Observed vertical structure of snow storms in Steamboat Springs, CO: Orographic enhancement in a high altitude environment

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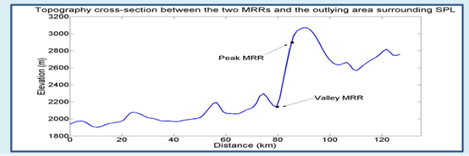
Clouds and Precipitation Processes and Patterns Group



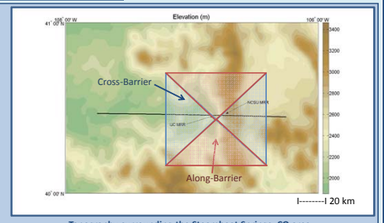
I. Introduction

Purpose

To study the impacts of wind speed and direction on orographic precipitation structure between the valley floor and mountain peak.

Methodology

Ground-based radar profiles and in situ observations were collected as part of the Inhibition of Snowfall by Pollution Aerosols (ISPA 2010) study centered at the Desert Research Institute's Storm Peak Laboratory (SPL) during January and February of 2010. Observations were taken using two vertically pointing Metek Microwave-Rain Radars (MRRs) and surface meteorology sensors. The NCSU MRR was deployed atop Mt. Werner at SPL, and the UC MRR was deployed in the valley near the town of Steamboat Springs. This is the first time vertical reflectivity profiles have been sampled at SPL.



Topography surrounding the Steamboat Springs, CO area.

All Data (hours)	All "Echo Cases" (hours)	Cross-Barrier (hours)	Along-Barrier (hours)	"No Echo" (hours)
1011	382	319	63	242

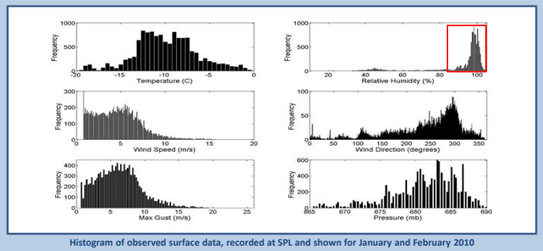
Instrument	Location
MRR	Valley/Peak
Surface Data	Valley/Peak
Radiometer	Valley
Disdrometer	Valley

•"Echo Cases" defined from MRR data as echo above 7dBZ with a lull in precipitation not exceeding 6 successive hours. "Echo Cases" were further separated into their prevailing surface wind direction (See above for case definitions).

•"No Echo" instances were defined as periods with clouds but without precipitation echoes.

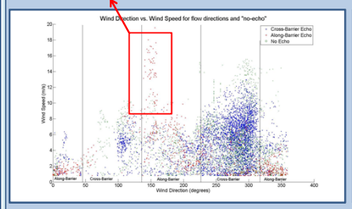
NOTE: Various cases exhibited wind directions which did not fit within a single criterion. In this instance, the cases were classified by their prevailing wind direction and the mode of the entire case.

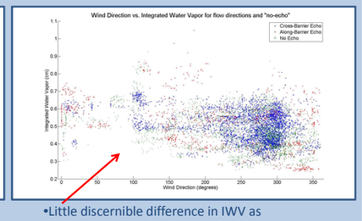
II. Environment: Jan-Feb 2010



Histogram of observed surface data, recorded at SPL and shown for January and February 2010

•Highest wind speeds coincided with "along-barrier" case.

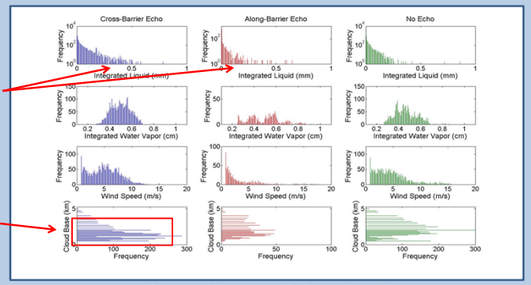




•Little discernible difference in IWV as a function of wind direction.

•Echoes exhibit longer tail of higher Integrated Liquid values

•Cross-Barrier echoes exhibit lowest cloud bases over valley, on average.

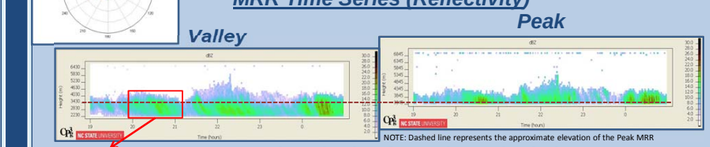


Histograms of SPL data for flow directions and "no-echo"

III. *Cross-Barrier*: 17 UTC 26 Jan 2010 to 08 UTC 27 Jan 2010

Wind rose of wind direction and frequency during this Cross-Barrier case.

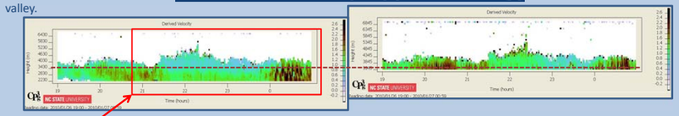
MRR Time Series (Reflectivity)



NOTE: Dashed line represents the approximate elevation of the Peak MRR

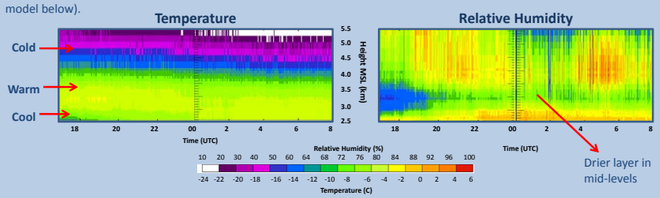
Evidence of fall streaks in valley.

