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

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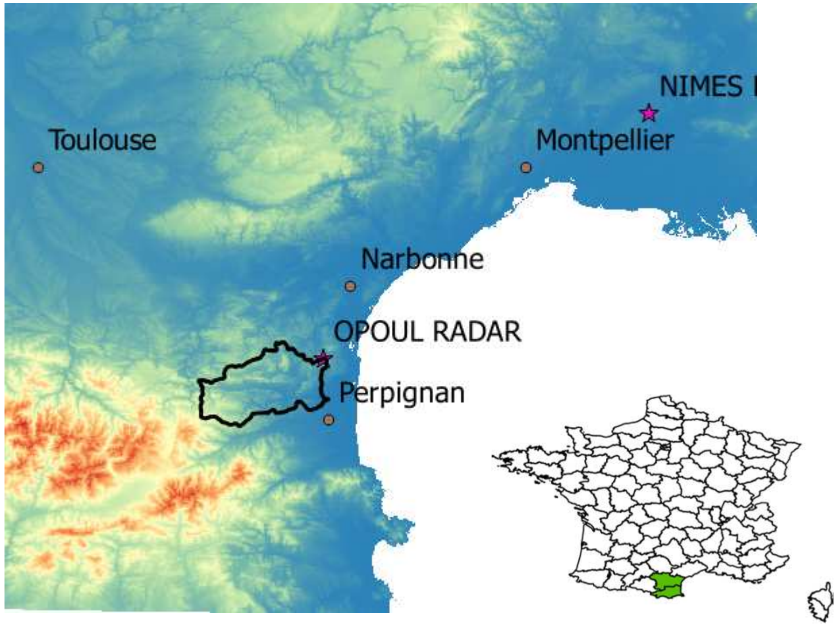
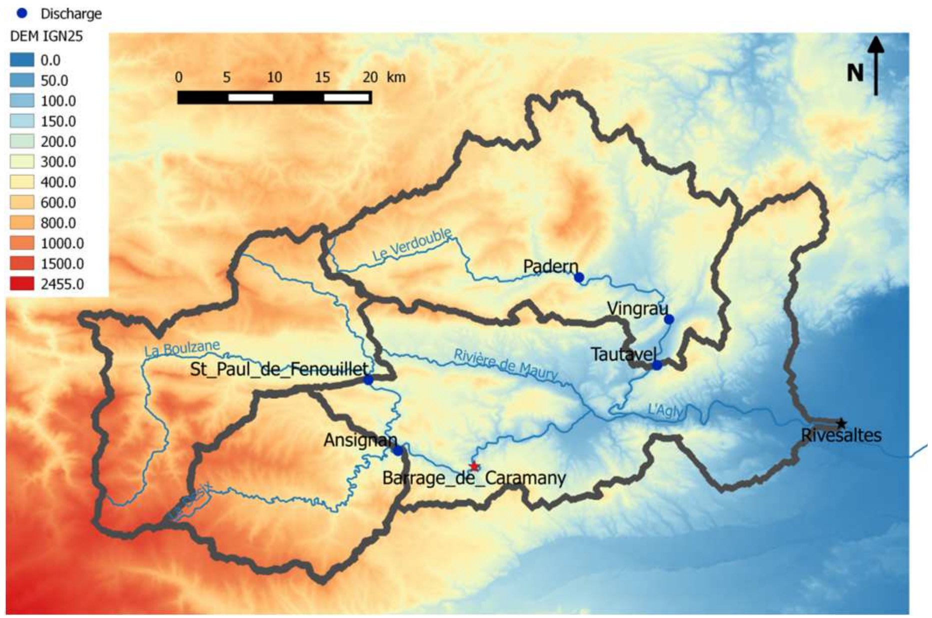
Euroregió Pirineus Mediterrània
Eurorégion Pyrénées-Méditerranée
Eurorregión Pirineos Mediterráneo

Study site: Agly catchment

- Whole catchment
  - 1050 km²
  - Mainly natural area (45% forests, 30% Mediterranean scrub)
  - Karstic region
  - Dam: around 50Mm³ for flood control and water management



- Upstream the dam
  - 408 km²
  - Climate: Oceanic (North-West) and mountain (South-West) influences



- North-eastern part
  - Verdouble catchment: 330 km²
  - Climate: Mediterranean

H. Roux

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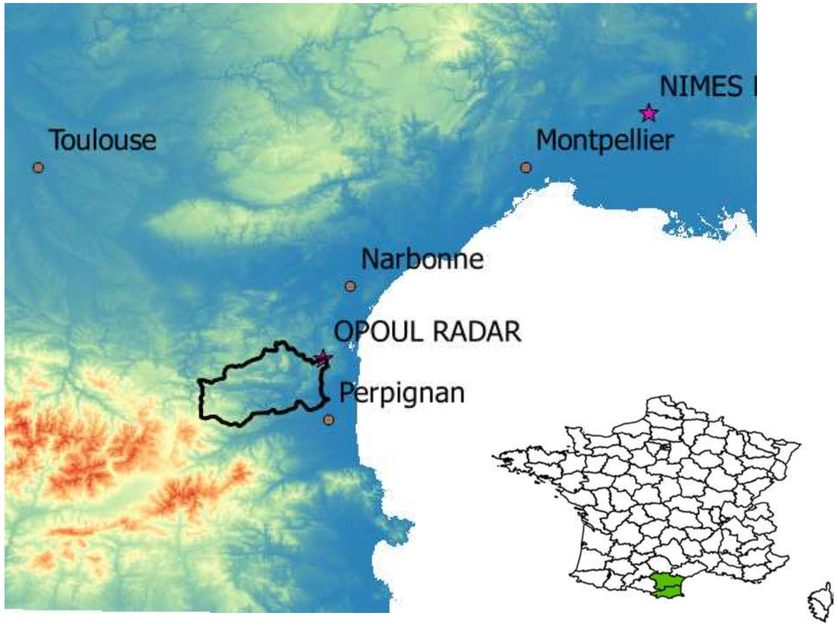

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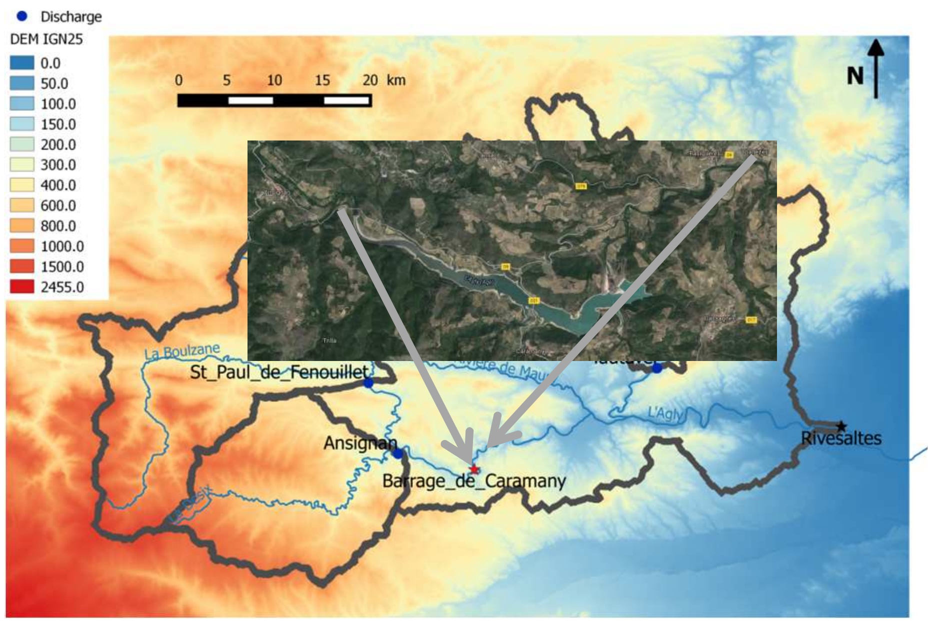

