Characterisation of flash floods in Europe: implications for flood risk management

Flash Flood and Pluvial Floods Working Group F Thematic Workshop

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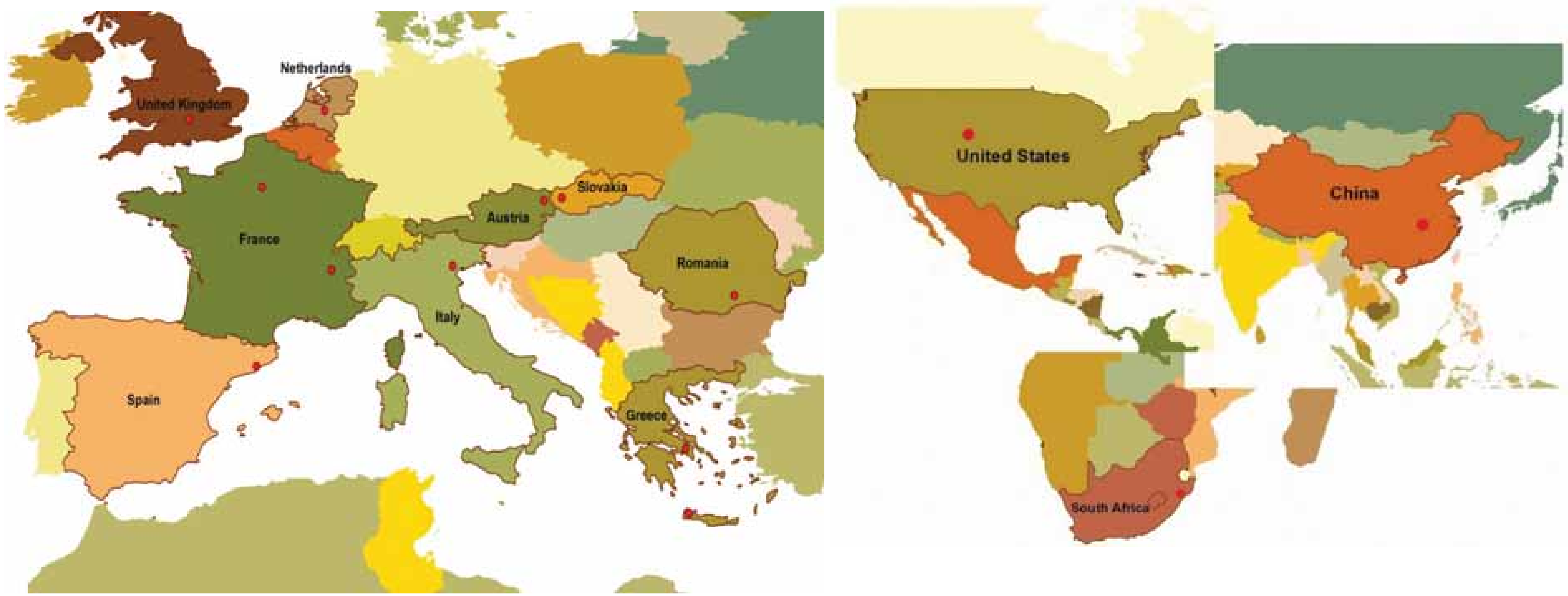
HYDRATE

- **Duration: start: Sept 1, 2006; end: May 31, 2010);**
- **17 partners (including China, Africa and US);**
- **Web Site: hydrate.tesaf.unipd.it**



Outline: an European Vision

- Flash floods: a working definition
- Flash floods *vs* riverine floods
- Observation challenges
- Establishment of an observation strategy
- The HYDRATE Observatories Network
- The flash flood catalogues: science questions and results
- Implications for risk management

Flash floods: a working definition

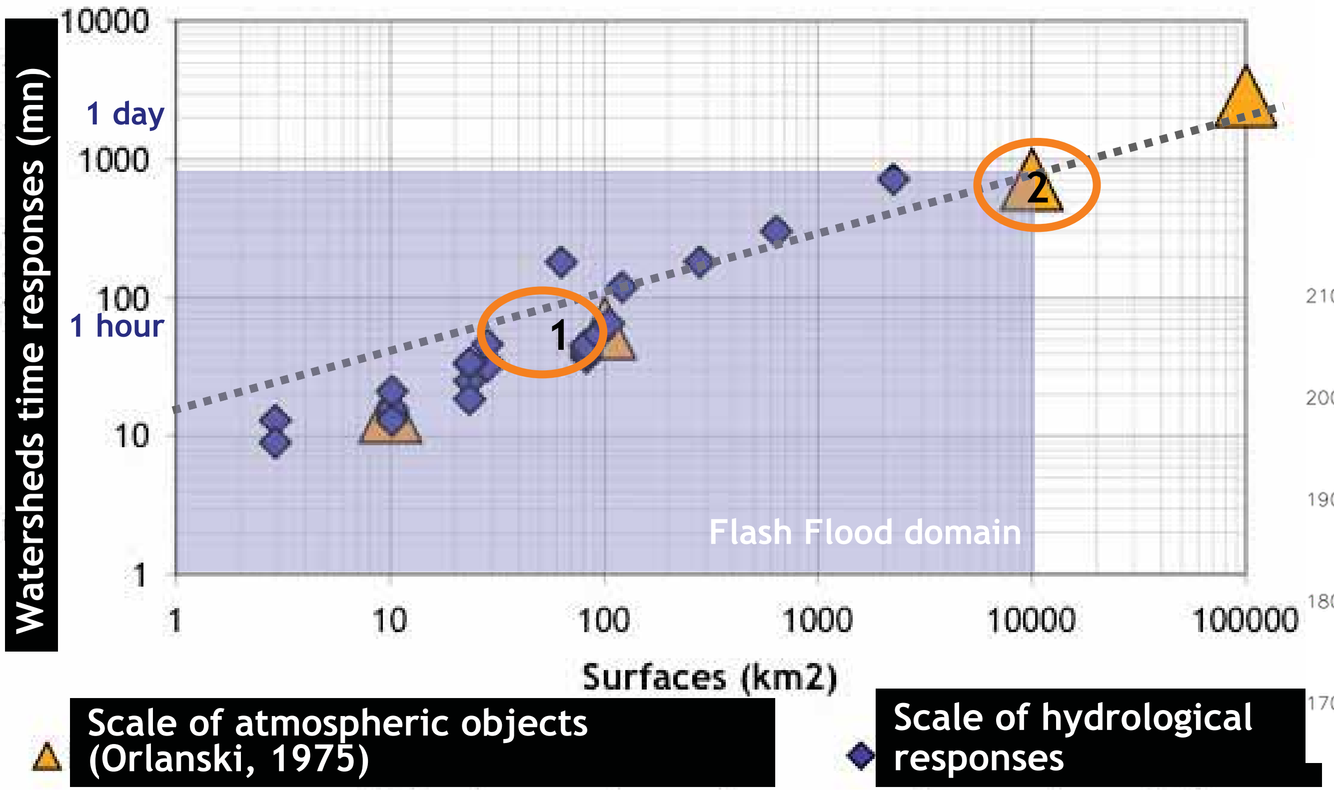
The principles:

- **A flash flood (FF) is a flashy event (6 hours from storm to flood peak..)**
- **Its ‘physical’ response time is less than the ‘social’ response time (physical response time: from rainfall to flood peak)**
- **In most European countries: the social response time is around 10-15 hours.**
- **Space-time scales for FF definition: duration <36 hr; area impacted <1000 km^2.**

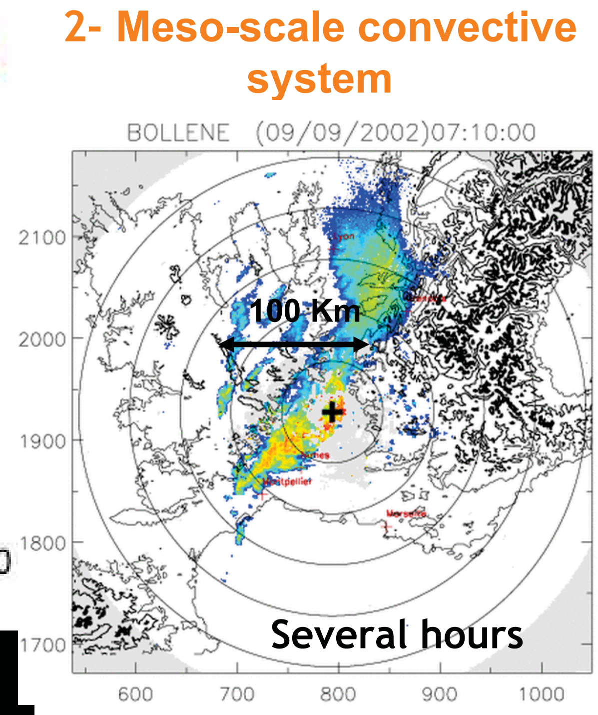
Flash floods vs riverine flood

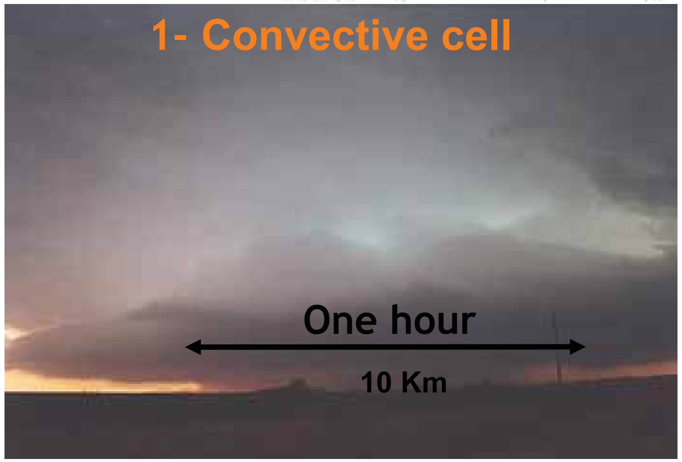
- Scales
  - **Characteristic times in hours**
- Intensities
  - **Water rising rates in m per hours**
  - **Water velocities of several ms^{-1}**
- *Observation*
  - *Ungauged watersheds (rainfall and levels)*
  - *Weather Radar detection*
- Forecasting
  - Coupling meteorology and hydrology
- Vulnerability
  - Point and distributed targets

