Arome-EPS in Meteo-France

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Météo-France CNRM

Outline

1. Arome-EPS operational and newer configuration
2. Verification over summer 2025 and winter 2025/2026
3. Case Studies
4. Future evolutions

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1. Arome-EPS operational and newer configuration
   - LBCs perturbations
   - Initial Conditions
   - Surface Perturbation
   - Model error representation
2. Verification over summer 2025 and winter 2025/2026
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Arome-EPS: Operational Configuration

Operational Configuration

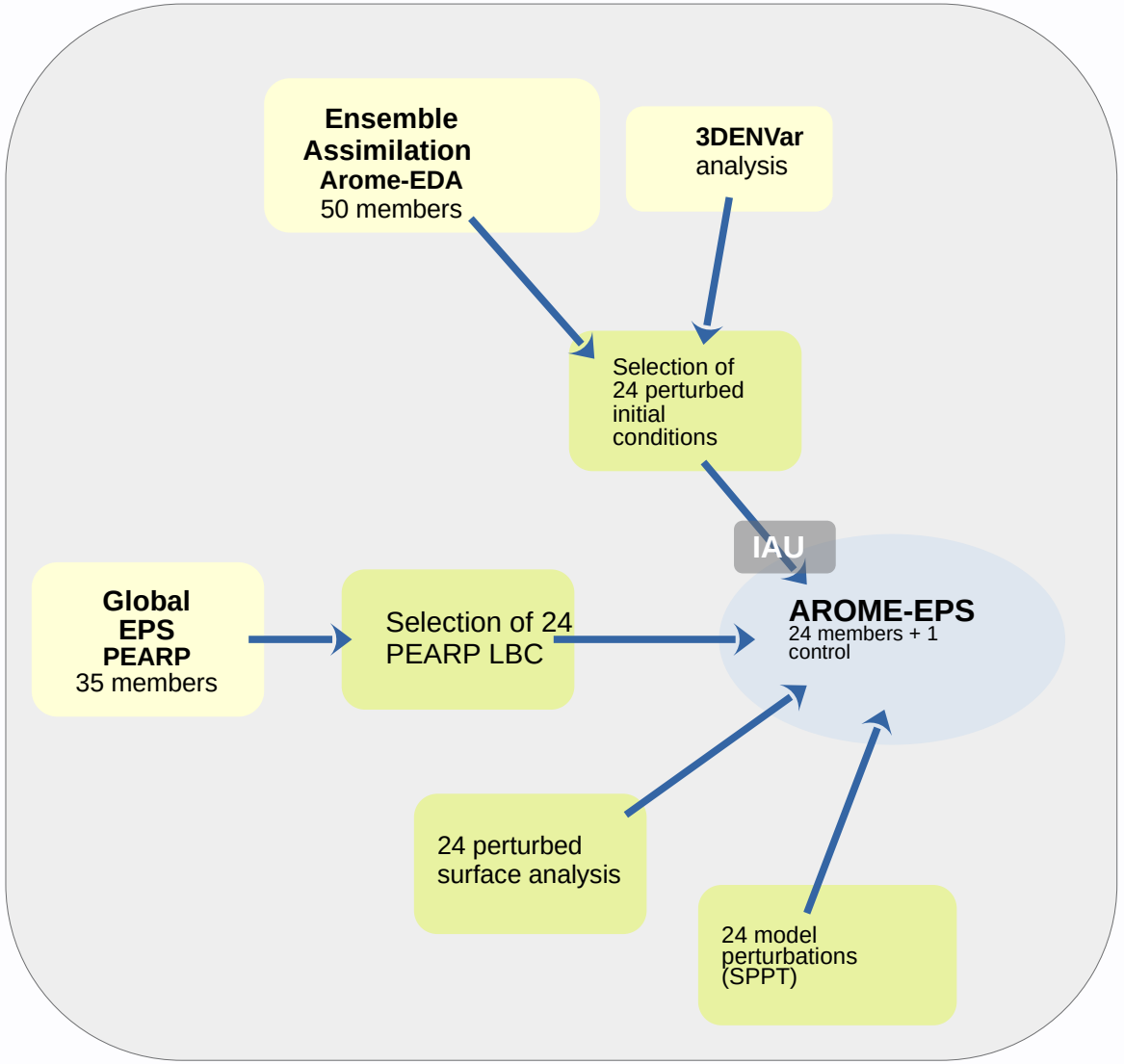
Operational cycle since October 2024: cy48t1_op1

Same configuration as AROME deterministic forecast,
1.3km horizontal resolution, 90 vertical levels, same domain

Four 51h-forecast a day
Initialized at 03h/09h/15h/21h UTC

Main characteristics (since October 2024) :

- 24 pertubed members + 1 control member
- representation of initial uncertainty
- representation of LBCs uncertainty with a coupling to the global EPS PEARP
- representation of model errors with SPPT
- representation of surface analysis uncertainty



Arome-EPS: New Configuration

Operational Configuration

Next Configuration

Operational cycle since October 2024: **cy49t1_op1**

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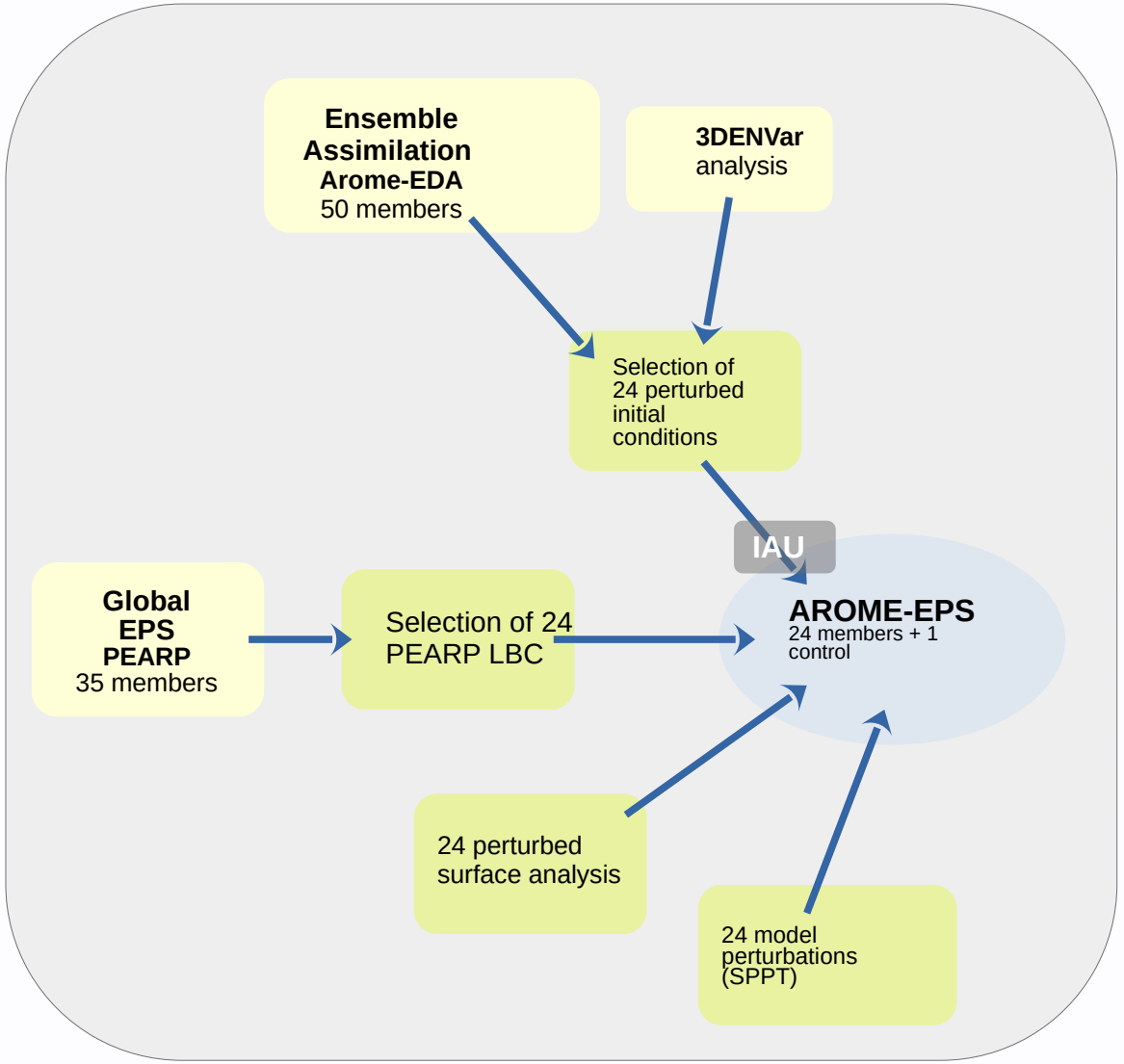