- North-eastern part
  - Verdouble catchment: 330 km²
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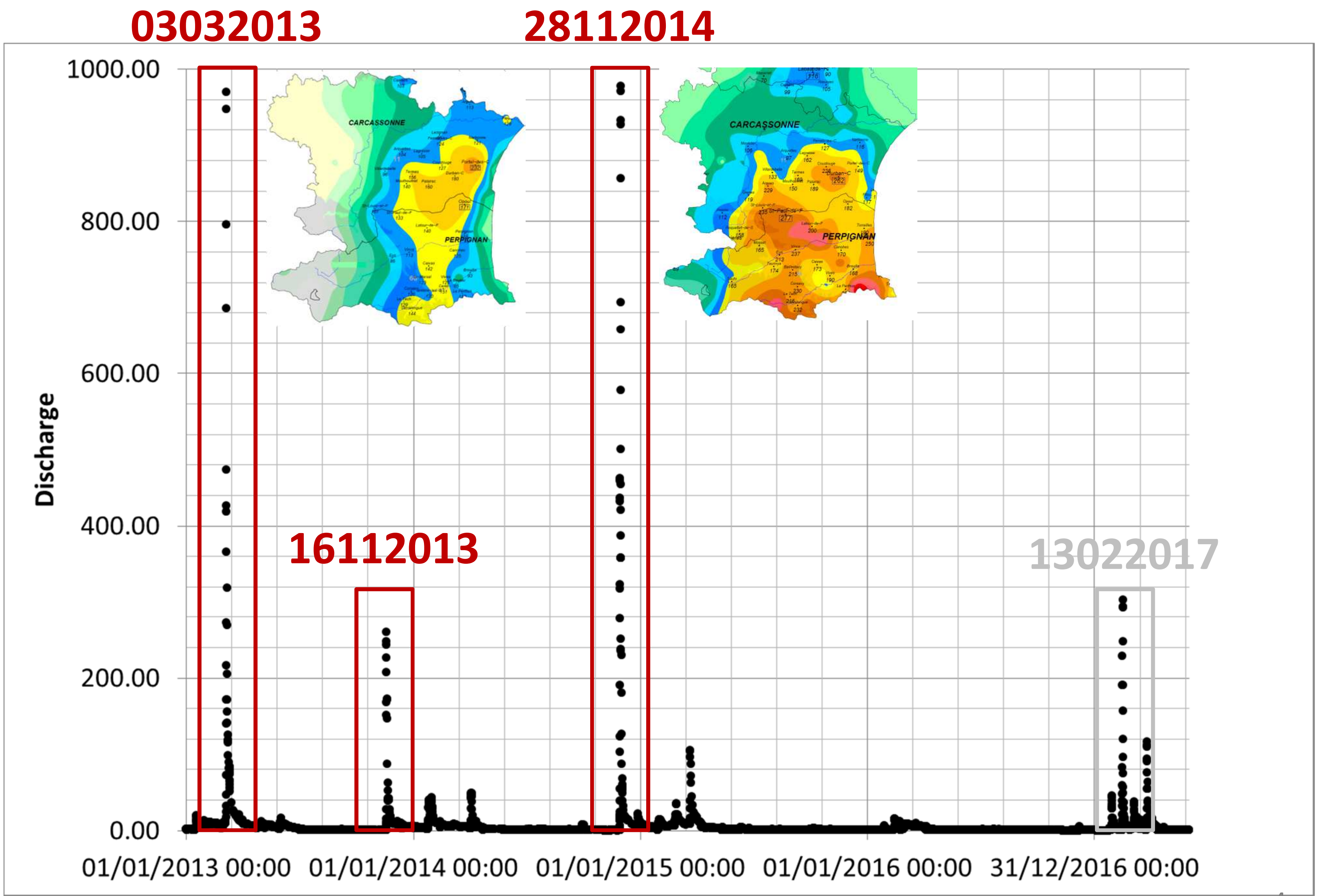
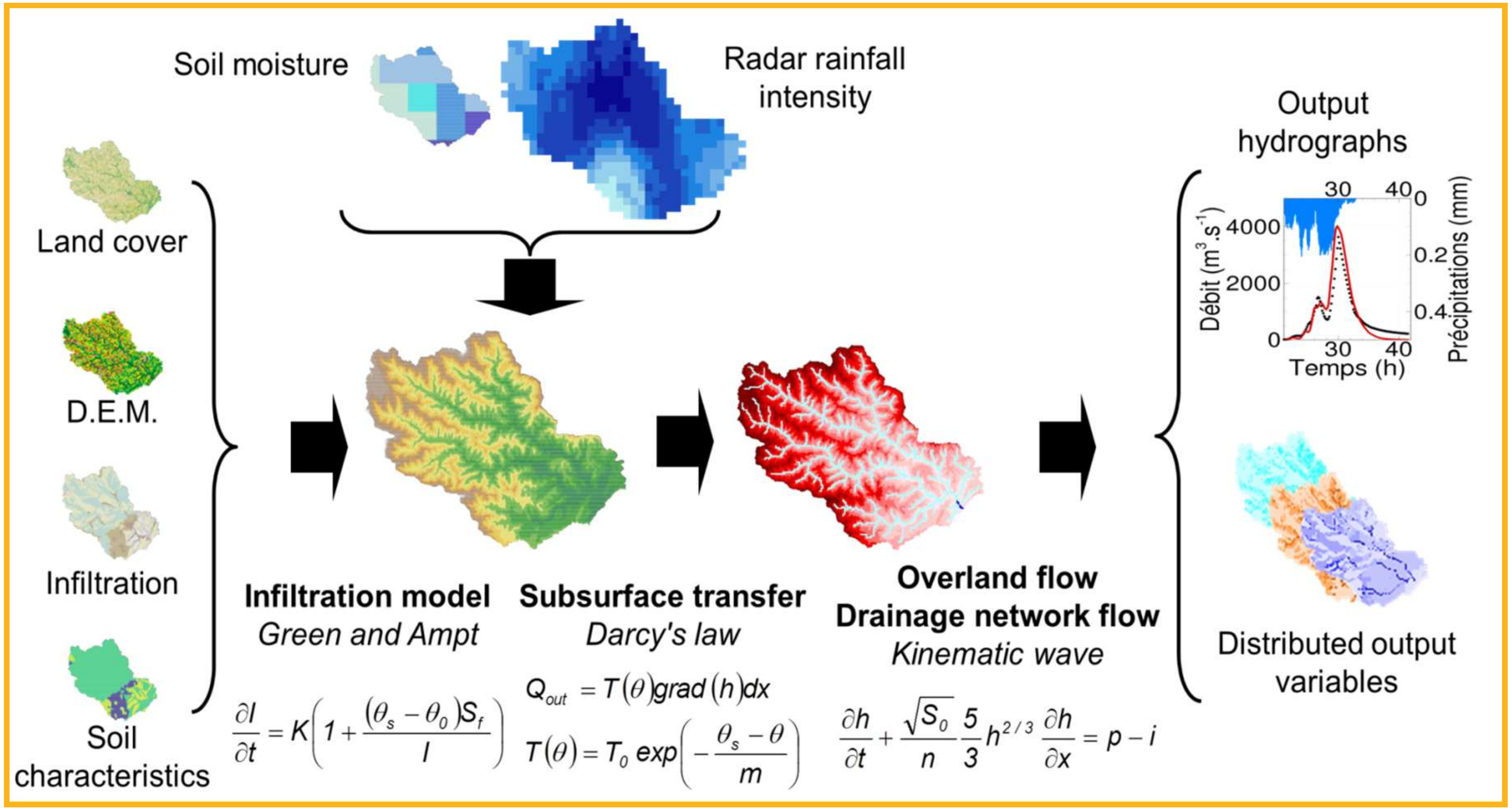
Recent floods at Rivesaltes (outlet)



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



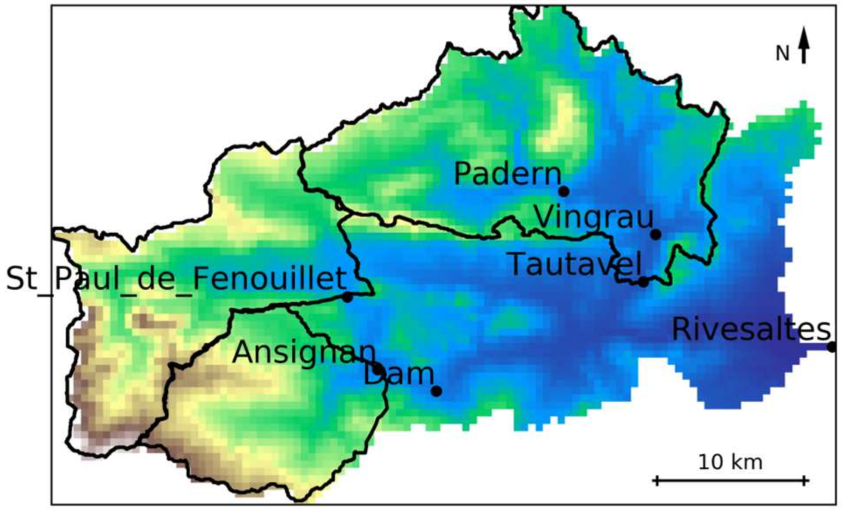
Roux, H., Labat, D., Garambois, P.-A., Maubourguet, M.-M., Chorda, J. and Dartus, D., 2011. A physically-based parsimonious hydrological model for flash floods in Mediterranean catchments. Nat. Hazards Earth Syst. Sci. J1 - NHESS, 11(9), 2567-2582.

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)

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

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, 0.2º; 62 vertical levels)

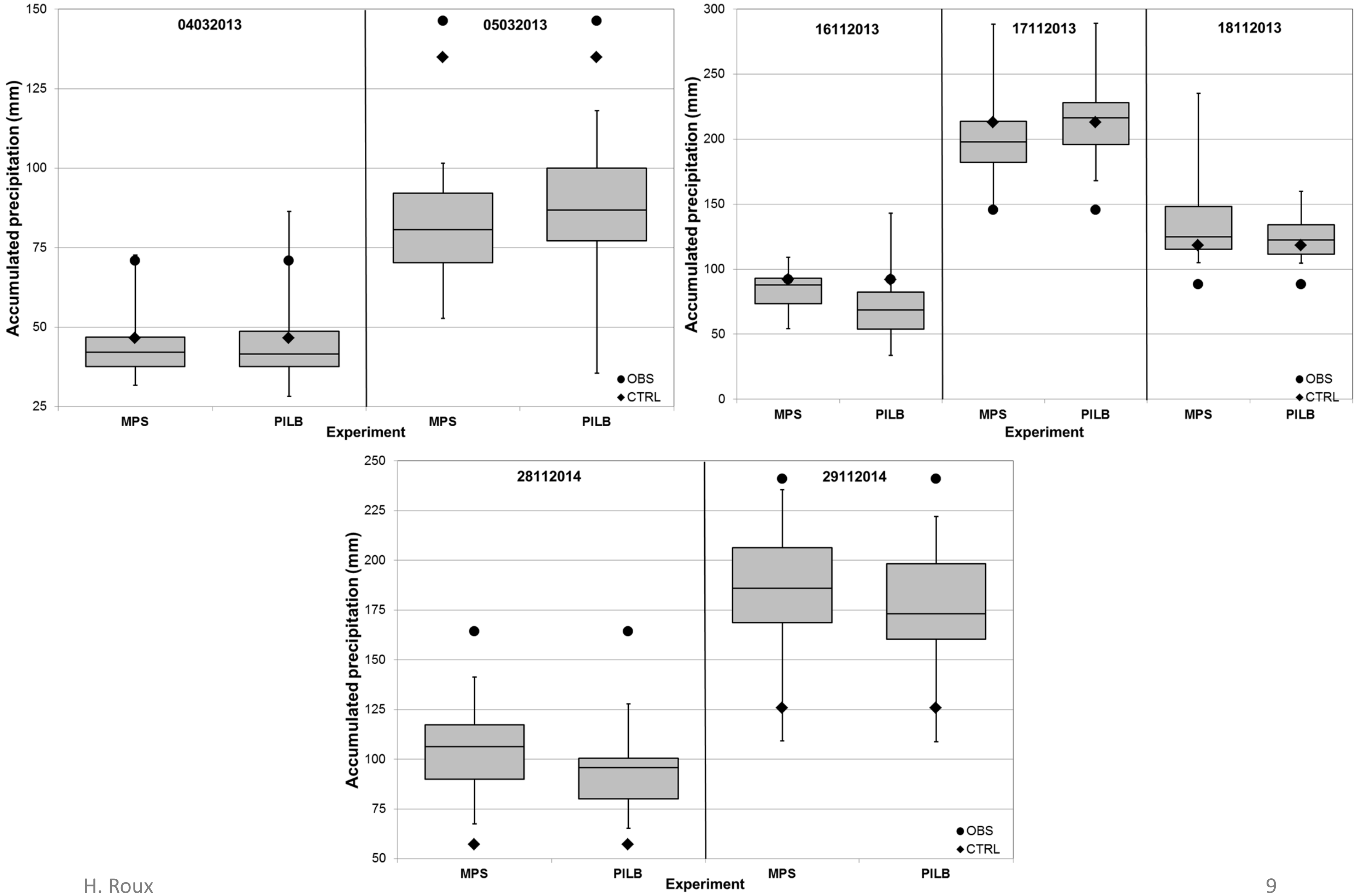
Ensemble Prediction Systems

- 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

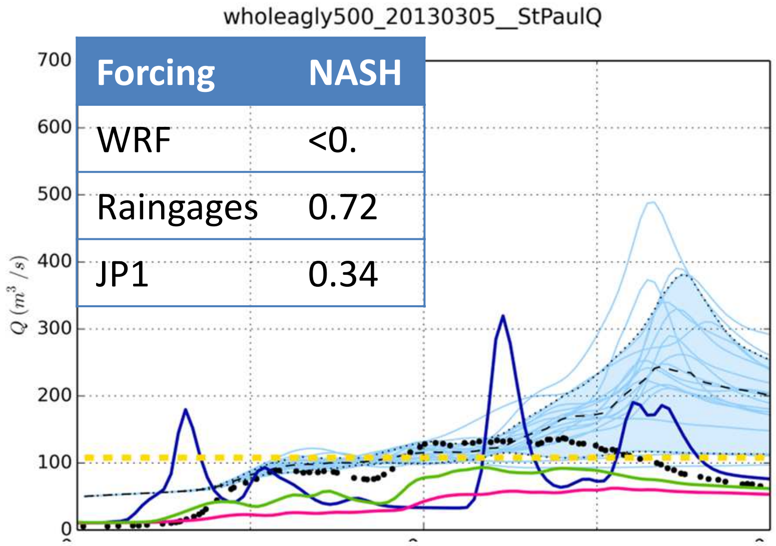
- Short-range EPSs aim at forecasting the probability of weather extremes as accurately as possible
  - PILB experiments: Encompass uncertainties in the atmospheric state
  - MPS experiments: Encompass uncertainties in physical parameterizations

