Spatial filtering of assimilation ensemble statistics: increase of sample size by local spatial averaging

Olivier Pannekoucke, Loïk Berre, Gerald Desroziers

Simona Stefanescu, Bernard Chapnik and Laure Raynaud

Introduction and Plan

Importance of sample size:

- amplitude of sampling noise in the estimated covariances.

- the ensemble size influences the ensemble cost.

1 - Increase of sample size by local spatial averaging

2 - Spatial filtering of standard deviations

3 - Spatial filtering of correlations

1 - Increase of sample size by local spatial averaging

Strategies for ensemble size and cost reduction (assimilation ensemble at Météo France)

- Experiments: a small number of members (e.g. 3 to 10) already provides a lot of information !

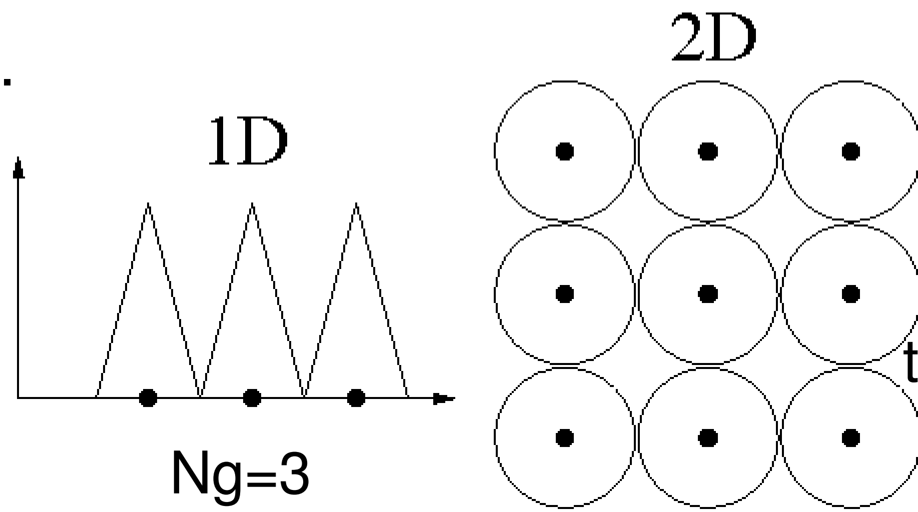
- Use ergodic properties: increase sample size by spatial averaging.

- The full assimilation system may be approximated in the error simulation (e.g. resolution or/and 4D-Var vs 3D-Fgat).

- Six global members T359 L46 with 3D-Fgat are running in nearly real time (Arpège).

Increase of statistical sample size through spatial sampling/averaging

Basic idea: MULTIPLY(!) the statistical sample size by a number Ng of gridpoint samples.



Ng = 9

ex: if Ne = 6

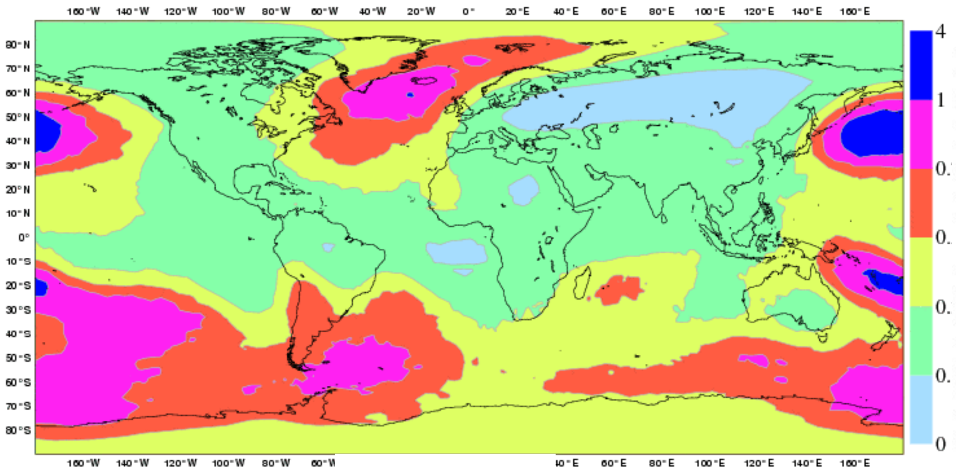
then Ne x Ng = 54

- An "ideal" case: local homogeneity of covariances and (relatively) short correlation length-scales.

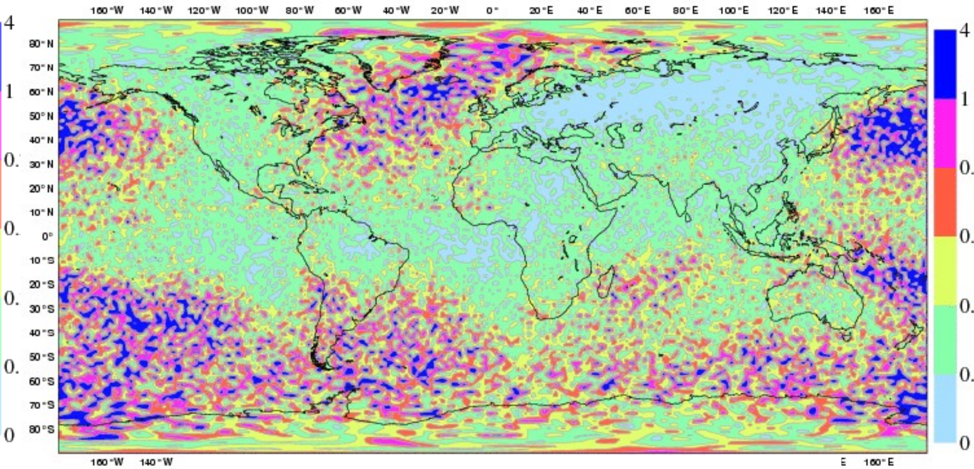
- Another way to justify spatial filtering: sampling noise ~ small scale.

2 - Spatial filtering of standard deviations

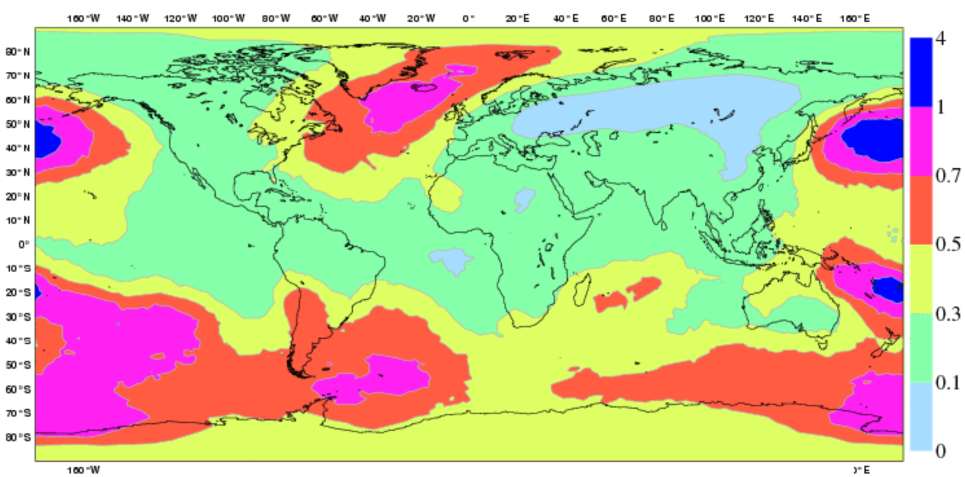
Illustration in a simulated framework



True σb



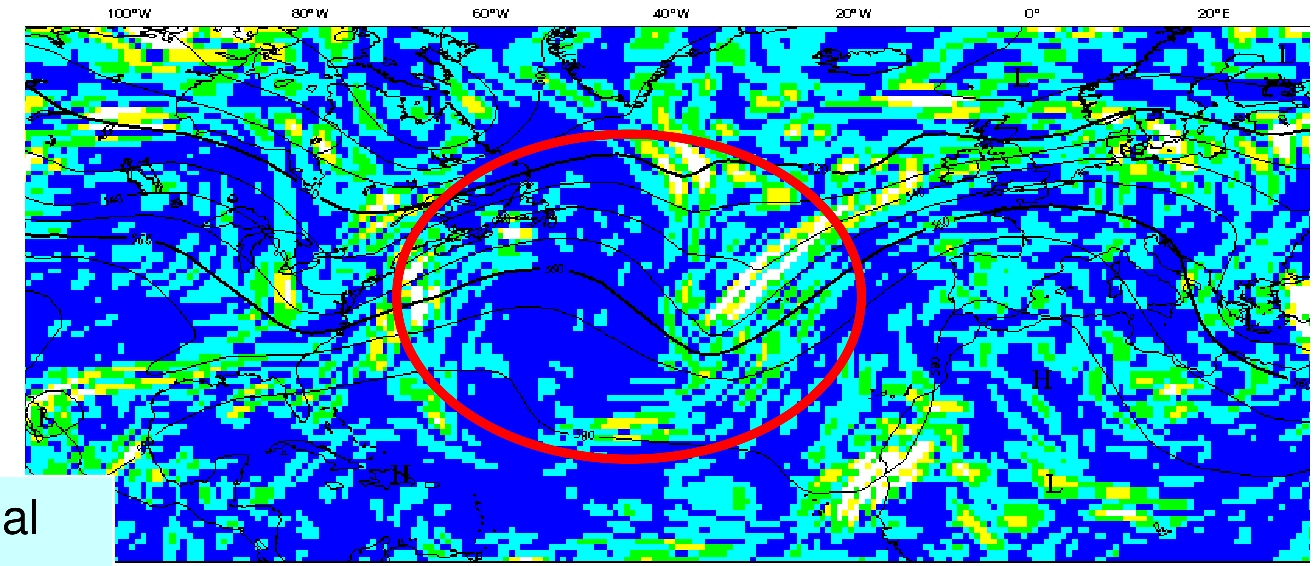
RAW 6-member estimated σb



FILTERED 6-member estimated σb

The spatial structure of signal and noise from two independent 3-member ensembles

