AROME-EPS development in Météo-France

Int.Conf.Ens.Methods Toulouse, 15 Nov 2012

francois.bouttier@meteo.fr

collaborators: Olivier Nuissier,
Laure Raynaud, Benoît Vié

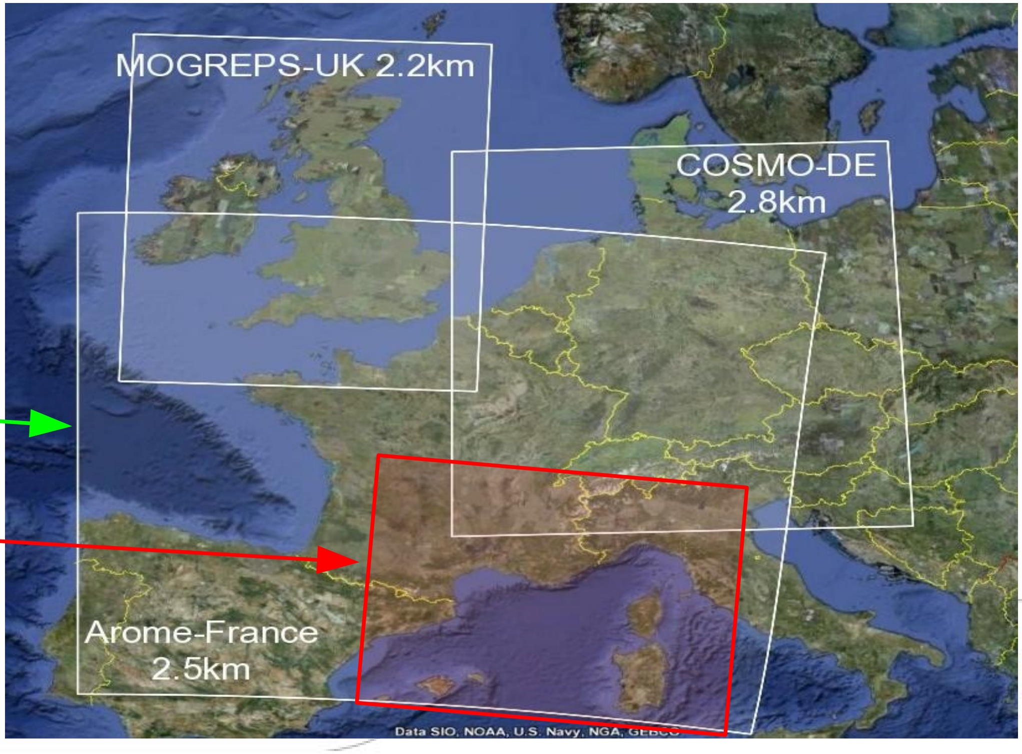
- Ensemble setup
- Boundary conditions
- Initial conditions
- Model error
- Examples

Overview of AROME-EPS

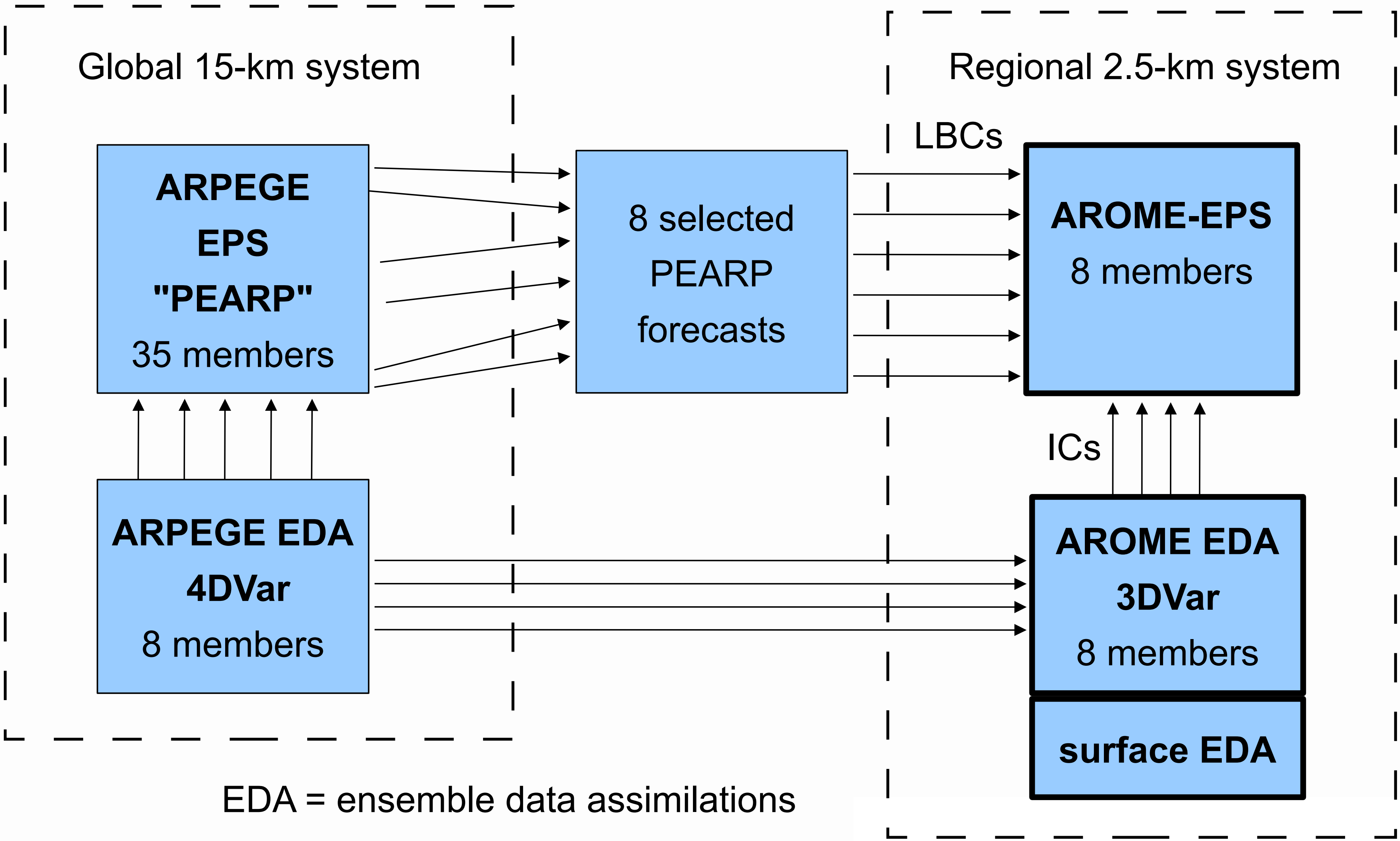
- AROME-France model: 2.5km grid, non-hydrostatic, 36-h range
- 2011/2012: offline research experiments over several 20-day periods
- 2012: real-time demonstration over small domain (HyMeX field experiment)
- 2013: real-time preoperational over full domain
- 2014: operational production, at least 8 members every 6 hours

