A statistical characterization of the Northern Italy rainfall regime through a precipitation events classification

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Introduction

Several approaches exist in the literature about the study of the spatial-temporal characteristics of the precipitation. In the most part of the operational cases the rainfall fields are obtained through interpolation techniques starting from the ground raingauges network observations, while in other cases space-continuous fields are available from satellite or meteo-radar estimates. Approaches for the study of the characteristics of these datasets are constituted, for instance, by the formulation of stochastic models that describe the correlation structures between the time series of the single cells of the domain or by the study of the multi-fractal properties of the field. In this study, an approach based on the definition of "precipitation events" is proposed, in order to statistically characterize the space-time variability of the rainfall regime in a given region. For this purpose, given a 3D rainfall field (a temporal sequence of 2D continuous rain maps) an "event" is defined as an aggregate, continuous in time and space, of cells whose rainfall height value is above a certain threshold. Given this definition it is possible to classify, on a given region and for a given period, a population of events and characterize them with of a number of statistics, such as their total volume, maximum spatial extension, duration, average intensity, etc. The probability distribution and the statistical moments of these variables consitute a series of sinthetic indexes that characterize the rain field and allow the comparison with other field on the same region or between different areas. This methodology was employed on rainfall fields obtained by interpolation of the raingauges observation in northern Italy for the period 2006-2013.

Methodology

Let $\mathbf{P}=P_{i,j,t}$ be a three-dimensional precipitation field (temporal sequence of two-dimensional maps on a regular grid), $i=1,...,N_i$, $j=1,...,N_j$, $t=1,...,N_t$, and let Dx be the horizontal dimension of the single cell and Dt the time step.

The procedure is based on the analysis of the populations of single "rainfall events" E_k, defined as aggregates of cells with rainfall height above a certain threshold P, continuous in space and time (with P possibly equal to 0).

Two cells are considered to be part of the same event if they are in contact with a face, edge or vertex, in space or in time:

$$E_k=\{P_{i,j,t}\}: \quad \forall P_{i,j,t}\in E_k \quad \exists\, P_{i',j',t'}>P,\ P_{i',j',t'}\in E_k: \quad (|i-i'|<=1 \cup |j-j'|<=1 \cup |t-t'|<=1)$$

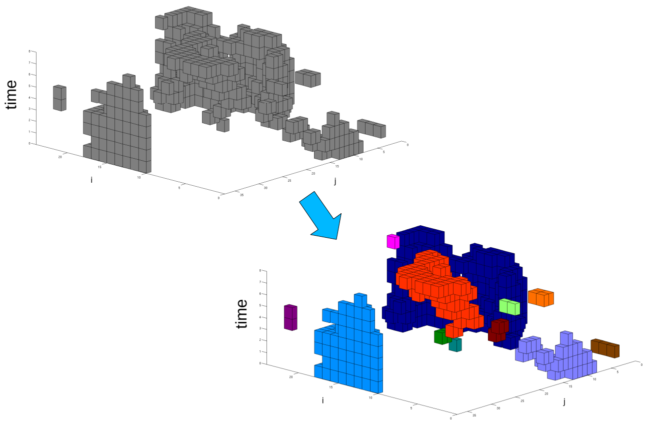

Figure 1. Definition of "rainfall events" as continuos aggregates in space-time, considering a time sequence of 2D rainfall height maps. Each color represents a different event.

Given a population of events E_k $(k=1,...,N)$ defined with the above criteria, the precipitation field is characterized in terms of statistics and probability distribution of several parameters:

$$V_k=\#E_k$$
(event "volume" [-])

$$P_k=\sum_{i,j,t\in Ek} P_{i,j,t}\,Dx^2$$
(total rainfall volume [m^3])

$$I_k=P_k/V_k$$
(average intensity [mm/h])

$$t_{min,k}=\min_{Ek} t\ ,\ t_{max,k}=\max_{Ek} t$$
(initial and final instant [h])

$$D_k=t_{max}-t_{min}+1$$
(total duration [h])

$$B_k=(i_k,j_k,t_k)=\left(\sum_{i,j,t\in Ek}(i,j,k)\cdot P_{i,j,t}/\sum_{i,j,t\in Ek}P_{i,j,t}\right)\cdot Dx$$
(center of gravity [m,m,m])

$$E_{k,t}=\{P_{i,j,t}\}|_{t=cost}$$

$$B_{k,t}=(i_k,j_k,t)=\left(\sum_{i,j\in Ek,t}(i,j)\cdot P_{i,j,t}/\sum_{i,j\in Ek,t}P_{i,j,t}\right)\cdot Dx$$

