AROME-EPS developments in Météo-France

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Outline

- Overview of AROME-EPS project
- Model error
- Initial conditions
- Boundary conditions
- Verification & postprocessing
- Demonstration projects: HyMeX & SESAR11.2.2

Collaborators:

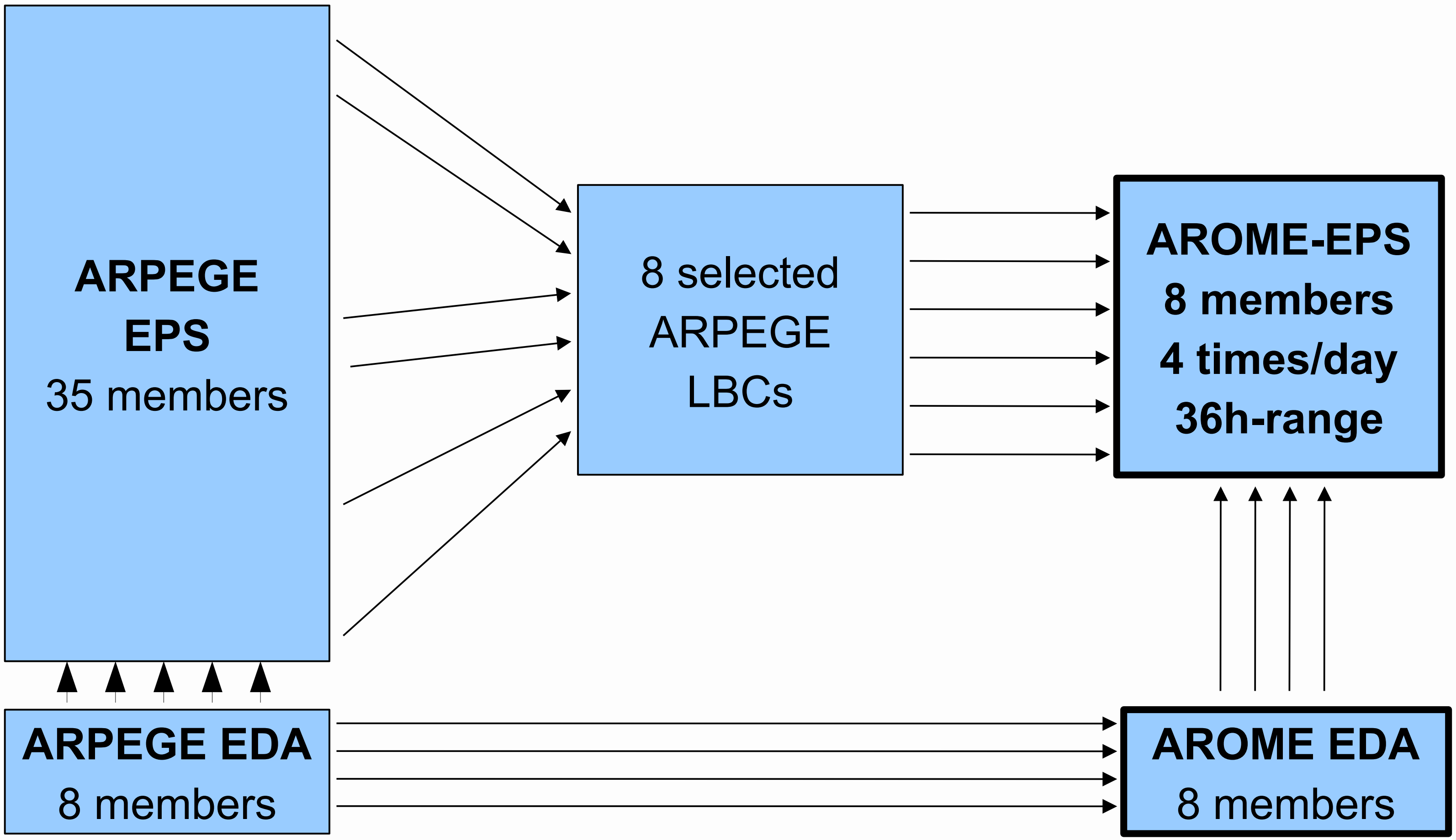
- *Olivier Nuissier, Laure Raynaud, Benoît Vié (MF)*
- *Mihaly Szucs (HMS), Alfons Callado (AEMET)*

Overview of AROME-EPS

- model= AROME-2.5km
- forced by ARPEGE EPS & EDA
- schedule:
  - 2011: 5 weeks research experiments
  - 2012: 8 extra weeks + real-time production since Sept 2012 over smaller HyMeX domain
  - 2013: start real-time production over full domain (on new computer)
  - 2014: operational
- collaborations:
  - Hungary on wintertime weather (ECMWF special project)
  - DWD & UK on aviation & merged convection products (SESAR project)
  - (Spain on stochastic physics)

Technical architecture

(details may change until operational stage)



