Mature Tornado

Tornado funnel and debris cloud

Mature Tornado
Tornado in Final Rope Stage

Source of Spin

Strong westerly flow aloft

Southeasterly surface winds
Source of Spin

Updraft Stretches Rotating Column

Simulation of Tornado Formation
Tornado Forecasting

Tornadoes 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.
Hook Echo in Radar Reflectivity

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

Vortex in Radar Winds

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

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

Visible and IR Imagery

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

Visible imagery shows location of overshooting tops, 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 Climatolgy

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

Tornados are most common in spring and early summer.

Tornado Climatology

Tornados are most common in the mid to late afternoon.
Average number of tornados per year per 10,000 km.
Tornado Climatology

Tornado Deaths in the U.S.

Tornado Climatology

Tornado Deaths in the U.S. per Million People
Tornado Damage

Oklahoma-Kansas Tornadoes

- May 1999. Outbreak of F4-F5 tornadoes hit the states of Oklahoma and Kansas, along with Texas and Tennessee,
- Oklahoma City area hardest hit
- At least $1.1 billion damage/costs; 55 deaths.

1999 OK Tornados
Tornado paths in and around Oklahoma City on May 3, 1999. Individual tornado tracks are identified by different colors. Tornado intensity is given by Fujita Scale values. Note that the largest tornado track, that cuts through the center of the city, has intensity values recorded along its entire path.
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).

Cause of Tornado Damage

Suction vortices cause maximum 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.

Severe Thunderstorm Damage

Percent of All Tornadoes 1950-1994
by Fujita Scale Class

- Weak F0-F1*: 74%
- Strong F2-F3: 25%
- Violent F4-F5: 1%
Severe Thunderstorm Damage

Percent of Tornado Related Deaths 1950-1994
by Fujita Scale Class

- Weak F0-F1*: 29%
- Strong F2-F3: 4%
- Violent F4-F5: 67%

‘89 Raleigh, NC F-4 Tornado
‘89 Raleigh, NC F-4 Tornado
‘89 Raleigh, NC F-4 Tornado

‘89 Raleigh, NC F-4 Tornado
Waterspouts and Landspouts

Landspouts or weak tornadoes over Oahu
Water Spouts

- Waterspouts and funnel clouds are fairly common in Hawaii.
- Water spouts form over warm water in cumulus clouds that are relatively shallow (~ 2 km deep).
- Water spouts have relatively weak winds, generally averaging 35 kt.
- Damage associated with water spouts is minimal, e.g., occasional car ports blown down.

Parting Shots
Parting Shots

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

Tornado Star Knife