HYDRATE PROJECT

4th HyMeX Workshop
8-10 June 2010
Bologna, Italy

Analysis of storm structure, motion and interaction with the drainage network for selected extreme flash floods

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Context - Analysis of individual flood events

Objectives:

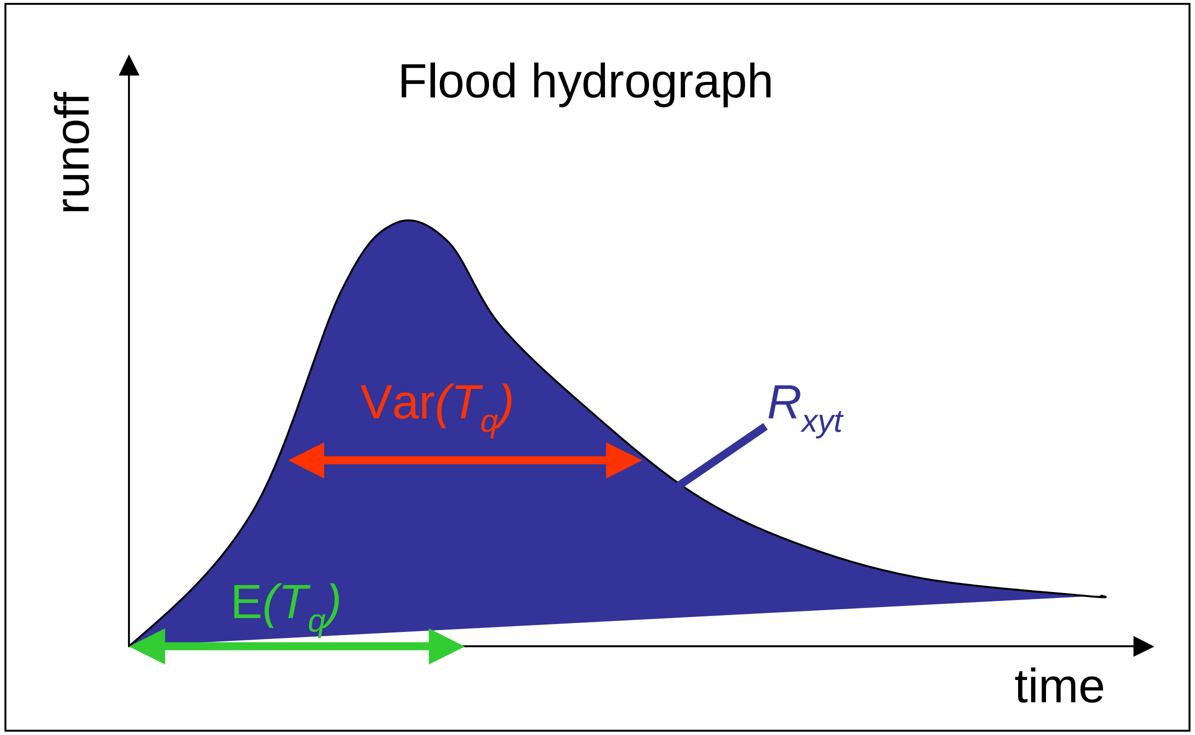
- Understand how **storm structure and motion** interact with **drainage basin properties** to determine the **flood hydrograph**;

- Quantify the interactions for **different extreme flash flood events**, providing a metric to assess the relative contribution in shaping the flood response for extreme runoff events.

Analytical framework

to derive **some characteristics of the flood hydrograph**

- **Storm-averaged catchment rainfall excess** R_{xyt} -> flood volume
- **Mean runoff time** $E(T_q)$ -> catchment response time
- **Variance of the runoff time** $Var(T_q)$ -> peakedness of the hydrograph



to derive R_{xyt}, $E(T_q)$ and $Var(T_q)$ as a **combination of metrics** that describe synthetically rainfall and catchment response (e.g., average rainfall, spatial covariance between rainfall and runoff coeff. etc.)

