Random Parameter Perturbations (RPP) in the AROME EDA

O. GUILLET, L. BERRE, G. ROUX, V. VOGT

Error propagation in data assimilation

- The analysis error and the forecast error evolution can be approximated by the following equations:

$$\epsilon^a = (\mathbf{I} - \mathbf{KH})\epsilon^b + \mathbf{K}\epsilon^o$$
$$\epsilon^f = \mathbf{M}\epsilon^a + \epsilon^m$$

- Effect on data assimilation cycling : accumulation of **observation and model errors** during successive analysis/forecast steps (Berre, 2019).
- Idea of EDA : simulate these error contributions by adding observation and model perturbations and propagating them in successive analysis/forecast steps.
- Purpose of EDA : provide **flow-dependent** $\mathbf{B}$ in AROME 3DEnVar and initialise the AROME EPS.

RPP methodology and framework

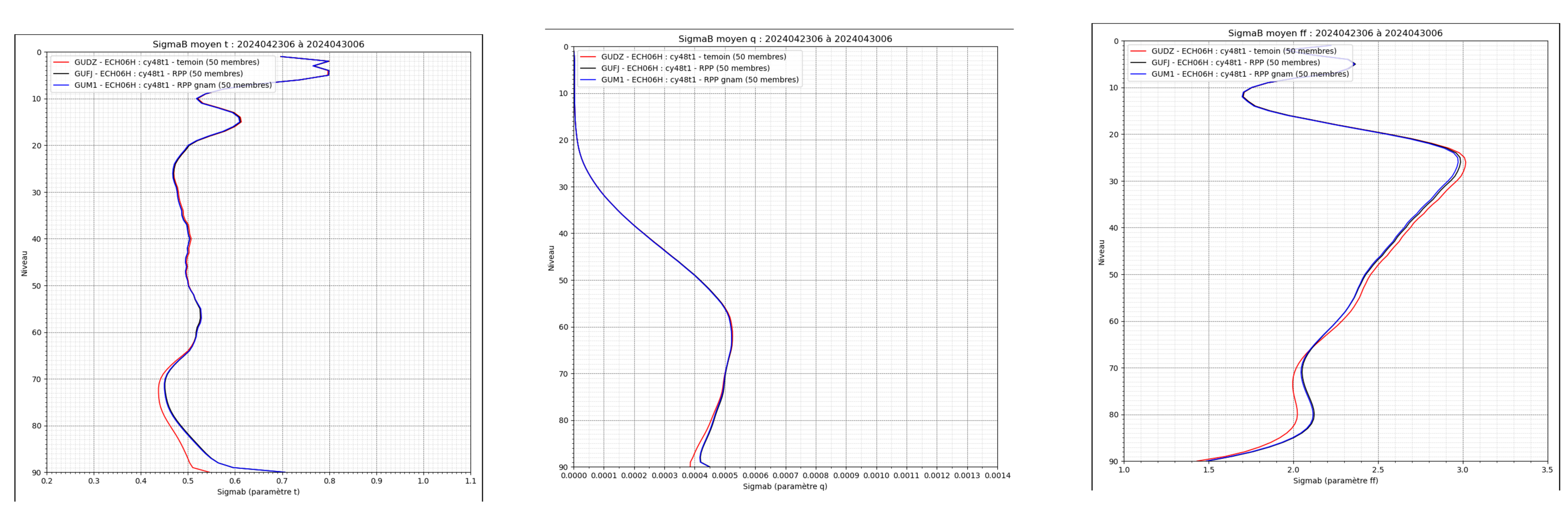
- Arome-EDA: 50 members, 3.2 km spatial resolution, 90 vertical levels, 3D-Var, lateral boundary conditions taken from the ARPEGE-EDA.
- Random observation perturbations (POBS) are generated using $\mathbf{R}^{1/2}$. Model perturbations are produced by the SPPT method, and additionally here by the **RPP method** (Wimmer et al., 2022).
- In the RPP approach, **model parameters are perturbed randomly** for each member of the EDA. Below is a list of perturbed parameters and their min / mean / max value.

