10.3 SYNERGISTIC USE OF POLARIMETRIC RADAR MEASUREMENTS AND SIMULATED CLOUD MICROPHYSICAL PROFILES FOR RAINFALL ESTIMATION IN MOUNTAINOUS REGIONS

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1. INTRODUCTION

Complex orography is a serious problem for radar rainfall rate estimation. Techniques based on the Vertical Profile of Reflectivity (VPR) are the most widely known to overcome this problem [Joss and Pittini]. In this paper a different approach is presented. It relies on the particle classification capabilities of a polarimetric radar, allowing a microphysical characterization of the cloud vertical profile. Using a proper set of elevation angles, the radar can provide estimates of the water content (WC) by sampling, at least, the upper portion of the cloud in a mountainous area. For such a situation, the extrapolation of rainfall rate at ground is completely arbitrary without other information. This paper investigates the utility of using upper level radar estimates as a constraint to identify likely WC profiles within an archive generated by detailed numerical simulations of severe Italian storms.

2. MODEL GENERATED WATER CONTENT PROFILES

A series of orographic rain producing storms were simulated by numerical cloud resolving model. Subsequently, a database of characteristic profiles of simulated hydrometeors, consisting of 2 categories of liquid and 4 categories of ice and the local state parameters, were constructed from the simulation results and catalogued.

The numerical simulations used to derive the precipitation database were cloud-resolving simulations of actual observed storms in the Italian Alps. The model used was the University of Wisconsin Nonhydrostatic Modeling System (UW-NMS). This is a fully compressible nonhydrostatic model cast on a rotated spherical grid. Terrain is represented by a variable stepped coordinate capable of representing both the most subtle and severe topography simultaneously. The model vorticity and enstrophy conserving dynamical scheme has been uniquely formulated to accurately represent flow interaction with topographic barriers. Bulk microphysics are employed to simulate cloud physics based on the prediction of rain, pristine crystals, snow, aggregates, and graupel.

For this study, profiles archived from a simulations of the September, 1992 Genoa flood producing storm. The simulation was of a strong convective orographic storm followed by a period of extended stable rain. Hence the data base of hydrometeor profiles is rich with a variety of orographically forced microphysical states, some of which will likely correlate well with the storm structure observed by radar in this study.

3. RADAR ESTIMATES OF THE CLOUD MICROPHYSICS

The radar data used in this study consist of the polarimetric measurements collected by the weather radar of Fossalon di Grado, in North-Eastern Italy [Dietrich et al.].

A fuzzy logic approach is used to identify the cloud particle type. The classification scheme is based on a set of membership functions defined for each hydrometeor. Nine species are considered: *rain*, *drizzle*, *wet snow*, *dry snow*,

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graupel, *hail*, *hail mixed with rain*, *crystals* and *super cooled droplets*. Once the particle type has been identified through the fuzzy logic classification scheme, the WC is estimated applying several proper relations [Dietrich et al.].
In fig. 1 is reported an example of the radar WC estimates, compared with the measurements collected by an equipped aircraft. An error within (-50%; 100%) was obtained for the comparison performed using the data collected during the MAP IOP n.5.

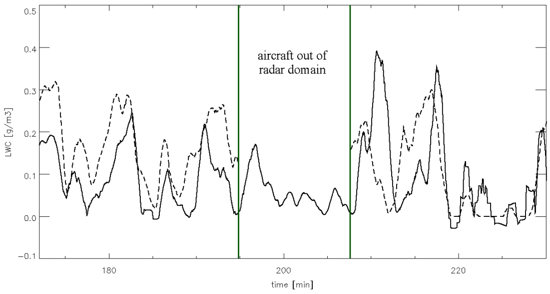

Figure 1. Liquid Water Content measurements collected by the ELECTRA aircraft during MAP IOP n.5 (solid line) and corresponding radar estimate (dashed line), from 09.53 UTC to 10.50 UTC. Minute 0 is 7.00 UTC.

