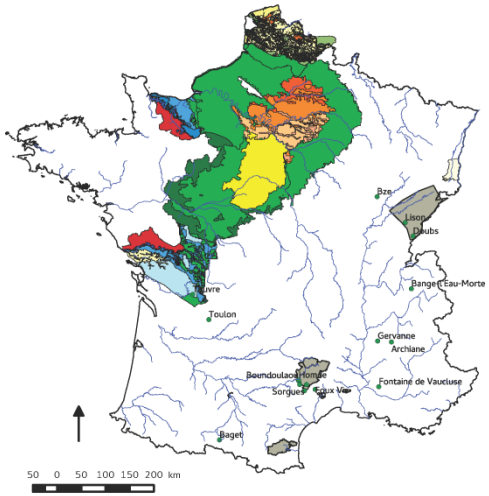
The Aqui-FR project: towards an operational forecast platform for the main regional multilayer aquifers in France.



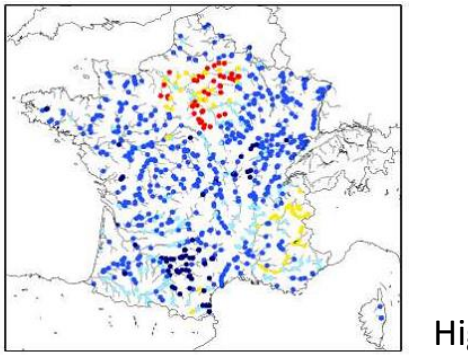
N. Roux (CNRM), F. Habets (Métis), N. Amraoui, Y. Caballero, D. Thiéry, J-P. Vergnes (BRGM), T. Morel (Cerfacs), P. Le Moigne (CNRM), J-R. De Dreuzy (Géosciences Rennes), P. Ackerer (Lhygès), F. Besson, P. Etchevers, F. Regimbeau (DCSC), N. Gallois, P. Viennot (Mines-Paristech)

CMWR 2018 - Saint Malo, 7 juin 2018

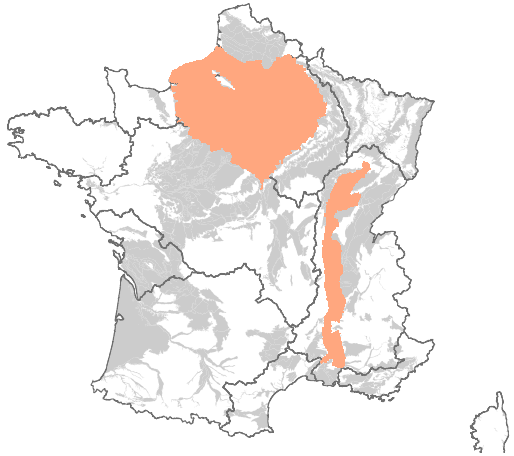
Why Aqui-FR ?

- The purpose is to have operational **hydrological** and **hydrogeological forecast** platform over France.
  - Surface water flow forecast skills are better where groundwater is represented (even with no explicit representation of water abstraction)
  - While numerous regional groundwater models are already available, they usually don’t take into account weather forecasts

Singla et al. 2012



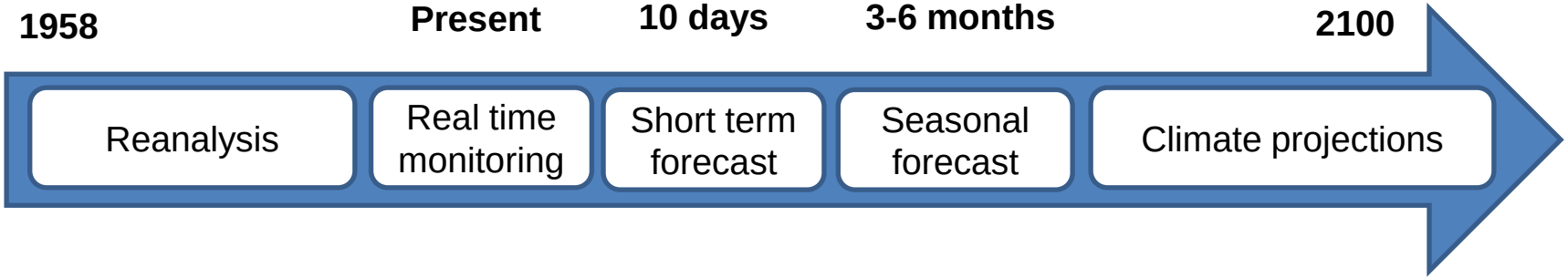
Forecast ability summer river flow 3 months ahead



The SIM hydro-meteorological system that runs operationally at Meteo France

Why Aqui-FR ?

- **Aqui-FR** thought as a **valorizing tool** of the groundwater modeling work done in France
  - Based on **existing** groundwater **modeling studies**, with a focus on well established **groundwater models** (EauDyssée from Mines-ParisTech and Marthe/Gardenia/Eros from BRGM)
  - Favor the **development** where such regional models are still lacking
- We aim at developing an **efficient** and **accurate** tool of groundwater level and surface water flow forecasts, for better **water management especially during droughts**



What is included ?

