Storm structure, freezing level height, and precipitation in the US Pacific Northwest

Sandra Yuter[1], Jake Crouch[1], Brian Colle[2], and Yanluan Lin[2]

[1] North Carolina State University, Raleigh, NC (USA), [2] Stony Brook University, Stony Brook, NY (USA)

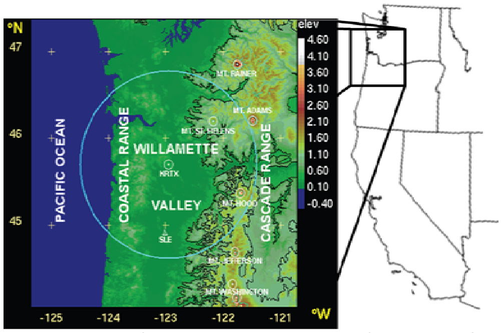

Figure 1. Location of study area. KRTX is the location of the radar site. SLE indicates upper-air sounding site. Blue circle shows the 120km range ring.

Introduction

In the winter season, extratropical cyclones pass over the US west coast after developing over the Pacific Ocean. These land-falling cyclones are modified by the Coastal and Cascade mountains, yielding frequent rainfall. Some west coast orographic precipitation events can become very intense, leading to flooding and mudslides. Several recent severe flooding events in the US Pacific Northwest were associated with higher freezing level altitudes compared to long-term seasonal averages. This study examines 47 winter storms to determine the differences in the distribution of precipitation frequency along the Cascade windward slope as a function of rain layer depth.

Data

Operational Radar: The winter storm season of 2005-2006 (March-November) plus select storms from the 2006-2007 winter storm season observed by National Weather Service S-Band radar in Portland, Oregon (KRTX). Radar data were interpolated to a Cartesian coordinate system with 1km horizontal and vertical resolution.
Vertically Pointing Radar: Doppler velocity obtained from a Ku-Band METEK Micro Rain Radar (MRR) in Portland.
Operational Upper-Air Sounding: 12 hourly sounding from Salem, Oregon (SLE).
SNOTEL and COOP Data: SNOwpack and TELemetry (SNOTEL) automated daily precipitation and National Weather Service Cooperative Observer Program (COOP) manual daily precipitation measurements.

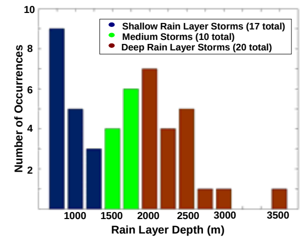

Figure 2. Histogram of storm maximum rain layer depth with storm groupings of shallow, medium, and deep.

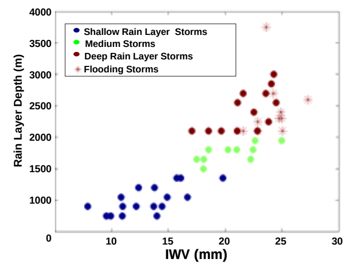

Figure 3. Scatter plot of vertically integrated water vapor from SLE sounding closest to storm onset and storm maximum rain layer depth.

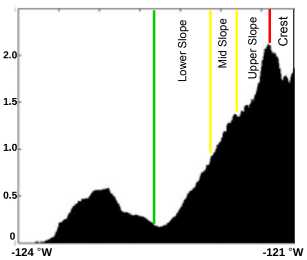

Figure 4. Meriodional average of terrain from -124 °W to -121 °W.

Methodology

- 47 winter storms were selected that had low level winds from the South-Southwest (87% of all storms).
- The MRR Doppler velocity provided rain layer depth.
- Because of varying freezing level heights associated with frontal passages, we used storm maximum rain layer depth to categorize storms.

Deep Rain Layer: > 2.0 km **Medium**: < 2.0 km and ≥ 1.5 km **Shallow Rain Layer**: < 1.5 km

Contoured Frequency by Distance Diagram - CFDD

We calculated the frequency of precipitation (Z >13 dBZ) for each radar grid point of each storm and each subset of storms. At every distance from the crest, we compiled a histogram of the precipitation frequency into a single filled-contour plot (B. Jewett). To minimize range dependence and terrain blockage issues, we focused on the region near the radar site eastward to the Cascade crest.

January 2, 2006: Shallow Storm

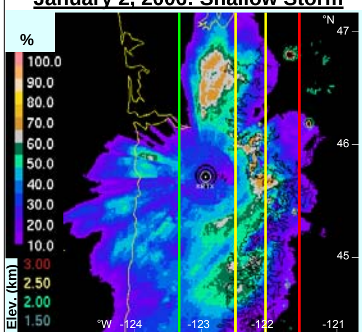

Figure 5a. Storm averaged Z>13 dBZ frequency at 2 km altitude for Jan. 2, 2006. Green line is western extent of CFDDs. Red line corresponds to the crest.

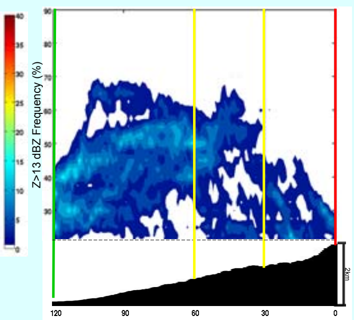

Figure 5b. Jan. 2, 2006 storm average CFDD of precipitation frequency at 2 km altitude. Color lines relate to the locations on Fig. 4. Average meridional terrain within radar domain shown.

