

# Hydrologic ensembles for Flash Flood Warnings at ungauged basins based on convection-permitting NWP forecasts

Julie Demargne<sup>1</sup>, Didier Organde<sup>1</sup>, Pierre Javelle<sup>2</sup>, Maria-Helena Ramos<sup>3</sup>, Céline de Satin-Aubin<sup>4</sup> & Nicolas Jurdy<sup>5</sup>

1. *HYDRIS Hydrologie*

2. *Irstea Aix-en-Provence*

3. *Irstea Antony*

4. *SCHAPI (National Service for Flood Prediction)*

5. *DREAL Lorraine (regional flood forecast office)*



www.irstea.fr



10th Anniversary Workshop  
26 June 2014



# Challenges in flash flood warnings



## • High space-time scale of FF events

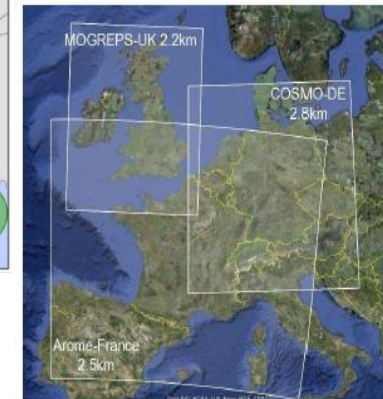
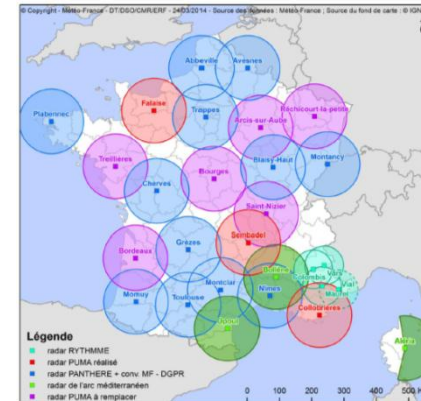
- local events with short lead time  
(a few km<sup>2</sup> , ~2 hours)



*Inondations dans le centre de Eragny-sur-Aisne (photographie APF)*

## • Few available observed datasets

- Small ungauged basins
- New high-res hydromet datasets
- Lack of ground impact database



## • Hydromet models

- Scale to match FF events
- New forecasts available but uncertainties to be accounted for
- Evaluation for ungauged basins



# Hydromet operational warning services in France

Met warnings produced by Meteo-France on extreme weather events based on radar-gauge QPE

Hydrologic warnings produced by regional and national flood centers using last flow observations and forecasters expertise

[vigilance.meteofrance.com](http://vigilance.meteofrance.com)

June 19, 2013 at 00:03 am

- Une vigilance absolue s'impose : des phénomènes dangereux d'intensité exceptionnelle sont prévus...
  - Soyez très vigilant : des phénomènes dangereux sont prévus...
  - Soyez attentif si vous pratiquez des activités sensibles au risque météorologique...
  - Pas de vigilance particulière.
- |  |  |
|--|--|
|  |  |
|  |  |
|  |  |
|  |  |
- Les vigilances pluie-inondation et inondation sont élaborées avec le réseau de prévision des crues du Ministère du Développement durable



[www.vigicrues.gouv.fr](http://www.vigicrues.gouv.fr)

June 19, 2013 at 03:54 am

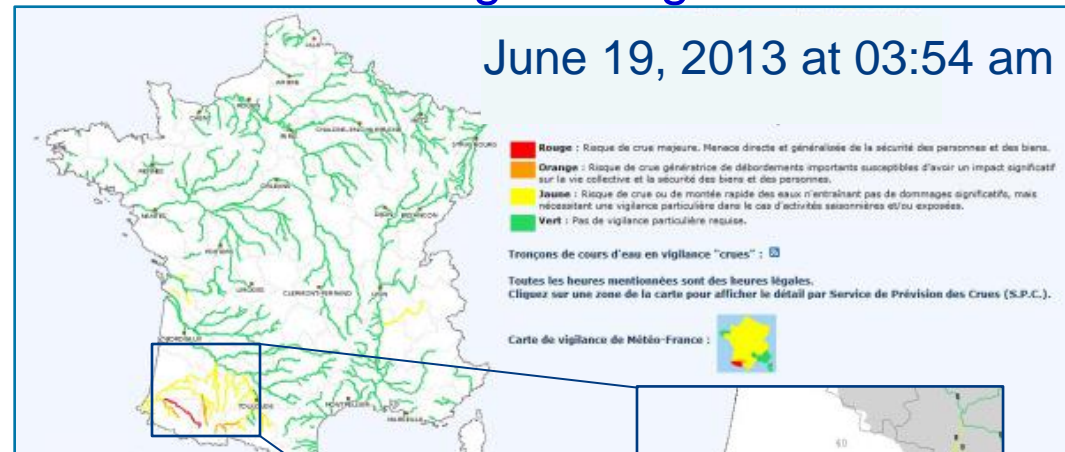
- Rouge : Risque de crue majeure. Menace directe et généralisée de la sécurité des personnes et des biens.
- Orange : Risque de crue génératrice de débordements importants susceptibles d'avoir un impact significatif sur la vie collective et la sécurité des biens et des personnes.
- Jaune : Risque de crue ou de montée rapide des eaux n'entraînant pas de dommages significatifs, mais nécessitant une vigilance particulière dans le cas d'activités saisonnières et/ou exposées.
- Vert : Pas de vigilance particulière requise.

Tronçons de cours d'eau en vigilance "crues" :

Toutes les heures mentionnées sont des heures légales.

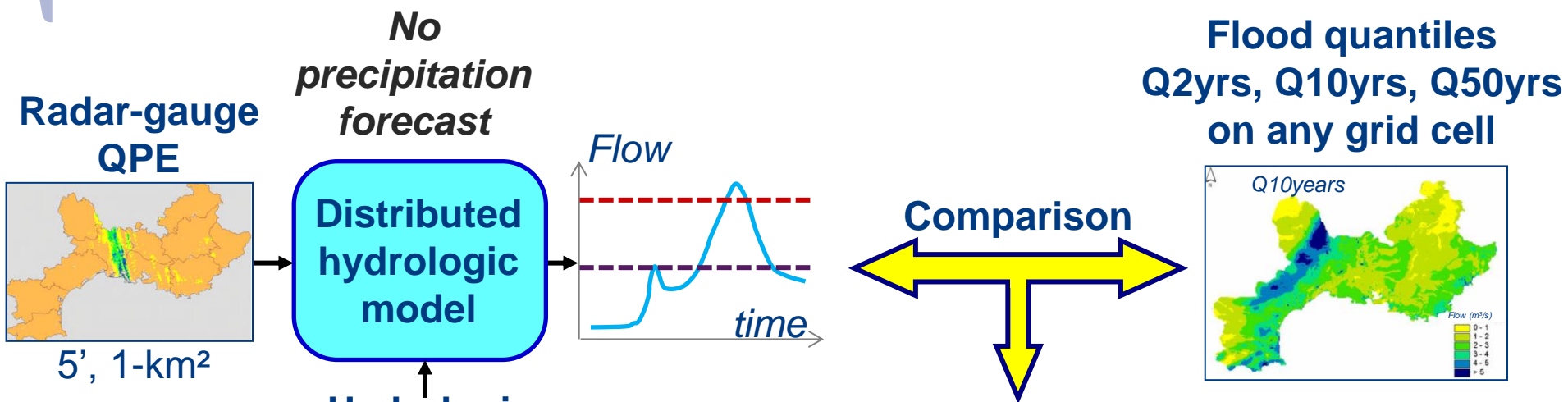
Cliquez sur une zone de la carte pour afficher le détail par Service de Prévision des Crues (S.P.C.).

