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Onshore Wind Acceleration Across the Indian River Lagoon

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ABSTRACT: *A study of the onshore (easterly) flow crossing the barrier island and Indian River Lagoon (IRL), in east central Florida, was conducted during the summer of 2015 in association with the DMES Field Projects. Wind observations were collected from three instruments including a vertically pointing lidar, a Kestrel sensor mounted at 10 m, and an AirMar sensor deployed (at 2 m) on a pontoon boat. The observations indicate that the downstream (IRL) wind speed (10 m) was actually higher than beachside. Surface roughness estimates are obtained from the lidar-observed wind profiles beachside and downwind along the western shore of the IRL. These roughness estimates were then used to calculate the 'potential wind' at the IRL location. Results indicate that the over-water roughness differences, between the IRL and open ocean, are sufficient to explain most of the wind speed difference between locations. When compared to the ocean, the shallow estuary has limited fetch and lower roughness and thus the flow downstream of the barrier island accelerates to speeds in excess of those observed directly along the coast. The Weather Research and Forecasting (WRF) model was run in an attempt to simulate the observed flow. While the WRF captures the deceleration across the barrier island, it does not reproduce the full acceleration seen in the observations at the Lagoon House.*

INTRODUCTION

Wave generation and its impact within fetch limited shallow water bodies, such as inland lakes and estuaries, has been the subject of numerous studies. In part, the purpose of this past work was to better understand the role that the wind plays in driving water movement and the generation of wave energy – both of which impact water quality (e.g., sediment suspension), erosion, etc. (e.g., Dupuis and Anis, 2012; Rubegni et al. 2013). These factors affect sea grass, oyster reefs, fish populations, etc. and are thus of importance and interest with respect to restoration projects, and resource management in general within the IRL. Unfortunately, wind observations within the IRL are few and far between – thereby limiting the scope of past work. Here I present a unique study in which wind observations, for two onshore flow events, are mined to examine the impact of the barrier island on the surface wind field.

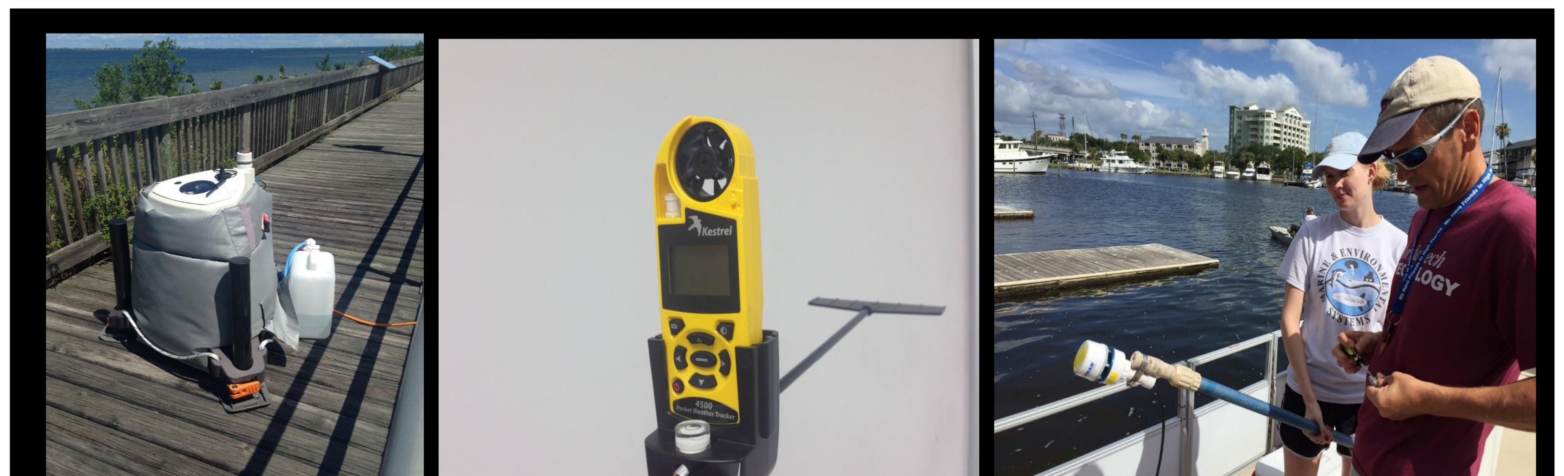


Figure 1a. Left: ZephIR300 Wind Lidar[3].
Figure 1b. Middle: Kestrel (4500), a flagship meter (wind speed and direction) attached to 10 meter pole.
Figure 1c. Right: AirMar (200WX) sensor (wind, temperature) affixed to a pole.