target operational domain

2012 HyMeX demonstration



AROME-EPS technical architecture



EDA = ensemble data assimilations

Large-scale boundary conditions

AROME model is hourly coupled at lateral & upper boundaries.

Several options for selecting LBCs in a bigger global ensemble:

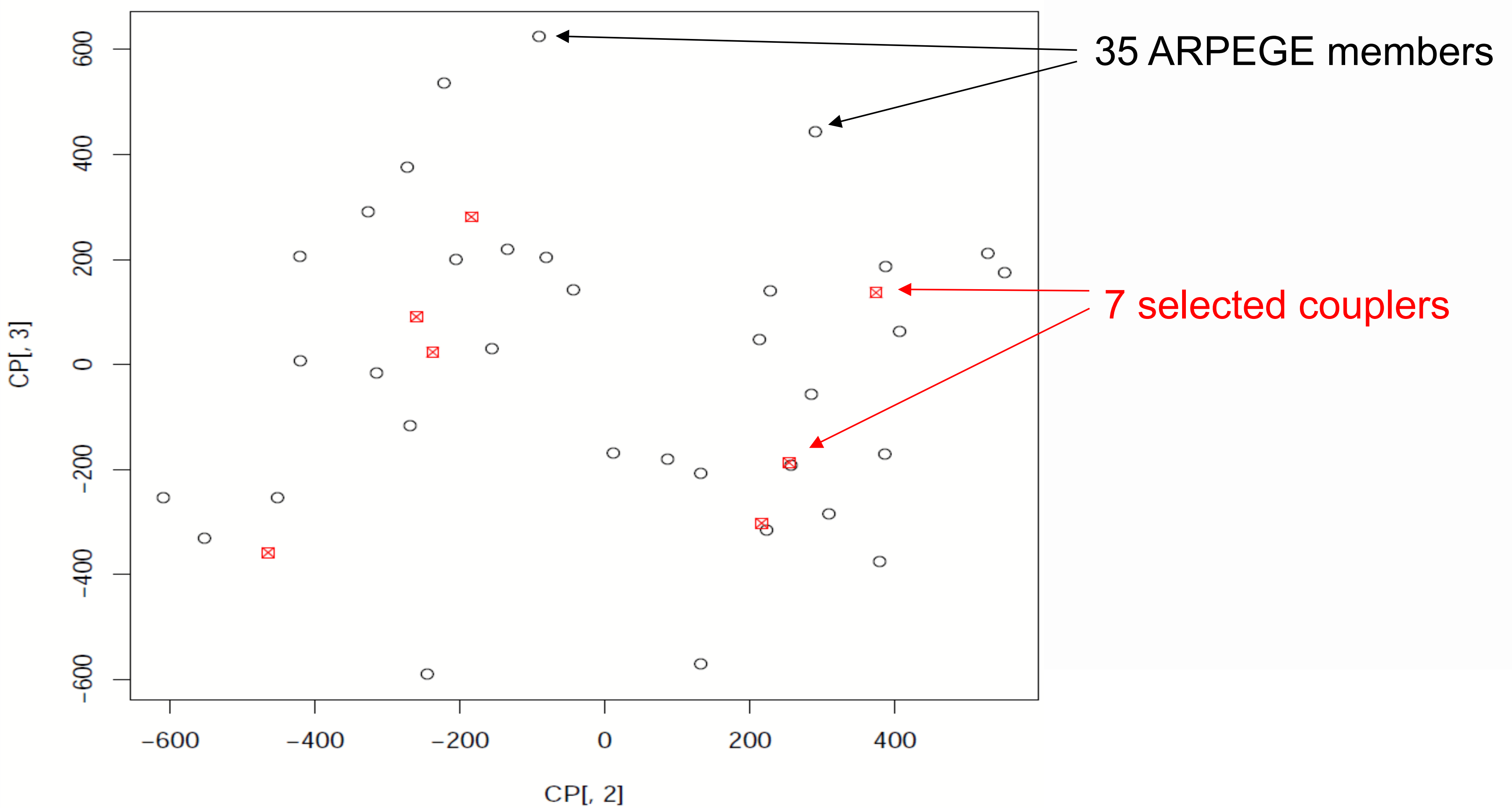
- random pick
- or, one PEARP multiphysics config per AROME member
- or, cluster PEARP forecasts using one of two methods:
  - K-means, more faithful to original PDF
  - hierarchical complete link (similar to COSMO-LEPS), maximizing interdistance between members

Results:

- impact on ensemble scores (ROC, Brier, CRPS) is tiny
- clustering improves a bit the high precip and wind scores, by promoting member diversity (ie sampling the PDF tails)

Clustering example

- empirical idea: self-avoiding subsampling of forecast trajectories
- example of K-means clustering topology (plotted along 2 leading principal components)



Initial perturbations: EDA in convective-scale model

Setup of AROME ensemble data analysis:

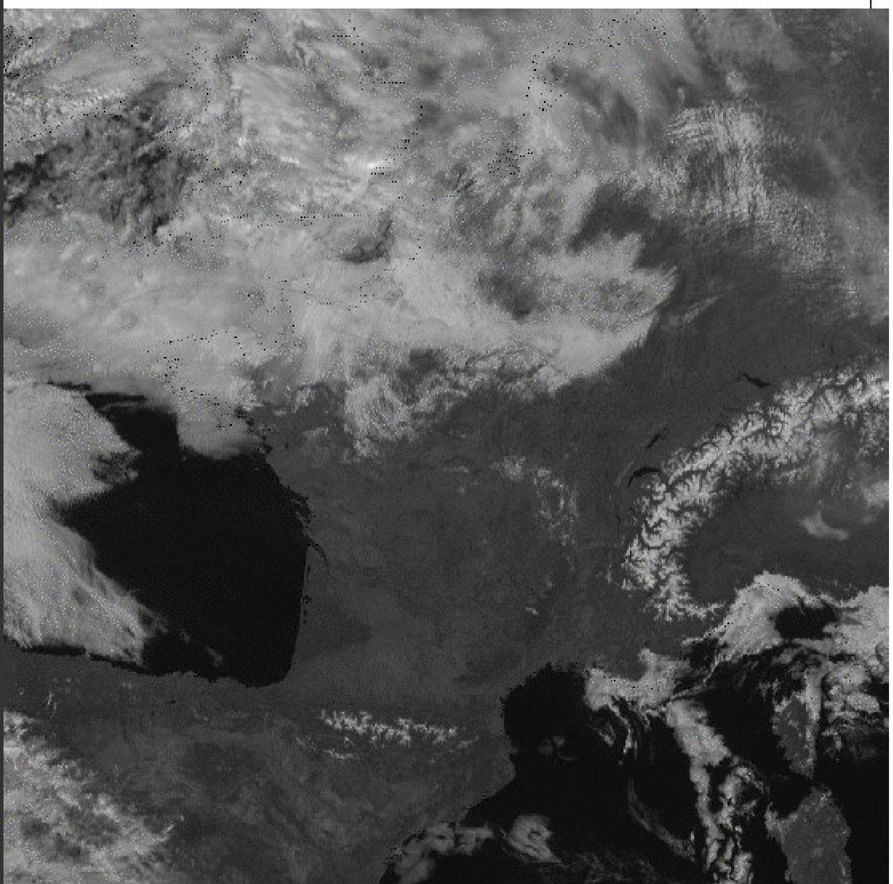
- 3DVar+surface DA system is like deterministic DA, except :
  - obs are randomly perturbed
  - LBCs taken from global ARPEGE EDA (4DVar)

Results:

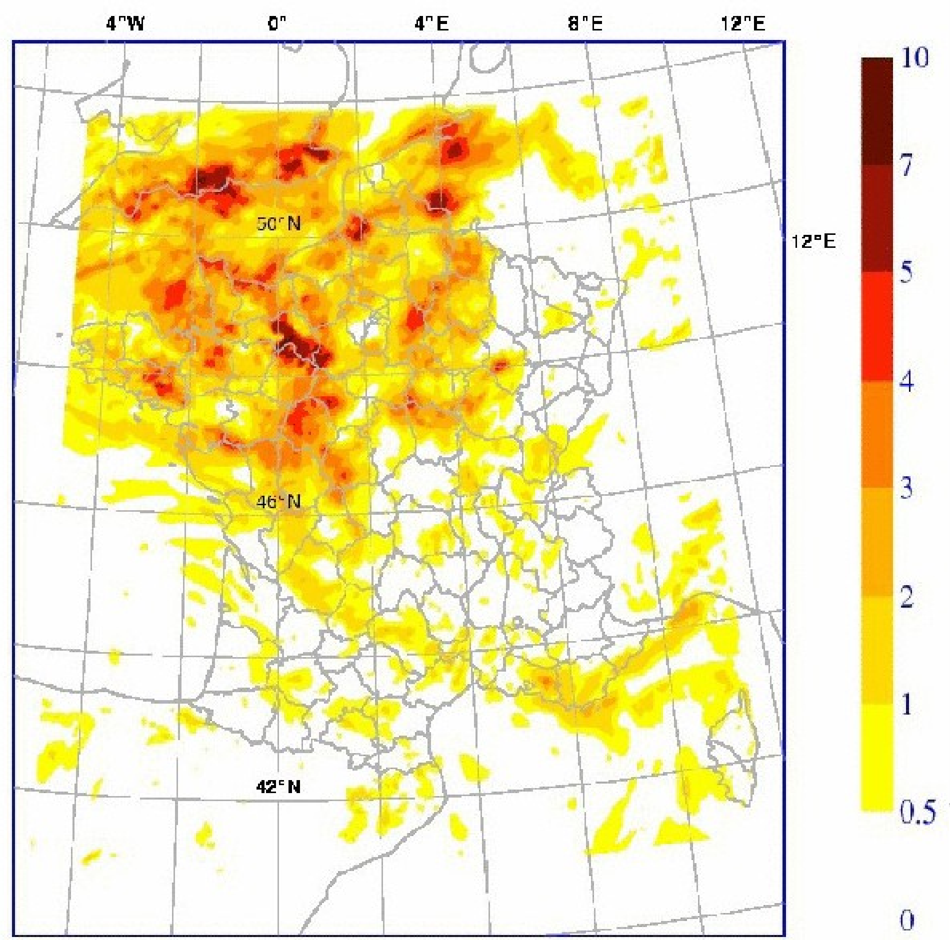
- provides acceptable forecast spread from step 0
- has physically believable low-level and surface spread
- no spin-up = ensemble suitable for probabilistic nowcasting ?
- (also used to produce background covariances for deterministic 3DVar, see posters)
- cost ~ 10% of AROME EPS forecast system

AROME EDA: example of physically convincing initial spread

Low cloud cover on
23/2/2008 (MSG)



Error std of the day (T 900 hPa)
(Arome EnVar, 6 members)



AROME EDA: inflation

Plain EDA is underdispersive: lacks representation of system errors (in model & in 3DVar algorithm).

