Flood early warning systems: operational approaches and challenges

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Climate change and natural disasters,
Athens, Greece
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Outline

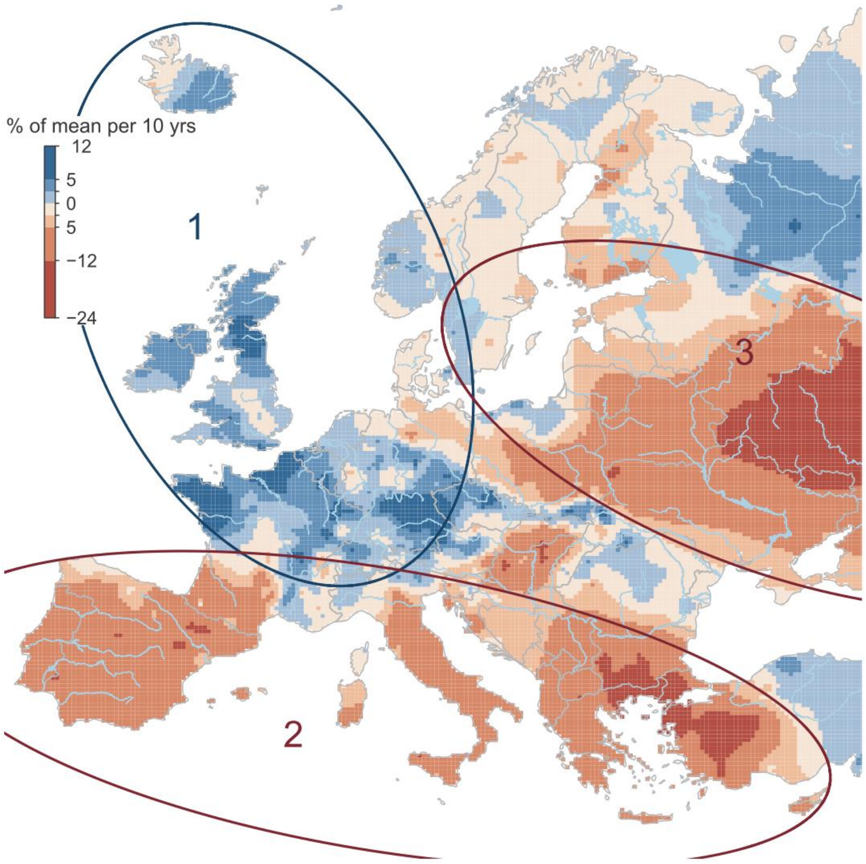
- Climate change: impacts on floods
- Flood early warning system: structure(s)
- Use of Ensembles Prediction Systems
- Flash floods: ungauged extremes

- The challenges of FF early warning systems

  - forecasts of flash flood – diagnostic methods;
  - flash flood forecasts by coupling hydro and meteo models

- Conclusions

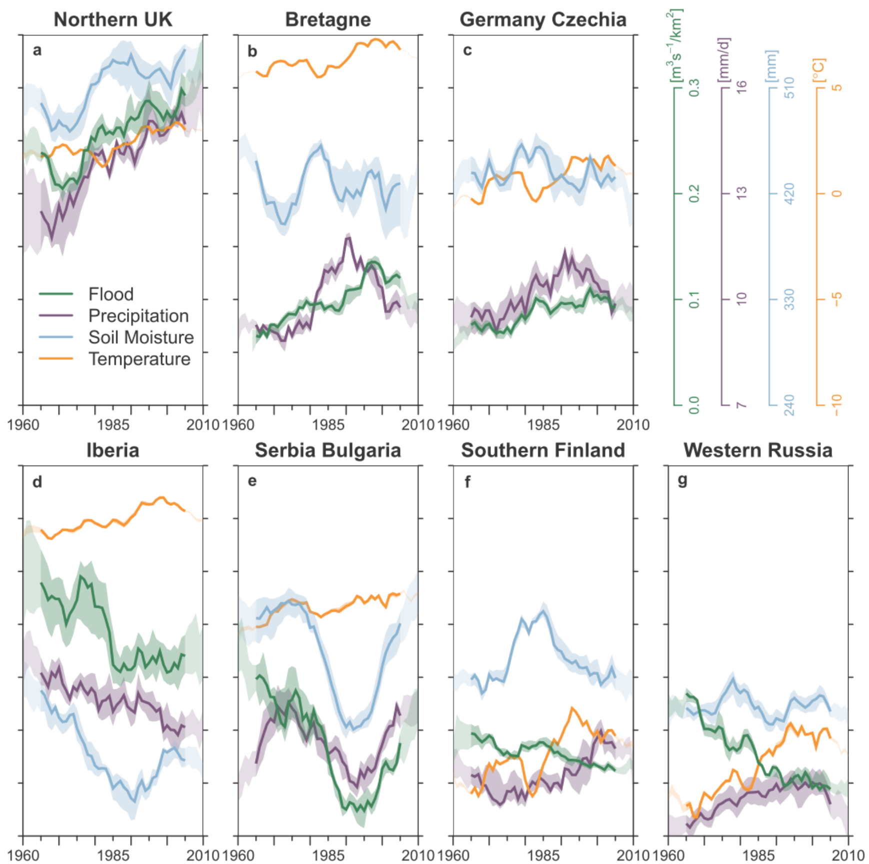
Changing climate both increases and decreases European floods - 1



Observed trends of river flood discharges in Europe (1960-2010).

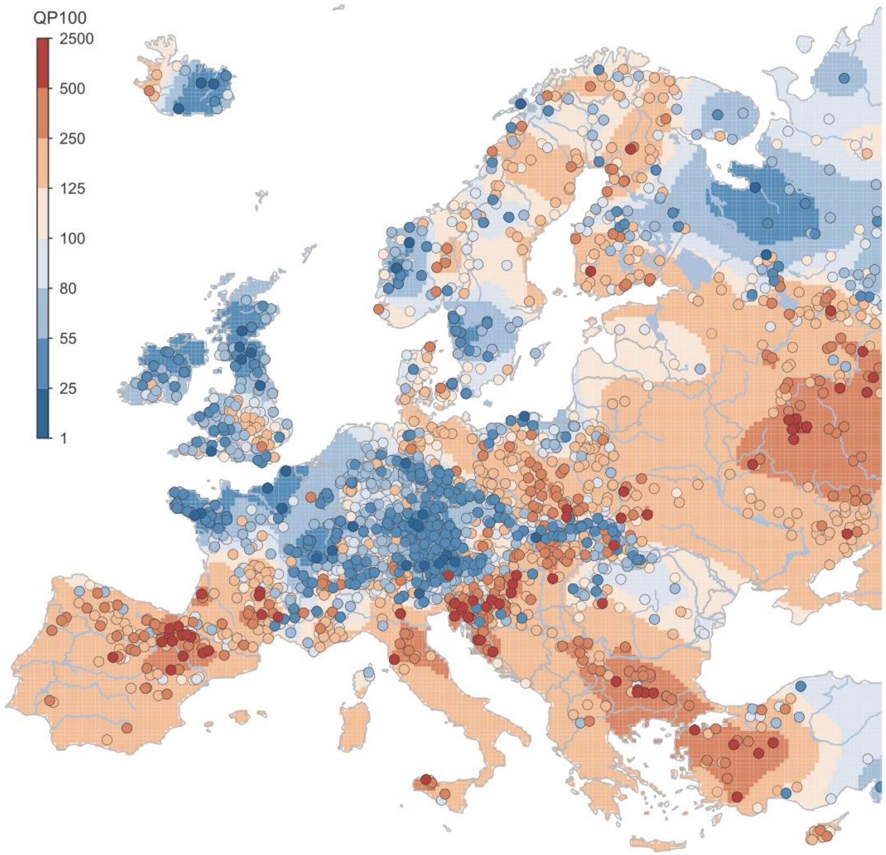
Bloeschl et al., 2018. Under submission

Changing climate both increases and decreases European floods - 2

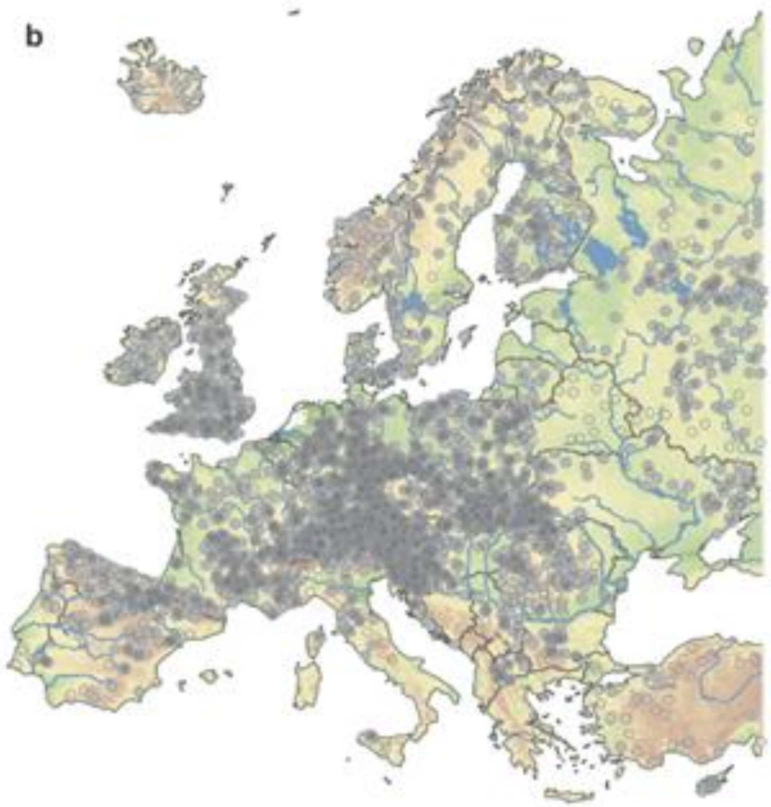


Long-term temporal evolution of flood discharges and their drivers for seven hotspots in Europe

