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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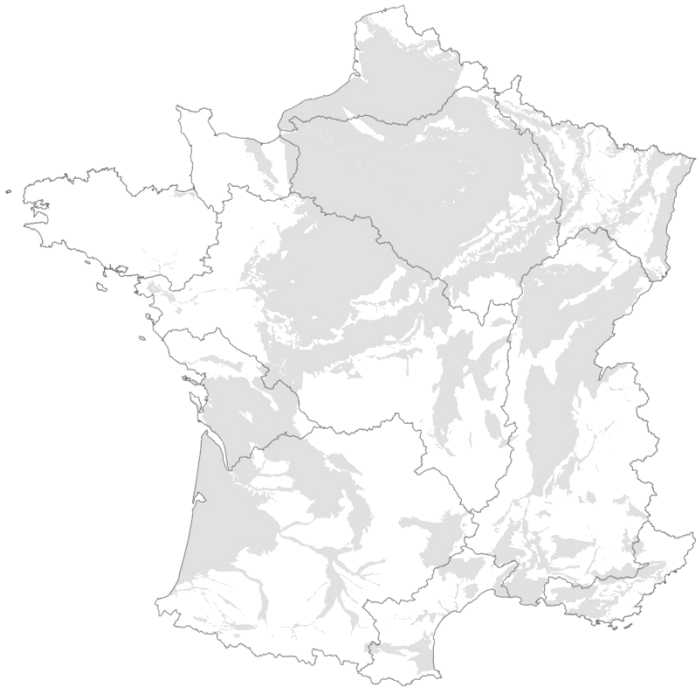


Why Aqui-FR ?

On one hand

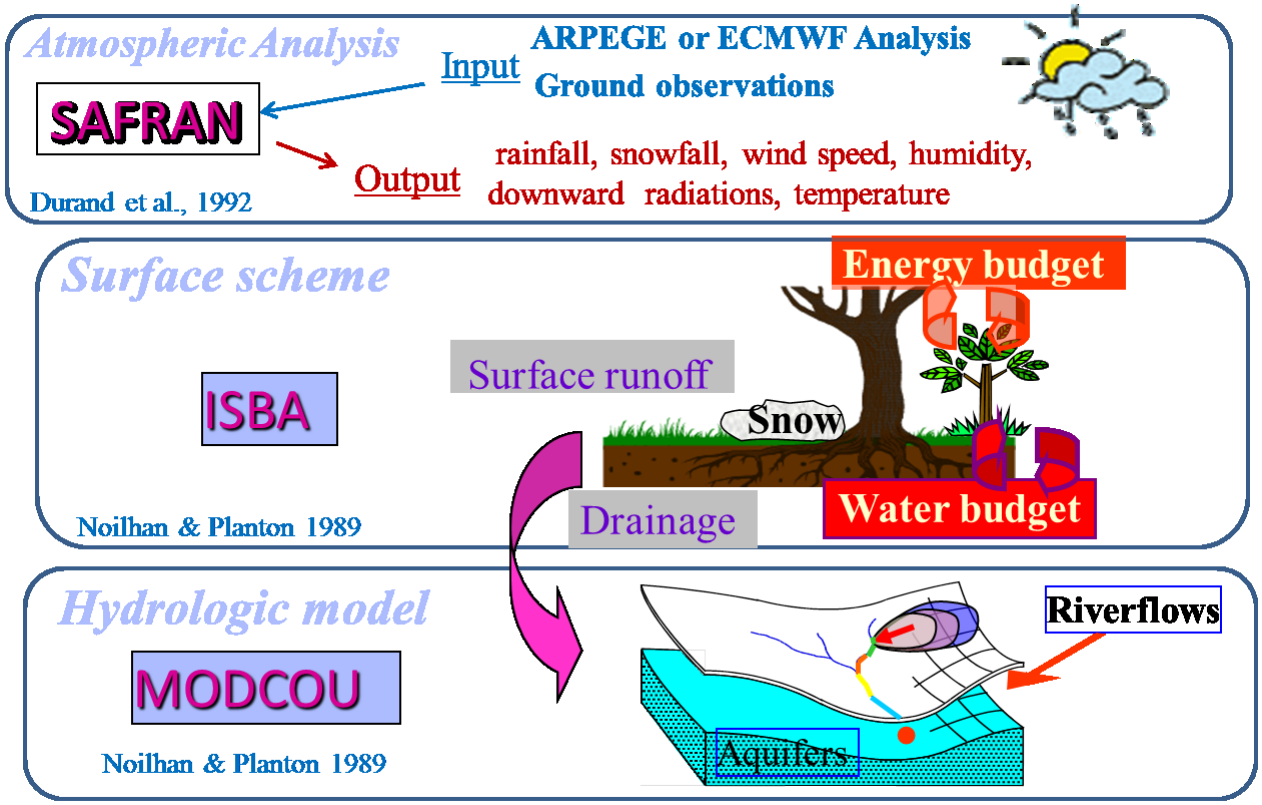
- Hydrological forecasts barely take into account groundwater
- The few existing GW forecast systems don’t take into account weather forecast
- Numerous regional GW applications developed for stakeholder are available

Why Aqui-FR ?

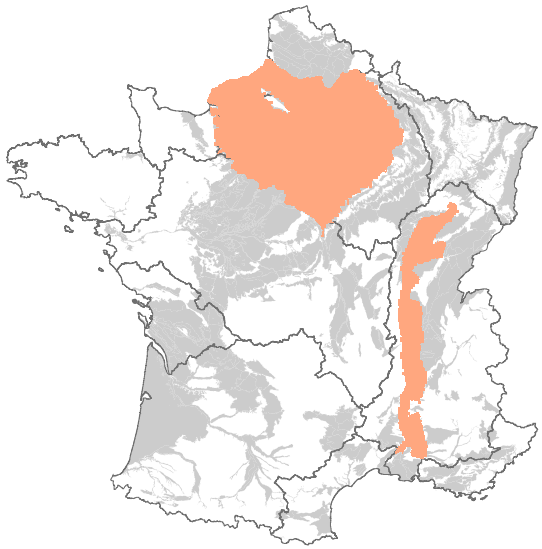
On the other hand

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



Habets et al., JGR 2008



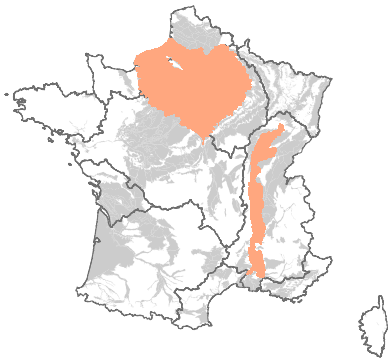
Among the limitations:
No explicit representation of the GW abstraction

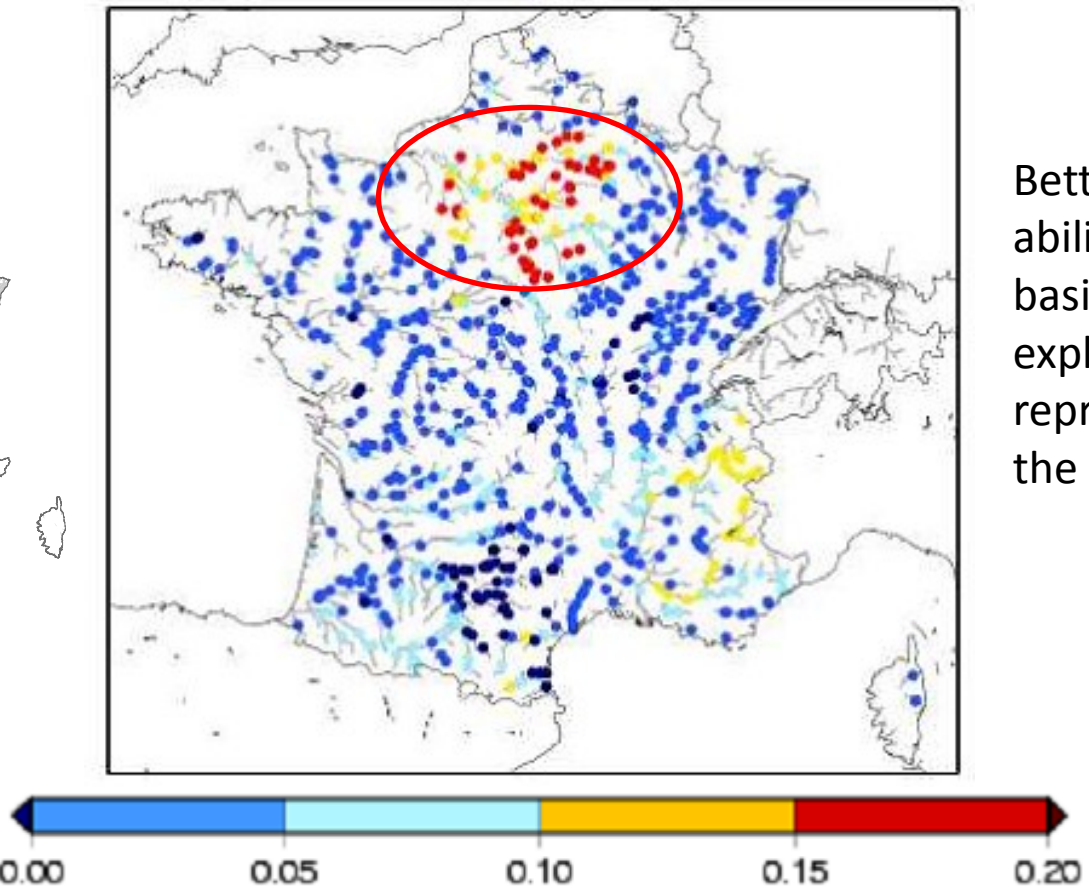
Why Aqui-FR ?

