7.1 OVERVIEW OF IMPROVE: VERIFICATION AND IMPROVEMENT OF BULK MICROPHYSICAL PARAMETERIZATIONS IN MESOSCALE MODELS

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1. INTRODUCTION

Despite steady and significant improvements in other aspects of numerical weather prediction, the improvement of quantitative precipitation forecasting (QPF) has advanced only slowly (Olson et al. 1995; Fritsch et al. 1998). One approach to potential improvement in QPF is a careful examination of the bulk parameterization of grid-resolved cloud and precipitation microphysics in mesoscale models. This is the motivation for IMPROVE (Improvement of Microphysical PaRameterization through Observational Verification Experiment), an research program in the Pacific Northwest that includes two field studies completed in 2001: a frontal precipitation study, which was conducted offshore of Washington State in January and February, 2001; and, an orographic precipitation study, which was conducted in the Cascade Mountains of Oregon in November and December, 2001. Each of these two field campaigns was aimed at studying heavy stratiform precipitation in environments that offer unique advantages in terms of quantity of precipitation and predictability of the controlling dynamics. See Fig. 1 for a map of the two study areas and the observational platforms deployed.

Current bulk parameterizations of cloud and precipitation microphysics are based on relatively few observational studies. Furthermore, few dedicated efforts have been made to comprehensively evaluate the underlying assumptions and predicted hydrometeor distributions of the parameterizations in current use, and to use such evaluations to improve the parameterizations. The only way to perform such a verification in a manner that yields definitive and unambiguous results is to observe all aspects of the studied precipitation system, from 3-D temperature and wind distributions to microphysical parameters such as mixing ratios and particle size distributions. This requires concurrent use of in situ cloud and precipitation microphysical observations from a well-instrumented aircraft and remotely sensed (radar), ground-based, and upper-air observations of the

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3-D wind, temperature, and humidity fields. This is the approach that was taken in IMPROVE. A list of the diverse instruments deployed to take measurements during IMPROVE are listed in Table 1, and are shown in Figs. 1 and 2.

This presentation provides an overview of IMPROVE, including the motivation for the project, a description of the rich data set obtained in the two field studies, and an outline of continuing research activities. This overview presentation is followed by several individual presentations by IMPROVE participants on specific research results.

2. INTENSIVE OBSERVING PERIODS (IOPs)

The winter of 2000/2001 (during which IMPROVE-1 was conducted) was drier than normal in the Pacific Northwest. The following winter (during which IMPROVE-2 was conducted) was wetter than normal. However, both field phases provided a number of opportune weather systems for studying the targeted types of clouds and precipitation.

Precipitation during IMPROVE-1 was below normal due to a persistent split flow pattern. The majority of the IMPROVE-1 events were occluding systems, which are climatologically the most frequent type of frontal passage in the area. Generally, model forecasting guidance was skillful and nearly all candidate weather systems were successfully targeted.

The IMPROVE-2 period was considerably wetter than normal over central Oregon. Persistent zonal flow or troughing over the eastern Pacific brought a series of strong cyclones and fronts, with significant orographic enhancement of precipitation, across the region during the first