Changing climate both increases and decreases European floods - 3



Return period in 2010 of the discharge that was a 100-year flood in 1960

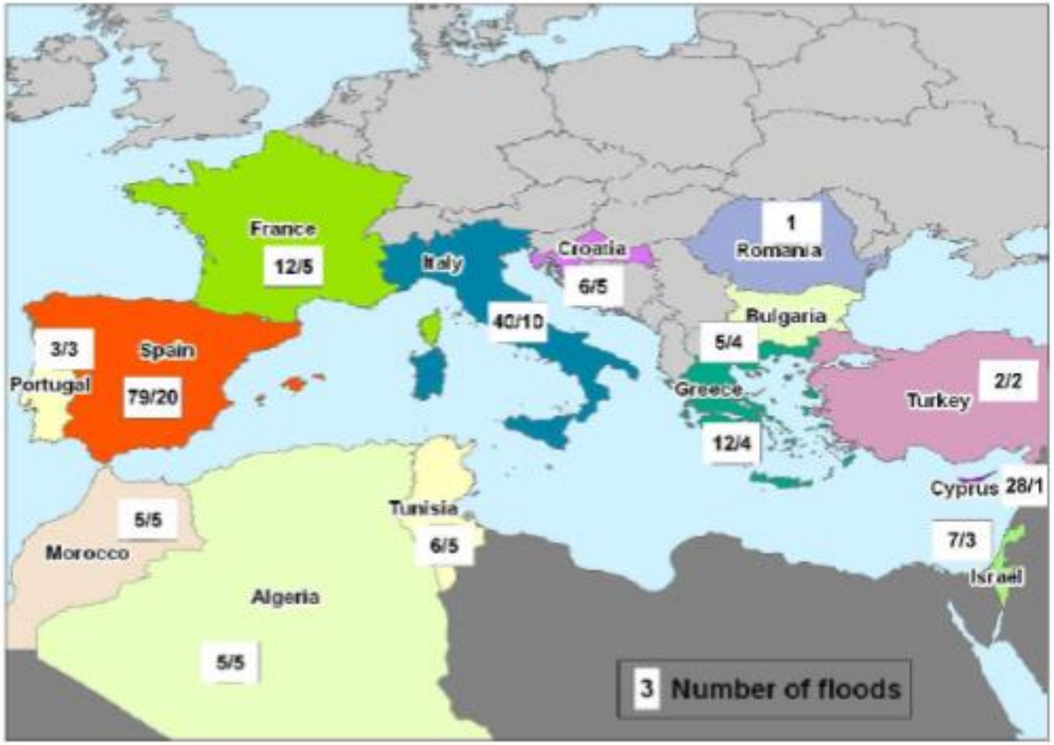


Location of the hydrometric stations analysed.

Flash flood events in Europe (1990-2006)

HOWEVER:

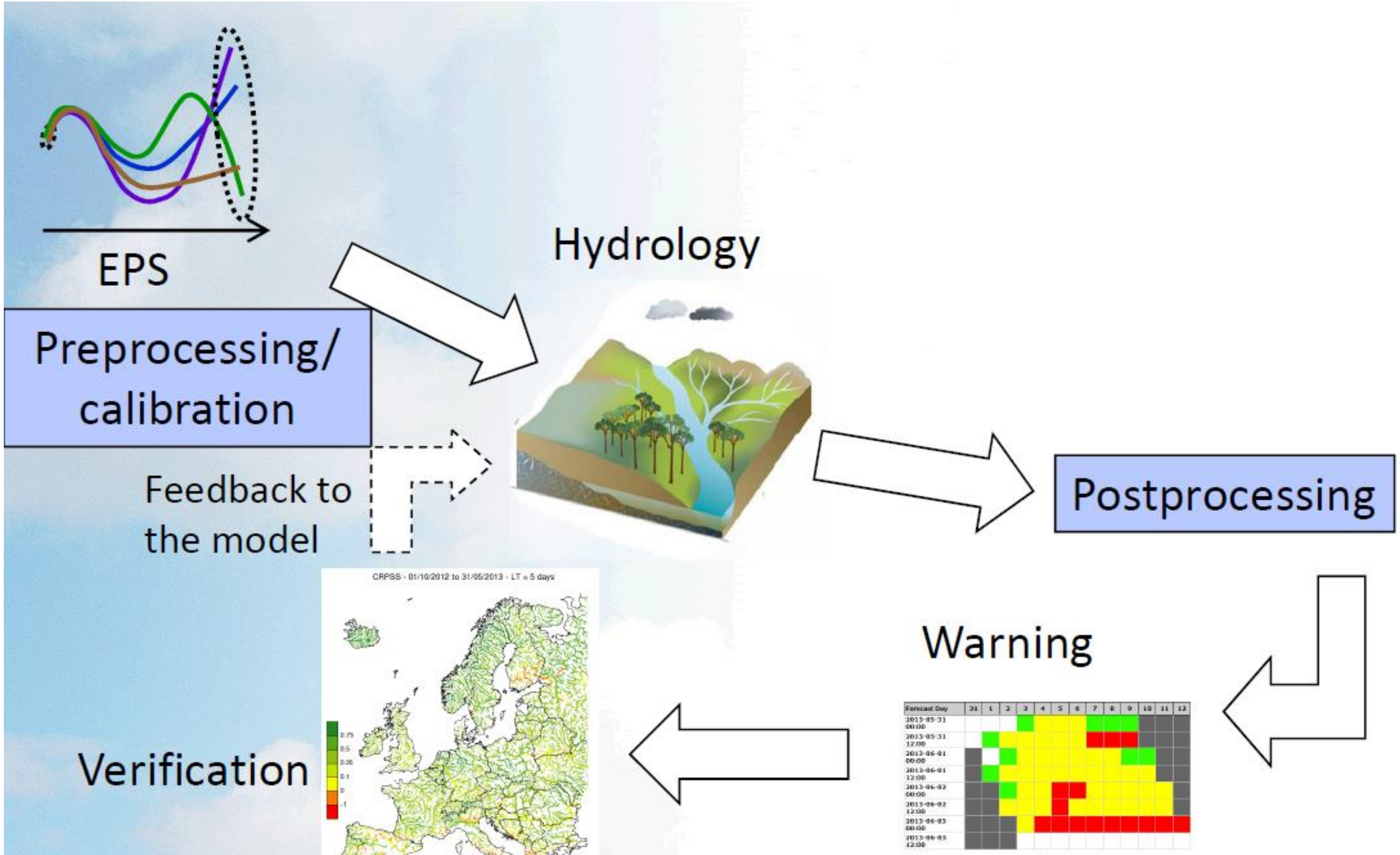
The decreasing flood discharges in southern Europe appears to be inconsistent with the occurrence of numerous devastating flash floods in recent years (Llasat et al., 2010; Marchi et al, 2010).



