

# 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/>



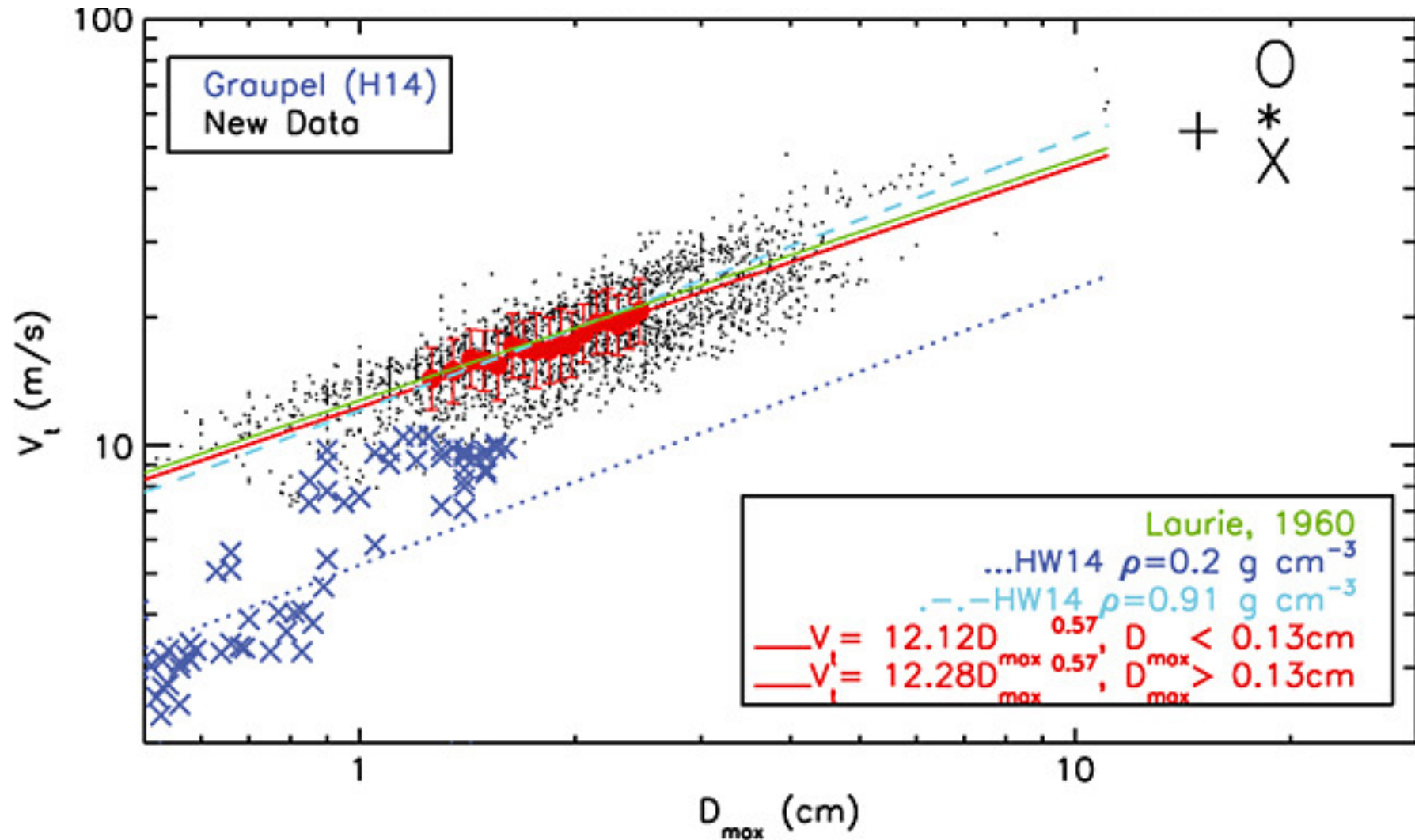
# Hail Formation

- 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.



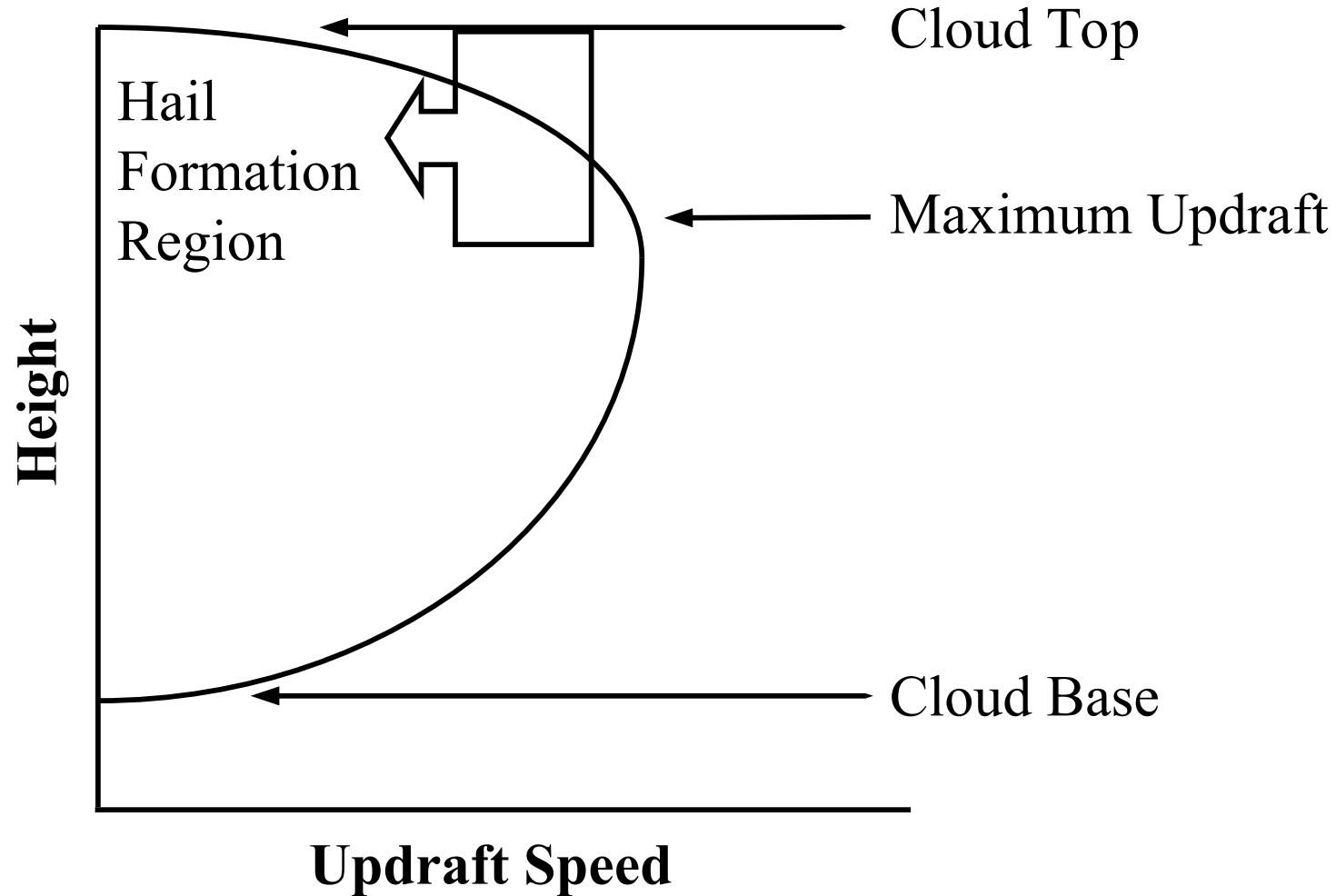
Soft rime form white ice deposition from droplets.  
[http://atmosgallery.atmos.und.edu/Treelcing\\_120203](http://atmosgallery.atmos.und.edu/Treelcing_120203)

