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# Potentiality of hydro-meteorological ensemble forecasting of flash floods for risk assessment: Application to the Agly catchment (Eastern Pyrenees)

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<sup>1</sup>IMFT - Université de Toulouse, CNRS-INPT-UPS, Toulouse, France

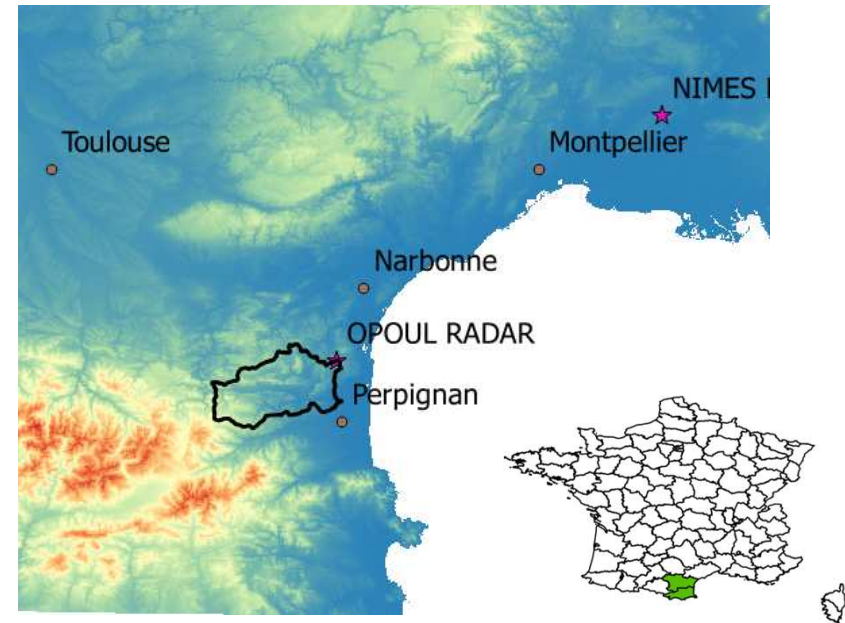
<sup>2</sup>Grup de Meteorologia, Dept. De Física, Universitat de les Illes Balears



Euroregió Pirineus Mediterrània  
Eurorégion Pyrénées-Méditerranée  
Euroregión Pirineos Mediterráneo

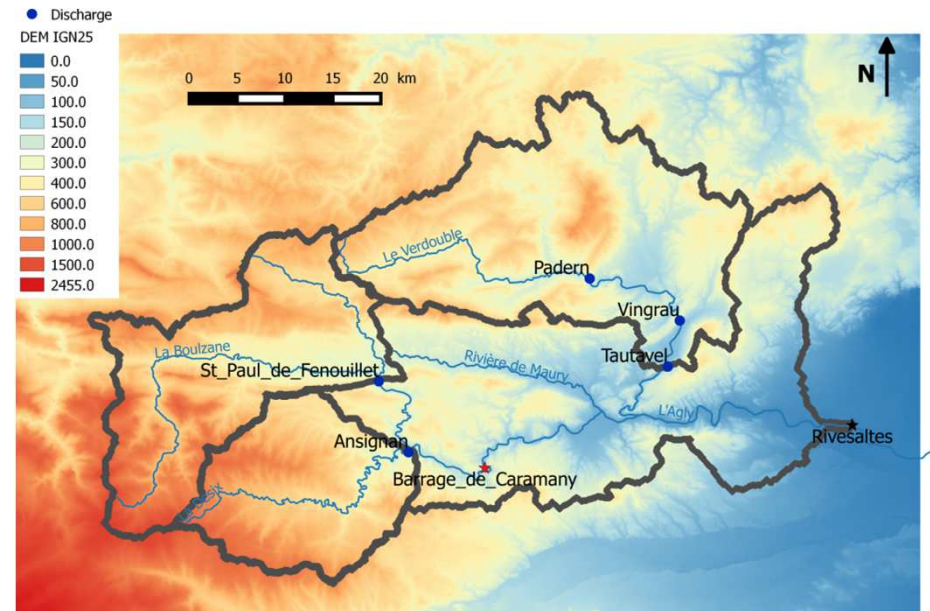
# Study site: Agly catchment

- Whole catchment
  - 1050 km<sup>2</sup>
  - Mainly natural area (45% forests, 30% Mediterranean scrub)
  - Karstic region
  - Dam: around 50Mm<sup>3</sup> for flood control and water management



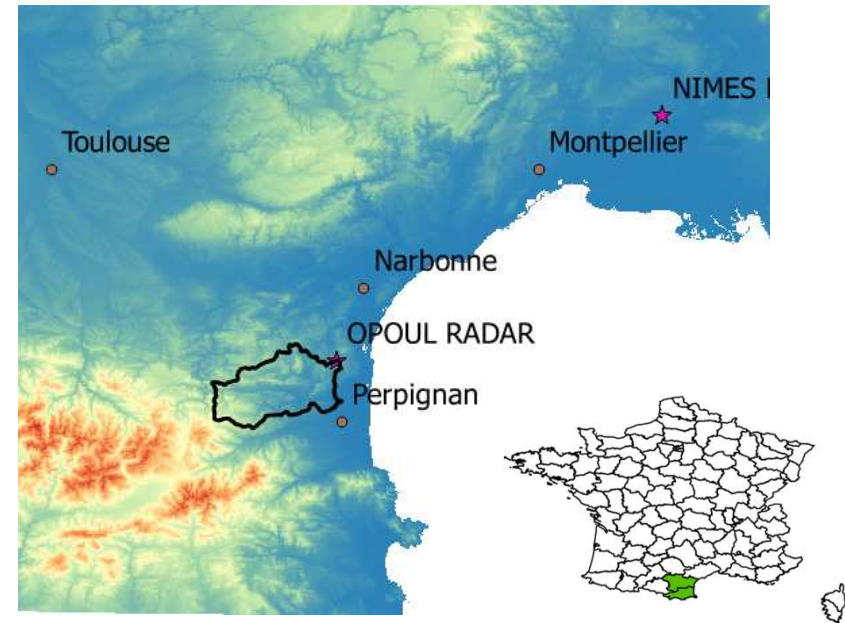
- Upstream the dam
  - 408 km<sup>2</sup>
  - Climate: Oceanic (North-West) and mountain (South-West) influences

- North-eastern part
  - Verdoble catchment: 330 km<sup>2</sup>
  - Climate: Mediterranean



# Study site: Agly catchment

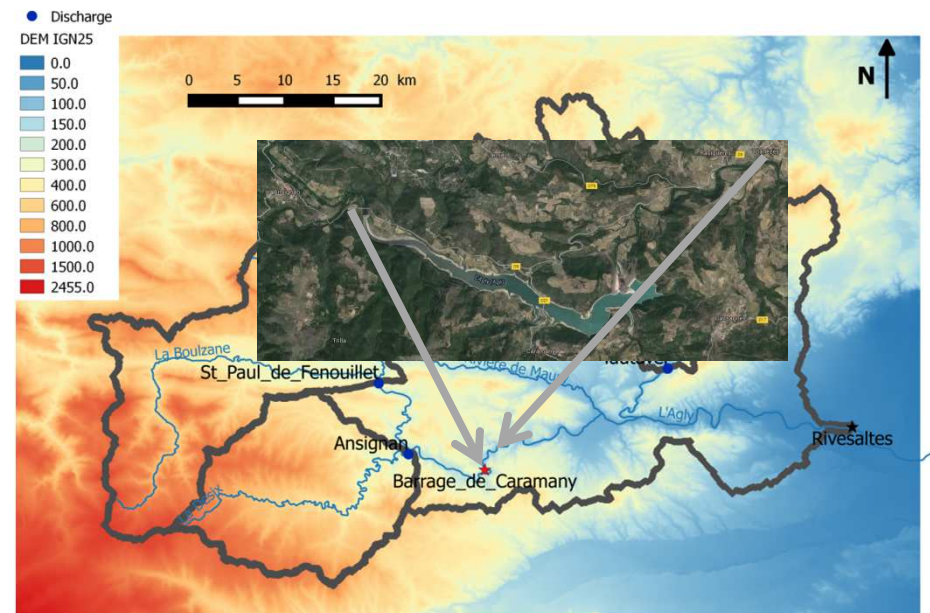
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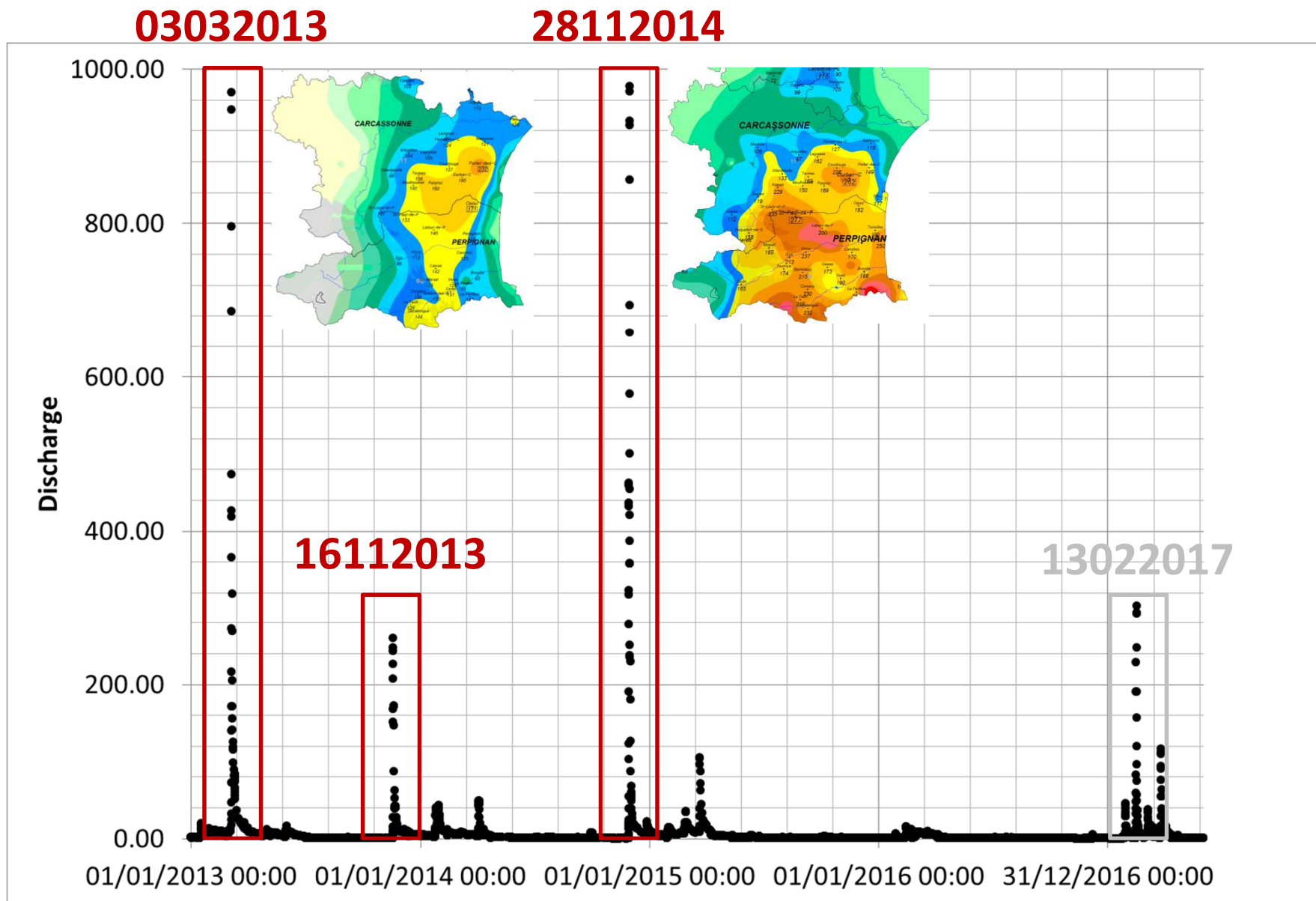
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# Recent floods at Rivesaltes (outlet)

