Evaluating NWP-based ensemble forecasts for distributed hydrological modelling and flash flood forecasting in France

Maria-Helena Ramos

Contributions from: Daniela Peredo & partners of the PICS project

Conference "Precipitation and Flash Flood Prediction from Minutes to Days"
Session: Flash Flood Prediction

7 October 2020

INRAE
la science pour la vie, l'humain, la terre

HYDRO

https://webgr.inrae.fr/

Flash floods in France

Observation and modelling challenges

2-3 October 2020

Storm Alex: Deadly flash floods hit France and Italy

BBC NEWS

23 hours ago

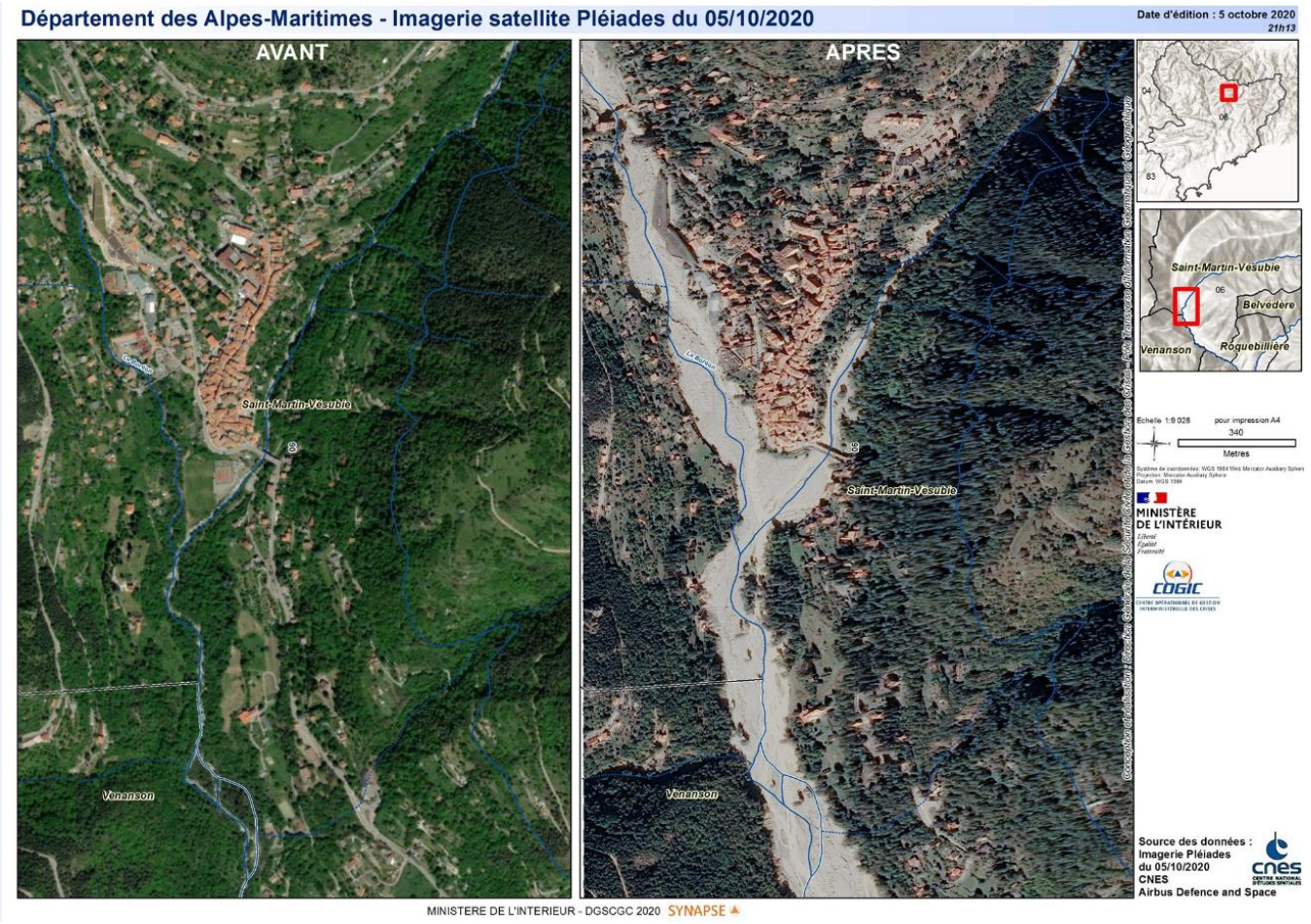
Heavy rains have caused flash floods in south-eastern France and north-western Italy, killing at least seven people on both sides of the border.

Cerema

INRAE

Flash floods in France

Observation and modelling challenges



Flash floods in France

Discharge

Station Utelle [Pont du Cros] (Vésubie)

382 km²

Maximums connus (par la banque HYDRO)

Débit instantané maximal (m3/s)	479.0 #	4/11/2014 21:29
Hauteur maximale instantanée (cm) *	518	4/11/2014 21:29
Débit journalier maximal (m3/s)	113.0 #	4/11/2014

** la synthèse étant effectuée sur la chronique complète de données (station ET stations antérieures comprises s'il en existe), la hauteur maximale connue affichée peut provenir d'une station antérieure*

Water levels

Max of records

From:

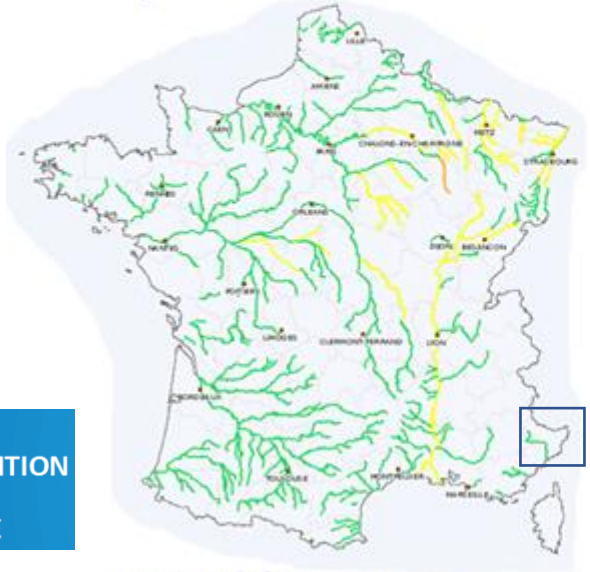
VIGICRUES

Flood forecasting and warning

FLASH: currently, a fully automated and deterministic system, based on real time observations (no rainfall forecasts)

VIGICRUES

Flood warnings for the next 24 hours
for 22,000 km of monitored rivers



www.vigicrues.gouv.fr

VIGICRUES FLASH

Flash flood warnings for
~10,300 municipalities

Vigicrues monitored rivers
Vigicrues Flash network (March 2017)