On the other hand

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

Forecast ability of summer river flow 3 months ahead





Low forecast ability

High forecast ability

Better forecast ability in the Seine basin due to the explicit representation of the aquifers

Singla et al., HESS, 2012

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

Marthe
10 layers
100m, daily
Buscarlet et al.2011

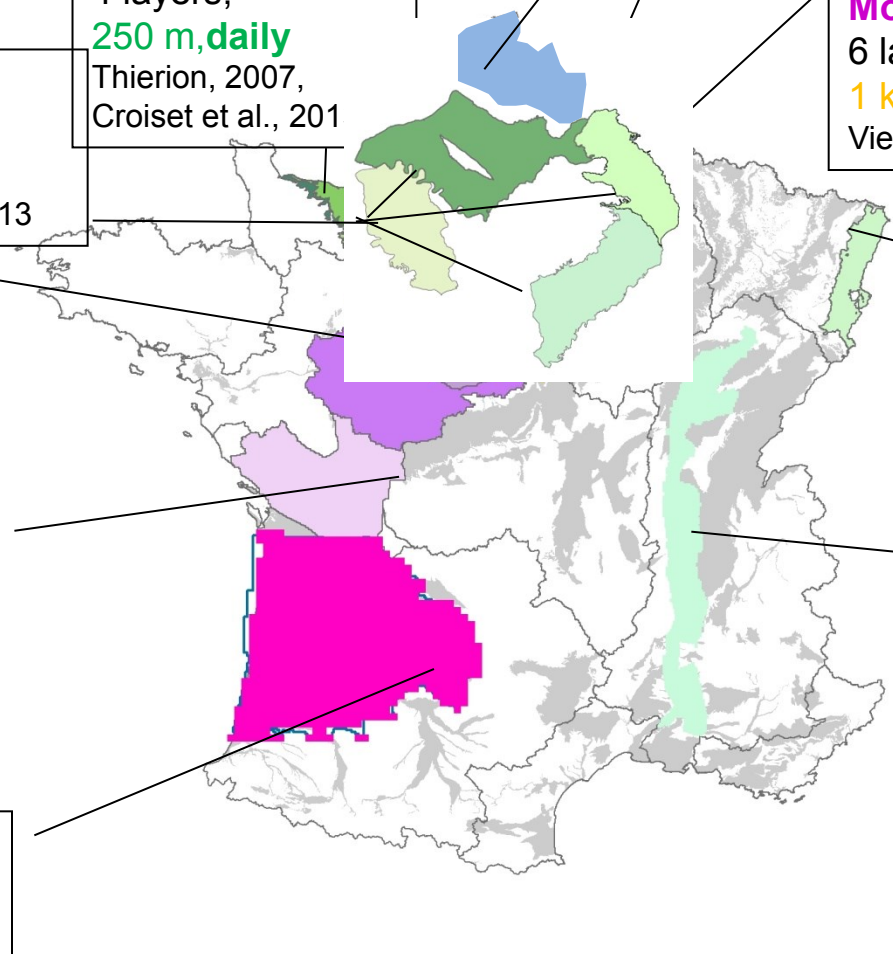
Marthe + Modcou
1 layer
100m, daily
Amraoui 2004, Korkmaz 2007

Modcou+ Marthe
4 layers,
250 m,**daily**
Thierion, 2007,
Croiset et al., 201

Modcou
6 layers
1 km, daily
Viennot 2009

Modcou
1 to 4 layers
125 m, **daily**
Viennot, Abasq, 2013

Modcou
3 layers
1km, **daily**
Monteil, 2011



Modcou +Marthe+ HPP-inv
1 layer,125m
Daily/10-day
Chardigny 2009, Thierrion 2011, Noyer & Elsass 2006

Marthe
8 layers
1 km,**10-day**
Douez et al., 2010

Modcou
1 layer
1km, daily
Golaz, 2000

Marthe
15 layers
2 km, **yearly**
Pédron et al., 2005

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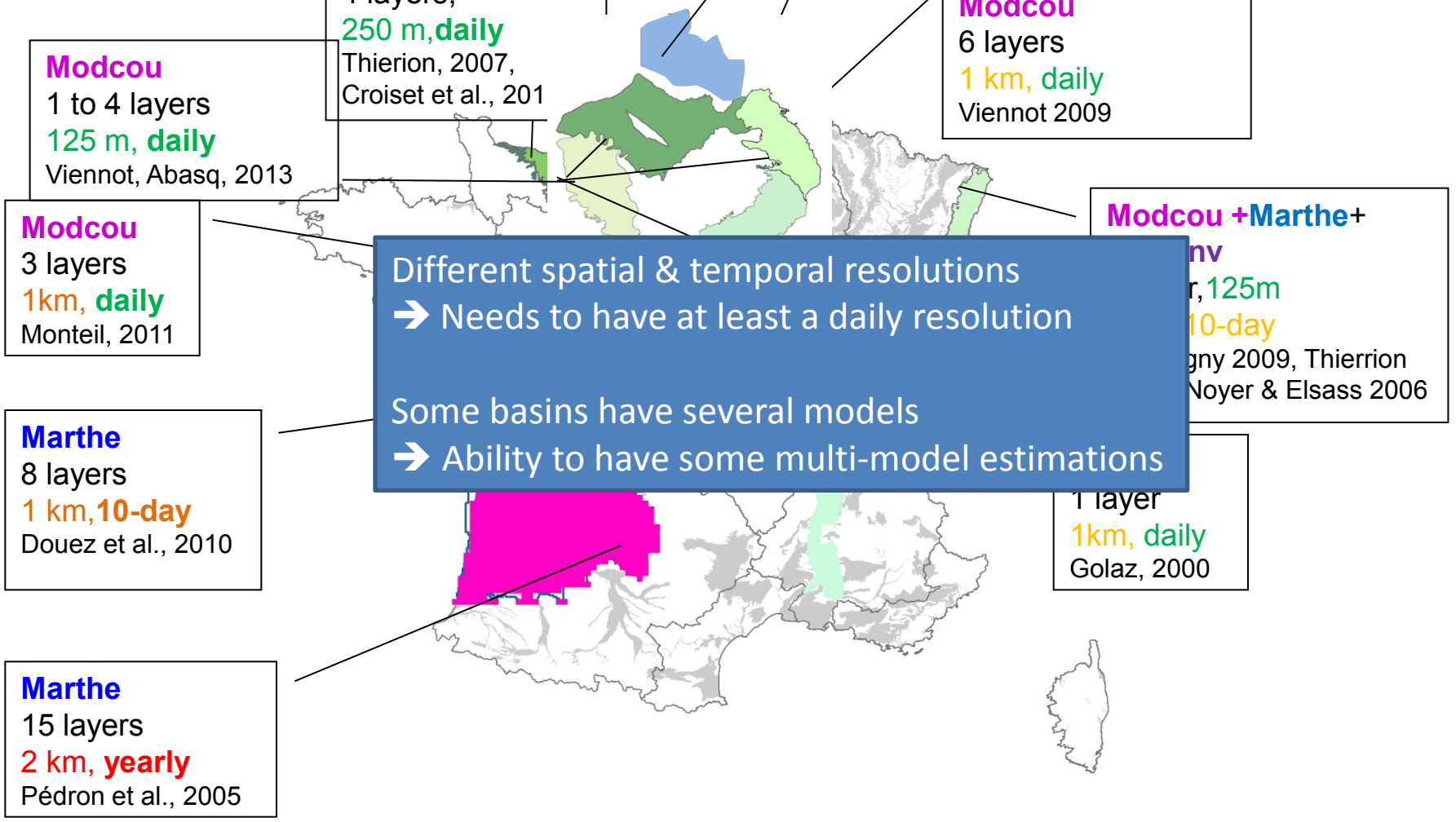

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Noyer & Elsass 2006

Different spatial & temporal resolutions
➔ Needs to have at least a daily resolution

Some basins have several models
➔ Ability to have some multi-model estimations

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1 km,**10-day**
Douez et al., 2010

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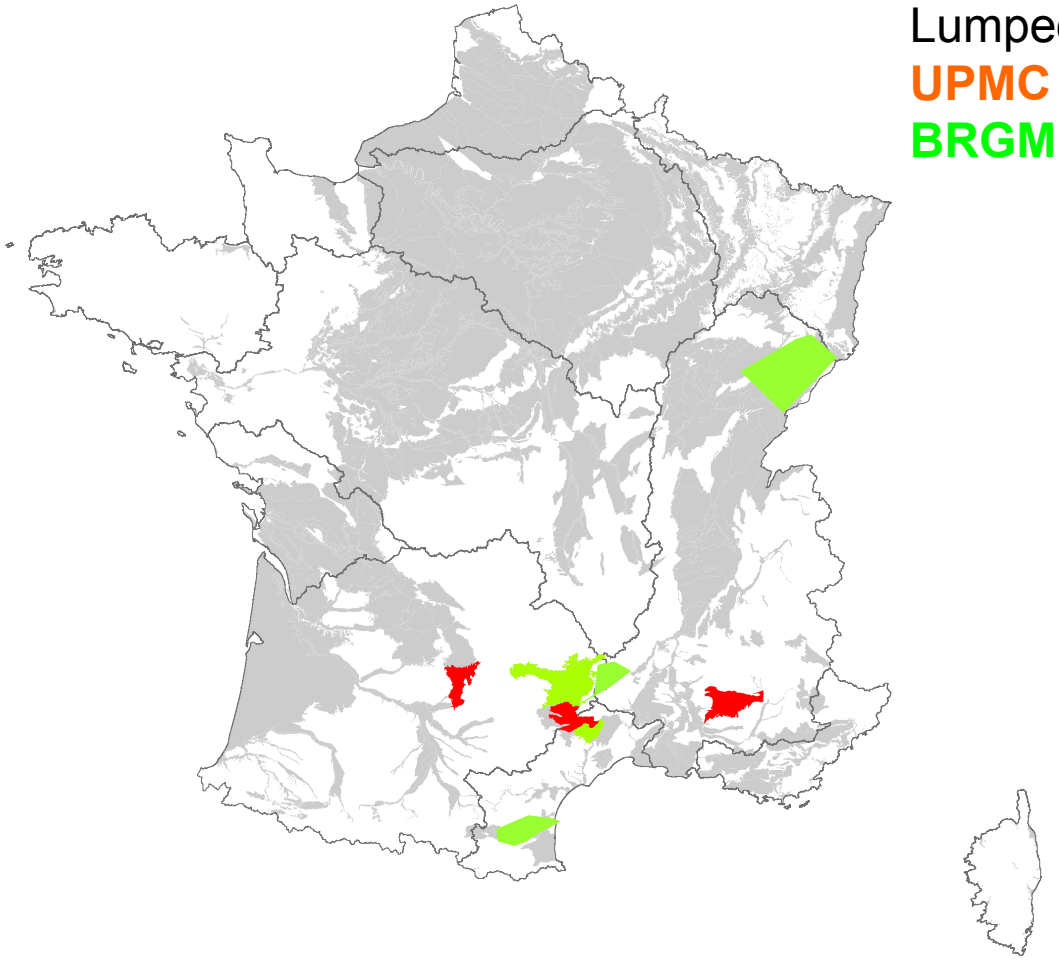
What's in Aqui-FR ?

