Hail Suppression Conceptual Models

Calgary, August 2, 2018
Courtesy of Darren Howard and Dan Gilbert

July 8, 2013 - Courtesy of NWS Gaylord.

Vivian Hail Stone (Largest in the World)

- Diameter:
  - 8 inches (20.32 cm)
- Weight:
  - 1.94 pounds (0.88 kg)
- Location:
  - Vivian, South Dakota
- Habitat:
  - July 23, 2010

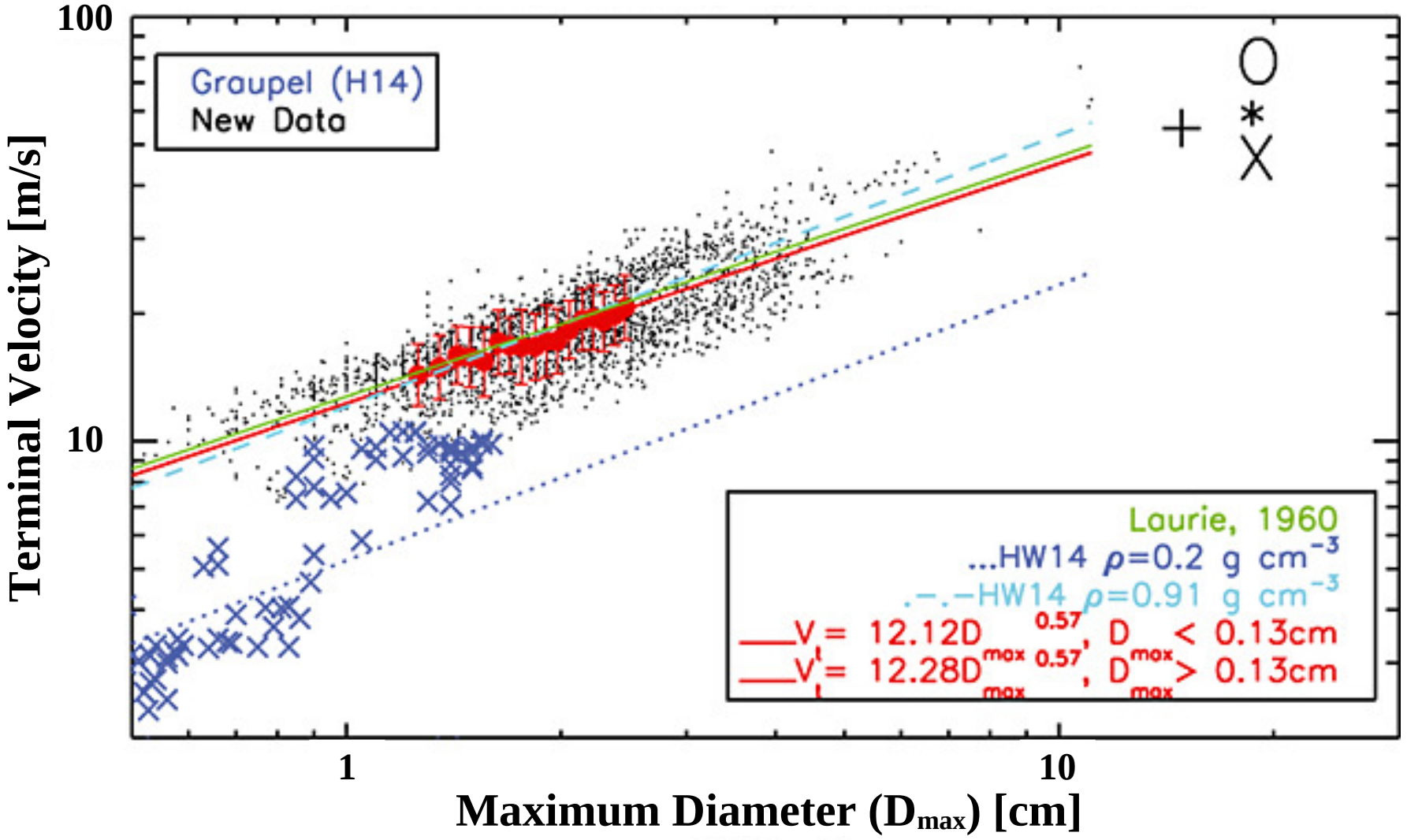
Source: https://largest.org/nature/hailstones/

Hail Formation Processes

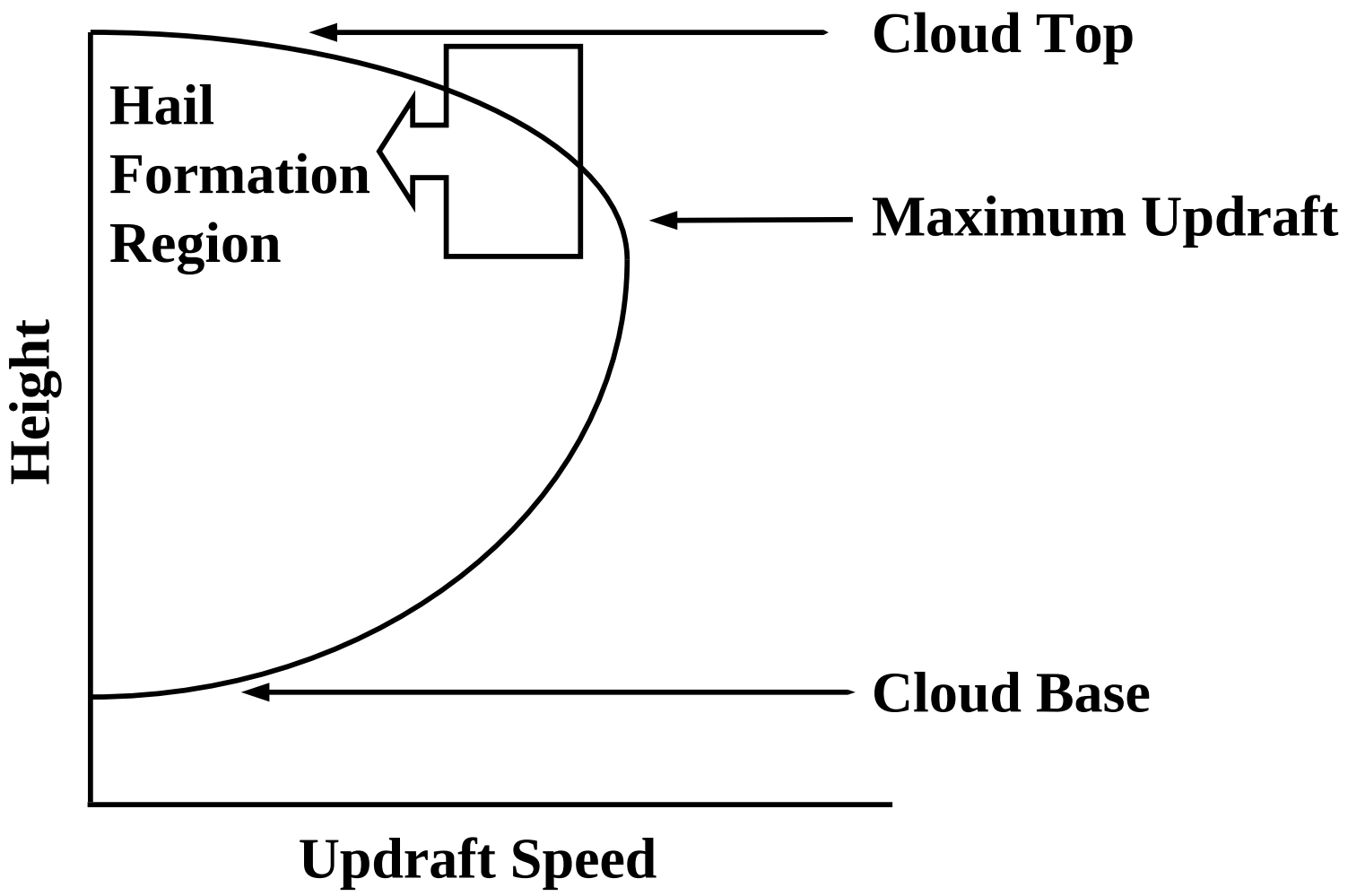
- Formed by riming an ice crystal over an extended time period.
- Hail particle needs to remain in cloud to continue to accumulate supercooled liquid water.
- Hail particle must remain in substantial updraft in order to remain in cloud for the necessary time for growth.