# Hail Stone Terminal Velocity (1000 hPa)



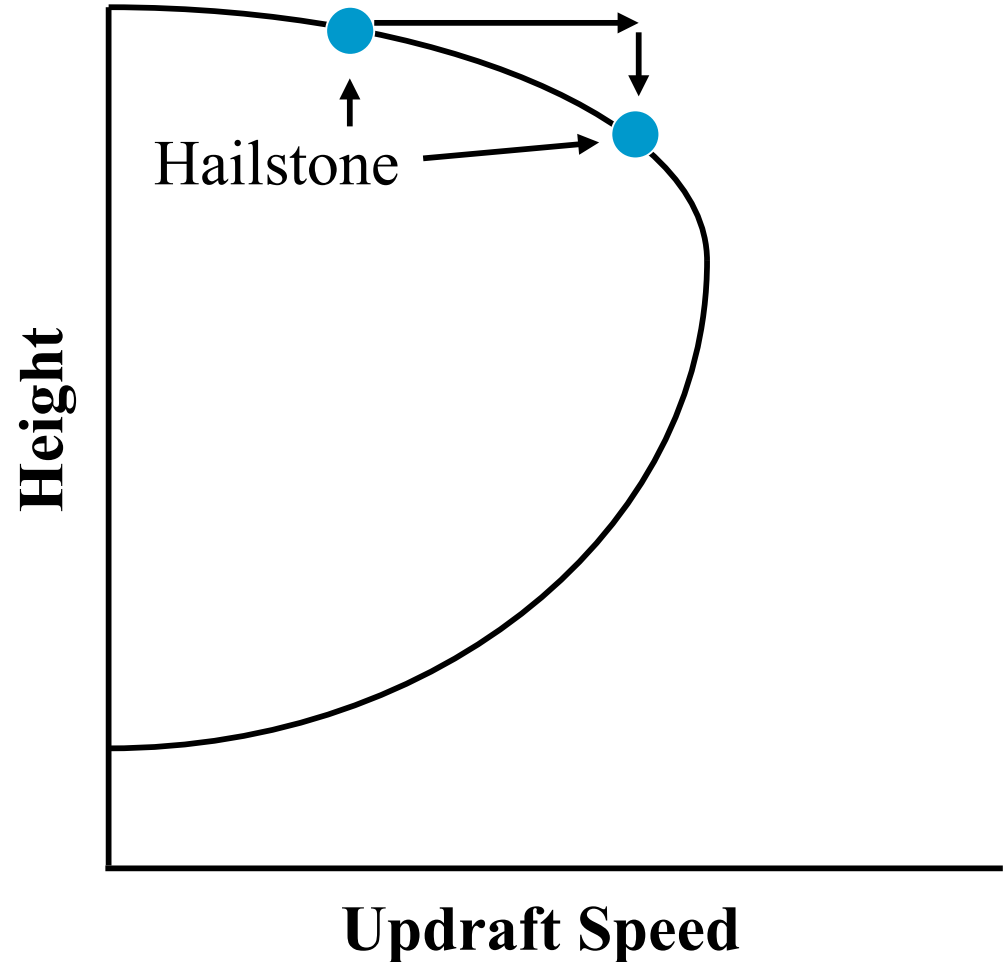


# Structure of Updraft in a Convective Cloud



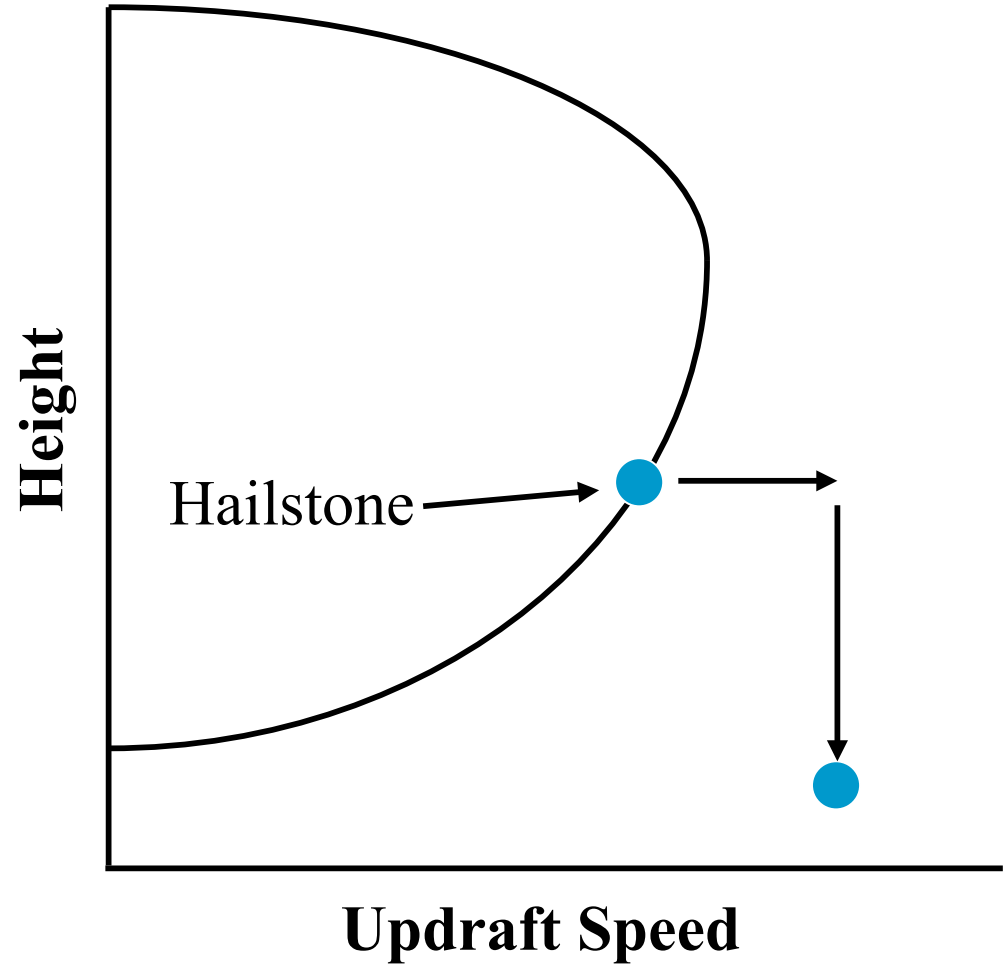
# Hail Formation

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.