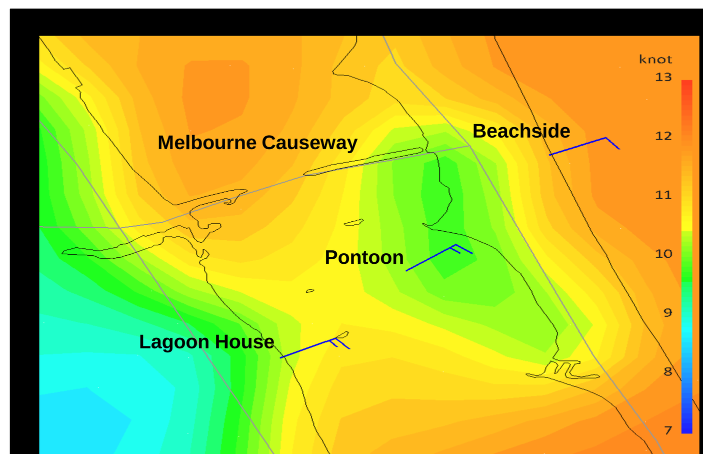
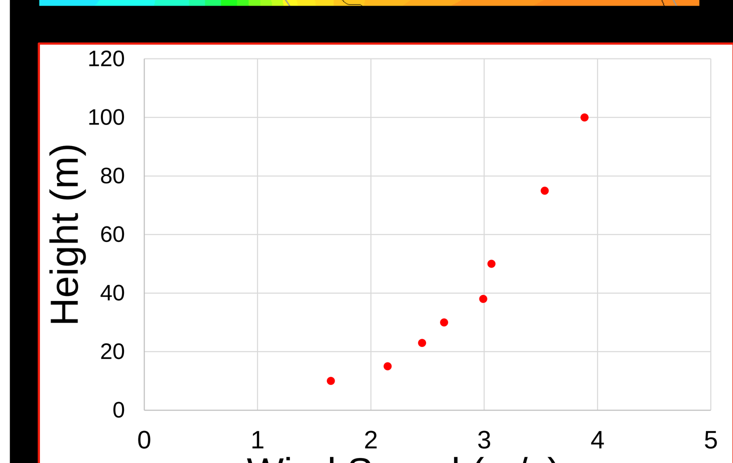


Figure 2: Wind barbs depict surface (10 m) wind observations (lidar, Kestrel, and AirMar) from the Lagoon House, within the IRL, and beachside respectively (full barb is 10 kt/half barb is 5 kt). Also shown is the Weather Research and Forecast Model (WRF) wind speed (kt, color shaded), valid 19 UTC 4 June 2015.



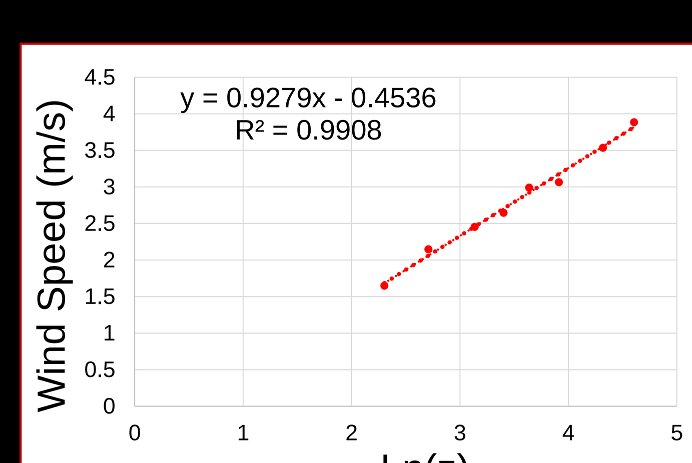


Figure 3a. Left): Lidar wind profile valid 19 UTC 4 June 2015, at the Lagoon House in Melbourne, FL. The wind speed does not increase linearly with height due to the impact of surface elements.
Figure 3b. Right: The same wind profile as in Fig. 3a but in logarithmic space (x-axis). Note that the axes have been switched where ln(z) is on the x-axis and the wind speed on the y-axis. Wind speed is increasing linearly with height.

METHODS

Three instruments were used to observe surface wind speed these includ a LIDAR (ZephIR300), Kestrel, and AirMar. Since the focus of this study is onshore flow (wind blowing from the ocean toward land) decceleration and reacceleration across the Indian River Lagoon (IRL), the instruments were strategically placed along an approximate east-to-west transect. In particular, the Kestrel was placed beachside, the AirMar was placed on a pontoon boat and measurements were made along transects across the (IRL), while the LIDAR was at both the Lagoon House (e.g., Figure 1a & 1b) and beachside.

