# Development and operational implementation of flow-dependent wavelet-based correlations using the Ensemble 4D-Var at Météo-France

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## Ensemble 4D-Var at Météo-France and covariance modelling

• An Ensemble 4D-Var system is used at Météo-France since 2008 (Berre et al 2007, Berre and Desroziers 2010), in order to simulate error cycling, using 6 members (Arpege T399 L70) with perturbed inputs, and inflation of forecast perturbations (Raynaud et al 2012) :

$$\varepsilon^a = (I - \mathrm{KH})\varepsilon^b + K\varepsilon^o \qquad \varepsilon^f = M\varepsilon^a + \varepsilon^m$$

• Background error variances are flow-dependent and objectively filtered spatially (e.g. Raynaud et al 2009).

• Error correlations were previously static (averaged from few-week series of ensemble perturbations) and nearly homogeneous (except for flow-dependent effects of non-linear balances).

• A climatological wavelet formulation (Fisher 2003) is used at ECMWF to represent heterogeneous but static correlations.

• Since the temporal dynamics of correlations is significant (Varella et al 2011), a flow-dependent wavelet model is considered here.

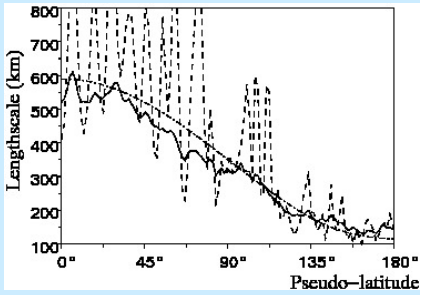
## Wavelet formulation and 4-day sliding average

• Wavelet functions (Fisher 2003) allow both scale and position information to be accounted for:

$\tilde{\varepsilon}^b_j = \varepsilon^b \otimes \psi_j$ , where $\psi_j$ are band-limited wavelet functions

$$\varepsilon^b = \sum_j \tilde{\varepsilon}^b_j \otimes \psi_j \qquad B = \sum_j C_j(x,y) \otimes \psi_j^2$$

• Wavelet block-diagonal correlation matrix : local spatial averages of correlation functions, allowing sampling noise to be reduced (Pannekoucke et al., 2007, Berre and Desroziers, 2010).

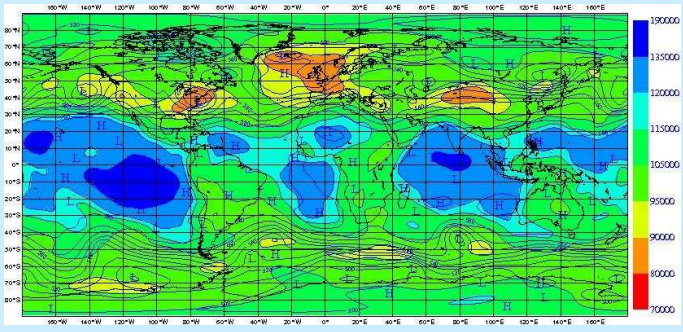



Local correlation length-scales in an idealized 1D case with 10 members: true (dash-dotted), raw (dashed), and wavelet-based (full) (Pannekoucke et al 2007 QJ).

• In order to increase further the sample size, a 4-day sliding average of correlations is calculated, leading to a 96-sample (6 members x 16 networks).

## Diagnostic and impact results in Arpege 4D-Var

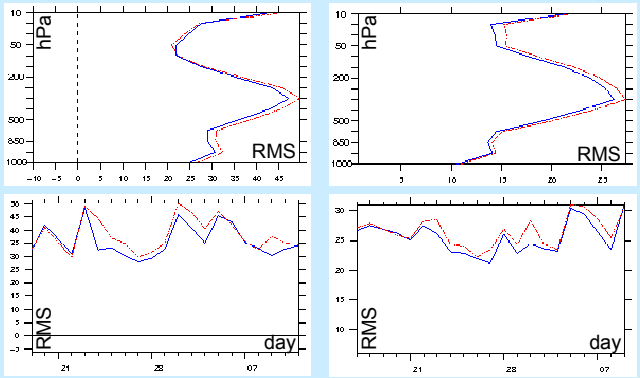
• Background error correlation length-scales of wind, diagnosed by reflect captured connexions with the underlying weather situation. $L(u,v) = \sqrt{\dfrac{\sigma_u^2 + \sigma_v^2}{\sigma_\zeta^2 + \sigma_\eta^2}}$




Flow-dependent wavelet-implied correlation length-scales (in m) for wind near 500hPa on 26 February 2010

96h forecast of geopotential over Europe and Northern Atlantic

48h forecast of geopotential over Southern Hemisphere extratropics




Impact of wavelet flow-dependent correlations
against spectral static correlations

• Using these correlations in 4D-Var has a positive impact on forecasts.

## Conclusions and future work

• This flow-dependent wavelet approach allows dynamics of error correlations to be represented.

• Such a formulation has been made operational at Météo-France on 2 July 2013.

• The ensemble size will be increased to 25-35 members in 2014, allowing for the use of 1-day sliding averages of correlations.

## References

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