Wind Resource Assessment in Tornado Prone Area in the United States

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Abstract
This case study presents wind and tornado climatology analyses combined with a wind resource assessment study for a modern development situated in the South Central Kansas, United States. The analyses are conducted using wind data from weather station located in Medicine Lodge and for the period 1984–2015. The WAsP package is used to conduct the wind resource assessment study.

Keywords: *WAsP, Tornado Alley, Climatology, Trend Analysis*

Introduction
This paper investigates wind and tornado climatologies, as well as wind resources with applications to sustainability and resilience of a modern development situated in "Tornado Alley", in the United States (US). This unique project investigates on how to design a resilient development that will realistically evoke relationship between people and weather in safe environment, and how can a design foster a more symbiotic relationship between people and weather? In order to answer these questions a series of numerical and experimental simulations are designed and executed by the Wind Engineering, Energy and Environment (WindEEE) Research Institute at Western University in Canada. In this paper, we present a part of this research that focuses only on wind and tornado climatologies, and wind resource assessment.

Data and Methods
The investigated site is 2.75 km^2 of pasture, meadows and buttes nestled in the rugged terrain of South Central Kansas, US. The wind data used for wind climatology and resource assessment studies are acquired from a near weather station (called KP28). This weather station belongs to the Automated Surface Observations System (ASOS) network of meteorological stations in the US.

The numerical model used to assess the wind resources at the site is WAsP 11. The elevation map of the terrain around the sites is obtained from the US Geological Survey products. The map has a grid spacing of 1/3 arc-second (~10 m). The roughness map used in this study is created combining the available information from the US National Land Cover Database 2011 and Google Earth Pro®. The whole region around the investigated site is characterized with 6 roughness lengths. Both maps extend approximately 15 km from both the project site and weather station.

Lastly, the tornado data are obtained from the Storm Prediction Center at the National Oceanic and Atmospheric Administration. This tornado catalog is the US official tornado database and the analyzed data cover the period 1950–2015.

Results
The mean wind speed at 10 m above ground is 4.45 m s^{-1}, and the strongest winds blow in January and July, while the weakest winds are observed in December and transitional seasons. The two prevailing wind directions are south and north and they are also associated with the strongest winds. Statistically insignificant, but nevertheless positive trends of the mean annual wind speeds are found for the period 1984–2015 (0.2 m s^{-1} in that period). The extreme value analysis was performed on the annual maximum 5–second gusts and annual maximum 2–minute mean wind speeds. The 5–second gust with a 50-year return period is 33.97 m s^{-1} at 10 m above ground.

The prevailing orientation of tornado tracks around the project site is from southwest to northeast with the total of 170 tornadoes recorded in the period 1950–2015. Most of F2 tornadoes were spawned in a close vicinity of the analyzed site and afterwards moved in the northeast direction for about 37 km. F3 tornadoes, on the other hand, were the deadliest and the most damaging twisters around the site.

The wind resource assessment analysis performed using the WAsP software demonstrated good wind potential at the project site, particularly in the hilly south region of the site. Three tentative locations were identified for installing wind turbines on the site (Figure 1a). The modelled mean wind speed at 100 m level is above 7 m s^{-1} and the wind power density at two sites with the best wind potential exceeds 420 W m^{-2} (Figure 1).

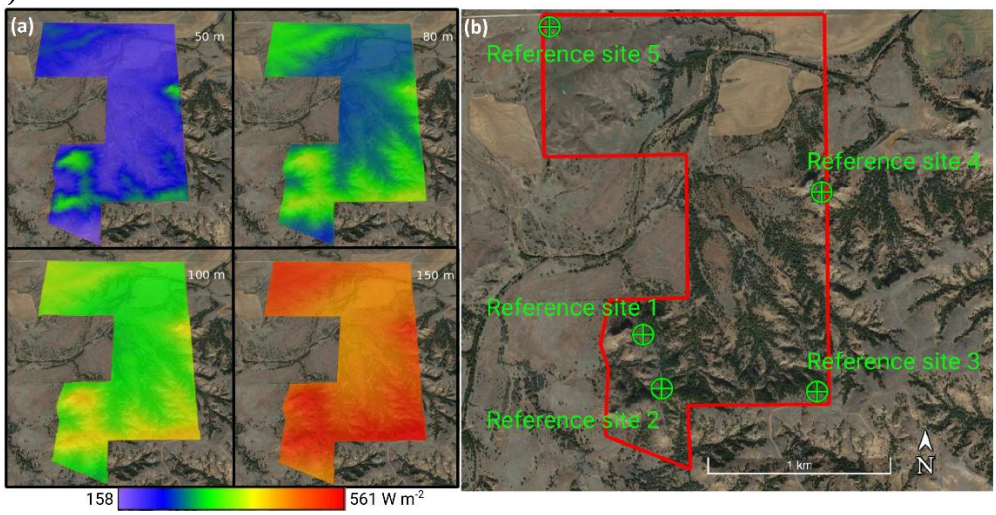

Figure 1. (a) Wind power density maps. (b) Five best sites for wind turbine installation.

Summary and Conclusions

A complete wind and tornado climatologies, as well as a detailed wind resource assessment study were performed for a one-of-a-kind development planned to be built in "Tornado Alley", in South Central Kansas, United States. This paper presents a brief summary of the obtained results, i.e.:

- The mean annual wind speed at the site is 4.45 m s^{-1}.
- The site is characterized with good wind potential.
- A positive but statistically not significant trend in wind speed observed.
- The extreme value analysis on annual 5-second and 2-minute maxima conducted for different return periods.
- The prevailing tornado trajectories are from southwest to northeast and F3 tornados were the most devastating twisters around the site.