Flood early warning system: fit for purpose

- **In flood forecasting there is no one-size fits-all.**
- **Integration of different systems and methods is a major challenge.**
- **Any system does not have to be perfect but suitable.**

FEWS with Ensemble Prediction Systems

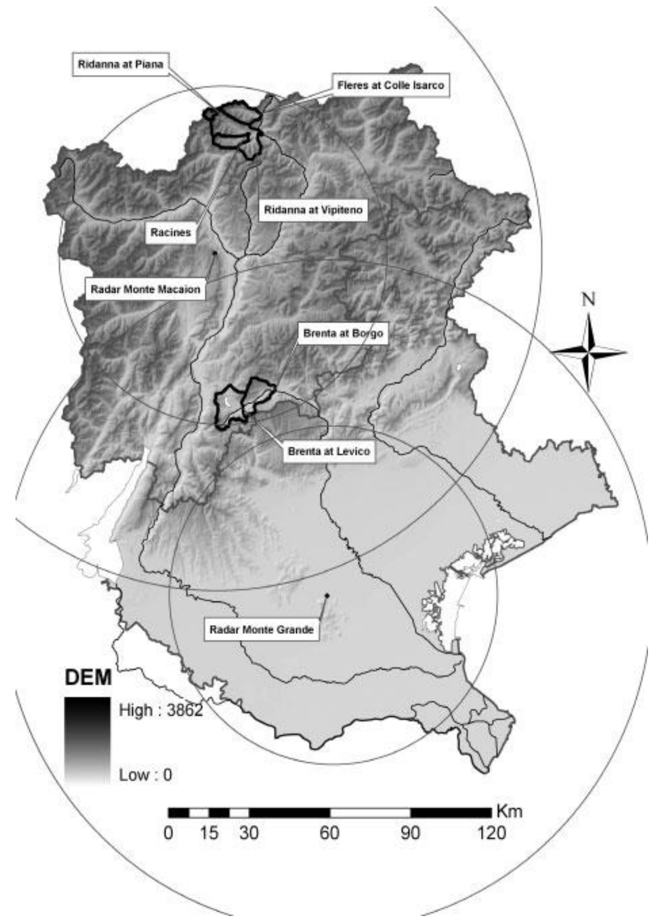


For a full summary see *Ensemble Flood Forecasting: A Review*, Cloke H.L., and Pappenberger, F., 2009, Journal of Flood Risk Management

Use of ensembles allows to take account of uncertainty in this boundary condition and eventually for a ‘better’ forecast

FEWS with Ensemble Prediction Systems:

how it was used yesterday (2018.10.29)



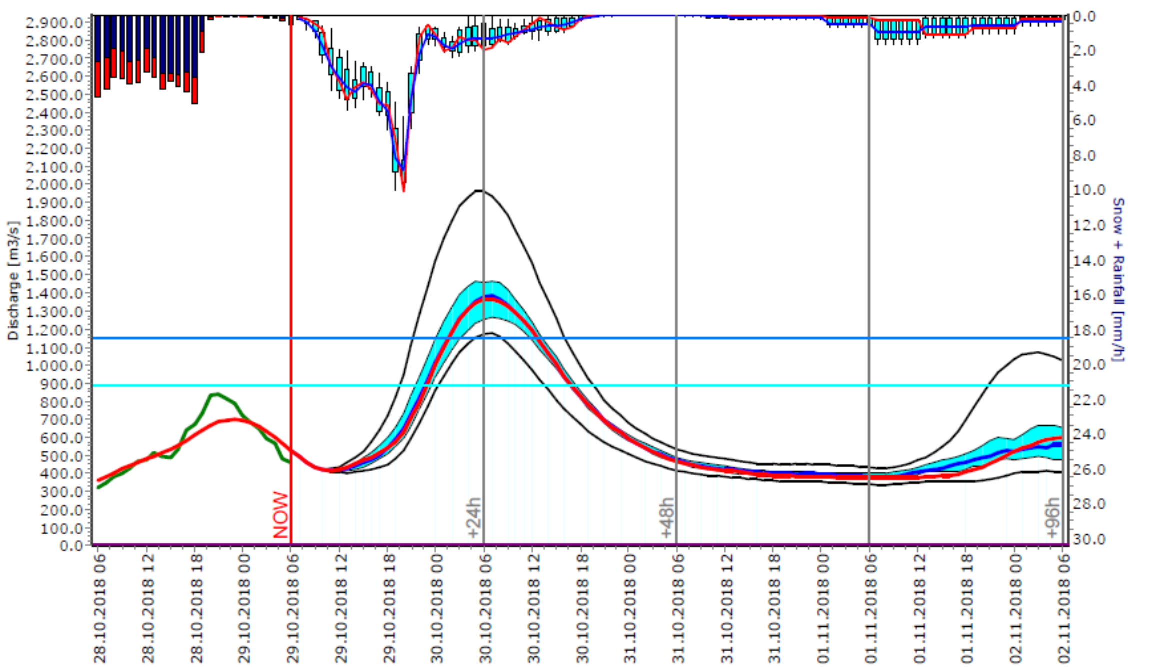
FEWS with Ensemble Prediction Systems:

how it was used yesterday (2018.10.29)

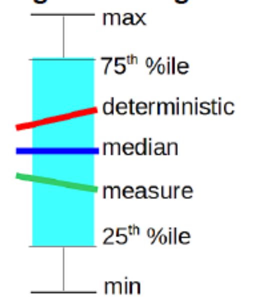
ETSCH BEI BRANZOLL ADIGE A BRONZOLO

Daten / Dati (NOW)	29.10.2018 06:00:00	Erstellt / Redatto	Stefan Ghetta
Aktualisierung / Aggiornamento	On demand.	Kontrolliert / Controllato	sg

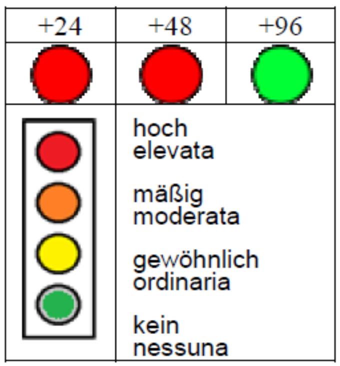
Allgemeine Modelllauf-Infos / Info generali run modello		Schwellenwerte / Valori di soglia	Q [m³/s]	W [cm]
Run => Ensemble ID	21508=>1086	Vorwarnstufe / Attenzione	882.6	430
Topology ID	48	Warnstufe / Guardia	1150.0	500
Parameter Set ID	9	Ausuferung / Esondazione	N.A.	620



Legende / Legenda



Gefahrenpotential / Criticità



FEWS with Ensemble Prediction Systems:

how it was used yesterday (2018.10.29)

ETSCH BEI BRANZOLL ADIGE A BRONZOLO

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Aktualisierung / Aggiornamento	On demand.	Kontrolliert / Controllato	rd	
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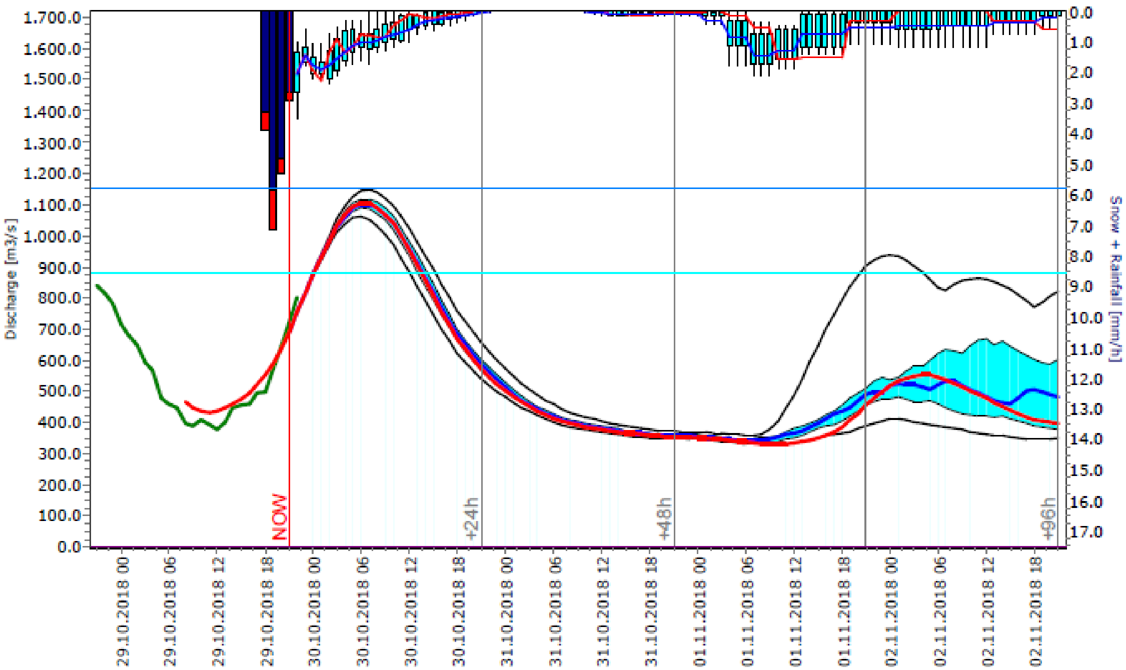
Topology ID	48	Warnstufe / Guardia	1150.0	500
Parameter Set ID	9	Ausuferung / Esondazione	N.A.	620