Scheme	Parameter	Meaning	Default	Range
Radiation	RSWINHF	Short-wave inhomogeneity factor	1	$0.6 - 1$
	RLWINHF	Long-wave inhomogeneity factor	1	$0.6 - 1$
Microphysics	RCRIAUTI	Snow autoconversion threshold	$0.2 * 10^{-3}$	$(0.02 - 0.25) * 10^{-3}$
	RCRIAUTC	Rain autoconversion threshold	$1 * 10^{-3}$	$(0.4 - 1) * 10^{-3}$
	VSIGQSAT	Constant for subgrid condensation	0.02	$0 - 0.1$
Turbulence	XLINI	Minimum mixing length	0	$0 - 0.2$
	XCTD	Dissipation of temp. and vapour press. fluctuations	1.2	$0.98 - 1.2$
	XCTP	Temp. and vapour press. correlations	4.65	$1.035 - 22.22$
	XCEP	Constant for wind–press. correlations	2.11	$0.225\breve{}4.0$
	XCED	Constant for dissipation of TKE	0.85	$0.4 - 2$
	XPHI_LIM	Threshold value for Sc^{-1} and Pr^{-1}	3	$1 - 4.5$
	XCET	Constant for transport of TKE	0.4	$0.072 - 1.512$
Diffusion	SLHDEPSH	Strength of SLHD	0.060	$0.01 - 0.09$
	SLHDKMIN	Diffusion function minimum	0	$-1 - 1$
	SLHDKMAX	Diffusion function maximum	6	$4 - 12$
Surface	XRIMAX	Critical Richardson number	0.2	$0 - 0.3$
	XFRACZ0	Coefficient for orographic drag	5	$2 - 10$
Convection	XCMF	Closure coefficient at bottom level	0.065	$0 - 0.1$
	XABUO	Coefficient for the buoyancy	1	$0.7 - 1.5$
	XBDETR	Coefficient for the detrainment	$1 * 10^{-6}$	$0 - 1$
	XENTR_DRY	Coefficient for dry entrainment	0.55	$0.1 - 0.699$

Effect of RPP on EDA spread

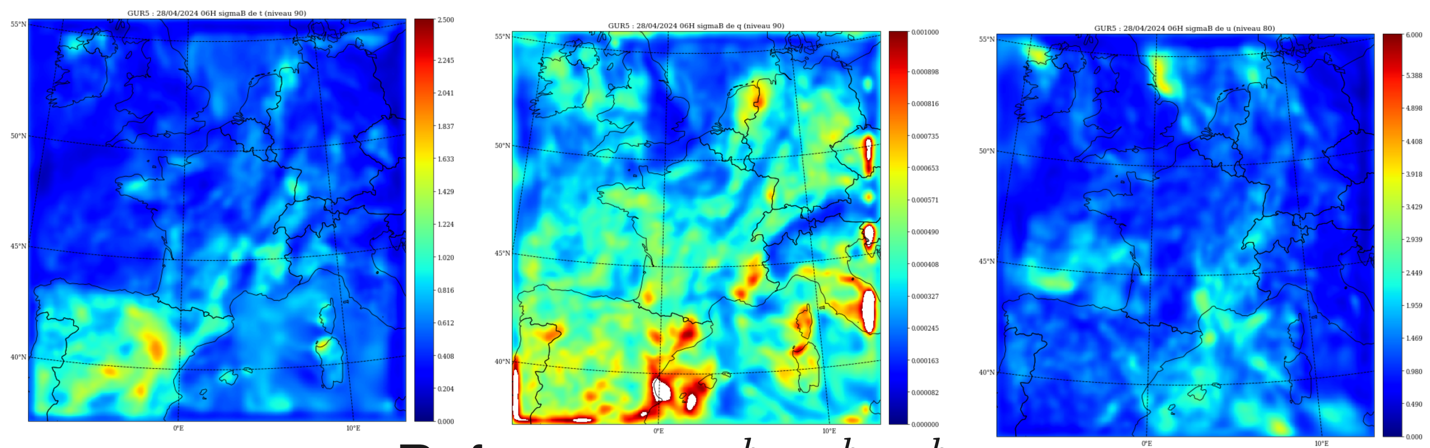
- While the SPPT method influences the spread of the ensemble in the middle troposphere, the effect of the RPP is mostly visible in the **lower troposphere**.
- The increased spread resulting from RPP is represented on the following vertical profiles. Variables : temperature T, specific humidity q and total wind error

