Investigation of the fetch effect using onshore and offshore vertical LiDARs

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Abstract

An offshore wind measurement campaign has been conducted, while using dual vertical LiDARs at an offshore research platform in Japan for investigating coastal wind modification along with the internal boundary layer (Fig. 1). The relationships between wind speed increasing ratio and fetch, which is a distance wind has blown over water, was continuously analyzed. As a result, coastal wind was found to gradually increase as fetch increases, and it raises approximately 20% at a fetch of 2 km. A similar result can be found in a previous study in the Baltic Sea [1].

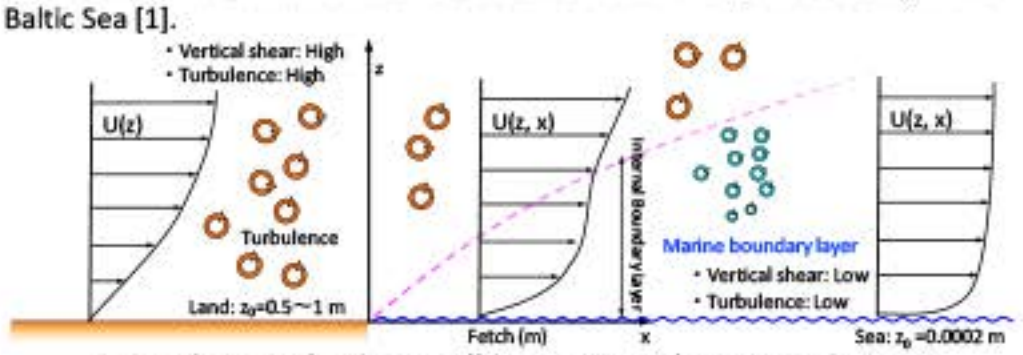

Fig. 1 Schematic of onshore to offshore wind modification near the coast.

Objectives

The purpose of this study is to answer a simple question that **"How much wind speed is increased by the fetch effect while the onshore wind is traveling over the sea?"**. Previous studies [1-3] suggested that wind speeds onshore increase between 5% and 45% in a long marine fetch. However, the relationship for short fetch that is less than a few kilometers is still unclear. The results in this study are expected to assist in the consideration of the optimal distance from land for nearshore windfarm development from a meteorological perspective.

Methods

There is a 400 m long pier at a height of 7 m above sea level at the Hazaki Oceanographical Research Station (HORS) in Japan (Fig. 2). One WindCube WLS7 (LiDAR#1) is installed at the top of the pier, and the other (LiDAR#2) is located at the foot of the pier for 3 months (22 March – 27 June, 2016).

Fig. 2 Location and orientation (left) and photograph (right) of the HORS research platform.

Since the region has a rectilinear coastline, the fetch at the top of the pier can be simply defined as a function of wind direction θ as follows.

$$\mathrm{Fetch}(\theta) = L_{pier}/\cos(\theta-\theta_{pier}-180) \qquad (1)$$

Here, Lpier and θpier indicate the pier length of 400 m and the heading angle of 59°, respectively. Moreover, some winds measured with both LiDARs from 165 ° and 215° are included in wake zones from nearby wind turbines (Fig. 3). Prior to this, LiDAR#2 was located at the top of the pier for two weeks to examine difference between the two instruments (Fig. 4).

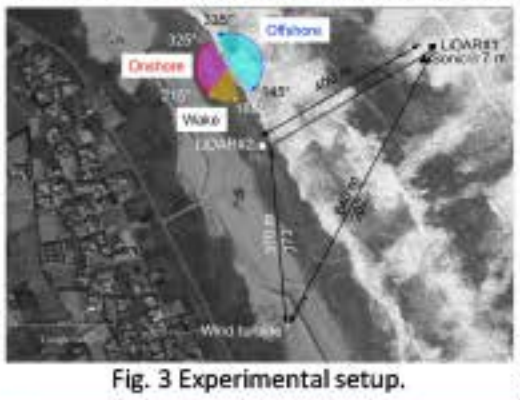

Fig. 3 Experimental setup.