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE
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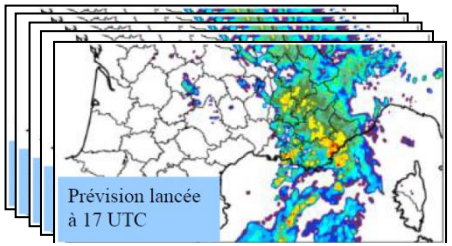
PICS project (2018-2021)

Integrated nowcasting of flash floods and related socio-economic impacts

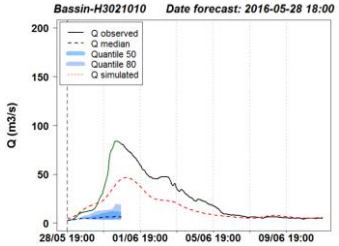
PICS

RAINFALL



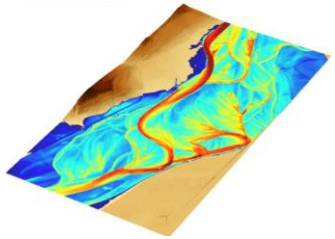
Radar + Num. Weather Prediction (0-6h)

DISCHARGES



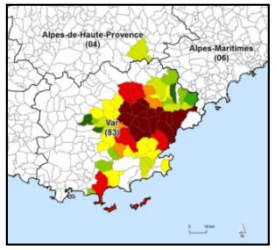
(semi)distributed Hydrological models

FLOOD AREAS



Hydraulic models

SOCIO-ECONOMIC IMPACTS



Vulnerability models

PI: Olivier Payrastre, Ifsttar (Univ. Gustave-Eiffel)

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

Partners:

Ifsttar (Univ. Gustave-Eiffel)
CCR
Cerema
CNRM / Météo-France
Géosciences Rennes,
IGE
Irstea (INRAE)
SCHAPI

PICS project (2018-2021)

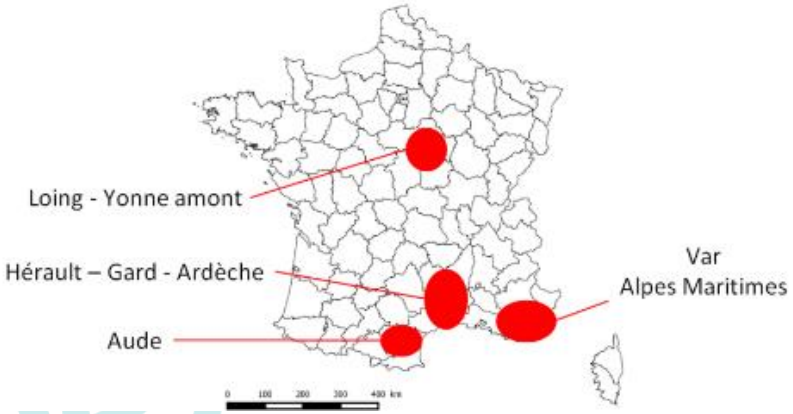
Integrated nowcasting of flash floods and related socio-economic impacts

PICS

Users group
(municipalities, fire and rescue services, railway company, insurance and energy companies, consultancy firms)

Priorities

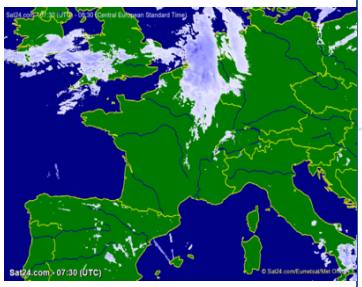
Case studies



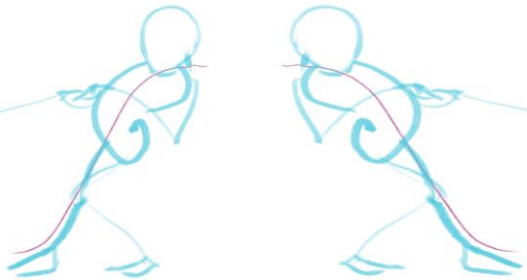
- ✓ Higher **spatial resolution**
- ✓ **Probabilistic** rainfall forecasts
- ✓ Real-time inundation **maps**

Ensemble-based approaches

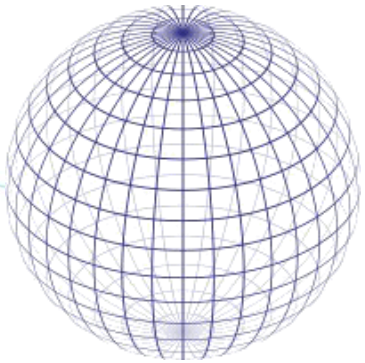
Provide early warnings with sufficient lead time: forecast the location, magnitude, onset, end of events



Observation



Nowcasting + NWP outputs

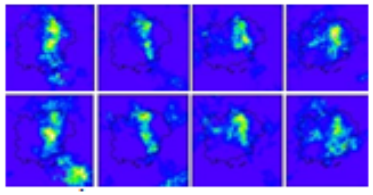


Numerical weather model

time

0 h 2 h 4 h 6 h

Adapted from A. Caseri (2017)



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Hydrological Models

...

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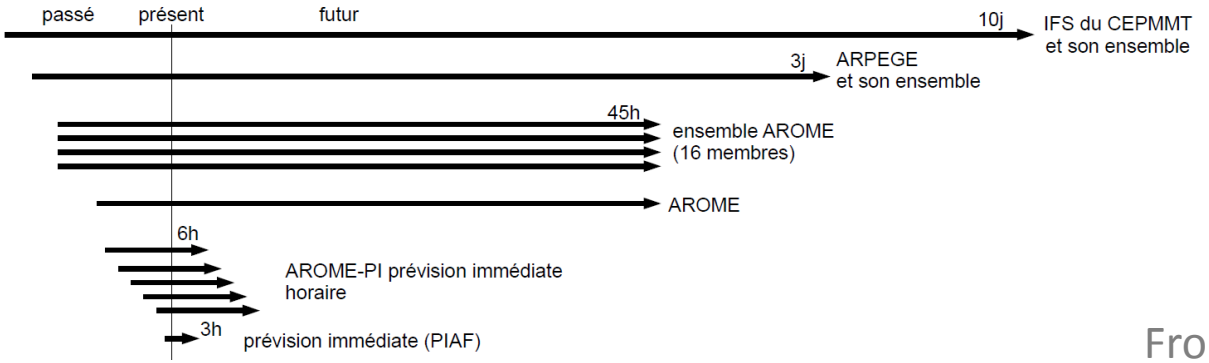
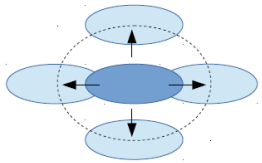
NWP-based ensemble forecasts for distributed hydrological modelling

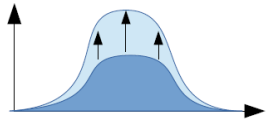
Main challenges in NWP-based ensemble forecasts

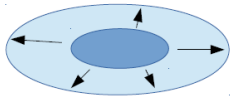
1. variable systems and forecasts (quality, resolution, real-time availability) **=> combination**



2. lack of diversity (ensemble size) **=> perturbations**







From: François Buttier et al.