Adaptive inflation of background fields:

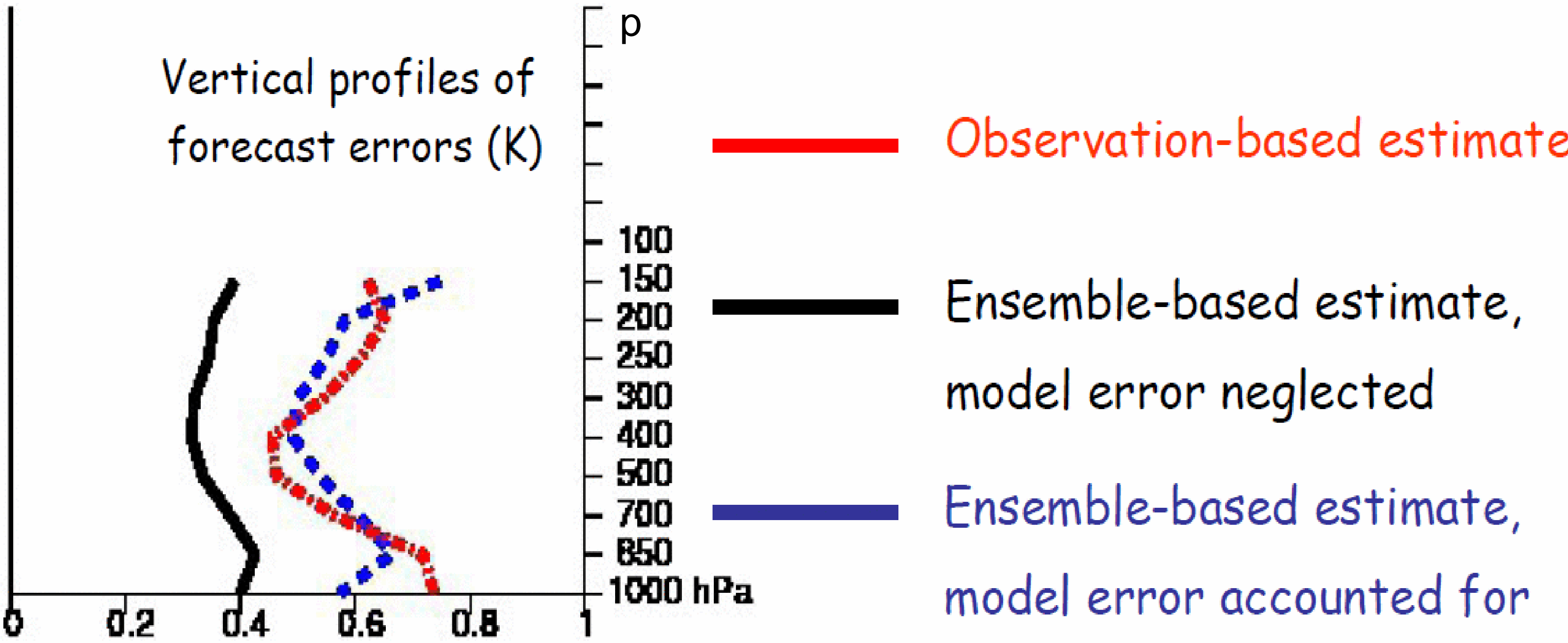
- compare variance of innovations $cov(y\text{-}Hx_b)$ with EDA-predicted variances $cov(M[x_{ai}])$
- inflate EDA background ensemble as a function of discrepancy:

$$e_i' = e_i + a\,(e_i - \overline{e_i}\,),\ a>1$$

- a~1.15 is applied in each 3DVar cycle (every 3 hours)
- improves short-range spread/skill consistency, better ensemble scores (reliability, CRPS, Brier, ROC).
- Impact is significant up to 24h-range.

Arome-EDA inflation

(This plot made using ARPEGE global EDA)



T prior stdev
against Aircraft T

Initial perturbations: cheaper alternatives to EDA

Consider IC perturbations of the form $x_i = x_a + a\,(z_i - \bar{z}_i)$

- x_i : initial condition of ensemble member i
- x_a : deterministic high-resolution analysis
- z_i : externally supplied ensemble
- a : scaling vertical profile (empirical tuning constant in mid troposphere, zero at top and bottom). Only applied to wind,T,ps.

Results:

- with z_i = ARPEGE EDA : better than no perturb, but very underdispersive
- with z_i = PEARP ICs : better than ARPEGE EDA (because of SVs ?)
- with z_i = 24-h breeding of AROME EPS: performance close to PEARP ICs
- AROME EDA easy winner until ~9h range or at low levels, not so superior otherwise.
- ranking is clear for spread/skill consistency and CRPS, not so clear for ROC.

Things to try: 6-h breeding, surface breeding, adaptive tuning of *a*.

Model error in AROME EPS

In atmosphere: SPPT stochastic physics tendencies (akin to ECMWF's)

