PROJECTE TRAMPAS

Segona reunió: 24/10/2023

The 22 October 2019 catastrophic flash flood in Catalonia, north-eastern Spain: hydrological and social factors

1. Background

Flash floods are typically associated with quasi-stationary heavy precipitation episodes (HPEs)

Physical factors:

1. Meteorological

2. Hydrological: (i) Small-to-medium coastal basins; (ii) thin soils, sparse vegetation cover and steep slopes

Formation of sudden flood bores leading to catastrophic effects downstream

Social factors: Basin modification and urbanization. Global warning

1. Background

Social impacts related to the decrease in catchment area

Time reduction in basin response

People more exposed to flash-flooding. Non-structural measures become crucial

Hydrometeorological monitoring and forecasting should provide warnings with the shortest lead times

Structured response in form of pre-established defense actions

1. Background

Flash flood monitoring and forecasting build on the relationship between catchment and social response times

Catchment response time > social response time: hydrological and/or hydraulic models can provide forecasts at the required lead times

Catchment response time < social response time: quantitative precipitation estimates/forecasts from radar/NWP models. Lead times: < 1 h to 48 h

2. Motivations and objectives

Objectives:

1. Examine the primary hydrometeorological factors that concurred to the unfolding of the episode

2. Assess the relationship between catchment dynamics and social response times

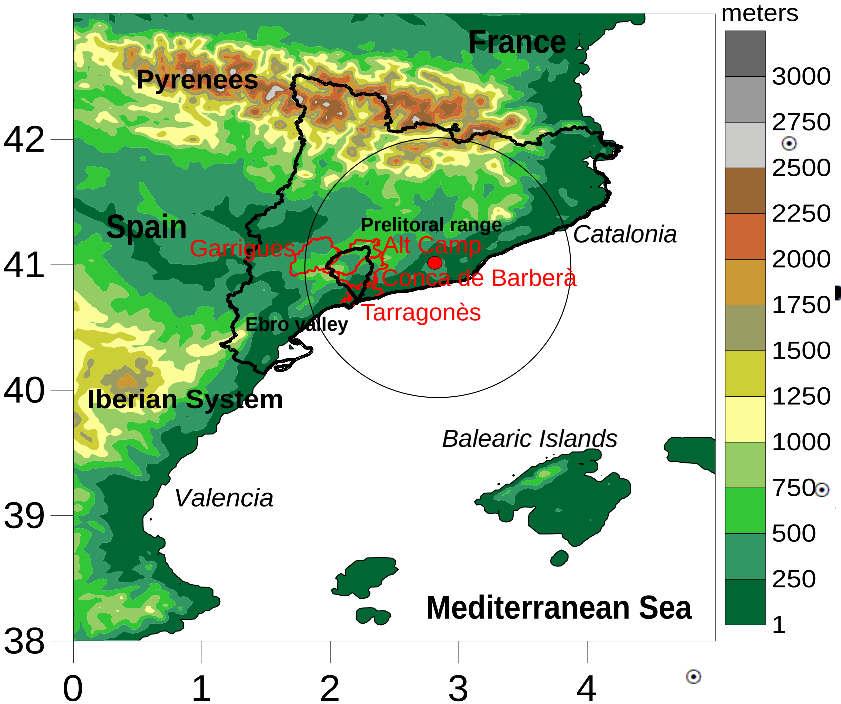
Are the social protocols effective in meeting the requirements of the population at risk?

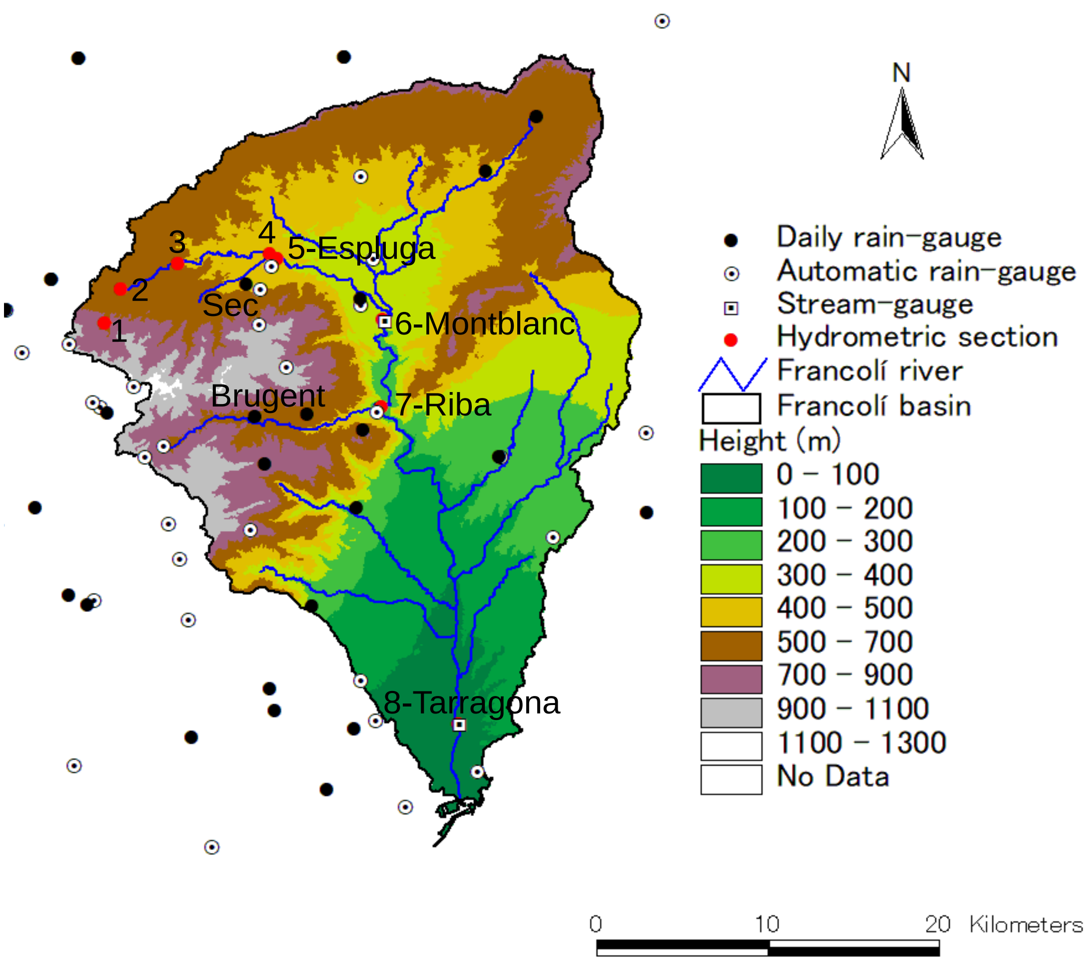
Identify potential areas for improvement in the management of catastrophic flash flooding

3. The 22 October 2019 flash flood

- The Francolí is a semi-arid basin with a drainage area of 858 km^2 located in Catalonia, northeastern Spain