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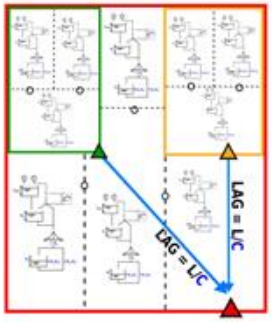
NWP-based ensemble forecasts for distributed hydrological modelling



Main challenges in distributed hydrological ensemble forecasting

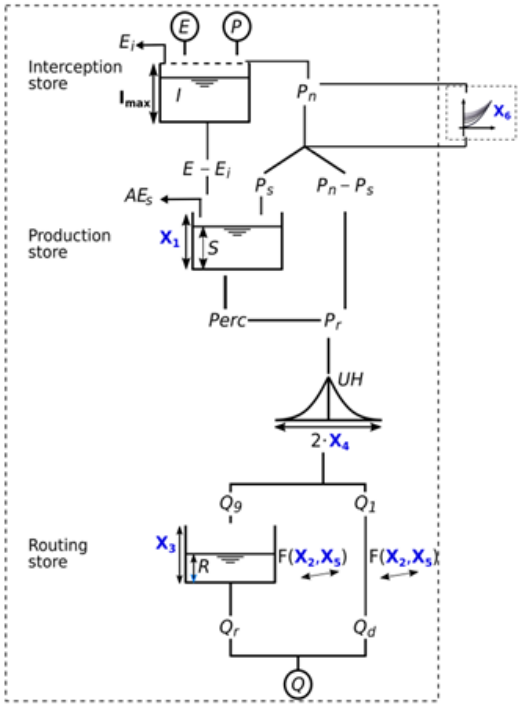
1. variable conditions in space and time to fit into a (parsimonious) model conceptualisation
   => improving model versatility

2. forecast evaluation (ungauged sites, performance measures, detection of source of errors)
   => diagnostic verification of forecasts *vs* 'details matter'

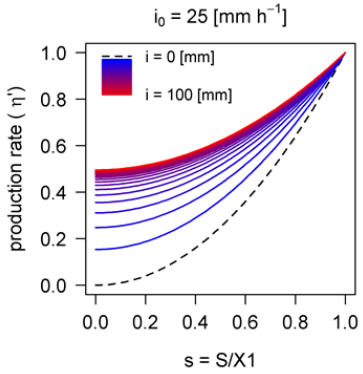
NWP-based ensemble forecasts for distributed hydrological modelling

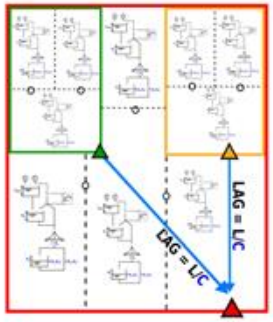
1. Improving hydro model versatility

GRSD: existing model



GRSDi: adapted model





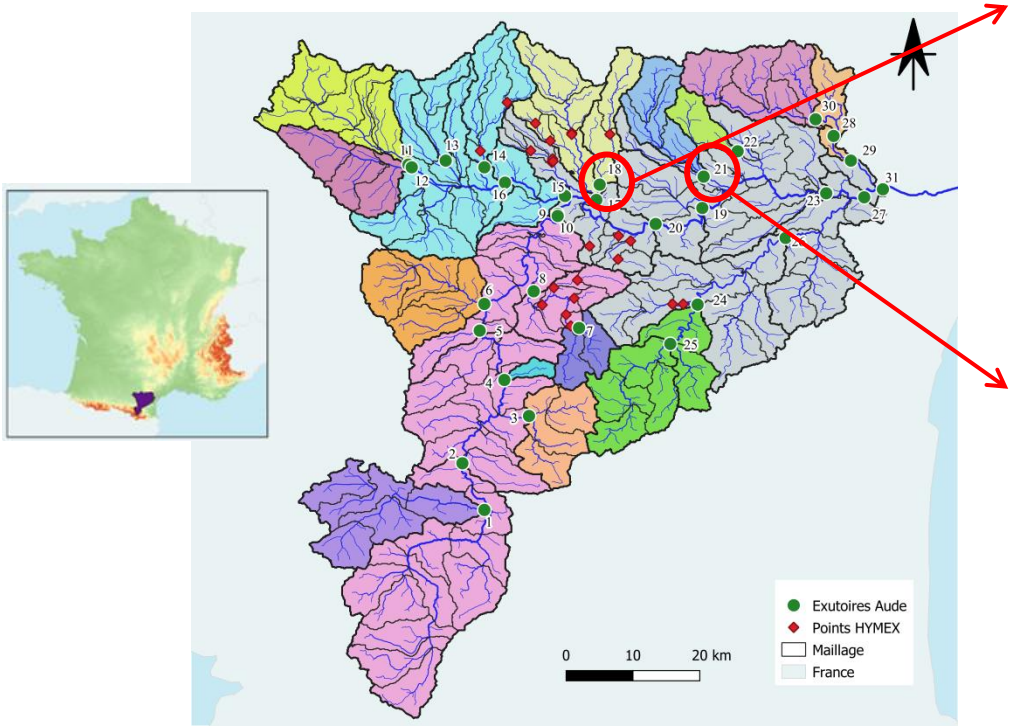
From: Daniela Peredo et al. (submitted)

