

Evolution of model error representation in Arôme-EPS: Implementation of a Random Parameter Perturbation (RPP)

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Outline

1. Arome-EPS operational configuration
2. RPP configuration
3. Verification over winter/summer 2023/2024/2025
4. Case Studies

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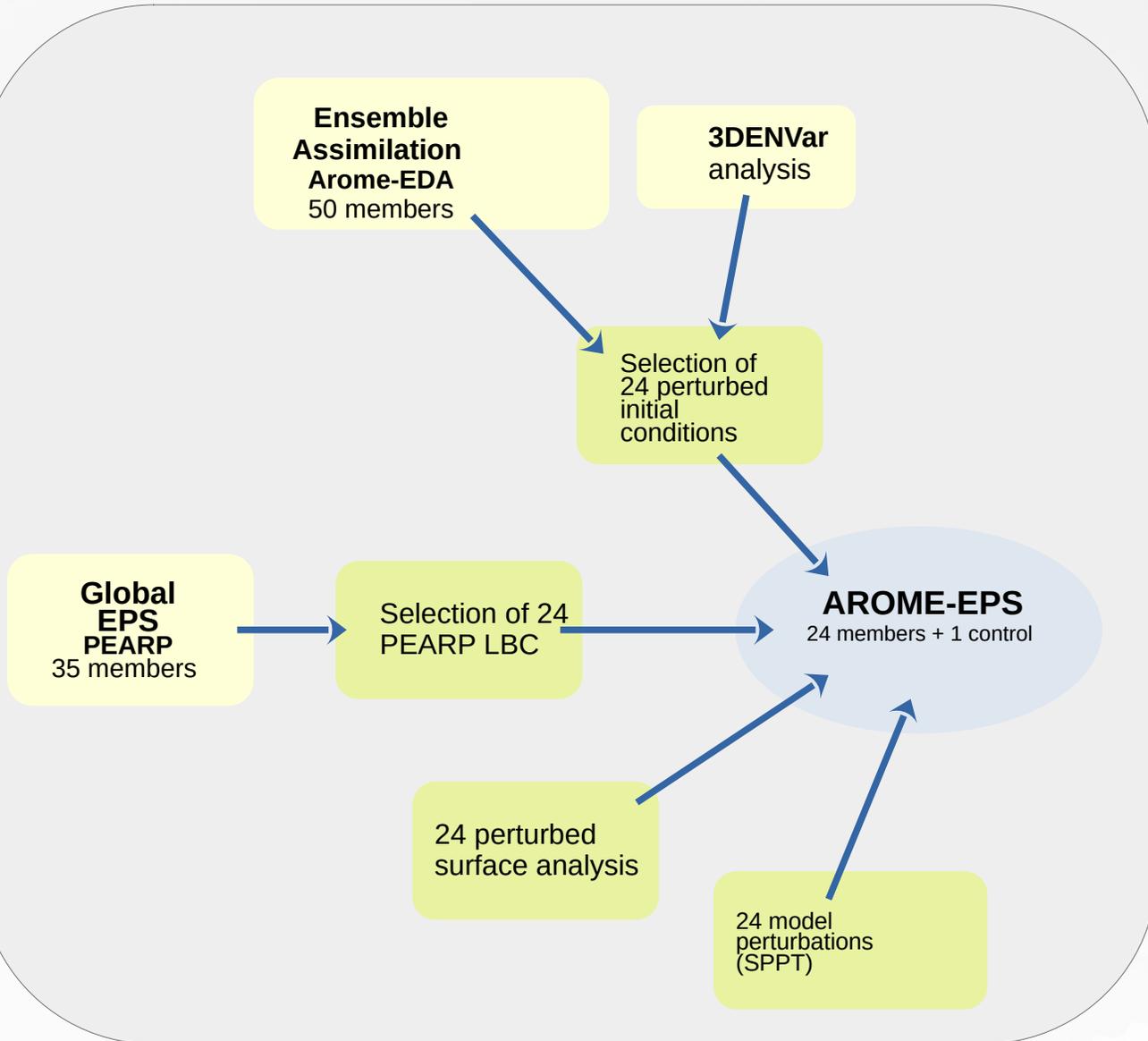
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Arome-EPS: Operational Configuration

Since Octobre 2024 (cy48t1):

- 25 members (including a non perturbed control member)
- 4 runs/day (03, 09, 15, 21 UTC), 51h forecast
- Same configuration as Arome: 1.3km horizontal resolution, 90 vertical levels, same domain
- Several perturbations : initial conditions, model errors, Lateral Boundary conditions, surface conditions

Arome-EPS: Perturbations



LBCs perturbations

24 LBCs from global EPS PEARP (34 members) using clustering

Initial conditions perturbations

Combination of Arome EDA (50 members) and 3DENVar analysis

Surface perturbations

24 perturbed surface analysis with random perturbations on 9 SURFEX variables

Model errors

Stochastic Perturbation of Physics Tendencies scheme (SPPT)

24 model perturbations based on the **SPPT** scheme (Stochastically Perturbed Parameterisation Tendencies) :

- Multiplicative perturbation for physical tendencies of wind, temperature and water vapor 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:

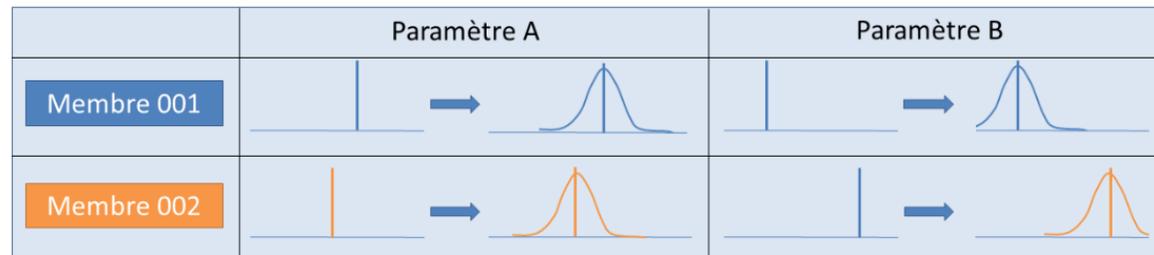
- assumes that the error on the trend is proportional to the trend (\Rightarrow no perturbation with a zero trend)
- no perturbation in the lower layers and towards the top of the model
- inconsistencies with surface fluxes (calculated from unperturbed trends) \Rightarrow energy is not conserved
- difficulty to adjust perturbations (amplitude, correlations)
- same perturbation applied to all physical processes

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Methods based on the perturbation of uncertain parameters of the parameterization schemes were tested by Dr Wimmer during her thesis:

- Perturbed Parameter (PP): each member gets a set of different parameters, that are fixed regardless of the forecast and do not evolve in space and time.
- Random Perturbed Parameter (RPP): this method 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.