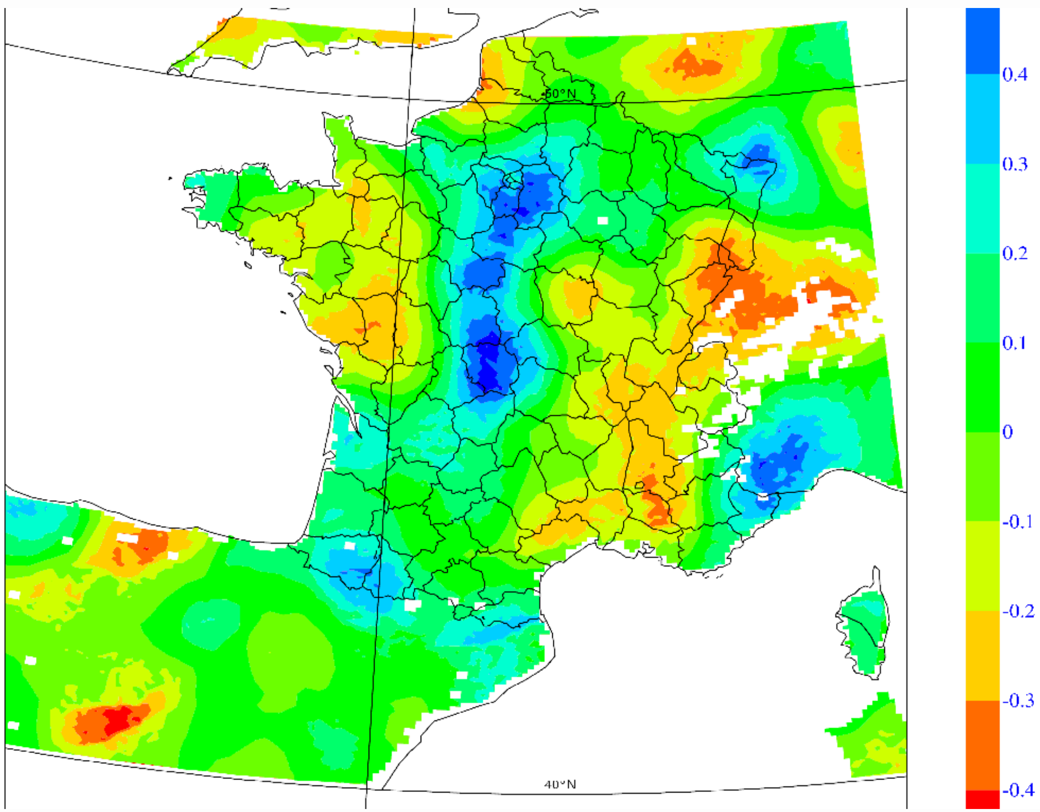
Model error

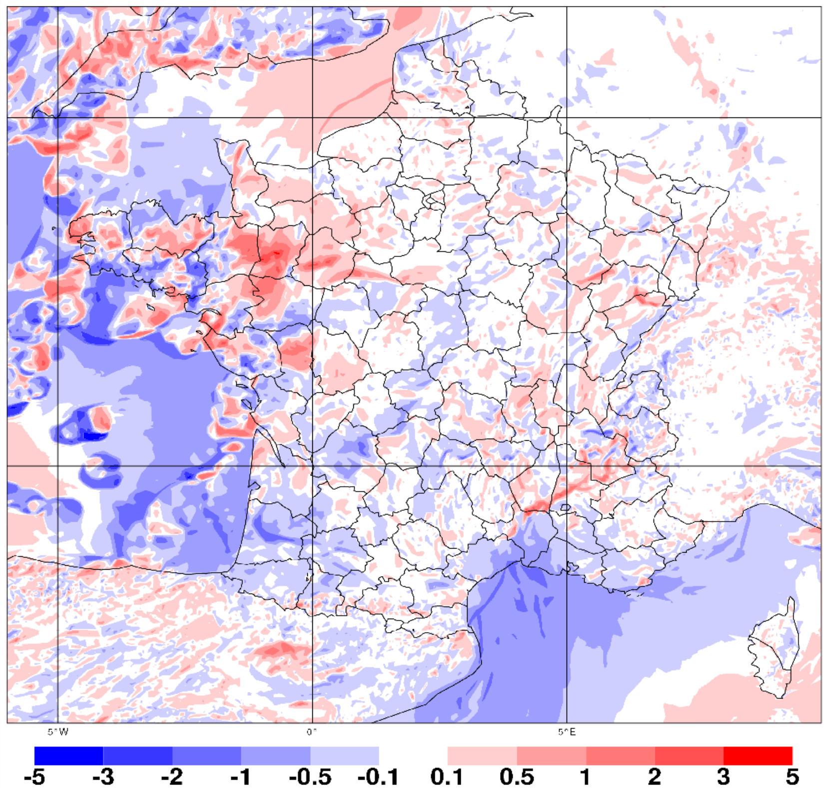
- in AROME atmosphere: SPPT stochastic physics tendencies
  - multiplicative noise, large-scale, slowly evolving
  - not active in PBL (under testing)
  - increased spread & rmse, most probabilistic scores are improved
  - also tried: microphysics & turbulence parameter perturbations
  - plan: better understand the physical impact of SPPT, improve SPPT tuning
- in AROME EDA: adaptive inflation of perturbations (see later)
- in AROME surface: perturb surface initial conditions

Surface perturbations

works well: SST, Wg, Rsmin, LAI, C_{veg}, Zo_{orog}

perturb LAI → perturb T2m ech 12h





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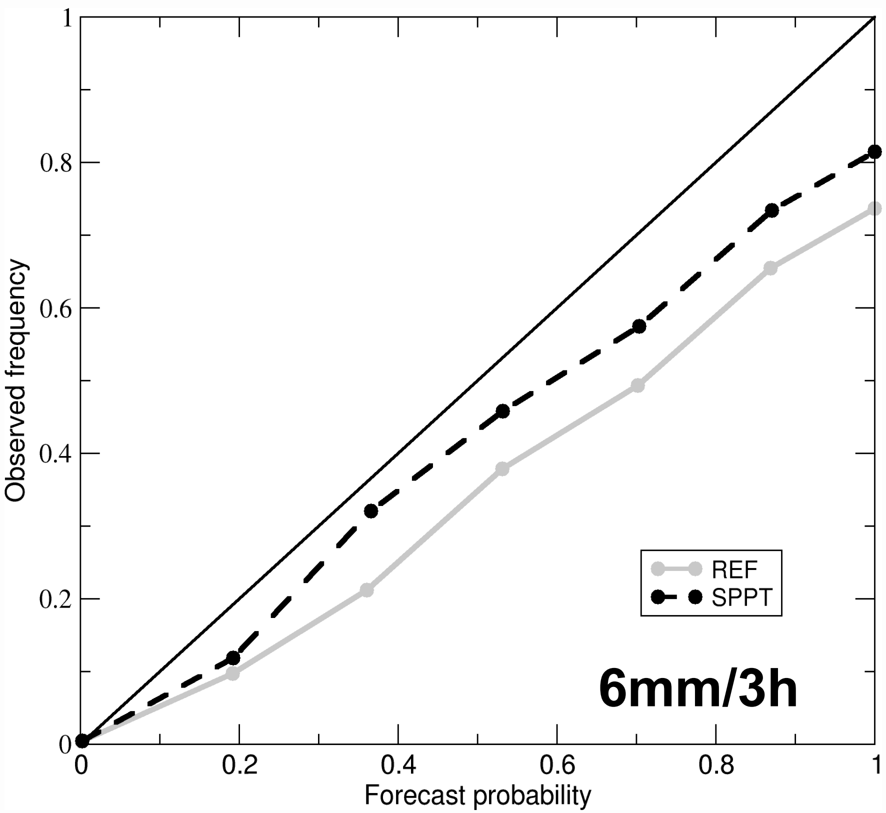
Impact of stochastic physics

