Flash floods in Europe: flow response and geomorphic impact

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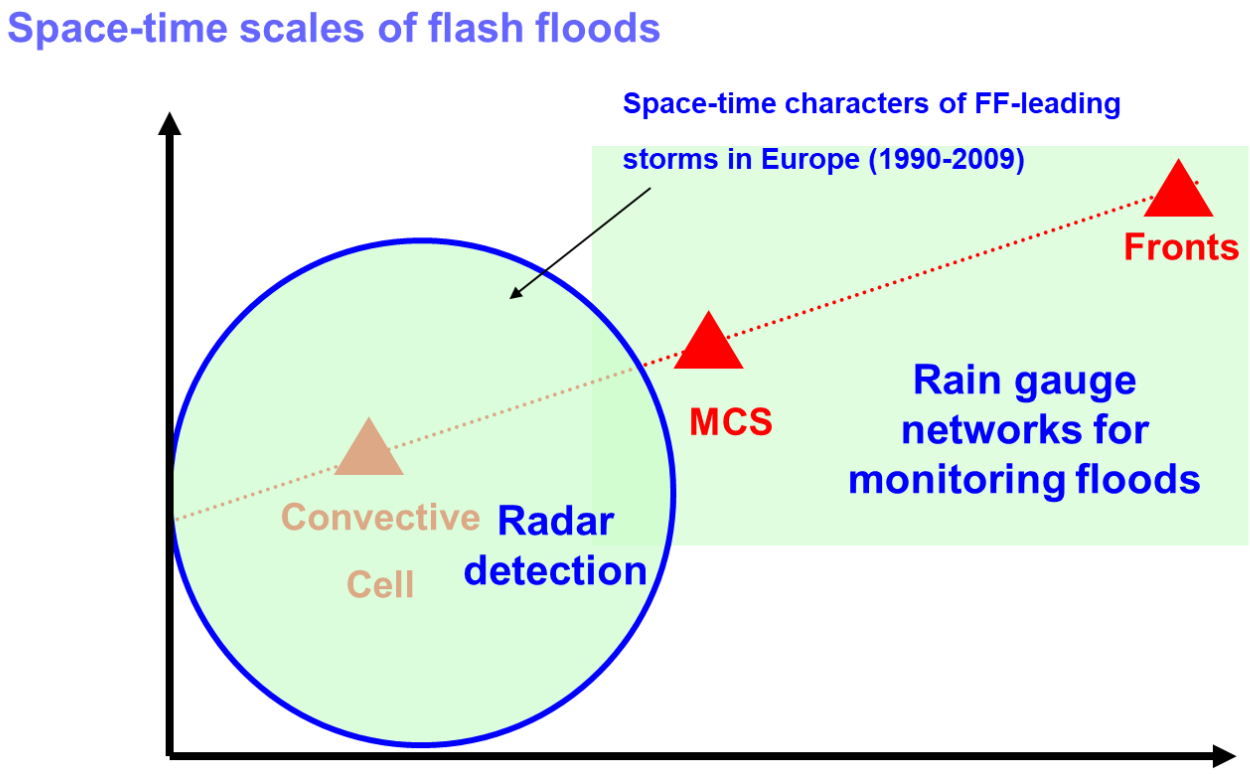
Background



Strong spatial gradients of causative rainfall and flood response

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Inadequacy of normal hydrometeorological networks