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Arome-EPS: LBCs Perturbations

LBCs from global **ARPEGE-EPS**

34+1 members with perturbations from global EDA, Singular Vectors, RPP, two convective parametrizations

24 clusters created from 34 perturbed members using a hierarchical clustering based on penalyzed Ward algorithm

Metric used : sum of point by point rmsd for 9 variables (U, V, T at 250 hPa, RH at 700 hPa, U, V, Z, RH, T at 850 hpa) at 6 forecast ranges (12h, 18h, 24h, 30h, 36h and 42h forecast)

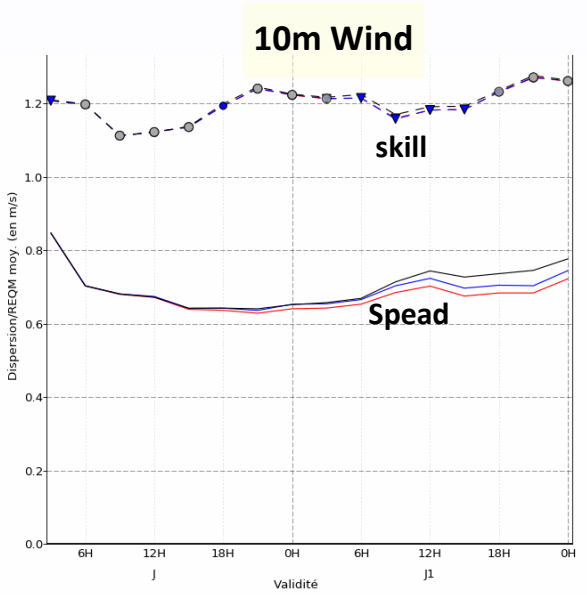
Representative member selected in each cluster: Closest PEARP member from the cluster centroid

Bouttier F, Raynaud L. *Clustering and selection of boundary conditions for limited-area ensemble prediction.* Q J R Meteorol Soc.2018;144:2381–2391.

ARPEGE-EPS changes :

- ARPEGE-EDA : Parameter Perturbation
- No more Singular Vectors
- Surface perturbation (T/Td)
- 1D Ocean Model Coupling

AROME-EPS :
Less dispersion after 24h forecast for all surface variables



Arome-EPS: Initial Conditions Perturbations

Combination of **AROME-EDA** and AROME **3DENVAR** analysis

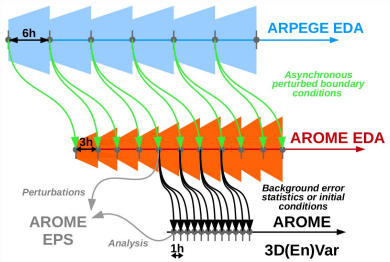
24 perturbed inititial conditions constructed as follows:

1) 24 members randomly selected from 50 Arome-EDA 3.2km members

2) perturbations calculated between each Arome-EDA selected member and Arome-EDA ensemble mean

3) perturbations added to the 3DENVar Arome analysis (1.3 km resolution) with an inflation coefficient

Perturbed analysis added through Incremental Analysis Update (IAU)



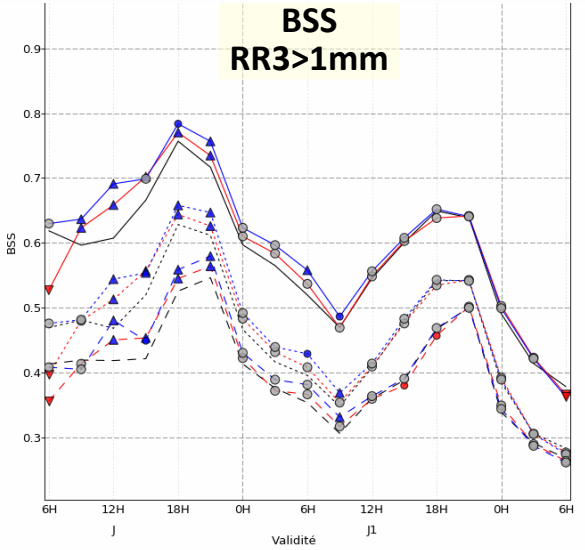
AROME changes :

- 4DENVAR analysis
- Scale Dependant Localisation (SDL)
- Direct assimilation of reflectivities

AROME-EPS :

Less dispersion for first 24h forecast

Improved scores for RR (CRPS, bias, BSS)



Arome-EPS: Surface Perturbations

24 perturbed surface analysis with random perturbations to 9 physiographic and prognostic parameters of the SURFEX surface scheme

Multiplicative perturbation for vegetation index, heat coefficient, leaf area index, soil moisture, land albedo, land roughness length, snow depth

Additive perturbation for soil temperature and sea surface temperature

Bouttier F, Raynaud L, Nuissier O, Ménétrier B. 2016. *Sensitivity of the AROME ensemble to initial and surface perturbations during HyMeX.* Quarterly Journal of the Royal Meteorological Society 142: 390– 403

Arome-EPS: Model Error Representation

Stochastic Perturbation of Physics Tendencies scheme (SPPT)

24 model perturbations based on the **SPPT** scheme

- Multiplicative pertubation for physical tendencies of wind, temperature and water vapour at each timestep : $\tilde{p} = (1 + \mu r)p$
- No perturbation near surface (below 2000m) and near the model top (above 200 hPa)

Bouttier, F. et al. 2012 : Impact of Stochastic Physics in a Convection-Permitting Ensemble. Monthly Weather Review

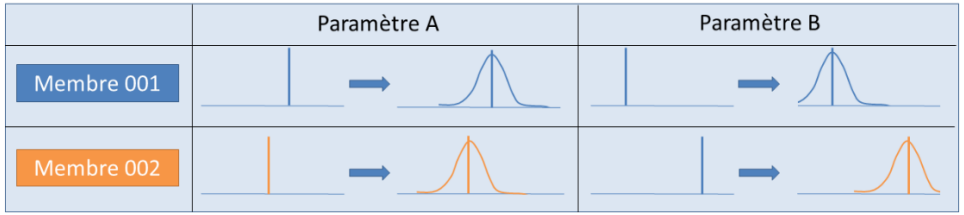
Simple and effective method with good results, but:

- no perturbation with a zero trend, in the lower layers and towards the top of the model
- inconsistencies with surface fluxes,
- same perturbation applied to all physical processes
- difficulty to adjust perturbations (amplitude, correlations)

Random Perturbed Parameter (**RPP**):

adds randomness to the parameter values for each member using a statistical distribution (uniform, Gaussian, log-normal, etc.).

The random draw is performed once at the beginning of the forecast for each member. It does not depend on space or time.

