SMHI

Correcting phase errors using optical flow and image warping

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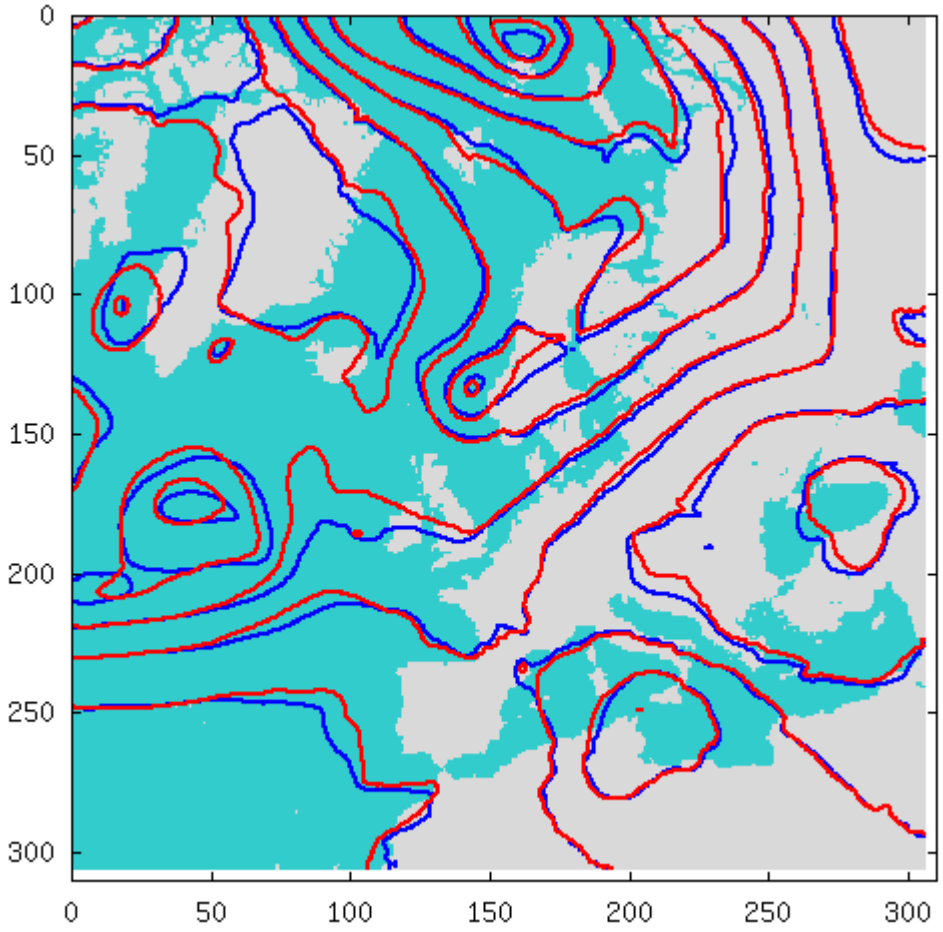
Phase / alignment / displacement errors



Problem: non-Gaussian error

A mixed alignment (phase) and additive error model

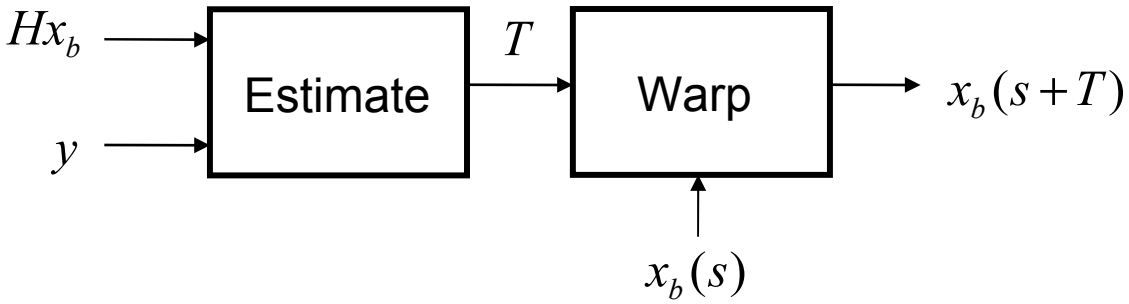
$$x_t(s) = x_b(s + \varepsilon_p(s)) + \varepsilon_a(s)$$

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

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

Solution - two step method

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



- Minimize the additive error using standard VAR-method.

Been there, done that

Hoffman 1995

Very simple model for the displacement field.

Alexander et al. 1998

Manually select corresponding features in fg and ob fields.

Brewster 2003

Similar. Less flexible estimation method. Full scale problem.

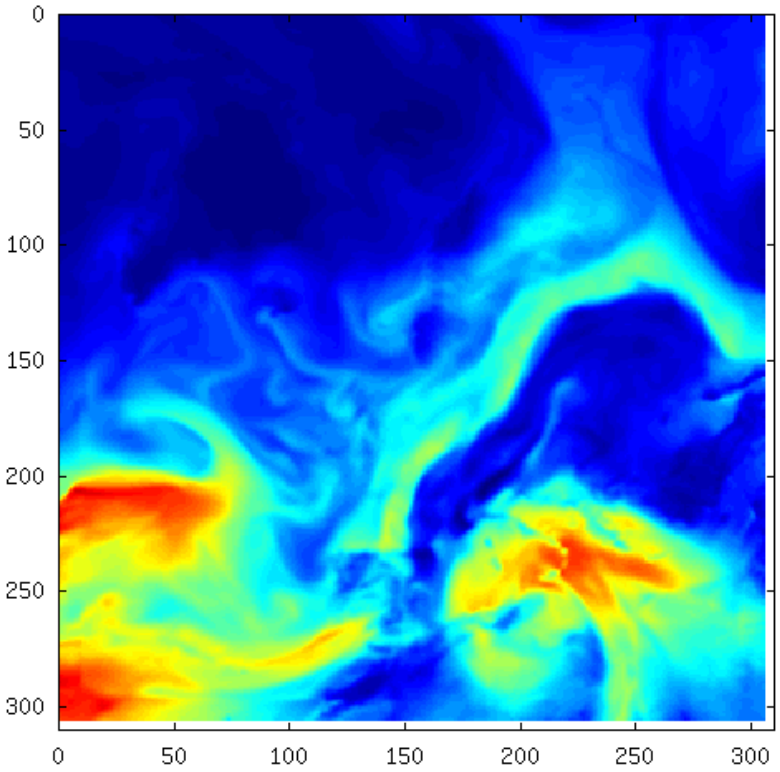
Ravela et al. 2007

Similar. Different estimation method. Toy problem.