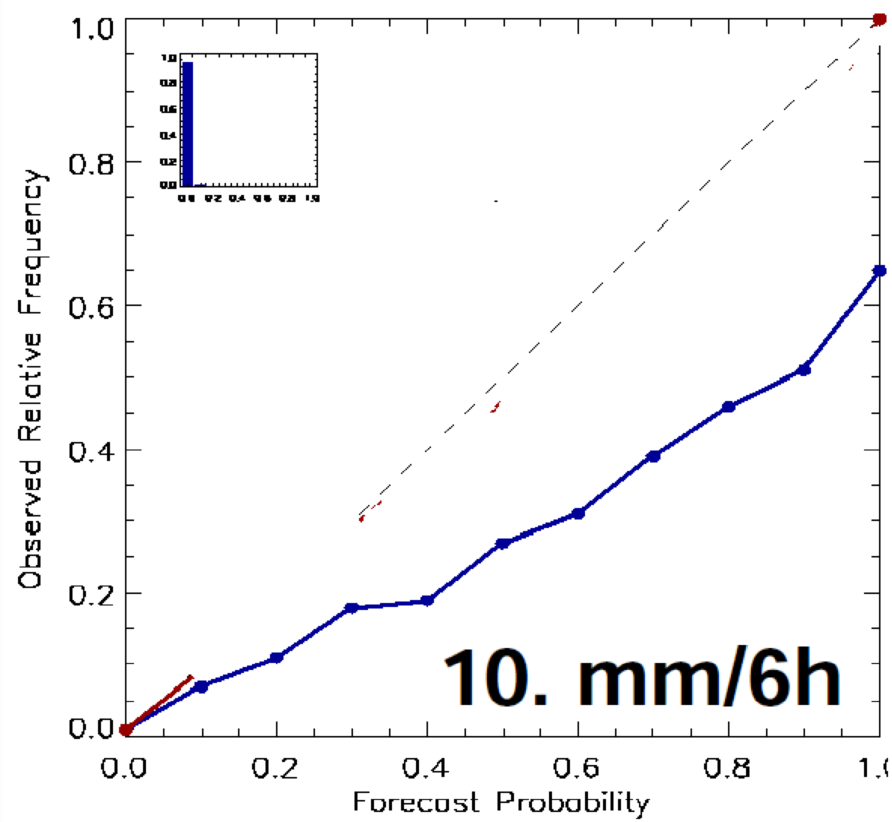
Nice impact on reliability of precip

(parameter & obs not fully consistent with Arome plot)