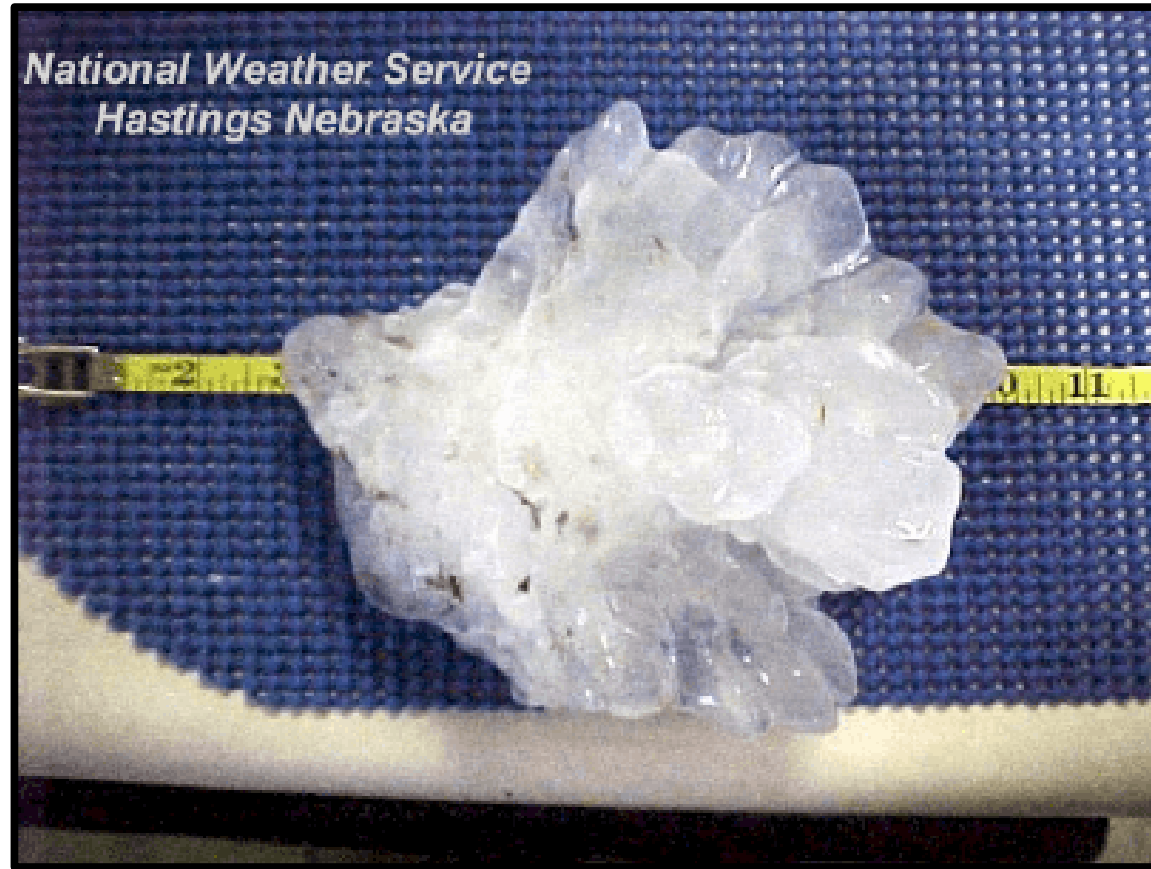




# Hail Formation Requires

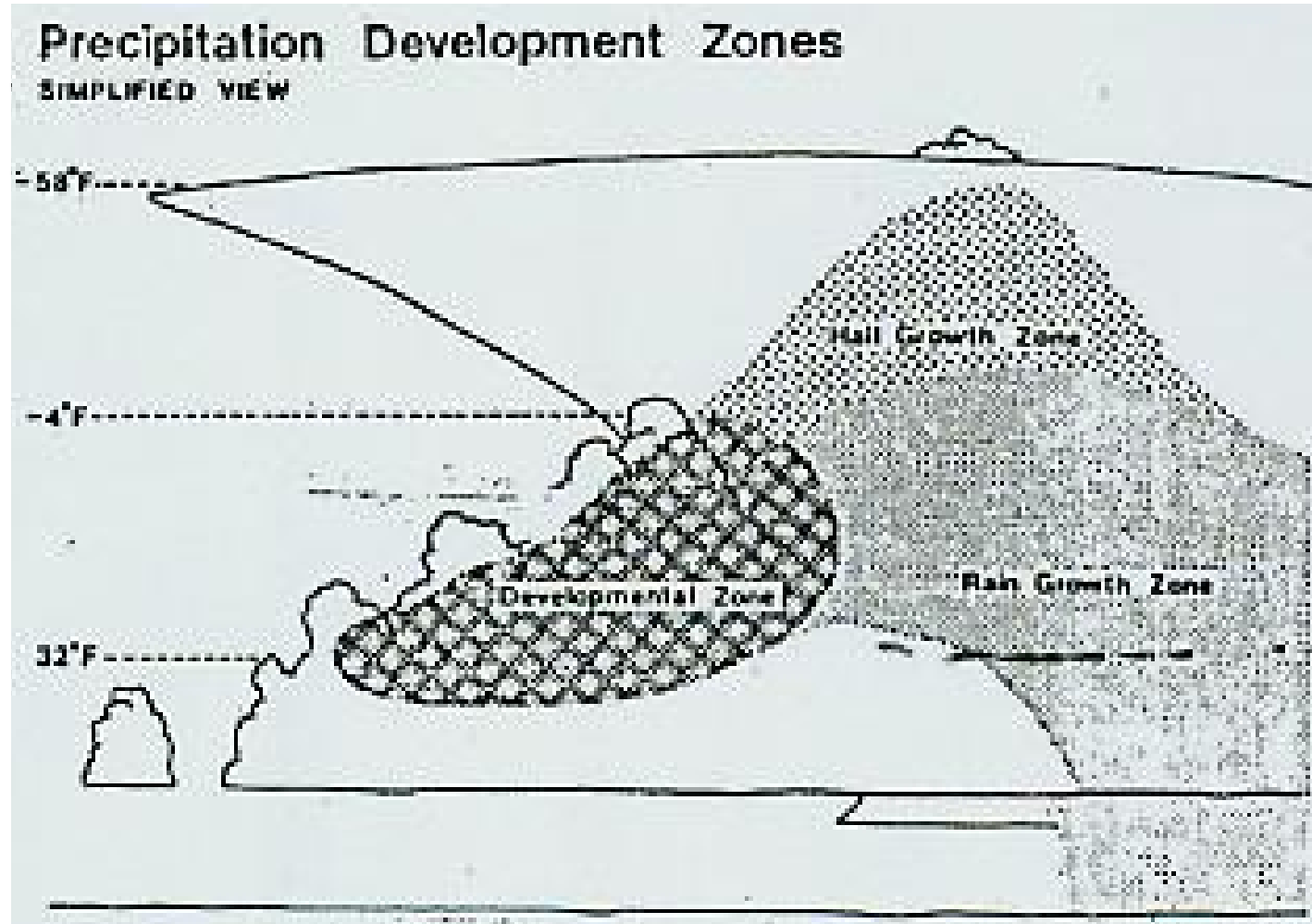
- Large updrafts.
- Supercooled liquid water in upper parts of storm.
- Very few ice particles in upper parts of storm.