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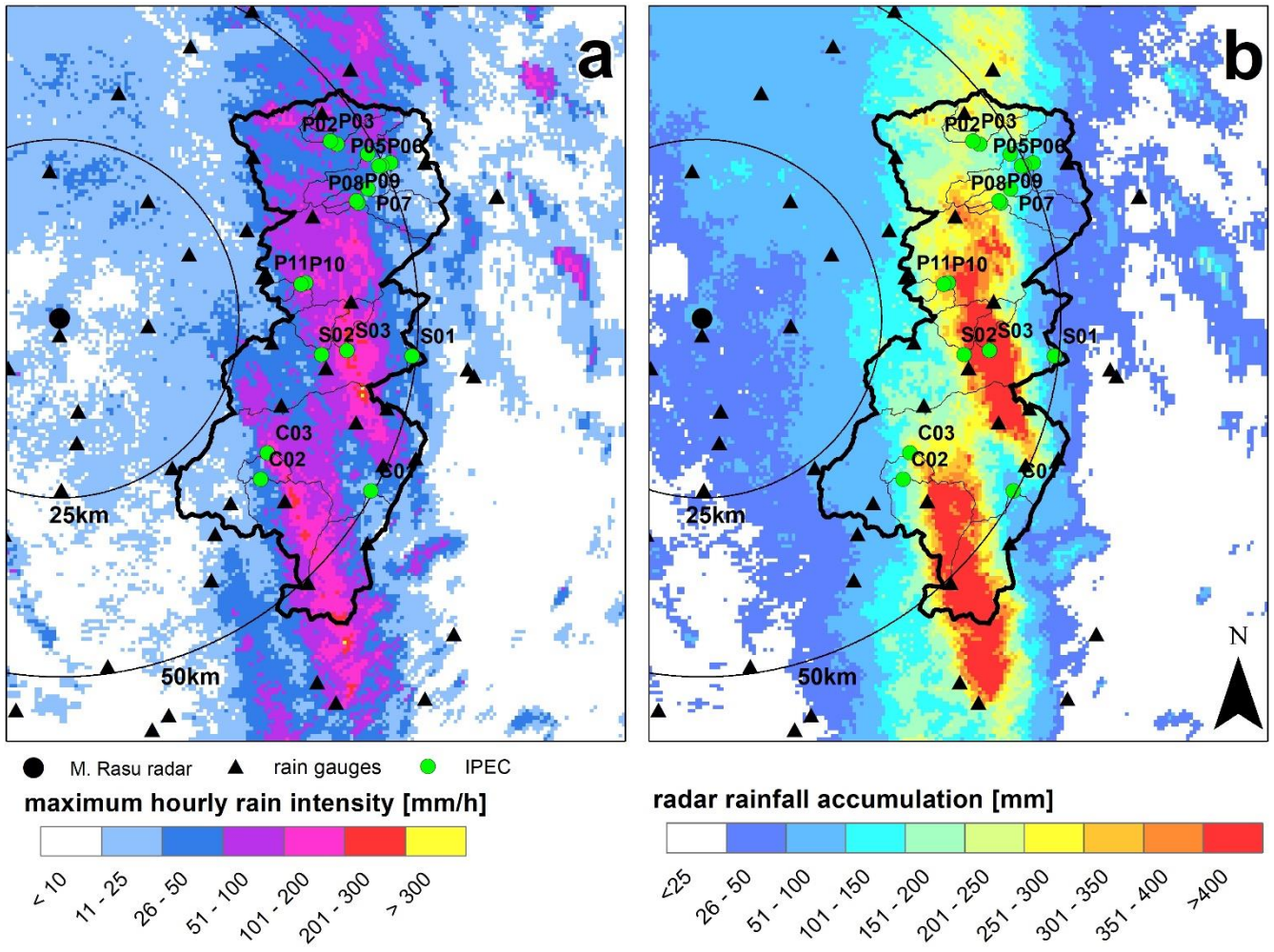
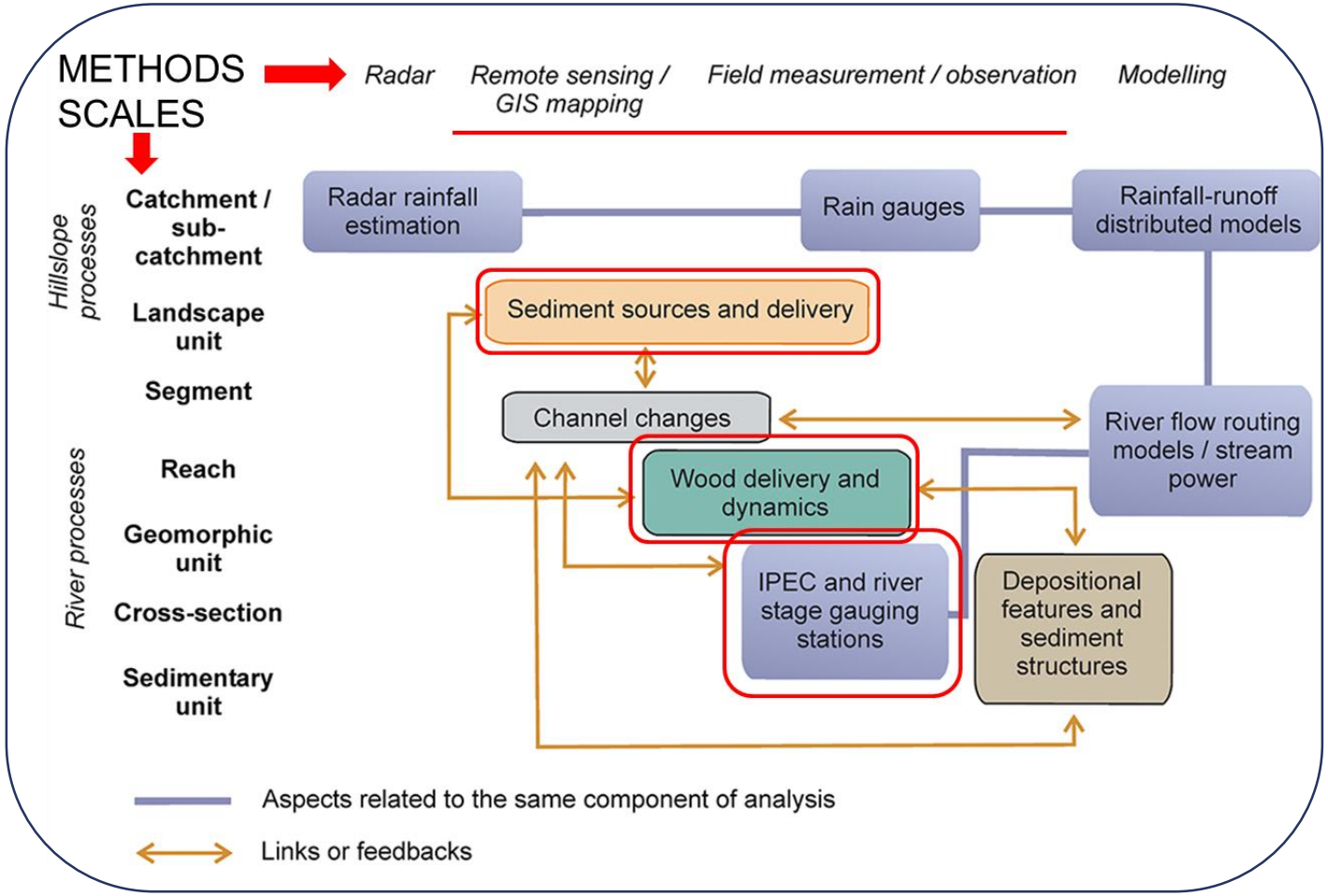
Need for a focused observation strategy: "*Gauging the ungauged extremes*"

Radar rainfall estimation: an example



The November 18, 2013 rainstorm over NE Sardinia (Monte Rasu weather radar and rain gauges)

A multidisciplinary approach



Rinaldi, M., Amponsah, W., Benvenuti, M., Borga, M., Comiti, F., Lucía, A., Marchi, L., Nardi, L., Righini, M., Surian, N., 2016. An integrated approach for investigating geomorphic response to extreme events: methodological framework and application to the October 2011 flood in the Magra River catchment, Italy. Earth Surface Processes and Landforms, 41, 835-846, doi: 10.1002/esp.3902

