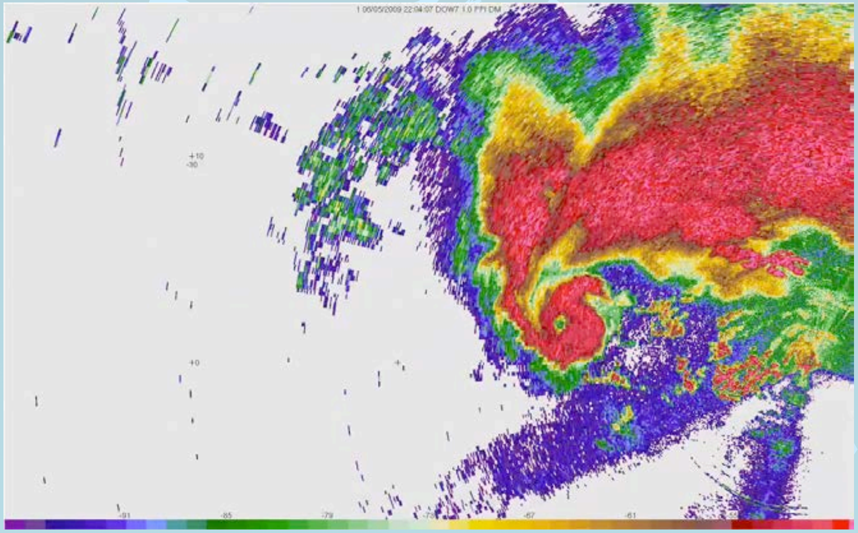
MET 200 Lecture 24 Severe Thunderstorms



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Damage Swath

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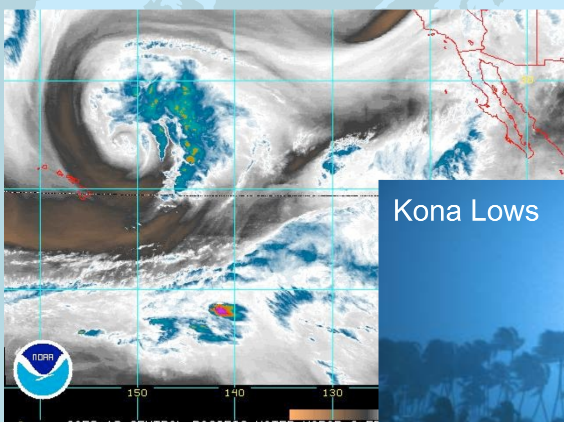
MET 200 Lecture 24 Flooding in Hawaii and Intro to Severe Thunderstorms



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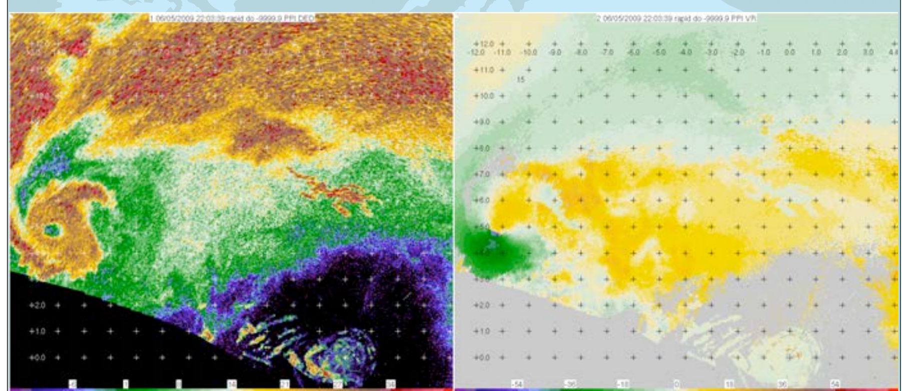
Severe Thunderstorms



- NWS Criteria
- Environment
- Structure
- Climatology

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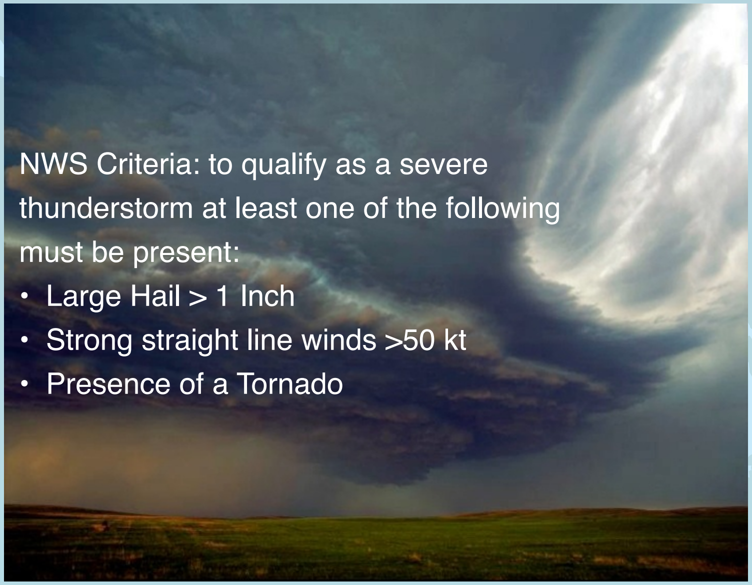
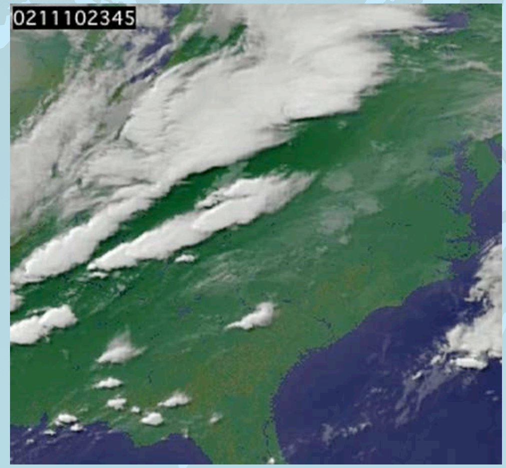
Severe Thunderstorms: NWS Criteria

