The 5th ISDA, Reading, UoR,

18-22 July 2016

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Cloud Cover Reanalysis Application

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UERRA
Uncertainties in Ensembles of Regional ReAnalyses

Swedish Meteorological and Hydrological Institute

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European cloud cover reanalysis using best available data at any given time, 1982 - 2013

Horizontal resolution:
– 5.5 km MESAN EURO4M

Time resolution:
– Hourly for the period 1982– 2013.

Observations:
– CMSAF polar orbit AVHRR cloud mask 1982 – 2009.
– CMSAF geostationary SEVIRI cloud mask 2004 – 2012.
– CMSAF new polar orbit & geostationary CM SAF cloud cover probability product for MFG (1983-2005) and MSG (2004-2013)
(in production MeteoSwiss)

First guess (alternatives):
– EURO4M 22 km HIRLAM 3DVar, 1982 – 2013.
– HIRLAM EURO4M 22 km interpolated to 5.5 km using LSM

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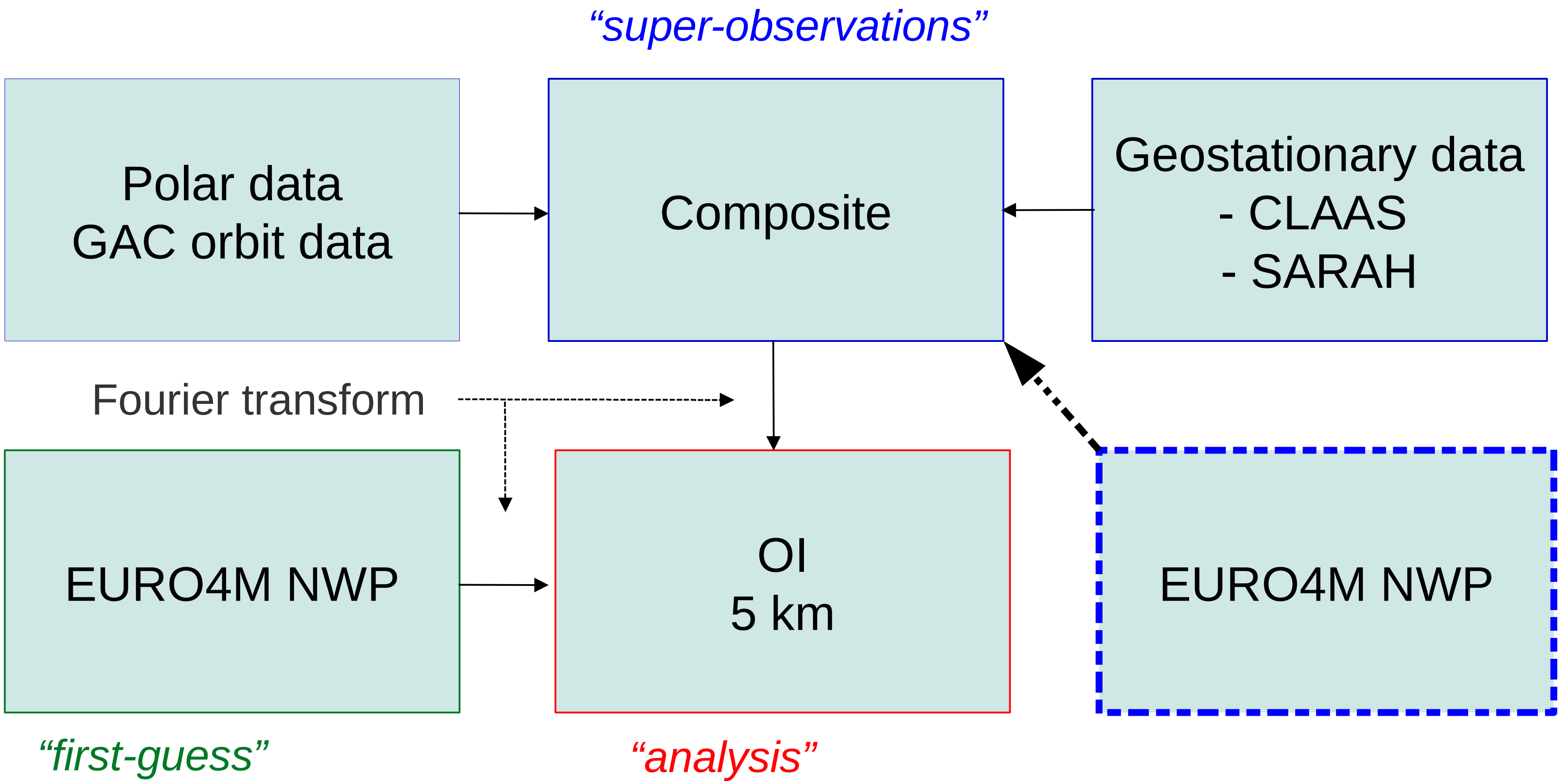
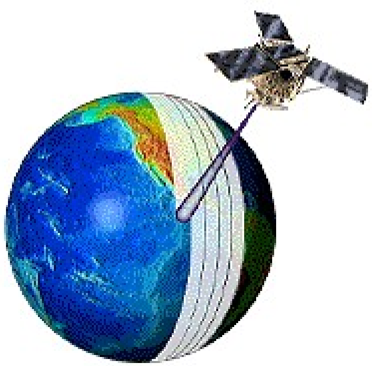
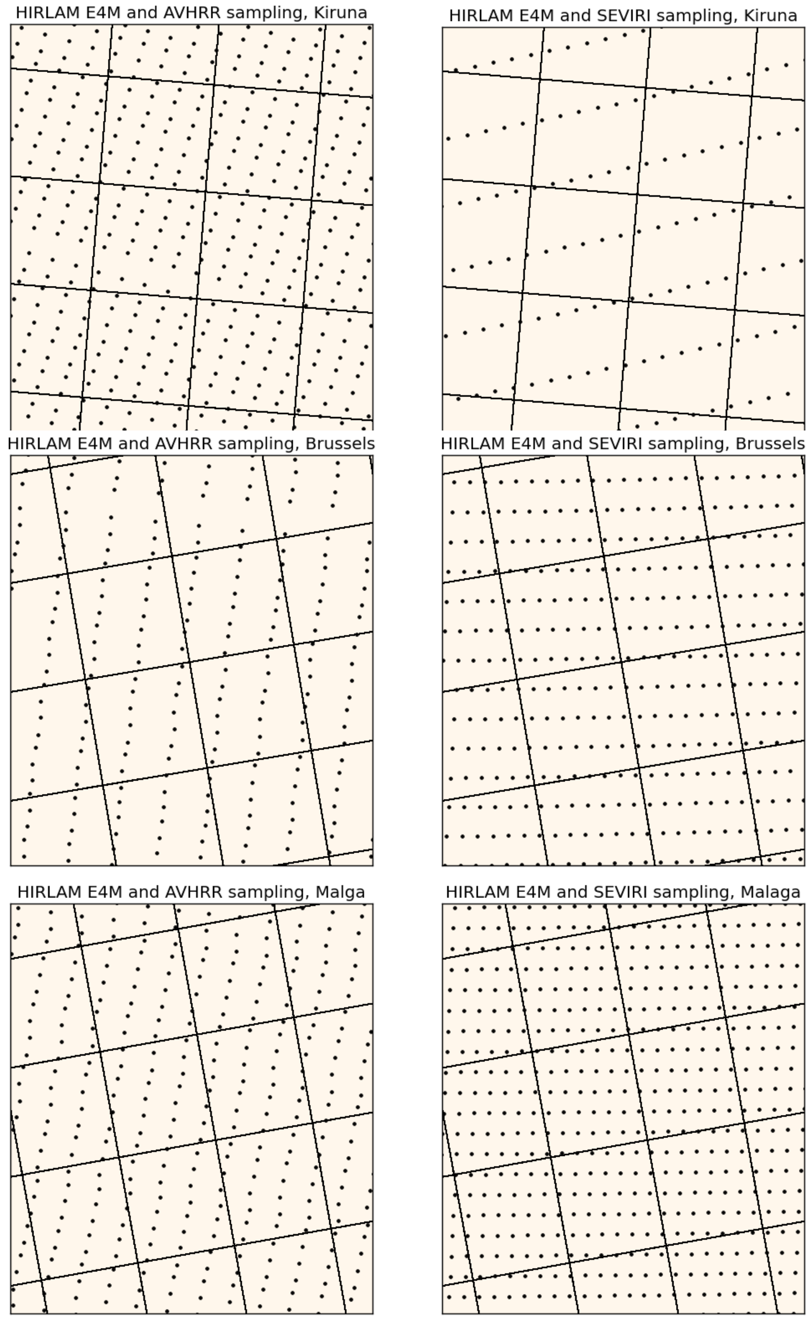
Processing chain



