ANALYSIS OF A RAINFALL STORM DYNAMICS OVER CALABRIA REGION, SOUTHERN ITALY

F. Fusto[1]

[1]*Civil Protection Meteo-Hydrological Center of Calabria Region, via F. Crispi n.19, Catanzaro ,f.fusto@protezionecivilecalabria.it*

(Dated: September 12, 2007)

I. INTRODUCTION

The paper present a study on the spatial and temporal characteristics of a rainfall event focusing on the dynamic evolution of the storm, with reference to velocity and direction of movement, recorded by rain gauges in Calabria Region, Southern Italy, between 22 and 25 December 2006.

Rainfall field come from hourly cumulated data collected by rain gauges network in the study area, with rain gauge density of 7 telemeter meteorological station per 1000 square kilometres.

Results of the movement and intensity of the storm are presented by mean of a specific graphical interface build with Esri Map Object ®.

A cross-correlation analysis is also presented. As indicator of storm movement sample cross-correlation function is computed between different rain gauge station to obtain estimated inter-gauge lags. In that way, known the distance between rain gauge and the inter-gauge lag, an estimate of storm velocity is computed.

Estimates of storm velocity and direction of movement are presented according to a modification of the original method proposed by Zhang (2006), based on the geometry of the rain gauge network together with temporal evolution of the storm at each rain gauge. Those estimates are related to observed wind velocities and directions recorded by network stations.

II. PRESENTATION OF RESEARCH

An analysis of space-time rainfall fields starting from observed hourly rainfall data description is developed.

The spatial and temporal variability of rainfall is central to a number of important problem in surface hydrology. In fact the average rain over same region is not sufficient to determine its hydrologic behaviour. The sensitivity of hydrologic behaviour to the rainfall field variability is, usually, the result of a non-linear interaction between the rainfall and some other component of the "watershed system". For example, the runoff generation is non linear in rain rate because phenomena like interception and infiltration involve threshold. In prediction of flood not only the variability of the rainfall is critical to the system's behaviour, but also the spatial structure of this variability, because the size and timing of the peak flow are produced by the interaction of the rainfall structure with river basin structure.

The chief feature of space-time rainfall event at the mesoscale is the scaling hierarchy of structure in space and time. In that way many models or theories have been proposed to capture this behaviour. It's generally observed in mesoscale rainfall event that instead of a homogeneous rainfall field extending over large area in space and time, there is a hierarchy of structures each with associated space and time scales and intensity, with a number of smaller structures comprising he larger. The temporal scale, or lifetime, of a given structure grows with spatial scale, while the average rainfall intensity over it decrease.

Also the spatial heterogeneity of convective rainfall, even in dense rain gauge network area, can produce flash flood with no rainfall observed.

The data analysed in this paper come from the array of 0.2 mm capacity rain gauges network. To describe the space-time rainfall evolution during the event a graphical interface has been build with Esri Map Object ®. Those support allow to use the capability of a Gis into the VB program. So in the view have been inserted the shape of the rain gauge location and of the watershed, over Calabria and Basilicata region, in which rain gauge are collocated.

The software build allow to look at time of occurrence of the situation described in the picture, reporting the year, month, day and hour; also the maximum value of rainfall recorded is visible and the average value over the gauge, both expressed in mm of rain.

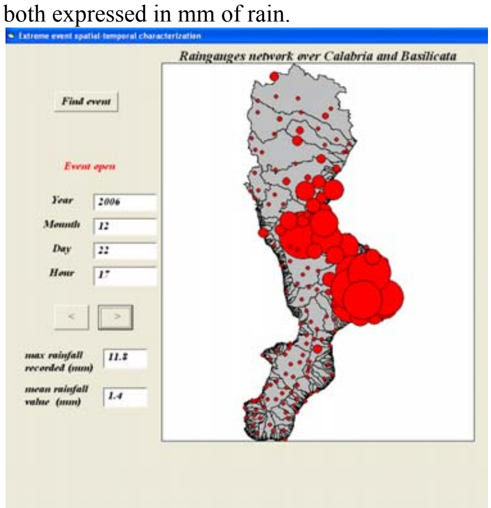

FIG. 1: Graphical interface of storm movement, bubble circle describe value of hourly rainfall. Time of occurrence: 22/12/2006 17.00.

In addition to a purely spatial study, the estimates of space-time correlation provides further insight into the rain phenomenon giving an idea of the time evolution of the spatial structure of rain fronts. This behaviour can be correlated with information concerning the direction and velocity of the prevailing wind in the region.

The space sample cross-correlation function allows looking into the direction of storm and its velocity of movement, because it possible understand if the rainfall series collected at two sites are representative of the same phenomenon, or saying better, if they're correlated.

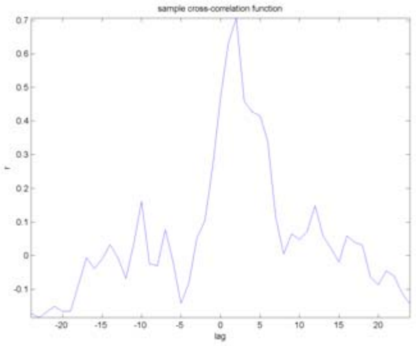

FIG. 2: Cross-Correlation sample function between stations of: Crucoli and Cropalati.