4. RESULTS

For the validation process the data collected during the MAP IOP n.2 (20-21 September 1999) are considered. The measurements of a station located at about 90 km from the radar in an Alpine valley provided the ground truth for comparisons (fig. 2).
Fig. 3 shows the time series (averaged over 30 minutes) for the rain gauge measurements, the radar rainfall estimates through the Marshall-Palmer relation ($Z=200R^{1.6}$, applied to the lowest non-blocked beam: 1.5 deg) and that obtained with the numerical model selected WC profiles. Both the Z-R and the model estimates show a fair agreement with the ground truth. But fig. 4 shows that the radar alone still provides better results in terms of the Fractional Standard Error.
Nevertheless, there are some specific circumstances that may affect the estimates based on the model profiles:

- for most of the cases only two elevations with non null data were available, since the vertical extent of the cloud ranged between 4000 and 5000 m. This affected the strength of the selection within the archive of the simulated vertical profiles.
- The freezing level was quite high (at about 3500 m), implying fair conditions for rain rate estimation with the straight application of a Z-R relation to the measured reflectivity, since these data are still referring to the water phase.

So, before to pronounce any conclusive word about this new approach, a wider validation data set have to be considered, in order to test the methodology in different and more critical (from the radar point of view) situations.

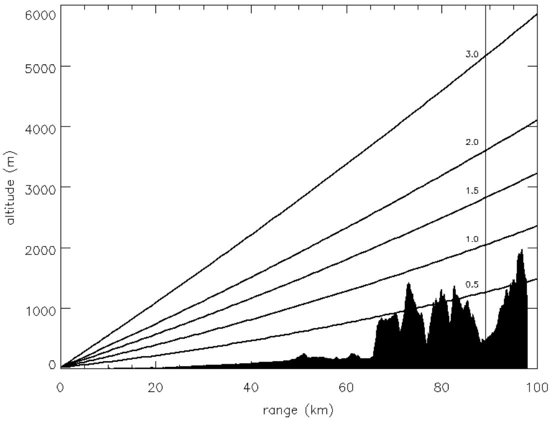

Figure 2. Orography and beam paths for the 5 low angle elevations set. The radar beamwidth is 0.9 deg. The first elevation (0.5 deg) is completely blocked, the second (1.0 deg) is partially blocked.

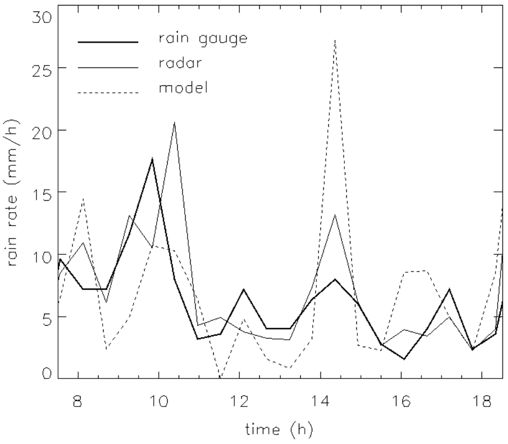

Figure 3. Time series of the 30 minutes averaged rain gauges measurements, radar Z-R and model estimates.

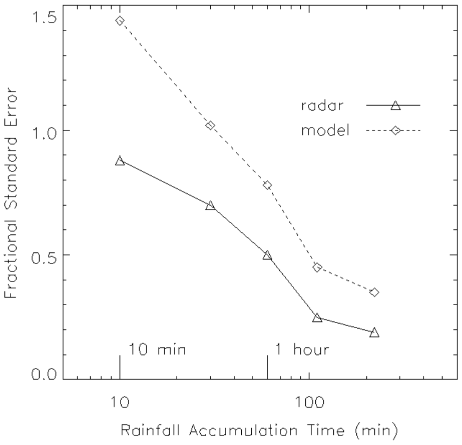

Figure 4. Fractional Standard Error for the radar and model estimates.

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