Soft rime form white ice deposition from droplets.
http://atmosgallery.atmos.und.edu/TreeIcing_120203

Hail Stone Terminal Velocity (1000 hPa)

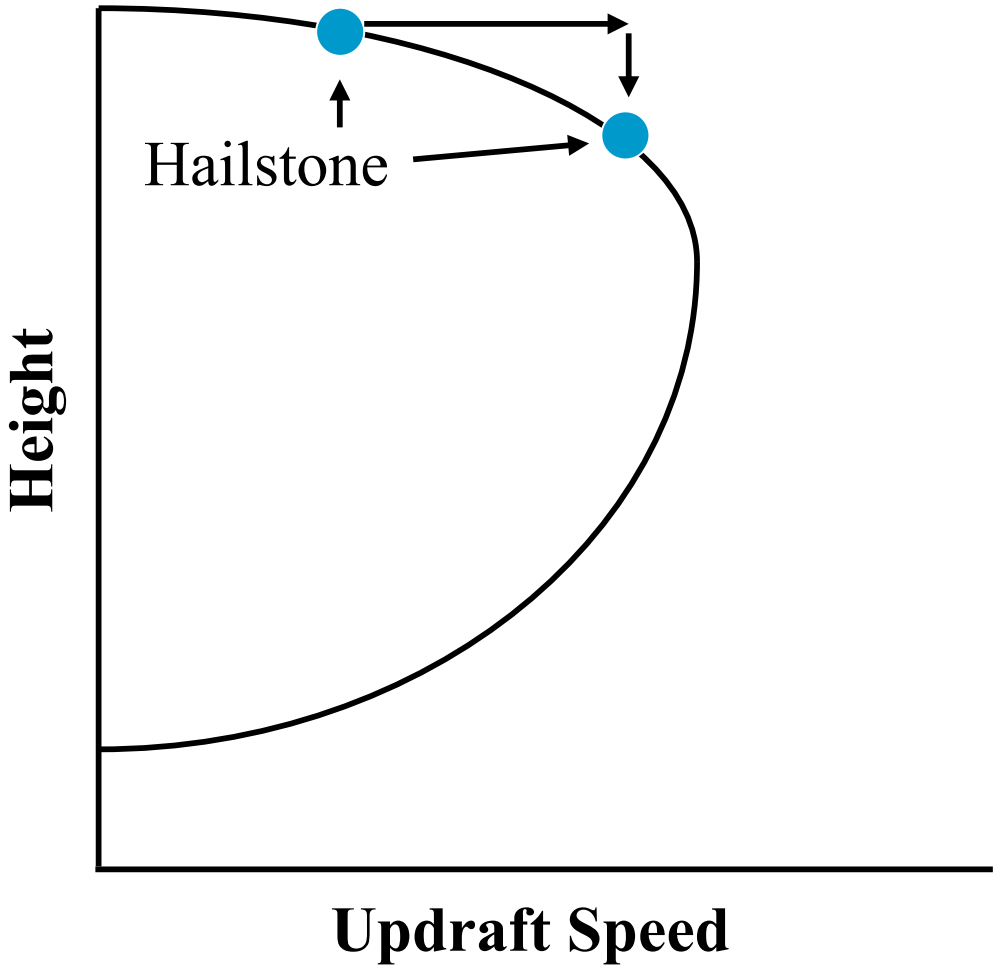


Structure of Updraft in a Convective Cloud



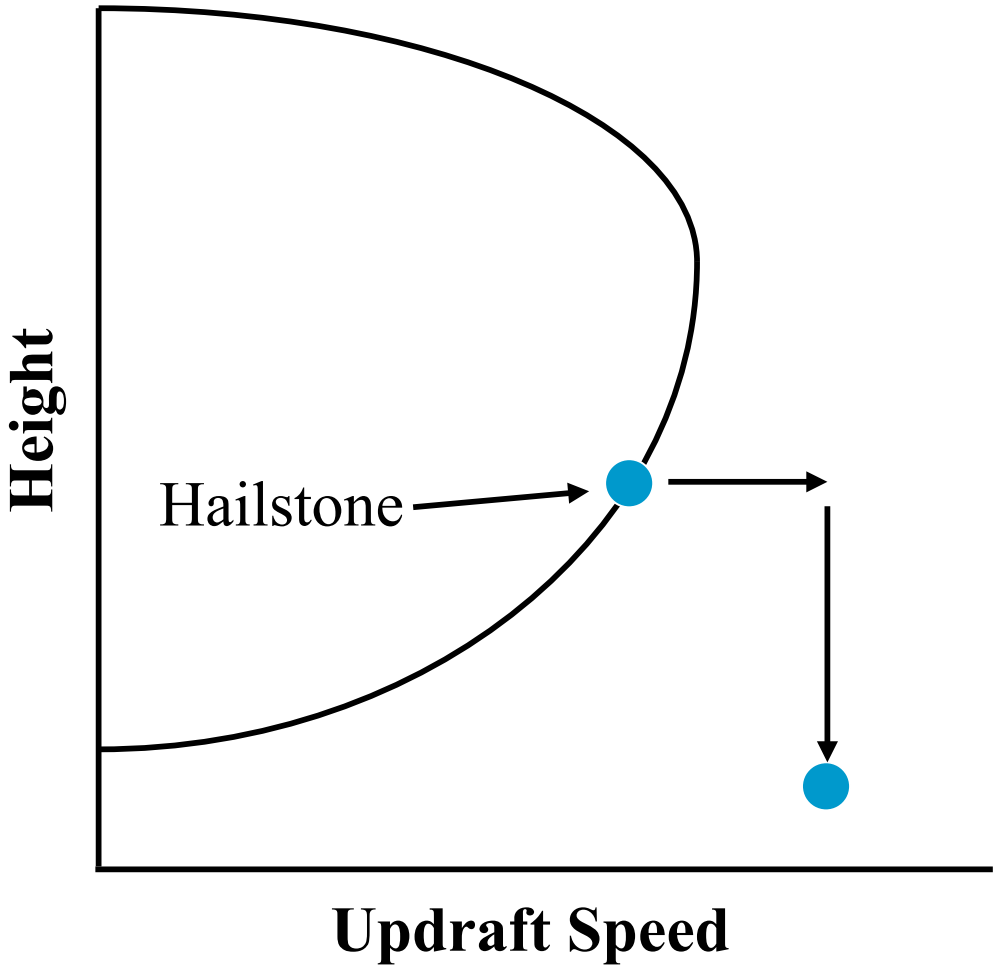
Hail Formation

As hailstone grows, it falls to a region of higher updraft speed, where it remains in balance with its terminal velocity.



Unsuccessful Hail Formation

Growing hailstone cannot remain suspended in cloud below the point of maximum updraft.



