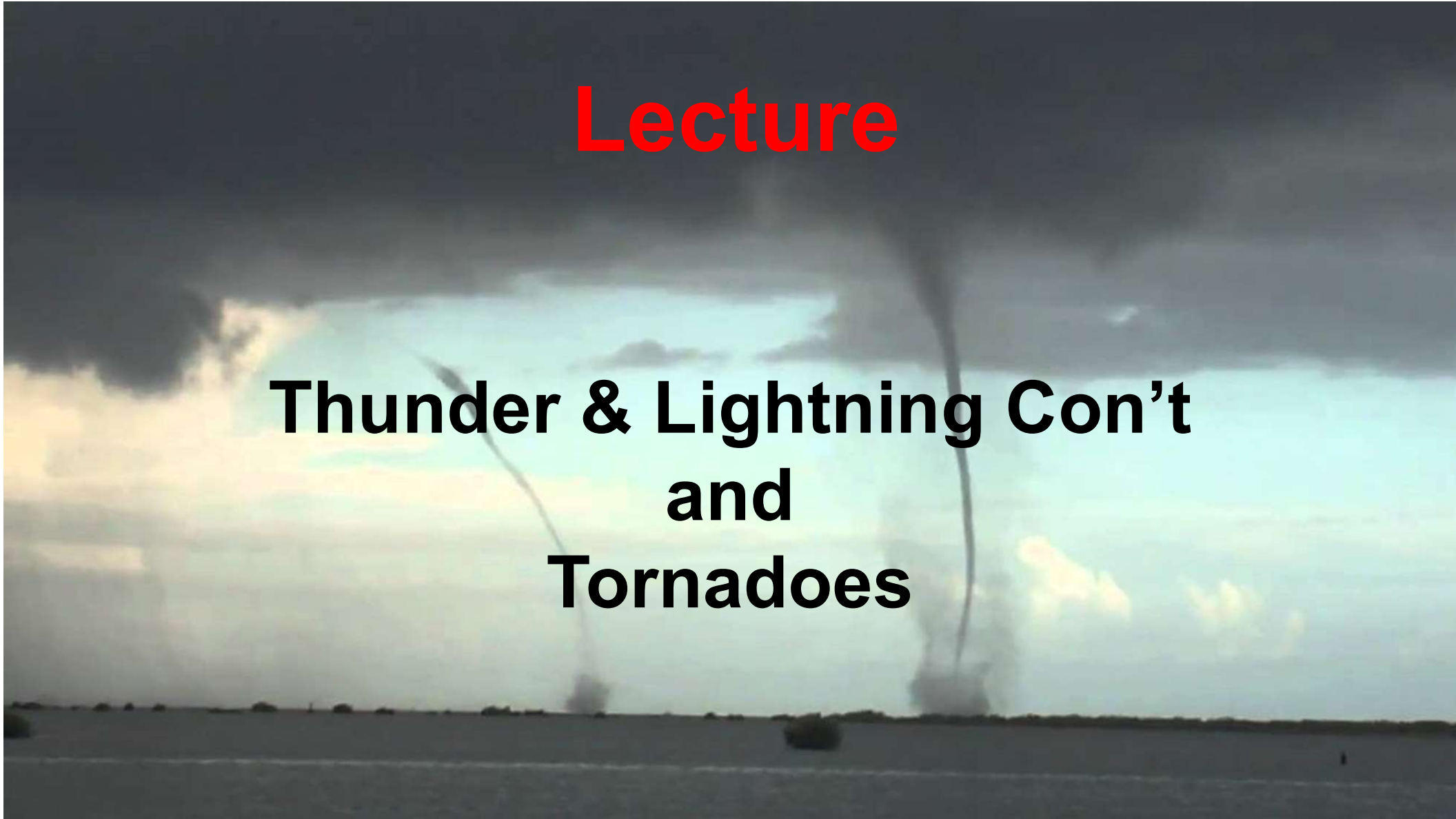


Lecture

Thunder & Lightning Con't and Tornadoes



Water Spouts



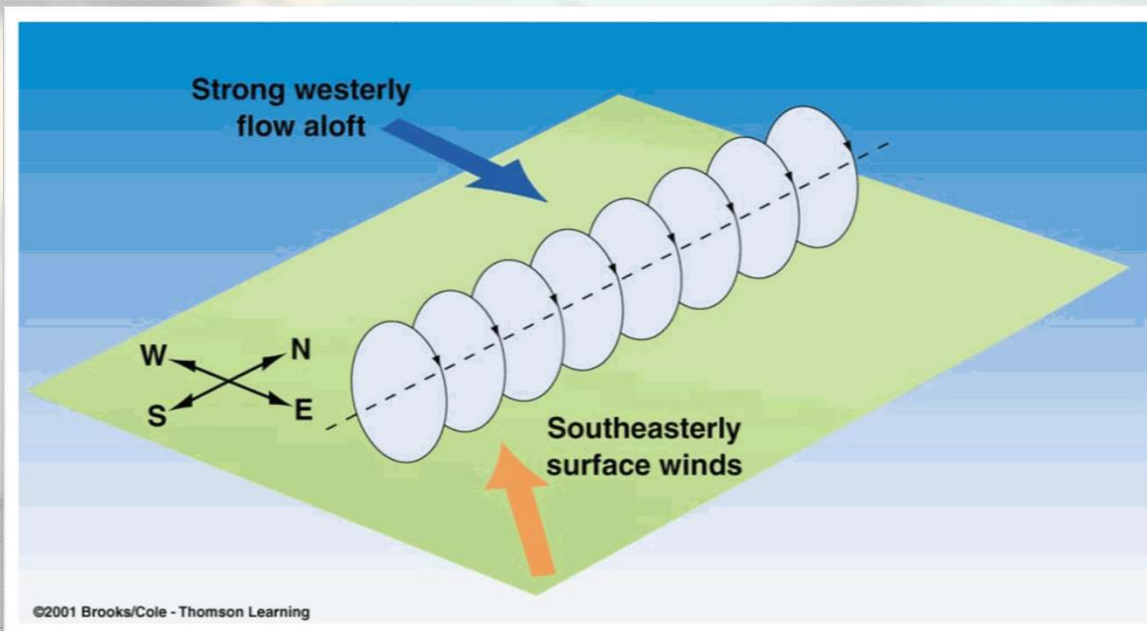
Tornado Introduction

- A **tornado** is a rapidly rotating narrow region of low pressure
- Wind speeds from **70-300 mph**
- Pressure can be as **low as 900 mb**
- **Tornadoes form during intense thunderstorms.**