NWP-based ensemble forecasts for distributed hydrological modelling

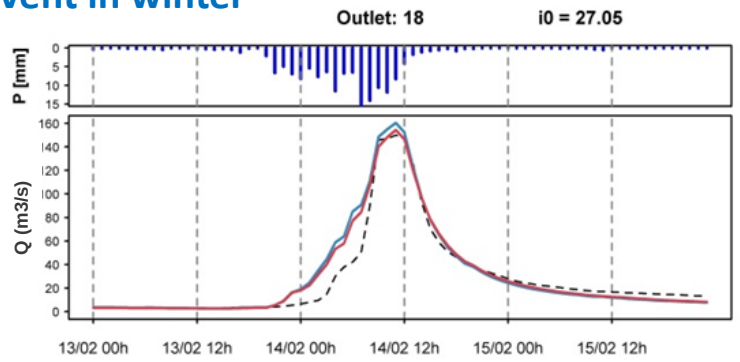
GRSDi: adapted model

1. Improving hydro model versatility

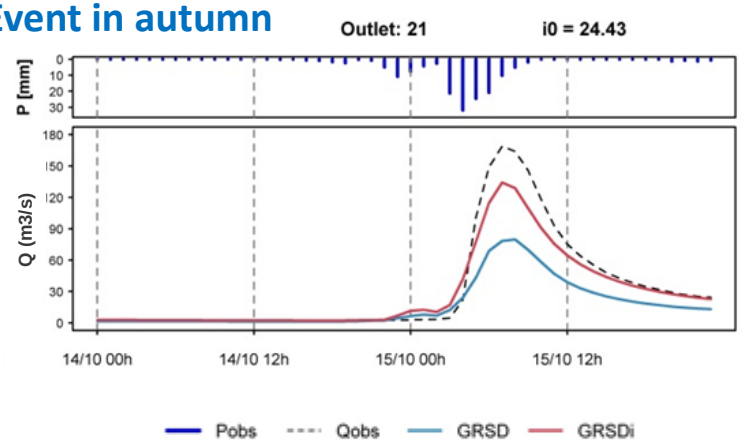
Case study: Aude River Basin



Event in winter



Event in autumn



From: Daniela Peredo et al. (submitted)

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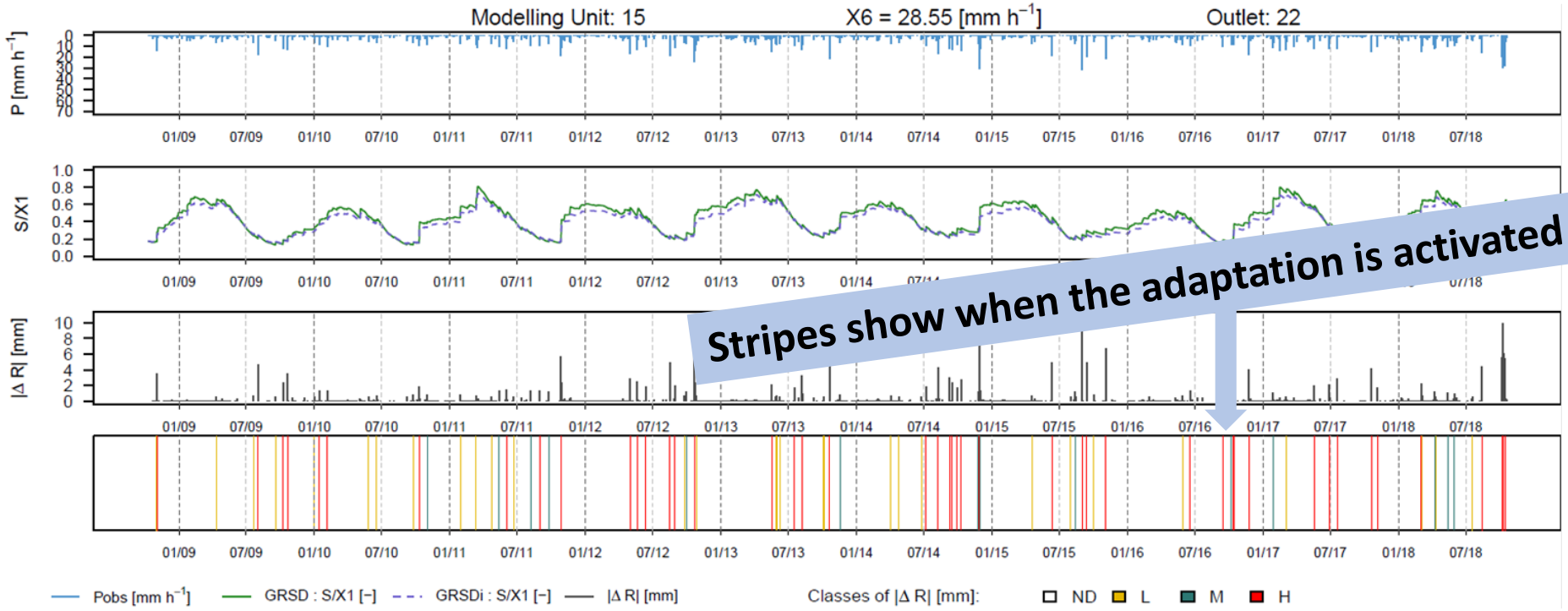
NWP-based ensemble forecasts for distributed hydrological modelling

1. Improving hydro model versatility

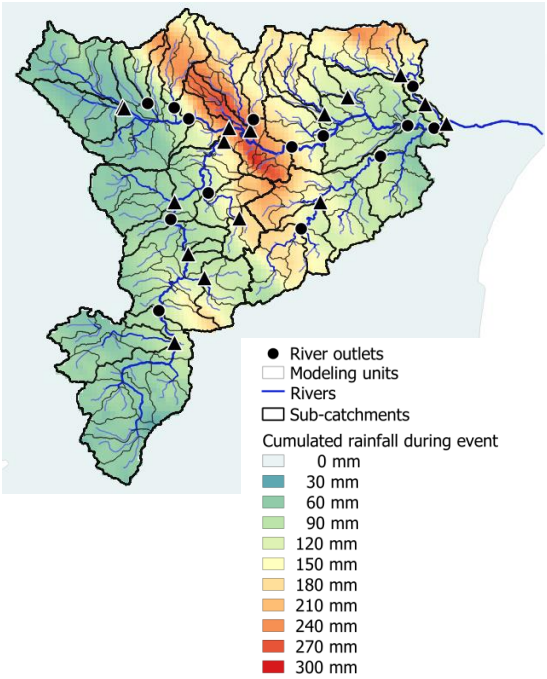


From: Daniela Peredo et al. (submitted)

NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

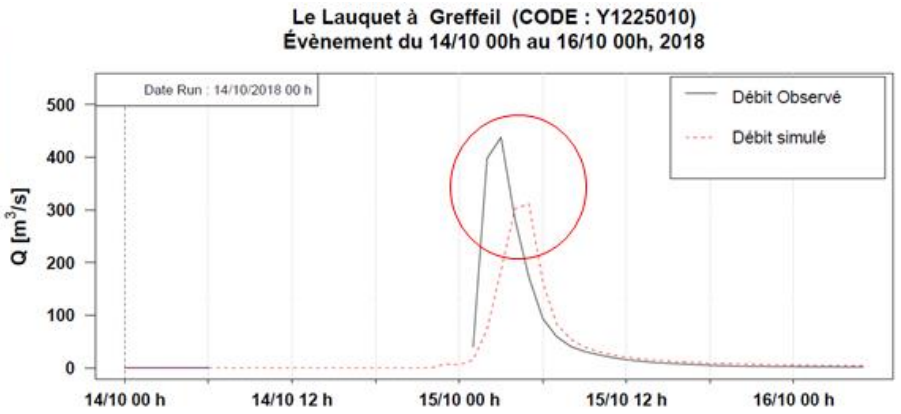
Radar precipitation (ANTILOPE J+1)
From 14/10/2018 0h to 15/10/2018 23h



NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Le Lauquet à Greffeil



Source: https://www.saint-hilaire-aude.fr/assets/uploads/2018/Retour_d_exp_rience_crue_lauquet_2018_V_SMAH.pdf

Maximums connus (par la banque HYDRO)		
Débit instantané maximal (m3/s)	496.0 #	15/10/2018 02:55
Hauteur maximale instantanée (cm) *	399	15/10/2018 02:55

Source: Banque HYDRO

Quelques chiffres :

Volume correspondant : 4, 5 M de m3

Un débit Saint Hilaire : 650 m3/s environ

Équivalent de la crue de l'Aude à Limoux

Station de Greffeil 320 m3/s

Montée : 6 m en 2 H

Probablement 10 m en 4 H

Bassin versant	Cours d'eau	Lieu	X (L 93)	Y (L 93)	Date du pic	Heure du pic (UTC)	BV amont (km²)	Qmin (m3/s)	Qp (m3/s)	Qmax (m3/s)
Lauquet	Lauquet	Greffeil	649109	6220066	15/10/2018		73,1	195	275	350

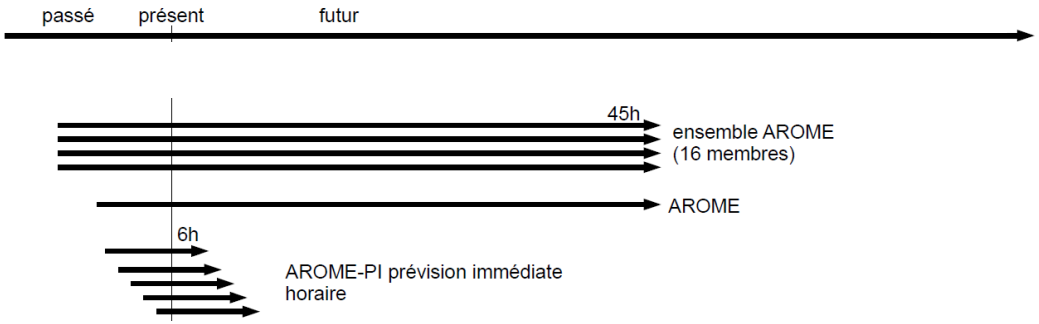
Source: Lebouc et al. (2019) https://hal.archives-ouvertes.fr/hal-02110612/document

NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Three sets of ensemble precipitation forecasts (from Météo-France/CNRM):

1. pe (AROME pe)
2. pepi (AROME pe + AROME pi)
3. pertDpepi (AROME pe + AROME pi + spatio-temporal perturbations)



Variable number of members

	+1	+2	+3	+4	+5	+6
pe	12	12	12	12	12	12
pepi	18	17	16	15	14	13
pertDpepi	90	85	80	75	70	65

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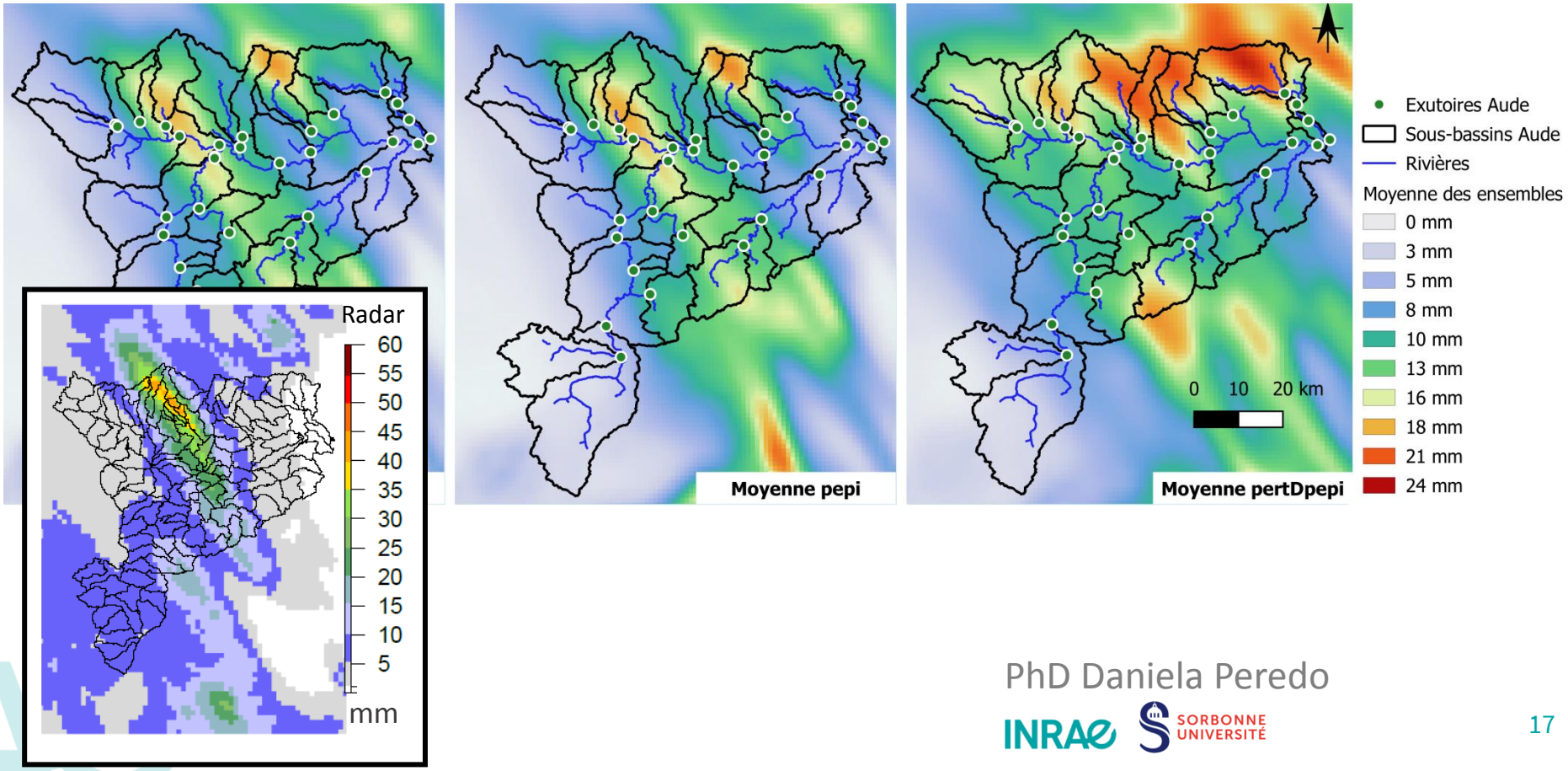
NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Example of forecast issued on 15 Oct at 1h, +1h (ensemble mean)