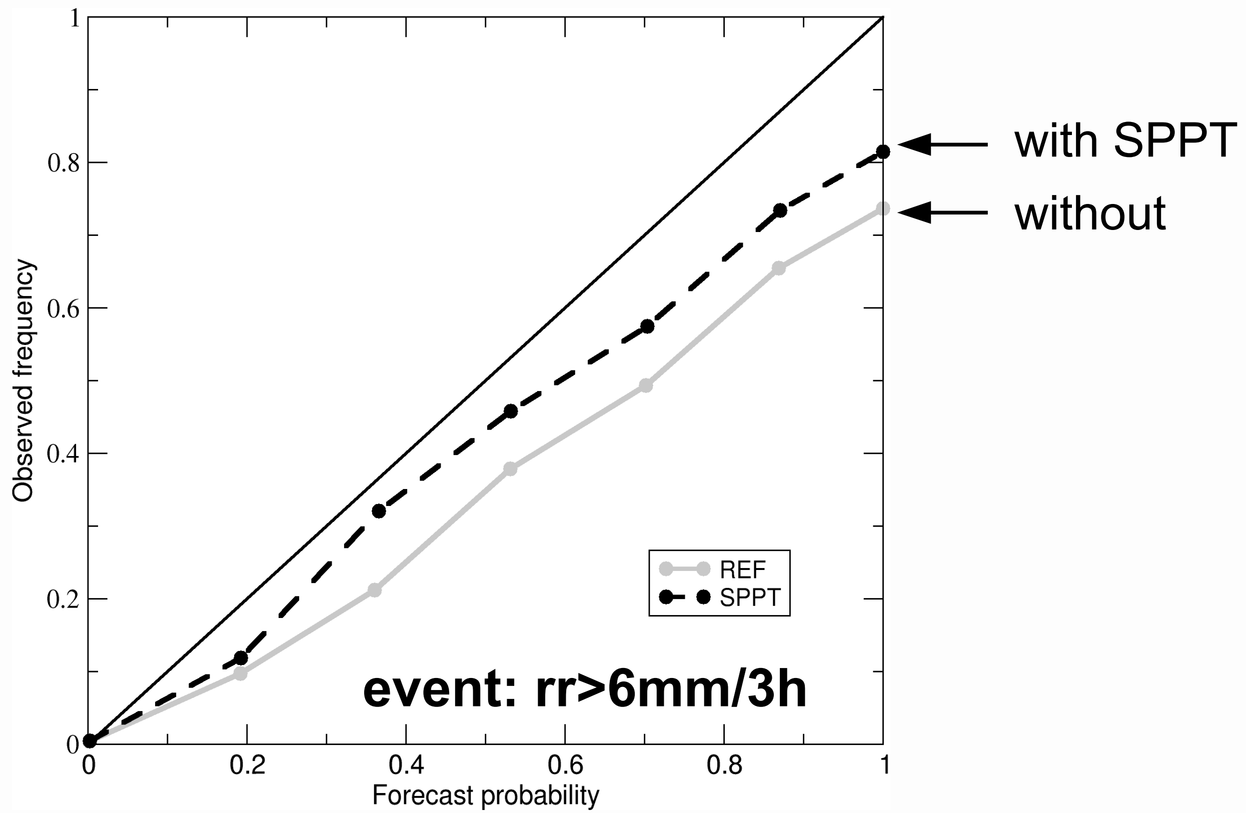
- multiplicative noise on model tendencies,
- noise autocorrelations : univariate, large-scale, slowly evolving
- recently extended into surface boundary layer
- increases spread & rms errors, most probabilistic scores are improved.
- drawback: drying in low troposphere
- not yet in EDA (model error represented by adaptive inflation)

Also tried physics parameter perturbations:

- in microphysics : negligible impact
- in turbulence : more promising

Impact of SPPT model error scheme

Reliability of precipitation over 5 weeks

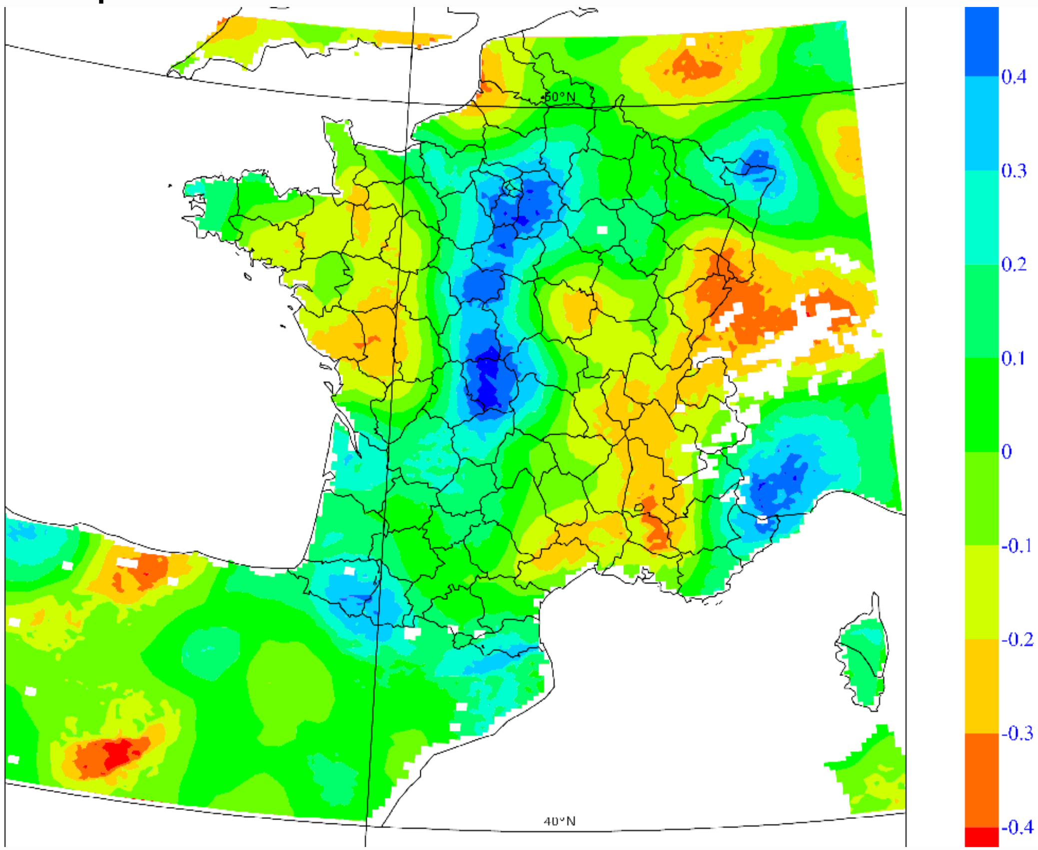


(without loss of sharpness)