Space-time scales



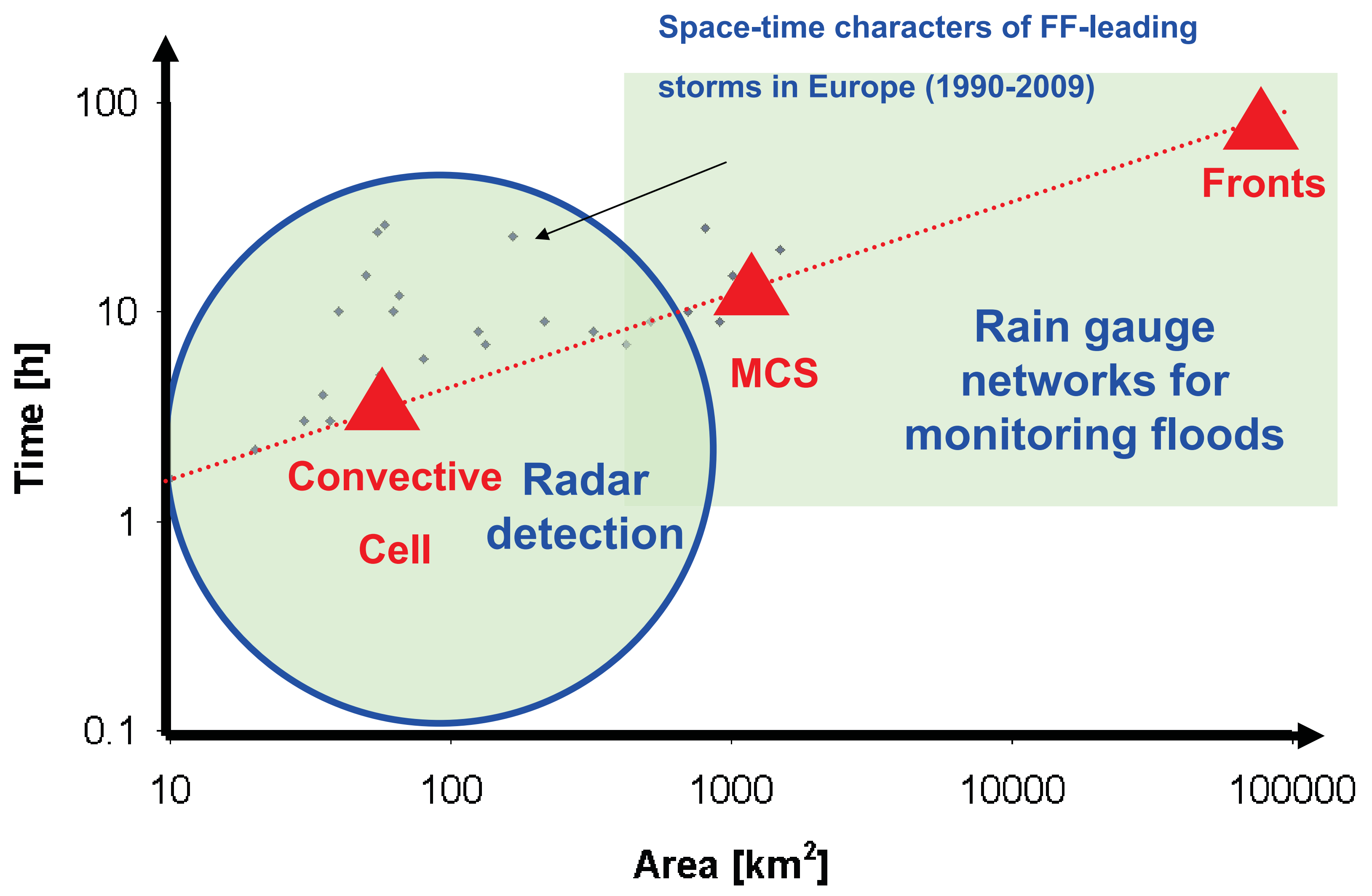
Source : Creutin, 2001



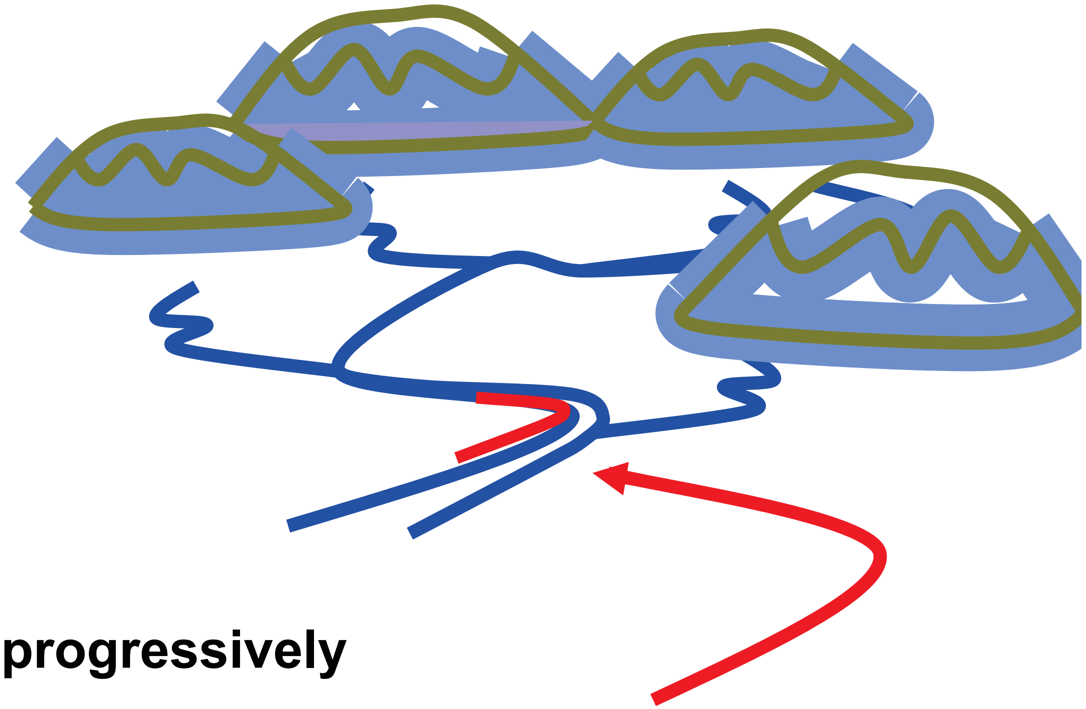


Observation challenges

Space-time scales of flash floods

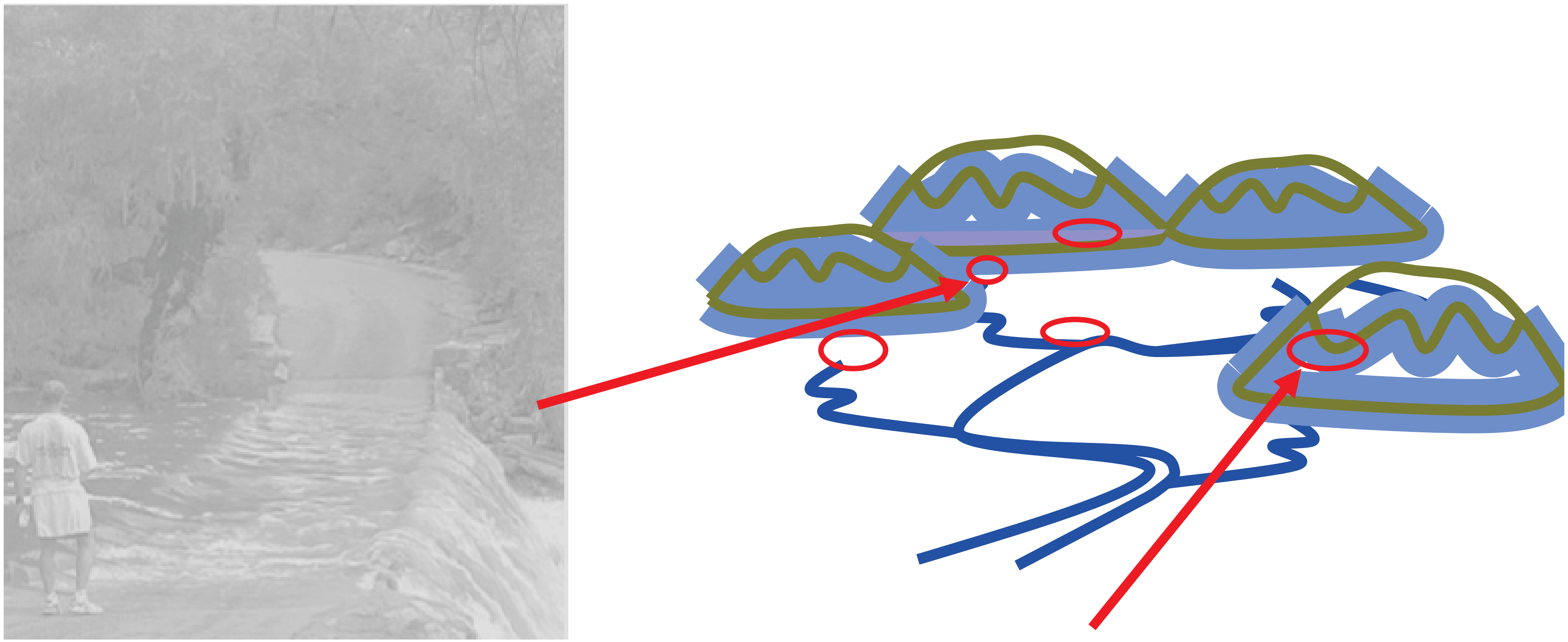


Ingredients of risk: vulnerability in riverine floods



Riverine flood hazard increases progressively with drainage area:
Vulnerability is concentrated in well identified "point targets", ***such as urban agglomerations***

