ICWE 16
August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering

Changes in tornado intensity ratings

Tanya M. Brown-Giammanco [1], Timothy P. Marshall [2], Samantha N. Krautwurst [3], Nicholas L. de Toledo [4], James G. LaDue [5,6], Marc L. Levitan [7]

[1]National Institute of Standards and Technology, Gaithersburg, United States, tanya.brown-giammanco@nist.gov
[2]Haag Engineering Co., Flower Mound, United States, tmarshall@haagglobal.com
[3]AECOM, Germantown, United States, samantha.krautwurst@aecom.com
[4]National Institute of Standards and Technology, Gaithersburg, United States, nicholas.detoledo@nist.gov
[5]National Institute of Standards and Technology, Gaithersburg, United States, james.ladue@nist.gov
[6]National Weather Service Warning Decision Training Division, Norman, United States, james.g.ladue@noaa.gov
[7]National Institute of Standards and Technology, Gaithersburg, United States, marc.levitan@nist.gov

SUMMARY: (10 pt)
From 1970-2007 the Fujita Scale (F-Scale), developed by Dr. Tetsuya Fujita (1971, 1973), was widely used to rate the intensity of tornadoes. The Enhanced Fujita Scale (EF-Scale) was introduced in 2006 (WSEC, 2006) and became widely used in the United States and elsewhere in 2007. While the EF-Scale brought many improvements, there were still wide variations in assigned EF-ratings in the US's Storm Data record (Edwards et al., 2013), and a revision was recommended (Kuligowski et al. 2014).

In 2015, the American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) and the American Meteorological Society (AMS) undertook an effort to develop a consensus standard for tornado wind speed estimation, which will officially standardize the EF-Scale, among other methods. This paper describes the proposed EF-Scale modifications in detail and provides an overview of, and comparison with, the recently-developed International Fujita (IF) Scale (IF-Scale Steering Group, 2018).

Keywords: Enhanced Fujita (EF-) Scale, tornado, damage

1. INTRODUCTION

1.1. Fujita Scale

Fujita (1971, 1973, 1981) developed the Fujita-Scale (or F-Scale) to rate wind damage to buildings caused by tornadoes, hurricanes, and straight-line winds and it became the benchmark to rate tornado damage in the United States and elsewhere and is still used today in parts of Europe.
It is a subjective, visual interpretation of the severity of damage, which assigns a numerical value ranging from 0 to 5 based on increasing severity of damage primarily to "well-constructed" or "strong" wood-framed houses. The F-Scale represents the "fastest 1/4-mile speed".

Engineering assessments of tornado damage by Minor et al. (1977) questioned the accuracy of the empirical F-Scale wind speeds, especially above 125 mph (56 m s-1). Grazulis (1993) noted that the single-paragraph descriptions of damage given by F-Scale were vague and limited in scope. Doswell and Burgess (1988) noted that building damage and tornado intensity are related but not correlated perfectly. Fujita (1992) recognized that residences were not homogeneously constructed, and he devised corrections to compensate for assigning F-Scale ratings. During their damage survey of the Jarrell, Texas tornado, Phan and Simiu (1998) determined that high-speed winds of longer duration resulted in greater damage to residences.

1.2. Enhanced Fujita Scale

Although the F-Scale had been used by NWS and the scientific community for several decades, the limitations led to inconsistent ratings and, in some cases, overestimations of tornado wind speeds. By contrast, if a tornado did not strike a building, it was not rated, leading to underestimates of tornado hazards. A steering committee was organized by researchers at Texas Tech University to re-examine the F-Scale, revise it where necessary, and attempt to develop a consensus between the meteorological and engineering communities (McDonald and Mehta, 2001; Mehta, 2013). There were no published studies where wind speed measurements were collected right at a damaged building. Thus, in development of the new scale, a panel of wind damage experts met in 2001 and assigned failure wind speed ranges to various "Degrees of Damage" (DoD) for 28 "Damage Indicators" (DIs) (Mehta, 2013), in a process, known as expert elicitation (SSHAC, 1997). The resulting Enhanced Fujita (EF-) Scale (WSEC, 2006) was based on a three-second gust, at 10 m above ground, in open, unobstructed terrain.

The 2006 EF-Scale addressed some of the major limitations of the original F-Scale, while at the same time preserved the same six damage categories, although with much lower wind speeds at the higher categories. It included various building types with failure wind speed ranges depending on the quality of building construction. However, while users of the 2006 EF-Scale can vary wind speeds within the lower bound (LB) and upper bound (UB) speeds for a given DI and DoD, there is no information on wind resistance characteristics to inform this decision-making.

Challenges still remain in rating the strength of tornadoes in open country when no damage occurs, and in addressing wind duration. Furthermore, the science behind the tree DIs in the 2006 EF-Scale was not well-developed, and wind speed estimates from tree DIs did not agree with those from building DIs (Blanchard, 2013). There have been specific requests for new DIs to be created, especially in rural areas where building DIs are not common, and adding additional guidance, including example DoD photographs (Kuligowski et al. 2014).

2. RECENT EFFORTS TO CREATE UPDATED RATING SCALES

Many countries adopted the EF-Scale when it was introduced, while others continued using the F-Scale. In 2013, Canada introduced a version of the EF-Scale with minor revisions to better suit the Canadian context (Environment Canada, 2013). In 2015, Japan introduced the Japanese EF-Scale to better account for their buildings and structure types (JMA, 2015). Two additional efforts for revised ratings rating scales are currently underway.

2.1. Development of an ASCE/SEI/AMS Wind Speed Estimation Standard

In 2010, an informal stakeholders' meeting of EF-Scale users and parties was organized in Norman, OK (Edwards et al. 2013). By 2015, many of the original participants and others undertook an effort to develop an American Society of Civil Engineers/Structural Engineering Institute/American Meteorological Society (ASCE/SEI/AMS) consensus standard for tornado wind speed estimation. The forthcoming ASCE/SEI/AMS Wind Speed Estimation standard will officially standardize the EF-Scale and other methods and provide a consensus process whereby changes can be implemented in future versions. The standard committee includes a subcommittee on international wind speed estimation techniques, and the leaders of the subcommittee released a report to the International Association of Wind Engineers in 2017 (Kopp et al., 2017).

The EF-Scale chapter will preserve the 2006 EF-Scale numbers 0 through 5. It will be limited to tornado-caused damage, and introduce the concept of wind "resistance" of a DI, ranging from "weaker-than-typical" to "typical" to "stronger-than-typical" resistance. The standard will include an extensive commentary, additional photographs, and references for each DI. DIs which contain similar systems and components will have the same failure wind speeds for similar DoDs across DIs. Damage descriptions in the new standard will include 25% increments of damage to key building components and estimated failure wind speeds will be rounded to the nearest 5 mph in the new standard, to convey the lack of precision. A variance of 20% or greater in the expected failure wind speeds is also included, and a coverage probability for the wind speeds will likely be introduced.

Additionally, some DIs will be merged. The tree DIs from the 2006 EF-Scale will be changed from hardwood and softwood trees to single and multiple trees in the new standard, addressing variability in tree type and maturity, soil conditions, etc. Since many tornadoes occur in rural areas with no buildings, new DIs for Center Pivot Irrigation Systems (CPIS), Wind Turbines (WT), Farm Silos and Grain Bins (FSGB), and Passenger Vehicles (PV) will be included in the new standard. Churches will be included as Religious Buildings (RB) and Classic Architecture Religious Buildings (CARB). Residences will be split into wood-frame (WFR) and concrete block stucco (CBS) construction. Many of these changes are partially adapted from the Canadian EF-Scale (Environment Canada 2013).

2.2 Development of an International Fujita Scale

In 2018, Groenemeijer and Holzer presented a first look at the European community's effort to create an International Fujita (IF) Scale. It created generic DoDs rather DoDs based on the specific building practices of a single particular country. It contains 14 DIs, including Road Vehicles (V), Train Cars (R), Fences (F), Signs and Billboards (S), and other new DI types. It also provides a central wind speed value with an associated error of 30%, which results in overlapping wind speed ranges.

3. SUMMARY

This paper will review the details of the forthcoming EF-Scale chapter of ASCE/SEI/AMS Wind Speed Estimation standard. It will provide an overview of the current IF-Scale and a comparison between the two methods.

ACKNOWLEDGEMENTS
The authors wish to acknowledge the contributions of the members of the ASCE/SEI/AMS Wind Speed Estimation committee, who have volunteered their time, efforts, and expertise to improve upon the 2006 EF-Scale and develop other methods for estimating wind speeds. This group of more than 80 scientists from various disciplines have put thousands of hours into this effort and it is anticipated the standard will be published within the decade.

REFERENCES
Blanchard, D. O., 2013. A comparison of wind speed and forest damage associated with tornadoes in Northern Arizona., Wea. Forecasting, 28, 408-417. https://doi.org/10.1175/WAF-D-12-00046.1.

