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EVALUATING MM5'S UPDATED BULK MICROPHYSICAL PARAMETERIZATION USING CASE STUDIES FROM THE IMPROVE FIELD CAMPAIGNS

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1. INTRODUCTION

Recently, the bulk microphysical parameterization in MM5 (specifically Reisner et al., 1998) has been extensively tested, updated, and improved. Sensitivities of the microphysics to primary ice initiation, autoconversion, CCN spectra, treatment of graupel, and parameters controlling the snow and rain size distributions were tested. These tests were performed by simulating various cloud depths (with different cloud-top temperatures) using flow over an idealized two-dimensional mountain (Thompson et al., 2003). Results were compared against simulations from a detailed, bin microphysical model (Rasmussen et al., 2002).

Upon testing the primary sensitivities of the microphysics using idealized flow conditions, the model was used in multiple case studies from various field projects. Particular emphasis was placed on prediction of freezing drizzle events. Garvert et al., (2003) and Colle et al., (2003) present results of MM5 simulations using these updated microphysics for the 13-14 Dec case from the IMPROVE-2 field campaign (Stoelinga et al., 2003). In contrast to that case with vigorous and deep precipitating clouds, this paper discusses preliminary observations from a shallow and relatively warm cloud system. Comparisons between these observations and MM5 simulations will be presented at the conference.

2. IMPROVE-2, IOP#1: 28 NOV 2001

2.1 Synoptic Overview

A vigorous low-pressure center and associated trough moved rapidly into the Pacific Northwest in the twenty-four hours prior to 0000 UTC 29 Nov 2001. Clouds associated with a warm front were prevalent in the Oregon Cascades during the first twelve hours whereas the latter twelve hours had clouds consistent with the surface cold front then post-cold frontal airmass. Winds at 850 hPa were generally from the southwest approaching 25 m s^{-1} and the air was nearly saturated at this level as the upper trough approached. These ingredients resulted in the first Intensive Observation Period (IOP) of the IMPROVE-2 field project.

The S-POL radar showed light precipitation starting around 0400 UTC on the 28th, gradually increasing in intensity throughout the day until embedded bands appeared in association with the cold front. Intermittent post-frontal precipitation continued well into the following day.

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Satellite images revealed very low cloud-top temperatures of approximately -65°C prior to 1800 UTC followed by a dramatic decrease in cloud depth and corresponding increase in cloud-top temperature to approximately -15°C (see Fig. 1). While this storm was observed by the project's remote sensing platforms and ground observers during the pre-cold front hours, it was not investigated by aircraft until after the passage of the cold front clearly seen in Fig. 1.

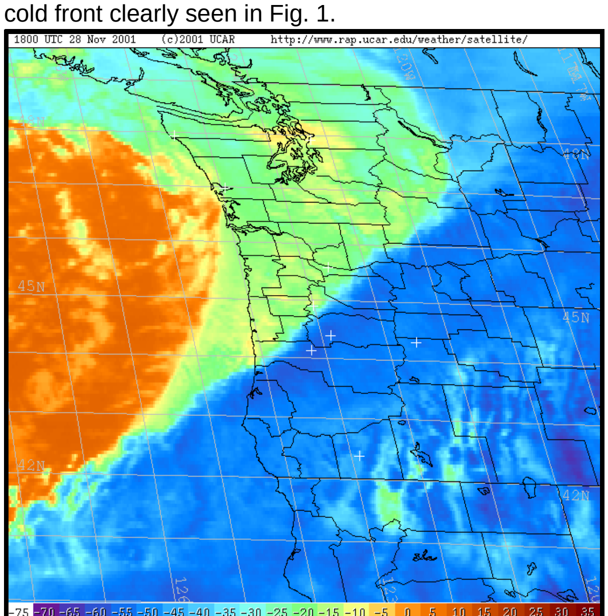

Fig. 1: GOES-10 channel 4 (infrared) satellite image taken at 1800 UTC 28 Nov 2001. Cloud-top temperature (°C) colorized using the scale at the bottom.

2.2 Observations at the surface

At the ground, the first author observed approximately 9 cm of snow on the ground at 1330 UTC near Sisters, OR with light snow still falling. During a drive westward into the Cascade mountains, the snow changed to rain around 1423 UTC then changed to freezing rain near Camp Sherman at 1500 UTC. While gaining significant elevation on the drive from Camp Sherman to Santiam Pass on U.S. Highway 20, the precipitation fell steadily in the form of light freezing rain, followed by rain, then rain mixed with snow, then all snow at the summit of the pass by 1600 UTC with a temperature of approximately 1-2°C. Rapidly-melting snow fell most of the day at Santiam Pass with rain at lower elevations. In fact the snow rapidly changed to rain with only a small decrease in elevation (~100 m) on a drive down the western slope of the Cascades into the town of Sweet Home. Not until after 2100 UTC did the temperature drop below 0°C at Santiam Pass beyond which time the snowfall rate became much more variable with generally light snow and intermittent periods of moderate snow.