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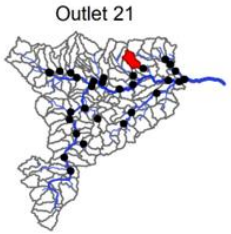
NWP-based ensemble forecasts for distributed hydrological modelling

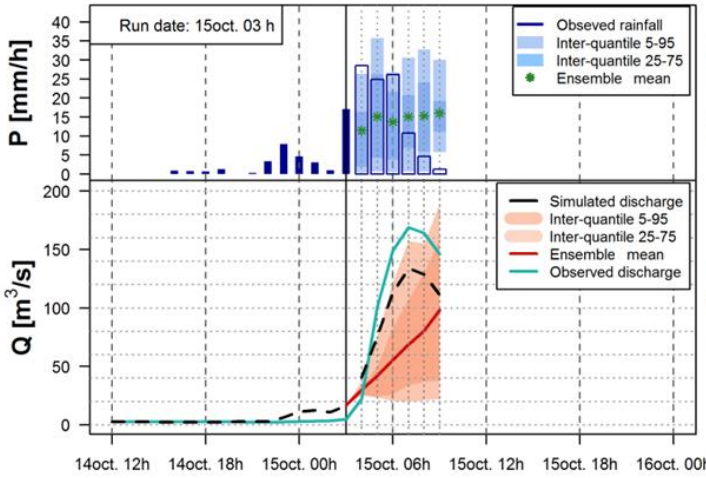
2. Hydro forecast evaluation

Inital over-estimation combined with high spread masks subsequent underestimation at the peak time

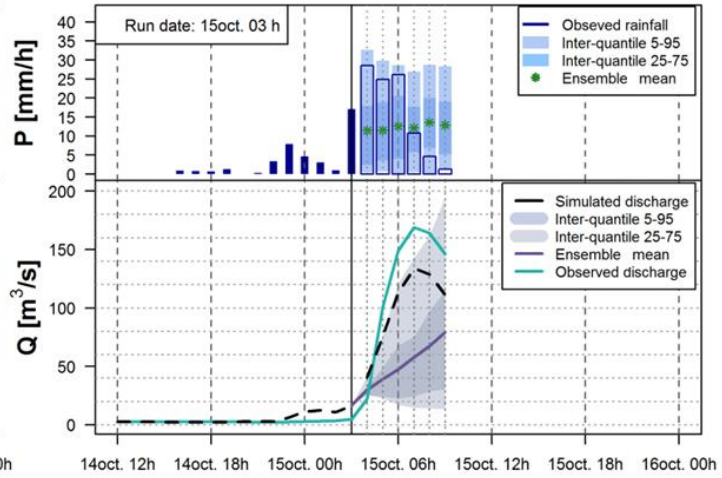
Example for a gauged site



pepi



pertDpepi



Simulated discharge: hydrological model with observed rainfall

NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

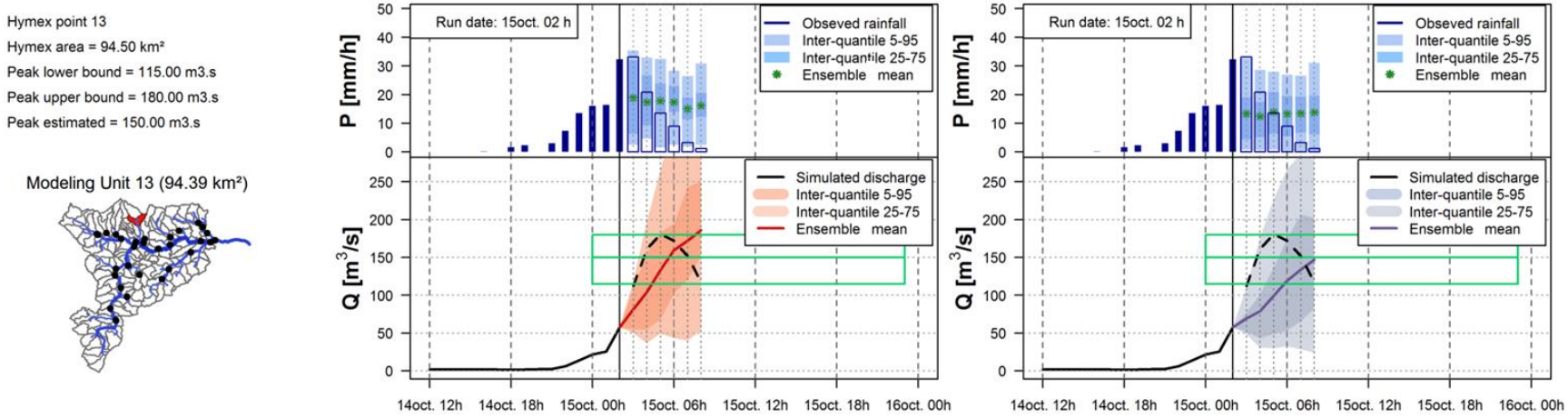
Inital over-estimation combined with high spread masks subsequent underestimation at the peak time

Example for an ungauged site

(HYMEX estimation of peak flow)