Hail Formation Requires

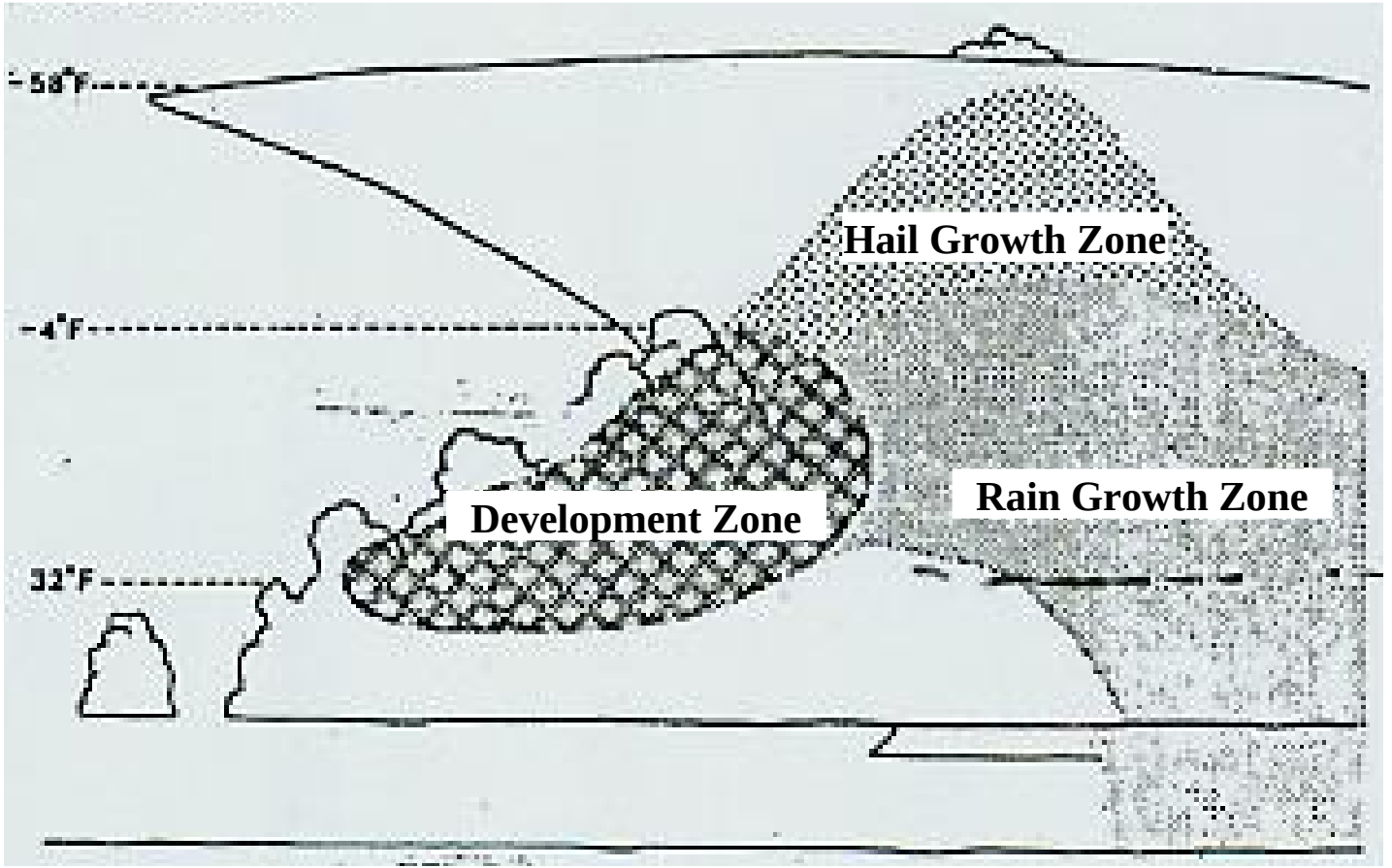
- Large updrafts.
- Supercooled liquid water in upper parts of storm.
- Very few ice particles in upper parts of storm.

Aurora, Nebraska
7 inches
1.33 pounds

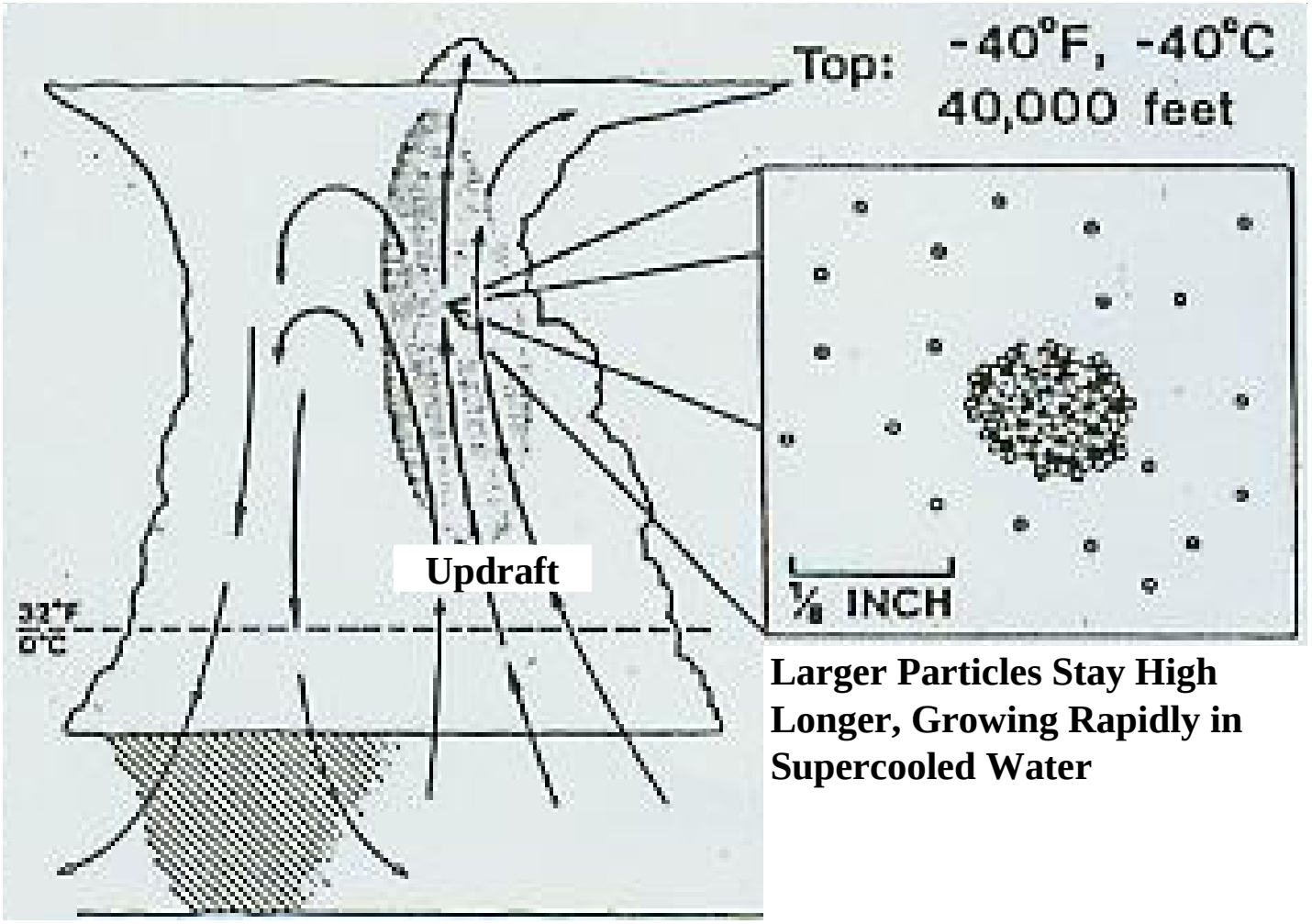
Source: https://largest.org/nature/hailstones/