Data resolution

North





Polar -orbiting

South

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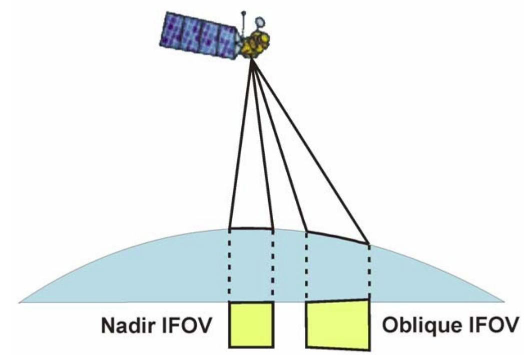

Geostationary

“Pilot” study :
OI scheme on
22km resolution

Data coverage around 20060622:10 UTC

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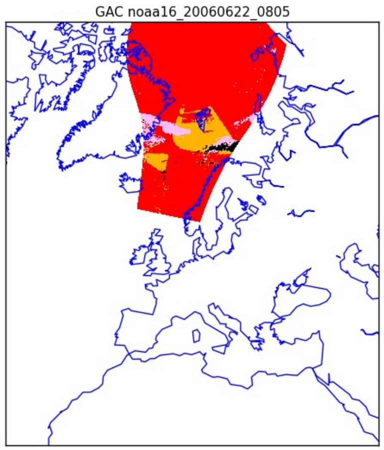
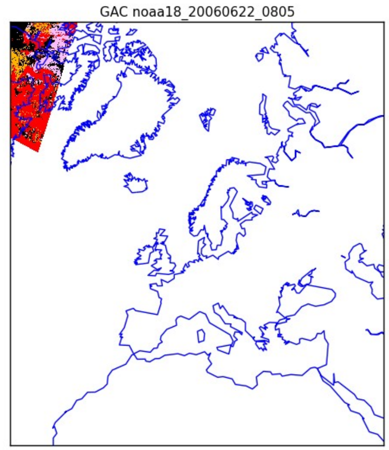
Polar-orbiting GAC

$T-\Delta T \leq T_k \leq T+\Delta T$

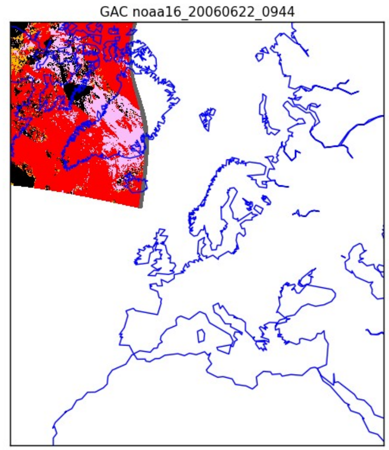
NOAA16 08:05



NOAA18 08:05

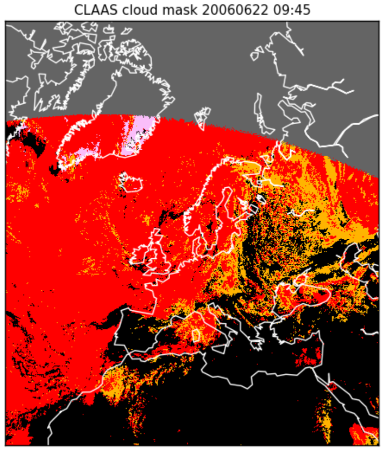


NOAA16 09:44

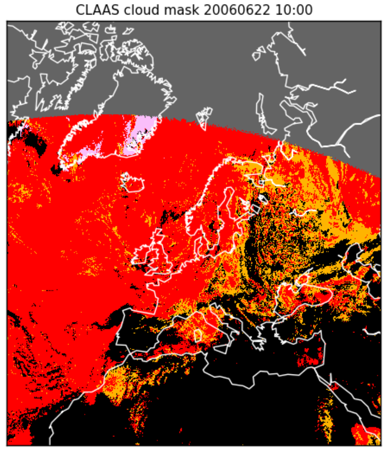


Geostationary CLASS

T_{k-1}, T_k, T_{k+1}



09:45



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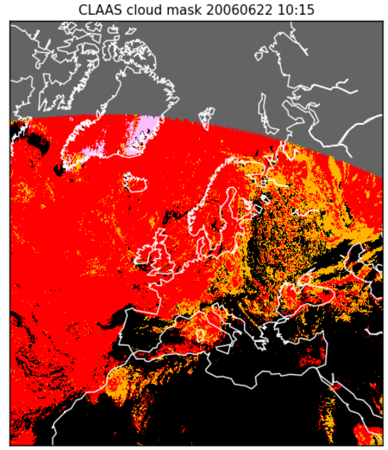

10:15

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Super observations

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Use the quality and scan geometry information available in CMSAF products to calculate weights:

$$w = f\left(quality\ flags, sat\ angles, time\ delta\right)$$

Calculate cloud fractional cover as a weighted fraction of cloudy pixels within a HIRLAM grid box:

$$CFC = \frac{\sum w_i\ CM_i}{\sum w_i}$$

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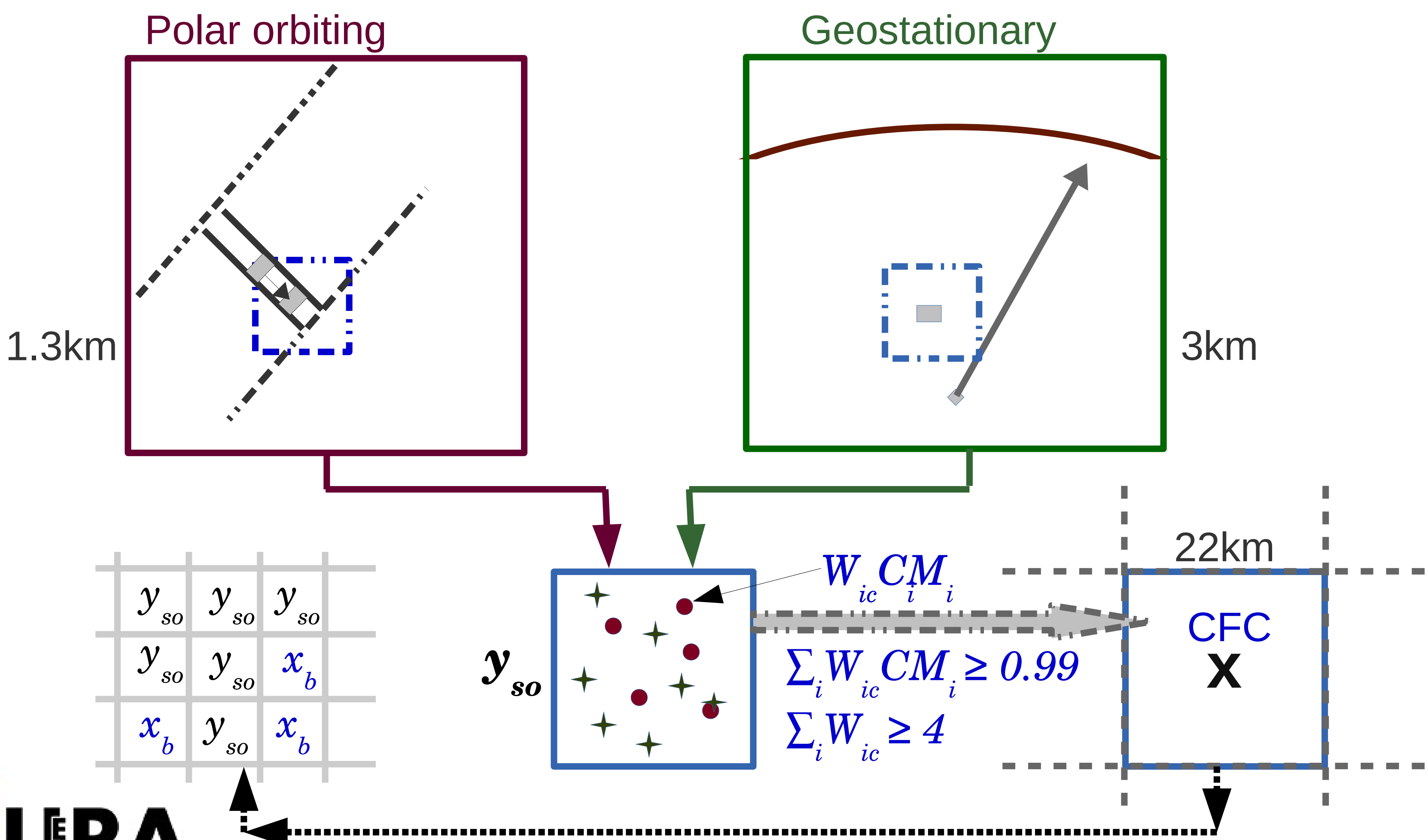
Super observations, continued ...

W_{ic}(*timeliness, view angle, cumulative quality flag*)



HIRLAM EURO4M Cloud Fraction is used as “gap-filler” in grids where no CM observations available

Optimal Interpolation

$$x_a = x_b + K\left(y - H\left(x_b\right)\right)$$
$$K = BH^T\left(HBH^T + R\right)^{-1}$$

B matrix

– Diagonal in Fourier space, i.e. homogeneous
– HIRLAM NMC statistics (fc differences) as the "first-guess" for σ_B and L_B

R matrix (spatially correlated errors)

– Diagonal in Fourier space, i.e. homogeneous
– The "first-guess" : $\sigma_R = 0.1^*\sigma_B$ and $L_R = 0.5\ L_B$

Re-estimate statistics based on Desroziers diagnostics from the "pilot" run

H operator : identity matrix
– extract Cloud Fraction from HIRLAM EURO4M forecasts

Estimation of statistics

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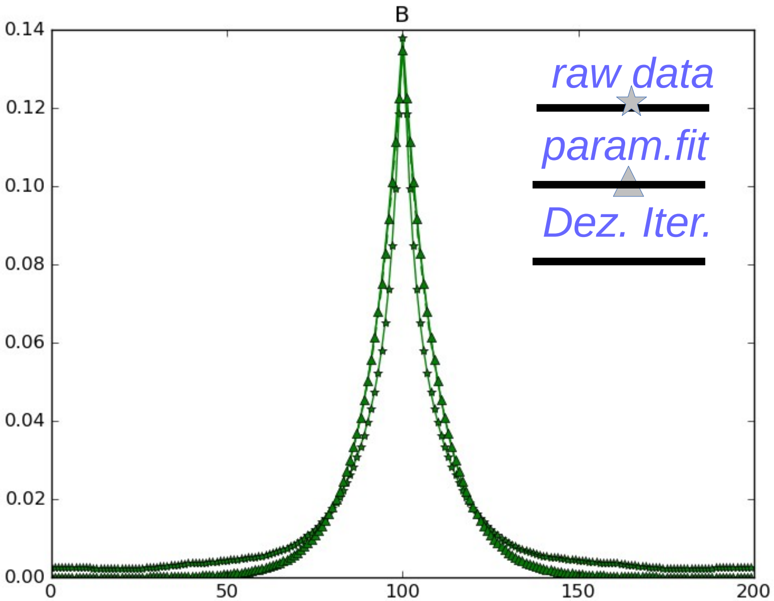
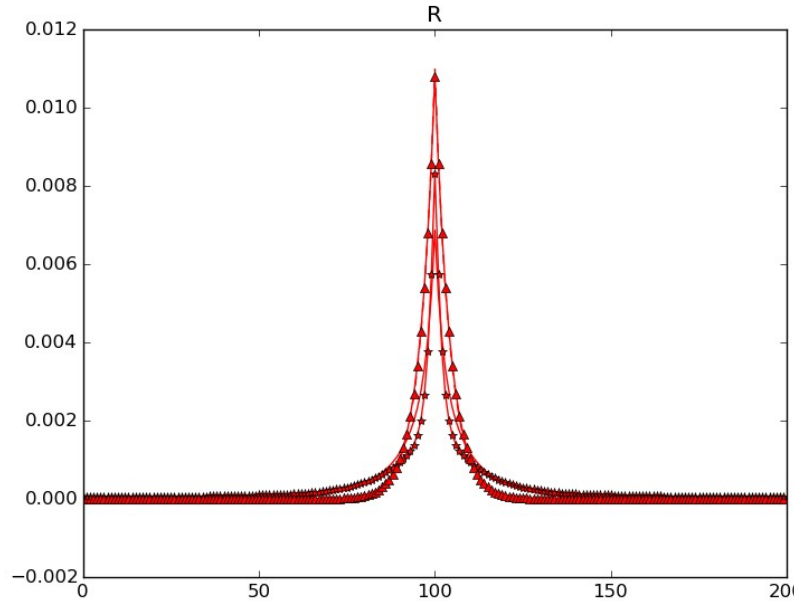
B



R



Desroziers diagnostics

Tends to underestimate R and introduce more energy on larger scales

$$d^y_b = y - H(x_b);\ d^y_a = y - H(x_a)$$

$$D = E(d^y_b d^{y\,T}_b) = (HBH^T + R - H\varepsilon_b\varepsilon_y^{\,T} - \varepsilon_y\varepsilon_b^{\,T}H^T)$$

$$R^* = E(d^y_a d^y_{bT}) =$$

$$R^o(H^TB^oH + R^o)^{-1}(H^TBH + R - H\varepsilon_b\varepsilon_y^{\,T} - \varepsilon_y\varepsilon_b^{\,T}H^T)$$