Geijo 2011

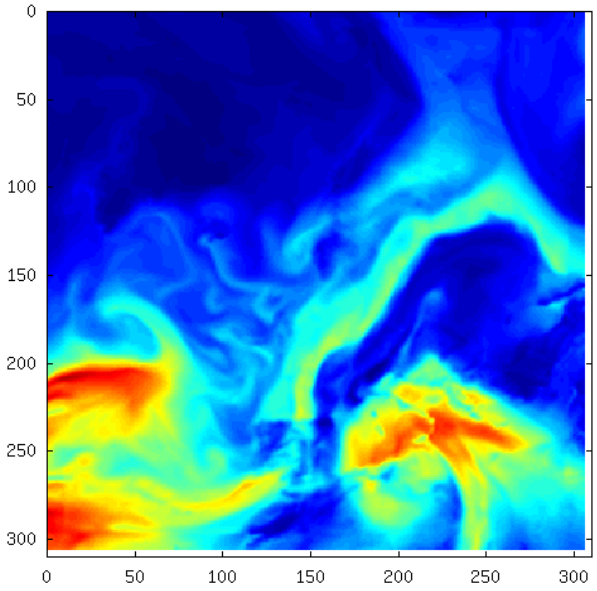
Let’s see after the next talk!

Example 1: Simulated imager data

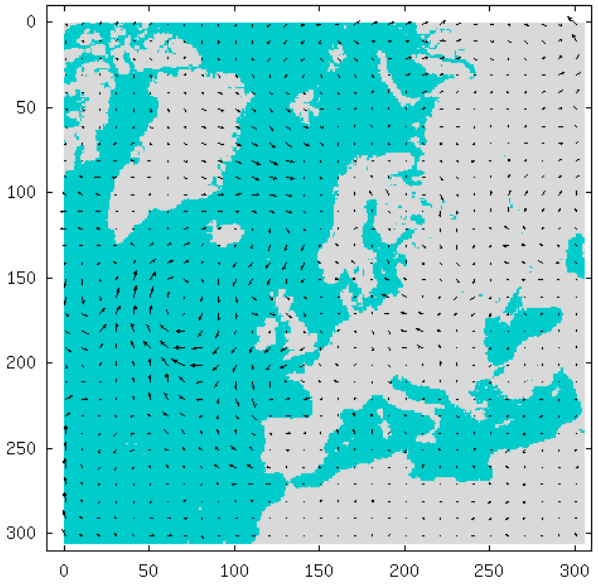


HIRLAM analysis of precipitable water as imager observations.

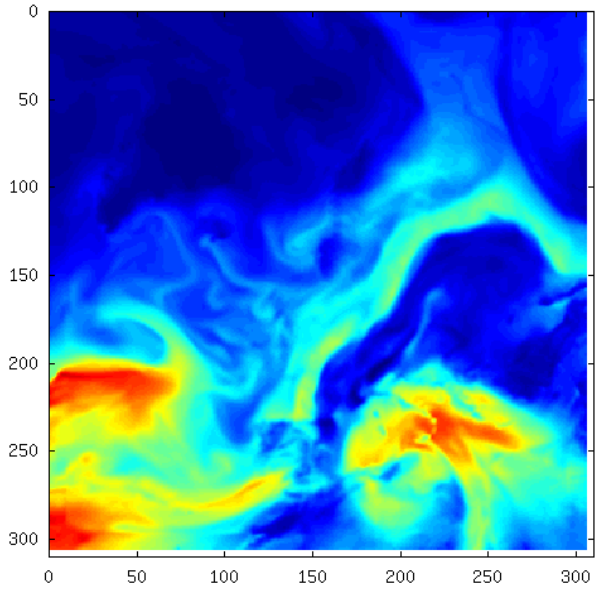
Estimate the displacement field



$fg(x, y)$



$T_x(x, y), T_y(x, y)$

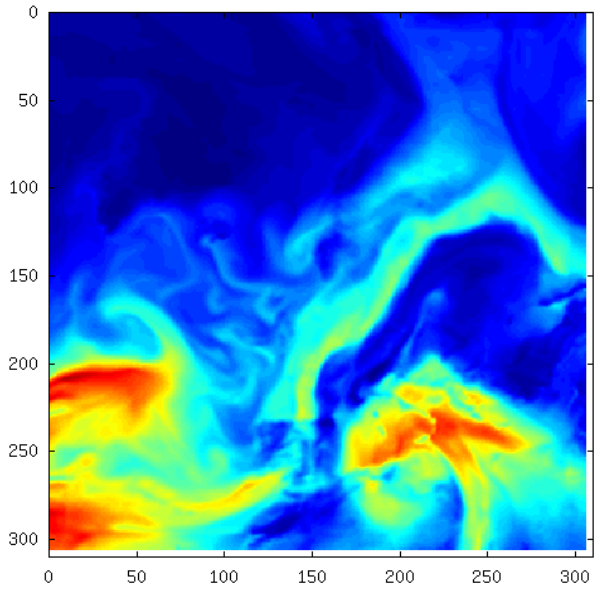


$ob(x, y) \approx fg(x + T_x(x, y), y + T_y(x, y))$

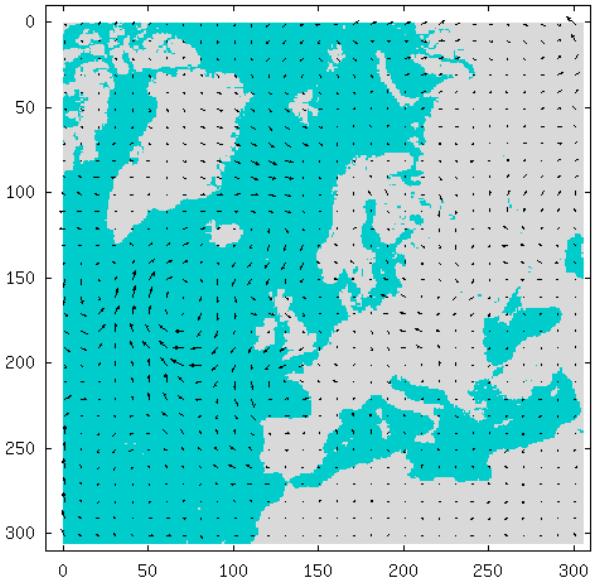
Estimate T from fg (+12h fc) and ob fields using your favourite method.