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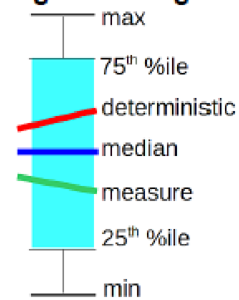

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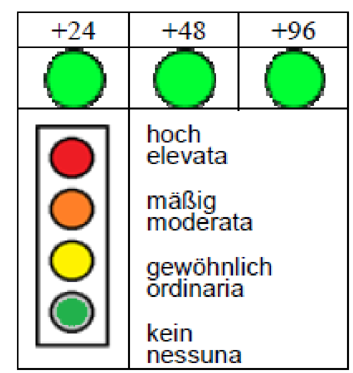


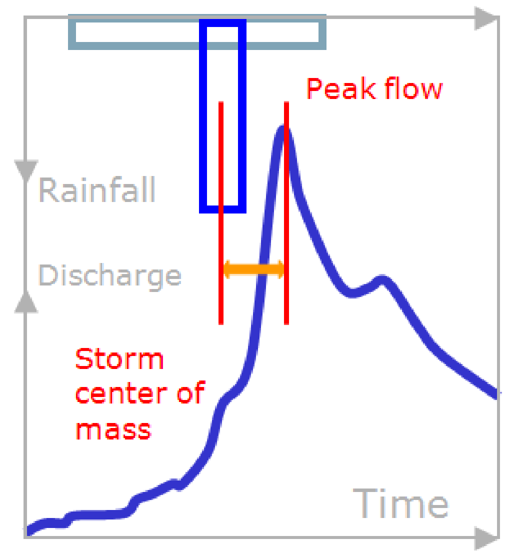
Flash flood early warning systems

Flash floods: a working definition

- **Flash floods are flashy events ('sudden' from the point of view of impacted people)**

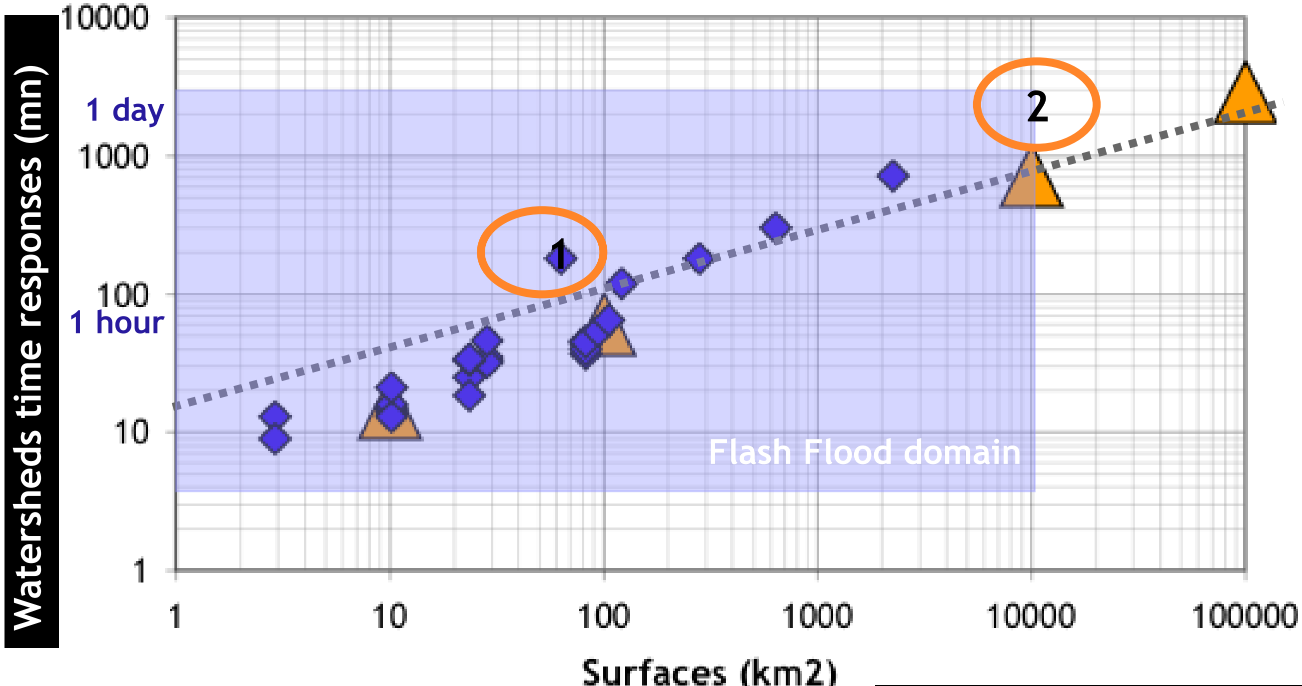
- **Response time of flood is from storm centroid time to peak time: flash flood response time is less than 'social response time';**

- **Literature-based assessments of the social response time: 10-15 hours.**

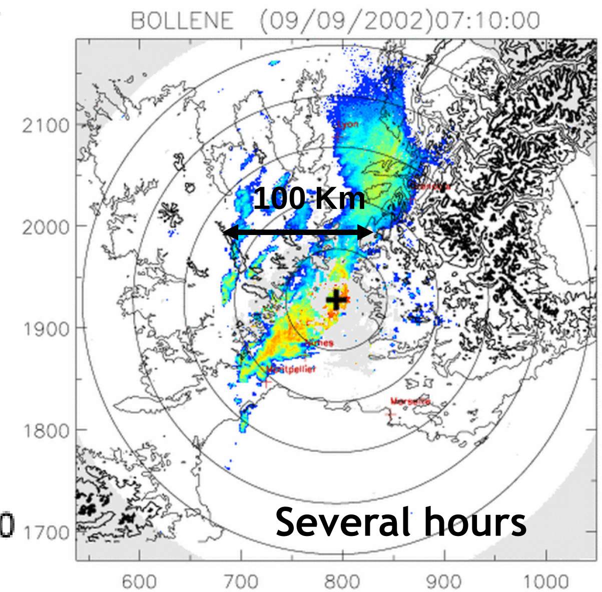


CREUTIN J.D., M. BORGA, E. GRUNTFEST, C. LUTOFF, D. ZOCCATELLI, I RUIN, 2013: A space and time framework for analyzing human anticipation of flash floods. Journal of Hydrology, 482, 14-24, ISSN: 0022-1694