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

Marthe + **EauDyssée**
1 layer, 100m
Amraoui 2004, Korkmaz 2007

EauDyssée + **Marthe**
4 layers, 250m
Thierion, 2007,
Croiset et al., 2013

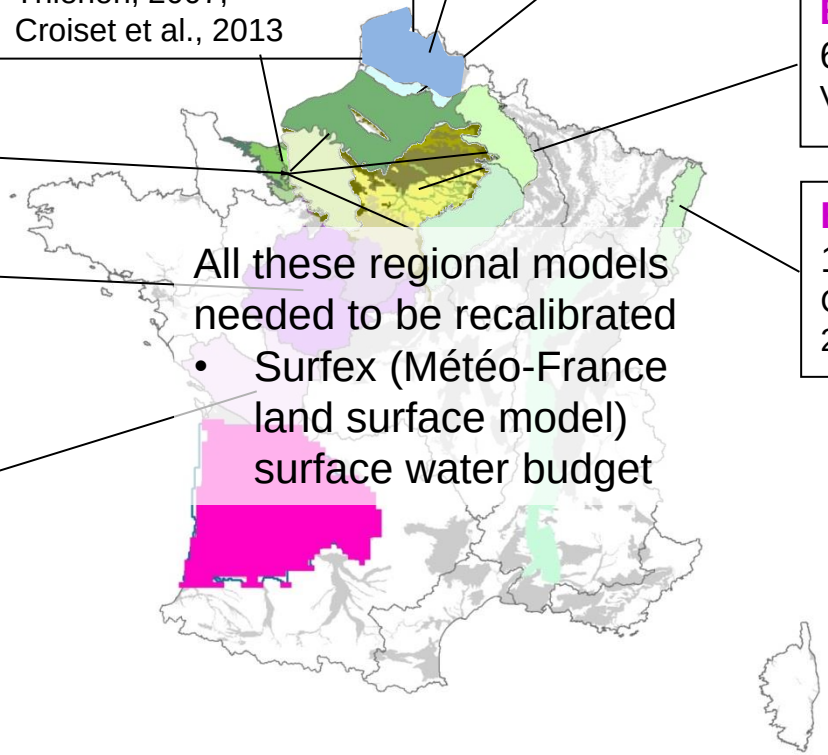
EauDyssée
1 to 4 layers, 125 m
Viennot, Abasq, 2013

EauDyssée
6 layers, 1 km
Viennot 2009

EauDyssée
3 layers, 1km
Monteil, 2011

EauDyssée + **Marthe**
1 layer,125m
Chardigny 2009, Thierrion 2011, Noyer & Elsass 2006

Marthe
8 layers, 1 km
Douez et al., 2010



All these regional models needed to be recalibrated

- Surfex (Météo-France land surface model) surface water budget

What is included ?

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

Marthe + EauDyssée
1 layer, 100m
Amraoui 2004, Korkmaz 2007

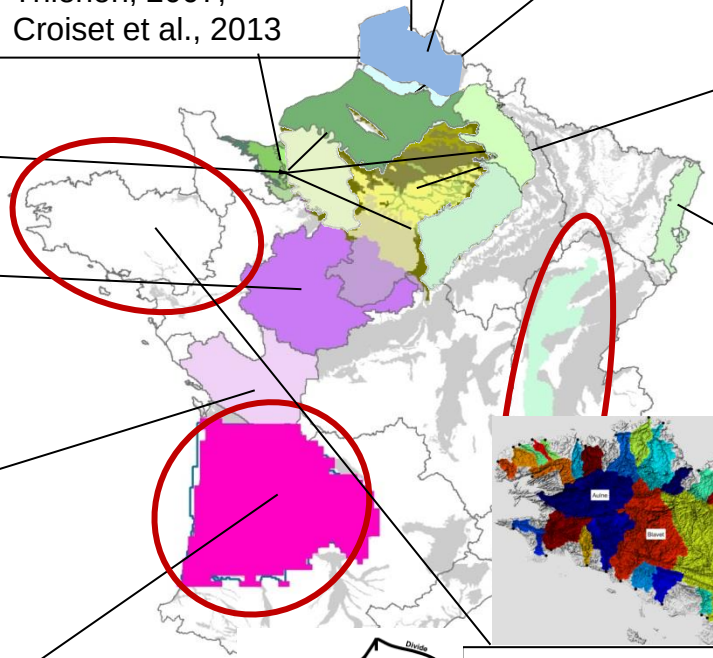
EauDyssée + Marthe
4 layers, 250m
Thierion, 2007,
Croiset et al., 2013

EauDyssée
1 to 4 layers, 125 m
Viennot, Abasq, 2013

EauDyssée
6 layers, 1 km
Viennot 2009

EauDyssée
3 layers, 1km
Monteil, 2011

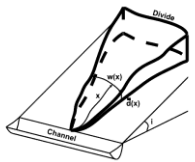
EauDyssée + Marthe
1 layer,125m
Chardigny 2009, Thierrion 2011, Noyer & Elsass 2006



Marthe
8 layers, 1 km
Douez et al., 2010

uDyssée
ayer, 1km
laz, 2000
der adaptation

Marthe
15 layers, 2 km
Pédron et al., 2005
Under adaptation

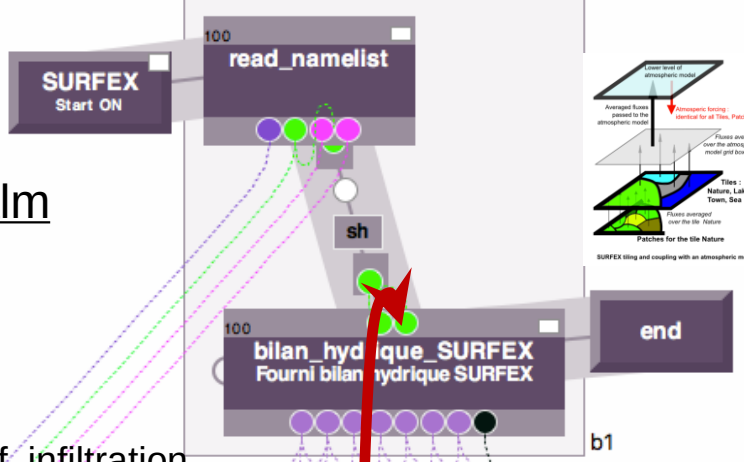


Geosciences-Rennes
Q. Courtois et al., 2019
Under development

METEO FRANCE

How does it work ?