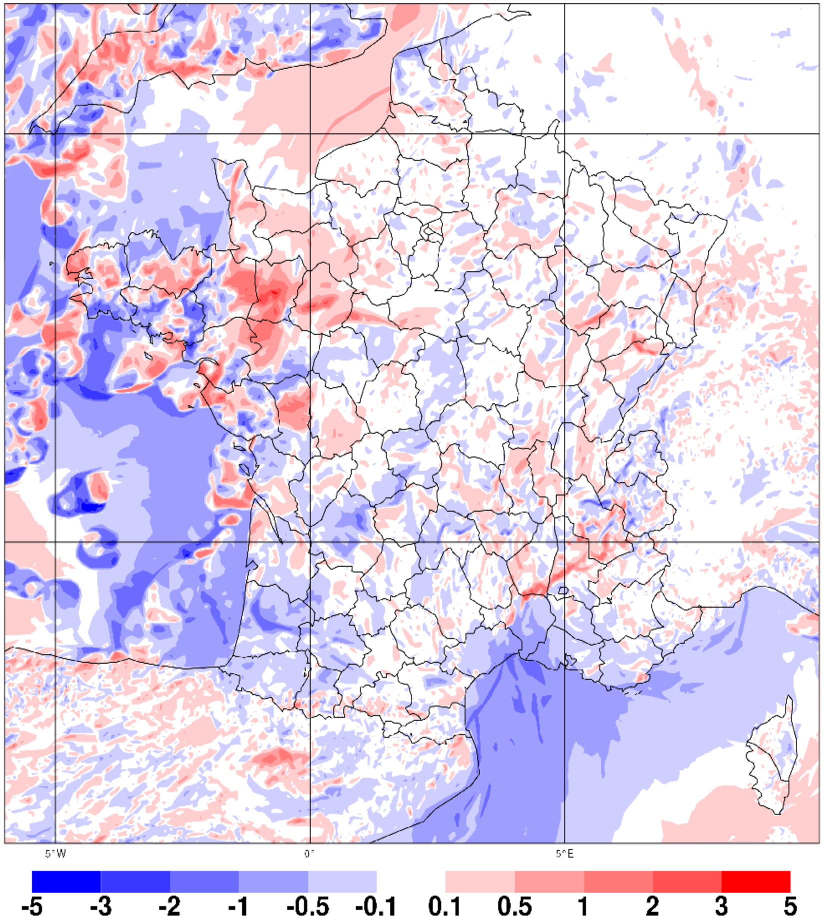
Surface perturbations (work in progress)

found promising in sensitivity studies: SST, Wg, Rsmin, LAI, C_{veg}, Zo_{orog}

random perturbation generator:
prescribed 2D Gaussian correlation



fc perturb T2m at 12h-range
resulting from small SST changes



Verification of short-range, high resolution ensembles

Lessons learned:

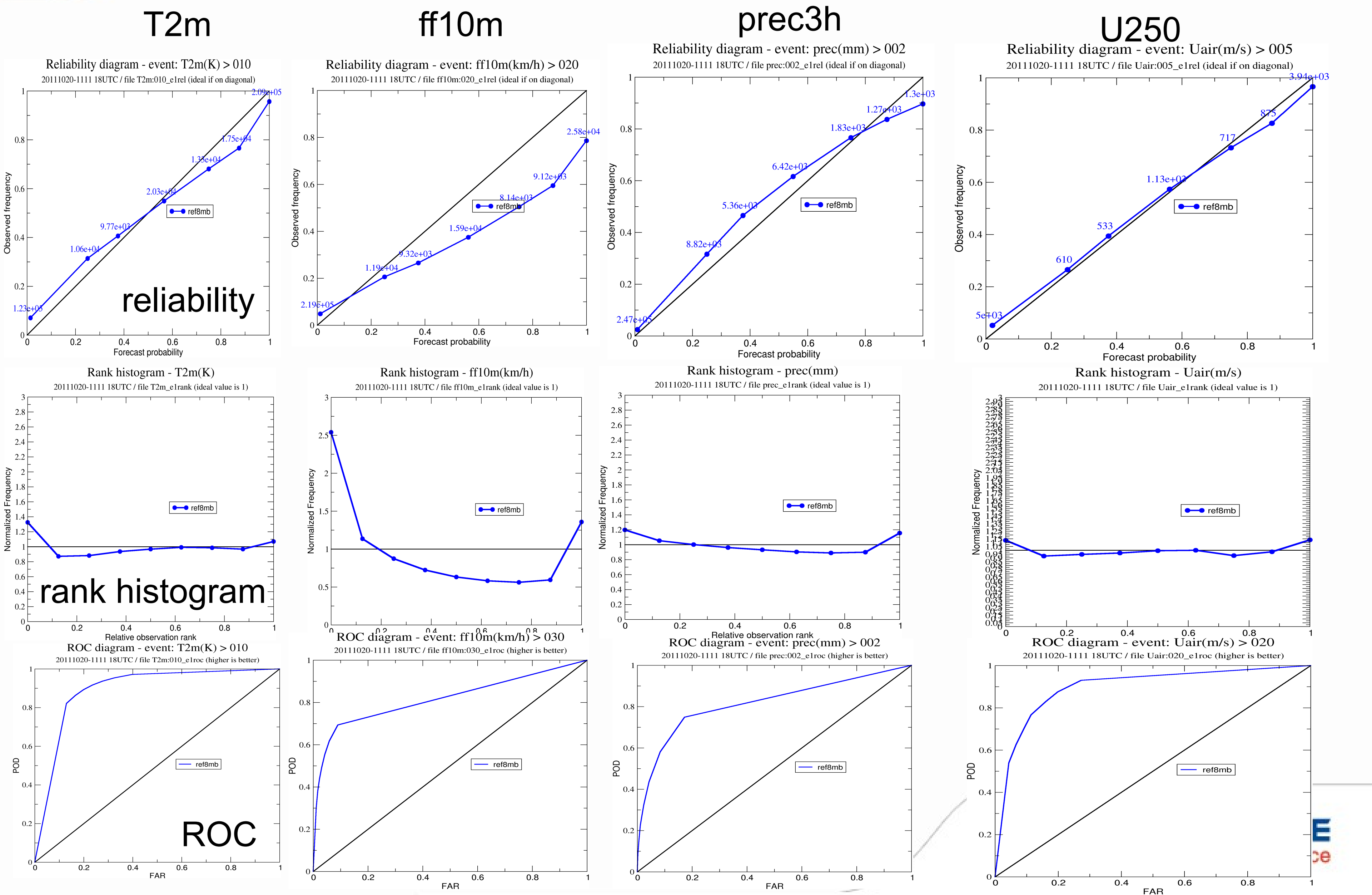
- Must use **real observations,** not analyses, as truth.
- **Observation errors** are significant
- **Model biases** are significant, with large diurnal cycle.
- **Error growth** over first 24h of forecasts is usually smaller than analysis errors.
- **Observation availability** limits significance of probabilistic scores (experiments are expensive, thus short)