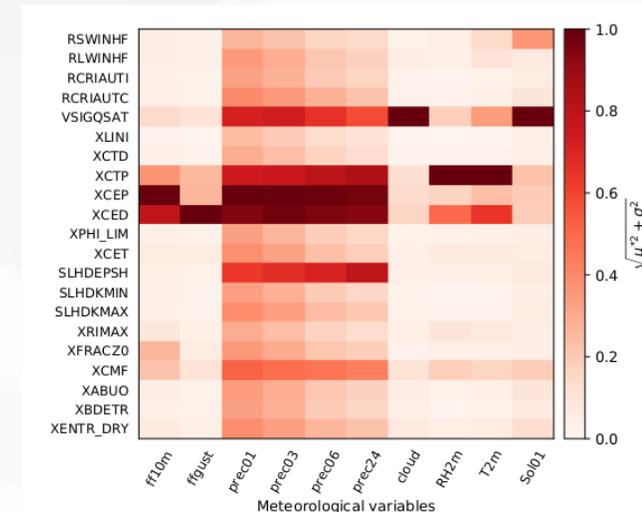
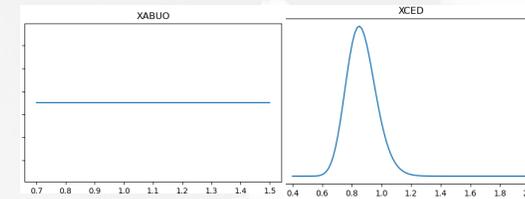
Wimmer, M. (2021) : Représentation de l'erreur de modélisation dans le système de prévision d'ensemble régional PEARO, Université Paul Sabatier Toulouse III

Identification of 21 key parameters from the parameterization schemes with sensibility tests

Wimmer, M., et al. (2022). *Sensitivity analysis of the convective-scale AROME model to physical and dynamical parameters*. Quarterly Journal of the Royal Meteorological Society, 148(743), 920–942

- 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 SPPT (despite drying out of the lower layers in some of the episodes studied)

| Scheme | Parameter | Physical meaning | Default | Range |
|--------------|-----------|-------------------------------------------------------------------------|----------------------------|------------------|
| Radiation | RCADDECOR | 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 pressure 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 |
| 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 |

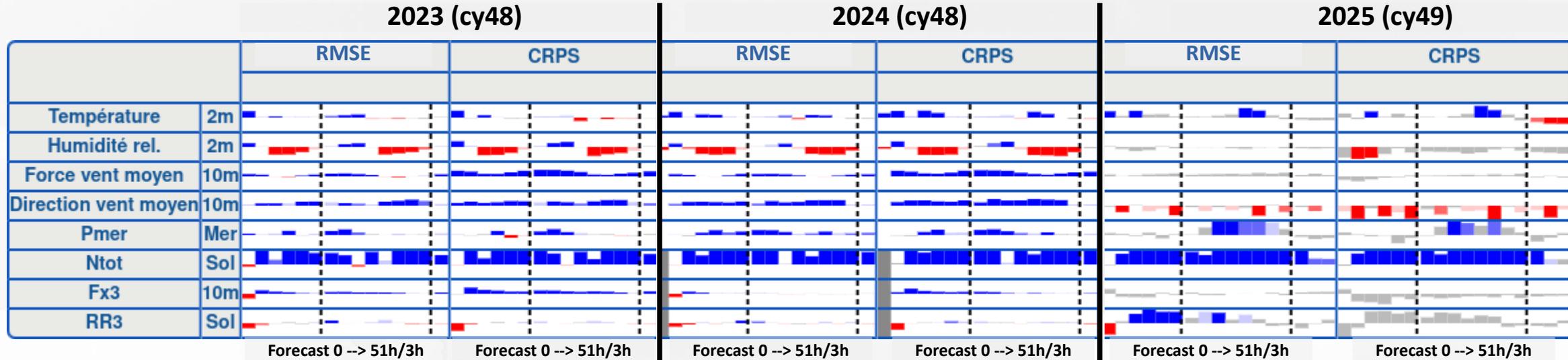


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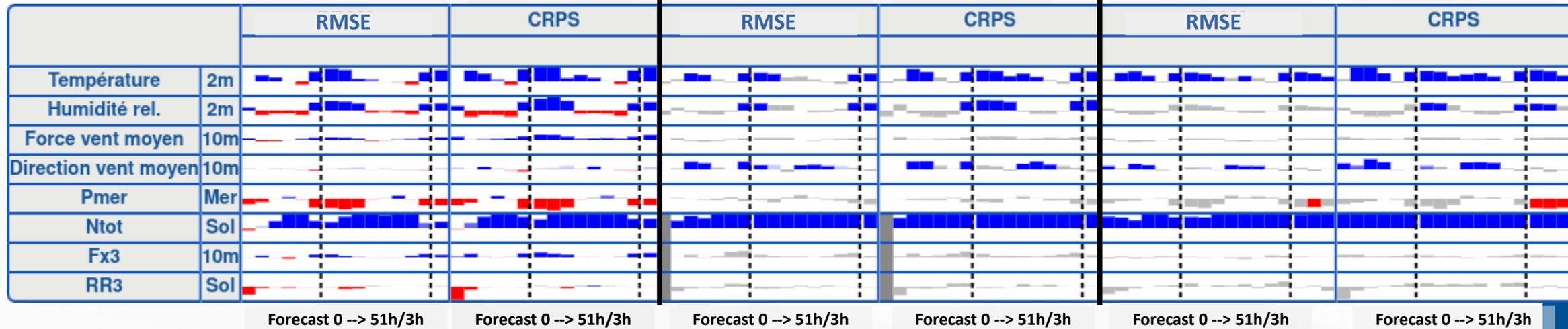
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Scorecards for winter/summer 2023/2024/2025

Winter



Summer

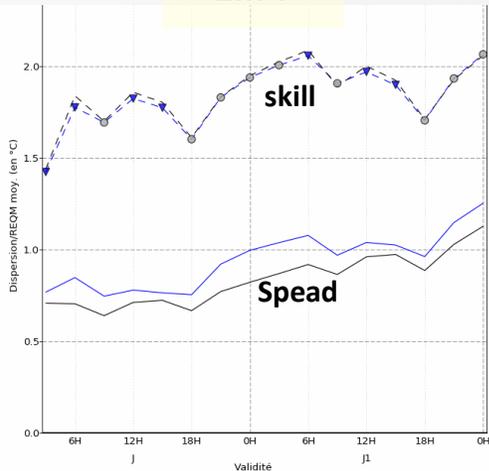


ScoreCards (Blue : RPP better / Red : RPP worse / Max = 8 % / Brighter : 95 % confidence)