Tornado Development

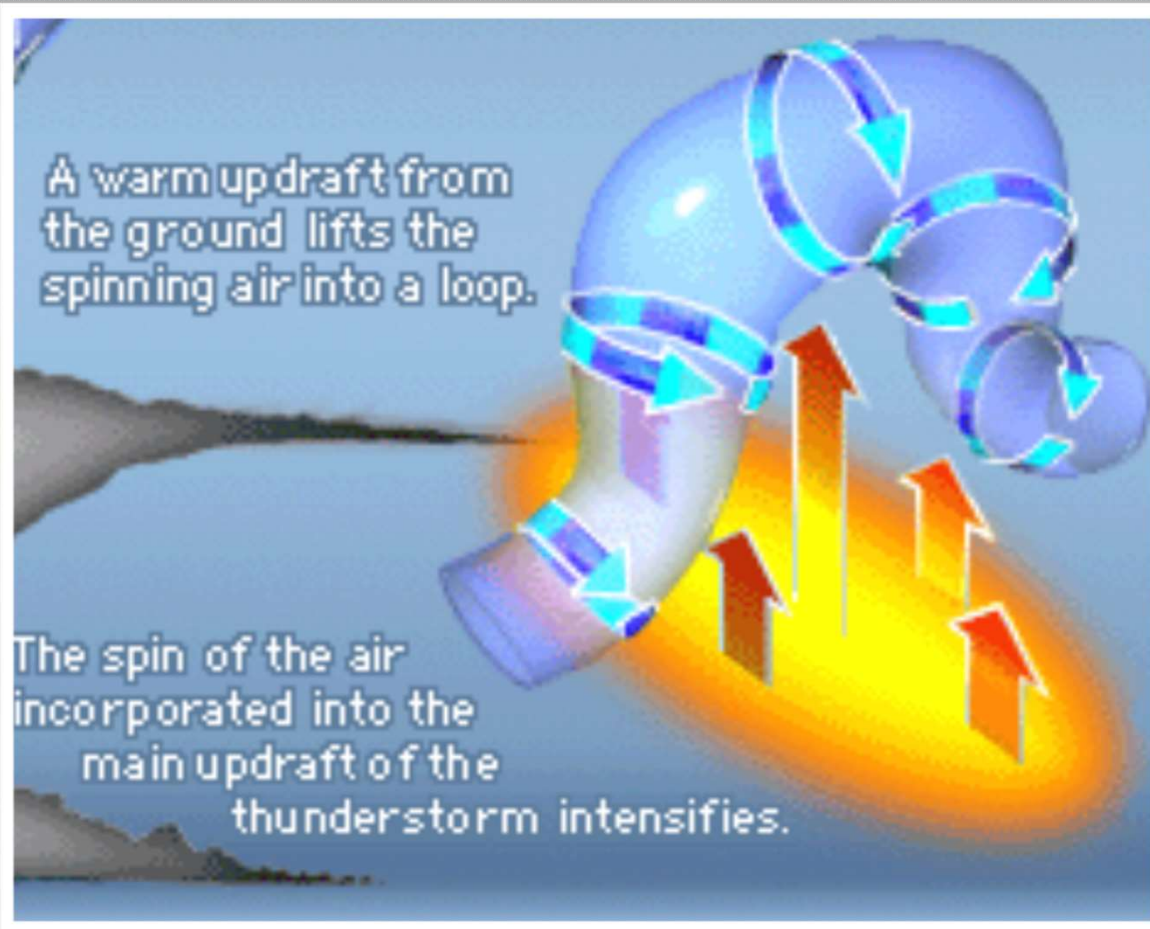
- Step 1: The first object that forms is a rotating body of air at the ground
 - This occurs because of vertical wind shear



a) Wind speeds are higher as you increase in altitude

b) Drag and Friction: Friction and drag at the surface cause the air at the ground to move more slowly.