- Peak discharge at Tarragona (809.1 km^2): 871 m^3s^{-1} at 22:30 UTC





3. The 22 October 2019 flash flood

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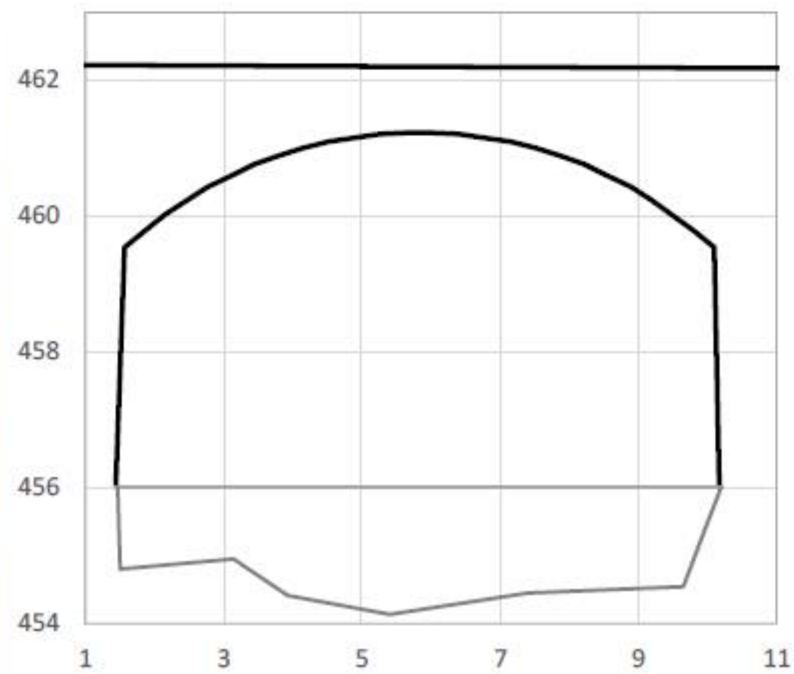
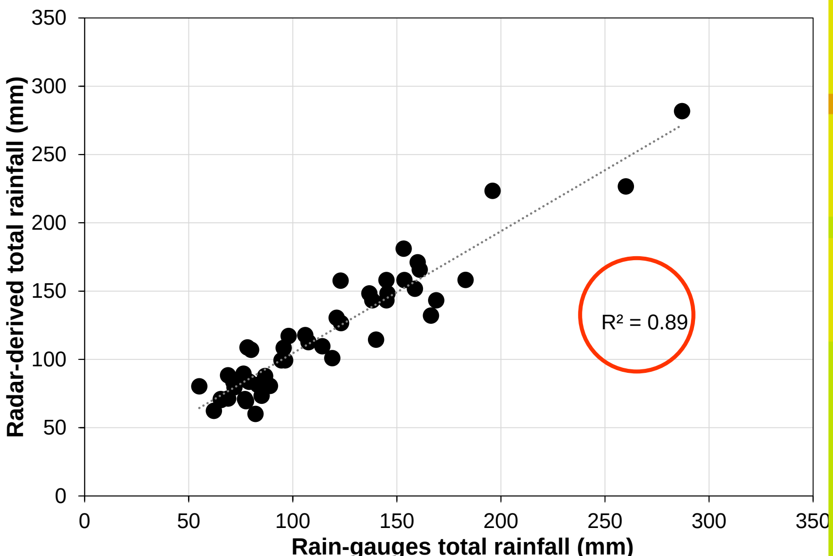


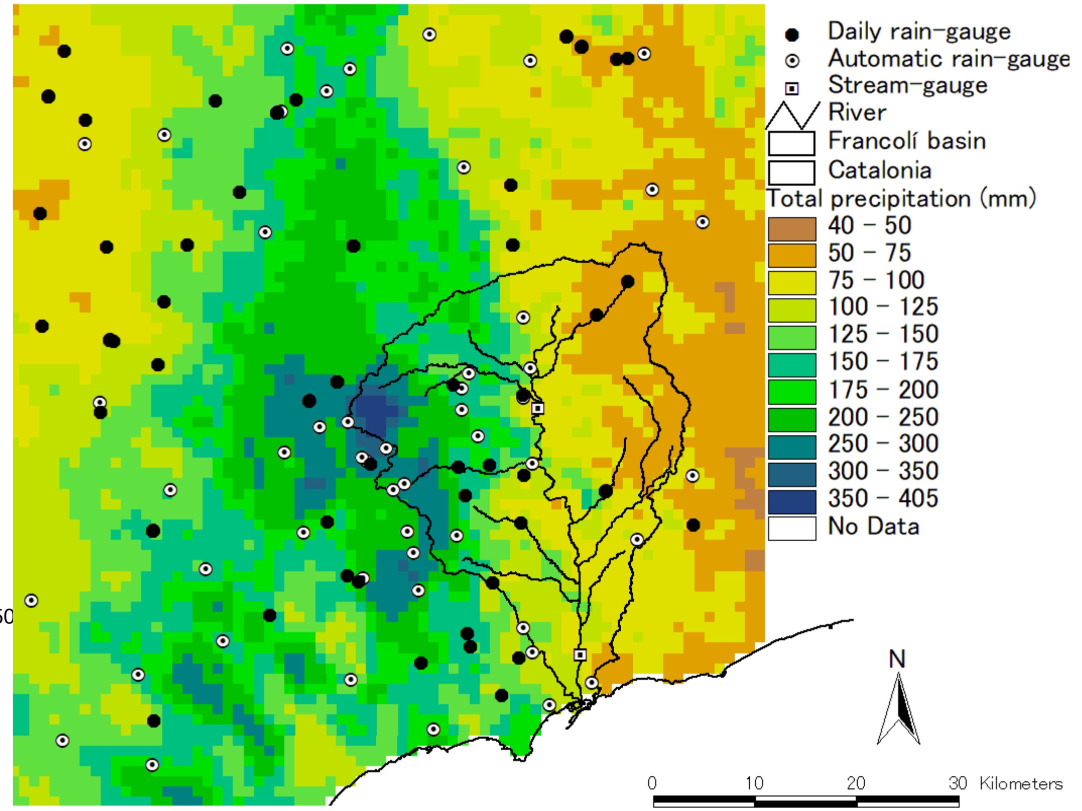
3. The 22 October 2019 flash flood

Montblanc
~ 300 km²
20:20–20:45 UTC

4. Observed databases

- Quantitative precipitation estimates (QPEs): reflectivity volume scans of Barcelona radar from 22 to 24 October 2019 00 UTC
- Spatial resolution: 1 km in range and 0.8º in azimuth. Every 10-min
- 5- and 10-min rainfall available from 59 automatic stations very close or inside the basin (AEMET + ACA + Meteoprades)
- 10-min runoff available in Tarragona





5. Precipitation organization: spatial and temporal scales

Observed rainfall amounts up to 299.5 mm. Three successive convective bands impacted the basin on 22 October:

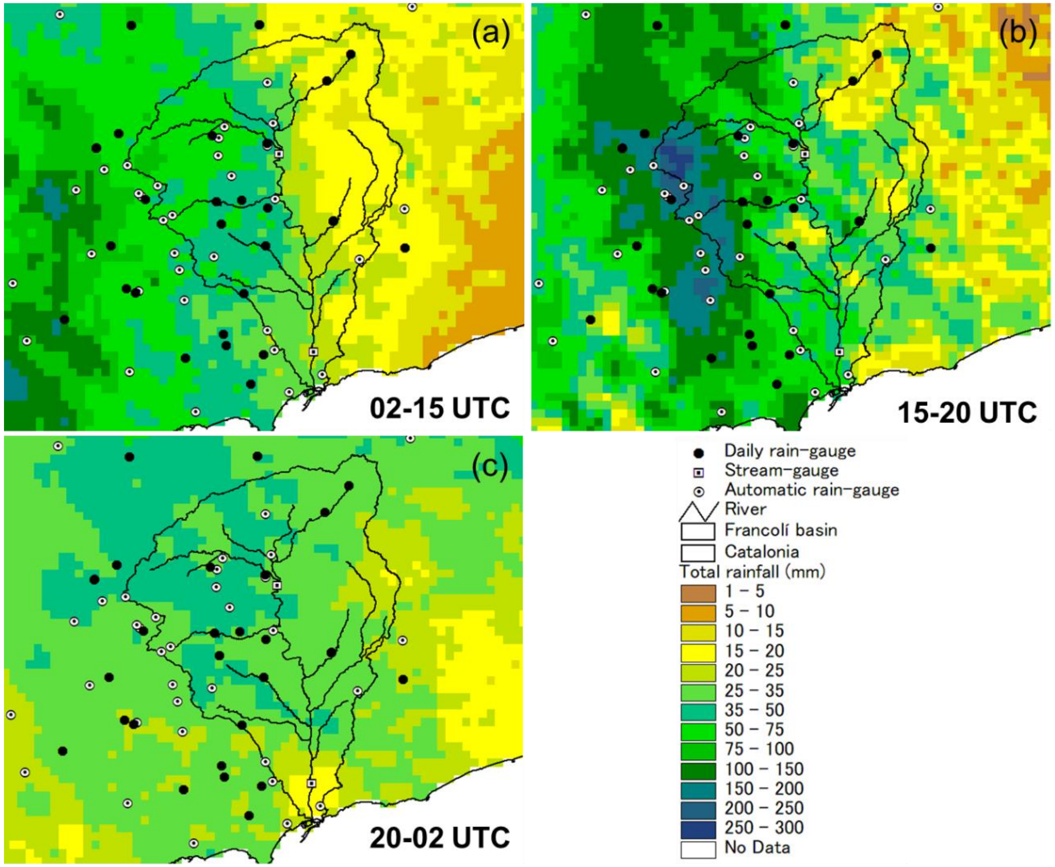
- 02-14 UTC: 72 mm and 10-min rainfall rate of 42 mmh^{-1}
- 16-20 UTC: 193.4 mm and 10-min rainfall rate of 124.8 mmh^{-1}
- 21-02 UTC: 39.5 mm and 10-min rainfall rate of 26.4 mmh^{-1}

Local topographic forcing played a crucial role in focusing and amplifying the maximum rainfall amounts.

