Status of Météo-France convection-permitting EPS

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1 - Convection-permitting EPSs

- Predictability of the atmospheric flow at convection-permitting scales is intrinsically low
  $\Rightarrow$ there is a need for probabilistic prediction at an early range
- Convective-scale EPSs are under development in a number of NWP centers, based on high-resolution limited-area models
- Examples of advanced convective-scale EPSs : COSMO-DE EPS (2.8km), MOGREPS-UK (2.2km), WRF-based ensembles
- In this context, Météo-France is currently developing a convective-scale EPS, based on the AROME-France model.

1 - The AROME model

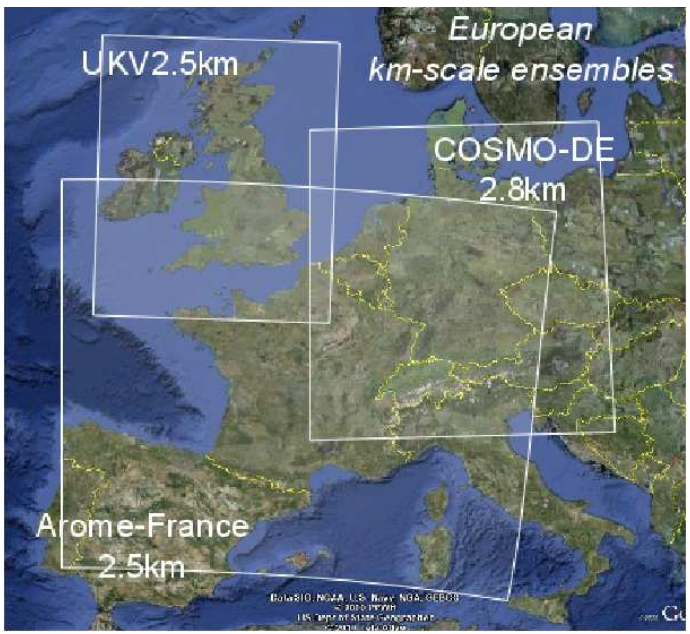
- AROME is a **non-hydrostatic limited-area convection-permitting model**, operational at Météo-France since December 2008
- The current configuration uses a **1.3km horizontal resolution** and **90 vertical levels**
- The analysis is provided by a **hourly 3D-Var scheme**
- In the near future an **AROME ensemble prediction system** will complement this deterministic version of AROME.

1 - Objectives of AROME-EPS

- Provide **high-resolution probabilistic forecasts** for the prediction of small-scale **high-impact phenomena**, e.g. heavy precipitating events, fog, strong winds etc.
- In addition to existing lower-resolution EPSs (e.g. Météo-France, ECMWF)
- Provide probabilistic atmospheric forcings to downstream systems (e.g. hydrology, flood, air traffic control)
- In operational use **by the end of 2016**.