Tornado Development



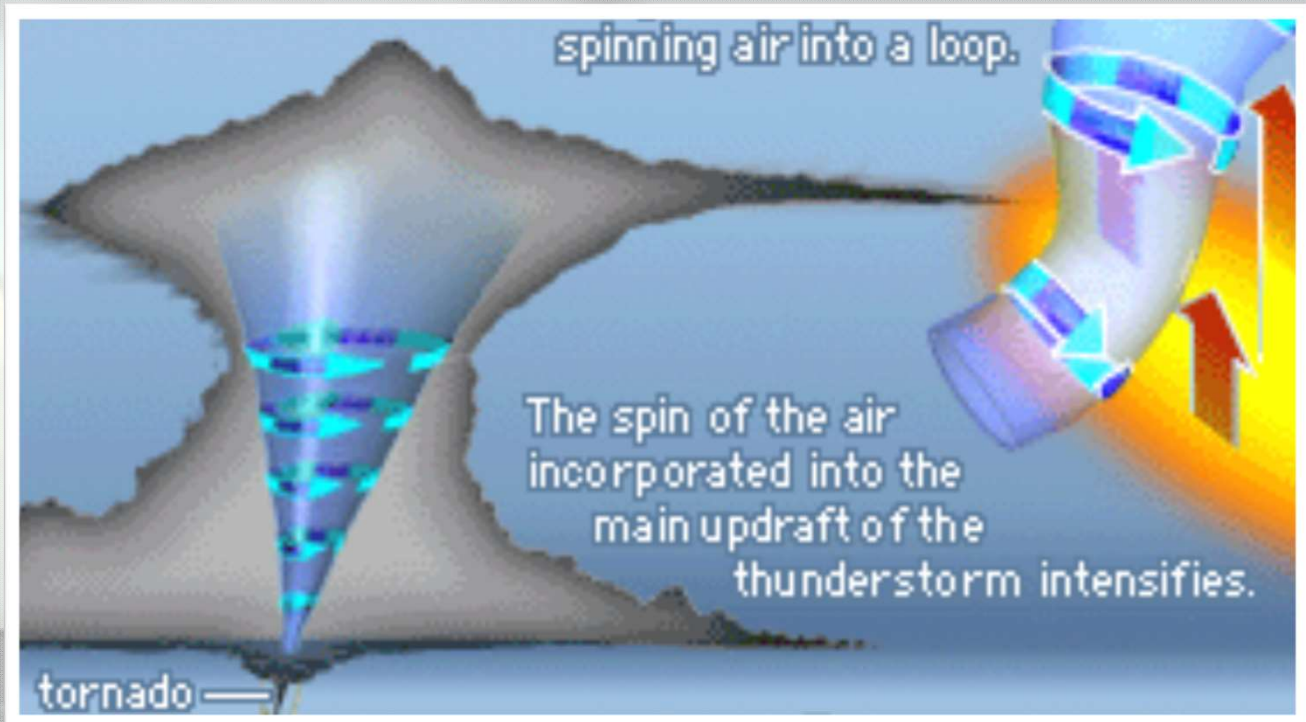
- Step 2: Horizontal rotating air is lifted off the ground by the Updraft of a Thunderstorm

Once the horizontal rotating air mass is lifted nearly vertically it is considered a

MESOCYCLONE!

Tornado Development

- Step 3: Mesocyclone is fully developed in the updraft of a thunderstorm
 - If a tornado develops it descends from the slowly rotating “wall cloud” in the lower part of the cloud.