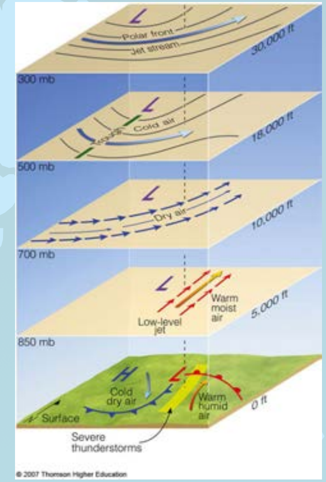


NWS Criteria: to qualify as a severe thunderstorm at least one of the following must be present:

- Large Hail > 1 Inch
- Strong straight line winds >50 kt
- Presence of a Tornado

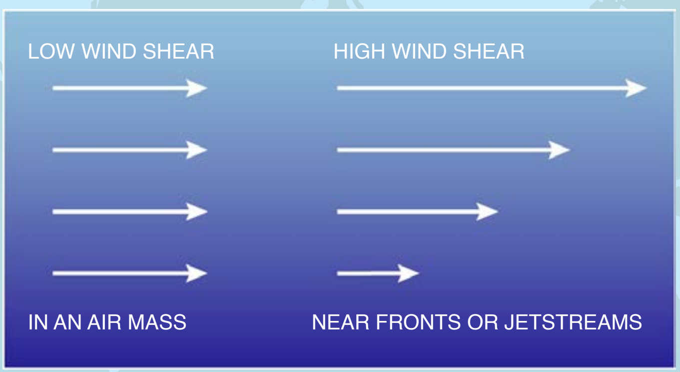
The Severe Thunderstorm Environment





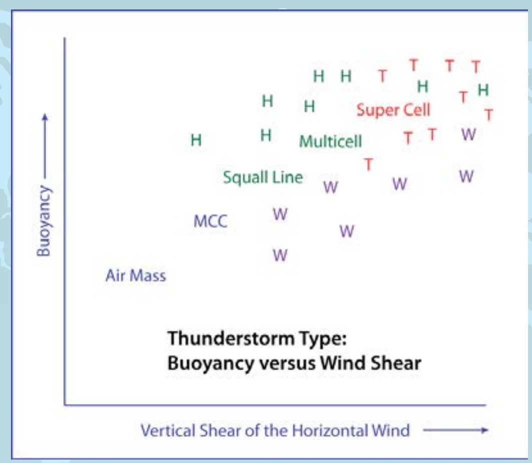
Air Mass vs Severe Thunderstorms

Environment: Severe thunderstorms form in regions of relatively strong winds and large wind shear. Thus they form near fronts and jet streams.



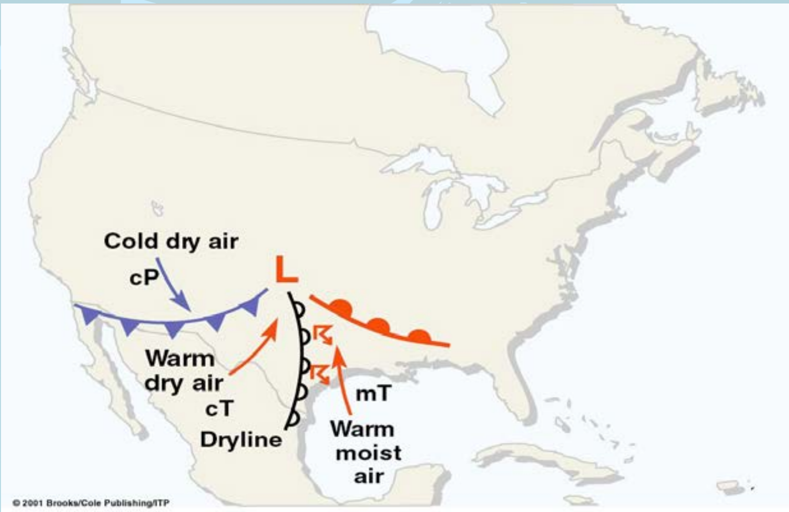
Air Mass Thunder Storm Severe Thunderstorm

The Thunderstorm Environment

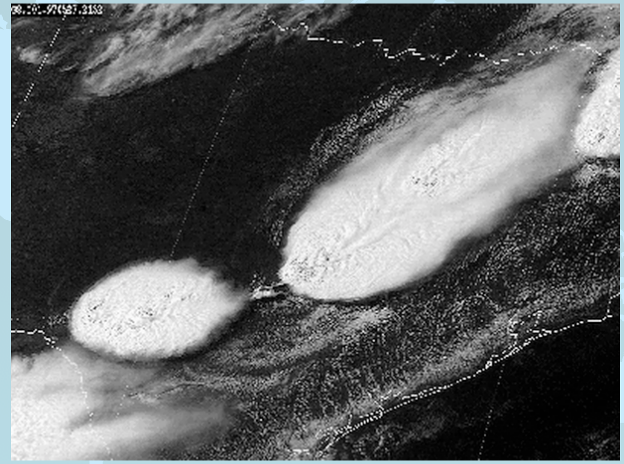


The type of thunderstorm development depends on the magnitude of the horizontal wind shear with height and the buoyancy.

The Severe Thunderstorm Environment



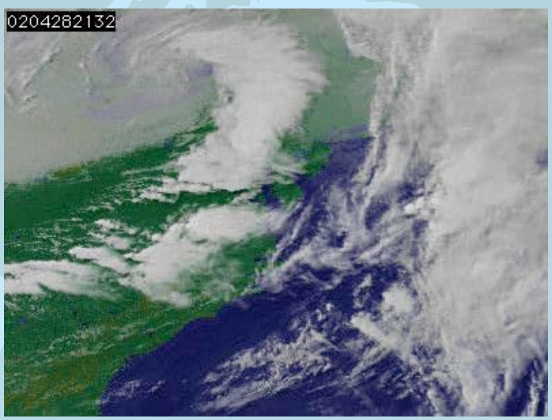
Texas Tornados



Visible imagery shows location of overshooting tops, anvil spreading, and storm motion.