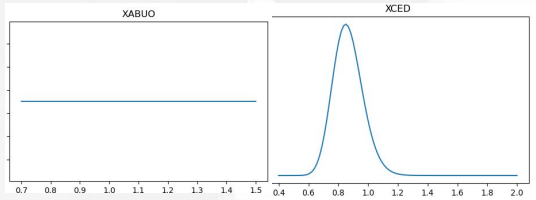


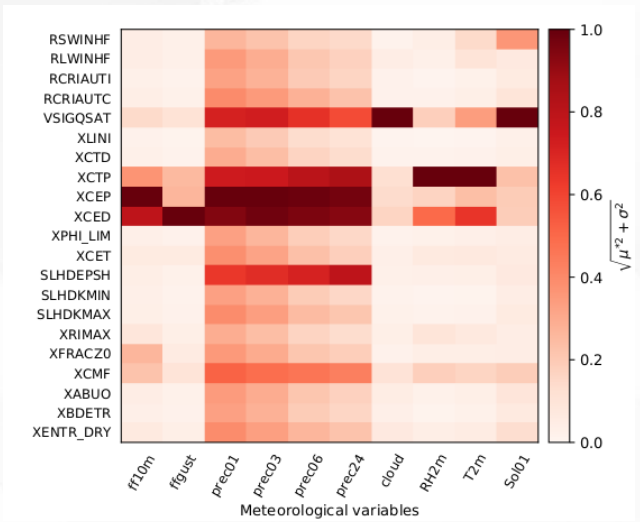
Wimmer, M. (2021) : Représentation de l'erreur de modélisation dans le système de prévision d'ensemble régional PEARO, Université Paul Sabatier Toulouse III

Model errors in Arome-EPS: RPP

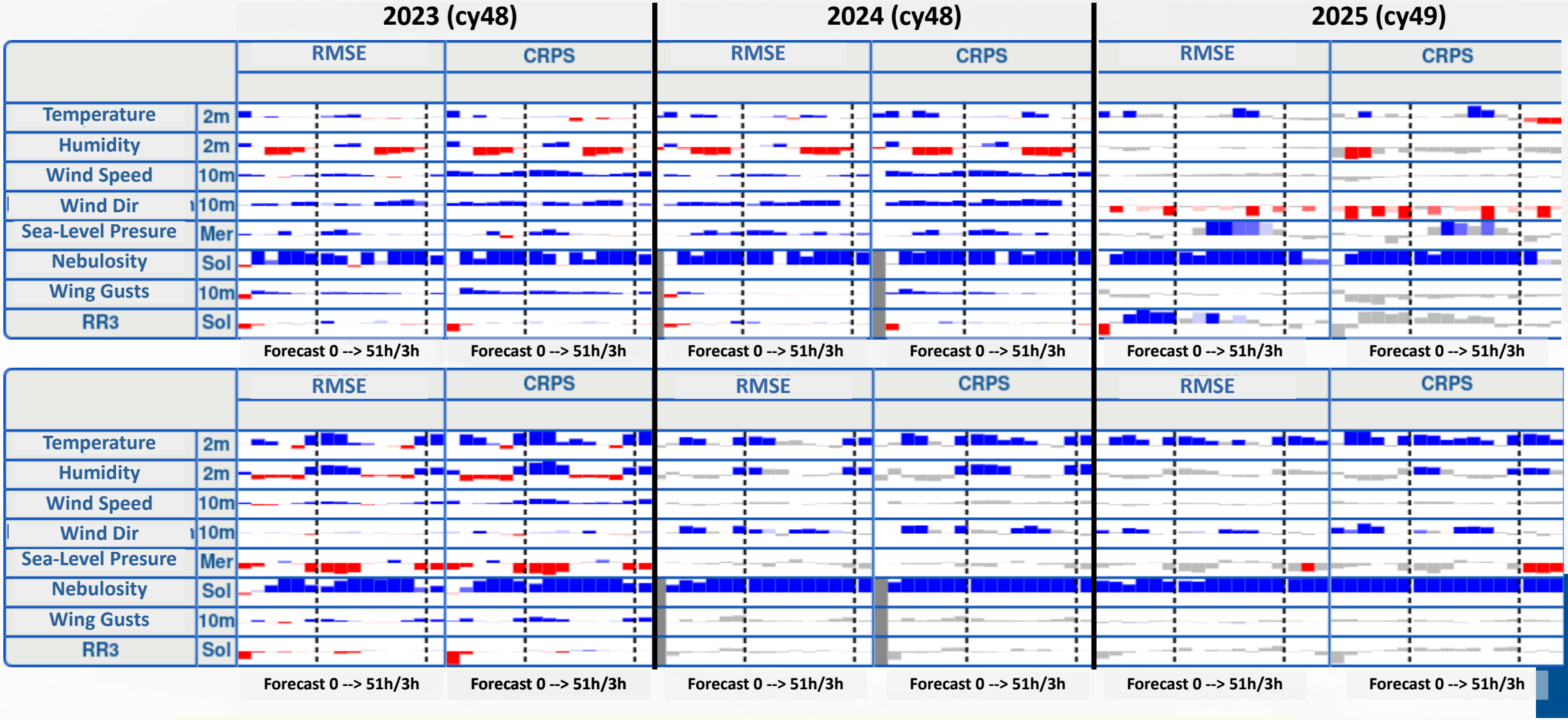
- Evaluations over several long periods between 2021 and 2025 and selective convective events.
- Best configuration chosen for each parameter: range of values, optimal value, distribution, and associated parameters.
- Best scores with Gaussian distributions around a preferred value (obtained using the PP method), but difficult to maintain and systematic biases for each member.
- Selected configuration: perturbation of 19 parameters (in radiation, microphysics, turbulence, surface, and convection schemes) by combining RPP (with uniform or Gaussian distribution for XCED and VSIGQSAT) and SPPT (despite drying out of the lower layers in some of the episodes studied)

Scheme	Parameter	Physical meaning	Default	Range
Radiation	RCADECOR	First coeff in the eq of Decorrelation	0,75	0,375-1,125
	RCBDECOR	Second coeff in the eq of Decorrelation	2,149	1,0745-3,2235
Microphysics	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 of temperature and vapor pressure fluctuations	1.2	0.98 - 1.2
	XCTP	Constant for temperature and vapor presure correlations	4.65	1.035 - 22.22
	XCEP	Constant for wind-pressure 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
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





Scorecards for winter/summer 2023/2024/2025

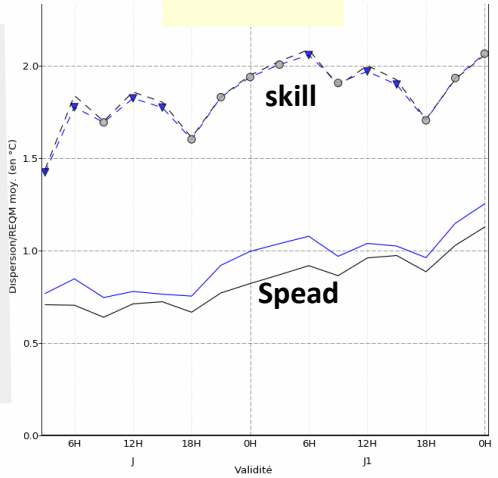


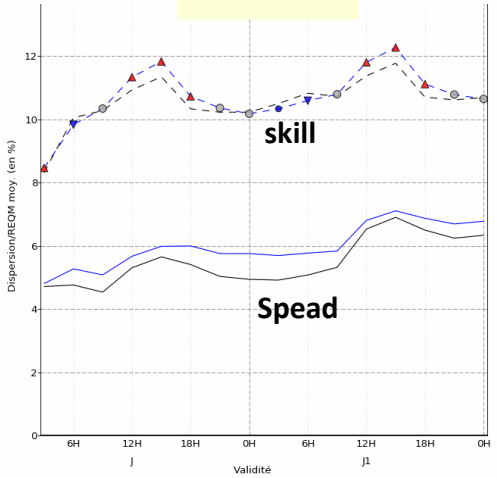
ScoreCards (**Blue** : RPP better / **Red** : RPP worse / Max = 8 % / Brighter : 95 % confidence)