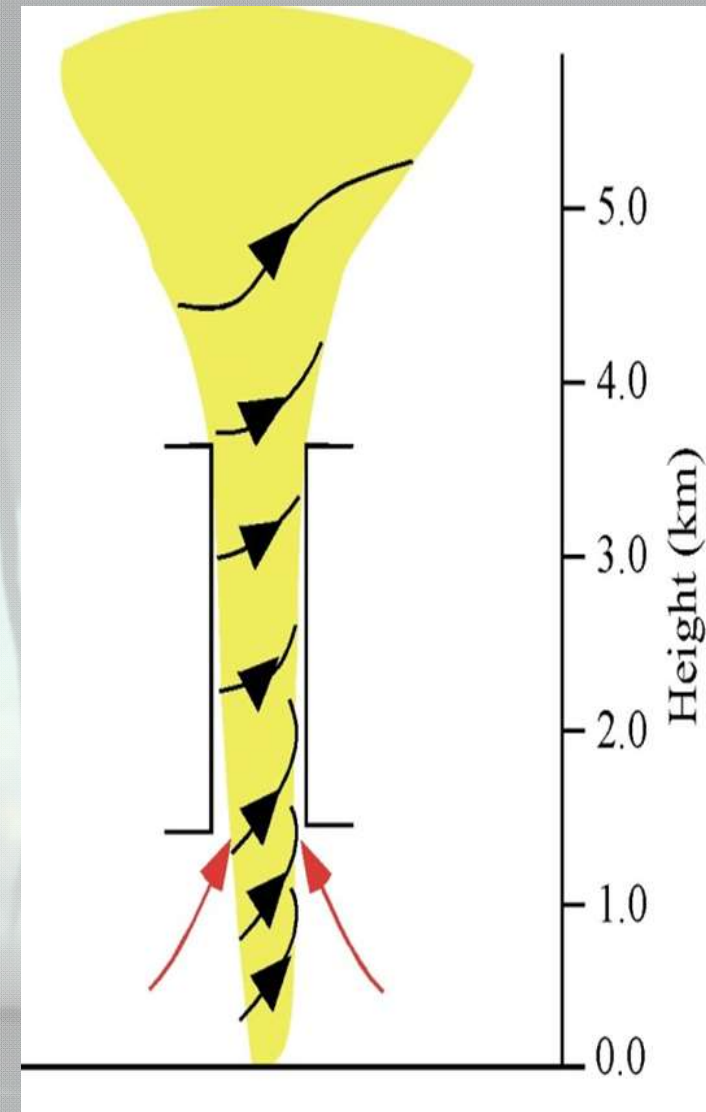


Photos of Wall Clouds



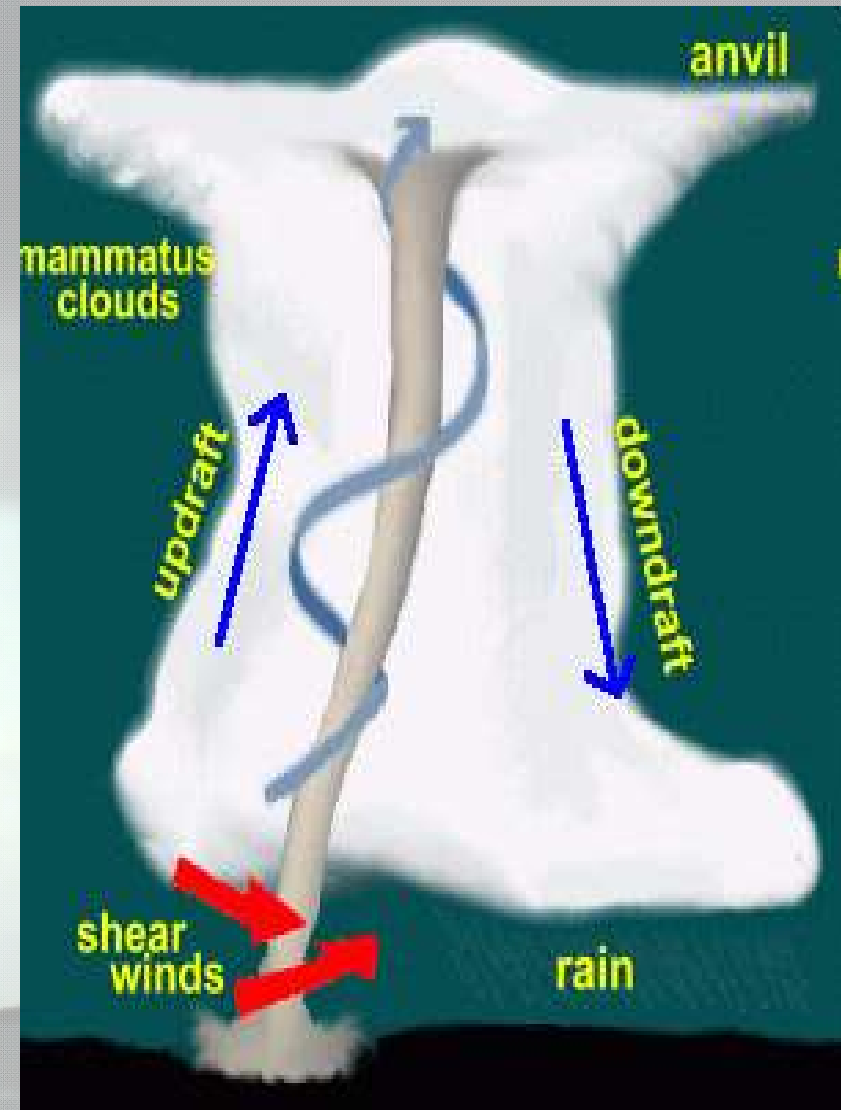
Mesocyclone Review

- Remember it is a vertical cylinder of rotating air, typically 3-10 km across (2-6 miles)
- Develops in the updrafts of severe T-Storms
- Usually precedes tornadoes by 30 min
- Stretching of the mesocyclone column causes faster rotation
 - Just like a figure skater!! Something that begins with a larger diameter rotating at a slow speed begins to rotate faster as the tube is elongated and the diameter decreases



Thunderstorm + Tornado

- From the wall cloud a very narrow, fast rotating structure emerges.
- This forms a **funnel cloud** (as long as the cloud does not touch the ground)
- As soon as the funnel cloud **touches the ground** it is called a **tornado**.