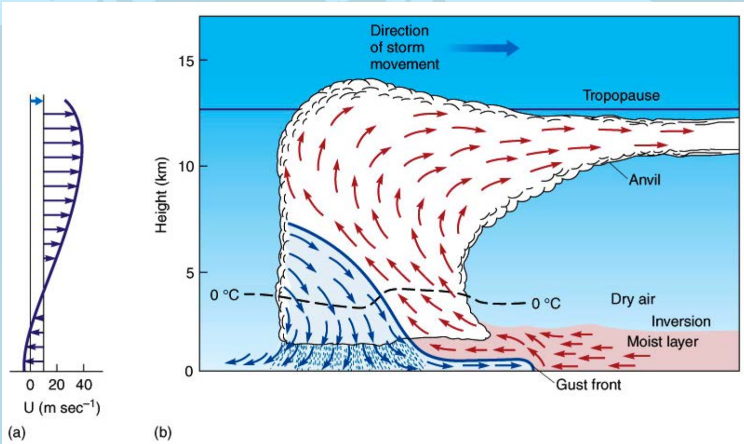
Squall line

A series of thunderstorms that form an extended line.

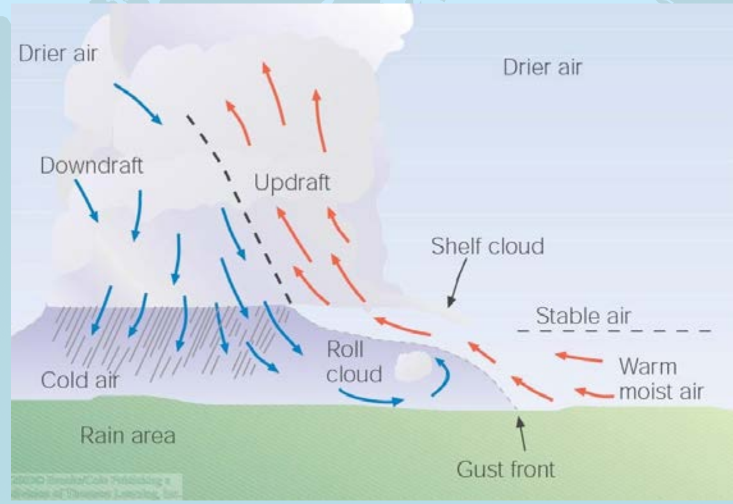


Supercell Thunderstorms

Supercell Thunderstorm Structure



Supercell Thunderstorm Structure



Supercell Thunderstorm Structure

Shelf cloud at leading edge of downdraft region.

Supercell Thunderstorm Structure

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Severe Thunderstorms

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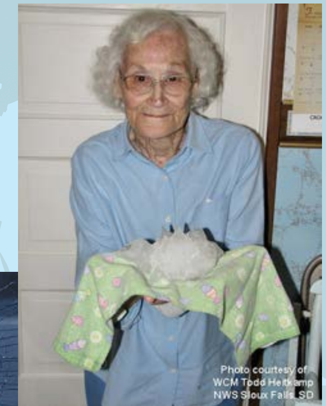
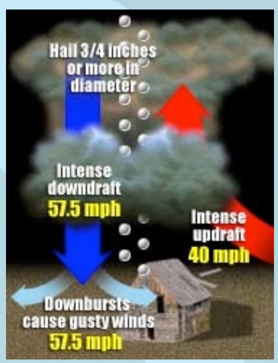
Large Hail



Large Hail



Large hail forms in clouds with

- High supercooled water content
- Very strong updrafts

Large Hail

Hail Damage

One Colorado hailstorm caused ~$1 billion damage in July 1990.

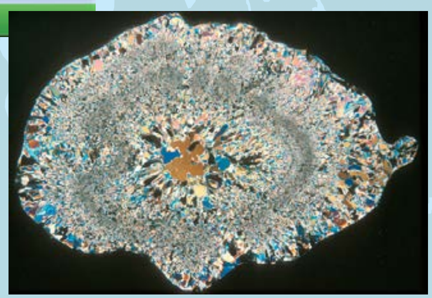
Hailstones have high density and fall fast (up to 90 mph)

- Hail damages
- Crops
- Cars, trucks…
- Livestock

This is one of the largest hailstones ever observed in the United States. The stone fell on June 22, 2003 in Aurora, Nebraska.

Large Hail

Large hailstones make several trips up into the cloud. Layers in the hailstone tells about its history.



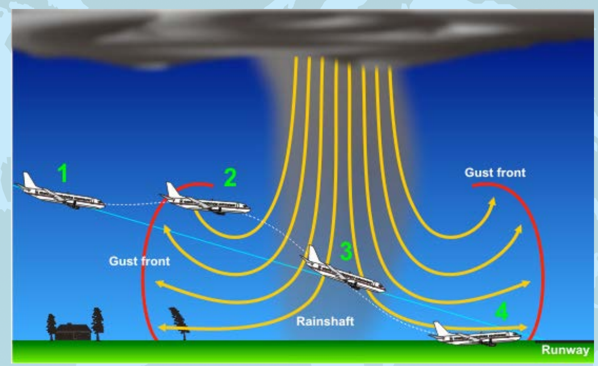
Strong Straight-line Winds

>50 knots (57 MPH)

Strong Straight-line Winds

Strong straight-line winds in thunderstorm are often the result of precipitation produced downdrafts called downbursts.

Downburst



- Downbursts can reach wind speeds of ~200 mph!
- Damage to forests and man made structures.
- Cause of numerous aviation disasters.