In the presented results the misfit due to cross-correlations is not addressed

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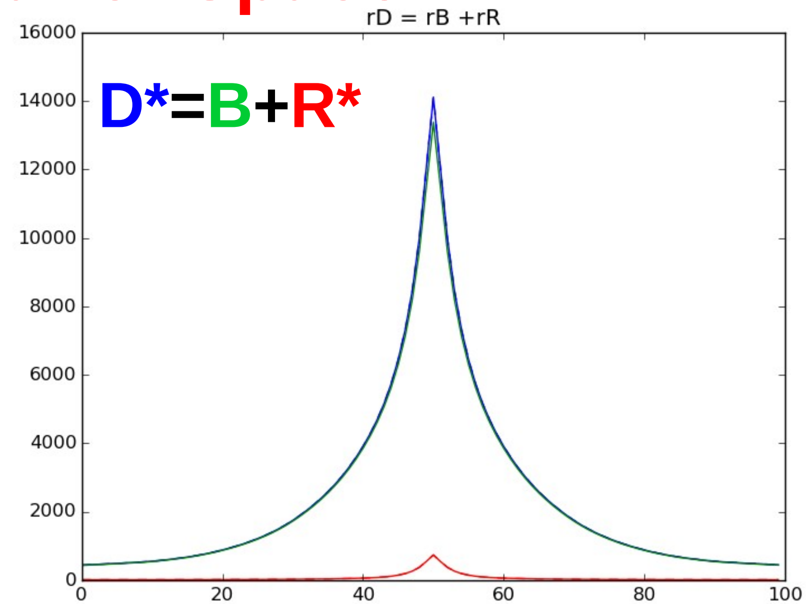
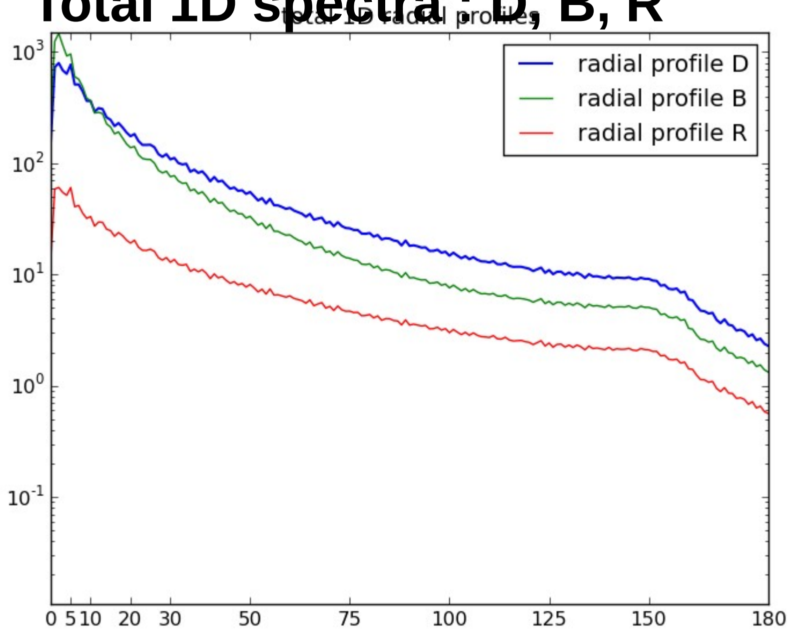
Optimal Interpolation in Fourier Space

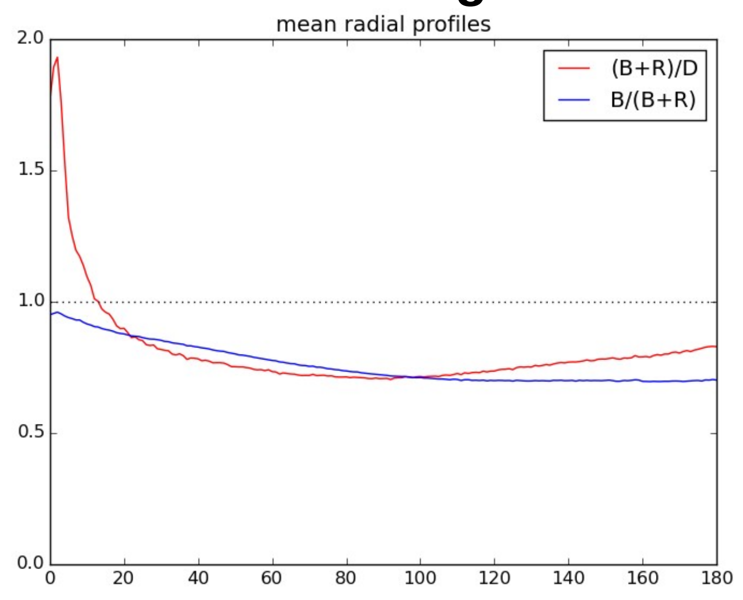
$$K_\nu = B_\nu (B_\nu + R_\nu)^{-1}$$
$$X^a_\nu = X^b_\nu + K_\nu (y_\nu - X^b_\nu)$$