The surface roughness was estimated using the lidar wind speed profile and the log law (e.g., Figure3a). Assuming neutral stability, (Roberto, Maurizio, and Teodoro, 1998):

$$u(z) = \frac{u_*}{k}\ln\left(\frac{z}{z_0}\right) \qquad (1)$$

where,
u_z = lidar wind speed at height z
z_0 = surface roughness
u_* = friction velocity
k = Von Karman constant (= 0.4)

Potential Wind Adjustment:

The potential wind can be used to adjust the wind speed at one location (local, z_o) so that it has the same surface roughness as another (reference, z_{o_ref}), provided the surface roughness at both locations is known. The potential wind between two locations at 10 meters height is given by (Andrews, and Patricia, 2014):

where:
$U_{potential}$ = potential (adjusted) wind
U = observed wind speed
z_{o_ref} = reference surface roughness
$z_{\_sensor}$ = instrument height
z_o = surface roughness

$$U_{potential} = U\,\frac{\ln\left(\frac{10m}{z_{0-ref}}\right)}{\ln\left(\frac{60m}{z_{0-ref}}\right)} \times \frac{\ln\left(\frac{60m}{z_0}\right)}{\ln\left(\frac{z_{sensor}}{z_0}\right)} \qquad (2)$$

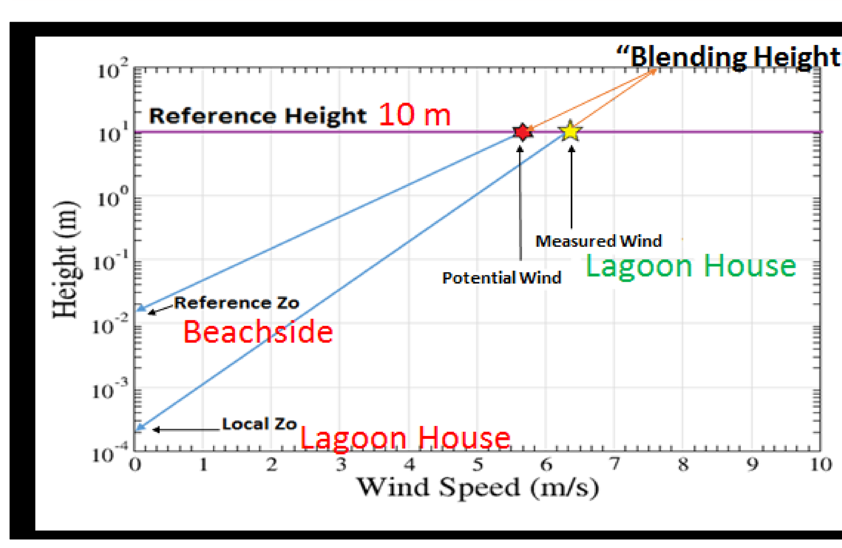


Figure4. A graphical example of the wind adjustment calculation (i.e., the potential wind). It illustrates the adjustment of the wind speed from one roughness to another. Here, the wind speed from the Lagoon House (yellow star) is adjusted to match the z_0 of the beachside location. Using the lagoon house roughness obtained from the lidar wind profile, the observed wind is brought up to the blending height (100 m, the level where the surface impacts are assumed to be negligible). The winds are then brought back down to 10 m using the beachside roughness estimate (also obtained from the lidar wind profile).

RESULTS

Given the onshore flow (i.e., open fetch), we expected that the beach wind speed would be greater than that observed at the Lagoon House. However, the observations indicated the opposite as the wind speed at the Lagoon House was observed to be greater than beachside. The surface roughness, defined as the level at which the wind speed goes to zero near the surface, was estimated directly from the lidar wind profiles via Equation (1). The surface roughness estimates for both locations (beachside and Lagoon House) and day in question are 0.0018m and 0.0000015m respectively. Hence, for the measurement days discussed here, the ocean surface is rougher than the Indian River Lagoon. When the Lagoon House winds were adjusted to match the beach roughness the winds at the two locations were in much better agreement (Figs. 5a & 5b). Interestingly, a high resolution WRF (Weather Research and Forecasting) simulation did not show the Lagoon side wind exceeding that of the onshore flow at the beach (e.g., Figure 2).

DISCUSSION AND CONCLUSION

It is somewhat surprising that we observed a greater flow at the downwind location (Lagoon House) than beachside. This is attributed to variations in the surface roughness at the two locations. It is not clear how often this occurs given that the water surface is dynamic, i.e., wind driven waves impact the surface as well as wave breaking in the nearshore. On the field project days discussed here, the potential winds adjustment accounted for most of the wind variation between sites. While the WRF model showed winds reaccelerating over the Indian River Lagoon, they do not reach speeds greater than those predicted beachside (e.g., Figure 2). The results indicate that the surface roughness is the primary cause of differences between expected and actual observations of onshore flow.

