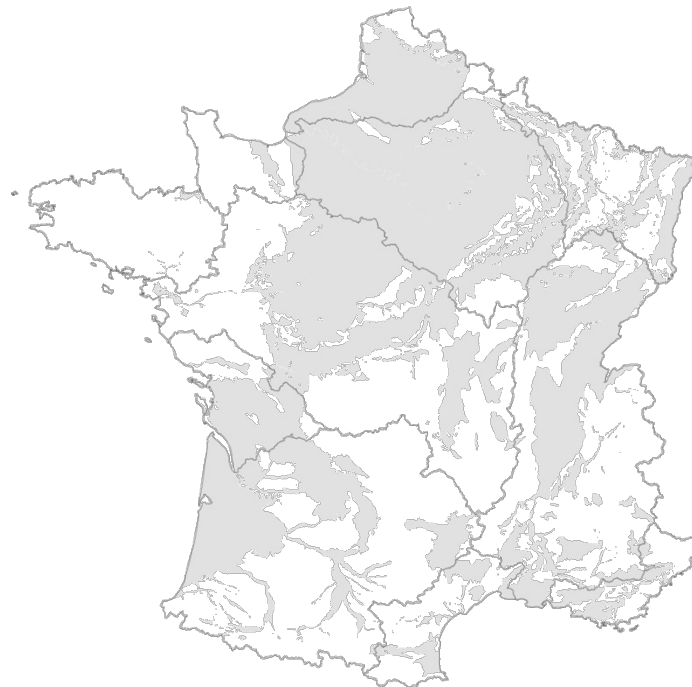


# Aqui-FR : a national multi-model hydrogeologic system

aiming at taking benefits of existing groundwater modelings used by stakeholders to develop new forecast products

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Bénédicte Augeard<sup>8</sup>



# Why Aqui-FR ?



On one hand

- Hydrological forecasts barely take into account groundwater
- The few existing GW forecast systems don't take into account weather forecast
- Numerous regional GW applications developed for stakeholder are available

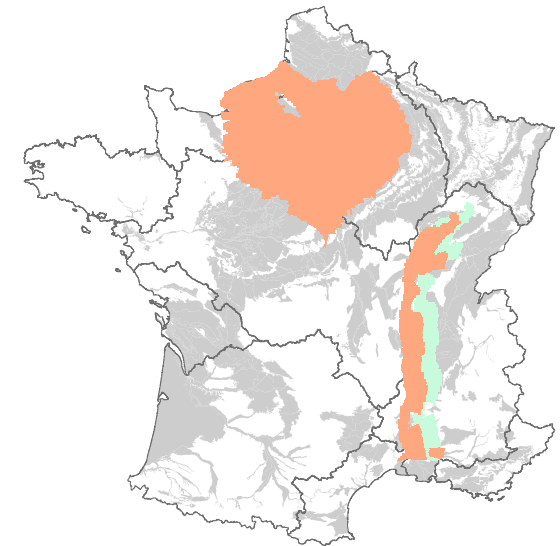
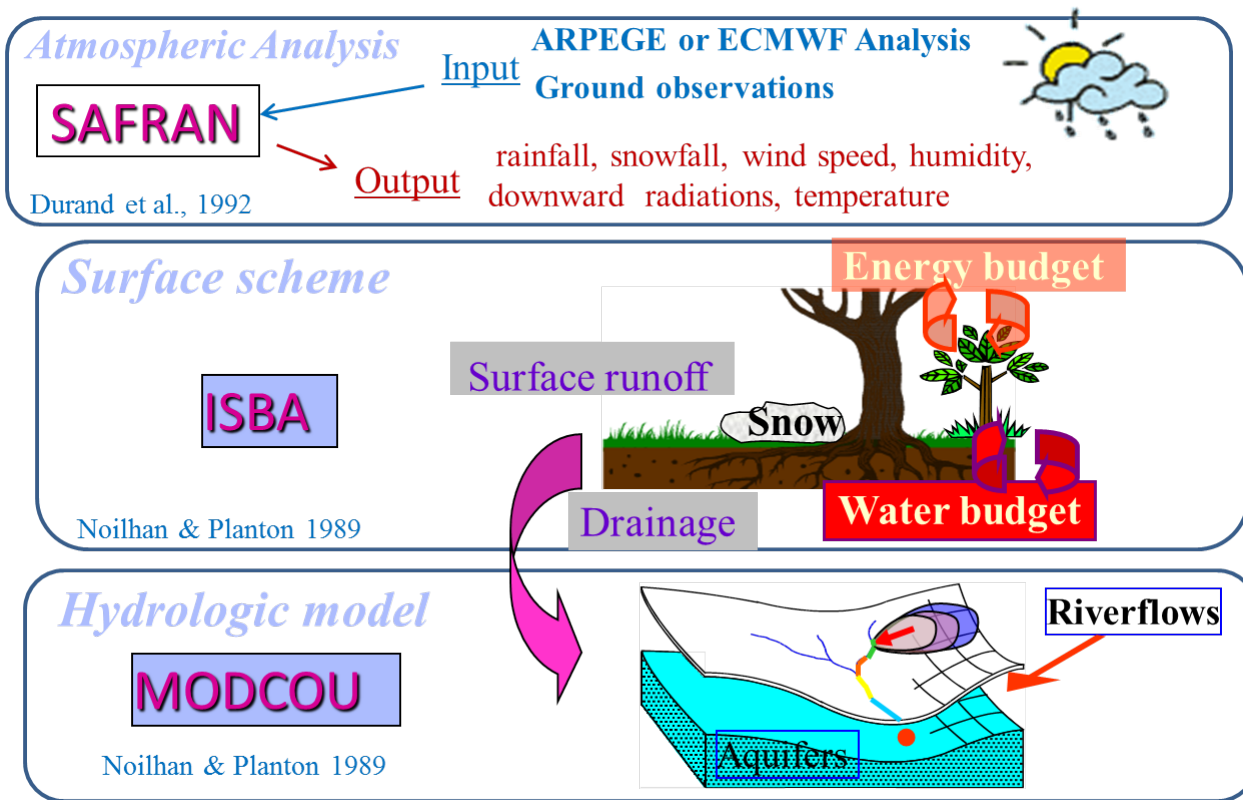
# Why Aqui-FR ?

On the other hand



First coupling between LSM scheme and GW models gives interesting results for monitoring and forecasting water resources in France

The SIM (Safran-Isba-Modcou) includes GW in 2 basins: 1 layer in the Rhone, 3-layer in the Seine basins



Among the limitations:  
No explicit representation  
of the GW abstraction

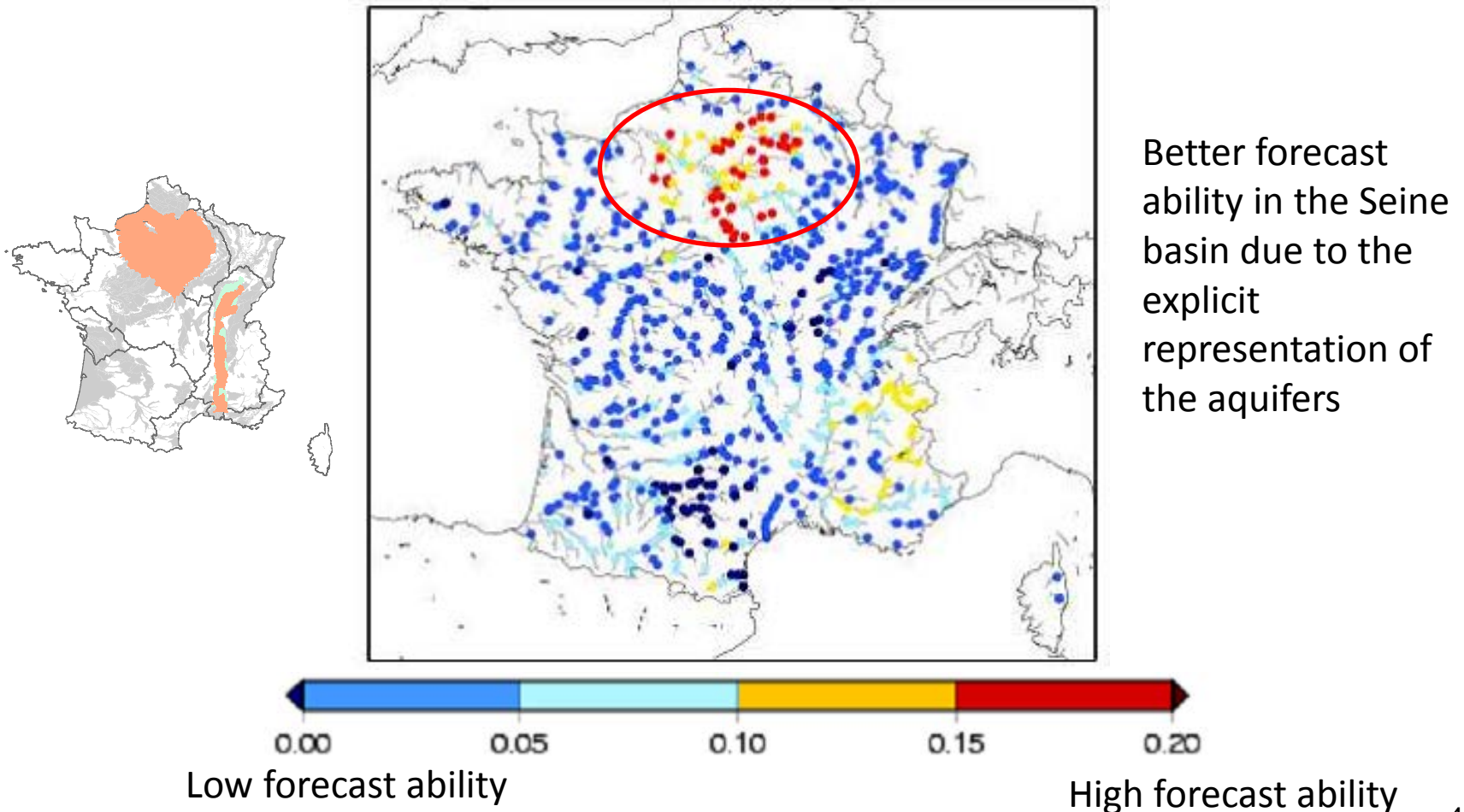
# Why Aquifer-FR ?