Carte de vigilance de Météo-France :



**⇒ Another service is needed for flash flood warnings in small-to-medium fast-responding ungauged basins (10 - 1000 km<sup>2</sup>, 2-6 hr response time)**

# AIGA Flash Flood Warning Method



**Flood risk map with estimated return periods of ongoing events**

METEO FRANCE

Notice Images radar Aléa pluviométrique Aléa hydrologique Carte d'avertissement Neige

Aléa hydrologique Aléa hydrologique et Synthèse des aléas pluviologiques Aléa hydrologique et cumuls de pluie

ALÉA HYDROLOGIQUE - Date de mise à jour : 06/11/2012 à 12h38

ven. 02 nov. sam. 03 nov. dim. 04 nov.

dim. 04 nov. lun. 05 nov. lun. 05 nov. lun. 05 nov. lun. 05 nov. lun. 05 nov. lun. 05 nov. lun. 05 nov.

23H45 00H00 00H15 00H30 00H45 01H00 01H15 01H30 01H45

Estimated Return Period

- < 2 years
- 2 ≤ < 10 years
- 10 ≤ < 50 years
- > 50 years

Digne-Jes-Bains

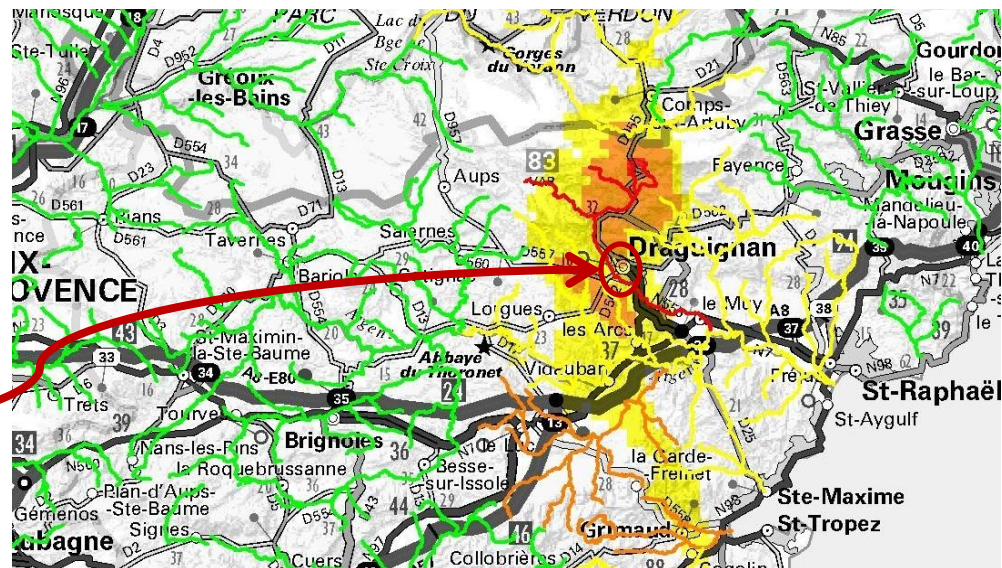
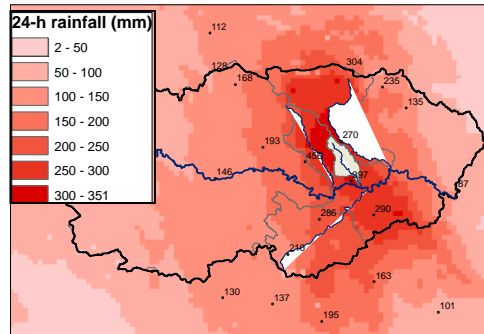
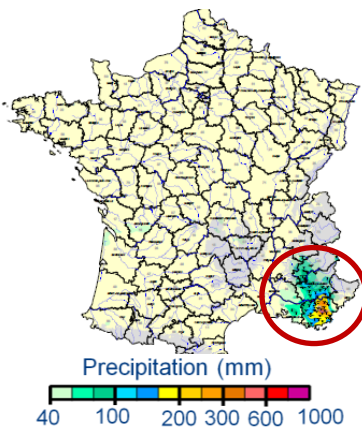
RHYTM

**Operational in South of France since 2005, to be implemented in entire France by 2016**

# AIGA Flash Flood Warning Method

## 15-16 June 2010 event around Draguignan (Côte d'Azur)

### AIGA Warning – 15 June 2010 at 17:15 am



EDITION SPECIALE  
VILLE DE DRAGUIGNAN  
juillet 2010



River	Sector	AIGA Warning Time			Observed damages (Lefort and Kouliniski, 2011)
		Level 1 (>Q2yr)	Level 2 (>Q10yr)	Level 3 (>Q50yr)	
Real	Les Arcs	15 :00	16 :00	19 :00	16:10 : Flooding in village

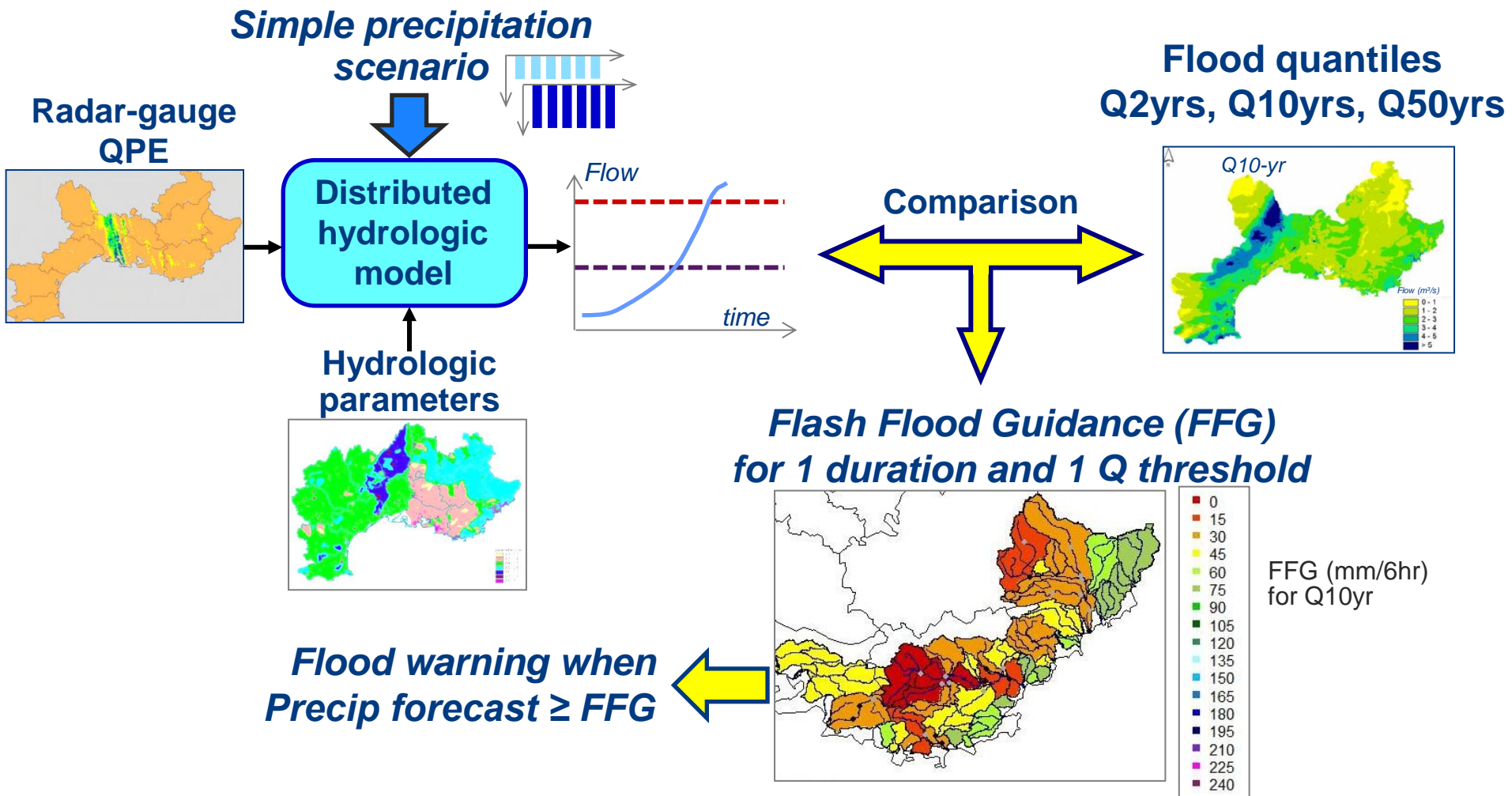
**AIGA gave meaningful warnings but *short or no lead time***