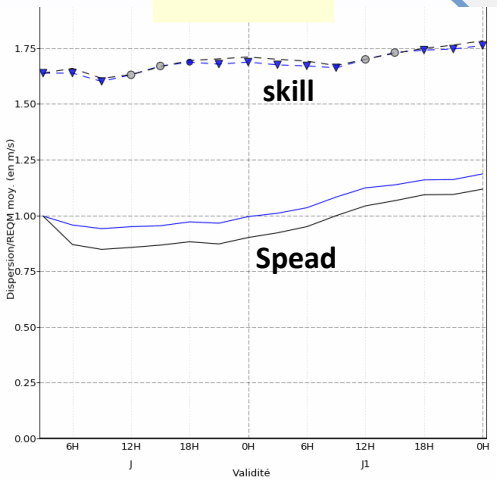
Skill/spread for winter/summer 2024

2m T | **2m RH** | **10m Wind**

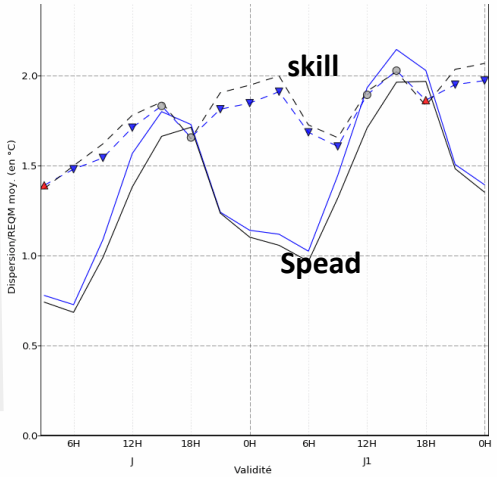
Hiver 2024

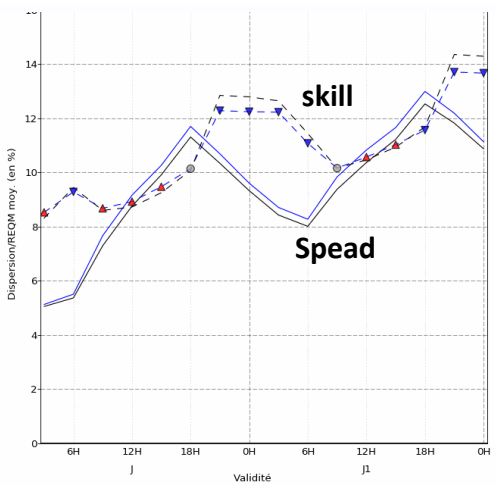


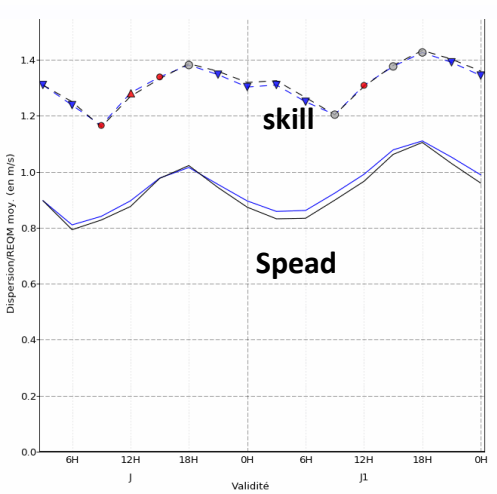




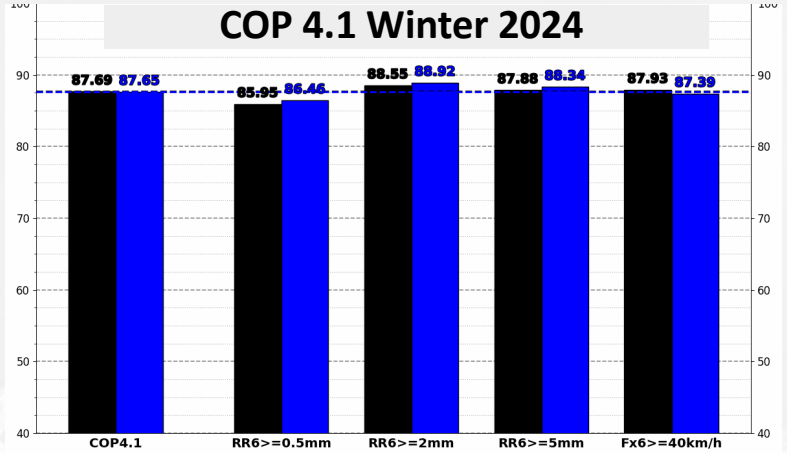
Eté 2024

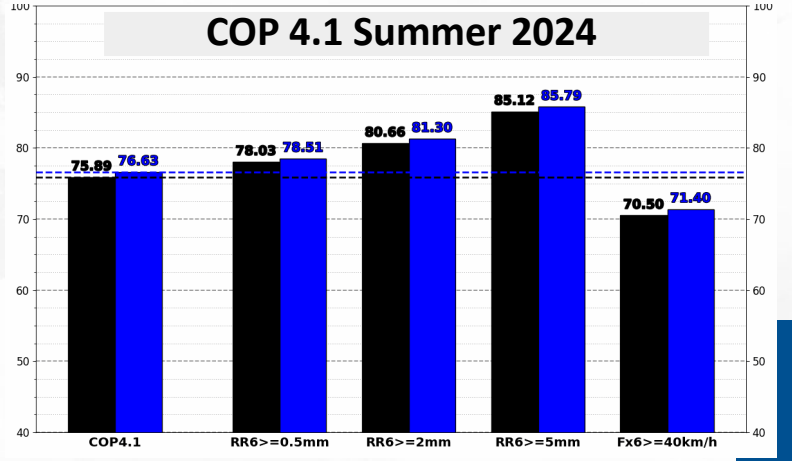






Blue : RPP / Black : NO RPP / Triangle : statistically significant





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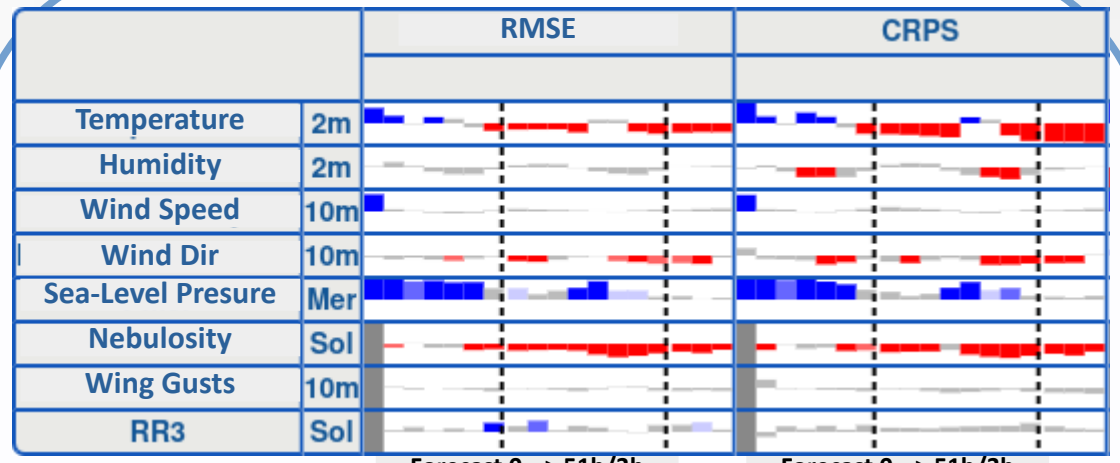