Ingredients of risk: vulnerability in flash floods



Flash flood hazard is dominated by the storm scale: it is localised.
Vulnerability is distributed and spread over the landscape;
Typical targets: ***developing urbanization, transportation, green tourism...***

The Flash Flood Observation strategy - 1

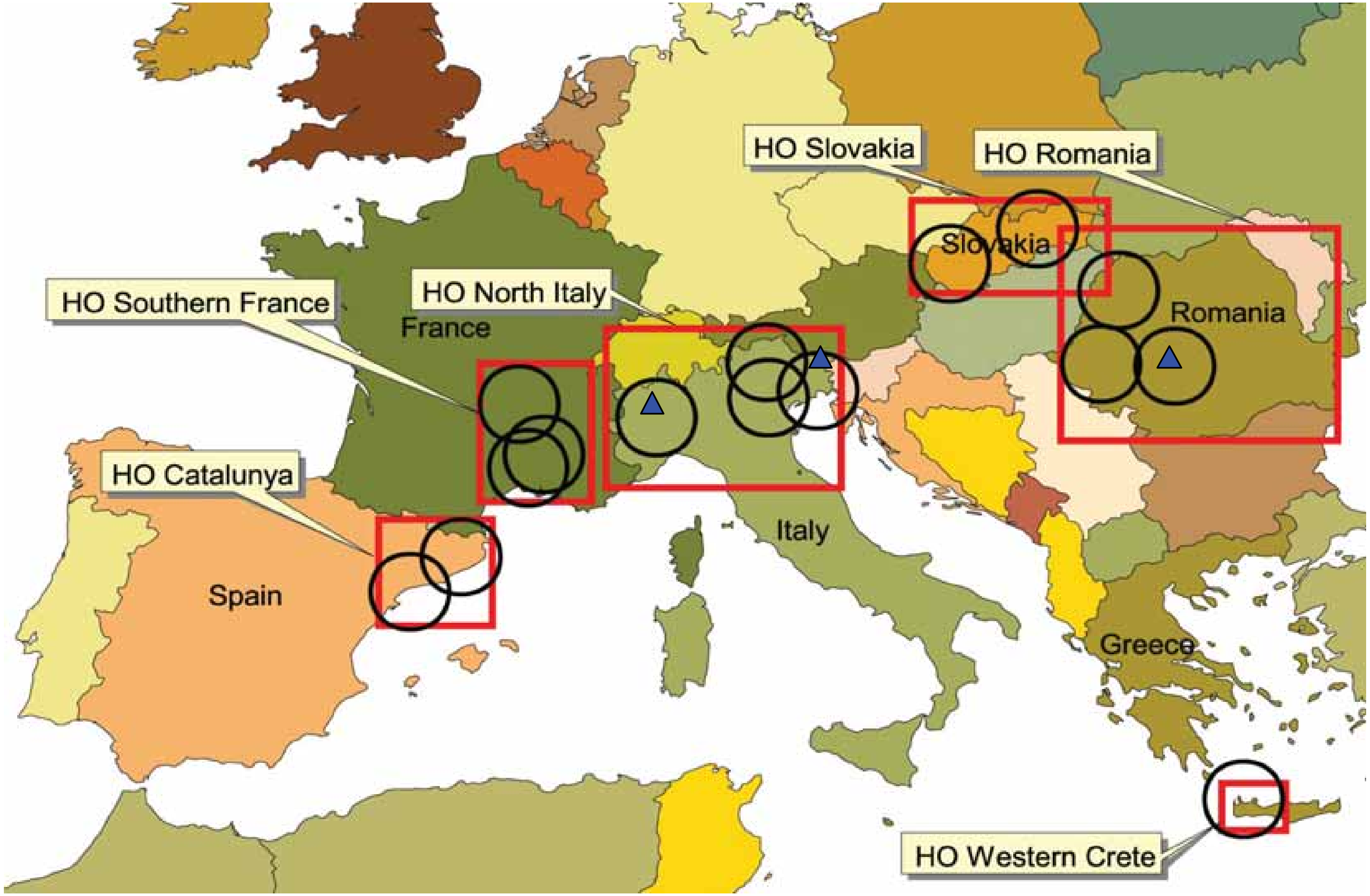
- Flash flood are locally rare phenomena. We need to observe flash floods where they happens in a wide region!
- Establishment of observatories over large geographical areas (about 10 000–30 000 km^2 area wide), sufficiently large to have a good probability of observing flash-flood events.
- Over HOs, operational and research observation systems are implemented to attain high space-time resolution.

The Flash Flood Observation strategy - 2

Development of a flash flood observation methodology

- **The principles**:
  - **To benefit from the density and the quality of the radar coverage as well as from dense rain and river gauging networks in order to collect physical variables.**
  - **To collect complementary information from field investigations carried out during the days following the event (*hazard* and *vulnerability*).**

The HYDRATE network of Hydro-Met Observatories



Post-event analysis - 1

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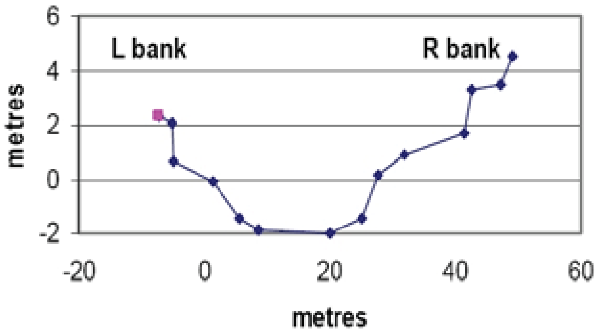
- Data
  - Flood traces
  - Witnesses accounts



