THE VIBO VALENTIA FLOOD AND MSG-1 RAINFALL EVALUATION

Salvatore Gabriele, Francesco Chiaravalloti

CNR-IRPI, Via Cavour,4 87036 Rende, Gabriele@irpi.cnr.it

(September 12,2007)

I. INTRODUCTION

Mediterranean regions, especially in autumn, are prone to severe convective rainfall that may produce intense flash-floods in small basins. In the last years, severe rainstorms hit the Italian peninsula from South to North with rainfall intensity greater than 100 mm/h. The latest event in Vibo Valentia (Calabria, Italy) has shown a rainfall rate of 220 mm in two hours over an area of about 20 km^2.

In such cases, the reconstruction of ground rainfall field may result very difficult because of its extreme variability over space-time scales that makes complicated the extrapolation of at-site data (*Lovejoy et al., 2006*). The use of meteorological radars represents an improvement since they provide widespread spatial coverage at high spatial and temporal resolution and produce spatially continuous values instead of local measurements. However, also meteorological radars present important disadvantages, namely the calibration of the Z-R relationship (*Hunter, 1996*) and their positioning in a complex topography (*Kitchne and Jackson*, 1993; *Young et al., 1999*), where mountainous obstructions of the radar beam can significantly reduce the radar coverage and its monitoring capabilities. Moreover, only a few countries are capable of providing radar presence. Therefore the coverage of the precipitation measurements by ground conventional means as rain gauge networks or weather radars is often inadequate.

In this context, the meteorological satellites are an important tool to provide indirect rainfall estimation, that introduces many advantages (*Levizzani, 2000; Scofield and Kuligowski 2003*), mostly the capability of monitoring widespread areas, independently from orography, with a good spatial resolution and a regular sampling time (every 15 minutes for METEOSAT 8); this allow monitoring the dynamical evolution of cloud structures. For example, in the thermal infrared band (10-12 μm) satellites supply indications on the temperature of the cloudy area, that is related to the cloud height. In general, clouds with very cold top indicate deep convection, and it is possible to correlate the temperature of convective cells with surface precipitations (*Adler et al. 1979, Vicente et al. 1998, De Luque et al., 2006*).

To evaluate rainfall from Meteosat satellites, particularly at equatorial latitude, many authors use general empirical law (*Adler et al., 1979; Vicente e al. 1998*), but for small basins and at the middle latitude direct calibration is necessary, for example using local simultaneous rain gauge data or radar (*Herman et al., 1997; Laurent et al.; 1998*). Indeed, at the European latitude, relation between the top cloud temperature and rainfall strongly depends on season, so that it is not possible find a general formula.

The satellite precipitation estimates are therefore complementary to rain gauge and/or radar measurements. In particular, the rain gauges represent an indispensable means for remote-sensor calibration and validation (*Ciach and Krajewski, 1999*).

In small basins, estimation of areal rainfall using Meteosat and rain-gauge requires also evaluation of parallax error due to the high elevation of top clouds (*Vicente et al. 2002*). During severe storms cumulonimbus may reach the troposphere layer at the altitude of 12-14 kilometres; at the Italian mean latitude of 40°, parallax error is about 3 pixels.

In this work we explore possible correlations between cloud characteristics deduced by Meteosat images and rainfall.

II. PRESENTATION OF RESULTS

To explore possible applications of Meteosat image analysis in evaluating areal rainfall in small basins, without involving direct cross relation with brilliance temperature, we analysed a very deep convective events which hit Vibo Valentia town on July 3rd, 2006.

After a fine pixel projection and parallax correction, a good cross relation between 10.8 μm brightness temperature and rainfall has been found to be compared with the new proposed approach (Fig. 1).

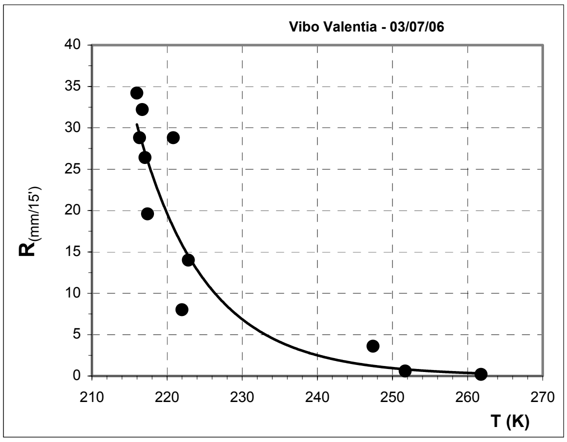

Fig. 1 Vibo Valentia flood July 3rd, 2006. Plot rainfall – T(K).