Hail Formation

Precipitation Development Zones

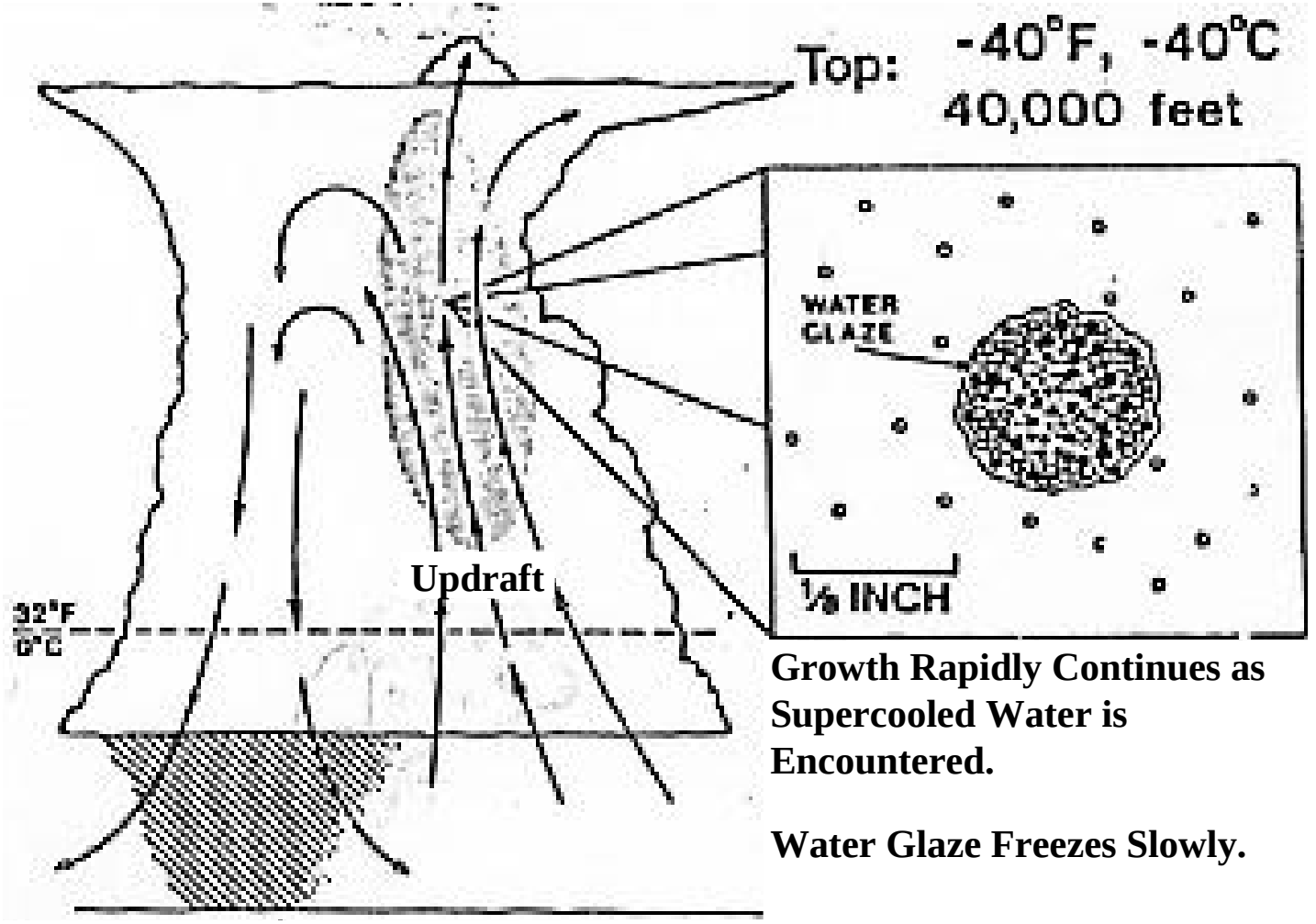


Thunderstorm – Strong Updraft



Larger Particles Stay High Longer, Growing Rapidly in Supercooled Water

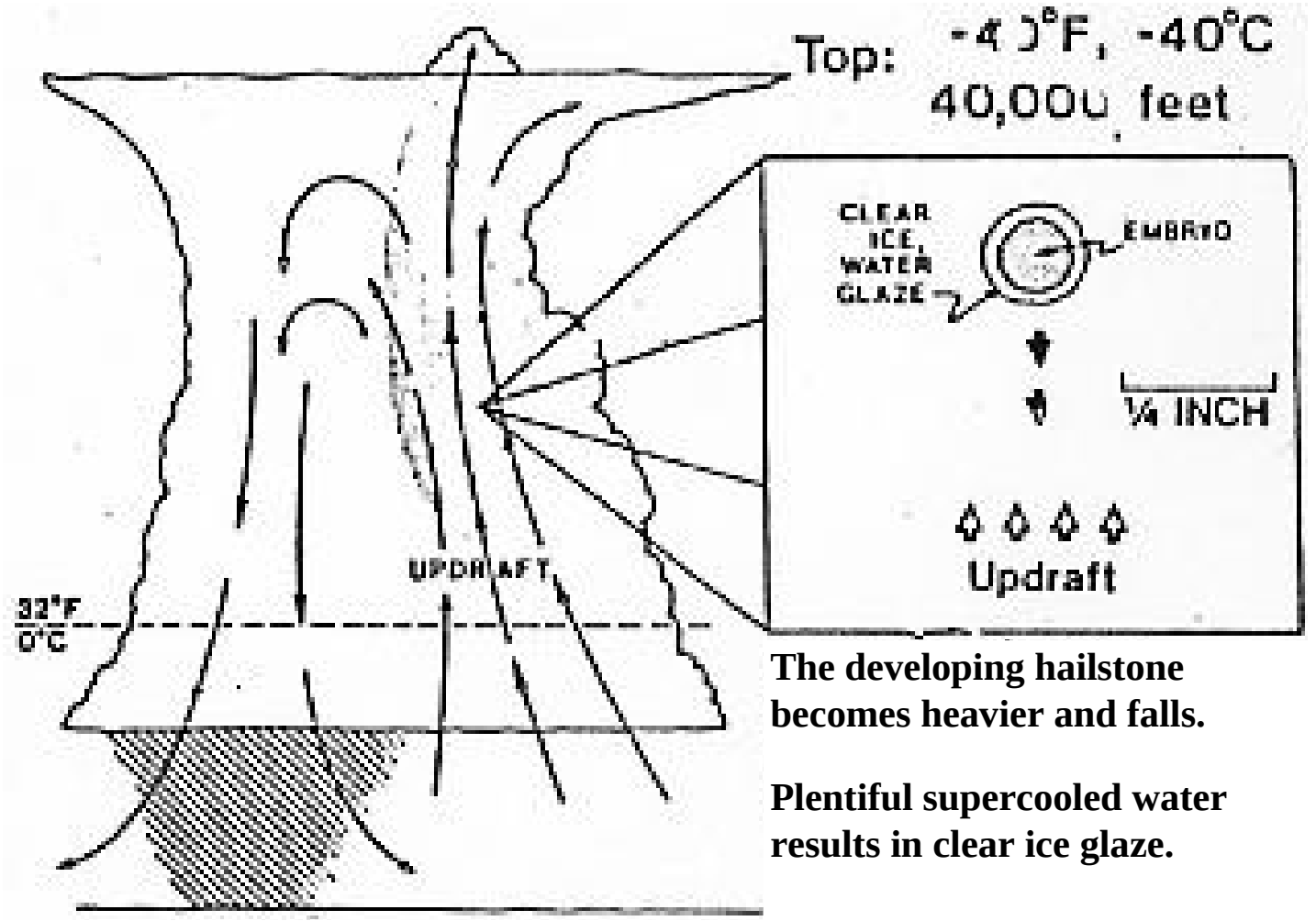
Hail Embryo



Growth Rapidly Continues as Supercooled Water is Encountered.

Water Glaze Freezes Slowly.