PE Arome



COSMO-DE EPS

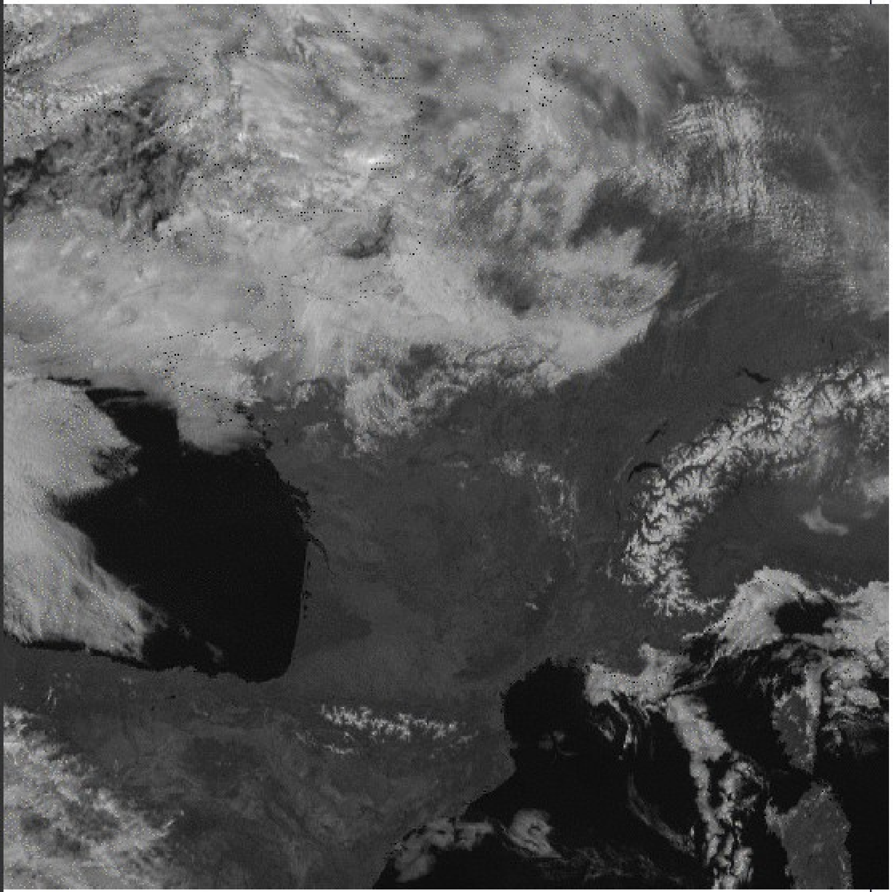


Initial perturbations

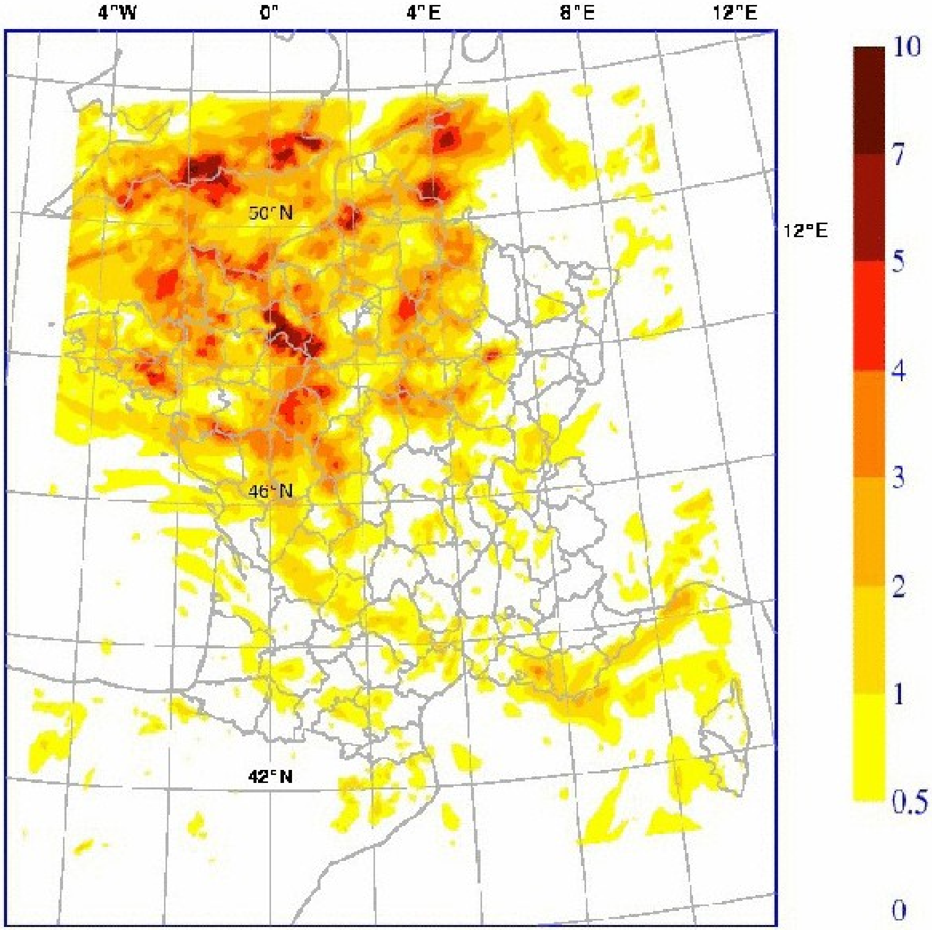
- EDA (ensemble data analysis)
  - same AROME-2.5km 3-h 3DVar as deterministic assim
  - coupled to ARPEGE EDA
  - randomly perturbed obs including surface analysis
  - also used to derive Jb covariances for AROME 3DVar
- EDA much better than unperturbed ICs until ~6h range...but expensive (would cost 1 ensemble forecast member in operations)
- cheaper ARPEGE EDA-based IC perturbations under testing
- later: revisit breeding/ETKF

Initial spread from AROME EDA

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



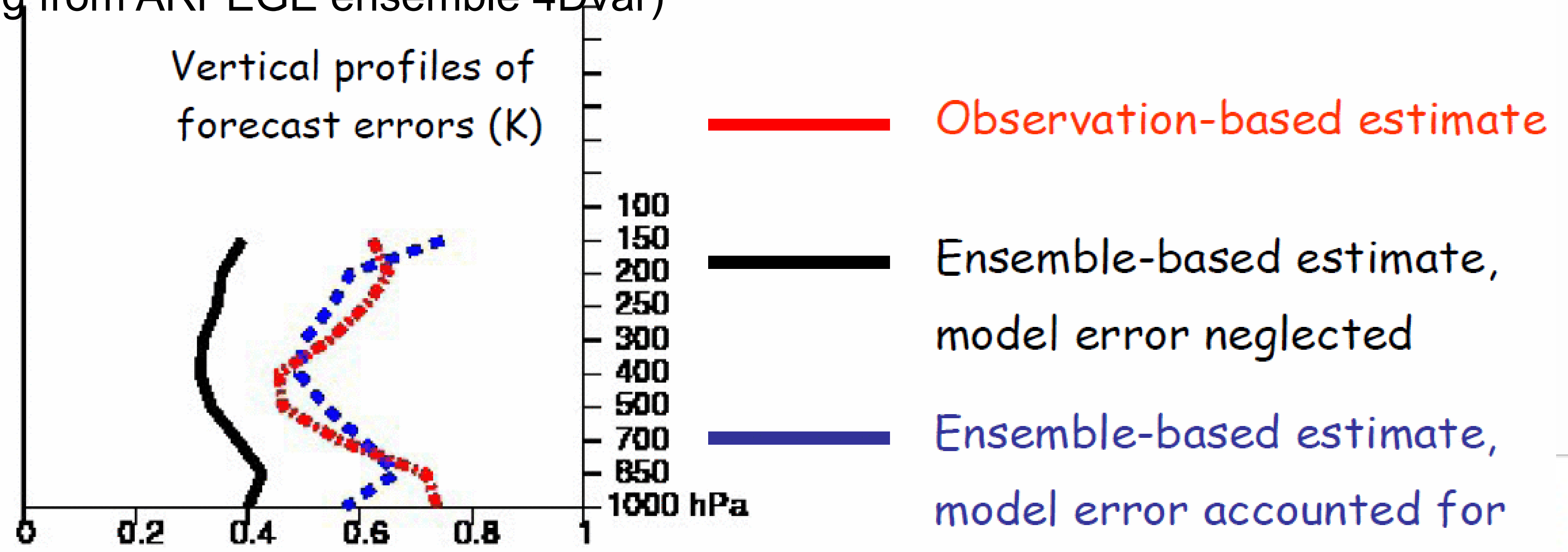
Error std of the day (T 900 hPa) (Arome EnVar, 6 members)



model error in EDA, using adaptive ensemble inflation

- total forecast error covariances estimated by innovations: $cov(y\text{-}Hx_b)=cov(Me_a + e_m)$ using Desroziers' a posteriori variational diagnostics (Jbmin)
- compare with EDA-predicted variances $cov(Me_a)$
- inflation of forecast perturbations: $e_i' = e_i + \alpha\,(e_i - \bar{e}_i)$, $\alpha>1$
- α~1.15 is applied every 3 hours
- **yields 'more realistic' initial spread, and better ensemble scores later on**

(Fig from ARPEGE ensemble 4Dvar)