Downburst

Downbursts can reach wind speeds of ~200 mph!
Damage to forests and man made structures.
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TORNADOS

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TORNADOS

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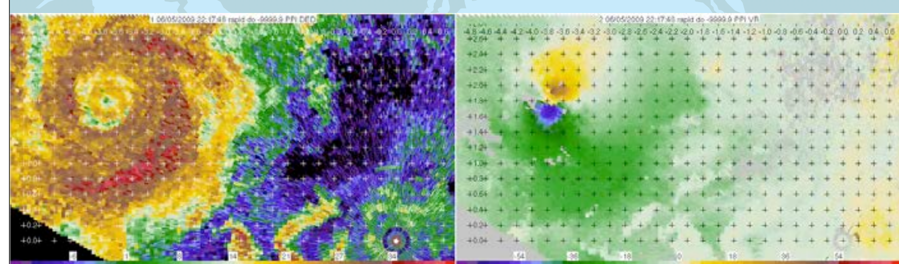
Tornado Radar Signature



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Tornados

- Environment
- Storm Structure
- Life Cycle
- Source of Spin
- Climatology
- Forecasting
- Damage

Marilee Thomas of Beaver City, NE took this photograph of her daughter Audra about two miles from a Furnas County tornado in April 1989.

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Supercells

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Definition of Supercell

Supercell storms are those storms with long-lived cores and rotating updrafts.

Supercells tend to have

- one of several distinctive radar reflectivity patterns
- they contain mesocyclones
- and they generally have a different storm motion than other nearby ordinary cells.

Supercells are frequent producers of large hail, strong winds, and tornadoes

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Tornado Environment

Many violent tornado outbreaks occur during "classic" synoptic conditions. The classic tornado out break pattern (Miller's Type "B" pattern) is characterized by:

1) A strong extratropical cyclone.
2) Rapidly moving 500 mb short wave trough.
3) Negatively tilted diffluent upper-level trough
4) Mid-level dry air intrusion.
5) Sufficient instability

The combination of these factors together result in a "Big tornado day"

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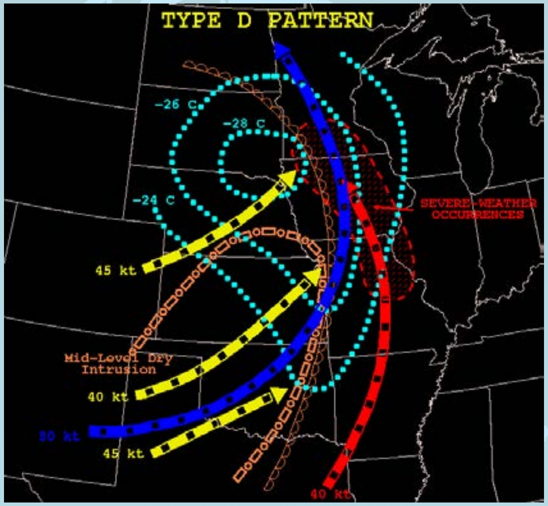
Synoptic Patterns

- Favorable conditions conducive to supercells often occur with identifiable synoptic patterns
- The favorable ingredients that support supercells in these environments are lots of instability and shear

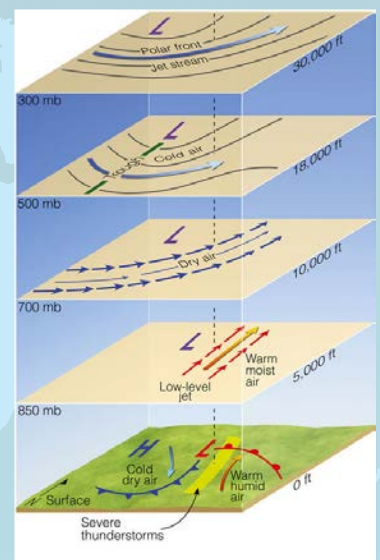


1st Tornado Photograph

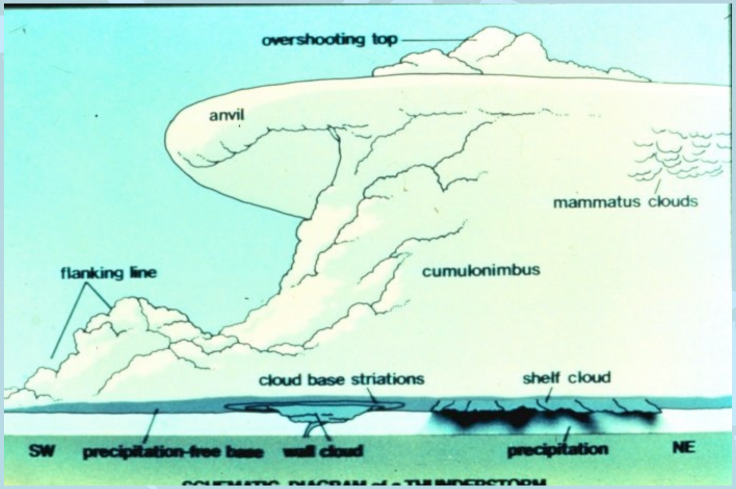
Tornado Environment

- Strong winds aloft (300mb, >25,000 ft), usually associated with the leading (east) side of a trough.
- Cool, dry air at mid levels (~18,000 ft, ~500 mb), usually brought by winds out of the southwest.
- Warm humid air at low levels (~5000 ft, 850 mb) brought in by strong gusty southerly winds.

Tornado Environment



Supercell Structure



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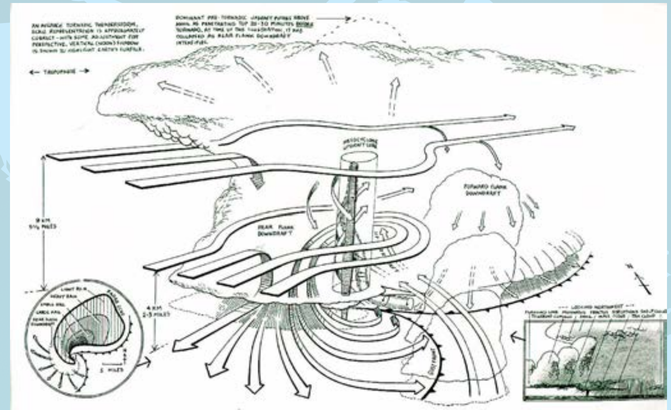
Tornadic Thunderstorm Structure



A mesocyclone is a rotating vortex in conjunction with the updraft in a supercell storm. Supercells develop mesocyclones by tilting environmental and/or locally generated horizontal spin (vorticity).

