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ANALYSIS OF MICROPHYSICAL DATA IN AN OROGRAPHIC ENVIRONMENT TO EVALUATE A POLARIZATION RADAR-BASED HYDROMETEOR TYPING ALGORITHM

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1. INTRODUCTION

Our overall research goal is to use polarization radar signatures to study microphysical processes that occur in orographic precipitation systems. Polarization radar technology provides a unique opportunity to address deficiencies in our understanding of the microphysical structure of cloud systems over mountain ranges. Polarimetric radar measurements are sensitive to the types, shapes, sizes and fall behavior of hydrometeors, and can be used to identify bulk hydrometeor types. Vivekanandan *et al.* (1999) developed a semi-empirical rule-based algorithm to classify microphysical hydrometeor types based on polarization radar parameters. Since this algorithm has not yet been subjected to objective testing, it is the aim of our research to evaluate this hydrometeor classification scheme in Alpine cloud systems using aircraft microphysical data.

To quantitatively evaluate Vivekanandan's algorithm, the research aircraft microphysical measurements collected during the Mesoscale Alpine Program (MAP) by the NCAR (National Center for Atmospheric Research) Electra are compared directly with polarization radar measurements from the NCAR S-Pol radar. The sampling strategies and sampling volumes of aircraft sensors and radar differ markedly. Exactly collocated observations are not useful because the radar echo from the aircraft will contribute to the polarimetric observables and may invalidate the typing algorithms. To deal with these complexities, we have developed an algorithm that matches the radar pulse volume corresponding most closely in space and time to the volume of cloud measured by the aircraft. In this paper we discuss and evaluate the matching algorithm.

2. DATA SET

The data used for this study were collected during MAP, a field project with intense observations of orographic precipitation systems forming along the Mediterranean side of the Alps in fall 1999. The orographic environment provides an ideal location to observe changes in frozen particle types, because the forcing for updrafts and the production of supercooled water is a function of the wind speed and local terrain slope. We are primarily interested in data from two instruments: first, the NCAR S-Pol dual-polarization radar, which was situated at the foothills of the southern Alpine range. From this position, the S-Pol was able to make high resolution observations as orographic cloud systems continually underwent transitions in structure associated with the passage of synoptic and mesoscale weather systems.

The second instrument of interest is the NCAR Electra, an aircraft equipped with 2D optical array probes. The Electra conducted research flights in the orographic precipitation systems, making *in situ* measurements in the vicinity of the S-Pol radar.

3. PROCEDURE FOR MATCHING DATA SETS

The process our matching algorithm is based on is the following: Starting with the location of the volume of cloud measured by the aircraft at a certain time, the algorithm finds the radar pulse volume that corresponds most closely in space and time. Based on the three-dimensional wind components measured by the aircraft, the algorithm calculates backwards and forwards trajectories of the air parcel within a small time interval. This time interval depends on the observed conditions of the precipitation system and ranges in duration from thirty seconds to five minutes. For example, in a stratiform precipitation system, where the precipitation is more widespread and uniform, a larger time interval might be suitable, whereas in precipitation systems with embedded convection, the time interval

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needs to be short.

After the position of the air parcel along its trajectory has been determined for each second within the time interval, the parcel's location is transformed from the Earth coordinate system (Longitude, Latitude and altitude) into the coordinate system of the radar (elevation angle, azimuth angle, and range). We would like to emphasize that the algorithm performs a coordinate transformation from one spherical coordinate system (Earth system) directly into another spherical system (radar system). This way we avoid uncertainties that can be introduced when interpolating the radar data onto the Latitude Longitude grid of the Earth system.

Finally, for each point along the parcel's trajectory, the algorithm calculates the distance between the parcel's location and the nearest radar beam at the same time. The algorithm then determines the shortest distance within the entire time interval and stores all polarimetric variables of the corresponding radar pulse volume presuming the shortest distance was less than a certain threshold (usually one kilometer). The end result is a data file with the best matched radar variables along the flight track of the aircraft.