Aurora, Nebraska  
7 inches  
1.33 pounds

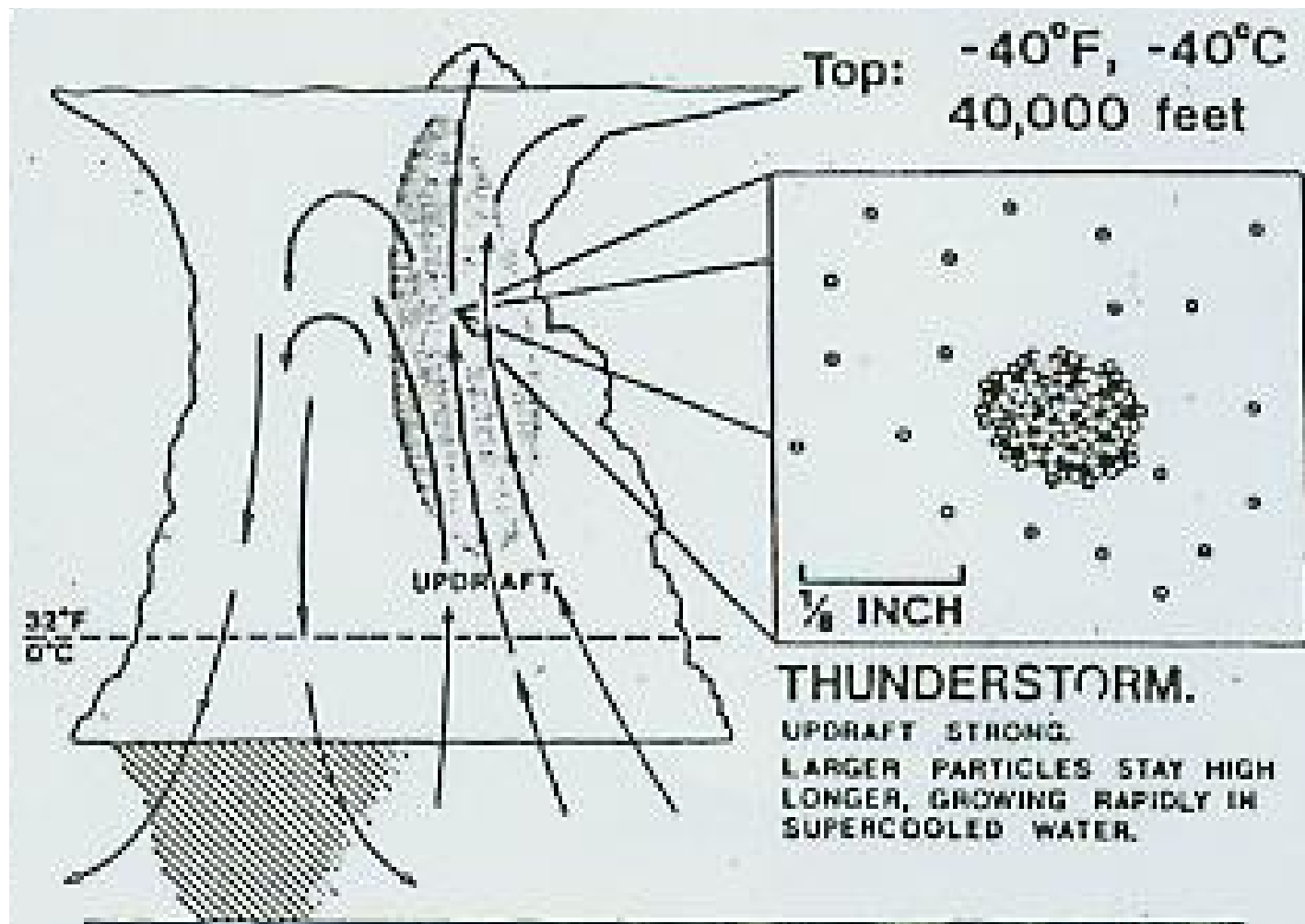


Source: <https://largest.org/nature/hailstones/>

# Hail Formation

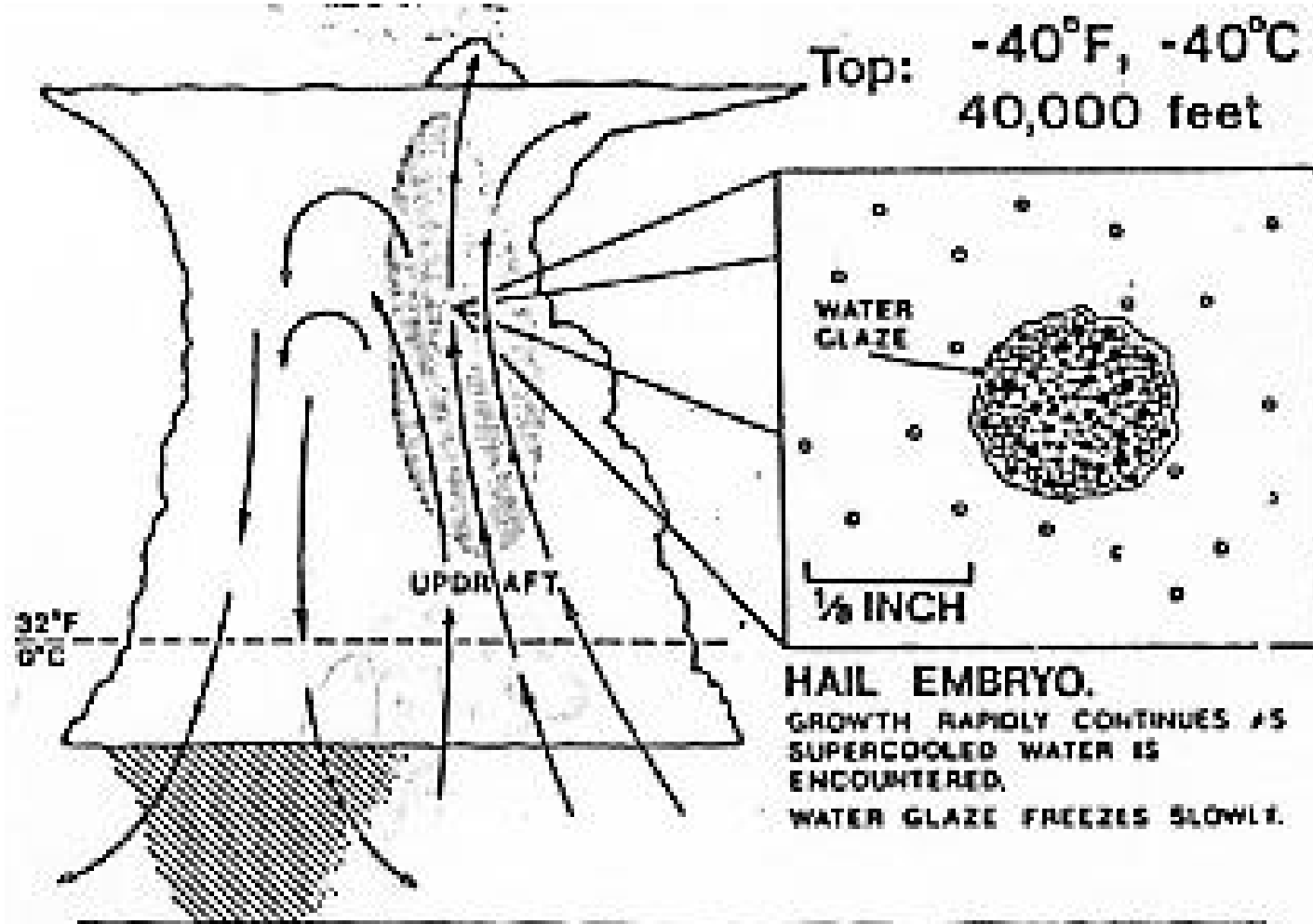