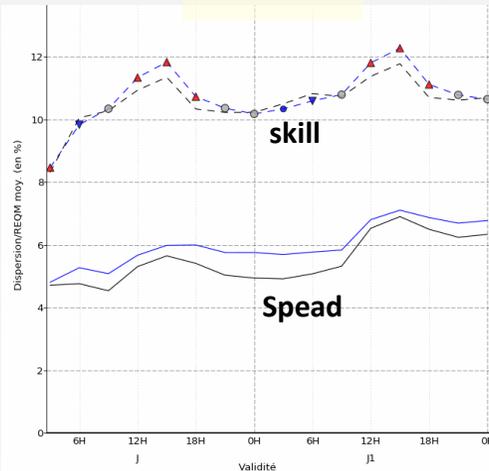
Skill/spread for 2024

Winter 2024

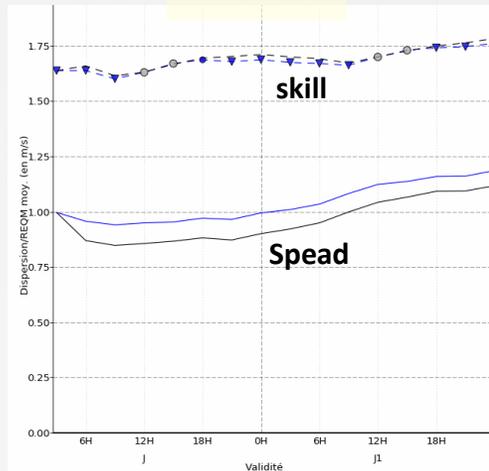
2m T



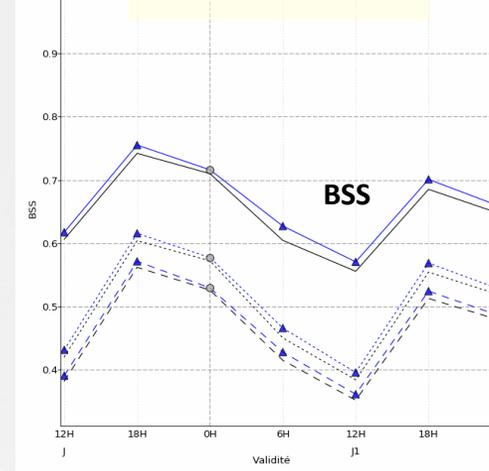
2m RH



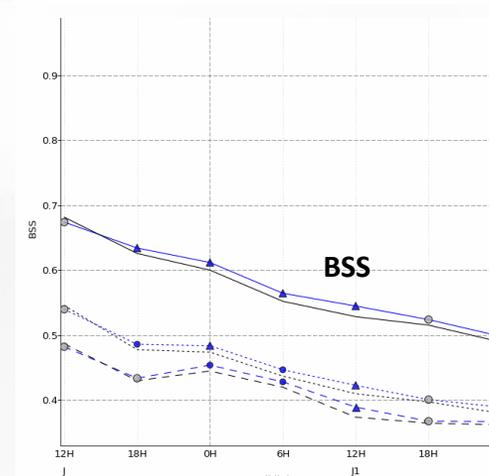
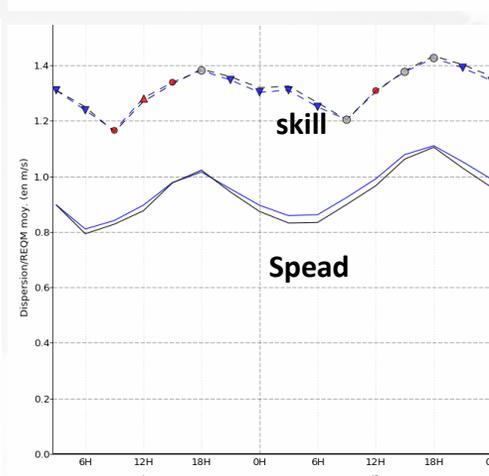
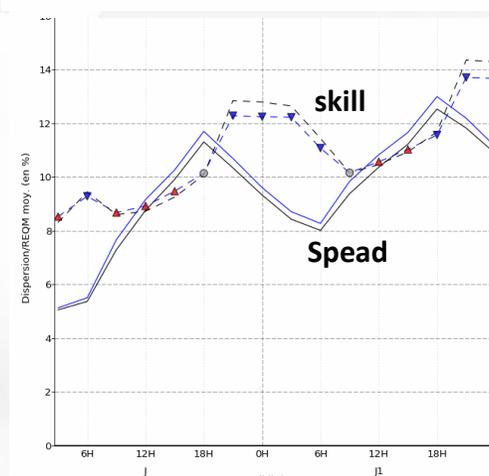
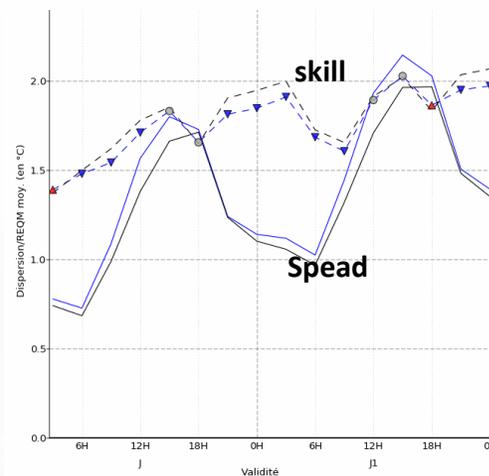
10m Wind