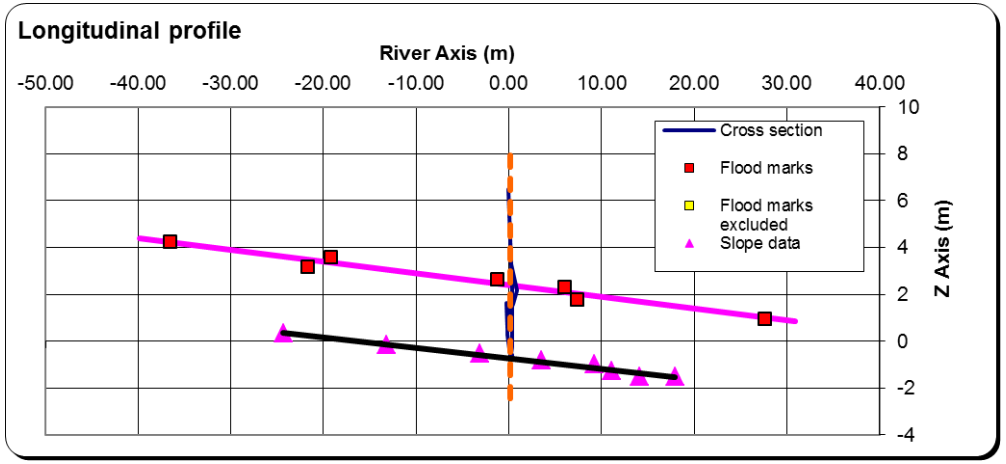
Estimation of peak discharge

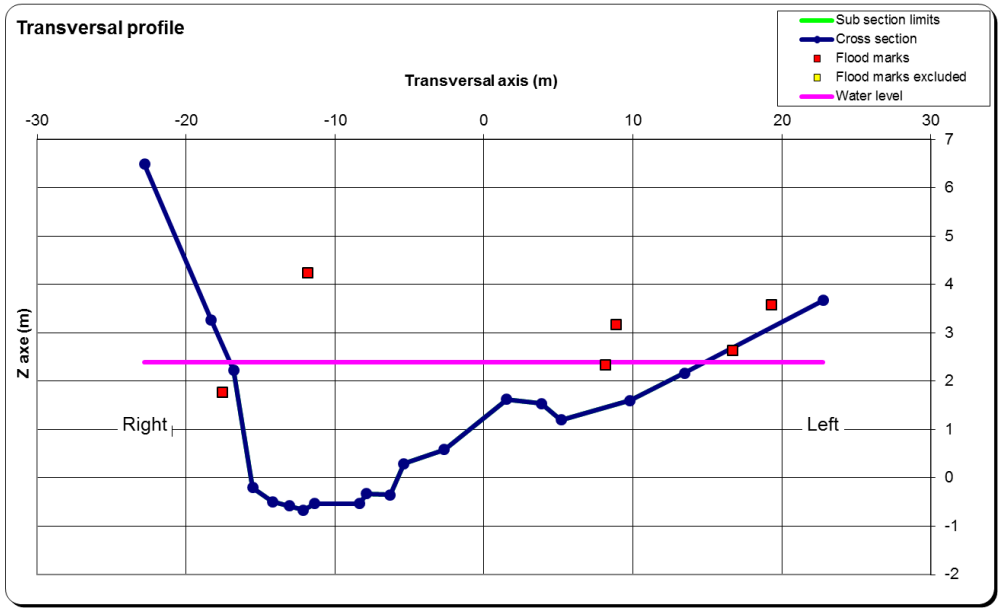
Topographic surveys:

- cross-sections;
- flood marks on channel banks;
- channel slope;
- water surface longitudinal slope.

Slope-conveyance method: assumption of uniform flow and application of the Manning-Strickler equation.