# Hail Formation

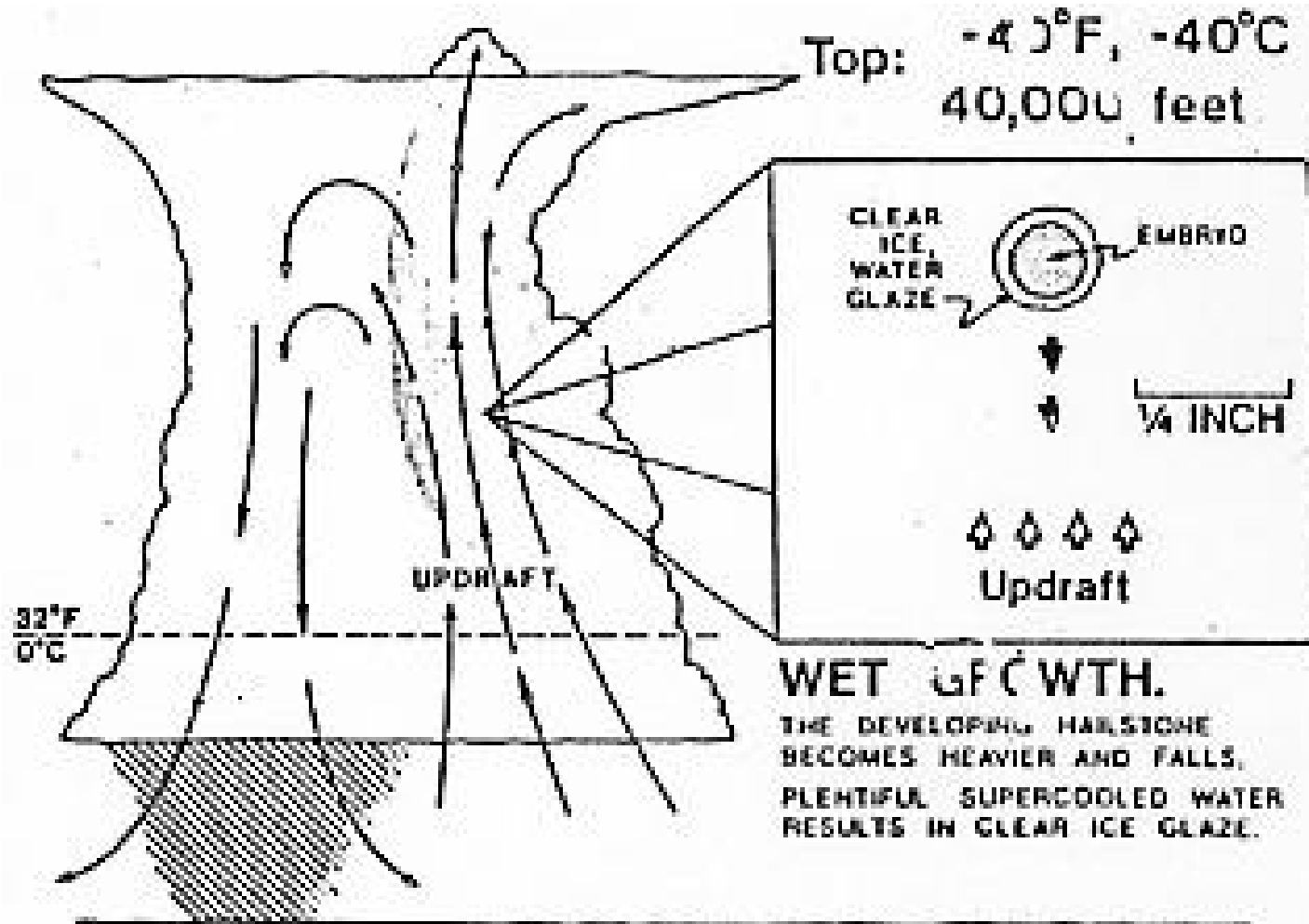




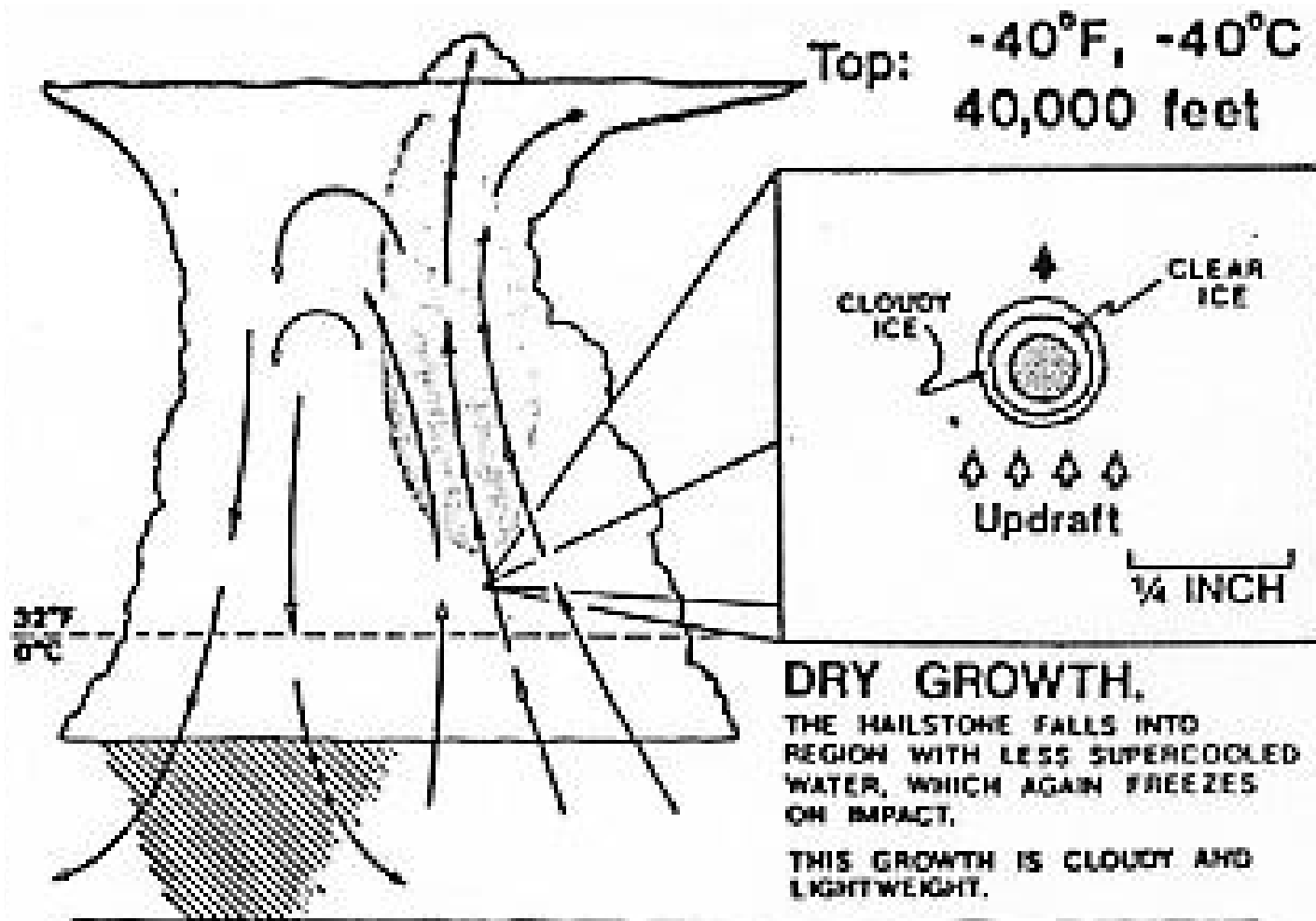
# Hail Formation



# Hail Formation



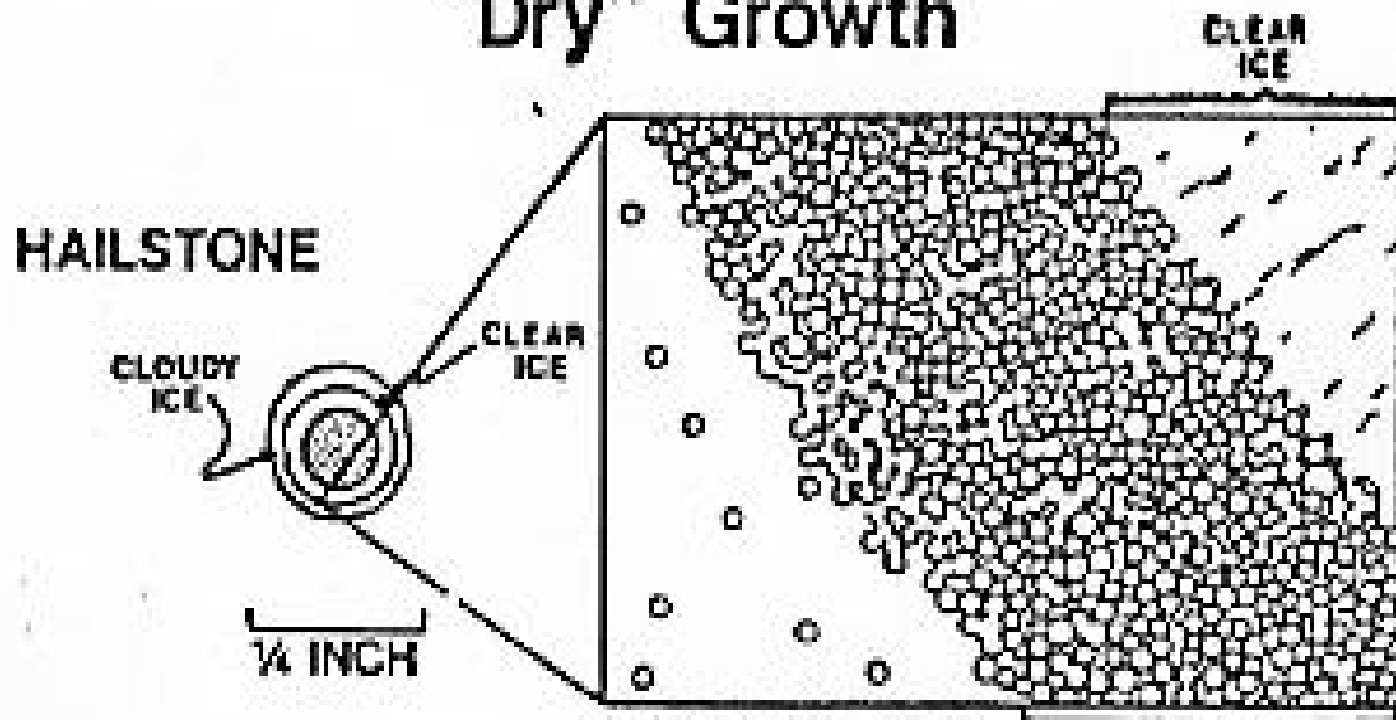
# Hail Formation





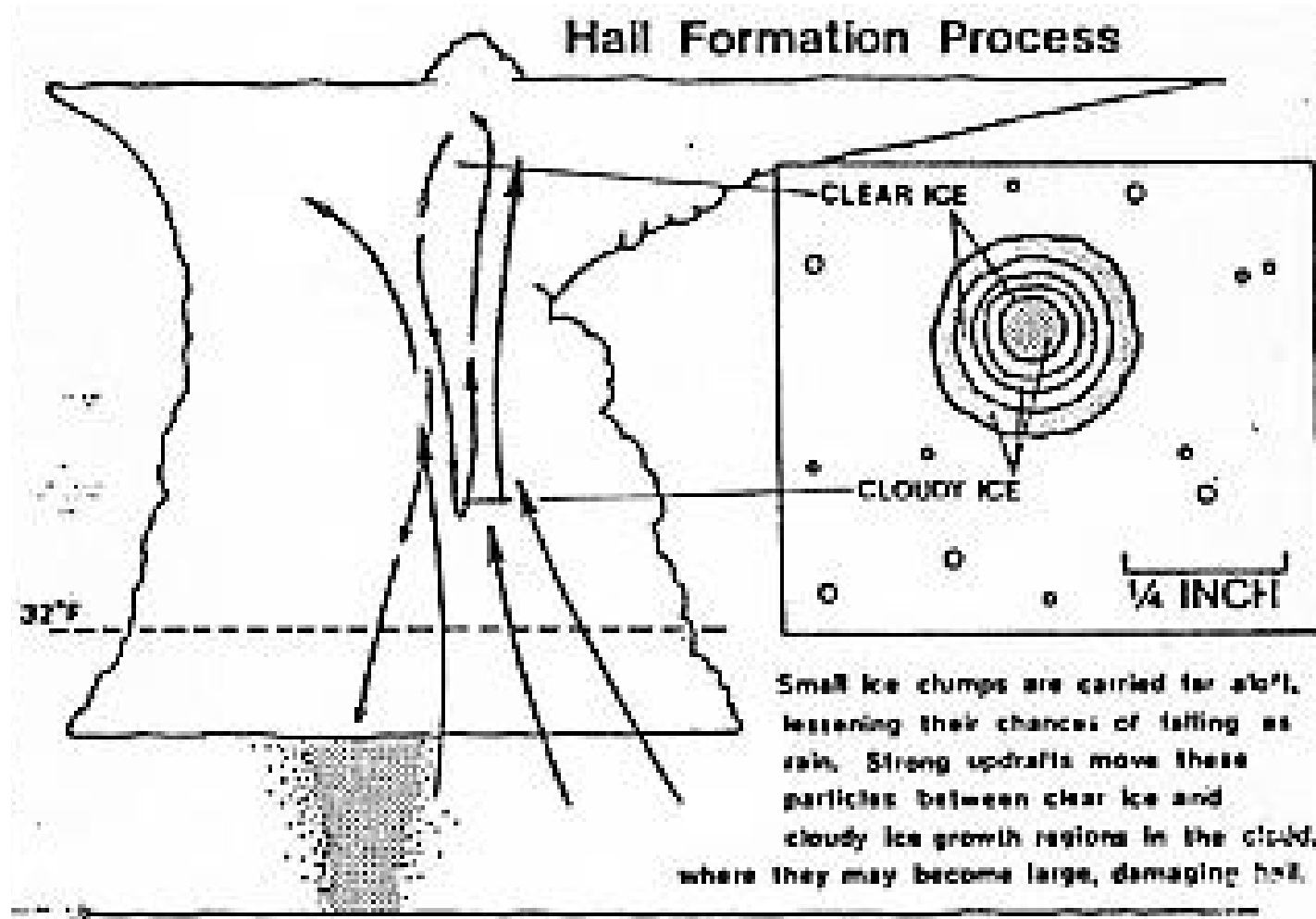