On the other hand



Hydrological seasonal forecast with SIM seems more skillful where GW is explicitly integrated:

Forecast ability of summer river flow 3 months ahead





# Why Aqui-FR ?

**Aqui-FR tries to takes benefit of the two aspects :**

Focus on few well established models:

- Marthe & Gardenia from BRGM
- MODCOU/Eau-dyssée from Mines-Paristech

+

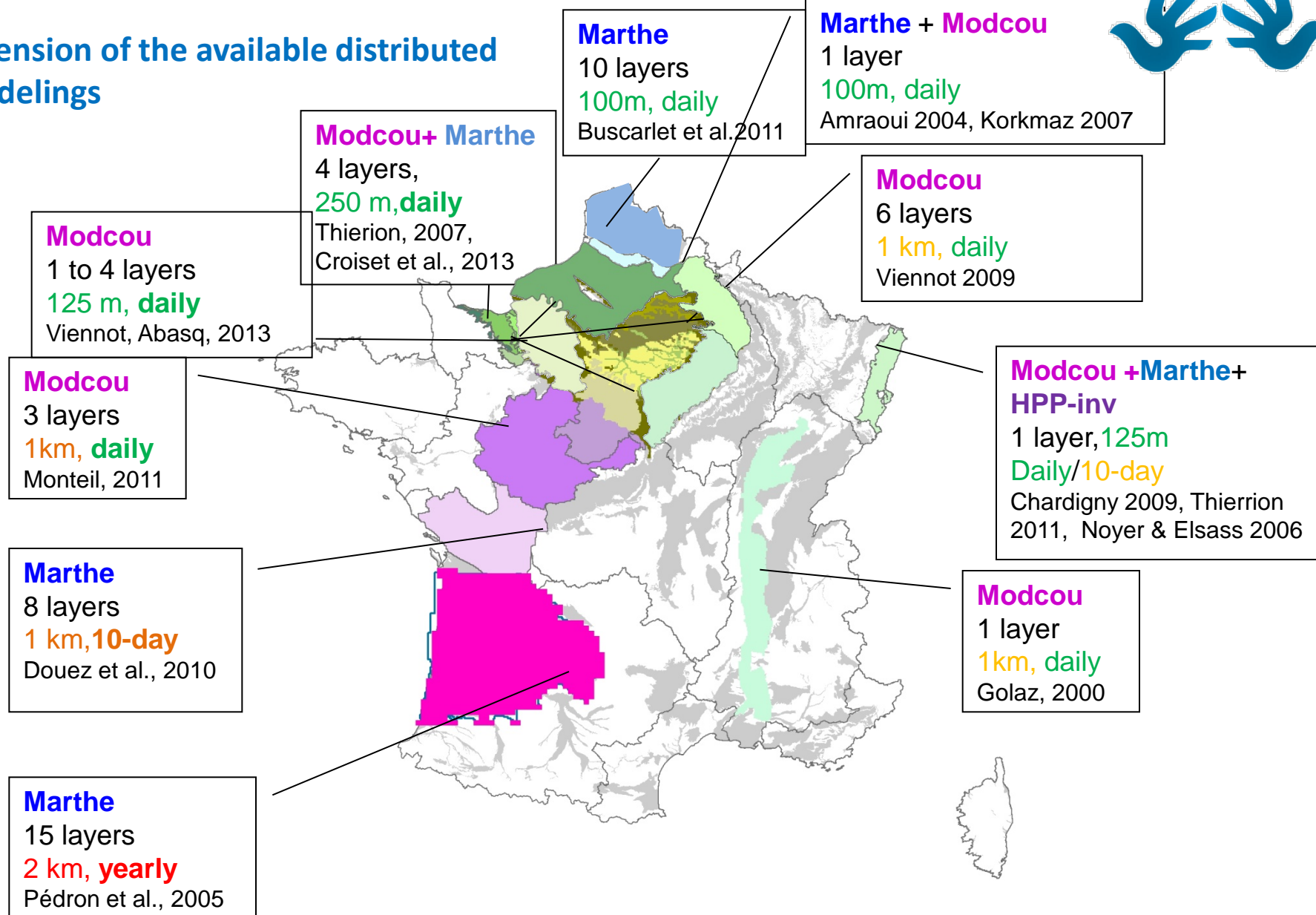
- HPP-inv from LHYGES to address inverse and assimilation data problems
- Development of a dedicated models on the hard rock aquifers by Geosciences-Rennes



# What's in Aqui-FR ?



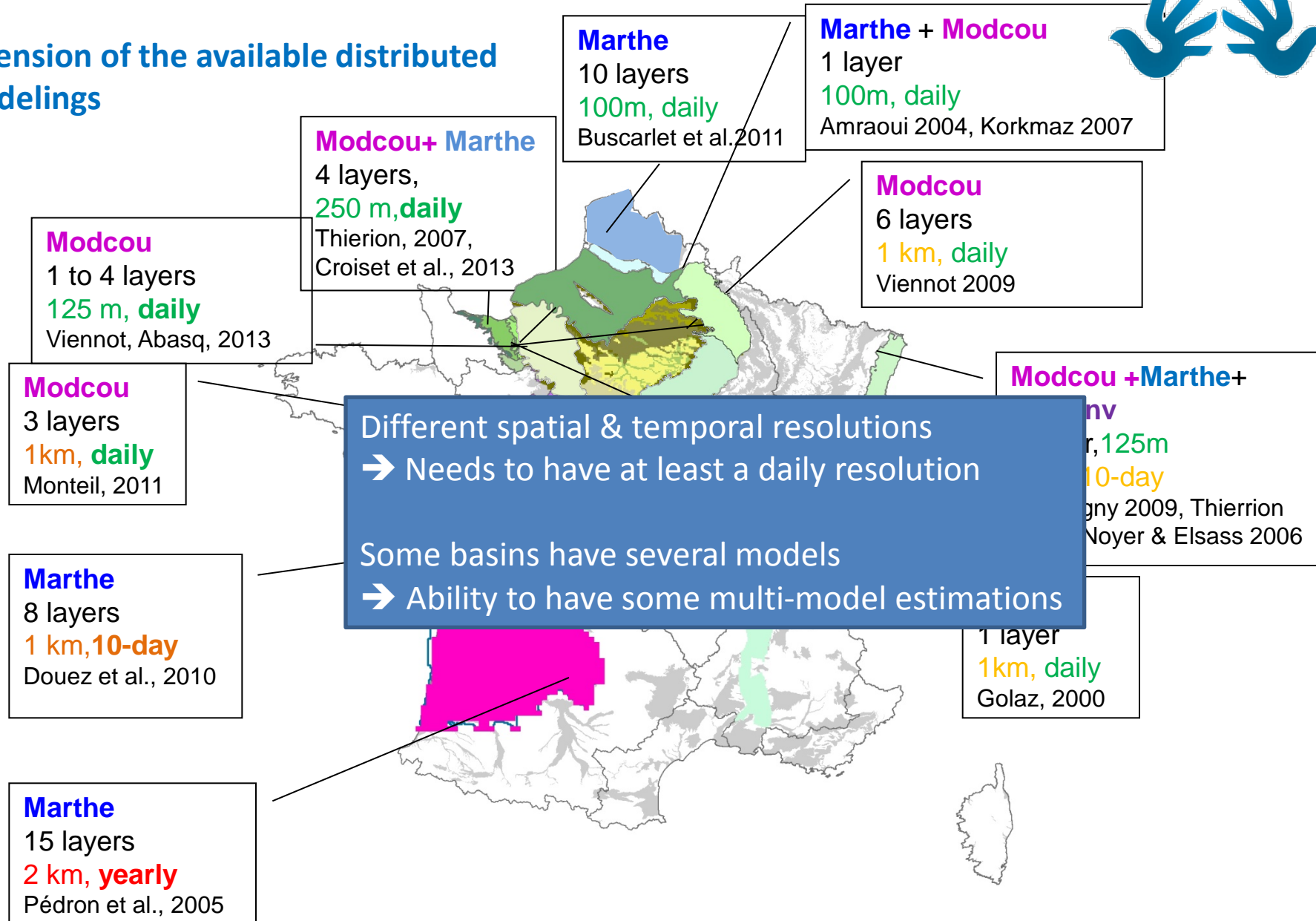
## Extension of the available distributed modelings