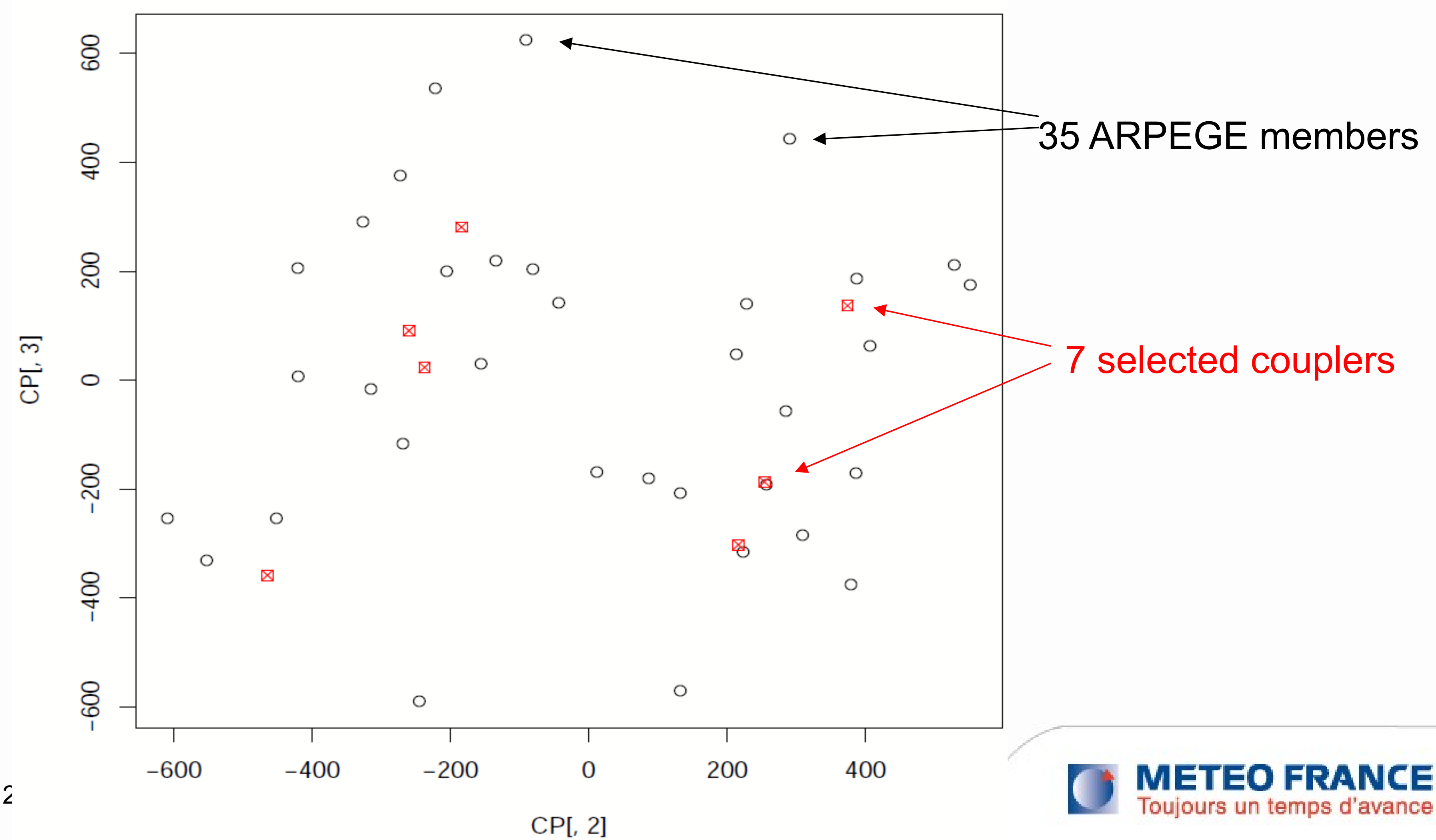


Boundary conditions

- From ARPEGE EPS (same short-range quality as EPS)
- AROME model is coupled at lateral & upper boundaries
- How to select the 'best' ARPEGE-EPS runs for AROME-EPS:
  - reference: randomly pick ARPEGE-EPS members
  - with "one ARPEGE physics package per member": neutral
  - with K-means clustering: improves wind scores, precip spread
  - with hierarchical complete link (similar to COSMO-LEPS): even better
  - impact on objective scores is small.

Boundary conditions

- Example of Kmeans clustering (plotted here in 2D PCA space)



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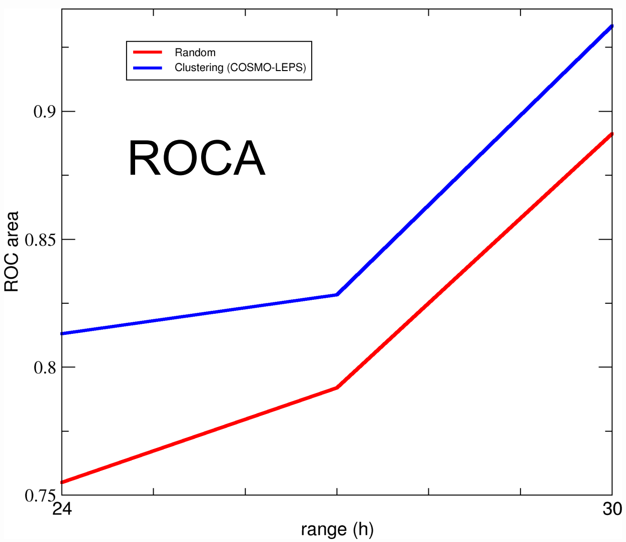
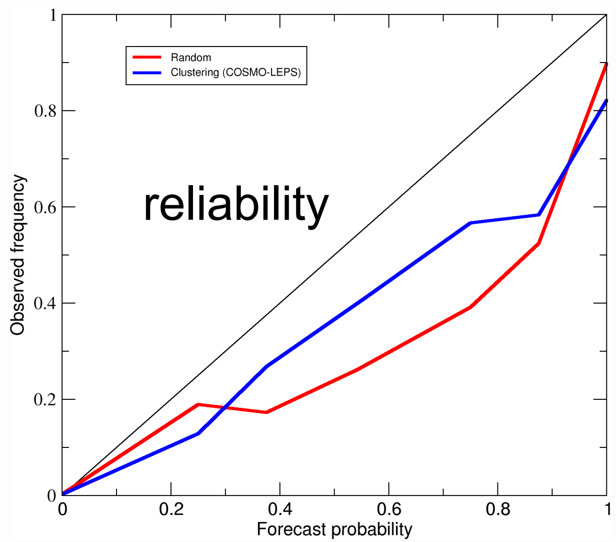
Boundary conditions

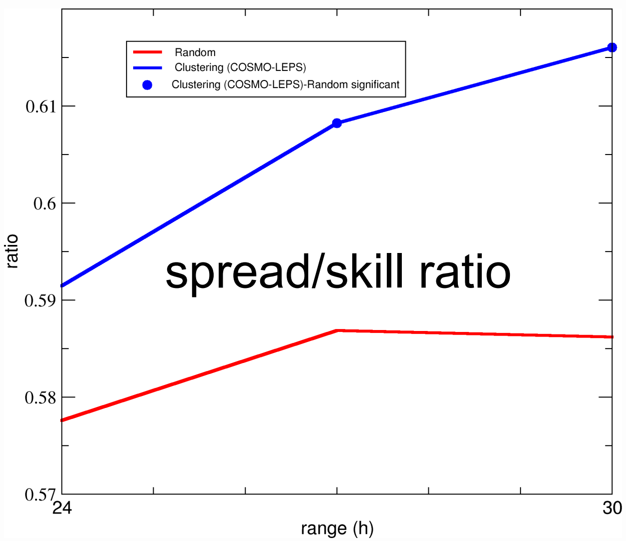
typical impact of selection method (Kmeans vs random choice) on precip scores