Extension of the available karst modelings



Lumped karstic models

UPMC : KDM

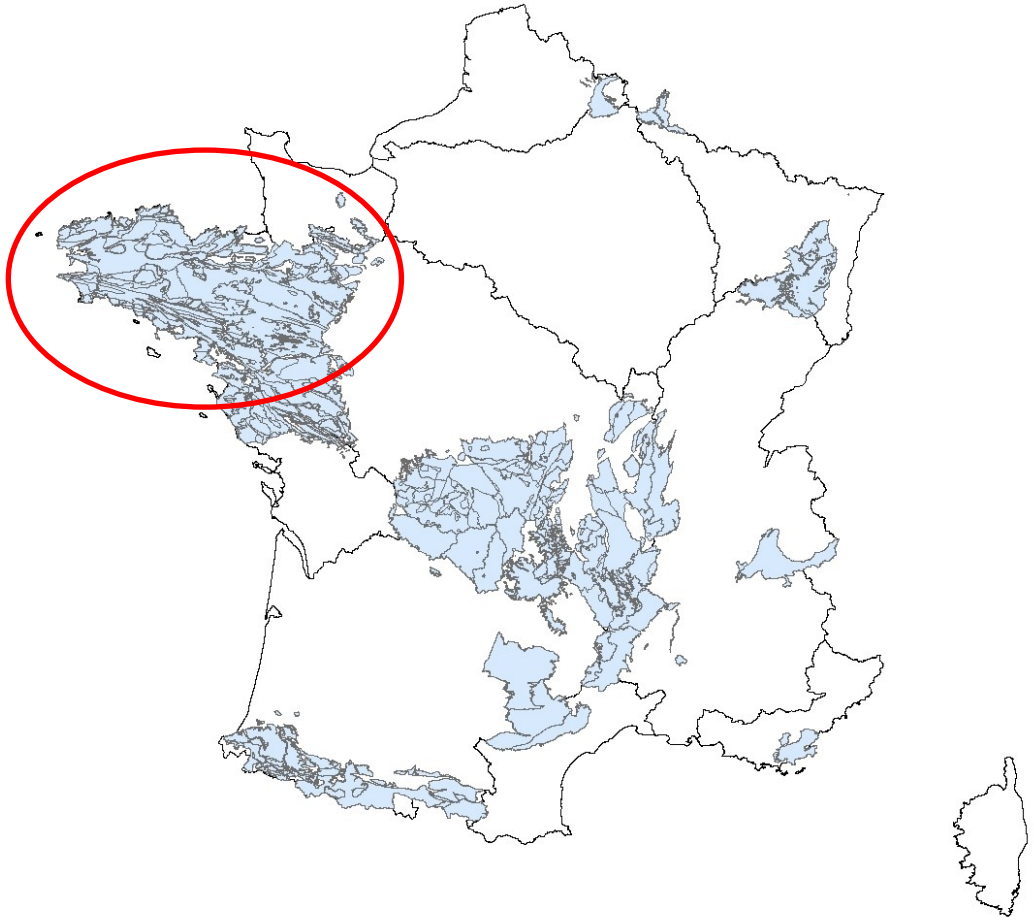
BRGM : Gardenia

Lanini & Maréchal, 2004
Maréchal et al., 2014
Charlier et al., 2014
Fleury et al., 2007
Moussu et al., 2011
Thiery, 2015

What's in Aqui-FR ?

Extension of the existing hard rocks aquifers

Development of a simple distributed model in Britany



Aurore Réfloch, 2014
Yann Sergent, 2016

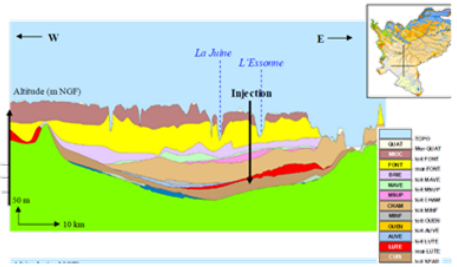
What's in Aqui-FR ?

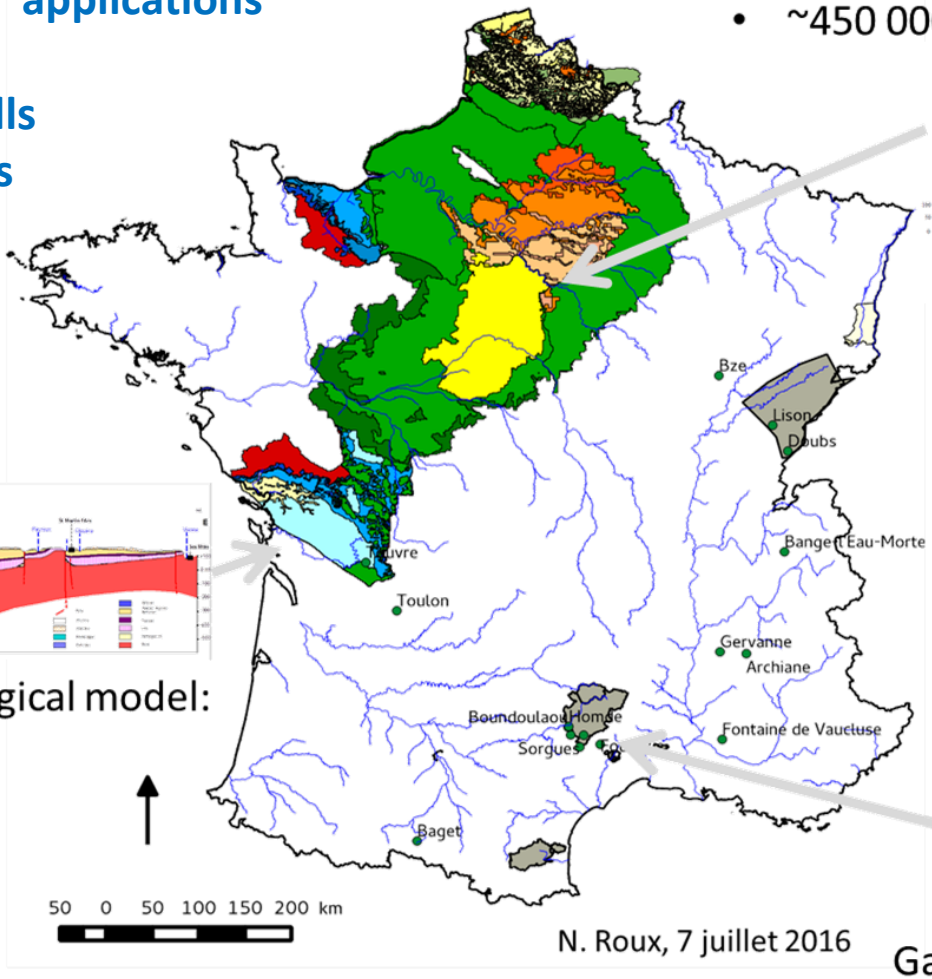
Actual extension of the GW basins included in Aqui-FR

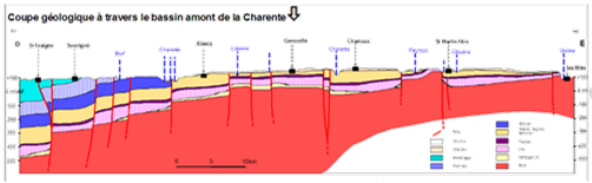
- 13 distributed applications
- 57 GW layers
- ~1 650 000 cells
- Some overlaps

Eau-dyssée hydrogeological model:

- 8 modelings
- ~450 000 cells

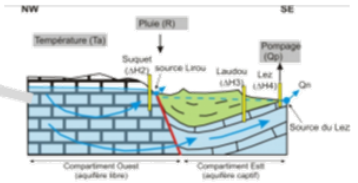






Marthe hydrogeological model:

- 5 modelings
- ~1 200 000 cells



Gardénia karstic model:

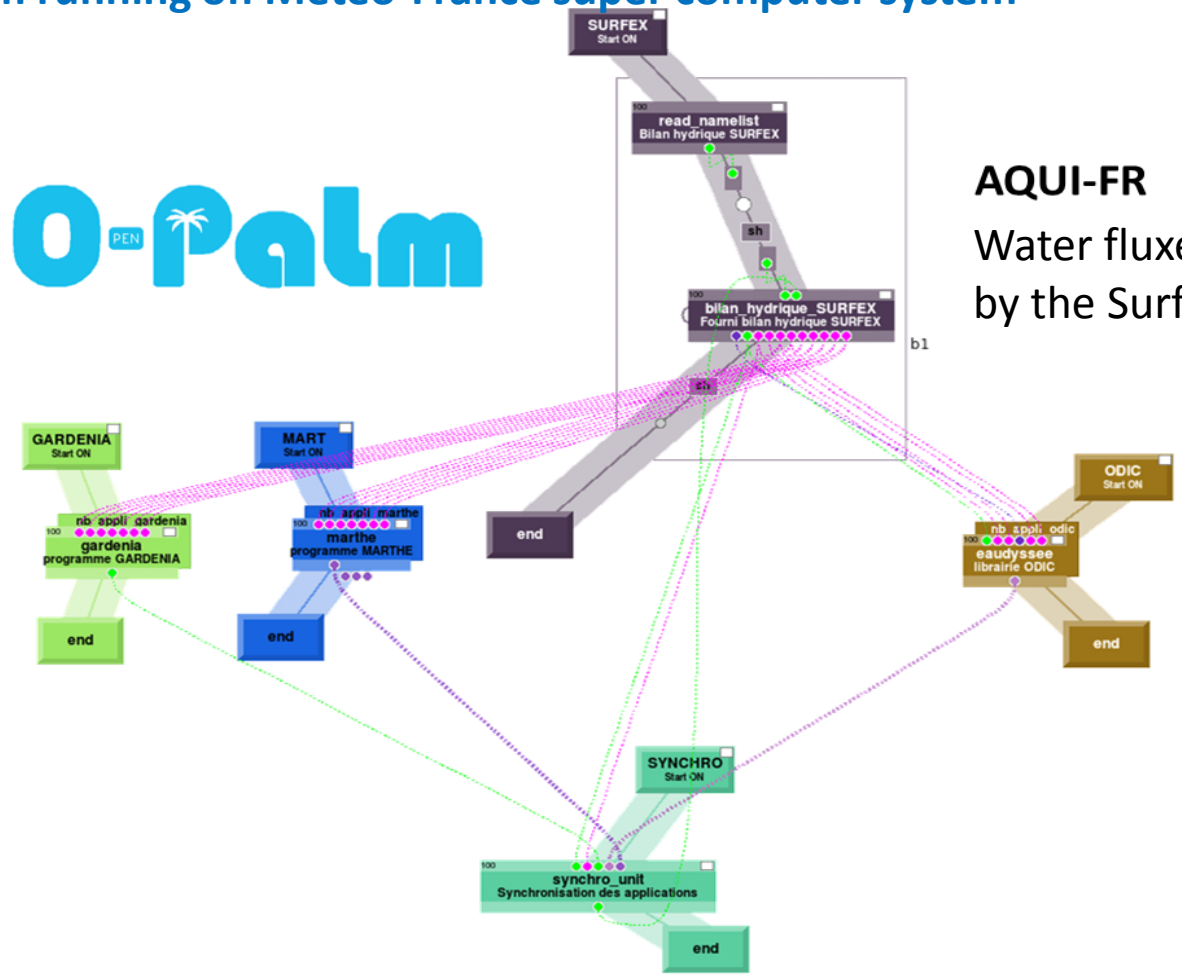
- 6 modelings

N. Roux, 7 juillet 2016

How Aqui-FR is working?