pepi

pertDpepi



Simulated discharge: hydrological model with observed rainfall

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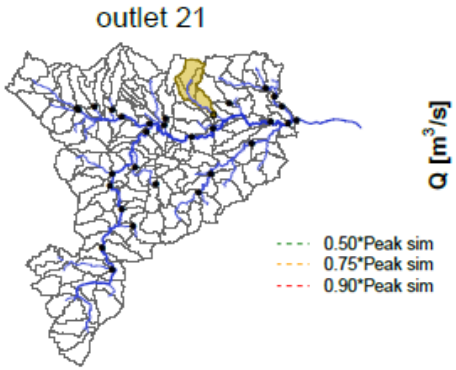
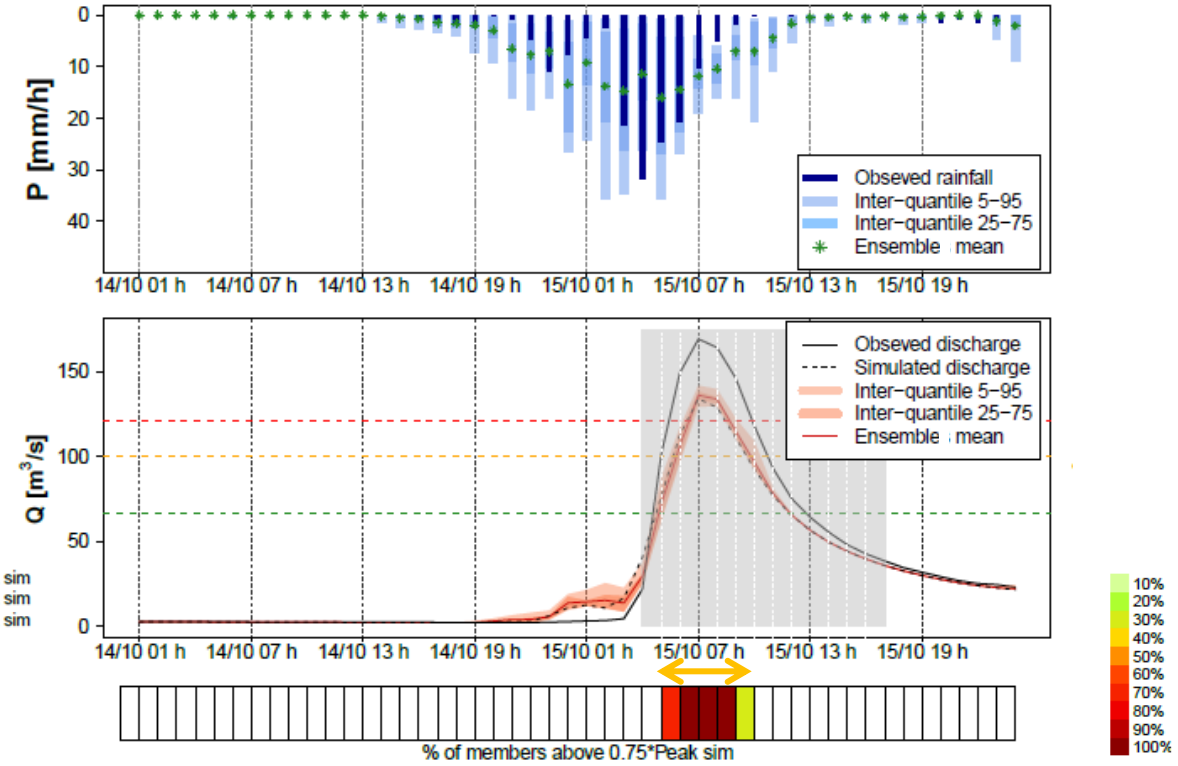
NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Impacts on anticipation of threshold exceedance and timing

Lead time: +1h
18 members





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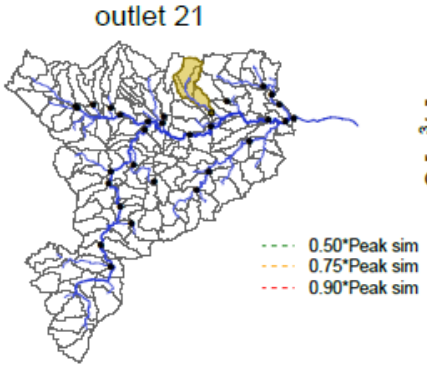
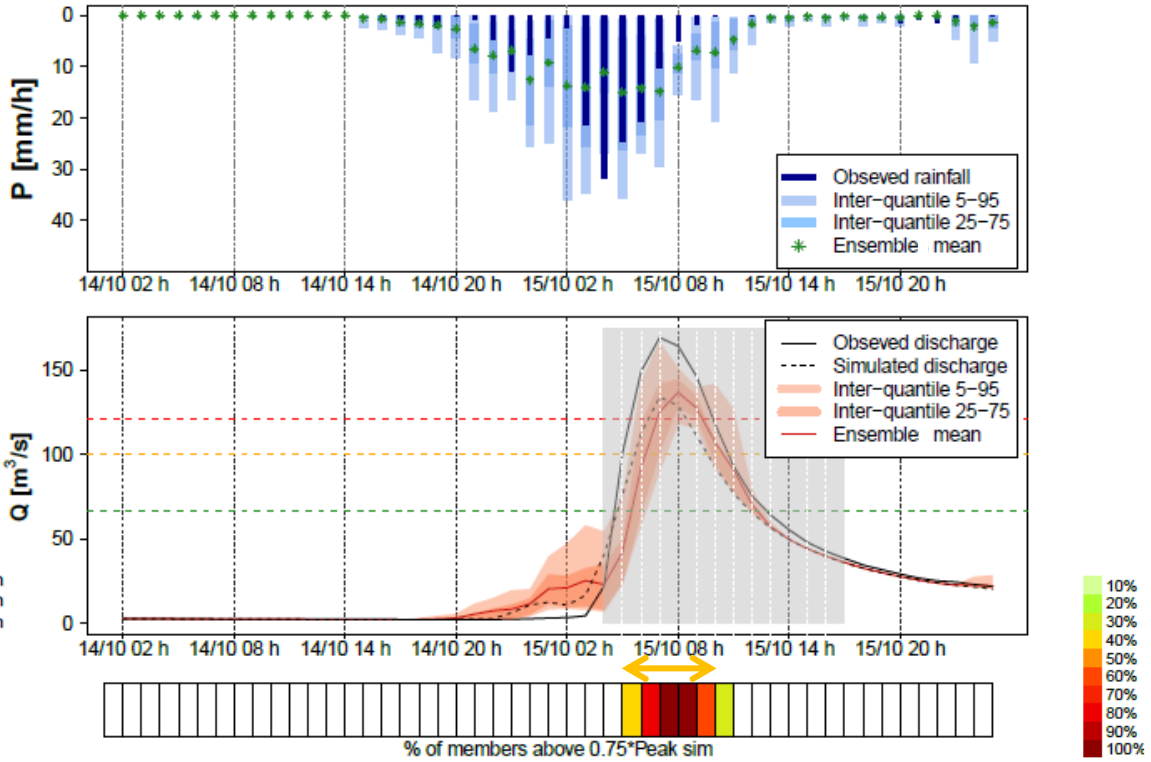
NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Impacts on anticipation of threshold exceedance and timing

