Effect of Latent Heating on Mesoscale Vortex Development During Extreme Precipitation: Colorado, September 2013
Annareli Morales1,2, Russ Schumacher2, and Sonia Kreidenweis2
1University of Michigan, Ann Arbor, MI, 2Colorado State University, Fort Collins, CO
Contact: annareli@umich.edu

• WRF simulations performed to explore the role of latent heating in mesovortex development and dominant microphysics processes involved
• Latent heating had strong impact on surface flow field, leading to enhanced upslope, convection, and precipitation over Boulder, CO
• High potential vorticity values in lower troposphere are associated with increasing latent heating with height from cloud water condensation
• A 50% reduction of the latent heating contribution from cloud water condensation resulted in no mesovortex development and significant reduction in precipitation along northern Colorado Front Range

Background
On the evening of 11 September, Boulder experienced flash flooding as a result of high rain rates accumulating over 180 mm in 6 hours (Fig. 1). From 0400-0700 UTC 12 September, a mesoscale vortex (mesovortex) was observed to travel northwesterly towards Boulder. This circulation enhanced upslope flow and was associated with localized deep convection (Fig. 2). The mesovortex originated in an area common for lee vortex formation (e.g. the Denver Cyclone), yet we hypothesize the mesovortex developed through the release of latent heat

Project Objectives
• Explore whether mesovortex was associated with lee vortex formation or through dynamic feedbacks from release of latent heat
• Understand the role of latent heating to mesovortex development
• Explore dominant microphysical processes and test sensitivity of mesovortex and precipitation to strength of latent heating

Methods

Model Configuration
• Advanced Research WRF v3.3.1
• 60 km forecast, initialized at 0000 UTC 11 September 2013
• Two-way nested grid, 3 domains: horizontal grid spacing (Ax) of 36km, 12km, and 4km
• 36 stretched vertical levels, 50-hPa model top
• Timeticks: 44 sec, 48 sec, and 16 sec (respectively)
• Initial and boundary (updated every 3 hrs) conditions from 0.5° NCEP GFS model

Results

Latent Heating Experiments
• LH_ON_LH_OFF results in no mesovortex development and weaker flow in northern Colorado
  – Lack of enhanced PV suggests lee vortex formation is not primary mechanism for mesovortex development
• LH_OFF_LH_ON shows features similar to those associated with the mesovortex (enhanced PV and low-level jet)
  – Suggests LH is needed to enhance pre-existing circulation and develop mesovortex
• LH had strong effect on surface flow field (feedback process)
  – Low-level jet enhanced in response to upward motions caused by LH, leading to enhanced upslope, which enhanced convection and surface precipitation

Exploring Control Simulation
• 12 Sept heating profiles had convective characteristics, consistent with observations
• High values of PV near the surface were associated with a strong, positive vertical gradient in LH located in the lower troposphere
  – Cloud water condensation was dominant process responsible for increase of LH with height

Sensitivity to Latent Heating Reduction
• Reducing the LH contribution from cloud water condensation by 50% (after 1800 UTC 11 Sept.) resulted in no mesovortex development and significant reduction in precipitation along northern Front Range
• Uncertainties do remain with respect to effect of LH on subsequent precipitation amount, thus future research is needed to explore complex dynamic-thermodynamic relationships involved in feedback process

Simulations and sensitivity studies suggest that the mesovortex was indeed responsible for the increased rain rates observed on 12 Sept. over Boulder, CO. Mesovortex development was more akin to a mesoscale convective vortex (MCV) than to the Denver Cyclone.

Conclusions

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