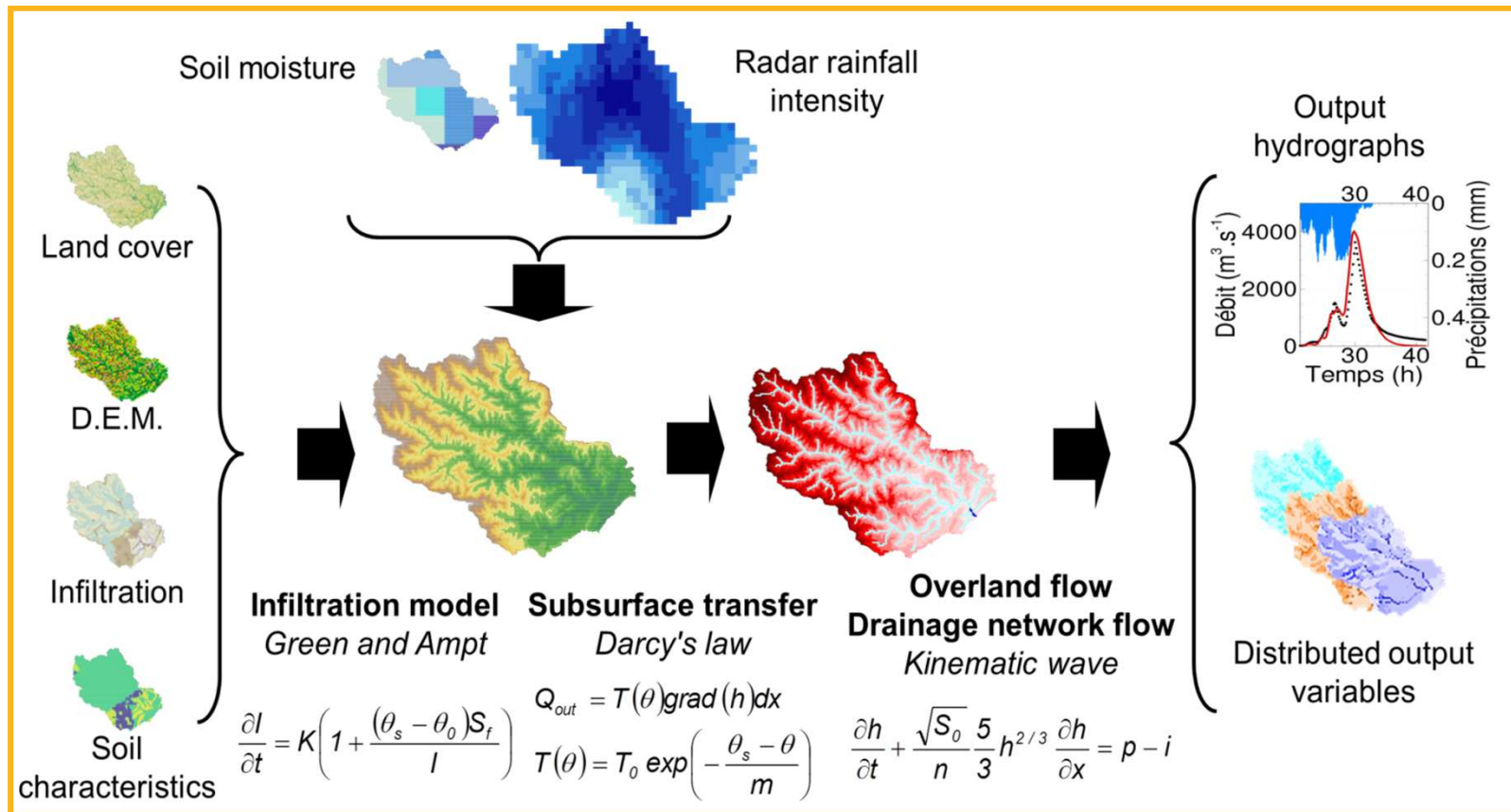


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Source : METEO-FRANCE, edited on 04/06/2016 (<http://pluiesextremes.meteo.fr>)

# Hydrological modelling tool: MARINE model

- Process-oriented, fully distributed and dedicated to flash floods



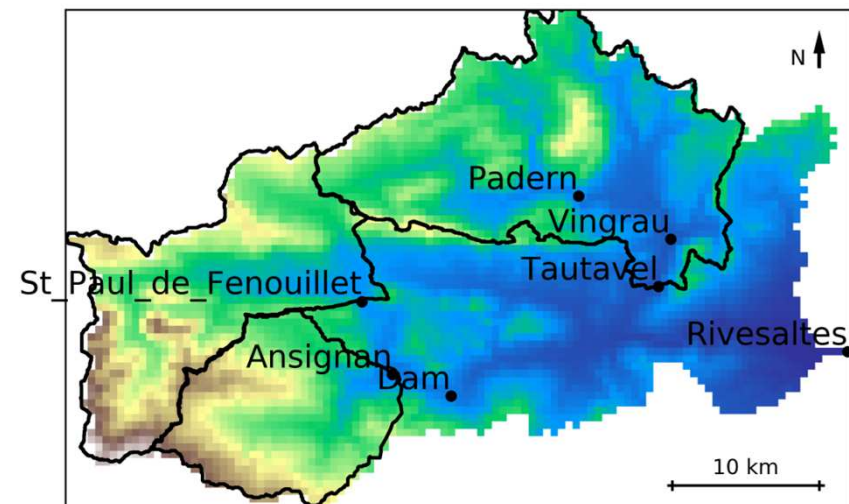
Roux, H., Labat, D., Garambois, P.-A., Mauborguet, M.-M., Chorda, J. and Dartus, D., 2011. A physically-based parsimonious hydrological model for flash floods in Mediterranean catchments. Nat. Hazards Earth Syst. Sci. J1 - NHESS, 11(9), 2567-2582.

# Calibration parameters and Strategy

- Calibration at St Paul de Fenouillet following Garambois et al. (2015)
  - 20130304\_JP1 : NASH=0.34
  - 20141128\_JP1 : NASH=0.65
- Evaluation overview (5 stations)

$$NASH = 1 - \frac{\sum_{t=1}^n (Q_t^o - Q_t^s)^2}{\sum_{t=1}^n (Q_t^o - \bar{Q}^o)^2}$$

Event_forcing	NASH Cal	NASH Val
19920926_PLU	-	0.93
20090411_PLU	-	0.26
20110304_PLU	-	0.77
20130304_JP1	0.68	-
20130304_PLU	-	0.65
20131116_JP1	-	<0.
20131116_PLU	-	<0.
20141128_JP1	0.68	-
20141128_PLU	-	0.24



# Meteorological modelling tool: WRF model

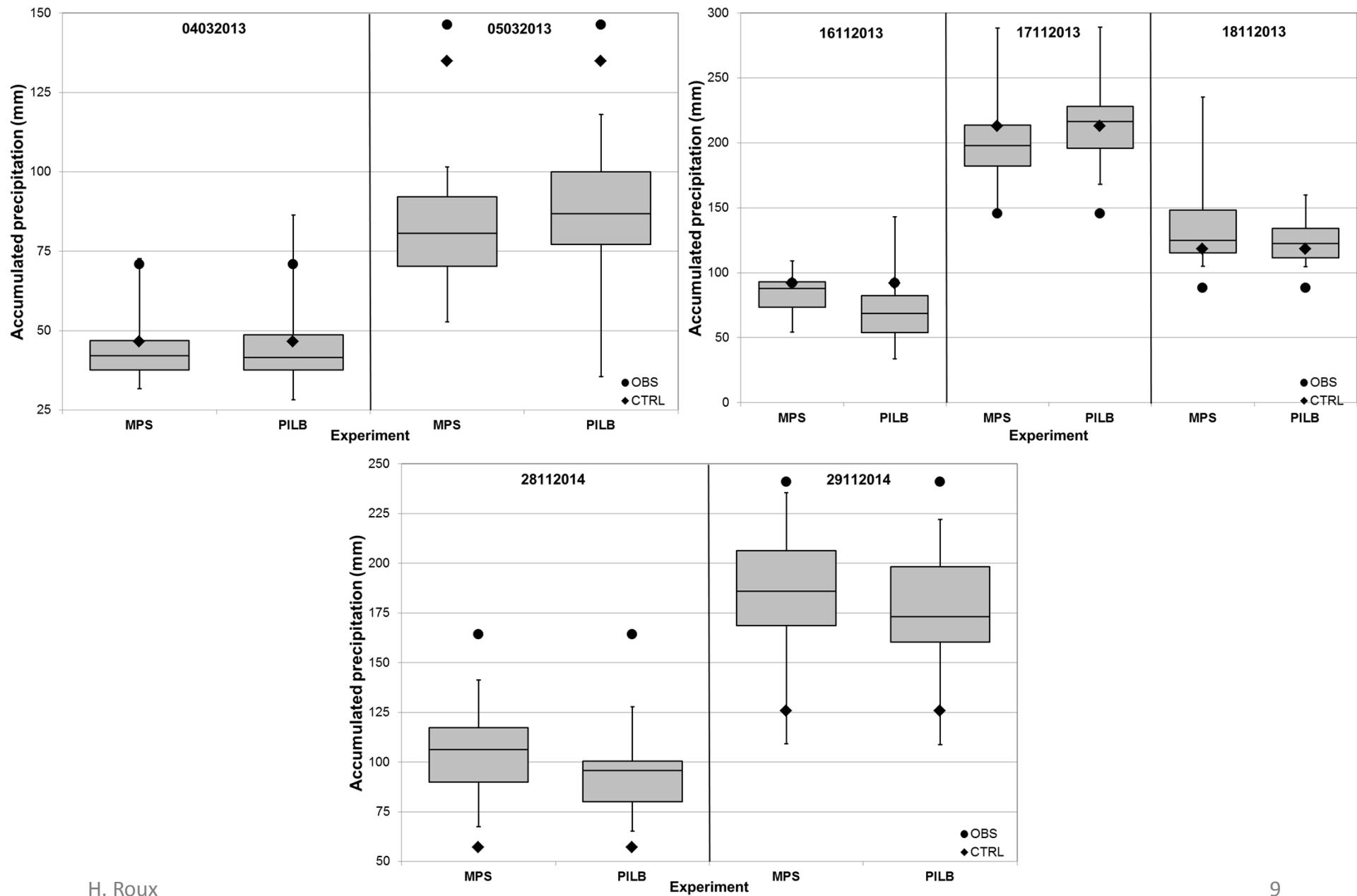
- Unperturbed experiment
  - Single domain at 2.5 km and 50 vertical eta-levels: deep moist convection explicitly resolved
  - Schemes: Microphysics: WSM6; Boundary Layer: MYJ; Long-wave radiation: RRTM ; Short wave radiation: Dudhia; surface model: NOAH; time-step: 12 s (<http://meteo.uib.es/wrf>)
  - The experiments consider 48-h period simulation, encompassing initialization and mature evolution of convective systems
  - Initial and lateral boundary conditions: unperturbed member of the ECMWF-EPS (update 3-h, 0.2°; 62 vertical levels)