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

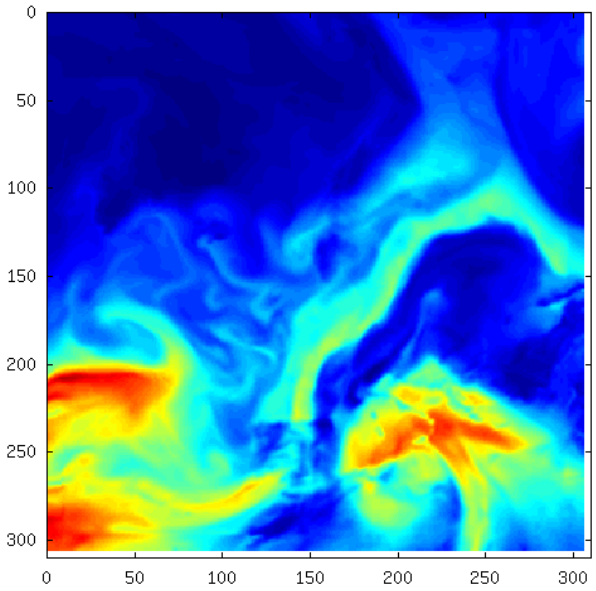
Warp the first guess



$fg(x, y)$

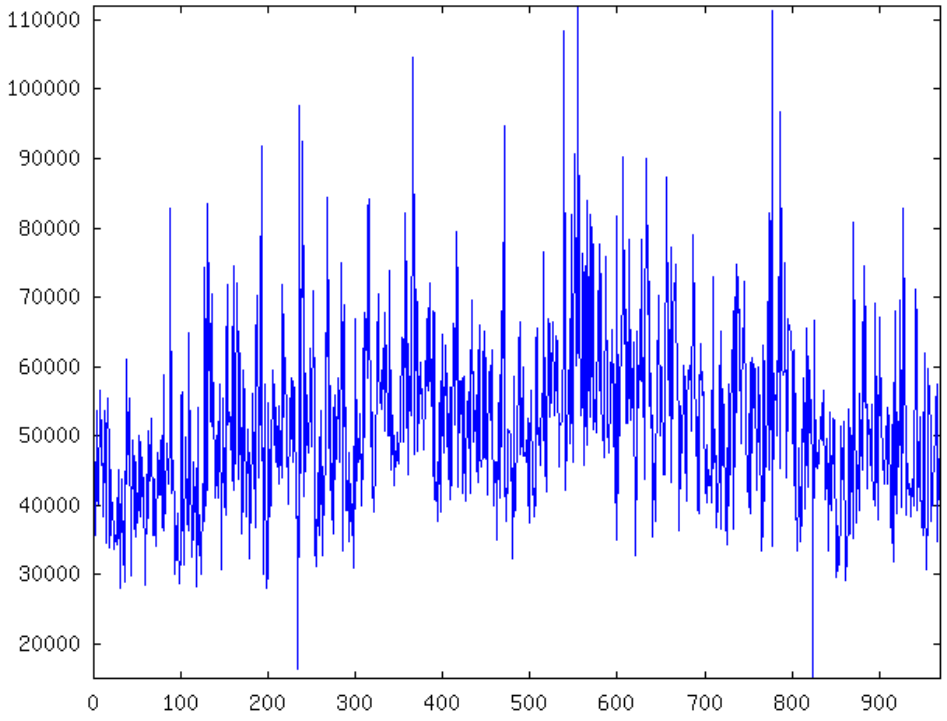


$T_x(x, y), T_y(x, y)$



$fg(x + T_x(x, y), y + T_y(x, y))$

Find 10 cases with large displacements

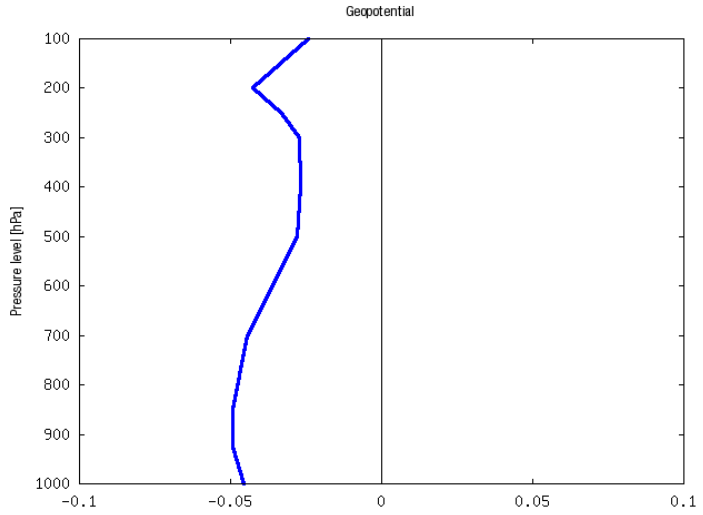


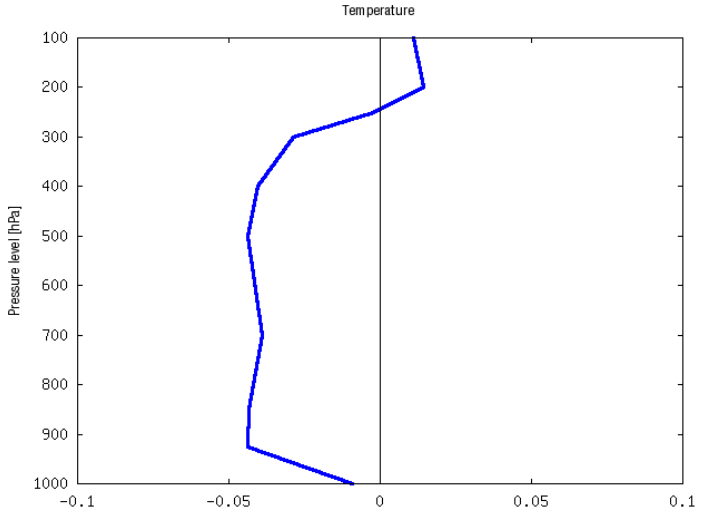
Scan through T for all +12 forecasts during 20080901 – 20090430.

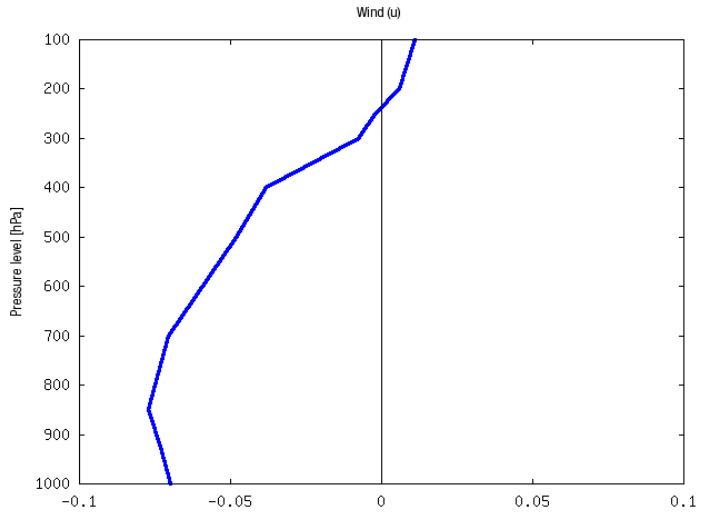
Impact study (10 cases)

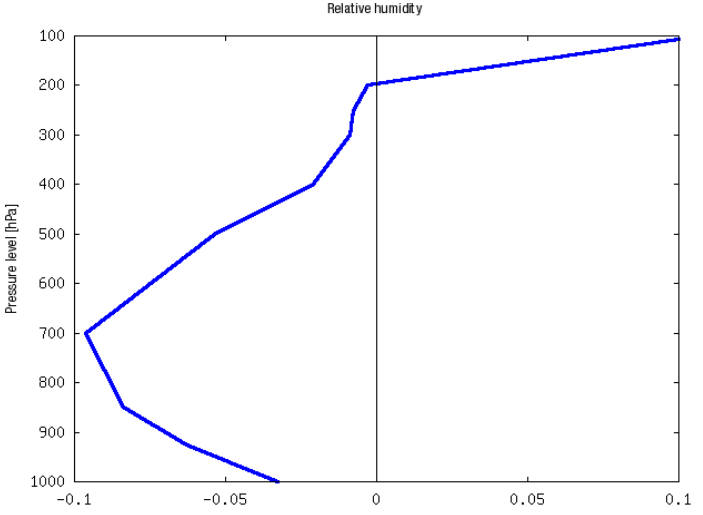
- Run +06 and +12 forecasts from non-warped and warped fg.
- Apply same warping to all parameters, except surface pressure.
- Apply same warping to all vertical levels.

