COMET OUTREACH FINAL COOPERATIVE PROJECT REPORT

University: Desert Research Institute, University of Nevada

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Type of Project: Cooperative Project

Project Title: Improving the Prediction of the Rapid Mesoscale Transition from Heavy Rainfall to Blizzard Conditions in Complex Terrain (COMET)

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Section 1: Summary of Project Objectives

The primary objective of this research project was to better understand the mechanisms for the rapid transition from rainfall to blizzard conditions in complex terrain. A secondary objective involved improving our understanding of the role of Narrow Cold Frontal Rainbands (NCFR) in this process as well as to diagnose the predictability of these phenomena.

Section 2: Project Accomplishments and Findings

One can diagnose three important findings from this research that represent advances in understanding and can therefore be considered accomplishments:

Project Finding #1: Large scale analysis datasets over the southwestern U.S. and southeastern Pacific Ocean may not properly resolve the atmosphere's mass and momentum structure prior to the landfall of major/intense Pacific baroclinic jet/front systems, which may be causing substantial operational model simulation errors of the NCFR and its precursor low-level jet in the Sierra Nevada Mountains.

Numerous simulation experiments with very high resolution versions of the Reno NWS WRF model involving differing initialization times unambiguously indicate that serious forecast errors in NCFR and low-level jet location and velocity occur at just 12-24 hours prior to the local passage of a NCFR over the Sierra Nevada Mountains. The strong sensitivity of model error to the initial dataset employed in the analyses at 12 and 24 hours was evident. These errors rendered the WRF simulations almost useless in simulating the strength and location of a NCFR when initialized 12-24 hours prior to the event. Only those simulations initialized 6 hours before the event were reliable. These errors occurred with the NAM analysis but were not substantially improved employing the RUC (or NARR) analysis. They also were to a large extent independent of the grid resolution employed in the simulations. This may mean that the structure of the baroclinic jet/front system for the 4 January 2008 case study was seriously misrepresented over the Pacific Ocean and along the southern California Coast just hours before the NCFR developed over the Sierra Nevada. More experiments with this and other case studies are necessary to clarify the importance of this finding.

Project Finding #2: Upstream diabatic heating on the windward slope of the Sierra Nevada Mountains due to latent heat release accompanying heavy precipitation may provide an important heat source to strengthen the low-level jet-induced warm air advection resulting in a prolonged period of unforecasted rainfall in the downstream complex terrain.

NOAA Hydrometeorological Site wind profiler/RASS observations at Truckee, California indicated that prior to NCFR passage, a 2-3 hour period of warming accompanied the strengthening of a low-level jet below 3 km. This jet accompanied a slight turning of the flow to the south-southwest between 3 km and the surface at Truckee along with a substantial increase in its velocity. The period during which this occurred was a period in which the freezing level rose ~400-500 m and the surface temperature warmed ~2C in the Truckee observations. It was during this time period that the NWS forecast anticipated a transition to possible blizzard conditions yet only heavy rainfall occurred. An analysis of the most reliable WRF simulation (based on the timing of NCFR and low-level jet structure) did indicate that a secondary meso-γ scale low pressure area formed just downstream from the observed and model-simulated upslope precipitation south-southwest of Truckee. The model-simulated low-level jet and warming were displaced slightly downstream and somewhat late from that observed warming and low-level jet strengthening in the Truckee profiler/RASS. It is likely that this model error could be the result of initialization problems or synergistic errors caused by the initialization problem's effect on upslope precipitation. MESOwest surface observations were likely too coarse and poorly positioned to resolve the complex mean sea level pressure fields simulated at the meso-γ scale near Truckee. Obviously, issues of this complexity require further research to unambiguously clarify, in particular model sensitivity experiments with and without condensational heating.

Project Finding #3: The NCFR is a mechanism for the transition from heavy rainfall to snowfall in complex terrain and its simulation accuracy is strongly contingent on the upstream simulation of the diabatically-enhanced low-level jet that is strengthened by latent heating on the upslope of the upstream mountains.

Radar, surface observations, the Truckee profiler/RASS and model simulations all unambiguously confirm that the rapid transition to blizzard conditions at Truckee resulted from the passage of the NCFR and that the NCFR timing, strength and location that controlled the transition from rain to snow at Truckee were strongly modulated by the antecedent low-level jet.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Lesson #1: A better understanding that the operational forecast models may not adequately resolve and/or simulate the NCFR, with resultant impacts on precipitation type and intensity forecasts.

Lesson #2: An increased appreciation for the effects of latent heat release on the windward side of the Sierra Nevada and the effects downstream on the flow pattern and low level thermal profile.

Benefit #1: The above two lessons will be addressed in future winter season training at NWS Reno.

Benefit #2: Continued partnership with the Atmospheric Sciences Graduate Program at the Desert Research Institute and the University of Nevada Reno and giving graduate students a taste of operational forecasting problems.

Section 4: Benefits and Lessons Learned: University Partner Perspective

Lesson #1: Upper-air analyses employed in initializing mesoscale numerical models may be seriously deficient when strong baroclinic jet/front systems approach the southwestern U.S.

Lesson #2: The strength and location of the precursor low-level jet to the NCFR over the Sierra Nevada is strongly dependent upon both the initial analyses and upstream upslope precipitation-induced condensational heating.

Lesson #3: The strength and location/timing of the NCFR must be accurately simulated if the transition from rain to snow is to be accurately forecasted in complex Sierra Nevada terrain.

Section 5: Publications and Presentations

King, KC, M. L. Kaplan and C. Smallcomb, 2009: Development and propagation of a narrow cold frontal rainband in Northern California. Preprints, 13th Conference on Mesoscale Processes, 17-20 August 2009, Salt Lake City, Utah. In Preparation.

Section 6: Summary of University/Operational Partner Interactions and Roles

University Partner's Interactions and Roles: The university partner: 1) performed an in depth literature review on the topic, 2) determined simulation experiments and observational analyses to be performed, 3) analyzed the results of both and 4) organized these results into a conference preprint.

Operational Partner's Interactions and Roles: The operational partner: 1) conducted an extensive suite of WRF model simulations at varying horizontal and vertical resolutions, 2) provided occasional feedback on the university partner's research findings and 3) provided advice to graduate students in producing maps and diagnostics of the model output.