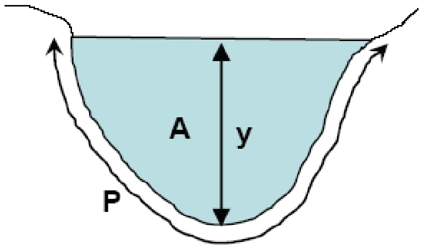

Post-event analysis - 2

post-event analysis - 2

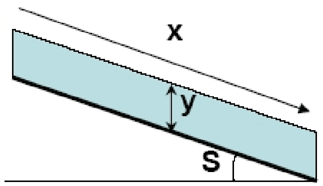
- River sections survey



- Use of hydraulic models for peak Q estimation

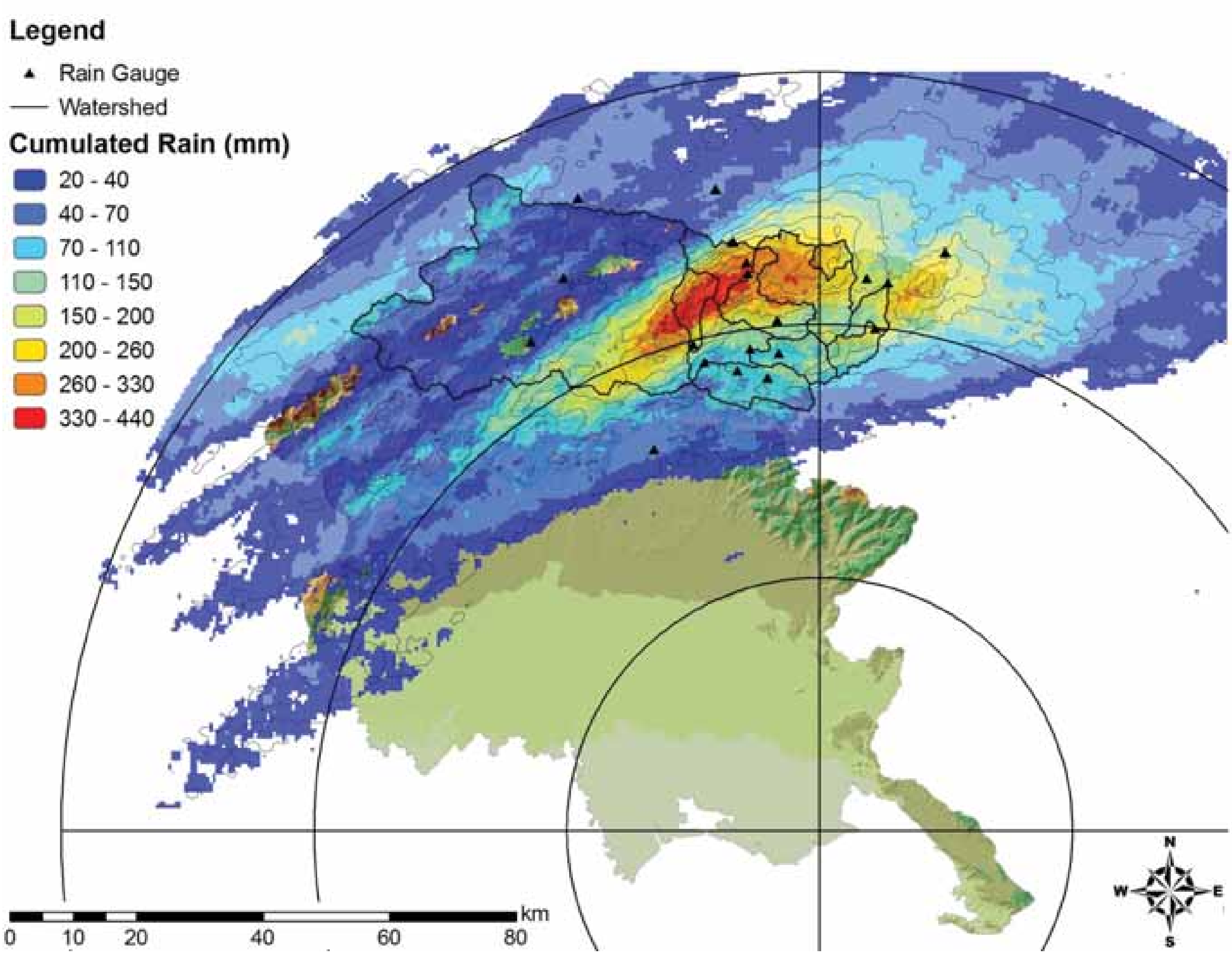


Longitudinal view



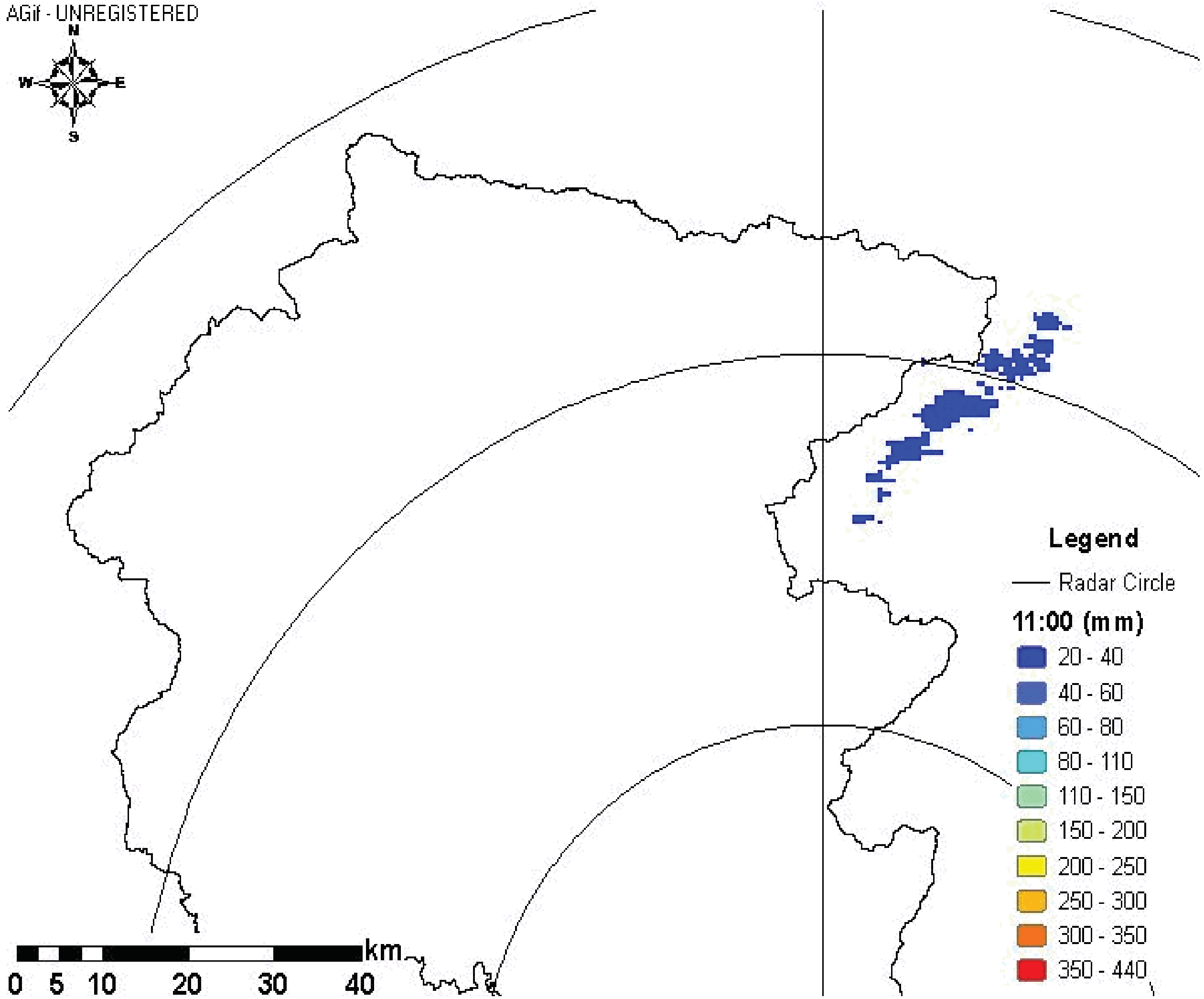
Cross-sectional view

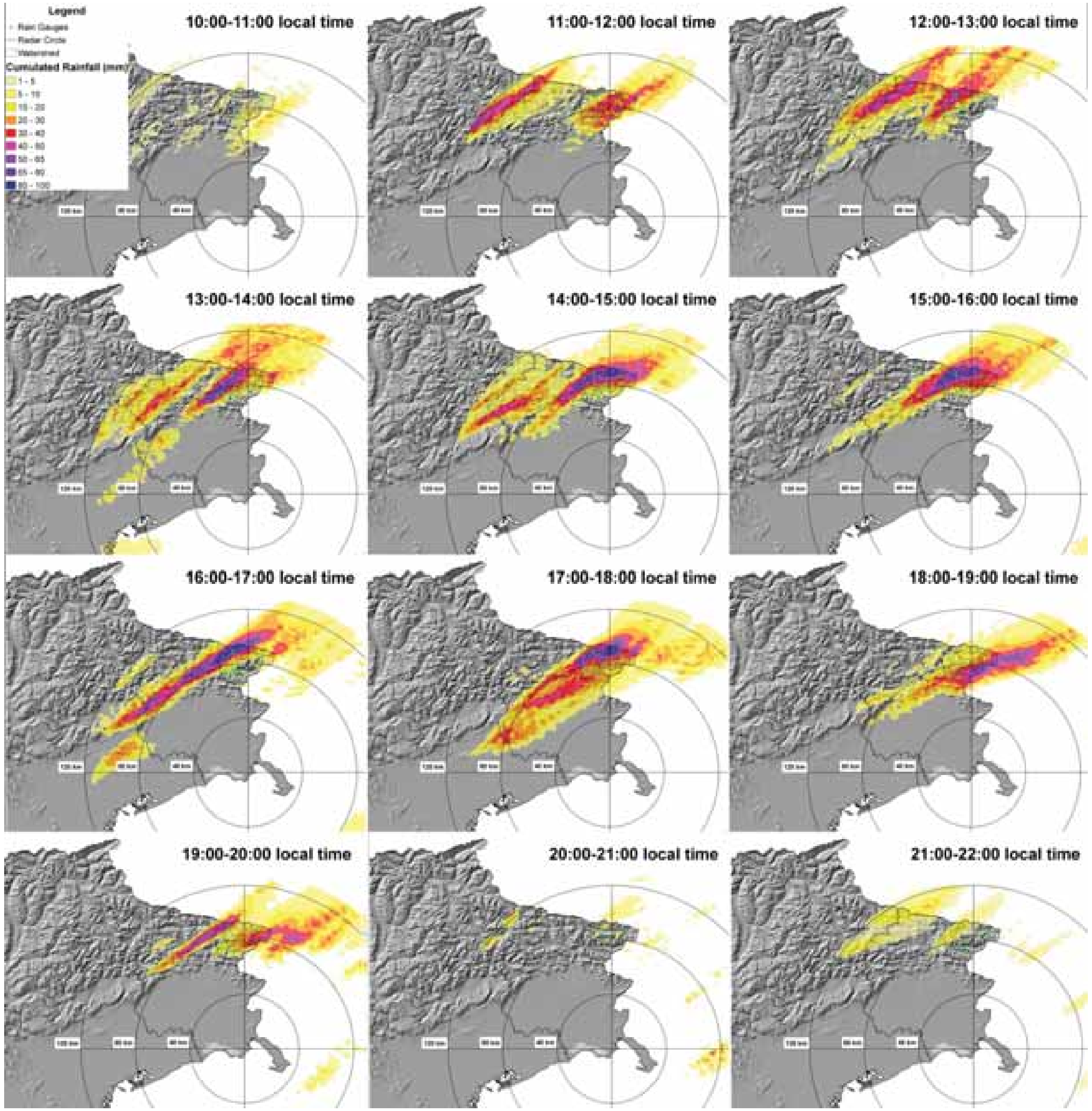
Case Study - North-eastern Italy 2003



Val Canale FF 29.08.2003

cumulata > 400 mm (in 6 ore) (RT> 500 anni)