- Usable: T2m, HU2m, 10m-wind, 10m-gusts, raingauge, aircraft wind & T
- Promising but more difficult: radar, satellite radiances (complex obs errors)

Sample results from AROME EPS

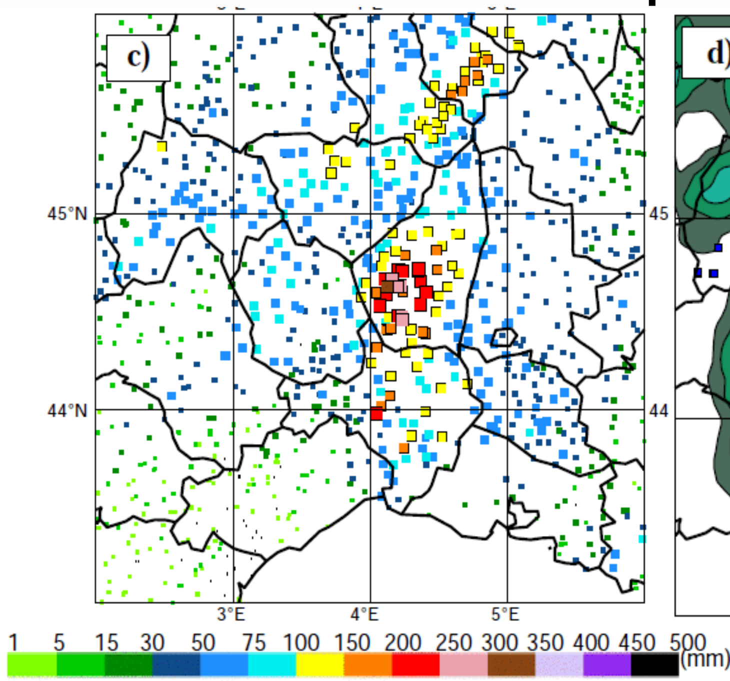
- Scores
- High-impact Mediterranean precipitation
- Scattered thunderstorms

AROME-EPS sample scores (23 days in Oct 2011)

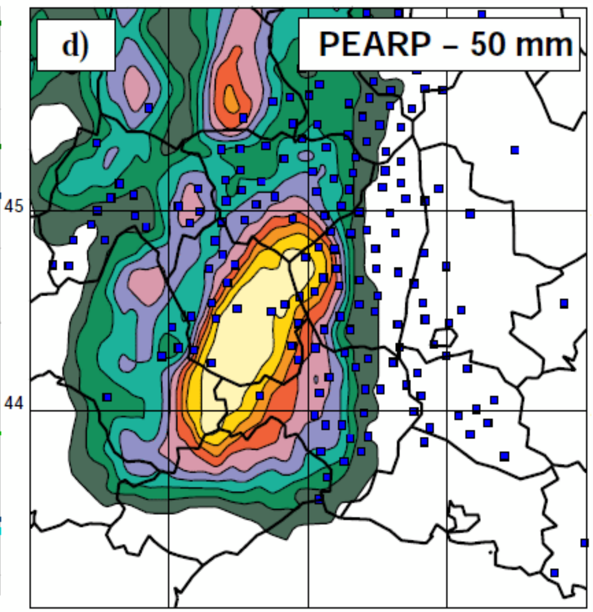


Orographically-forced heavy convective precipitation (SE of France)

