Module 11 - Lecture 32

The spring 2011 tornado season has been particularly destructive and deadly. In this lecture we will look how tornados cause damage and introduce the Fujita Scale, which is used to rate tornado strength and intensity.

It is very hard to actually measure the speed of the rotating winds in a tornado. Researchers usually survey the damage caused by the tornado and assign a Fujita Scale (http://en.wikipedia.org/wiki/Fujita_scale) rating. The original 1971 scale has recently been revised because the estimated wind speeds were probably too high. The Enhanced Fujita Scale (http://en.wikipedia.org/wiki/Enhanced_Fujita_Scale) (EF) became operational in 2007. The chart below compares the two scales.

Fujita Scale	Winds (MPH)	Enhanced Fujita Scale	Winds (MPH)	
F0	40-72	EF 0	65-85	74% of all tornadoes
F1	73-112	EF 1	86-110	4% of tornado deaths
F2	113-157	EF 2	111-135	
F3	158-206	EF 3	136-165	
F4	207-260	EF 4	165-200	~1% of all tornadoes
F5	261-318	EF 5	> 200	67% of tornado deaths
F6	319-379			

Roughly three fourths of all tornadoes are assigned to the EF0 or EF1 categories and have winds that are less than 100 miles per hour. EF4 and EF5 tornadoes are rare but cause the majority of tornado deaths. The original Fujita Scale actually goes up to F12, which has winds with a speed of 740 miles per hour or the speed of sound.

The Enhanced Fujita Scale considers 28 different "damage indicators", which are the types of structures and vegetation that could be damaged by a tornado. The table below gives some examples.

Damage Indicator	Description
2	1 or 2 family residential home
3	Mobile home (single wide)
10	Strip mall
13	Automobile showroom
22	Service station canopy
26	Free standing light pole
27	Tree (softwood)

For each damage indicator, there is a standardized list of "degrees of damage" that an investigator uses to estimate the intensity of the tornado. Here are the degrees of damage for a single family home or duplex. You will find the entire set of damage indicators and lists of degrees of damage here (http://www.spc.noaa.gov/faq/tornado/ef-scale.html).

Degree of Damage	Description	Approximate wind speed (MPH)
1	Visible damage	65
2	Loss of roof covering material	80
3	Broken glass in doors and windows	95
4	Lifting of roof deck, loss of more than 20% of roof material, collapse of chimney, garage doors collapse inward, destruction of porch roof or carport	100
5	House slides off foundation	120
6	Large sections of roof removed, most walls still standing	120
7	Exterior walls collapse (top story)	130
8	Most interior walls collapse (top story)	150
9	Most walls in bottom floor collapse except small interior rooms	150
10	Total destruction of entire building	170

The photos below show examples of damage caused by EF2, EF4, and EF5 tornadoes.

EF2 Damage: roof is gone, but all walls still standing

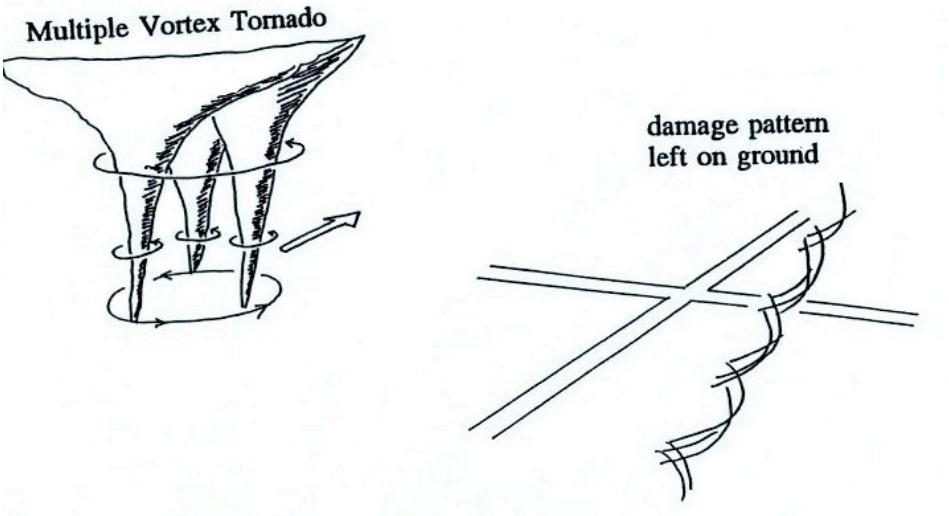
EF4 Damage: only the strong reinforced concrete basement walls are left standing