Aqui-FR structure in the Open-Palm parallel coupler

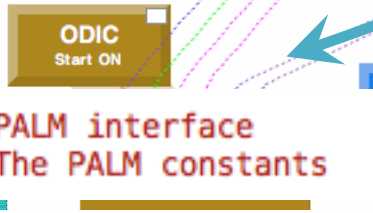


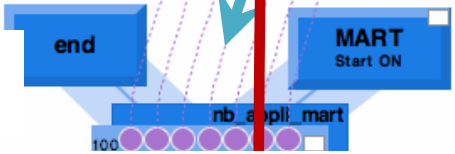
$t_n \rightarrow t_{n+1}$

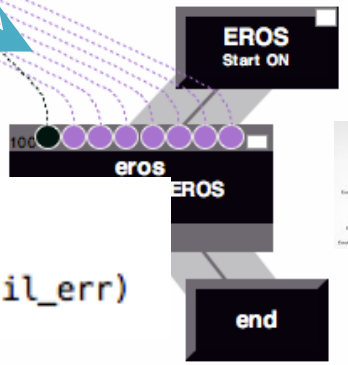
Runoff, infiltration

Atmospheric forcing/
Runoff, infiltration

Efficiently communicating through a buffer



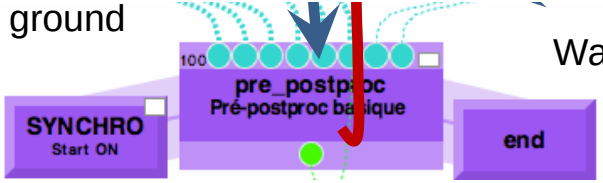





```
USE palmlib      !*I The PALM interface
USE palm_user_param !*I The PALM constants
```

```
cl_space = 'one_double'
cl_object = 'main_dt_time'
CALL PALM_PUT(cl_space, cl_object, PL_NO_TIME, PL_NO_TAG, ZMAIN_DT_TIME, il_err)
```

Water head, river ground water exchanges

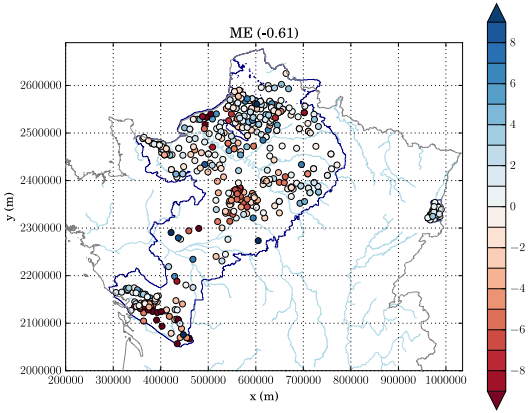


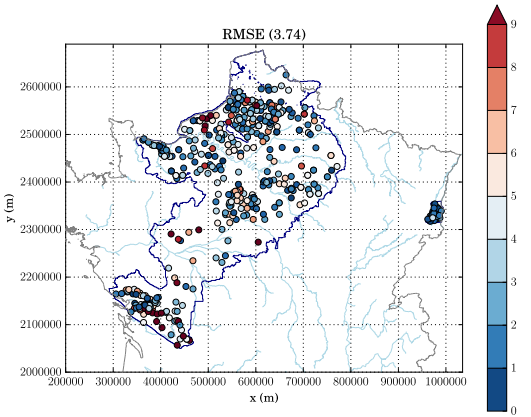
Water flow

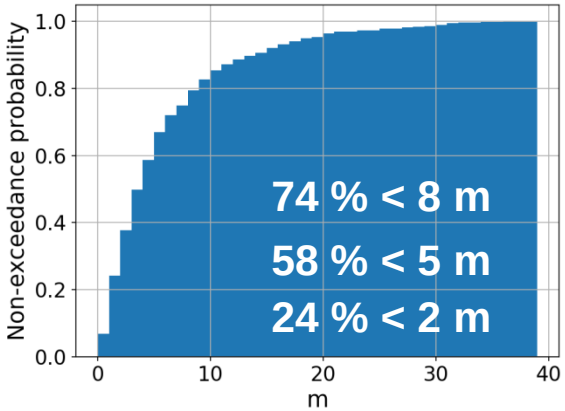
O-Palm

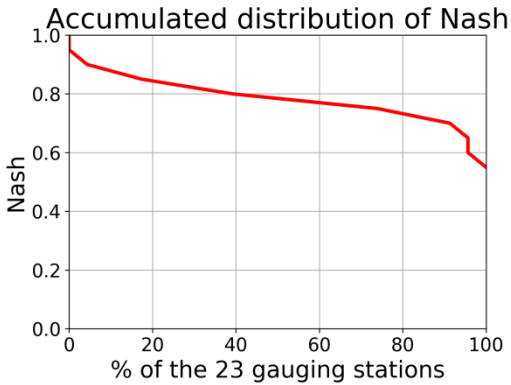
(http://www.cerfacs.fr/globc/PALM_WEB)