Relative change in rmse (an @ +06 & +12)

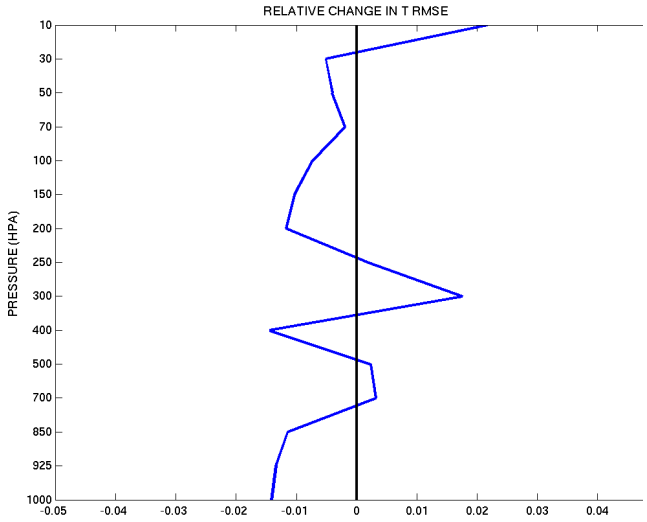




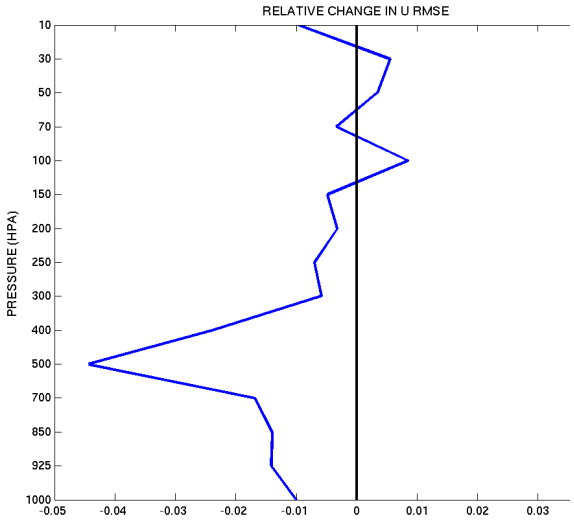




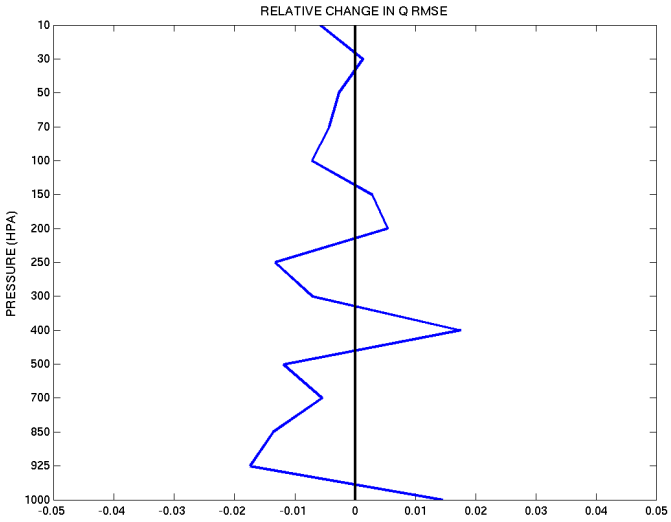
Relative change in rmse (obs @ +06)



T (TEMP)

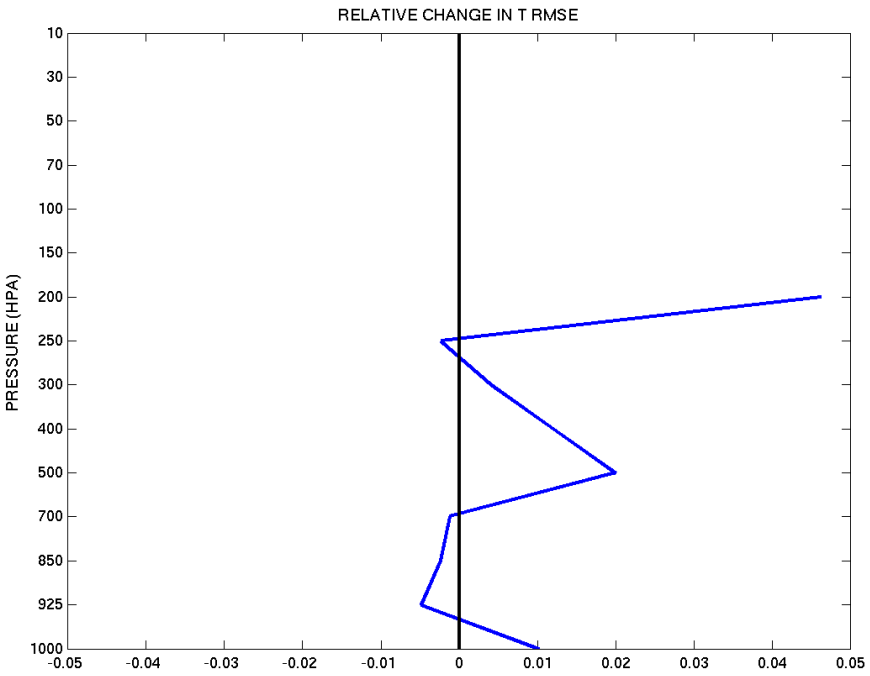


u (TEMP)

