



MET 4300

Lecture 24
Tornadoes III (CH19)

Outline

- Definition, life cycle, & climatology of tornadoes
- Tornado formation within supercells
- Tornado formation within non-supercell thunderstorms
- **Fujita scale**
- tornado statistics
- Historic cases
- Tornado detection, forecasting, and safety

Tornado Intensity Categories

- Can NOT be determined by observing it or using radar. It can only be determined by a damage survey after the fact.
- Fujita developed the Fujita scale (F-scale) in 1971.
- F-scale served as a measure of tornado intensity from 1971-2007.

Theodore (Ted) Fujita



- Studied aftermath of Nagasaki bombing for Japan
- Brought to US (U. of Chicago) by H. Byers in 1950s
- Developed
 - Compiled an archive of 31054 tornados 1916-1985
 - Concept of Tornado Families
 - Terminology of supercells
 - Fujita scale ...
 - Means to distinguish tornadic from non-tornadic winds
 - Concept of downbursts and microbursts

Fujita Scale For Tornadoes (1971-2007)

#	Wind	Description
0	< 73 mph < 33 m/s	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged
1	73-112 mph 33-50 m/s	Moderate damage. The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
2	113-157 mph 50-70 m/s	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated.
3	158-206 mph 71-92 m/s	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
4	207-260 mph 93-116 m/s	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
5	261-318 mph 117-142 m/s	Incredible damage. Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 m (100 yd); trees debarked; steel reinforced concrete structures badly damaged.

Replaced by Extended Fujita Scale Using 3-s GUST

Weaknesses of the F-scale

- Overestimate the winds in the more violent tornadoes
- Damage assessment guidelines were not detailed

Enhanced Fujita (EF) Scale

- To more accurately rate the damage and winds
- All EF scales match with the old F-scales correspondingly
- Effective on Feb 2007

EF-Scale Wind Speed Ranges and corresponding wind speeds from the Fujita scale

Fujita Scale	3-second gust speed (mph)	Operational Enhanced Fujita Scale	3 Second Gust Speed (mph)
F0	45-78	EF0	65-85
F1	79-117	EF1	86-110
F2	118-161	EF2	111-135
F3	162-209	EF3	136-165
F4	210-261	EF4	166-200
F5	262-317	EF5	> 200

Damage indicators & damage table

- **28 Damage Indicators:** Table 19.2 gives 28 types of structures that storm surveyors typically encounter
- Each of these structures has a separate **damage table** similar to Table 19.3 (an example for one to two-family residence)
- For example, if a damage assessor found a house with its exterior wall collapsed but interior walls still standing, **what is the EF scale?**

Table 19.2 Damage Indicators for establishing EF-Scale ratings

For the structures listed below, damage assessors use detailed tables that describe the degree of damage, together with example photographs from damaged structures to establish the likely wind speed and EF scale rating for a tornado

No.	Damage Indicator
1	Small Barns or Farm Outbuildings
2	One or Two Family Residences
3	Manufactured Home – Single Wide
4	Manufactured Home – Double Wide
5	Apartments, Condos, Townhouses
6	Motel
7	Masonry Apartment or Motel
8	Small Retail Building
9	Small Professional Building
10	Strip Mall
11	Large Shopping Mall
12	Large Isolated Retail Building
13	Automobile Showroom
14	Automobile Service Building
15	Elementary School
16	Junior or Senior High School
17	Low-Rise Building (1-4 stories)
18	Mid-Rise Building (5-20 stories)

No.	Damage Indicator
19	High-Rise Building (> 20 stories)
20	Institutional Building
21	Metal Building System
22	Service Station Canopy
23	Warehouse Building
24	Electrical Transmission Lines
25	Free Standing Towers
26	Free Standing Light Poles, Luminary Poles, Flag Poles
27	Trees (Hardwood)
28	Trees (Softwood)

Estimating the EF scale rating from damage to a one or two family residence (Indicator 2 in Table 19.2)

Degree of Damage	Damage Description	EXPECTED WIND SPEED (mph)	LOWEST WIND SPEED (mph)	HIGHEST WIND SPEED (mph)
1	Threshold of visible damage	65	53	80
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79	63	97
3	Broken glass in doors and windows	96	79	114
4	Uplift of roof deck and loss of significant roof covering material (> 20%); collapse of chimney, garage doors collapse inward, failure of porch or carport	97	81	116
5	Entire house shifts off foundation	121	103	141
6	Large sections of roof structure removed; most walls remain standing	122	104	142
7	Exterior walls collapsed	132	113	153
8	Most walls collapsed, except small interior rooms	152	127	178
9	All walls collapsed	170	142	198
10	Destruction of engineered and/or well constructed residence, slab swept clean	200	165	220

F0: 40-72 mph



EF0: 65-85 mph 3-s Gust

F1: 73-112 mph



EF1: 86-110 mph 3-s Gust

F2: 113-157 mph

Photo courtesy NWS Memphis



EF2: 111-135 mph 3-s Gust

F3: 158-206 mph



NWS photo by Mike Branick

EF3: 136-165 mph 3-s Gust

F4: 207-260 mph

NWS photo by Mike Branick



EF4: 166-200 mph 3-s Gust

F5: 261-318 mph



EF5: > 200 mph 3-s Gust

Summary

- Type I Tornadoes form in supercells through 3 steps: formation of mid-level mesocyclone, formation of low-level mesocyclone, and rotation reaching the ground
 - 1) the 3rd step has 3 mechanisms: top-down, bottom-up, and vortex breakdown
 - 2) vorticity tilting and stretching are important in tornadogenesis
- Tornado family: Succession of tornadoes in the same supercell (distinct from Outbreaks)
- Type II Tornadoes form by stretching shear along outflow boundaries
- Fujita—Tornado pioneer
- Enhanced Fujita Scale introduced Feb 2007, based upon 3-s gust
 - EF0: Light damage, Branches broken off trees (65-85 mph)
 - EF1: Moderate damage, Shingles lost from roofs (86-110 mph)
 - EF2: Considerable damage, Roofs torn off frame houses (111-135 mph)
 - EF3: Severe Damage, Roofs and some walls torn off well-constructed house, cars thrown (136-165 mph)
 - EF4: Devastating damage, Well-constructed houses leveled (166-200 mph)
 - EF5: Incredible damage, Reinforced concrete structures badly damaged, trees debarked (> 200 mph)