Lead time: +2h
17 members





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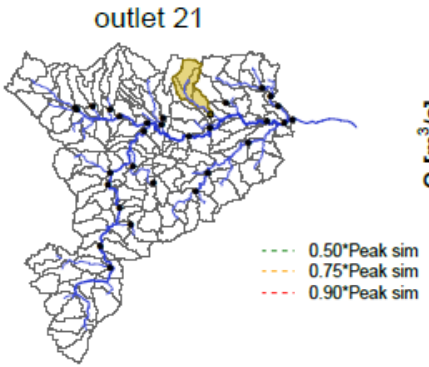
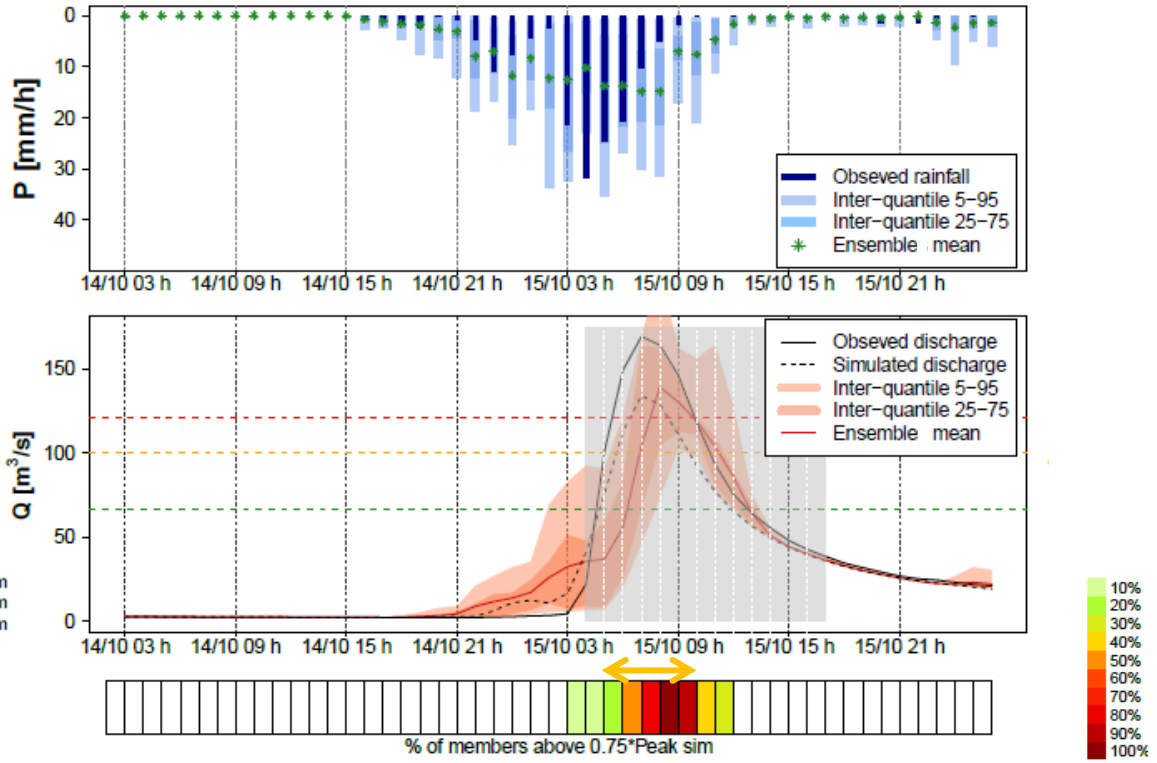
NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Impacts on anticipation of threshold exceedance and timing

Lead time: +3h
16 members



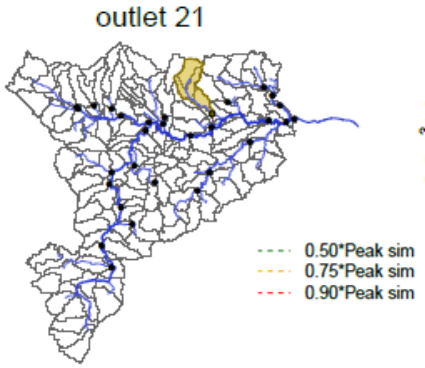


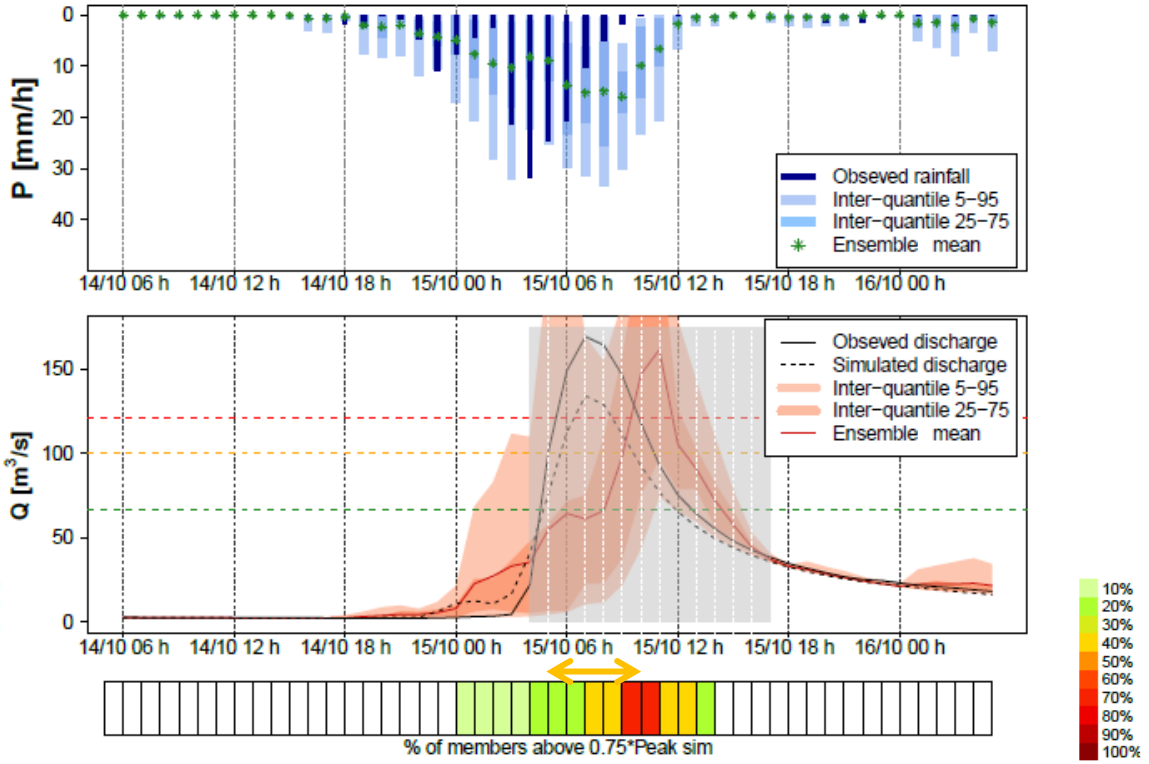
NWP-based ensemble forecasts for distributed hydrological modelling

2. Hydro forecast evaluation

Impacts on anticipation of threshold exceedance and timing

Lead time: +6h
13 members





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Conclusion and way forward

- ***"Models sometimes generate more questions than it answers"***: adaptive models can be great, but still need to maintain 'simplicity' (operational context)

- ***"It would have been a good hydro forecast if it was not for the bad rainfall forecast"***: we may not be able to live without post-processing (focus on impact chain)

- ***"Hindsight is a wonderful thing but foresight is better…"* [W. Blake]**: a good understanding of past events, with more structured event-based evaluations may contribute to better forecasts (community effort)

Thank you for your attention!

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