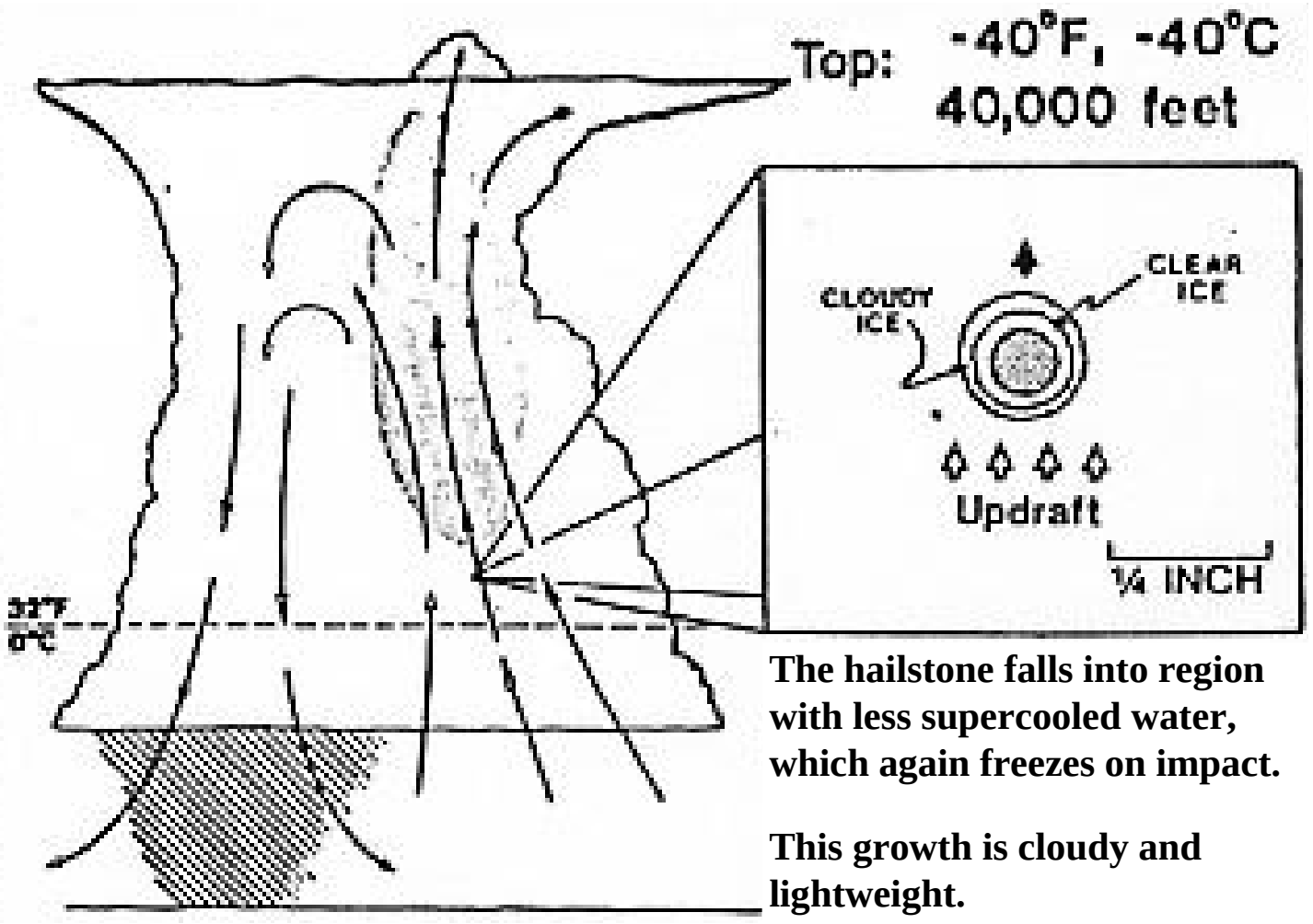
Wet Growth



The developing hailstone becomes heavier and falls.

Plentiful supercooled water results in clear ice glaze.

Dry Growth

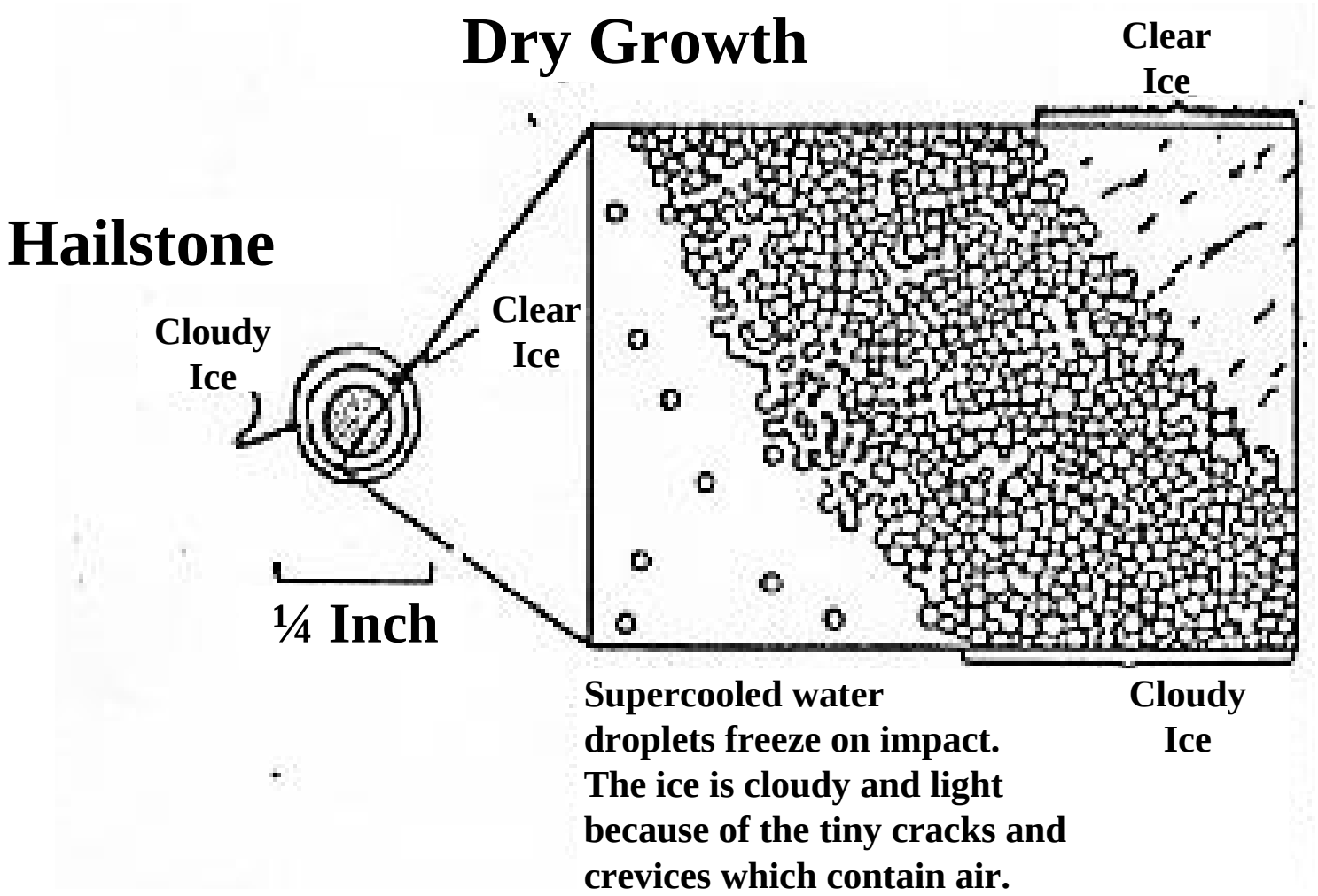


The hailstone falls into region with less supercooled water, which again freezes on impact.

This growth is cloudy and lightweight.