$$\sigma^b_{wind} = \sqrt{(\sigma^b_u)^2 + (\sigma^b_v)^2}.$$

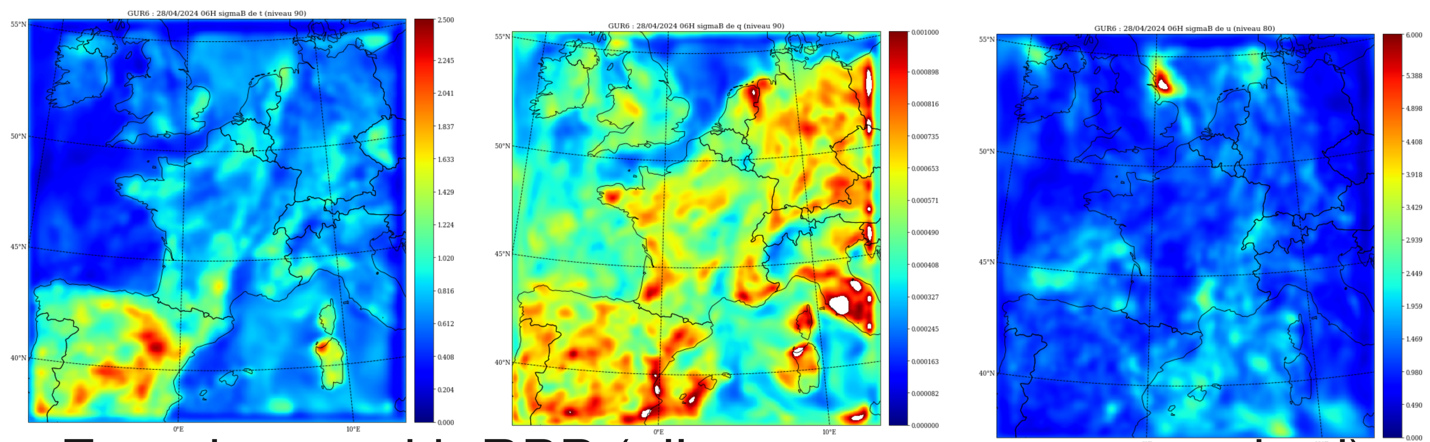


Uncertainty contributions

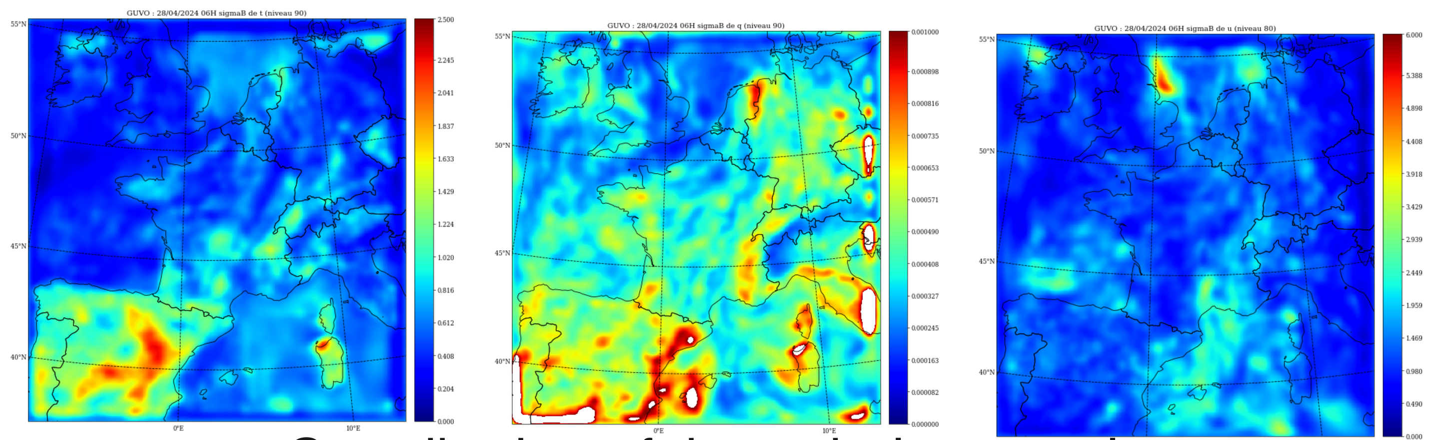
- In practice, the spread of the ensemble obtained via the RPP method is more sensitive to some parameters than to others.
- In the AROME-EDA, the most impactful parameters are related to the **turbulence scheme** and the **surface parameterization**.
- Other parameters, despite their less impactful contribution overall, may be responsible for certain local features (*e.g.* on land vs on the ocean).
- Here are the maps of σ_b for T (level 90) / q (level 90) / wind (level 80). We show the reference (POBS + SPPT), and different versions of RPP (POBS + SPPT + RPP). Date : 28/04/2024.