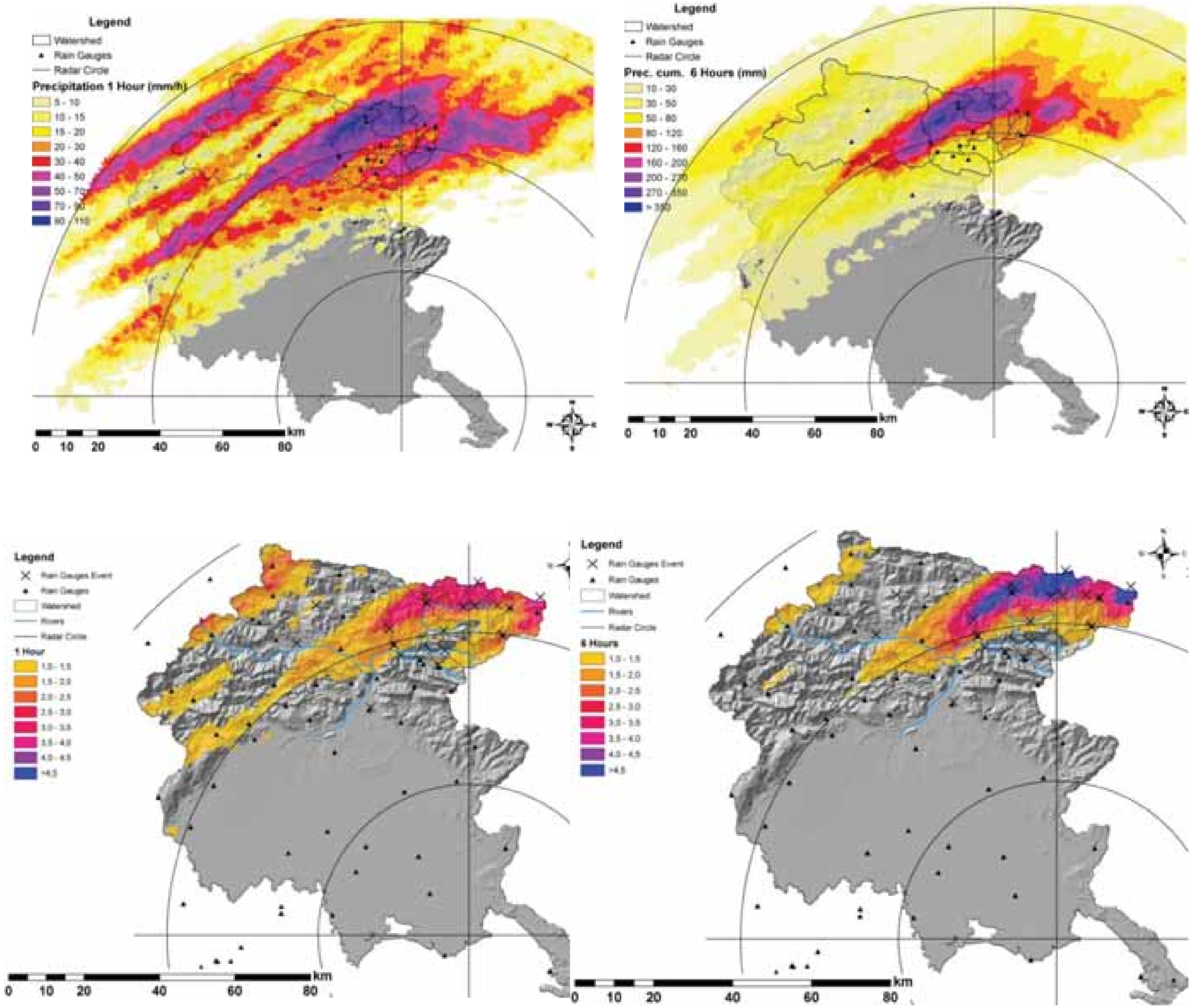

Legend
Rain Gauges
Radar Circle
Watershed
Cumulated Rainfall (mm)
10:00-11:00 local time
11:00-12:00 local time
12:00-13:00 local time
13:00-14:00 local time
14:00-15:00 local time
15:00-16:00 local time
16:00-17:00 local time
17:00-18:00 local time
18:00-19:00 local time
19:00-20:00 local time
20:00-21:00 local time
21:00-22:00 local time

Analysis of rainfall maxima:

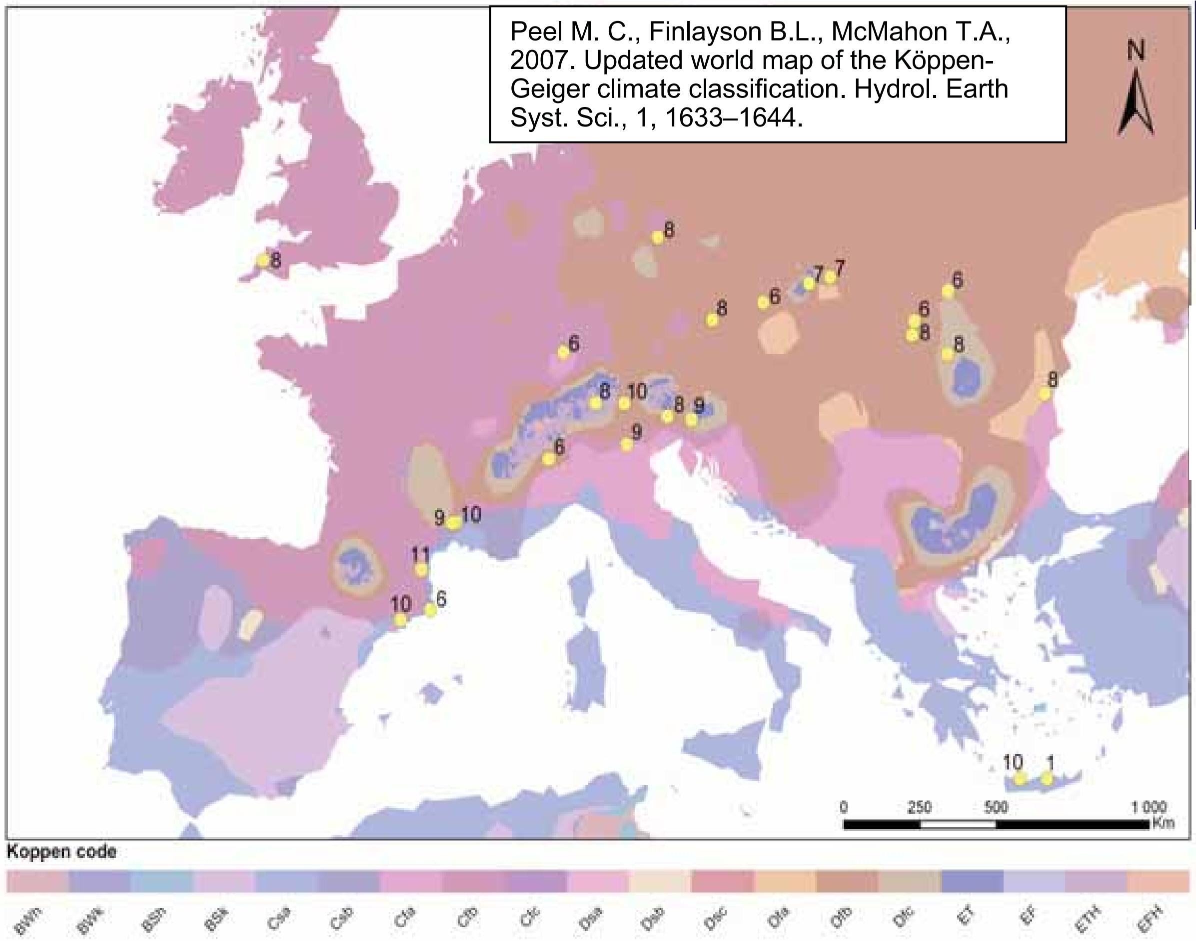
spatial patterns for rainfall maxima over 1 hour (a) and 6 hours (b);

ratio of the event rainfall maxima to the local average of annual rainfall maxima for for 1 hour (e) and 6 hours (f) (values of ratio < 1 are not displayed).

f)



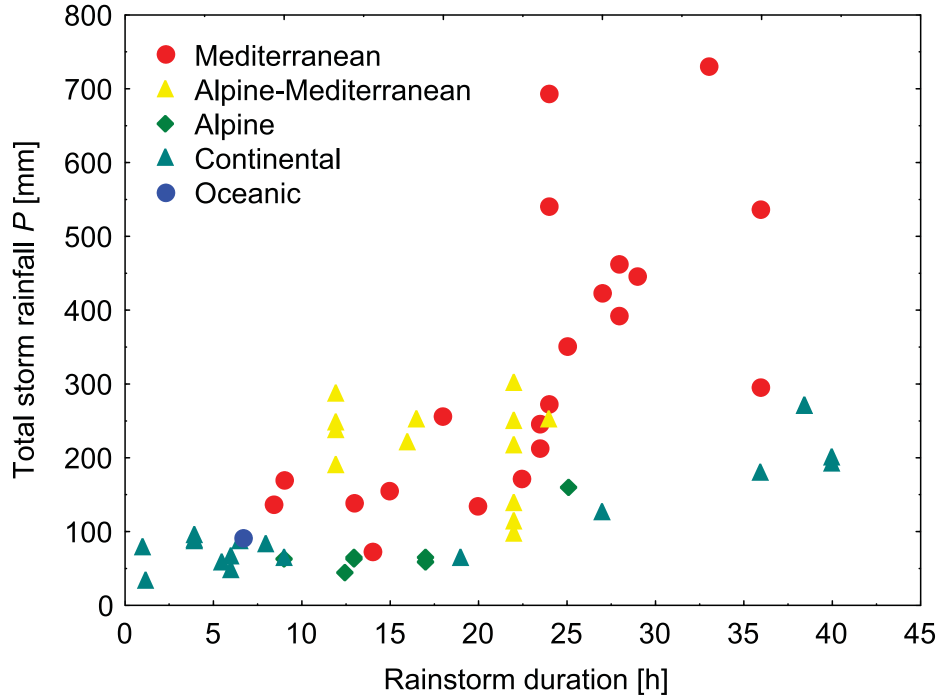
The flash flood catalogue: climatic organisation and seasonality