6h RR6 > 0,5 mm

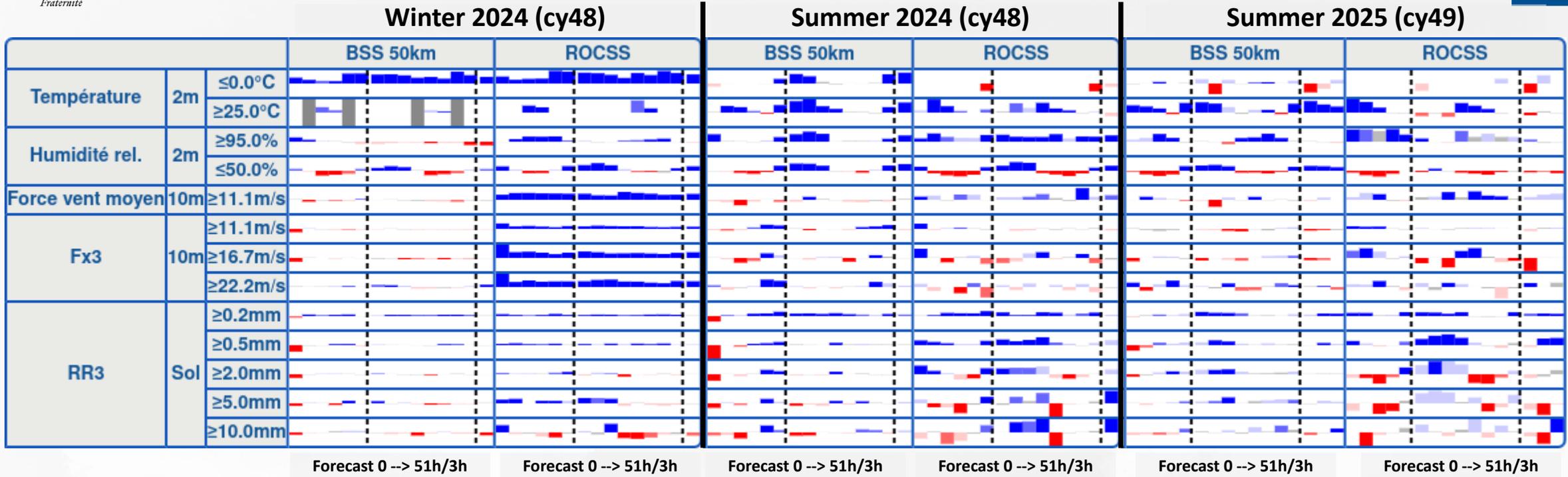


Summer 2024

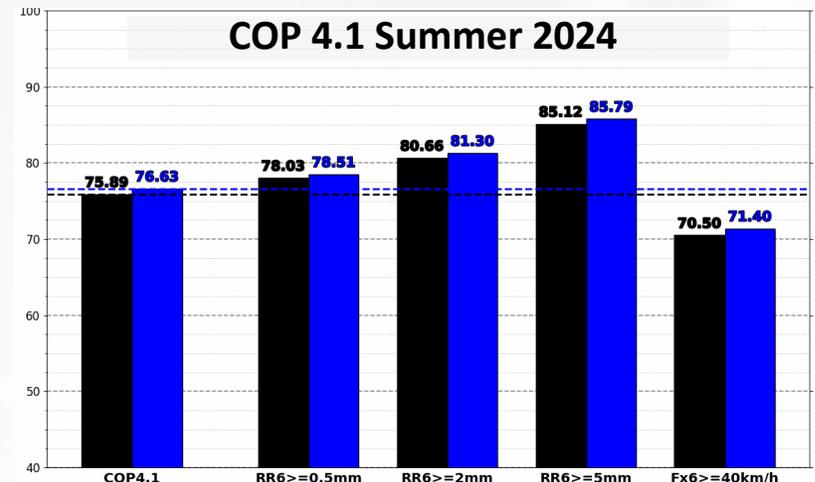
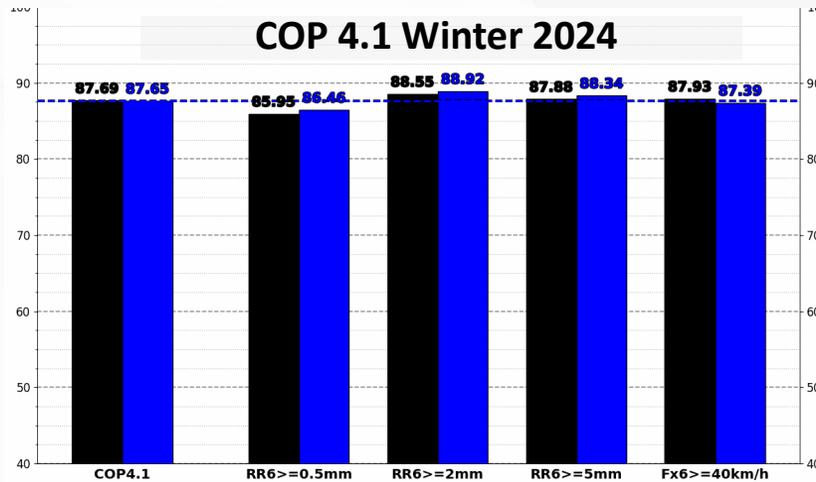