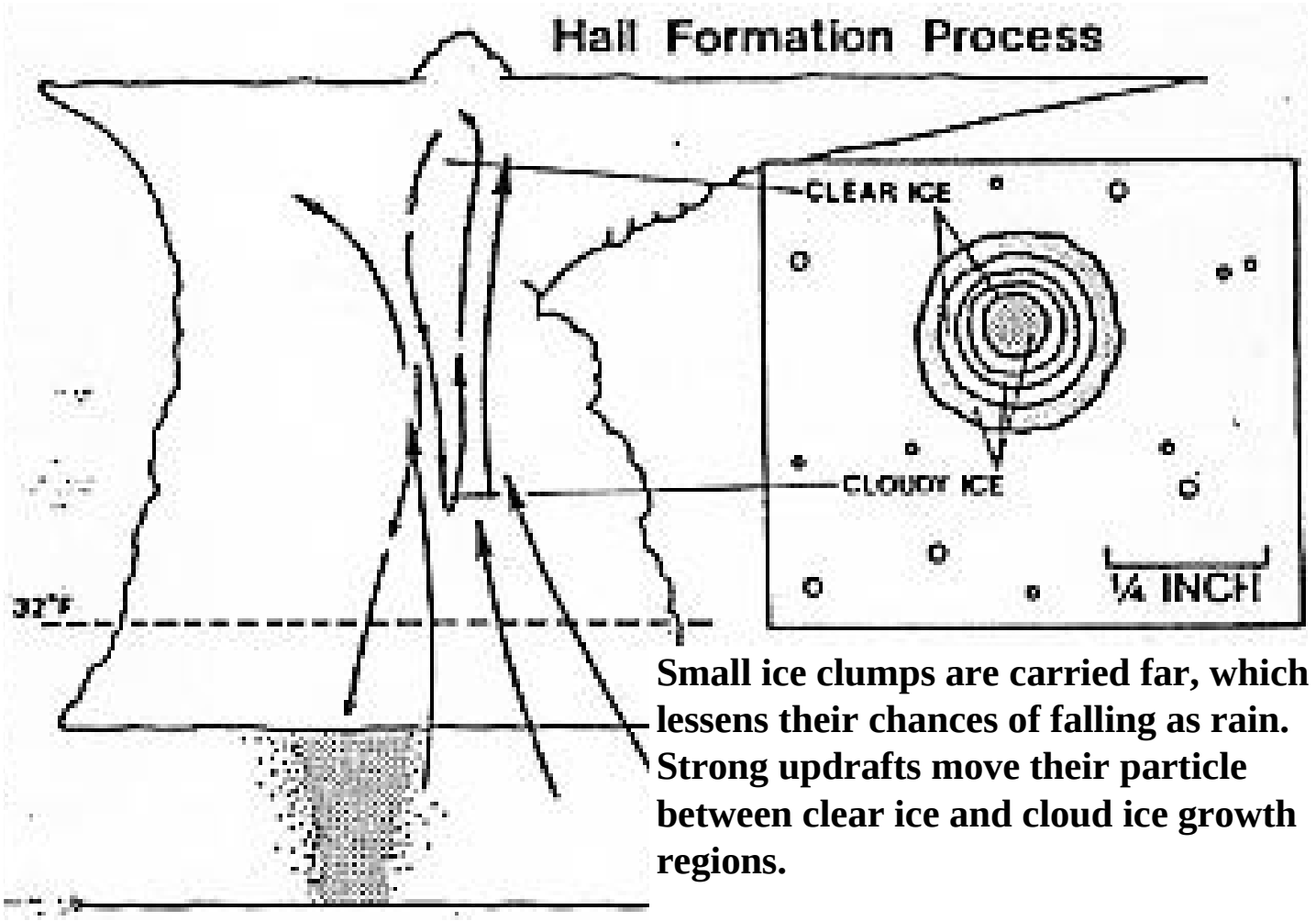
Hailstone Growth Types

Dry Growth



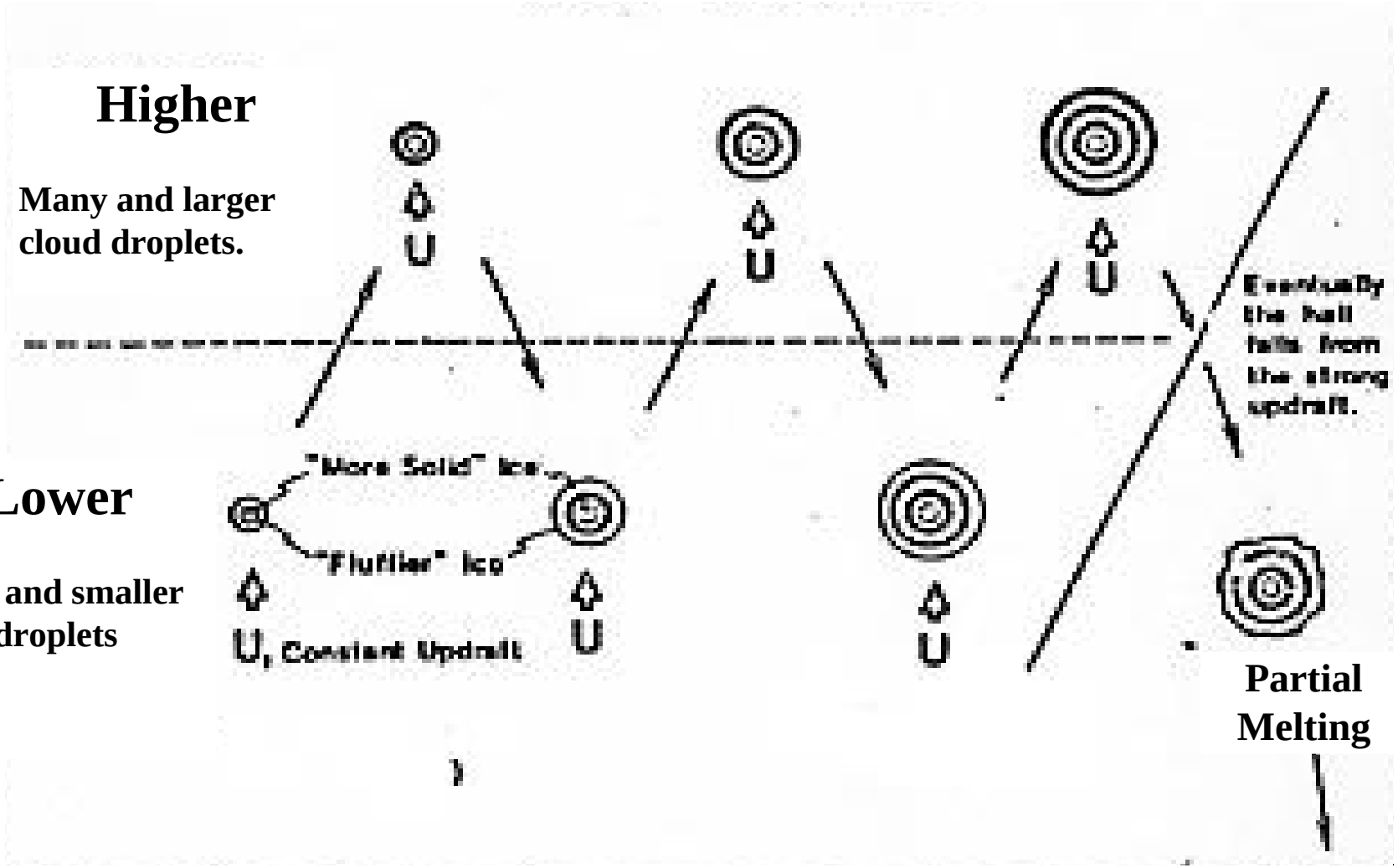
Supercooled water droplets freeze on impact. The ice is cloudy and light because of the tiny cracks and crevices which contain air.

Growth Type Regions

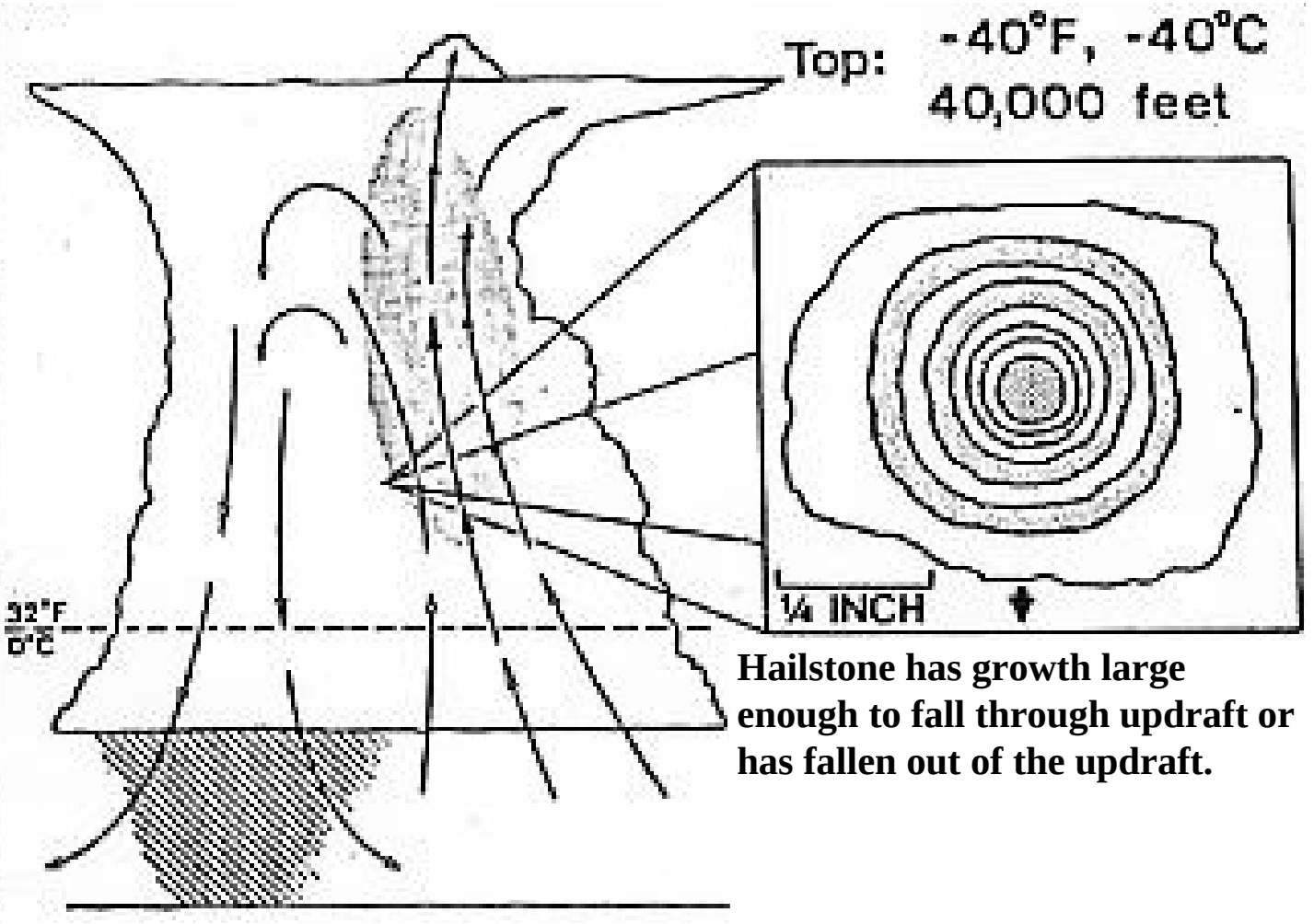


Small ice clumps are carried far, which lessens their chances of falling as rain. Strong updrafts move their particle between clear ice and cloud ice growth regions.