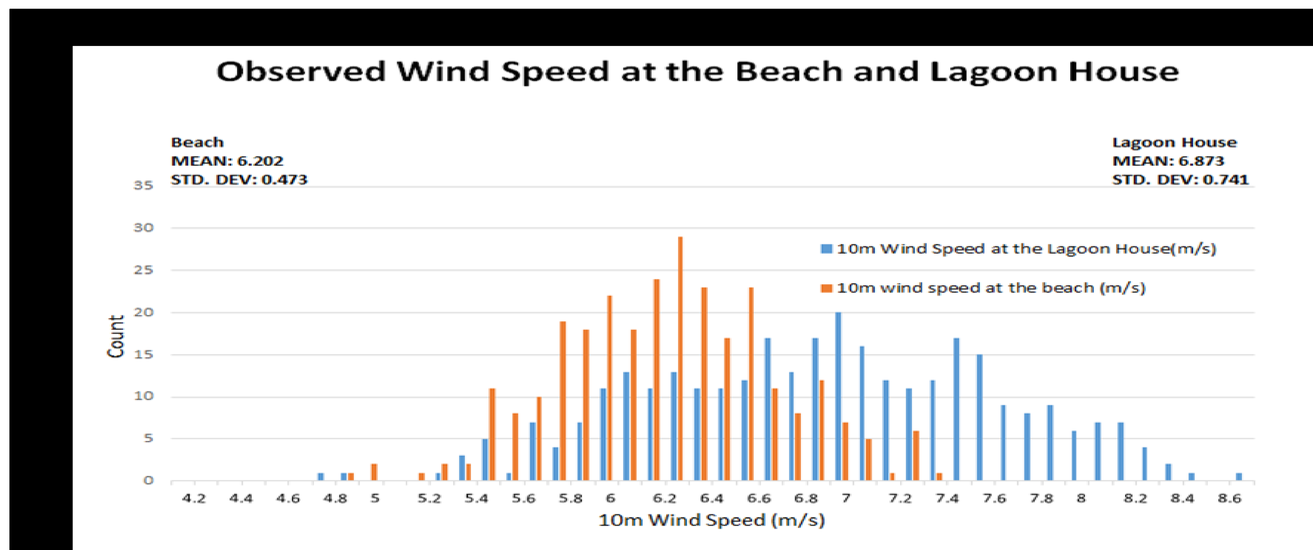


Figure5a. Histogram (counts) of the observed 10 m wind speed (m/s) from the Lidar (at the Lagoon House, blue) and Kestrel (beachside, orange) for the period 17.5 to 19 UTC 4 June 2015. Bin width is 0.1 m/s.

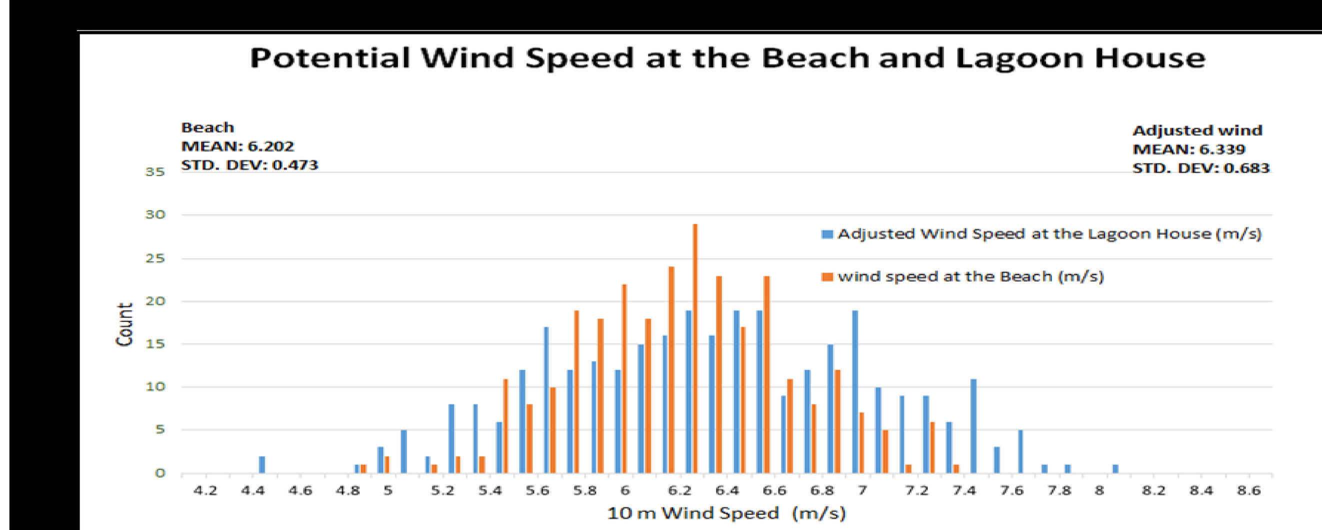


Figure 5b: Same as Fig. 5a above but for the potential (i.e., adjusted) wind speed (m/s) at the Lagoon House location.

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