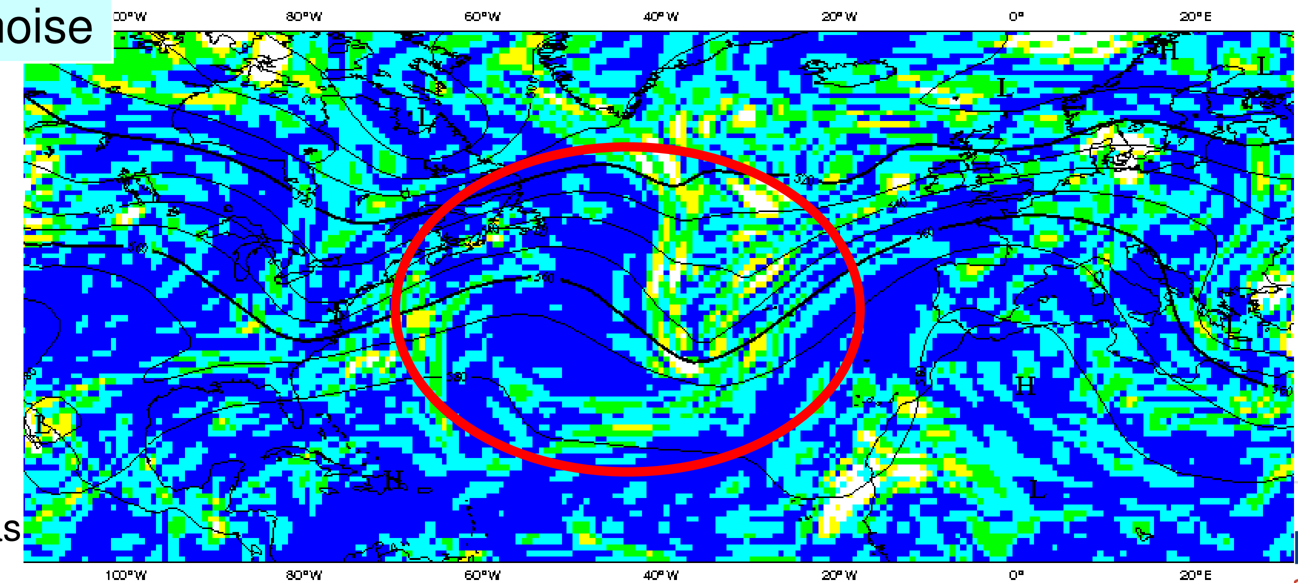
"RAW" σb ENS 1



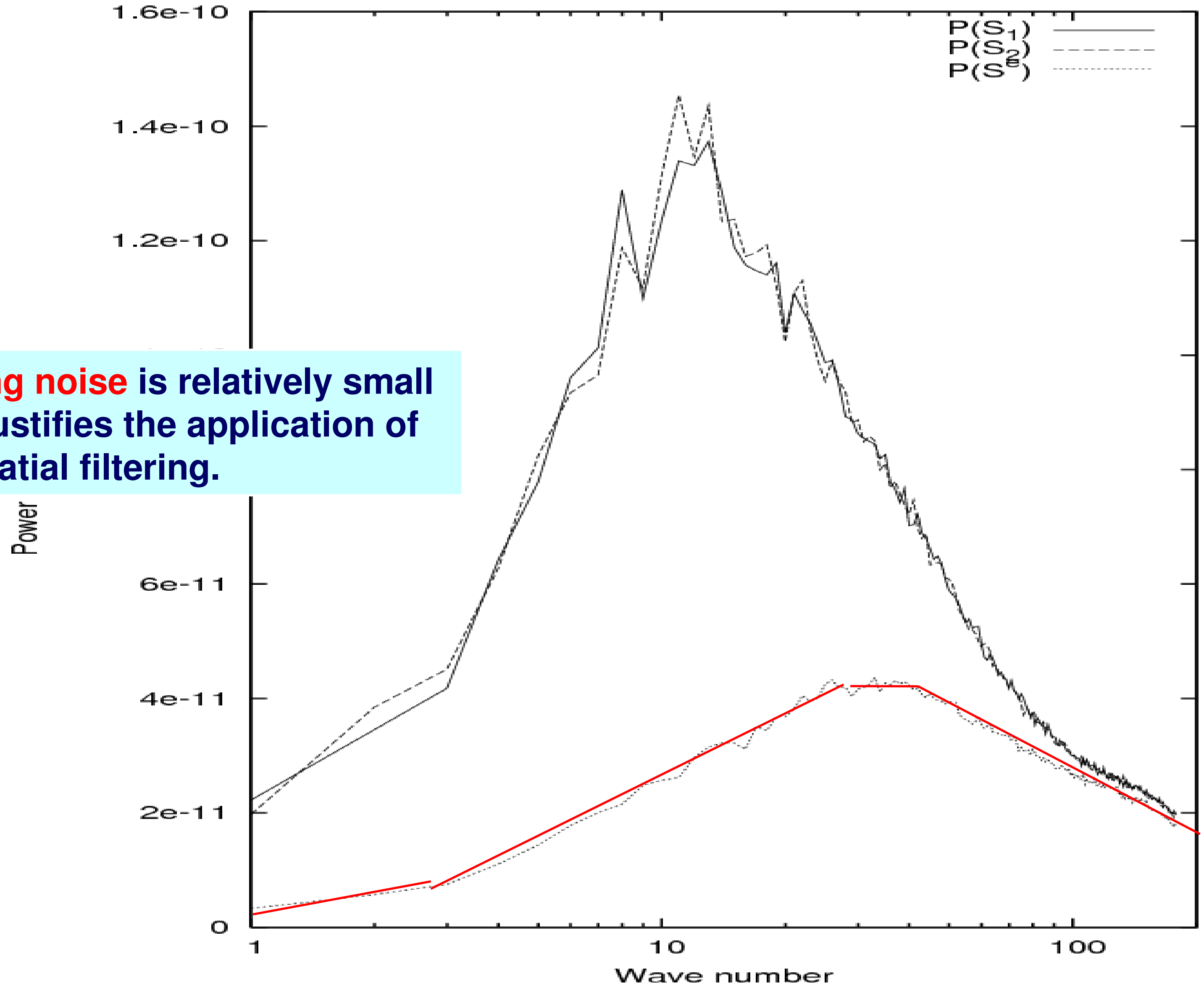
Common features ~ signal

Differences ~ sampling noise

"RAW" σb ENS 2



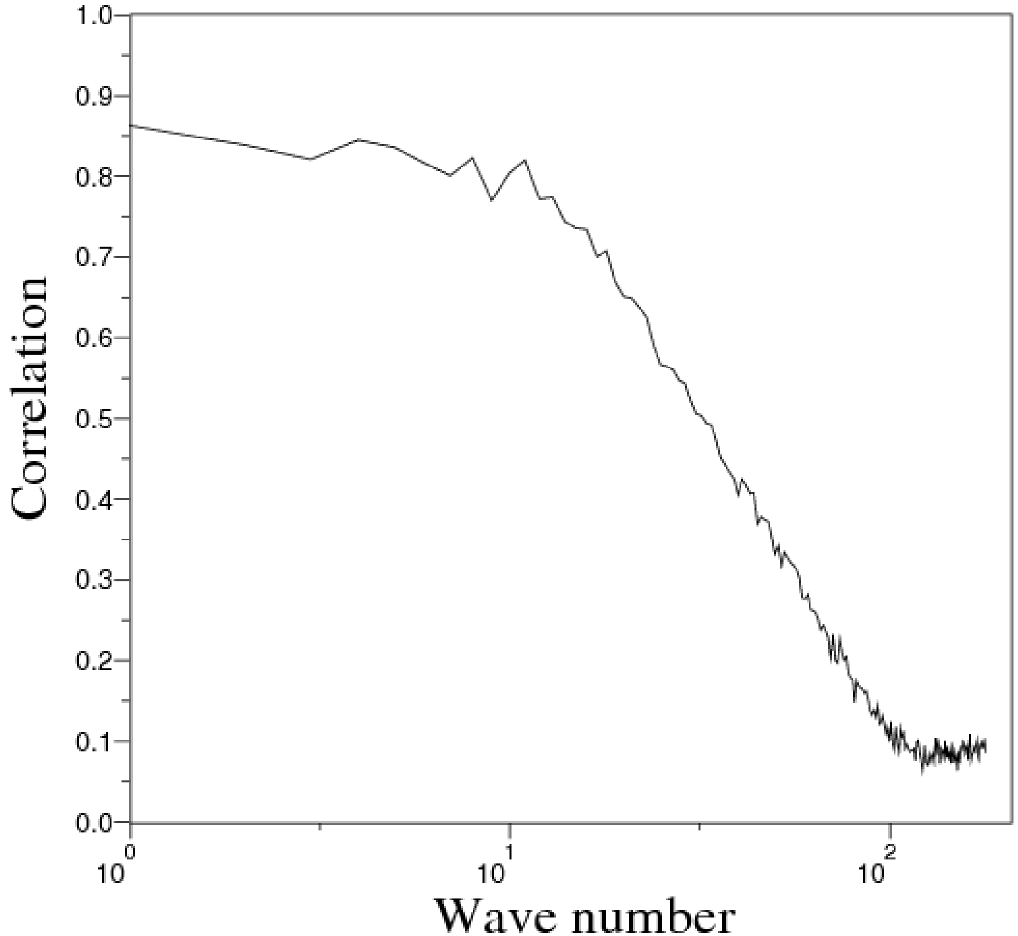
Spectra of sigmab maps and of sampling noise



=> The sampling noise is relatively small scale, which justifies the application of spatial filtering.

Can we design an objective and optimal filter ?

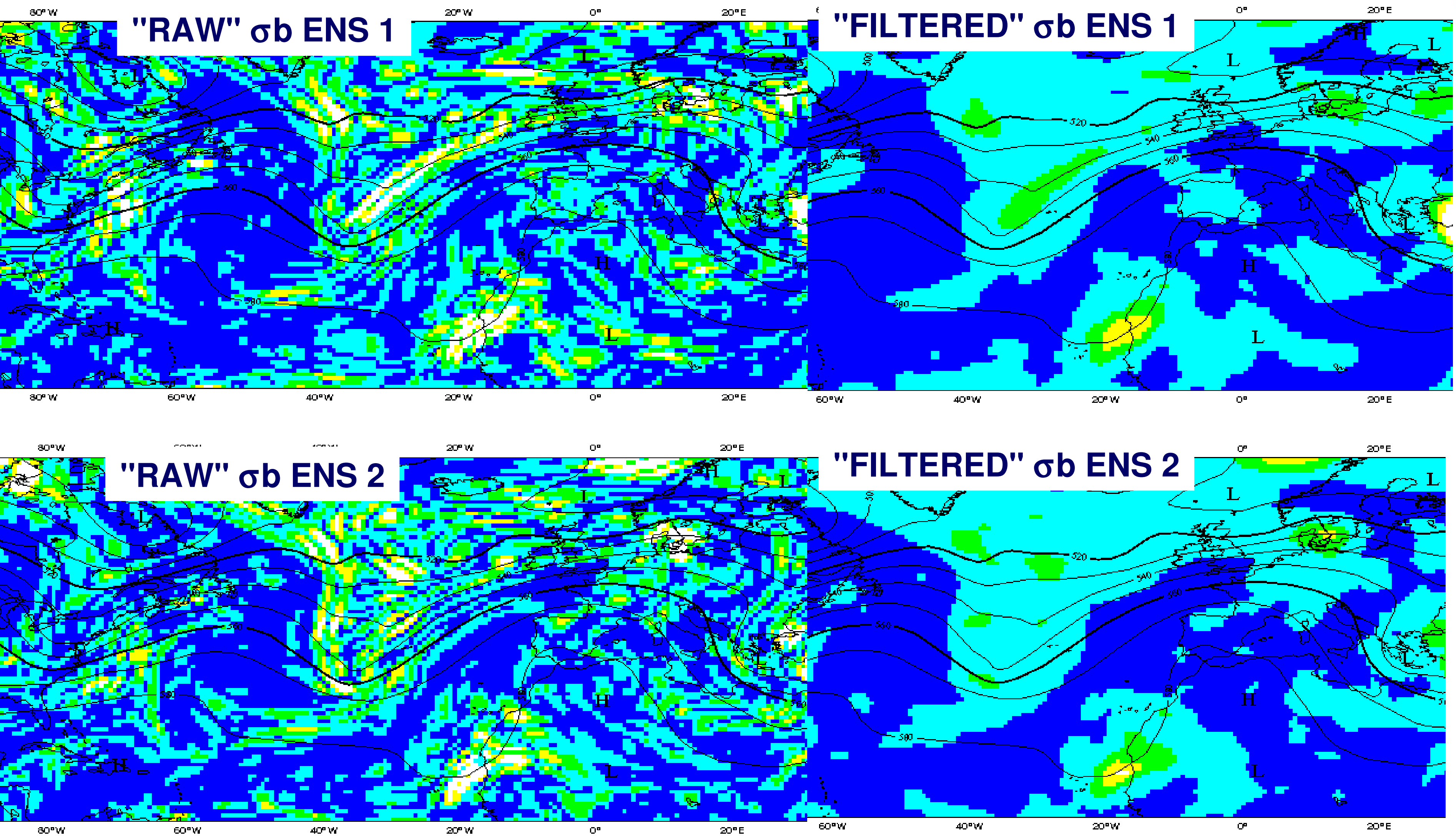
$\rho = cor(S_1, S_2)$



⇒The two σb fields are more coherent in the large scales than in the small scales.

