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## The Enhanced Fujita Tornado Scale



Wind speeds in tornadoes range from values below that of weak hurricane speeds to more than 300 miles per hour! Unlike hurricanes, which produce wind speeds of generally lesser values over relatively widespread areas (when compared to tornadoes), the maximum winds in tornadoes are often confined to extremely small areas and can vary tremendously over very short distances, even within the funnel itself. The tales of complete destruction of one house next to one that is totally undamaged are true and well-documented.

### *The Original Fujita Tornado Scale*

In 1971, Dr. T. Theodore Fujita of the University of Chicago devised a six-category scale to classify U.S. tornadoes into six damage categories, called Fo-F5. Fo describes the weakest tornadoes and F5 describes only the most destructive tornadoes. The Fujita tornado scale (or the "F-scale") has subsequently become the definitive scale for estimating wind speeds within tornadoes based upon the damage caused by the tornado. It is used extensively by the National Weather Service in investigating tornadoes, by scientists studying the behavior and climatology of tornadoes, and by engineers correlating damage to different types of structures with different estimated tornado wind speeds.

The original Fujita scale bridges the gap between the Beaufort Wind Speed Scale and Mach numbers (ratio of the speed of an object to the speed of sound) by connecting Beaufort Force 12 with Mach 1 in twelve steps. The equation relating the wind velocities (V in mph) with the F scale (F) is  $V = 14.1 * (F+2)^{1.5}$ .

F1 on the original Fujita scale is equal to B12 (73 mph) on the Beaufort scale, which is the minimum wind speed required to upgrade a tropical storm to a hurricane. F12 on the Fujita scale is equal to M1 (738 mph) on the Mach scale. Although the Fujita scale itself ranges up to F12, the strongest possible tornadoes are in the F5 range (originally estimated to be between 261 to 318 mph).

### ***The Enhanced Fujita Tornado Scale***

The devastating tornadoes in Jarrell, TX on 27 May 1997 and Moore/Oklahoma City on 3 May 1999 demonstrated to many engineers, emergency managers and meteorologists that the wind estimates in the original F-scale may be too high. Their findings are described in the FEMA document #342: "Building Performance Assessment Team Report, Midwest Tornadoes of May 3, 1999, Observations, Recommendations and Technical Guidance", available at [the FEMA web site](#). For example, it is difficult to estimate wind speeds from structures designed to withstand 100 mph winds if it is struck by winds above 200 mph.

In addition to the limitations of weak structures in conveying strong tornado damage, the original Fujita scale has several other weaknesses:

- Rankings are subjective and based solely on the damage caused by a tornado
- Difficult to apply with no damage indicators (if a tornado hits no structures, large trees, etc.)
  - No account of construction quality and variability
    - Subject to biases of the surveyors
- No definitive correlation between damage and wind speed

From 2000-2004, the Wind Science and Engineering Research Center at Texas Tech University, in cooperation with numerous expert meteorologists, civil engineers and the [National Weather Service](#) (NWS), developed an [Enhanced Fujita scale](#), or EF-scale. In addition to improving the ranking process, it was essential to the development team that the new EF-scale support and be consistent with the original F-scale. The [EF-scale documentation](#) includes additional enhanced descriptions of damage to multiple types of structures and vegetation with photographs, a PC-based expert system, and enhanced training materials.

The EF-scale was unveiled by the NWS to the public and the full meteorological community early in 2006. On 1 February 2007, the Enhanced Fujita scale replaced the original Fujita scale in all tornado damage surveys in the United States. It is important to note that, despite the improvements, the EF-scale still remains a set of *wind estimates* based on 8 levels of damage to 28 different types of structures and vegetation.

Below is a table comparing the estimated winds in the original F-scale and the operational

EF-scale that is currently in use by the NWS.

### *The Enhanced Fujita Tornado Scale*

FUJITA SCALE			OPERATIONAL EF-SCALE	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85
1	73-112	79-117	1	86-110
2	113-157	118-161	2	111-135
3	158-207	162-209	3	136-165
4	208-260	210-261	4	166-200
5	261-318	262-317	5	Over 200

Fujita, T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci.*, **38**, 1511-1534.

For more information, please see the [original PDF report](#) by the Wind Science and Engineering Center at Texas Tech University or visit the [Storm Prediction Center](#).



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<http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/educational/fujita.html>

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