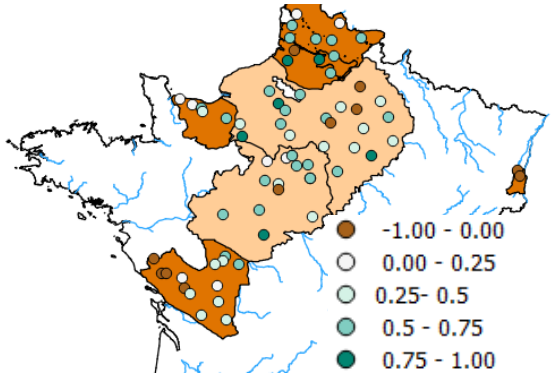
1958-2018 Reanalysis – long term evaluation









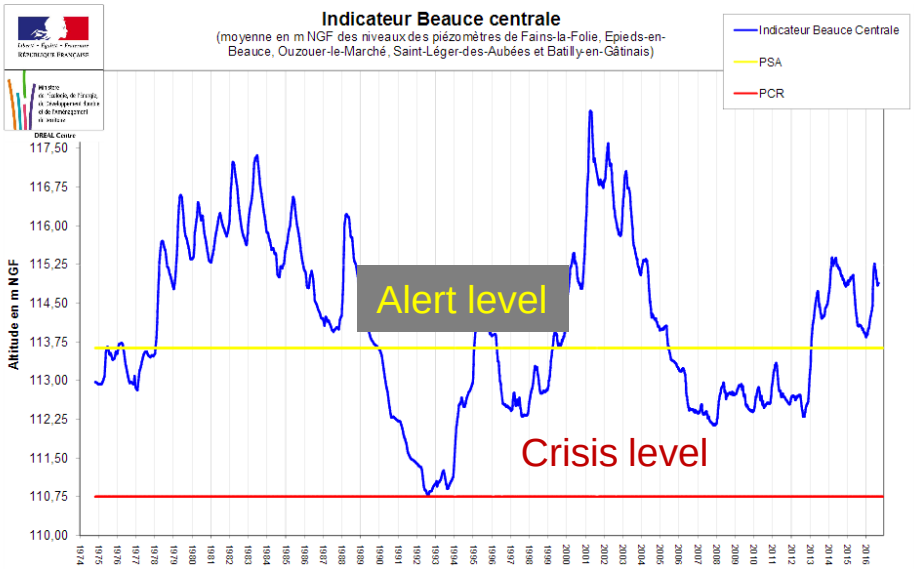


Nash Coefficient

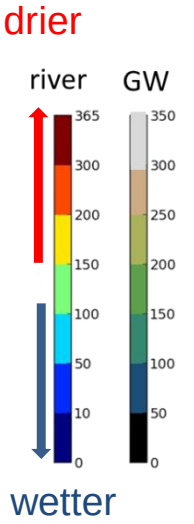
See Vergnes et al.
(CMWR 2018 and in prep.)

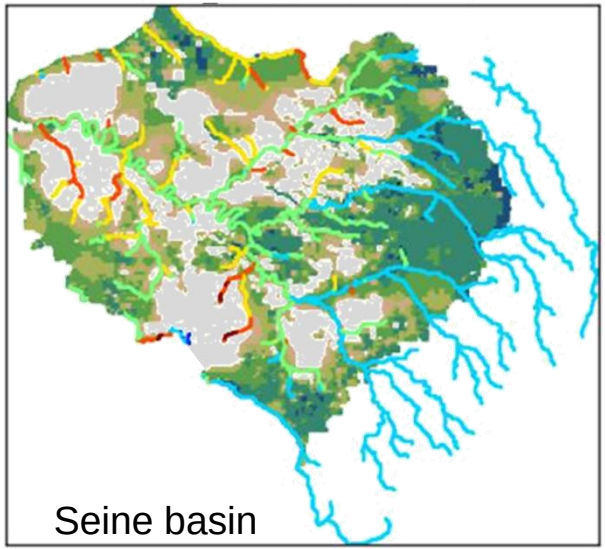
Main application – tool for decision makers

- Indicator for making the best management decisions ?
  - Based on averaged levels
  - Based on ground water and river flow anomalies



