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Improved Near-surface Wind Speed Characterization Using Damage Patterns

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## ACCEPTED MANUSCRIPT

1	Improved Near-surface Wind Speed Characterization Using Damage Patterns
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5	
6	ABSTRACT: Tornadoes have caused significant damage and casualties in the past decades. These
7	losses have spurred efforts toward tornado-based design, which require an accurate estimate of the
8	tornadic near-surface wind speeds. Due to the difficulty of obtaining in-situ measurements and
9	various issues regarding Enhance Fujita (EF) scale, a promising method of estimating near-surface
10	wind speed based on damage inflicted is developed. The method utilizes fall directions of trees
11	and other objects with distinct fall patterns to describe the characteristics of the tornado and other
12	wind storms. The observed fall patterns are used to estimate Rankine vortex parameters and
13	reproduce near-surface wind field. The wind field then can be compared to structural damage as
14	an independent method. The near-surface wind speeds of different tornado cases were estimated
15	using this method, one of which (Sidney, IL) exhibited 'crop-fall' patterns and yet another
16	(Naplate, IL) caused damage to trees and other infrastructures such as street signs. Based on the
17	damage to structures and estimated wind speeds from tree-fall analysis, empirical fragility curves
18	are also developed, which allows to interpret the vulnerability to tornadoes. The entire process of
19	wind speed, wind load, structural resistance and ultimately how to mitigate damage then can be
20	better understood.
21	
22	KEYWORDS: Tornado, Wind speeds, Tree-fall, Crops, Fragility
23	
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25	1. INTRODUCTION
26	During 1996–2017, the annual total loss from property and crop damage due to tornadoes reached
27	nearly \$1.5 billion (NOAA, 2018). As a result, tornado-based design for all structures, including
28	residential and commercial structures, is gaining traction in the engineering community in order
29	to minimize the structural damage (ASCE, 2016; Prevatt et al., 2012; van de Lindt et al., 2013).
30	However, tornado-based design is particularly complicated because tornadoes induce more
31	complex and extreme wind loading on buildings than straight-line winds (Amini and van de Lindt,

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