Doswell, C. A., III, and Burgess, D., 1988. On some issues of United States climatology. Mon. Weather Rev., 116, 495–501. https://doi.org/10.1175/1520-0493(1988)116<0495:OSIOUS>2.0.CO;2.

Edwards, R., LaDue, J.G., Ferree, J.T., Scharfenberg, K., Maier, C., and Coulbourne, W.L., 2013. Tornado intensity estimation: Past, present, and future. Bull. Amer. Meteor. Soc., 94, 641-653. https://doi.org/10.1175/BAMS-D-11-00006.1.

Environment and Climate Change Canada, 2013. Enhanced Fujita Scale-Canada. https://www.canada.ca/en/environment-climate-change/services/seasonal-weather-hazards/publications/enhanced-fujita-scale-damage-indicators.html.

Fujita, T. T., 1971. Proposed characterization of tornadoes and hurricanes by area and intensity (SMRP Research Rep. 91). Chicago, IL: University of Chicago. https://ntrs.nasa.gov/api/citations/19720008829/downloads/19720008829.pdf.

Fujita, T. T., 1973. Experimental classification of tornadoes in FPP scale (SMRP Research Rep. 98). Chicago, IL: University of Chicago.

Fujita, T. T., 1981. Tornadoes and downbursts in the context of generalized planetary scales. J. Atmos. Sci., 38, 1511–1534. https://doi.org/10.1175/1520-0469(1981)038%3C1511:TADITC%3E2.0.CO;2.

Fujita, T. T. (1992). Mystery of severe storms. Chicago, IL: University of Chicago Press.

Grazulis, T. P. (1993). Significant tornadoes. St. Johnsbury, VT: Environmental Films.

Groenemeijer, P., Holzer, A.M., 2018. The International Fujita Scale: A globally applicable scale for tornado and wind damage classification. American Meteorological Society 29th Conference on Severe Local Storms, Stowe, VT. https://ams.confex.com/ams/29SLS/meetingapp.cgi/Paper/348695.

IF-Scale Steering Group, 2018. The International Fujita (IF) Scale Tornado and Wind Damage Assessment Guide v. 0.1. 48 pp. https://www.essl.org/media/publications/IF-scale_v0.10.pdf.

Japan Meteorological Society, 2015. Guidelines for the Japanese Enhanced Fujita Scale. 133 pp. https://www.data.jma.go.jp/obd/stats/data/bosai/tornado/kaisetsu/guideline_en.pdf.

Kopp, G.A., Holzer, A., Tamura, Y., Sills, D., 2017. International approaches to tornado damage and intensity classification. International Association of Wind Engineers (IAWE), International Tornado Working Group, 29 pp. https://www.essl.org/media/pdf/KoppReport2017draft.pdf.

Kuligowski, E. D., Lombardo, F.T., Phan, L.T., Levitan, M.L., and Jorgensen, D.P., 2014. Technical investigation of the May 22, 2011, tornado in Joplin, Missouri, National Institute of Standards and Technology. NIST NCSTAR 3. https://doi.org/10.6028/NIST.NCSTAR.3

McDonald, J. R., Mehta, K. C., 2001. Summary report on Fujita-Scale Forum. Lubbock, TX: Wind Science and Engineering Research Center, Texas Tech University.

Mehta, K. C., 2013. Development of the EF-scale for tornado intensity. Journal of Disaster Res. Vol 8, No. 6, 8 p. https://www.fujipress.jp/jdr/dr/dsstr000800061034/.

Minor, J. E., McDonald, J. R., & Mehta, K. C., 1977. The tornado: An engineered-oriented perspective (NOAA Tech. Memo. ERL-NSSL-82). Silver Spring, MD: National Oceanic and Atmospheric Administration. https://repository.library.noaa.gov/view/noaa/7227.

Phan, L., & Simiu, E. (1998). The Fujita tornado intensity scale: A critique based on observations of the Jarrell tornado of May 27, 1997 (NIST Tech. Note 1426). Gaithersburg, MD: National Institute of Standards and Technology. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=860192.

Senior Seismic Hazard Analysis Committee (SSHAC), 1997. Recommendations for probabilistic seismic hazard analysis: Guidelines on uncertainty and use of experts (NUREG/ CR6372, UCRL-ID- 122160). Livermore, CA: Lawrence Livermore National Laboratory. https://www.nrc.gov/reading-rm/doccollections/nuregs/contract/cr6372/vol1/ index.html.

Wind Science and Engineering Center, 2006. A recommendation for an enhanced Fujita scale (EF-Scale), revision 2. Texas Tech University Publ., 95 pp., http://www.depts.ttu.edu/nwi/pubs/fscale/efscale.pdf.