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Tornado Life Cycle

Wall Cloud

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Tornado Life Cycle

The wall cloud usually exhibits a lot of rotation.

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Tornado Life Cycle

The wall cloud usually exhibits a lot of rotation.

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Tornado Life Cycle

The wall cloud usually exhibits a lot of rotation.

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Funnel Formation

Tornados usually develop out of the wall cloud, which is located at the bottom of the updraft portion of the storm.

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Young Large Tornado

Early stage of large tornado; stubby funnel

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Mature Tornado

Rotation has reached the ground. Debris cloud kicked up by the winds is visible.

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Mature Tornado

Tornado funnel and debris cloud

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Mature Tornado

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Tornado in Final Rope Stage

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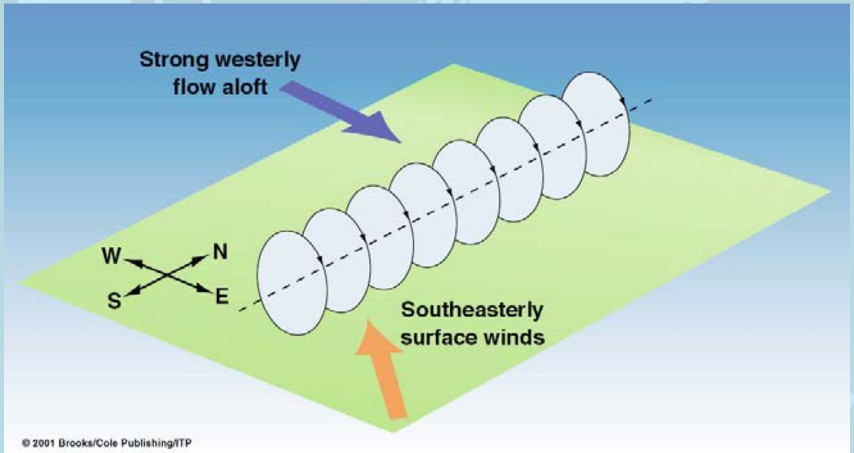
Source of Spin



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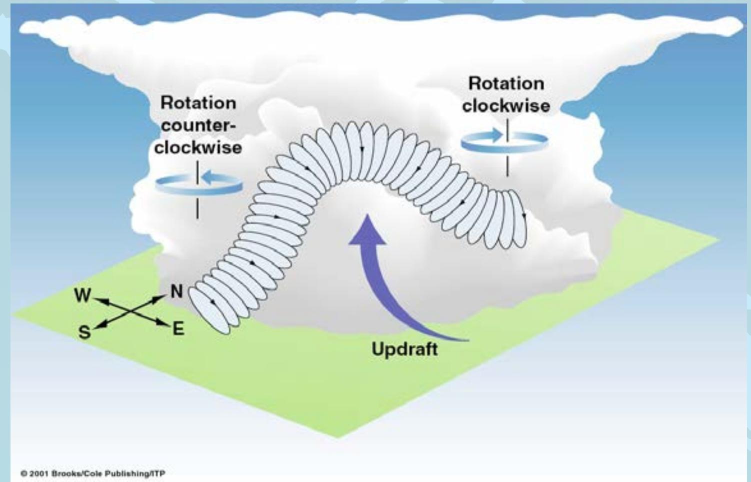
Source of Spin



Updraft Stretches Rotating Column

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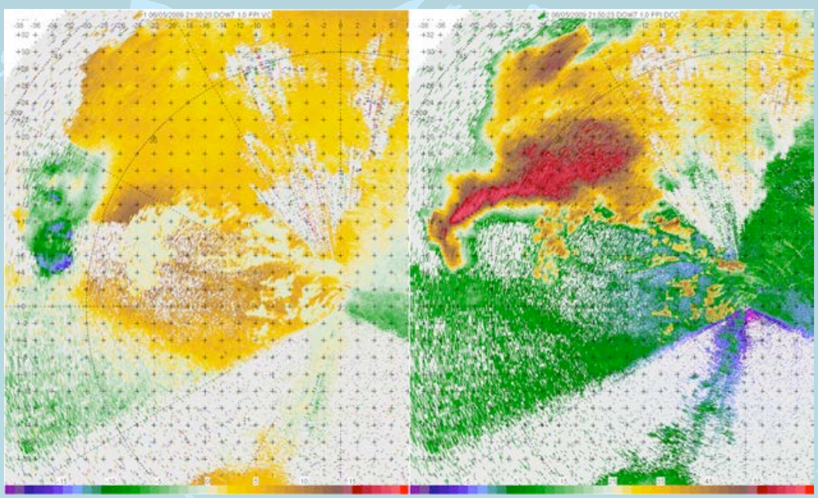
Radar Velocity and Reflectivity



Updraft Stretches Rotating Column

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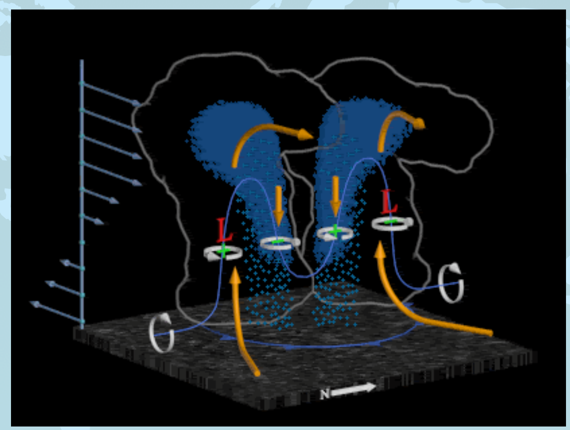
Supercell Storm Splitting