# What's in Aquifer-FR ?



## Extension of the available distributed modelings



# What's in Aquif-FR ?

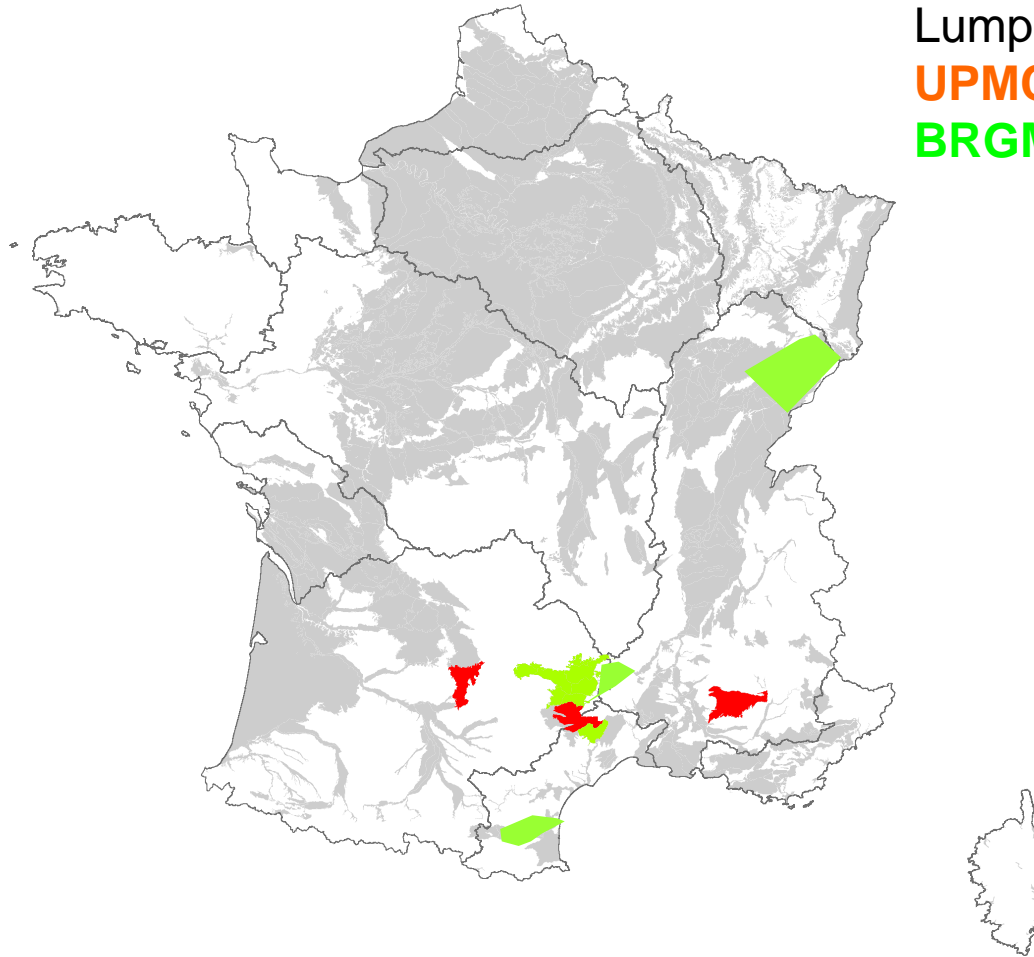


## Extension of the available karst modelings

Lumped karstic models

**UPMC : KDM**

**BRGM : Gardenia**



*Lanini & Maréchal, 2004*

*Maréchal et al., 2014*

*Charlier et al., 2014*

*Fleury et al., 2007*

*Moussu et al., 2011*

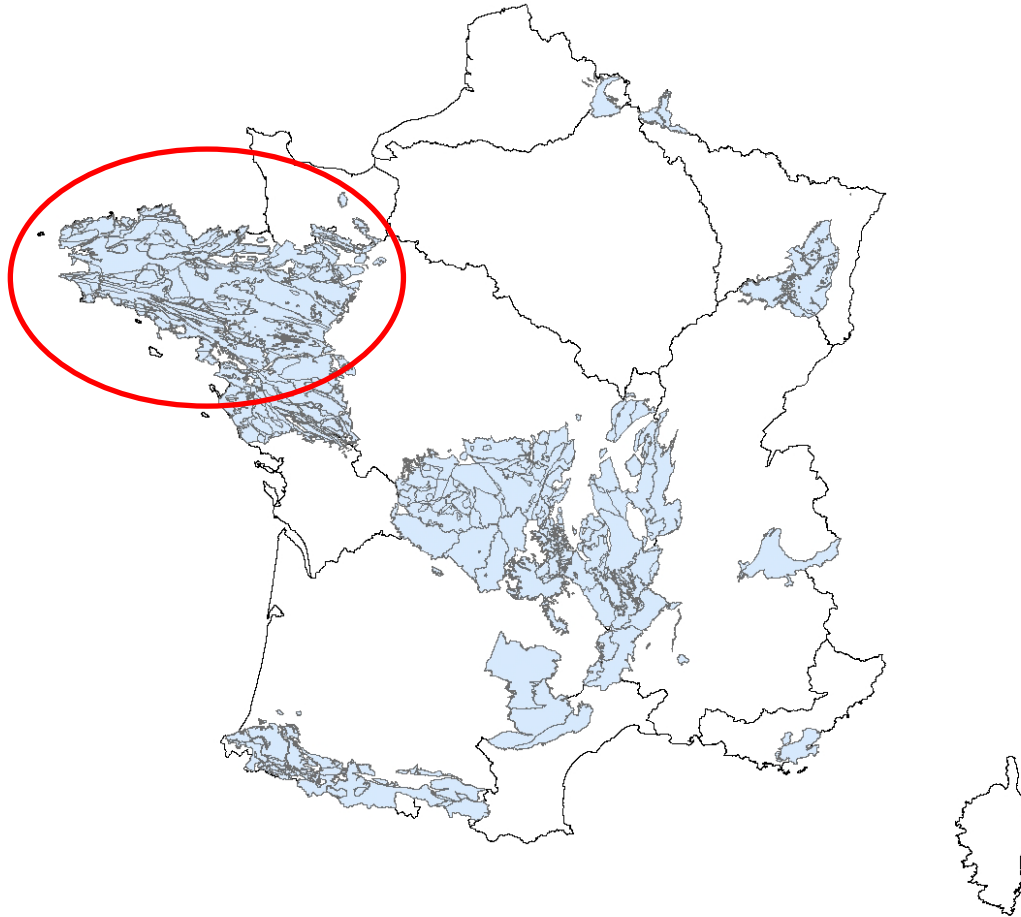
*Thiery, 2015*

# What's in Aquif-FR ?



## Extension of the existing hard rocks aquifers

Development of a simple distributed model in Brittany



*Aurore Réfloch, 2014*  
*Yann Sargent, 2016*

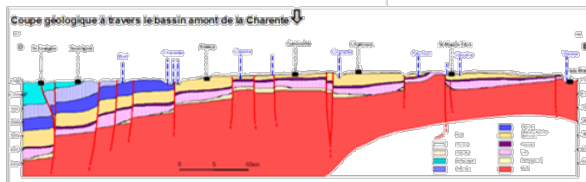
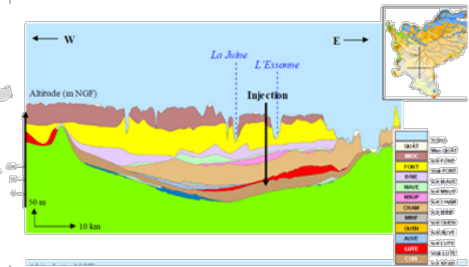
## What's in Aqui-FR ?

## Actual extension of the GW basins included in Aqui-FR

- 13 distributed applications
- 57 GW layers
- ~1 650 000 cells
- Some overlaps

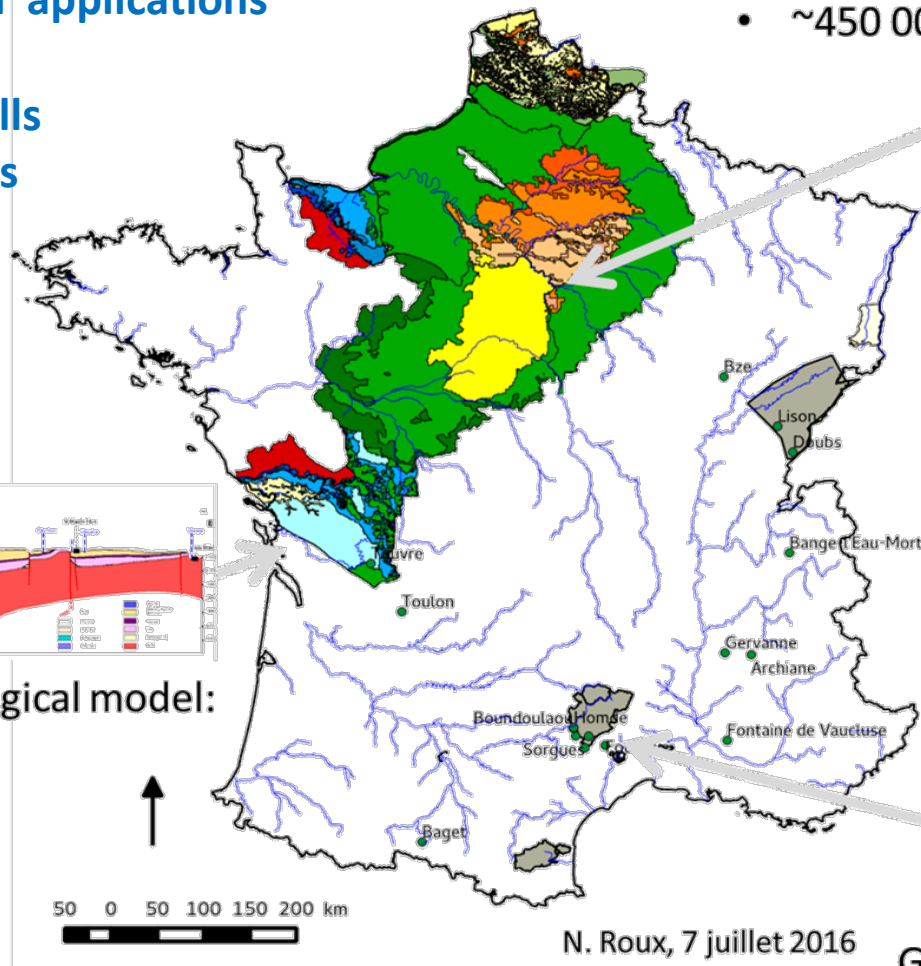
### Eau-dyssée hydrogeological model:

- 8 modelings
- ~450 000 cells

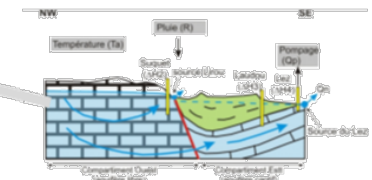


### Marthe hydrogeological model:

- 5 modelings
- ~1 200 000 cells



N. Roux, 7 juillet 2016



### Gardénia karstic model:

- 6 modelings



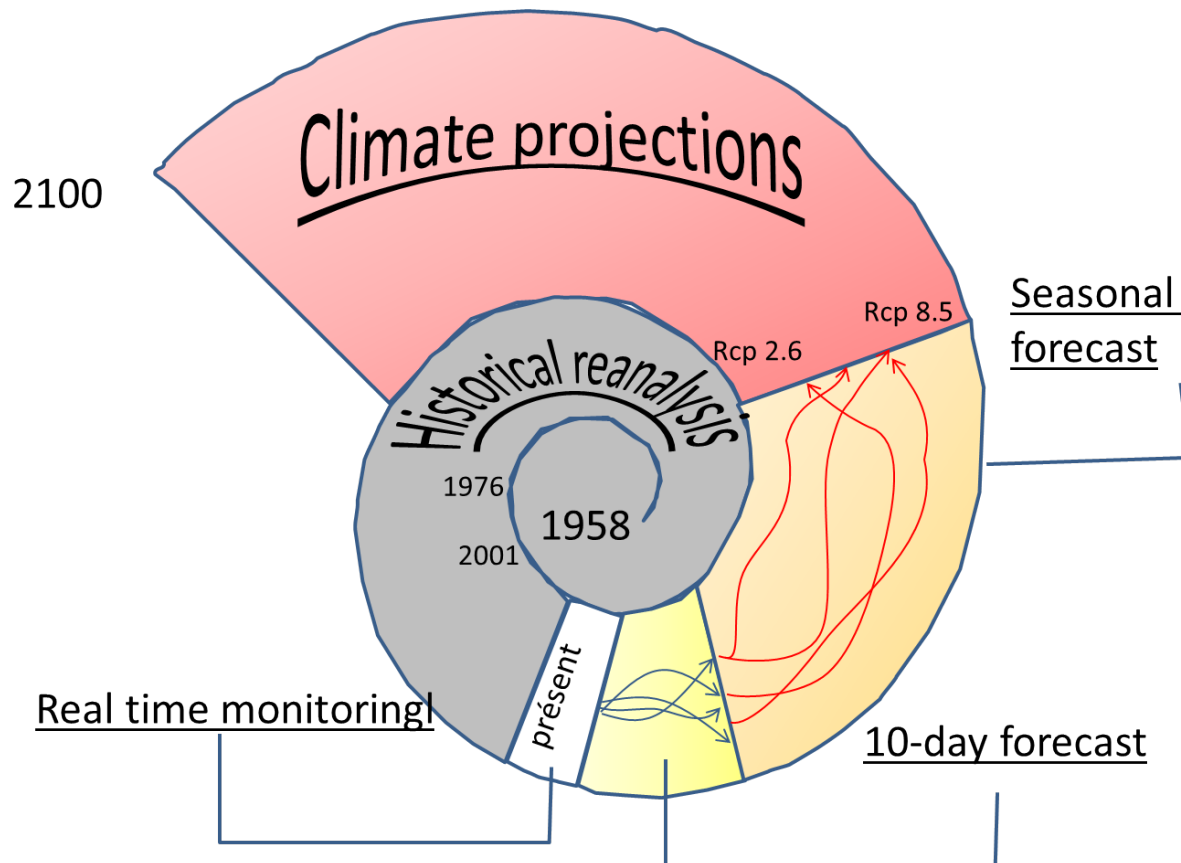


# How Aqui-FR is working?

Aqui-FR is expected to run:

- On real time for monitoring and to provide initial conditions to forecasts
- For 10-day and seasonal forecasts
- For climate projections

So far, it is used on past climate for assessment



# First assessment of Aqui-FR

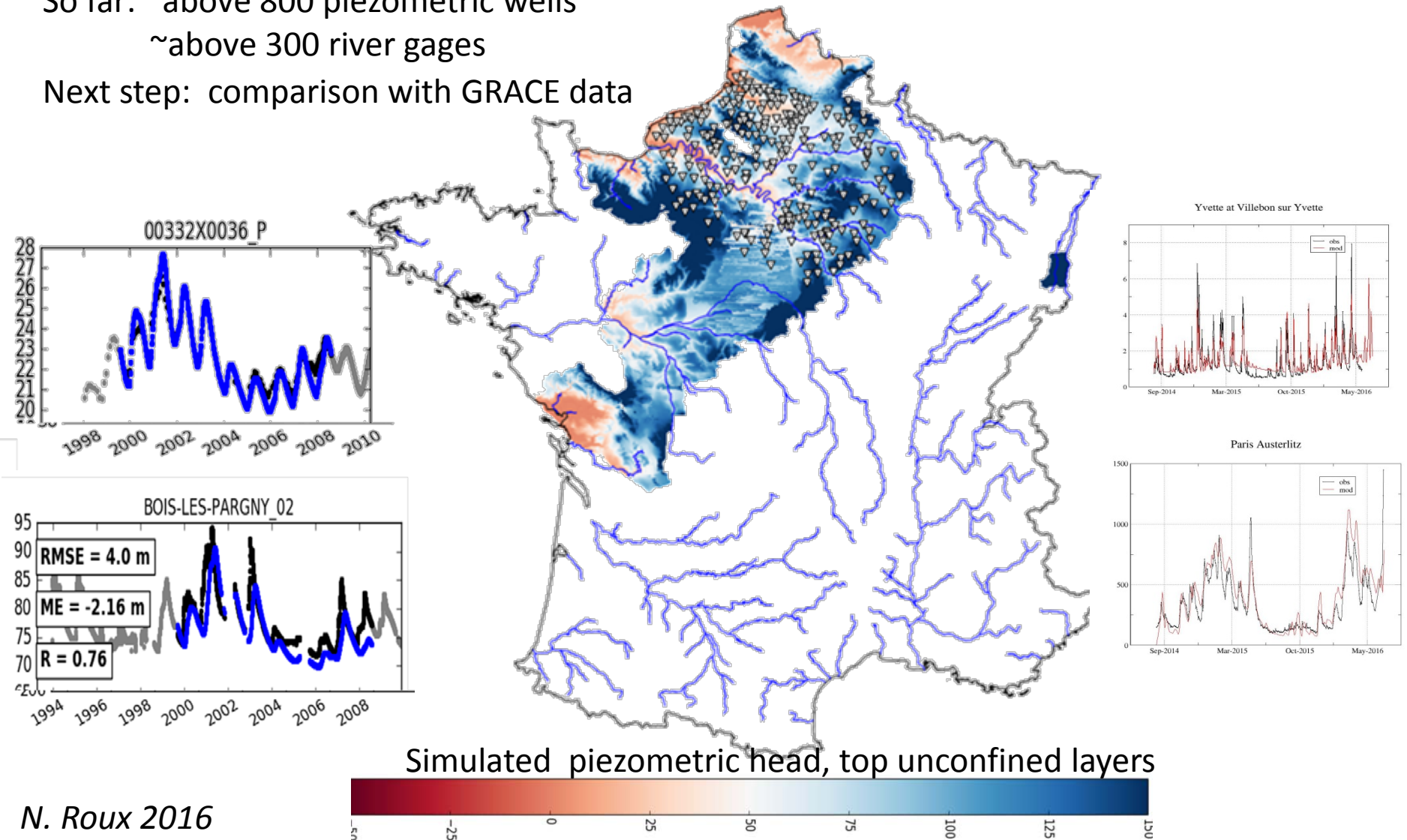
## Example of results:

- comparison with the observed piezometric head for a 14-year simulation
- Comparison with the observed river flows

So far: ~above 800 piezometric wells

~above 300 river gages

Next step: comparison with GRACE data



# Which issues AQUI-FR has to face ?

## 1. Modification of the estimation of the water budget

Using the Surfex LSM instead of the original water budget (based on PET) leads to some differences on the flux dynamic. The differences are also partly due to implicit representation of the unsaturated zone in GW models

➔ most GW applications were re-calibrated

## 2. Need to define Which kind of results to help GW managers ?

## 3. Need to find How to include the numerous uncertainties?

## 4. Need to connect GW models (included overlapping ones) to get consistent results at the national scale

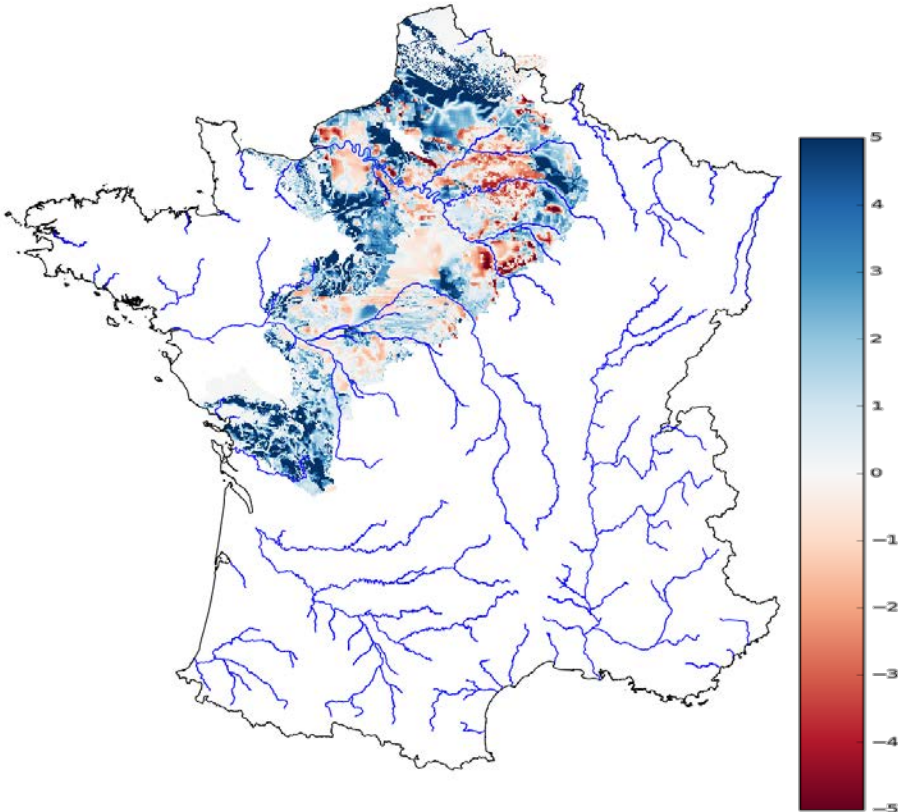
## Issue #2: Which kind of results to provide to stakeholder

A first stakeholders surveys showed that numerous types of output could be useful

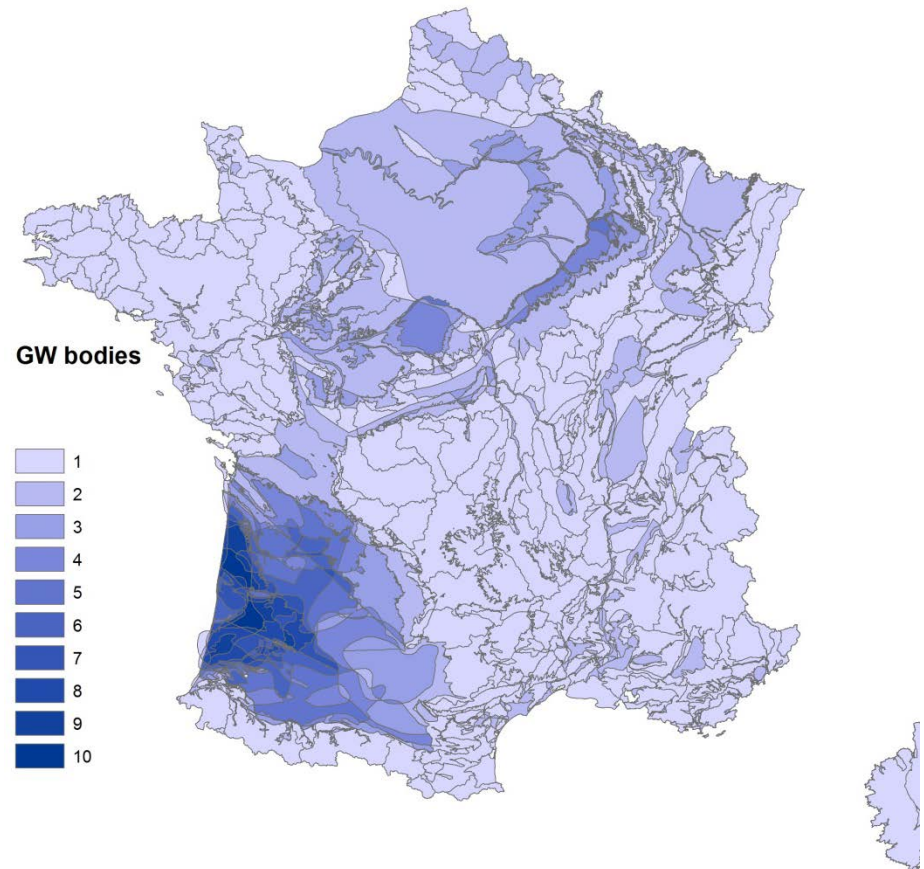
Avignon, 2014

For instance:

Maps of the anomaly of the piezometric head of the top layers at the model's resolutions



Could be computed on the ground water bodies used to report the WFD



N. Roux, 2016

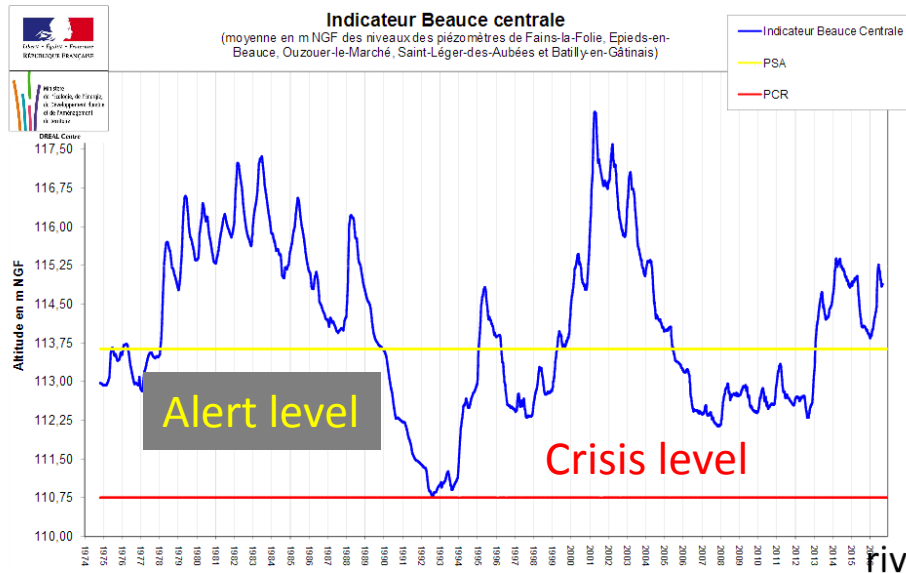


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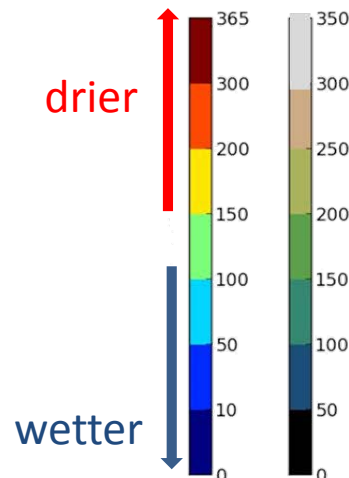
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Avignon, 2014

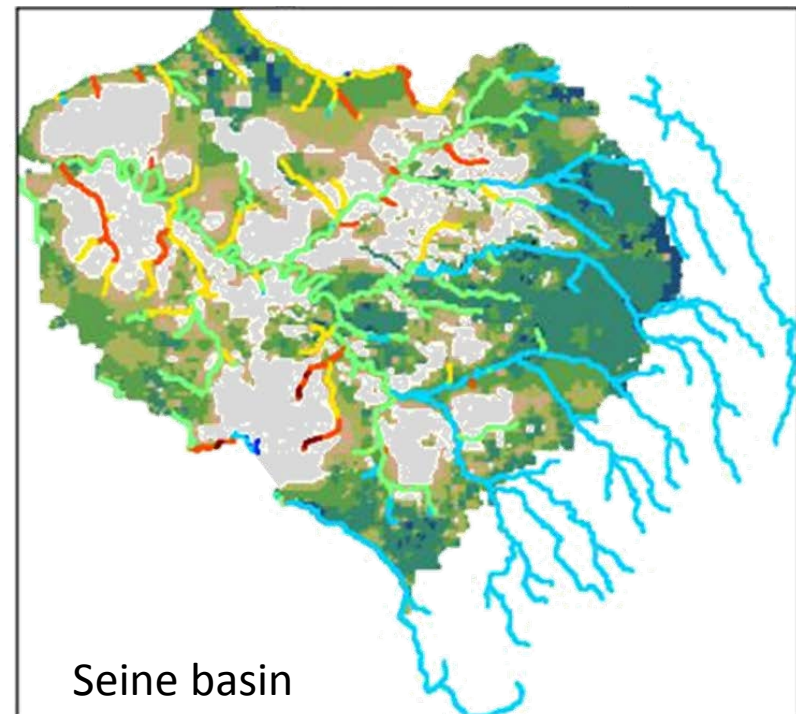
Reproduction of indicators based on  
an averaged of several wells



Beauce Central indicator



Combined maps of GW & river flow anomalies





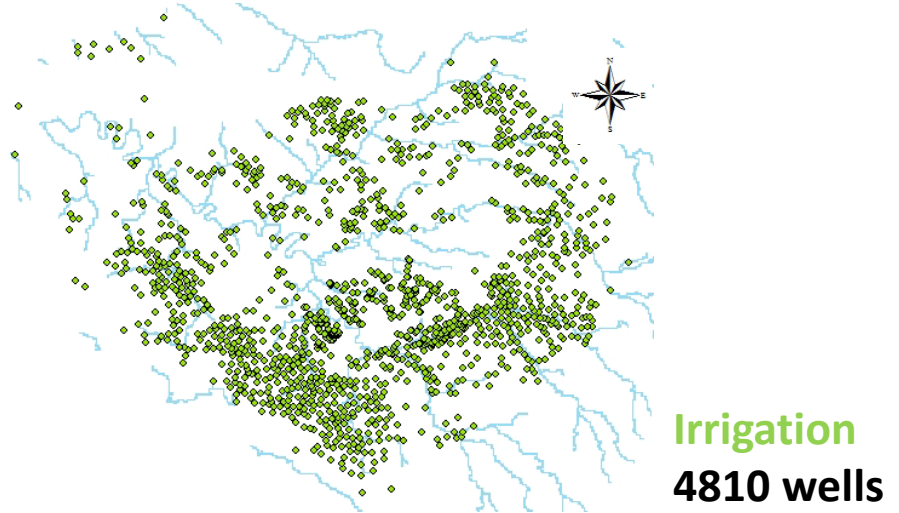
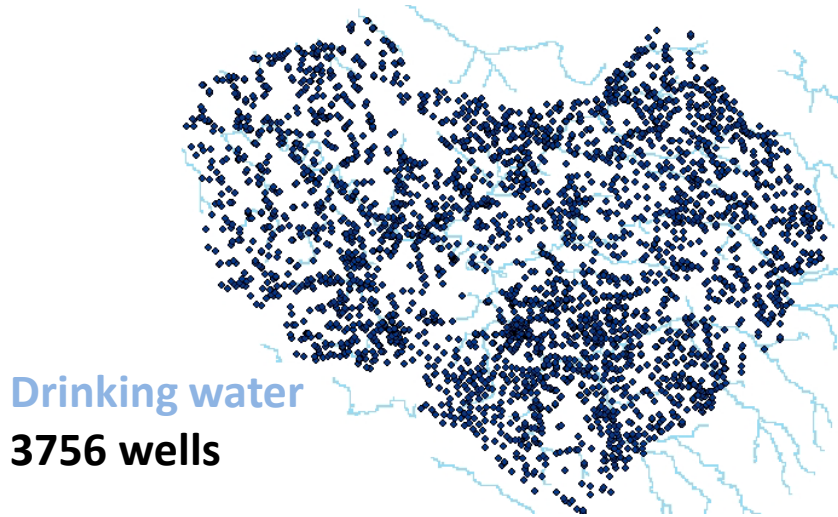
## Issue #3: How to include the uncertainties ?

At least 3 sources of uncertainties:

- Uncertainty linked to the weather forecast → taken into account via ensemble
- Uncertainty due to the GW modeling → in some basins, multi-model simulation
- Uncertainty due to human activity → needs some scenarios

# Issue #3: Illustration of the uncertainties linked to human activities

## Spatial repartition of the abstraction wells in the Seine basin

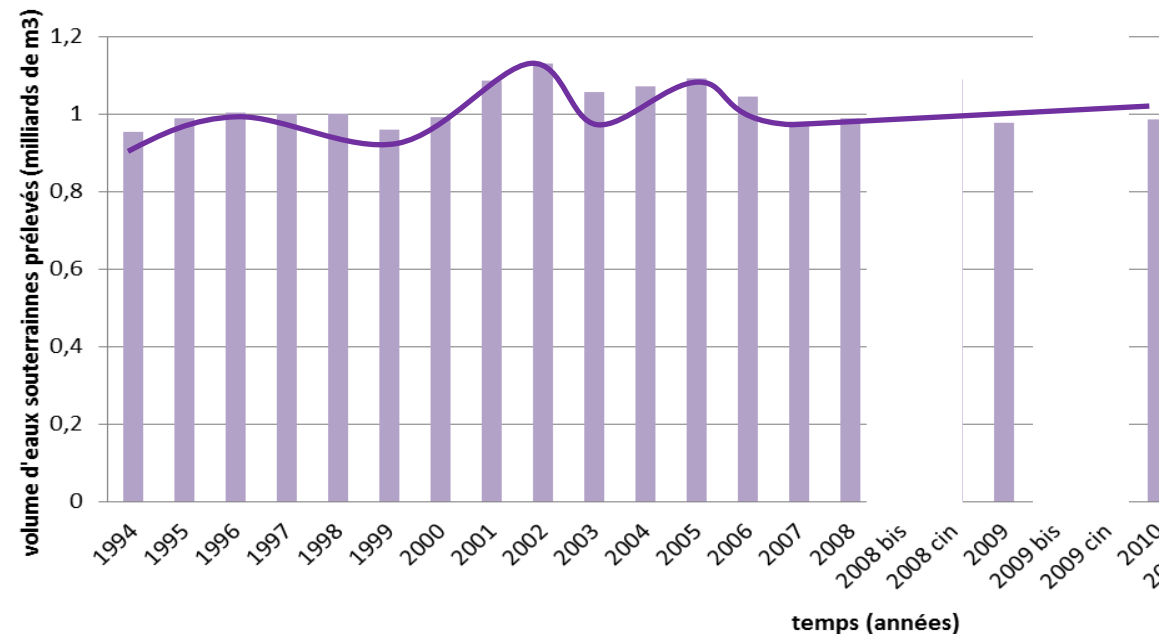


**Industry**  
1740 wells

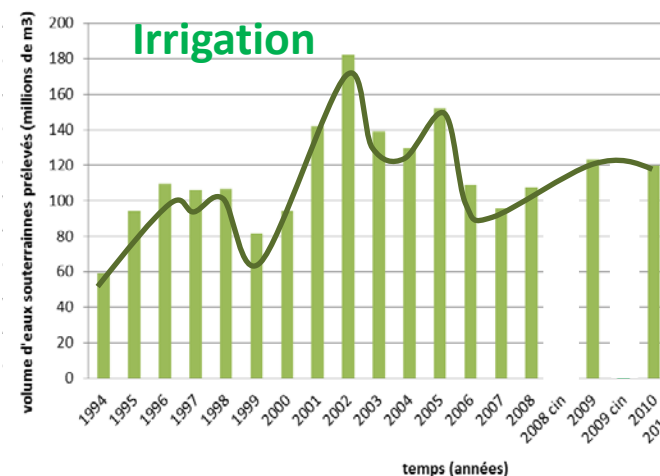
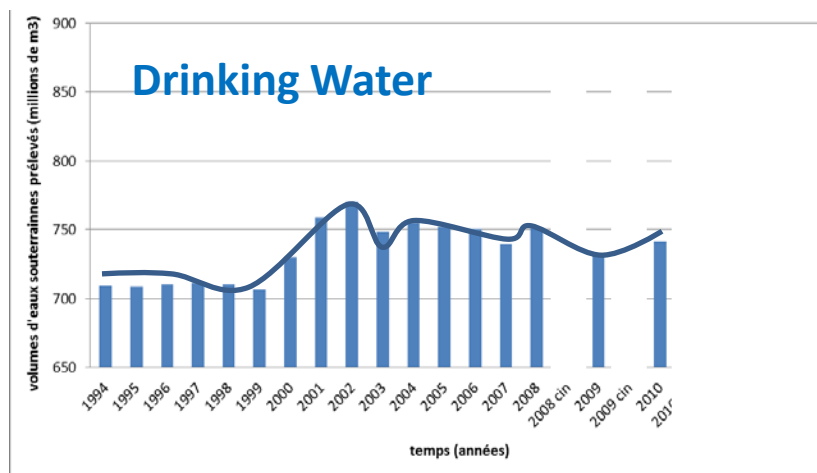
- Around 10 000 wells
- Around 1 billion m<sup>3</sup>/year
- Estimated with 2-year delay
- Annual variability and uncertainty according to the sources

# Issue #3: Illustration of the uncertainties linked to human activities

## Annual volume of the groundwater abstraction in the Seine basin

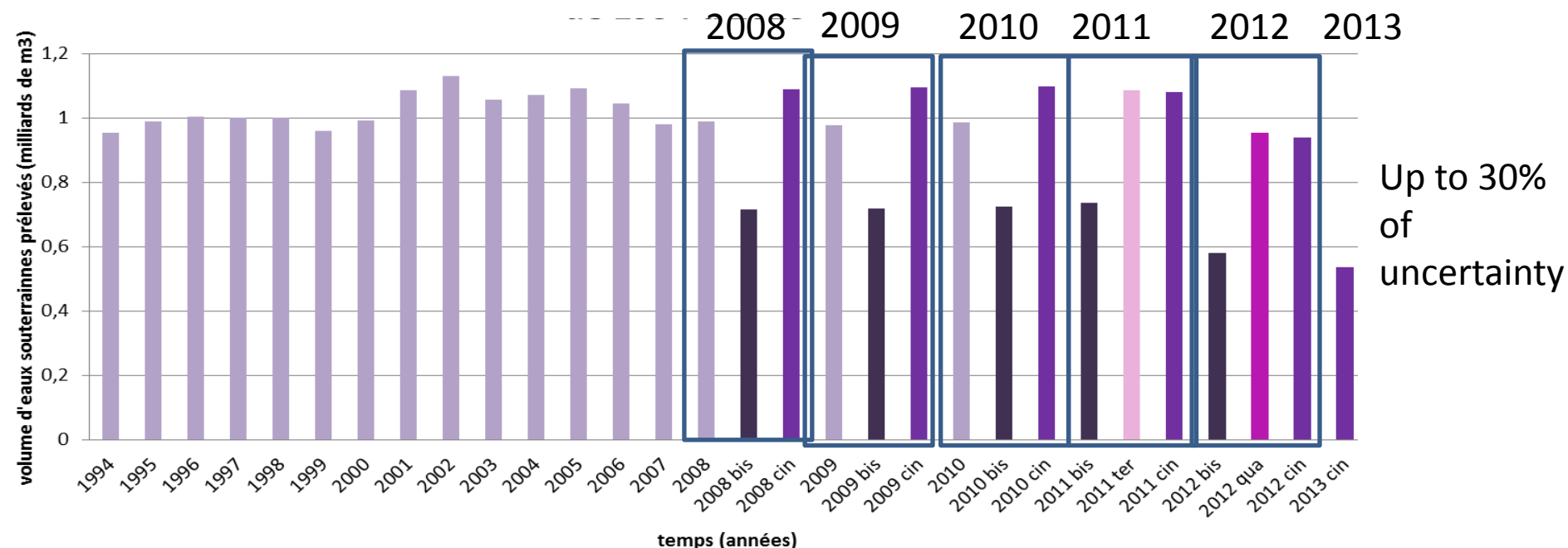


Some variabilities in total volume and for each use

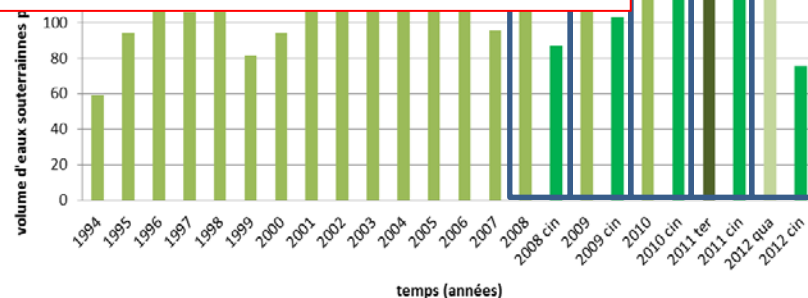
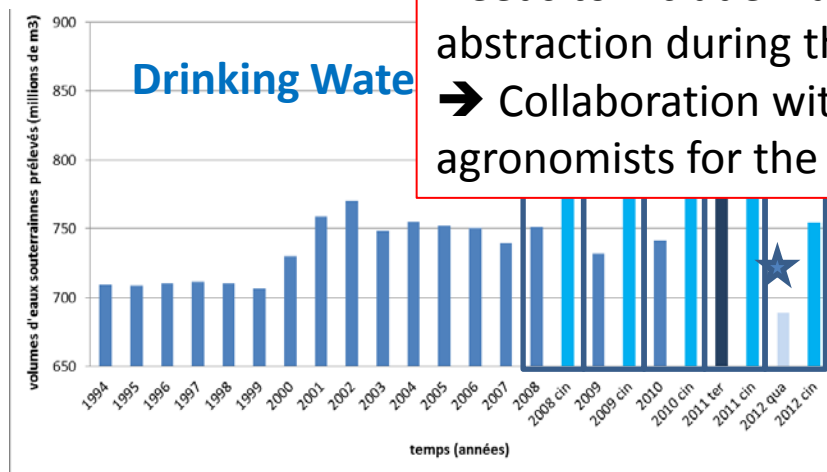


# Issue #3: Illustration of the uncertainties linked to human activities

## Annual volume of the groundwater abstraction in the Seine basin



Needs to include way of estimating groundwater abstraction during the time of the forecast  
 ➔ Collaboration with stakeholders for drinking water and agronomists for the irrigation



## Issue #3: How to include the uncertainties ?

At least 3 sources of uncertainties:

- Uncertainty linked to the weather forecast → taken into account via ensemble
- Uncertainty due to the GW modeling → in some basins, multi-model simulation
- Uncertainty due to human activity → needs some scenarios

→ There may be a need to explicit the uncertainty associated to each case

## Issue #4: Connect all the GW applications at the national scale

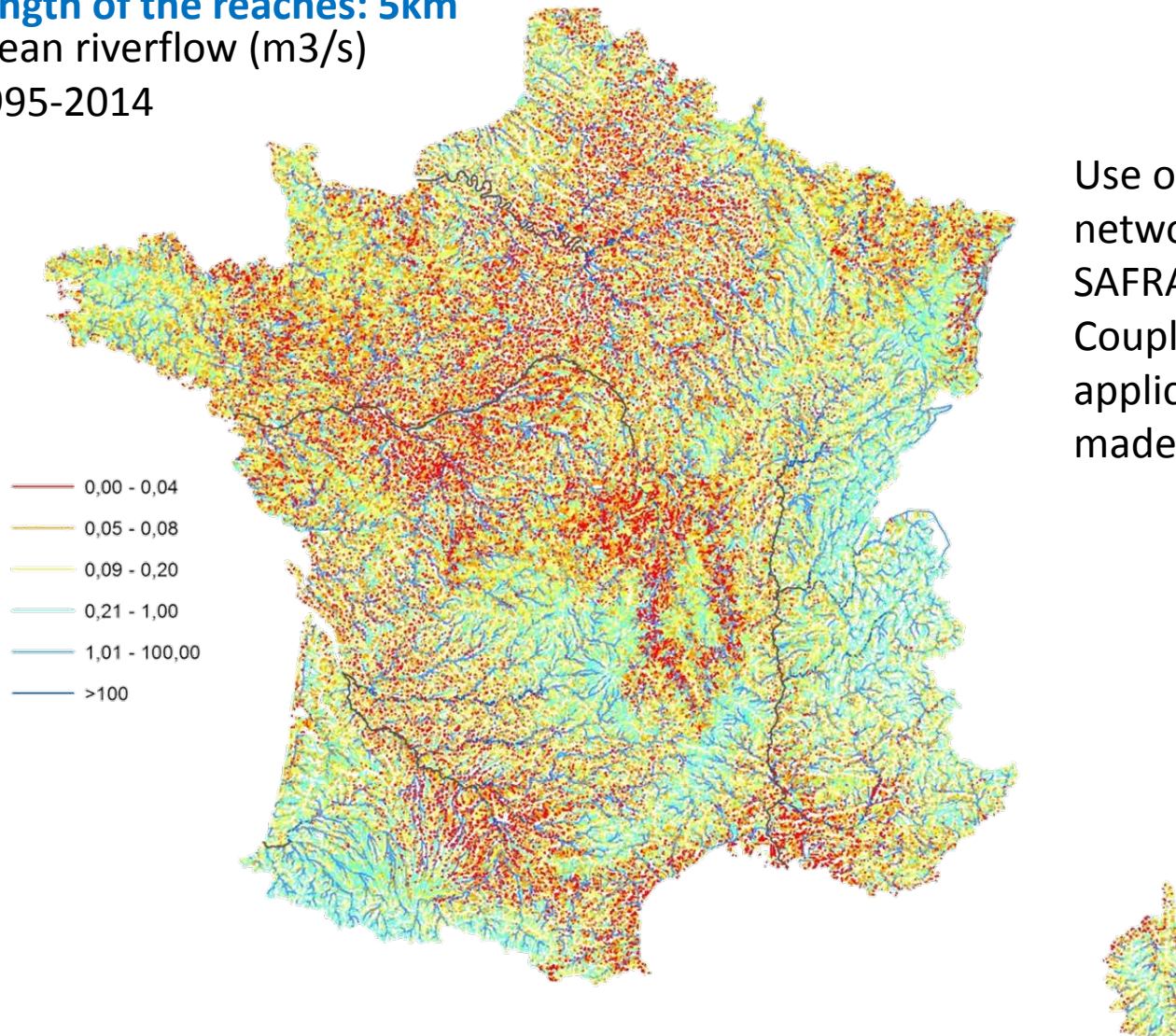
Pb: spatial resolution varies from coarse (1km) to fine (100 m)