# Ensemble Prediction Systems

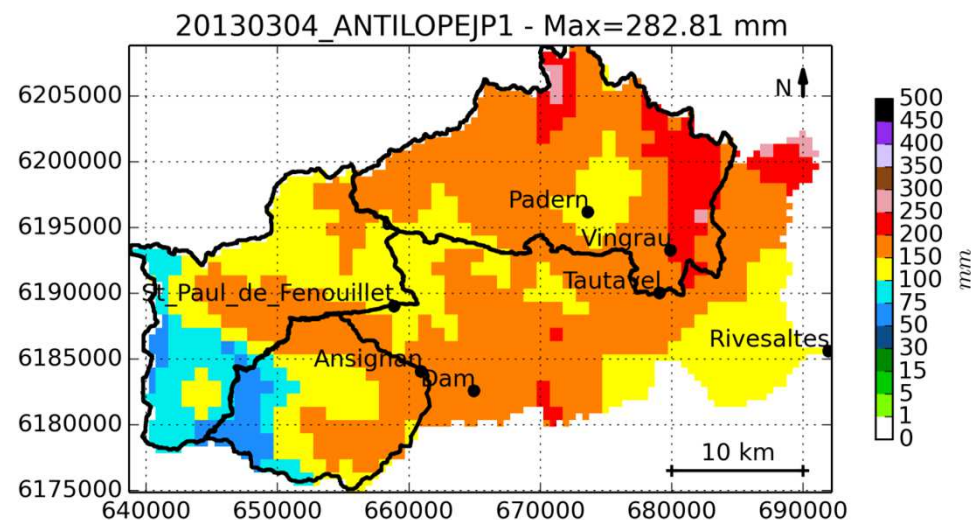
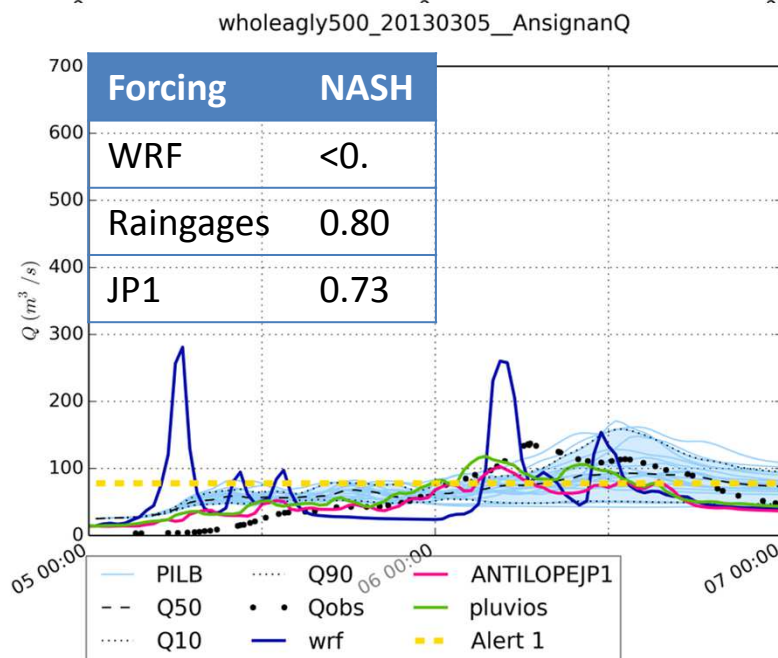
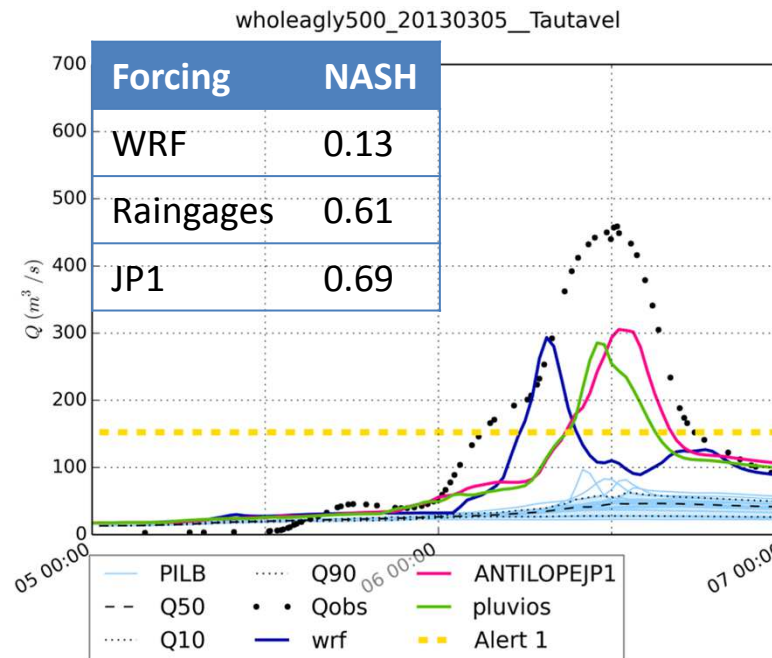
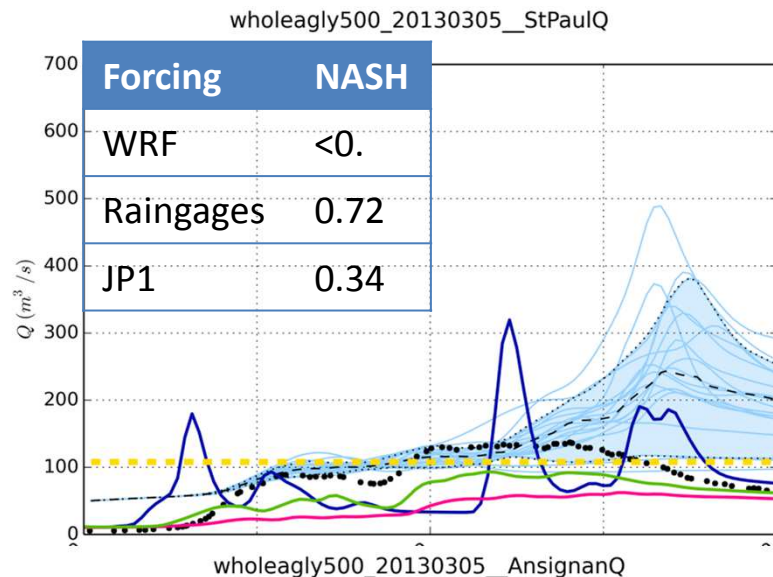
- Accurate numerical prediction of deep moist convection is challenging
  - Misrepresentations of the atmospheric state in nonlinear systems
  - Imperfect representation of convection, PBL, land physics and moist microphysical processes
- Errors can grow fast during the forecast for mesoscale convective developments
- Short-range EPSs aim at forecasting the probability of weather extremes as accurately as possible
  - PILB experiments: Encompass uncertainties in the atmospheric state
  - MPS experiments: Encompass uncertainties in physical parameterizations

