Photographing Snowflakes in Freefall at Alta

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Collaborations with
Sandra Yuter (NC State)
Ken Libbrecht: Snowcrystals.com
Edward LaChappelle, Alta, 1966

A young Ed LaChappelle checks the slopes with Gable, the first avalanche dog in the United States.

Diagram showing the relationship between magnitude and degree of riming, with initial instability and soft slab avalanche hazard indicated.
200 micron resolution silhouettes from two angles with fall speed

2D Video Distrometer from Joanneum Research in Austria
Multi Angle Snowflake Camera (MASC) at Alta Ski Area
Up to 10 micron resolution photographs of snowflakes in freefall with fallspeed
0.97 m/s fall speed
Crystals
Snow
Graupel
Vertically pointing radar at Alta
Multi-Angle Snowflake Camera (MASC) at Greenland Summit
Last weekends storm, local time

- Fall speed \( \text{m/s} \)
- Size (mm)
- Complexity of shape
- Aspect ratio
From Jim Steenburgh’s Wasatch Weather Weenies
~ 7:12 am
11/9 12 UTC
-0.5° @ 700 mb

Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
~ 7:12 am
11/9 12 UTC
-0.5° @ 700 mb

Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
~ 2:12 am
11/10 12 UTC
-11.5° @ 700 mb

- Fall speed m/s
- Size (mm)
- Complexity of shape
- Aspect ratio
~ 2:12 am
11/10 12 UTC
-11.5° @ 700 mb

- Fall speed m/s
- Size (mm)
- Complexity of shape
- Aspect ratio
Fall speed m/s

Size (mm)

Complexity of shape

Aspect ratio

~ 12:00 pm
11/11 00 UTC
-13.5° @ 700 mb
~ 12:00 pm
11/11 00 UTC
-13.5° @ 700 mb

Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
- 7:26 am MST
- 11/11 12 UTC
- -15.9° @ 700 mb

Fall speed m/s
Size (mm)

Complexity of shape
Aspect ratio
~ 11:24 am
11/12 00 UTC
-16.7° @ 700 mb

Fall speed m/s
Size (mm)
Complexity of shape
Aspect ratio
Fall speed m/s

Size (mm)
Flakes originate from liquid clouds
Wegener-Bergeron-Findeison Process
Common Crystal Habits and Formation Conditions

Excess vapor pressure over ice at water saturation

Temperature (°C)

Excess vapor pressure over ice (hPa)
The Growth of Atmospheric Ice Crystals: A Summary of Findings in Vertical Supercooled Cloud Tunnel Studies

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Fig. 8. Illustration of three growth stages of an isometric crystal.
Ingredients for riming

• A crystal falls
• It collects droplets
• It’s cross-section grows and it gets heavier
• It falls faster with a larger cross-section
• Therefore a chain-reaction for growth
• The key limitations are too few droplets or too shallow a storm
The extent of rimeing is related to the concentration of liquid.
Graupel can grow larger in deep juicy storms with stronger convection.

Fig. 16. Variation of crystal fall velocity with time at −10.5°C with a liquid water content of 2 g m⁻³. The dashed line shows the case with a liquid water content of less than 0.5 g m⁻³ (Takahashi and Fukuta 1988b).
Fig. 21. Relationship between mass and fall distance for diffusional ice crystal growth and riming of graupel/hail.
In the end, prediction is hard...

- Jim Steenburgh: “Graupel is more common in warm storms (more cloud water) and storms with convection *or* intense orographic ascent”
But are things actually much more simple?

Very weak dependence of fallspeed on size
No dependence of fallspeed on shape
Spinning Graupel?
Thank you