Thanks to its good spatial and temporal resolution of 15 min, the Meteosat-8 permitted the space-time monitoring of the deep convective clouds associated with the severe thunderstorms. At Vibo Valentia the latitude pixel resolution is close to 4 km.

Following *Adler and Fenn* (1979), the number of pixel N_i with brightness temperature $T_B \leq T_i$ in the satellite infrared image is considered to be able to monitor the thunderstorm space-time trade-off. The temperature threshold T_i ranges from the lowest temperature in the image, on the cloud top, to the highest temperature T_M that corresponds to a closed isotherm representing the cloud edges. The areal expansion of infrared isotherms is a measure of the outflow divergence and can be correlated with the vertical velocity in the thunderstorm.

The individuation of cloud edges is troublesome when thunderstorm's anvil comes into contact with others, making a cirrus overcast. In the Vibo Valentia case, the cumulonimbus associated to the flood is sufficiently isolated and a T_M=220.5 K is assumed.

The core of the cloudy structure interested Vibo Valentia between 09:30 TU and 10:30 TU. This interval corresponds approximately to the phase of enhanced convection of the thunderstorm. For this interval, ground measured rainfall is assumed to represent the rain in the cumulonimbus core, and correlations between cumulonimbus morphology, deduced by isotherm evolution, and rainfall has been analyzed.

The rain gauge time resolution is 5 min and the measures have been combined in order to confront them with the Meteosat data directly.

A linear trend between the number of pixel in the 220.5 K isotherm, $N_{220.5}$, and ground rainfall R is found, with a time delay of 10 min between rain gauge measures and satellite data (Fig. 2).

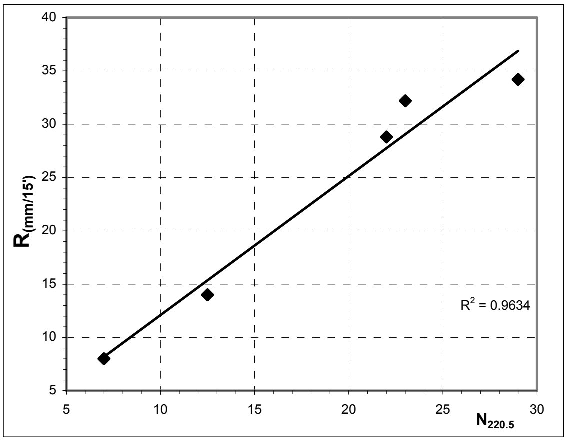

Fig. 2 Linear trend between pixel number in the 220.5 K isotherm, $N_{220.5}$, and ground rainfall R.

A linear trend between the normalized growth rate of 220.5K isotherm (defined as $\Delta N = \dfrac{N_{220.5}(t) - N_{220.5}(t-\Delta t)}{N_{220.5}(t-\Delta t)}$) and an analogous quantity for rainfall ($\Delta R = \dfrac{R(t^*) - R(t^* - \Delta t)}{R(t^* - \Delta t)}$) is also found, at the same time delay (Fig. 3).

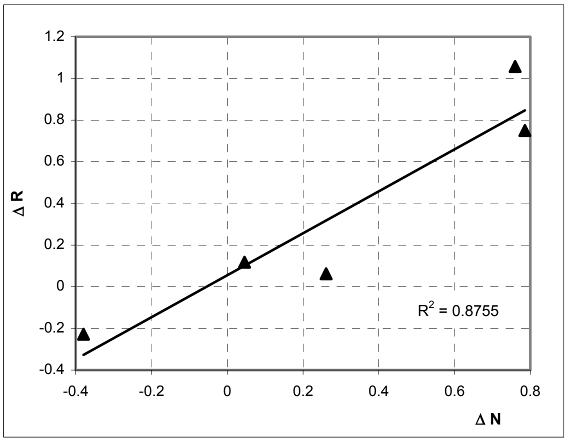

Fig. 3 Linear trend between normalized growth rate of 220.5 K isotherm and normalized rainfall

At last, a linear correlation between rainfall and the isotherm “gradient” defined as $\nabla N \equiv N_{220.5} - N_{220}$, is found, with a time delay of 25 min between the data (Fig. 4).