EF5 Damage: complete destruction of the structure

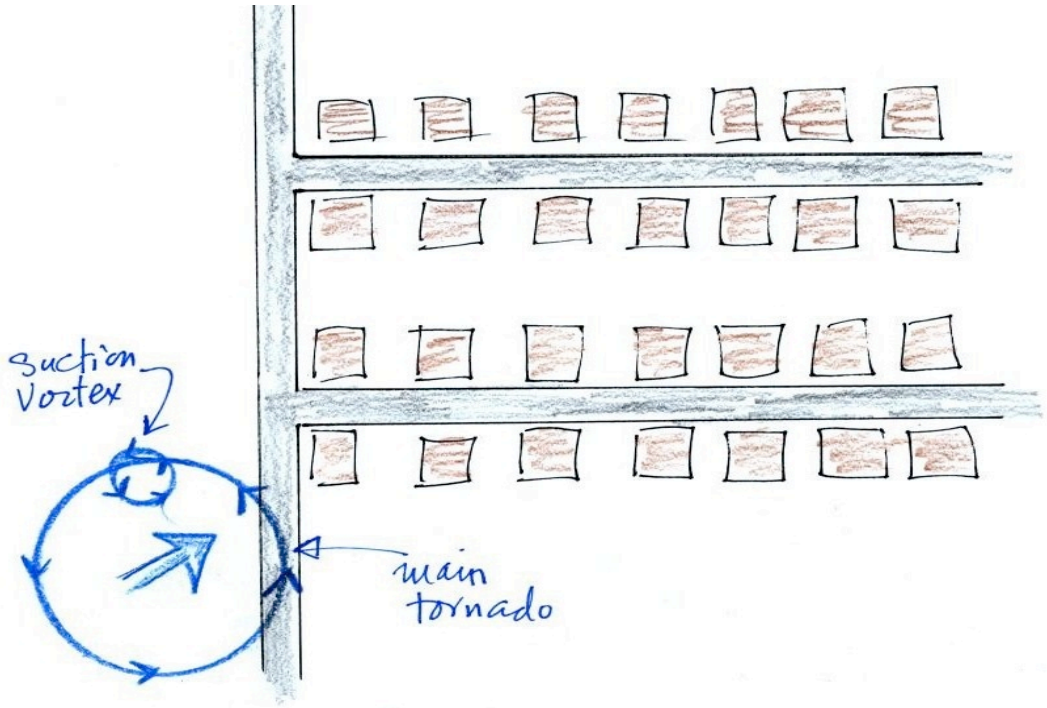
Several levels of damage (EF1 to about EF3) are visible in the Red Cross photograph below. It seems puzzling why some homes were nearly destroyed while nearby homes were only slightly damaged.

LESS THAN ONE IN EIGHT tornadoes ever reach F-3 intensity, so a well constructed home provides a lot of life-saving protection... if you know in advance where the safest places are. A suction vortex may form at F-3, so complete home destruction may occur next to minor damage.

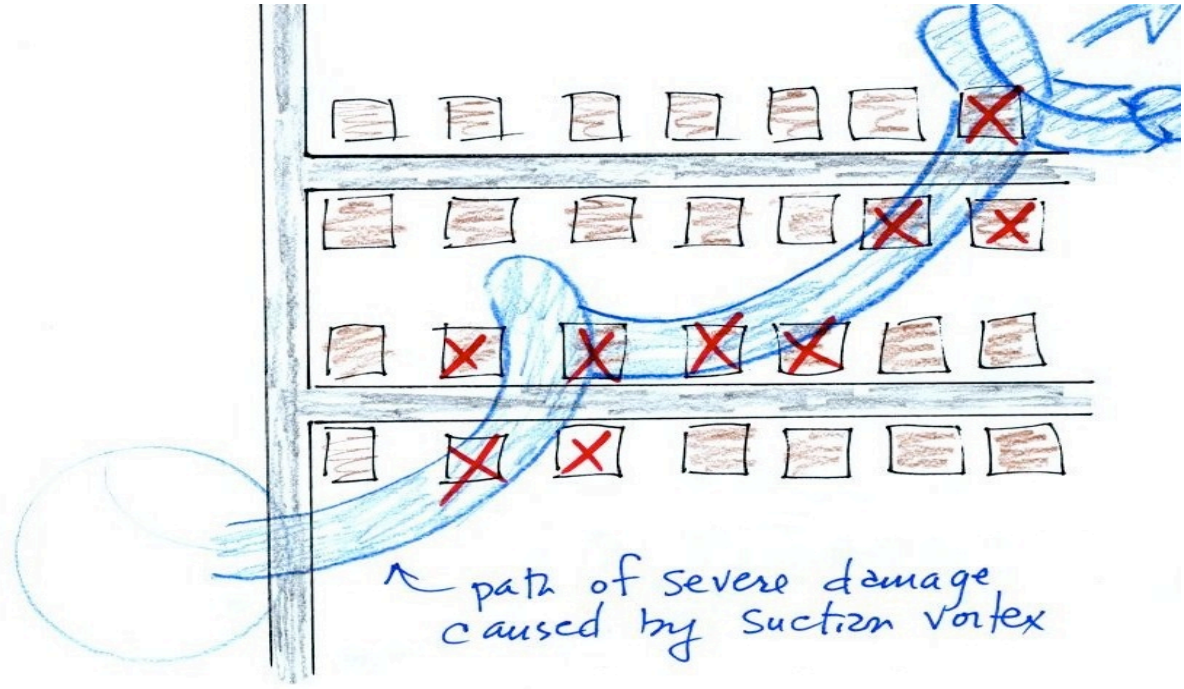
A possible explanation is illustrated below. Some large, strong tornadoes may have smaller more intense "suction vortices" that spin around the center of the tornado. Tornado researchers have actually seen the pattern shown at right scratched into the ground by the multiple vortices in a strong tornado.



