

## Hail



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Photo Courtesy of Amarillo Globe News

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## What is hail?

- Hail is a ball or irregular clump of ice
- Hail is different from winter precipitation!
  - Not sleet (raindrops that have frozen)
  - Not freezing rain
  - Not snow
  - Not graupel
- Hail forms **only** in convective processes
  - Hail cannot exist without a thunderstorm
- Hailstones range in size from that of a pea to that of a grapefruit (more precisely  $\geq 5$  mm)



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## Lots of Hail



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## World Record Hailstone



Courtesy of NOAA

Aurora, Nebraska, 22 June 2003

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## An Aurora resident with a handful of hail



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## The old record holder (but still the heaviest!)



Coffeyville, Kansas, 3 September 1970

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## My biggest hail stone

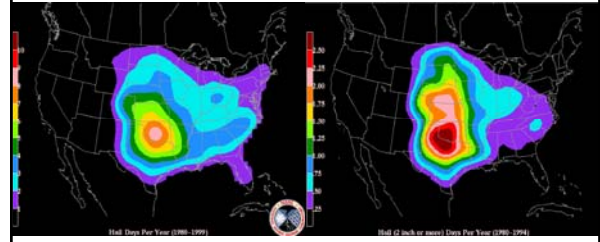


29 May 2004

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## U.S. Hail Climatology



# Days per year with hail  $\geq 0.75$  inches in diameter

# Days per year with hail  $\geq 2.0$  inches in diameter

Hail causes nearly \$1 billion in damage to crops and property annually

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## Hail Damage



Amarillo, TX, 21 June 2004

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## Hail Formation

- Above  $\sim -15^{\circ}\text{C}$  within a cumulonimbus cloud, supercooled droplets freeze on contact with ice nuclei (the frozen equivalent of condensation nuclei)



- At the surface, the equivalent process produces **rime ice**
- For rime ice accretion, the feathers of the crystals point in the direction of the wind (i.e., where the wind is coming from)

Photo: Derek Brown

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## Rime Ice

PICTURE STORIES



The top of Mount Washington in New Hampshire is coated in a thin ice, freezing moisture in the air.

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## Hail Formation

- Supercooled drops collide with and coalesce onto a frozen particle, forming a hail embryo
- Hail embryos in the strongest part of the updraft are carried upward to the anvil
- Embryos on the edges of the updraft fall back into supercooled water and grow to form graupel (diameter  $\sim 1\text{--}5\text{ mm}$ ).

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## Hail Formation

- Some graupel particles grow into hail
- Largest hail forms when a graupel particle grows within the turbulent updraft in a rich environment of supercooled water
- Largest hail falls nearest to the main updraft
- Hail eventually falls out of the thunderstorm because the updraft can no longer sustain the weight of the hailstone

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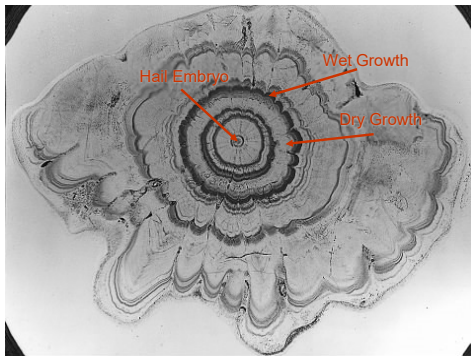
## Hail Formation

- Wet Growth
  - So many supercooled drops freeze onto the hailstone that the resulting latent heat release raises the surface temperature so that the water briefly remains unfrozen
  - Liquid water fills the porous regions, removing air bubbles
- Dry Growth
  - Supercooled water freezes on contact and leaves air bubbles (like rime ice)

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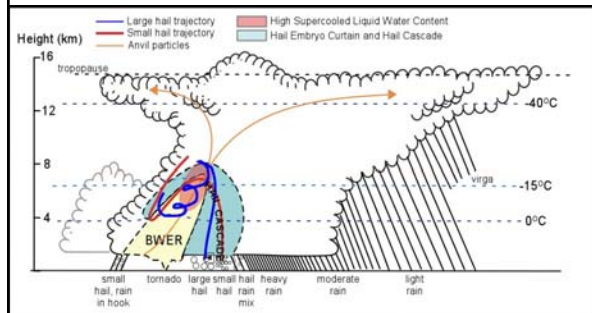
## Wet vs. Dry Growth



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## Hail Growth in a Supercell



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## Forecasting Hail

- Strong updrafts
  - Measured by convective available potential energy (CAPE)
- Low freezing levels (or high terrain)
- Thunderstorm with large liquid water content
- Most hail occurs during late afternoon (when severe thunderstorms are lurking about)

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## Some commonly used hail sizes

<b>Pea</b>	.25 inch	<b>Golf Ball</b>	1.75 inch
<b>Half-inch</b>	.50 inch	<b>Hen Egg</b>	2.00 inch
<b>Dime</b>	.75 inch	<b>Tennis Ball</b>	2.50 inch
<b>Nickel</b>	.88 inch	<b>Baseball</b>	2.75 inch
<b>Quarter</b>	1.00 inch	<b>Tea Cup</b>	3.00 inch
<b>Half Dollar</b>	1.25 inch	<b>Grapefruit</b>	4.00 inch
<b>Ping Pong Ball</b>	1.50 inch	<b>Softball</b>	4.50 inch

These sizes refer to the diameter of the hailstone. When reporting hail to the National Weather Service, they prefer actual measurements over these estimates.

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