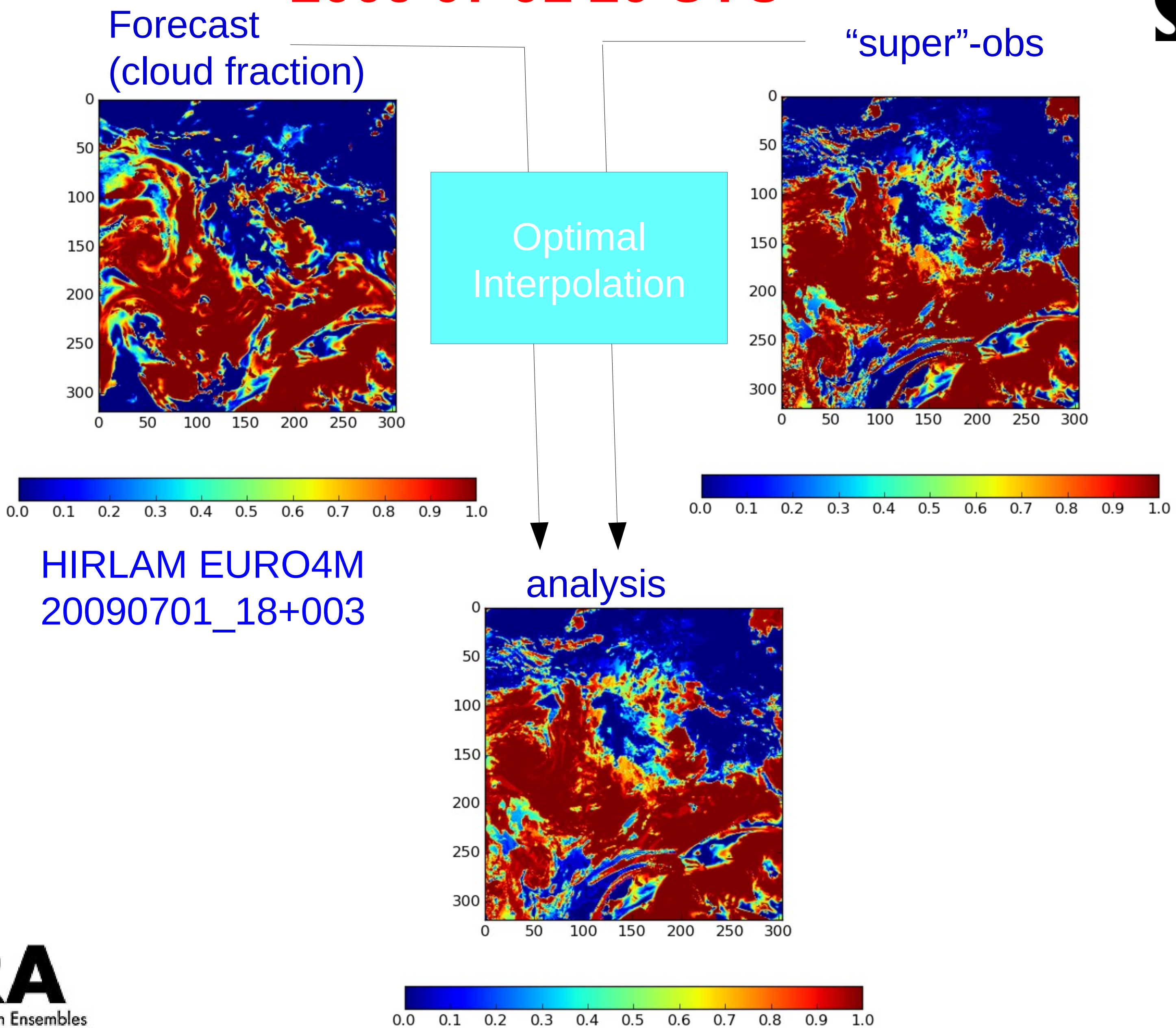
Total 1D spectra : D, B, R



Mean 1D filtering and misfit



2009 07 01 20 UTC



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Comparison with SYNOP obs for 2009

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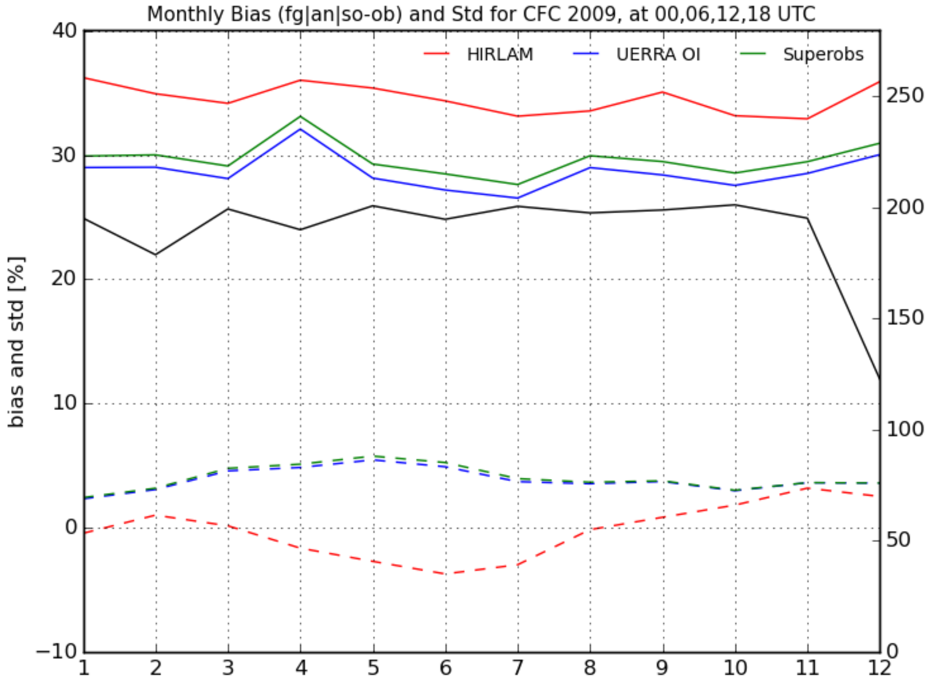
+ Analysis has lower std than both the first-guess and super-observations.

– On average the analysis has too much clouds against SYNOP



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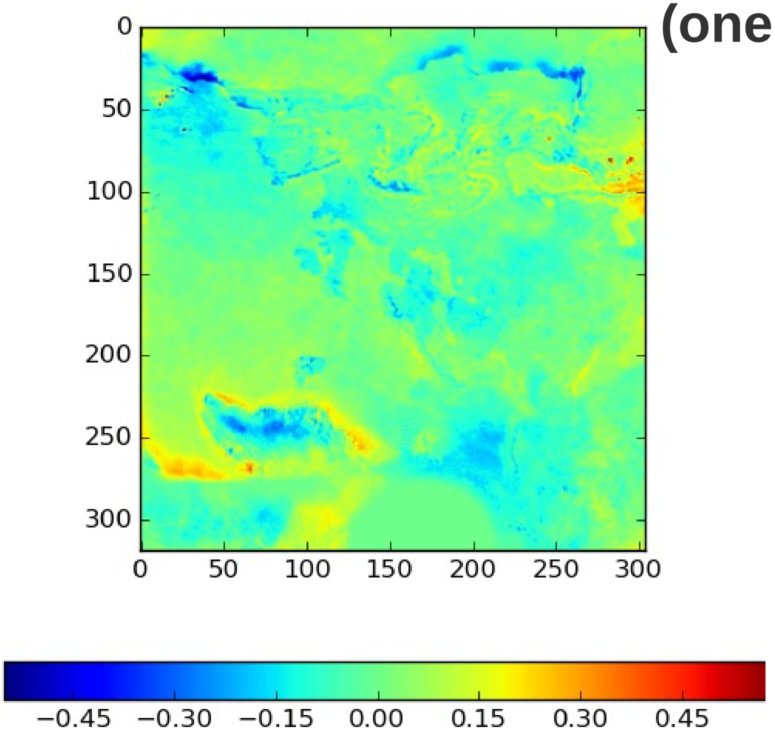
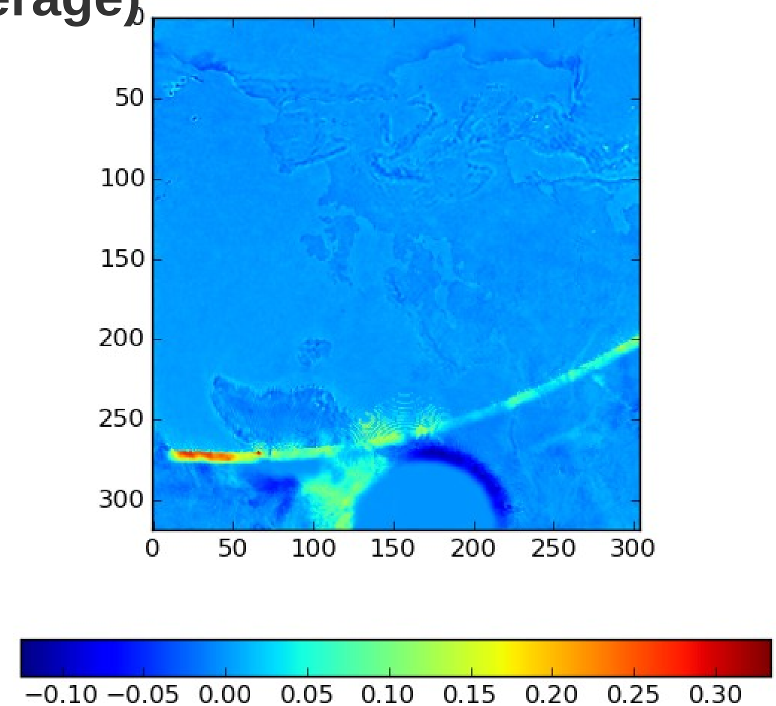
Limitations of the optimal interpolation:

Total cloud cover (03 UTC 2009) (one year average)



"Obs-minus-Forecast"