⇒ It can be shown that this spectral correlation can be used as an objective and optimal filtering coefficient !

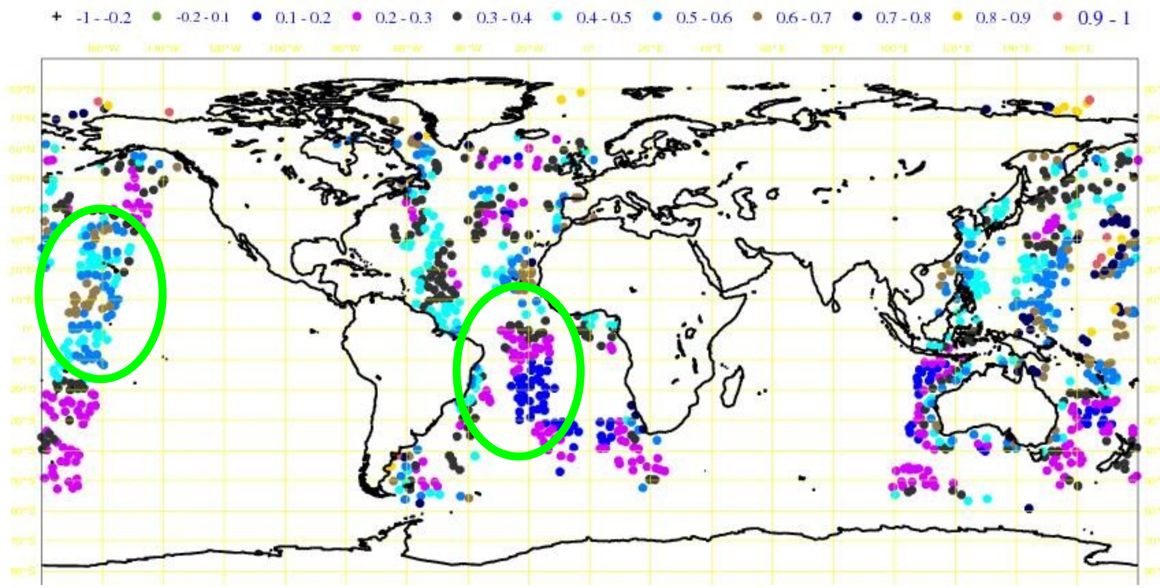
Spatial filtering of standard deviations



Validation with innovation diagnostics
(for one specific day and for HIRS-7)

Ensemble

sigmab's

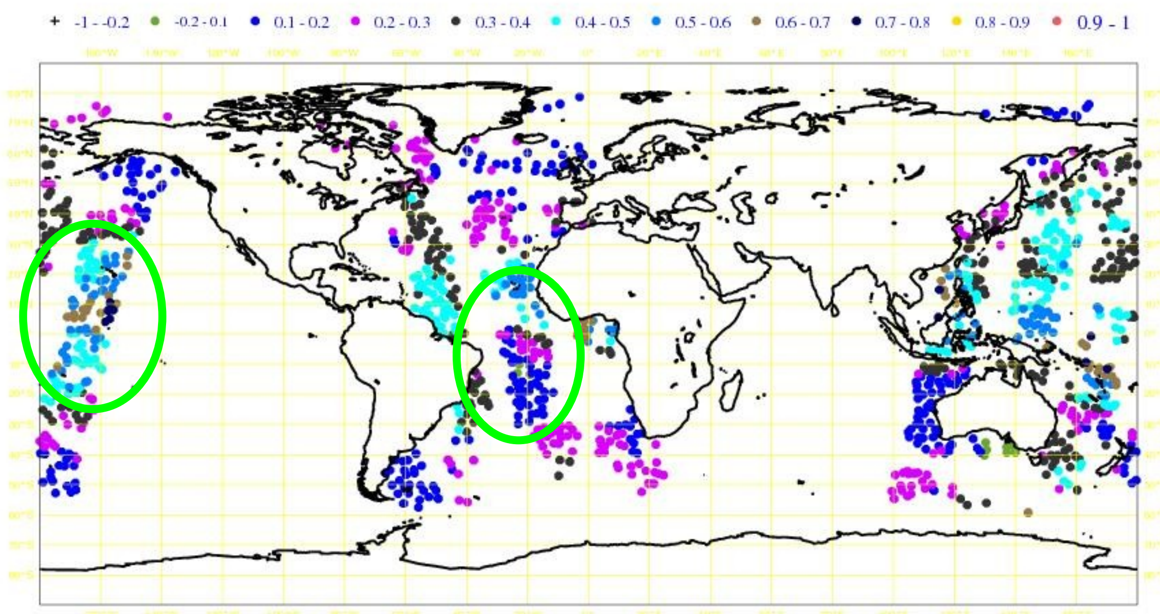


"Observed"

sigmab's

cov(H dx , dy) ~ H B H^T

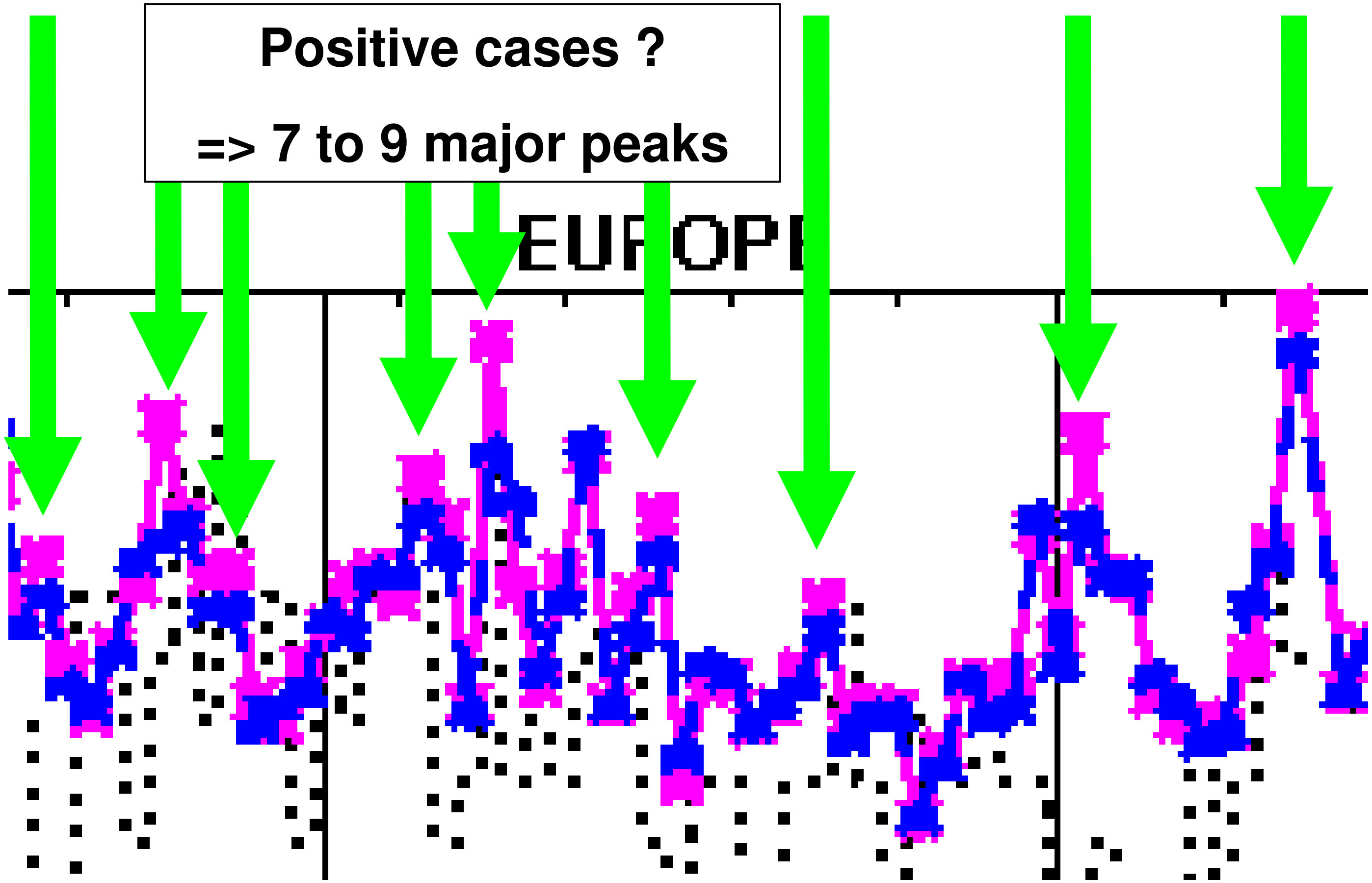
(Desroziers et al 2005)



Impact of sigmab's of the day in the Arpège 4D-Var (~over two months ; versus "climatological" sigmab's)

Positive cases ?

=> 7 to 9 major peaks



Europe wind RMS 500hPa +24h / TEMPs

3 - Spatial filtering of correlations

Local averaging of correlations via wavelets

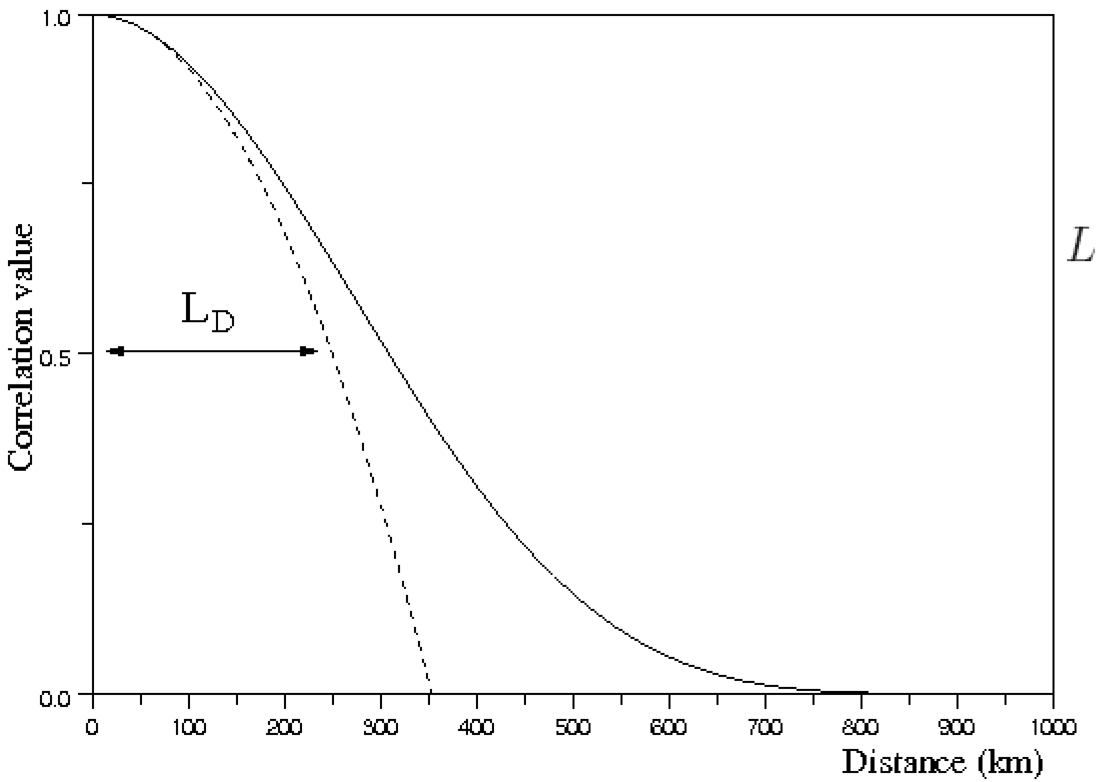
Two extreme approaches in correlation modeling:

- Ens KF: local correlation functions are calculated for each gridpoint. => heterogeneity, but it needs a large ensemble.