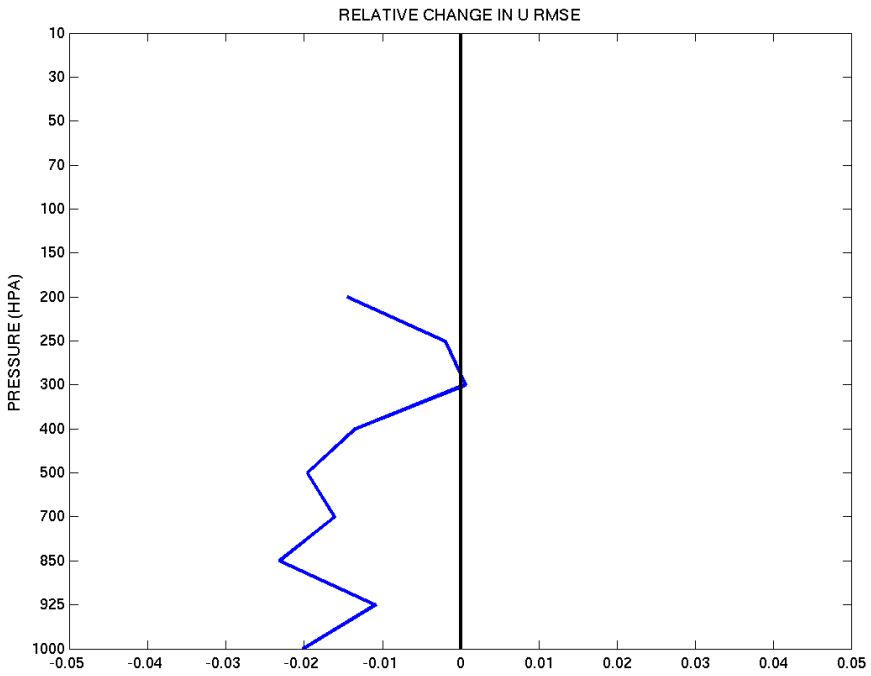


q (TEMP)

Relative change in rmse (obs @ +06)

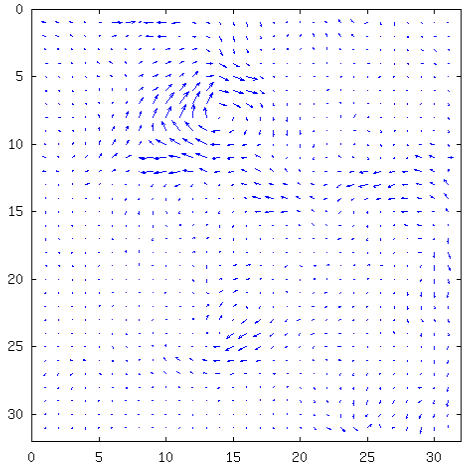


T (airrep)

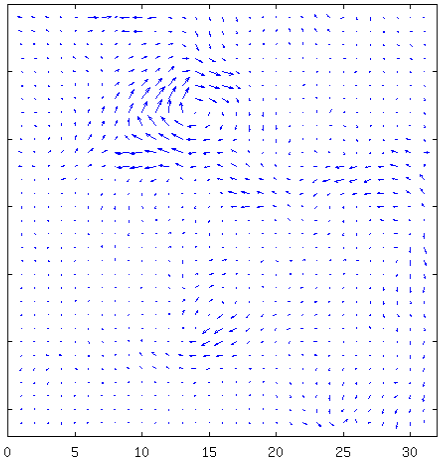


u (airrep)

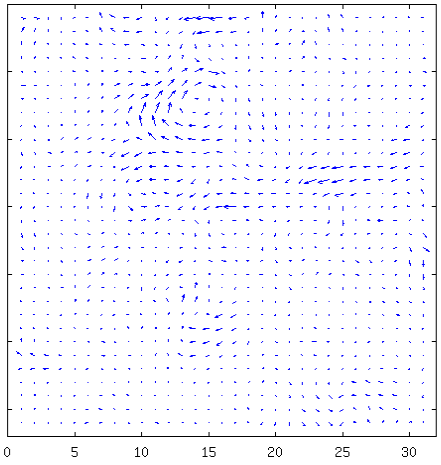
Correlation between displacement fields for wv and other parameters (lev 33)