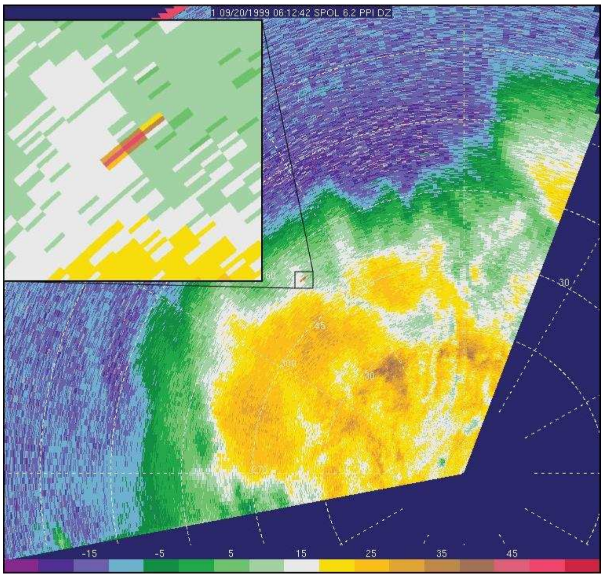

Figure 1: Example of a skinpaint observed in the PPI scan strategy. Data from MAP IOP 2b, 20 Sept. 1999, 6:12:42 UTC

4. EVALUATION OF THE MATCHING ALGORITHM

To evaluate the performance of the matching algorithm, we need to compare aircraft and radar positions. We looked at "skinpaints" - instances in which the aircraft actually intercepted a radar beam - to test our ability to match locations between the aircraft and radar data. Skinpaints appear as a few pixels of high radar reflectivity ($>$ 40 dBZ), standing out well from the background radar reflectivity (Fig. 1), and can be easily detected automatically. With the aid of the skinpaints, we are able to evaluate the accuracy of the position determination of the aircraft by the radar by comparing the location of the skinpaint to the direct GPS aircraft position.

Thirty-three skinpaints were found during the 20 Sept. 1999 research flight. From the positions of these skinpaints, we calculated the mean differences (aircraft $-$ skinpaint) and standard deviations in elevation angle, azimuth angle, and range, which are $-0.19 \pm 0.36°$, $0.18 \pm 0.36°$, and 86 ± 183 m, respectively (Fig. 2). The results are surprisingly good and provide strong support both for the accuracy of the radar positioning and the position processing used to generate the aircraft data.

5. WORK IN PROGRESS

We are currently matching aircraft and radar data for seven NCAR Electra research flights during MAP. During time periods when the aircraft was within the 100 km unambiguous range of the radar and co-located radar and aircraft measurements could be found, we are analyzing aircraft *in situ* measurements. Figure 3 shows an example of Particle Measuring System (PMS) 2DP (two-dimensional precipitation) probe data from 20 September 1999 at 6:16 UTC. From these data, we calculate size distributions, determine their shape, and derive quantities such as hydrometeor bulk densities.

Figure 3 further shows the variability in particle types over a short time interval, from smaller, less rugged particles (a) to larger aggregates (b). Due to this variability, we will be able to evaluate the polarization radar based hydrometeor typing algorithm by Vivekanandan *et al.* (1999) over a range of hydrometeor types.

ACKNOWLEDGMENT

This work was supported by the National Science Foundation under the research grant ATM-0438071. Opinions expressed are those of the authors and not necessary those of the Foundation.

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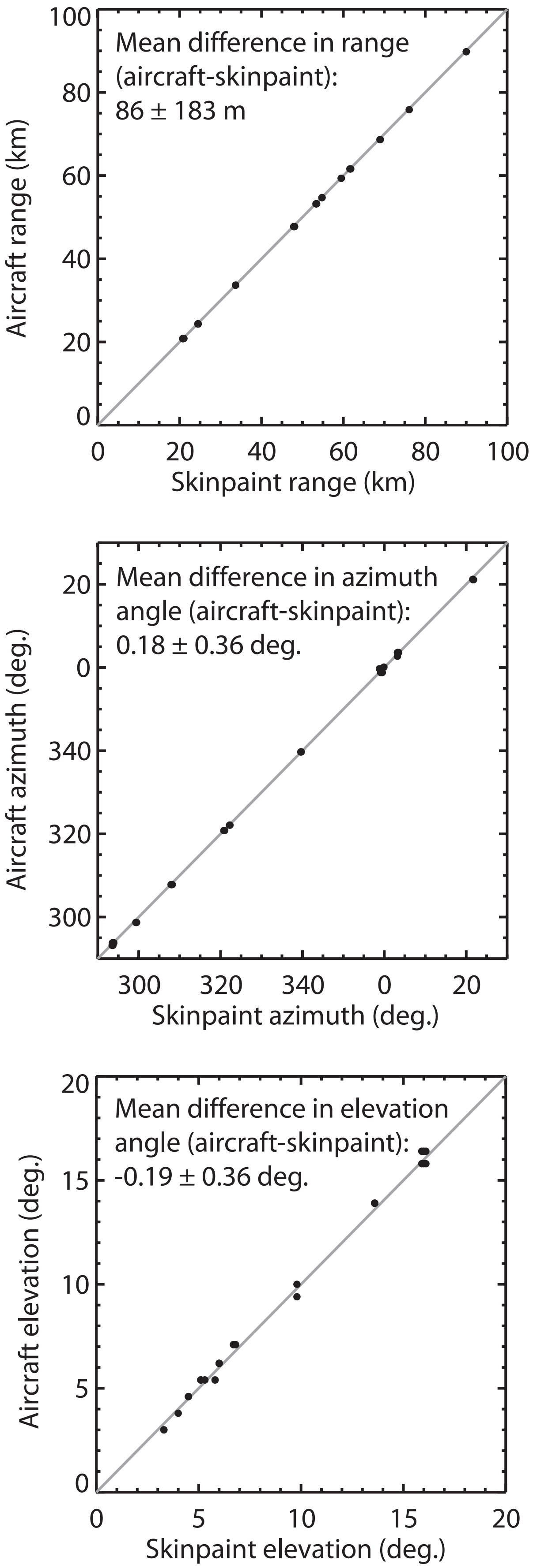