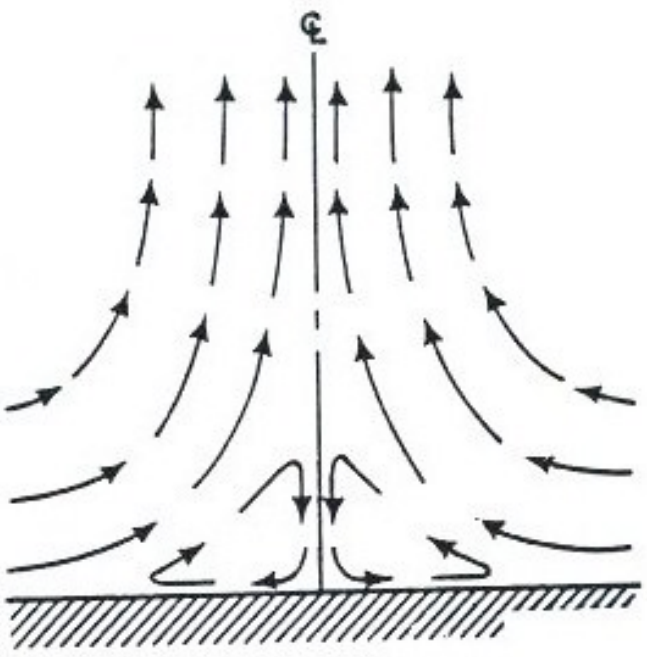
The sketch below shows a tornado located southwest of a neighborhood. As the tornado sweeps through the neighborhood, the suction vortex will rotate around the core of the tornado.



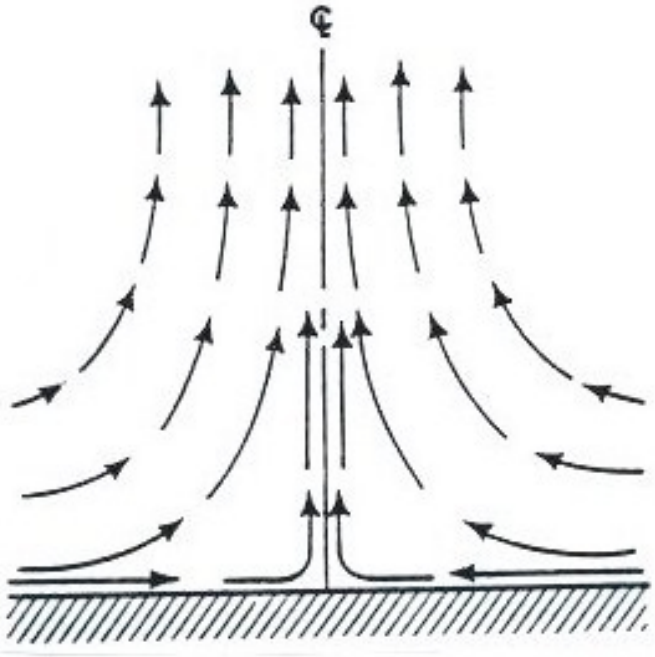
The homes marked with red will be damaged severely while the other homes will receive less damage. Remember that there are multiple suction vortices in the tornado and the tornado diameter is probably larger than shown here.