Blue : RPP / Black : NO RPP / Triangle : statistically significant

BSS scorecards



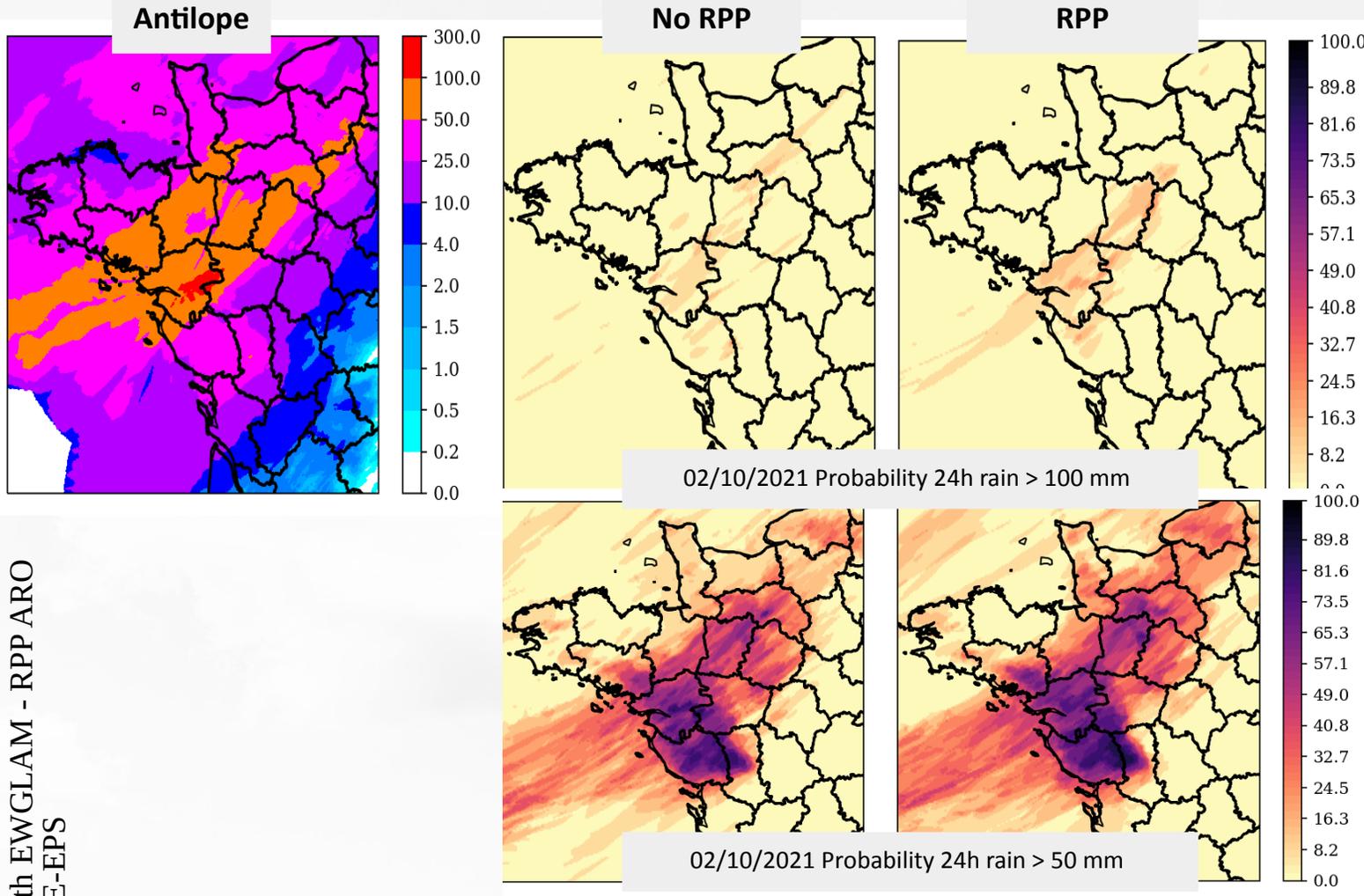
COP 4.1
 Blue : RPP
 Black : NO RPP



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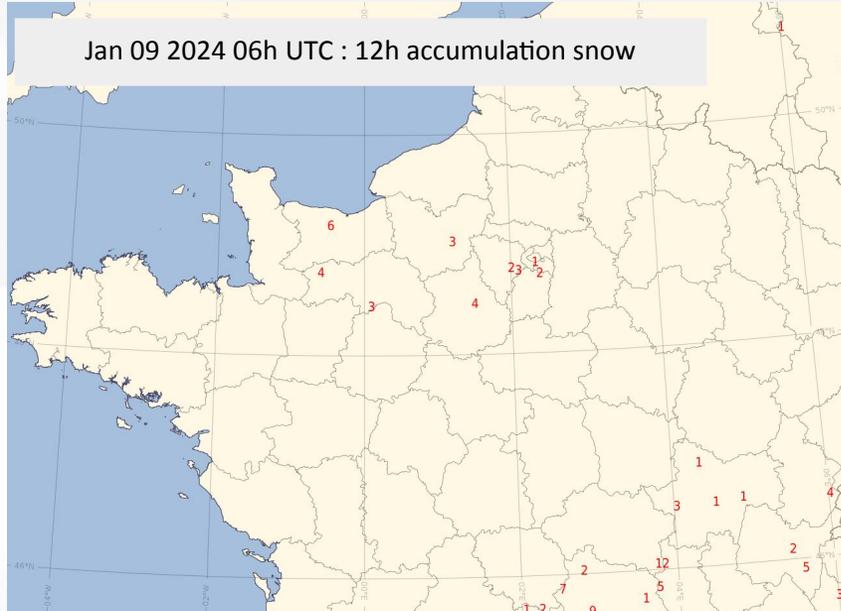
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Perturbation over North-West of France (02/10/2021)

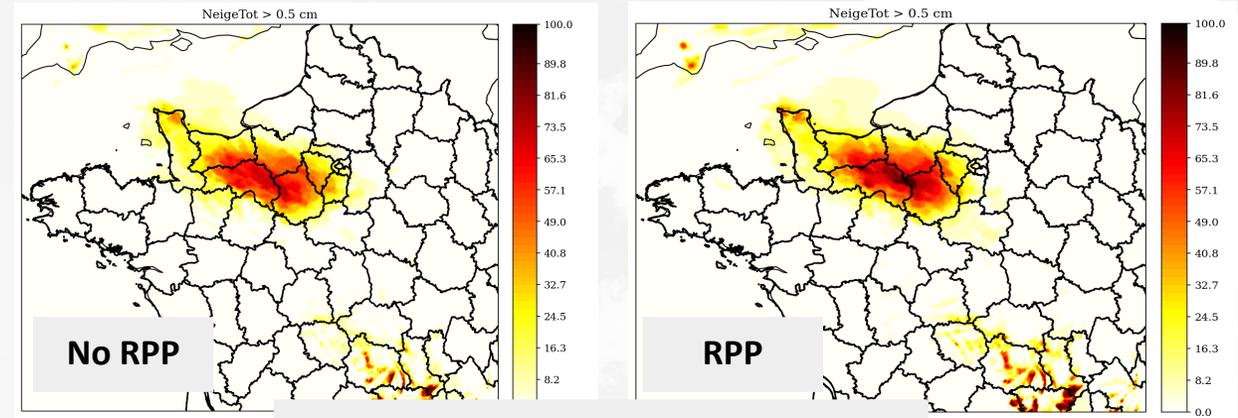


Active perturbation over North-West of France.
Red alert over Loire-Atlantique.
24h rain accumulation between 60 and 80 mm, up to 100 mm over Nantes.

Snow storm over Normandy/Paris region (January 09 2024)