According to QPEs, basin areas

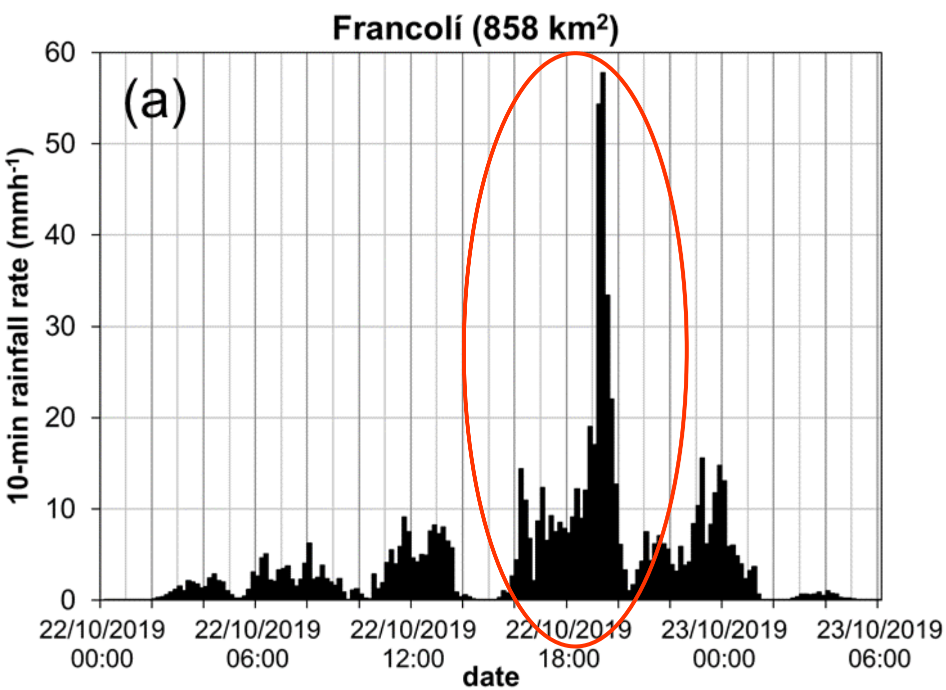
~ 110 km^2 with > 200 mm

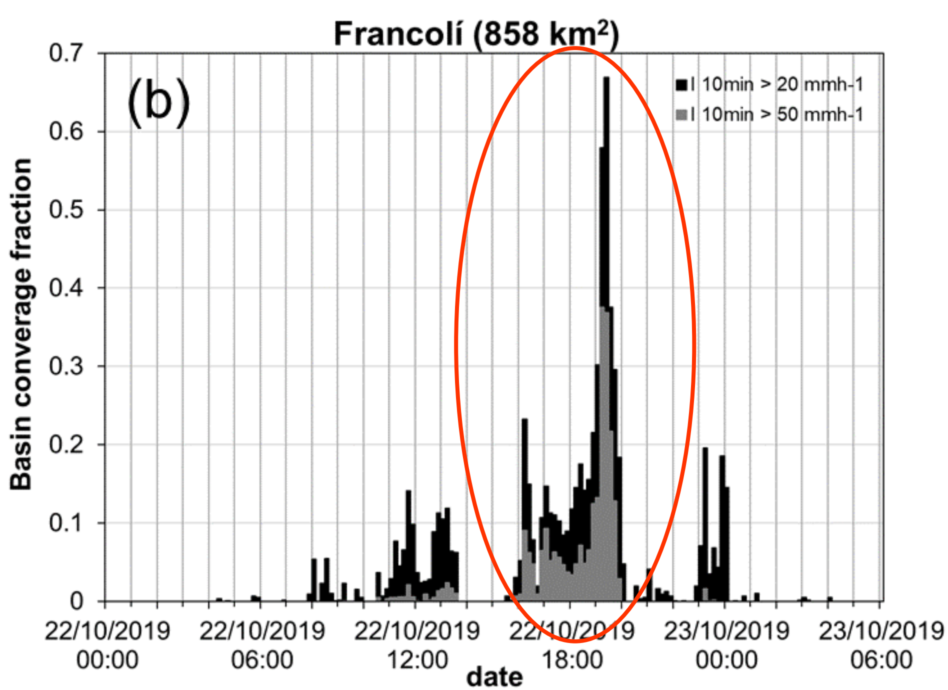
~ 25 km^2 with > 300 mm



5. Precipitation organization: spatial and temporal scales

- 10% of basin experienced 10-min rainfall rates > 20 mmh^{-1} for more than 4 h and > 50 mmh^{-1} for 1 h
- 5% of basin experienced 10-min rainfall rates > 20 mmh^{-1} for 7 h and > 50 mmh^{-1} for 2.5 h
- Most intense rainfall period 18:50–19:40 UTC. Rainfall intensities greater than 20/50 mmh^{-1} affected drainage areas of 574.0/322.6 km^2



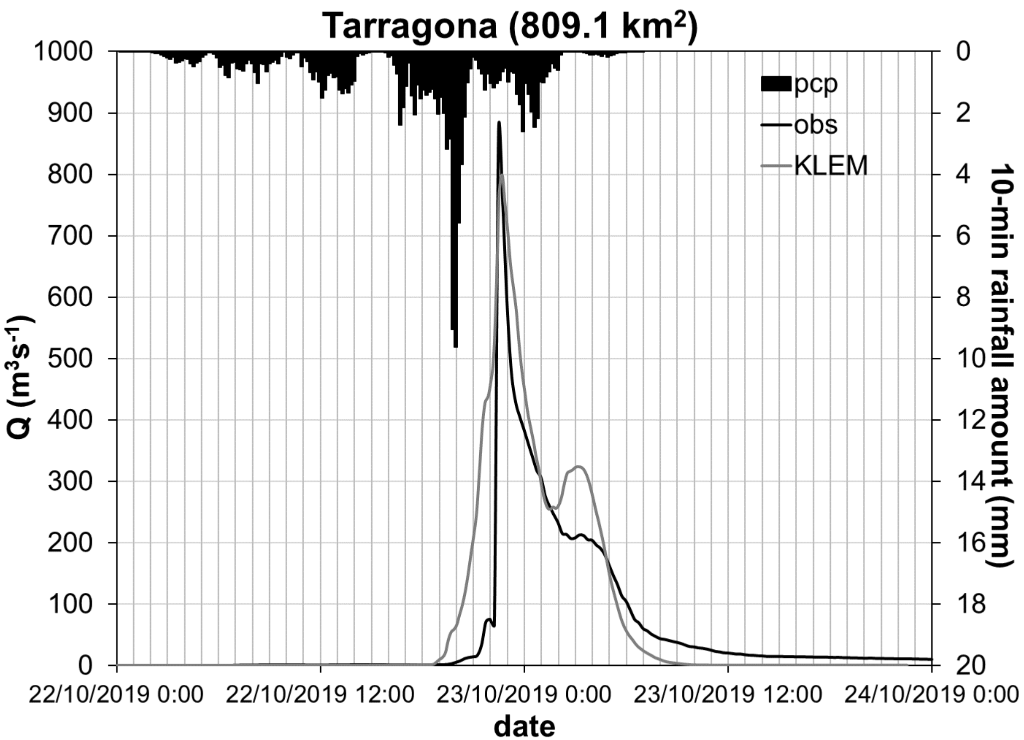


6. Flood response: hydrological modelling

- Flash flood with catastrophic impacts over drainage areas < 500 km^2
- Infiltration parameters from field measurements. Set to dry soil moisture conditions. Channel flow velocity from field estimations
- Calibrated parameters: initial abstraction and hillslope flow velocity

CN (AMC I)	I_a (mm)	S (mm)	V_h (ms^{-1})	V_c (ms^{-1})
44.9 (11.6)	125.6 (66.7)	358.9 (190.5)	0.25	4.5

Flow volume			Flow peak			NSE
Observed (mm)	KLEM (mm)	Error (%)	Observed (m^3s^{-1})	KLEM (m^3s^{-1})	Error (%)	0.7
12.4	15.1	21.5	871.0	798.8	-10.9	



6. Flood response: sensitivity tests

Assess the role of:

1. Test 1: Soil moisture content. Only rainfall from 16:00 UTC is considered. Infiltration parameters: Normal moisture conditions (antecedent rainfall ≤ 53.3 mm)

2. Test 2: Antecedent precipitation. Effect of rainfall 02:00–14:00 UTC on 22 October, before the most intense rainfall period. Precipitation is disregarded. Infiltration parameters: control simulation

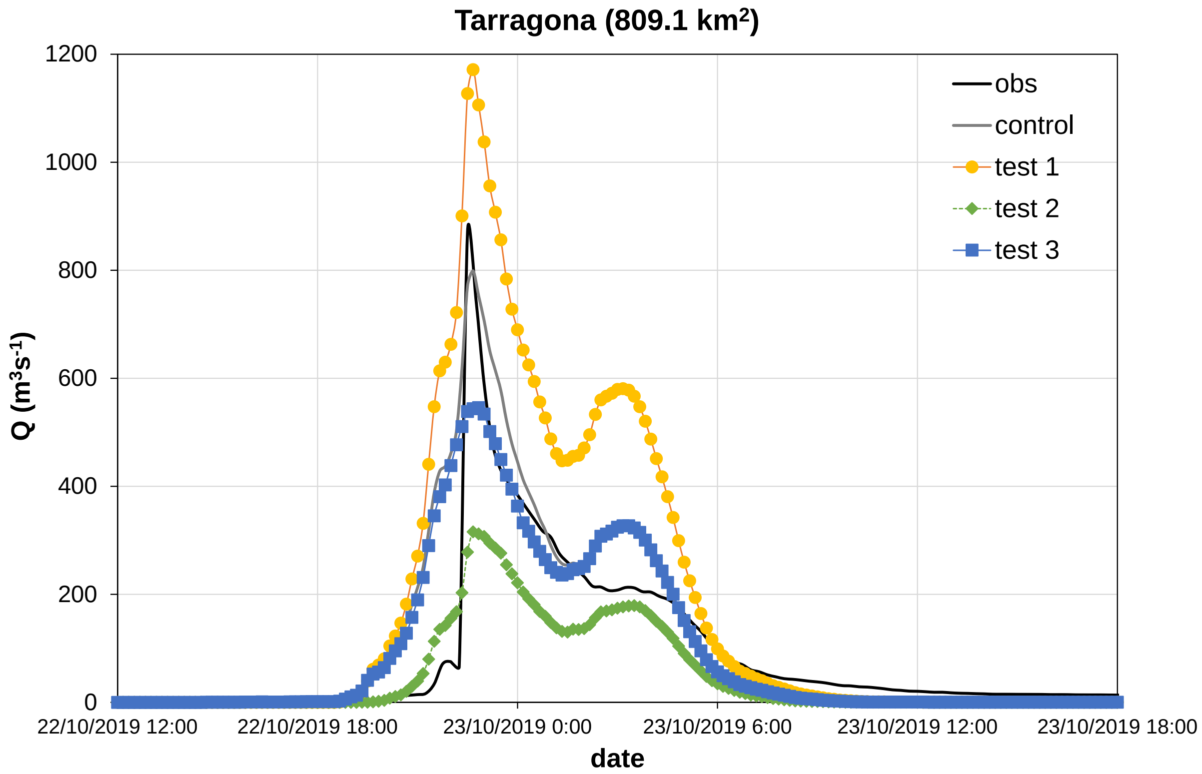
3. Test 3: Heaviest rainfall rates (18:50-19:40 UTC). 10-min rainfall variability is smoothed out by considering its temporal average. Constant rainfall rate of 33.9 mmh^{-1}. Infiltration parameters: control simulation