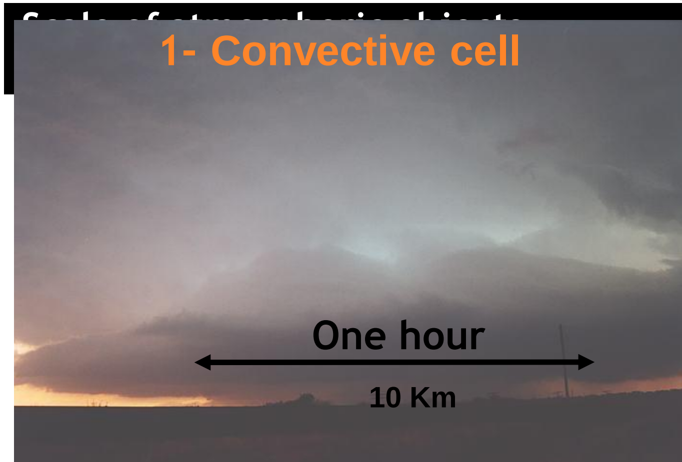
Flash floods: space-time scales



2- Meso-scale convective system



Scale of hydrological responses

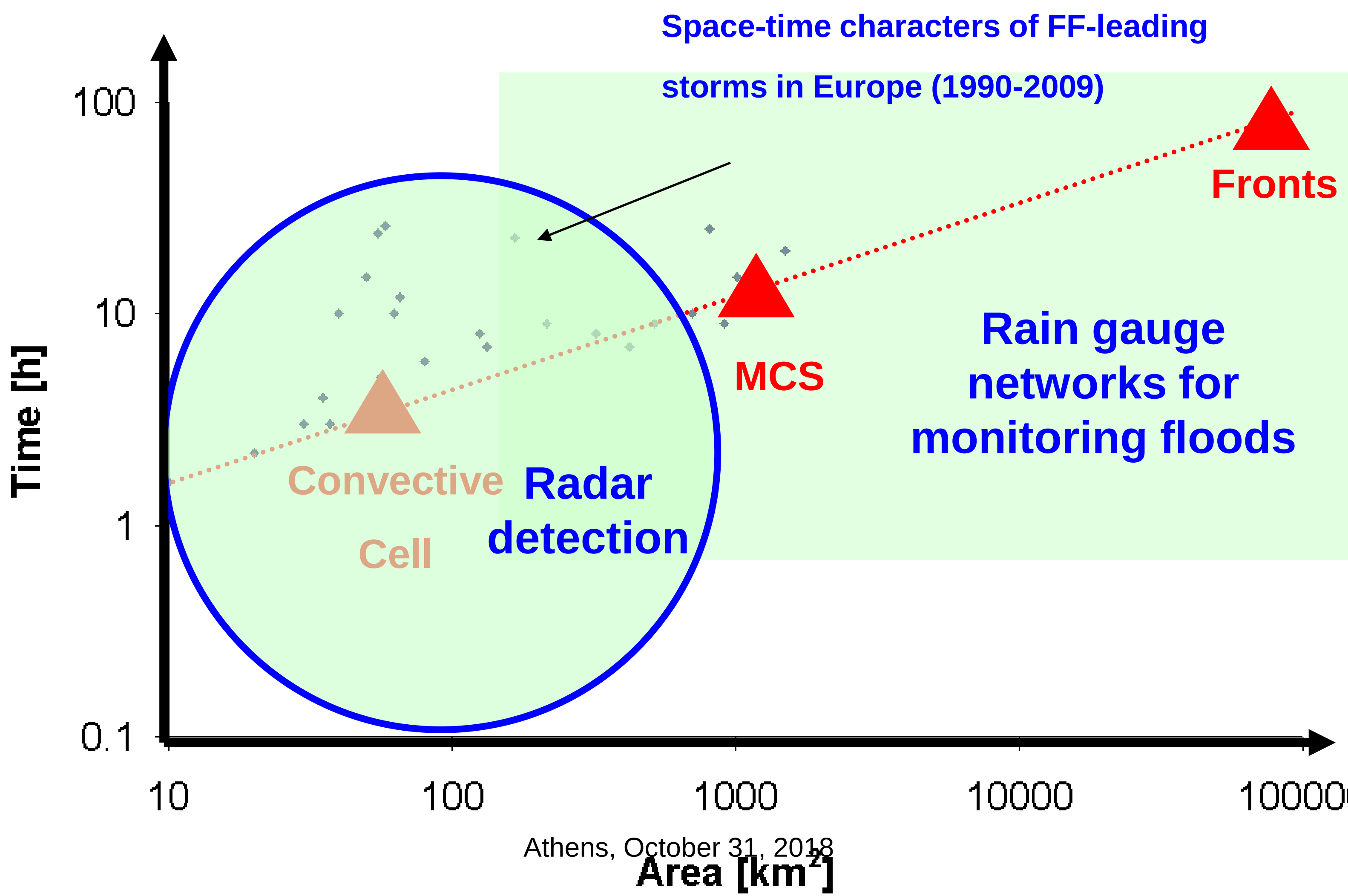


BORGA, M., M. STOFFEL, L. MARCHI, F. MARRA, M. JAKOB, 2014: Hydrogeomorphic response to extreme rainfall in headwater systems: flash floods and debris flows. Journal of Hydrology, 518, 194–205, http://dx.doi.org/10.1016/j.jhydrol.2014.05.022, ISSN: 0022-1694.

RUIN, I., C. LUTOFF, B. BOUDEVILLAIN, J.D. CREUTIN, S. ANQUETIN, M. BERTRAN ROJO, L. BOISSIER, L. BONNIFAIT, M. BORGA, L. COLBEAU-JUSTIN, L. CRETON-CAZANAVE, G. DELRIEU, J. DOUVINET, E. GAUME, E. GRUNTFEST, J.-P. NAULIN, O. PAYRASTRE, O. VANNIER, 2014: Social and hydrological responses to extreme precipitations: An interdisciplinary strategy for postflood investigation. Weather, Climate and Society, 6(1), 135-153, http://dx.doi.org/10.1175/WCAS-D-13-00009.1, ISSN: 1948-8327

Flash floods: observation challenges - rain

Space-time scales of flash floods

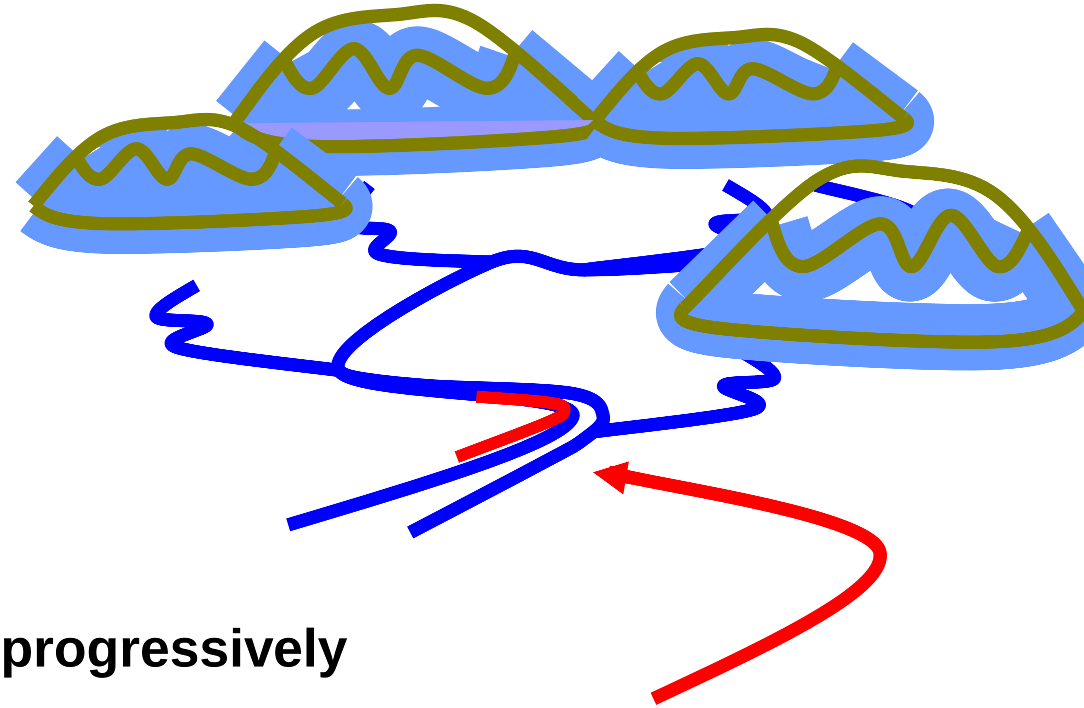


Flash floods: observation challenges - flows

Vulnerability: flash floods vs riverine floods - 1

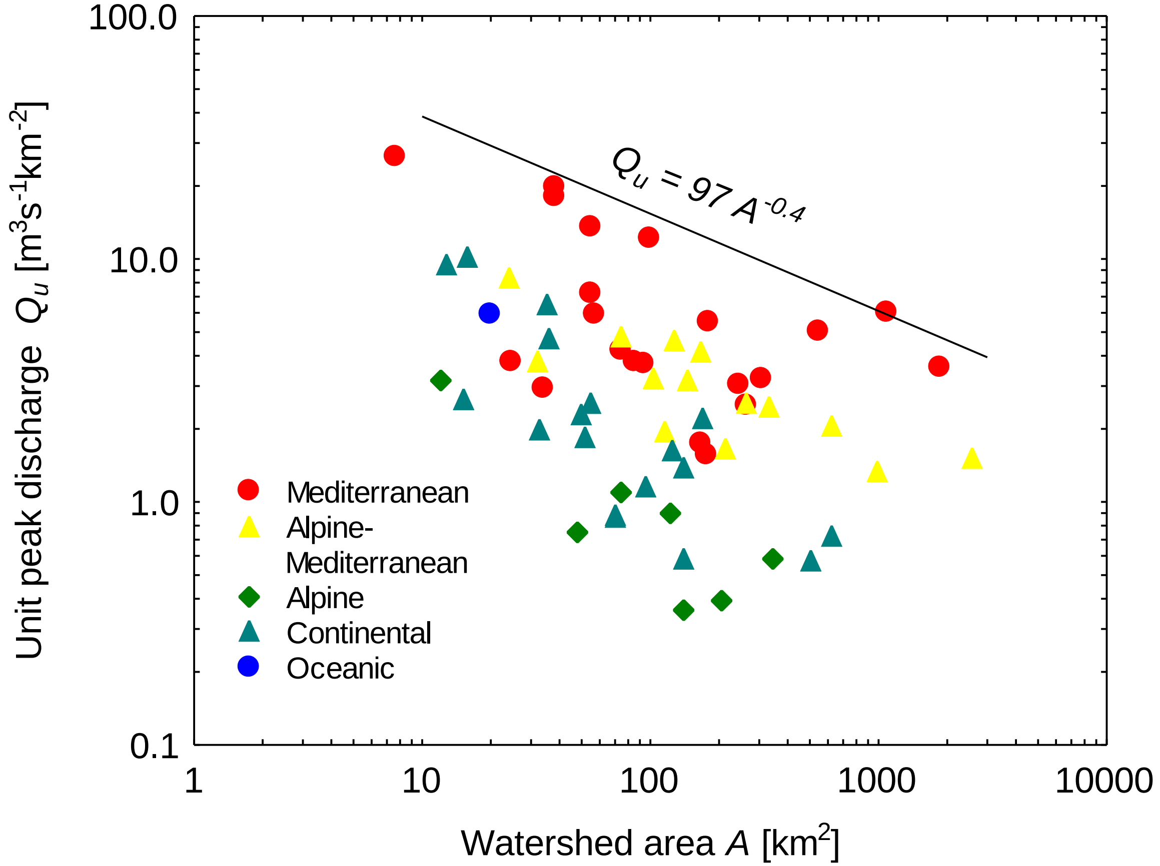
Flash flood hazard is dominated by the storm scale: it is localised.
Vulnerability is distributed and spread over the landscape;
Typical targets: *developing urbanization, transportation, green tourism...*

