Aerosol-Cloud-Precipitation Interactions During STORMVEX

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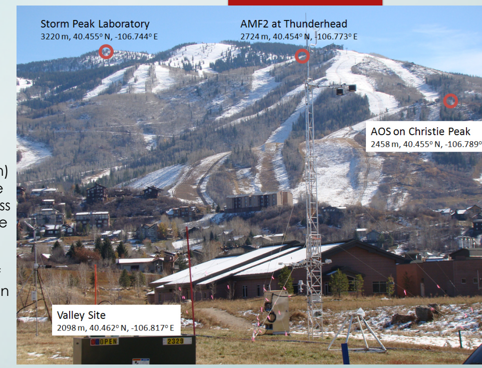

Abstract:

One of the motivating aspects of StormVEx was to collect in situ microphysical measurements of cloud and snow properties at Storm Peak Laboratory (SPL) while instruments below the lab collected typical remote-sensing measurements. The Scanning W-band Cloud Radar (SWACR) routinely pointed directly at the lab so that we have coincident radar reflectivity measurements and in situ microphysics. One of our objectives has been to analyze this coincident data to determine the microphysical properties of the snow such as mass-dimensional relationships. Such relationships are typically assumed and tend to cause very large uncertainties in microphysical retrievals. To this end we have created a record of mixed-phase microphysics from the raw 2-D imagery and cloud probe data by fitting the PSDs with bimodal (cloud and precipitation) gamma functions. Additionally, the cloud probe data were reprocessed using OASIS software. In general, the average 1-D and 2-D particle size distributions overlap quite well. The largest discrepancy appears to be for the small crystals (75-200 μm), and is described. To interpret the radar data in terms of the microphysics, we have developed a T-Matrix radar-scattering application that gives co- and cross-polar backscatter cross sections for the geometry of the radar-lab set up. These two adaptations allow us to characterize the microphysical properties of the snow using an optimal estimation retrieval algorithm. The results of this analysis are described. The second aim of this study is to test for a statistically significant connection between New Particle Formation (NPF) and growth to Cloud Condensation Nuclei (CCN). Previous work at SPL has shown a frequent occurrence of NPF events, documented seasonality, and demonstrated an association with elevated Sulfur Dioxide (Hallar et al., 2011 and 2016). During the StormVEx field campaign, NPF was observed on 29 of the 173 measurement days (17% of the time) at SPL. The growth rates at SPL were 7.6 +/- 5.4 nm/hr. NPF was more frequent at Christy Peak (lower elevation site) during StormVEx. In fact, NPF was observed 75 of the 159 measurement days (47%). These events had a grown rate of 5.7 +/- 4.5 nm/hr. SPL was frequently in cloud during the StormVEx field campaign, which limited NPF days. A correlation was investigated between days with NPF and enhanced CCN concentrations. Statistical analysis was conducted on these data sets to determine significance.

Studying the Role of New Particle Formation in Cloud Condensation Nuclei Production (1)

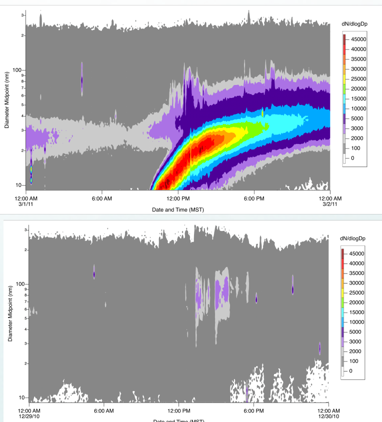

Figure 1: Presents particle size distributions from the AOS located at Christy Peak as a concentration matrix, with the x-axis representing the particle size and the colors represents the concentration. Top figure illustrates NPF day, Bottom figure illustrates day without NPF event.

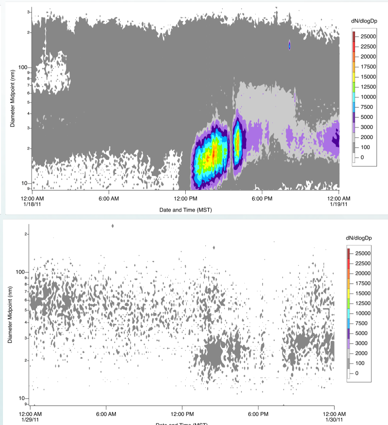

Figure 2: Presents particle size distributions from Storm Peak Lab as a concentration matrix, with the x-axis representing the particle size and the colors represents the concentration. Top figure illustrates NPF day, Bottom figure illustrates day without NPF event.

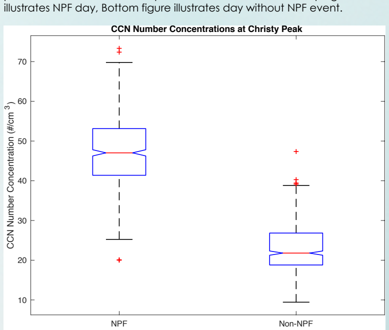

Figure 2: CCN concentrations (#cm^{-3}) during the 2000 MST hour at 0.2% supersaturation for an associated NPF day (03/01/11) and non-NPF day (12/29/10) at the Christy Peak AOS. The center of the box indicated the median, with the top and bottom associated with the 75th and 25th percentile, respectively. The whiskers extend to the most extreme data points not considered outliers, and outliers plotted with a '+' symbol.