# Verification of weather predictions

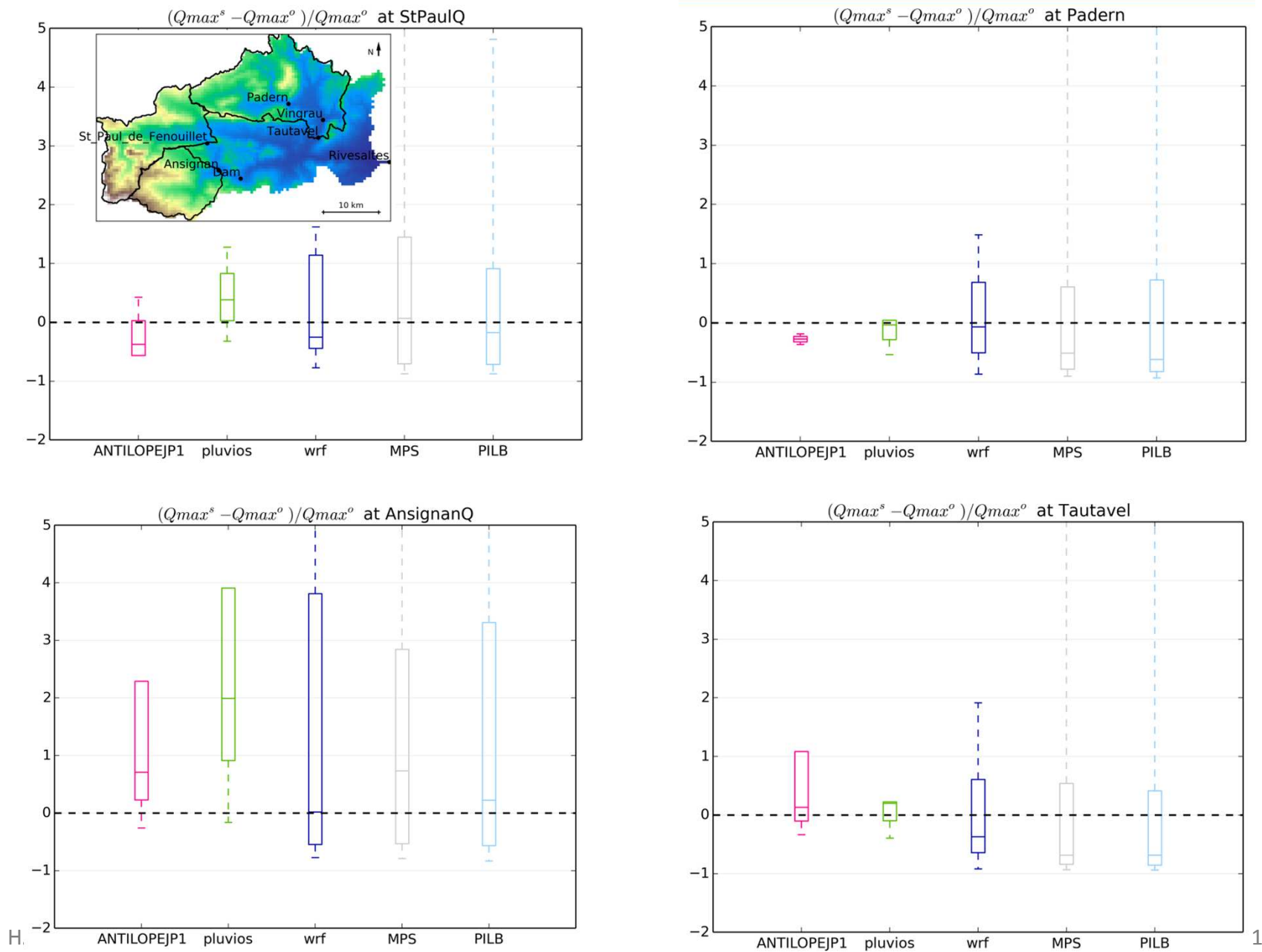


# Local performances of the hydro-meteo predictions

- Spatial distributions



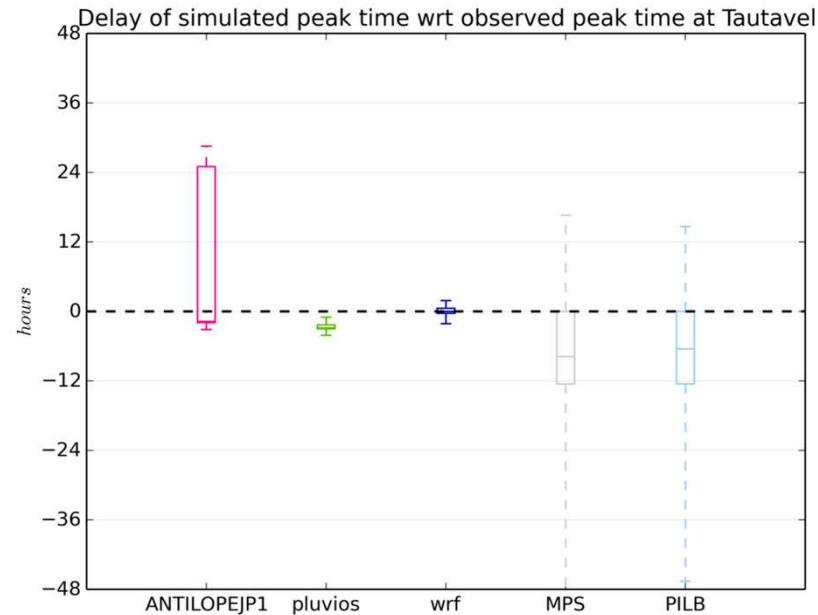
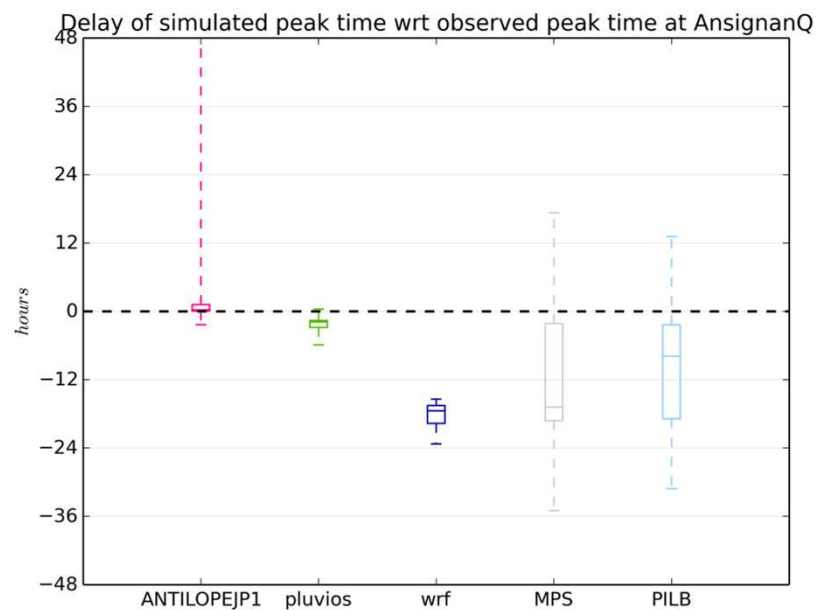
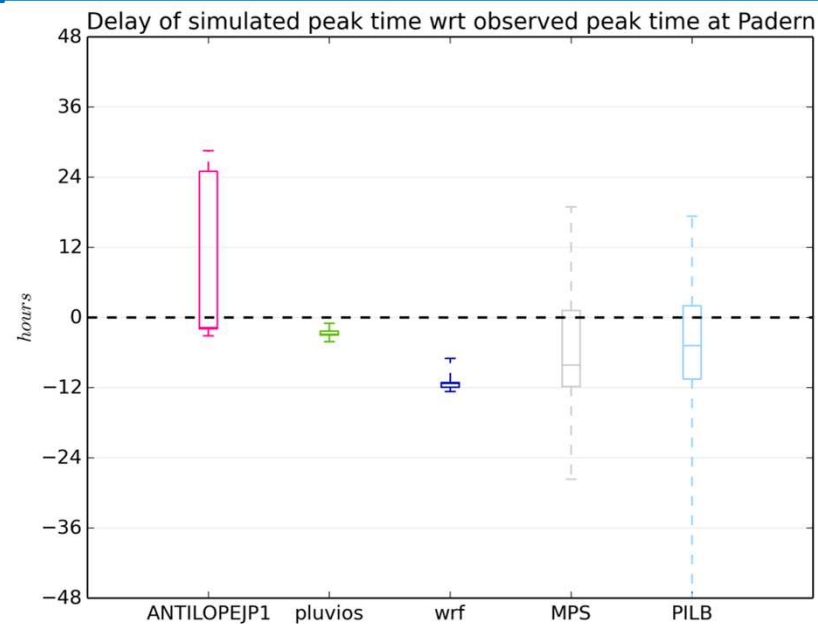
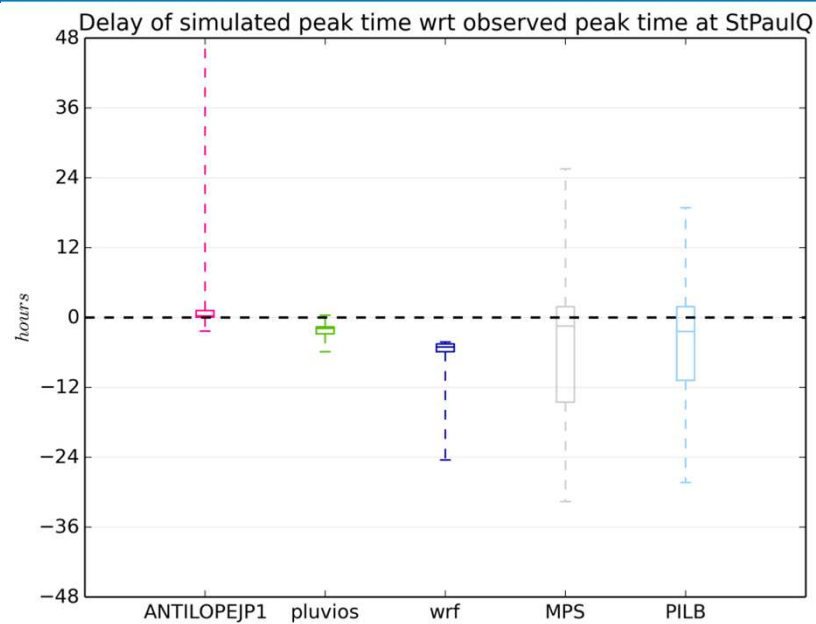
# Relative error on peak discharge



H.

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# Error on peak time



# Global performances of the hydro-meteo predictions

- Forecast Verification Metrics: 2-category evaluation

Forecast	Observed	
	Yes	No
Yes	Hits	False alarms
No	Misses	Correct rejections

- **Critical Success Index (CSI)** or Threat Score [0; 1]

➤ Fraction of events that were correctly predicted → kind of accuracy

$$CSI = \frac{Hits}{Hits + Misses + False\ alarms}$$

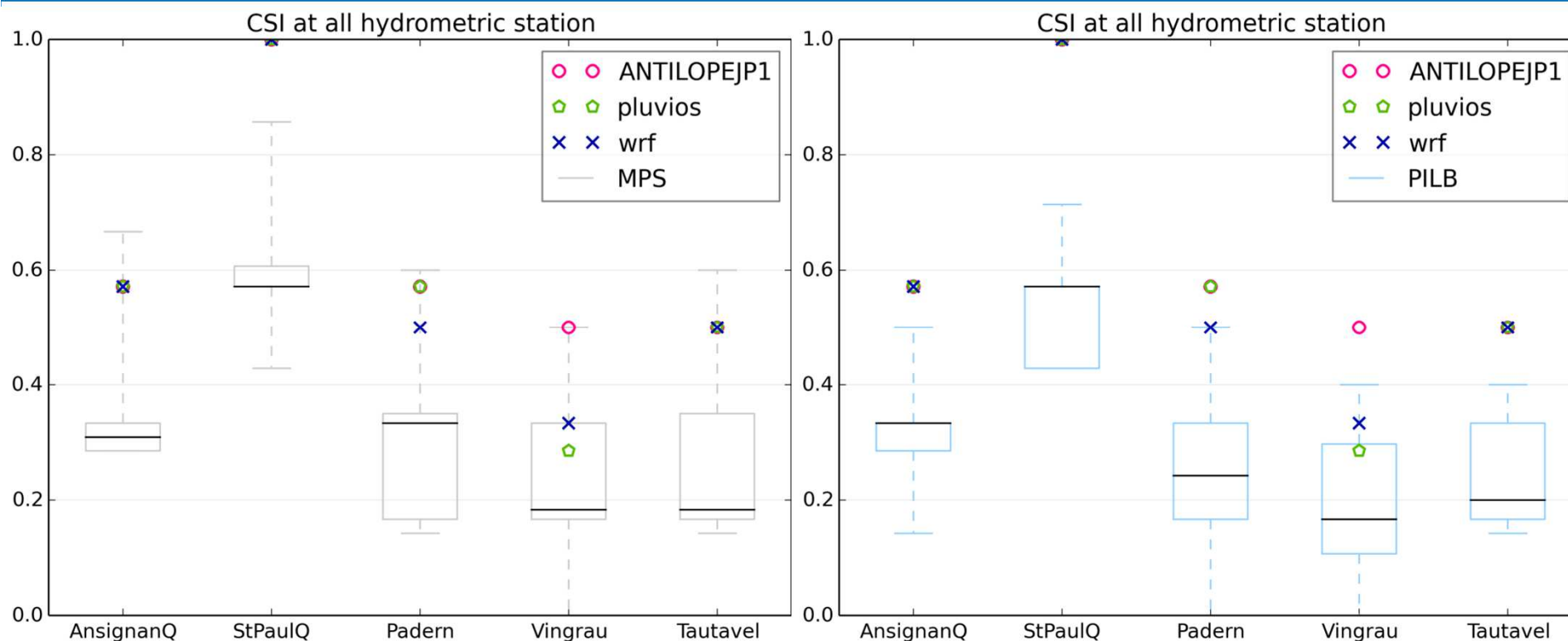
- **Bias** [0; +∞]

➤ ratio of the number of times an event was forecast to the number of times an event was observed

➤ Bias < 1 → underforecast, Bias > 1 → overforecast

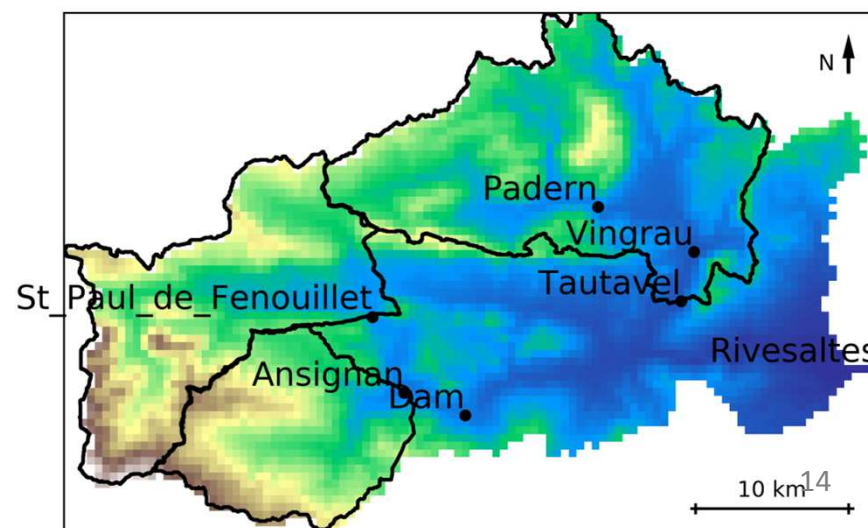
$$BIAS = \frac{Hits + False\ alarms}{Hits + Misses}$$