Between about 1600 and 2100 UTC, the snow crystals were dominated by bundles of needles/sheaths, occasional plates and, at times, large aggregates. Light riming was noted occasionally but not often. After 2100 UTC, when melting no longer occurred, many needles/sheaths continued but with moderate or heavy riming along with sporadic graupel plus periods of very large aggregates (~1 cm). This continued for a few hours until the clouds showed signs of thinning (faint pink sunset color) and the rate of snow decreased then stopped around 0045 UTC. No precipitation was noted on the eastbound drive down the Cascades between 0100 and 0130 UTC.

2.3 Aircraft observations

The University of Washington Convair arrived in the vicinity of the Oregon coast at 2040 UTC (reference flight number 1891). Between 2135 and 2149 UTC, on a southwest to northeast transect at roughly 5300 m (refer to the yellow flight track in Fig. 2), the Convair encountered no cloud or precipitation until 2143 UTC when it penetrated the western edge of a cloud and encountered numerous small spherical particles. The 2DC probe imagery is not conclusive but there appear to be water drops between approximately 40 and 100 µm. Within one minute, these were followed by some very large irregular particles, probably graupel and/or heavily-rimed snow crystals. A mixture of these particles continued for the remaining 35 km (6 min) of this transect at 5.3 km.

Then, between 2149 and 2153, the Convair turned back and descended to 4600 m and encountered large stellars/dendrites (~1 mm) with potential rime (the FSSP indicated low cloud water amounts of ~0.05 g m^{-3}), irregulars, graupel, and possibly needles (see Fig. 3). From 2153 to 2212 UTC, the Convair flew a constant altitude return transect to the southwest at 4.6 km with nearly constant temperature of -15°C. During this flight segment, the Convair accumulated significant ice on the wings. The FSSP-100 and PVM-100A instruments recorded cloud liquid water amounts steadily increasing from 0.1 to nearly 0.25 g m^{-3} by 2205 UTC. The icing accumulation was considered hazardous and from 2212 to 2224 UTC, the Convair ascended and circled in clear air at 4900 m to shed the ice (flight path seen in Fig. 4). Then, it returned northeast-bound and ascended again to 5300 m and followed the previous flight segment at this altitude and re-encountered the cloud at 2227 UTC.

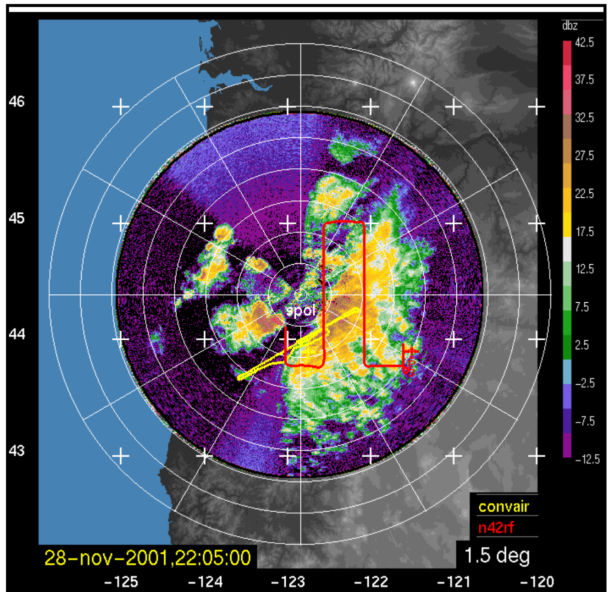

Fig. 2: S-POL radar 1.5-degree reflectivity image at 2205 UTC 28 Nov 2001 along with aircraft track of UW-Convair (yellow line) and NOAA-P3 (red line).

Upon re-entry into the cloud, numerous irregular and spherical particles, large and small, were seen in the 2DC imagery indicating possible graupel combined with drizzle drops (see Fig. 5). After a ten-minute descent and about-face maneuver between 2235 and 2245 UTC, the Convair returned southwest at 5000 m and encountered more graupel or other irregular particles consistent with the previous fifteen minutes. After 2300 UTC, the Convair slowly descended and encountered more airframe icing on its southwestward track and landed at the Eugene airport at 2330 UTC. After refueling, cloud and precipitation measurements resumed on the climb out of Eugene (0020 UTC) as the Convair returned to Paine Field, WA.

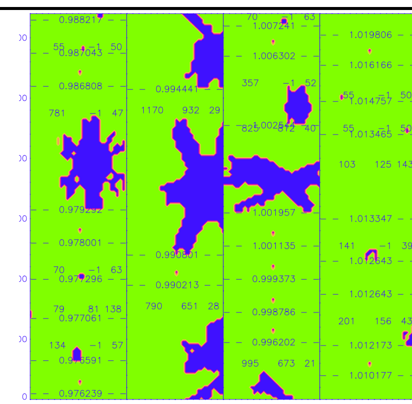

Fig. 3: 2DC probe images from the Convair at 21:51:17 UTC 28 Nov 2001. Width of each column is 800 µm. Two crystals appear to be plates with extensions, another may be a stellar or bundle of needles. Most images from this time showed far less distinct shapes.