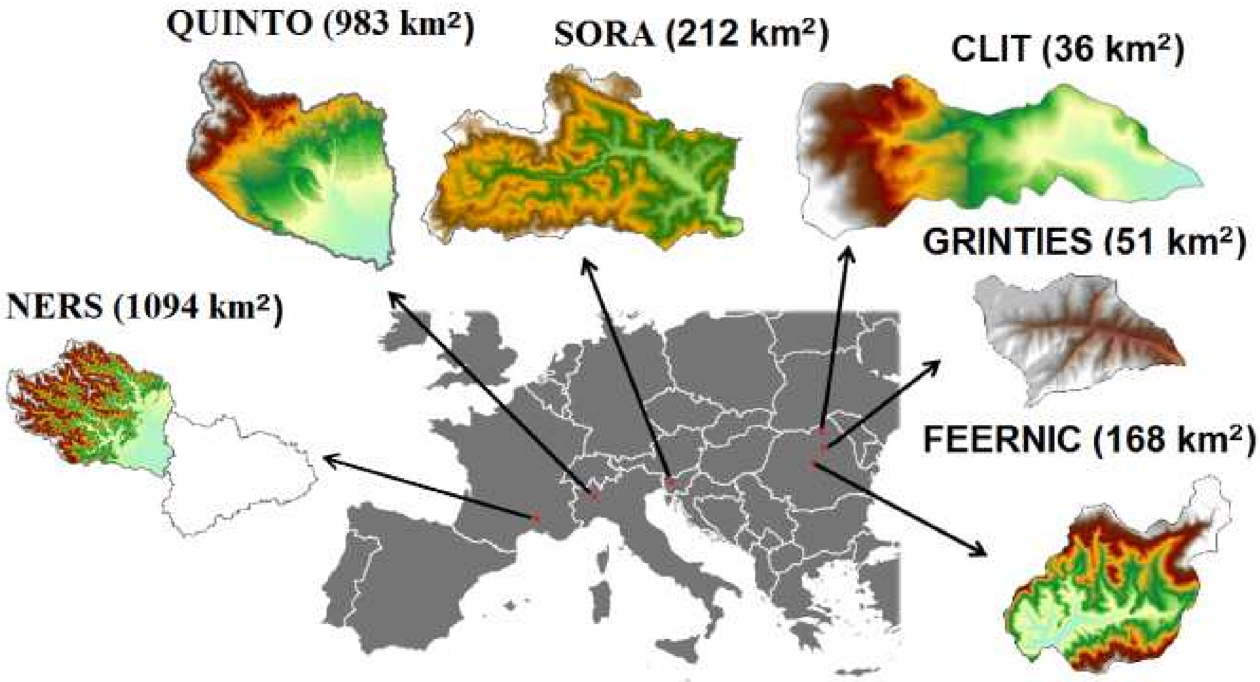
Analytical framework: the background

Woods, R.A. and M. Sivapalan, 1999: A synthesis of space-time variability in storm response: Rainfall, runoff generation and routing, *Water Resour. Res.* , 35(8), 2469-2485

Viglione, A., G. B. Chirico, R. Woods, and G. Blöschl, 2010, Generalised synthesis of space-time variability in flood response: an analytical framework. *Journal of Hydrology, in print.*

Viglione, A., G.B. Chirico, J. Komma, R. Woods, M. Borga and G. Blöschl, 2010: Quantifying space-time dynamics of flood event types. *Journal of Hydrology, in print.*

The case studies



Ners:	GARD Sept 2002
Quinto:	May 2002
Sora:	Sept 2007
Clit:	June 2006
Grinties:	Aug 2007
Feernic :	Aug. 2005

Storm-averaged catchment rainfall excess R_{xyt}

Rainfall excess = rainfall rate * runoff coefficient:

$$R(x,y,t) = P(x,y,t) \cdot W(x,y,t)$$

from rain-gauges + radar

from rainfall-runoff model

Average term: lumped time and

Temporal covariance term: > 0 if it is raining more **when** the runoff coefficient is higher

Spatial covariance term: > 0 if it is raining more **where** the runoff coefficient is higher

$$R_{x,y,t} = P_{x,y,t} \cdot W_{x,y,t} + \mathrm{cov}_t(P_{x,y}, W_{x,y}) + \mathrm{cov}_{x,y}(P_t, W_t) + \left[\mathrm{cov}_t\left(P - P_{x,y}, W - W_{x,y}\right)\right]_{x,y}$$

Spatial variation in temporal covariance: accounts for the variability not accounted by the 2nd and 3rd terms, e.g., due to the movement of the storm over the catchment.