AQUI-FR takes benefit of the OPEN-Palm parallel coupling system

- **All the branches run independently and exchanges some information**
- **Each GW model can run as many applications as necessary**
- **A PostProc module (in python) prepare selected outputs**
- **Number of application, duration and beginning of the simulation are defined by user**
- **System running on Météo-France super computer system**



AQUI-FR

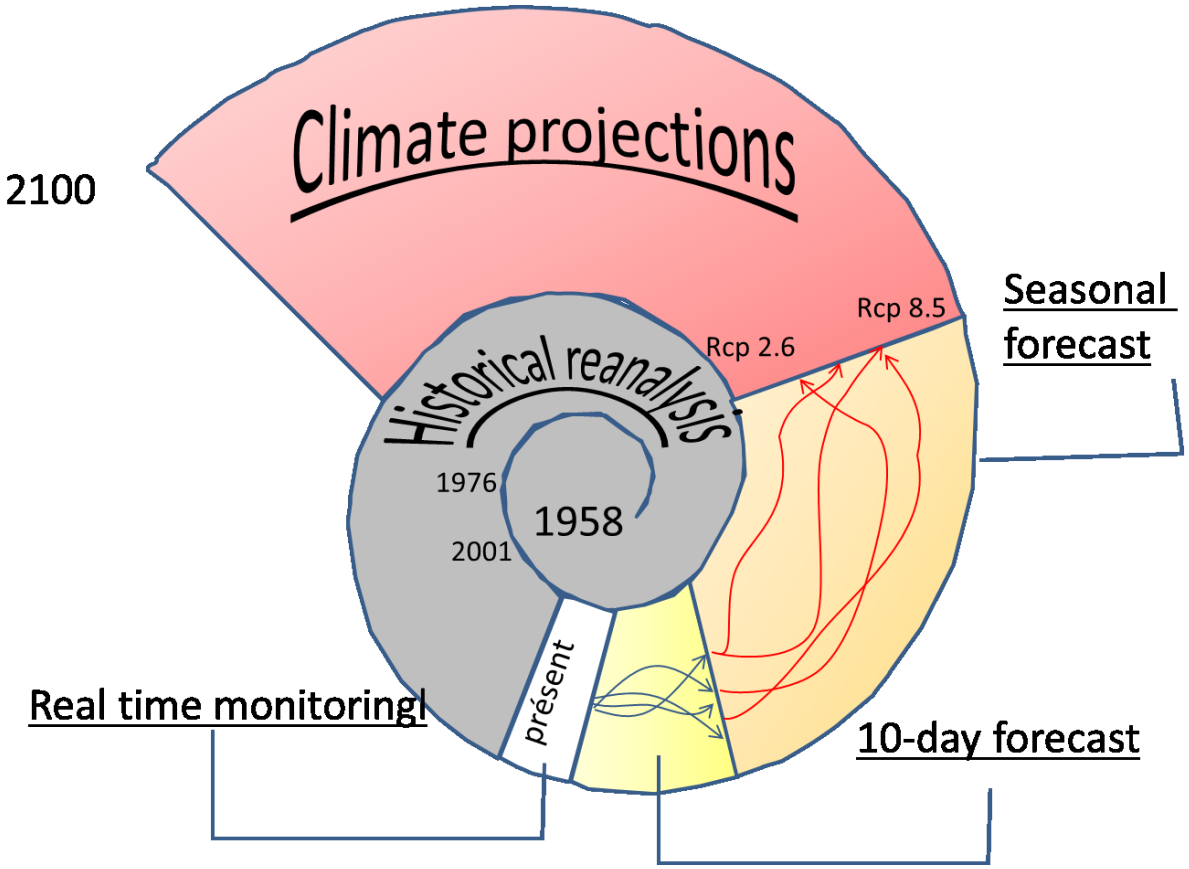
Water fluxes (recharge) is estimated by the Surfex LSM

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

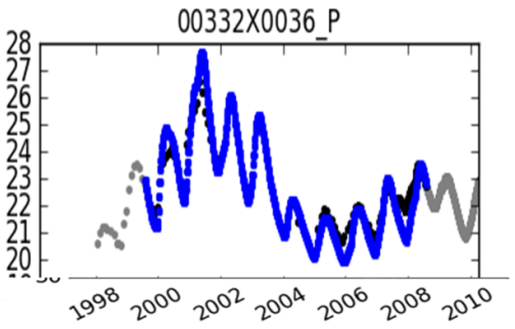
Example of results:

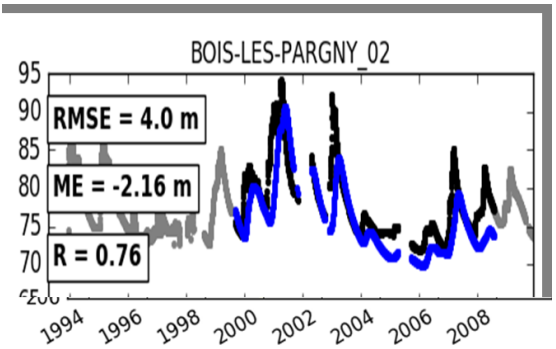
- **comparison with the observed piezometric head for a 14-year simulation**
- **Comparison with the observed river flows**

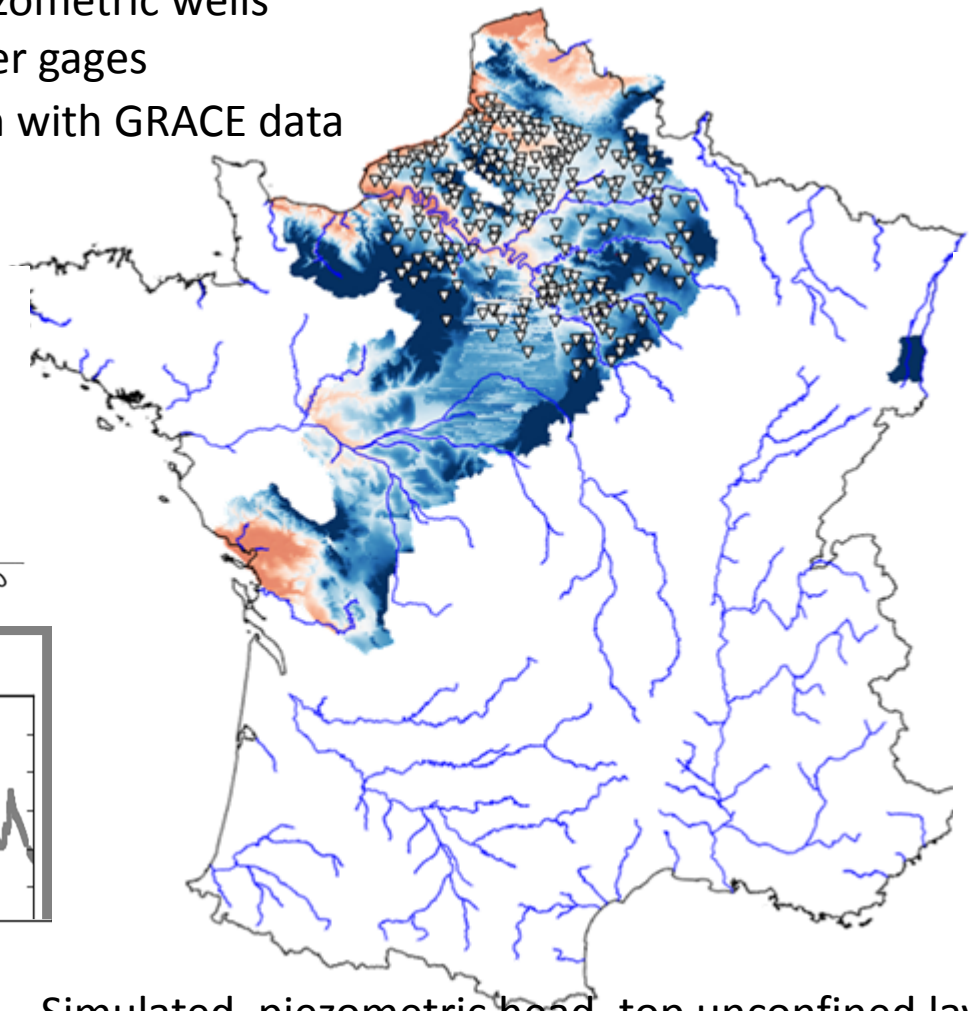
So far: ~above 800 piezometric wells

~above 300 river gages

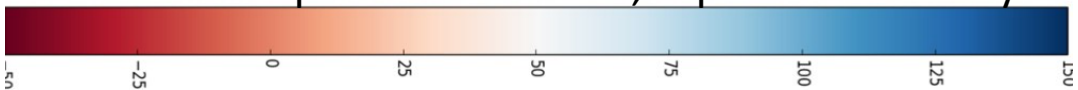
Next step: comparison with GRACE data

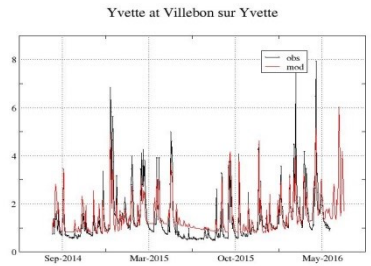


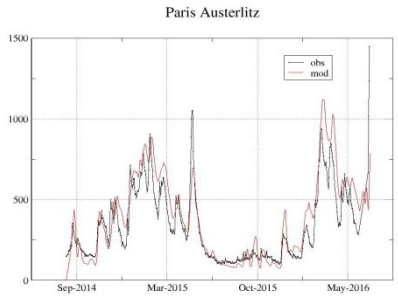




Simulated piezometric head, top unconfined layers







N. Roux 2016

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

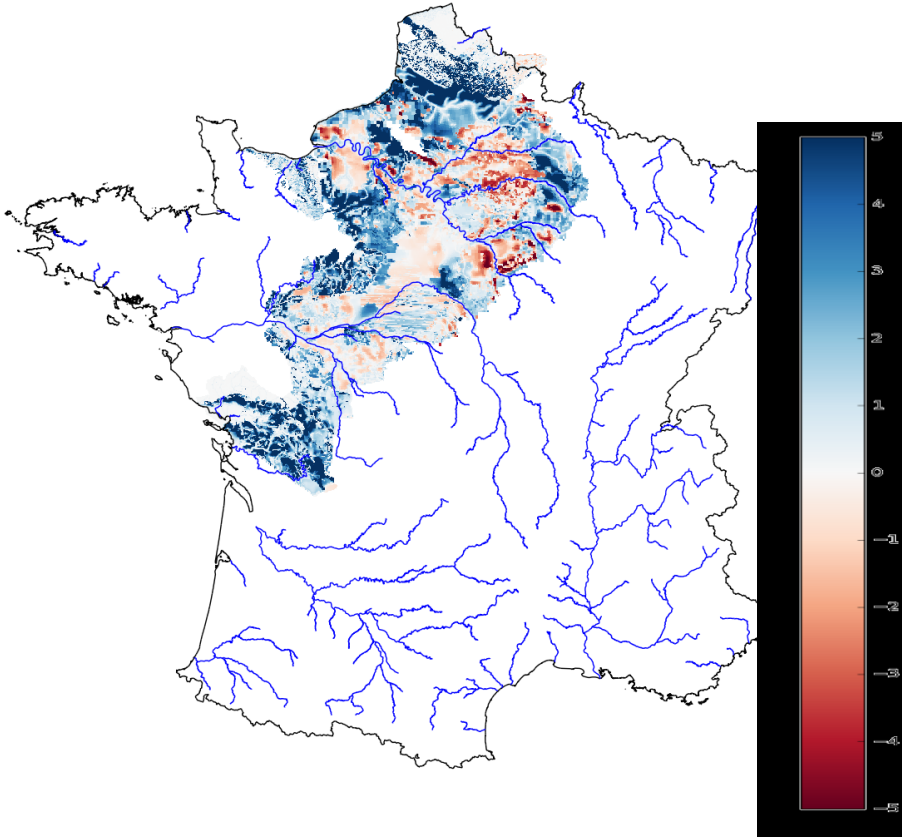
Issue #2: Which kind of results to provide to stakeholder