III. RESULTS AND CONCLUSION

Starting from a well-defined convective event, it has been shown that it is possible to find cross relation between cloud features, as growth rate of isotherm, and rainfall. Further analysis is needed to check the sensibility of the proposed approach to season and latitude and verify possibility of defining general formulation.

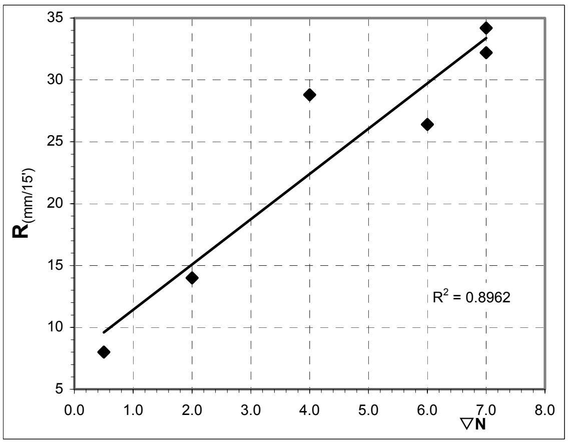

Fig. 4 Plot of rainfall and the isotherm “gradient” defined as $\nabla N \equiv N_{220.5} - N_{220}$.

IV. REFERENCES

Adler R.F., Fenn D.D.; 1979: Thunderstorm intensity as determined from satellite data. *J. Appl. Metor.*, **18**, 502-517.

Ciach, G.J., Krajewski, W.F. Radar-rain gauge comparisons under observational uncertainties, *J. Appl. Meteor.*, **3**8, 1519-1525, 1999.

De Luquel A. et al.; 2006. A case of severe flood over Albania: a rainfall analysis from a satellite perspective. *Advances in Geosciences*, **7**, 65–72.

Herman A. et al.; 1997. Objectively determined 10-day African rainfall estimates created for famine early warning. *Journal of Remote Sensing*, **18** (10), 2147-2160.

Hunter S.M.; 1996. WSR-88D radar rainfall estimation: capabilities, limitations and potential improvements, *Natl. Wea. Dig.*, **20** (4), 26-38.

Kitchen M., Jackson P.M.; 1993. Weather radar performance at long range: simulated and observed, *J. Appl. Meteor.*, **32**, 975-985.

Laurent H., Jobard I., Toma A.; 1998. Validation of satellite and ground based estimates of precipitation over the Sahel. *Atmospheric Research*, **47-48**, 651-670.

Levizzani V.; 2000. Satellite rainfall estimates: a look back and a perspective. Proc. The 2000 *EUMETSAT Meteorological Satellite Data Users' Conference*, EUMETSAT, Bologna, 29 May - 2 June 2000, pp. 344-353.

Lovejoy S., Schertzer D.; 2006. Multifractals, cloud radiances and rain. *Journal of Hydrology*, **322**, issue 1-4, 59-88.

Scofield R.A., Kuligowski R.J.; 2003. Status and Outlook of Operational Satellite Precipitation Algorithms for Extreme-Precipitation Events. *Weather and Forecasting*, **18**(6), 1037-1051.

Vicente GA, Scofield RA, Menzel WP (1998) The operational GOES infrared rainfall estimation technique, *Bulletin of Am. Meteorol. Soc.*, **79**(9), 1883-1898

Vicente G.A., Davenport J.C., Scofield R.A.; 2002. The role of orographic and parallax corrections on real time high resolution satellite rainfall rate distribution. *Int. J. Remote Sensing*, **23**(2), 221–230.

Young C.B. et al.; 1999. An evaluation of NEXRAD precipitation estimates in complex terrain, *J. Geophys. Res.*, **104**, 19691-19703.