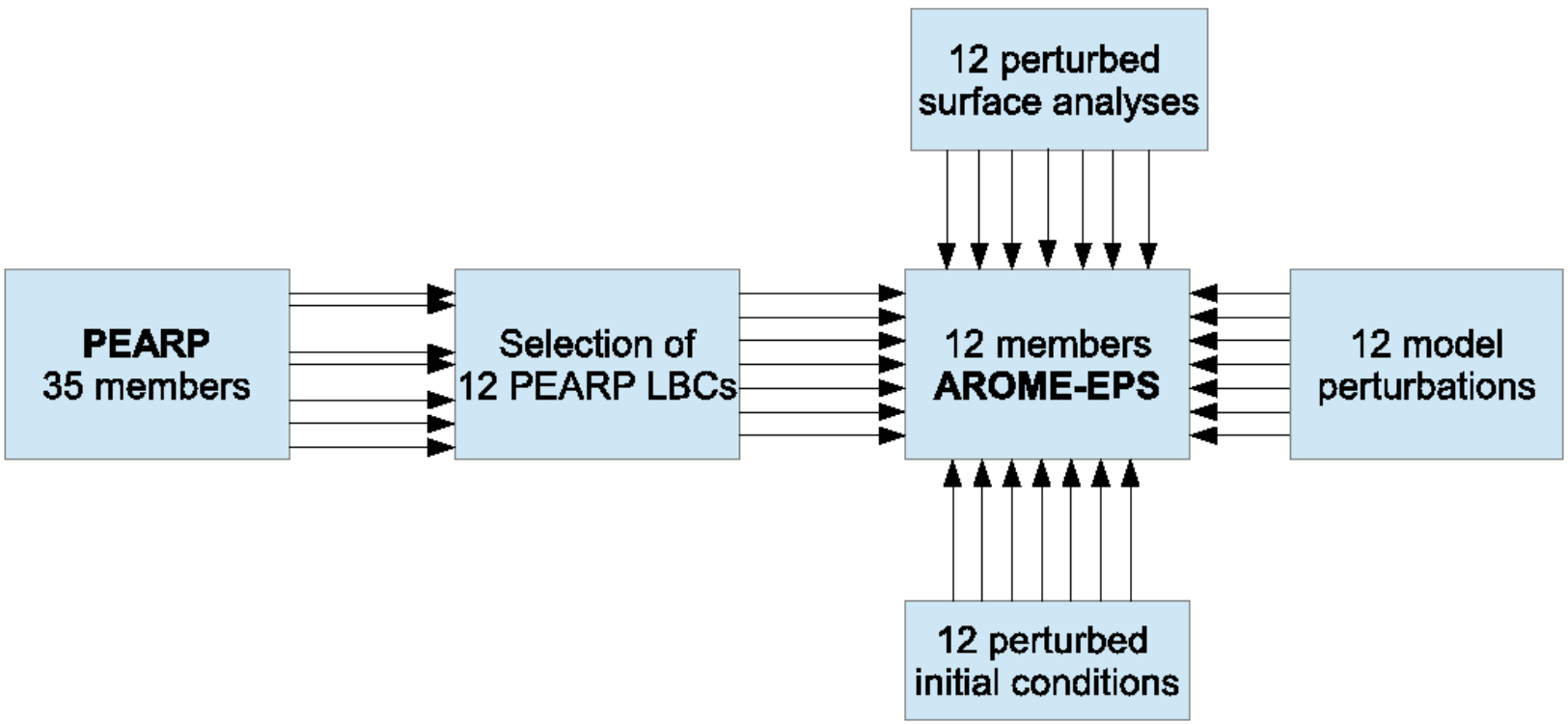
1 - Main features of AROME-EPS

- Same configuration as the AROME-France model except the horizontal resolution : **2.5km** (instead of 1.3km)
- **12 members**
- **2 productions/day** (at 9h and 21h UTC), up to a **45h lead time**
- Lateral boundary conditions provided by PEARP (Météo-France global EPS, 35 members - 10km resolution over France)



Each member of the AROME-EPS is built by perturbing a standard AROME forecast in order to represent the main sources of uncertainty regarding :

- initial conditions
- lateral boundary conditions
- surface conditions
- the model.



1 - Perturbation strategies

▷ Initial conditions : downscaled PEARP perturbations are added to the AROME-France analysis following

$$x_i = x_a + \alpha(z_i - \overline{z_i}),$$

x_i initial condition of member i
x_a AROME-France deterministic analysis
z_i initial PEARP perturbation of member i
α vertical amplitude modulation.

▷ Lateral boundary conditions : "clever" selection of PEARP members based on a **clustering algorithm** (Nuissier et al., 2012).

▷ Surface conditions : **auto-correlated random perturbations** are applied to various aspects of the SURFEX surface model (Bouttier et al., 2015) for some *physiographic* - vegetation index, vegetation heat coefficient, leaf area index, land albedo, land roughness length - and *prognostic variables* - **SST, soil temperature and humidity**, snow depth.

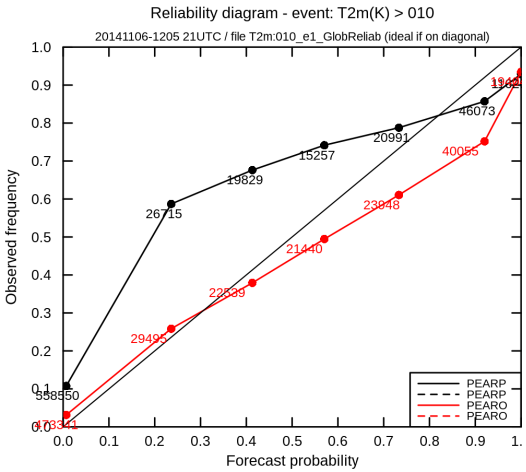
▷ Model errors are represented with the **SPPT scheme** (Stochastic Perturbation of Physics Tendencies, Bouttier et al. (2012)).