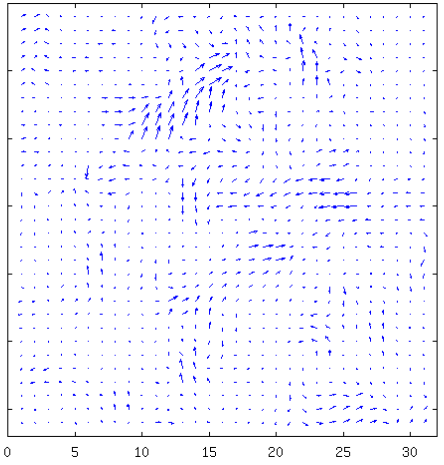
q, ρ=0.75



T, ρ=0.66

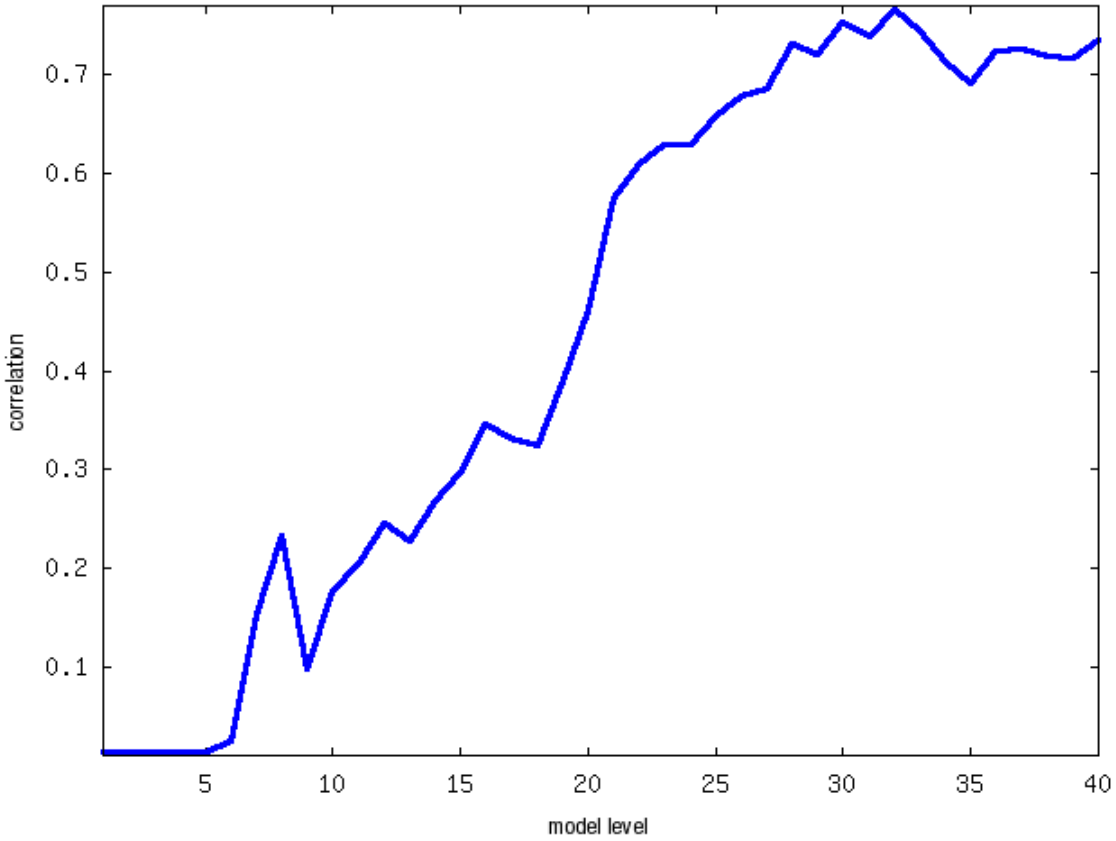


u, ρ=0.66

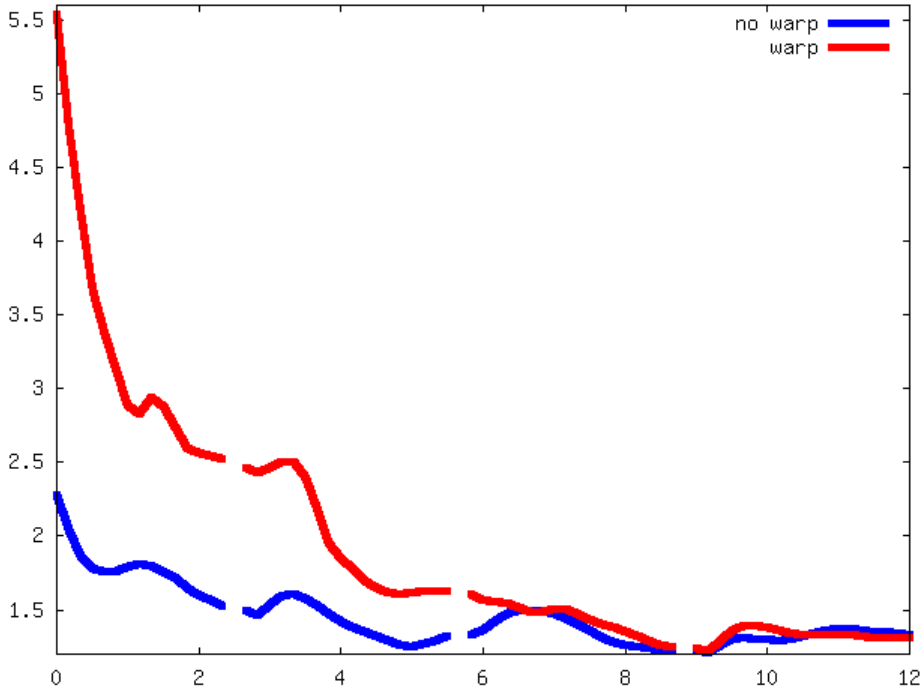


ps, ρ=0.39

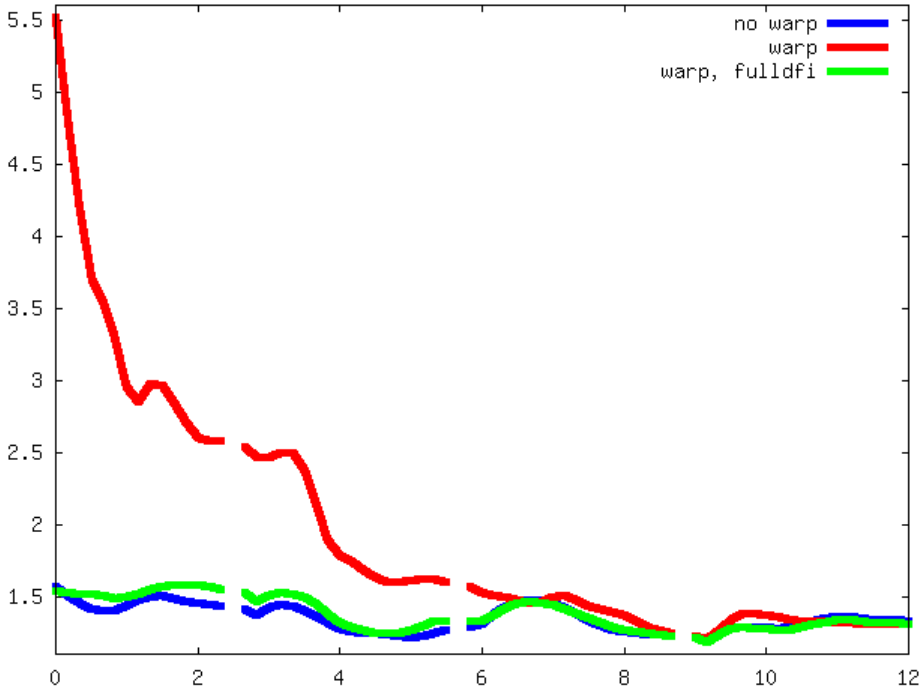
Correlation btw pw and q warp fields



Imbalances - abs(dps/3h)