Verification of weather predictions

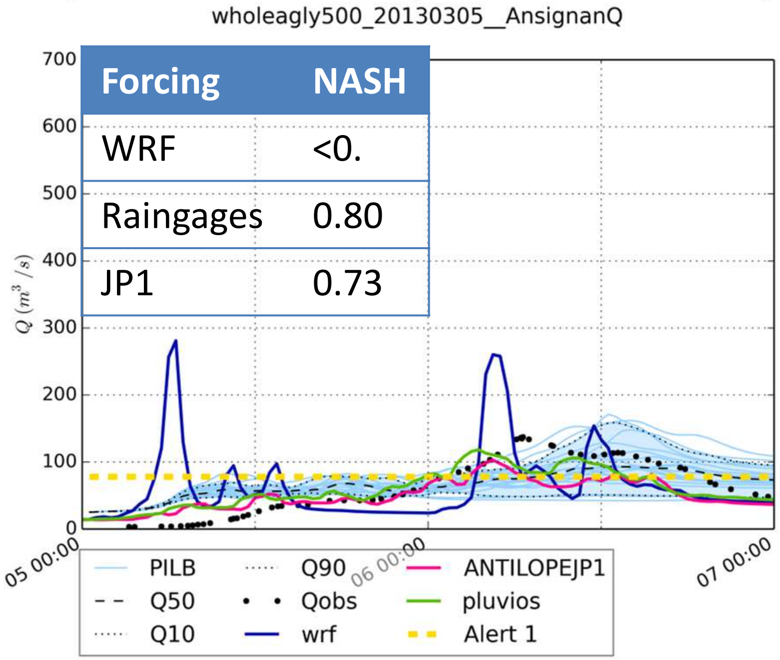


Local performances of the hydro-meteo predictions

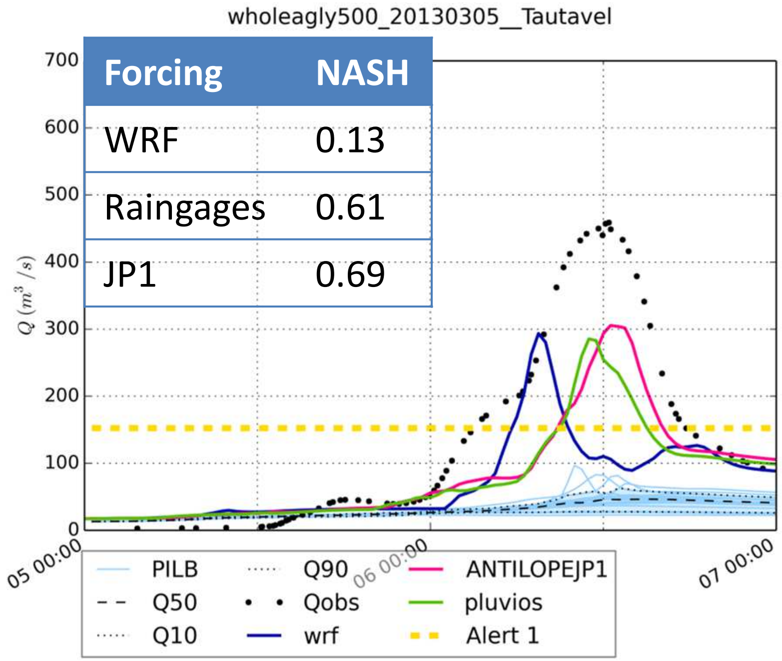
- Spatial distributions



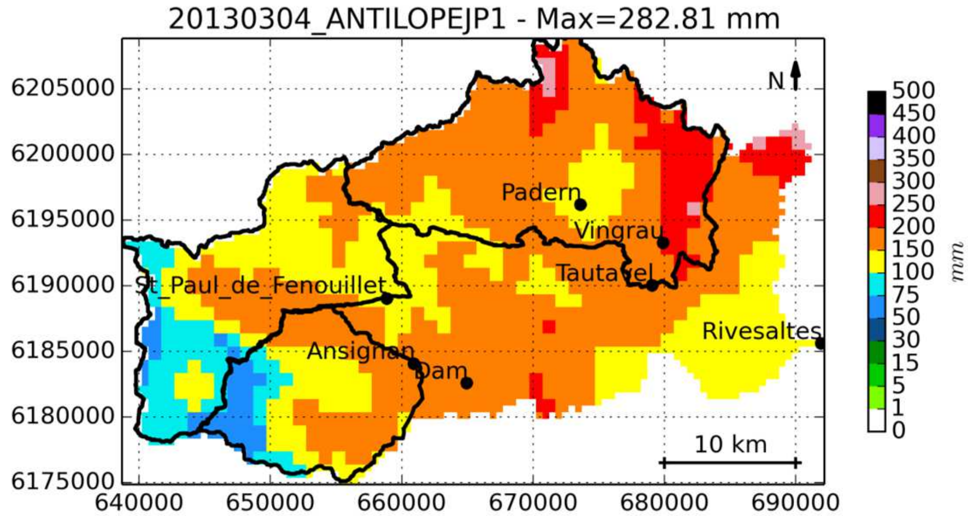
Forcing	NASH
WRF	<0.
Raingages	0.72
JP1	0.34



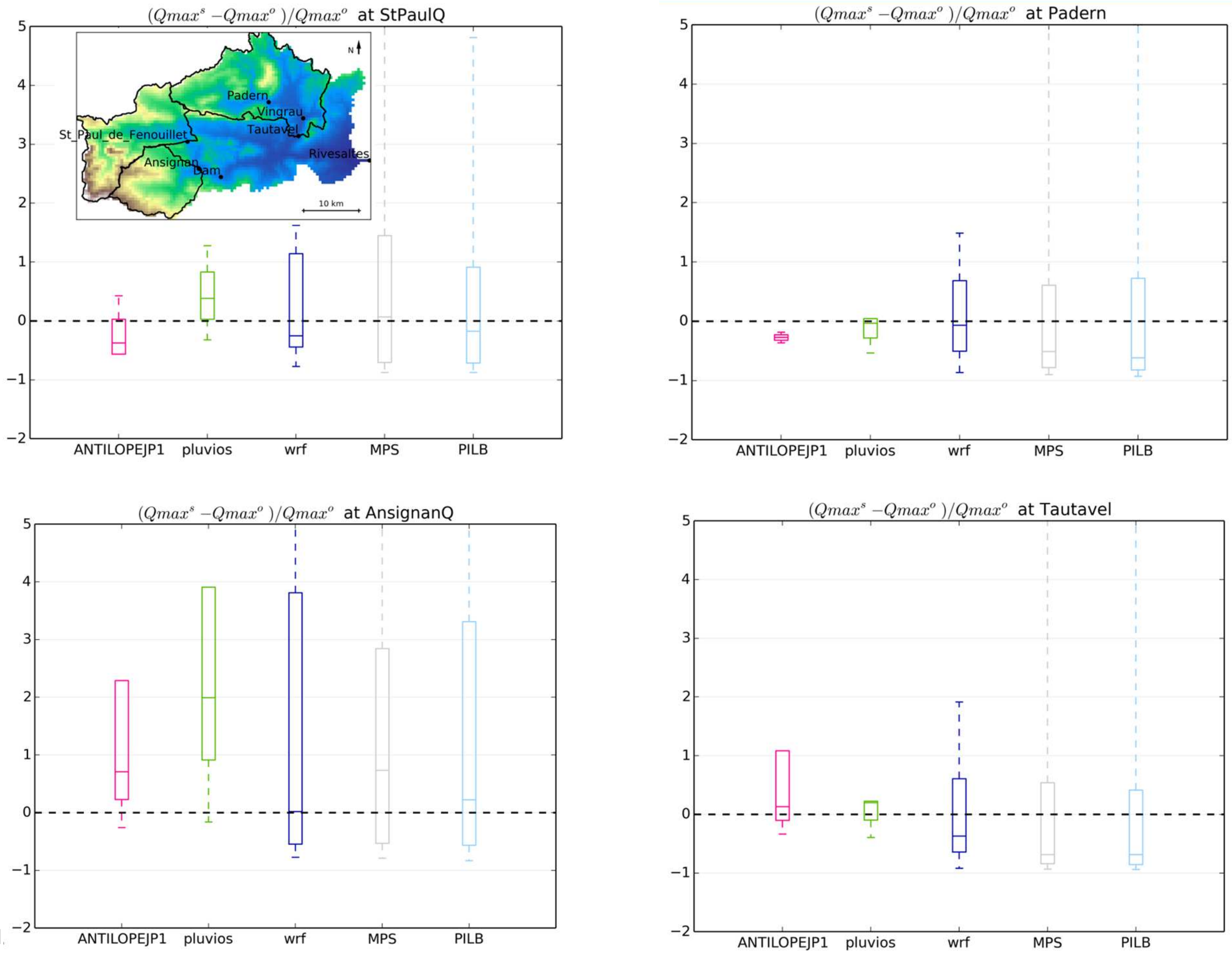
Forcing	NASH
WRF	<0.
Raingages	0.80
JP1	0.73



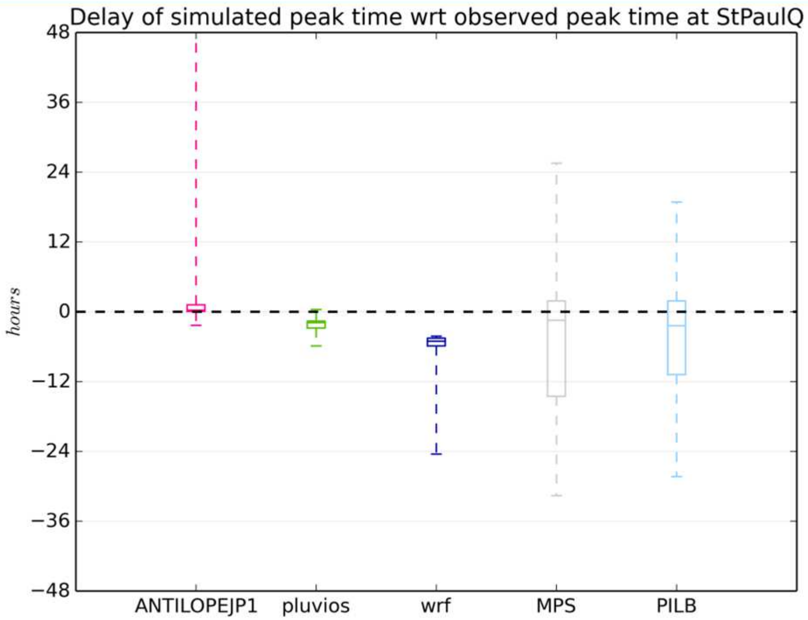
Forcing	NASH
WRF	0.13
Raingages	0.61
JP1	0.69