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

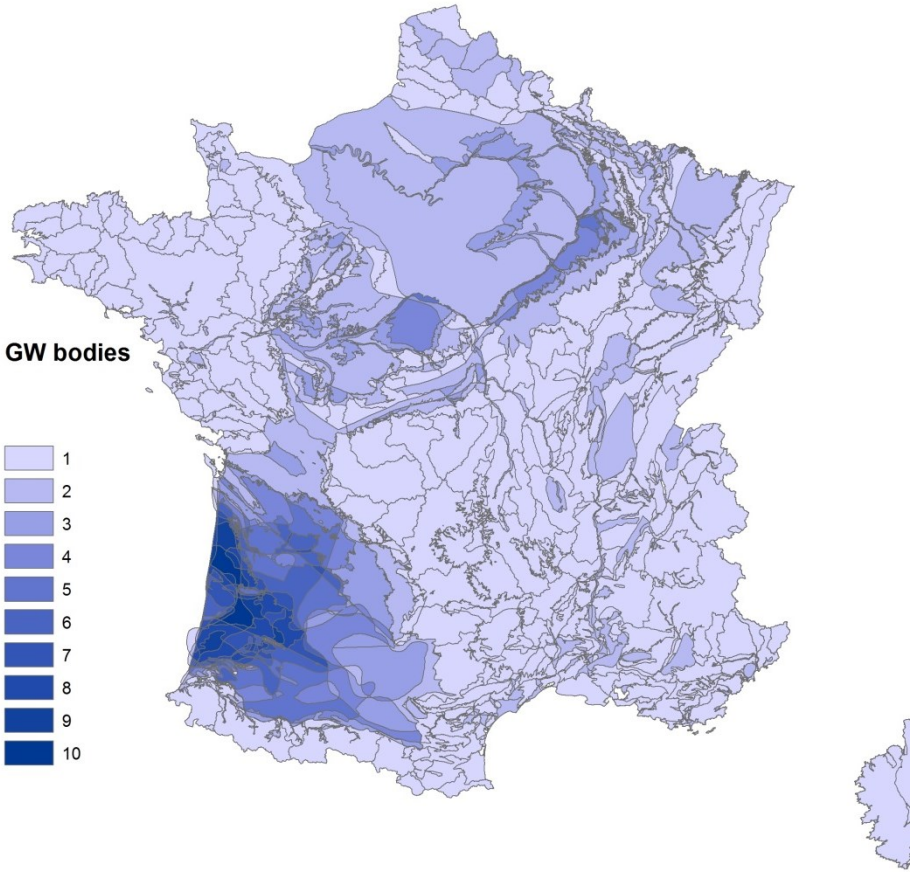
Avignon, 2014

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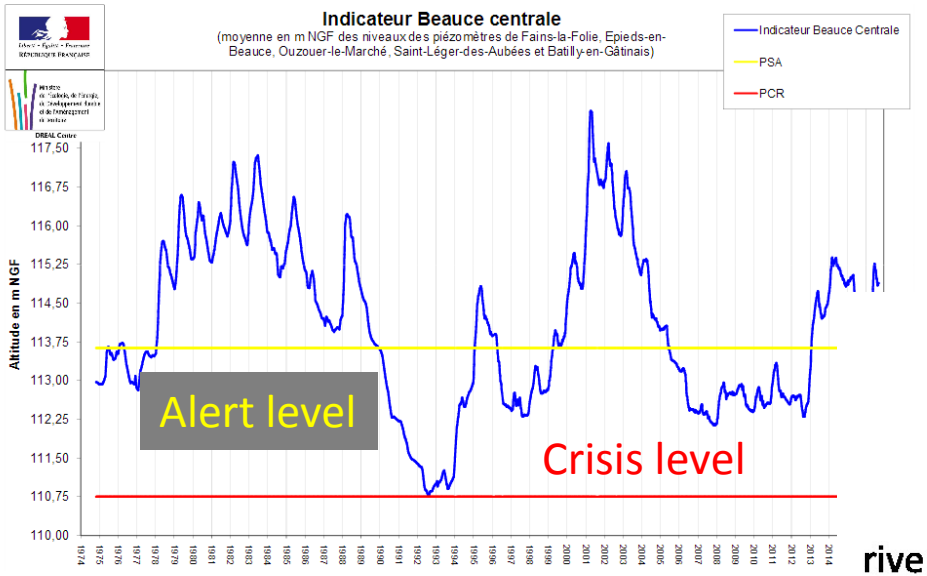
A first stakeholders surveys showed that numerous types of output could be useful

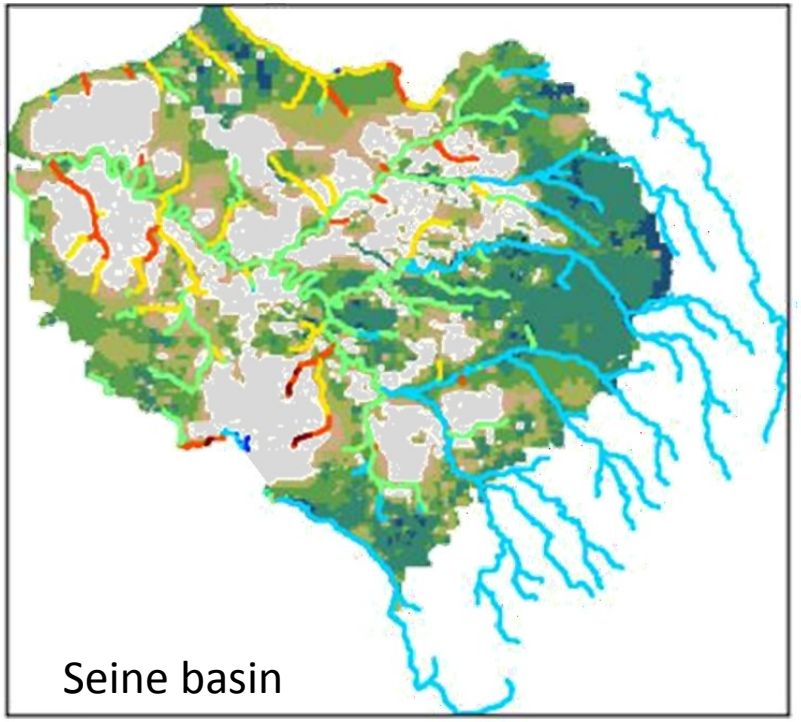
Avignon, 2014

Reproduction of indicators based on an averaged of several wells



Beauce Central indicator

Combined maps of GW & river flow anomalies



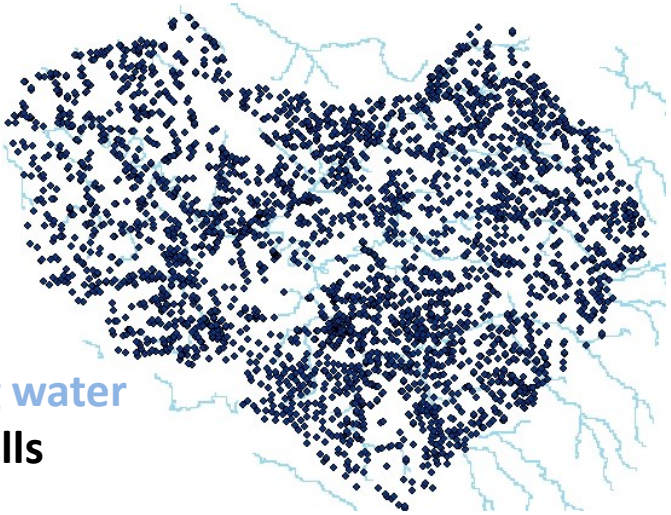
Issue #3: How to include the uncertainties ?

At least 3 sources of uncertainties:

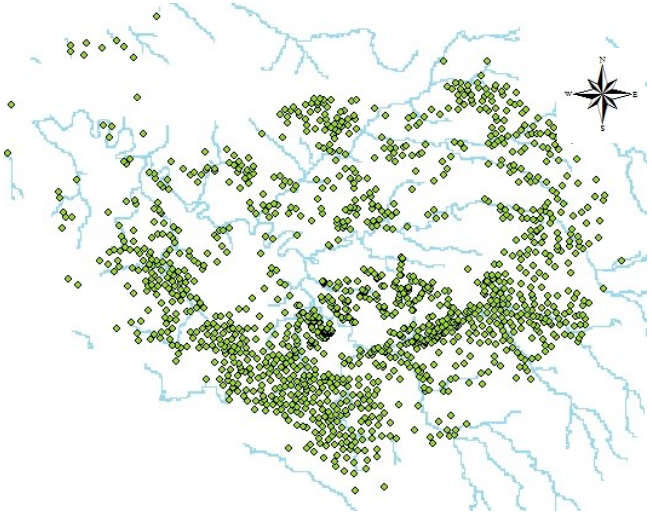
- **Uncertainty linked to the weather forecast ➔ taken into account via ensemble**
- **Uncertainty due to the GW modeling ➔ in some basins, multi-model simulation**
- **Uncertainty due to human activity ➔ needs some scenarios**

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

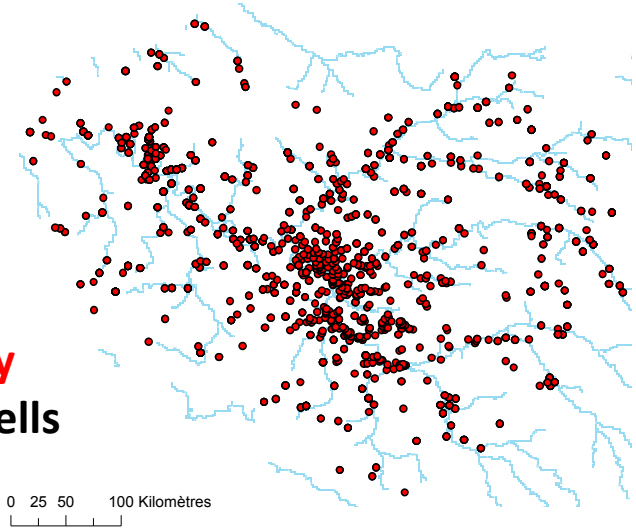
Spatial repartition of the abstraction wells in the Seine basin