⇒ ***Need to extend lead time by using precipitation forecasts***

⇒ ***Prefer high-res ensembles to capture convective precipitation***

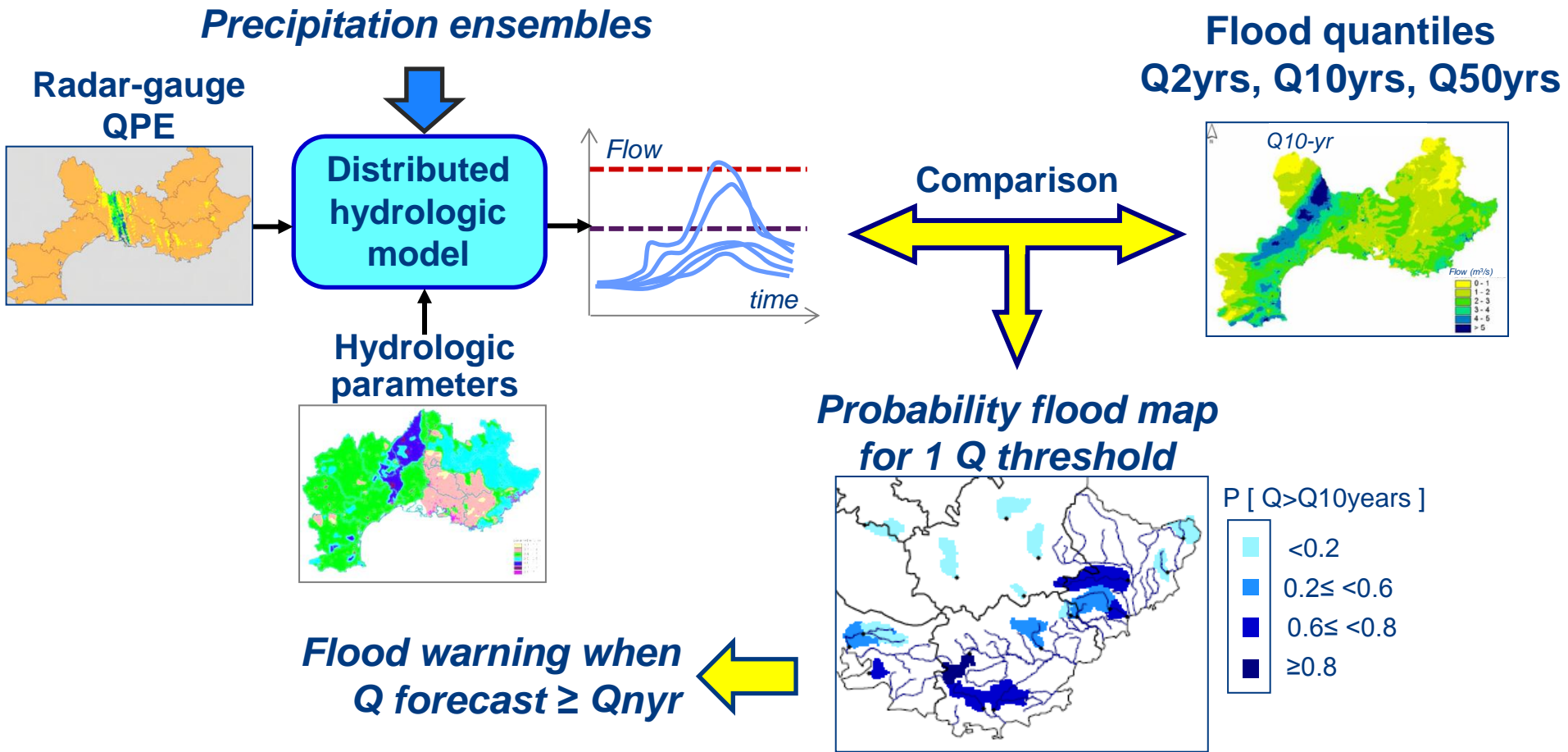
# Integration of future precipitation: approach 1 – Flash Flood Guidance

Rainfall amount for 1 duration and for 1 basin to reach a given Q threshold



**FFG maps facilitate discussions between meteo and hydro forecasters**

# Integration of future precipitation: approach 2 – hydro ensemble prediction



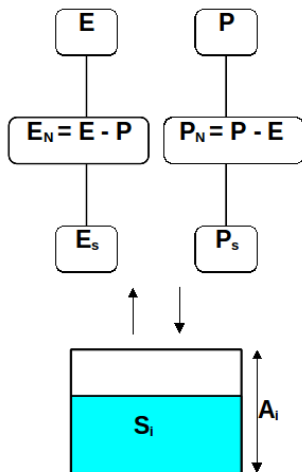
⇒ **Demonstrate how FF warnings would benefit from using precipitation ensembles with the 2 different approaches**

# Initial experiments with pre-operational AIGA

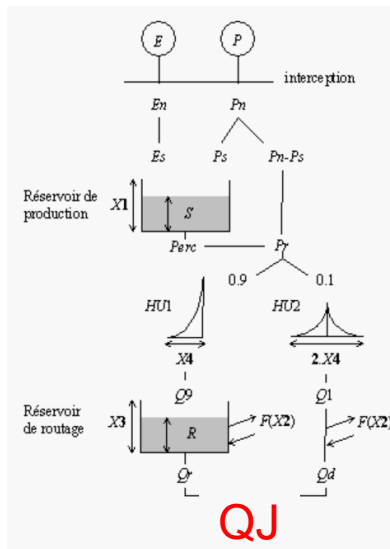
- Event-based semi-distributed hourly model coupled with continuous lumped daily models