Run 2024010803 :
12h snow accumulation



Probability 12h snow > 0,5 cm

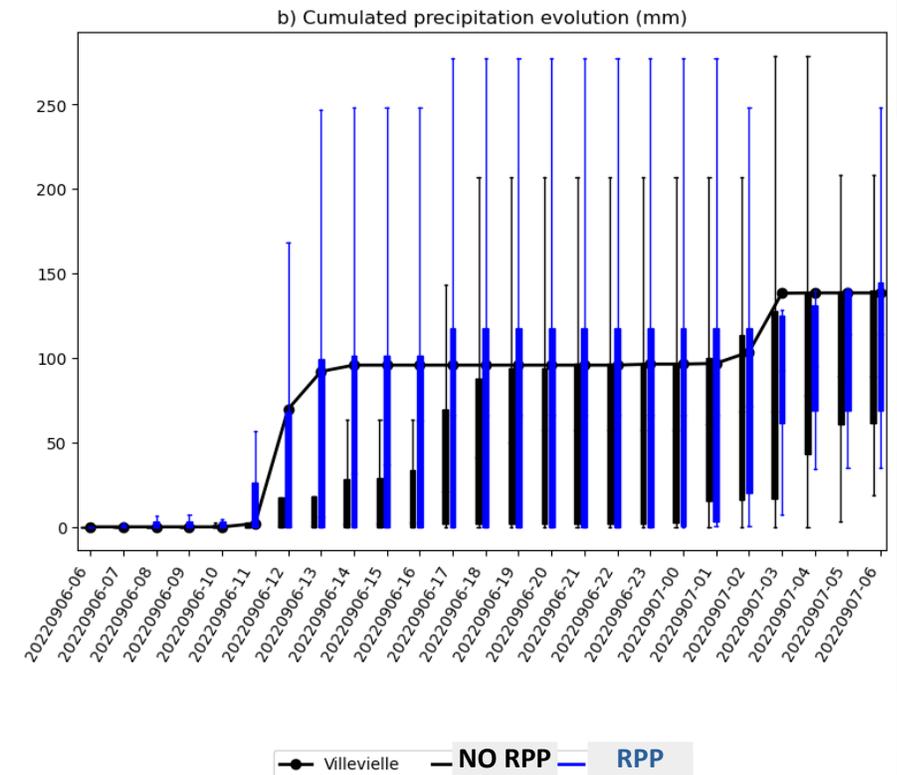
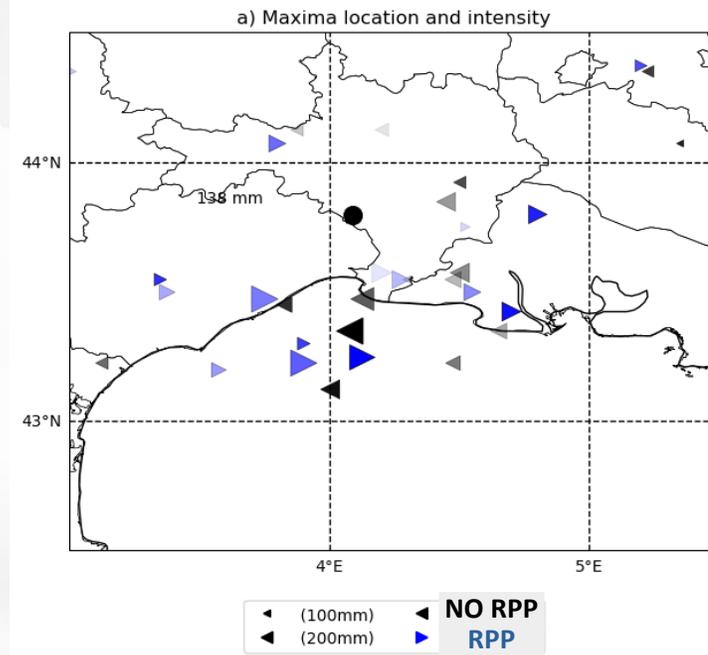
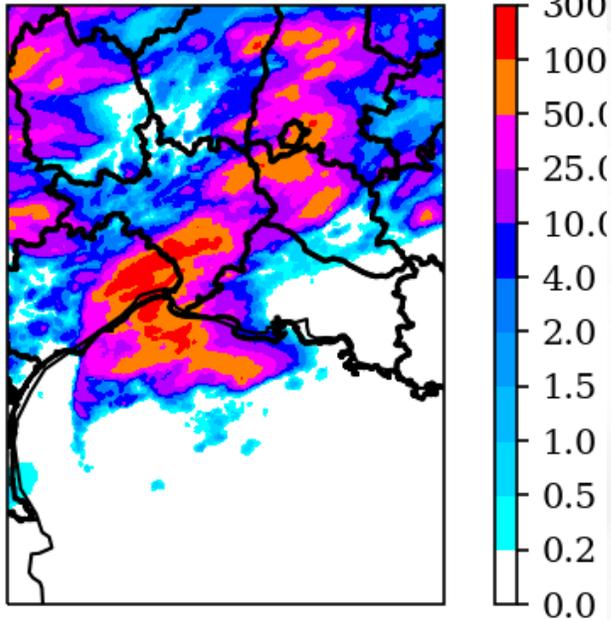
An advection of cold, dry air from the northeast and a perturbation moving up from the southeast, resulted in a snow fall during the night of January 8 to January 9, from Paris region to Normandy.

Uneven layer of snow, reaching 5 to 10 cm in Normandy.

Violent storms around Gard (September 06 2022)

Violent storms started around noon over the Hérault and Gard departments. At around 4 p.m., both departments were placed on red alert. A storm formed north of Montpellier remained virtually stationary for three hours: 200 mm of rain fell in a few hours.

Antilope



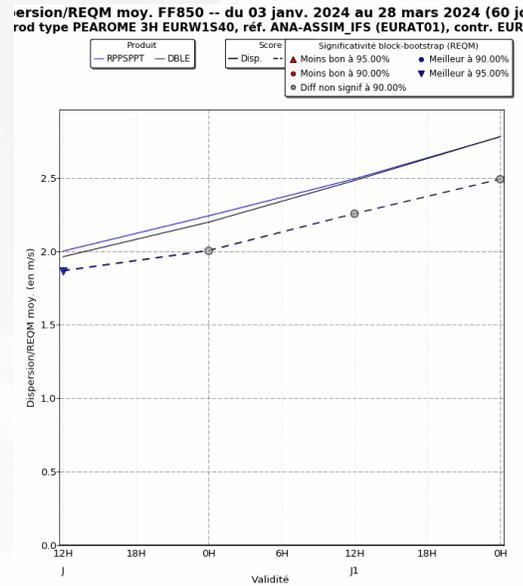
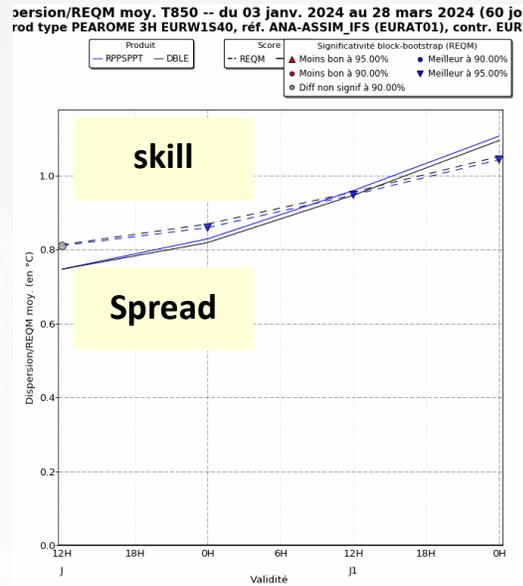
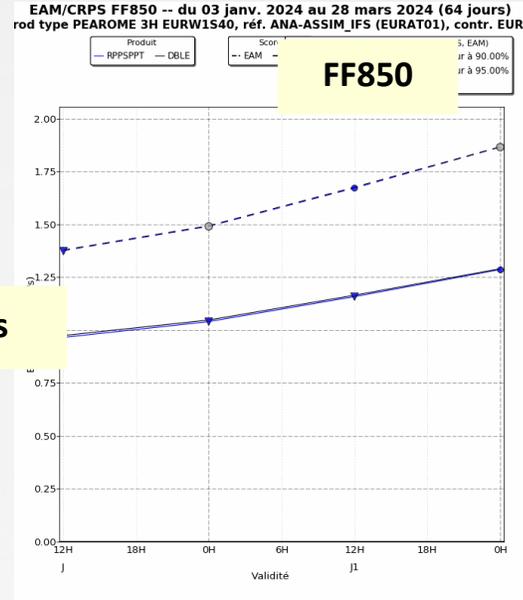
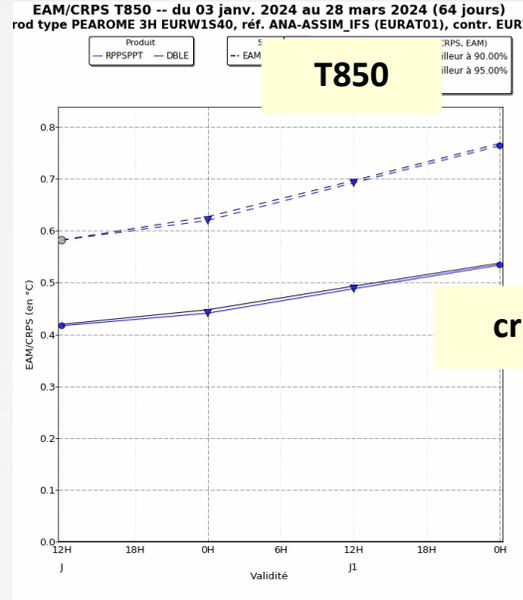
Conclusion