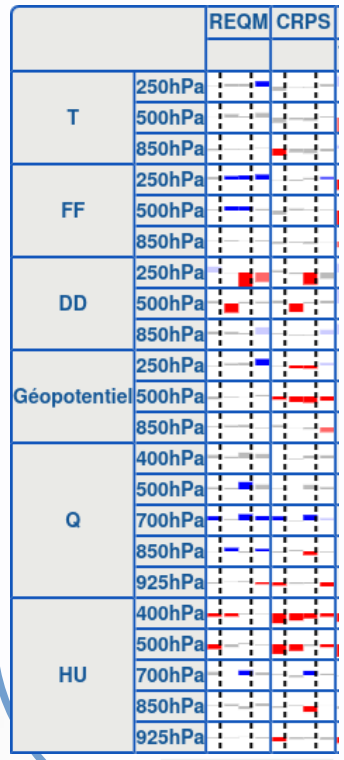
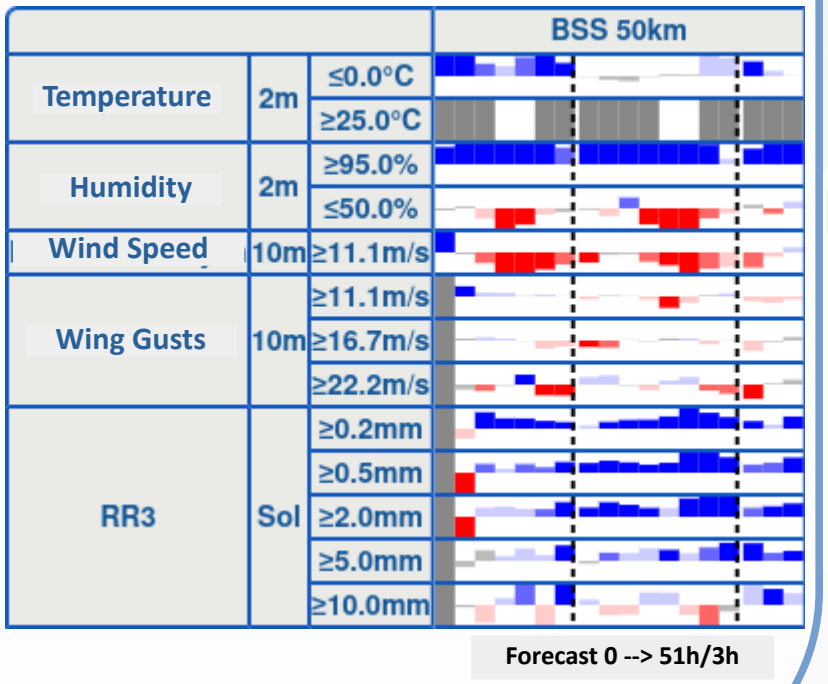
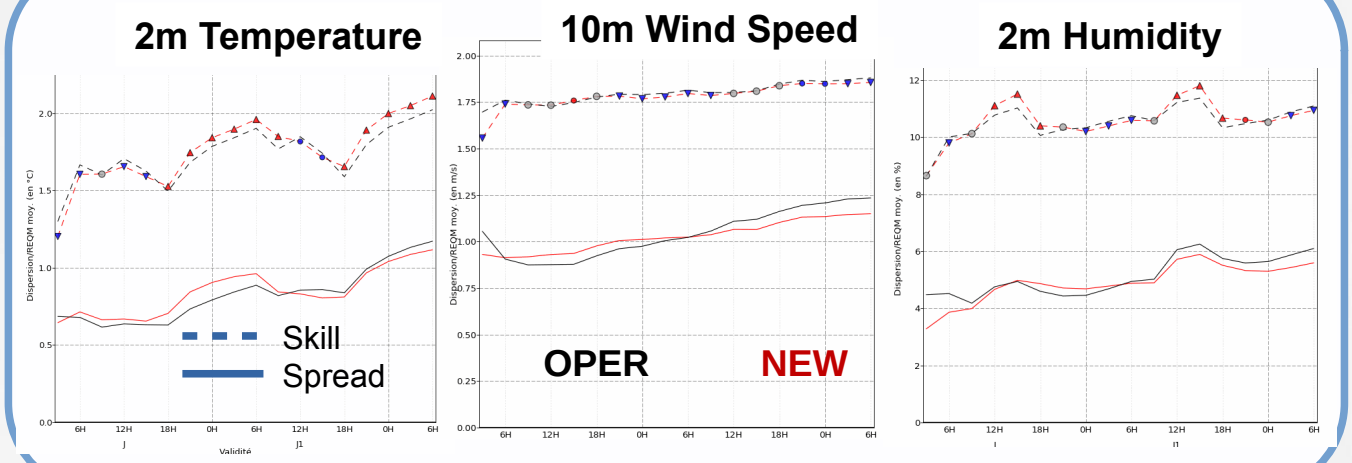
Newer Arome-EPS verification: Dec 2025 – Feb 2026

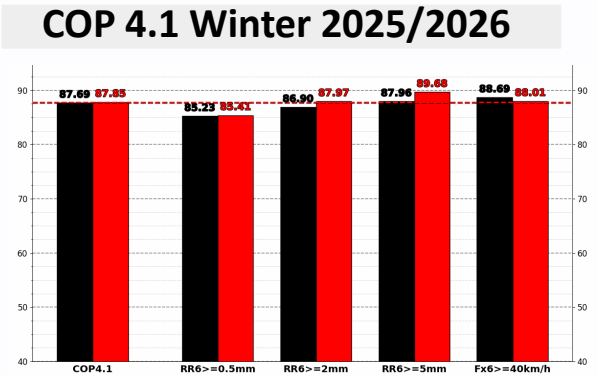






ScoreCards (**Blue** : better / **Red** : worse / Max = 8 % / Brighter : 95 % confidence)



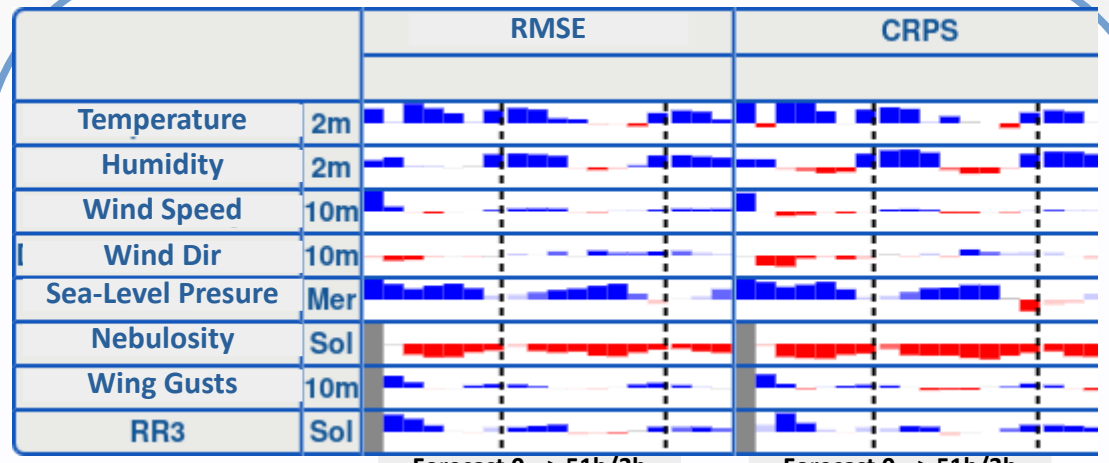


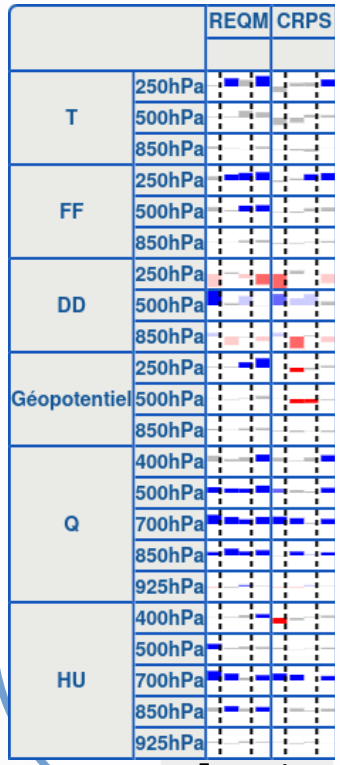
Improvement for wind speed, sea-level pressure and RR.

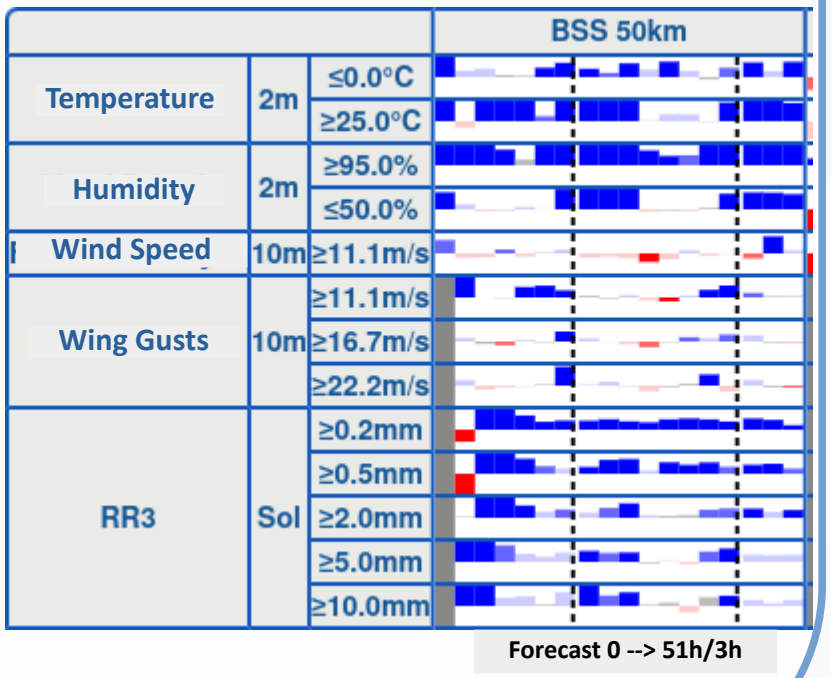
Bias degradation for humidity et BSS for wind gusts.