Vulnerability: flash floods vs riverine floods - 2



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

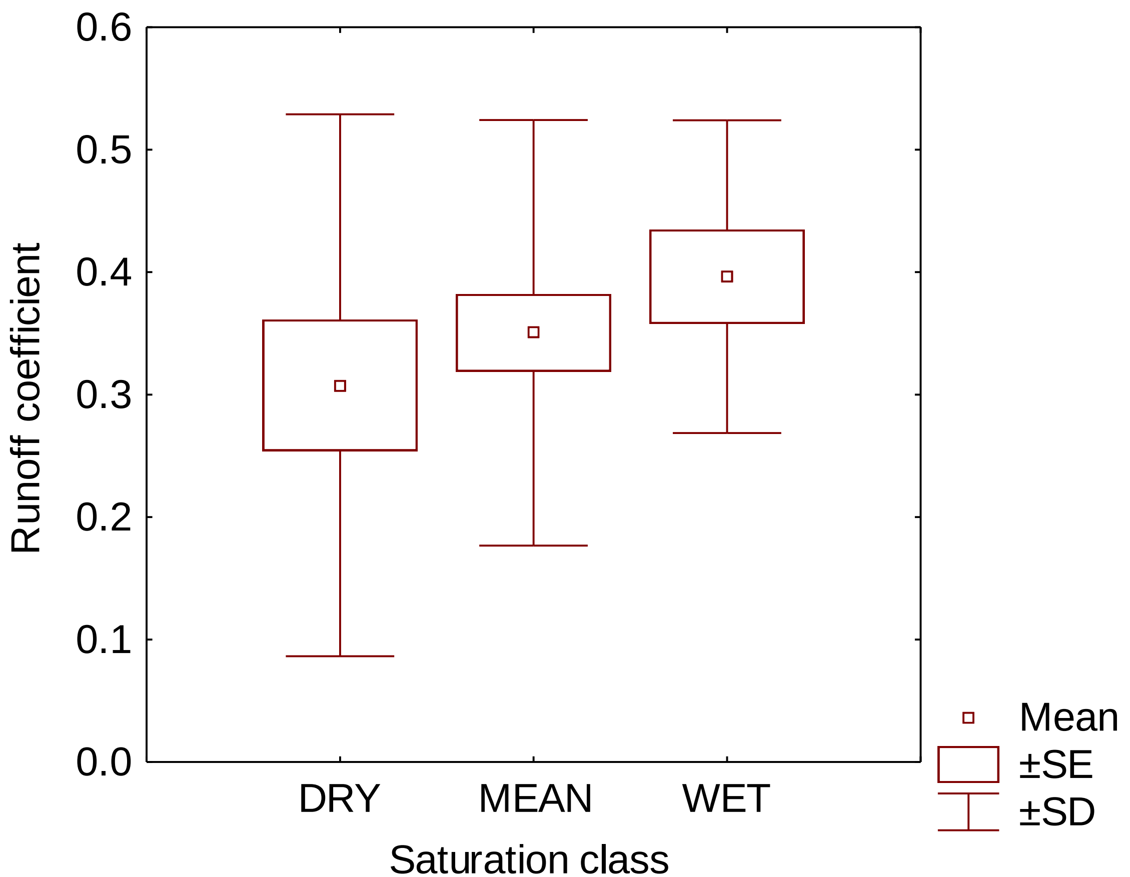
FF in Europe – Unit peak discharges



Highest values in Mediterranean and Alpine-Mediterranean regions

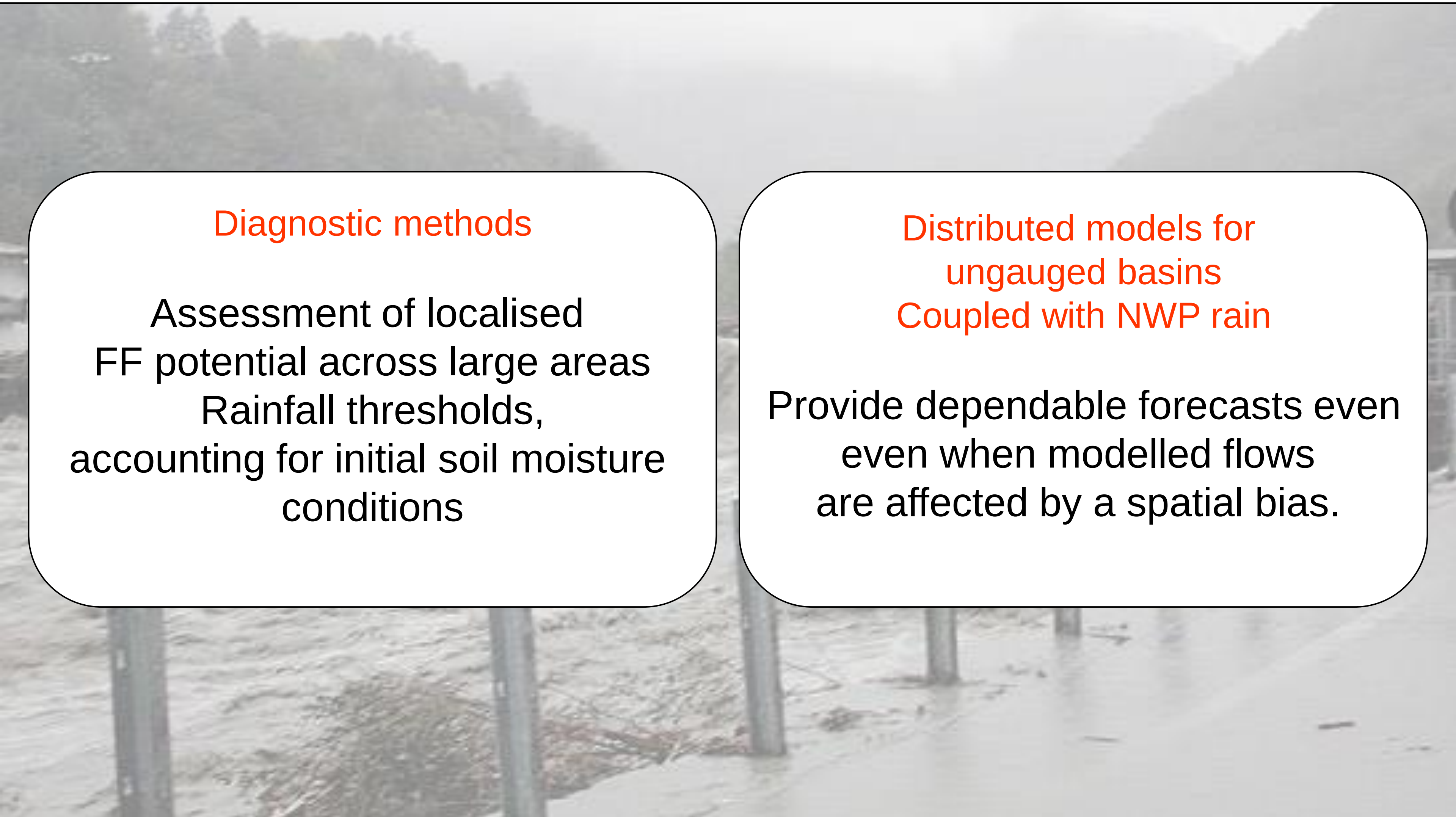
FF in Europe – Impact of initial conditions

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)

Flash flood early warning systems



Diagnostic methods

Assessment of localised
FF potential across large areas
Rainfall thresholds,
accounting for initial soil moisture
conditions