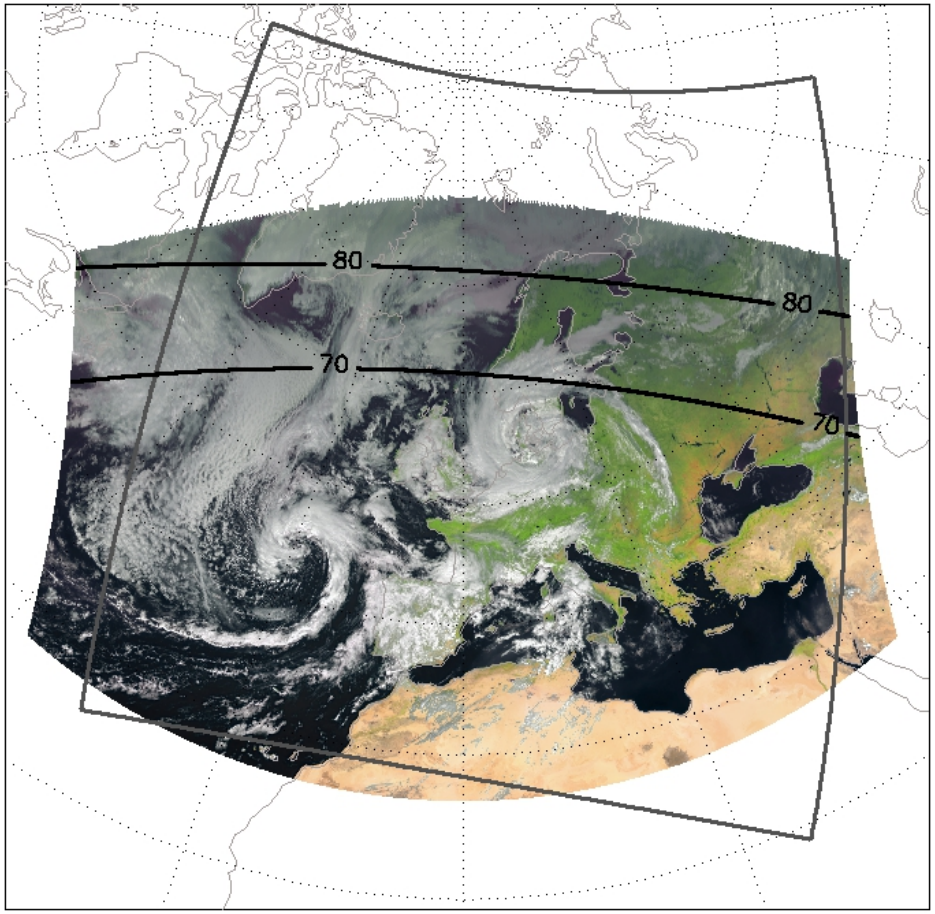


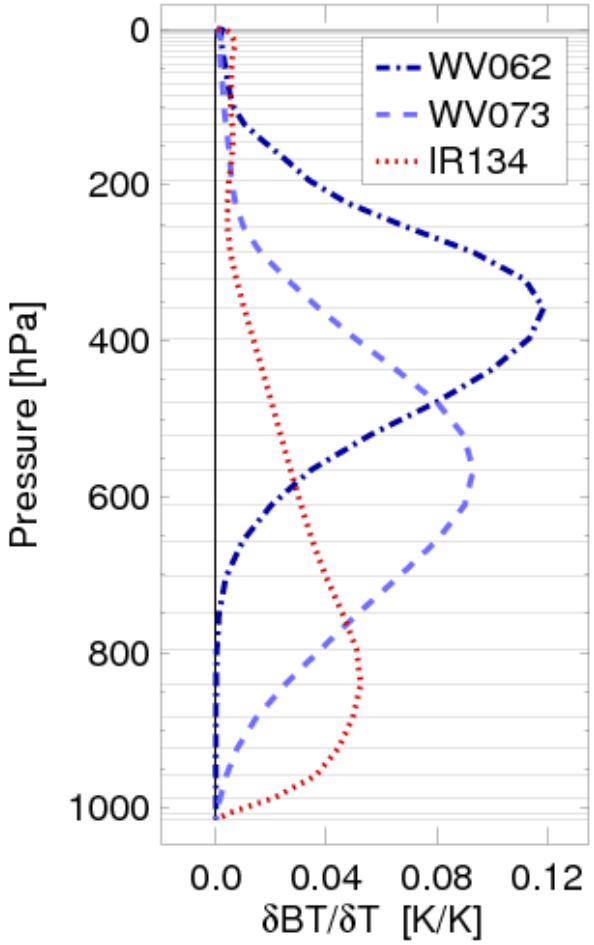
no digtal filter



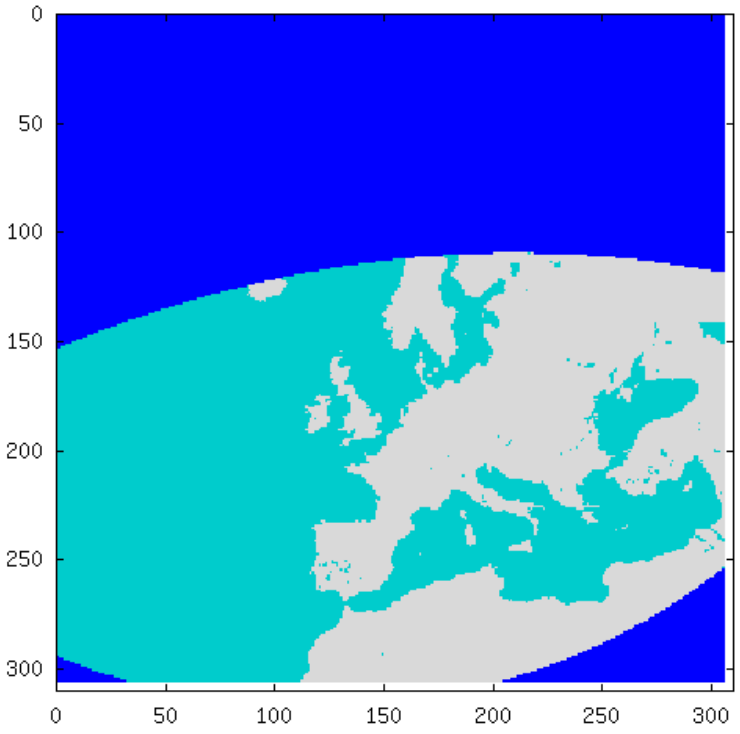
with digital filter

Example 2: real SEVIRI data (WV)

