Aerosol-Cloud-Precipitation Interactions During STORMVEX

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Abstract:
One of the motivating aspects of StormVEX was to collect in situ micrometeorological 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 micrometeorics. One of our objectives has been to analyze this coincident data to determine the micrometeorological properties of the snow such as mass-dimension relationships. Such relationships are typically assumed and tend to cause very large uncertainties in micrometeorological retrievals. To this end, we have collected a record of mixed phase microphysics from the 3-D imaging 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 micrometrix, we have developed a 1-Markov radiative scattering application that goes co- and cross-polar backscatter cross-sections for the geometry of the radar-lab set up. These two adaptations allow us to characterize the micrometeorological 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 seasonally, 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 +/- 3.4 nm/hr. NPF was more frequent at Christy Peak (lower elevation site) during StormVEX. In fact, NPF was observed 75 of the 197 measurement days (40%). These days had a growth rate of 5.7 +/- 4.5 nm/hr. SPL was frequently in cloud during the StormVEX field campaign, which limited NPF events. 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 y-axis representing the concentration. Top figure illustrates NPF day. Bottom figure illustrates day without NPF event.

Figure 2: CCN concentrations (log10) during the 2000 MST hour of 0.5 supersaturation for an associated NPF day (03/01/11) and non-NPF day (12/19/11) 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 3: CCN concentrations (log10) during the 2000 MST hour of 0.5 supersaturation for an associated NPF day (01/18/11) and non-NPF day (01/19/11) at Storm Peak Laboratory, 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.

Figure 4: CCN concentrations (log10) during the 2000 MST hour of 0.5 supersaturation for an associated NPF day (01/18/11) and non-NPF day (01/19/11) at Storm Peak Laboratory, 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.

Figure 5: Top) Relationship between wind speed and small crystal concentrations from the Cloud Imaging processing was completed (i.e. OASIS) on CIP data. 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. Snow on Ice production (2)

Figure 6: Relationship between 30-second average large cloud droplet (300-1000 µm and < 1 mm) concentration in mixed-phase cloud at 3PL for selected CAMP field periods during StormVEX.

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

Figure 7: Example CIP time series with observed snow images compared with a time series of SWACR DZ2 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 3D-radiating snow properties of the ice crystals to infer the mass-dimension properties of the snow using the technique described in Mascio and Mace (2017).

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

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:

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