MRR Time Series (Doppler Velocity)



Rapid changes in reflectivity and velocity observed between these times (see radiometer data and conceptual model below).

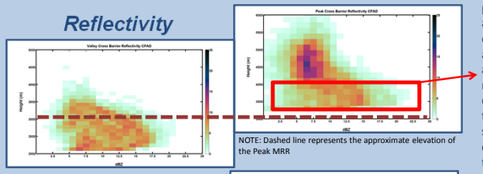
Radiometer Time Series



Drier layer in mid-levels

Contour Frequency by Altitude Diagrams

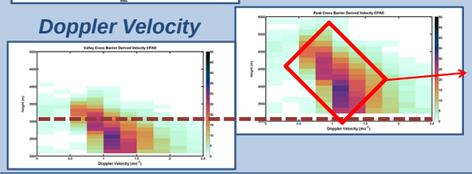
Reflectivity



NOTE: Dashed line represents the approximate elevation of the Peak MRR

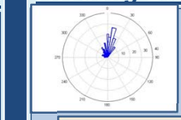
The mountain peak displays an increase in echo top altitude, and a widening reflectivity distribution toward the surface, as compared to the valley.

Doppler Velocity



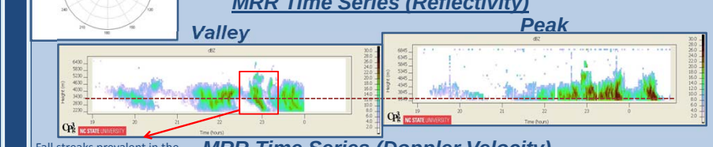
Observed increase in doppler velocity with a decrease in height, suggesting hydrometeor growth.

IV. *Along-Barrier*: 14 UTC 28 Feb 2010 to 00 UTC 1 Mar 2010



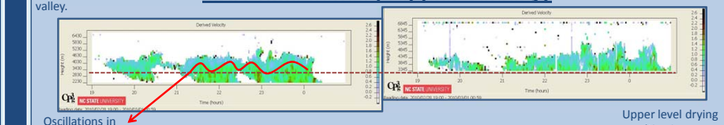
Wind rose of wind direction and frequency during this Along-Barrier case.

MRR Time Series (Reflectivity)



Fall streaks prevalent in the valley.

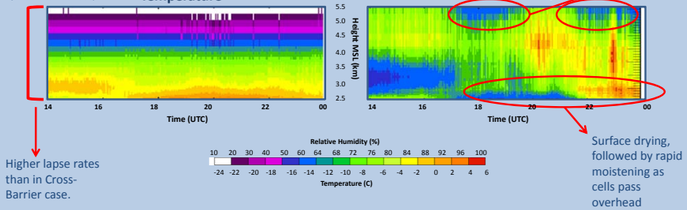
MRR Time Series (Doppler Velocity)



Oscillations in Derived velocity near height of SPL (mountain crest).

Upper level drying resulting in potential instability

Radiometer Time Series

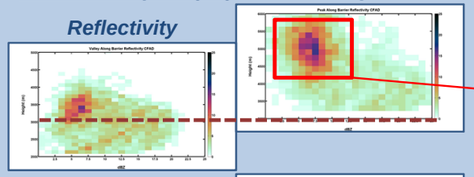


Higher lapse rates than in Cross-Barrier case.

Surface drying, followed by rapid moistening as cells pass overhead

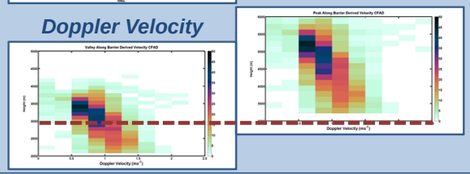
Contour Frequency by Altitude Diagrams

Reflectivity



Higher echo top than cross-barrier case.

Doppler Velocity



V. Conclusions

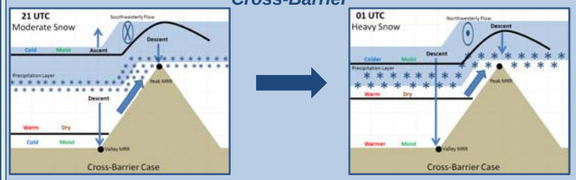
Investigation of the observed vertical structures of two snow events reveals complicated interactions with the local Park Range mountains.

- Orographic enhancement is observed in both flow direction cases. Other cases (not shown) reveal similar results. Enhancement is manifested in a widening distribution to include higher reflectivity values, and higher echo tops over the mountain (peak).
- Fall streaks are observed in both cases, primarily over the valley

Additional cases will be examined to determine the generality of the preliminary conclusions.

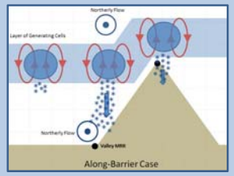
Conceptual Model

Cross-Barrier



•Complicated, multi-layer flow is observed in the Cross-Barrier case.

Along-Barrier



•Clear evidence of generating cells is seen in the Along-Barrier case

•Oscillations in the Derived Velocity field at mountain crest altitude are observed over the valley in the Along-Barrier case

Acknowledgements

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