AROME-EPS
Current status and future directions

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METEO FRANCE
Toujours un temps d'avance

Current AROME-EPS

▷ Operational at Météo-France since 2016

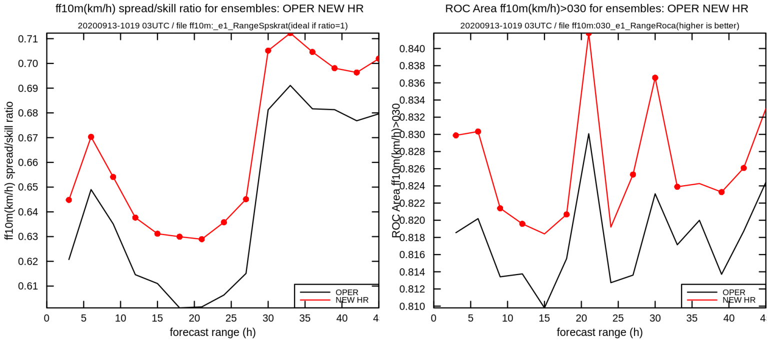
- Based on AROME-France with a 2.5km resolution, 90 levels
- 16 perturbed members (no control run)
- 4 runs/day (03, 09, 15 et 21 UTC) up to 45/51h
- LBCs : subset of ARPEGE-EPS members selected with a clustering algorithm (Bouttier et Raynaud, 2018)
- ICs : from the AROME EDA (ens. of 3D-Vars, Raynaud *et al.*, 2016)
- Model error : SPPT (Bouttier *et al.*, 2012)
- Surface conditions : random perturbations of some variables (e.g., SST, Tground, HUground ; Bouttier *et al.*, 2016)

Future AROME-EPS

▷ Double suite summer 2021, operational early 2022

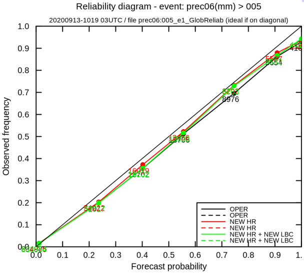
- Horizontal resolution upgrade to 1.3km, same as the deterministic forecast
- 16 perturbed members + control run (deterministic)
- 4 runs/day (03, 09, 15 et 21 UTC) up to 51h
- New AROME physics (see Y. Seity talk : SLHD removed, ECUME v6)
- LBCs from new ARPEGE-EPS (upgrade from 7.5km to 5km over France, new ARPEGE physics, multiphysics replaced by perturbed parameters)
- Perturbations of ICs, model and surface conditions unchanged

Evaluation - 10m wind speed

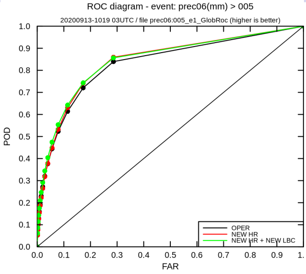


(a) spread/skill ratio (b) ROC area

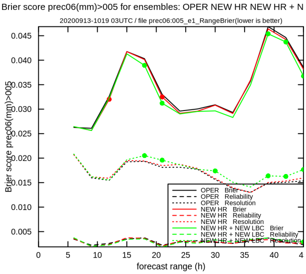
Evaluation - 6h rainfall



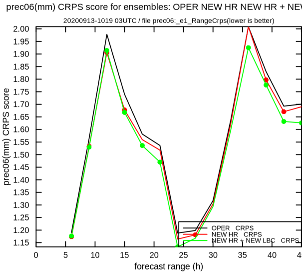
(a) Reliability



(b) ROC



(c) Brier



(d) CRPS

Toward an improved representation of model error

▷ SPPT is known to work quite well but it suffers from a number of limitations, e.g.,

- lack of energy conservation
- vertical tapering still needed to avoid model crashes
  $\Rightarrow$ lower and upper levels are not directly perturbed
- SPPT does not distinguish between different parametrization schemes
- objective tuning of perturbations (amplitude, correlations) requires intensive trial-and-error (computationally expensive)

▷ Two other model error representations are currently under investigation at CNRM : parameter perturbations (PhD M. Wimmer, F. Bouttier) and stochastic parametrizations (PhD A. Fleury)

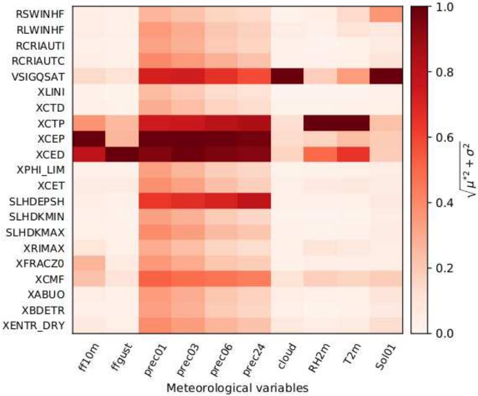
Parameter perturbations

▷ A set of 21 'uncertain' parameters has been defined with physics experts, along with their variation ranges

