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# Near surface wind measurements during the 2022 Atlantic hurricane season

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**SUMMARY:**
Two landfalling tropical cyclones impacted Satellite Beach, FL during the 2022 Atlantic hurricane season, Ian (27 September- 1 October) and Nicole (9-11 November). Florida Tech's LiDAR and wireless sensor network system (WSNS, Zhang et al., 2022) were deployed to collect near surface data at a coastal residential location. The 11 m LiDAR wind data are presented along with winds from RM Young anemometers that were mounted at 5.8 m for both storms and a second one that was placed at 4.2 m and 3.3 m for Ian and Nicole respectively. The LiDAR range gates were configured to sample at 11 levels up to 300 m (the LiDAR maximum). The tropical cyclone data are compared with data that were collected by the LiDAR and RM Young during an extended period, 27 April – 10 June 2022. Additional data during high wind events is needed verify whether the proposed relationships can be extrapolated to hurricane conditions.

*Keywords: near surface wind measurements, LiDAR, tropical cyclone*

## 1. INTRODUCTION

In order to understand the behavior of the airflow at mean roof height, an understanding of the highly localized winds within the canopy layer is necessary. With this goal in mind, the Florida Tech WSNS research group deployed their wireless sensor network system including pressure sensors and anemometry along with the Florida Tech LiDAR during the 2022 Atlantic hurricane season. The study site is a single-story residence in Satellite Beach, FL approximately 400 m from the coast in a suburban neighborhood. The data were used to calculate a direction dependent gust factor and a relationship between the gusts near roof height (5.8 m) and mean wind at a reference level (11 m). Both the field measurements and derived fields will be published on DesignSafe-CI.

## 2. DATASETS AND METHODOLOGY

Meteorological data from the LiDAR and WSNS were collected during Hurricanes Ian (27 September- 1 October 2022) and Nicole (9 – 11 November 2022) as well as for an extended period (27 April – 10 June 2022) during typical weather conditions at the WSNS residential structure in Satellite Beach, Florida. Using the 11 m LiDAR wind direction, the data were subset into 15° sectors and analyzed with respect to mean wind speed (10-min) and 3-s gust.

For each of the data collection periods, an RM Young anemometer was mounted to the east roof at a height of 5.8 m AGL. An additional RM Young was deployed during the hurricanes. For Ian the anemometer was mounted on the west edge of the roof at a height of 4.2 m AGL while during Nicole it was placed on a tethered telescoping pole in the front yard (i.e., north side) of the residence at a height of 3.3 m AGL. With the exception of Nicole, the anemometry-based winds were sampled at a 1-s temporal resolution (WSNS) and a rolling 3-s average was applied to estimate the gusts. For Nicole, the additional RM Young was connected to a different logger (Hobo) and the 3-s gust was output directly. During the April-June window, the LiDAR range gates (11 levels) ranged from 11 to 120 m. For the other three periods, the range gates were extended up to 300 m (LiDAR maximum). A single LiDAR volume scan is completed in about 20 seconds. Time series of 10-min average pressure and winds for Hurricane Ian are presented in Fig. 1.