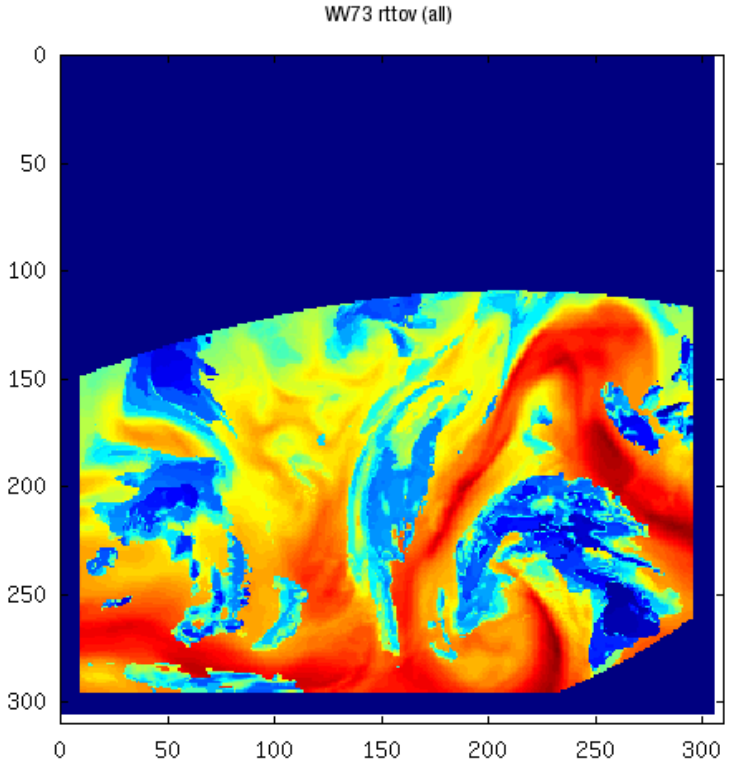




RTTOV

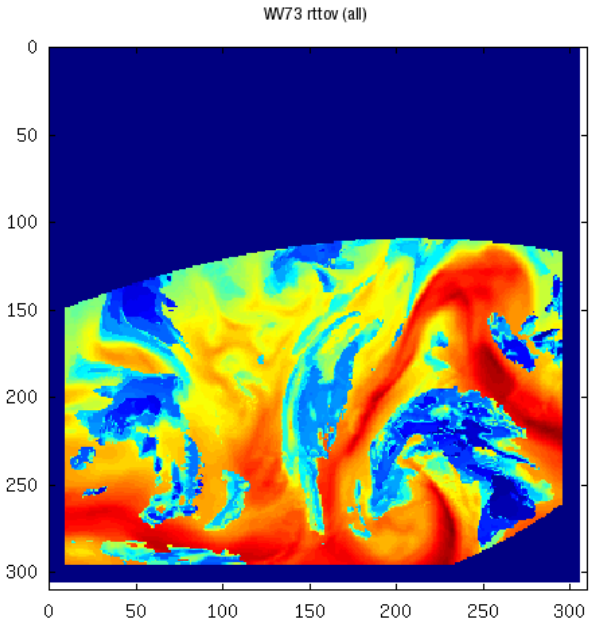


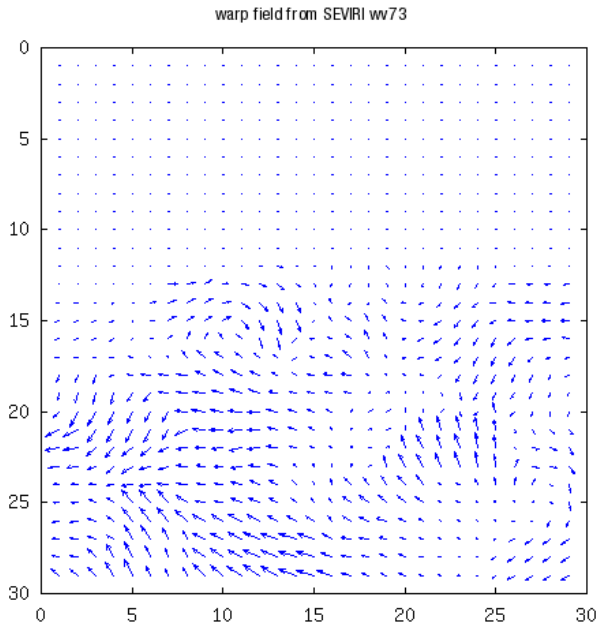
satzen limit at 75 deg

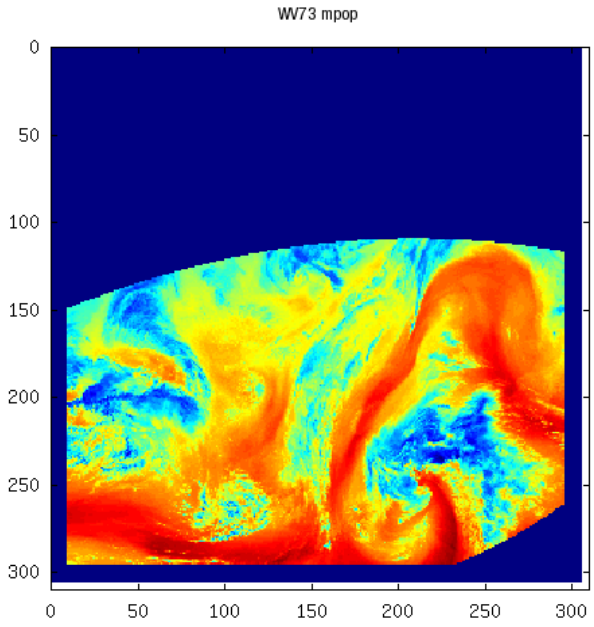


simple clouds (ctp, cfr)

SEVIRI WV073 @ 20090113:12





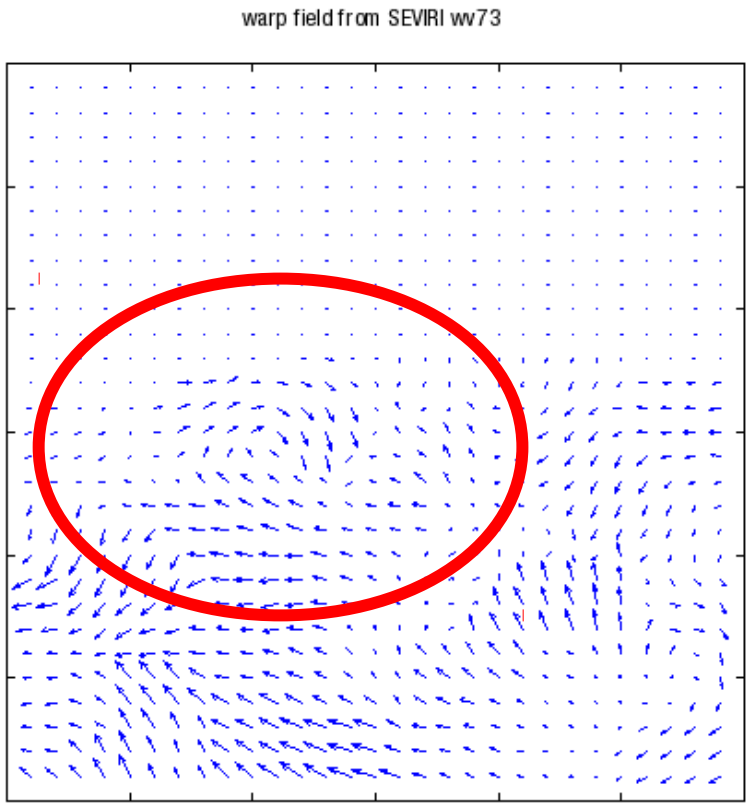


H(fc(00+12))

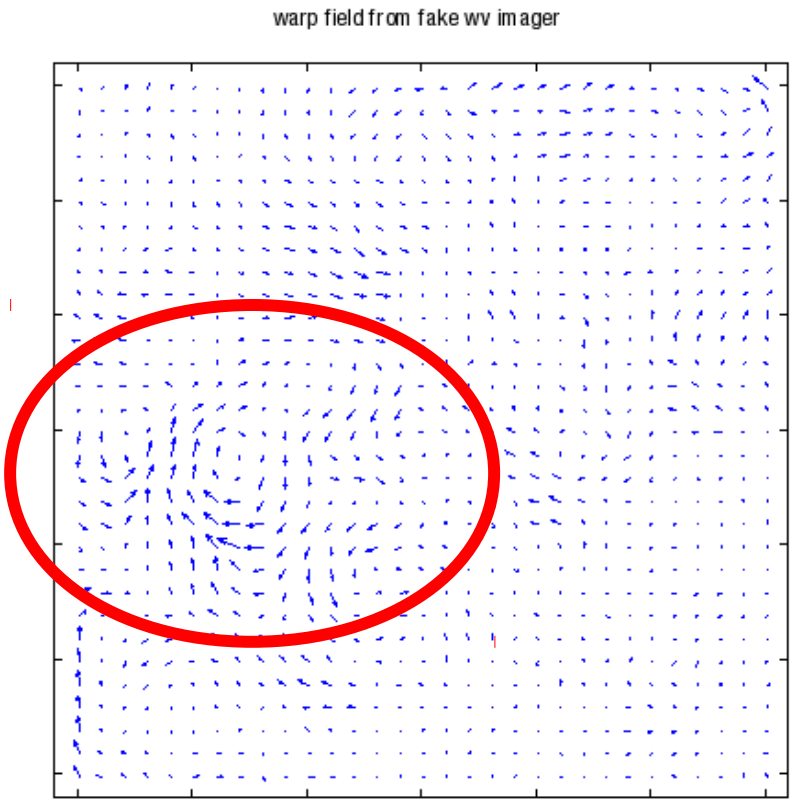
Estimated T

SEVIRI

Warp estimated from WV73 and an WV



T from SEVIRI



T from fake wv imager

Conclusions

- 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

Future

- Impact experiments with real SEVIRI data
- Develop the warp method (balances, vertical variation, mslp, ...)
- Test to impose balance by using warped field as pseudo observations
- Test with sounder data like AMSU
- Warp experiments with the hybrid ETKF system: