

Fine-Tuning Fujita

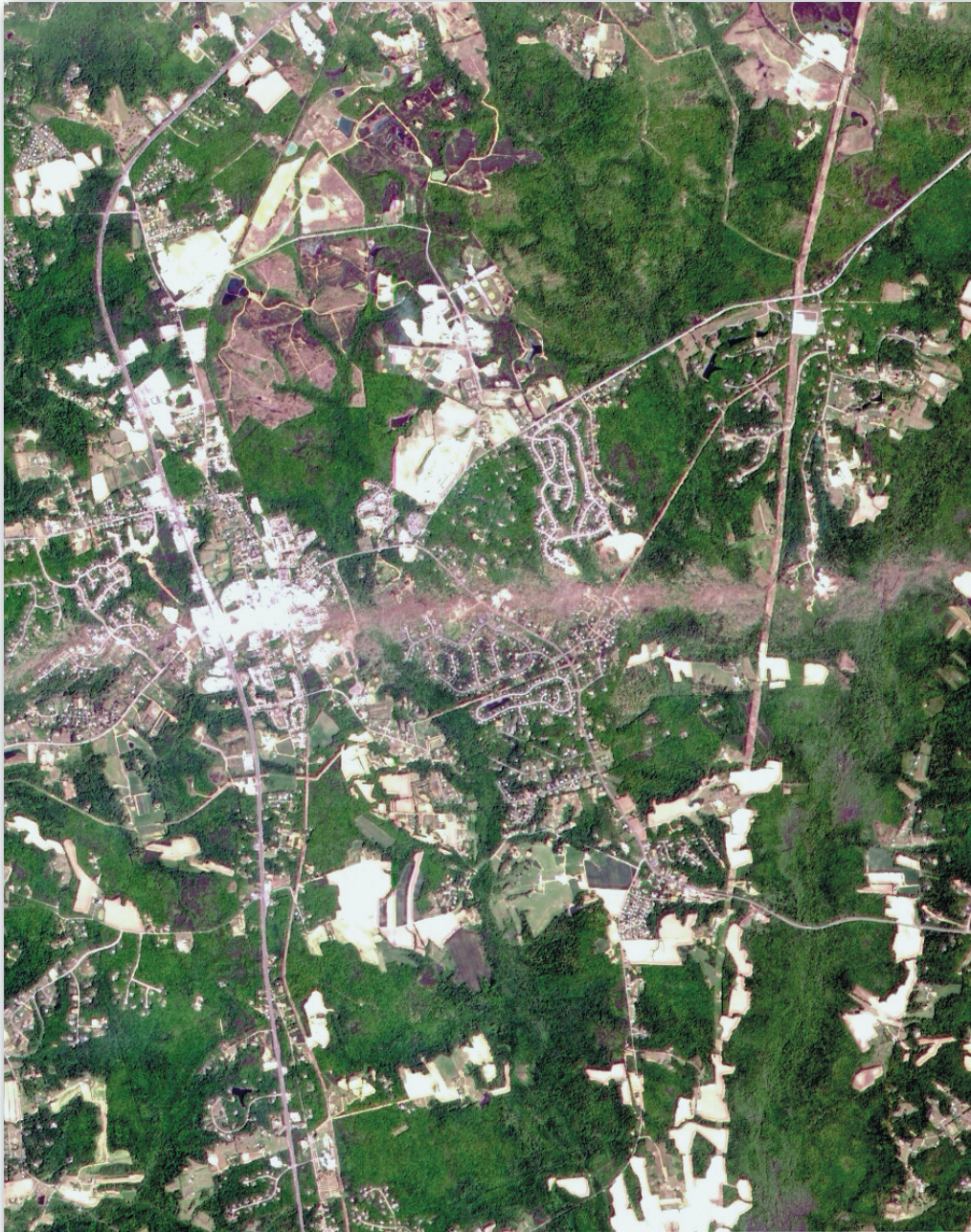
After 35 years, a new scale for rating tornadoes takes effect.

by Sean Potter



On the evening of April 28, 2002, a devastating tornado tore across southern Maryland, cutting a path of destruction 64 miles long, killing 3 people and injuring more than 100 others. As the tornado entered the town of La Plata, about 30 miles southeast of Washington, D.C., the powerful winds swirling around the storm's vortex of low pressure ripped the roofs off buildings and gas stations, blew houses off their foundations, and leveled the town's water tower. In downtown La Plata, where the damage was the worst, 65 percent of the buildings were either damaged or destroyed, including the red-brick United Methodist Church, whose wooden steeple lay on its side in the churchyard, separated from the rest of the building.