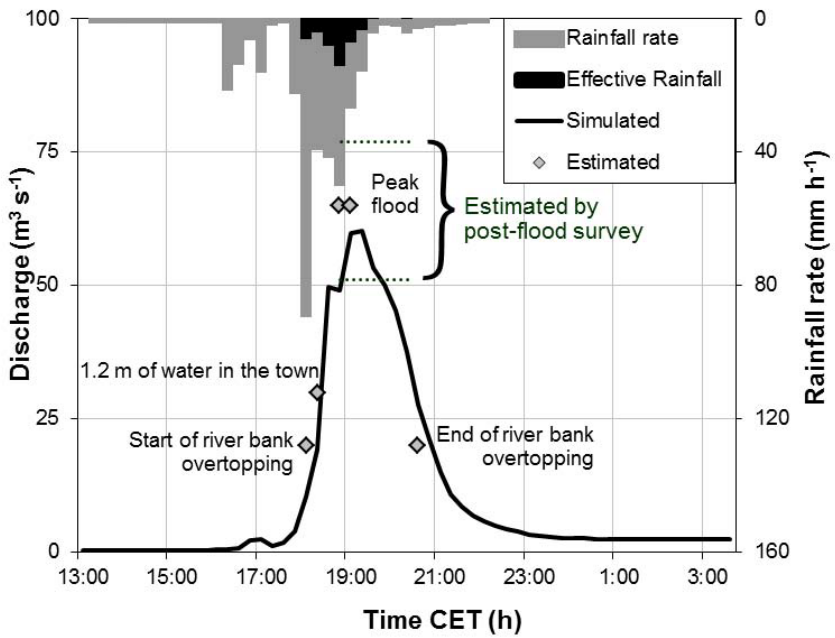
$$V = K \cdot R^{2/3} \cdot S^{1/2}$$

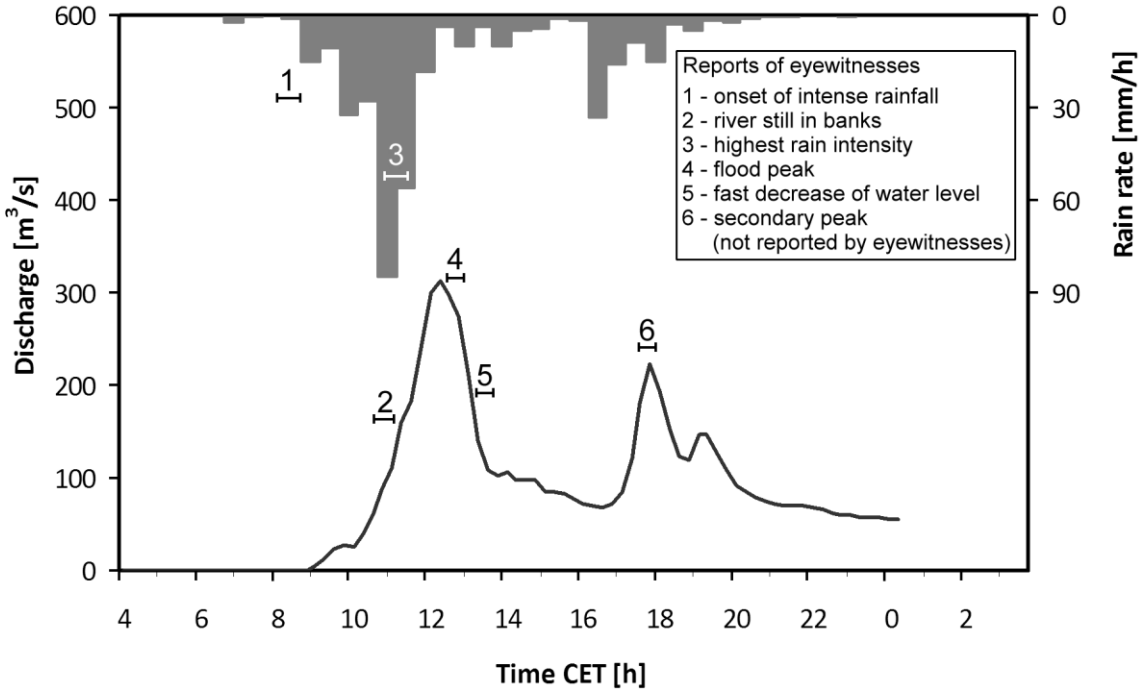




Collection of witnesses accounts

- Occurrence of hail, strong wind…
- Time evolution of the flood
- Flood description from visual observation: transport of large wood, entrainment of cars, bridge blockage…