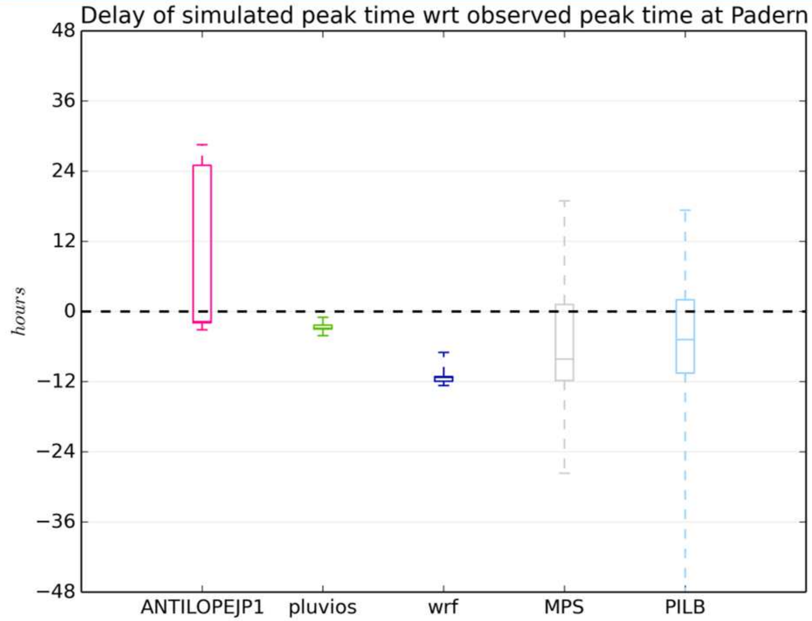


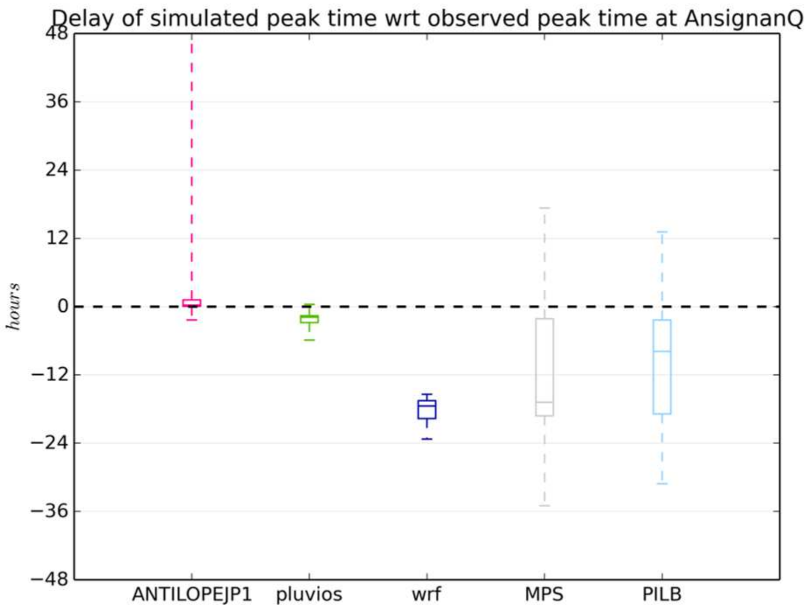
Relative error on peak discharge

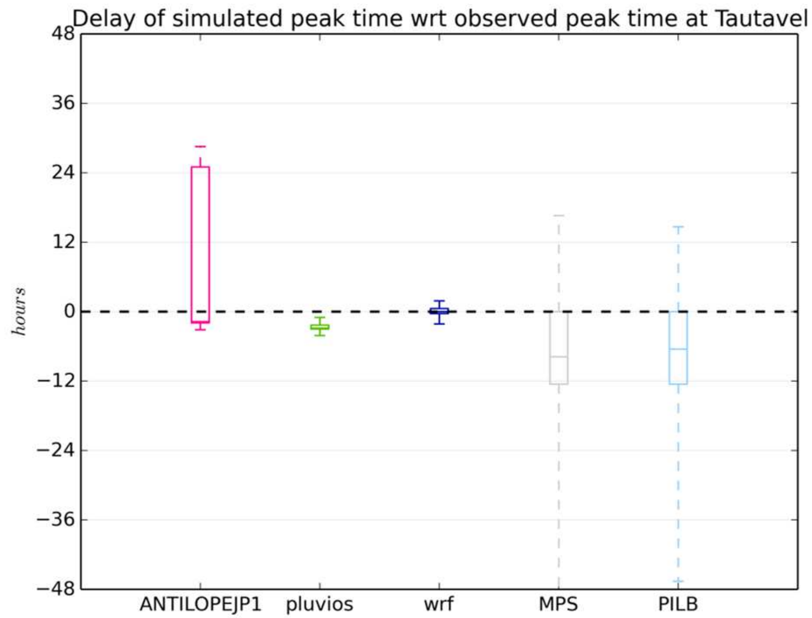


Error on peak time









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 $[0; 1]$

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

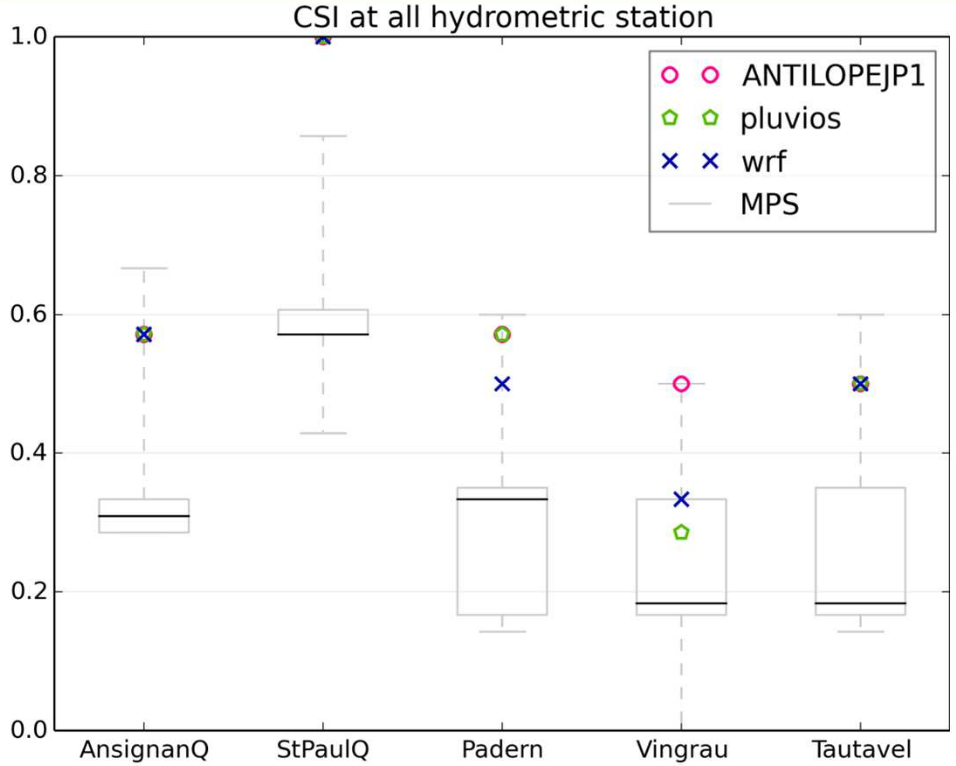
  - Fraction of events that were correctly predicted $\longrightarrow$ kind of accuracy

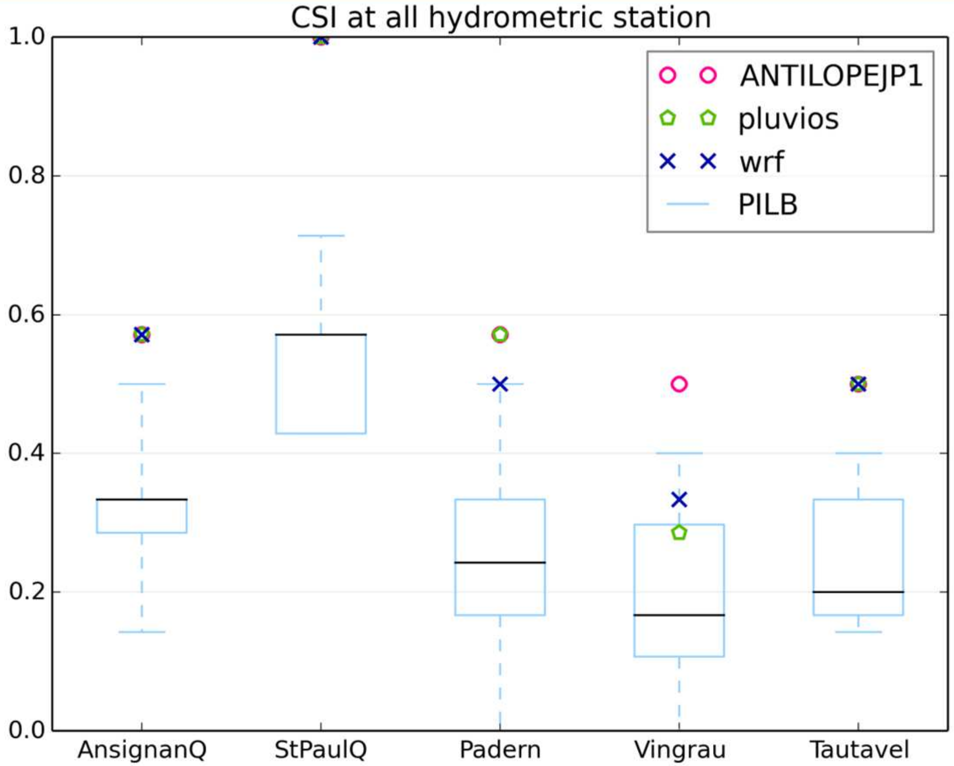
- Bias $[0; +\infty]$

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

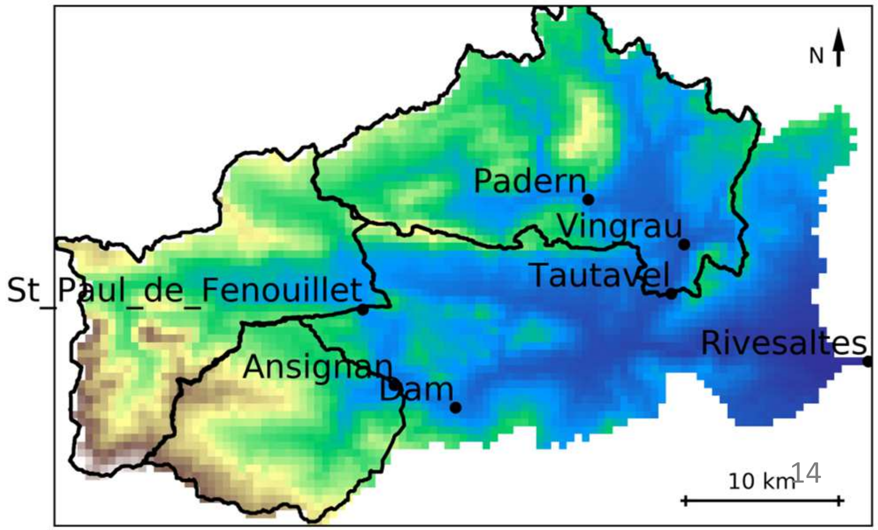
  - ratio of the number of times an event was forecast to the number of times an event was observed
  - Bias < 1 $\longrightarrow$ underforecast, Bias > 1 $\longrightarrow$ overforecast

