Effects of snowflake characteristics on the collection efficiency of snow gauge

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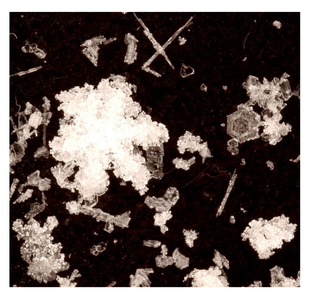
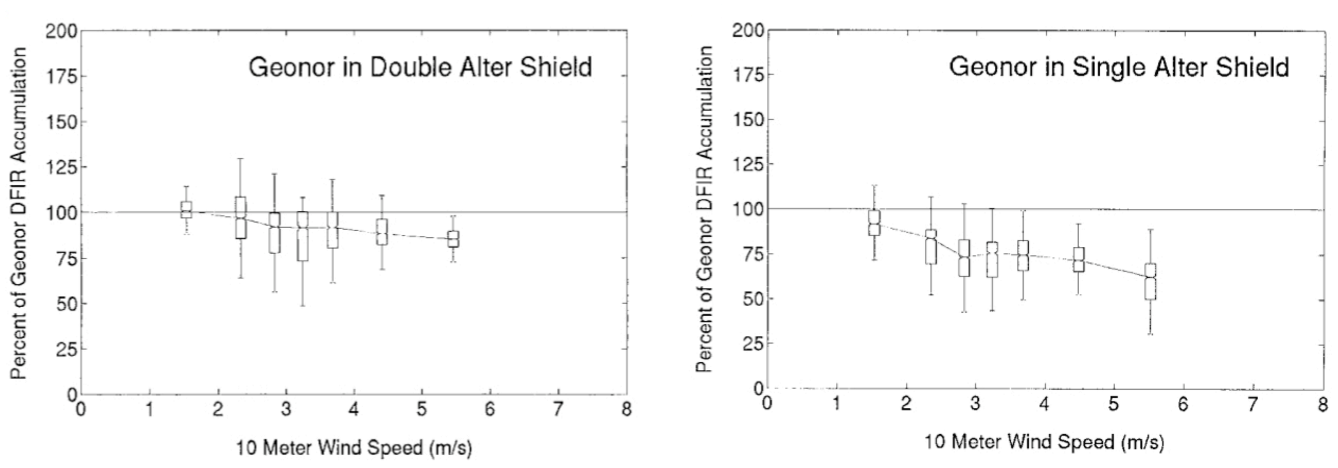
1. Motivation



Accurately measuring snowfall amounts is difficult because many types of snowflakes of different density are commonly observed. Also, measuring snowfall amount is highly sensitive to the wind speed.

Effects of the wind



Rasmussen et al. 2001

2. Objective

To better understand the error induced by the wind on the snow gauge collection efficiency.

3. Experimental Design

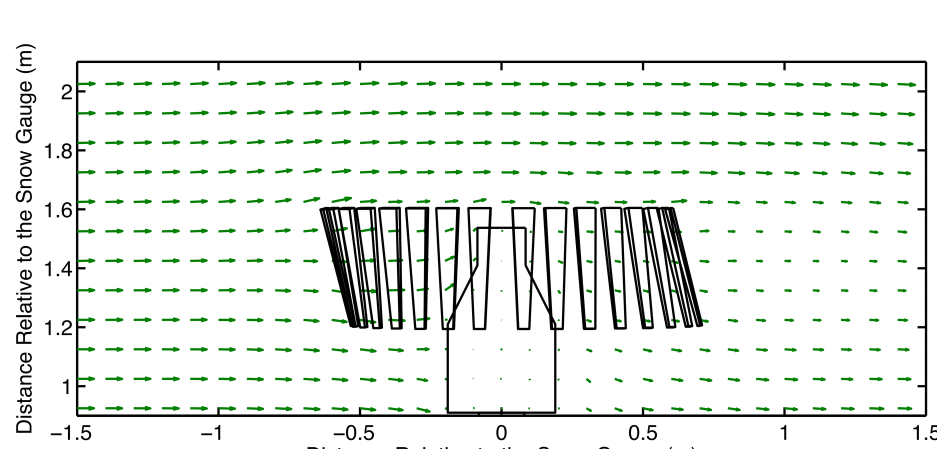
Field Experiment

- Collect snowflake inside and outside the gauge and photograph them every 20 minutes.
- Analyze snowflake type and size.
- Over 3000 pictures were analyzed.