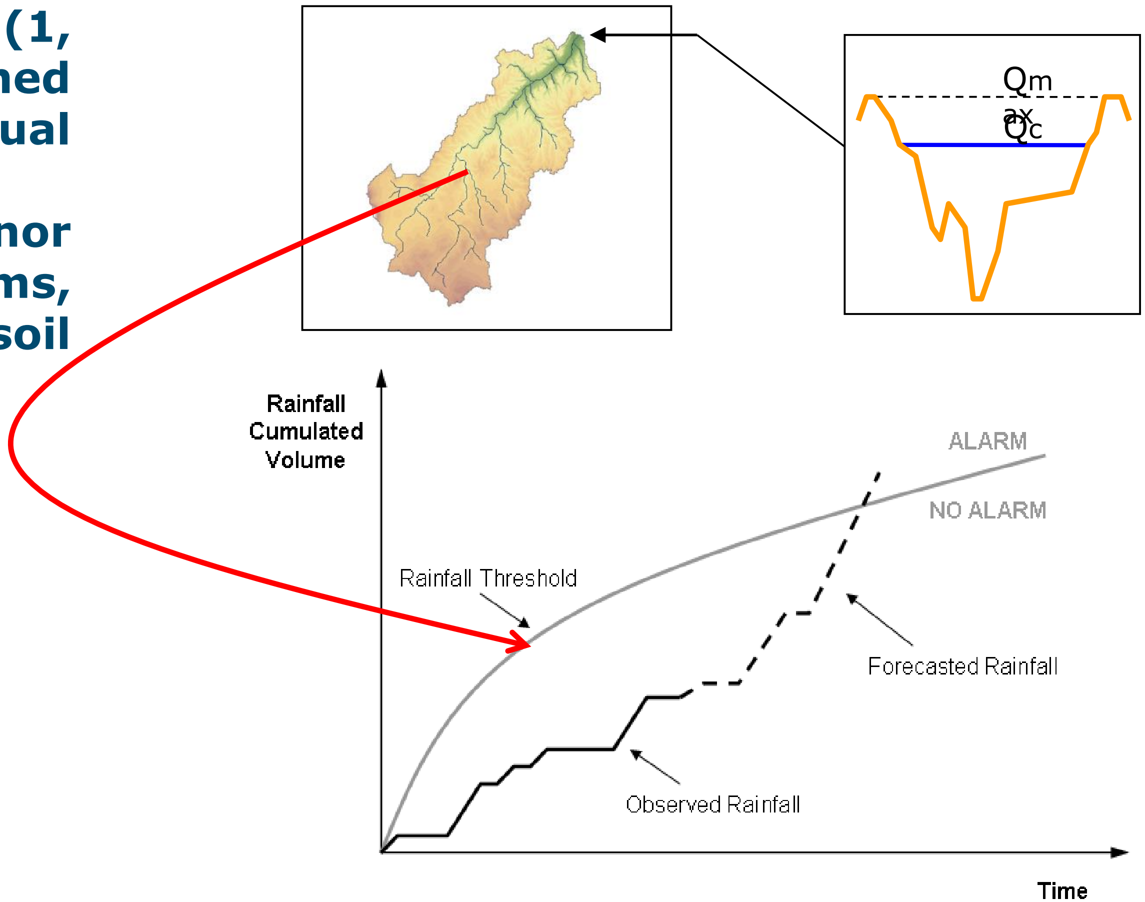
Distributed models for
ungauged basins
Coupled with NWP rain

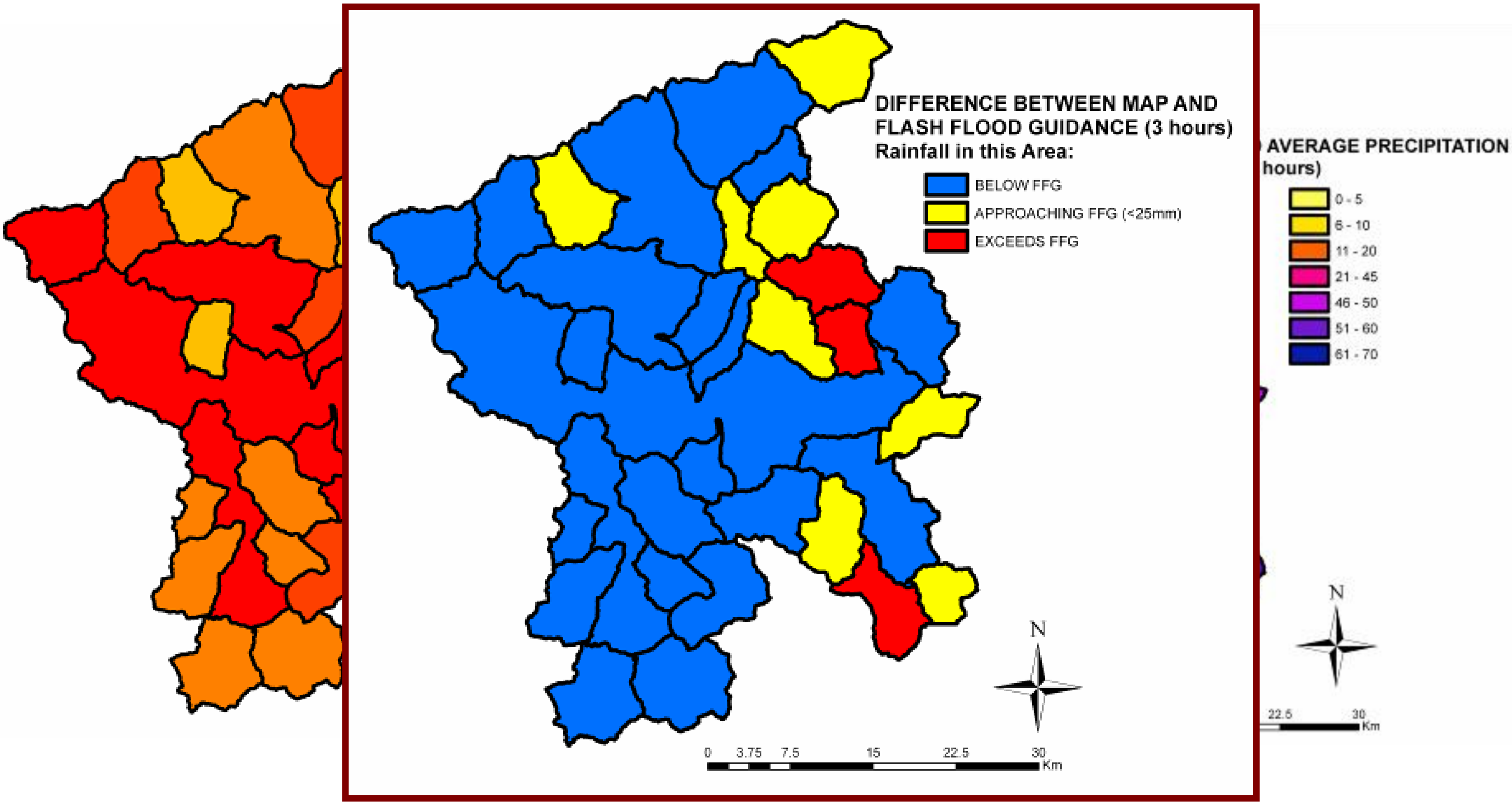
Provide dependable forecasts even
even when modelled flows
are affected by a spatial bias.

Diagnostic methods

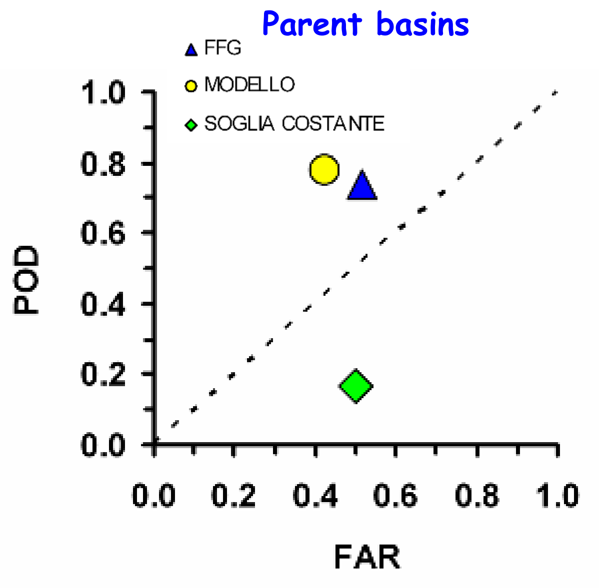
Flash Flood Guidance CONCEPT

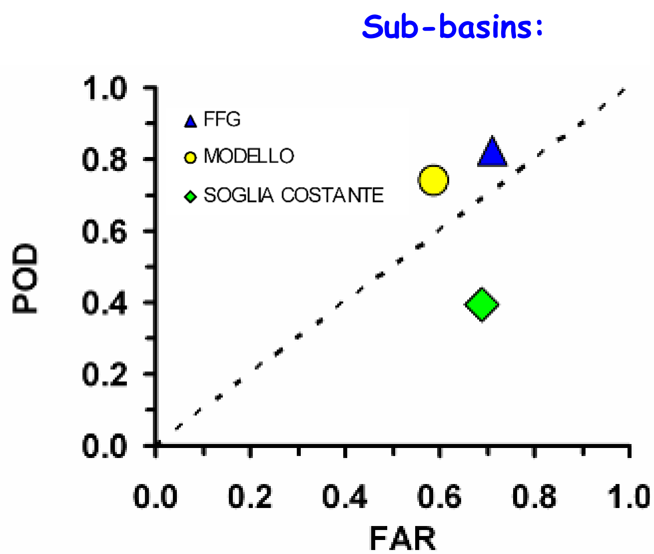
FFG, of a given duration (1, 3, 6, 12, 24 hrs), is defined as the volume of actual rainfall (mm) that generates minor flooding on small streams, given the current soil moisture