## Daily lumped models for initialization

### SMA



### GR4J

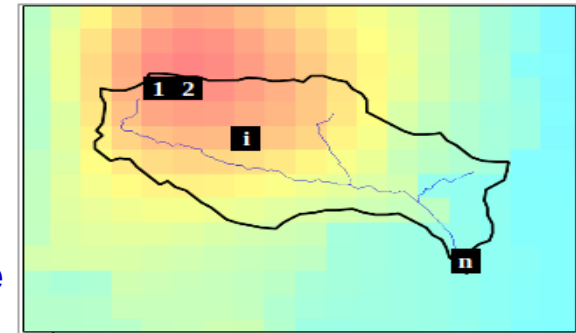


$$S_{i0}/A_i = a \cdot S_i \cdot A_i(J)$$

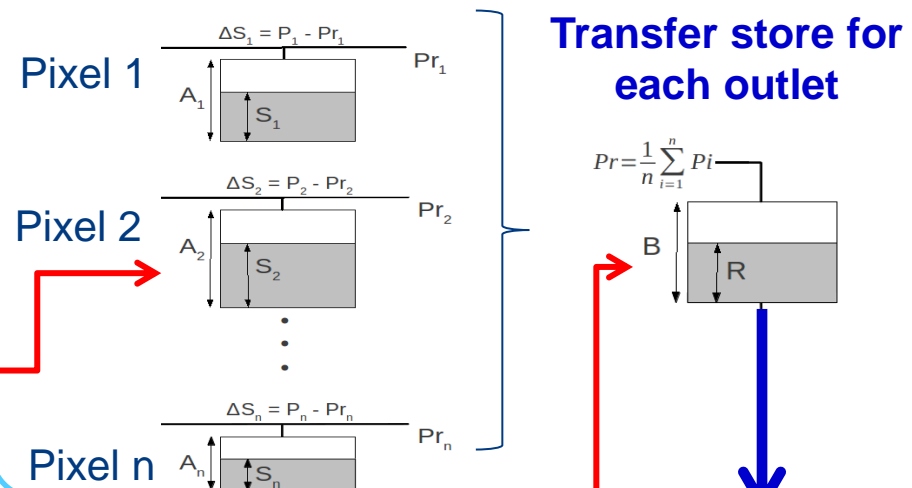
## Semi-distributed GRSD model

$$\Delta x = 1 \text{ km}$$

$$\Delta t = 1 \text{ hr}$$



### Production store for each pixel



$$R_0 = f(QJ)$$

Hourly Q



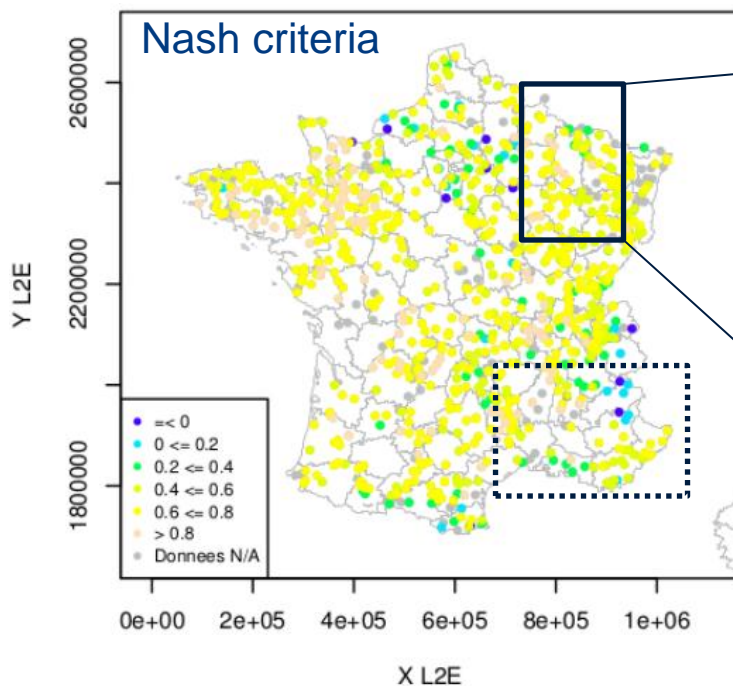
# Initial experiments with pre-operational AIGA

## • Calibration of hydrologic models

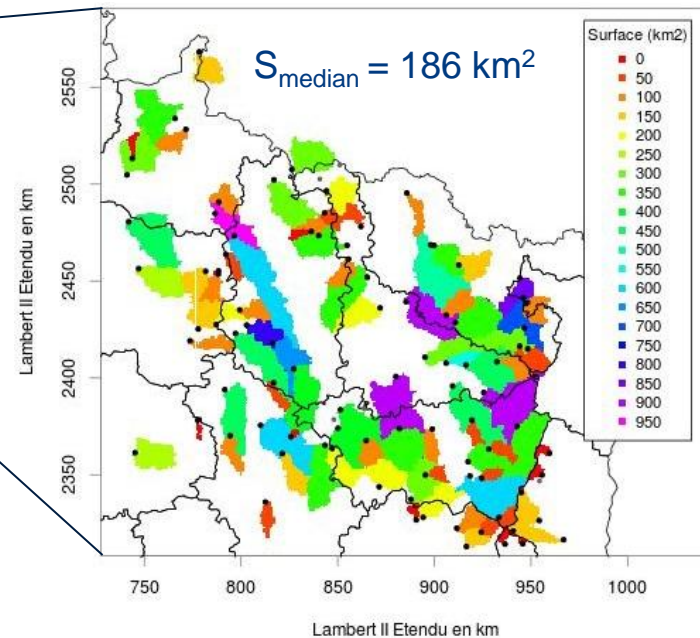
- Reanalysis of radar-gauge QPE from 2002-2006 from Meteo-France
- Calibration and regionalization of model parameters
  - 4 for lumped daily models and 2 for semi-distributed hourly model

## • Reforecasting: real-time radar-gauge QPE (Panthere) starting in 2009

## • Basin selection: $<1000 \text{ km}^2$ , limited missing Qobs & dam impact



## Meuse-Moselle rivers area

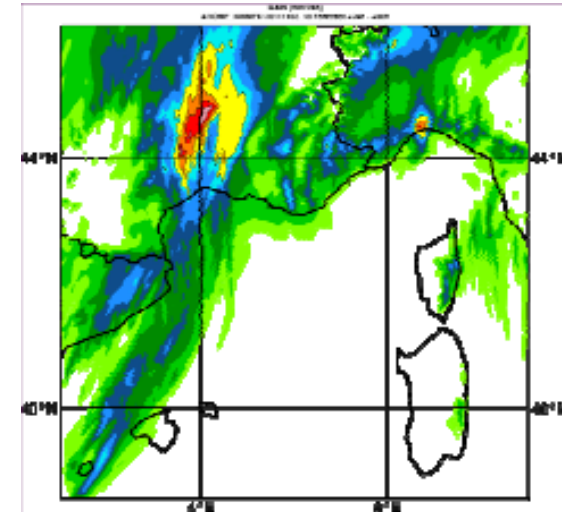


92 calibrated basins

# Initial experiments with AROME forecasts

## • High-resolution NWP model modeling convections

- Meteo-France's AROME model
  - $\Delta x=2.5\text{km}$ ,  $\Delta t=1\text{hr}$ , horizon +30hr,
  - 4 times/day (00, 06, 12, 18TU)
  - operational since Dec08
- AROME ensembles ready by ~2015
  - AROME QPF used to build **time-lagged ensembles** every 3hrs
- Selection of 20 events from Jan 2009-Dec 2012



*Credit: B. Vincendon*

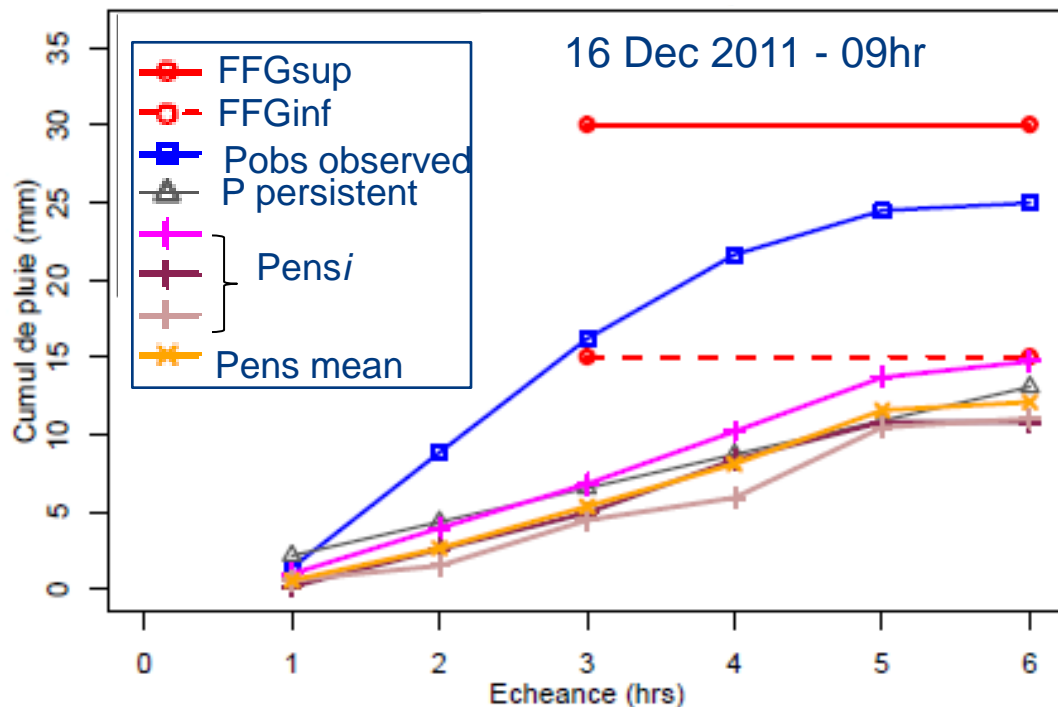
## • Flash flood warnings derived with 2 approaches