Critical Success Index: 2-year return period

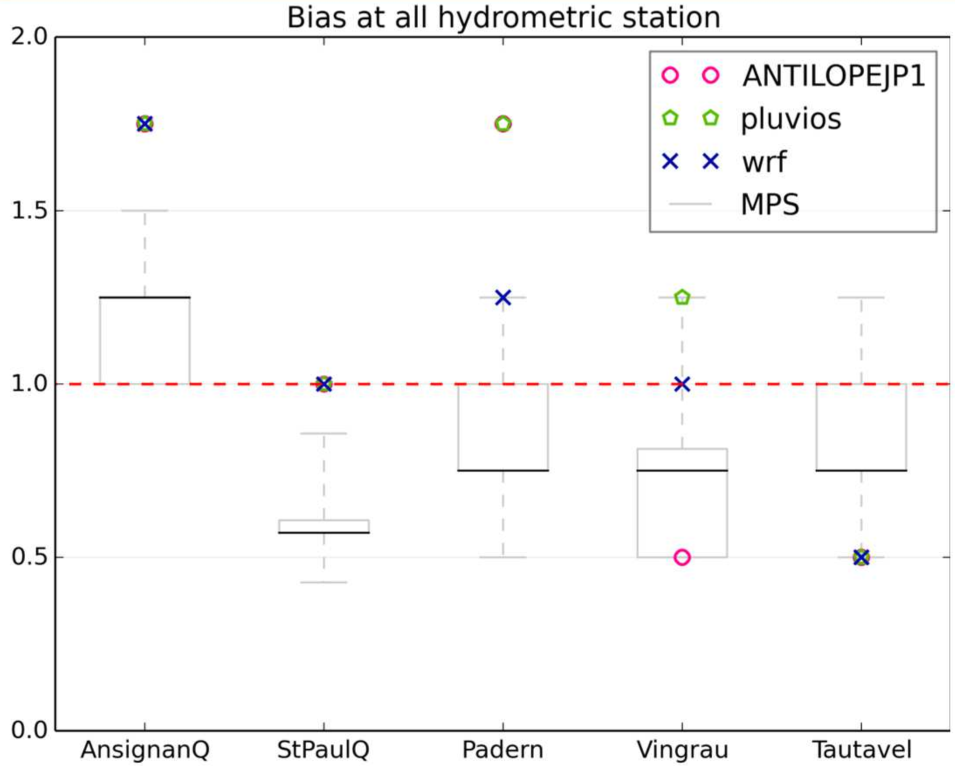


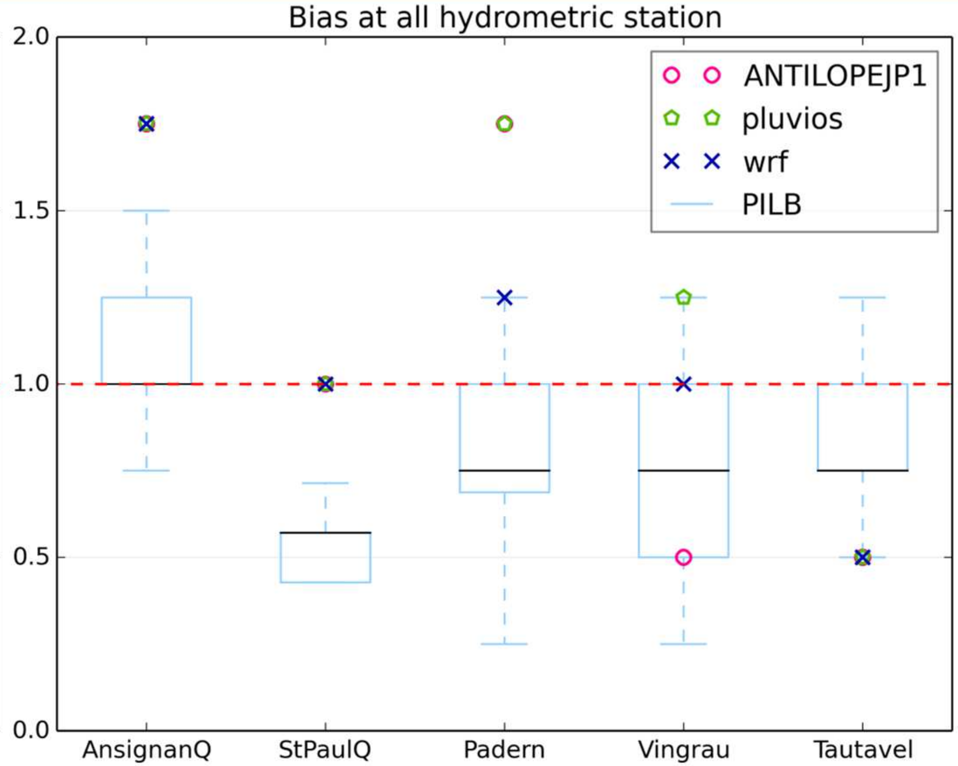


- Western part and downstream eastern part: same CSI for observed and deterministic forcing
- Uspstream eastern part: distinct behaviors

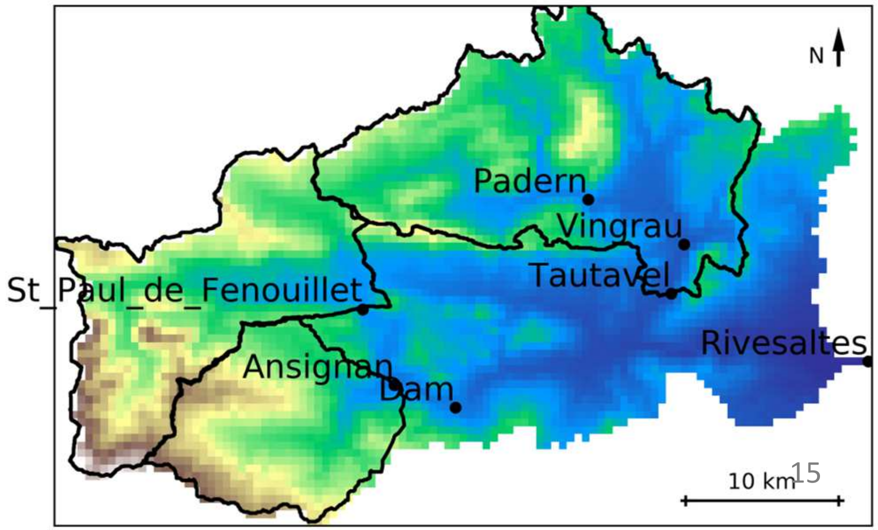


Bias: 2-year return period





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



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 forescast 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.

- Roux, H., Labat, D., Garambois, P.-A., Maubourguet, 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.

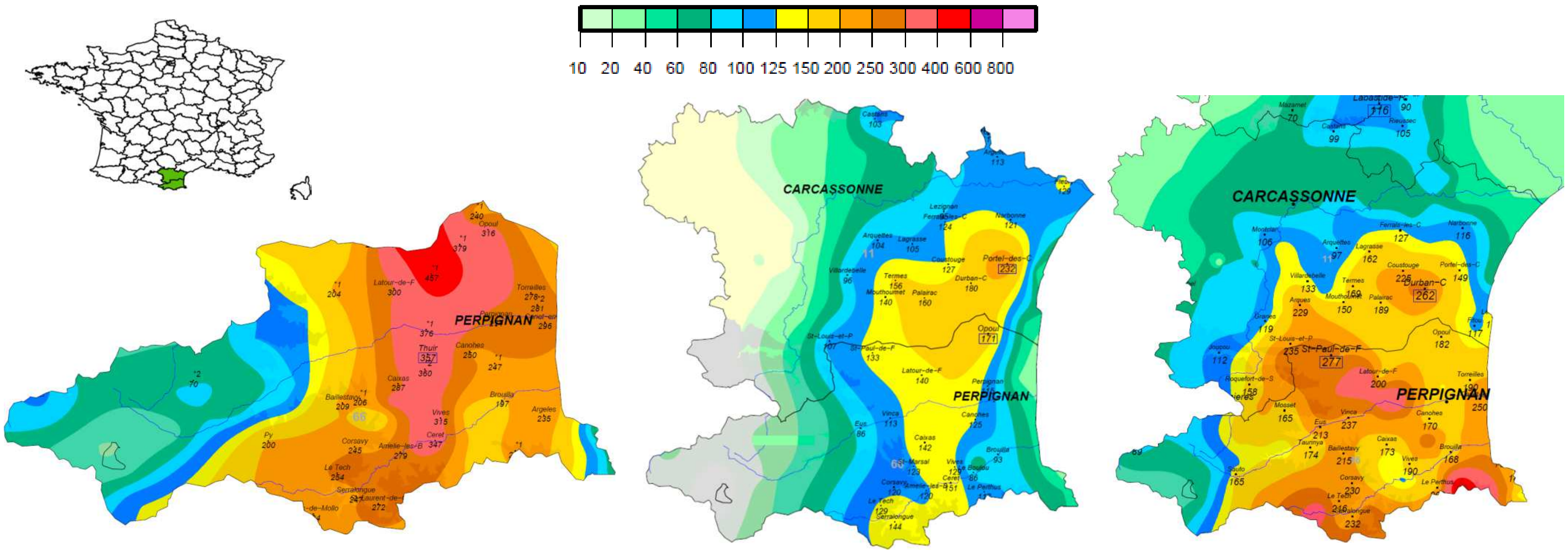
Content

- 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



1999/11/12-14 2013/03/05-07 2014/11/29-12/01

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

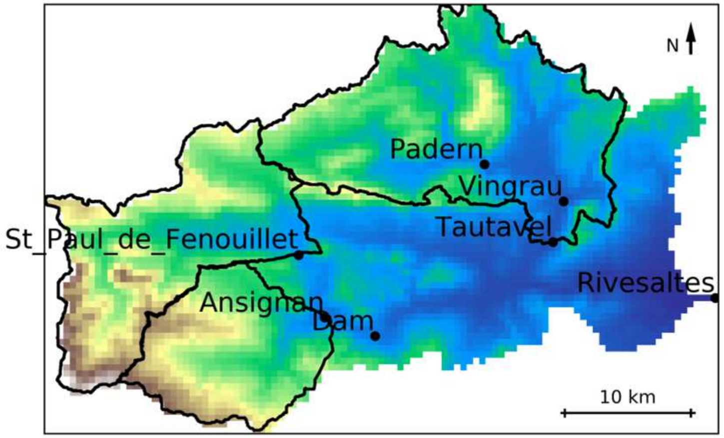
Calibration parameters and Strategy

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 (K_{min}, K_{maj})

Flood volume and peak magnitude (C_Z, C_K, C_T)

- 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, 0.2º; 62 vertical levels)

Perturbations are derived from flow-dependent singular vectors technique

All PILB ensemble members use the operational set of physical parameterizations

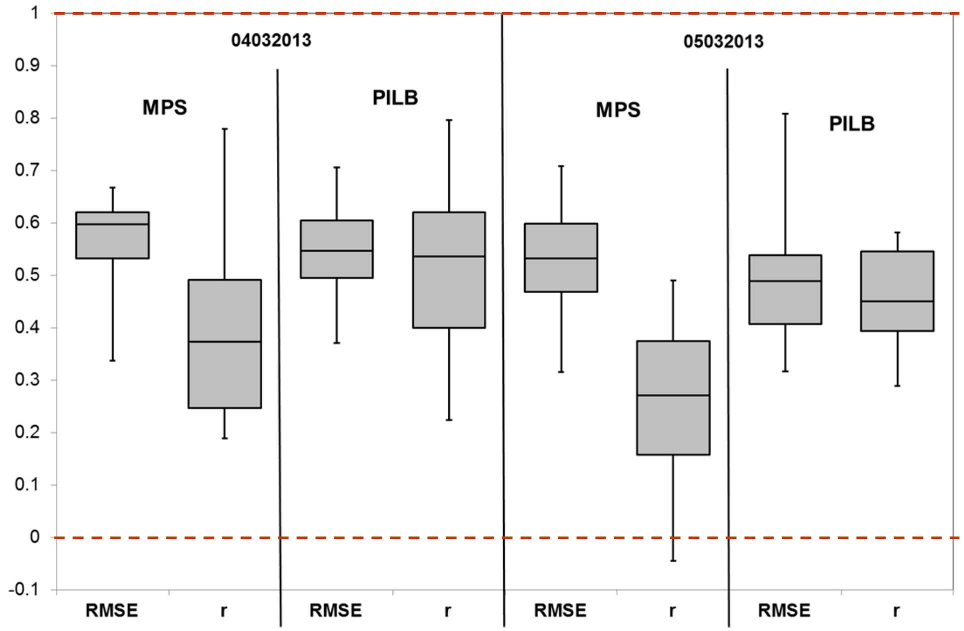
- MPS experiments:

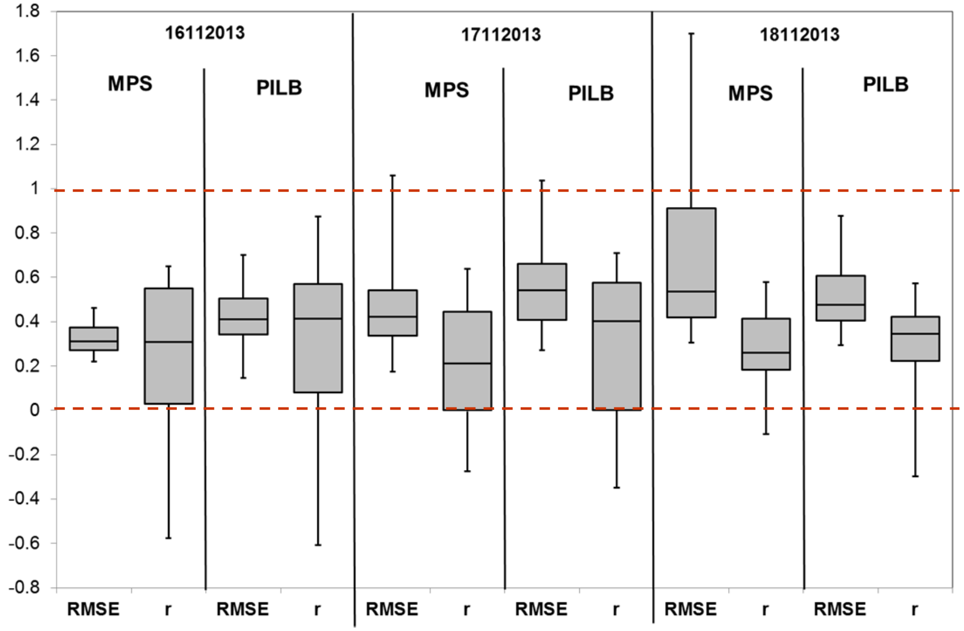
20 combinations of 5 microphysics and 4 Planetary Boundary Layer (PBL) schemes

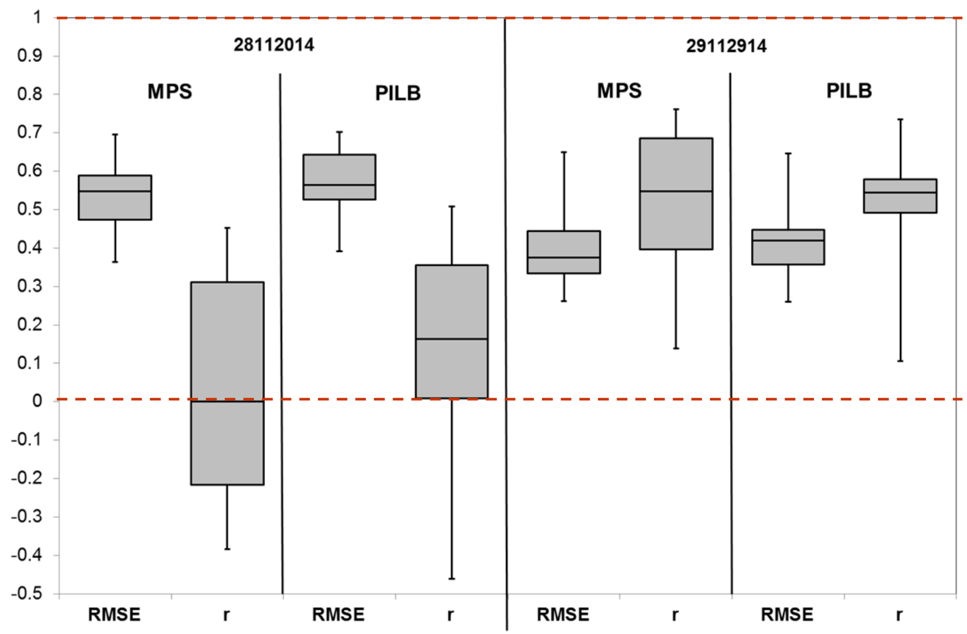
Microphysics schemes are used to model the processes resulting in the several forms of precipitation. The PBL schemes are used to parameterize the sub-grid turbulent vertical fluxes of heat, momentum and moisture within the boundary layer and throughout the atmosphere