Hail Growth within a Cloud

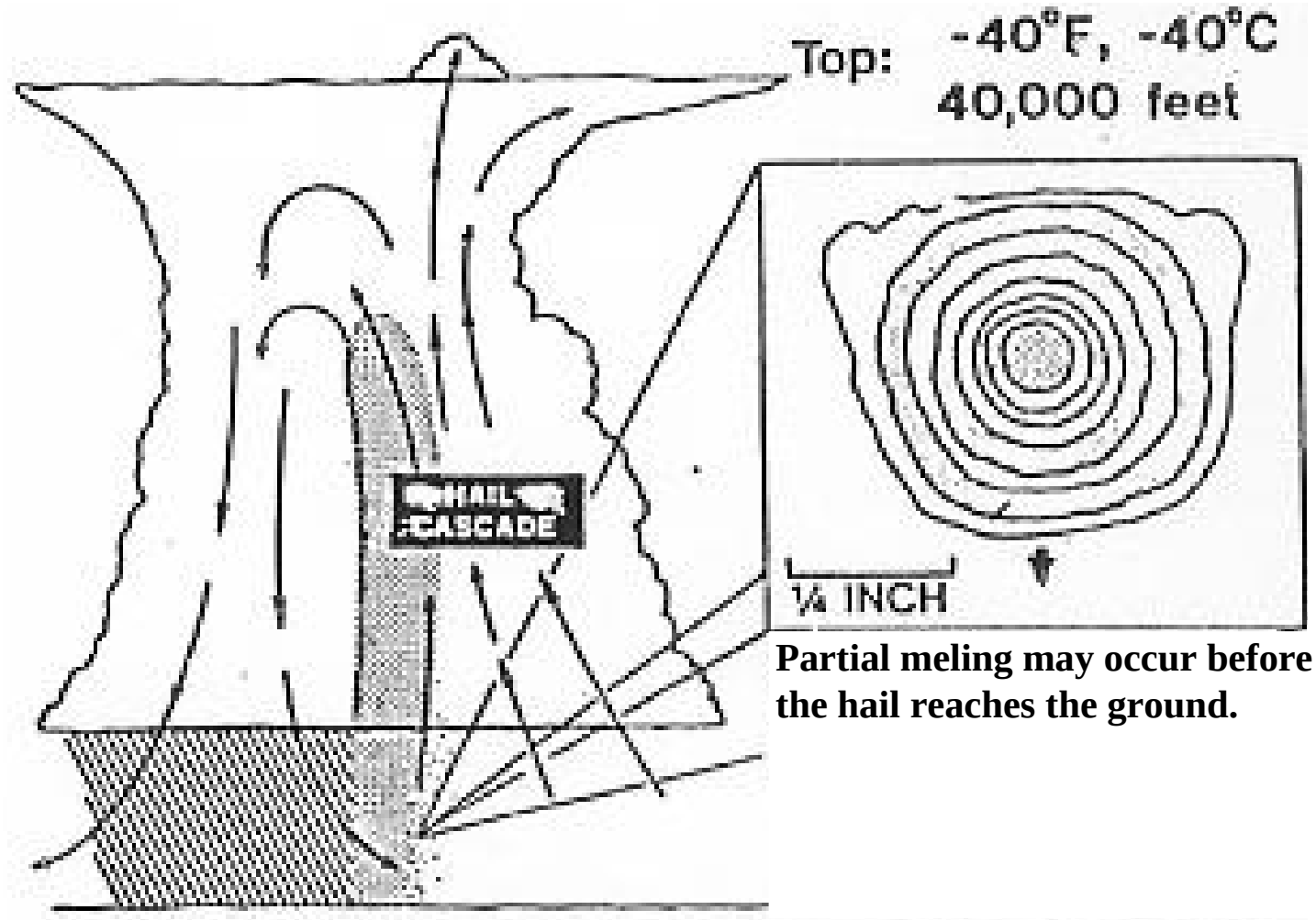


Final Descent



Hailstone has growth large enough to fall through updraft or has fallen out of the updraft.

Melting



Partial meling may occur before the hail reaches the ground.

Hail Suppression

- Not much attention paid to hail suppression until 1960s.
- Russians claimed great success with a hail suppression program.
- This started the National Hail Research Experiment (NHRE) in the US.

Coffeyvlle, Kansas: 5.7 inches, 1.67 pounds

Source: https://largest.org/nature/hailstones/

Soviet Hail Suppression Program

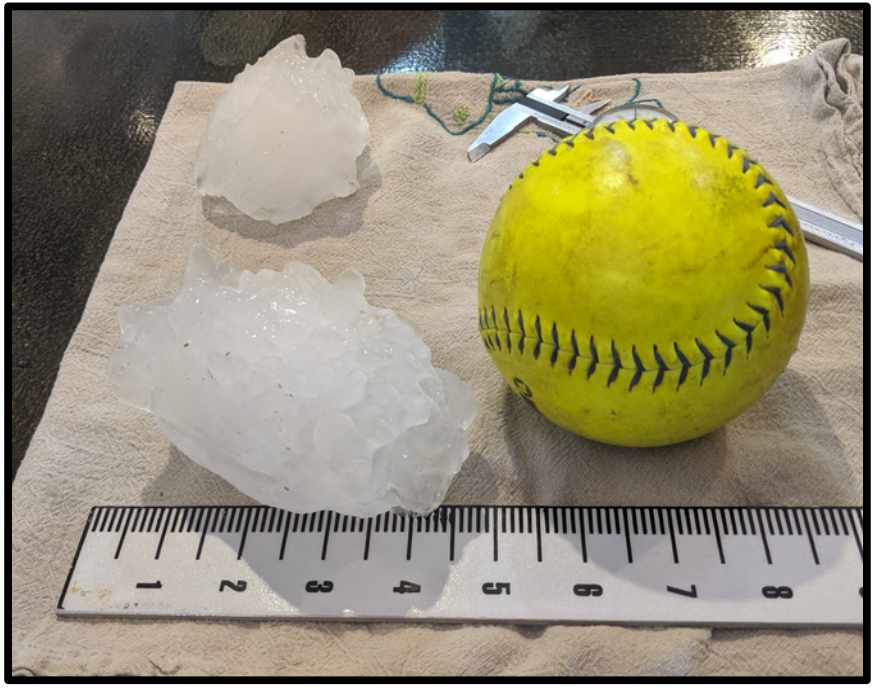
- Utilized artillery shells targeted by weather radar.
- Many questions regarding how the operations were carried out and the statistics that were reported.

Southwest Germany: 5.5 inches, 0.79 pounds

Source: https://largest.org/nature/hailstones/

National Hail Research Experiment (NHRE)

- Attempt to replicate the Soviet results.
- A number of things were different, including the seeding material used and the manner in which the seeding material was dispensed.
- Was a dismal failure, as far as getting the same results as were reported by the USSR.



Colorado 4.83 inches, 0.53 pounds

https://www.weather.gov/gld/8132019CORecordHailstone

Hail Suppression Conceptual Models

- Why does hail cause damage?
- What might be done to reduce hailstorm damage?