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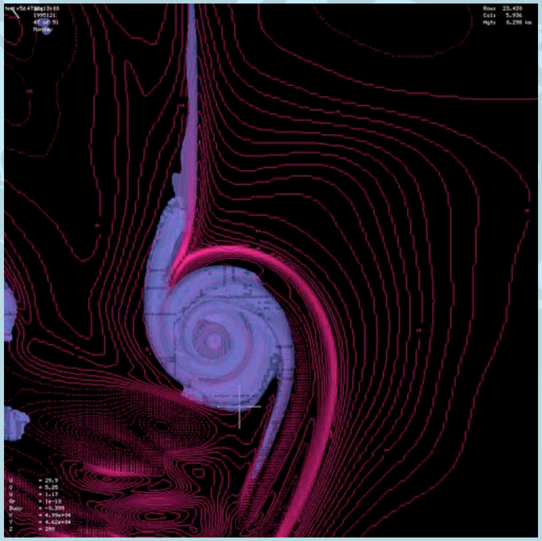
Simulation of Tornado Formation



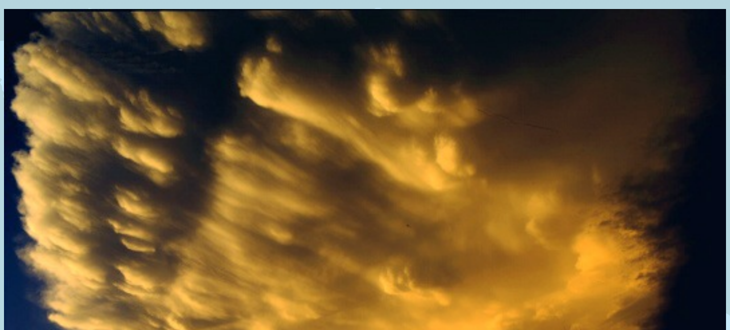
Tornado Climatology

Tornados can occur whenever severe thunderstorms occur, including in hurricanes.

Tornados are most common in spring and early summer and are most common in the latter half of the afternoon.

However, tornados have occurred during every month of the year and during every hour of the day in the U.S.

Tornado Climatology



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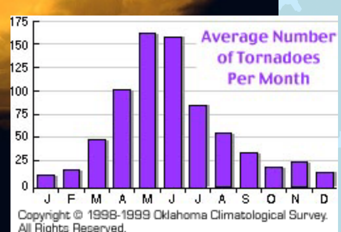
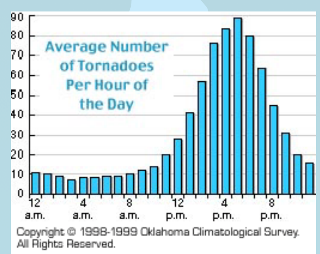
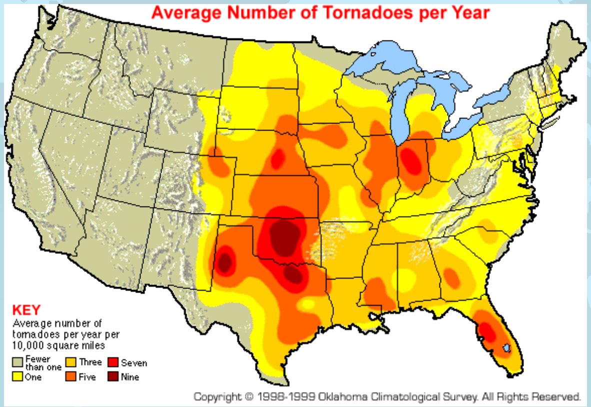


Tornado Climatology

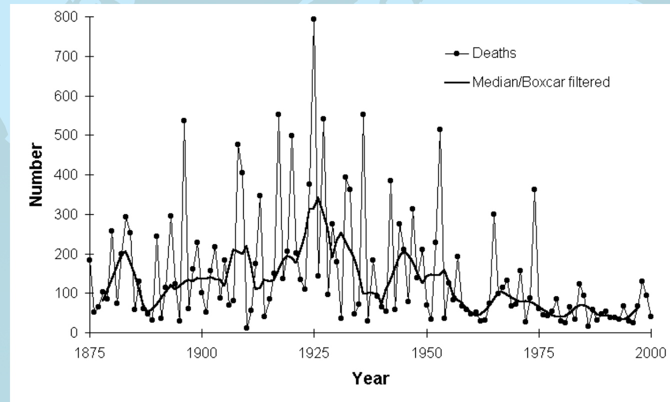


Tornados are most common in the mid to late afternoon.