- RPP method added in Arome-EPS, with random perturbation of 19 parameters (in radiation, microphysics, turbulence, surface, and convection schemes)
- With the current configuration:
 - Overall improvement on average (CRPS, dispersion, BSS) for most variables (especially T and RR)
 - Improves Arome-EPS dispersion in several convective cases
- Problems: increased moisture bias in winter, lower layers too dry during some convective events, cloud cover distribution shifted to higher values
- Next steps:
 - Integration of this development into the next operational Arome-EPS (cy49)
 - Testing of a stochastic parameter perturbation (SPP) version to assess its potential added value compared to the non-stochastic version (with the same parameters, a subset or adding other parameters from the IFS SPP scheme)

Questions ?

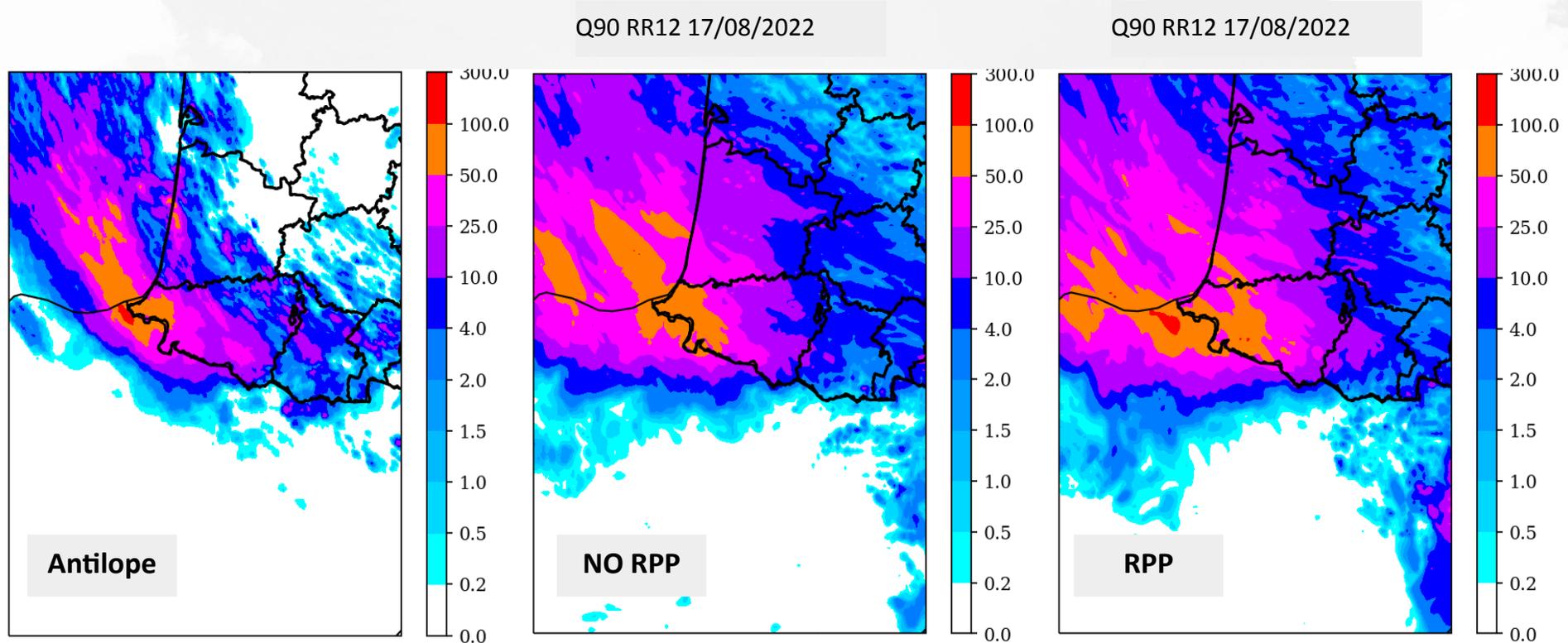
Altitude scorecard Winter 2024

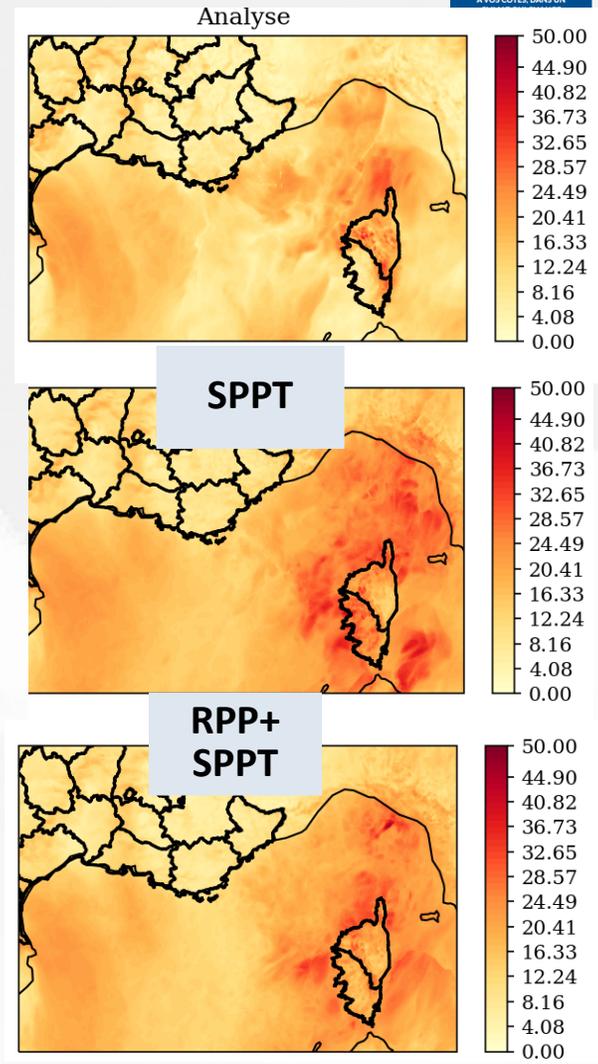
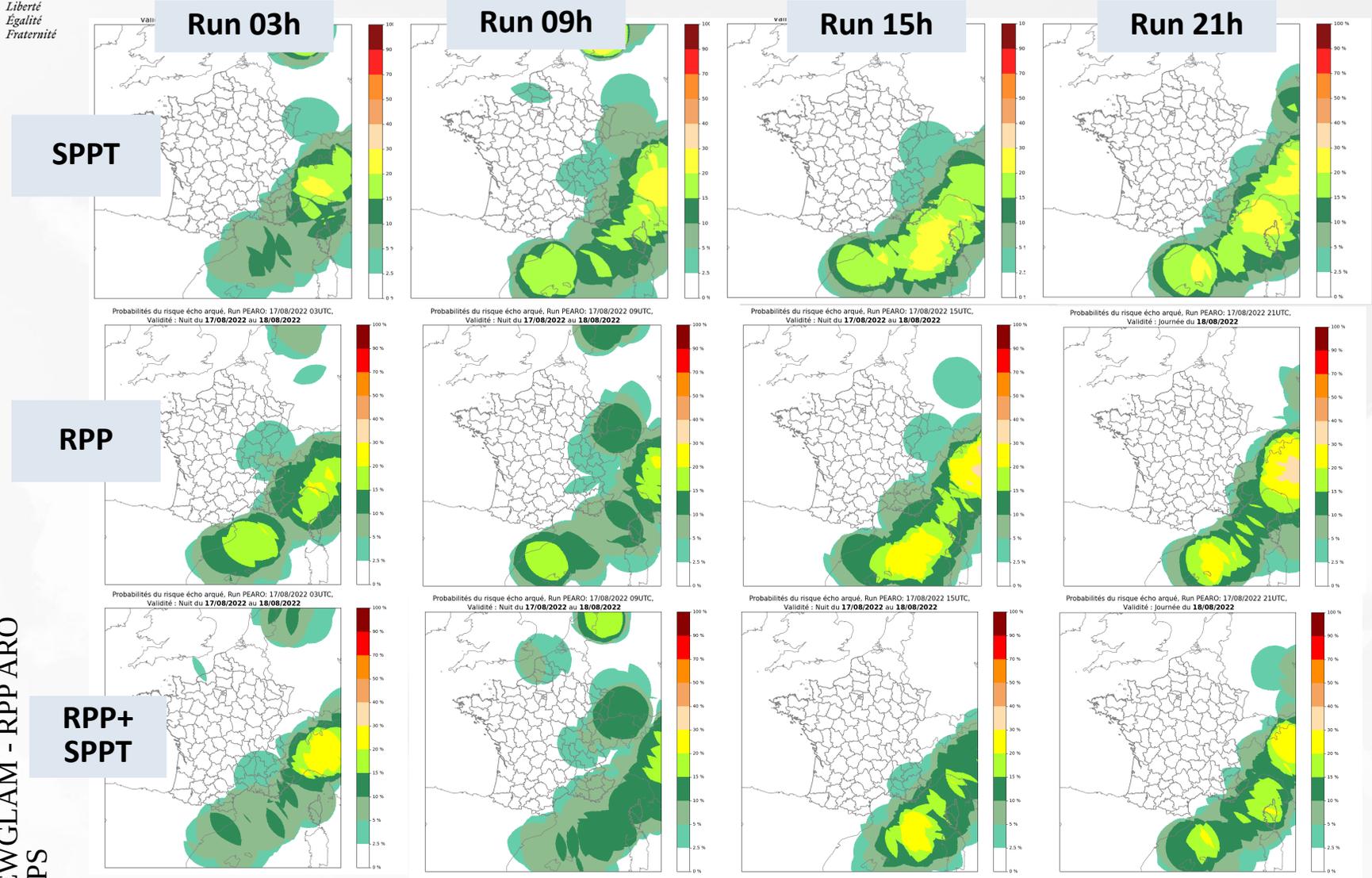
| | | REQM | CRPS |