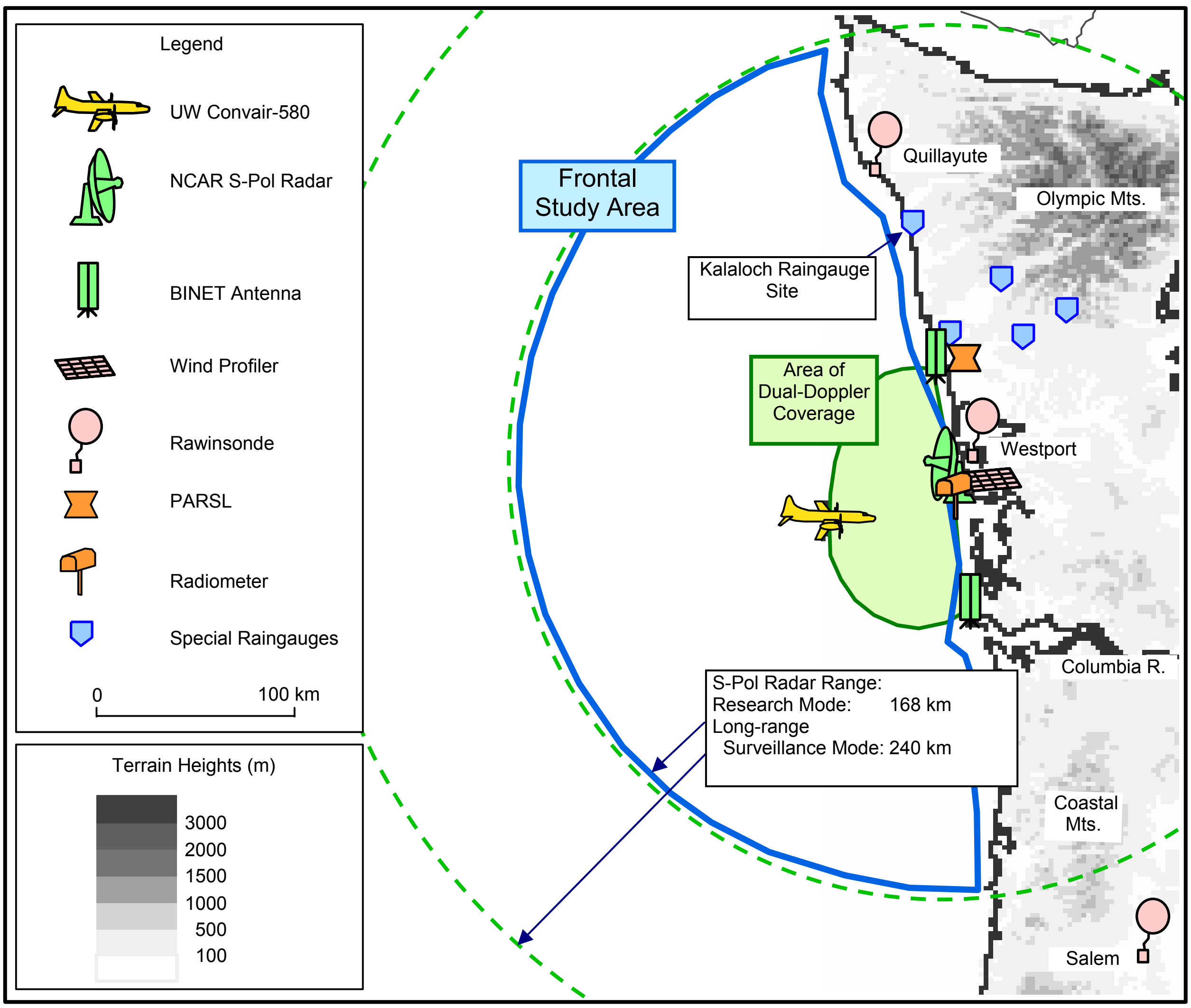

FIG. 1. Map of the IMPROVE-1 Frontal Study Area, showing locations of observational facilities.

three weeks of the experiment. Stations in the Orographic Study Area generally received half a standard deviation above the normal precipitation amount for the month of December. The strongest and wettest weather systems were accurately targeted by IMPROVE operations.

With the wide array of observing platforms deployed, and a wide variety of precipitating systems targeted during both field phases, the IMPROVE field studies produced a vast, comprehensive set of measurements of cloud and precipitation microphysical parameters, as well as measurements of the thermal and kinematic context in which the clouds and precipitation developed.