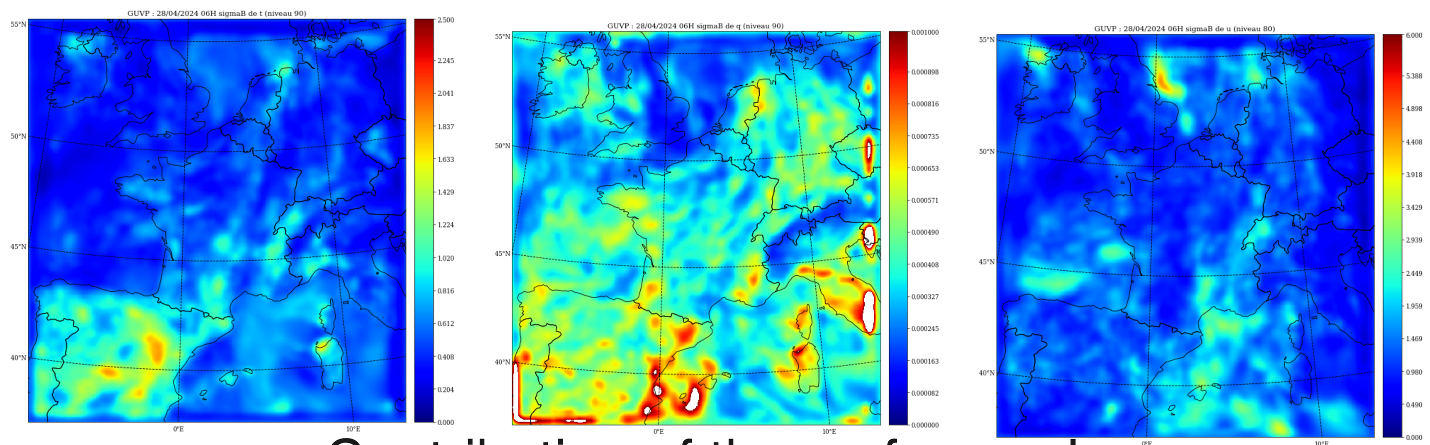
Reference : σ^b_T, σ^b_q, σ^b_{wind}.



Experiment with RPP (all parameters are perturbed).



Contribution of the turbulence only.



Contribution of the surface only.

Conclusions and outlook

- RPP is used to represent model error and increase the spread of the ensemble in the planetary boundary layer.
- It is mostly sensitive to parameters linked with the turbulence and the surface parameterizations.
- Future works will focus on the sensitivy of RPP to the perturbation ranges (mean, min and max values).
- The impact of the new AROME-EDA covariances with RPP on the AROME EnVar system is to be evaluated in the future.

References

- M. Wimmer, L. Raynaud, L. Descamps, L. Berre, and Y. Seity. Sensitivity analysis of the convective-scale arome model to physical and dynamical parameters. Quarterly Journal of the Royal Meteorological Society, 2021.
- Berre L. Simulation and diagnosis of observation, model and background error contributions in data assimilation cycling. Quarterly Journal of the Royal Meteorological Society, 2019.