Beauce Central indicator

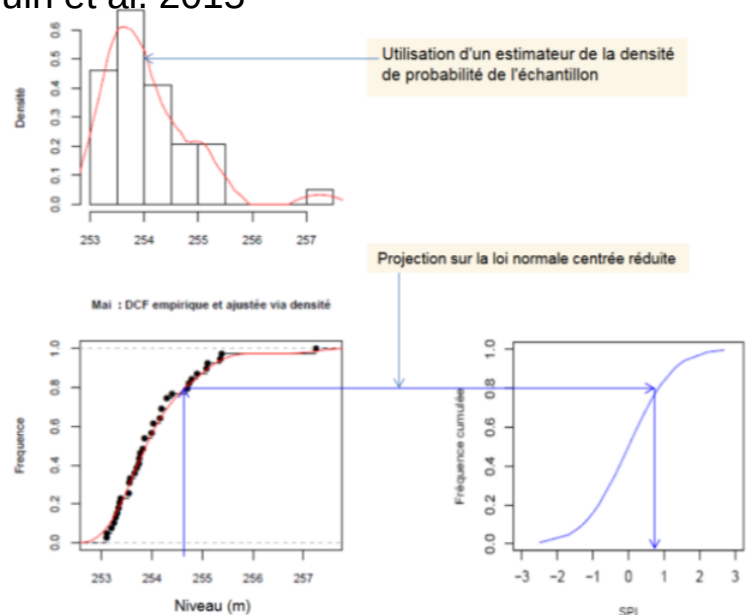


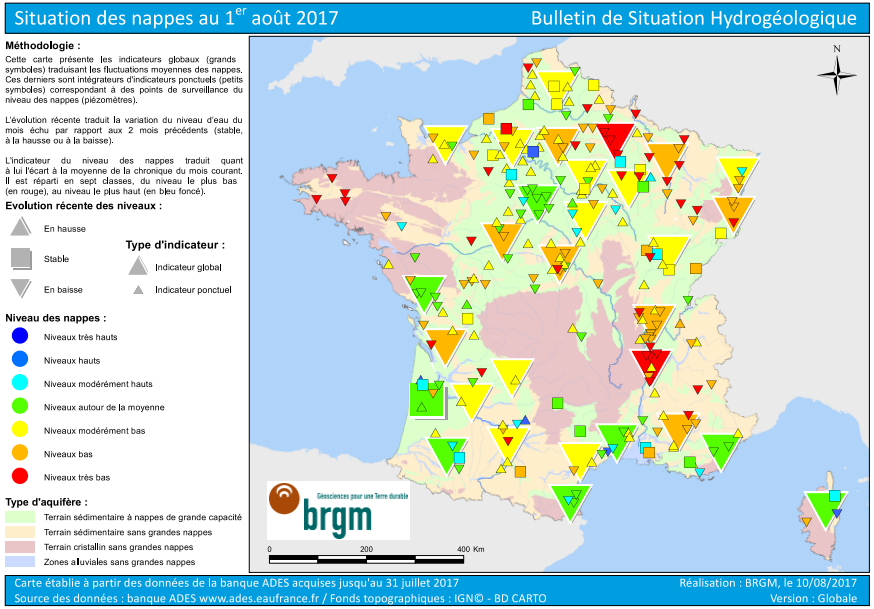


1958-2018 Reanalysis

- **Standardized Piezometric Level Index** (Similarly to the **Standardized Precipitation Index** ant the **Standardized Soil Wetness Index**)
  - More coherent comparison
  - In place since 2017 for the BRGM Hydrogeological Report (based on observed levels) – snapshot