|--------------|--------|------|------|
| T | 250hPa | | |
| | 500hPa | | |
| | 850hPa | | |
| | 925hPa | | |
| FF | 250hPa | | |
| | 500hPa | | |
| | 850hPa | | |
| | 925hPa | | |
| DD | 250hPa | | |
| | 500hPa | | |
| | 850hPa | | |
| | 925hPa | | |
| Géopotentiel | 250hPa | | |
| | 500hPa | | |
| | 850hPa | | |
| | 925hPa | | |
| Q | 400hPa | | |
| | 500hPa | | |
| | 700hPa | | |
| | 850hPa | | |
| HU | 400hPa | | |
| | 500hPa | | |
| | 700hPa | | |
| | 850hPa | | |
| | 925hPa | | |



Pyrénées-Atlantiques 17/08/2022

Masse d'air instable avec flux de Nord-Ouest humide en basses couches qui amène des pluies durables et instables sur le département des Pyrénées-Atlantiques : jusqu'à 110 mm de pluies sur l'Ouest du département.





47th EWGLAM - RPPARO
ME-EPS

- RPP : cohérent, peu de dispersion spatiale, signal plus fort dès run de 03h, diminution pour le run de 21h
- RPP+SPPT : tendance à diminuer le signal au niveau de la probabilité et du nombre d'échos arqués prévus.