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Standardizing methods of estimating wind speeds: The ASCE Wind Speed Estimation Committee

James G. LaDue [1,2], Marc Levitan [3], Frank Lombardo[4], Josh Wurman[5], Tanya Brown-Giammanco[6], Fred Haan[7], Chris Karstens[8], Richard Wood[9], John Robinson[10], Greg Kopp[11], David Roueche[12], Christina Standohar-Alfano[13], Pataya Scott[14]

[1]National Institute of Standards and Technology, Gaithersburg, MD, United States, james.laDue@nist.gov
[2]National Weather Service Warning Decision Training Division, Norman, OK, United States, james.g.laDue@nist.gov
[3]National Institute of Standards and Technology, Gaithersburg, MD, United States, Marc.Levitan@nist.gov
[4] University of Illinois, Champaign, IL, United States, lombaf@illinois.edu
[5] University of Illinois, Champaign, IL, United States, JWurman@illinois.edu
[6]National Institute of Standards and Technology, Gaithersburg, MD, United States, tanya.brown-giammanco@nist.gov
[7] Calvin College, Grand Rapids, MI, United States, frederick.haan@calvin.edu
[2]National Weather Service Storm Prediction Center, Norman, OK, United States, Chris.Karstens@noaa.gov
[9]University of Nebraska, Lincoln, NE, United States, rwood@unl.edu
[10]National Weather Service (retired), Little Rock, AR, United States, koppe6ns@gmail.com
[11]Western University, London, ON, Canada, gakopp@uwo.ca
[12]Auburn University, Auburn, AL, United States, dbr0011@auburn.edu
[13]Haag Engineering, Minneapolis, MN, United States, calfano@haagglobal.com
[14]FEMA, Washington DC, United States, Pataya.Scott@fema.dhs.gov

OVERVIEW:
A committee supported by the American Society of Civil Engineers (ASCE)/ Structural Engineering Institute (SEI) and the American Meteorological Society (AMS) has worked to develop a consensus standard on Wind Speed Estimation (WSE) of severe storms. The WSE committee is nearing the completion of a draft standard containing several methods in which to estimate wind speeds, including in-situ observations, radar, forensics engineering, the EF-Scale, tree-fall pattern, and remote sensing methods. This provides information on the development and standardization of each method, and how they may be applied to a severe storm event.

Keywords: wind speed estimation, EF Scale, Enhanced Fujita (EF-) Scale, damage, tornadoes, severe wind storms

1. INTRODUCTION

Since 2015 the American Society for Civil Engineering (ASCE)/ Structural Engineering Institute (SEI) has supported a Wind Speed Estimation (WSE) committee to develop a standard or estimating wind speeds in severe storms. The WSE came about from a convergence of interests to improve the quality of post-storm information that involved a grass-roots stakeholders' group (Edwards et al., 2013), a service assessment from the National Weather Service (NWS 2014), and the National Institute for Standards and Technology report on the Joplin, MO tornado (Kuligowski et al. 2014). All three interests arrived at similar conclusions: one is that the EF-Scale (WSEC 2006) needs to be improved, and second, other methods for estimating wind speeds should be considered (hence forth called "methods").

Thus began the development of a process to update the EF-Scale and introduce other methodologies for estimating wind speeds of severe storms. In 2014, the EF Scale stakeholder's group submitted a proposal to the ASCE to create an ANSI-compliant standards committee (LaDue, 2016). The standards development process within ASCE's supporting structure allowed the best method to engage all the stakeholders and the affiliations they represented. The proposal was accepted by ASCE, and the committee began to meet in 2015. In 2017, the committee was re-branded as a joint standard between the ASCE and the American Meteorological Society (AMS). The committee organized its structure based on the wind speed estimation methods mature enough to advance into the standard with each method having its own subcommittee. The committee objectives are to identify: (1) appropriate usage of the methods, (2) appropriate archival strategies of the data and metadata in standards quality, and (3) appropriate interpretations to share on its usage. A draft of the standard is expected to be available for public comment in late 2024.

2. WIND SPEED ESTIMATION METHODS

The methods are categorized by whether they are based on real-time wind observations (in-situ observations, radar) or post-storm impacts (EF-Scale, forensic engineering analysis, tree-fall pattern and forest damage, and remote sensing-based condition assessment). The standards committee is designing its content so that each method generates a wind speed estimate for a point or a small area. More than one method can be utilized for any location if supported by underlying data, but no method can be used to modify an estimate from another method.