# Critical Success Index: 2-year return period

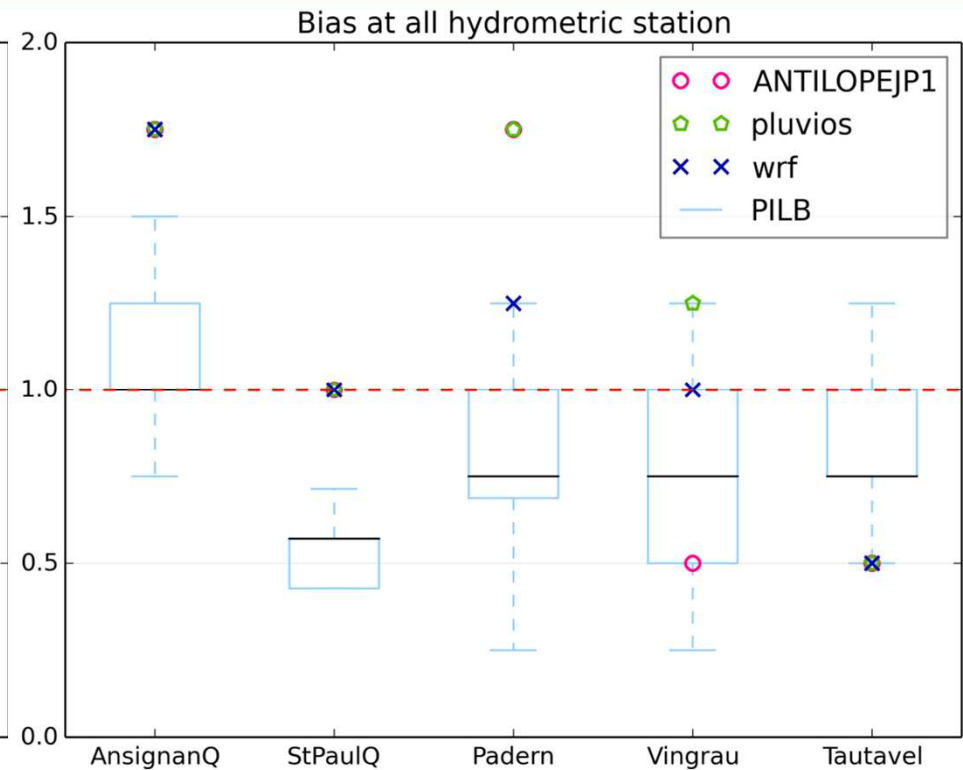
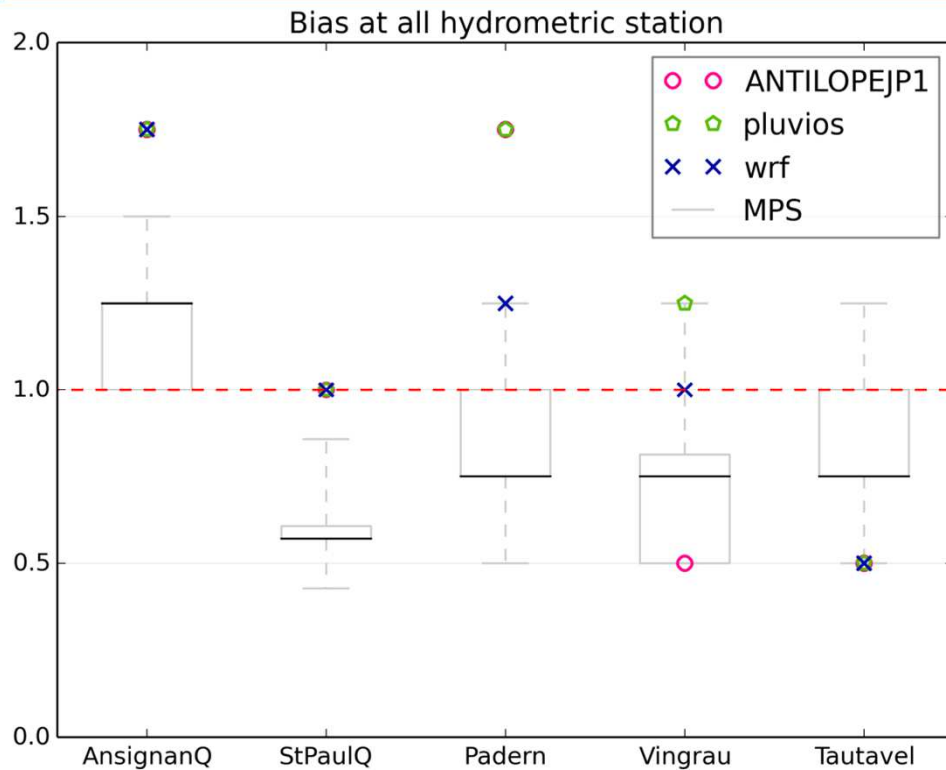


- Western part and downstream eastern part: same CSI for observed and deterministic forcing
- Upstream eastern part: distinct behaviors

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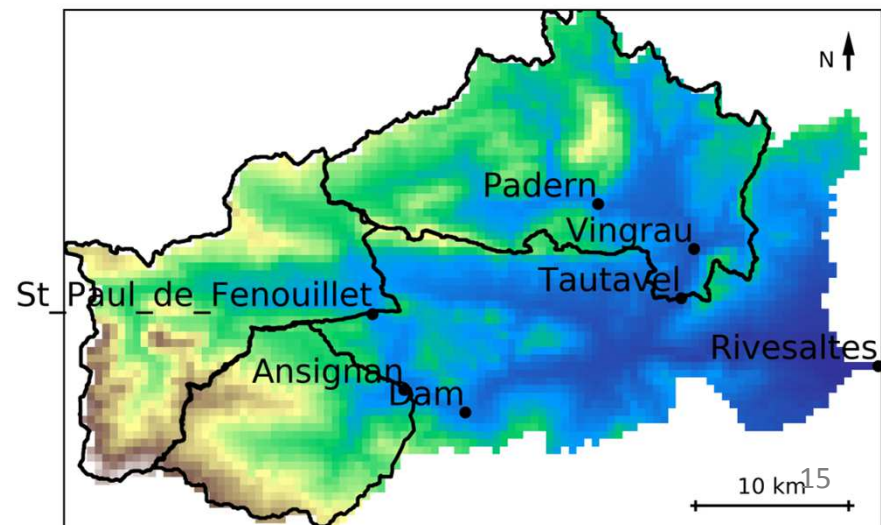


# Bias: 2-year return period



- Ensemble: tendency to underestimate, excepted at Ansignan
- Obs, ctrl: tendency to overestimate, excepted for the eastern part

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# Conclusions and future work

- Main results
  - Correct for alarm detection
  - Difficulty to reproduce the spatial variability of the catchment behavior
  - No substantial differences between the 2 ensemble strategies
- Future strategies
  - To improve the hydrological modelling
    - Calibration station
    - Error criterion
  - To improve the quantification of uncertainty
    - Hydrological model ensemble
  - To improve the forecast quality
    - Data assimilation

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## Cited references

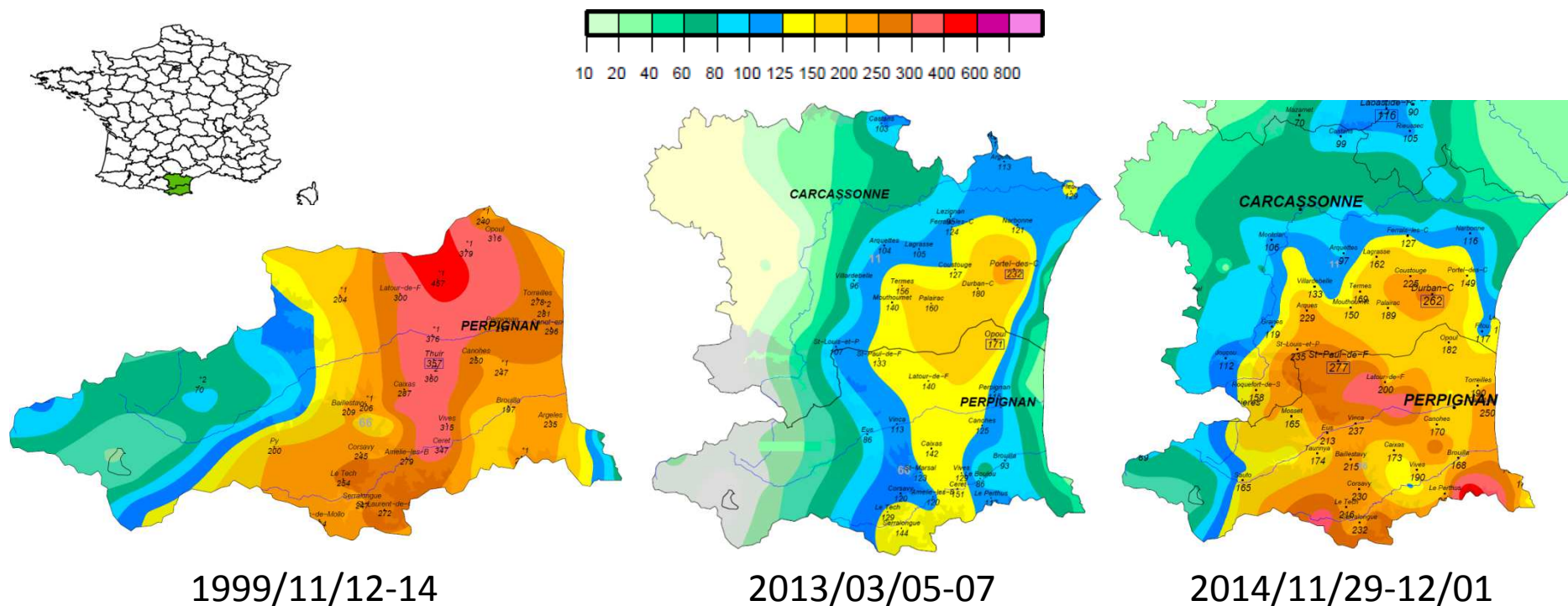
- Garambois, P.-A., Roux, H., Larnier, K., Labat, D. and Dartus, D., 2015. Characterization of catchment behaviour and rainfall selection for flash flood dedicated hydrologic model regionalization: catchments of the eastern Pyrenees. *Hydrological Sciences Journal*. 60(3), 424-447.
- Laurantin, O., 2008. ANTILOPE: hourly rainfall analysis merging radar and raingauges data. *Proceedings of Weather Radar and Hydrology Conference 2008, Grenoble*.
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# Content

- Motivations and aims
- Study site: The Agly catchment
- Modelling tools and implementation: hydrology and meteorology
- Results
- Conclusions and future work

# Motivations and aims

- HyMeX science objective: improve the understanding of the hydrological cycle, with emphasis on extreme events to better predict them
- → Evaluate the predictive skill of deterministic simulations and ensemble strategies for short-range flash-flood forecasting



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Source : METEO-FRANCE, edited on 04/06/2016 (<http://pluiesextremes.meteo.fr>)