6. Flood response: sensitivity tests

Test 1: Paramount role of the very low antecedent soil moisture conditions

Test 2: Fundamental role of the early rainy period. Soil was far from saturation but decreased infiltration rates. Runoff threshold exceedance behavior

Test 3: Rainfall variability resulted in an enhanced and very narrow peak discharge, promoting a very flashy basin response



7. Catchment response

The Francolí basin experienced fast dynamic processes. Risk management must cope with unusually short lead times

Lag time: temporal difference between the center of mass of the rainfall hyetograph and the timing of peak discharge

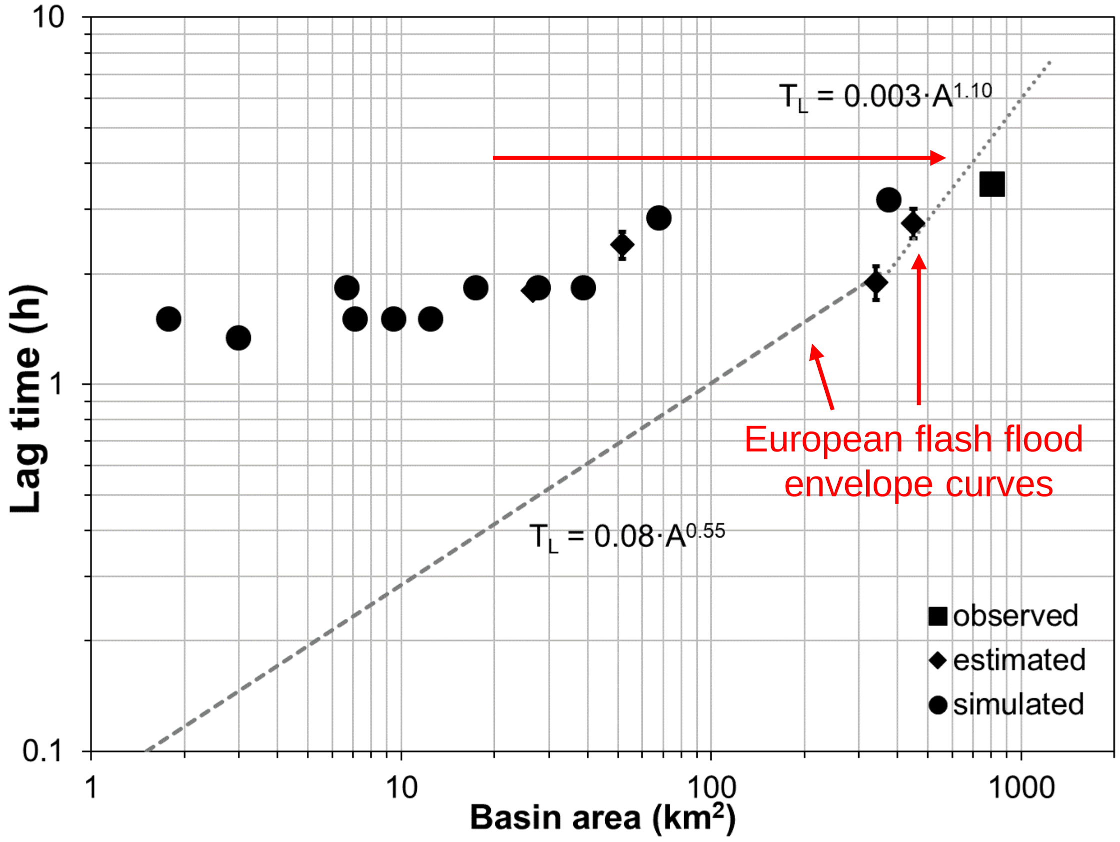
Lag times

< 50 km^2: 1.5–2 h

50–350 km^2: 2.5–3 h

375–810 km^2: 3–3.5 h

Sharp transition in lag time with increasing drainage size



8. Social response

Categorized in 3 different stages:

1. Information: Data collection. This phase starts the warning cycle

2. Organization: Analyses information. Leads to the implementation of structured responses in the form of pre-established defense plans

3. Protection: Deployment of preventive safety measures

8. Social response

Information stage started in the morning of October 21, in response to forecasts of heavy rain, strong wind and sea waves by the SMC

SMC issued a warning: High probability of rainfall > 100 mm/24 h; Certain areas ~ 200 mm/24 h; Rainfall rates ~ 20 mm/30 min

Risk	**Colour code**	**Accumulated rainfall threshold (mm/24 h)**	**Probability of occurrence**	**Numerical scale of risk**
No	Green	–	–	0
Moderate	yellow	> 100	Low	1
			Medium	2
High	orange	> 100	High	3
		> 200	Low	4
Very high	red	> 200	Medium	5
			High	6