# Hail Formation

## "Dry" Growth



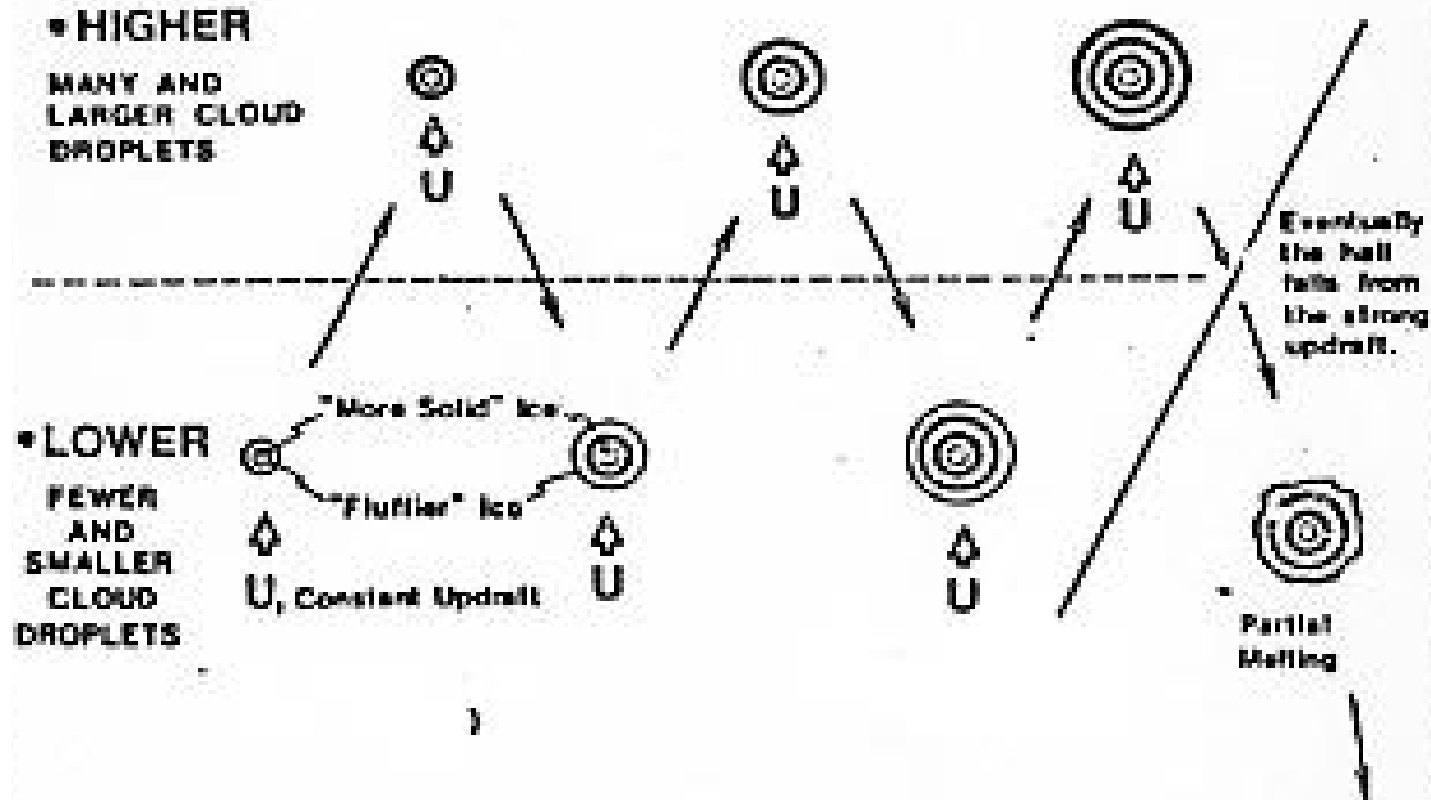
SUPERCOOLED WATER  
DROPLETS FREEZE ON  
IMPACT. THE ICE IS CLOUDY AND LIGHT-  
WEIGHT BECAUSE OF THE TINY CRACKS AND  
CREVICES WHICH CONTAIN AIR.