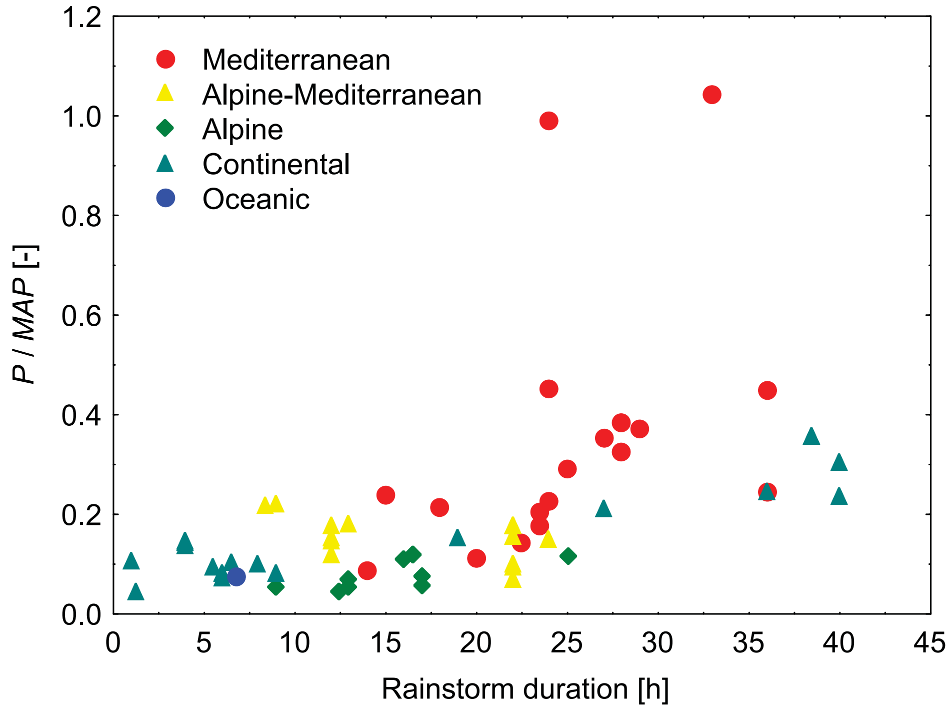


25 flash floods in 10 Countries
Data from 61 cross-sections
Temporal coverage: 1994 - 2008

Collected data: discharge, distributed rainfall (raingauge – radar), geographical data

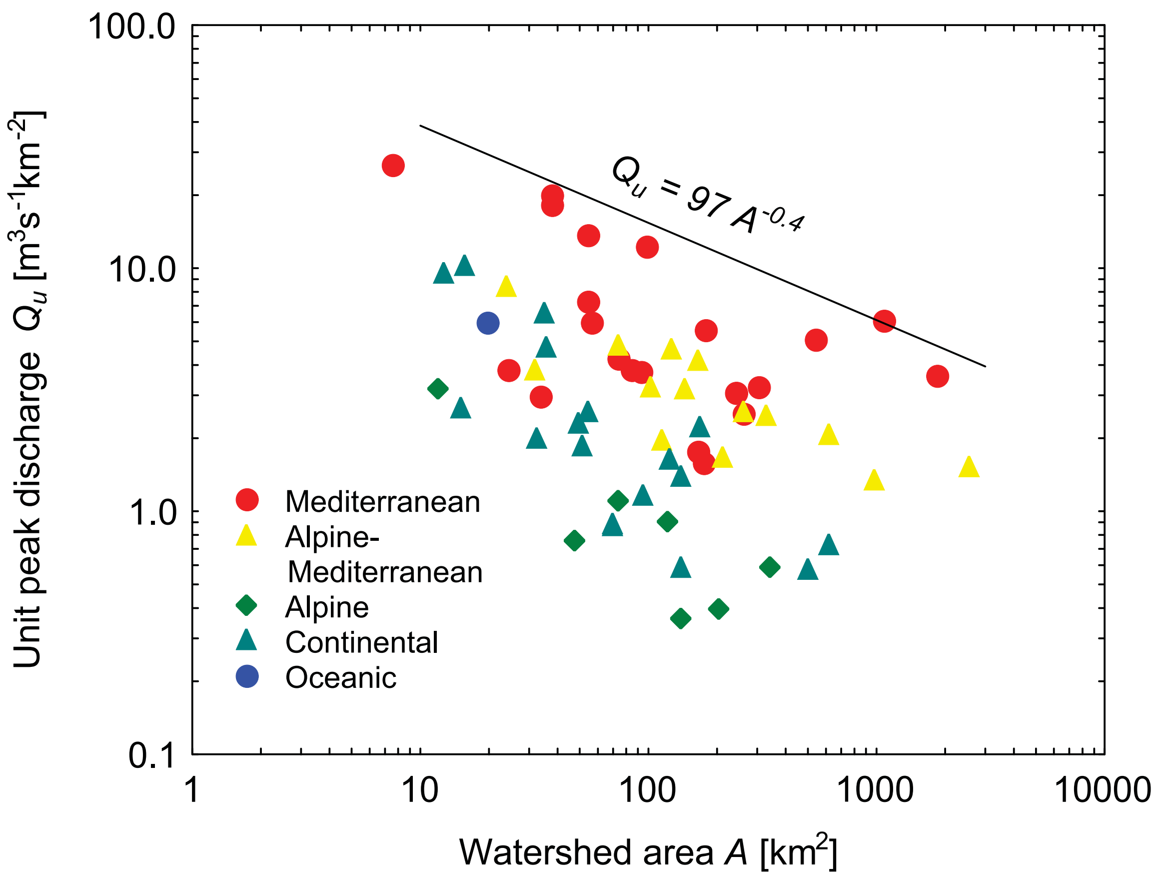
Summary of results – storm amount and duration





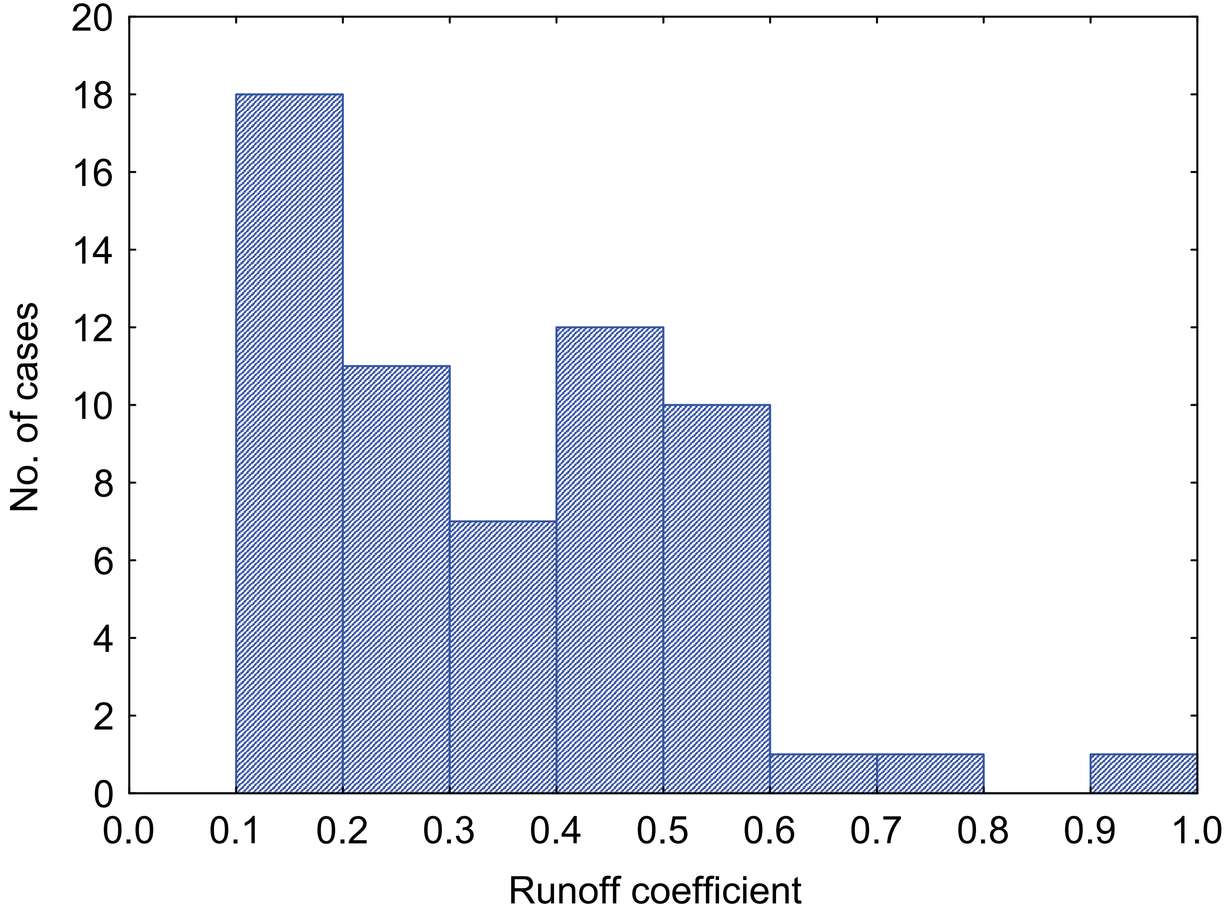
P: total event rainfall
MAP: mean annual precipitation