8. Social response

Organization stage started on October 21 around 12 UTC

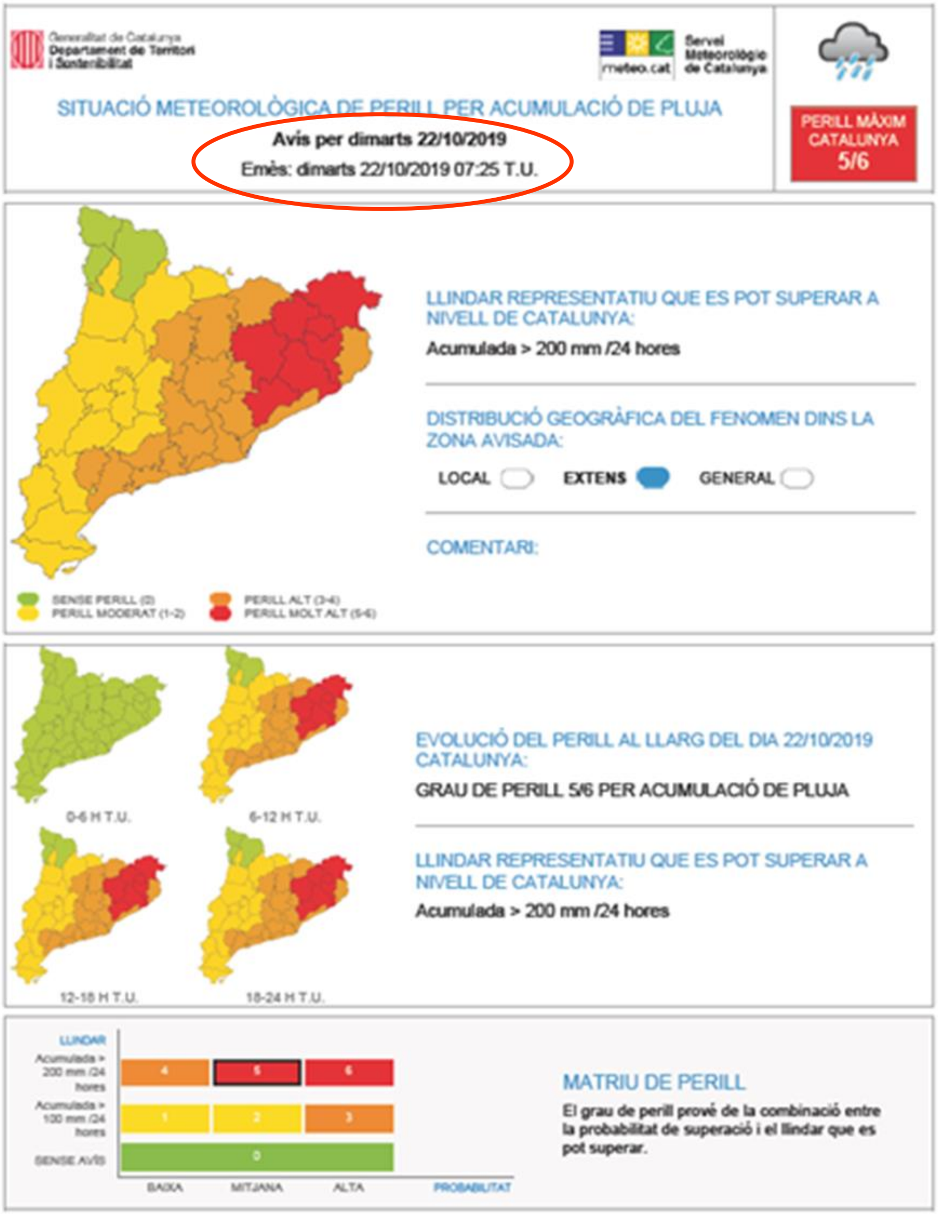
Civil protection activated the pre-alert phase of the INUNCAT

8. Social response

Protection stage started in the afternoon of October 21

Civil protection activated the alert phase of the INUNCAT

On October 22, the SMC continuously updated the alerts



8. Social response

Protection stage

Institutional response in terms of the organization-protection-prevention cycle started ~ 30–24 h before the flow peak

8. Social response

On October 22, at 21:30 UTC, INUNCAT entered the emergency phase

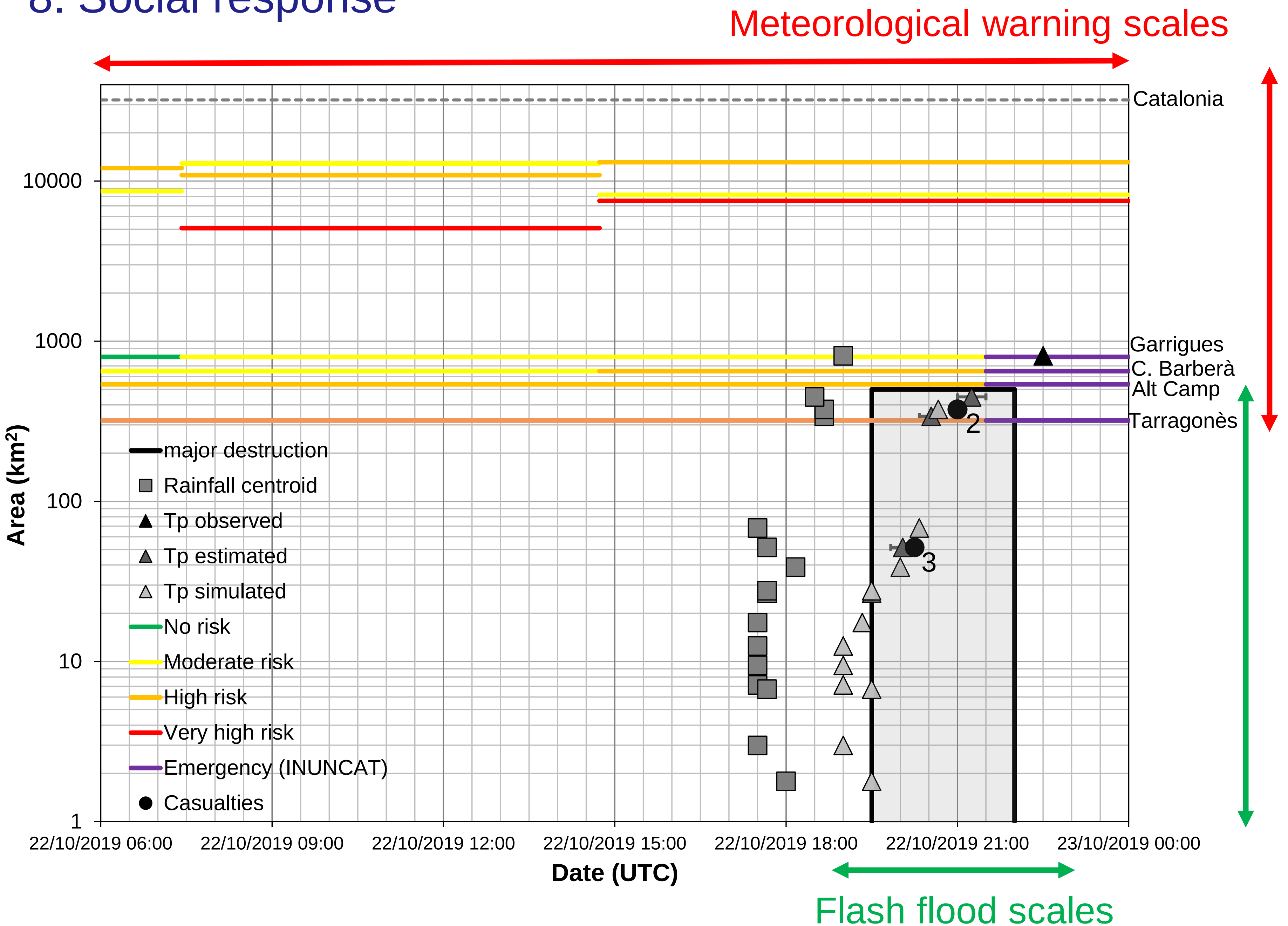
Aftermath

6 fatalities

Destruction of some riverside buildings, roads and 3 bridges.