- FFG-based method: FFG values for durations of 3hr, 6hr, 9hr compared to QPF
- Flow forecast method: QPF directly ingested into hydro model

# Approach 1: warnings based on Pens/FFG

- FFG given by 15-mm interval (computational choice)
- Comparison with AROME-timelag precipitation ensembles and reference forecasts (observed, persistent, ens mean)
- Warning if precipitation forecast  $\geq$  FFG for a given duration

Bassin A1252010 (2) – La Doller a Reiningue ( 179.1175 km<sup>2</sup> )



**Flow threshold: Q2yrs**

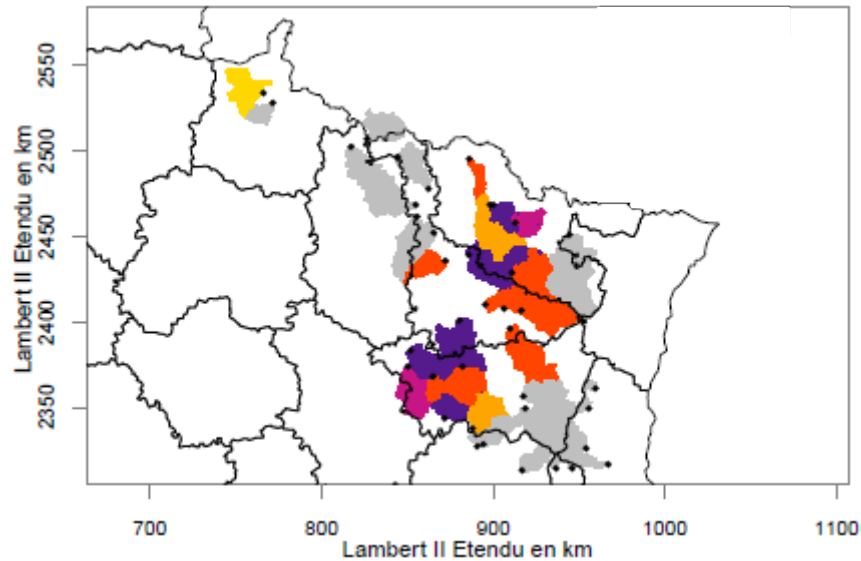
**] FFG<sub>inf</sub> , FFG<sub>sup</sub> ]**

*Warning with Pobs  
No warnings with other QPF*

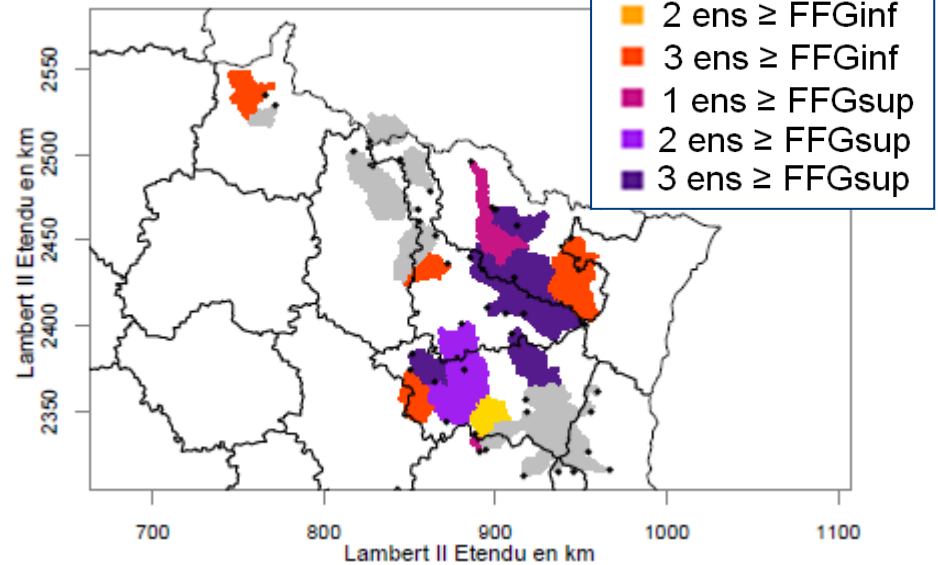
# Approach 1: warnings based on Pens/FFG

- Example: FFG for 6-hr duration and Q2yrs threshold compared to AROME-lag precipitation ensembles

16 Dec 2011 - 06hr



16 Dec 2011 - 09hr



Pens/FFG Warning

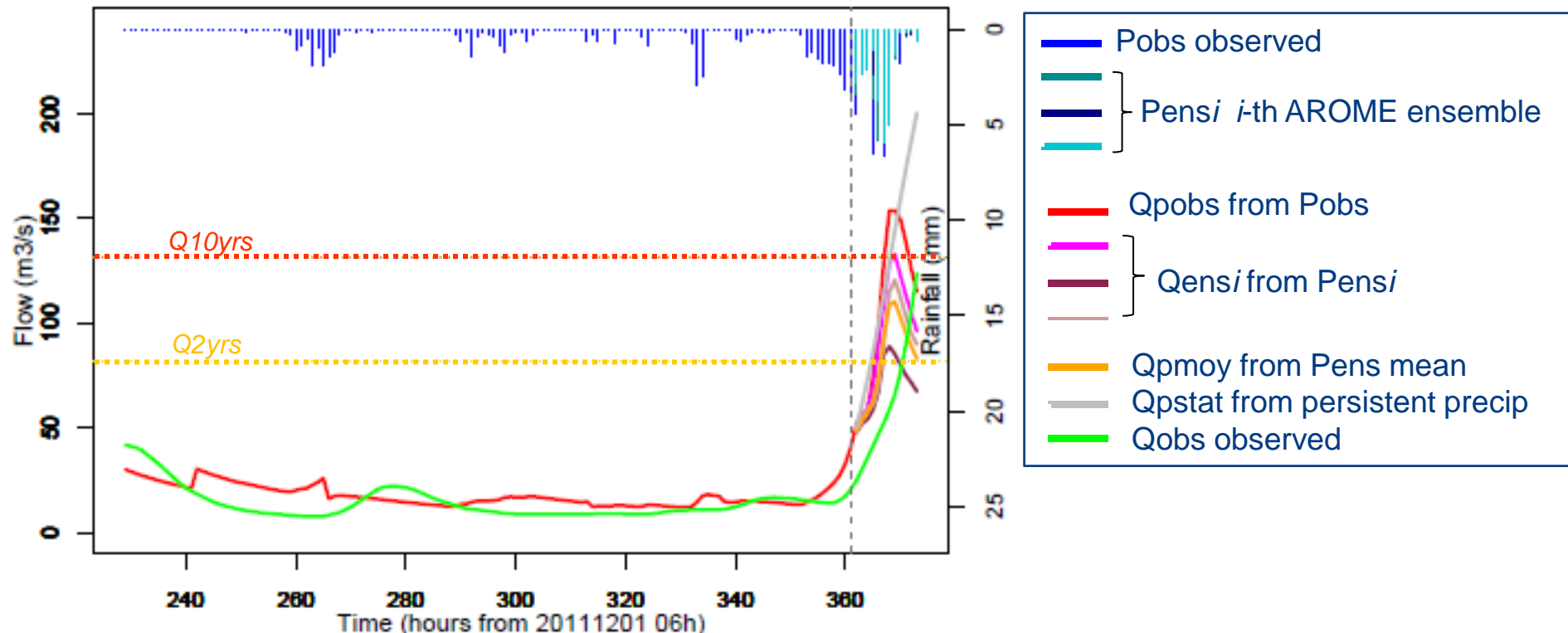
- 3 ens < FFG
- 1 ens  $\geq$  FFGinf
- 2 ens  $\geq$  FFGinf
- 3 ens  $\geq$  FFGinf
- 1 ens  $\geq$  FFGsup
- 2 ens  $\geq$  FFGsup
- 3 ens  $\geq$  FFGsup

