Observations of Falling Snow

Steven R. Long (NASA/GSFC/WFF), David B. Wolff (NASA/GSFC/WFF), Walter A. Petersen (NASA/MSFC)

The Data Source: Precipitation Imaging Package (PIP)

PIP was designed and developed by Larry F. Bliven of NASA GSFC / WFF.

Between the camera module and the halogen lamp is a virtual rectangle measuring 640 by 480 pixels. Each pixel is 0.1 mm on a side, so that the rectangle covers 64 by 48 mm in space. This rectangle is the focal plane of the lens, and the entire area of the video data.

Although originally designed for rainfall studies, PIP runs 24/7 year round, so that video data was also obtained at about 380 images/sec during snow events. This study makes use of that video data of snowfall.

Objective: Determine the mass/water content of snow flakes that can be summed into a water equivalent per unit area of the complete snowfall, using available PIP high speed video of the event.

Fig. 1

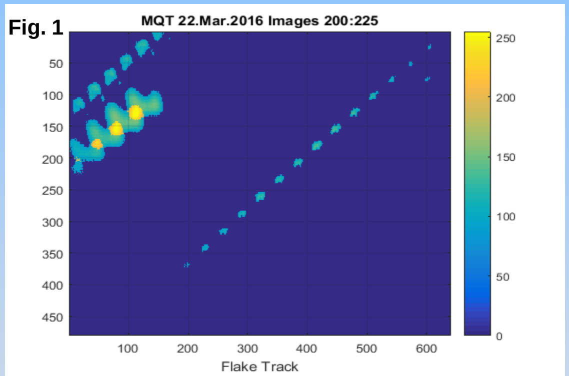


Fig.1 The Marquette (MQT) field site. Overlay of 26 consecutive images, each 640 by 480 pixels. Color bar is the camera grey scale intensity of pixels converted to color for clarity. Out of focus flakes appear much larger and are ignored. From the track shown, vertical fall velocity and horizontal wind drift is obtained. The flake horizontal width is used to find flake area, using **r = ½ width, and area A = πr^2 .**

Notice the single flake below the complete track in the top right corner. This is the beginning of a new flake track. All tracks not out of focus are followed simultaneously.

Knowing the time between individual flakes shown in the composite track of Fig. 1, and the horizontal and vertical pixels moved at each step, allows the vertical (fall) velocity and horizontal velocity (wind drift) to be calculated.

From the book *Ice Physics*, by Peter V. Hobbs (1974), mass m can be found from: $(½)\rho(u^2)(AC) = mg$, where ρ is air density, u is vertical fall velocity, **A is flake area (πr^2), C is drag coefficient (C for rods was used),** and g is the gravitational acceleration.

A typical winter storm produces tens of millions of images. The largest storm obtained thus far has 455 GB of images.

Fig. 2

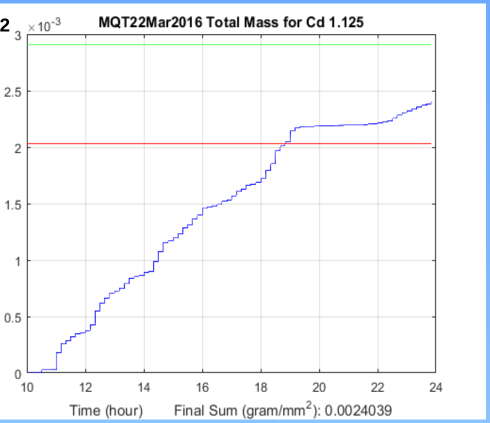


Fig. 2 The cumulative mass as the storm continues through time. The red line is the single NOAA value of mass equivalent from a collection bucket recorded for the entire day. The green line is a test correction on the NOAA value, based on the fall angle of the snowflake track due to horizontal wind, such as shown in Fig.1. Flakes falling at an angle would see an elliptical opening to the NOAA bucket, with reduced capture area.

Because turbulence is often present in storms, only complete tracks, as shown in Fig. 1, enter the calculations. The use of fence enclosures around the NOAA capture bucket can reduce the localized wind effects, but the PIP setup measures flakes in freefall above the ground without using fences.

Fig. 3

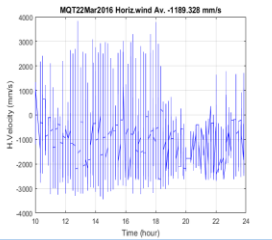
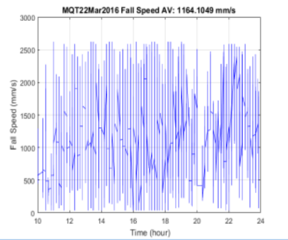


Fig. 4



The variation in the horizontal wind speed (Fig. 3) and flake vertical fall speed (Fig. 4) during the storm event. If turbulence interrupts the flake track by turning the flake too abruptly, that track is marked as complete and the data up to that point in the track is used. Fig. 3 demonstrates that the wind blows from both the right and left sides of the video imaging area during a multi-hour snow storm, causing the flake tracks to tilt right and left alternately, and giving the horizontal wind the appropriate change of +/- sign. Aside from the maximum excursions, the average trends can be seen as darkened lines along the central area in Figs. 3 and 4.

Fig. 5

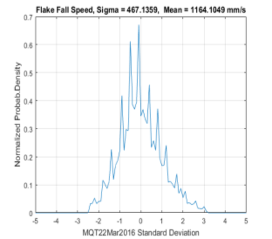


Fig. 5 The normalized probability distribution of vertical flake fall speed, presented in the usual way with standard deviation units (σ) +/- about the mean (at 0), with the area under the plot summing to 1. Other statistical measures of the snow flakes are also produced in the analysis, such as mass, area, flake dimensional ratios, grey scales, etc.

Conclusion: This demonstrates that a video method can be used to find the water equivalent of a snowfall in addition to various statistical measures of the flakes and storm totals. This method will be applied to many other storms to determine patterns and trends in the snow flake statistics in order to identify critical parameters while measuring water equivalence for each storm.

Contacts: Steven.R.Long@nasa.gov
David.B.Wolff@nasa.gov
Walter.A.Petersen@nasa.gov