The CCS paid a total compensation of 44 million euros

8. Social response



8. Social response

Citizen perception: the FLOOD-UP FRANCOLÍ citizen campaign

- > 50% respondents received the warnings. TV the most mentioned media, followed by the City Council and social networks
- 100% reported an understanding of the warnings. Most remembered being advised to avoid proximity to rivers and displacements
- Respondents felt very well informed. 60% expressed a lack of comprehension of the probability classification provided by the SMC
- 66% of participants did not perceive any threat to their homes or properties
- None of them felt endangered in terms of their personal safety

9. Conclusions and further remarks

Forecasting process should rely of hydrologic-hydraulic models driven by high-resolution and reliable rainfall fields

Uncertainties in the IC/BCs and physics of NWP models, non-linearities, weather phenomena initiated over the sea impact predictability

QPEs driven hydrological-hydraulic forecasts + high-resolution HEPSs

Incorporation of real-time observations of rainfall and streamflow in headwater catchments

Monitoring predetermined rainfall threshold exceedance and sudden increases in discharge. Sound alarms along river valley towns

Enhance social awareness of the danger associated with flash flooding

9. Conclusions and further remarks

Better interpretation of probabilistic alerts and understanding of the inherent scales and uncertainties related to weather forecasting

Awareness campaigns. Text messages sent to mobile phones in areas on alert, informing about the weather situation and providing recommendations

Further technical details and results:

Martín-Vide, J.P., A. Bateman, M. Berenguer, C. Ferrer-Boix, A. Amengual, M. Campillo, C. Corral, M.C. Llasat, M. Llasat-Botija, S. Gómez-Dueñas, B. Marín-Esteve, F. Núñez-González, A. Prats-Puntí, R. Ruiz-Carulla, R. Sosa-Pérez (2023). Large wood debris that clogged bridges followed by a sudden release. The 2019 flash flood in Catalonia. J Hydrol: Reg. Stud., 47, 101348

Amengual, A., Romero, R., Llasat, M. C., Hermoso, A., and Llasat-Botija, M. (2023): Hydrometeorological controls and social response for the 22 October 2019 catastrophic flash flood in Catalonia, north-eastern Spain. NHESS, in review.

PROJECTE TRAMPAS

Segona reunió: 24/10/2023

Preliminary TRAM- and WRF-driven runoff simulations

1. Background

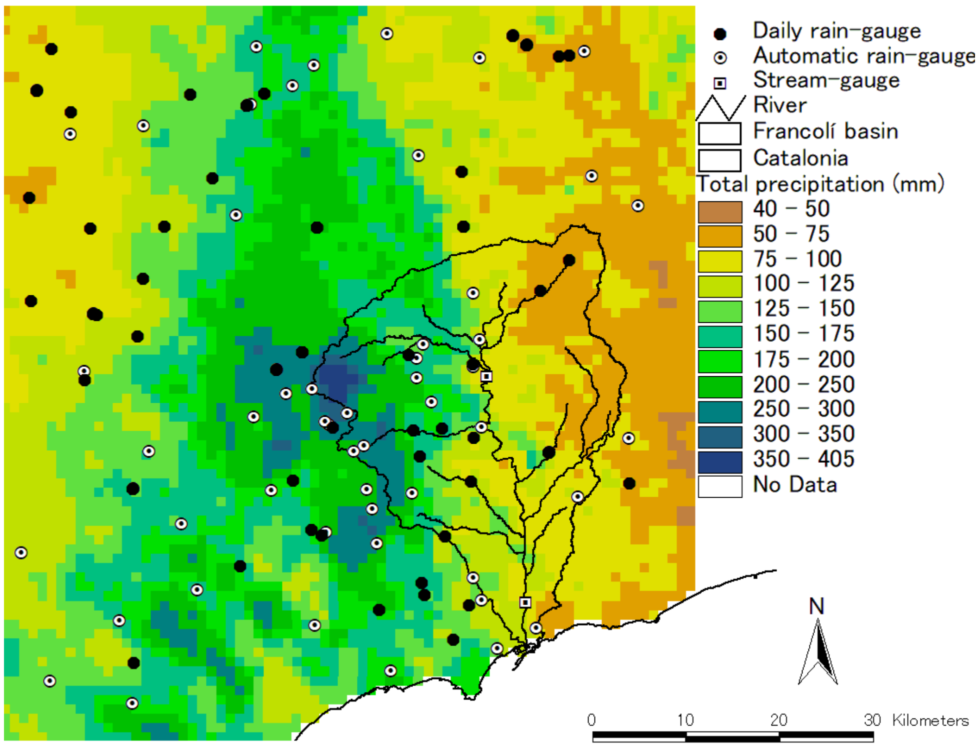
Identification of the most suitable techniques for generating advanced HEPSs and quantifying their added value are an active research area

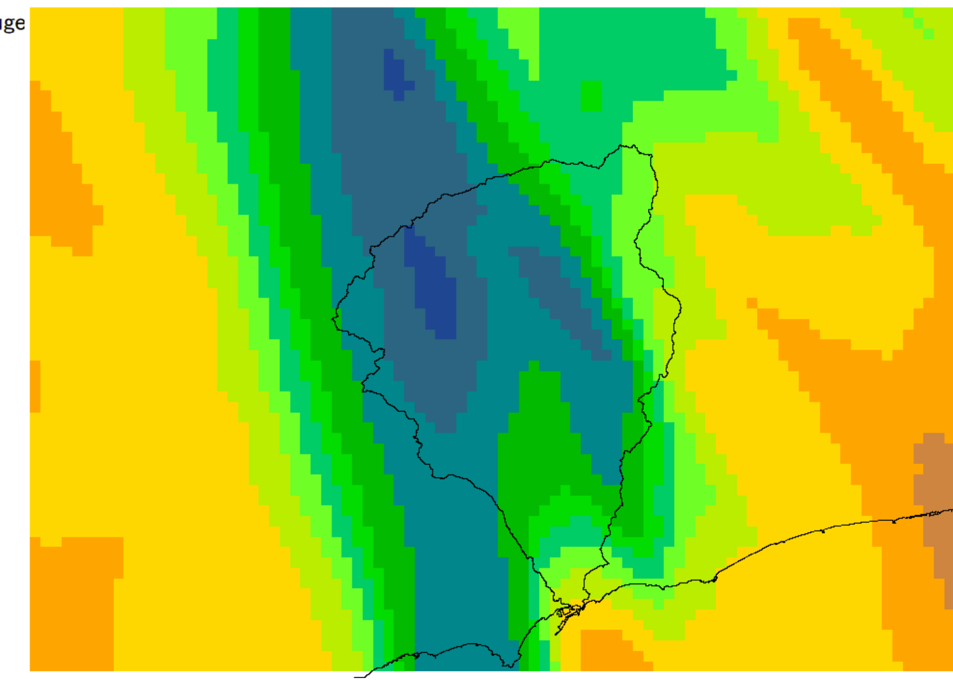
Hydrological verification has become an important facet of the evaluation of high-resolution NWP models for flash flood prediction purposes