- Var: a global average of correlation functions, via a spectral diagonal approach. => large (spatial) sample, but homogeneity.

=> An attractive compromise is to use wavelets, to calculate a local average of correlations.

Diagnosis of length-scale



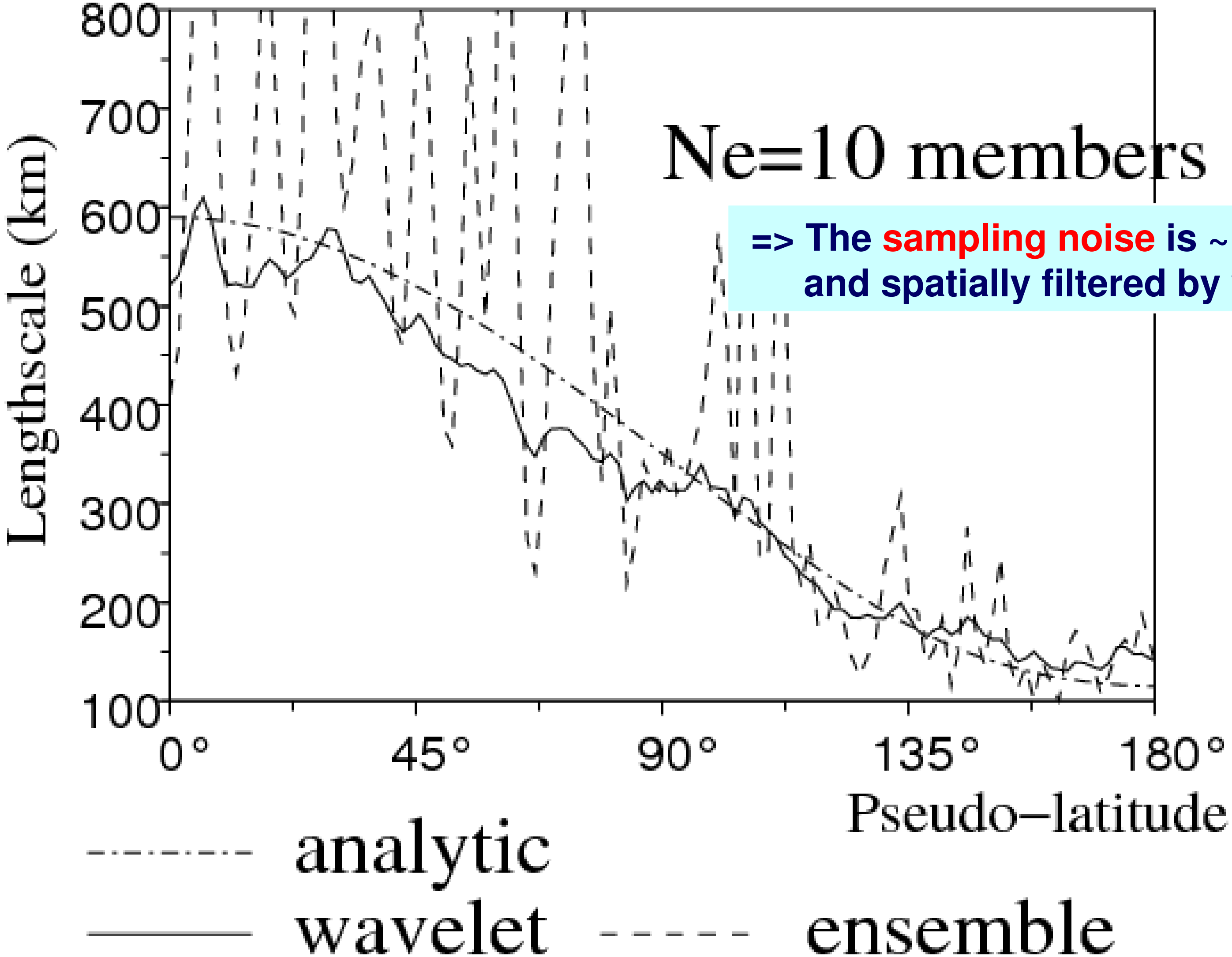
$$L_D = \sqrt{-\frac{1}{\Delta\rho(0)}}$$

$$L_{B\&B} = \sqrt{\frac{\sigma(\varepsilon_b(x))^2}{\sigma(\partial_x \varepsilon_b(x))^2 - (\partial_x \sigma(\varepsilon_b(x)))^2}}$$

$$L_{Pb} = \frac{|\delta x|}{\sqrt{2\,(1-\rho(\delta x))}}$$

$$L_{Gb} = \frac{|\delta x|}{\sqrt{-2\ \ln\,\rho(\delta x)}}$$

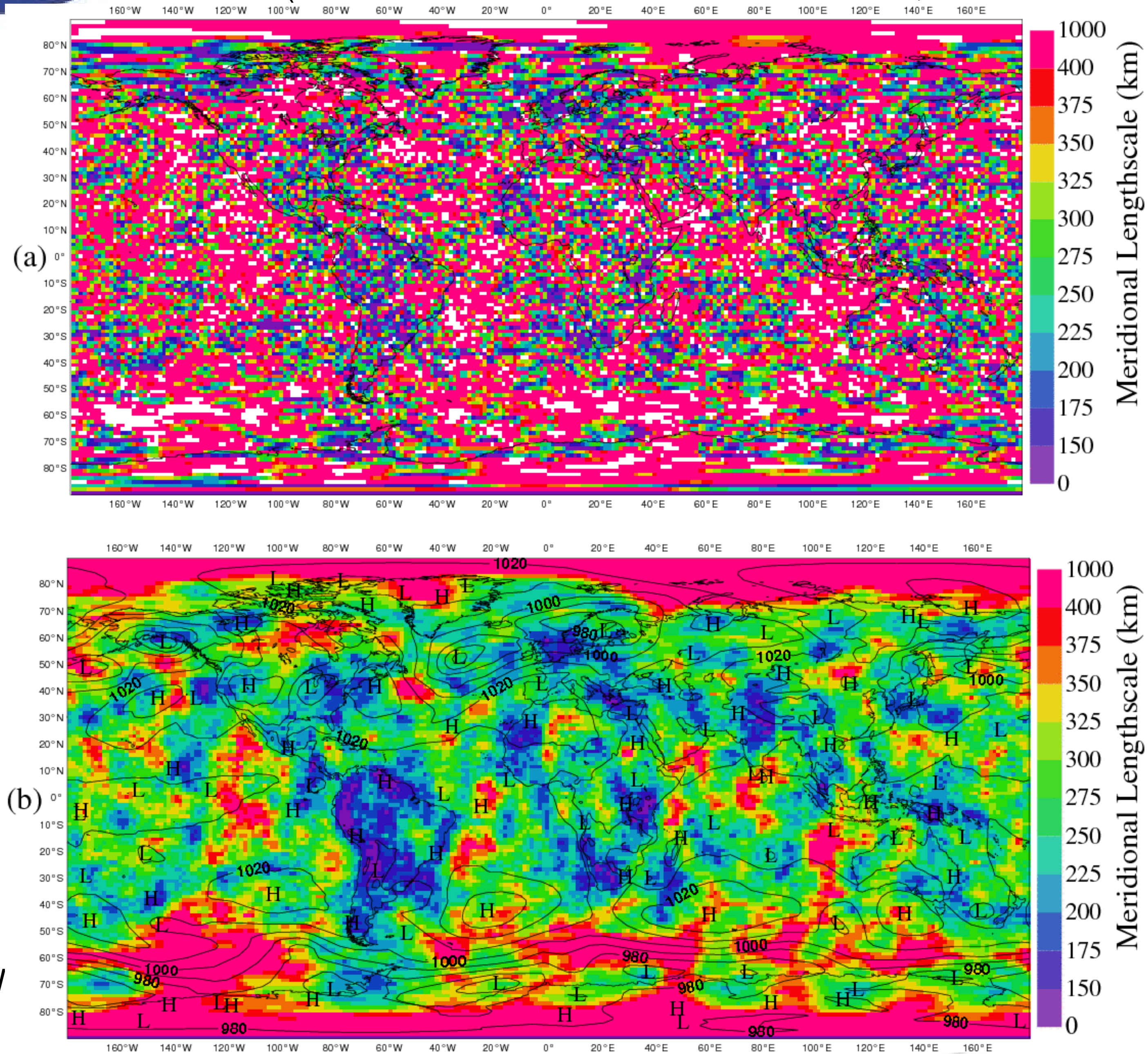
Sampling noise reduction



=> The sampling noise is ~ small scale, and spatially filtered by wavelets.

Correlation length-scales of the day

(from a 6-member assimilation ensemble; Pannekoucke et al 2007)