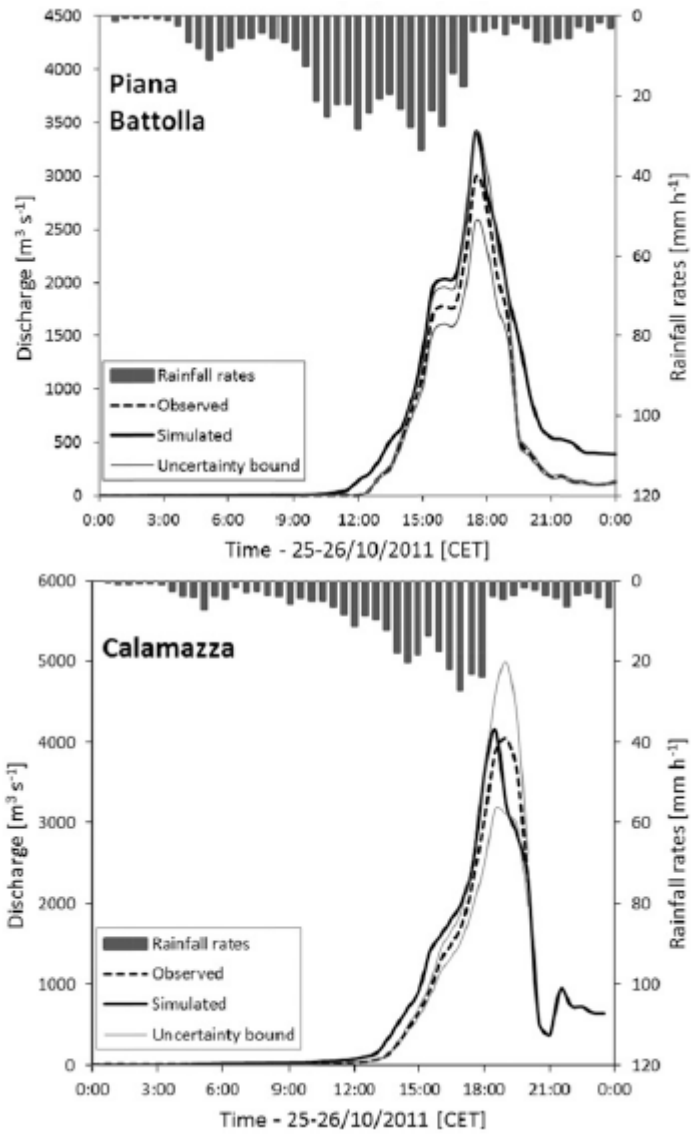


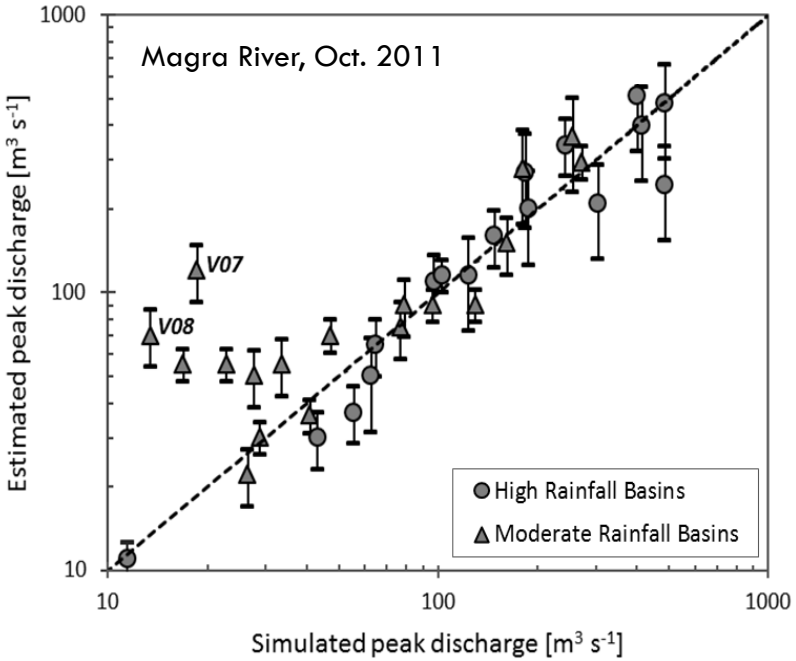


Ruiz-Villanueva V., Borga M., Zoccatelli D., Marchi L., Gaume E., Ehret U., 2012. Extreme flood response to short-duration convective rainfall in South-West Germany. Hydrol. Earth Syst. Sci., 16, 1543-1559, doi:10.5194/hess-16-1543-2012

Marchi, L., Borga, M., Preciso, E., Sangati, M., Gaume, E., Bain, V., Delrieu, G., Bonnifait, L., Pogačnik, N., 2009. Comprehensive post-event survey of a flash flood in Western Slovenia: observation strategy and lessons learned. Hydrological Processes, 23(26), 3761-3770, DOI: 10.1002/hyp.7542

Rainfall-runoff modeling and consistency check





Amponsah W. et al., 2016. Hydrometeorological characterisation of a flash flood associated with major geomorphic effects: Assessment of peak discharge uncertainties and analysis of the runoff response. J. Hydromet., 17, 3063-3077.

Post-flood surveys 2007-2020

Projects:

- HYDRATE (6° Framework Programme)
- HYMEX
- NextData
- FOE Clima 2020-2021

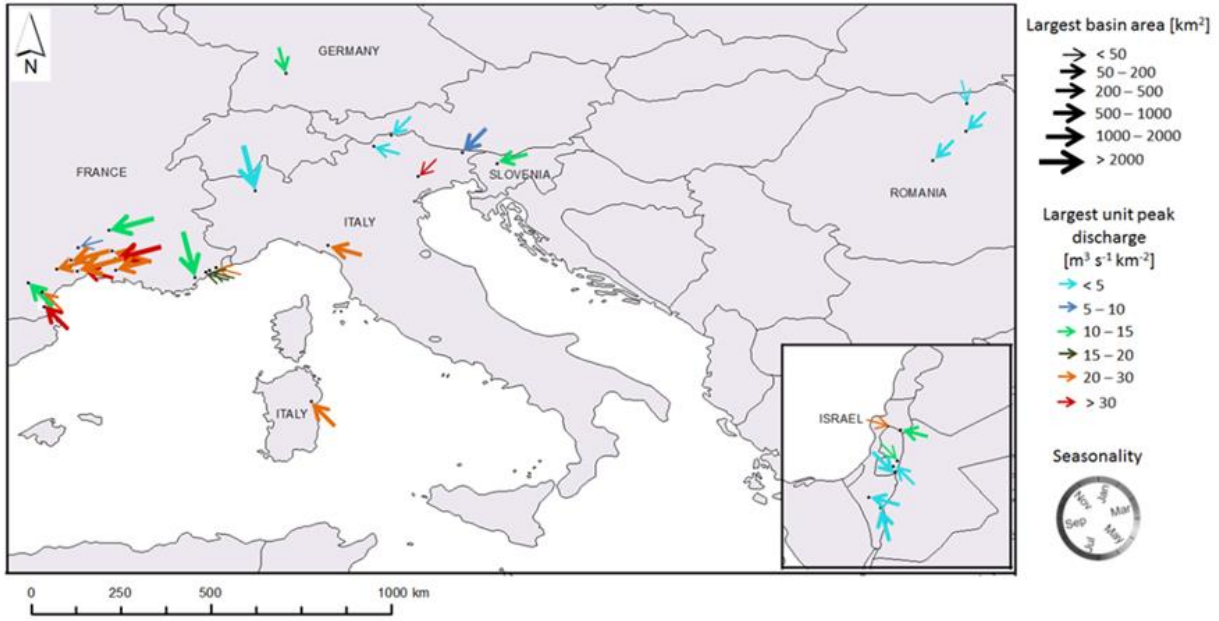
Collaborations IRPI:

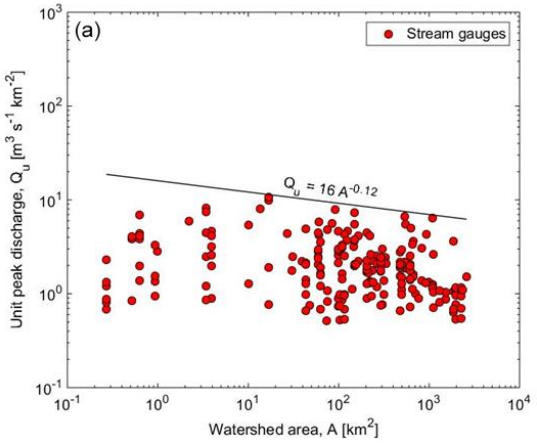
- Perugia Hydrology (NextData Project 2014-2017)
- Perugia Geomorphology (FOE Clima Project)