# Approach 2: warnings based on Qens prediction

- Flow prediction with
  - 3 AROME-timelag ensembles
  - Reference forecasts: observed, persistent, ensemble mean

T0 : 16 Dec 2011 06 UTC

Bassin A5261020 (14) - Le Madon a Mirecourt (381.1925 km<sup>2</sup>)

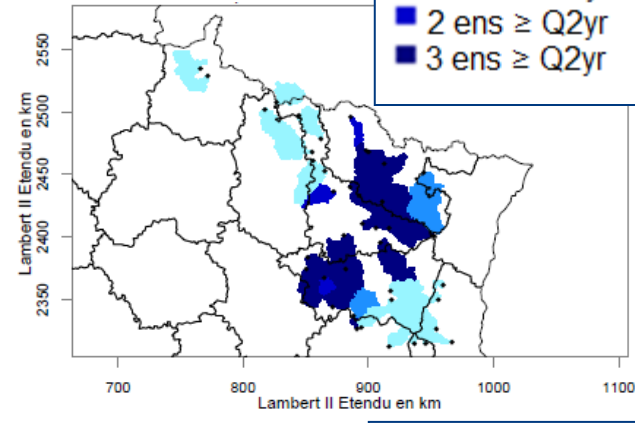
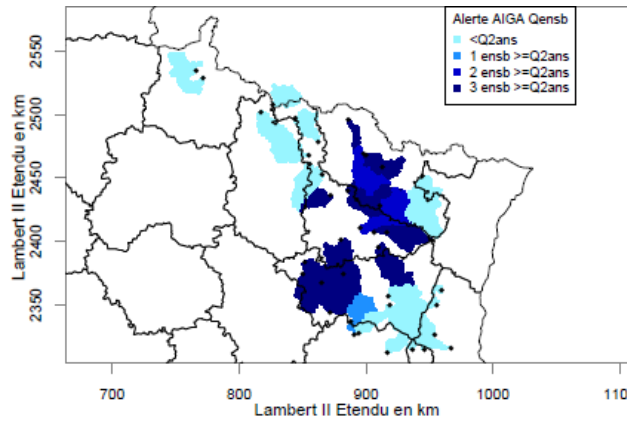
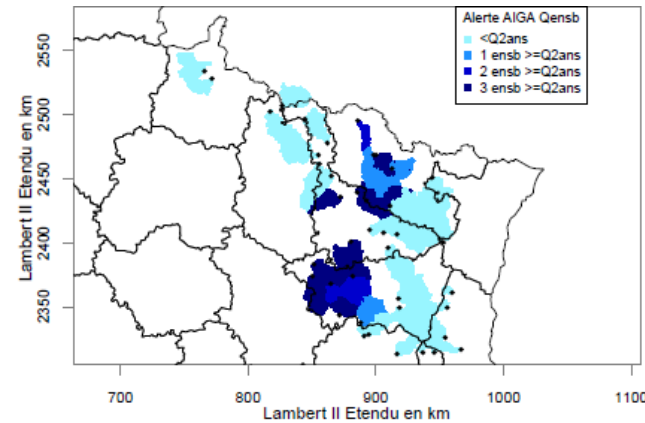


# Different warnings from 2 approaches

## Warnings based on flow ensembles (approach 2)

Qens Warning

- 3 ens < Q2yr
- 1 ens  $\geq$  Q2yr
- 2 ens  $\geq$  Q2yr
- 3 ens  $\geq$  Q2yr



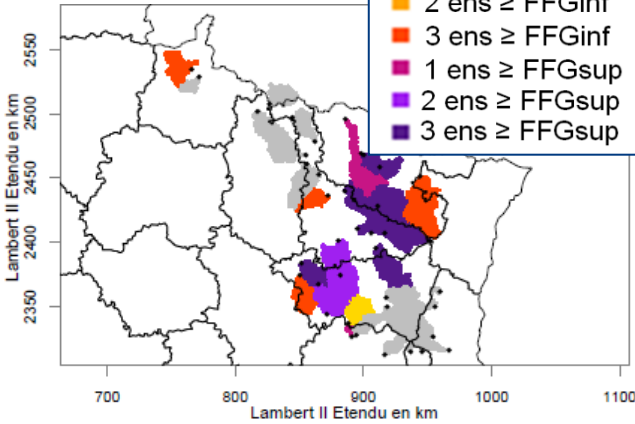
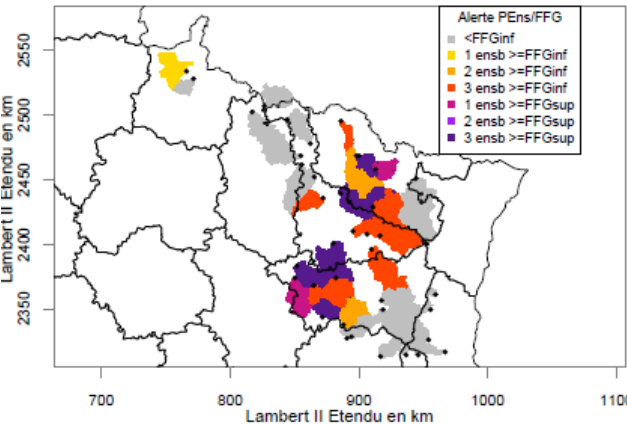
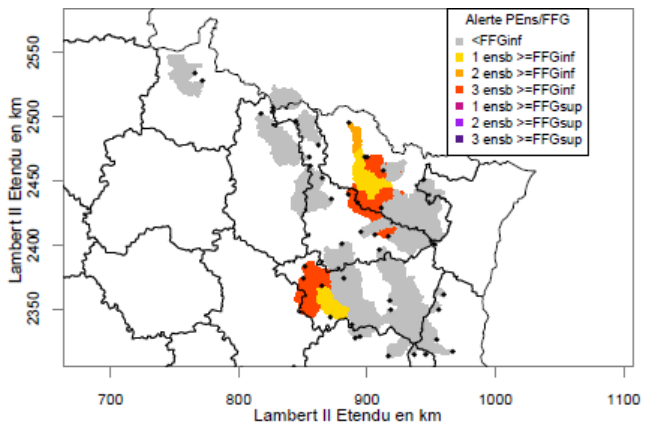
16 Dec 2011 T0=3hr

T0=6hr

T0=9hr

Pens/FFG Warning

- 3 ens < FFG
- 1 ens  $\geq$  FFGinf
- 2 ens  $\geq$  FFGinf
- 3 ens  $\geq$  FFGinf
- 1 ens  $\geq$  FFGsup
- 2 ens  $\geq$  FFGsup
- 3 ens  $\geq$  FFGsup