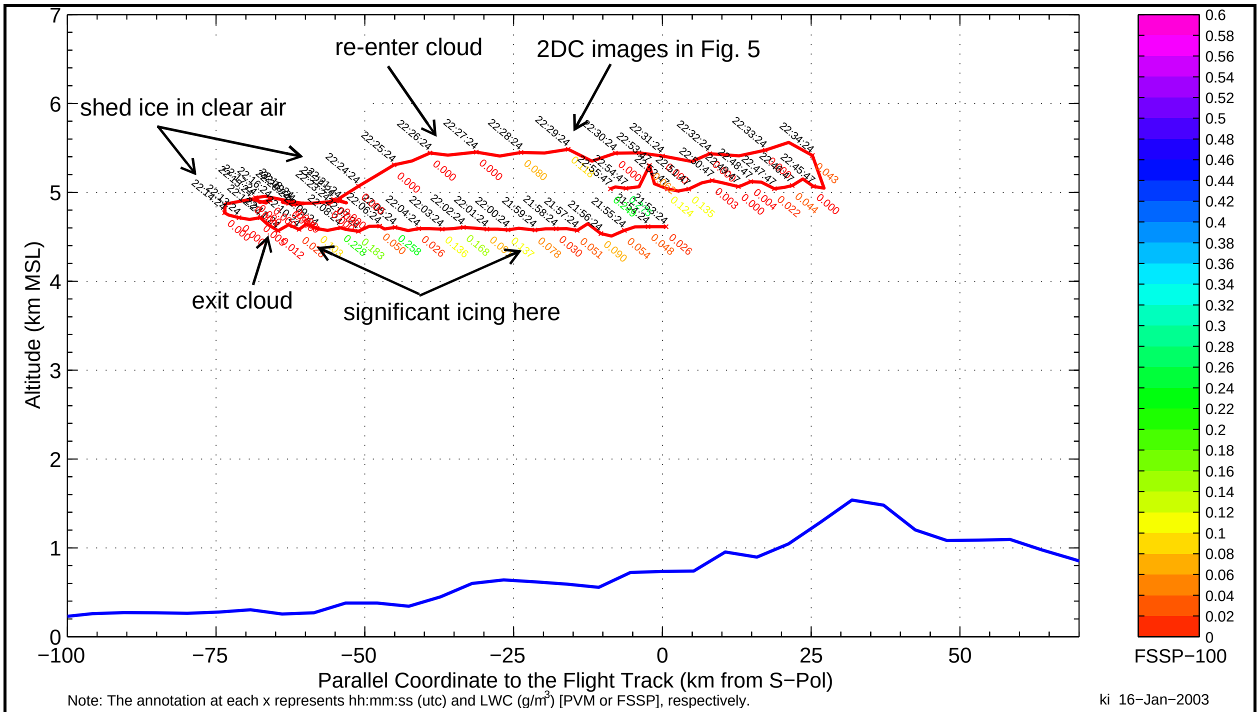

Fig. 4: Vertical view of flight track of UW-Convair from 2153 to 2256 UTC. Time and corresponding liquid water content (g m^{-3}) measured by FSSP-100.

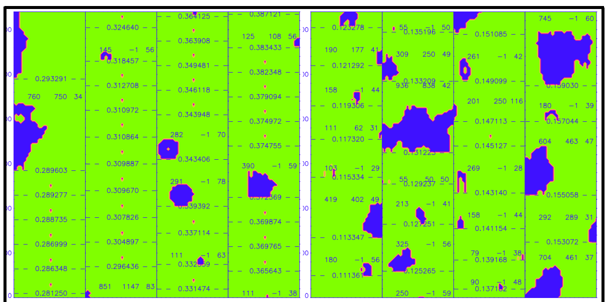

Fig. 5: 2DC probe images from the Convair at 22:29:36 (left) and 22:29:55 UTC (right) 28 Nov 2001 on the second penetration into the cloud after shedding ice from the wings. Note the ~300 µm drizzle drops in left image and irregular (probably graupel or heavily-rimed snow) particles on the right.

Besides the UW-Convair, the NOAA-P3 aircraft flew a support mission in the same vicinity (refer to the red flight track in Fig. 2) and collected Eldora radar data as well as microphysical and state variable data. The P3 collected pertinent data between approximately 2049 and 0023 UTC including specific mention at 2150 UTC of "significant rime on wings" and liquid water measurements reaching 0.5 g m^{-3} at 1670 m. Further analysis of the P3 data is underway.

3. FUTURE WORK

As mentioned in the introduction, results of MM5 simulations including sensitivity tests of this case will be presented at the conference. Besides the 28 Nov case, significant effort comparing model simulations to observations from other IMPROVE-2 cases will be pursued, particularly 29 Nov (IOP#2), 13-14 Dec (IOP#9), and 4-5 Dec (IOP#4). Specific microphysics aspects that need significant attention are the treatment of converting rimed snow to graupel, the assumed size distribution and associated terminal velocity of snow (and other species), and conversion of cloud water to rain water.

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