➔ To connect each application (especially for imposed river condition), use of RHT hydrographic network (Pella et al, 2012 [www.irstea.fr/rht](http://www.irstea.fr/rht)). More than 280 000 km of river .

Mean length of the reaches: 5km

Mean riverflow (m<sup>3</sup>/s)

1995-2014



Use of RHT hydrographic network together with SAFRAN-SURFEX  
Coupling with GW applications needs to be made



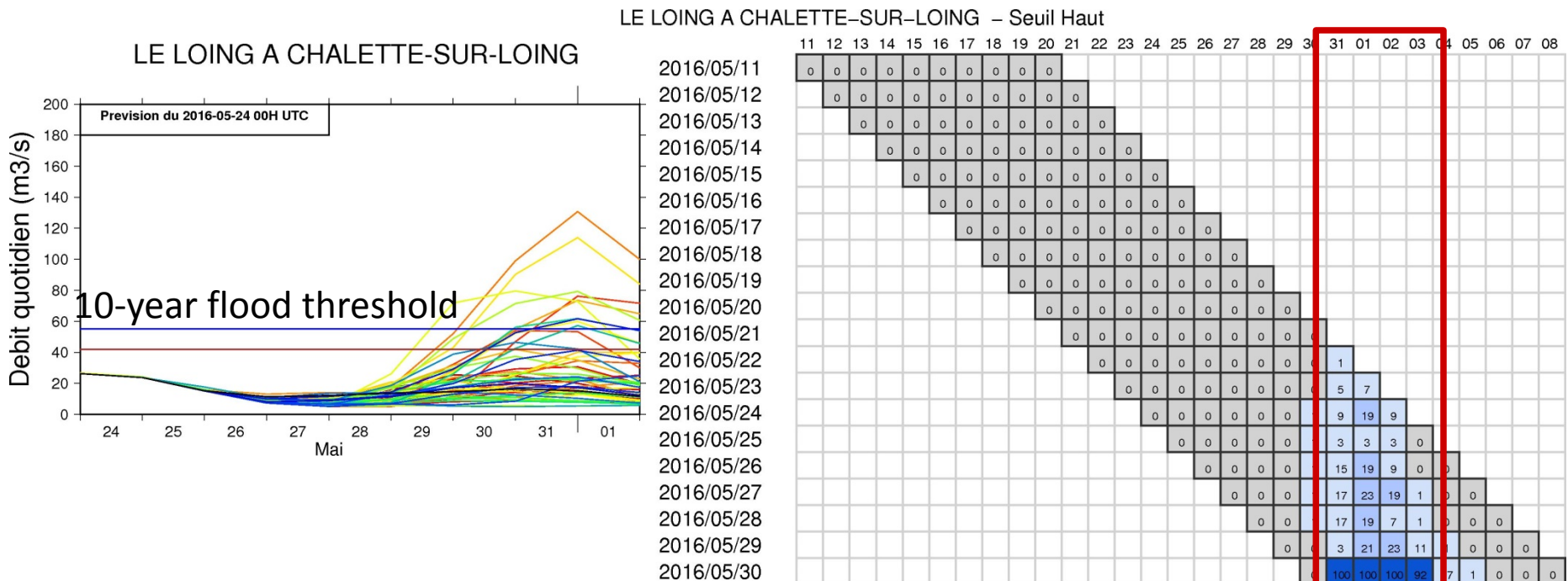
# Aqui-FR : A case study: the flood of June 2016

## Real-time forecast of the event with SIM PE



Forecast with SIM-PE for the Loing tributary  
20% of the forecast above 10-year river flow  
➔ Warning 5-day ahead

Forecast of overpassing the 10-year flood threshold

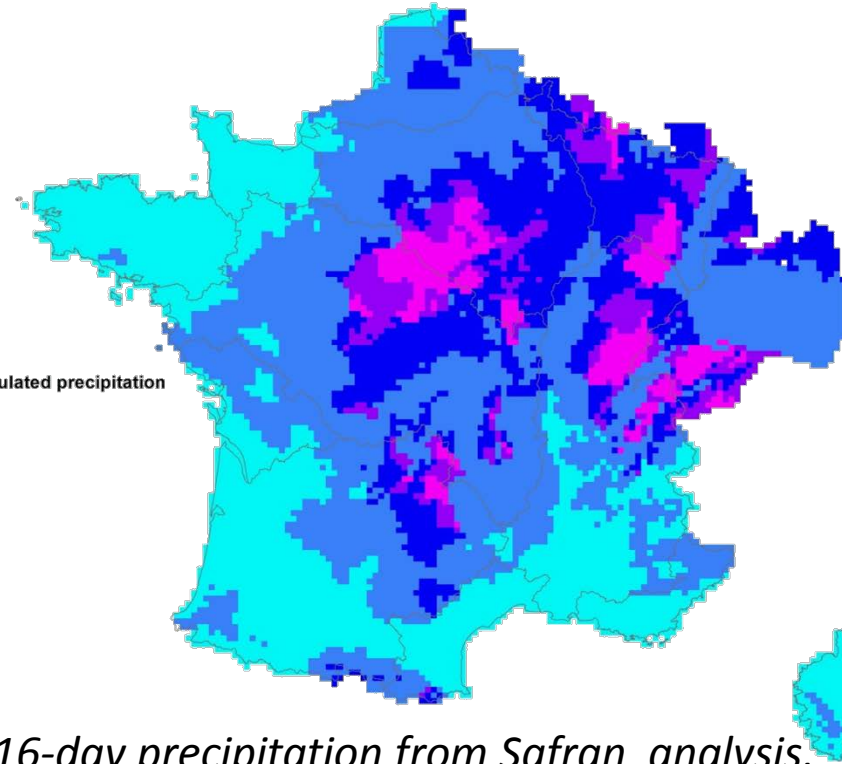


# Aqui-FR : A case study: the flood of June 2016

## Re-run of the flood events



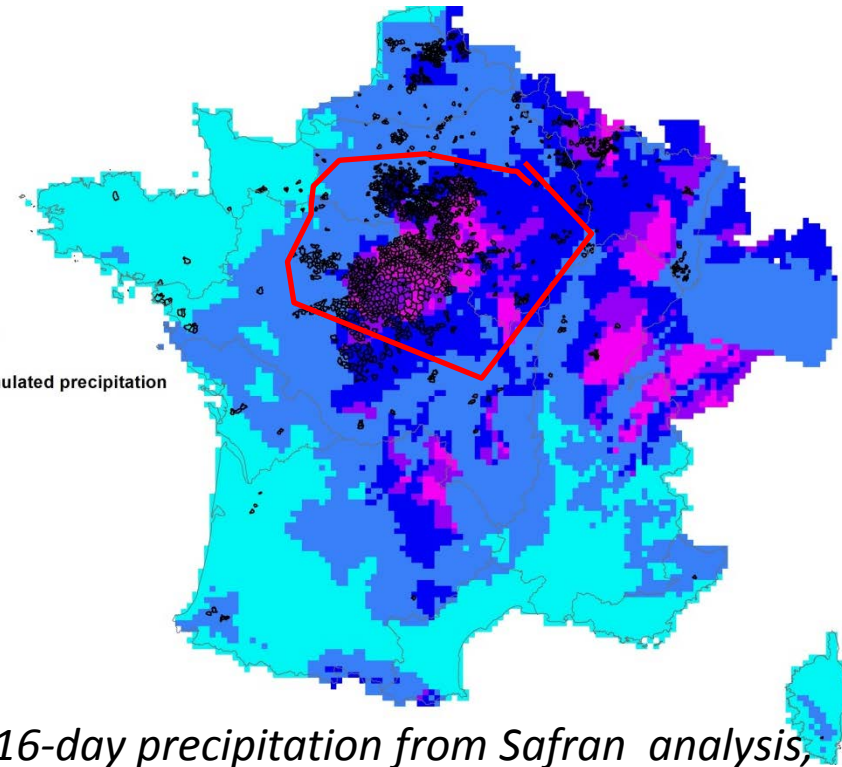
16-day accumulated precipitation



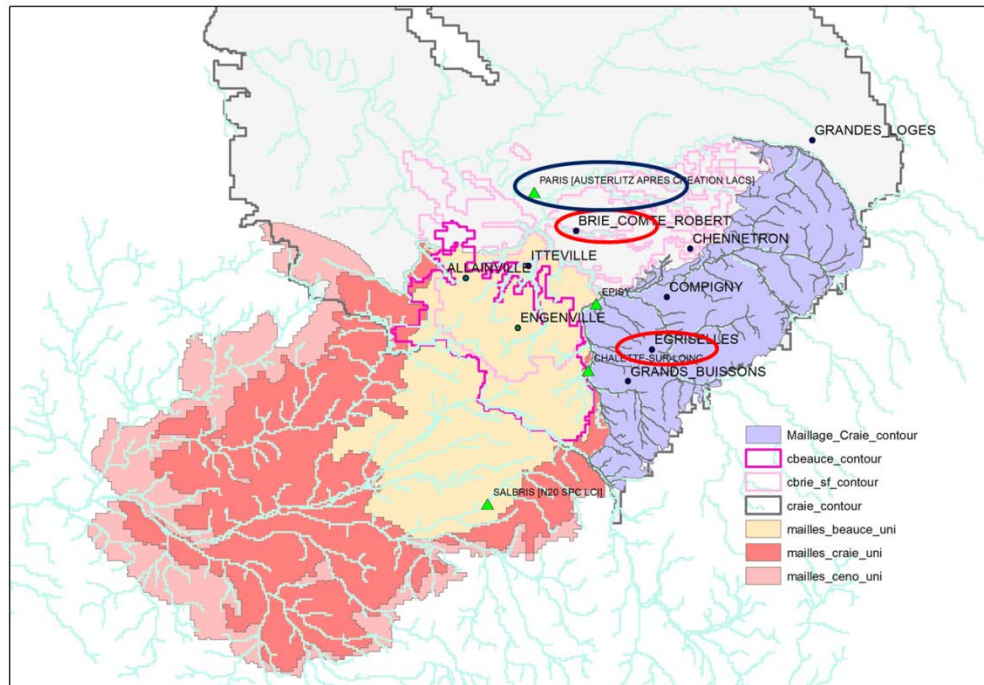
*16-day precipitation from Safran analysis,  
Courtesy of François Besson*