# Hail Formation

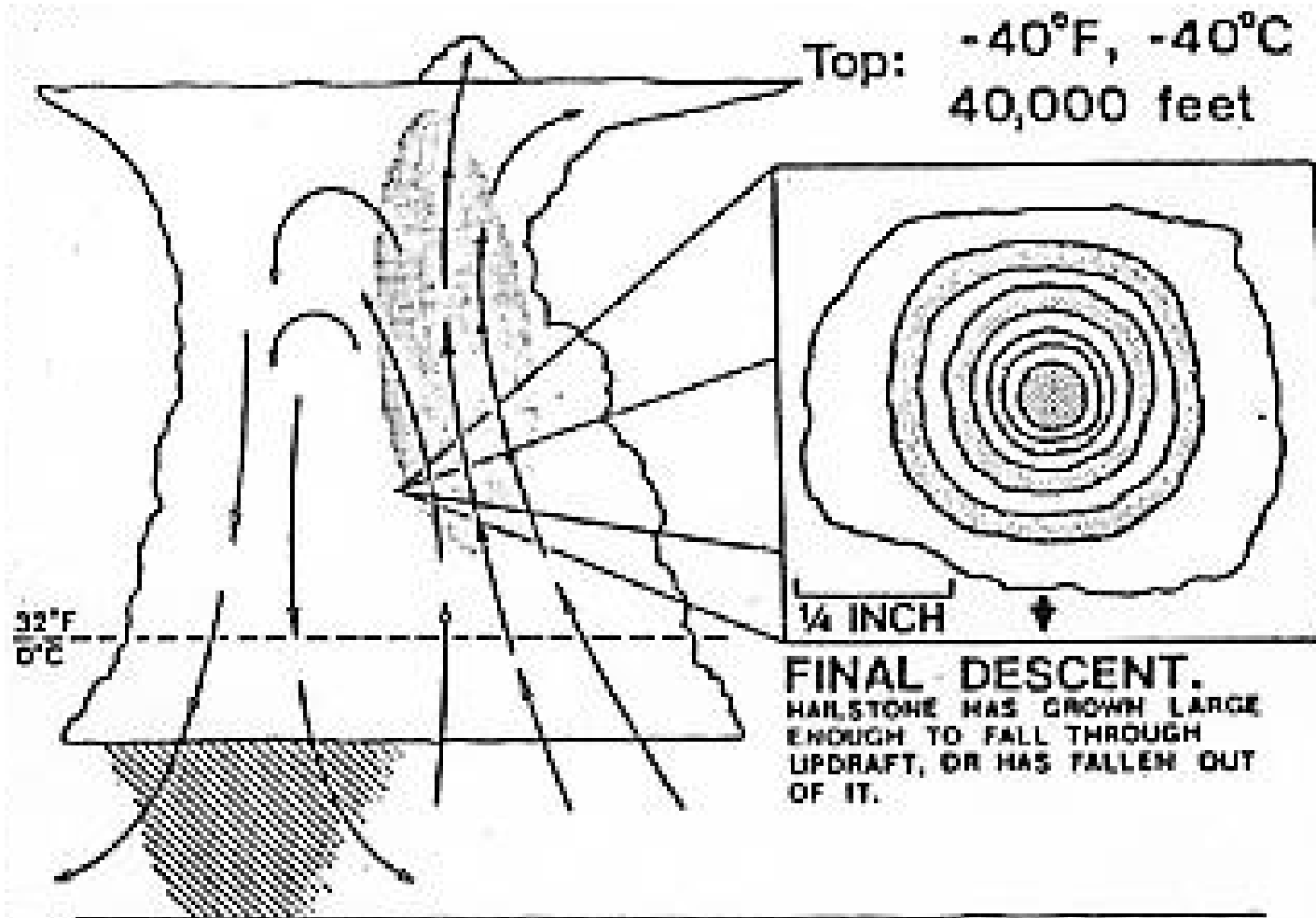


# Hail Formation

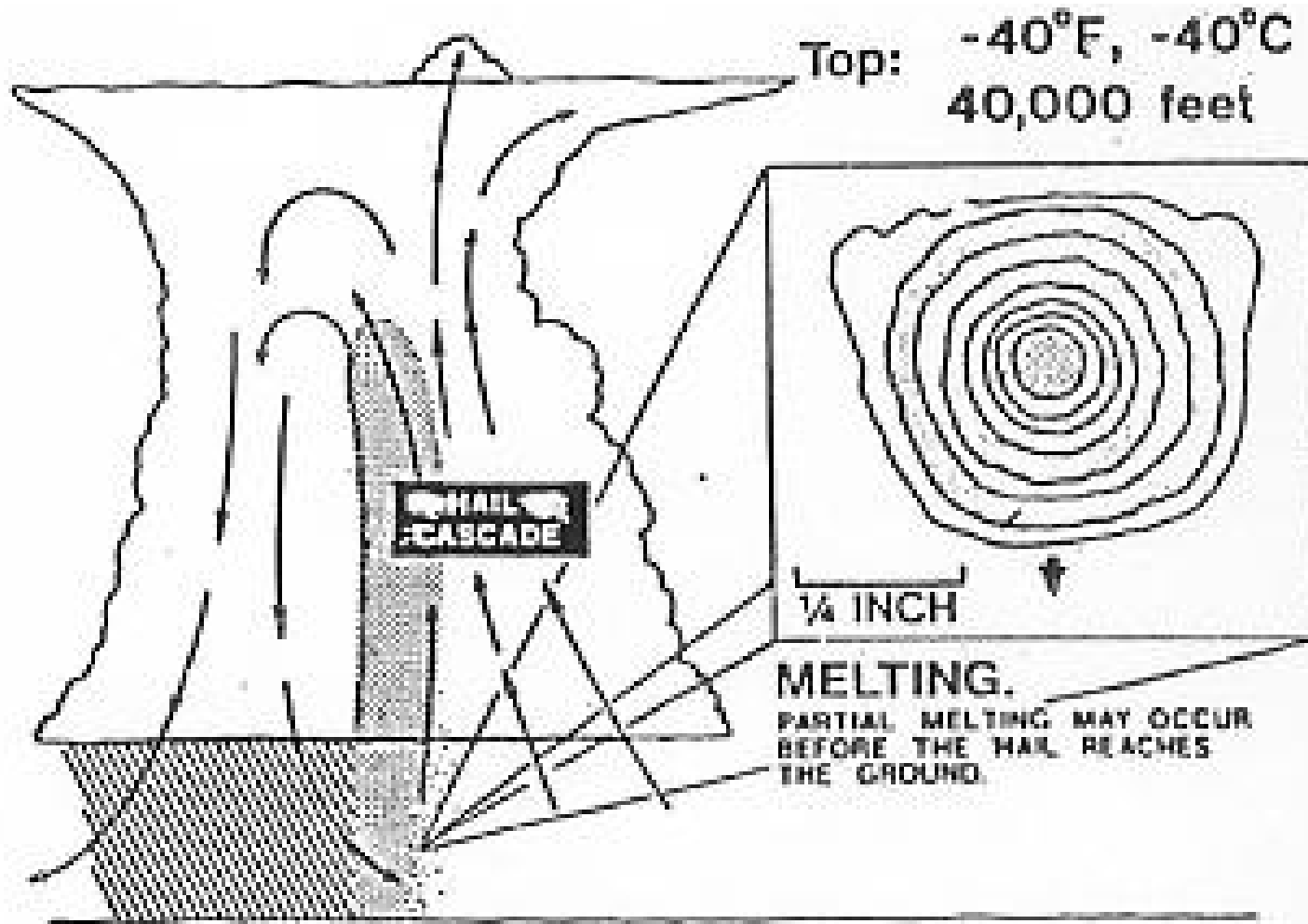
## ...WITHIN A CLOUD Hail Growth



# Hail Formation



# Hail Formation





# 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.



Coffeyville, 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).