RAW

WAVELET FILTERING

W

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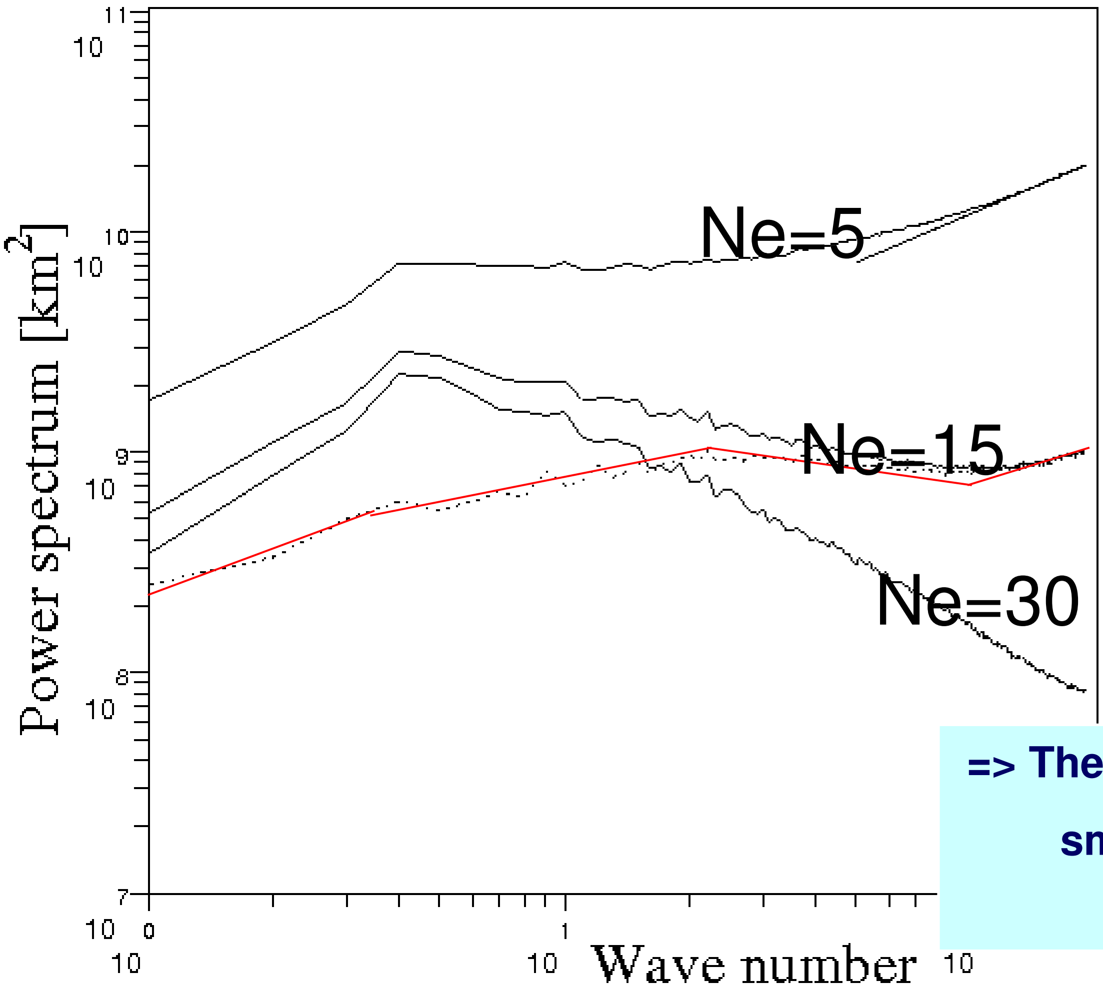
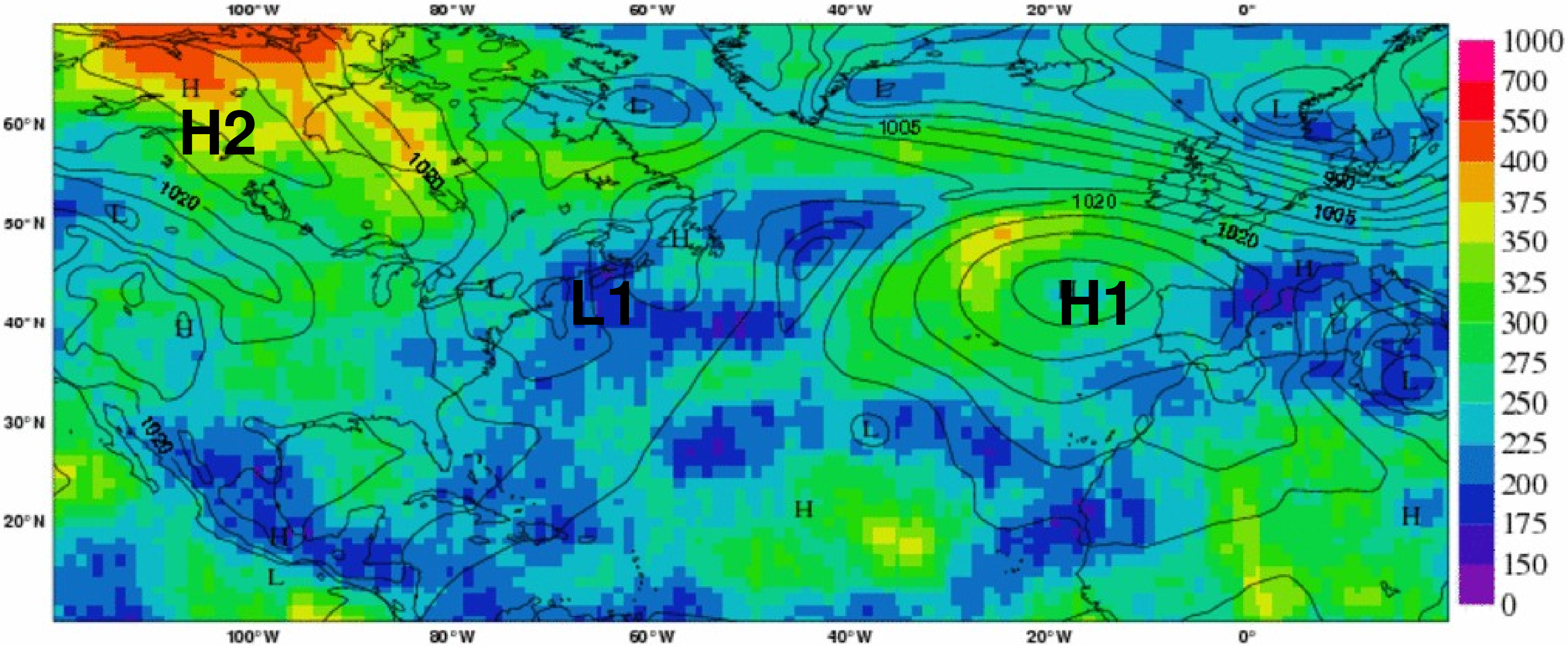
Spectrum of unfiltered length-scale map versus ensemble size



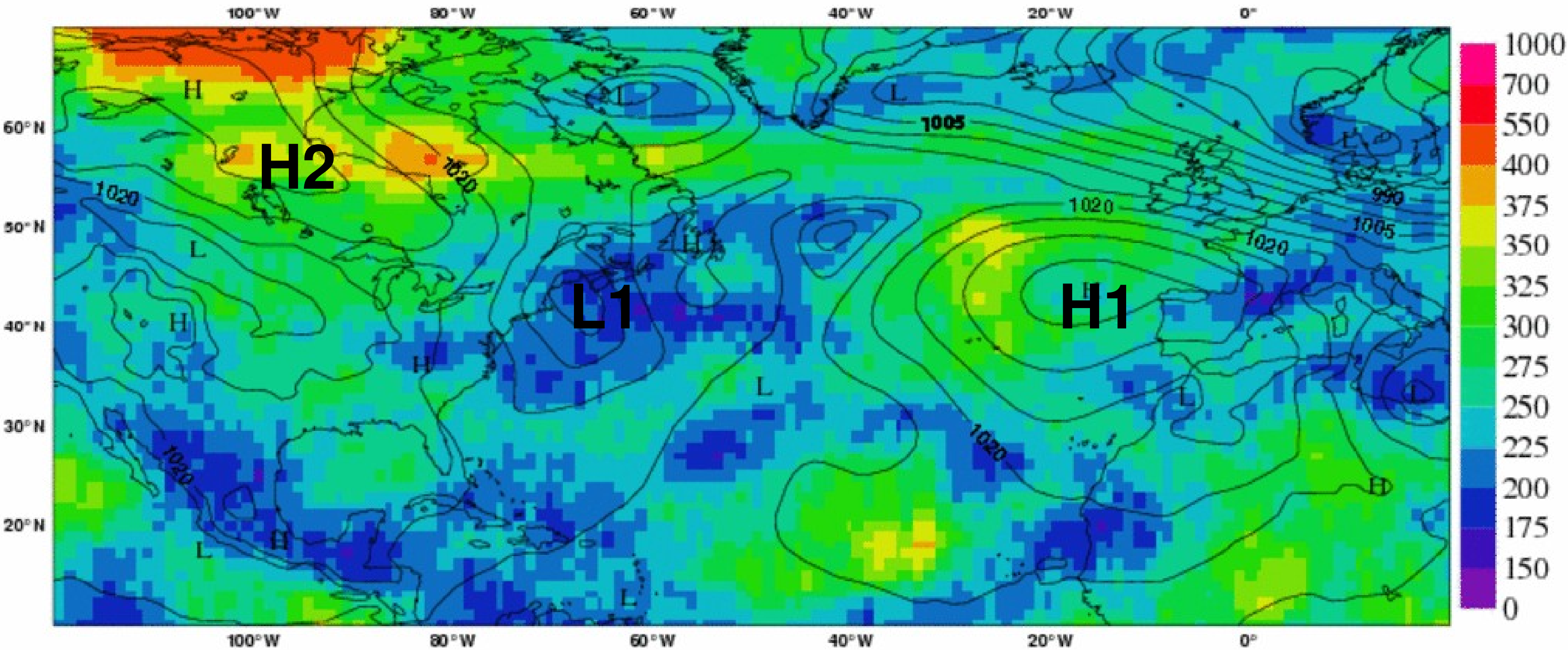
=> The noise contribution is relatively small in the large scales, and large in the small scales.

Length-scales of the day



20/01/2005 06UTC (1/12)

Length-scales of the day



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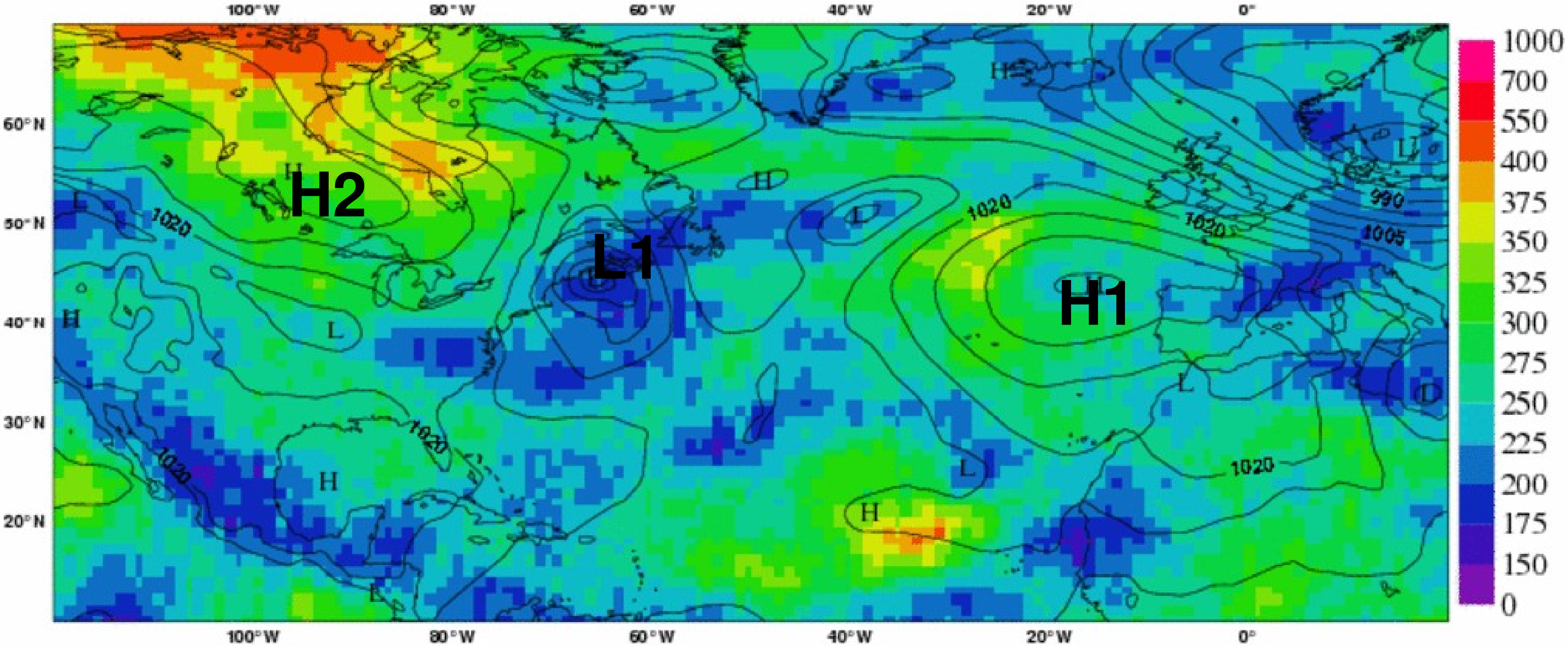
Length-scales of the day