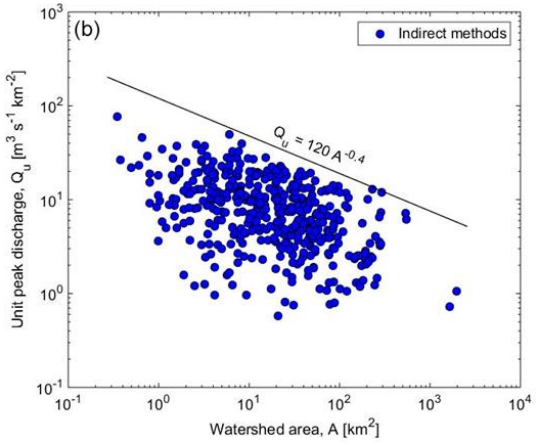
Other collaborazions:

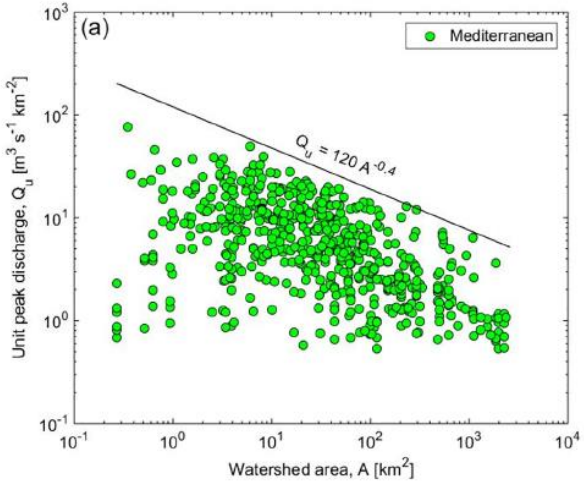
- CNR ISAC
- University of Padova (Dept. TESAF and Geoscienze)
- Free University of Bozen-Bolzano (Faculty od Science and Technology)
- CNRS/Université Grenoble Alpes
- Université G. Eiffel