Tornado Climatology

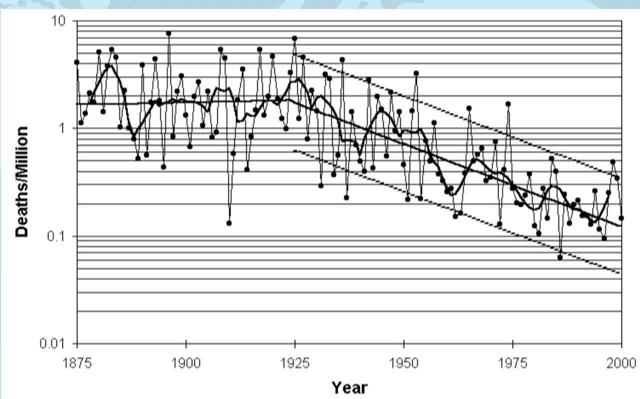


Tornado Climatology



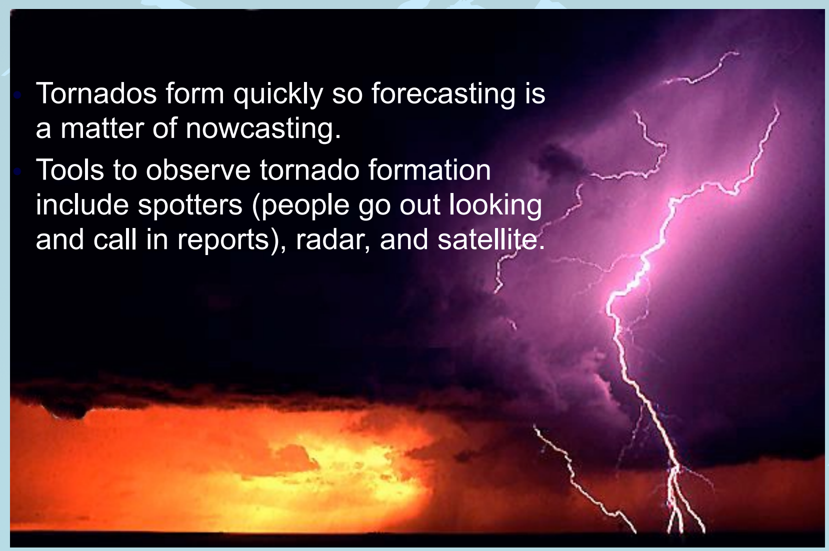
Tornado Deaths in the U.S.

Tornado Climatology



Tornado Deaths in the U.S. per Million People

Tornado Forecasting



- Tornados form quickly so forecasting is a matter of nowcasting.
- Tools to observe tornado formation include spotters (people go out looking and call in reports), radar, and satellite.

Tornado Forecasting is a matter of Nowcasting

- Radars can see impact of rotation on reflectivity (hook echo).
- Doppler radars can see wind shear over short distances.
- Radars can track storm motion.
- Satellite imagery can document rapid anvil growth and unusual storm motion.
- Radiosonde and aircraft soundings show environmental conditions: large instability and wind shear.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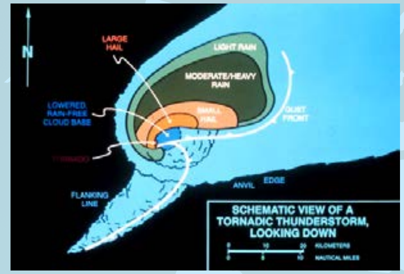
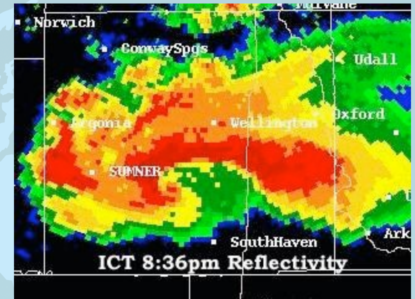
Hook Echo in Radar Reflectivity





A hook shaped echo in the radar reflectivity PPI indicates rotation associated with larger circulation associated with tornados.

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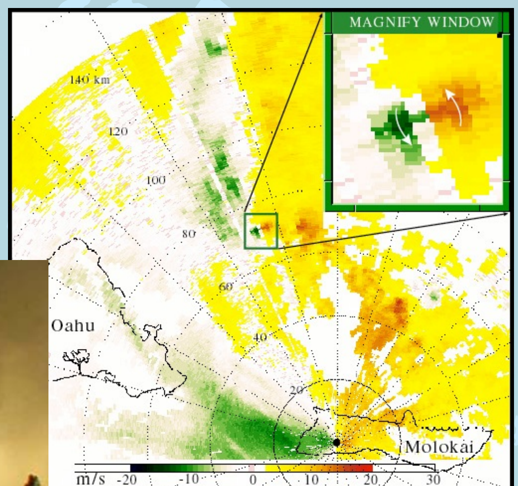
Vortex in Radar Winds

Vortex signature in radial velocity data from Molokai NWS Doppler radar on 25 January 1996 at 5:34 PM HST.



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Satellite Imagery as a Tool

Tornadic thunderstorms form ahead of an upper-level trough. Anvils usually blow to the NE by strong SW jet.


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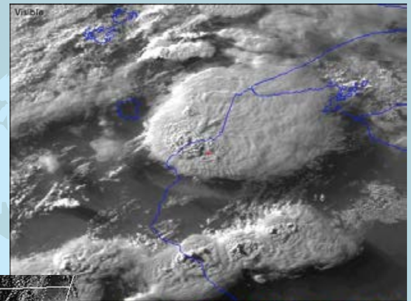
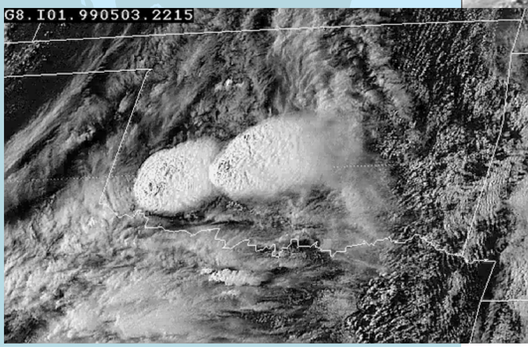
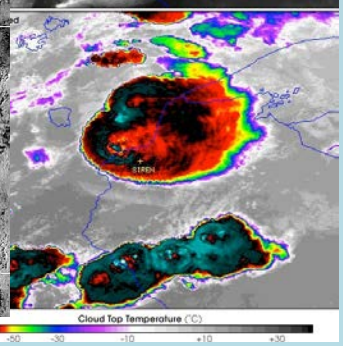
Visible and IR Imagery

Visible and IR imagery shows overshooting top, anvil spreading, and storm motion.



NWS Tornado Advisories

The NWS issues two levels of advisories to the public concerning tornados.

1. Tornado Watch: when the conditions are favorable for the formation of tornadic thunderstorms.
2. Tornado Warning: when a tornado or evidence for a tornado circulation has been observed. The location and track of the feature is given and if it is headed your way head for the basement!!