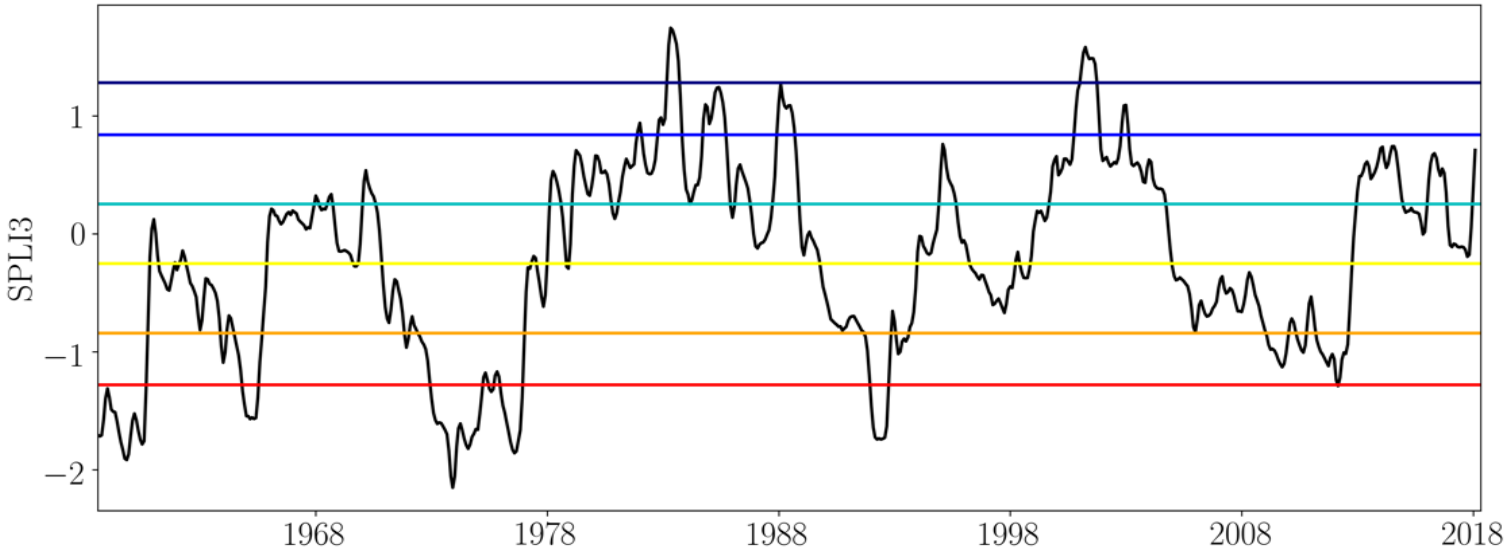
Seguin et al. 2015





1958-2018 Reanalysis

- Mean SPLI over the whole Aqui-FR domain
  - Reference period from 1981 to 2010



> 10 years wet

> 5 years wet

> 2.5 years wet

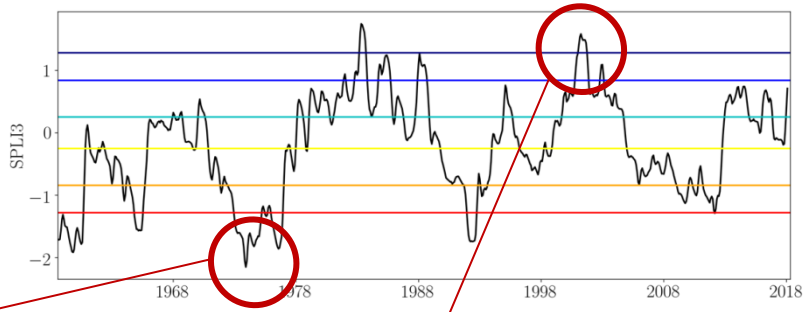
> 2.5years dry

> 5 years dry

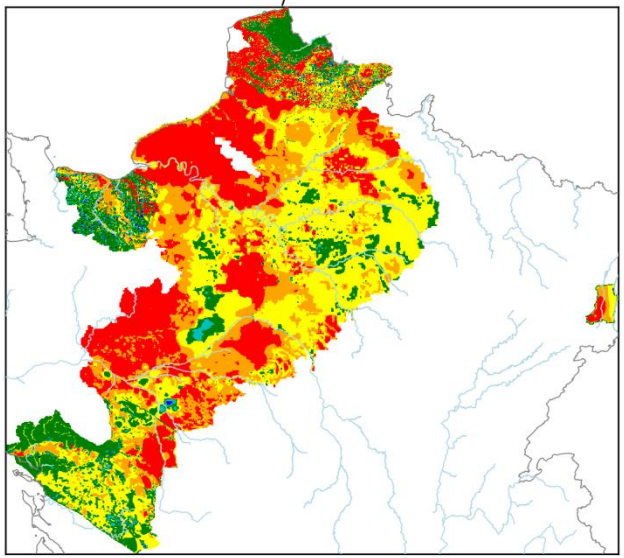
> 10 years dry

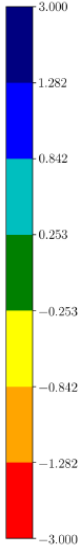
1958-2018 Reanalysis

- Mean SPLI over the whole Aqui-FR domain
  - Better interpretation of future water level in terms of return period