2 - Objective evaluation of the pre-operational AROME-EPS

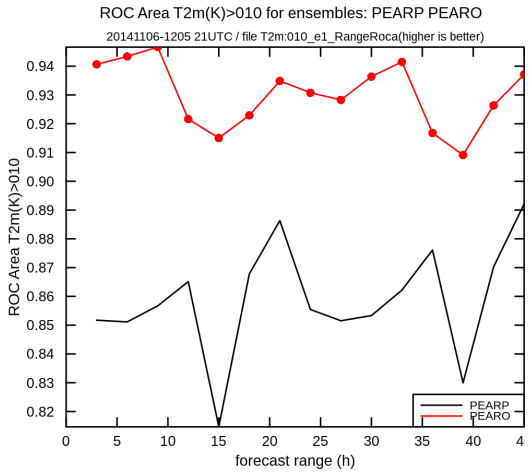
▷ The AROME-EPS performance has been extensively evaluated, in particular :

- as part of several **research experiments** over long periods
- during the **HyMeX campaign**, with one real-time AROME-EPS production per day during $\sim$ 2 months.

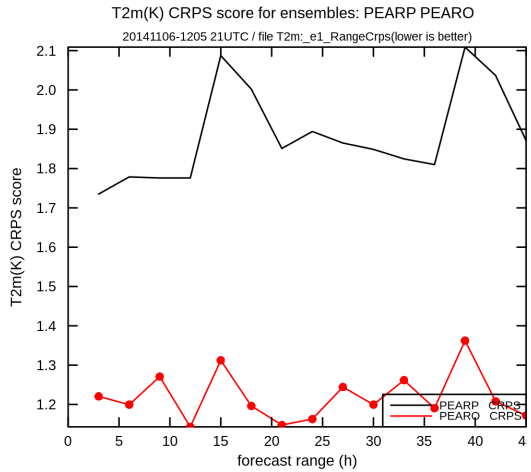
2 - Objective evaluation : AROME-EPS vs PEARP