## Warnings based on FFG for 6-hr duration (approach 1)

# Evaluation of warnings and Pens/Qens forecasts

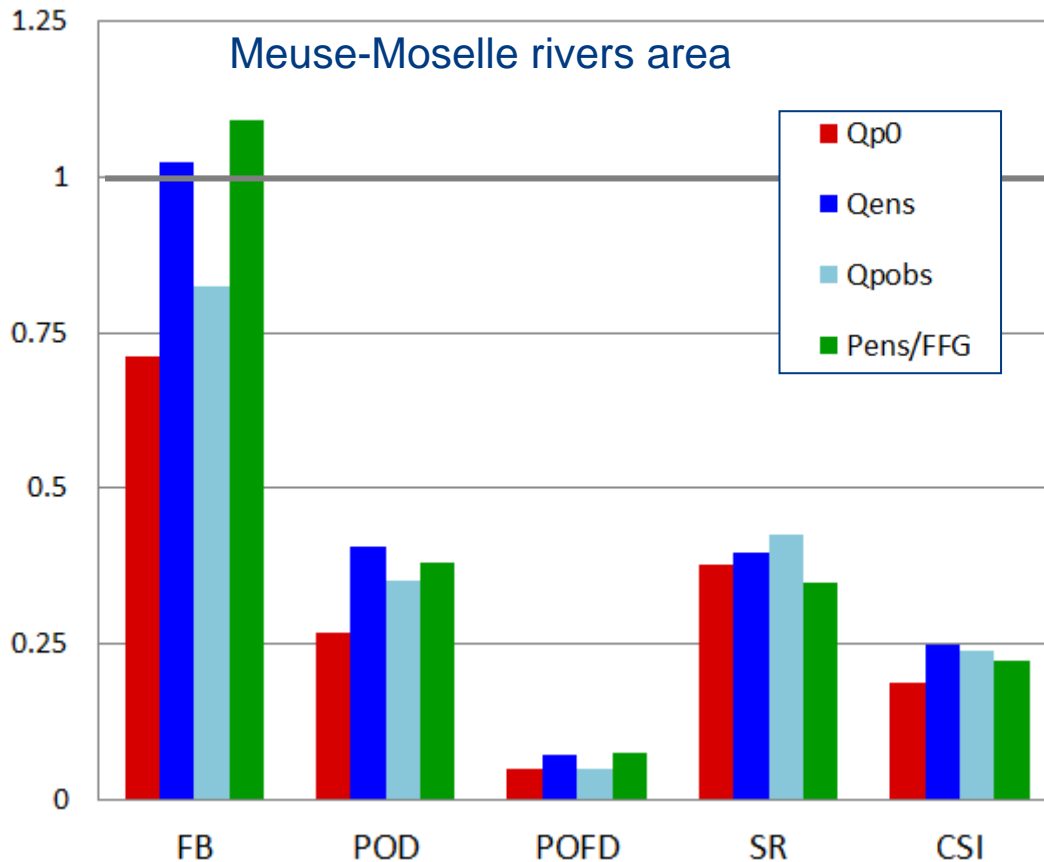
- Evaluation for 1 event (exceeding a given Q threshold) with contingency table statistics

<i>Q &gt; Threshold</i>		<i>Observed</i>	
		<i>Yes</i>	<i>No</i>
<i>Forecasted</i>	<i>Yes</i>	<b>Hits</b>	<b>False Alarms</b>
	<i>No</i>	<b>Misses</b>	<b>Correct Negatives</b>

- Frequency Bias:  $FB = (H+FA) / (H+M)$
  - Prob. Of Detection (conditioned on obs.):  $POD = H / (H+M)$
  - Probability Of False Detection (conditioned on non-obs.):  
 $POFD=FA / (FA+CN)$
  - Success Ratio (forecast reliability):  $SR= H / (H+FA)$
  - Critical Success Index:  $CSI=H / (H+FA+M)$
- Ensemble forecast verification with EVS (Brown et al. EMS 2010)

# Preliminary results: contingency scores for Qens & Pens/FFG

- Comparison for flow threshold Q2yrs
- Gain when using Pens and Qens
- Errors from Pens compensate hydrologic model errors



All dates (20 events), 39 basins, threshold Q2yr

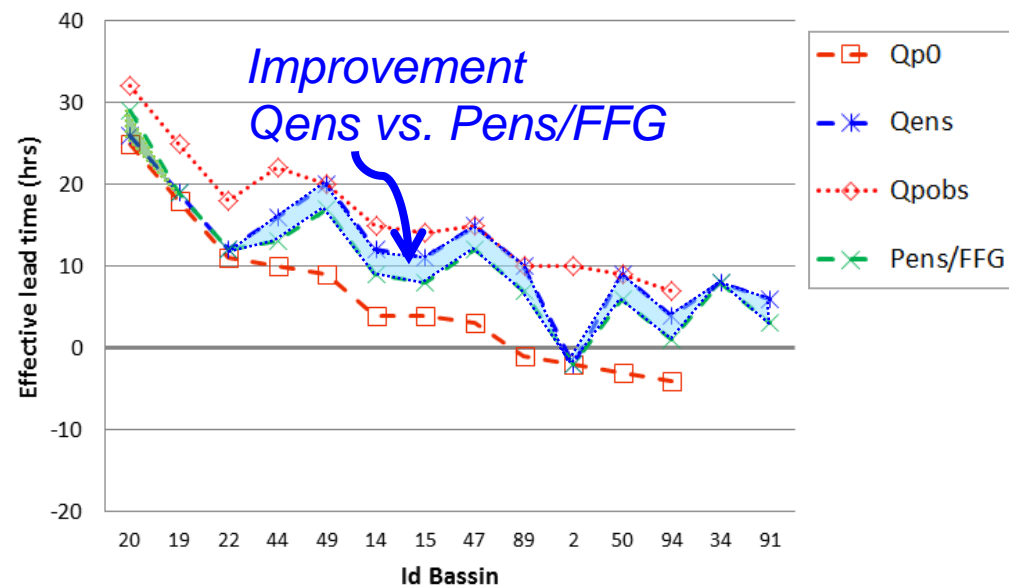
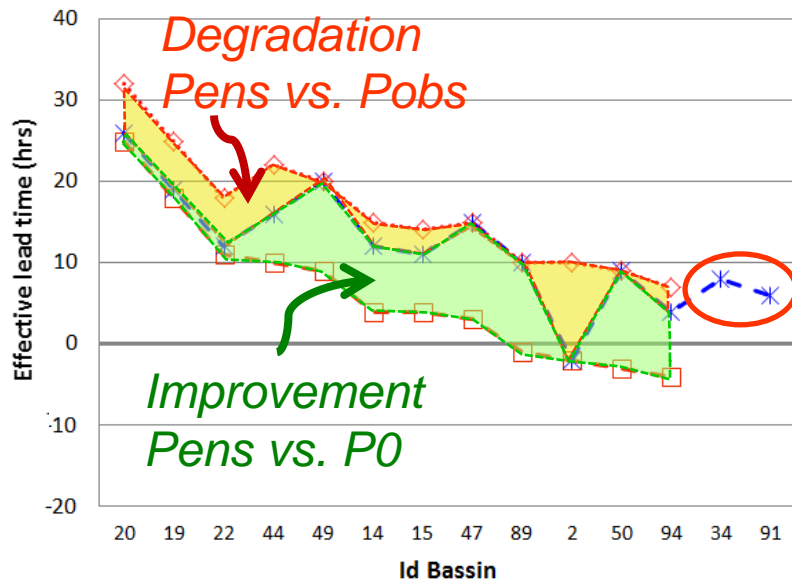
Room for improvement!