Main assumption: runoff coeff uniform in space and time

Rainfall excess = Rainfall rate

Mean catchment runoff time E(T_q)

Average terms: lumped time and space

Temporal covariance term: additional time because the rainfall input is not constant **in time** (e.g., rainfall time pattern)

$$E(T_q) = \frac{T_m}{2} + \frac{\mathrm{cov}_t[T, R_{x,y}(T)]}{R_{x,y,t}} + \quad \text{Temporal variability}$$

$$+ \frac{D_{x,y}}{v} + \frac{\mathrm{cov}_{x,y}(D, R_t)}{v \cdot R_{x,y,t}} \quad \text{Spatial variability}$$

Spatial covariance terms: additional time because the rainfall input is not uniform **in space** (e.g., does it rain far from the outlet?)

Variance of the catchment runoff time Var(T_q)

Temporal variability

$$\mathrm{Var}(T_q) = \frac{T_m^2}{12} + \left\{ \frac{\mathrm{cov}_t[T^2, R_{x,y}(T)]}{R_{x,y,t}} - \frac{\mathrm{cov}_t[T, R_{x,y}(T)]}{R_{x,y,t}} \left[T_m + \frac{\mathrm{cov}_t[T, R_{x,y}(T)]}{R_{x,y,t}} \right] \right\} +$$

$$+ \frac{\mathrm{var}_{x,y}(D)}{v^2} + \left\{ \frac{\mathrm{cov}_{x,y}[D^2, R_t]}{v^2 R_{x,y,t}} - \frac{\mathrm{cov}_{x,y}[D, R_t]}{v R_{x,y,t}} \cdot \left[2\frac{D_{x,y}}{v} + \frac{\mathrm{cov}_{x,y}[D, R_t]}{R_{x,y,t}} \right] \right\} +$$

$$+2 \left\{ \frac{\mathrm{cov}_t[T, \mathrm{cov}_{x,y}(D, R)]}{v R_{x,y,t}} - \frac{\mathrm{cov}_t(T, R_{x,y})}{R_{x,y,t}} \frac{\mathrm{cov}_{x,y}(D, R_t)}{v R_{x,y,t}} \right\} +$$