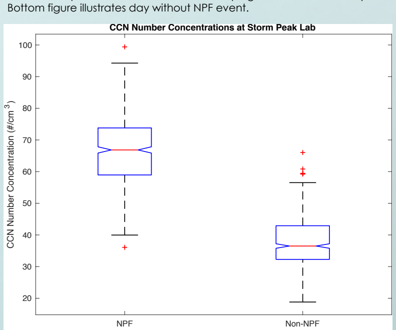

Figure 4: CCN concentrations (#cm^{-3}) during the 2000 MST hour at 0.2% supersaturation for an associated NPF day (01/18/11) and non-NPF day (01/29/11) at Storm Peak Laboratory in Steamboat Springs, CO. The center of the box indicated the median, with the top and bottom associated with the 75th and 25th percentile, respectively. The whiskers extend to the most extreme data points not considered outliers, and outliers plotted with a '+' symbol.

Summary: 1) Previous work has shown frequent NPF events in this region (Hallar et al., 2011 & 2016). These new results suggest that NPF in this remote region are directly impacting the number of available CCN at a supersaturation relevant to orographic cloud formation.

Investigating the Role of Blowing Snow on Ice production (2)

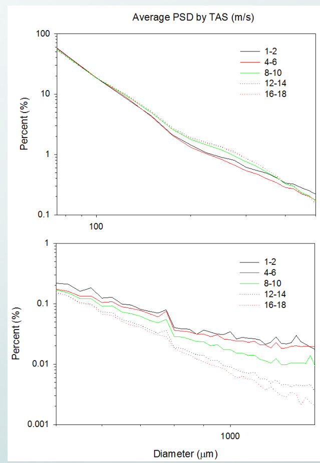

Figure 5: Top) Relationship between wind speed and small crystal concentrations from the Cloud Imaging Probe at Storm Peak Laboratory Bottom) Same relationship looking at larger channels. 2-D image processing was completed (i.e. OASIS) on CIP data.

Summary: 2) We observe no relationship between wind speed and small crystal concentrations. Previous work has suggested that small crystals should be resuspended most readily and that this points to blowing snow as the mechanism for enhanced small crystal concentrations (e.g. Geerts et al, 2015).

Is nucleation of small ice crystals related to heterogeneous freezing of large cloud drops (3)

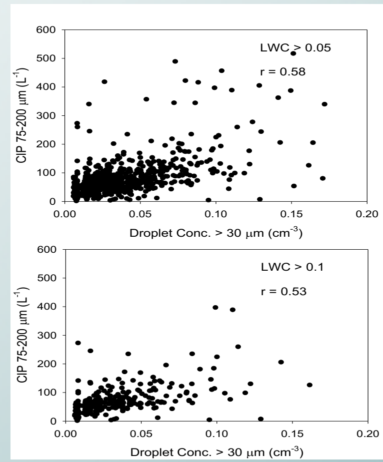

Figure 6.: Relationship between 30-second average large cloud droplet (>30 um) and small ice crystal (75-200 um) concentration in mixed-phase clouds at SPL for selected CAMPS flight periods during StormVEx.

Summary: 3) Initial data suggest that cloud droplet may be freezing and creating small ice particles.

Characterizing the Bulk Mass-D properties of snow using radar and in situ PSD (4)

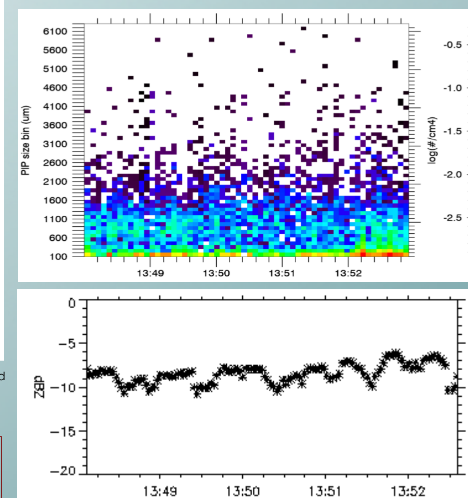

Figure 7. Example PIP PSD time series with observed snow images compared with a time series of SWACR dBZ in the range bin in front of Storm Peak Lab collected during a period when the radar pointed directly at SPL. We are modeling the off nadir scattering properties of the ice crystals to infer the mass-dimensional properties of the snow using the technique described in Mascio and Mace (2017)

Summary: 4) Bulk measurements provided by millimeter radar will provide a unique means of characterizing the bulk properties of in-situ measured snow

Citations Referenced:

Geerts, B., Pokharel, B., & Kristovich, D. A. (2015). Blowing snow as a natural glaciogenic cloud seeding mechanism, Monthly Weather Review, 143(12), 5017-5033.

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Acknowledgments: Thank you to the StormVEx team, especially Stephen Springston, Gunner Senum, Art Sedleacek, Nicki Hickmon, Mike Ritsche, Matt Shupe, Roj Marchand, Sergey Matrosov, and many others including SPL volunteers and graduate students