03/1973





> 10 years wet

> 5 years wet

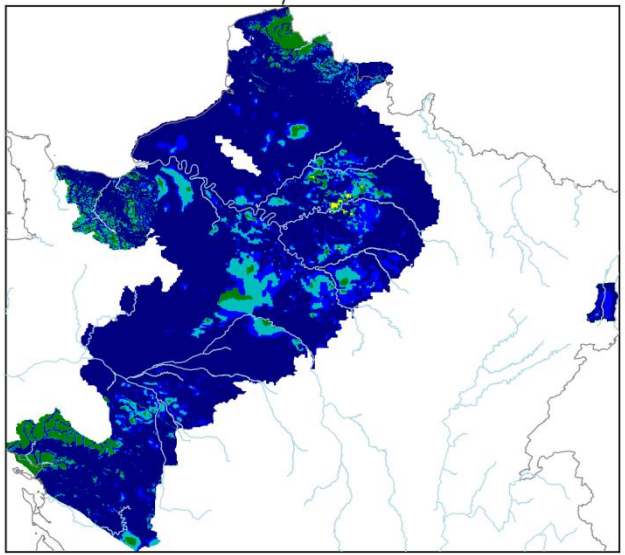
> 2.5 years wet

> 2.5years dry

> 5 years dry

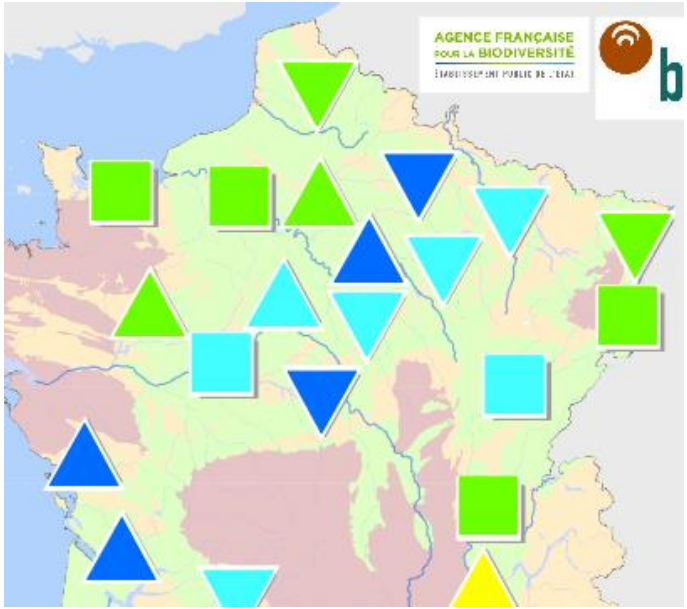
> 10 years dry

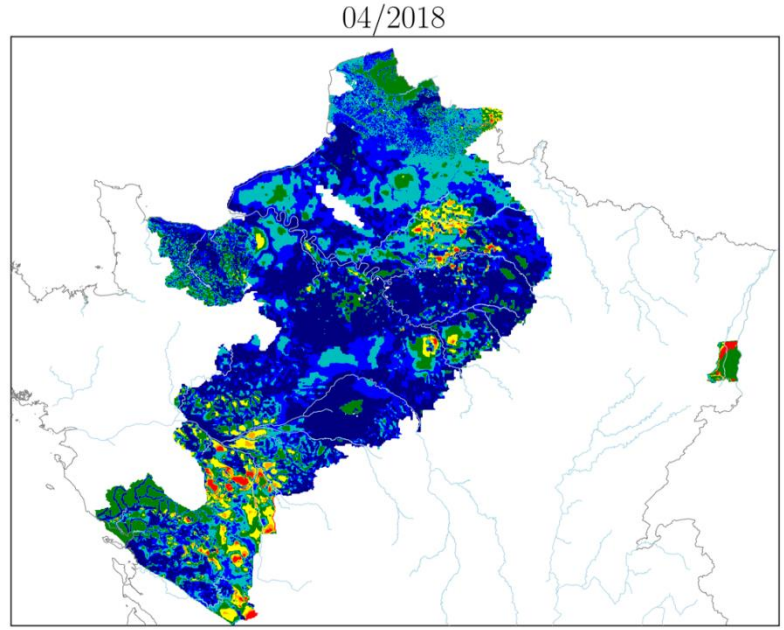
04/2001



« Real time » monitoring of SPLI

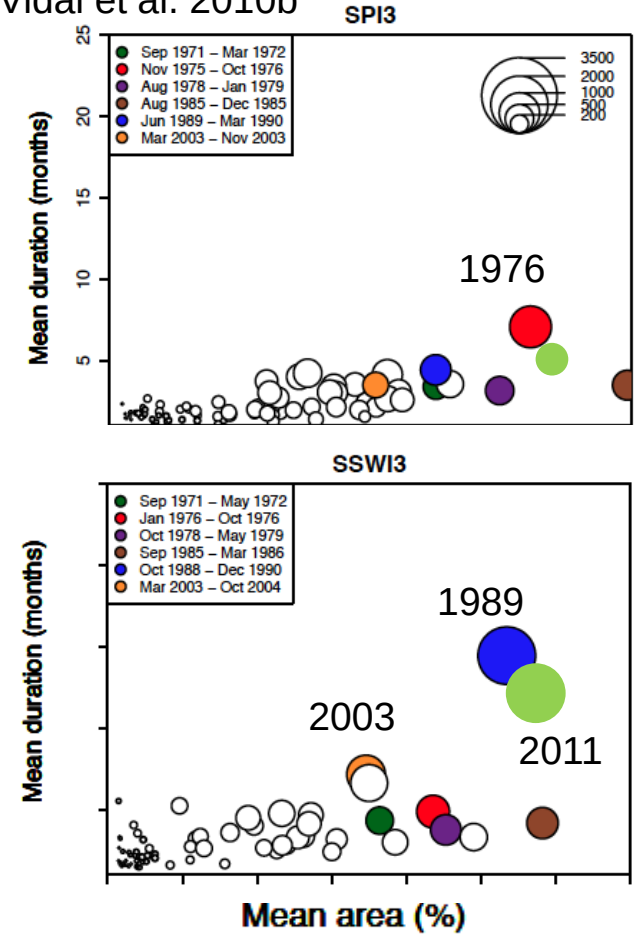
- We aim at producing such maps 3 to 6 month ahead



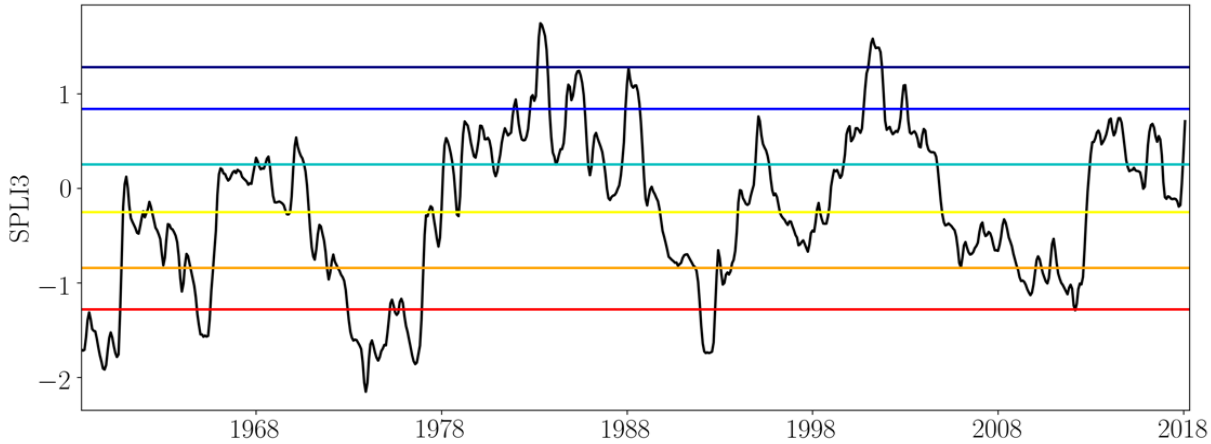


Brief comparison between surface and groundwater droughts

Vidal et al. 2010b



- Complex non linear relationships between the surface droughts and groundwater droughts