Verification does not rely on classical pointwise measures, as flash flooding develops from integrated values of rainfall intensity and total amount over specific watersheds

2. Preliminary TRAM- and WRF-driven runoff simulations

- WRF. 2.5 km. 36 h (22/10/2019 00 UTC – 23/10/2019 12 UTC)
- No convection





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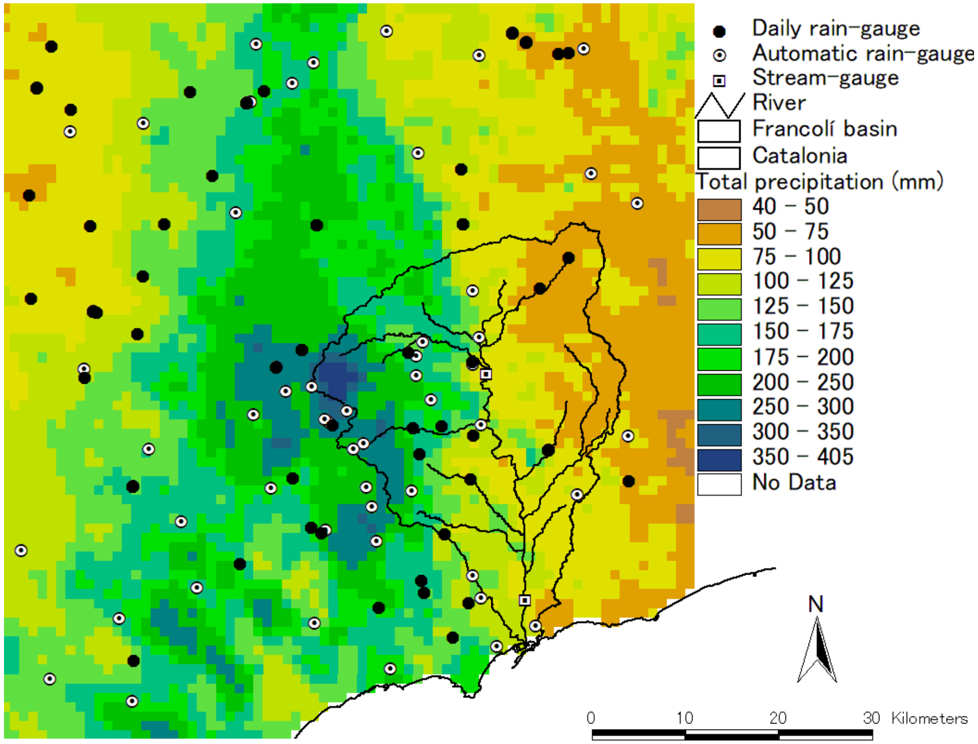
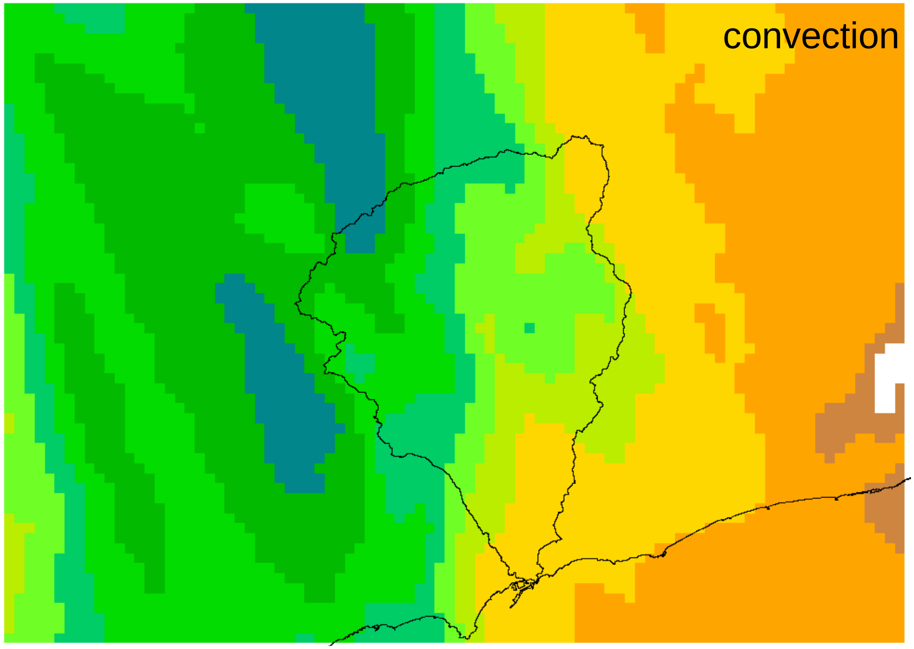
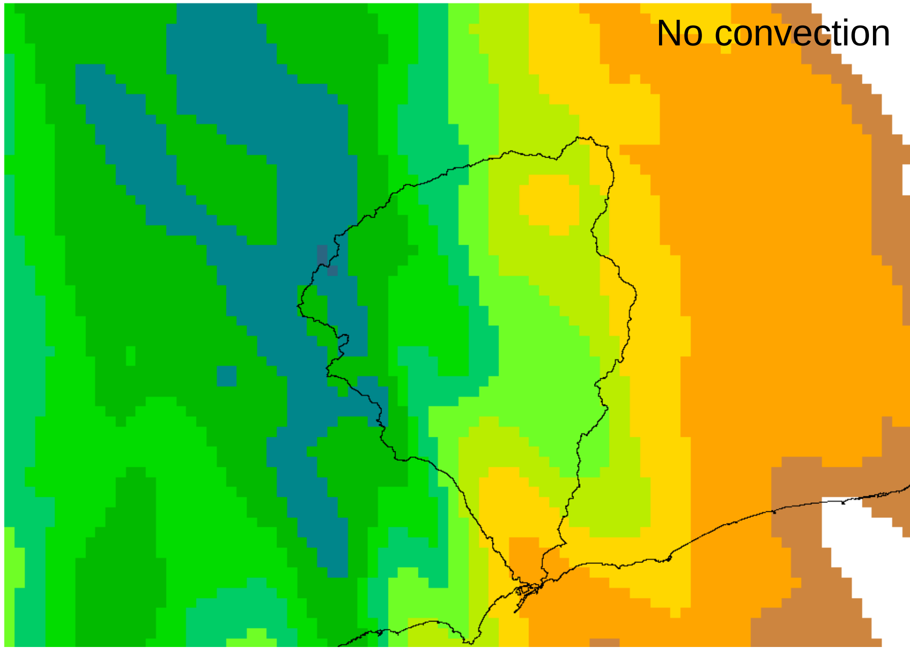
- TRAM. 2 km. 48 h (22-24/10/2019 00 UTC)







2. Preliminary TRAM- and WRF-driven runoff simulations

- WRF. 2.5 km. 36 h (22/10/2019 00 UTC – 23/10/2019 12 UTC). No convection
- TRAM. 2 km. 48 h (22-24/10/2019 00 UTC). Convection/No convection