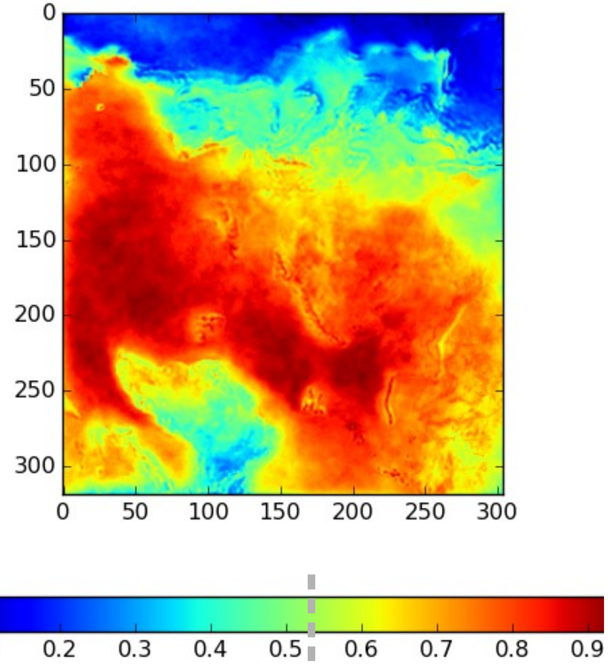


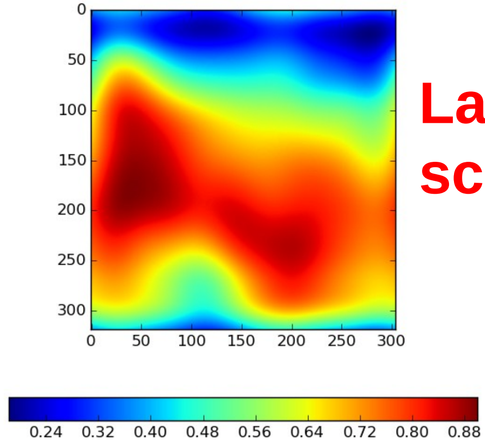
"Obs-minus-Analysis"

Note clear response to orography in the error statistics due to homogeneity assumptions

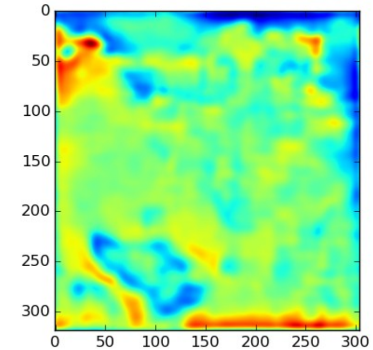
Scale-dependent decomposition

Total cloud cover 03 UTC 2009 (one year average; Background forecast)