Suppose that the storm velocity is constant during the travel time between the three station estimate of velocity can be computed, as presented below, in table 1.

1st gauge	2nd gauge	Distance	Max lag	Mean velocity
Crucoli	Cropalati	26 km	2 hr	13 km/h
Cropalati	Acri	28,7 km	1 hr	28,7 km/h
Crucoli	Acri	52,9 km	2 hr	26,5 km/h

TABLE I: Estimates of velocity between rain gauge station.

The storm velocity is estimated from the rainfall data by analyzing relations between observations of the same storm at multiple stations (Zhang et al., 2006).

Suppose a storm is recorded by k station $P_i : (x_i, y_i), i = 1,2,..k$. For each station there is an observed reference time t_i, that according to Mary and Julien (1998) is computed as the centroid of the hyetograph at each station. This hypothesis gives more reliable results than using the one proposed by Zhang(2006), that propose to calculate the reference time as the average of the beginning and end of the storm at each station.

For each of the *k(k-1)/2* stations pairs, the difference of the two observed reference times is related to the storm speed u and direction θ by means of:

$$t_i - t_j = \frac{d_{j,i}\cos(\theta - \alpha_{j,i})}{u} + \delta_{j,i} = (x_i - x_j)\frac{\cos\theta}{u} + (y_i - y_j)\frac{\sin\theta}{u} + \delta_{j,i}$$

The storm speed and direction are obtained by solving system obtained from equation before subject to minimization of sum of $\delta_{j,i}^{\;2}$, arriving to:

$$\begin{bmatrix} (\cos\theta)/u \\ (\sin\theta)/u \end{bmatrix} = \begin{bmatrix} \sum(x_i - x_j)^2 & \sum(x_i - x_j)\cdot(y_i - y_j) \\ \sum(x_i - x_j)\cdot(y_i - y_j) & \sum(y_i - y_j)^2 \end{bmatrix}^{-1} \cdot \begin{bmatrix} \sum(t_i - t_j)\cdot(x_i - x_j) \\ \sum(t_i - t_j)\cdot(y_i - y_j) \end{bmatrix}$$

The application of the method mentioned before to the rainfall event recorded between 22th and 25th December in upper Ionian side of Calabria region gives this results, in terms of velocity *v=12,30 km/h*, while direction of movement *θ=143°* respect nord, as shown in polar graph here after.

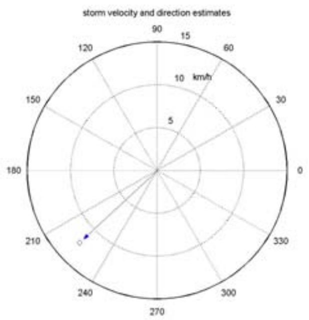

FIG. 3: Polar graph of storm velocity and direction movement estimates for upper ionian side.

III. RESULTS AND CONCLUSIONS

In this work it is shown a method to compute storm velocity and direction movement. A comparison with other method of estimates, like cross correlation analysis, show difference of values. Also in the comparison of estimates with the recorded wind data of gauge network over Calabria Region, show sensible differences. This fact could came from the not yet dense wind network compared to rain gauge.

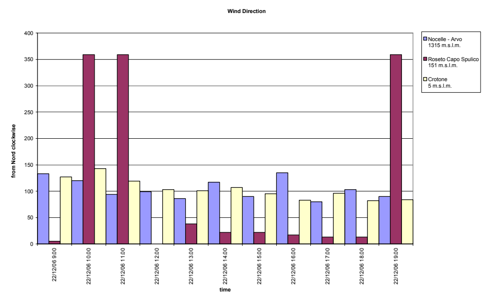

FIG. 4: Wind direction recorded by Crotone, Nocelle-Arvo and Roseto Capo Spulico stations in the upper Ionian side of Calabria.

Taking into account these differences and using a simple analytical model for storm velocity and direction, it has been possible to reproduce the order of magnitude of the parameters. This could be taken as indicator for a simple forecasting model for approaching severe storm over area with problem of landslides or flooding.

IV. AKNOWLEDGMENTS

The author would like to thank Prof. Beniamino Sirangelo and Prof. Giuseppe Mendicino, of the University of Calabria CAMILAB laboratory, for scientific suggestion and especially Ing. Giuseppe Iiritano, Calabria Civil Protection Meteo-Hydrological Center coordinator, for the opportunity of human and professional growth.

V. REFERENCES

Niemczyniwicz J., 1987: Storm tracking using rain gauge data. *J. Hydrol.,* 53 135–152.

Romo J. A., Anitzine I. F., Fontan F.P., Marino P., 2005: Analysis of rain rate spatial cross-correlation coefficients in the Basque country area. *Radioengeneering*, 14 n. 1 24-29.

Zhang Z., Switzer P., 2006: Stochastic space-time regional rainfall model adapted to historical rain gauge data. *WRR*