Slight improvement for COP4.1 thanks to better BSS for RR for all thresholds.

Newer Arome-EPS verification : May-August 2025







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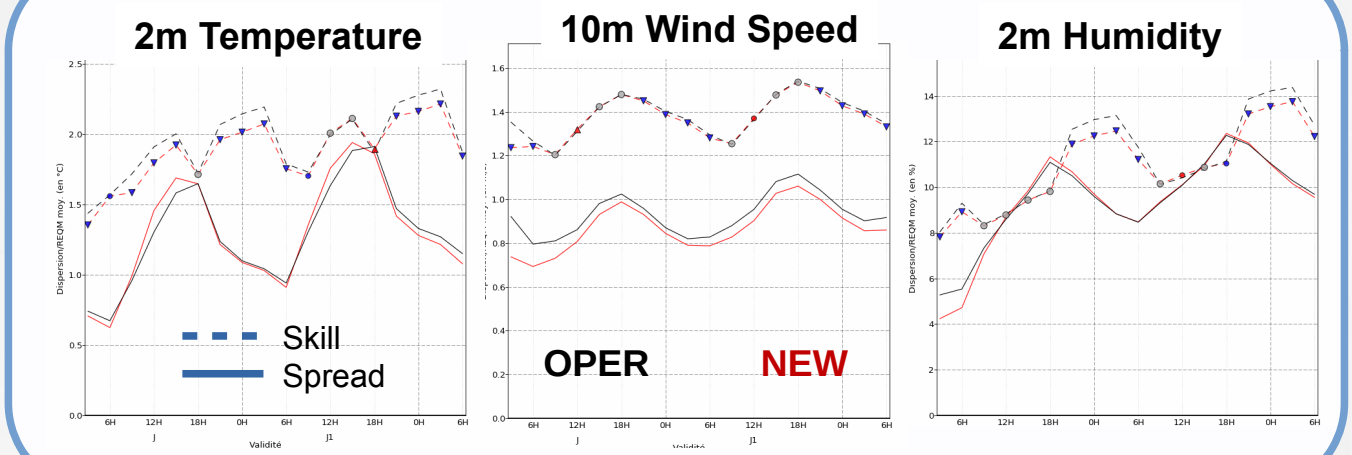

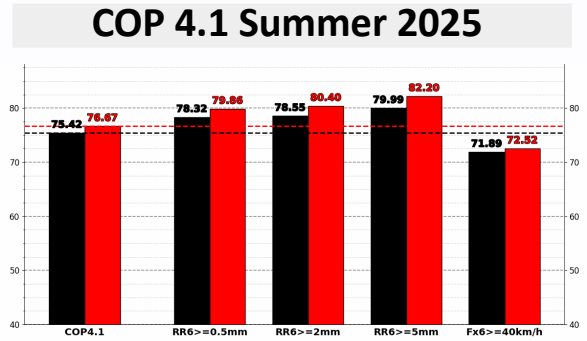

Improvement skill/CRPS for temperature, humidity, sea-level pressure and wind speed (less spread).

Improvement COP4.1 (BSS wind gusts and RR).

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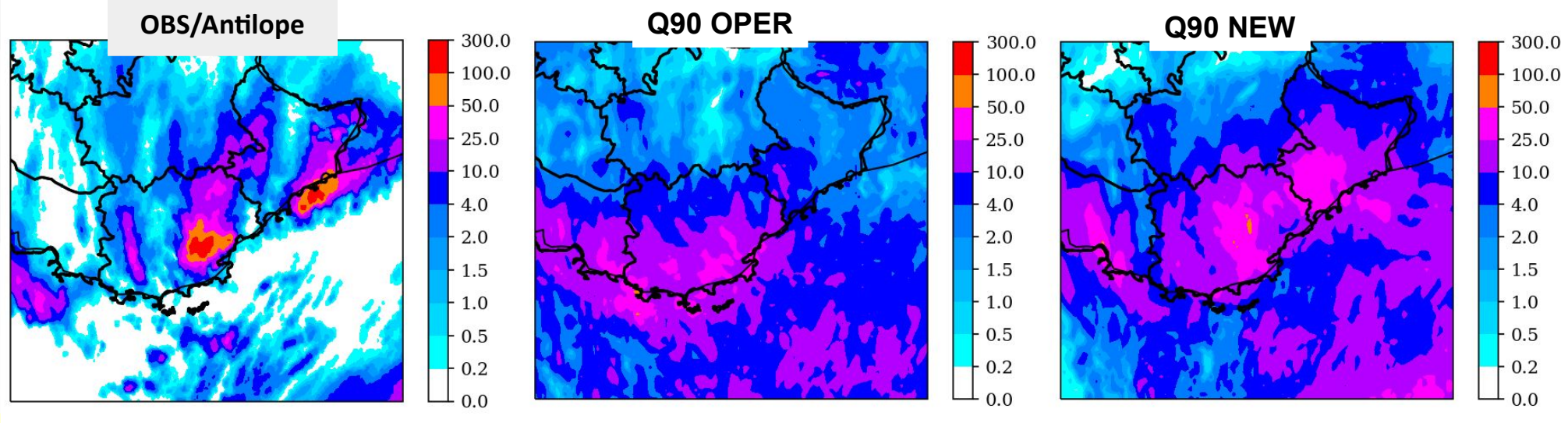
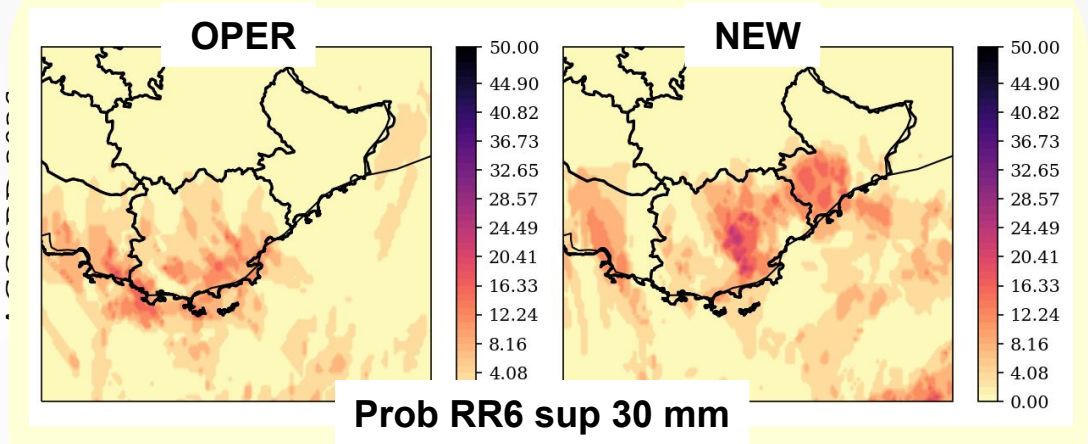
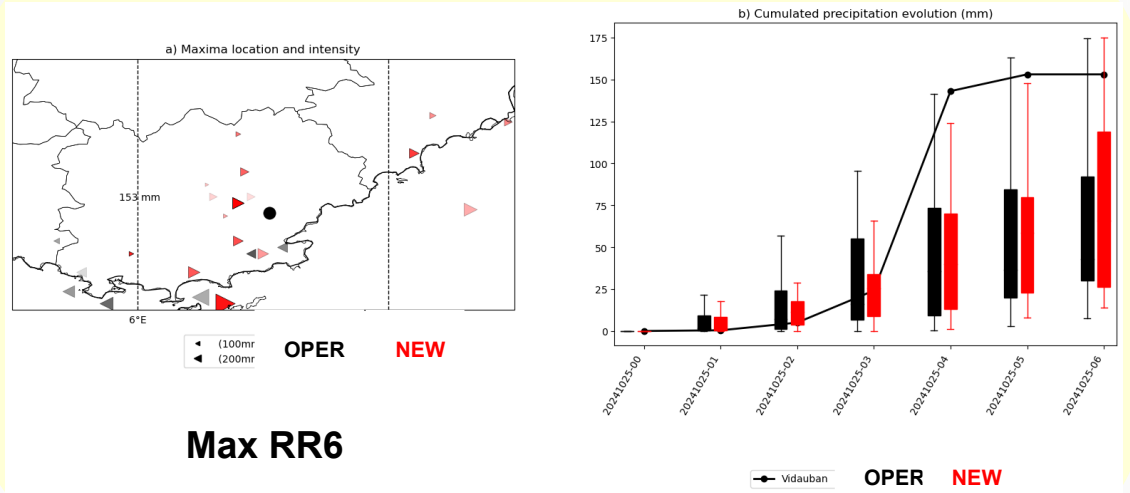
Violent storm around Vidauban (Oct 25 2024)