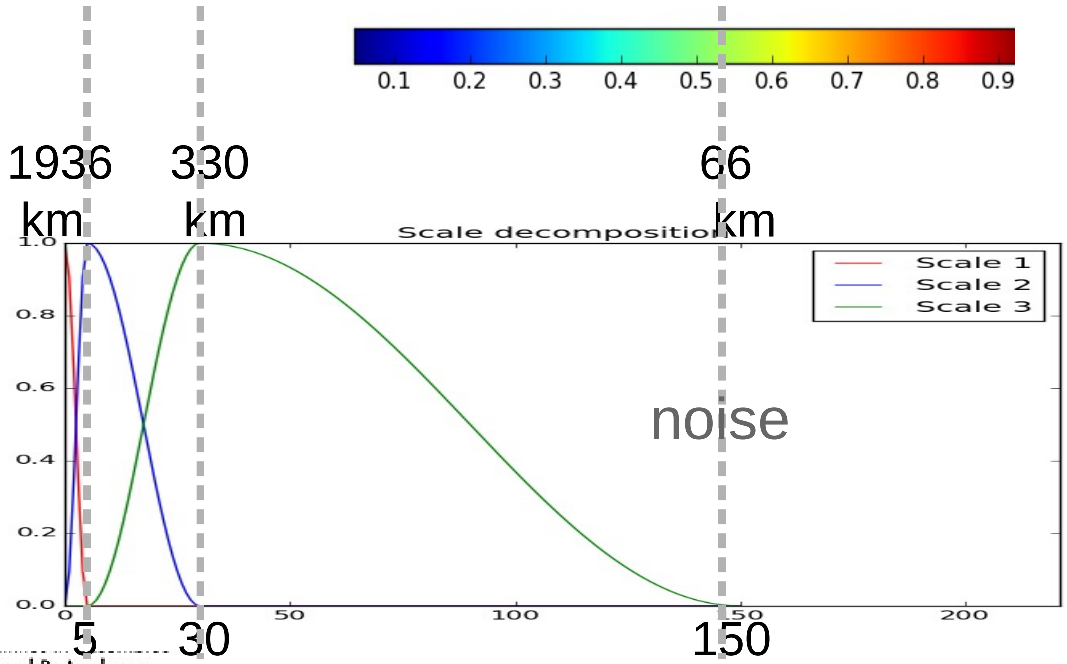


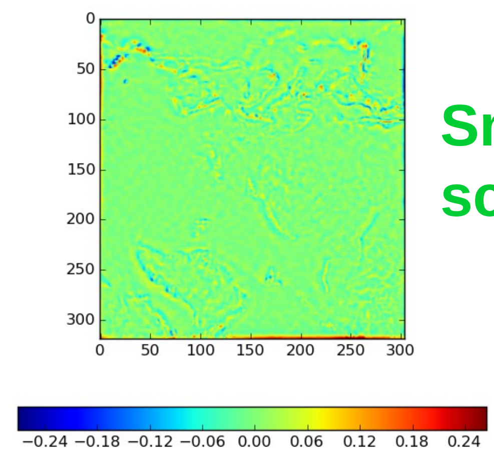


Large scales



Medium scales



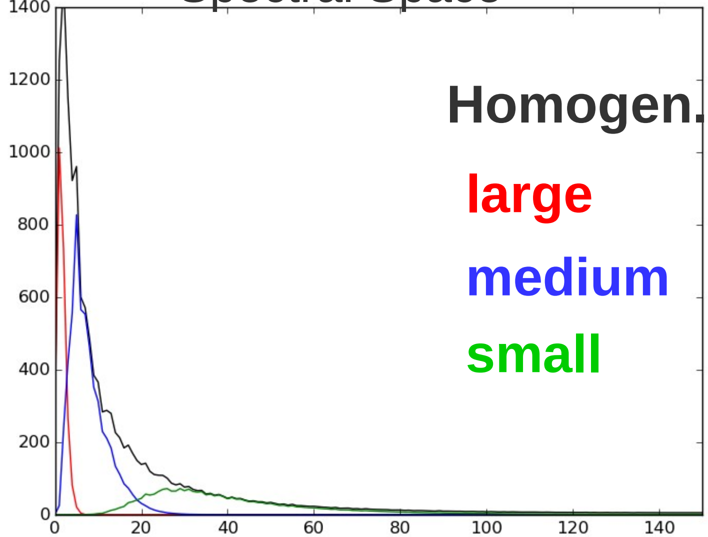


Small scales

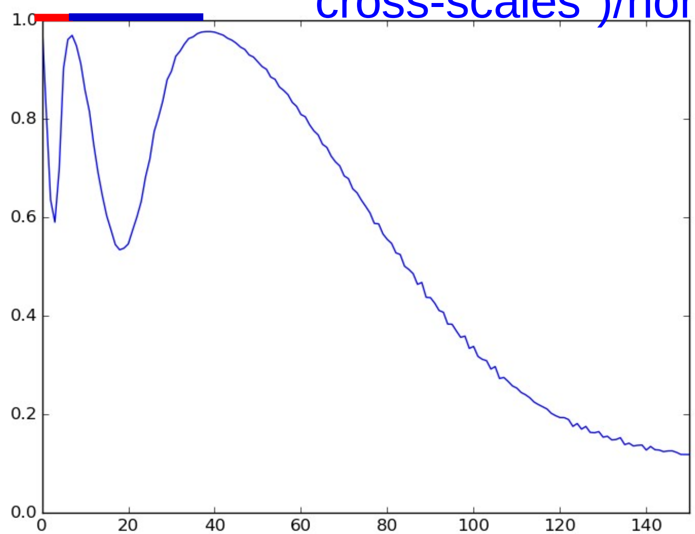
of Regional ReAnalyses

Scale-dependent decomposition

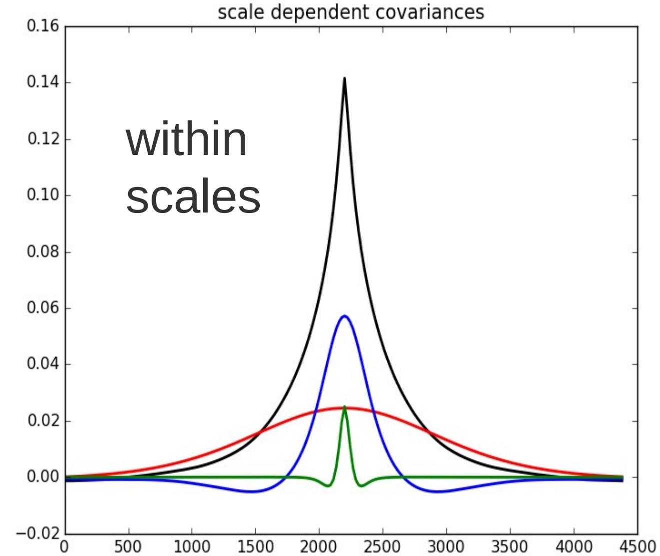
Spectral Space

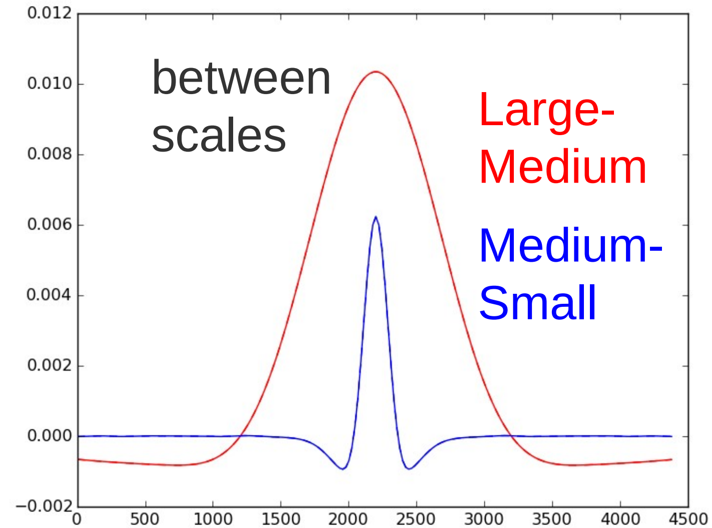


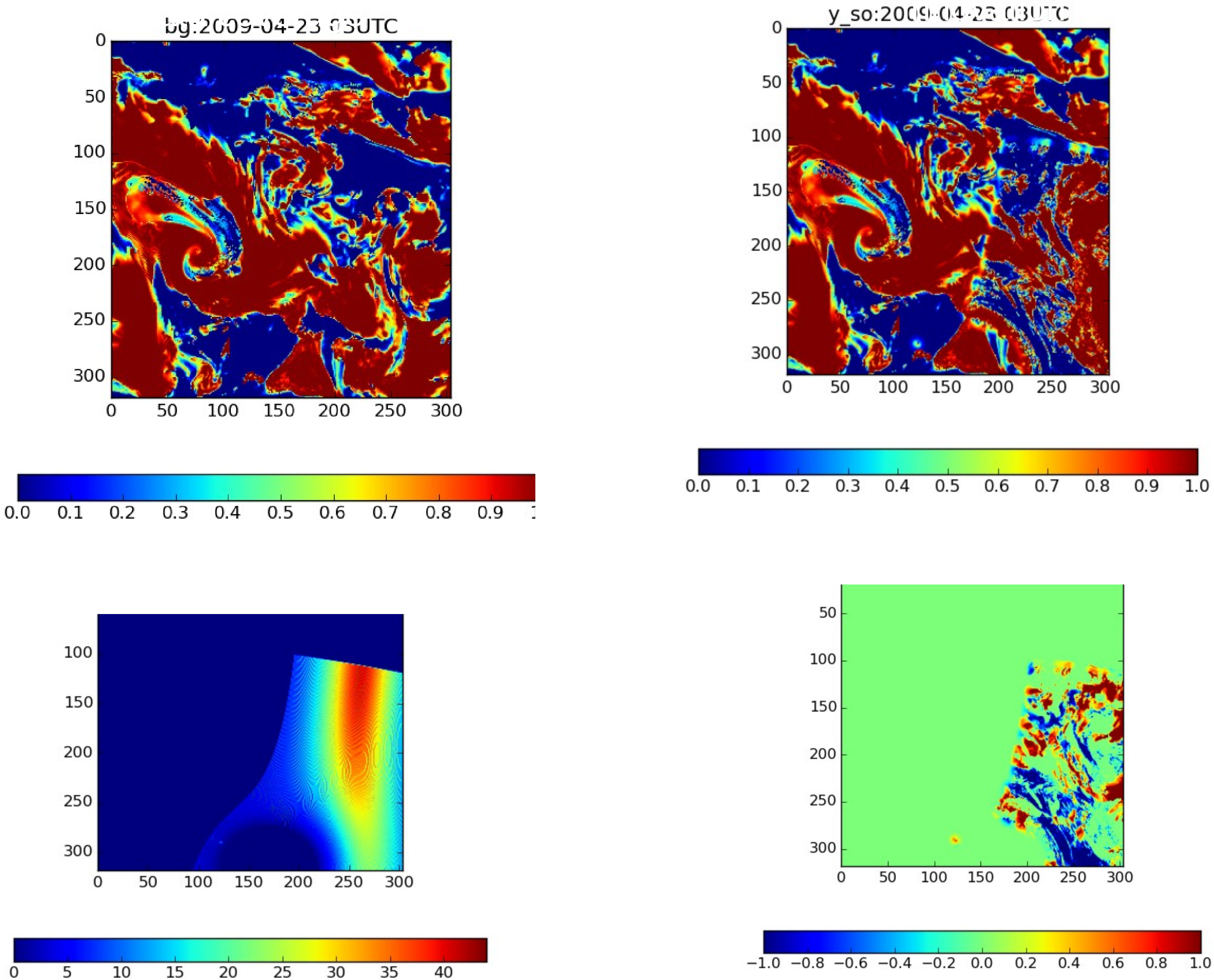
(large+medium+small-
”cross-scales”)/homog.

