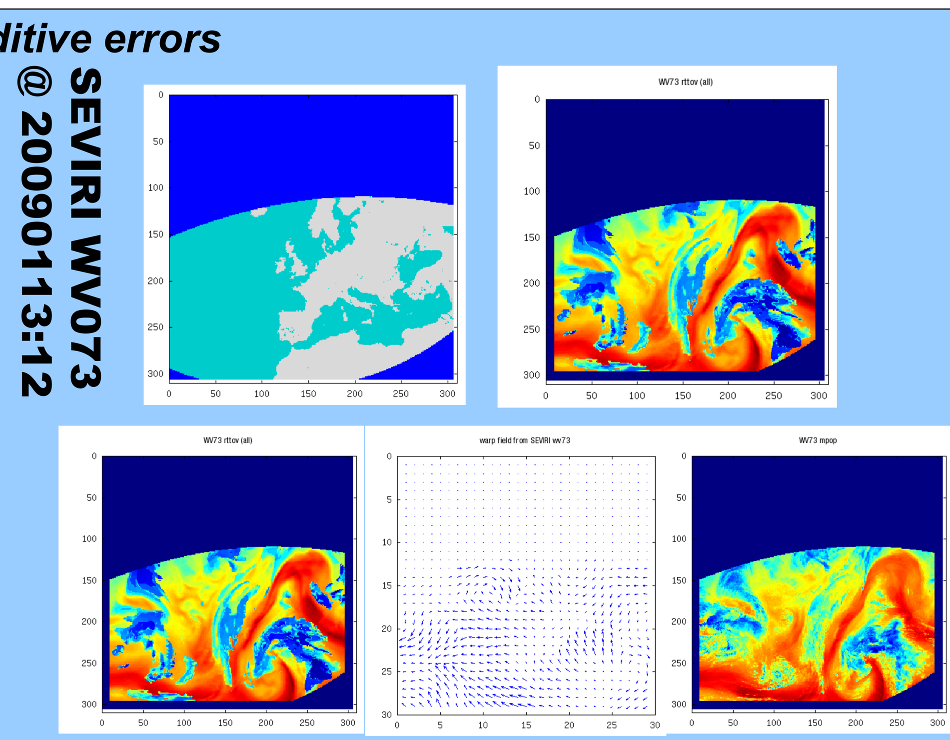
Treatment of non-additive errors

Solution – two step method

- Estimate the phase error (displacement field) and warp the first guess.



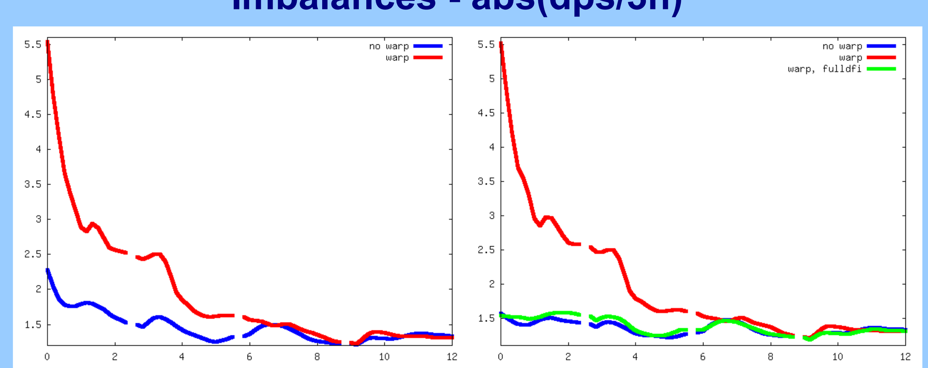
- Minimize the additive error using standard VAR-method.



H(fc(00+12)) Estimated T SEVIRI

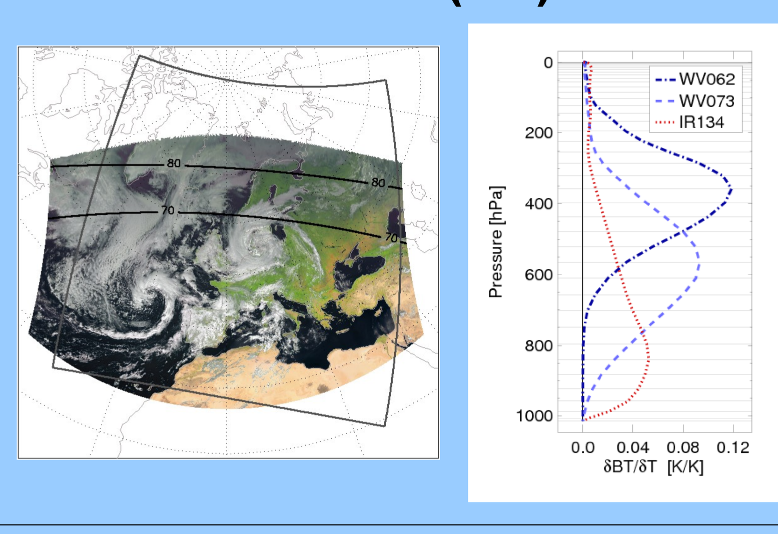
- Promising positive impact for synthetic imager data
- Same displacement for all parameters OK assumption
- Same displacement for all vertical levels not so good
- Warping effect survives the full digital filter
- Tests with real SEVIRI data result in realistic displacement fields

Imbalances - abs(dps/3h)



no digtal filter with digital filter

real SEVIRI data (WV)



References

Gustafsson, N., et al., 2010:Use of a non linear pseudo-relative humidity variable in a multivariate formulation of moisture analysis. Q. J. R. Meteorol. Soc. 137: 1004-1018 , DOI: 10.1002/qj.813

Lindskog, M., et al, 2007: Background error variances in HIRLAM Variational data assimilation. Proceedings of ECMWF Workshop on flow-dependent aspects of data assimilation, 11-13 June 2007

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