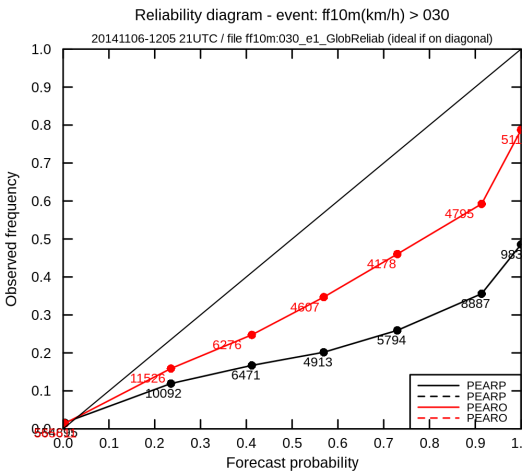
(a) T2m - Reliability



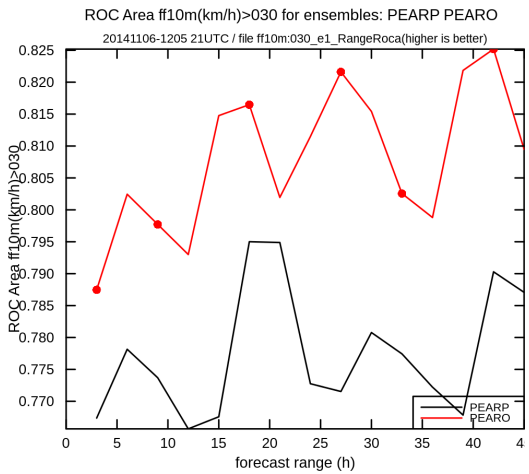
(b) T2m - Resolution



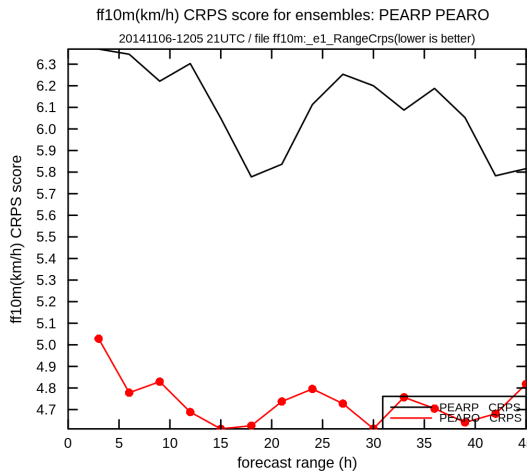
(c) T2m - CRPS



(d) ff10m



(e) ff10m



(f) ff10m

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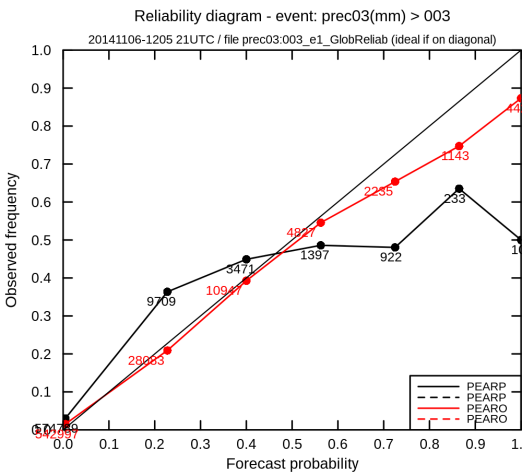
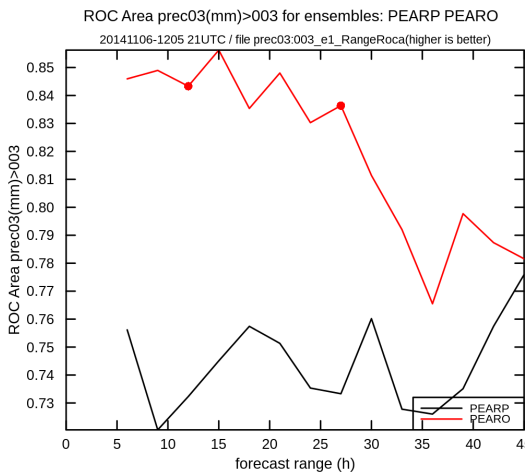
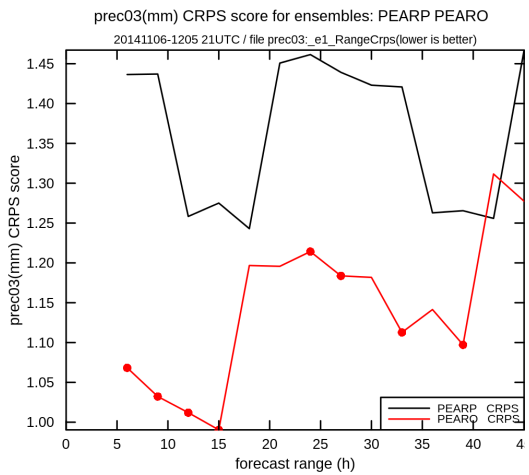


(a) rain 3h - Reliability



(b) rain 3h - Resolution



(c) rain 3h - CRPS

⇒ **AROME-EPS outperforms PEARP for surface variables.**

3 - Introducing AROME-EPS to forecasters

▷ Forecasters have been involved quite early in the development of the AROME-EPS with :

- discussions about the ensemble setting (number of productions per day, size of the ensemble *etc.*)
- the organization of **forecasting exercises** :
  - 2 forecasting exercises have been organized so far.
  - Around 10 (volunteered) forecasters from the different forecast centers participated to each session.
  - The goal of these exercises is to discover and utilize the AROME-EPS on a set of past events (chosen by the forecasters), in addition to the existing models (deterministic global and convection-permitting, global ensembles).
  - Forecasters were asked to **evaluate the ensemble guidance**, gradually **develop a methodology to use the EPS**, and give a feeback regarding their **preferred ensemble outputs**.
  - Develop exchanges between forecasters and scientists.

3 - About the methodology

▷ A **two-stage** forecast process :

- after having looked at the weather situation/observations, the examination of the deterministic models remain a first necessary step for most forecasters
  ⇒ a first scenario arises from this multi-model analysis.

- ensemble model outputs are examined in a second step to see if they add confidence to this forecast or not.
  ⇒ the initial scenario is potentially revised according to the ensemble guidance.