RR24>100 mm



RR24>100 mm





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Verification

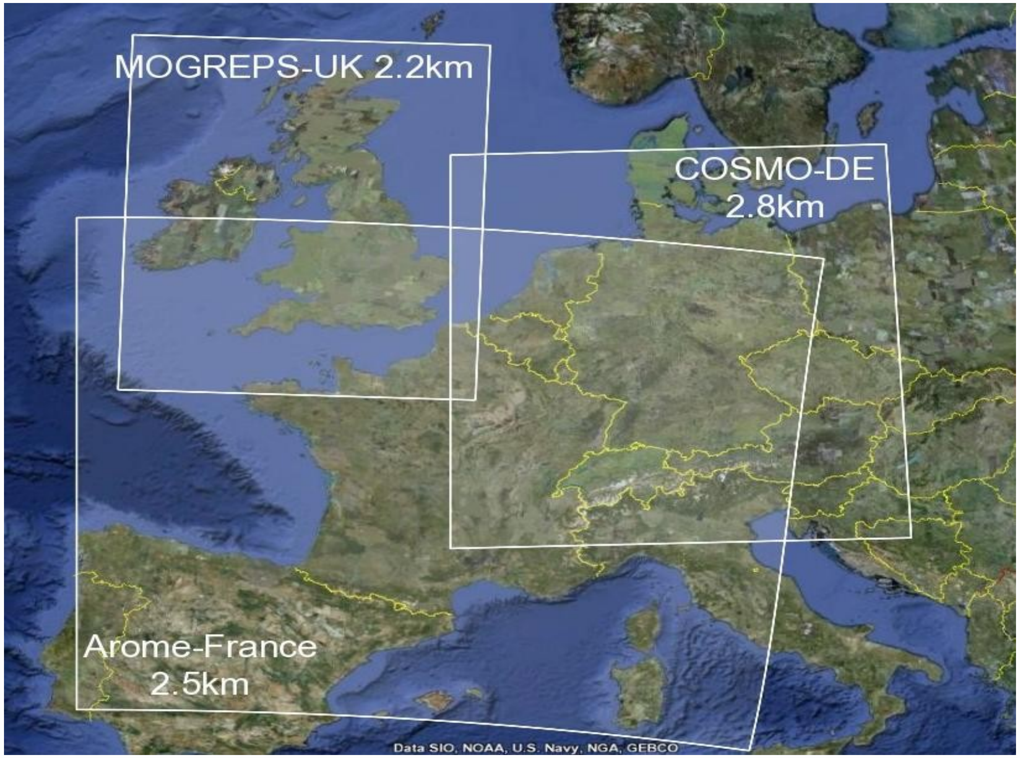
- Lessons learned:
  - analyses is a poor truth. **Real observations** are needed.
  - significant observation errors & model **biases**. Strong **diurnal cycle** of bias.
  - **forecast error growth** over first 24h is much smaller than step-zero errors
  - lack of upper-level high-frequency observations for verification (satellite, radars have difficult observation operator issues)
- New MF ensemble verification package:
  - observation-based, accounts for blacklists & observation errors
  - uses surface obs & **aircraft** T,U,V (plan: use 3D radar reflectivities)
  - probabilistic scores with **significance testing**
- Plans:
  - need to improve precip verification (because complex score behaviour)
  - evaluate value for real-time decision-making

Post-processing aspects

- **Kernel dressing** of output probabilities
  - unavoidable because ensemble is so tiny
  - plan: account for location uncertainties in output
- **Lagging**:
  - tests show BMA not useful (ie quality of old runs is not much worse than latest ones)
  - **benefits of lagging**:
    - lagging gives better spread & resolution (independently of ensemble size)
    - with <20 members, ensemble size is the top improvement opportunity
- **Calibration:** need to span several years (to sample 'extreme' weather)

SESAR11.2.2 'superensemble' demonstration

- demonstrate convection probability products for aviation
- 'seamless' products spanning several model domains
- over two 40-day periods



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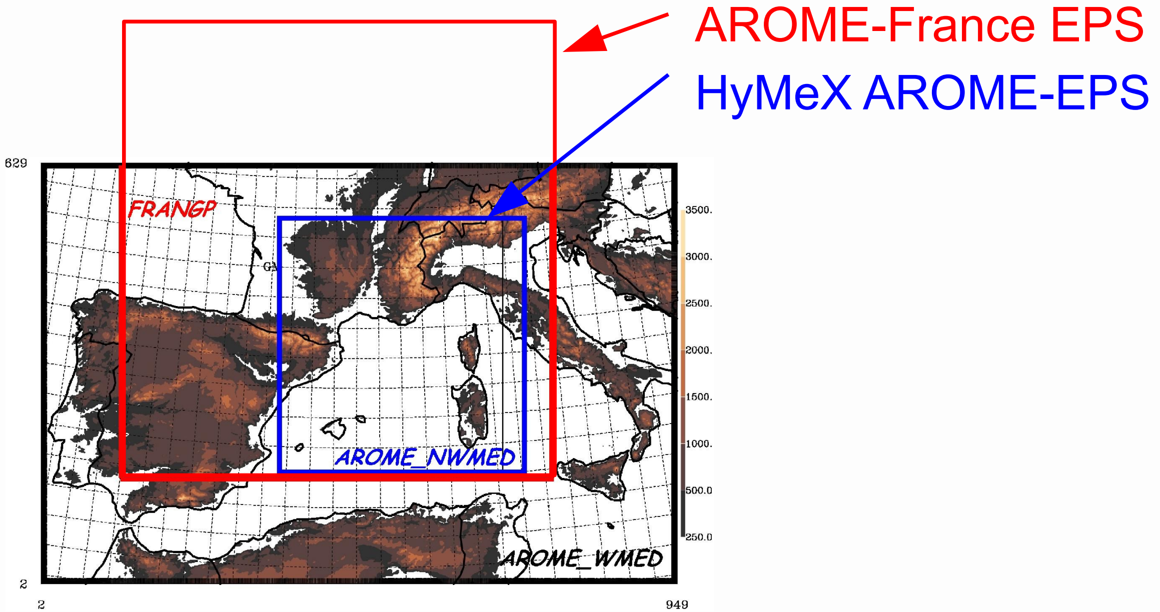
HyMeX 2012 SOP demonstration