Conceptual Models for Hail Suppression

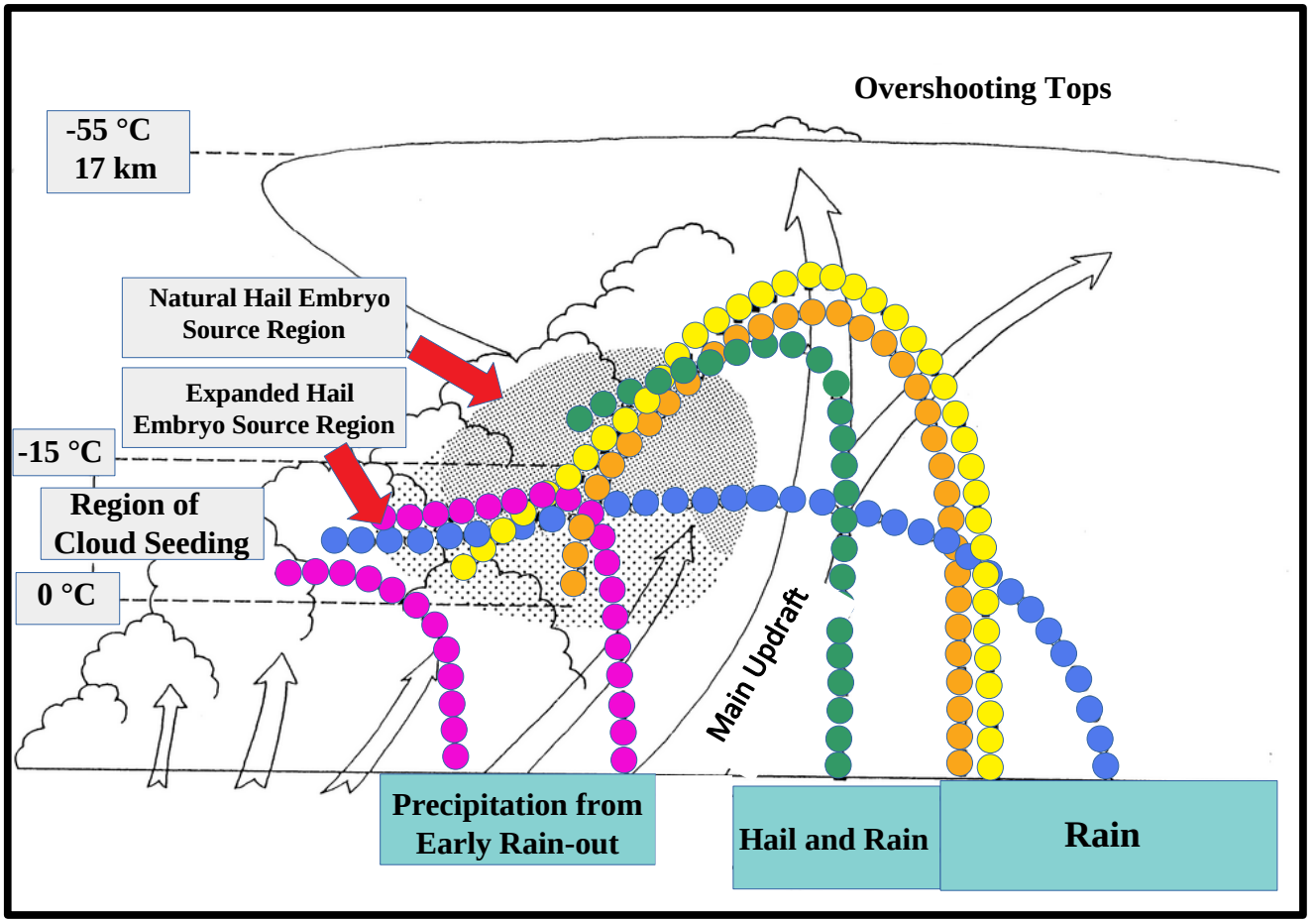
- Complete Glaciation of Cloud Water
- Competing Embryos.
- Trajectory Lowering.
- Promotion of Coalescence.
- Dynamic Effects.

Complete Glaciation of Liquid Water?

- Attempt to deplete all liquid water so that riming cannot occur.
- Elimination of all supercooled liquid is virtually impossible.
- This is especially true of very large storms (supercells).

Summary of Hail Suppression Model Types

- Natural Hail Trajectory
- Early Rain-out
- Beneficial Competition
- Trajectory Lowering
- Promotion of Coalescence



Courtesy of Bruce Boe, Weather Modification International

Beneficial Competition (Competing Embryos)

- Attempt to create more hail particles, but smaller ones (the ice is split up into more, smaller packages).
- Hailstones travel to a greater height.
- This is also difficult to do with super-cells.

A Super-cell Thunderstorm in Kansas

Trajectory Lowering

- Attempt to get growth started lower in the cloud, below the point of maximum updraft.
- As hailstone starts to grow, it cannot be supported by the updraft and will fall out while it is relatively small.

Promotion of Coalescence

- Attempt to get raindrops falling out of the cloud at low elevations in the cloud, depleting the liquid water in the upper portions of the cloud.

Low-precipitation Super-cell Storm
Photograph by Roger HIll

Dynamic Effects

- This is a different type of dynamic seeding than was discussed in the case of precipitation augmentation.
- One approach is to weaken the updraft earlier in its life cycle.
- Another approach is to encourage growth in regions that will cut off moisture supply.

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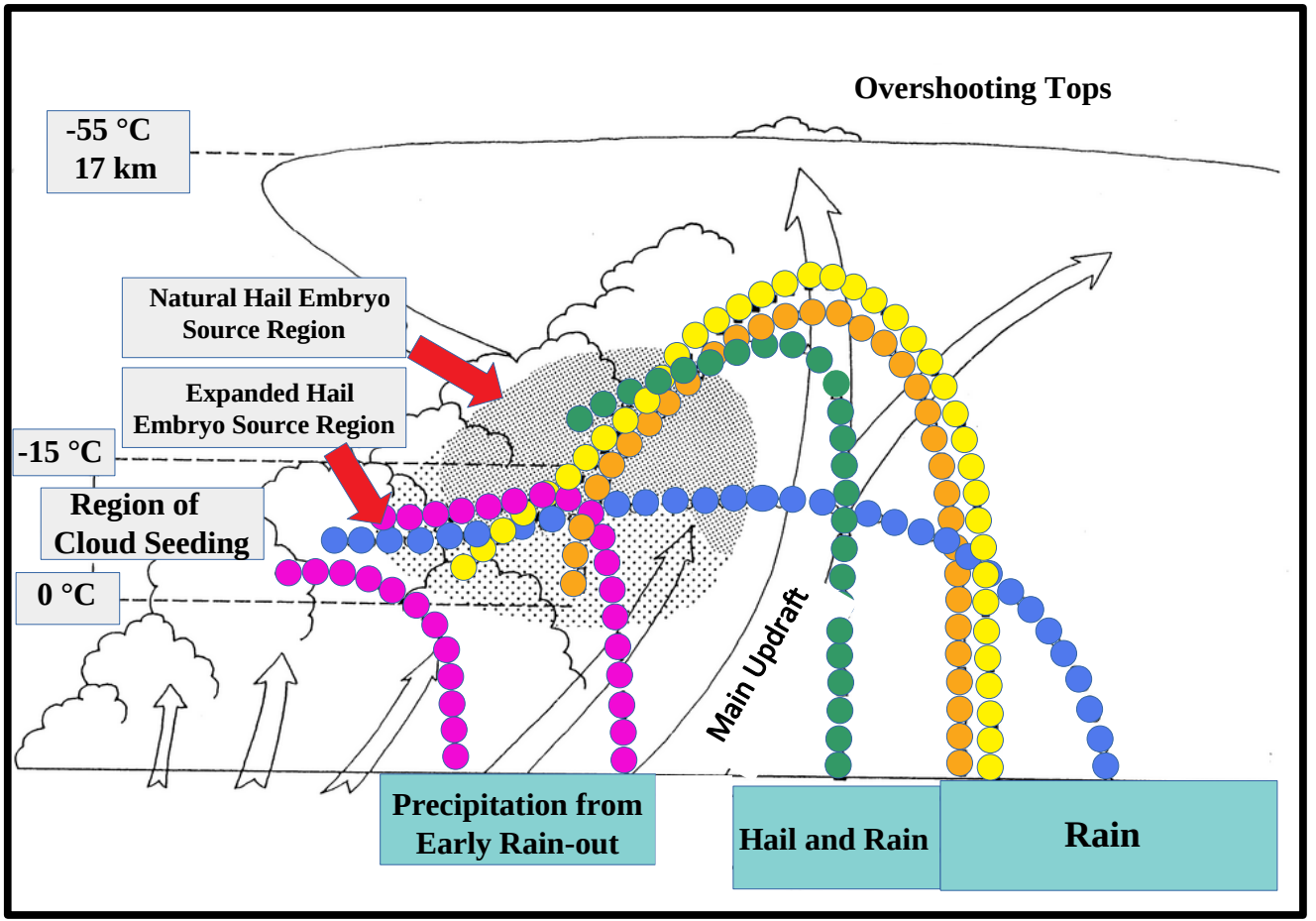

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