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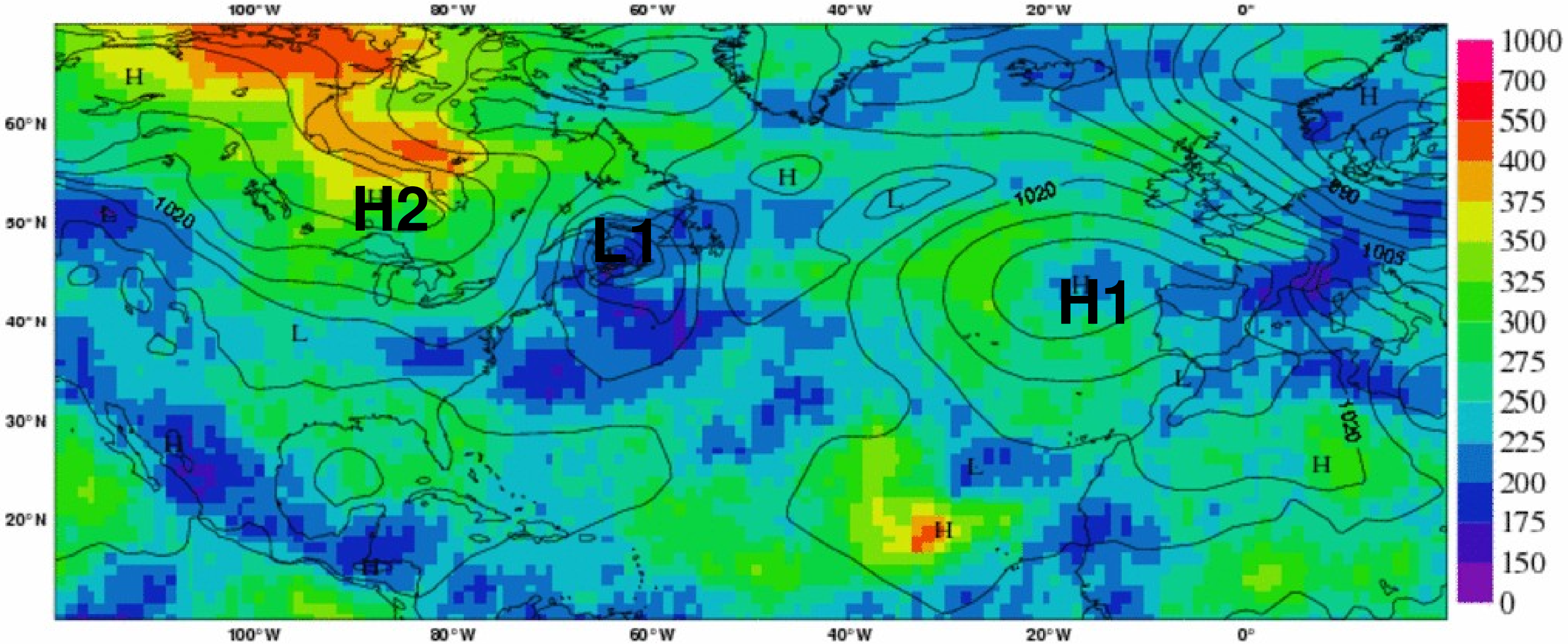
Length-scales of the day



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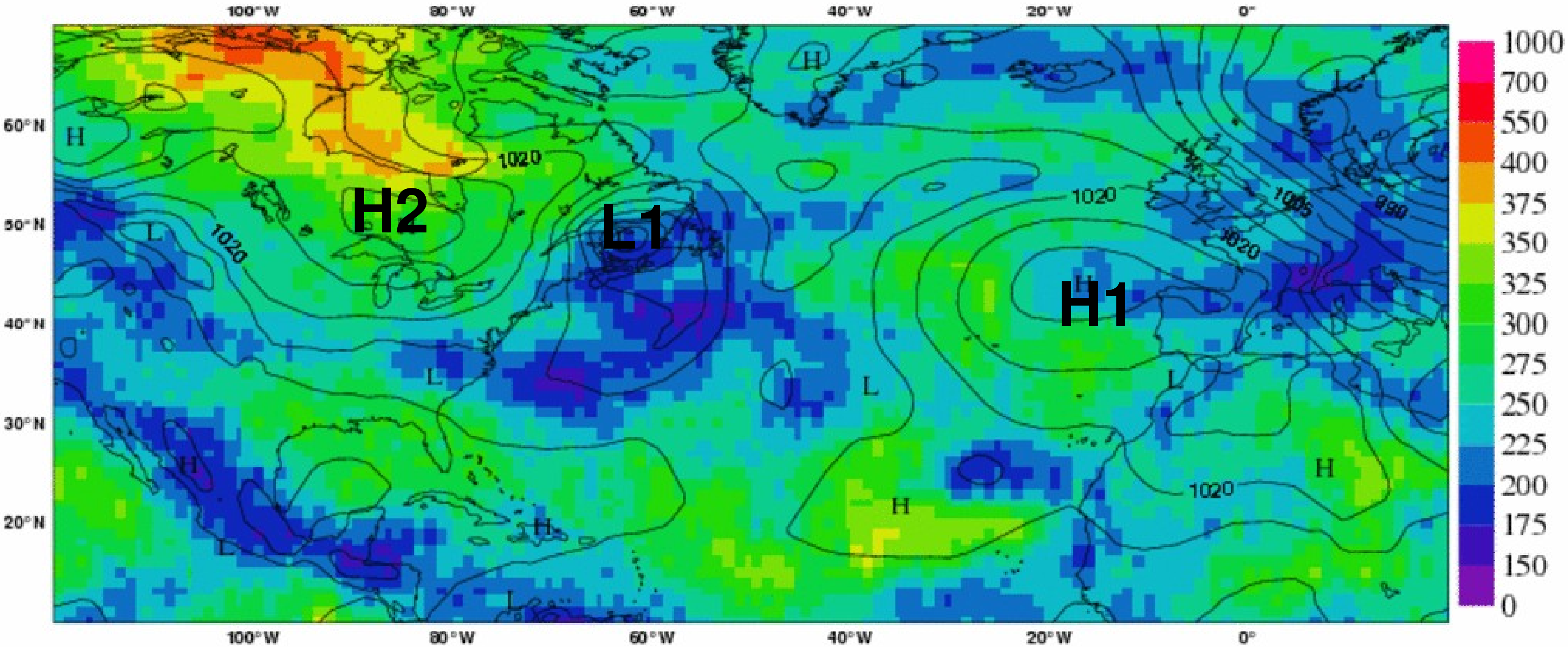
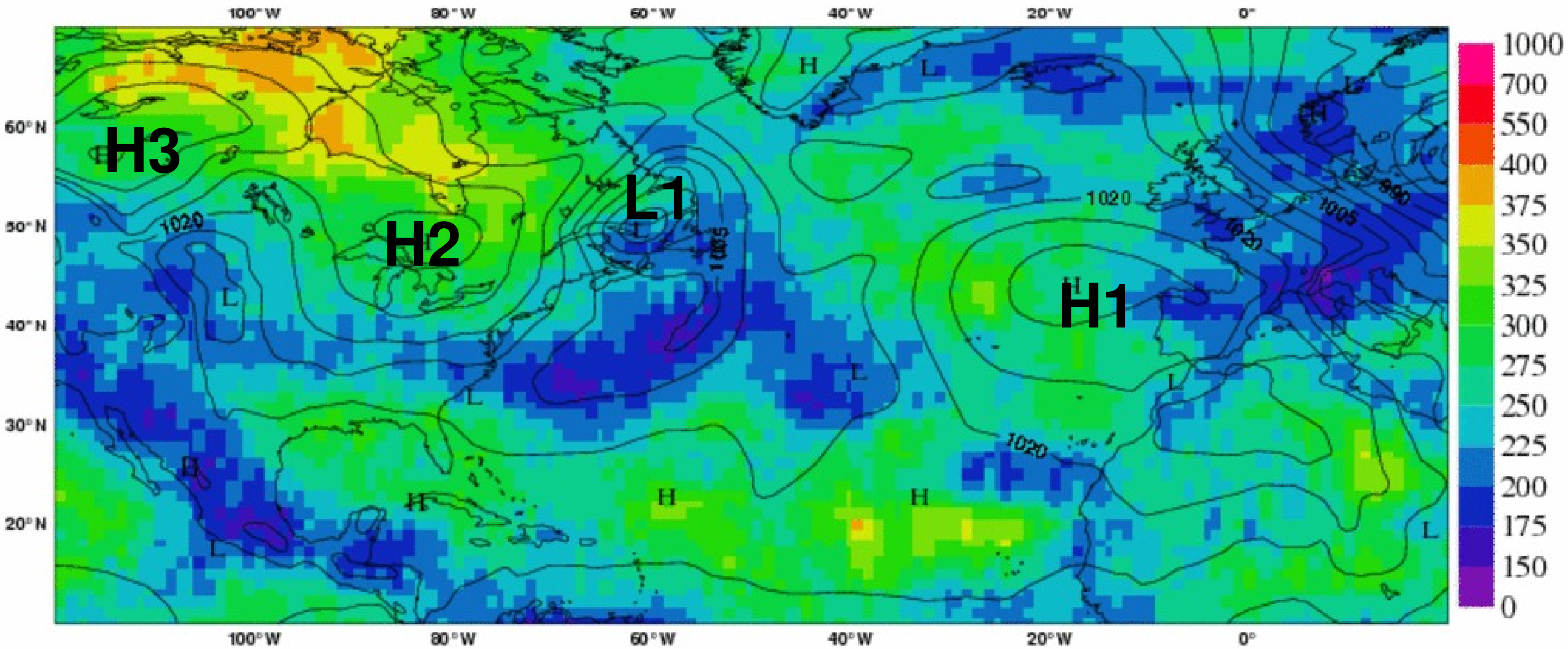
Length-scales of the day



21/01/2005 06UTC (5/12)