Scheme	Parameter	Physical meaning	Default	Range
Radiation	RSWINHF	Shortwave inhomogeneity factor	1	0.6 - 1
	RLWINHF	Longwave inhomogeneity factor	1	0.6 - 1
Microphysic	RCRIAUTI	Snow Autoconversion threshold	0.2e-3	0.2e-4 - 0.25e-3
	RCRIAUTC	Rain Autoconversion threshold	1e-3	0.4e-3 - 1e-3
	VSIGQSAT	Constant for subgrid condensation	0.02	0 - 0.1
Turbulence	XLINI	Minimum mixing length	0	0 - 0.2
	XCTD	Constant for dissipation	1.2	0.98 - 1.2
	XCTP	Constant for T-P correlations	4.65	1.035 - 22.22
	XCEP	Constant for V-P correlations	2.11	0.225 - 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 of orographic drag	5	2 - 10
Convection	XCMF	Closure coefficient at bottom level	0.065	0 - 0.1
	XABUO	Coefficient of the buoyancy	1	0.7 - 1.5
	XBDETR	Coefficient of the detrainment	1e-6	0 - 1
	XENTR_DRY	Coefficient for dry entrainment	0.55	0.1 - 0.699

Sensitivity analysis

▷ A sensitivity analysis of AROME to these parameters has been performed using the Morris screening method



▷ 8 parameters have a strong influence : RSWINHF, VSIGQSAT, XCTP, XCEP, XCED, SLHDEPSH, XFRACZ0, XCMF

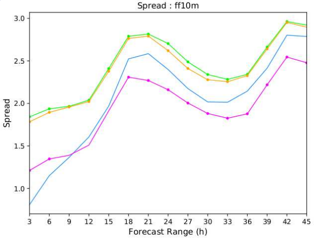
Implementation of PP in AROME-EPS

▷ Two implementations of PP so far :

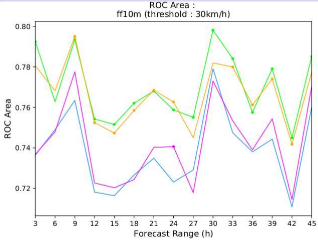
- Optimized PP : parameters values are different for each member but fixed
- Random PP : new parameters values are randomly sampled for each member from a uniform distribution at each production

▷ In both cases there is no spatio-temporal perturbations of the parameters during the forecast.

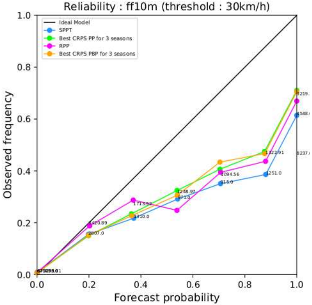
Evaluation of PP - 10-meter wind speed, summer



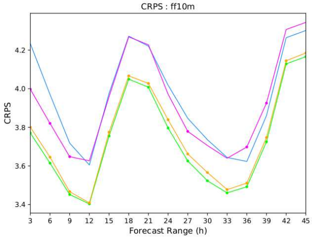
(a) Spread



(b) ROC Area

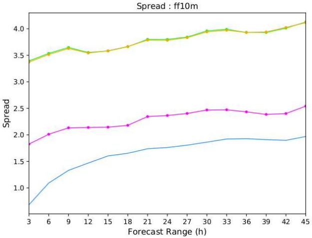


(c) Reliability

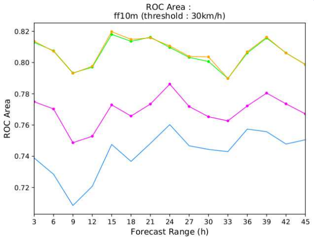


(d) CRPS

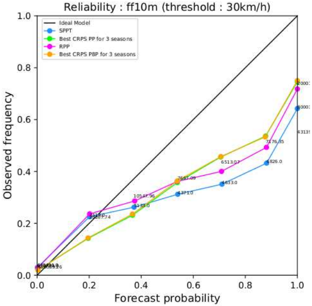
Evaluation of PP - 10-meter wind speed, winter