Summary of results – Unit peak discharges



Highest values in Mediterranean and Alpine-Mediterranean regions

Summary of results – Runoff coefficients

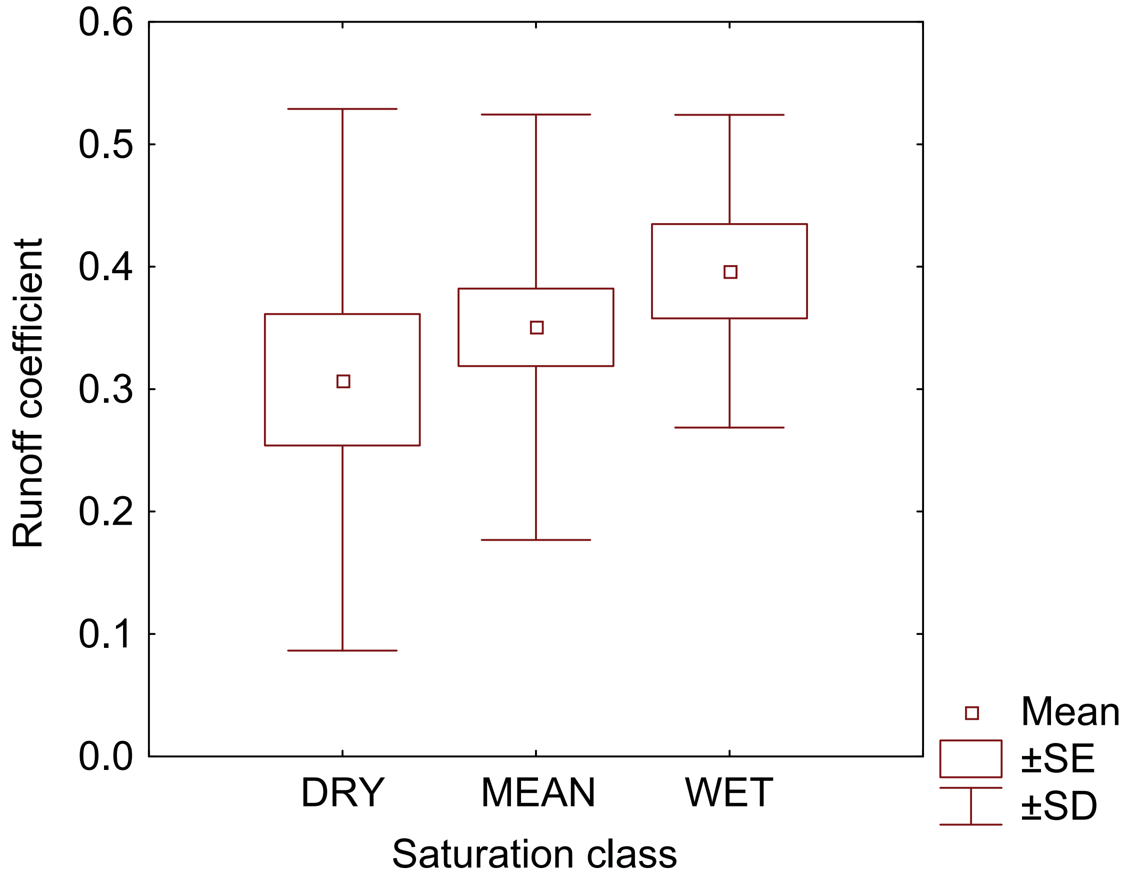


Runoff coefficients are generally low:

- mean: 0.35
- std. dev: 0.18
- median: 0.39
- lower quartile: 0.19
- upper quartile: 0.45

Summary of results – Impact of initial conditions

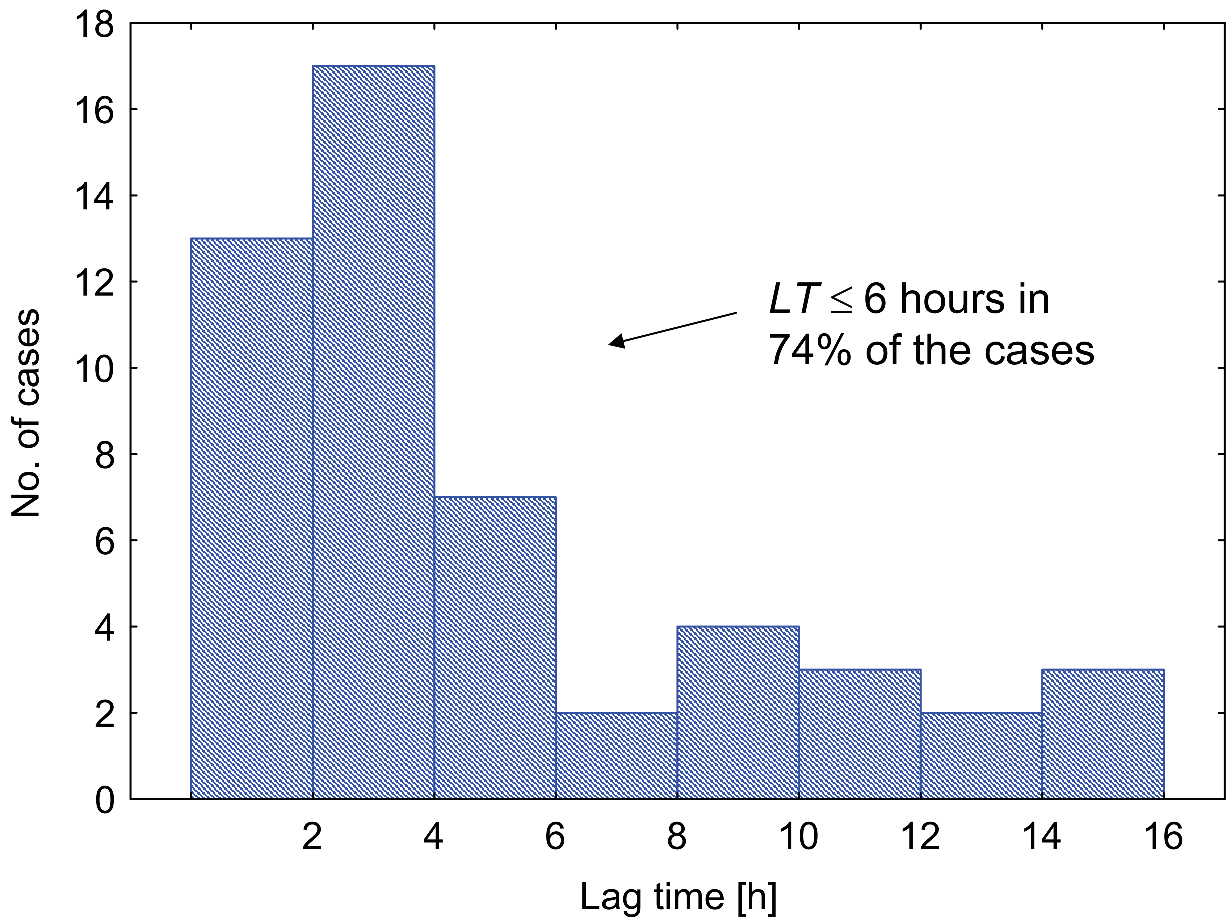
Three classes of antecedent saturation: ratio of cumulated rainfall in 30 days before the flood to long term average in the same period



- Larger variability for “Dry” antecedent conditions
- Significant differences in Runoff coefficient between “Dry” and “Wet” conditions (Mann-Whitney U test)

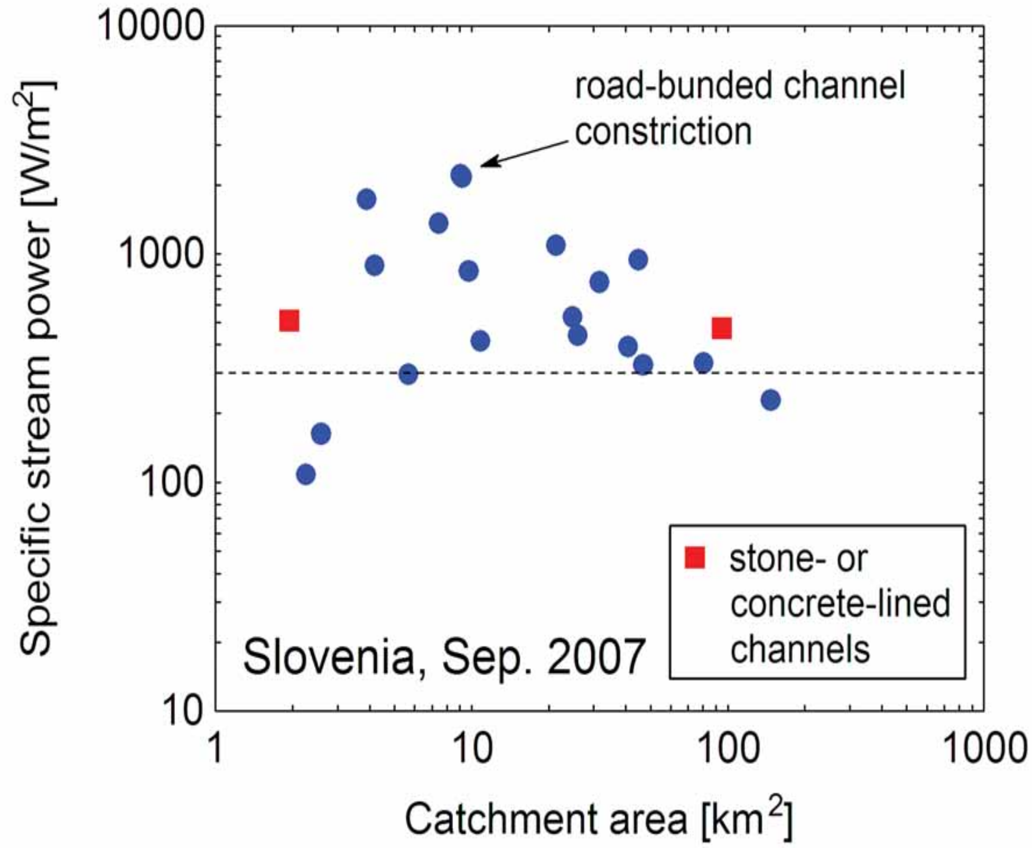
Summary of results – Lag time

Lag time:
from rainfall centroid
to flood peak



Summary of results – Peak of stream power

Stream power
(erosive processes)
peak around 10 km2



Policy implications - 1

The Observation problem:
effective analysis of flash flooding requires a systematic effort aimed to carry out in a **routinary way the program of field visits and post-event analysis after each flash flood event**

Seasonality and space-time scales:
Shift from summer to fall season when moving from Central Europe to Mediterranean regions. Consistently with this seasonality effect, spatial extent and duration of the events is generally smaller for the Continental events with respect to those occurring in the Mediterranean region. .

Low value of runoff coefficient:
Atmospheric models + Hydrological models required to understand and forecast flash floods. On the other hand, it indicates the potential effects of land use change on runoff generation for these events.