3. CURRENT RESEARCH DIRECTIONS

IMPROVE research is now focusing on analysis of the observational data and model simulations of the cases studied in the field. Both the observational and modeling studies can be divided into three main objectives: (1) to understand and quantify the mesoscale processes

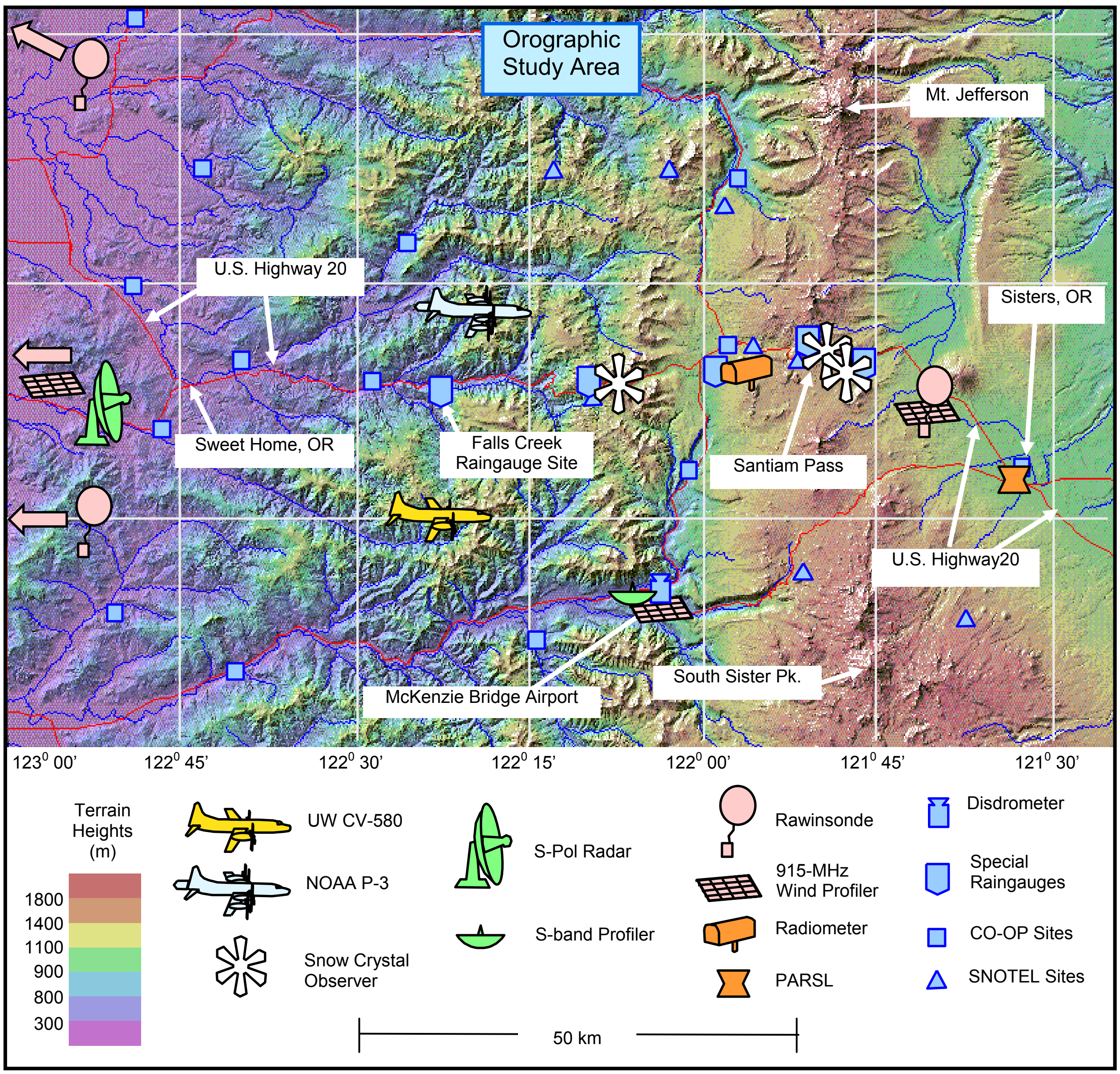

FIG. 2. Map of the IMPROVE-2 Orographic Study Area, showing locations of observational facilities.