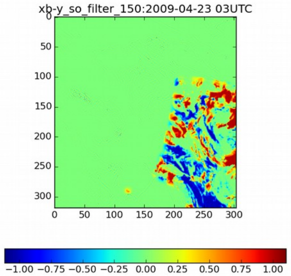


Gridpoint Space






bg:2009-04-23 03UTC
y_so:2009-04-23 03UTC



Scale-dependent analysis increment

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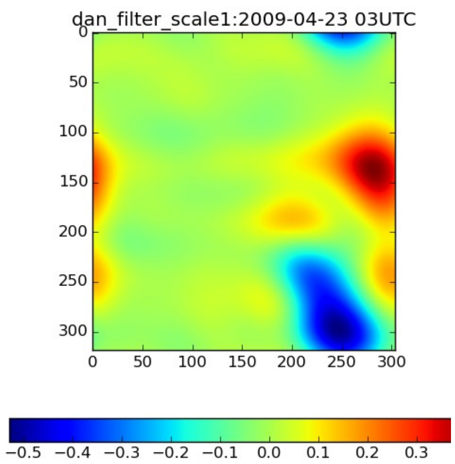
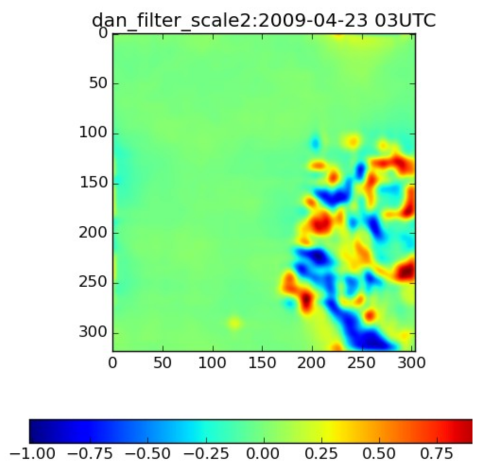
$$dx_a^{ssd} = \Sigma_{1\le j\le J} (B^j)^{1/2}\ \Sigma_{1\le k\le J} \Psi^k\ [B^{1/2}/(B+R)^{1/2}]dy/D^{1/2}$$

Large



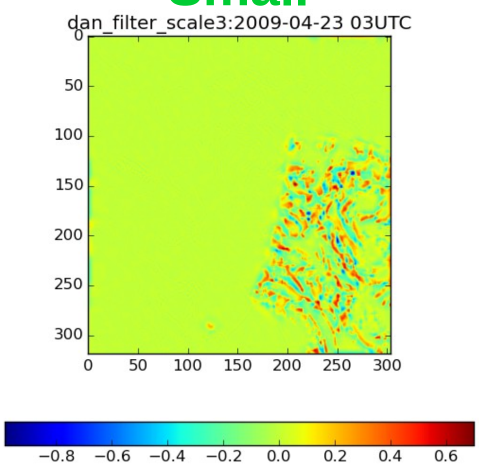
+

Medium



+

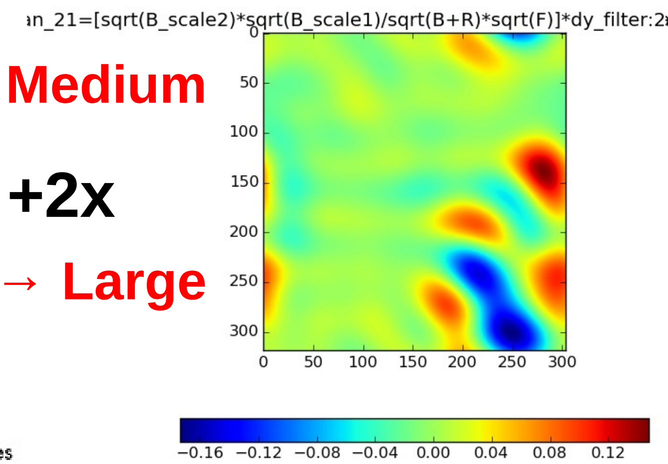
Small



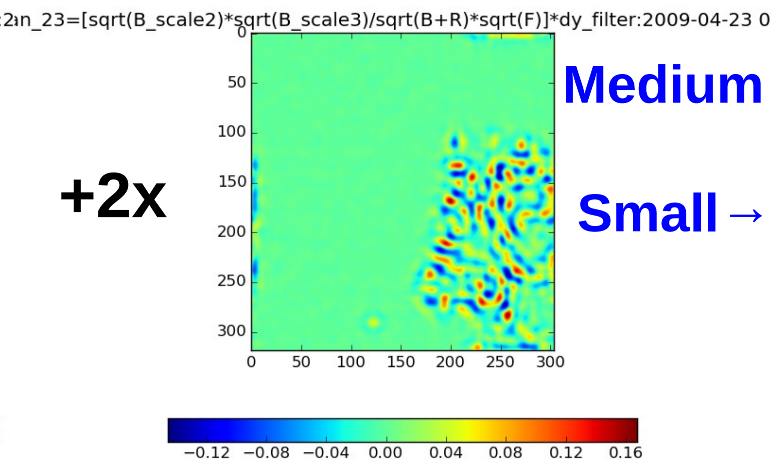
Large → Medium

+2x

Medium → Large



+2x



Medium → Small

Small → Medium

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Impact of scale dependent analysis

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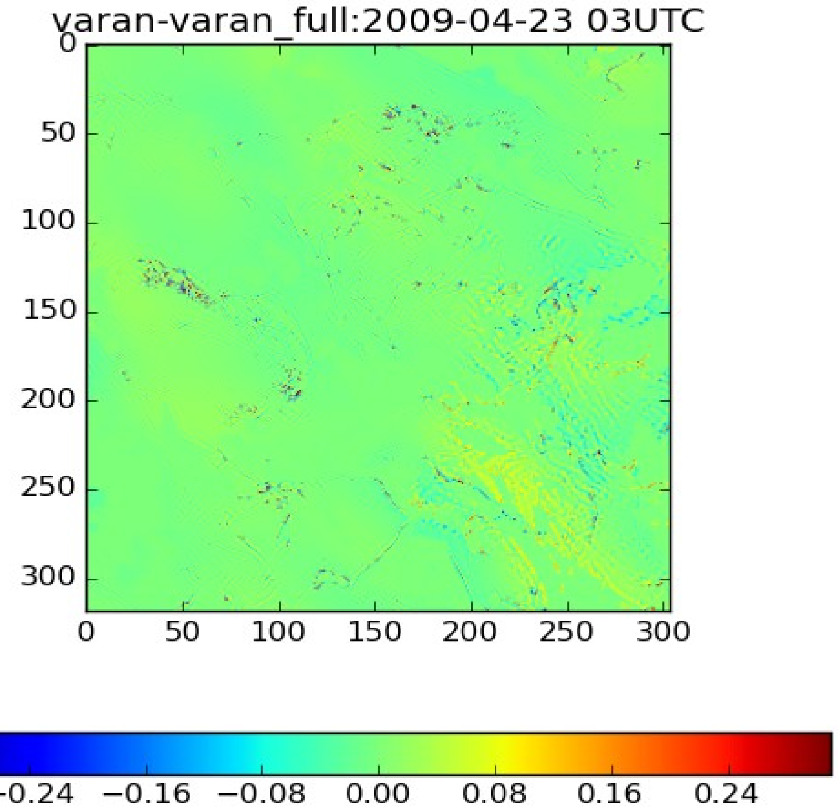

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To conclude....

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What next?

– Super observations and OI analysis on 5.5 grid
– One more overlapping band to model convective scale phenomena?

Lessons learned....

– Space/Scale-dependent decomposition can efficiently be used to model local in space phenomena

– Space/Scale-dependent decomposition allows to model “cross-scale” dependencies and to relax homogeneity assumption staying in spectral space.

– The decomposition on the overlapping bands will induce and impact “cross-scale” correlations

– Space/scale localization seems to be a promising technique for flow-dependent data assimilation. However more research is needed to understand the impact of space-scale dependent localization on the spectra and the error propagation properties.

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