- real-time runs of AROME-EPS over small domain
- focus on heavy rain & strong wind events
- coupled to hydrological EPS system
- intercomparison with other ensembles & models
- reruns & physical studies planned for 2013



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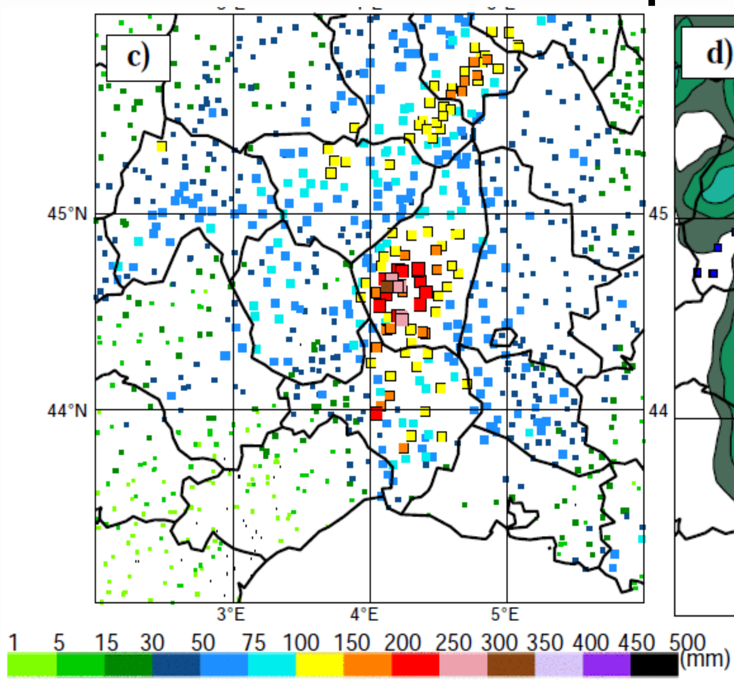
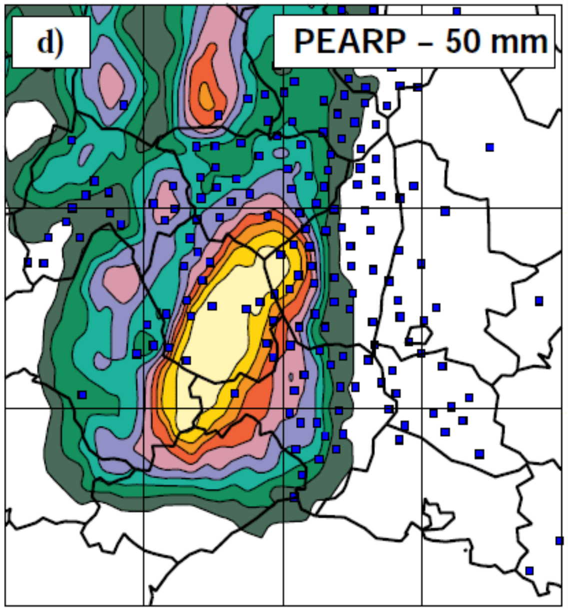
pre-HyMeX test on high precip cases