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

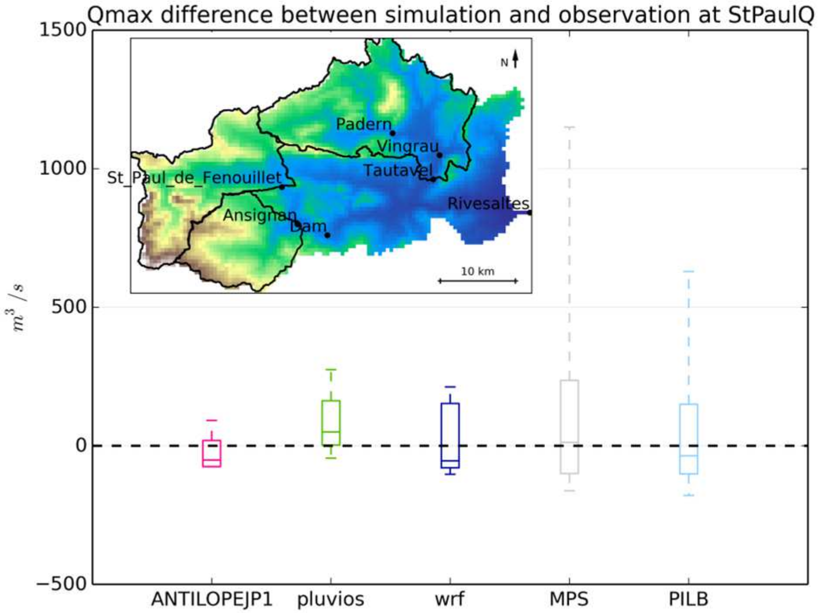
Verification of weather predictions

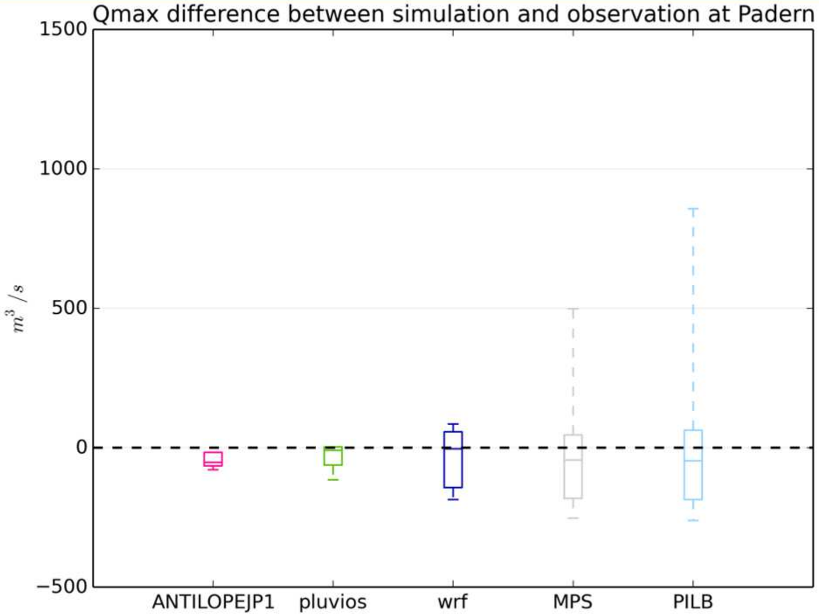


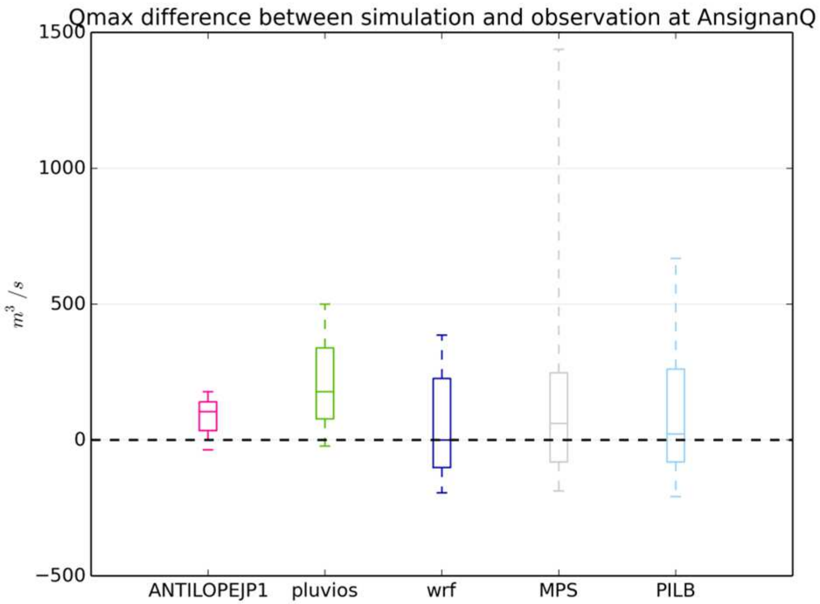


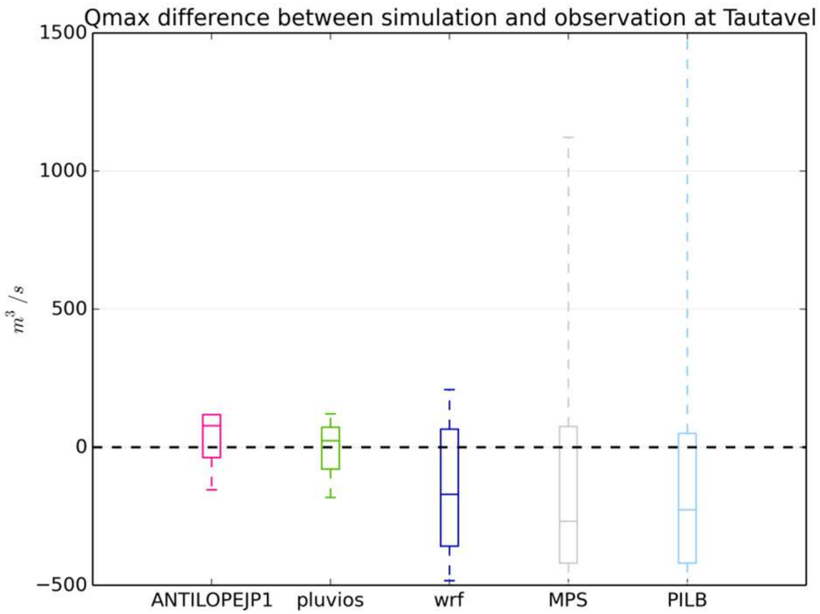


Peak characteristics: error on discharge





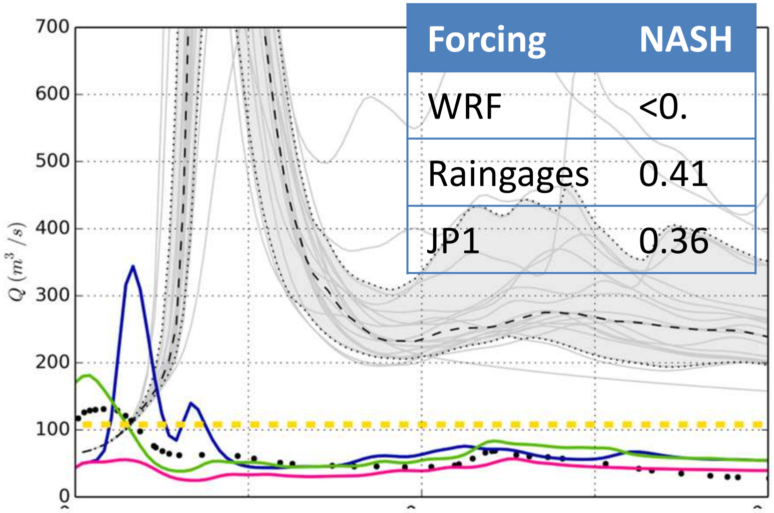




What lies behind: by event 20131118-20

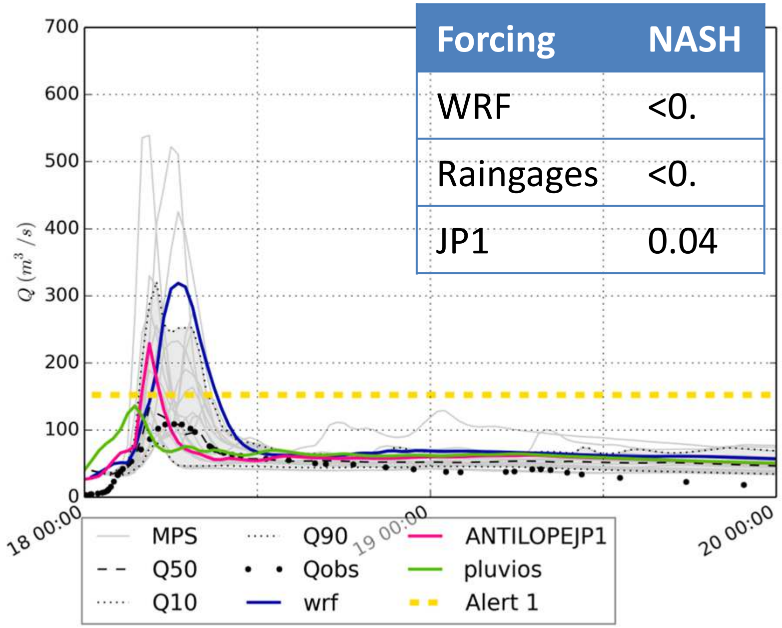
- Spatial distributions

wholeagly500_20131118__StPaulQ



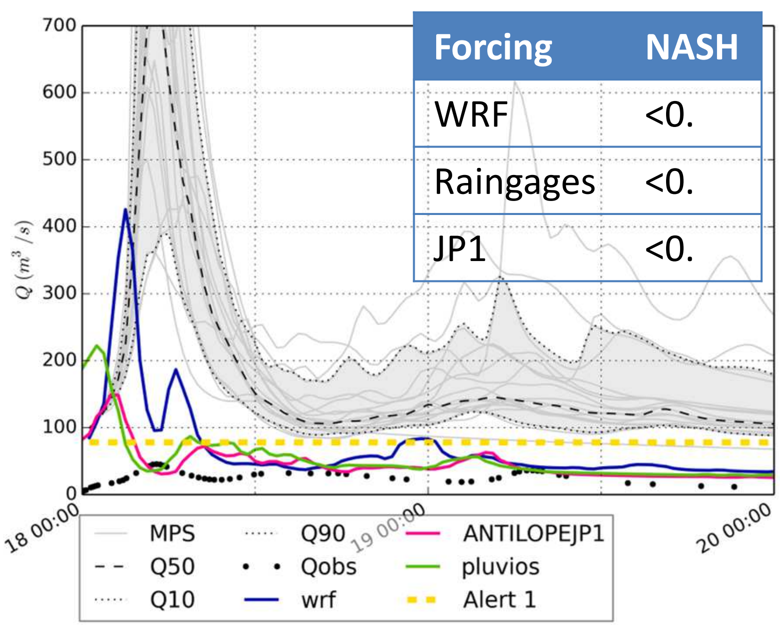
Forcing	NASH
WRF	<0.
Raingages	0.41
JP1	0.36

wholeagly500_20131118__Tautavel

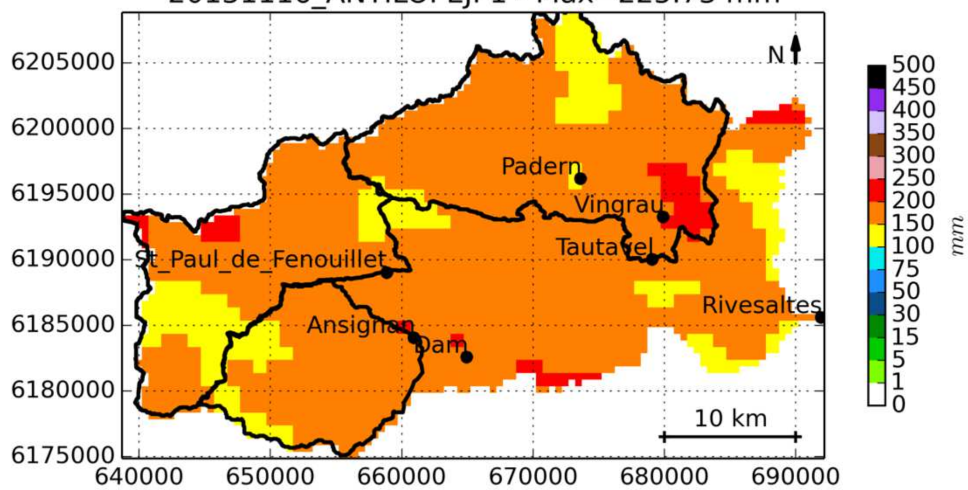


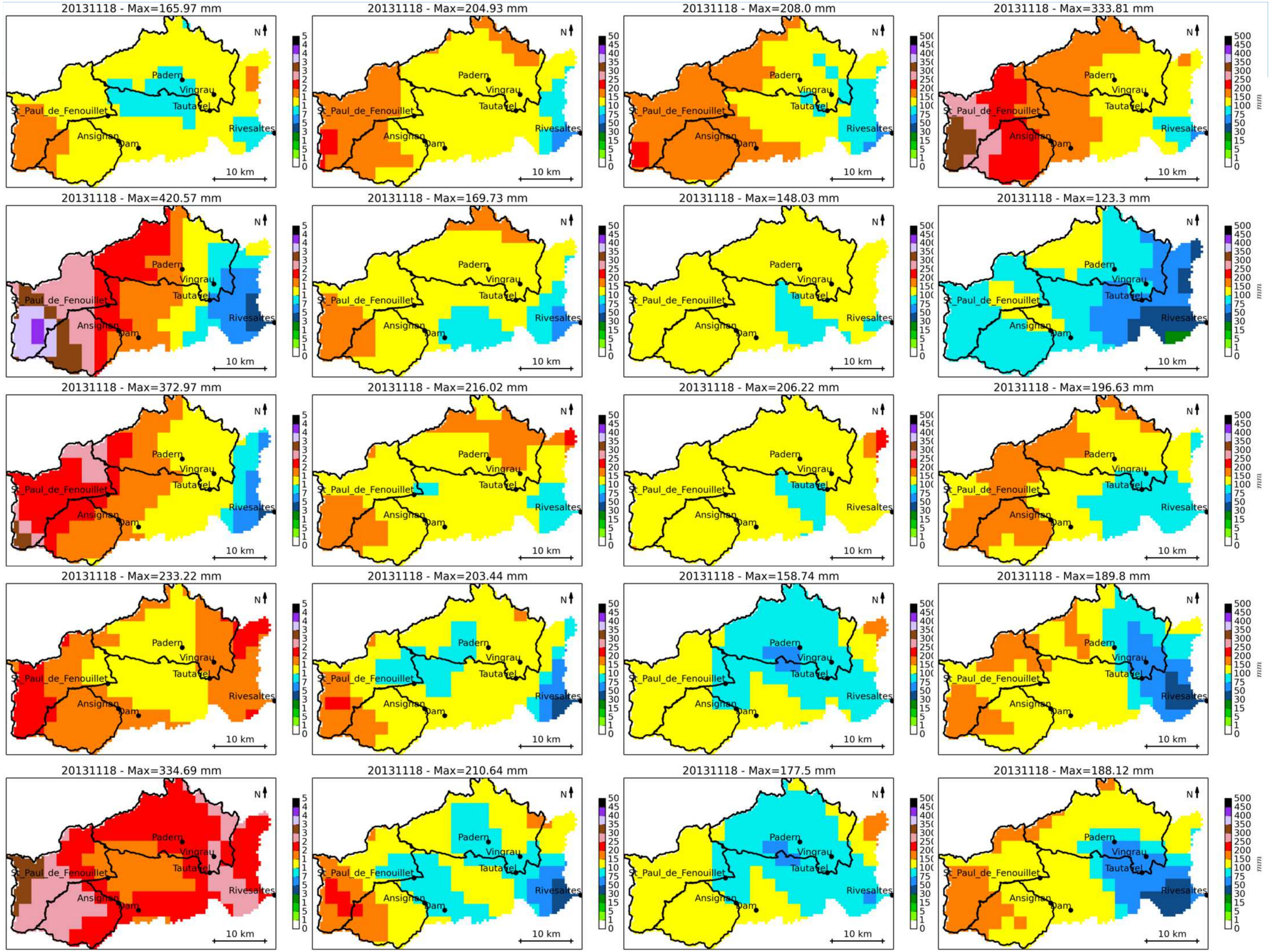
Forcing	NASH
WRF	<0.
Raingages	<0.
JP1	0.04

wholeagly500_20131118__AnsignanQ



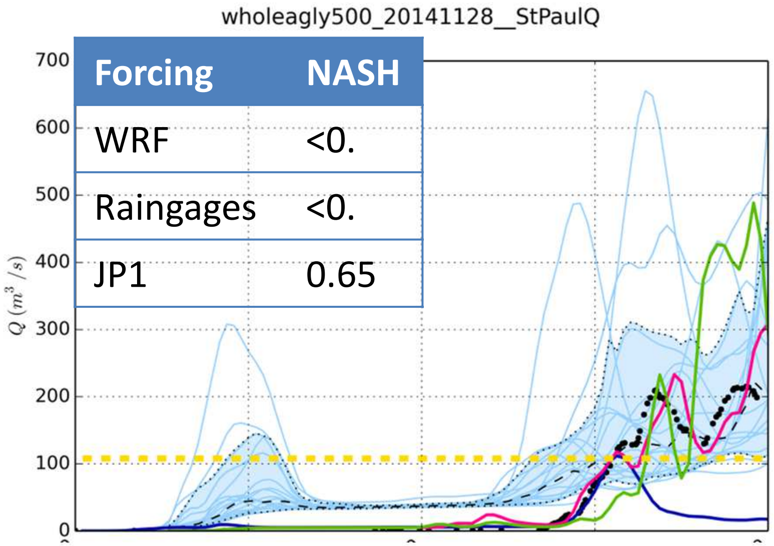
Forcing	NASH
WRF	<0.
Raingages	<0.
JP1	<0.