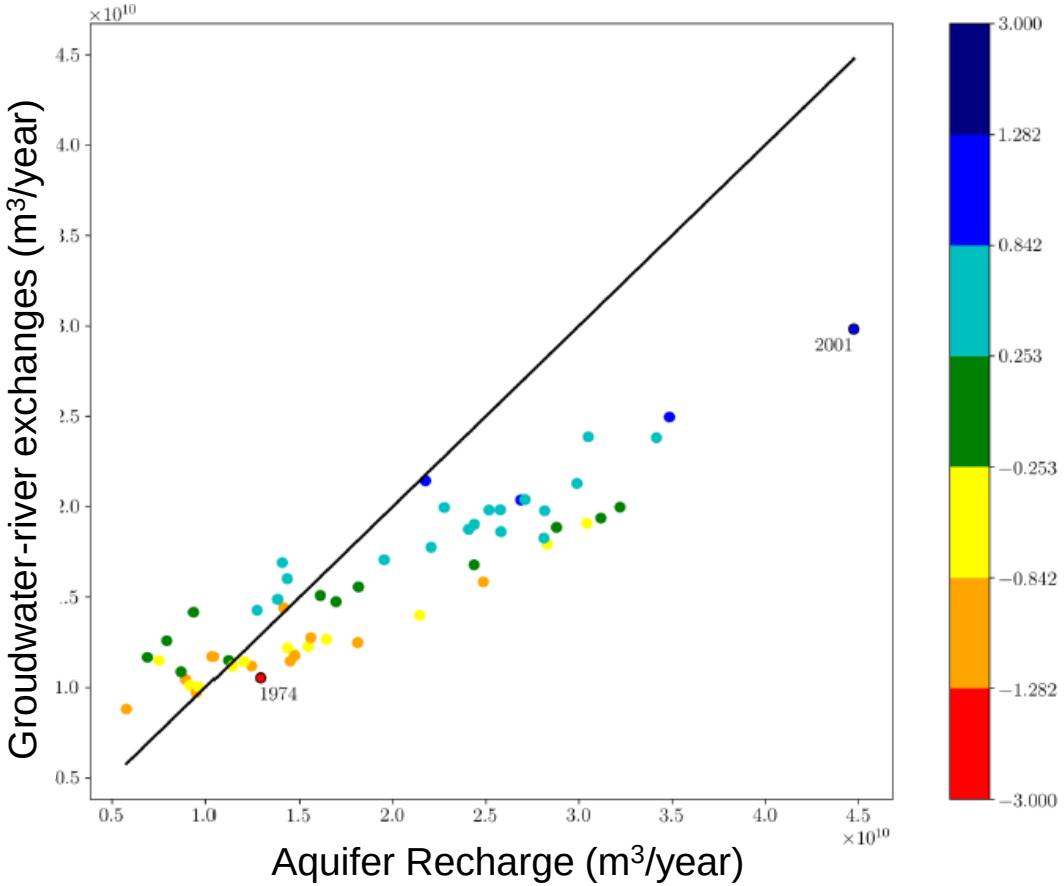


1973 **1992** **2006** **2012**

- Importance of groundwater dynamic (spatial and temporal)

METEO FRANCE

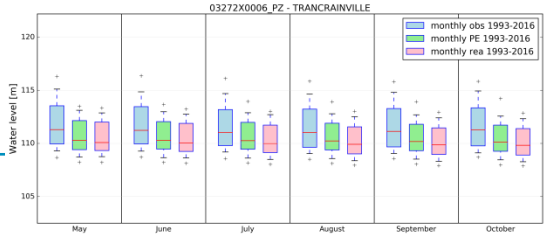
Relationship between Groundwater-river exchanges, recharge and SPLI – preliminary analysis



- For the same recharge value, there is more than 60% variation in groundwater-river exchanges
- Low SPLI related to lower groundwater-river exchanges
  - Dynamic of the aquifer
  - Importance of groundwater in supporting the river flow
  - Towards a better understanding quantification of the water available for abstraction and human use

METEO FRANCE

Ongoing and future tasks

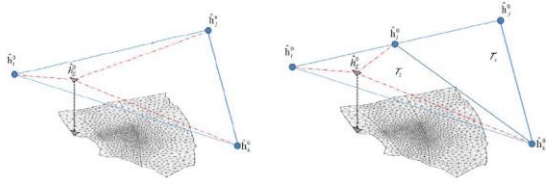


- Take into account **new aquifers** and **models**
- Run **hindcasts** in order to test Aqui-FR **forecast ability** with Arpege-S6)
  - Seasonal hindcasts (Post-Doc D. Leroux)
- Further assessment of **uncertainties**
  - Ensemble simulations (weather forecast uncertainty)
  - Sensitivity studies (anthropic activities)
  - Multi-models comparison (groundwater modelling)

Principle: reduce error between observed and simulated initial state
➔ Numerical method from LHYGES

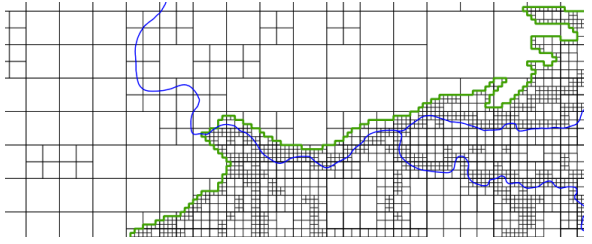
Specificities: adaptive spatial resolution with finer or coarser resolution
Objective function adapted for initial conditions

$$J(\mathbf{h}_0) = \left(\mathbf{h}-\hat{\mathbf{h}}\right)^T\left(\mathbf{h}-\hat{\mathbf{h}}\right) + \mu\left(\mathbf{h}_0-\hat{\mathbf{h}}_0\right)^T\left(\mathbf{h}_0-\hat{\mathbf{h}}_0\right)$$



1st test on well gauge site : *Maina, Delay & Ackerer, JH 2017*

- Better assessment of initial condition (**Data assimilation** and inverse methods, Master student A. Gervereau)
- **Connect the regional basins together** (especially for imposed river boundary conditions) through the use of the RHT hydrological network
- Build **output products** with end users



Thank you for you attention