3 - About ensemble outputs

- The **analysis of the coupling PEARP members** is essential for most forecasters, in order to evaluate the synoptic uncertainty.
- The examination of the AROME-EPS often makes use of :
  - the “stamps” : since the AROME-EPS is relatively small forecasters are interested in looking at the scenario proposed by each member
  - neighborhood probabilities at different thresholds
  - quantiles
  - diagnostics for, e.g., convective activity, fog
  - time-lagged visualization
- A number of forecasters reported the lack of a **3D vizualization of ensemble outputs** to understand and describe phenomena such as convection, fog, snow.
  $\Rightarrow$ This is an important and complicated aspect that will be further examined.

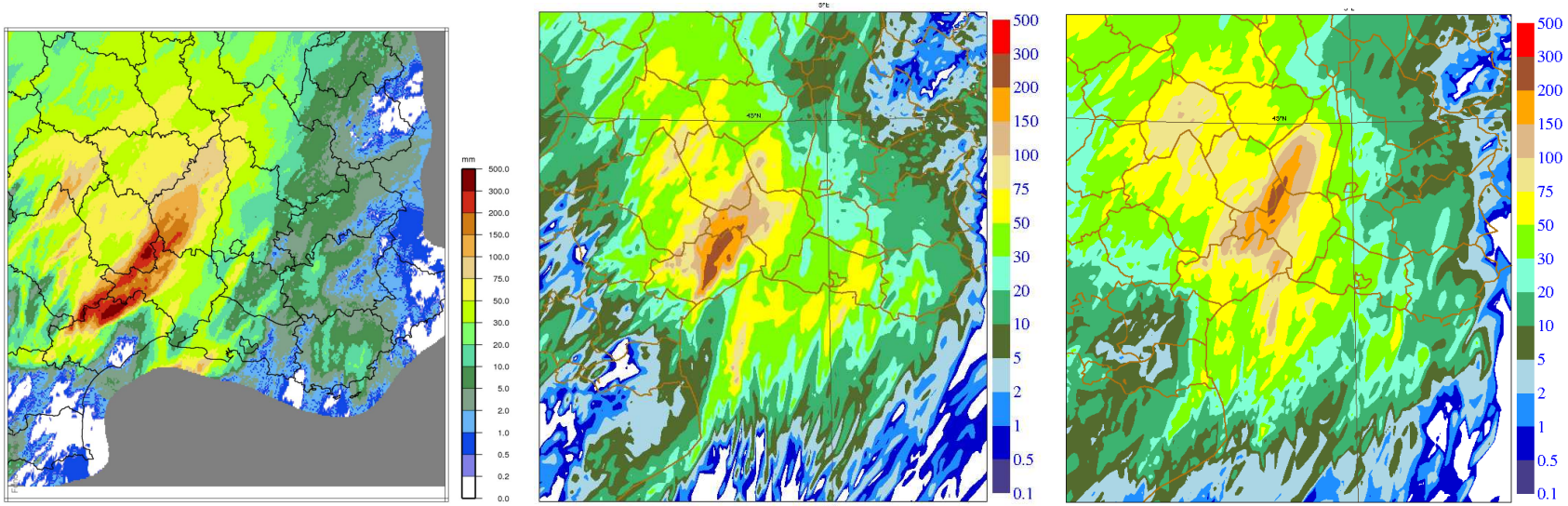
3 - Pre-operational phase

▷ These training sessions are now followed by **weekly forecasting exercises** :

- Started on 1st October 2015
- The AROME-EPS is run in near real-time once per day
- 2 days a week forecasters can work on a recent-past situation
- At the end of each session forecasters are asked to fill out a feedback questionnaire.

4 - Case 1 : Heavy precipitation on 12 september 2015

RR24 valid on 13/09/15 03TU.