Policy implications - 2

The influence of the initial conditions:
Our results challenge the common wisdom that antecedent soil moisture is of little importance in determining the magnitude of extreme flash floods. **Hence, accounting for antecedent soil moisture conditions is paramount for operational flash flood forecasting**.

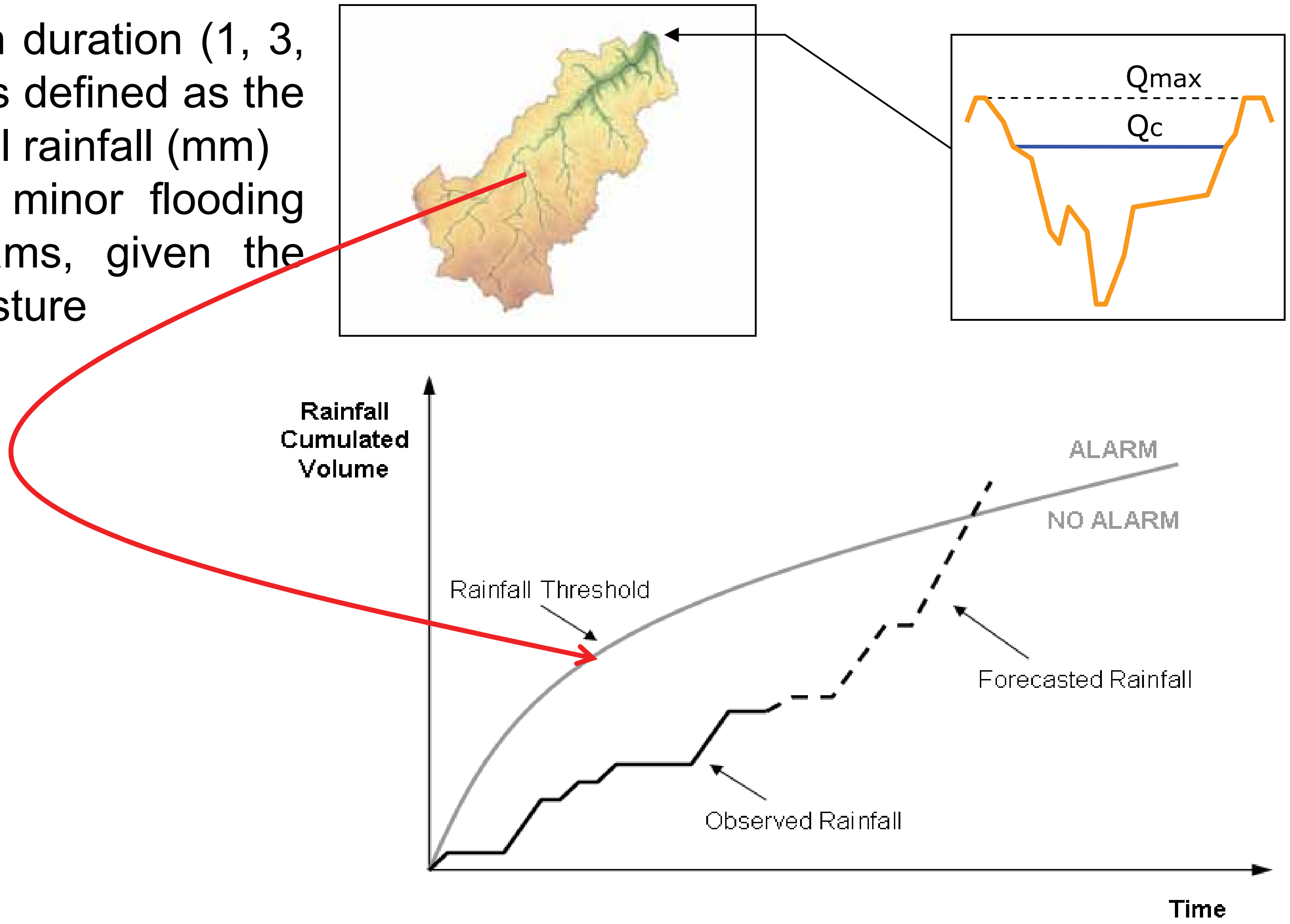
The co-occurrence of flash flood and landsliding and debris-flows:
The high kinetic potential of flash floods may lead to large geomorphic impacts, including landslides and debris flows. This may have huge impact on society.

Flash floods are flashy events:
Preparedness is a key element to reduce the impact of these events on society. **The observation strategy (when extended to capture social vulnerability features) may reveal key social elements capable to improve preparedness programs.**

The tools: Flash Flood Guidance

Flash Flood Guidance CONCEPT

FFG, of a given duration (1, 3, 6, 12, 24 hrs), is defined as the volume of actual rainfall (mm) that generates minor flooding on small streams, given the current soil moisture



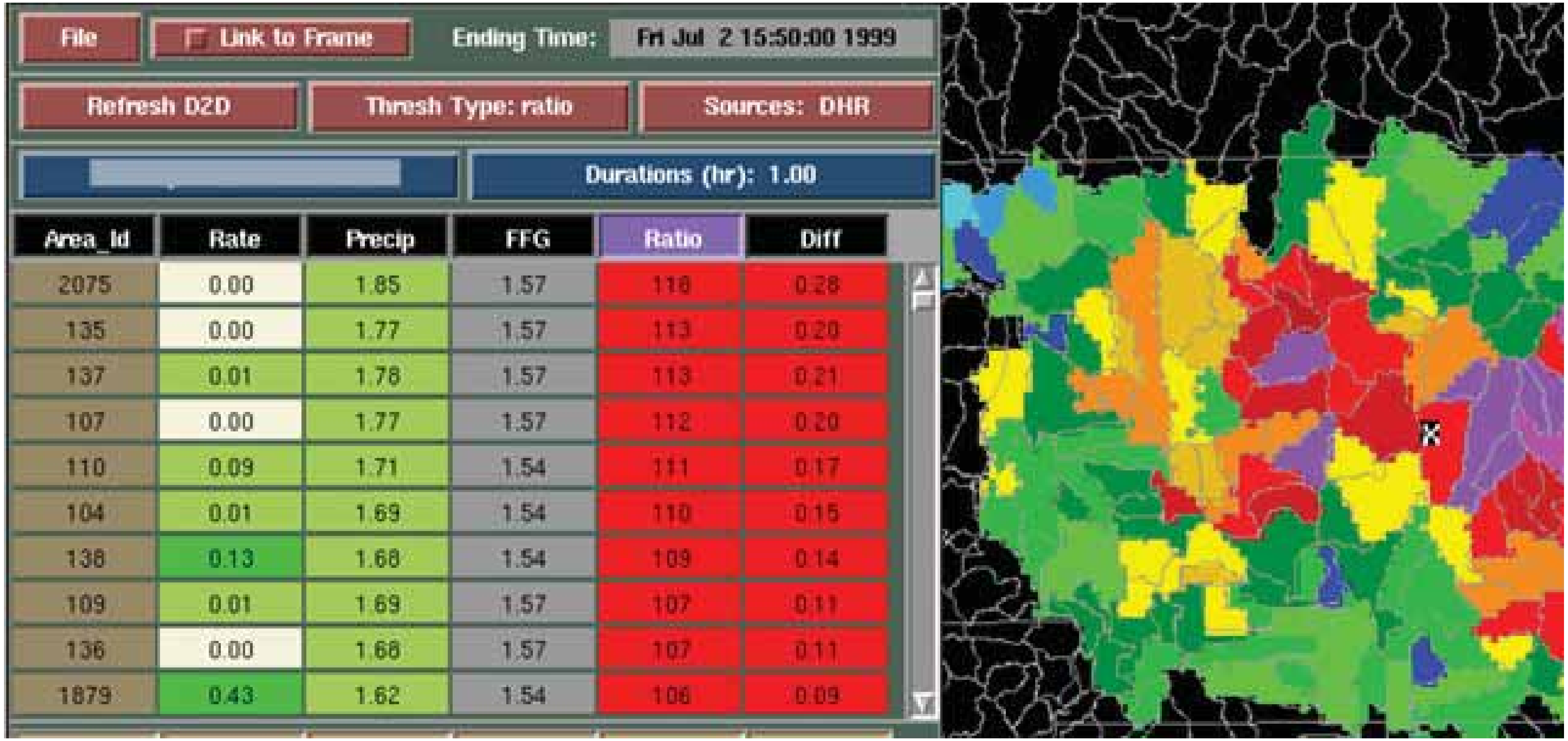
The tools: Flash Flood Guidance

- FFG is based on running (in an inverse mode) the hydrological model on each sub basin where the FFG is computed. To support flash flood computations and using the predefined initial conditions, the model runs off-line in ‘what if’ scenario runs with increasing amounts of rainfall input of a given duration.

- FFG for a given duration is the rainfall of that duration which corresponds to the predefined flooding flow.

•**Graphic displays of:**

Basin rainfall accumulation
Ratio of basin accumulations to FFG
Accumulations – FFG (Difference)
For time periods of from 30 minutes to 6 hours



Area_Id	Rate	Precip	FFG	Ratio	Diff
2075	0.00	1.85	1.57	118	0.28
135	0.00	1.77	1.57	113	0.20
137	0.01	1.78	1.57	113	0.21
107	0.00	1.77	1.57	112	0.20
110	0.09	1.71	1.54	111	0.17
104	0.01	1.69	1.54	110	0.15
138	0.13	1.68	1.54	109	0.14
109	0.01	1.69	1.57	107	0.11
136	0.00	1.68	1.57	107	0.11
1879	0.43	1.62	1.54	106	0.09

Conclusions

- **Improved flash flood (FF) risk management requires ad hoc observation strategy;**
- **A FF observation methodology, based on: HOs, radar observations, and post-event surveys was developed.**
- **The strategy showed the potential to provide the knowledge on FF hydrometeorological processes we currently lack.**
- **Examples of risk management approaches were developed and successfully tested (FFG).**