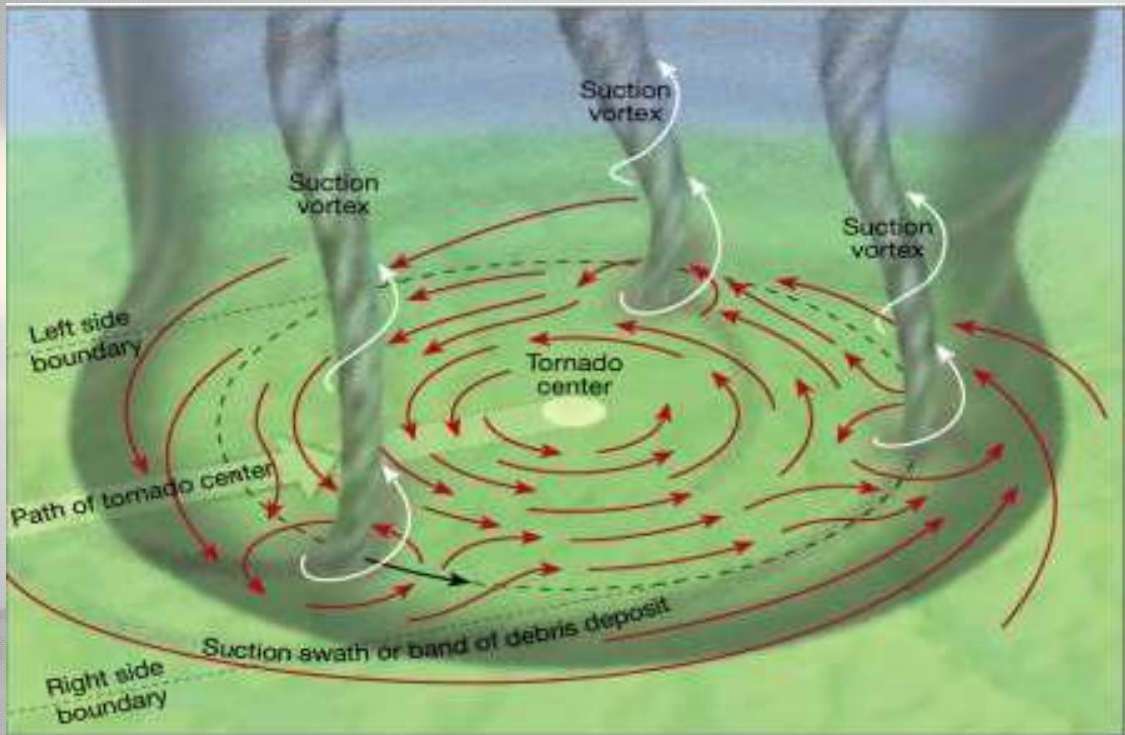


Tornado!



Suction Vortices

- Some tornadoes have multiple suction vortices
- Intense areas of high winds that are part of ONE tornado