Results

The above-described analysis was applied to a set of interpolated rainfall maps (from ground raingages measures) on a domain that covers Northern Italy. The interpolation was perfomed with the Inverse Distance Weight (IDW) method (exponent $p=2$) on hourly basis in the period 1/1/2006 – 12/31/2013 , at a spatial resolution of 4 km.

$$V_i=\frac{\sum_{j=1}^{n}\frac{1}{d_{ij}{}^{p}}V_j}{\sum_{j=1}^{n}\frac{1}{d_{ij}{}^{p}}}$$

The maps obtained with this interpolation method were then masked with the Thiessen polygons of the null rainfall height raingauges. In this way the rainfall-no rainfall structure was maintained on the territory avoiding excessive interpolation artifacts far from the non null rainfall observations.

Figure 2. Domain of the study.

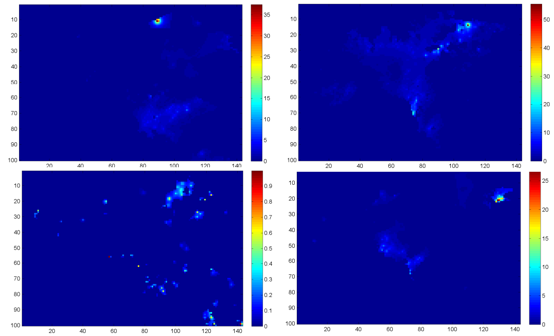

Figure 3. Examples of rainfall height intepolated maps (values in mm).

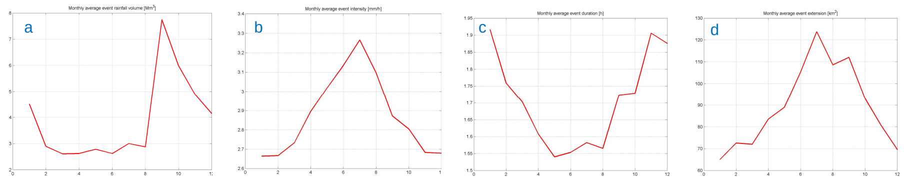

Figure 4. Monthly average rainfall volume (a), event intensity (b) duration (c) and spatial extent (d) for the average year.

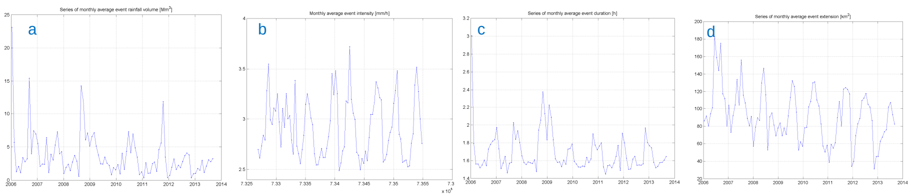

Figure 5. Monthly time series for average rainfall volume (a), event intensity (b) duration (c) and spatial extent (d) for the average year.

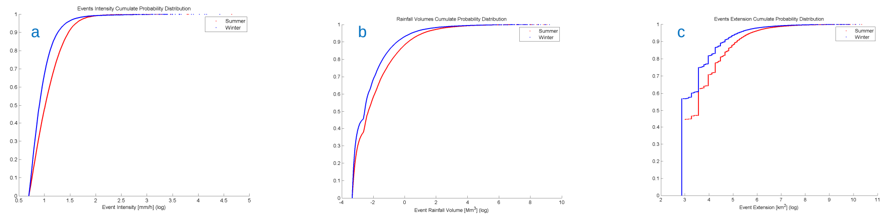

Figure 6. Cumulate probability distribution of events intensity(a), rainfall volumes(b) and spatial extent (c).

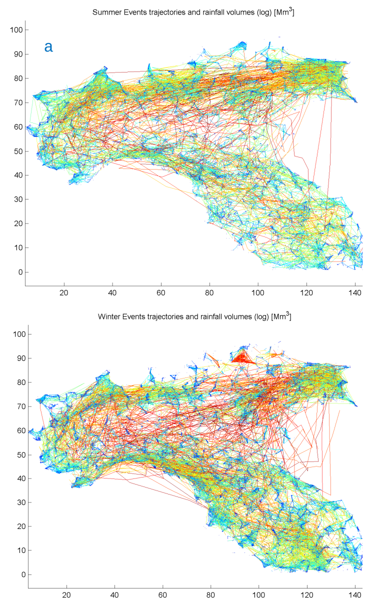

Figure 7. Trajectories of the events for summer (a) and winter (b) periods. It is represented the trajectory of the istantaneous center of gravity for each event. The color represent the total rainfall volume of the event, from very low (blue) to very high (red)