Length-scales of the day



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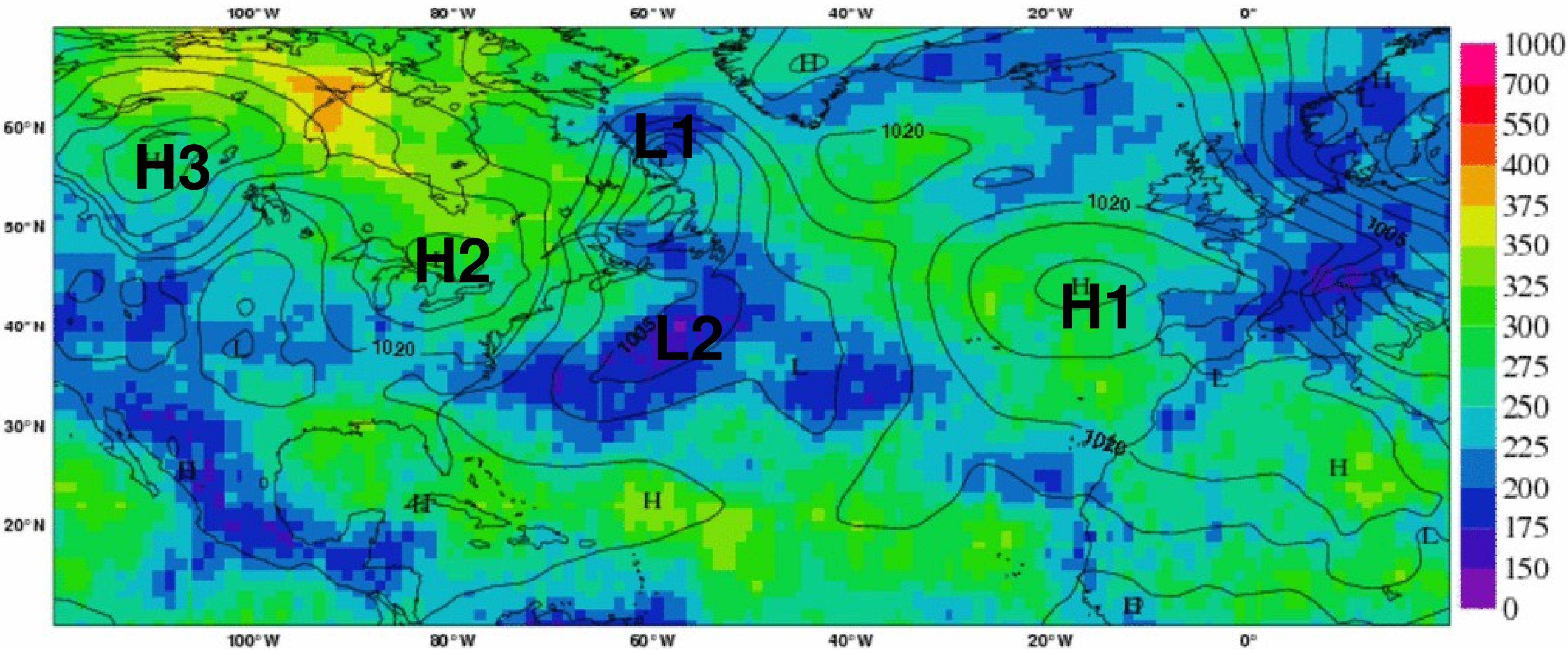
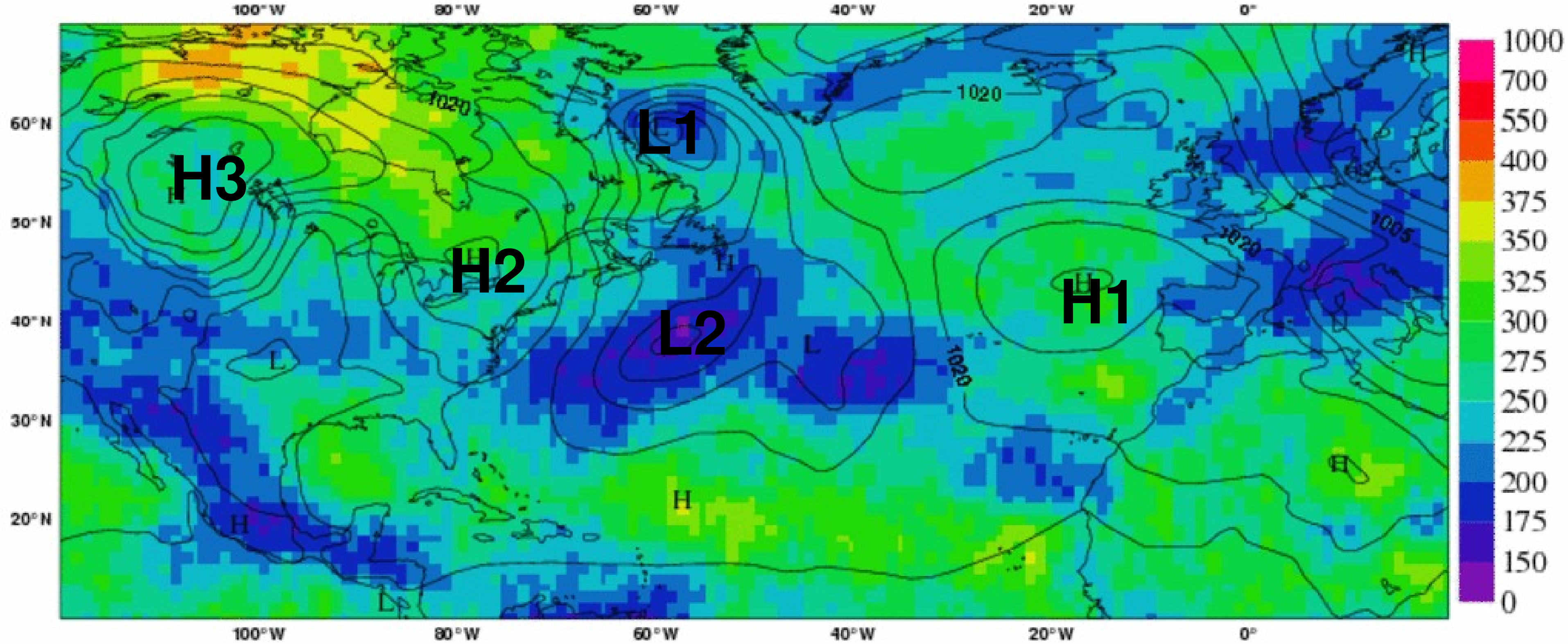
Length-scales of the day



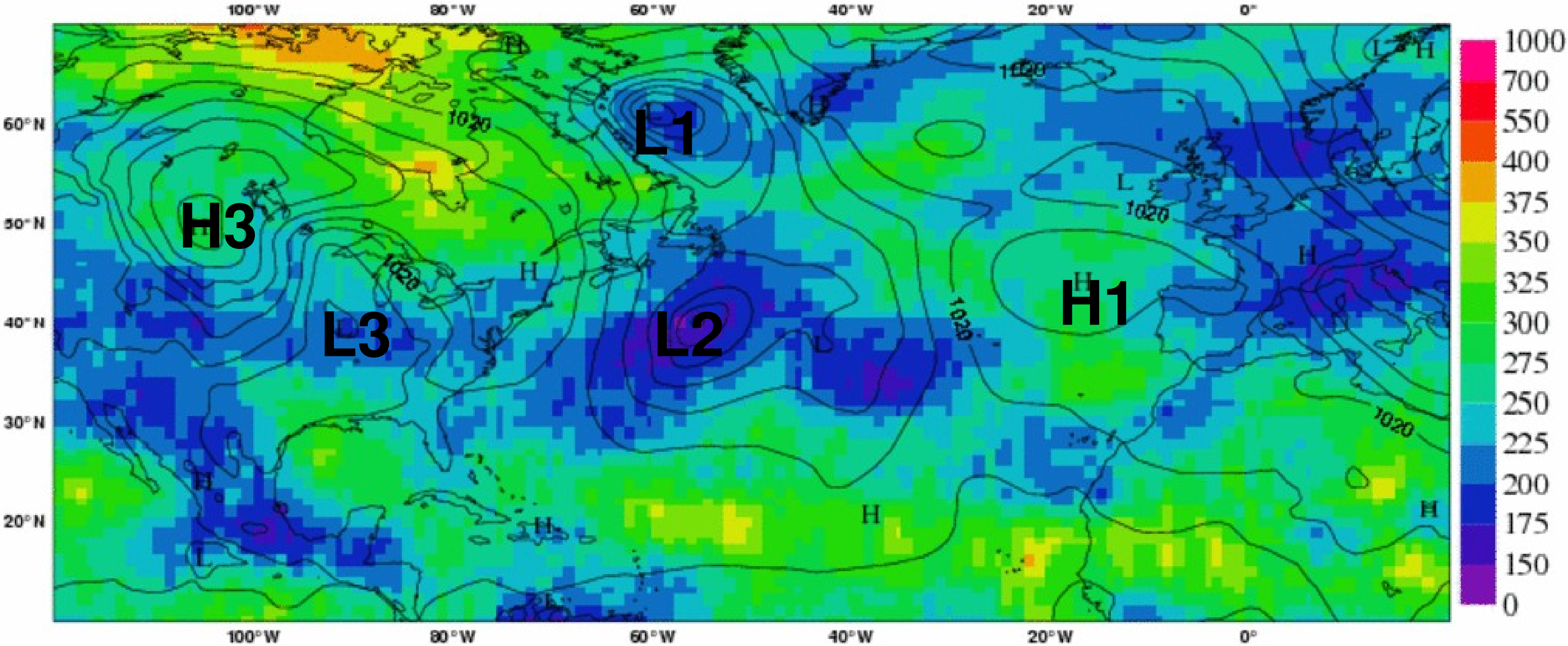
21/01/2005 18UTC (7/12)

Length-scales of the day



22/01/2005 00UTC (8/12)

Length-scales of the day



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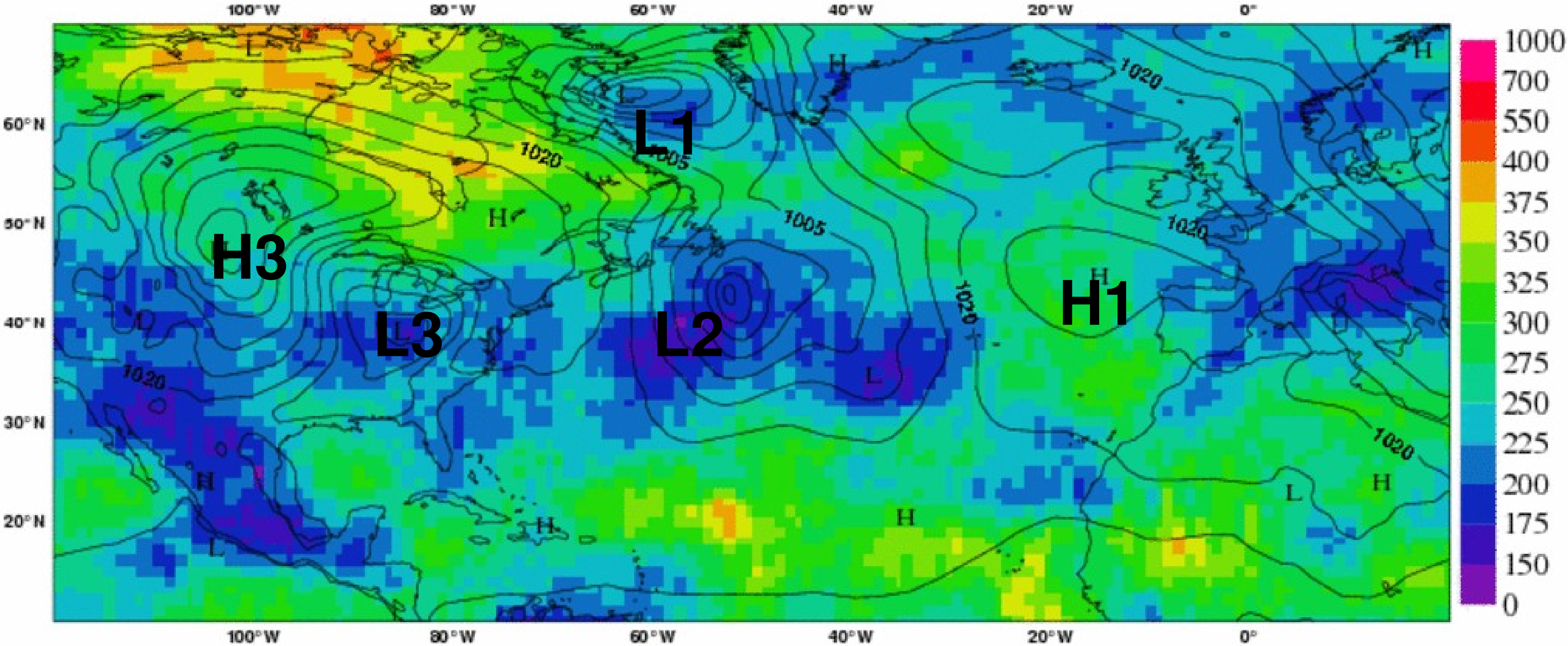
Length-scales of the day