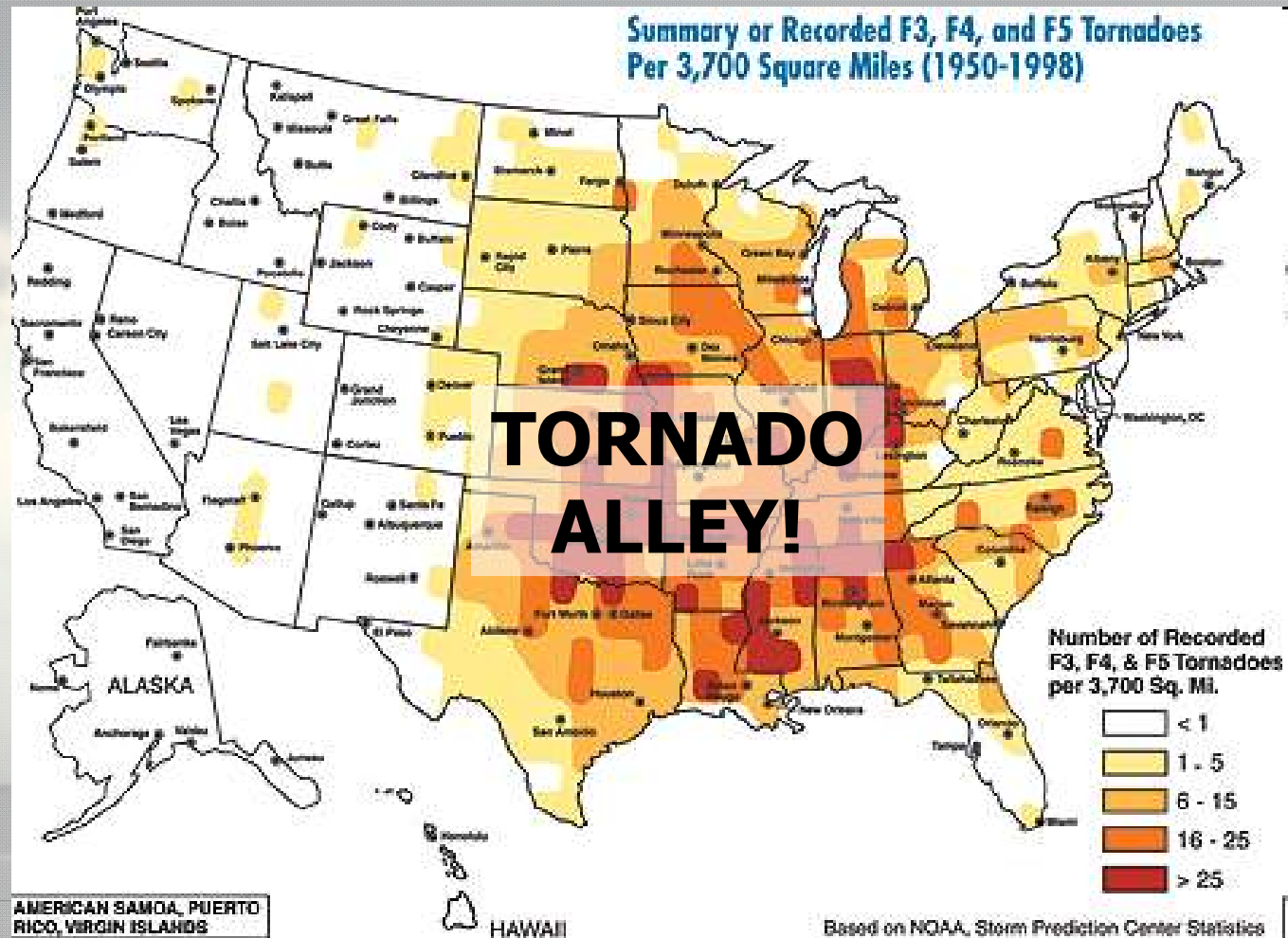


There can be 4-6 suction vortices.

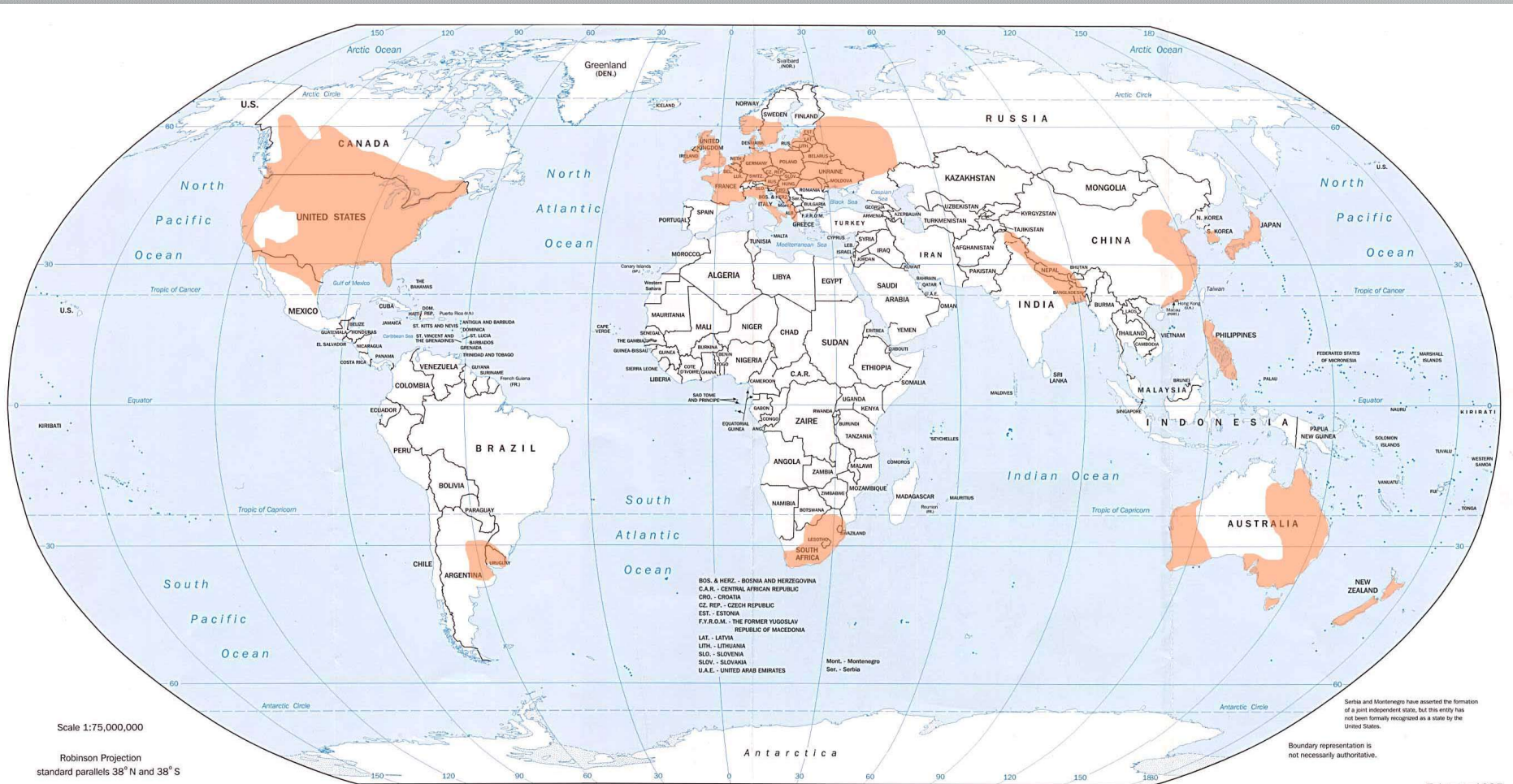
The stronger the tornado the more vortices you're likely to get.