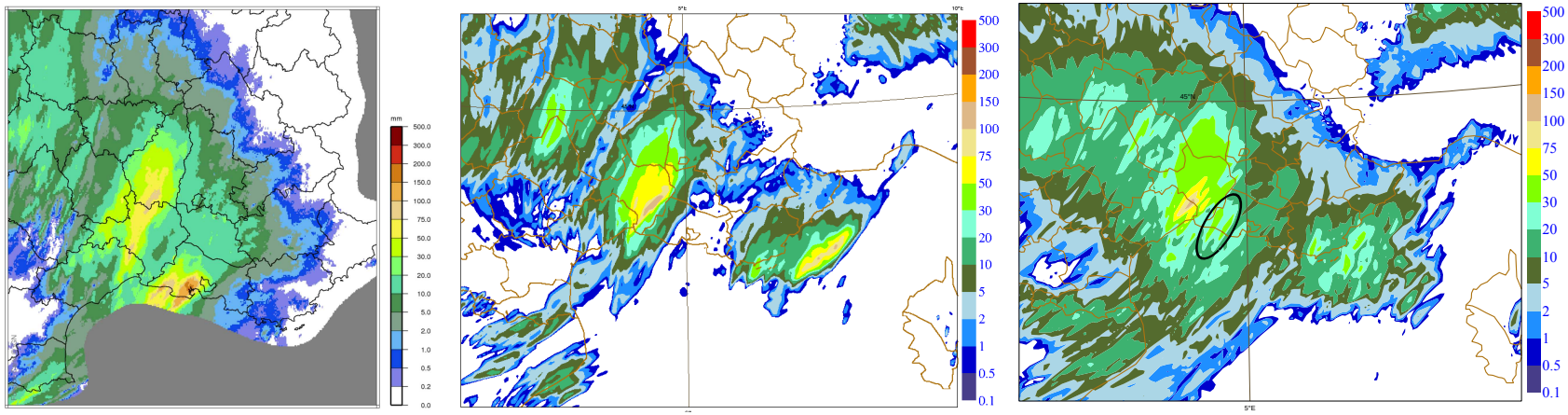


(a) obs (b) AROME (c) Q90 AROME-EPS

⇒ AROME-EPS provides a better localization of heavy rainfall than AROME.

4 - Case 2 : Heavy precipitation on 3 september 2015

RR6 valid on 03/10/15 12TU.

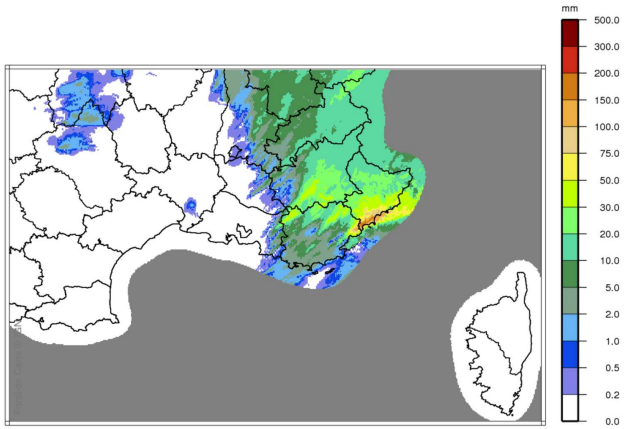


(a) obs (b) AROME 20151003r0 (c) Q90 AROME-EPS 20151002r21

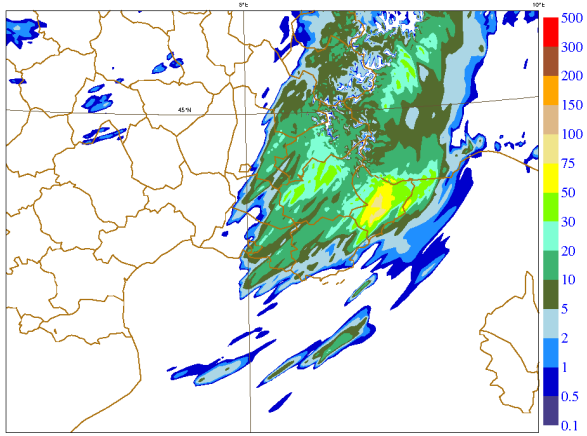
⇒ AROME-EPS indicates the possibility of rain occuring in the highlighted area.

4 - Case 3 : Flashfloods

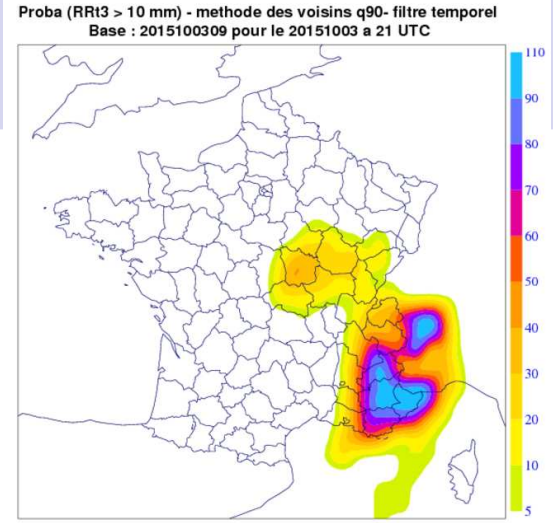
RR3 on 03/10/15 21TU.