A stationary storm developed around Vidauban during the night of Oct 24 to 25, cumulating 152.9 mm in 6h (119 mm in 1h between 5h et 6h UTC).

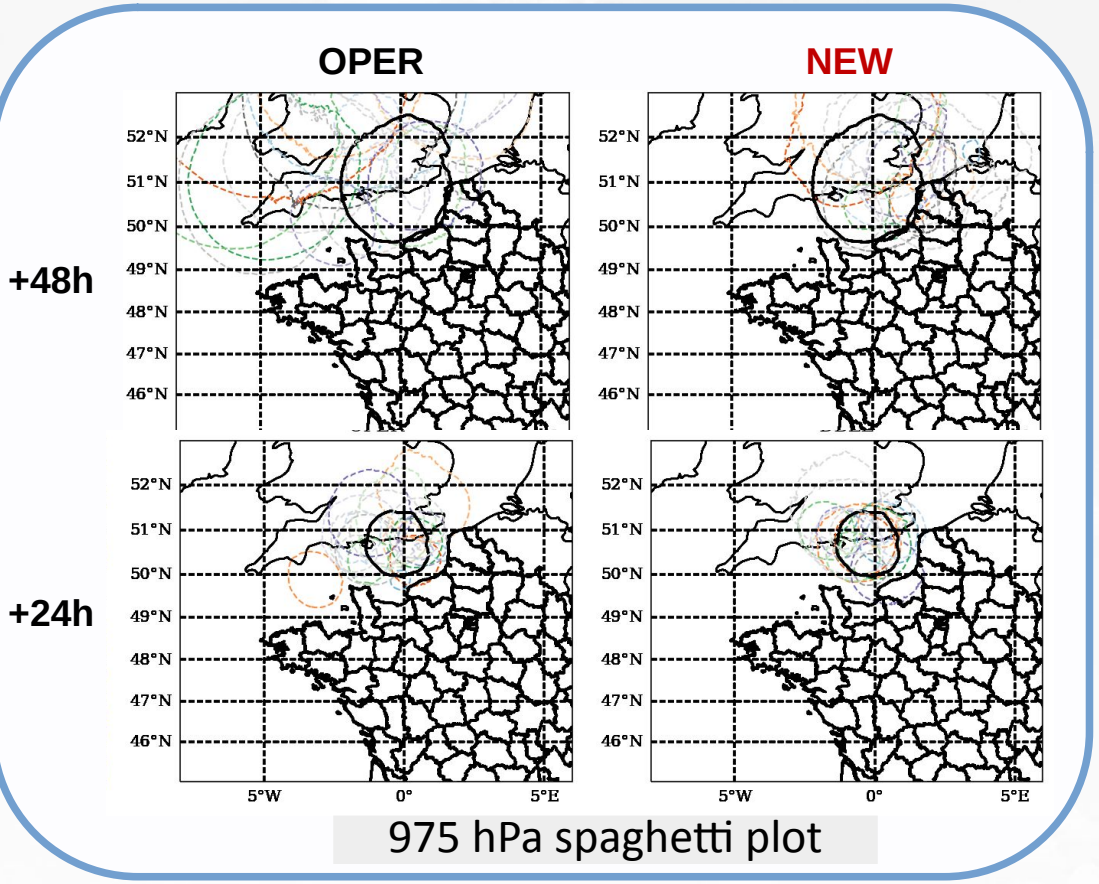




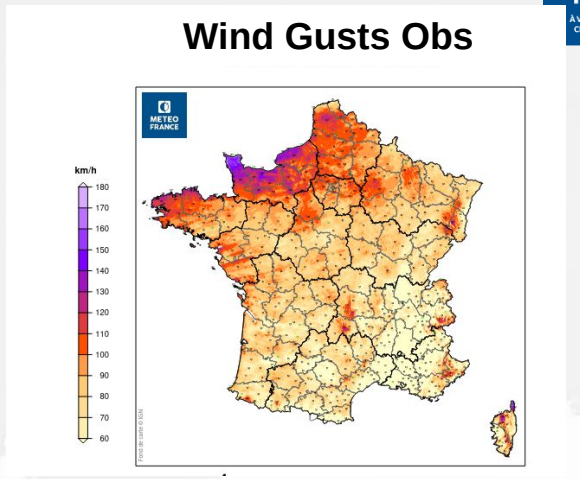


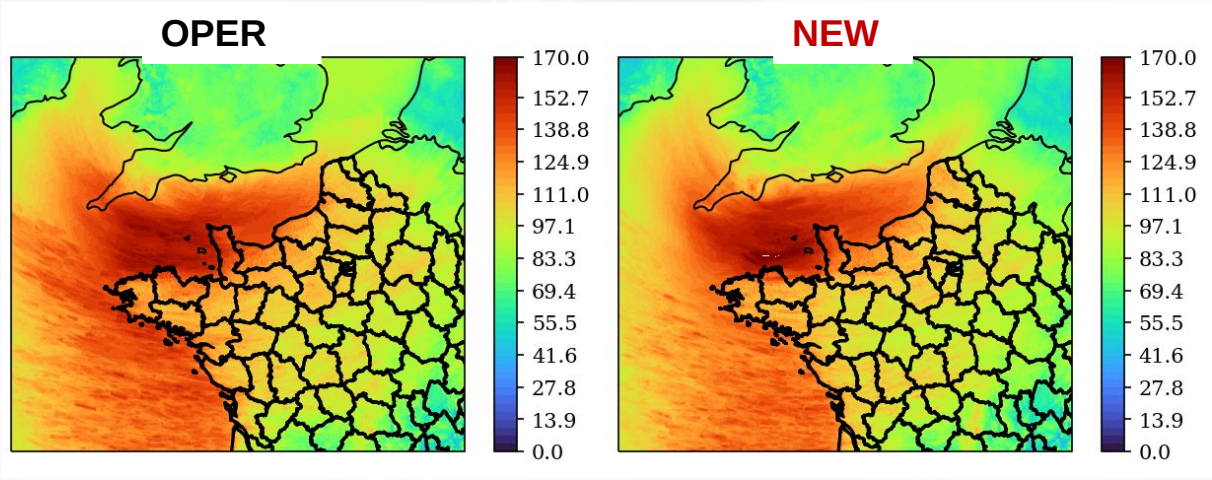
Storm Goretti (January 8-9 2026)

Violent storm rapidly intensifying south of Ireland, followed by zonal flow over southern England. Strong westerly winds, particularly along the French coastal departments on the evening of January 8 and the folowing night, with winds exceeding 150 km/h along the coast.