obs rr24

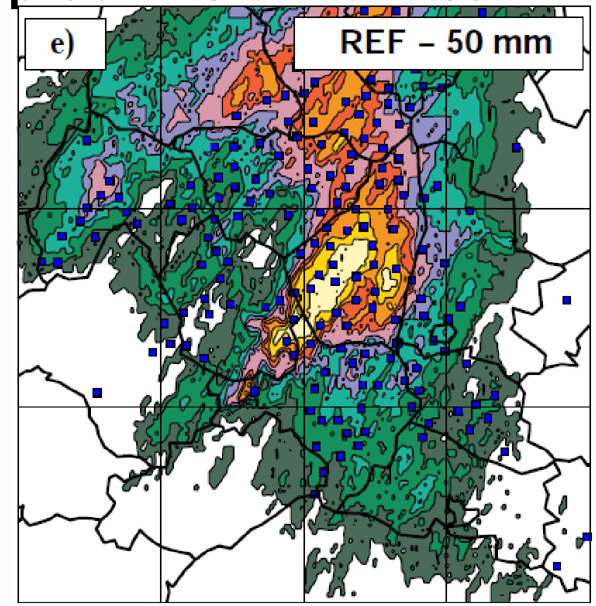


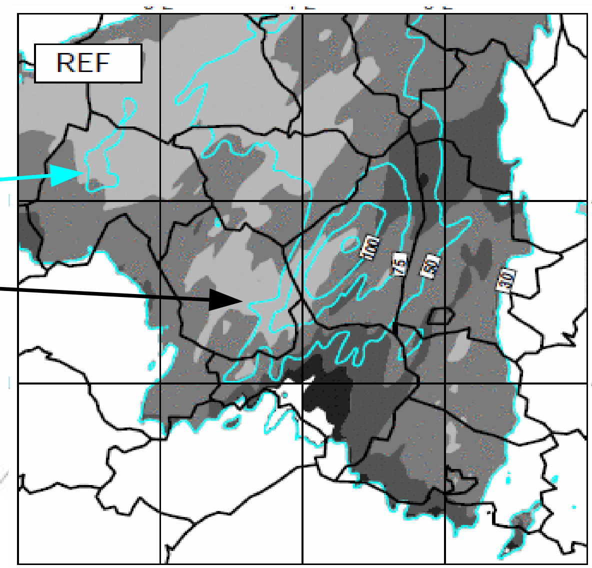
prob ARPEGE rr24>50mm



100km

prob AROME rr24>50mm





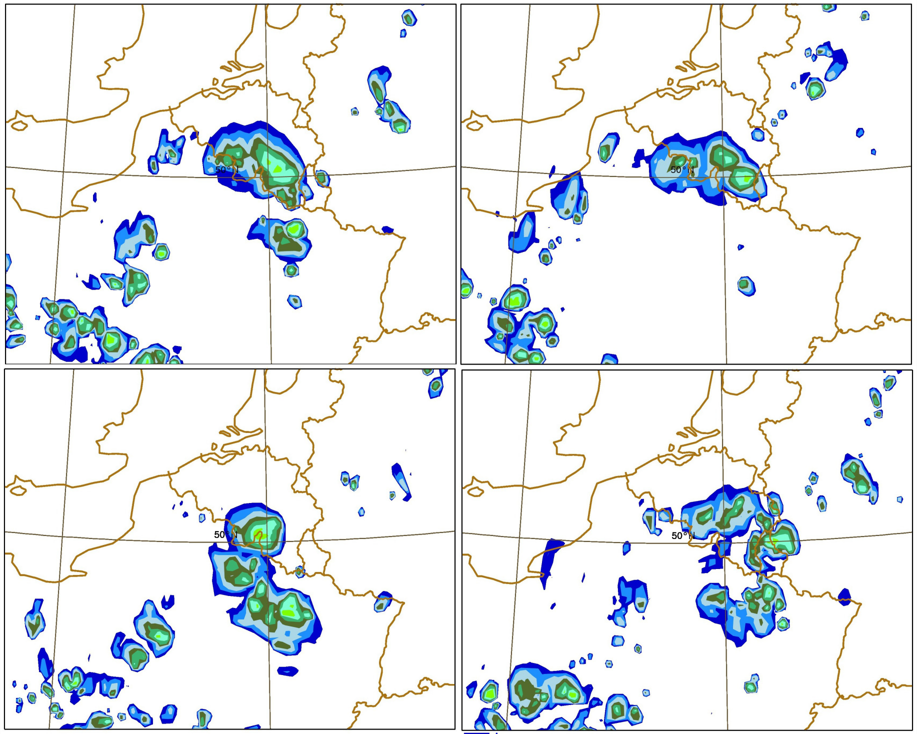
AROME ens mean (blue)

ratio spread/ensmean (grey)

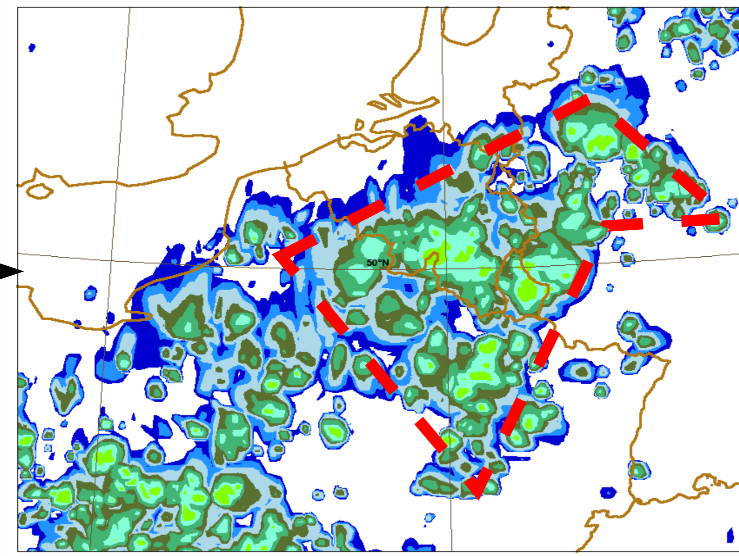
=good guidance (clear signal, limited spread, good detection, fewer false alarms than PEARP)

Scattered thunderstorms over flat terrain: from members to probabilities

flight-level simulated reflectivity,
4 random members



90% quantile, computed
point-by-point using 12 members



All the structure inside the red area is sampling noise.

The *curse of convective dimensionality*: in a situation like this, ~100 members would be needed for adequate sampling.
PDF dressing is needed, with a mislocation error model.

Summary

- nearly complete system setup (need surface perturbations)
- spread & reliability are mostly adequate,
  - we need to improve statistical resolution
  - low-level weaknesses on RH2m, ff10m
  - convection needs some kind of smoothing
- *ensemble size* is a major performance driver. Key events cannot be simulated using a lower-resolution model.
- model errors mostly seem *systematic* ones (diurnal biases, structure of precip field), they have a clear effect on probabilistic scores.
- is there a good perturbation tuning methodology ? currently, we risk compensation between various types of perturbations.

Thank you for your attention

Recent papers

- Bouttier, F., B. Vié, O. Nuissier and L. Raynaud, 2012: Impact of stochastic physics in a convection-permitting ensemble. *Mon. Wea. Rev*., early online release
- Brousseau, P., Berre, L., Bouttier, F. and Desroziers, G., 2012: Flow-dependent background-error covariances for a convective-scale data assimilation system. *Quart. Jour. Roy. Meteor. Soc*. 138, 310-322. doi: 10.1002/qj.920
- Nuissier, O., B. Joly, B. Vié and V. Ducrocq, 2012: Uncertainty on Lateral Boundary Conditions in a convection-permitting ensemble: A strategy of selection for Mediterranean heavy precipitation events. *Nat. Hazards Earth Syst. Sci*., accepted.
- Raynaud L., L. Berre, G. Desroziers, 2012: Accounting for model error in the Météo-France ensemble data assimilation system. *Quart. Jour. Roy. Meteor. Soc.*, 138, 249-262.DOI: 10.1002/qj.906
- Vié, B., Molinié, G., Nuissier, O., Vincendon, B., Ducrocq, V., Bouttier, F., and Richard, E. 2012: Hydro-meteorological evaluation of a convection-permitting ensemble prediction system for Mediterranean heavy precipitating events, *Nat. Hazards Earth Syst. Sci.*, 12, 2631-2645, doi:10.5194/nhess-12-2631-2012.