A satellite view of the path torn by the tornado that struck La Plata, Maryland, on April 28, 2002. The tornado destroyed La Plata's historic downtown and flattened everything in its path as it tore east for 24 miles. La Plata is on the left side of the photo.

Personnel from the Baltimore/Washington National Weather Service (NWS) office conducted an initial damage survey the following day. While they initially rated the tornado as an F4 on the Fujita Tornado Damage Scale (F-scale), they later increased their preliminary rating to an F5—the highest level on the scale—after surveying building damage just east of downtown. They based their findings on the fact that several homes were lifted off their foundations and a brick office building downtown was completely destroyed. Because of the severity and rarity of the event—only one other tornado with a rating of F4 or higher had been reported in Maryland since 1950—NWS dispatched a national “service assessment team” to the area on May 1 to conduct

a more thorough survey of the damage. After examining in detail the damage caused by the storm, the team determined that the damage initially rated as F5 by local officials was actually caused by somewhat weaker winds or, in the case of the brick office building, by flying debris from a nearby lumber yard.

“We found tremendous amounts of what I call ‘fatal flaws,’ in the building construction,” said Tim Marshall, a meteorologist and engineer with Haag Engineering Co., who was part of the national assessment team. “These homes were half-a-million, [or] million-dollar homes and they’re simply not anchored.” Marshall explained that the fact that mailboxes, shrubs, and lampposts were still standing in areas where houses were completely destroyed provided investigators with clues about the true strength of the tornado’s winds. “So

rather than the winds being the difference in the damage, I was saying it’s just the way the houses were built and we all agreed to that.”

Based on this evidence, the assessment team subsequently lowered the tornado’s rating back to its original F4 status. Marshall said that even the F4 was a stretch, because F4 damage only occurred with one or two houses in downtown La Plata. “If it were solely up to me, it would be an F3,” he said. At a May 7, 2002, news conference John Ogren, meteorologist-in-charge of the NWS office in Indianapolis, Indiana, and leader of the La Plata assessment team, stressed that regardless of the final rating assigned, the storm was still devastating. “Because we’re bringing it from a 5 to a 4,” he said, “that’s nothing to sneeze at.”

The Need for a Change

The incident underscored what many in the research and operational meteorology communities have known for years—that the tornado scale first described by T. Theodore “Ted” Fujita in 1971, although valuable, was not without its shortcomings. In fact, the incident in La Plata was not the first time officials had struggled with the concept of assigning F-scale ratings to tornadoes. After a devastating tornado struck Jarrell, Texas, on May 27, 1997, virtually wiping an entire subdivision off the map, some structural engineers questioned its official F5 rating by the NWS, claiming that the poorly-constructed homes failed under winds below the F5 threshold. The most recent tornado to officially receive an F5 rating was one that struck the Oklahoma City suburb of Bridge Creek on May 3, 1999. Researchers using a mobile “Doppler on Wheels” radar measured wind speeds in the tornado at 318 mph (with a degree of error of about ± 9 mph), the upper limit of the F5 category on the Fujita scale. This led some to wonder if this or other tornadoes could be rated as F6, a category which Fujita considered to be “inconceivable.” Such complications raised the issue of just how precisely the Fujita scale classifies the damage caused by tornadoes, as pointed out in the preface to an April 2003 NWS publication titled *A Guide to F-Scale Damage Assessment*: “Recent tornado events have highlighted the need for a definitive F-scale assessment guide to assist our field personnel in conducting reliable post-storm damage assessments and determine the magnitude of extreme wind events.” In an acknowledgement of the F-scale’s limitations, the guide states that “the Fujita scale is under review by meteorologists and engineers, and its implied relationship between damage and wind speed is the object of considerable scrutiny. Alternative rating criteria are being reviewed, and it is likely that in the future a new scheme will be developed to replace the existing one.” That new scheme is the Enhanced Fujita scale (EF-scale), which the NWS officially put into effect on February 1 of this year.

The New Scale

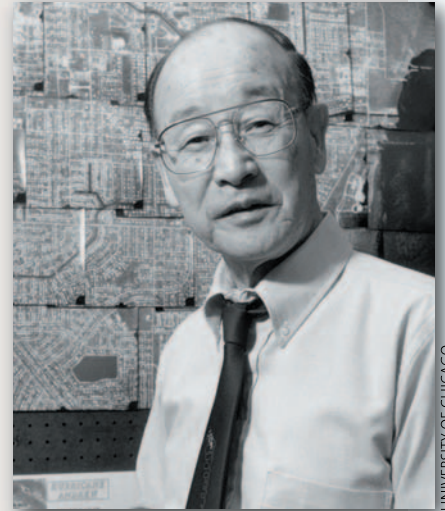
“After 35 years, the Fujita scale began to show its age,” said Joe Schaefer, director of the NOAA/NWS Storm Prediction Center. Schaefer served on the steering committee formed in 2000 by the Wind Science and Engineering (WISE) Research Center at Texas Tech University to oversee the development of the new scale. According to Schaefer, when Fujita designed the original F-scale in 1971, he based it on the type of damage that would be inflicted upon a well-constructed frame house. “Basically, the Enhanced Fujita scale is an attempt to come up with consistent evaluation criteria for things other than frame houses,” Schaefer explained.

A Matter of Scale: Tornado Rating in a Historical Context

When tornado researcher T. Theodore “Ted” Fujita proposed the now-famous tornado damage scale that bears his name in 1971, it was not the first attempt to devise a systematic means for classifying tornadoes. Efforts to create useful tornado scales date back to at least 1890, when Henry A. Hazen of the U.S. Signal Service (and later the Weather Bureau) devised a three-step scale based on the average dollar loss caused by tornadoes. In 1945, New Zealand scientist C.J. Seeyle developed a scale that rated tornadoes using three classes: Class 0, in which a funnel cloud is visible but there is little or no ground disturbance; Class 3, in which outbuildings, verandas, and roofs are carried away; and Class 5, which results in the destruction of well-constructed buildings. More recently, in 1975, British researcher Terence Meaden developed the 11-step TORRO scale (named for the TORnado and Storm Research Organization, which he founded the previous year), which classifies tornadoes based on their wind speeds.

While Fujita designed his 12-step scale to “connect smoothly” the well-established Beaufort wind scale with Mach 1, the speed of sound, it does not provide a one-to-one correlation in terms of wind speeds and there is some overlap where the scales connect. Also, since only wind speeds associated with the lowest six steps on the F-scale (Fo-F5) are considered realistic, even for the most violent tornadoes, the entire scale cannot be used operationally to assign F-scale numbers to actual tornadoes. On its Web site (www.torro.org.uk), TORRO claims that based on these limitations, “If there had been a world scientific committee meeting at this time, Fujita’s non-rigorous and arbitrary handling of the matter would never have been accepted.” Nevertheless, Fujita’s scale soon became widely accepted by both the meteorological research and forecast communities, and the NWS began assigning F-scale ratings to tornadoes in 1972 on an experimental basis. The scale became fully operational several years later. Fujita and his colleagues also went through the historical database of past tornadoes—as far back as 1916—to assign F-scale ratings based on accounts or photographs of the damage they caused.

The F-scale also gained popularity with engineers, who relied on it in design studies as a way to correlate tornado wind speeds and damage potential. In fact, it is the F-scale’s reliance on damage in assigning ratings to tornadoes that sets it apart from the TORRO scale. For this reason, F-scale (or now EF-scale) ratings are only assigned after a tornado has caused damage, which can then be surveyed. It is, therefore, improper to “rate” a tornado using the F-scale (or EF-scale) while it is in progress, as is sometimes done in the broadcast media or in storm chaser videos.



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The Enhanced Fujita scale begins with 28 damage indicators (DIs), which represent various types of structures or items that may be damaged by a tornado's winds. These include items such as small barn, a double-wide manufactured home, a strip mall, or a hardwood tree. Associated with each DI are several degrees of damage (DODs), which might range from loss of shingles to total destruction of the building. For each combination of DI and DOD, a range of probable wind speeds is given, which allows for the identification of the appropriate category (EF0-EF5) on the scale.

As part of the development process of the new EF-scale, the WISE Center at Texas Tech organized a "Fujita Scale Forum" in 2001 to identify issues related to the original F-scale and to make recommendations for either a new scale or a modified version of the existing scale. The forum brought together users of the Fujita scale from the government, academic, and private sectors.

Marshall, the engineer who was part of the La Plata assessment team, was one of about two dozen experts who participated in the forum. He was also one of six experts who helped define the DIs, DODs, and associated wind speeds used in the EF-scale. "The six of us were actually coming up with wind speeds to fit the damages to various types of buildings and other objects, including trees," he said. Marshall further explained that while wind speeds at the lower end of the scale did not require much revision, those at the higher end did because those wind speeds represent the values at which

buildings and other structures are destroyed. Often, Marshall pointed out, the damage caused by tornadoes rated as F4 or F5 result in an overestimation of wind speeds. For example, although wind speeds of 300 mph might have occurred in a tornado, it might have only required winds of 200 mph to destroy houses in the storm's path. "That's partly why engineering is so important in this Enhanced Fujita scale," he said. "Because it brings a sense of the wind speeds and what those could actually do as far as the damage is concerned."

However, not everyone feels that the change is necessary. Tom Grazulis, director of The Tornado Project and author of *The Tornado: Nature's Ultimate Windstorm and Significant Tornadoes 1680-1991: A Chronology and Analysis of Events*, feels that the original F-scale served its purpose well. "The Fujita scale has worked, and I didn't think it necessarily needed to be changed," said Grazulis, who also served on the panel of experts at the Fujita Scale Forum. "I think the modified idea was exactly what was needed," he said, referring to a suggestion Fujita himself had made in his memoirs. In his *Memoirs of an Effort to Unlock the Mystery of Severe Storms During the 50 Years, 1942-1992*, published in 1992 by the University of Chicago Press, Fujita proposed a modified version of his original scale that included variations based on different types of structural damage, much like the new EF-scale uses.

Schaefer and Marshall argue that the EF-scale is essentially a modification of Fujita's original design. "We're tuning the scale; we're really not



NOAA

This home in La Plata, Maryland, was swept off its foundation after a tornado on April 28, 2002, devastated the town.



The 2002 tornado that destroyed this home in La Plata, Maryland, cut a path of destruction 64 miles long, killed 3 people, and injured 100.

changing the scale,” said Schaefer. “You’ve got to remember the original scale was only accurate to a plus or a minus one,” he cautioned. “So an F5 could’ve been an F4 or an F4 could’ve either been an F3 or an F5.”

“This is really our first attempt to calibrate the damages,” noted Marshall. “That’s what this whole EF-scale does—it calibrates the F-scale.”

How it Works

A summary report of the “Fujita Scale Forum” lists four basic flaws inherent in the original F-scale, namely that it fails to account for variations in the quality of construction; it is difficult to apply consistently; it does not yield accurate assessments when there are no DIs; and it is not based on a correlation of damage descriptions and wind speeds.

The EF-scale addresses the first issue through its 28 DIs and subsequent DODs. Each DOD within a particular DI category is assigned a range of wind speeds capable of producing that kind of damage. This range of wind speeds acts as a sliding scale that allows survey teams to account for faulty construction, deteriorating materials, or other circumstances that would result in damages occurring at wind speeds lower than what would be expected for typical construction. For example, if a single-family home were damaged by a tornado, the damage would be evaluated based on the DI for one- or two-family residences. There are 10 DODs for this DI, ranging

from “threshold of visible damage” to “total destruction of entire building.” DOD number six indicates “large sections of roof structure removed, but most walls remain standing.” The expected wind speed required to cause this type of damage to a home of typical construction is 122 mph. The range of wind speeds listed, however, is 104-142 mph. Thus, if the home were found to be of substandard construction or to have rotting wood where the roof connects to the walls, the surveyor could infer that the damage most likely was caused by winds less than 122 mph but not less than 104 mph in strength. Similarly, if steps were taken to secure the home beyond what is considered typical—for example, through the use of hurricane clips—higher wind speeds would be required to inflict the same type of damage. In this case, these speeds would be estimated as being somewhere between 122 and 142 mph. Once the survey team has narrowed down a range of estimated wind speeds that likely caused the damage, they can assign the appropriate EF-scale rating to that damage. In the case of a single-family home of typical construction, the expected wind speed required to inflict the damage described in DOD number six, 122 mph, would result in a rating of EF2. Once the survey team has completed its evaluation of all the damage caused by a tornado, it assigns an overall EF-scale rating for the storm based on the highest level of damage observed. If the worst damage is found to be EF4, the tornado is assigned an EF4 rating.

Within days of officially implementing the EF-scale, NWS officials had their first opportunity to put it to use operationally after a series of devastating tornadoes ripped through central Florida on February 2, 2007, damaging or destroying at least 1,500 homes and killing 20 people. It was the second-largest death toll from a tornado outbreak in Florida's history. A preliminary storm survey conducted the following day by the NWS office in Melbourne, Florida, concluded that at least three tornadoes were responsible for the death and destruction. The survey team classified two of the tornadoes as EF3, based on the complete destruction of mobile homes, the debarking of large trees, and damage to structures where most walls collapsed except for those of interior rooms. Wind speeds were estimated as high as 165 mph. A third tornado, which uplifted roofs and collapsed chimneys and garage doors, was rated EF1, with estimated winds of 100-105 mph.

Consistency Rather Than Confusion

To better enable objective and consistent application of the criteria used in assigning EF-scale ratings, the NWS is developing specialized software that will run on a handheld computer, enabling evaluators in the field to go through a series of steps in order to arrive at an appropriate EF-scale rating. "The goal," explained Schaefer, "is that when we're done, people will be able to come out with a little handheld PDA and it will ask you questions about what you see, you type in the answers, and a decision tree will give you the final answer."

This type of consistency is what Grazulis, who has collected data on some 50,000 historic tornadoes in the United States, feels is lacking in the way F-scale ratings have been applied in the past.

"I think the whole fact that they're training people and there are training modules that they can use and there are all these different levels of destruction with lots of pictures—this, I think, will clearly bring more consistency." He added, "But you could have done that with the old Fujita scale. You didn't need a new Fujita scale to do that." Grazulis feels that inconsistency in how different states—or even NWS offices—assigned F-scale ratings using the original scale led to the push for the new scale. He also suggests that tornadoes that might have been erroneously rated as F5, such as the one that struck Jarrell, Texas, in 1997, could create a "defeatist attitude" through their suggestion of extremely high wind speeds that aren't supported by engineering assessments of the damage. Although an F5 rating implies that a tornado's wind speeds might have exceeded 300 mph, Grazulis argues that the fact that "you can't build against 300-mph winds," might lead some contractors to construct houses in a way that makes them more vulnerable. "It's an excuse not to put special ties on the roof rafters or to properly anchor the foundation," he said. "There are people that just wanted the whole 300 mph idea out of the system. And they got it." Unlike the original F-scale, the EF-scale has no upper limit to the wind speed in its Category 5.

When word got out in May 1999 that researchers probing the Bridge Creek, Oklahoma, tornado had measured a wind speed of 318 mph—the upper limit for F5 on the original Fujita scale—it spawned a storm of media attention. A headline that ran in the *Tulsa World* two days after the tornado struck read, "Tornado may be fiercest on record." According to an online set of frequently asked questions maintained by NWS, this tornado was "probably not" the strongest or most violent ever. "There was confusion, and the press loves to hype this," said Grazulis. "So it was an effort, I think, to rein in the press, to get them out of the 300-mph mental thought process and also to get the F6 idea out of the press." This idea is supported by the report submitted by the Texas Tech group to the NWS recommending the EF-scale, which states, "Having no stated upper bound for EF5 will prevent the news media from always assuming the worst case scenario."