975 hPa spaghetti plot



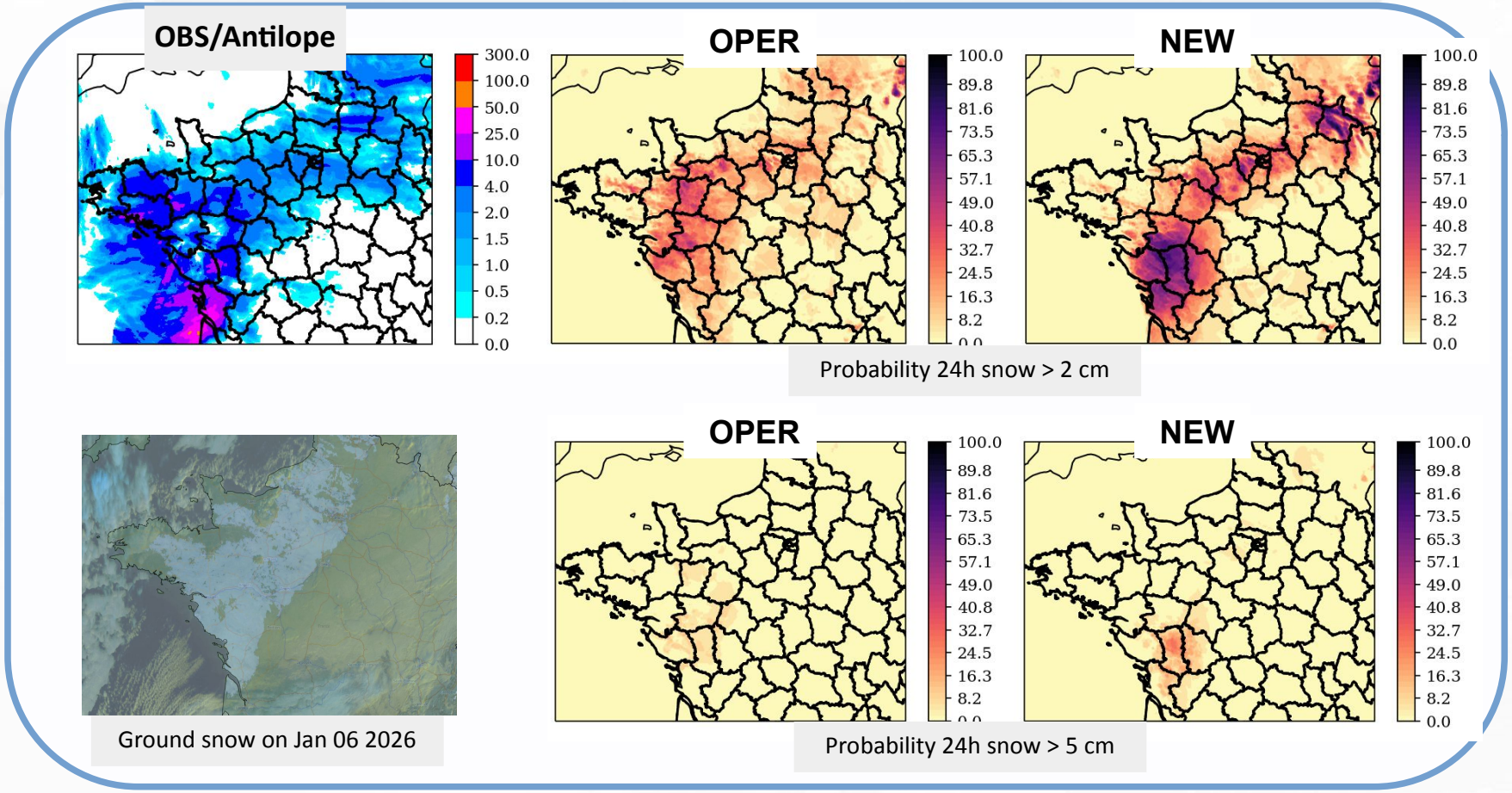


Q90 max wind gusts (km/h)

Significant differences between ARPEGE-EPS operational and newer versions, with a decrease in dispersion, which is also observed in Arome-EPS.

Winter snow storm January 5-6 2026

Winter snow storm over northern and western France on January 5 and the following night, bringing significant snowfall in Normandy (5 to 10 cm), 3 to 5 cm in the Paris region, 5 to 10 cm and locally up to 30 cm on western France.



Ground snow on Jan 06 2026

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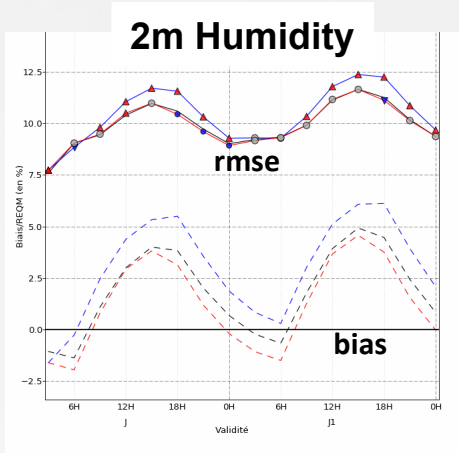
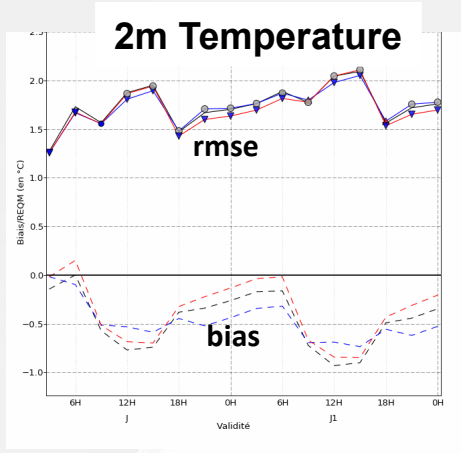
Conclusion

- Arome-EPS cy49 is currently being tested in operational mode, available to forecasters:
  - During the summer season, overall improvement (CRPS, skill, BSS) for all surface variables, particularly for temperature and precipitations. Less spread for wind speed.
  - During the winter season average scores are more mixed, with improved scores for wind speed, sea-level pressure, and precipitation, but a degradation in humidity during afternoons (bias).
  - Improved forecasting of precipitation and wind speed (in terms of location and intensity) during several convective events

Arome-EPS current testings

- RPP : add new parameters (mainly in the EcRad radiative scheme), add parameter correlations, add differentiation/seasonality in parameter perturbation





OPER

NEW

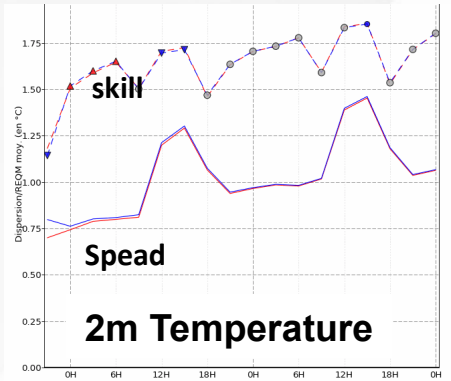
MODRPP

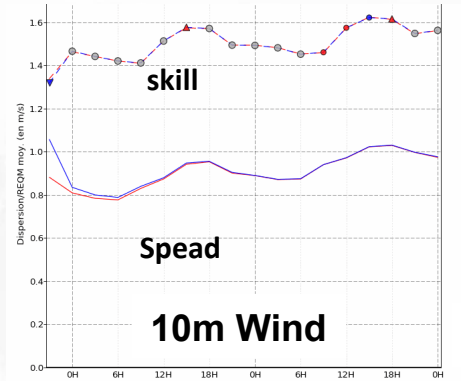
Jan 2025

- Testing of a stochastic parameter perturbation (SPP) version to assess its potential added value compared to the non-stochastic version (on a subset of RPP parameters)

- Random Parameter Perturbations in Arome-EDA

  (cf V. Vogt presentation)





DBLE

AE_RPP

Sept 2025

- Surface perturbations with PertSFC and SPP (CV, LAI, RSMIN)
- Perturbation of Oceanic Mixed Layer 1D model
- AI based systems: probabilistic approaches under development (Arome-AI); enrich Arome-EPS with generative AI

Questions ?

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

METEO FRANCE
À VOS CÔTÉS, DANS UN CLIMAT QUI CHANGE

ACCORD 2026