Theoretical Study

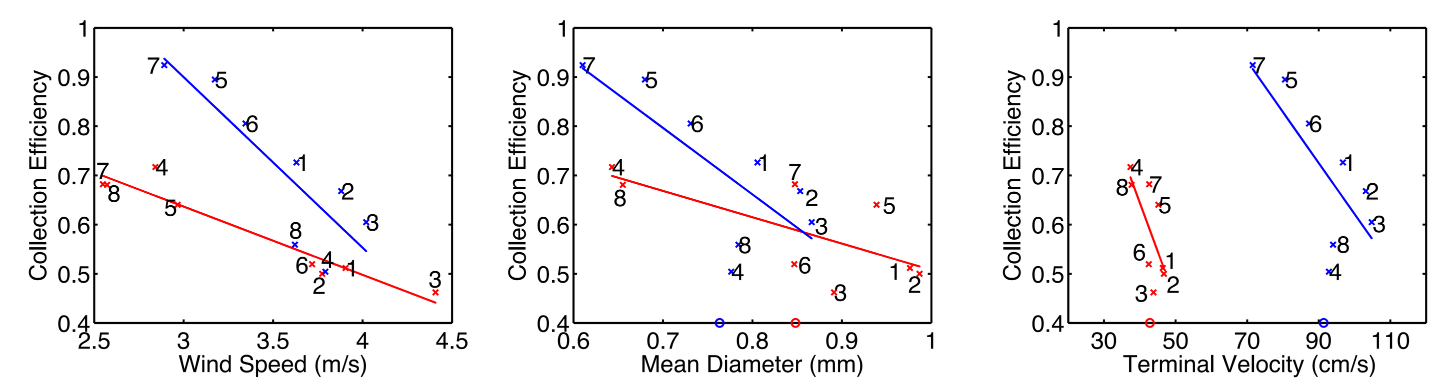
- A turbulent k-epsilon flow around the gauge is simulated using fluid dynamic finite element modeling [FLUENT and GAMBIT].
- Used the simulated flow to compute the trajectory of many snowflake types.
- Assumed different shield slat orientations (0, 15, 30 and 45 deg) and wind speeds (1, 2, 3, 4 and 5 ms^{-1}).

Example of the flow around the shielded gauge. Assuming a wind speed of $5 ms^{-1}$ and a slat orientation of 15 deg.



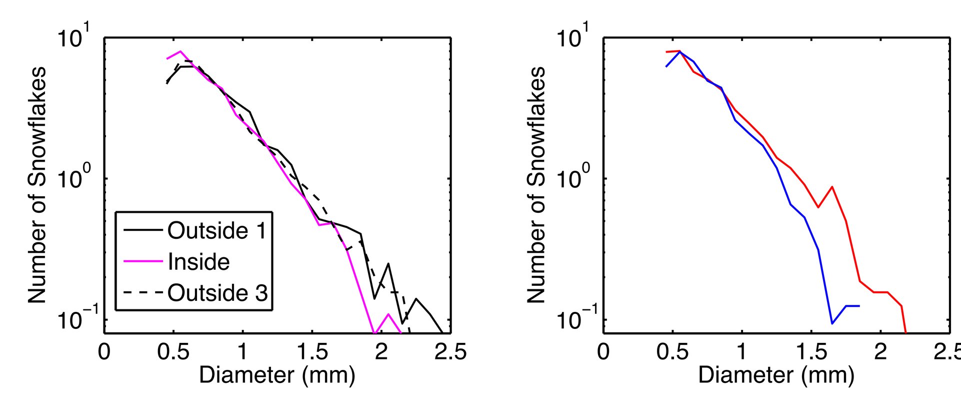
4. Observations: 20 February 2010

A. The Collection Efficiency is the ratio of the precipitation rate averaged over 10 minutes measured by a GEONOR in Single-Alter shield over a GEONOR in DFIR.