Drinking water
3756 wells



Irrigation
4810 wells

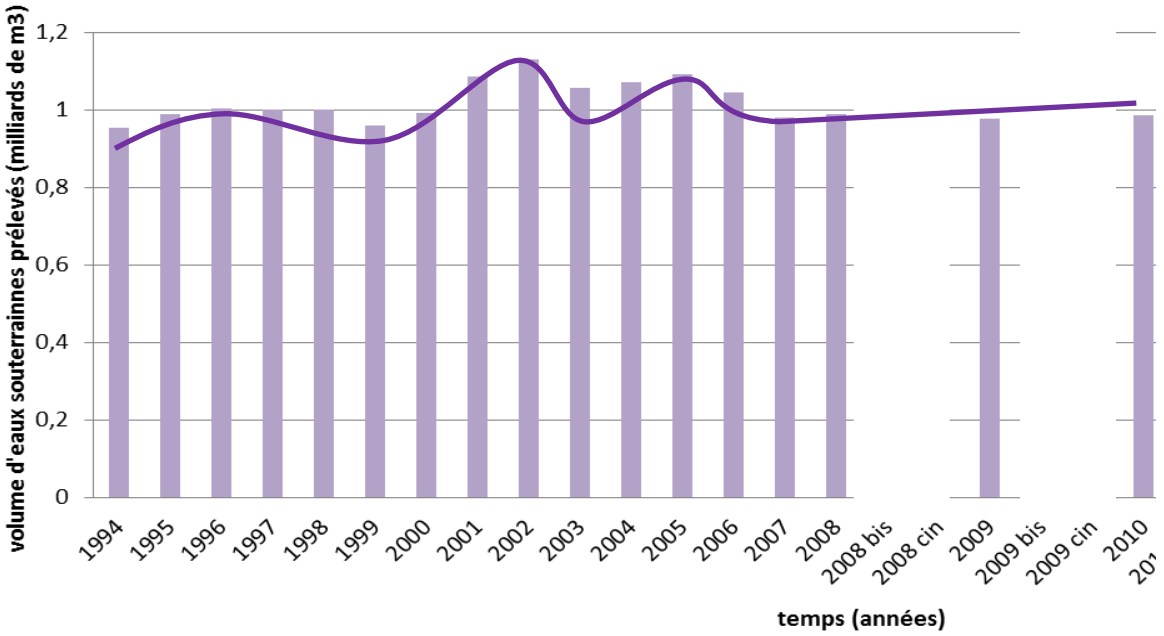


Industry
1740 wells

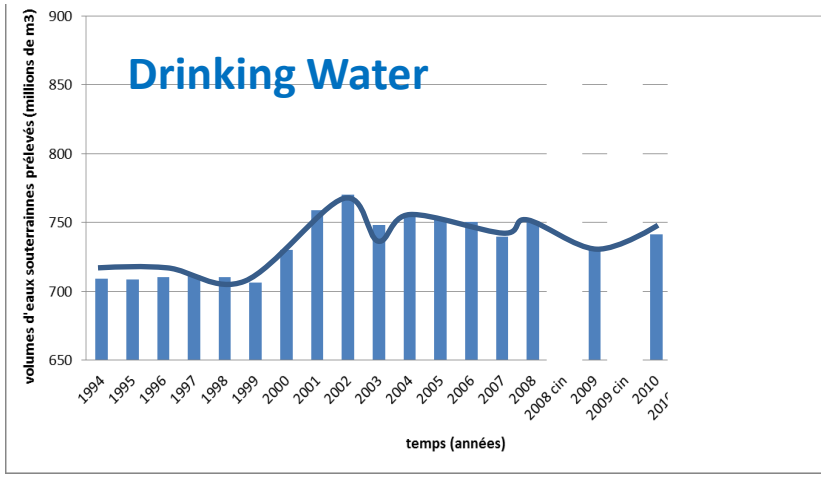
- **Around 10 000 wells**
- **Around 1 billion m3/year**
- **Estimated with 2-year delay**
- **Annual variability and uncertainty according to the sources**

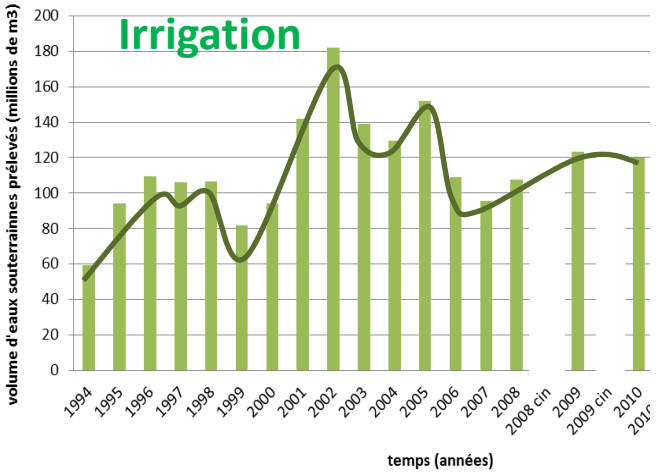
Issue #3: Illustration od the uncertainties linked to human activities

Annual volume of the groundwater abstraction in the Seine basin



Some variabilities in total volume and for each use





Carluer Candillon, 2016

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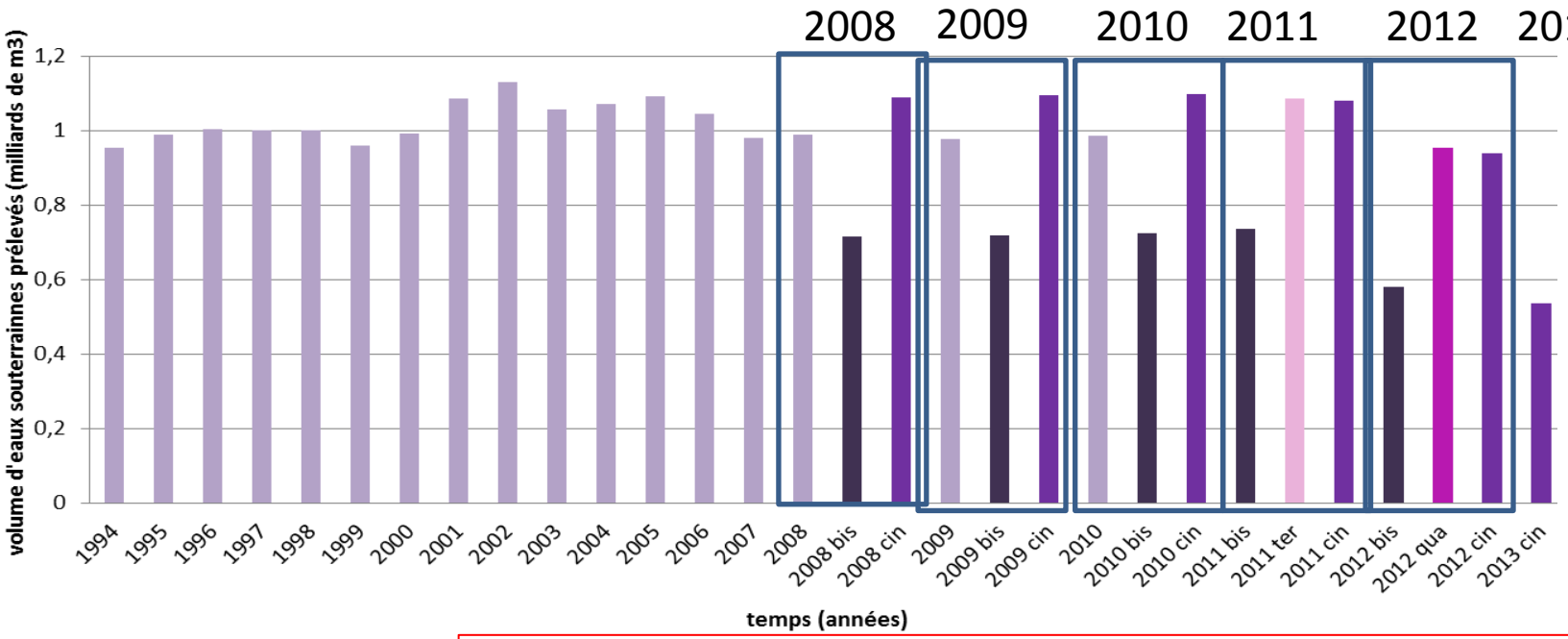
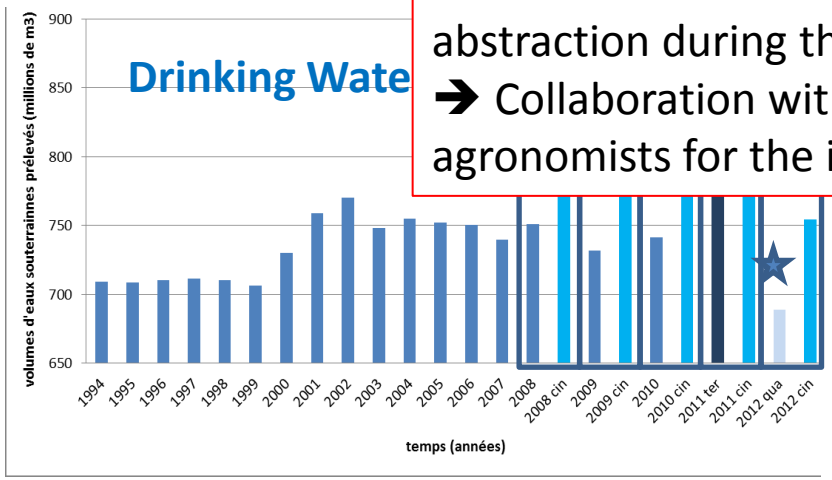
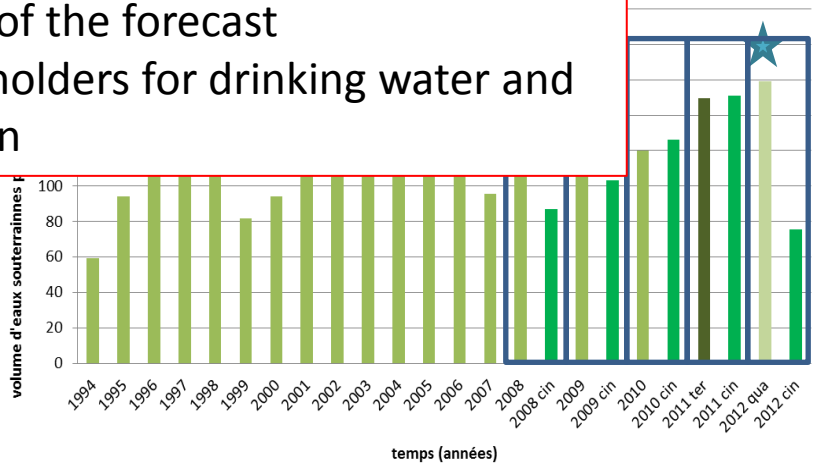


Up to 30% of uncertainty

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





Carluer Candillon, 2016

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- **Uncertainty due to human activity ➔ needs some scenarios**