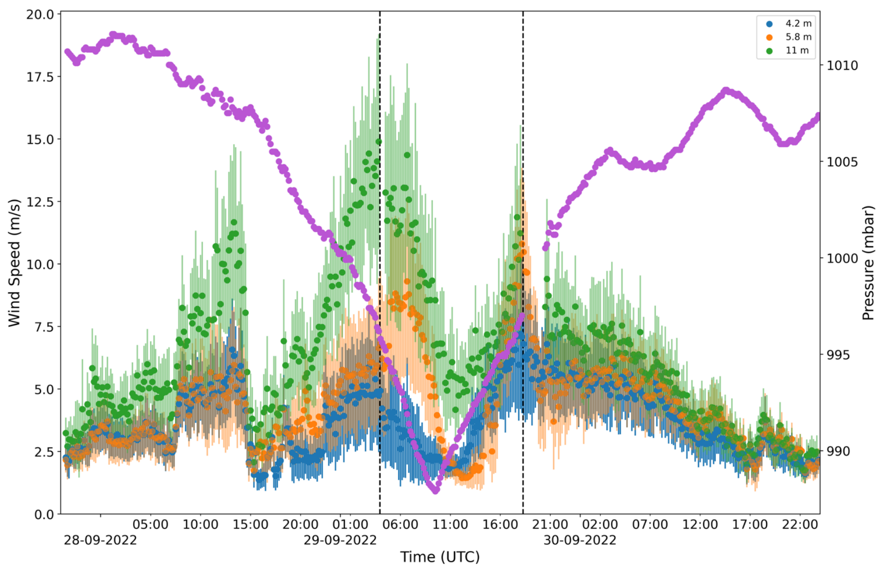


**Figure 1.** 10-min mean wind speed ($ms^{-1}$) and barometric pressure (mbar) collected 27 to 30 September during the passage of Hurricane Ian in Satellite Beach, FL. Data shown include two anemometers mounted on the gable ends on the east and west side of the roof (orange – 5.8 m and blue – 4.2 m respectively) and the lowest range gate of the Florida Tech LiDAR (green – 11 m). The barometric pressure is from an independent LiDAR mounted Airmar sensor at 1 m height (purple). Wind speed standard deviation for each 10-min window is given by colored vertical lines. Time of the maximum observed 11 m and 5.8 m wind speeds are denoted by the dashed vertical lines (left and right respectively).

For Hurricane Ian (Fig. 1), the maximum 11 m LiDAR wind speed was 28.8 $ms^{-1}$ which occurred (3:56 UTC 29 Sept.) during the passage of the eastern portion of the eyewall. The anemometer (5.8 m) recorded peak wind speed was 21.9 $ms^{-1}$ (at 18:16 UTC 29 Sept.) which occurred on the backside (i.e., western portion) of the eyewall. However, during this time window the LiDAR had lost power and thus the peak wind at 11 m was likely higher. A power outage also occurred during the period of peak winds for Nicole – but prior to this time, the LiDAR recorded a maximum 11 m wind speed of 26.4 $ms^{-1}$ at 6:30 UTC whereas the maximum anemometer (at 5.8 m) wind speed of 27.1 $ms^{-1}$ occurred approximately two hours later (8:11 UTC, not shown).

The 3-s WSNS data and corresponding 10-min block averaged wind speed are used to estimate a gust factor (GF) for 24 wind directions. The GF (Eq. 1) is defined as the ratio of the maximum three second gust to the corresponding 10-min average wind speed for the same height and instrument, i.e.,

$$GF = \frac{Maximum\ 3\ s\ gust}{Average\ 10\text{−}min\ wind\ speed} \quad (1)$$

Here we also attempt to develop a relationship between the above canopy winds (LiDAR at 11 m) and near canopy (roof height) flow (anemometer at 5.8 m). Note that in those cases when there are no in-situ 10 m winds, they can be estimated using observations from a nearby ASOS or mesonet station provided the roughness at both locations is known (potential wind, Wever and Groen, 2009). The extrapolated 10 m (mean) wind speed could then be used in lieu of local measurements to predict the peak gust near roof height.

## 3. PRELIMINARY RESULTS

Data from Hurricane Ian are used to create polar plots of the GF. The gust factor is a proxy for turbulence and thus related to the roughness – and are larger for unsteady flow. The values in Fig. 2 are averaged by wind direction and are shown for both the east (5.8 m, Fig. 2A) and west (4.2 m, Fig. 2B) roof mounted anemometers. While there is enough data to populate each of the direction bins, the observation period is relatively short (4 days) and thus the data distribution, which varies between the two anemometers, is somewhat uneven.

The GF is elevated for WSW (SSE) flow for the east (west) mounted anemometers. The enhanced turbulence at the west anemometer is likely a result of the tall oak trees that line the southern perimeter of the property (not shown). While along-roof westerly flow may contribute somewhat to the enhanced turbulence observed at the downwind portion of the roof (i.e., east anemometer), the vegetation adjacent to the west side of the residential structure cannot be ruled out. The turbulence is reduced somewhat for NNW flow (both anemometers) where, with the exception of couple of small palms, the fetch extends approximately 30-50 m across a street to single-story homes. For ENE flow, the GF is lower at the west anemometer – the reduced turbulence may be vegetation-related.