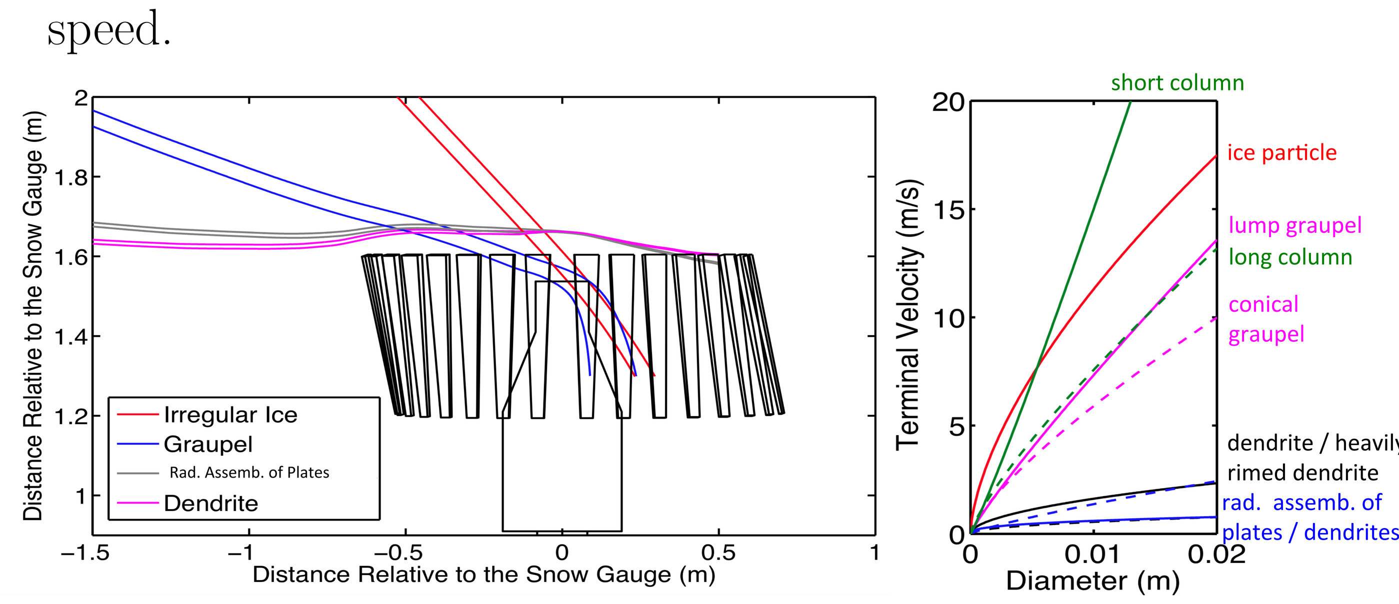
Crystal Types:
Plate-like includes dendrite, heavily rimed dendrite, radiating assemblage of plates or dendrites
Irregular includes graupel, column, irregular ice

B. Size distribution



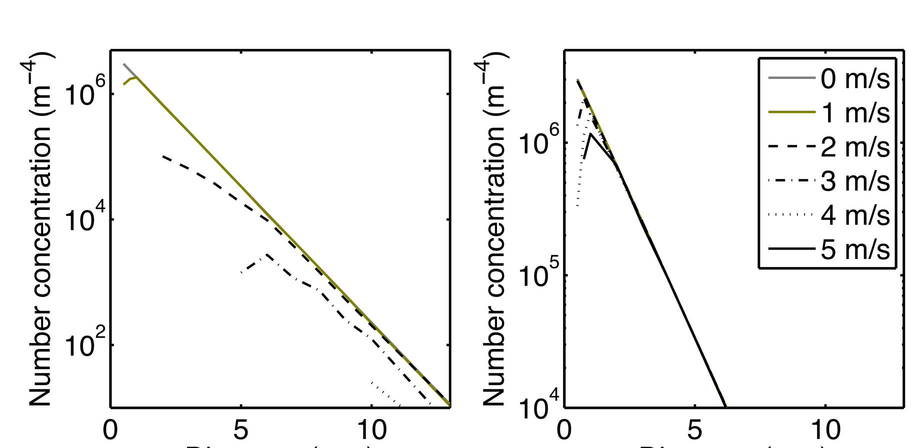
5. Theoretical Study

A. Shown below are the snowflake trajectories for different snowflake types (Diameter = 5 mm) assuming a 3 $m^{-1}s$ wind speed.



[Rasmussen et al. 1999]

