Modelling of flow-dependent ensemble-based background error correlations using a wavelet formulation

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1) Variational ensemble data assimilation and covariance modelling

- A variational ensemble data assimilation system is used at Météo-France to simulate the error cycling during the successive analysis and forecast steps:

\[ \varepsilon^a = (I - KH)\varepsilon^b + KE^o \quad \varepsilon^f = ME^a + \varepsilon^m. \]

- Background error variances are flow-dependent and are calculated from a 6-member ensemble by using objective spatial filtering techniques to reduce sampling noise effects.
- Background error correlations are currently static (averaged from few-week series of ensemble perturbations) and nearly homogeneous (except for flow-dependent effects of non-linear balances).
- A wavelet formulation (Fisher, 2003) is used at ECMWF to represent heterogeneous but static correlations.
- Since the temporal dynamics of correlations can be significant (Varella et al., 2011), a flow-dependent wavelet modelling is considered here to estimate robust flow-dependent correlations.

2) Wavelet formulation and sliding temporal average

- The wavelet formulation can be considered as a spatial filtering tool of ensemble-based correlations, since raw ensemble correlations are noisy.
- Wavelet functions (Fisher, 2003) allow both scale and position information to be accounted for:

\[ \tilde{\varepsilon}_j^b = \varepsilon^b \otimes \psi_j, \text{ where } \psi_j \text{ are band-limited wavelet functions} \]

\[ \varepsilon_w^b = \sum_j \tilde{\varepsilon}_j^b \otimes \psi_j. \]

- A wavelet diagonal model of the correlation matrix is considered by \( C_w = \text{diag} \left( \varepsilon_w^b \right) \), which amounts to calculate local spatial averages of correlation functions, allowing sampling noise to be reduced (Pannekoucke et al., 2007, Berre and Desroziers, 2010).
- In order to increase the sample size (for estimating robust correlations), a 4-days sliding average of correlations is calculated (instead of the usual few-week off-line static average), leading to 96-member sample.

3) Diagnostic and impact results in Arpege 4D-Var

- Background error correlation length-scales of wind are diagnosed by \( L(u, v) = \sqrt{\frac{\sigma_u^2 + \sigma_v^2}{\sigma_\zeta^2 + \sigma_\eta^2}}, \) where \( u, v, \zeta \) and \( \eta \) are zonal and meridional wind, vorticity and divergence.

- Impact results are calculated in terms of RMS by running the Arpege 4D-Var system over a few-week period.

4) Conclusions

- A flow-dependent wavelet modelling can be considered to represent the spatio-temporal dynamics of error correlations.
- Testing this in the Arpege 4D-Var system has a strong positive impact on forecast scores.
- Such a formulation is considered for operational implementation at Météo-France.