Weak tornadoes usually don't have them

Tornado Occurrence on the Mainland



Global Tornado Distribution



Tornado Classification

- Tornadoes are classified as “weak,” “strong,” and “violent”
 - **WEAK** – usually rope like and narrow
 - **STRONG** – usually the classic funnel shape
 - **VIOLENT** – usually have lots of debris associated with them and can be quite dark in color.



Fujita and Enhanced Fujita Scale

- **Scale for Damage caused by tornadoes**

- Wind Speed
- Amount and Type of damage






Timber driven by a tornado into a large tree

- **There are two scales used:**

- Fujita Scale (F)
- Enhanced Fujita Scale (EF)

Fujita Scale		Enhanced Fujita Scale* <small>* In use since 2007</small>	
F-0	40–72 mph winds	EF-0	65–85 mph winds
F-1	73–112 mph	EF-1	86–110 mph
F-2	113–157 mph	EF-2	111–135 mph
F-3	158–206 mph	EF-3	136–165 mph
F-4	207–260 mph	EF-4	166–200 mph
F-5	261–318 mph	EF-5	>200 mph

EF Rating	Wind Speeds	Expected Damage	
EF-0	65-85 mph	<p>'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.</p>	
EF-1	86-110 mph	<p>'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.</p>	
EF-2	111-135 mph	<p>'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.</p>	
EF-3	136-165 mph	<p>'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.</p>	
EF-4	166-200 mph	<p>'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.</p>	
EF-5	> 200 mph	<p>'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.</p>	

Tornado in Kapolei in 2009



Funnel Cloud in 2011 over Central Oahu



Hawaii Tornadoes

- **Hawaii ranks 48th in tornado occurrence**
- Hawaii averages about **one per year**.
- **40** confirmed tornadoes since 1950.
- None of these tornadoes have caused loss of life and none exceeded **F2 intensity**.