B. Comparison of the size distribution of snowflakes falling inside the gauge for different wind speeds.

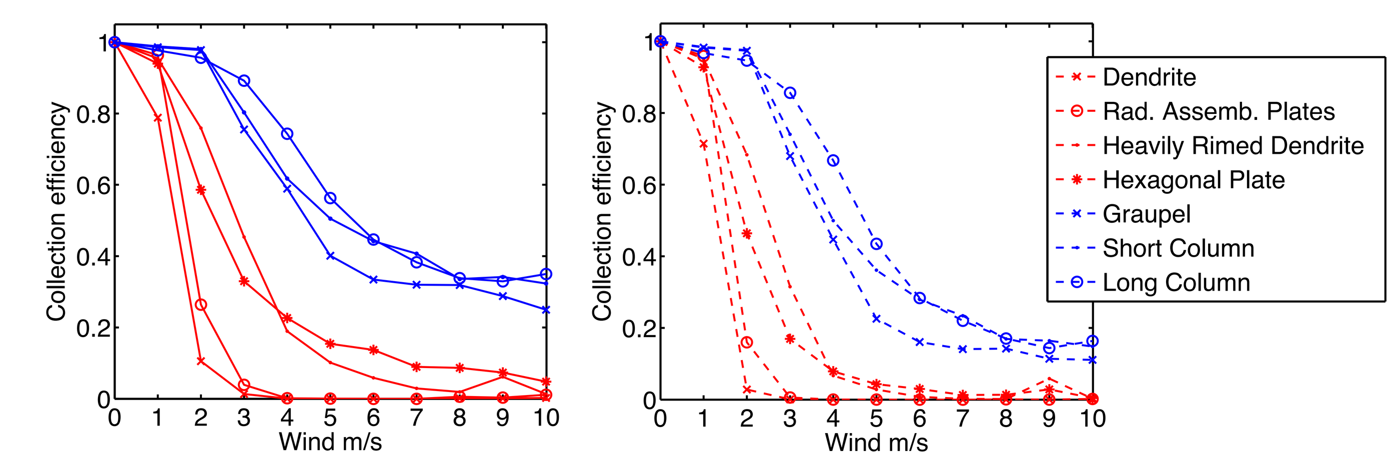


6. Collection Efficiency Comparison

A. The collection efficiency is

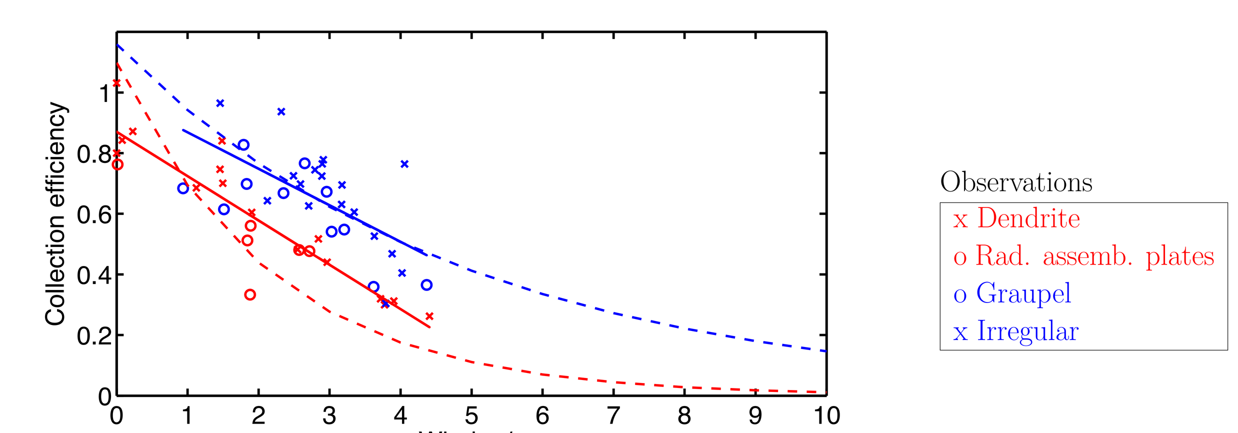
$$C(D) = \frac{\int A_{inside}(D) N_0 exp(-\lambda D) dD}{\int A_{gauge}(D) N_0 exp(-\lambda D) dD} \quad (1)$$

- D is the snowflake diameter
- $N_0 = 5 \times 10^6$ m^{-4} and $\lambda = 1$ mm^{-1} [Houze et al. 1979],
- A_{inside}(D) is the area associated with the number of snowflakes falling inside the gauge, and
- A_{gauge}(D) is the area of the gauge orifice.



B. Comparison with Observations

- Observations [markers] include all 4 storms. The solid lines are the best-fit for irregular and plate-like crystals.



- The theory for irregular and plate-like crystals are the dashed-lines.
- The collection efficiency was computed with different slope parameters: $\lambda_{irregular} = 1$ mm^{-1} and $\lambda_{plate-like} = 0.5$ mm^{-1}.

7. Concluding Remarks

- Size distributions inside and outside the gauge are similar but the size distribution of plate-like and irregular are different.
- The snowflake trajectory simulation suggests that plate-like crystals more closely follow the air flow around the gauge in comparison to the irregular crystals.
- The decrease in collection efficiency due to wind speed for plate-like crystals is less than for irregular crystals. The results suggest that it is because irregular crystals fall faster than plate-like crystals even if they have a smaller diameter.
- Future work will include linking the measured snowflake terminal velocity with the collection efficiency.

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