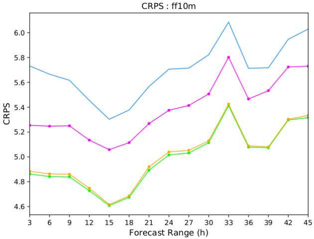
(a) Spread



(b) ROC Area

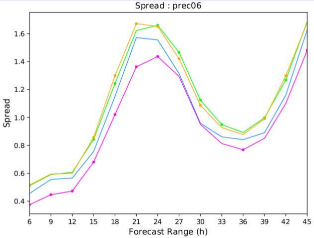


(c) Reliability

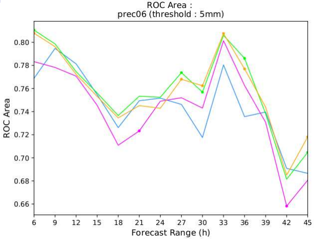


(d) CRPS

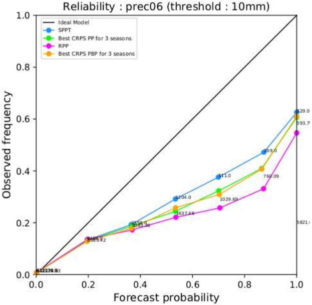
Evaluation of PP - 6h rainfall, summer



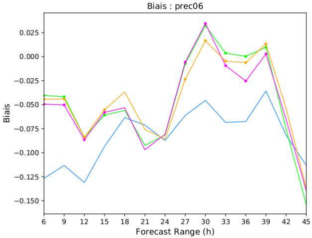
(a) Spread



(b) ROC Area



(c) Reliability

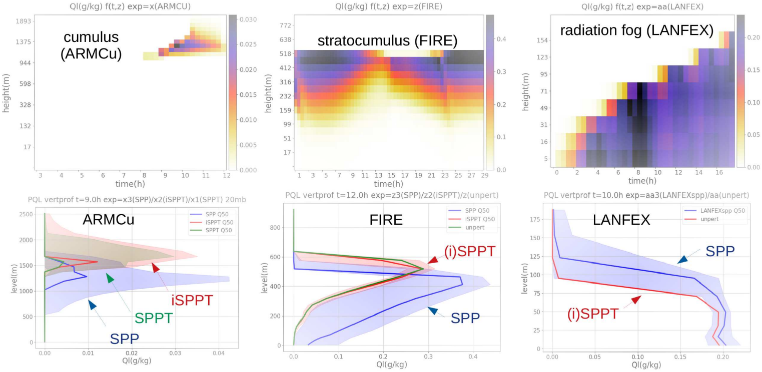


(d) Biais

AROME-1D comparison of SPPT, iSPPT and SPP in 3 regimes

evolution of cloud water profile in deterministic run

vert. prof. ensemble distribution of cloud water



Conclusions:

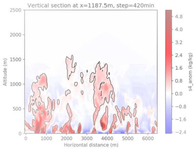
- ensemble response to model perturbations is very situation-dependent
- ensemble perturbations can create unphysical behaviour (e.g. unrealistic cloud structures)
- iSPPT is numerically more robust & more dispersive than SPPT. Both are quasi centered on deterministic run.
- SPP creates more spread, but heavy biases because of locally nonlinear response to physics parameters

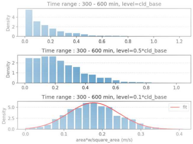
Process-oriented perturbation of turbulence and shallow-convection

- **Stochastic term added to turbulence tendencies which depends on the subgrid variance** (Kober and Craig 2016) :

$$\left(\frac{\partial \phi}{\partial t}\right)^{stoch} = \frac{\partial \phi}{\partial t} + \frac{1}{\Delta t}\,\frac{l_{BL}}{9\,\Delta x}\left(\overline{\phi'^2}\right)^{\frac{1}{2}} \eta$$

- **Stochastic shallow convection scheme** inspired from Sakradzija et al. (2015, 2016) : stochastic closure of the mass-flux based on coarse-graining of LES





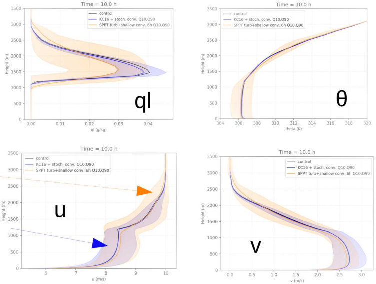
Spread of 100-member Arome-1D ensembles

ARMCu

(cumulus case)

SPPT turb+conv

KC16+stoch.conv.



Conclusions :
- the process-oriented perturbation-based ensemble has lower bias with respect to the reference than the SPPT-ensemble
- reduced spread for temperature and humidity
- wind spread comparable with SPPT but structurally different

Conclusions and future works

- The future AROME-EPS configuration leads to enhanced forecasts, in particular for 10m wind and precipitation
- Perturbed parameters is a promising approach for improving AROME-EPS, but optimization is needed
- Future works will consider RPP with optimized parameters distributions, and SPP
- Comparison and combination of SPPT, iSPPT and PP/RPP/SPP will be pursued.