# Japanese Enhanced Fujita Scale: Its Development and Implementation

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This paper introduces the Japanese Enhanced Fujita scale (JEF scale) recently developed and operationally implemented at Japan Meteorological Agency (JMA) in 2016. Like the EF scales in the United States and Canada, the JEF scale was designed to have a continuity with tornado statistics based on the F scale, but the corresponding wind speed estimates were revised based on the latest knowledge of wind engineering.

Enhanced Fujita scale (EF scale), which remedied several problems in the original F scale, was developed in the United States and was implemented by the US Weather Bureau in 2007. It has 28 Damage Indicators (DIs). Canadian EF scale, which slightly modified the EF-scale and has 31 DIs was operationally implemented at Environment Canada in 2013. Since the DIs in the US and Canada are not directly applicable to Japanese structures, JMA decided to develop the JEF-scale based on DIs typical of Japanese structures, and a committee consisting of 9 experts in wind engineering and meteorology was set up in 2013. The guideline of the JEF scale developed by the committee was publicized on the web site of JMA in Japanese in December 2015, and its English version is under preparation.

The JEF scale has 30 DIs. It gives estimated wind speeds corresponding to degree of damages (DODs) for each DI based on state-of-the-art knowledge of wind engineering which are obtained through large-scale wind tunnel experiments, computer simulations and experiments on damage to structures by strong winds. The detailed procedure for estimating the wind speed was as follows: Firstly, damage photographs from tornadoes between 2007 and 2013 and three F3 tornadoes after 1990 were collected. Secondly, five JMA experts on F-scale rating determined, from the photographs, the corresponding F-scale class $Fn$ with three subdivisions such as weak $Fn$, medium $Fn$, and strong $Fn$, each of which has a corresponding wind speed converted to 3-sec mean, and the resulting 3-sec mean winds were averaged to give the wind speed $U$ based on the F-scale. Thirdly, five experts in wind engineering used the photographs and the DIs and DODs of the JEF scale to estimate the wind speeds, and these wind speeds were averaged to give the wind speed $V$. Finally, a scatter diagram between $U$ and $V$ is plotted for a regression analysis using a power function fitting, where the best fitting gave $V = 2.8 \times U^{0.74}$. The lower and upper bounds of 3-sec mean wind speeds for JEF class JEF$n$ are given by 14x$n$+25 and 14x$n$+38 (m/s), respectively. JMA now records both the JEF scale rating and the estimated maximum 3-sec mean wind in their tornado database.