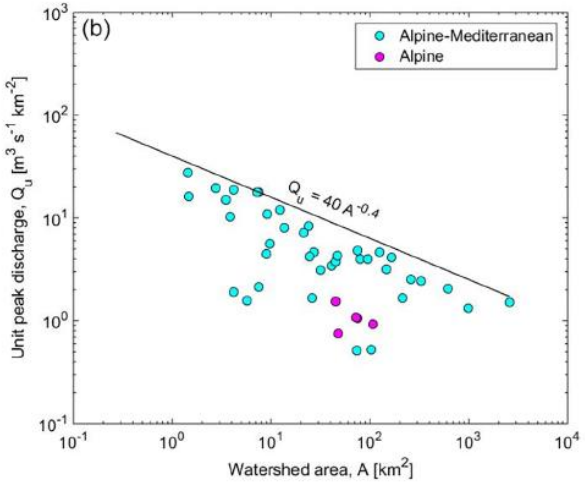
Selected results: unit peak discharge

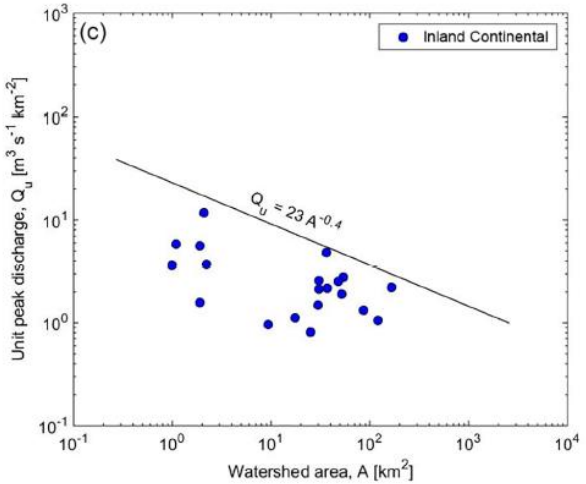


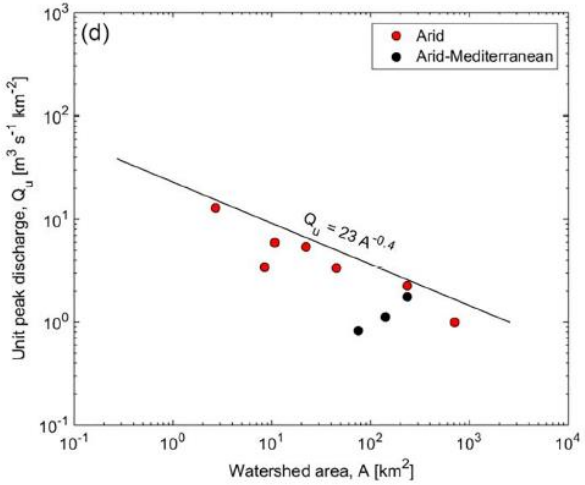






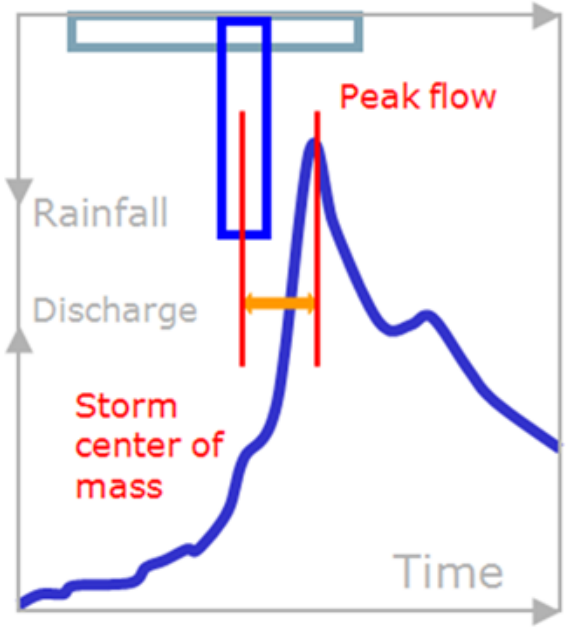


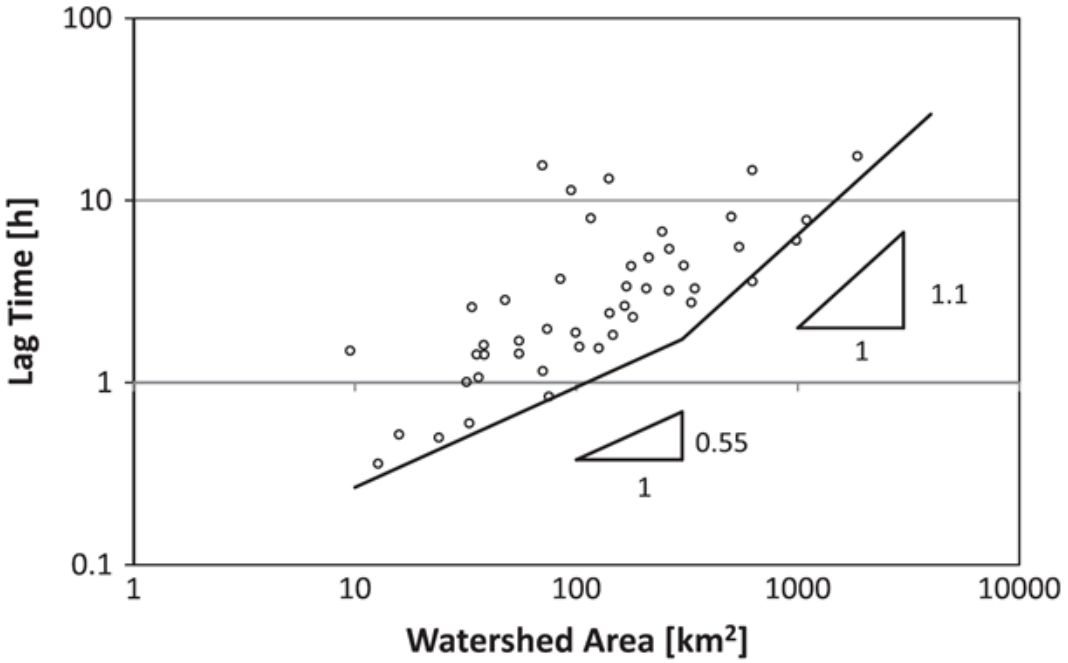




Amponsah, W., et al., 2018. Integrated high-resolution dataset of high-intensity European and Mediterranean flash floods. Earth Syst. Sci. Data, 10, 1783–1794.