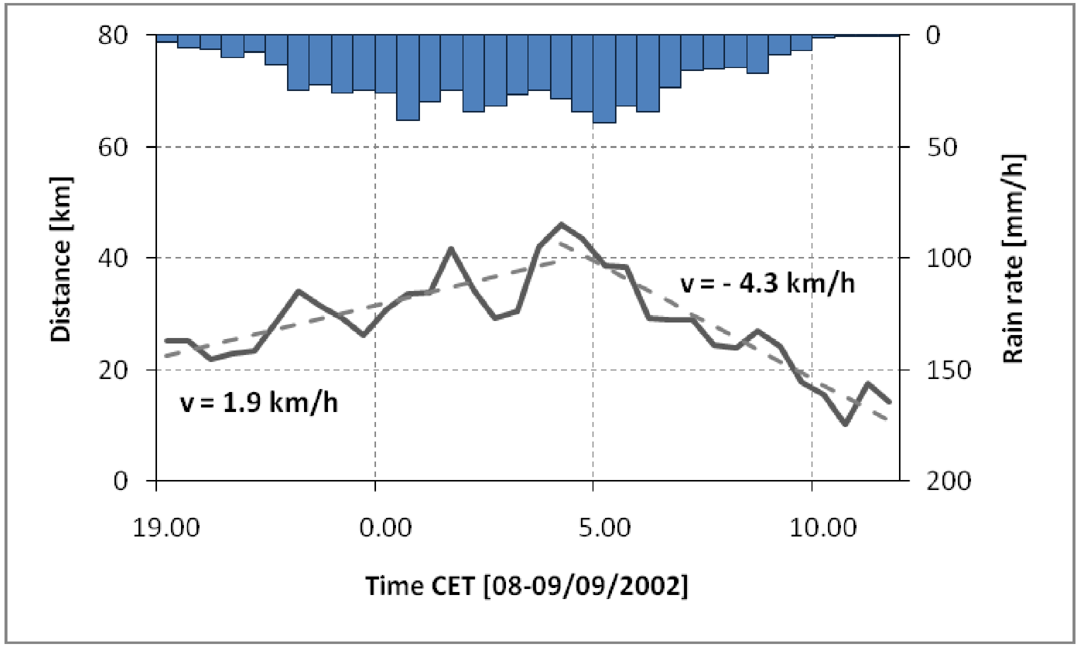
Average terms

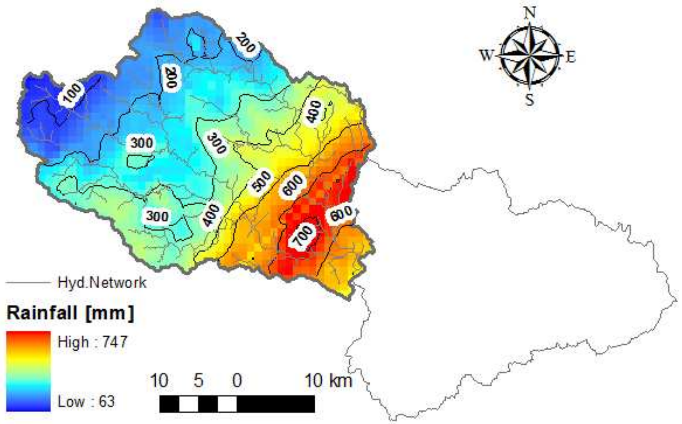
Movement of the storm

Spatial variabilities

Computation of the storm velocity term

The analytical framework allows to derive the computation of the storm velocity based on the dynamics of the storm baricenter relative to the basin morphology.



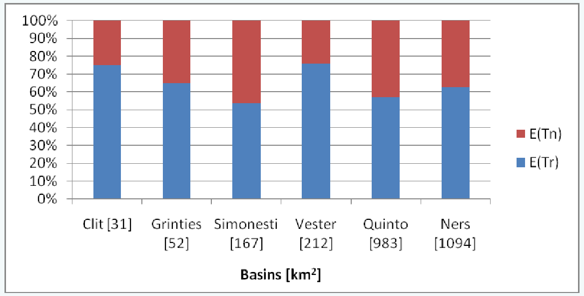


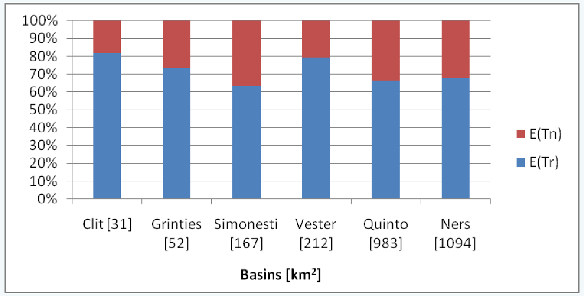
Relative importance of average and variance terms

The framework allows to quantify the different terms of average and variance and to quantify their relative importance. This provides indications on how we need to observe the space-time dynamics of rainfall to ensure correct description of flash flood events.