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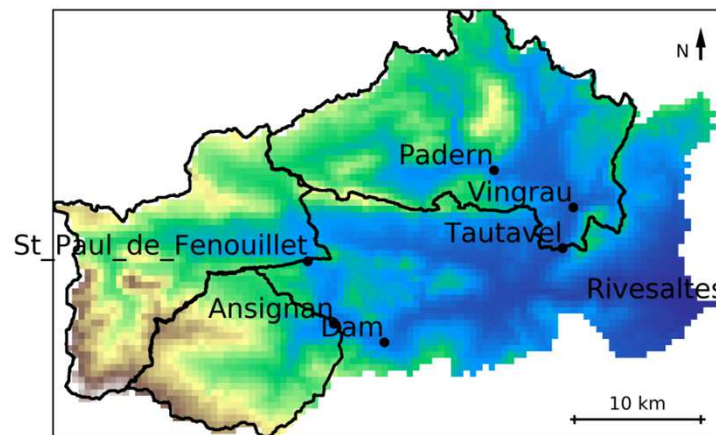
# Calibration parameters and Strategy

Parameter		Value
Main channel roughness	$K_{min}$	30
Overbanks roughness	$K_{maj}$	20
Soil depth correction	$C_Z$	5.0
Hydraulic conductivity correction	$C_K$	1.9
Lateral transmissivity correction	$C_T$	10000

Hydrograph shape  
and peak time

Flood volume and  
peak magnitude

- Following the methodology of Garambois et al. (2015)
- 2 events (20130304 and 20141128) with ANTILOPEJP1 forcing (Laurantin, 2008)
- 1 hydrometric station (St Paul de Fenouillet)



# Ensemble Prediction Systems

- **PILB experiments:**

Initial and boundary conditions: 20 ECMWF–EPS members exhibiting maximum perturbations over the WRF domain (update 3-h, 0.2°; 62 vertical levels)

Perturbations are derived from flow-dependent singular vectors technique

All PILB ensemble members use the operational set of physical parameterizations

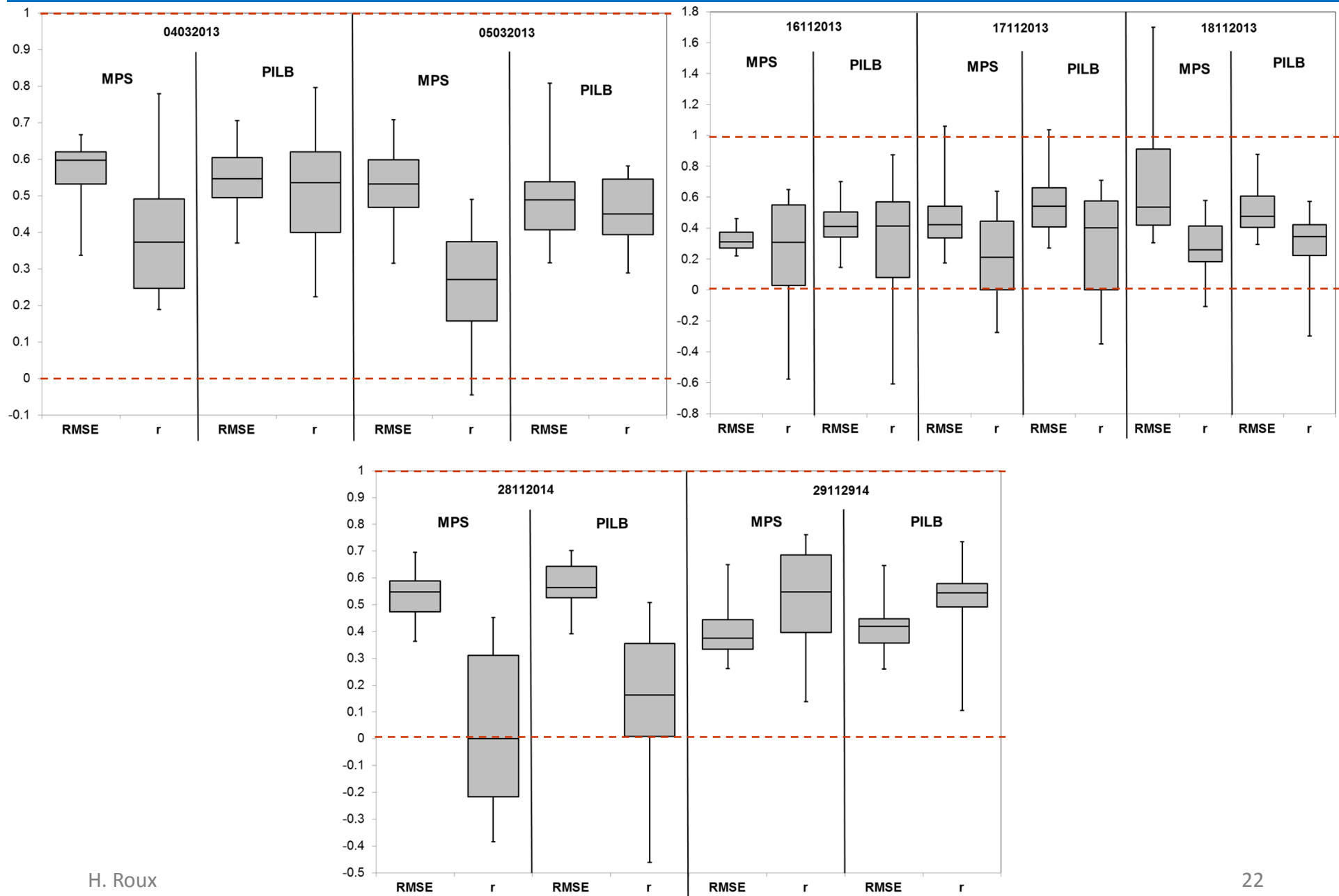
- **MPS experiments:**

20 combinations of 5 microphysics and 4 Planetary Boundary Layer (PBL) schemes

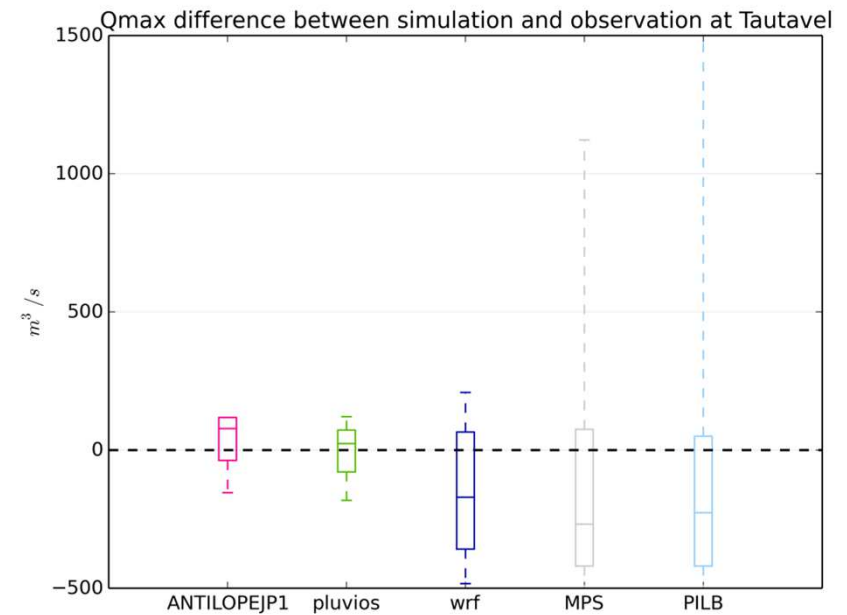
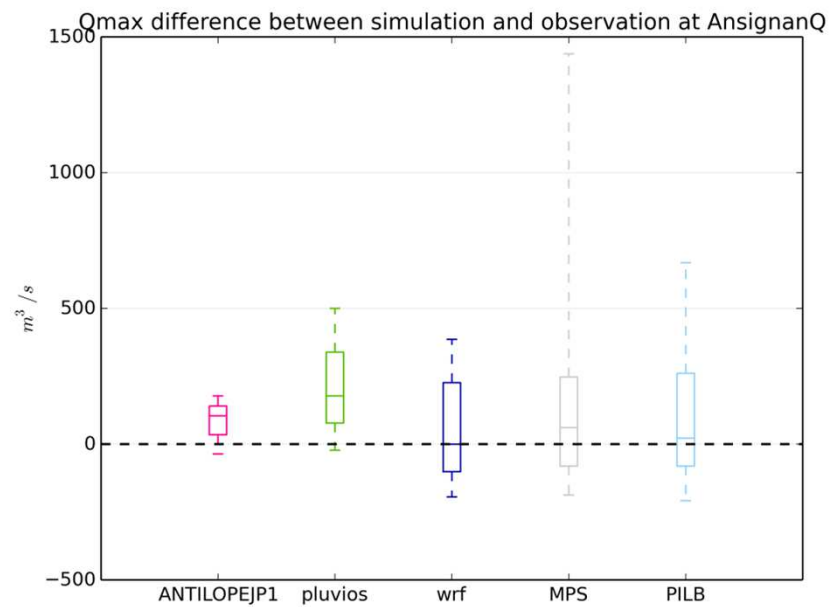
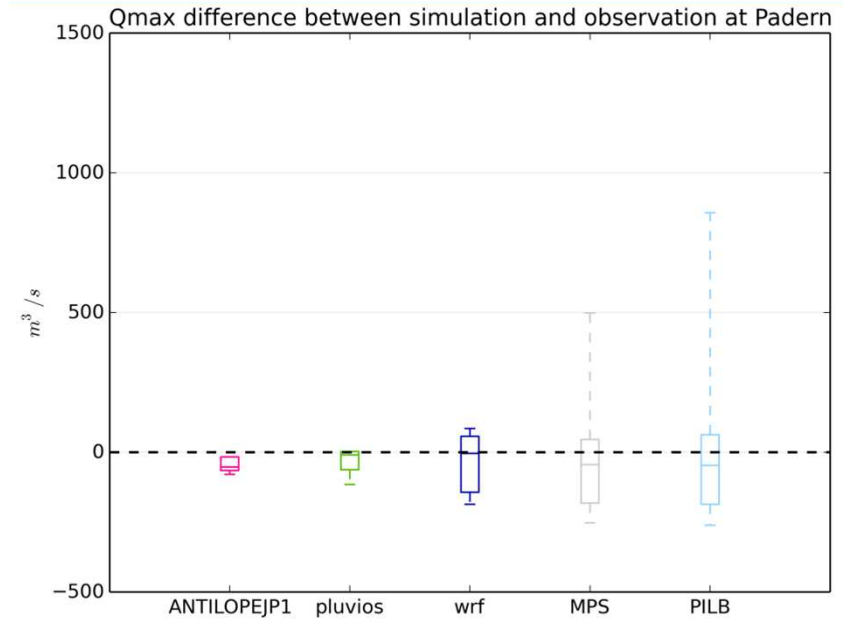
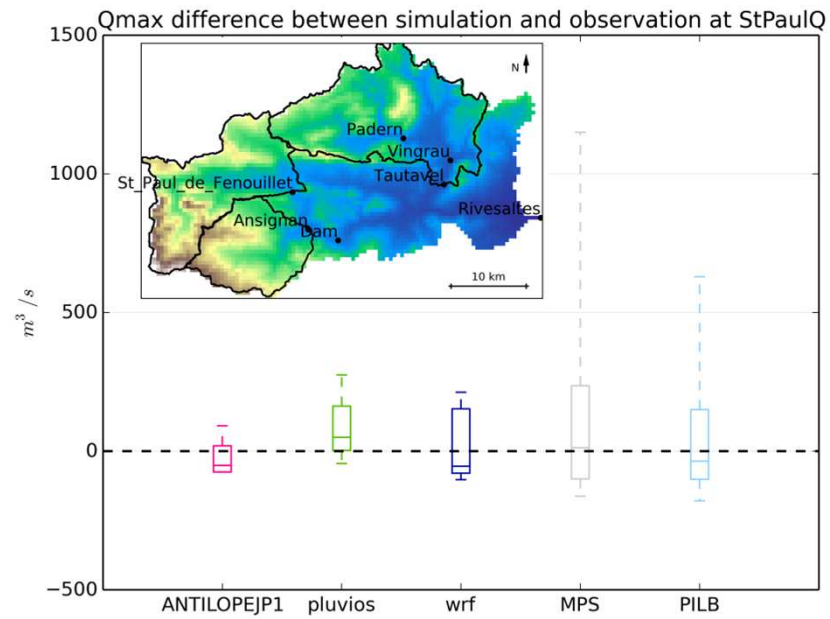
Microphysics schemes are used to model the processes resulting in the several forms of precipitation. The PBL schemes are used to parameterize the sub-grid turbulent vertical fluxes of heat, momentum and moisture within the boundary layer and throughout the atmosphere