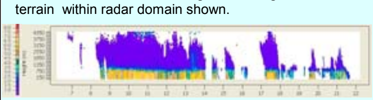

Figure 5c. MRR Doppler velocity: Jan 2, 2006.

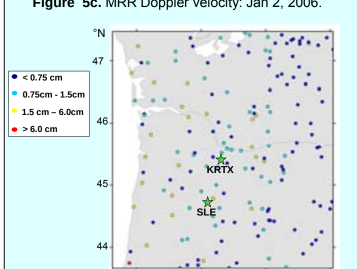

Figure 5d. Storm total precipitation: Jan. 2, 2006.

November 5-8, 2006: Deep/Flood Event

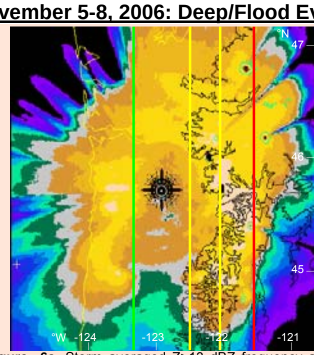

Figure 6a. Storm averaged Z>13 dBZ frequency at 2 km altitude for Nov. 5-8, 2006.

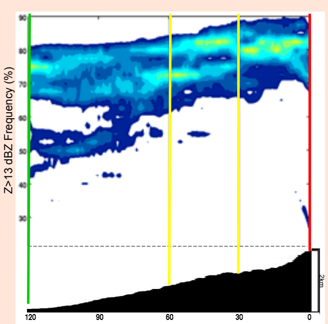

Figure 6b. Nov. 5-8, 2006 storm average CFDD of precipitation frequency at 2 km altitude.

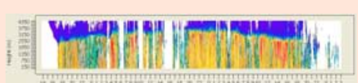

Figure 6c. MRR Doppler velocity: Nov. 5-8, 2006.

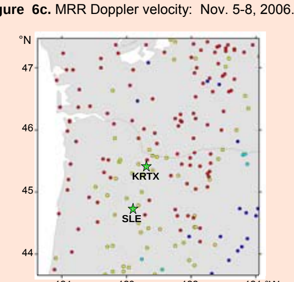

Figure 6d. Storm total precipitation: Nov. 5-8, 2006.

All Shallow Storms

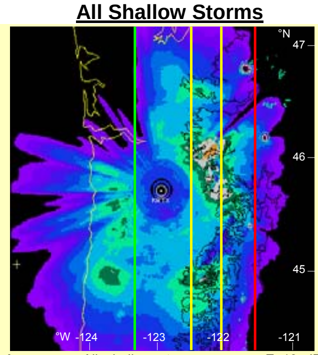

Figure 7a. All shallow storms average Z>13 dBZ frequency at 2 km altitude for 17 storms.

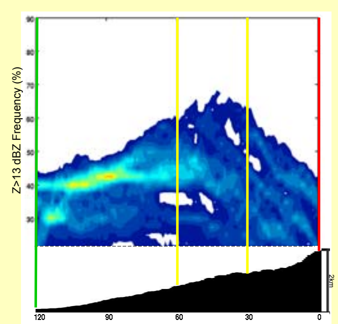

Figure 7b. All shallow storms average CFDD of precipitation frequency at 2 km altitude.

All Deep Storms

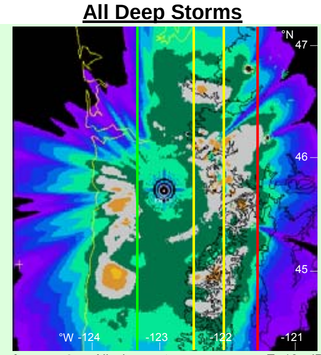

Figure 8a. All deep storms average Z>13 dBZ frequency at 2 km altitude for 20 storms.

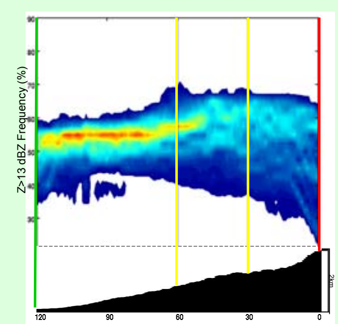

Figure 8b. All deep storms average CFDD of precipitation frequency at 2 km altitude.

Conclusions

- The distribution of maximum rain layer depths for Portland winter storms is bimodal with peaks at 750 m and 2000 m MSL.
- Rain layer depth and vertically integrated water vapor are positively correlated.
- Rainfall is more frequent and more areas receive rainfall in deep rain layer storms; flooding events occurred in deep rain layer storms.
- Along the lower windward slope of the Cascade Range, the modal frequency of precipitation increases W to E for the shallow rain layer storms and remains steady near 55% W to E for the deep rain layer storms.
- There is an abrupt increase in precipitation frequency near mid-slope in deep rain layer storms, which may be related to the superposition of the smaller scale gravity waves associated with ridges along the slope (Colle 2008, JAS).
- The frequency distribution of precipitation frequency near the crest is very broad for both storm types and tends to have higher values in deeper rain layer storms.

Acknowledgements: This work was funded by National Science Foundation grants ATM-0544766 and ATM-0450444.