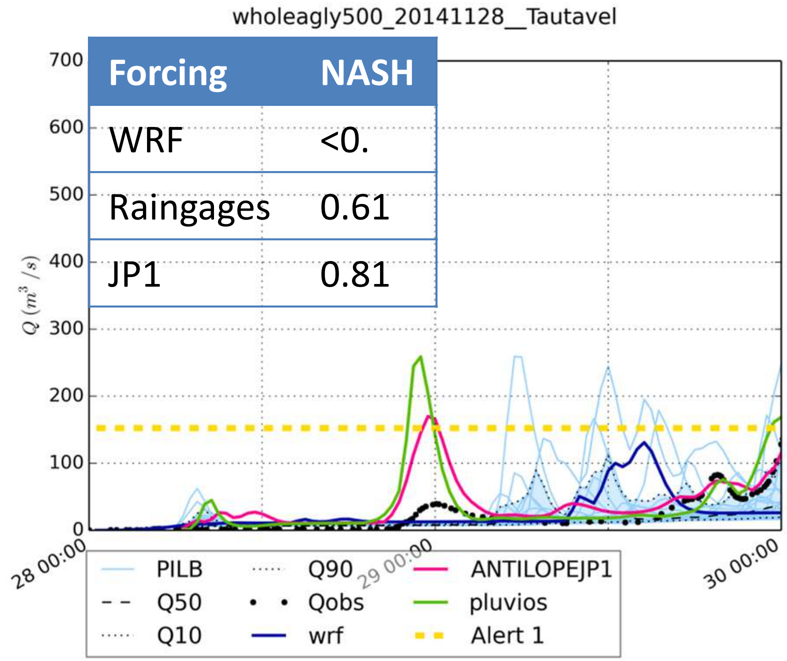

20131118 - Max=165.97 mm
20131118 - Max=204.93 mm
20131118 - Max=208.0 mm
20131118 - Max=333.81 mm
20131118 - Max=420.57 mm
20131118 - Max=169.73 mm
20131118 - Max=148.03 mm
20131118 - Max=123.3 mm
20131118 - Max=372.97 mm
20131118 - Max=216.02 mm
20131118 - Max=206.22 mm
20131118 - Max=196.63 mm
20131118 - Max=233.22 mm
20131118 - Max=203.44 mm
20131118 - Max=158.74 mm
20131118 - Max=189.8 mm
20131118 - Max=334.69 mm
20131118 - Max=210.64 mm
20131118 - Max=177.5 mm
20131118 - Max=188.12 mm
N
Padern
Vingrau
Tautavel
St_Paul_de_Fenouillet
Rivesaltes
Ansignan
Dam
10 km
500
450
400
350
300
250
200
150
100
75
50
30
15
5
1
0
mm

What lies behind: by event 20141128-30

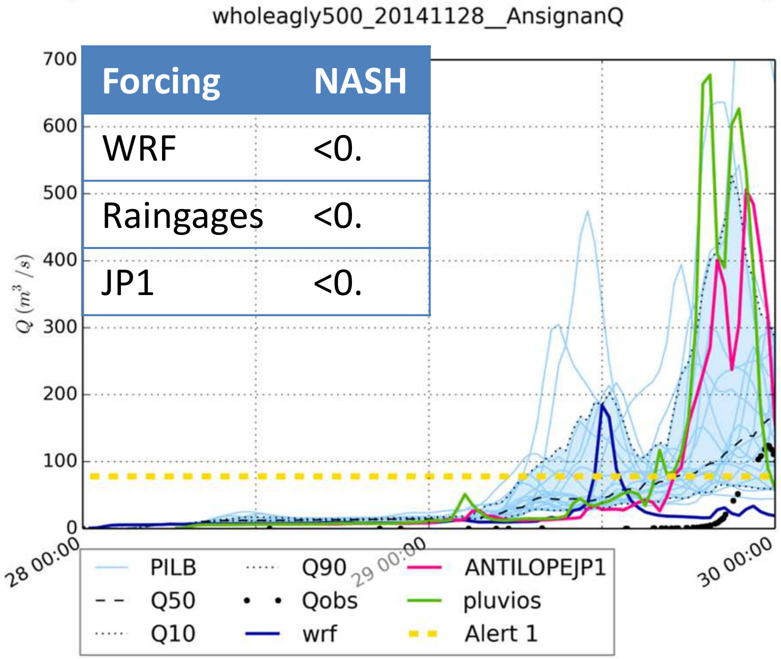
- Spatial distributions



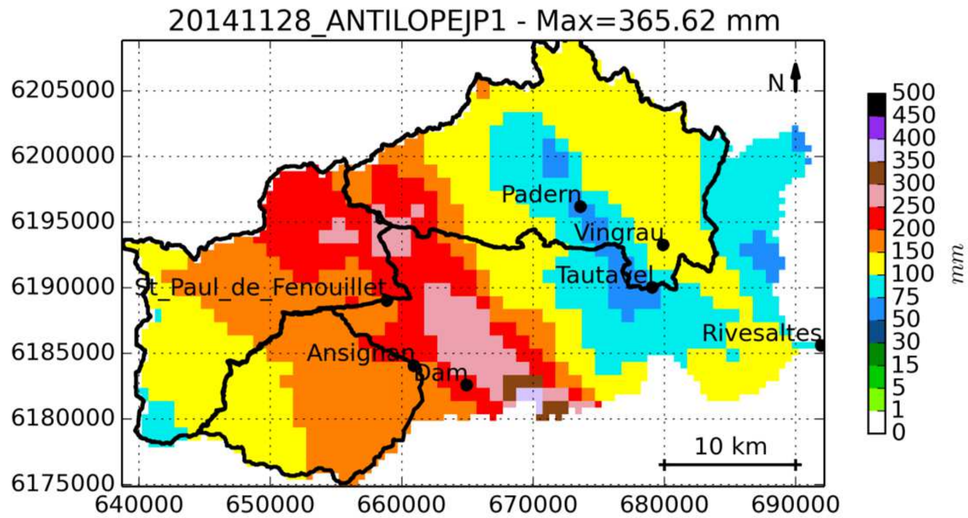
Forcing	NASH
WRF	<0.
Raingages	<0.
JP1	0.65



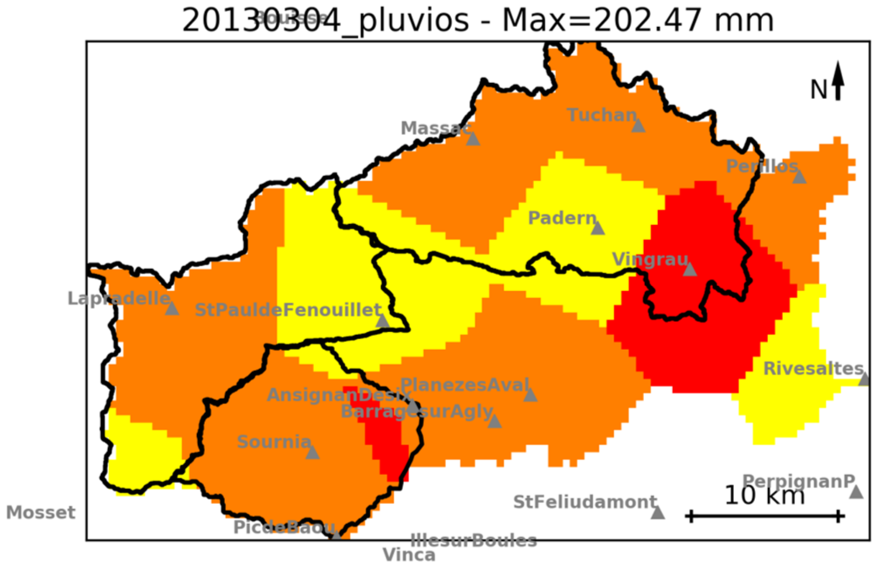
Forcing	NASH
WRF	<0.
Raingages	0.61
JP1	0.81



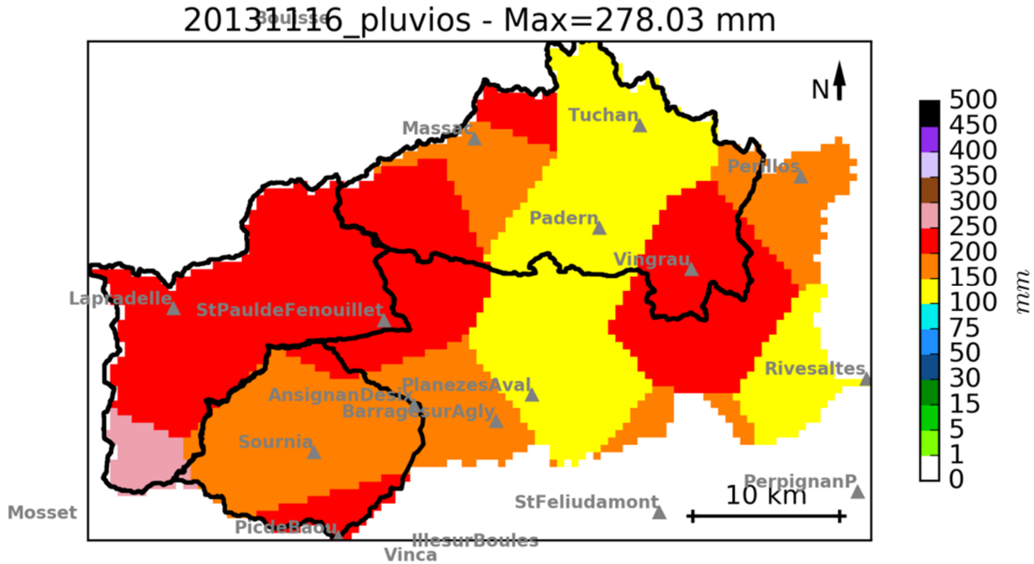
Forcing	NASH
WRF	<0.
Raingages	<0.
JP1	<0.



Raingauges accumulated rainfall



04/03 00:00 – 07/03 00:00



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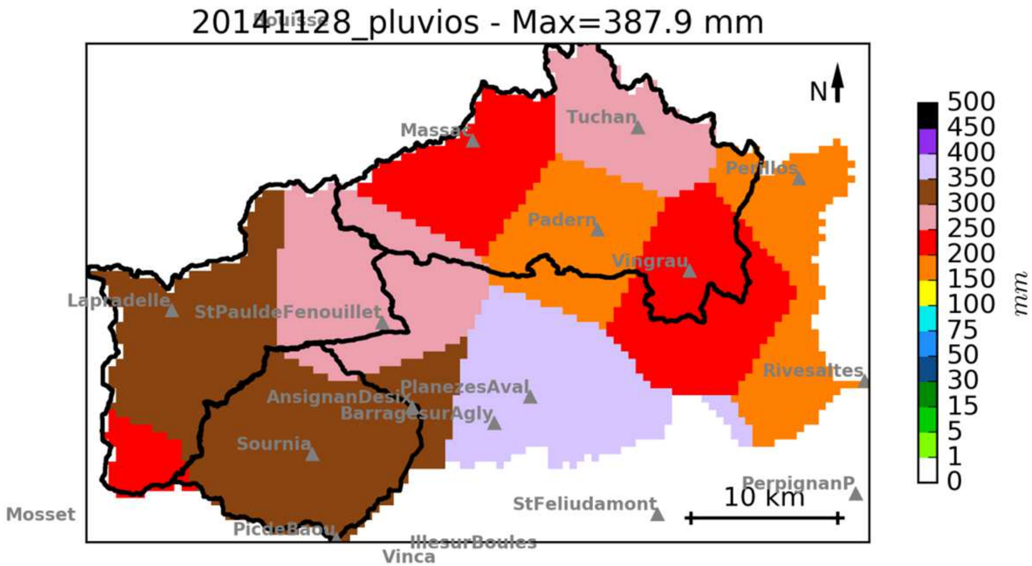

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