Figure 2: Mean difference in location, (aircraft position−radar-indicated position) for (a) range, (b) azimuth angle, and (c) elevation angle during MAP IOP 2b, 20 Sept. 1999

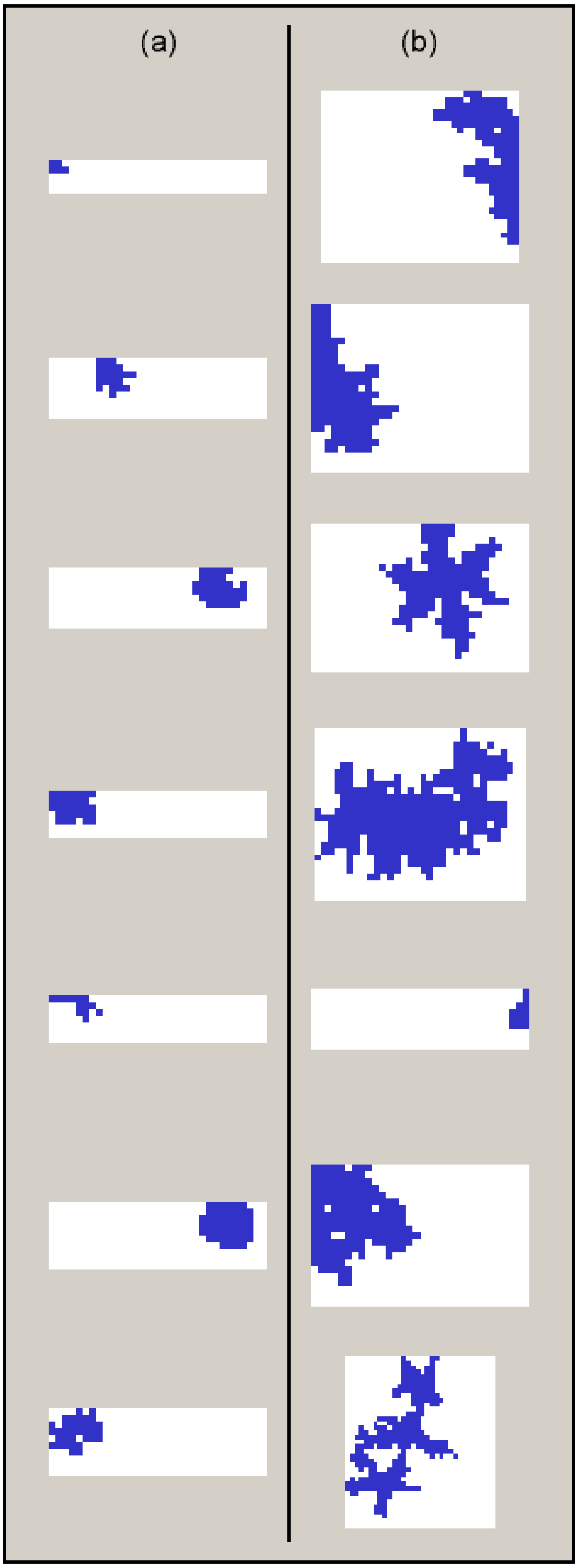

Figure 3: Example shadow images of hydrometeors observed during MAP IOP 2b, 20 Sept. 1999 at (a) 6:16:01 UTC and (b) 6:16:31 UTC. Horizontal scale for each particle image is 6.4 mm