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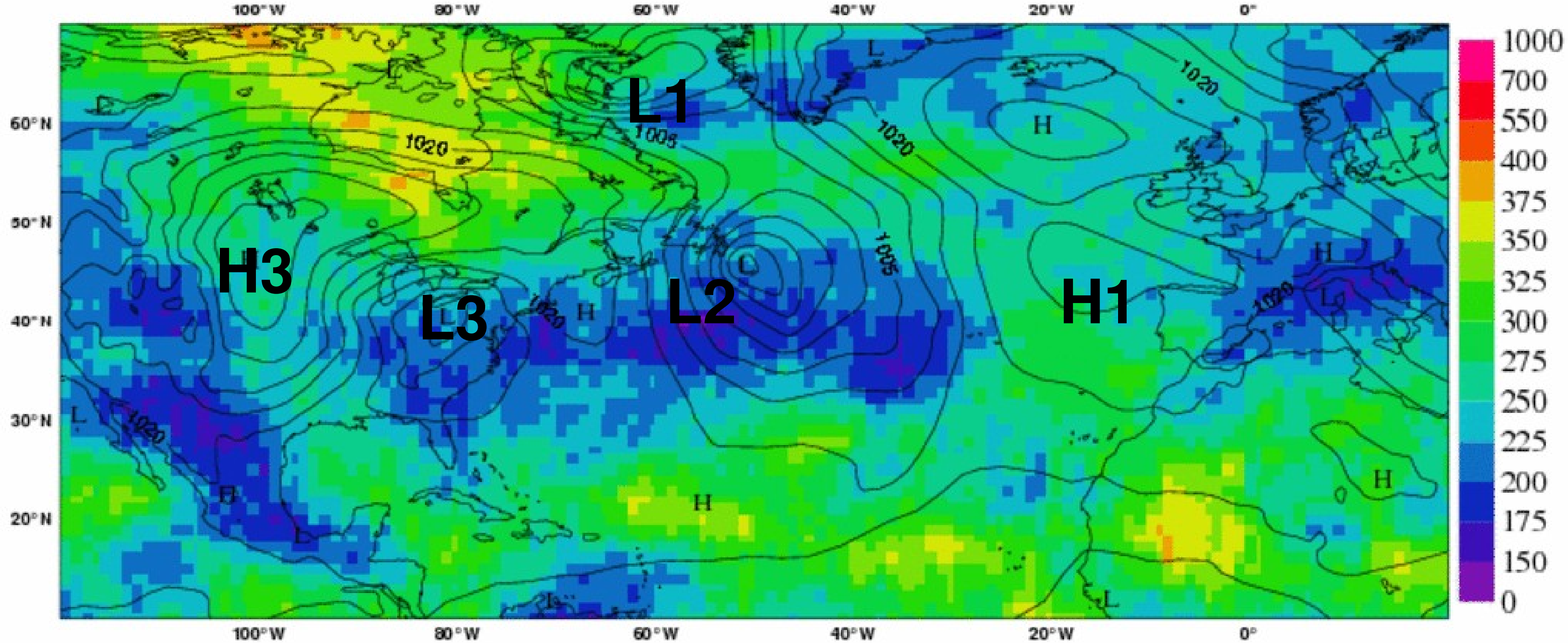
Length-scales of the day



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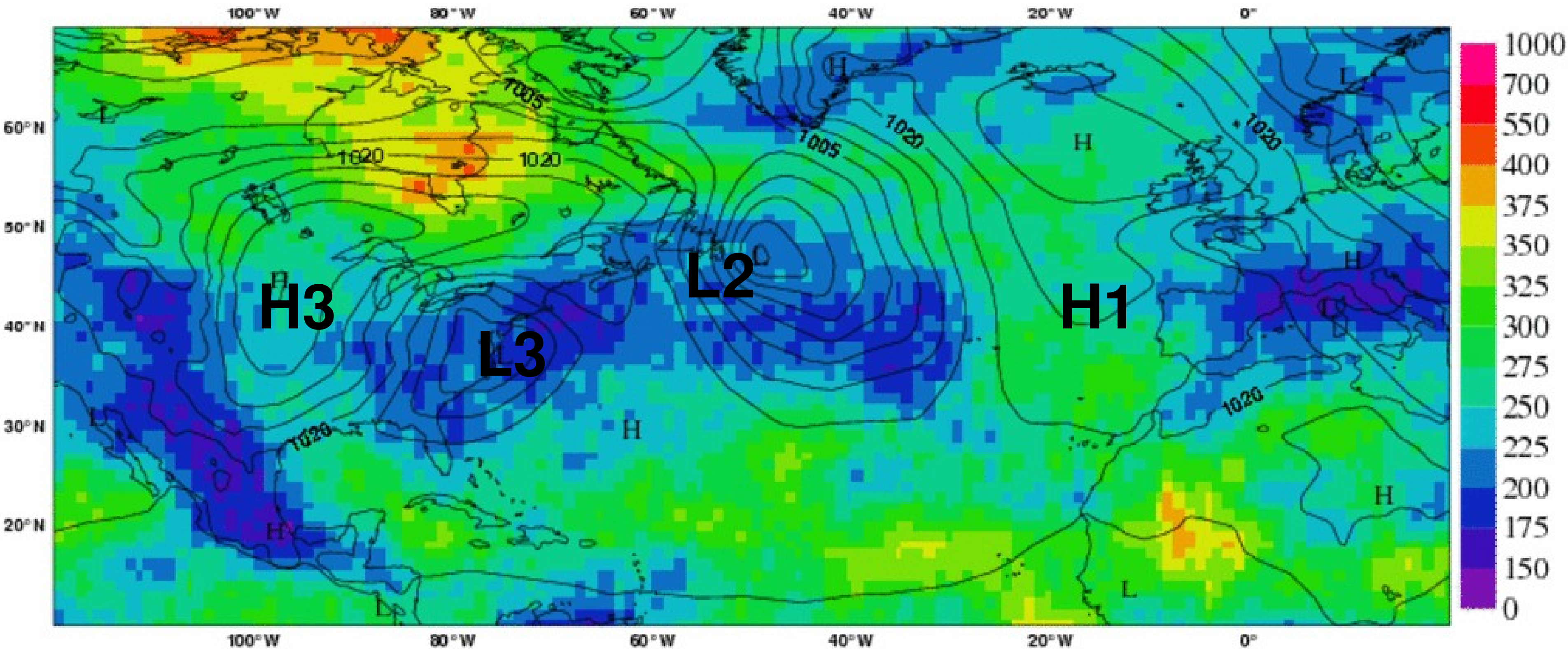
Length-scales of the day



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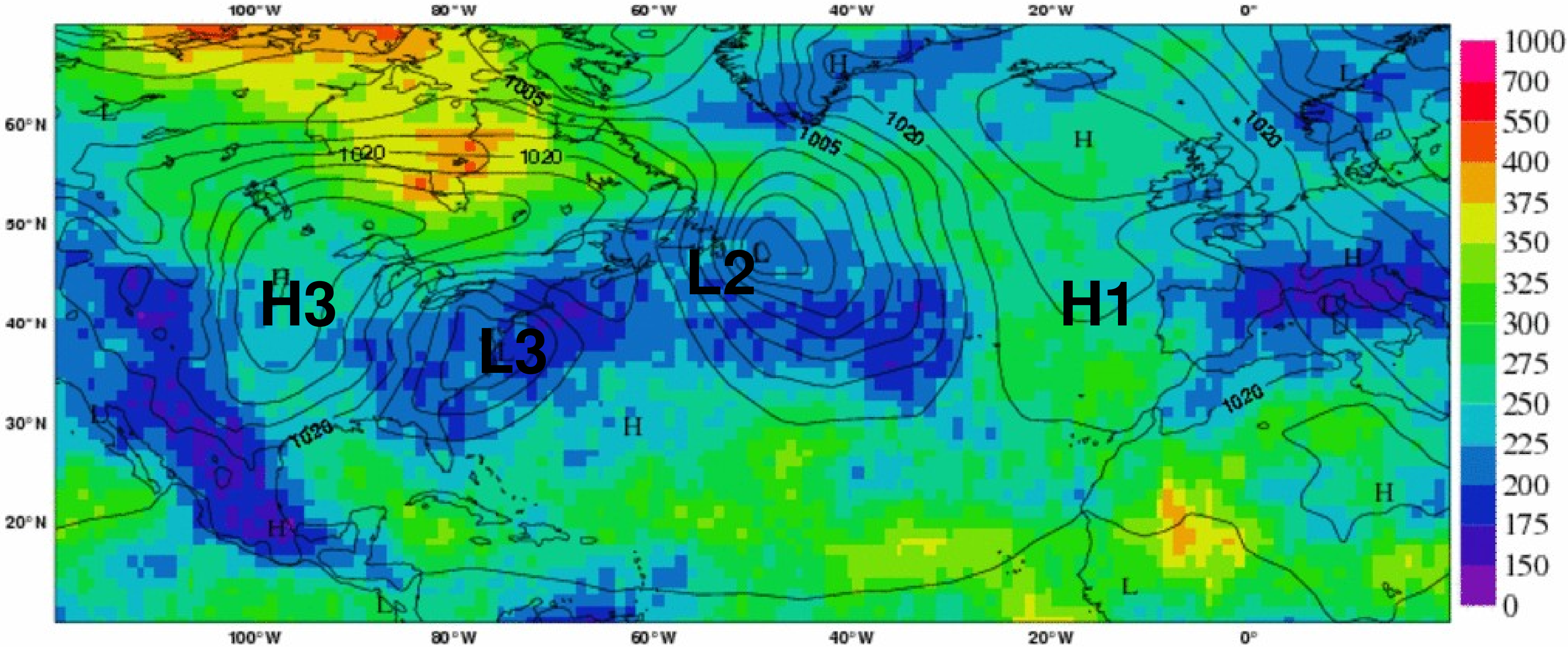
Discussion



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Conclusions and perspectives

- Using an assimilation ensemble and spatial filtering is a promising way to obtain flow-dependent covariances (+ balances) (in a more realistic way than with a simplified background state dependence)

- The spatial filtering is justified by the small scale structure of sampling noise, and it can be optimized objectively.

- The local spatial averaging allows the sample size to be much increased, the ensemble size being MULTIPLIED by a 2D spatial sample size.

Conclusions and perspectives

- The spatial filtering is costless: it may help to make the ensemble size and cost reasonable.

- First impact experiments and comparisons with innovation diagnostics are encouraging. => operational in 2007-2008 ?

- Applications for assimilation diagnostics and ensemble prediction too.