# Preliminary results: effective lead time for Qens & Pens/FFG

- Comparison for flow threshold Q2yrs

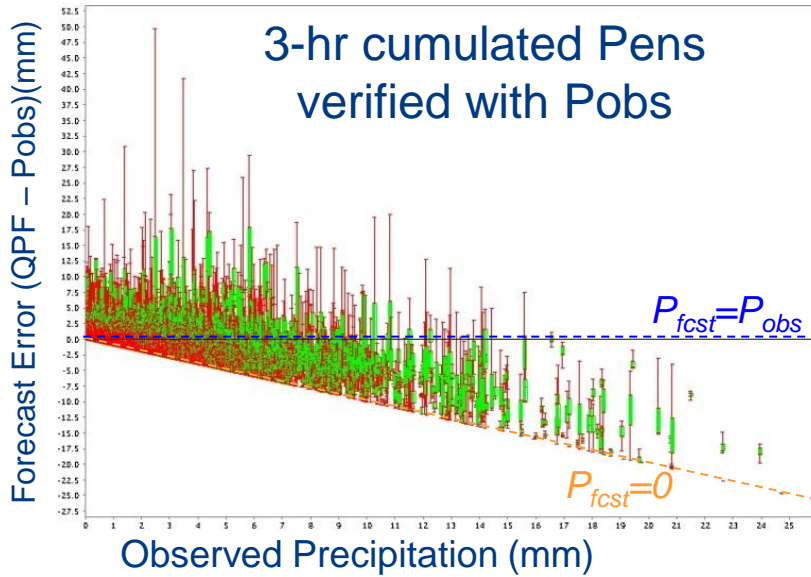
Event of 1-19 December 2011



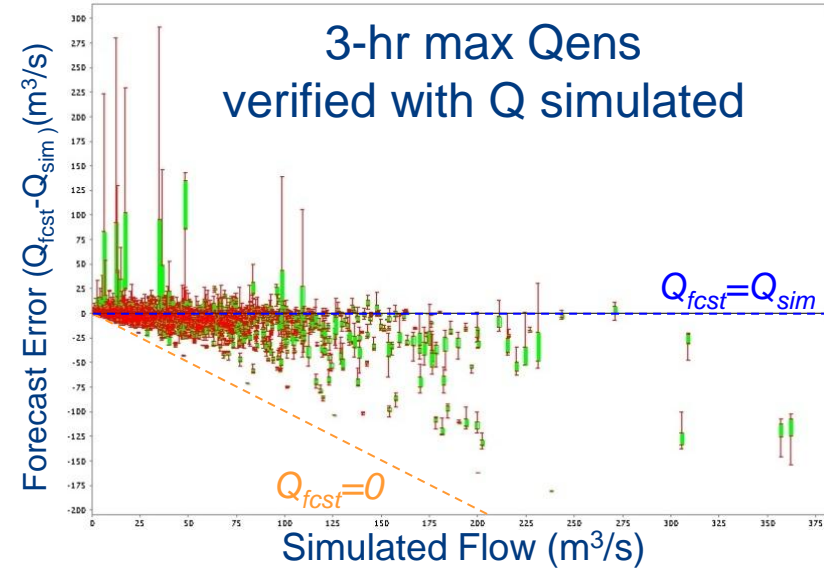
Average gain in lead time compared to current ALGA warnings (Qp0) for all 20 events and all 20 basins w/ flooding

- **+6.5 hr with Qens**
- **+5.9 hr with Qdet**
- **+23hr with Pens/FFG<sub>inf</sub> and +2.6hr with Pens/FFG<sub>sup</sub>**

# Ensemble quality: aggregated results for Qens & Pens



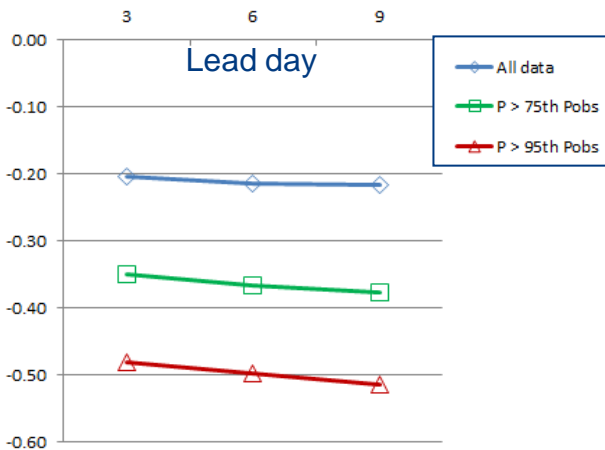
Lead  
time  
+3d



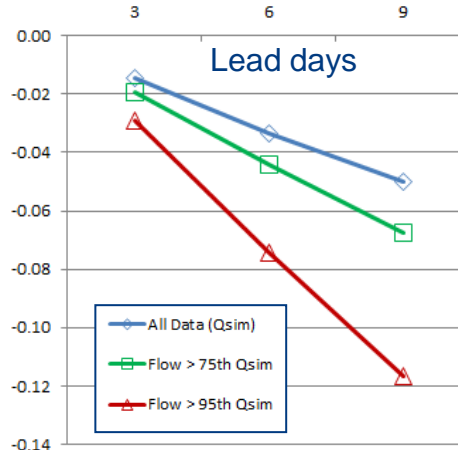
All basins in Meuse-Moselle rivers area

RME of ensemble mean (closer to 0: less biased)

3-hr Pens

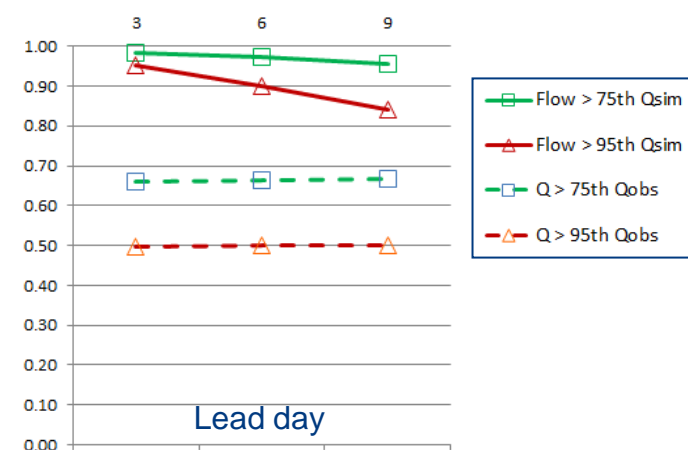


3-hr max Qens



ROC Score (higher is better)

3-hr max Qens



# Summary and perspectives

- Work in progress

- Integrate NWP convection-permitting forecasts

- Meteo-France's **AROME** ensembles (in 2016?)

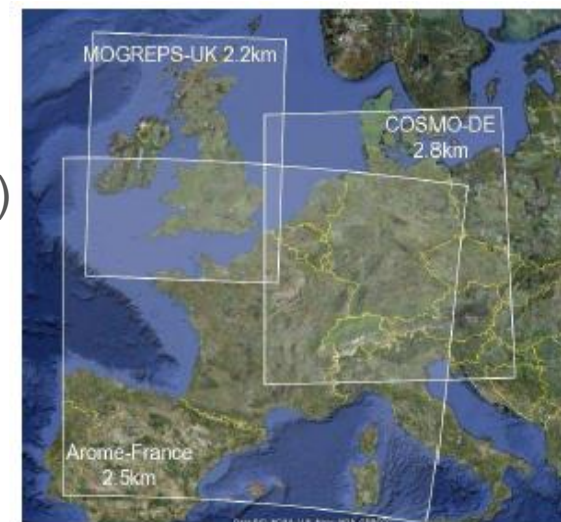
- DWD's **COSMO-DE-EPS** ensembles

(multi-model, 2.8km, 20 members, +21 hrs, 8x/day, operational since May 2012, archived since Dec 2010)

- Account for other sources of uncertainty

- model parameters and initialization

- radar-gauge QPE



- In future, include

- Evaluation component

- Snow modeling component

- Vulnerability-based flow thresholds (collaborations w/ users)



## Challenges in accessing...

- **high-res precipitation ensemble forecasts and reforecasts** for multiple years
- **reliable QPE estimates for areas with poor radar coverage** and for multiple years
- **archive database of flood damage reports and post-event information** for system evaluation and improved description of vulnerability

***Thank you!***

Contact: [julie@demargne.com](mailto:julie@demargne.com)