# Aqui-FR : A case study: the flood of June 2016

## Re-run of the flood events



*16-day precipitation from Safran analysis,  
Courtesy of François Besson  
Flooded cities (from catnat)*

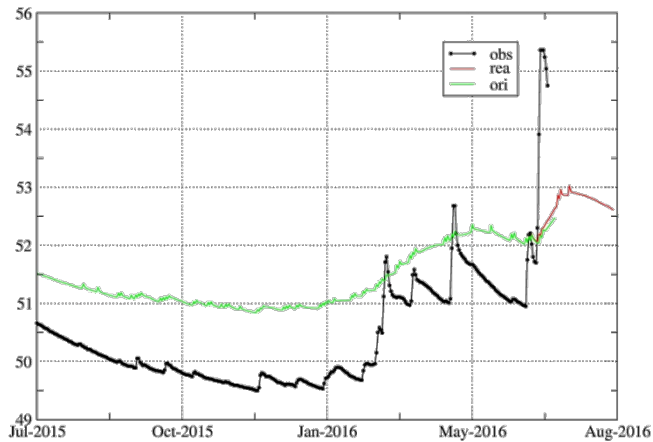




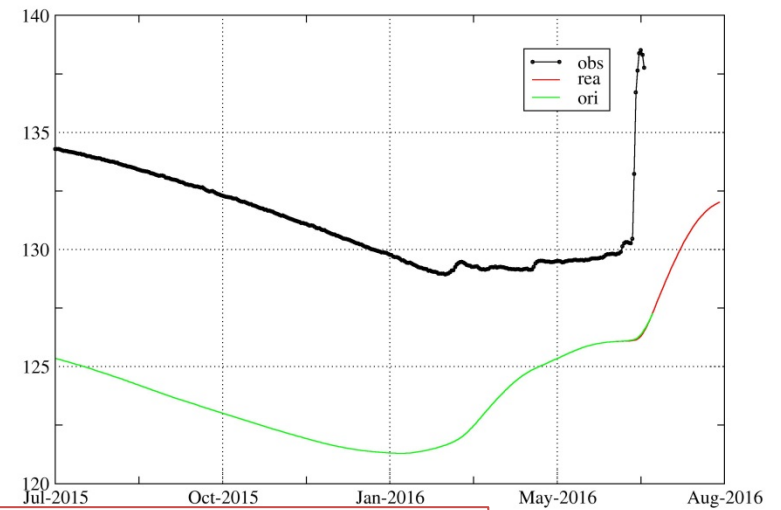
# Aqui-FR : A case study: the flood of June 2016

## Re-run of the flood events

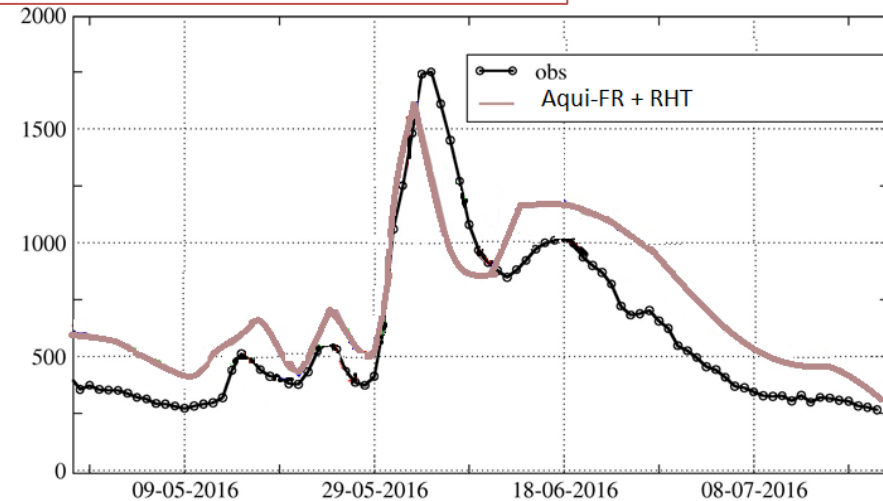
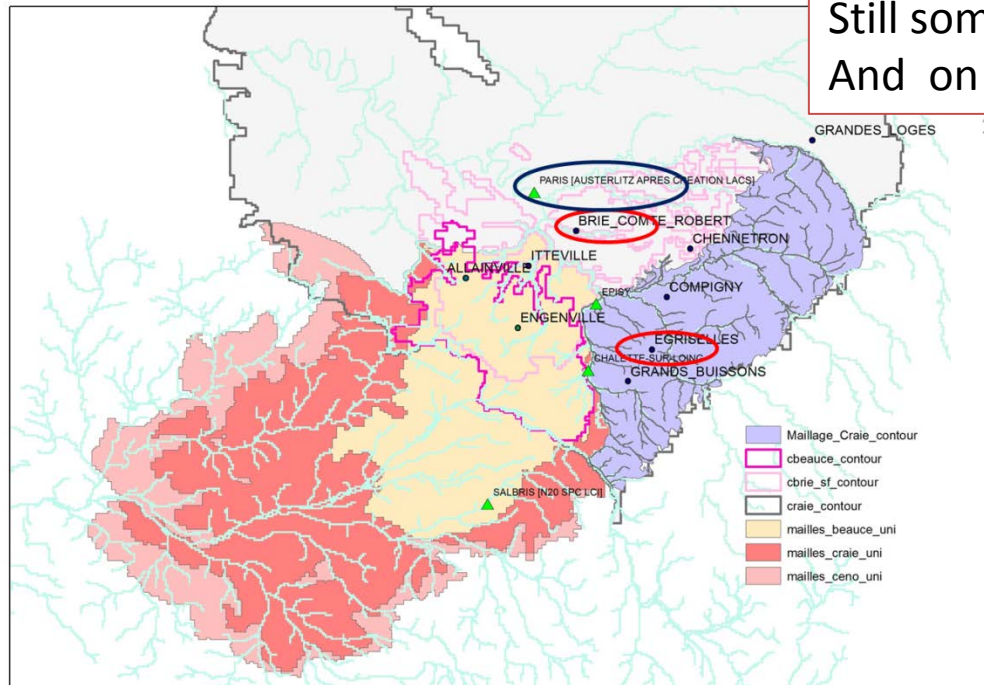
BRIE-COMTE-ROBERT -27.017696



ST-MARTIN-CHENNETRON -75.857887



Still some bias on the GW dynamic  
And on the flood peak

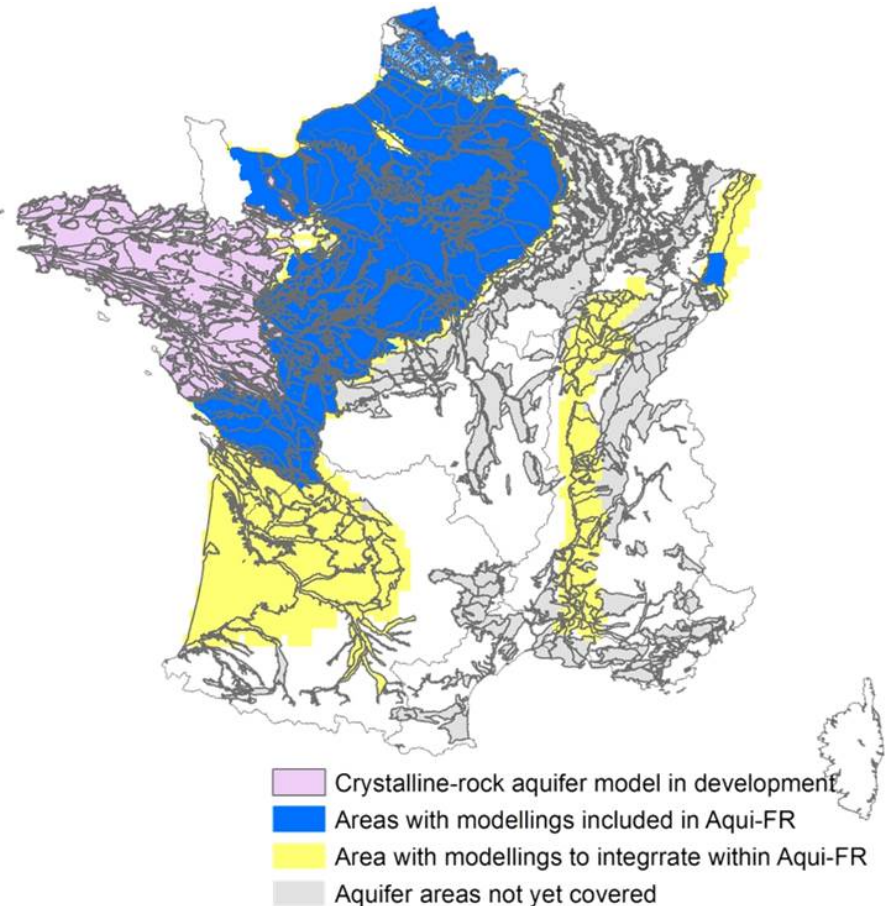


# Aqui-FR : a national multi-model hydrogeologic system

- Set up of the structure is now almost finished
- Long term assessment is now in progress

## Next steps:

- Hind cast with 10-day forecast (with a focus on the May-June 2016 flood)
- Hind cast with seasonal forecast
- Build output products with end-users
- Include additional GW applications
- Include additional models (KDM, Modflow...)



More informations:

<http://www.metis.upmc.fr/~aqui-fr>

[Florence.habets@upmc.fr](mailto:Florence.habets@upmc.fr)