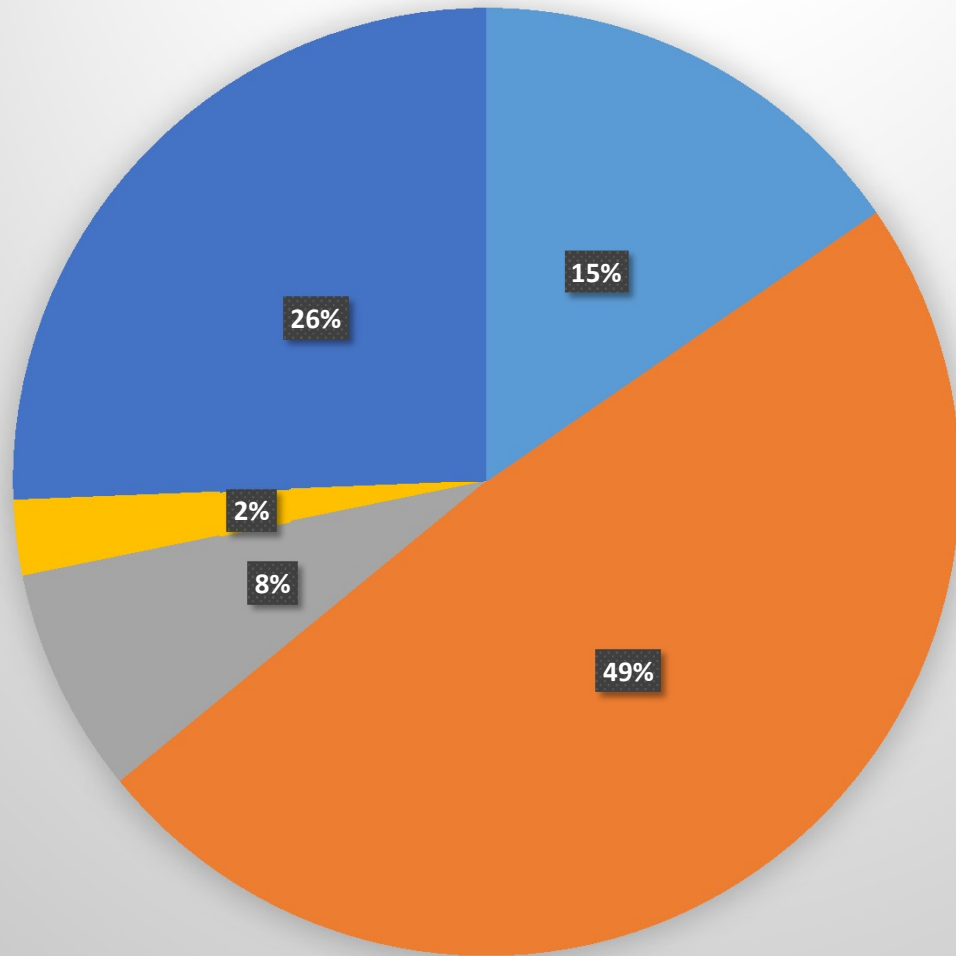
Hawaiian Tornado - 2011



Hawaii Tornadoes

Date	Intensity	Description
Mar 24, 2002	F0	tornado touched down in Anahola, Kauai . The tornado first formed in the Anahola Valley and skipped along a 1 mile (1.6 km) path, ending in Moloaa Valley. Along the track, several sheds were destroyed, numerous trees were snapped and six homes sustained roof and wall damage. Damages from the tornado amounted to \$60,000.
Jun 7, 2003	F0	tornado touched down roughly 3 miles (4.8 km) northeast of Mililani, Honolulu . A meteorologist from the National Weather Service spotted the tornado and reported that it was tracking towards Pearl City; however, the tornado dissipated before causing any damage.
Jan 25, 2004	F0	tornado touched down roughly 3 miles (4.8 km) northwest of Waipahu, Honolulu ; no damage was reported in relation to the tornado.
Feb 7, 2004	F0	tornado touched down roughly 3 miles (4.8 km) east of Aiea, Honolulu ; no damage was reported in relation to the tornado.
Feb 27, 2004	F0	tornado tracked for 5 miles (8.0 km), starting roughly 2 miles (3.2 km) southeast of Pahala, Hawaii . No structural damage occurred along the path; however, numerous trees were downed and several power poles were snapped.
Jan 8, 2005	F0	tornado touched down in Waimea, Kauai and tracked east for 5 miles (8.0 km). Along the tornado's path, a carport was damaged and numerous trees were downed.
Dec 4, 2005	F0	tornado touched down in Aiea, Honolulu , downing several trees and damaging the roof of a home. One tree also fell on a truck.
Mar 23, 2006	F0	tornado touched down in Kaumalapau Harbor, Maui . The tornado flipped over a construction trailer and carried it for about ten feet, damaged an adjacent small building, and snapped a power pole.
Mar 25, 2006	F0	tornado touched down roughly 2 miles (3.2 km) west of Haiku, Maui . No damage was reported in relation to it.
Sep 23, 2008	EFO	tornado touched down about 1 mile (1.6 km) northeast of Lanai Airport on Lanai . No damage was reported in relation to it.
Dec 13, 2008	EFO	tornado touched down in Pakala Village, Kauai , causing only minor crop damage.
Feb 11, 2009	EF1, EFO	Two tornadoes touched down on Oahu in Hawaii . At 12:50 pm local time, the first tornado touched down near a quarry, damaging nearby buildings. The tornado moved through a golf course next, throwing a utility cart about 50 to 60 ft. The tornado lifted at 1:10 pm, 20 minutes after it touched down. Numerous trees were damaged throughout the tornado's mile long path. Following an assessment by the National Weather Service, the tornado was rated as an EF1. During the assessment of the tornado, another weaker tornado was discovered to the northeast. The tornado touched down in a construction site and damaged dust barriers. The second tornado was on the ground for about ten minutes and traveled less than half a mile. The National Weather Service rated the tornado as a low-end EFO.
May 2, 2011	WS	During a massive thunderstorm, twin waterspouts appeared off the southeast coast of O'ahu at 5:50pm, moving slowly westward and dissipating after about 12 minutes.
Mar 9, 2012	WS, EFO	A tornadic waterspout associated with a supercell thunderstorm moved ashore on Lanikai Beach, Oahu at 7:10 AM. The tornado, rated an EF-0, tracked inland for 1.5 miles, reaching the Enchanted Lakes subdivision of Kailua.

Tornadoes by Island Since 1950



- Kauai
- Oahu
- Maui
- Lanai
- Hawaii