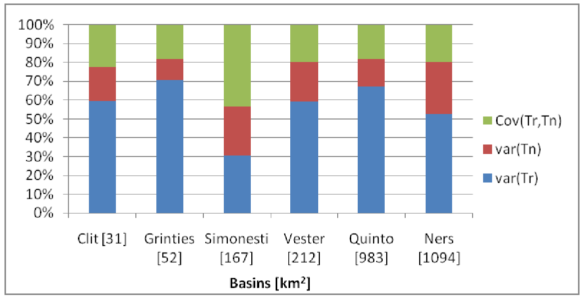
Velocity = 2 m/s | **Velocity = 3 m/s**

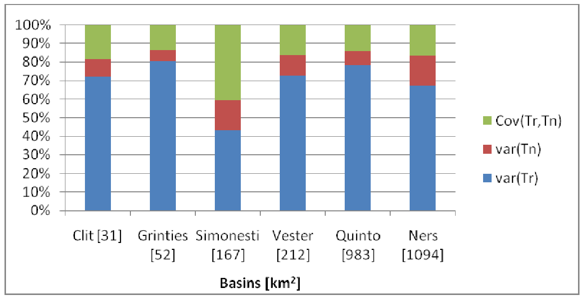
$E(T_q)$



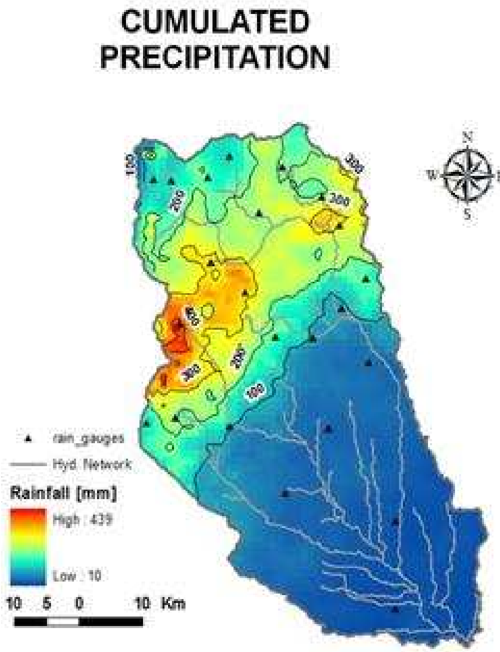


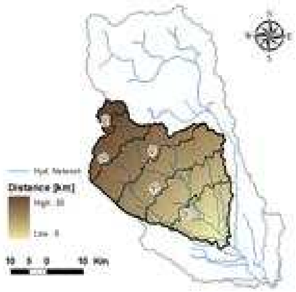
$Var(T_q)$

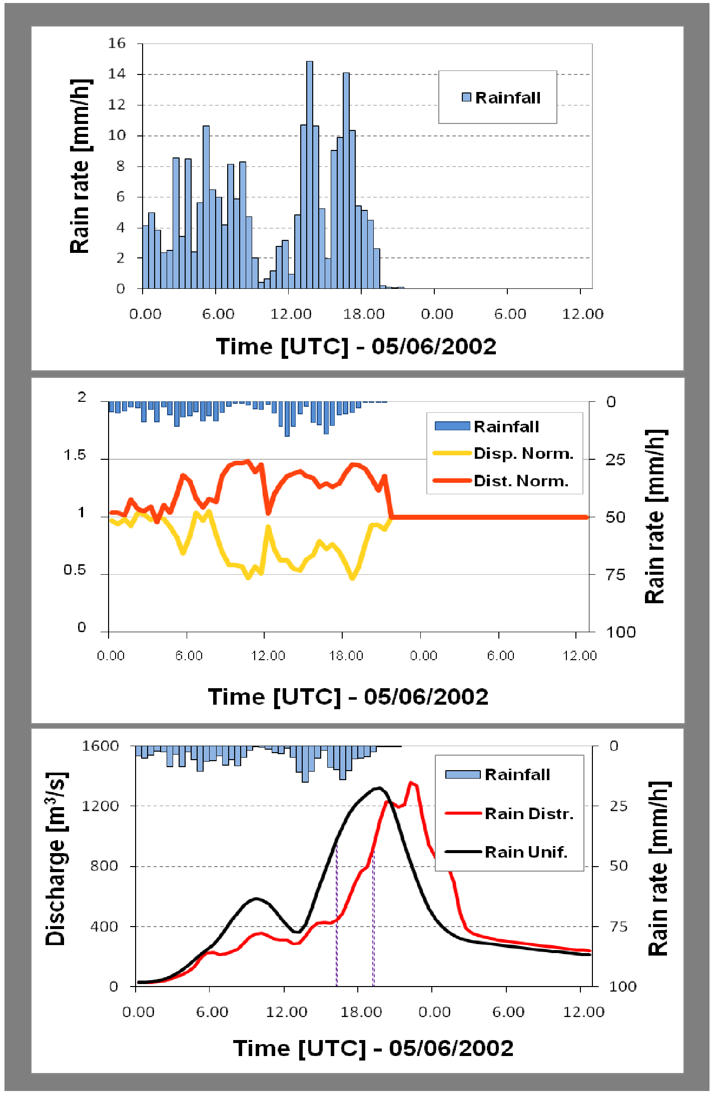




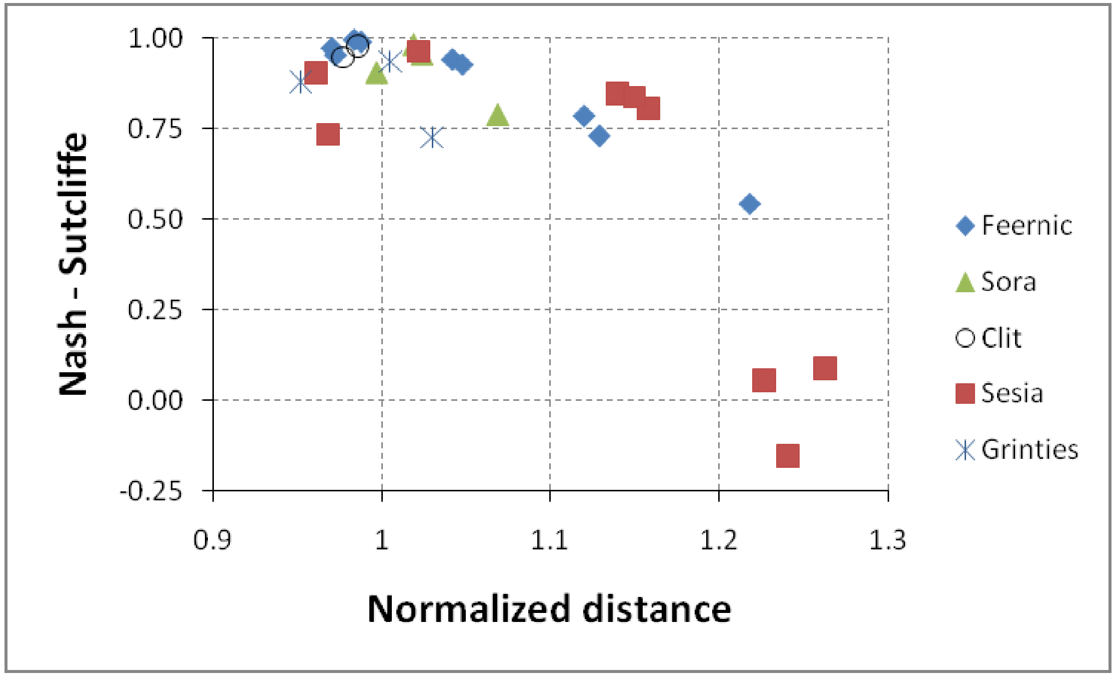
Case study: Sesia 2002







Dimensionless rainfall structure parameter



Ignoring the spatial rainfall variability results in a considerable loss of simulation efficiency (*NS* less than 0.75) in almost 30% of the cases, with *NS* less than 0.55 in four of the cases.

This provides a significant documentation of the influence of the spatial rainfall variability on runoff modeling for catchment scale less than 1000 km^2 (often less than 300 km^2).

Discussion - 1

- the method is complex enough to distinguish several sources of variability but simple enough to avoid overwhelming detail.
- the framework is capable to identify which sources of rainfall variability are dominant in determining the flood hydrograph
- dimensionless numbers can be based on the components of the equations and used for classification and understanding
- the framework can be used to compare different estimation methods (namely: raingauges, radar, and different ways of adjusting radar rainfall estimation errors)

Discussion - 2

- the information obtained in this way may integrate methods like the FFG, currently based on the comparison between the threshold basin-averaged rainfall, thus providing an improved portray of the forecasted flash flood hazard at the regional scale.

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THANK YOU