Marshall, who also surveyed the F5 tornadoes that struck Jarrell, Texas, and Bridge Creek, Oklahoma, said that putting an upper bound on the wind speeds associated with the scale is problematic, since most structures simply do not survive winds as high as 300 mph, making it difficult to pin down what the wind speeds actually were. "With the stronger tornadoes, we simply run out of data points," he explained. "Unless something survives in the path, we're not able to get an upper bound. What survives, to me, is just as important as what doesn't survive."

Category	Enhanced Fujita Scale	Fujita Scale
5	Over 200	262-317
4	166-200	210-261
3	136-165	162-209
2	111-135	118-161
1	86-110	79-117
0	65-85	45-78

Wind speeds are 3-second gusts in mph

SEAN POTTER

Another key concern that the developers of the EF-scale had was the preservation of the historical database of tornadoes that have already been rated using the original F-scale. "The driving thing was the desire not to destroy the past data," said Schaefer. "We've got a pretty good database going back to 1950." Although the NWS does not plan to re-evaluate past tornadoes using the EF-scale, a mathematical relationship was developed to correlate the wind speed values of the original F-scale to those of the EF-scale. This allows for a tornado to have the same rating on both scales. So a tornado that was rated F4 using the original scale would be equivalent to an EF4 on the new scale, although the associated wind speeds would be different.

Although wind speeds associated with the higher categories of the EF-scale are lower than they were for the original F-scale, this does not necessarily mean that there will be more EF3, EF4 and EF5 tornadoes reported in the future, since ratings are based on the damage that occurs, not on actual wind speeds (which are very rarely ever directly measured). "The wind speed changes are a reflection of the maturing of the discipline of wind engineering," Schaefer said. "We now have a better idea of the damaging potential of winds than we had back in the early 1970s when the F-scale was developed." Schaefer also said that the EF-scale uses 3-second wind gust values at a standard height of 10 meters, whereas the original F-scale relied on fastest 1/4 mile wind speeds with no standard reference height. "This is important when measurements from mobile Doppler radars are used as wind indicators," he said. "The observed wind must be modified to what would be observed at a standard height before it can be compared to the wind estimated by the EF-scale from damage."

An Evolving Scale

Another issue Grazulis has with the new scale is the fact that automobiles were left out of the list of DIs. "An automobile is pretty aerodynamic, and of all of the things that are out there, probably an automobile is the one that is the most predictable," he said. "We know that cars can be lifted off the ground at about 118 mph. I think it's disappointing that cars are not one of those indicators."

Schaefer points out that "there are many variables with vehicles" that make their use as DIs difficult. "Because cars are streamlined, the height of the car off the ground and relative direction of the wind as well as the speed come into play," he said. "Also, cars tip, roll, and if the brakes or parking gear is weak, can be pushed along. The feeling was that there are just too many unknowns for a simple answer."

Still, it's possible, if not probable, that future revisions to the EF-scale will take place. According



This house was damaged in a tornado near Whitehouse, Texas, on November 15, 1987. The damage would be rated EF1 on the Enhanced Fujita Scale.

to an online training module created by the NWS, "continued development of the EF-scale is likely," and more damage indicators can be added once the necessary research has been conducted. This might also allow for more accurate ratings of tornadoes that occur in open terrain, such as fields or prairies. Marshall acknowledges this as one of the main challenges that researchers will need to address in refining the EF-scale. "We have a lot of open country," he pointed out. "Big tornadoes traverse them, scour the ground, remove pavement, but yet they don't hit a house. So it's very difficult for us to come up with an actual number or a wind speed." According to Marshall, such problems mean that as the EF-scale evolves, it ultimately will incorporate various modifications and additions, including the use of cars as DIs. "Eventually we will have to include vehicles. We will have to include crops. We will have to include other things like that," he said. "This is not a perfect system by any means, and the EF-scale still has some problems." Schaefer noted. "Is it perfect?" he asked rhetorically. "No, but it's better than anything else we've got."

Grazulis, who said he feels the EF-scale represents "too big a change," called the original F-scale "one of the great educational tools ever invented in any science. It took this totally mysterious thing and gave it organization and gave it a focus of discussion. It was a wonderful contribution to meteorology." What the lasting effects of the Enhanced Fujita scale will be remains to be seen, but it is clear that enhanced or otherwise, Fujita's scale—along with his name—will remain linked to tornadoes for years to come. **W**

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