Microphysics	WSM6	Goddard	New Thompson	NSSL 2-moment	
				CNN=0.5	CNN=1.0 ( $\cdot 10^9 \text{ cm}^{-3}$ )
PBL	YSU	MYJ	MYNN	TEMF	

# Verification of weather predictions



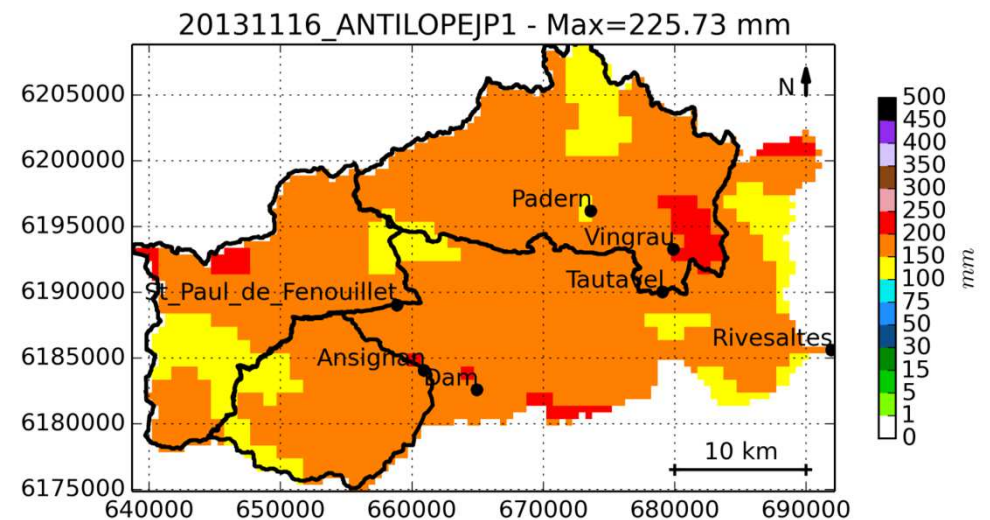
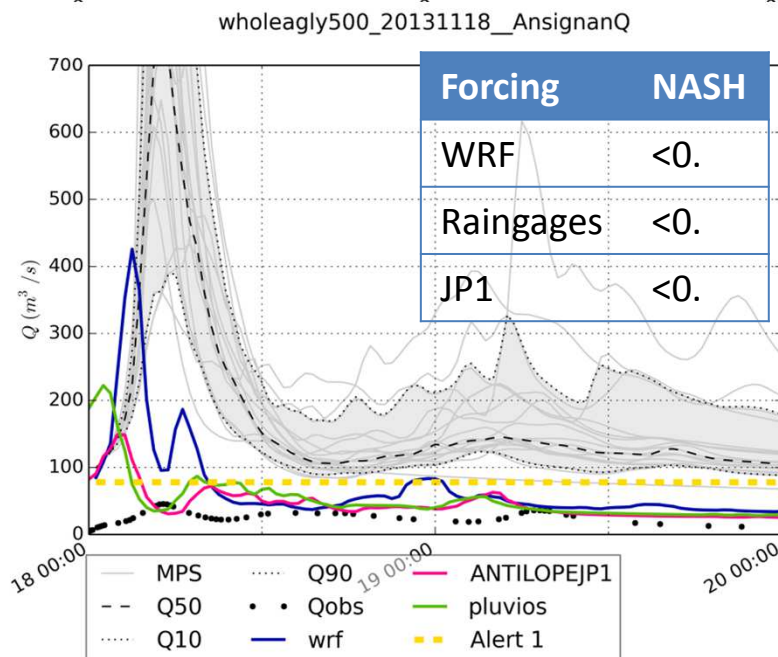
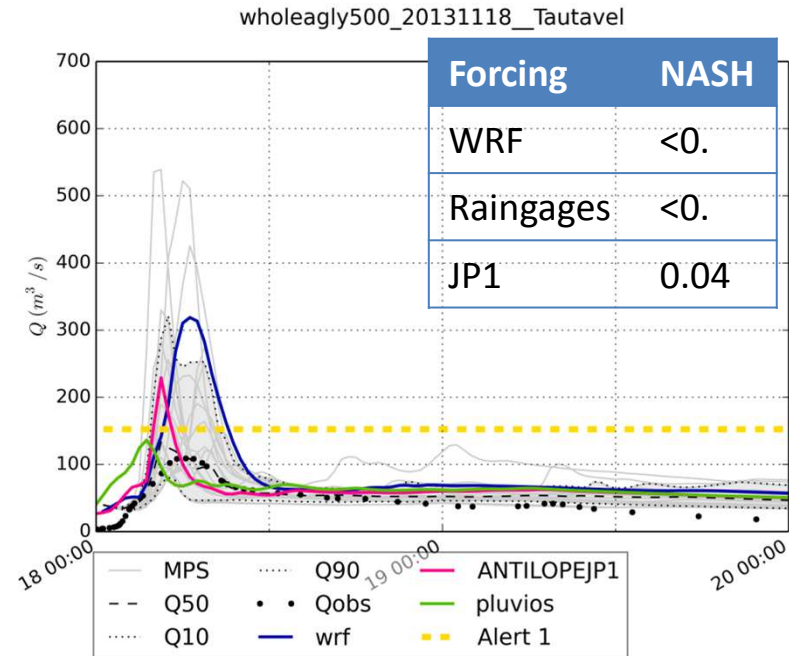
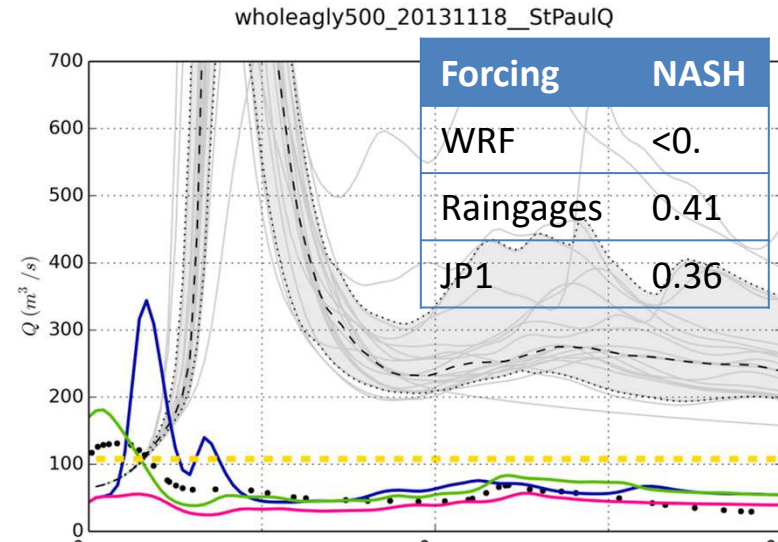
# Peak characteristics: error on discharge