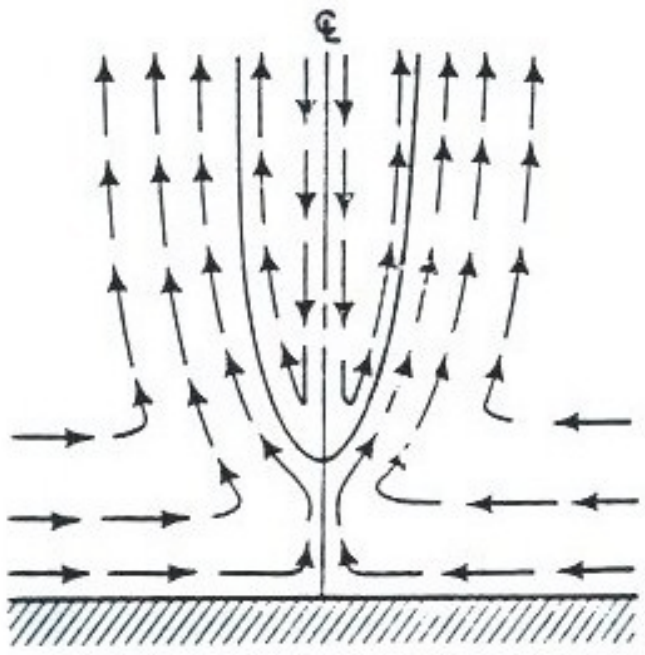
Because the air motions inside tornadoes are complex and difficult to study directly, researchers resort to laboratory simulations and computer models. The figures below show some of the air motions thought to occur inside tornadoes. The first picture illustrates the wind motions inside a fairly weak tornado. The winds would be spinning in addition moving upward as shown here.



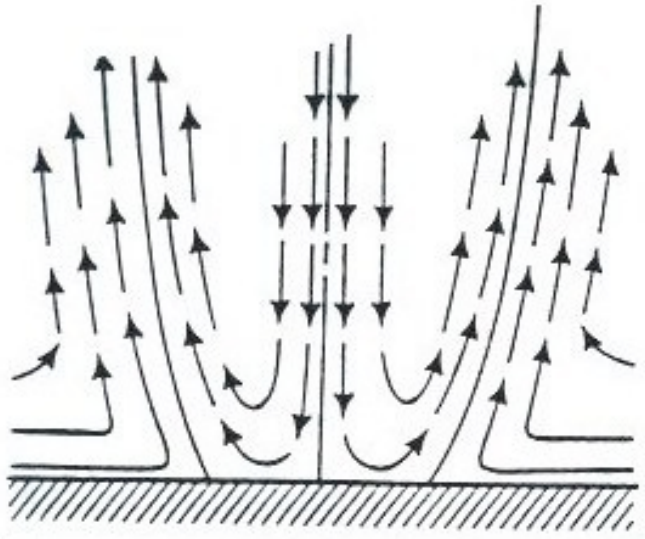
The tornado below is a little stronger.

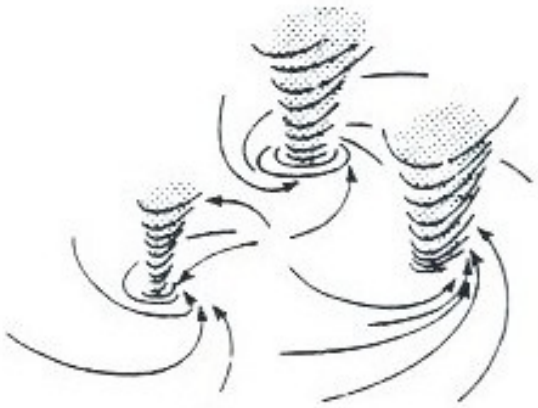


This tornado is even stronger. The air in the center has started to sink (this is called vortex breakdown), but the sinking air does not reach the ground. The diameter of the tornado has also grown.



It is when the sinking air in the middle reaches the ground that multiple vortices may form.





You will find a lot of tornado videos online. One that we often show in the classroom version of this course is a tornado that occurred in Pampa, Texas. Here are a couple of videos on YouTube: video 1 http://www.youtube.com/watch?v=_-PdZr2PAC0, video 2

http://www.youtube.com/watch?v=g6eF2TKI-PQ). Near the end of the segment, the video photography showed several vehicles (pickup trucks and a van) that had been lifted 100 feet or so off the ground and were being thrown around at 80 or 90 miles per hour. Winds speeds of about 250 miles per hour were estimated from the video photography. The wind speeds were measured above the ground and may not have extended all the way to the ground.