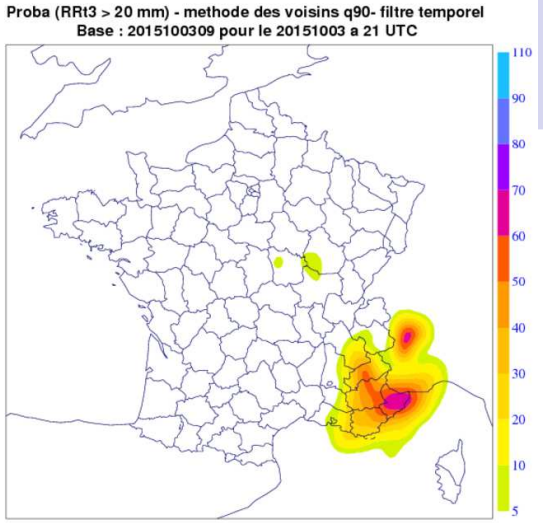
(a) obs



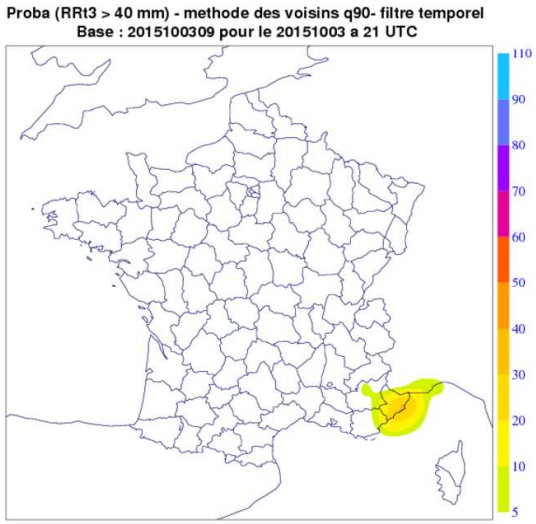
(b) AROME 20151003r6



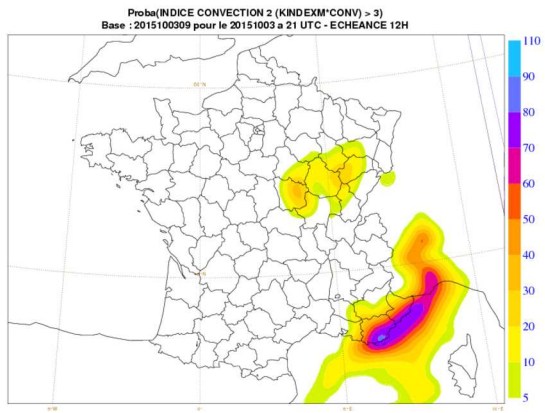
(a) AROME-EPS 20151003r9



(b) AROME-EPS



(c) AROME-EPS



(d) AROME-EPS

⇒ The strong signal in AROME-EPS probabilities of precipitation at different high thresholds confirms the risk of heavy rainfall in this area.

5 - Conclusions

- The first operational version of the AROME-EPS has been defined and evaluated.
- This system provides satisfactory results, on average and for particular case studies.
- Forecasters started getting familiar with this new ensemble system with the organisation of forecasting exercises.
- This is now followed by weekly training sessions, which started on 1st october, to gradually integrate the AROME-EPS in the future operational production.

5 - Future works

- Draw some conclusions from the weekly training sessions, to better understand the expectations of forecasters about the system itself and its utilization
- Experiments will be performed to evaluate improvements provided by an **increase of horizontal resolution and/or ensemble size**, in order to define later versions of the EPS
- Initial conditions of the AROME-EPS will be improved in the next few years by using perturbed analyses from an **AROME ensemble data assimilation**
  $\Rightarrow$ this helps improve scores up to 9-12h range on average (Raynaud and Bouttier, 2015 ; Bouttier *et al.*, 2015).
- Ensemble **calibration**
- Work will be done regarding the development of appropriate **visualization tools** to help forecasters utilize the (huge) ensemble information.