2.1 Real-time measurements

Radar and In-situ data represent real-time measurements, but they differ in the method used to acquire observations. Radars employ active remote sensors while physical anemometers gather in-situ measurements. Both platforms can provide wind measurements from many different phenomena. Yet they have challenges in providing guidance to adjust winds to a common height, exposure setting and gust factor within thunderstorms and tornadoes. Anemometers have significant challenges in providing a gust factor as they increase dramatically in convectively induced winds (Lombardo et. al. 2014) and anemometers vary in responsiveness to gusts. Doppler radars, conversely, provide instantaneous measurements of radial velocity but only at the height of the lowest unobstructed beam which can be well above the standard 10 m height above ground (Rauber and Nesbitt 2018; Wurman et al. 2021a). The beam height also likely overshoots the maximum winds in tornadoes (Kosiba and Wurman 2013; Wurman et al. 2013; 2021b) and downbursts, while beam broadening limits the distance at which tornadoes can be adequately resolved.

Given the challenges described, this standard provides a requirement for sufficient metadata to inform a user on how to interpret radar and in-situ data as well as methods to produce usable information. Radar data are categorized into tiers; tier 1 represents research quality data with the closest proximity to the event. For tornadoes, well-sampled radar data may be used to create swaths of wind speed isopleths as well as time series data for any point. In-situ data can be used to generate wind speed estimates adjusted for height and exposure in large-scale wind events. At this point whereas no adjustments are likely to be applied to in-situ data in tornadoes.

2.2: Post-storm wind speed estimation

Forensics analysis, EF Scale, and Tree-fall pattern and damage analysis represent separate methods to estimate wind speed whereas remote sensing provides supporting evidence to assist the main methods.

The forensics analysis provides a methodology for estimating a range of probable wind speeds, based on analysis of data collected from windstorm damage investigations, using engineering mechanics, wind engineering fundamentals, and probabilistic or deterministic methods of analysis. This method can be applied to any wind phenomenon, however a storm type must be known to match the proper exposure setting, such as setting the vertical profile of winds with height for tornadoes (Kosiba and Wurman, 2013). Other factors considered include building shielding (Li et al., 2007), topographic effects (Razavi and Sarkar, 2017), wind directionality, external pressure coefficients, gust effect factor, and windborne debris.

The EF-Scale method is being updated to improve existing Damage Indicators (DI)s, merge some DIs, and introduce new DIs. Where possible, the wind speed- to- damage relationships for new and existing DIis are being tied to the latest research findings rather than relying solely on expert elicitation (Brown-Giammanco et al., 2023). When the EF-Scale is standardized, this committee will work with the U.S. National Weather Service to adopt it into operations.

The tree-fall pattern and damage methods are a compilation of three sub-methods. Two of them match the observed tree-fall pattern to a simulated tree-fall pattern in a tornado using an idealized vortex model (Karstens et al., 2013; Lombardo et al., 2015). The third method estimates wind speed by determining a tree-fall fraction in blocks of wooded areas following a tornado track (Godfrey and Peterson, 2017). The pattern-matching techniques generate multiple products including wind speed isopleths and time series.

Remote sensing data contributes to all three post-storm methods by either providing detailed data or images of specific structures and vegetation (small scale), or by examining the bulk properties of the land surface changes following a storm (large scale) (see Womble et al. 2018). Small scale data typically are from platforms capable of providing <1 m field of view sufficient in detail to resolve the individual features (structures and vegetation) to the level required of each of the above methods. Large scale data provide >1 m field of view data to assist in determining the geographical damage extent which includes the presence or absence of damage. As with radar and in-situ data, the metadata accompanying the remote sensing data is critical to the standard, including wavelength band(s), resolution, platform type, and viewing angle.

3. APPLICATIONS OF THE STANDARD

This paper will also report on the process of applying this standard to a severe wind event. The tornado that struck Monroe, Louisiana in April 2020 provided an opportunity to evaluate each method. This event allowed this standard to generate wind speed estimates to fill in gaps, such as in an area devoid of DIs. In other areas, this standard provided estimates from three methods. We will compare the wind speed estimates derived from each method and discuss how the methods may be used to modulate our confidence in estimating wind speeds at various points along its track. In addition, we will portray how a diversity of wind speed estimates may be used by a practitioner.

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