# Competing Embryos (Beneficial Competition)

- 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.



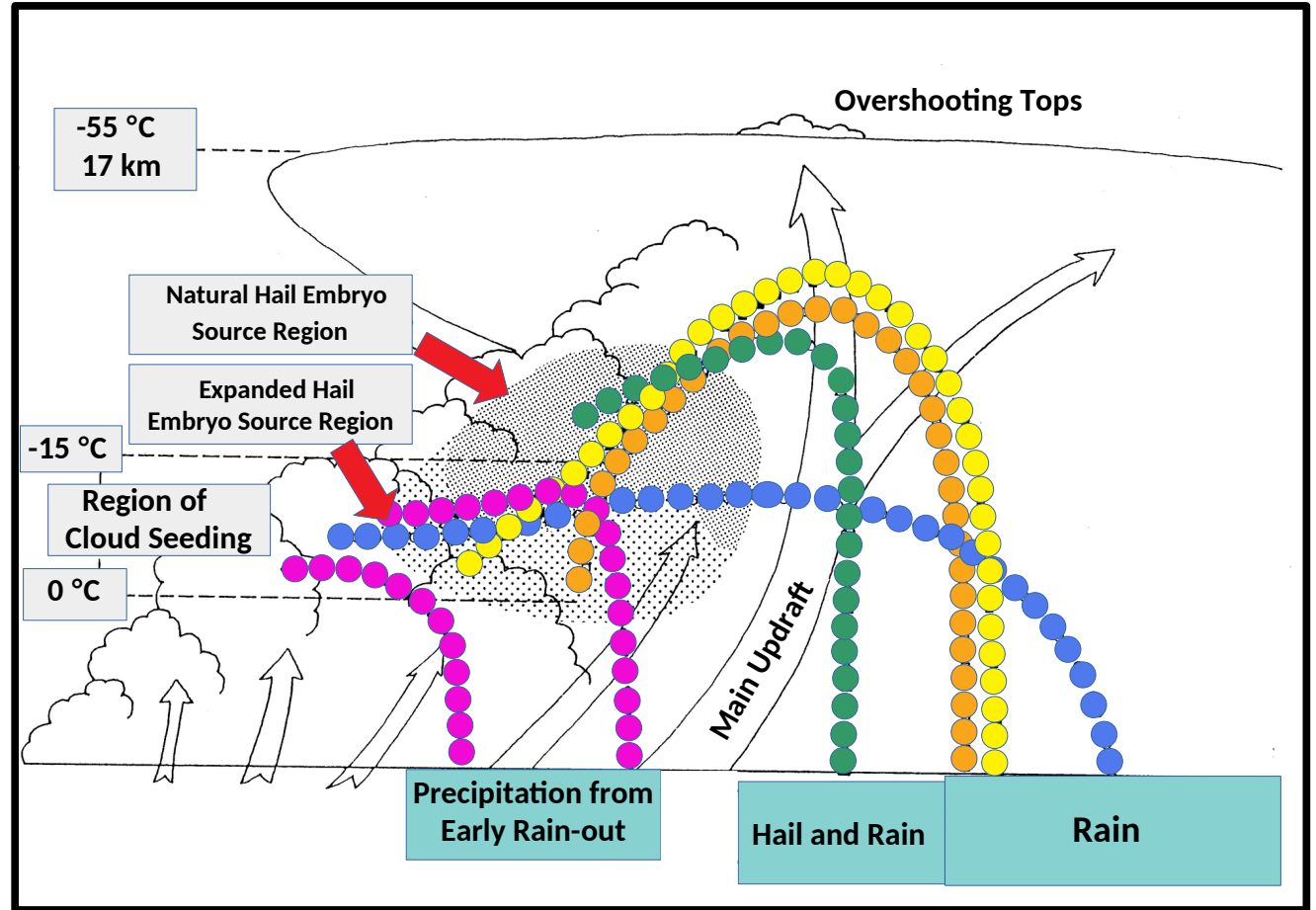
Low-precipitation Super-cell Storm  
Photograph by Roger Hill

# 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.

# Summary of Hail Suppression Models

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



Courtesy of Bruce Boe, Weather Modification International