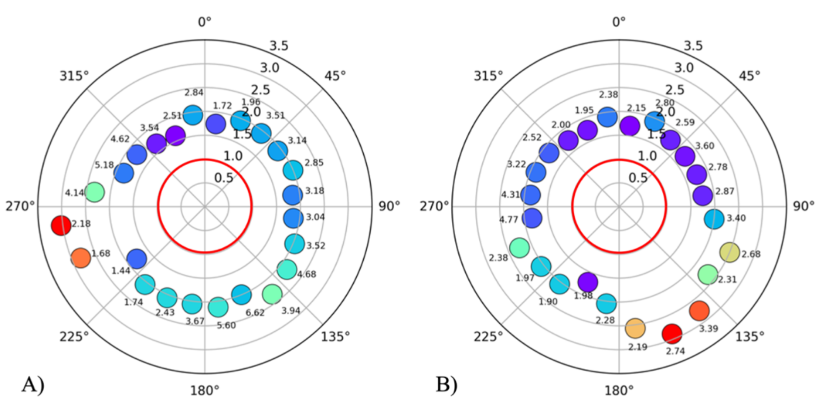


**Figure 2.** Average gust factors (color-filled circles) for the A) east gable anemometer (at 5.8 m height) and B) west gable anemometer (at 4.2 m height). Data for Hurricane Ian (27 September - 1 October 2022, N = 570). A GF is calculated using Eq. 1 with a 10-min mean wind speed ($ms^{-1}$) and corresponding peak 3-s gust and then averaged for each wind direction bin. The red line delineates a GF=1. Mean 10-min wind speed ($ms^{-1}$) for bins are shown.

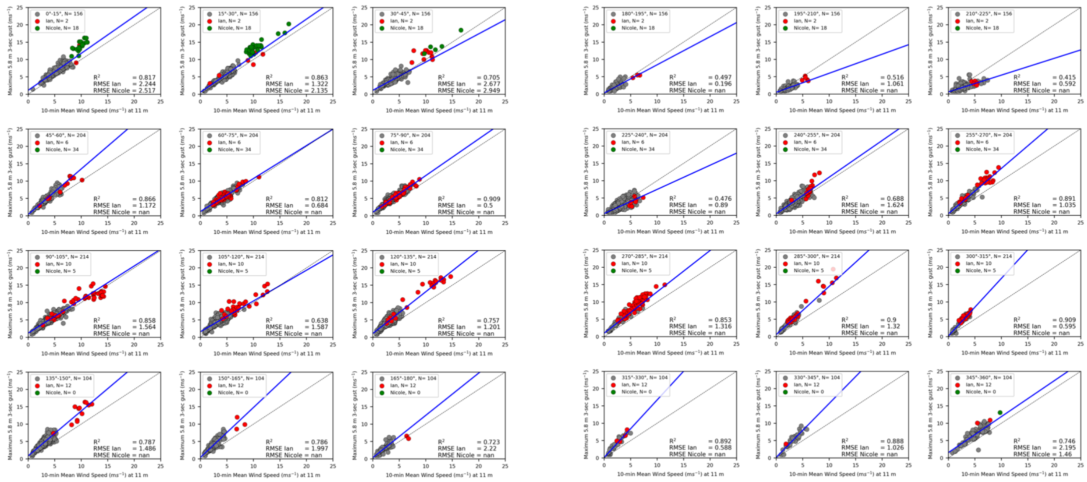

**Figure 3.** Best-fit linear regression (blue line) and $R^2$ values for the 0° to 180° (left panels) and 180° to 360° (right panels) wind direction bins and 27 April-10 June period (filled-gray circles). The root mean square error is calculated from the predicted (i.e., from the linear regression) and observed 3-s gust for both Ian (red) and Nicole (green). A one-to-one line is also shown (dashed gray line).

Scatter diagrams of the peak 3-s gust from the east anemometer (5.8 m) versus 10-min mean LiDAR 11 m wind speed are shown in Fig. 3. A least squares fit was applied to the 45-day period only (i.e., Ian and Nicole were not included). Assuming a zero intercept, the slope is a proxy for a modified GF where the mean wind in Eq. 1 is taken from the LiDAR. The regression slopes are less than 1 for SSW flow due to the upstream flow obstruction (i.e., oak trees) which limits the gust magnitude while the above canopy flow at 11 m is relatively undisturbed. The slopes are greater than 1 for both NW and SE flow indicating increased turbulence from these wind directions. For the most part, the higher wind speeds observed during the two hurricanes correspond well with the independent regression with a maximum RMSE (based on differences in the predicted and observed wind speeds for the two storms) on the order of 3 $ms^{-1}$ for NE flow (30°- 45°) but less than 1 $ms^{-1}$ for roughly one third of the wind direction bins. Given that only 10 of the 24 directional bins have more than 15 10-min samples, additional high wind events would verify whether or not the regression can be extrapolated to hurricane conditions.


## ACKNOWLEDGEMENTS

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