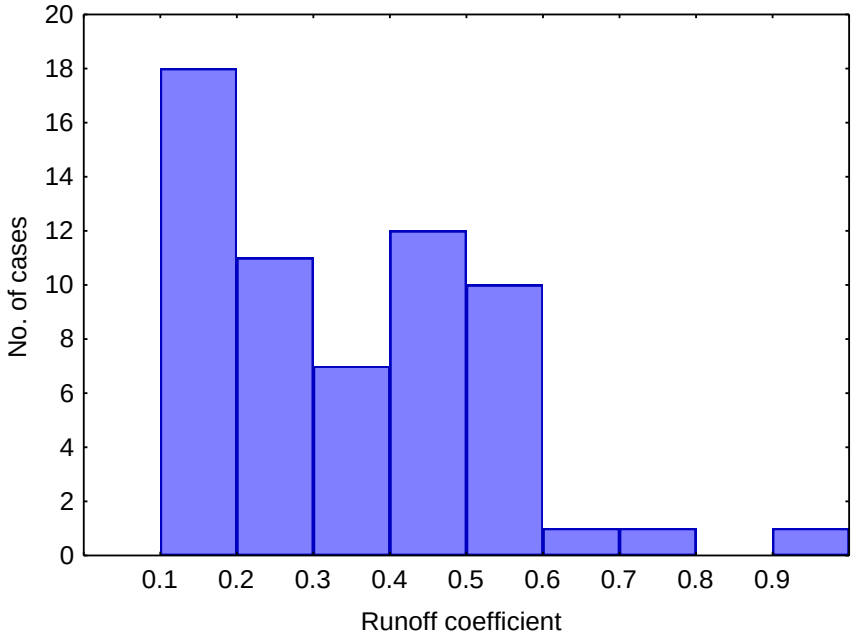
Selected results: lag time



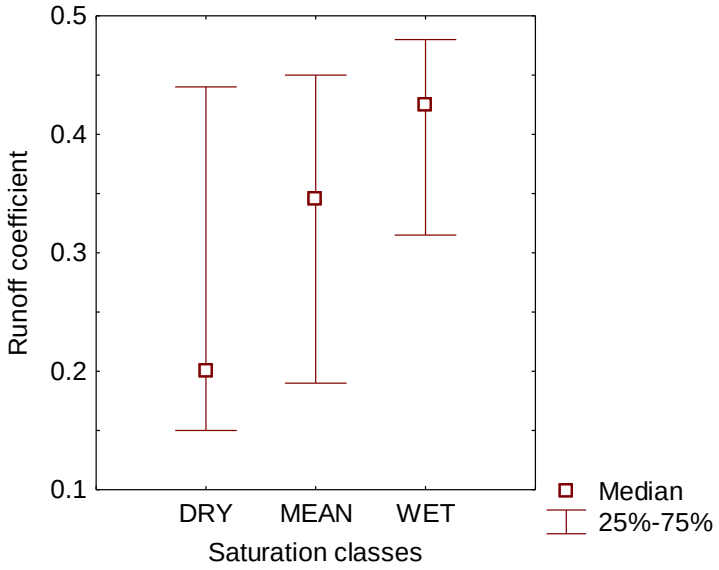


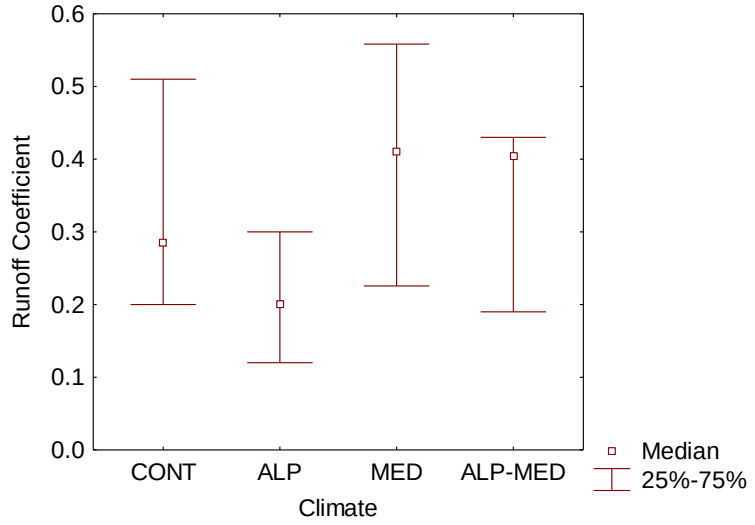
- Lower envelope: characteristics of the catchment-valley system
- Scatter above the lower limit: watershed characteristics; intensity, size and location of rainstorms

Selected results: runoff coefficient



mean: 0.35
std. dev: 0.18
median: 0.39
25th percentile: 0.19
75th percentile: 0.45





Index of antecedent saturation: ratio of the precipitation fallen on the watershed in the 30 days before the flash flood to the long-term monthly average rainfall for the same period

Three classes:

< 0.5 DRY (17 cases)

0.5 – 1.5 MEAN (30 cases)

> 1.5 WET (11 cases)

Higher values in Mediterranean and Alpine-Mediterranean watersheds
(longer duration of rainstorms and floods).

Channel widening

width ratio *Wr*: channel width after / channel width before the flood

confinement index *Ci*: alluvial plain width / pre-flood channel width

Channel widening – controlling factors

Tributaries of Magra River – flood of 25 October 2011

Analysis at channel reach scale

Surian N. et al. 2016. Channel response to extreme floods: Insights on controlling factors from six mountain rivers in northern Apennines, Italy. Geomorphology, 272 (1), 78-91.

channel slope > 4%

$Wr = -2.118 + 0.317 \cdot \omega_{before} + 0.366 \cdot C_i + 0.004 \cdot SedSour$

$R^2 = 0.65$

channel slope < 4%

$Wr = -0.719 + 0.174 \cdot \omega_{before} + 0.292 \cdot C_i + 0.275 \cdot AS + 0.026 \cdot SedSour$

$R^2 = 0.36$

C_i : confinement index

ω_{before} : unit stream power computed on pre-flood channel width ($W \cdot m^{-2}$)

AS : percentage of the channel reach with artificial structures

SedSour : sediment source areas (m^2)

Conclusions and opportunities

- Collection of a large dataset of radar rainfall data, flow response, and geographical data in European countries and Israel.
- Differences in seasonal occurrence, unit peak discharge and runoff coefficient between climatic regions.
- Identification of hydraulic and topographic factors that control channel changes during flash floods.

- An open scientific question: the impact of climate changes on flash floods in Europe (different or similar to fluvial floods?)
- Need for expanding and updating the dataset (many Italian regions and Euro-Mediterranean countries are not covered).
- Channel changes caused by flash floods: from the statistical analysis of causative factors to physically-based modeling?

<u>In the frame of CNR IRPI:</u> possible integration with post-flood studies carried on by other research groups of the Institute.

<u>Selected papers</u>

- Brenna, A. Marchi, L., Borga, M., Ghinassi, M., Zaramella, M., Surian, M., 2021. Sediment–water flows in mountain catchments: Insights into transport mechanisms as responses to high-magnitude hydrological events. Journal of Hydrology, 602, 126716
- Brenna, A., Surian, N., Ghinassi, M., Marchi, L., 2020. Sediment–water flows in mountain streams: Recognition and classification based on field evidence. Geomorphology, 371, 107413.
- Amponsah, W., et al., 2018. Integrated high-resolution dataset of high-intensity European and Mediterranean flash floods. Earth Syst. Sci. Data, 10, 1783–1794.
- Marchi, L., 2017. Linking Debris Flows and Landslides to Large Floods in Gravel-Bed Rivers. In: Gravel-Bed Rivers: Processes and Disasters. Edited by Daizo Tsutsumi and Jonathan B. Laronne, John Wiley & Sons Ltd., 467-495.
- Amponsah W., et al., 2016. Hydrometeorological characterisation of a flash flood associated with major geomorphic effects: Assessment of peak discharge uncertainties and analysis of the runoff response. Journal of Hydrometeorology, 17, 3063-3077.
- Marchi L., Cavalli M., Amponsah W., Borga M., Crema S., 2016. Upper limits of flash flood stream power in Europe. Geomorphology, 272(1), 68-77.
- **Marchi, L., Borga, M., Preciso, E., Gaume, E., 2010. Characterisation of selected extreme flash floods in Europe and implications for flood risk management, Journal of Hydrology, 394(1-2), 118-133.**