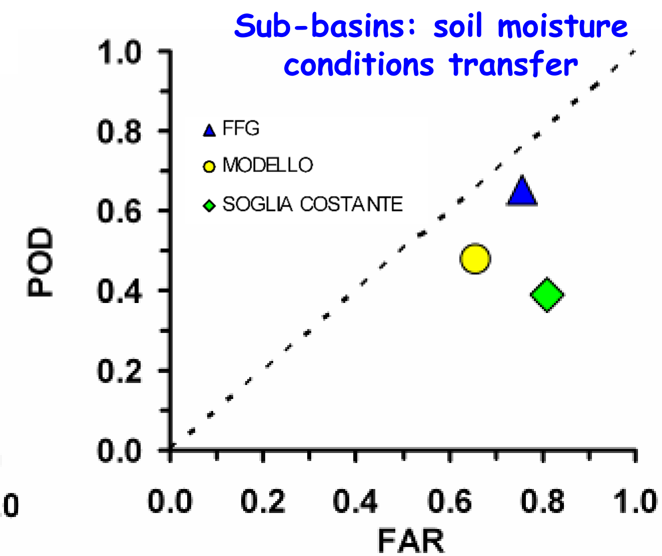



DIFFERENCE BETWEEN MAP AND
FLASH FLOOD GUIDANCE (3 hours)
Rainfall in this Area:
BELOW FFG
APPROACHING FFG (<25mm)
EXCEEDS FFG
N
0 3.75 7.5 15 22.5 30
Km
AVERAGE PRECIPITATION
hours)
0 - 5
6 - 10
11 - 20
21 - 45
46 - 50
51 - 60
61 - 70
N
22.5 30
Km

FFG ASSESSMENT: OVERALL STATISTICS







CSI

	PARENT BASIN (CALIBRATED)	SUB-BASINS (PARAMETER TRANSFER)	SUB-BASINS (SOIL MOISTURE CONDITIONS TRANS)
FFG	0.55	0.37	0.22
MODEL	0.60	0.40	0.25
CONST THRESH	0.14	0.21	0.15

Distributed models for ungauged basins
Coupled with NWP rain

Problem

- Flashfloods develop rapidly and can be life-threatening.
- warning time is of the order of a few hours, sometimes less

Proposed solution

•drive rainfall-runoff model with high-resolution weather forecasts for early warning of flashfloods

•instead of quantitative predictions assess relative difference to model-consistent warning thresholds

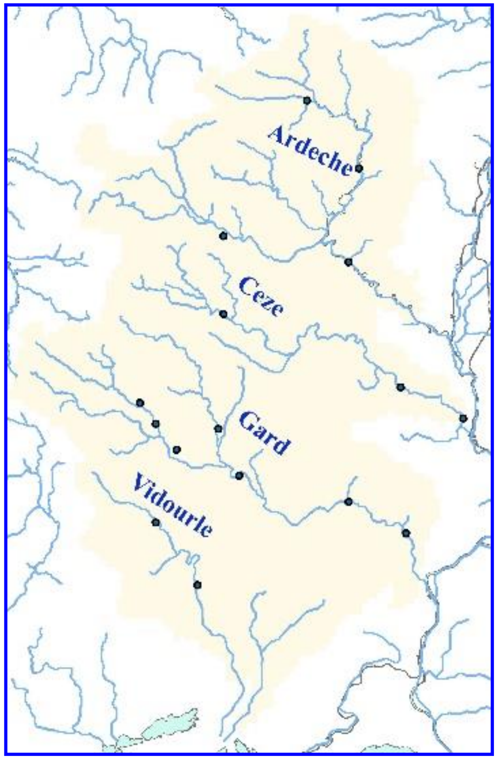
How does it work?

Principle	Case study
a) Set-up a distributed rainfall-runoff model for the region	LISFLOOD
b) Run model with available meteorological observed data and standard parameters for a long time period	17 meteo stations in Cevennes region, few in hilly terrain
c) Determine from long-term simulation critical thresholds, e.g. highest Q simulated, 2 year return periods, etc.	4 thresholds (severe, high, medium, low)
d) Run model with weather forecasts	DWD-Lokal Modell (7km, 48 hrs in 2002)
e) Compare forecasted Q against model consistent thresholds	Alert maps

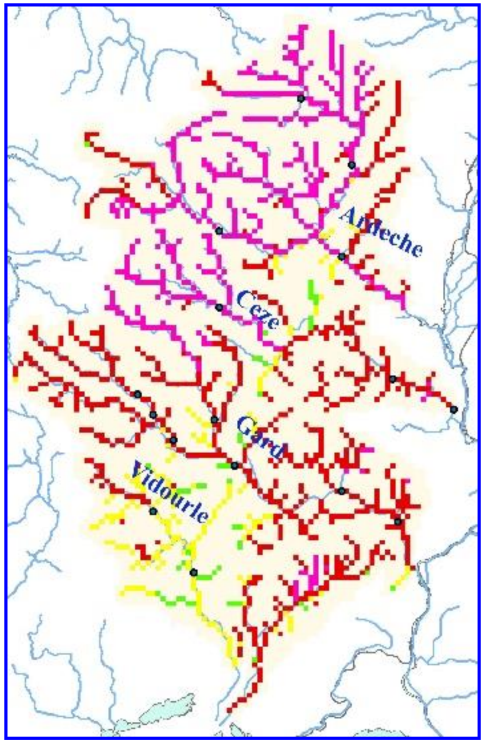
Spatial distribution of threshold exceedances

(highest threshold exceeded during forecasting period)

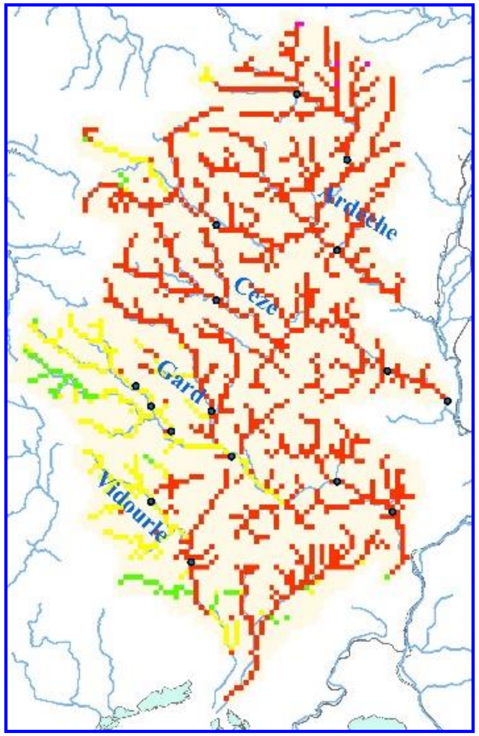
FF 20180907 00:00



FF 20180908 12:00



FF 20180909 12:00



Conclusions - 1

- A simple EWS system may be as effective as a sophisticated one, in particular if it leads to a better match between the available risk information, the forecasting system and the response capability of authorities and the at-risk population;
- Engaging local communities and authorities in the EWS design can improve the effectiveness of the whole early warning process and hence results in a higher response to an alert warning;
- EWS can also deliver adaptation benefits. EWS are shown to strengthen the knowledge, coordinate authorities across sectors and engage local communities

Conclusions - 2

- The forecast language is important: e.g. FF Guidance provides a powerful communication links between hydrologists and meteorologists – it takes a quick picture of the status of a basin, it reduces mis-understanding
- FFG allows to quickly update the forecasts based on local data and knowledge (radar monitoring and nowcasting)
- Comparison with observations shows that:

i) Taking initial soil moisture into consideration is critical for FF prediction in the small-medium catchments considered;

ii) The method provides overall CSI around 0.6 (which is good)

ii) Problems remain in the application to ungauged basins: CSI deteriorates by 25%.

THANK YOU!