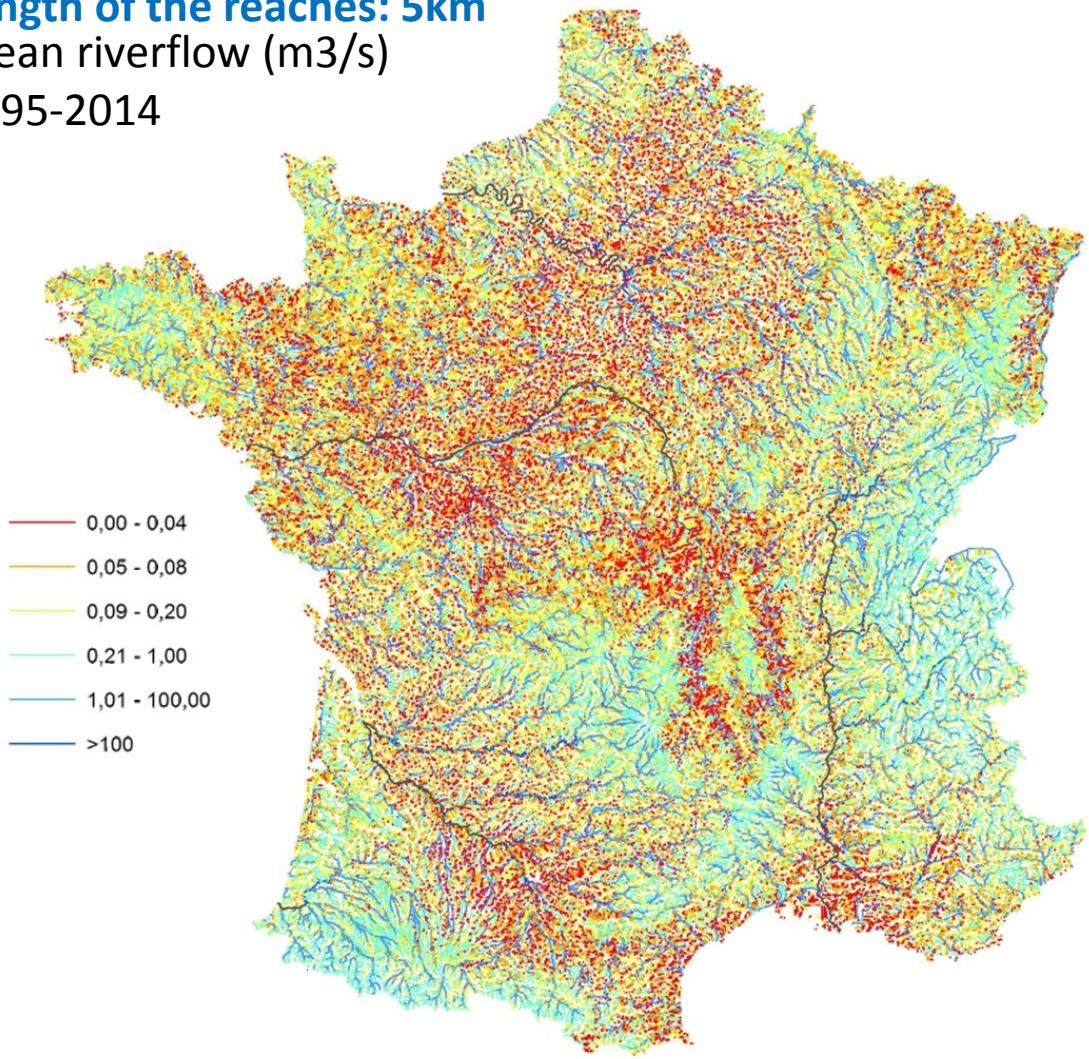
➔ **There may be a need to explicit the uncertainty associated to each case**

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). More than 280 000 km of river . Mean length of the reaches: 5km

Mean riverflow (m3/s)
1995-2014



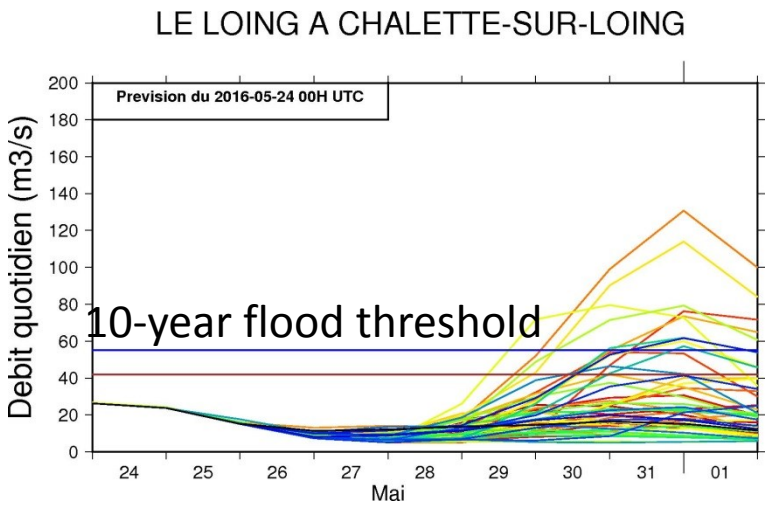
Use of RHT hydrographic network together with SAFRAN-SURFEX Coupling with GW applications needs to be made

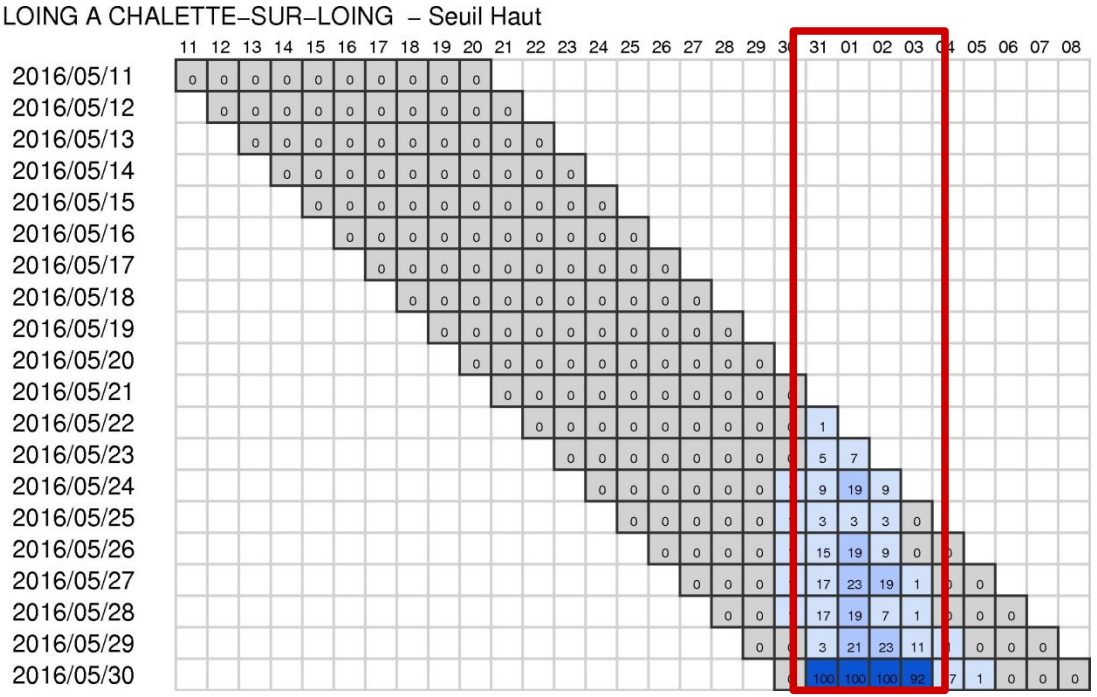
Aqui-FR : A case study: the flood of June 2016

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

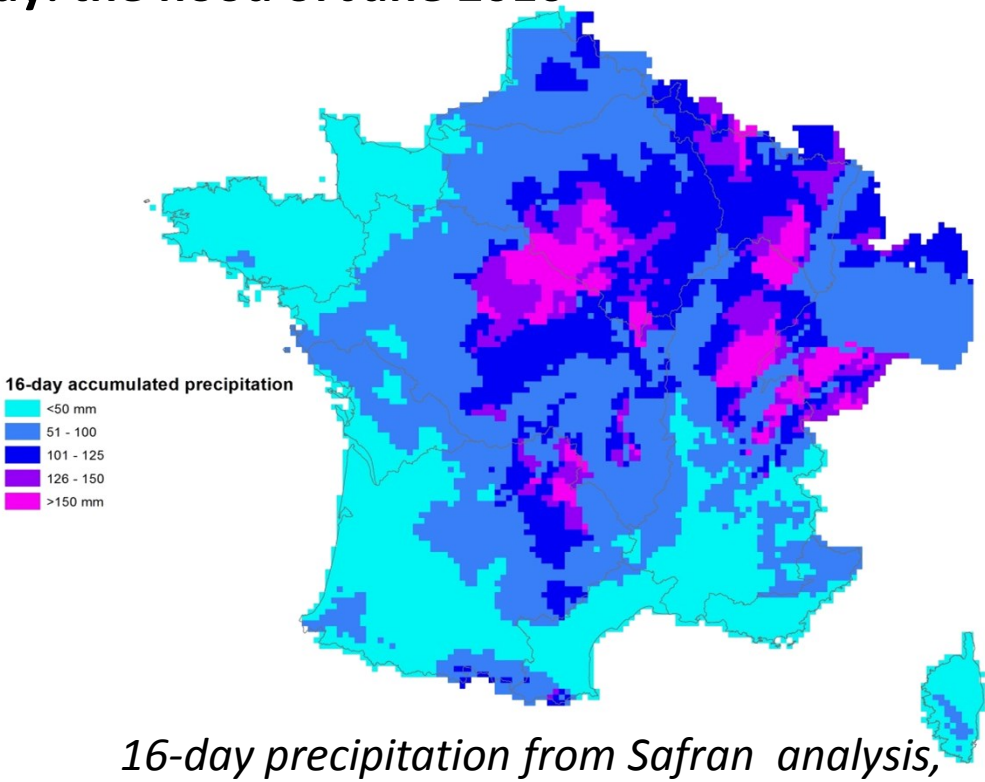




Rousset-Regimbeau et al., 2016

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

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

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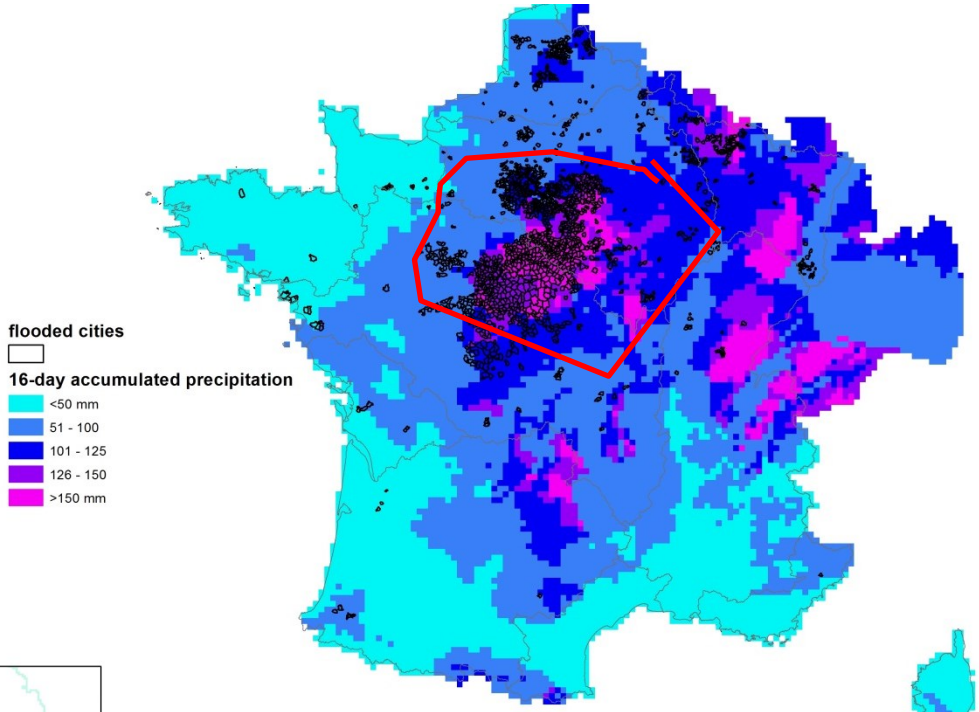
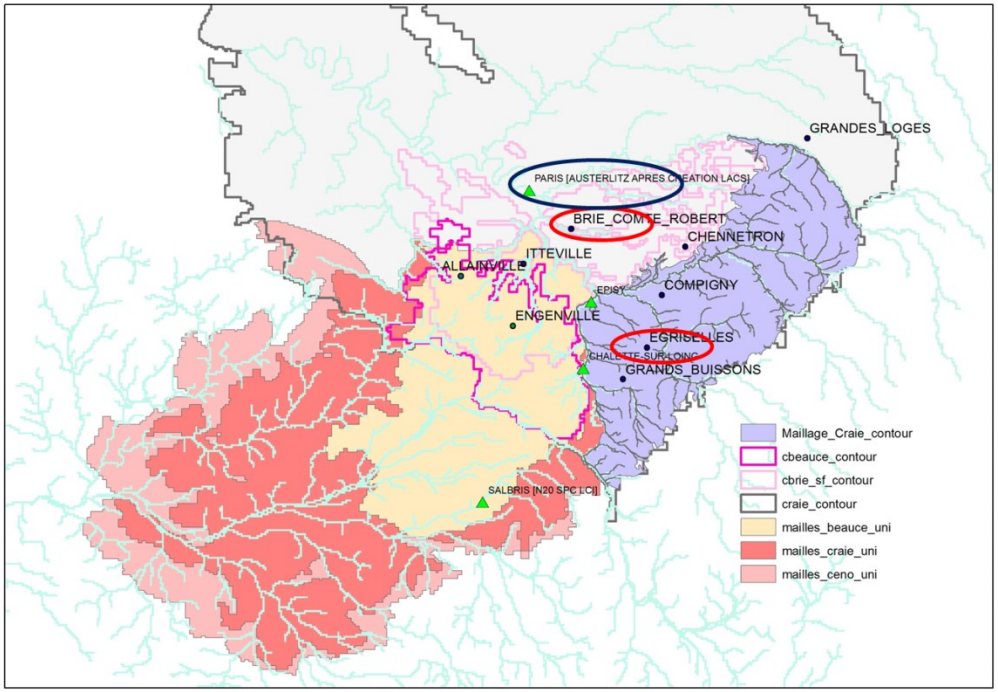