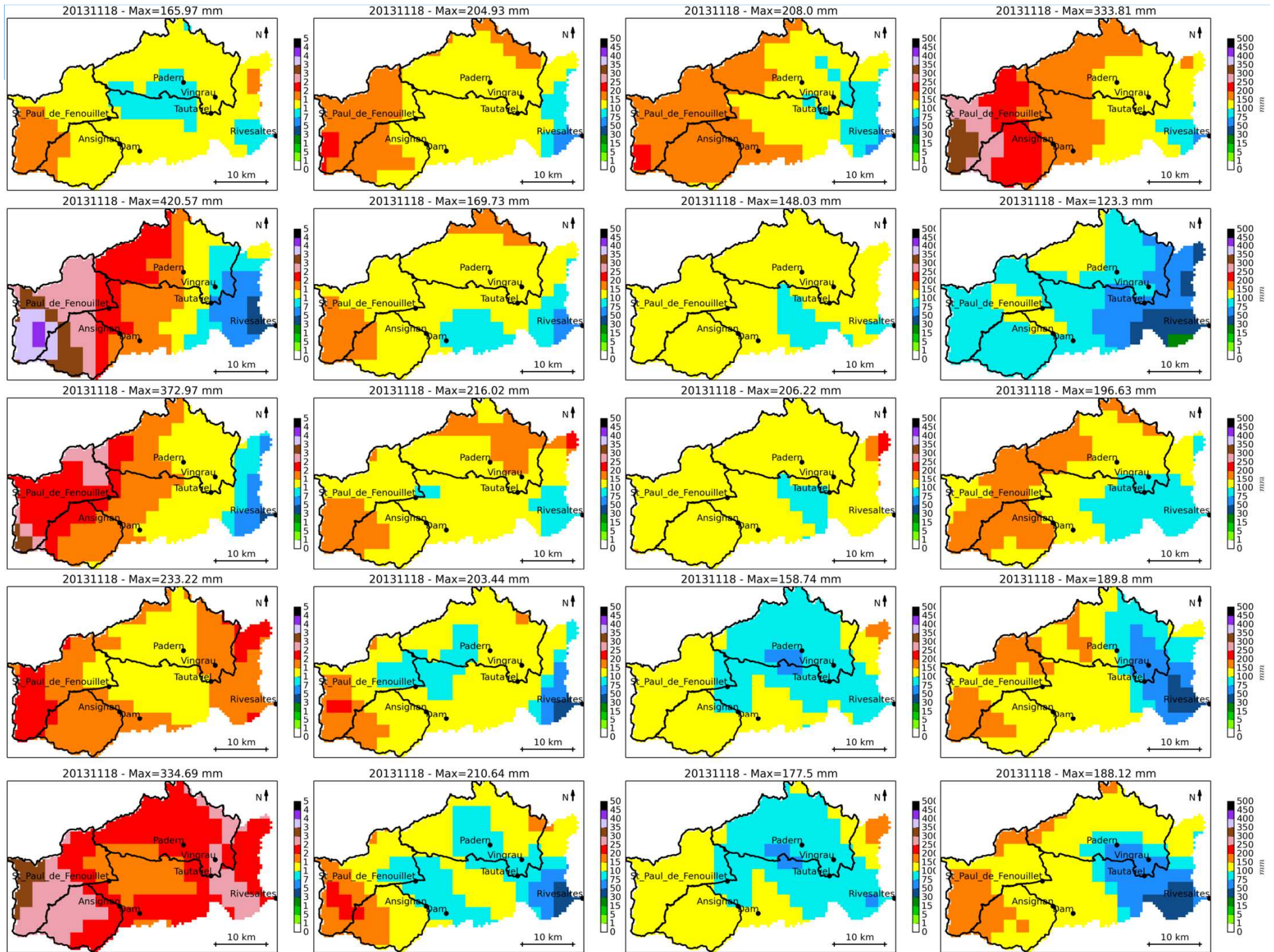




# What lies behind: by event 20131118-20

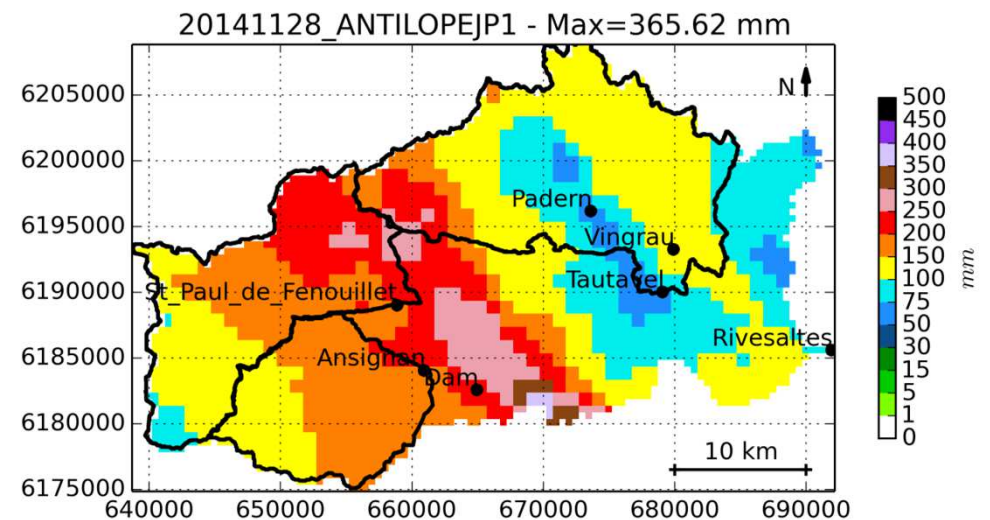
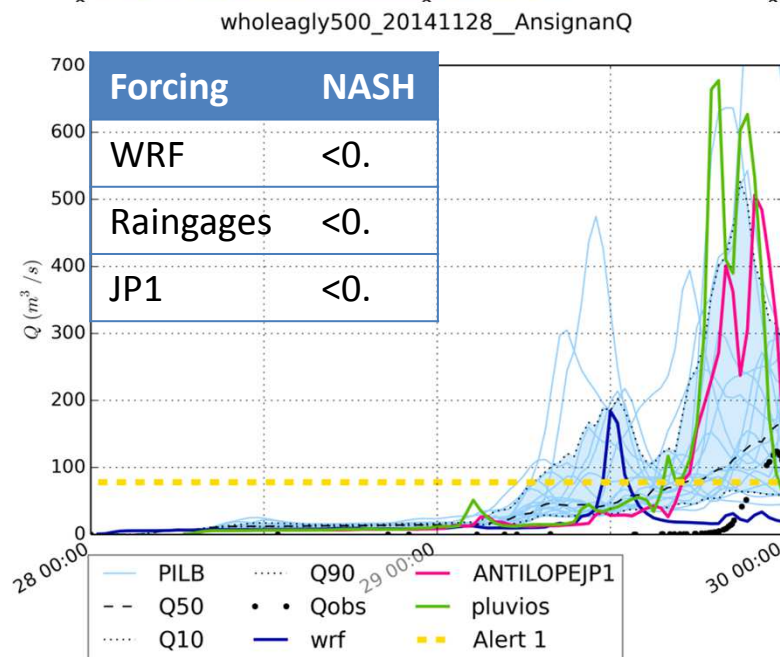
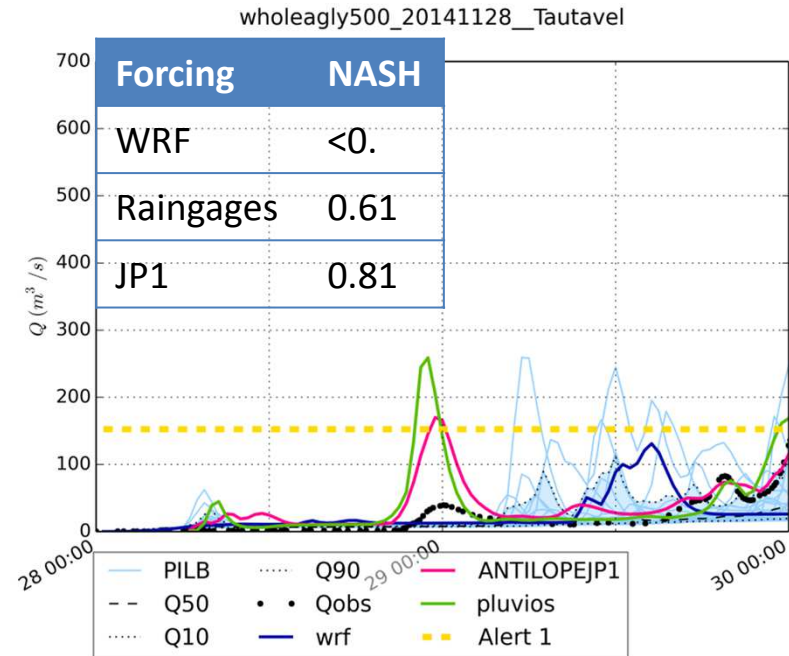
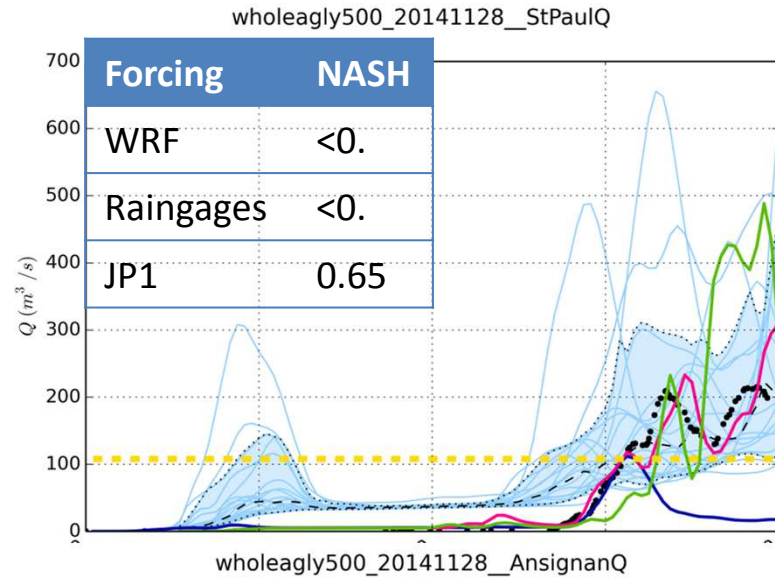
- Spatial distributions





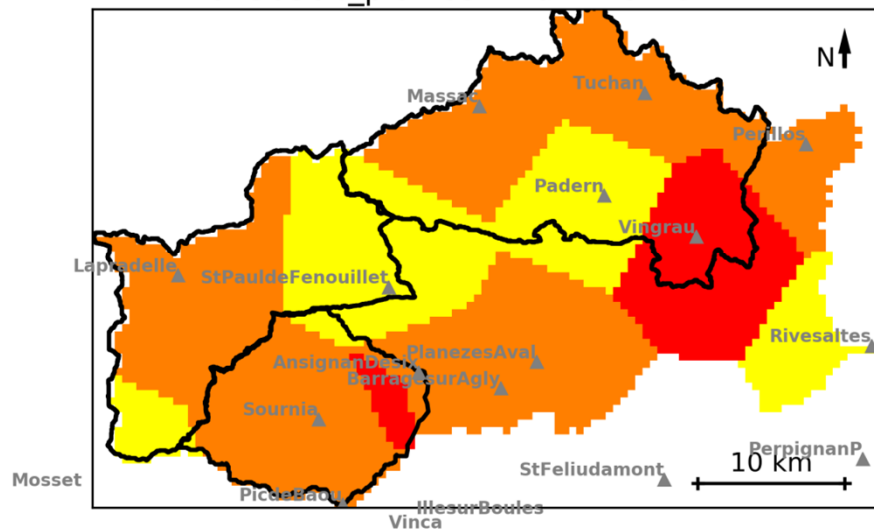
# What lies behind: by event 20141128-30

- Spatial distributions



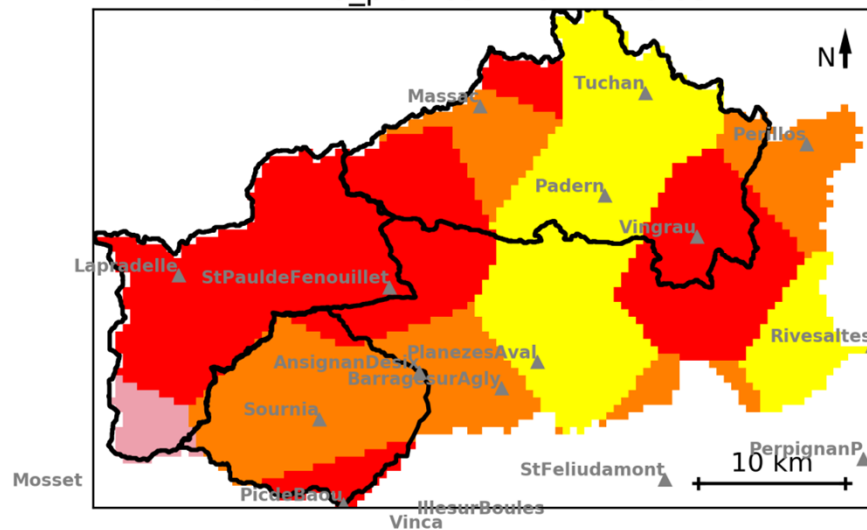
# Raingauges accumulated rainfall

20130304\_pluvios - Max=202.47 mm



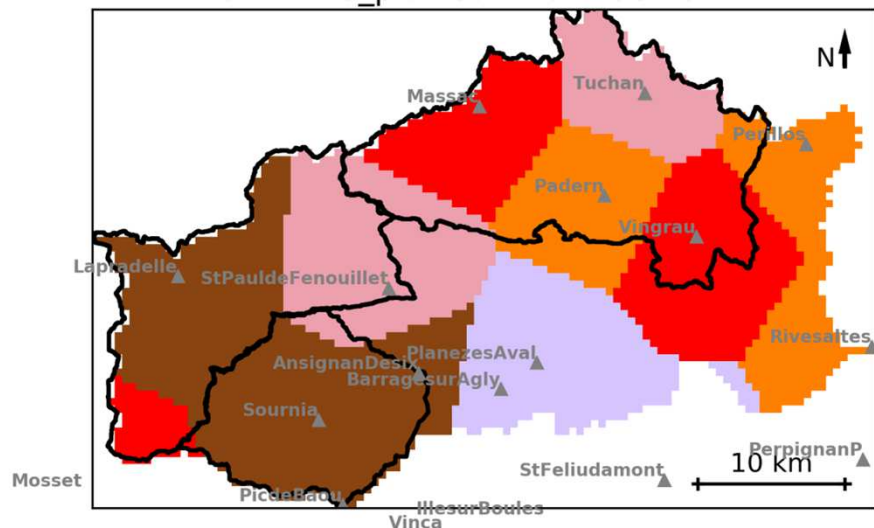
04/03 00:00 – 07/03 00:00

20131116\_pluvios - Max=278.03 mm



16/11 00:00 – 20/11 00:00

20141128\_pluvios - Max=387.9 mm



28/11 00:00 – 01/12 00:00