TABLE 1. Instrument platforms deployed during the two IMPROVE field studies.

Instrument Platform	Source*
UW Convair-580 research aircraft [1,2]	UW
NOAA P-3 research aircraft [2]	NOAA/AOC
NCAR S-Pol radar [1,2]	NCAR/ATD
NCAR bistatic network (BINET) receivers [1]	NCAR/ATD
Ground-based snow crystal observations [2]	UW
NCAR integrated sounding systems (ISS) [2]	NCAR/ATD
ETL S-band profiler [2]	NOAA/ETL
ETL wind profilers [1,2]	NOAA/ETL
Special NWS rawinsondes [1,2]	NOAA/NWS
Special rawinsondes [1,2]	UW, U.S. Navy, PNNL, NCAR/RAP
NCAR scanning microwave radiometer [1,2]	NCAR/ATD
UW raingauge network [1,2]	UW
UW disdrometer [2]	UW
PNNL remote sensing laboratory (PARSL) [1,2]	PNNL

* UW: University of Washington; NOAA: National Oceanographic and Atmospheric Administration; AOC: Aircraft Operations Center; NCAR: National Center for Atmospheric Research; ATD: Atmospheric Technology Division; ETL: Environmental Technology Laboratory; NWS: National Weather Service; PNNL: Pacific Northwest National Laboratory; RAP: Research Applications Program.

[1] Operated during IMPROVE-1.
[2] Operated during IMPROVE-2.

that lead to the development and modulation of precipitation; (2) to understand and quantify the microphysical processes that lead to the development of precipitation; and, (3) to quantify the spatial and temporal distributions of cloud and precipitation hydrometeors and precipitation fallout at the surface. For each of these objectives, the goal is the comparison of model outputs with the observations. If the mesoscale kinematic, thermal, and moisture evolution in the model simulations can be verified against observations, any remaining errors in the precipitation evolution can be attributed to the BMP scheme used in the model simulation. For example, specific phenomena that will be examined are the model's handling of mountain waves in the orographic cases and of upper-level instability and generating cells in deep frontally forced precipitation systems. Incorrect kinematic fields associated with these phenomena will likely affect the accuracy of the model-simulated precipitation, irrespective of possible problems in the BMP scheme. We will attempt to correct these kinematic and dynamical deficiencies using tools such as 4D data assimilation on the outer grids. Adequate simulation of mountain waves may also require the use of a higher-resolution model grid (~1 km. The microphysical processes and quantitative outputs from the model will be compared with observations to determine where the BMP scheme is handling precipitation development properly and where it is not. These comparisons should reveal any weaknesses in the BMP schemes and motivate improvements. The revised schemes will then be tested on other IMPROVE cases and in an operational forecasting environment.

4. SUMMARY

During the past several years, there has been increasing evidence for deficiencies in bulk microphysical parameterizations in numerical weather prediction models. Improvements in these parameterizations have been difficult because coincident and comprehensive measurements of both the basic state flow and microphysical parameters have not been available. In response to the need for such data, two field campaigns were carried out: an offshore frontal precipitation study off the Washington coast in January/February 2001, and an orographic precipitation study in the Oregon

Cascade Mountains in November/December 2001. Twenty-eight intensive observation periods yielded uniquely comprehensive data that include in situ airborne observations of cloud and precipitation microphysical parameters; remotely sensed reflectivity, dual-Doppler, and polarimetric quantities from both the surface and aloft; upper-air wind, temperature, and humidity data from balloon soundings and vertical profilers; and a wide variety of surface-based meteorological, precipitation, and microphysical data. These data are being used to test mesoscale model simulations of the observed storm systems and, in particular, to evaluate and improve bulk microphysical parameterization schemes used in the models. These studies should lead to improved quantitative precipitation forecasting in research and operational forecast models.

A comprehensive description of IMPROVE and its data sets are available on the IMPROVE web site: http://improve.atmos.washington.edu.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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