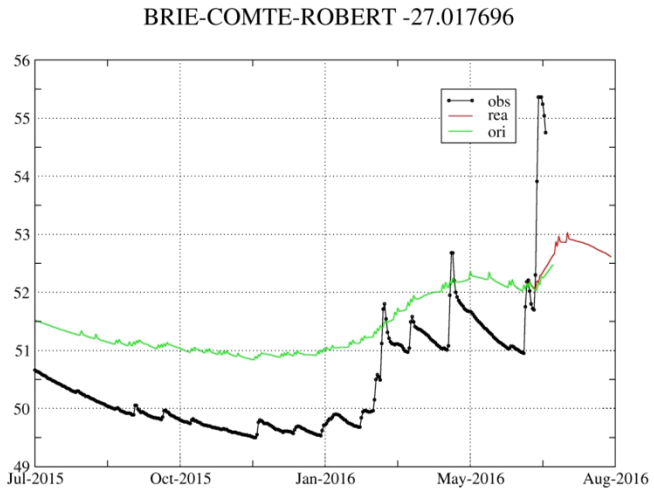


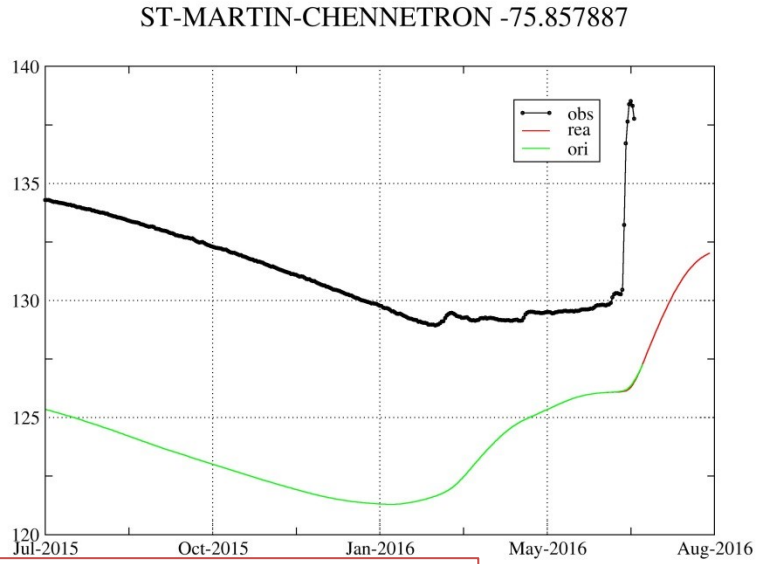
16-day precipitation from Safran analysis, Courtesy of François Besson

Flooded cities (from catnat)

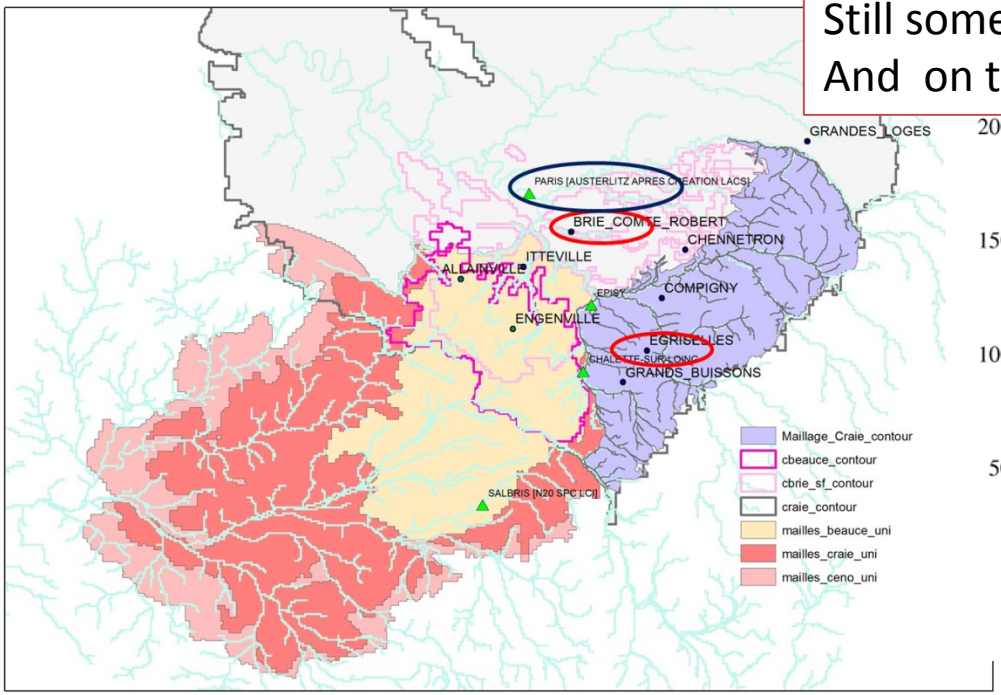
Aqui-FR : A case study: the flood of June 2016

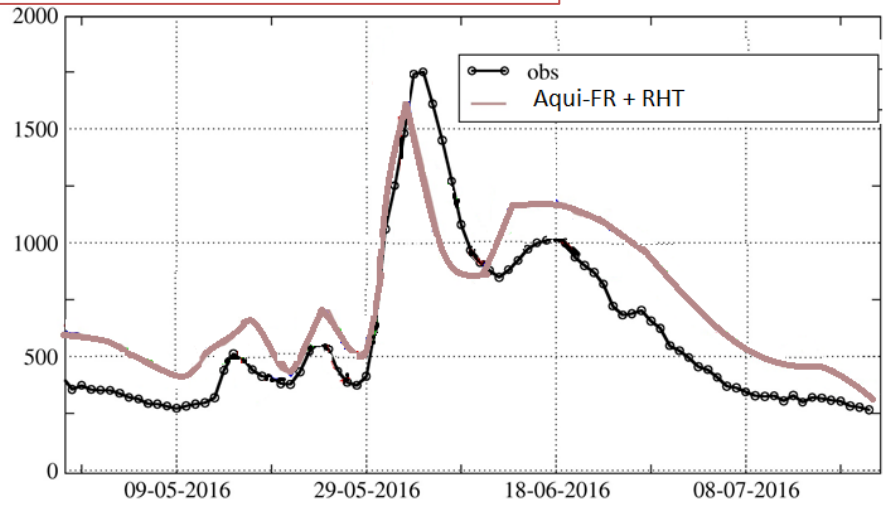
Re-run of the flood events





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



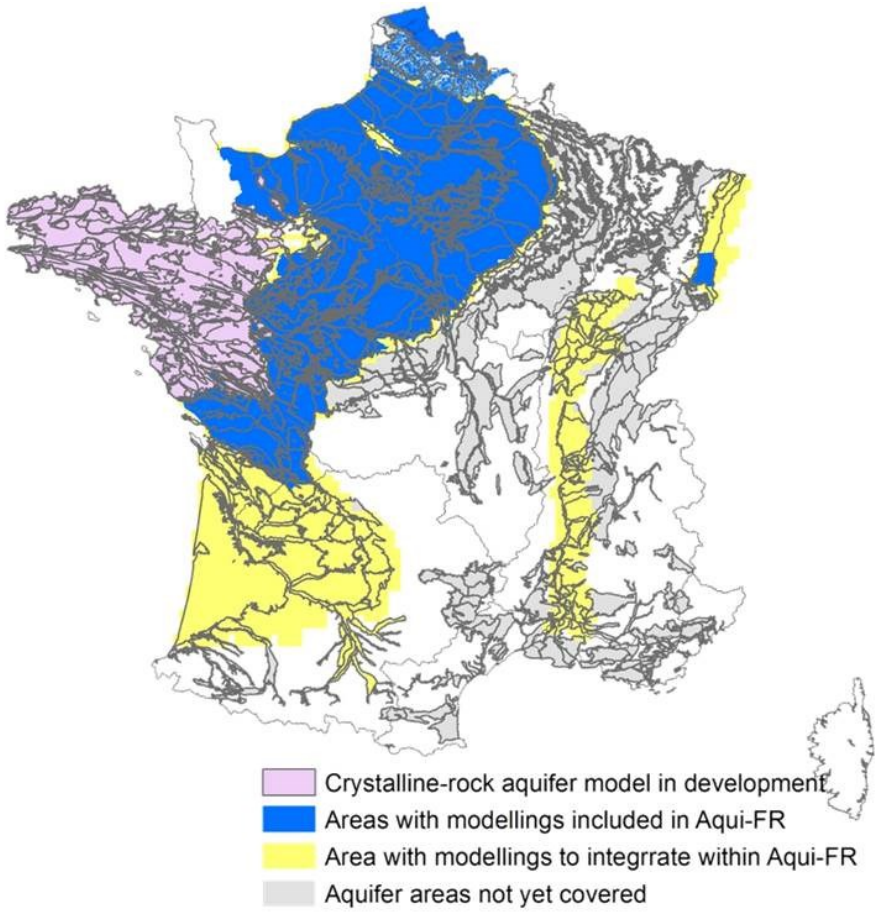


Aqui-FR : a national multi-model hydrogeologic system

- **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…)**



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