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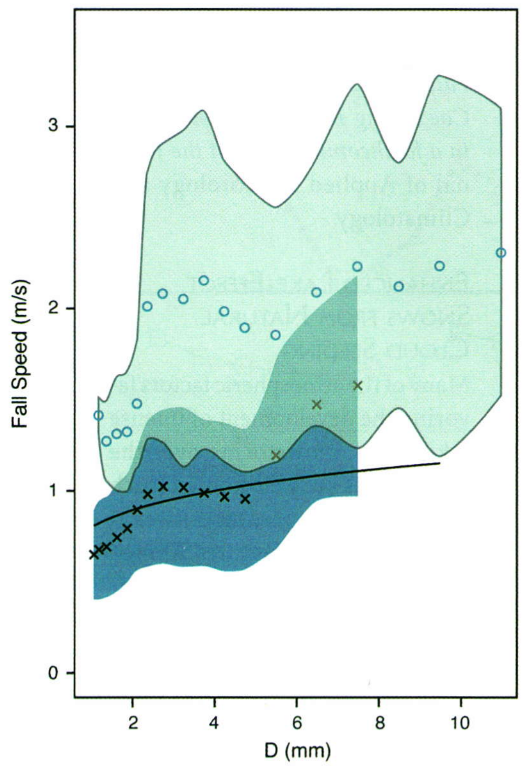
Observations of Size and Fall Speed in Coexisting Rain and Snow

An accurate description of the physical characteristics of coexisting rain and snow near the freezing level is important for cloud and regional forecast models and for the accurate retrieval of precipitation from satellite microwave measurements. Melting aggregates of snow crystals have been investigated in the laboratory, but examination of naturally occurring populations has been lacking because of the practical difficulties of distinguishing between the coexisting particle distributions of rain and snow. Snow particles with diameters greater than 4 mm are also difficult to observe with aircraft probes because they often break up in probe-associated turbulence. We used a ground-based optical sensor to highlight in a new way the unique characteristics of wet snow.

The sensor, a Parsivel disdrometer, simultaneously measures the size and fall speed of each particle, making it possible to distinguish among liquid, frozen, and partially melted precipitation. We compared Parsivel disdrometer measurements obtained in mixed precipitation (rain and wet snow) and rain in the Oregon Cascades and in dry snow in the Colorado Rockies, and classified the coexisting rain and snow particles based on their size and fall-speed properties.

In contrast to dry snow and rain, wet snow has a much weaker correlation between size and fall speed. Wet snow exhibits a variation of fall speed 120%–230% larger than dry snow for a given particle size. The large variability is likely related to the coexistence of particles of similar physical size with different percentages of melting. Our results suggest that different particle sizes are not required for aggregation since wet snow particles of the same size can have different fall speeds. This makes the collision efficiency for wet snow likely larger than that of dry snow.



Mean and standard deviation of particle fall speed as a function of particle diameter (*D*) for wet snow at McKenzie Bridge, Oregon (circles and light blue shading), and dry snow at Snow Peak, Colorado (x's and dark blue shading). Overlaid line is Locatelli and Hobb's fall-speed relation for aggregrates of unrimed dendrites. Fall speeds are adjusted to air density at 0°C and 1000 hPa. (Yuter et al.)

As air temperatures rose above 0.5°C, the volume fraction of snow between 1 and 10 mm in diameter dropped dramatically and raindrops became dominant. The value of 0.5°C for the sharp transition from snow to rain is slightly lower than the 1.1° to 1.7°C range often used in hydrological models.

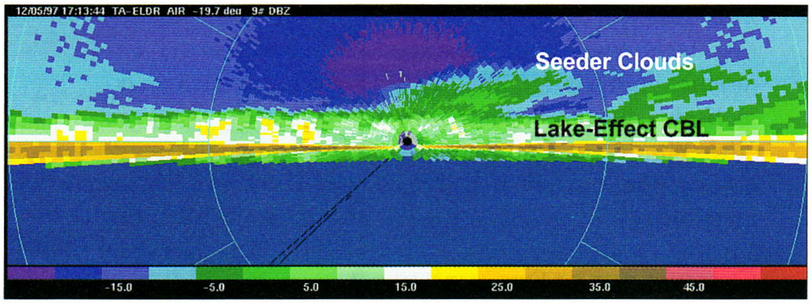
The bimodal distribution of the particles' joint fall-speed–size characteristics at air temperatures from 0.5° to 0°C suggests that wet snow particles transition quickly to rain once melting has progressed sufficiently. As air temperatures increase to 1.5°C, the reduction in the number of very large aggregates with diameters greater than 10 mm coincides with the appearance of rain particles larger than 6 mm. In this setting, very large raindrops appear to be the result of aggregrates melting with minimal breakup rather than formation by coalescence.

Future measurements are needed to extend the in situ dataset, particularly for large particles within mixed precipitation and under a wider range of conditions. In addition, our future deployments of the Parsivel disdrometer will ideally include instrumentation to distinguish among particle types less than 1 mm in diameter and to measure the equivalent liquid water content of falling snow.—Sandra E. Yuter, D. E. Kingsmill, L. B. Nance, and

M. Löffler-Mang. *"Observations of Precipitation Size and Fall Speed Characteristics within Coexisting Rain and Wet Snow," in a forthcoming issue of the* Journal of Applied Meteorology and Climatology.

Enhanced Lake-Effect Snows from Natural Cloud Seeding

Many of the atmospheric factors favoring the development of intense lake-effect snowstorms over the Great Lakes are well-known (such as cold air temperatures, warm lake-surface temperatures, limited low-level stability, etc.). Occasionally, however, lake-effect processes and large-scale cyclones team up to produce particularly intense snowfalls in conditions thought to be less favorable. A lack of detailed observations of such "lake-enhanced" snowstorms has limited our ability to fully understand the processes involved. A fortuitous placement of special observational facilities during the Lake-Induced Convection Experiment (Lake-ICE), along with conventional NOAA facilities, allowed for an unprecedented and detailed examination of the influence of a cyclone on lake-effect convection.



Near-vertical cross-section of radar reflectivity observed by the NCAR *Electra* Doppler radar (ELDORA) on 5 December 1997, 1713 UTC. Range rings (light-blue thin lines) are at 5-km intervals. (Schroeder, Kristovich, and Hjelmfelt)

On 5 December 1997, the NCAR ELDORA airborne radar and in situ observations indicated that snow from a high-level cloud deck associated with a departing cyclone was seeding a growing lake-effect snowstorm over Lake Michigan. Where the University of Wyoming King Air research plane took measurements in the storm that day, the Green Bay, Wisconsin, WSR-88D radar was only able to detect snow from the higher-level clouds. Combining these observations allowed us to separate the flight legs of the King Air into seeded and non-seeded portions. Comparing the observations in seeded and non-seeded portions made it possible to quantify the effects of the seeding process on the lake-effect boundary layer and snowfall.

We found that the presence of the nearby cyclone altered the lake-effect snowstorm in several ways. When the lake-effect boundary layer penetrated an elevated layer of decreased atmospheric stability associated with the cyclone, lake-effect cloudiness deepened rapidly over midlake regions. Over western portions of the lake, average water-equivalent precipitation rates, estimated from aircraft particle observations, were more than an order of magnitude greater in seeded regions than in nonseeded regions. In addition, the lake-effect clouds were also observed to be locally deeper in regions of seeding.