Tornado Safety Tips

- Take cover on the lowest floor of a sturdy building, preferably a basement.
- Go to a windowless, inner room such as a closet, hallway or bathroom.
- Avoid windows.
- Avoid buildings such as strip malls with large unsupported roof spans.
- Get under a mattress, table, desk, etc.
- Avoid automobiles and mobile homes.
- If caught in the open, lie flat in a ditch or depression.
- Move at right angles to the tornado's motion, if possible.
- Be careful of downed power lines, broken gas lines, etc.

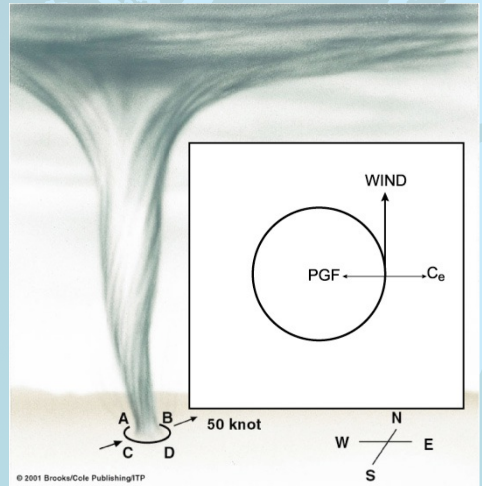
Tornado Damage

Tornado Damage

Fujita Tornado Intensity Scale

F-0 Light damage. Wind up to 72 mph.
F-1 Moderate damage. Wind 73 to 112 mph.
F-2 Considerable damage. Wind 113 to 157 mph.
F-3 Severe damage. Wind 158 to 206 mph.
F-4 Devastating damage. Wind 207 to 260 mph.
F-5 Incredible damage. Wind above 261 mph.

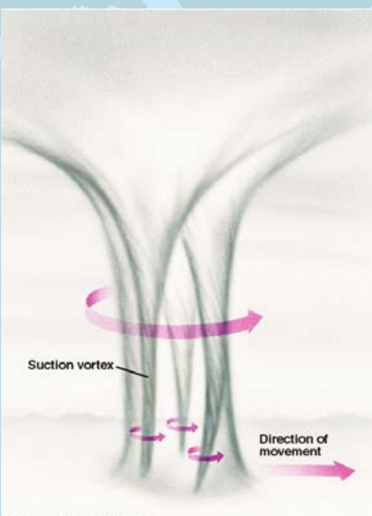
Cause of Tornado Damage



Recall that the winds in a tornado funnel are nearly in cyclostrophic balance where the pressure gradient force (directed inward) is balanced by centrifugal force (directed outward).

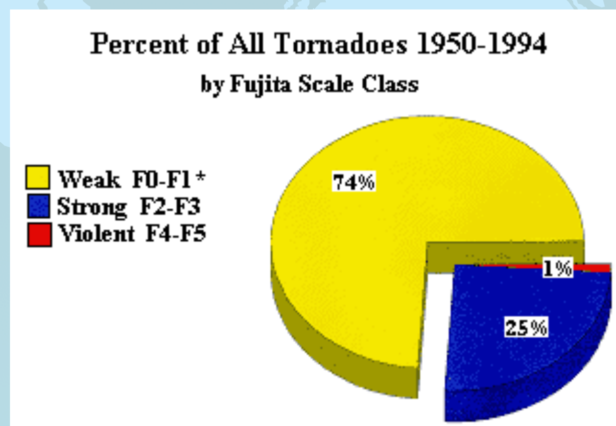
$mV^2/r = 1/\rho \; dp/dr$

Cause of Tornado Damage

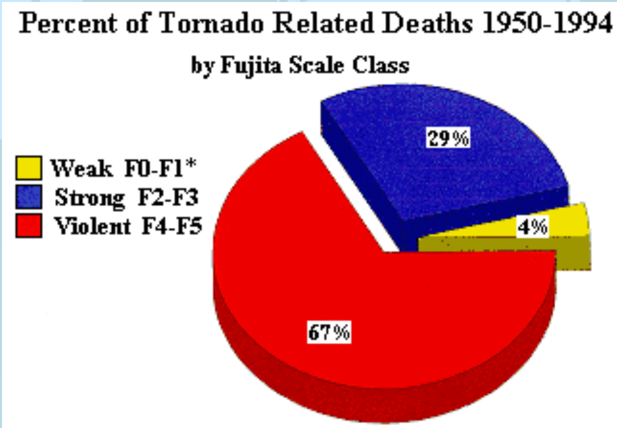


Suction vortices cause maximum damage

Severe Thunderstorm Damage



Severe Thunderstorm Damage



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‘89 Raleigh, NC F-4 Tornado

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‘89 Raleigh, NC F-4 Tornado

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‘89 Raleigh, NC F-4 Tornado

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‘89 Raleigh, NC F-4 Tornado

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‘89 Raleigh, NC F-4 Tornado

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Parting Shots

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Parting Shots

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Parting Shots

The updraft region of the storm can sometimes have an eerie green color.

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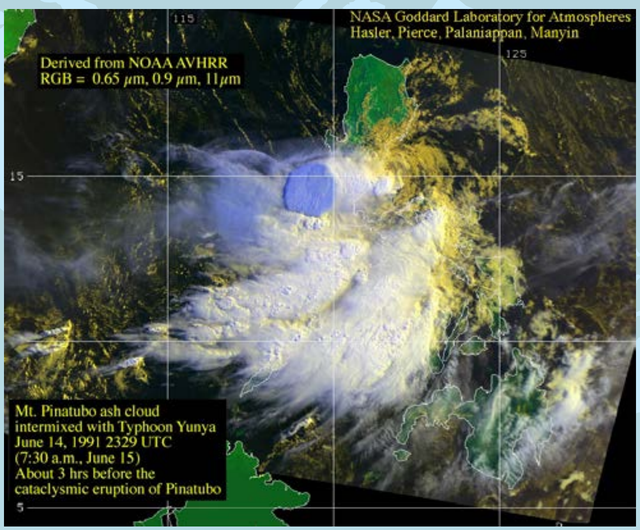
Volcanic Thunderstorm



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Questions?

Tornado Star Knife

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