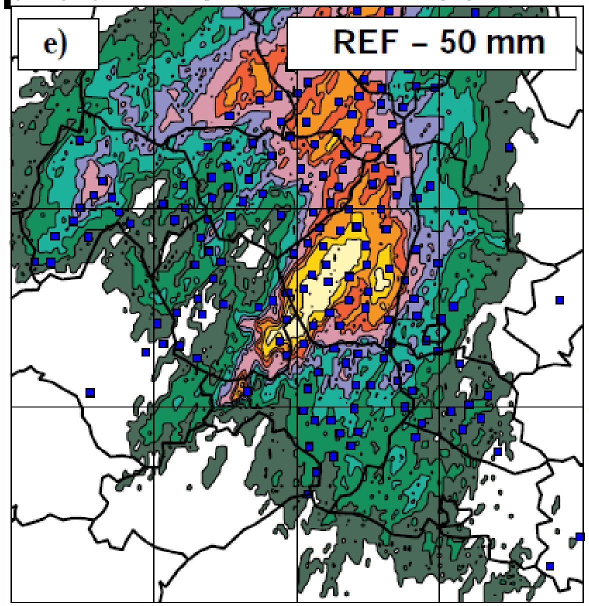
obs rr24

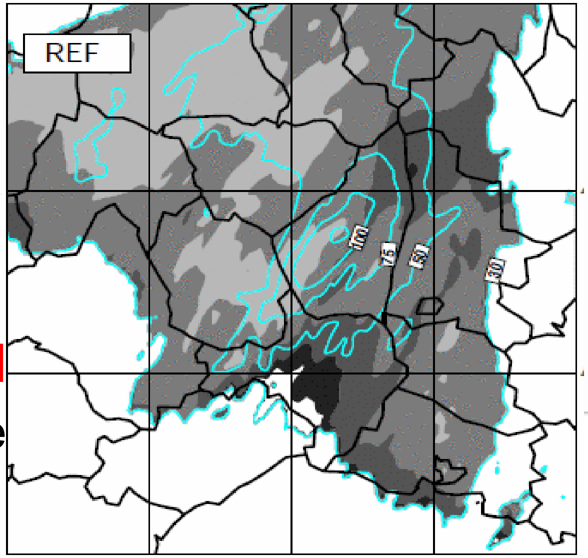


prob ARPEGE rr24>50mm



prob AROME rr24>50mm





ensemble mean provides good detection with low spread/mean ratio

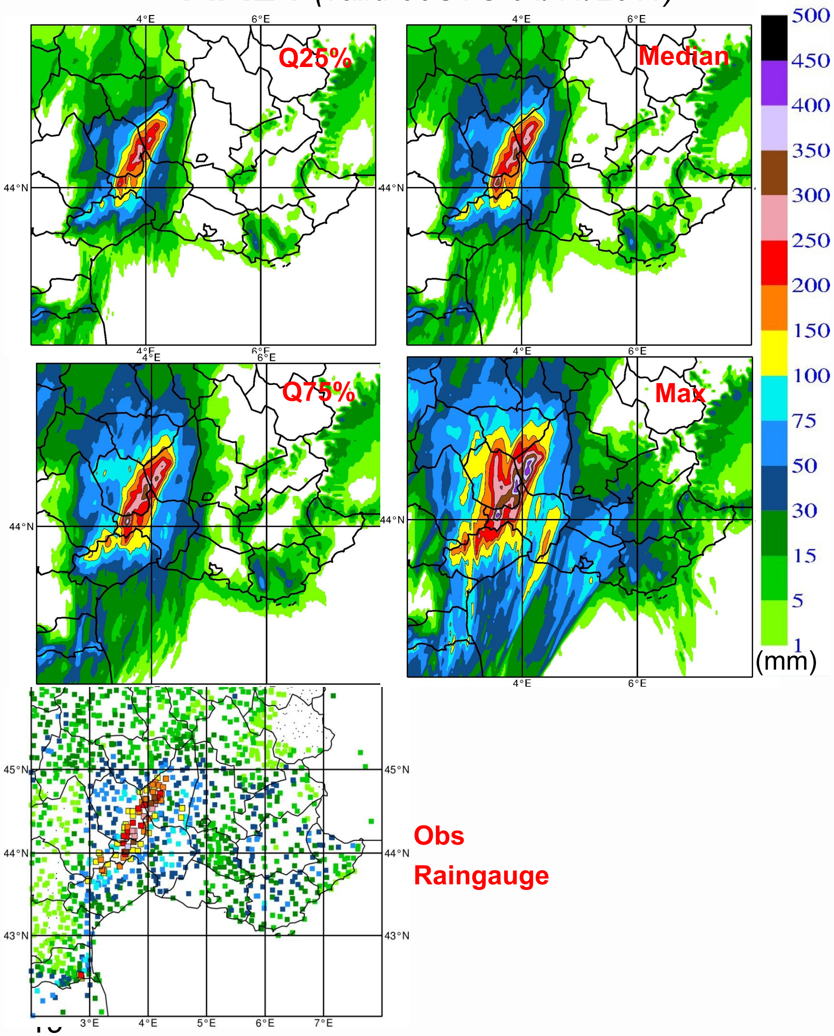
moy &

relative spread

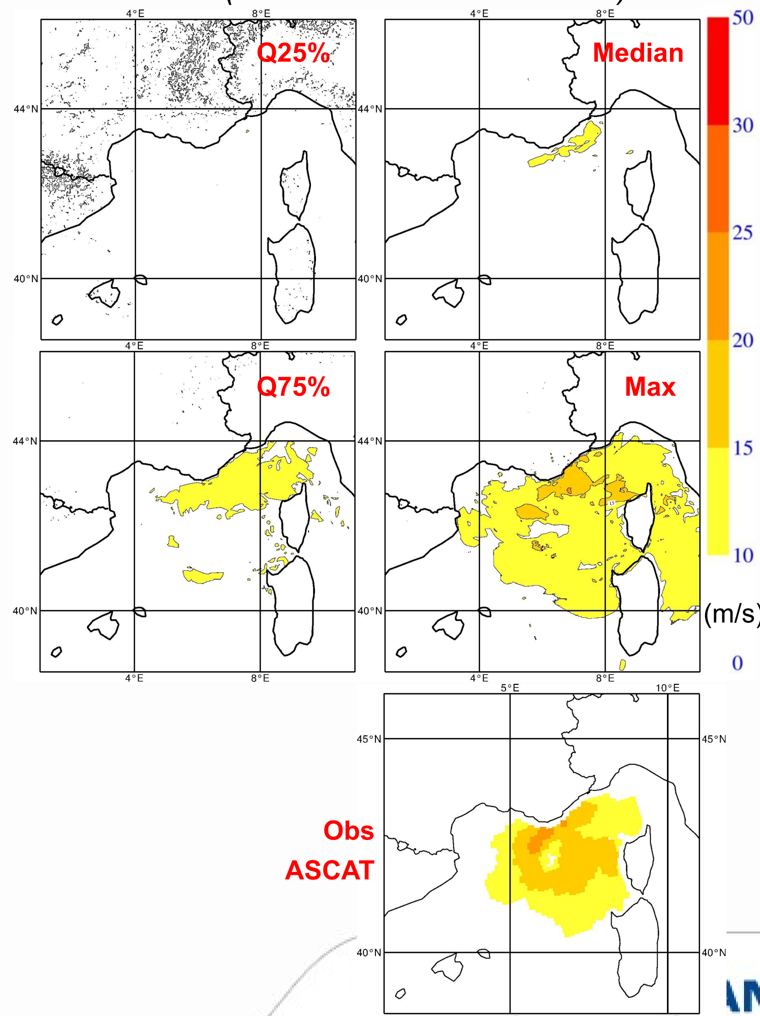
rr24 PEArome

other pre-HyMeX test cases, with web plots

RR24 (valid 00UTC 04/11/2011)



ff10m (valid 20 UTC le 08/11/2011)



In summary

AROME ensemble performance so far

- is much better than lower-resolution systems for low levels & precip
- looks comparable to available DWD & UK ensemble results
- lack of dispersion on some parameters
- precip is overdispersive (model bias issues)
- need more weather-type-specific physical understanding

Final thoughts

Open issues

- Some forecasters are mainly interested in choosing between several deterministic models.
- Strategic link with ensemble assimilation to mutualize CPU resources.
- We need reforecasts for calibration (which means heavy work !)
- Current EPS R&D is pragmatic, with some scientific flaws e.g.
  - lagging is handy, but theoretically incorrect.
  - inconsistent notions of 'statistical consistency' between data assimilation and EPS worlds.

Thank you for your attention

Questions ?

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.

Additional slides

In EPS, it is said that a "statistically consistent ensemble"...

- has spread: $cov(x_i - \overline{x_i}) = cov(x_t - \overline{x_i})$= the 'skill'
- ie at 6-h range, the spread is B, the background error cov matrix

In data assimilation, a "well-built ensemble" at 6-h range...

- has $cov(x_i - \overline{x_i}) \sim cov(x_i - x_b) = B$ = spread around the control
- since by definition $B = cov(x_b - x_t)$, it means that (under usual DA hypotheses):
- $cov(x_i - x_t) = cov(x_i - x_b + x_b - x_t) \sim cov(x_i - x_b) + cov(x_b - x_t) = 2B$ because the control is not perfect

I.e. DA ensembles tuned to have perfect covariances will be underdispersive whenever verified against observations (only nonlinear error growth can save us !)