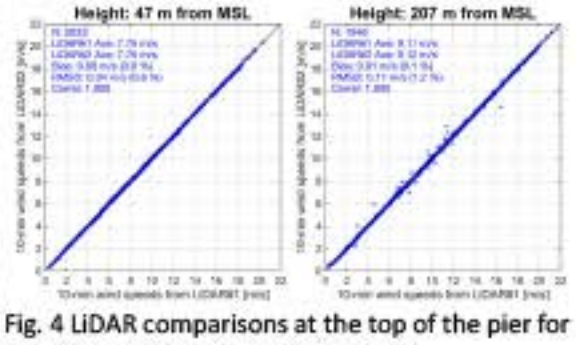

Fig. 4 LiDAR comparisons at the top of the pier for the period from 7 to 21 March, 2016.

Results

The wind speed increasing ratio (LiDAR#1/LiDAR#2) at several heights as function of wind direction (Fig. 5) and fetch (Figs. 6-8) are depicted below.

Wind speed increasing ratio (LiDAR#1/LiDAR#2) as function of wind direction

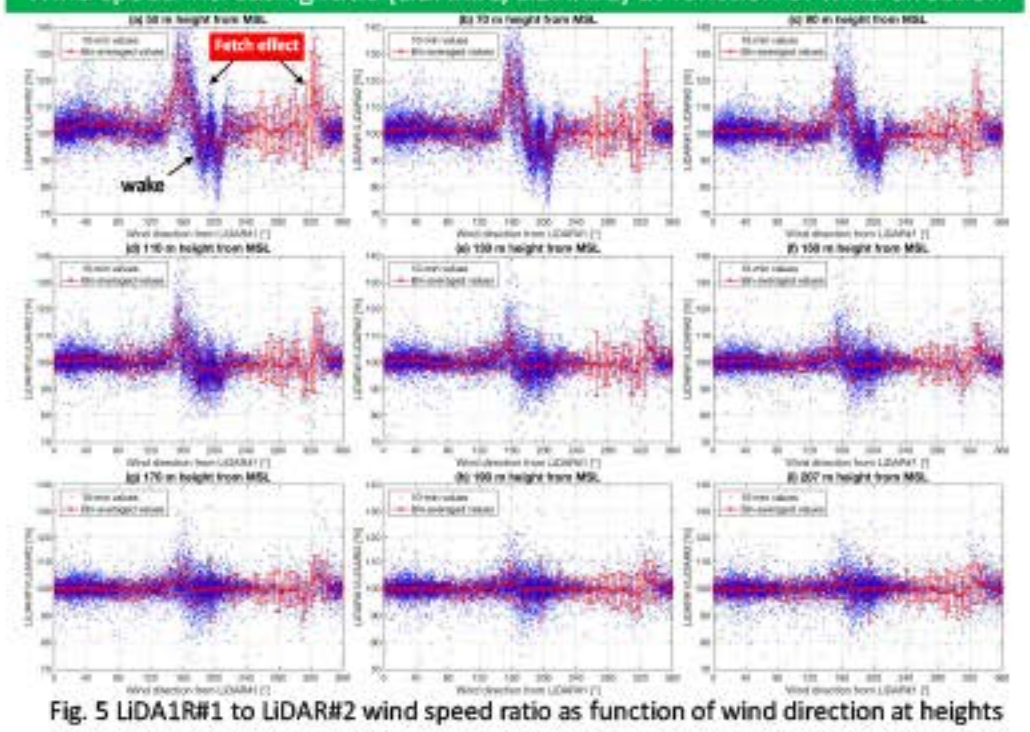

Fig. 5 LiDA1R#1 to LiDAR#2 wind speed ratio as function of wind direction at heights of 50, 70, 90, 110, 130, 150, 170, 190 and 207 m above mean sea level. The LiDAR#1 wind speeds more than 2 m/s were only used for the analysis.

Wind speed increasing ratio as function of fetch

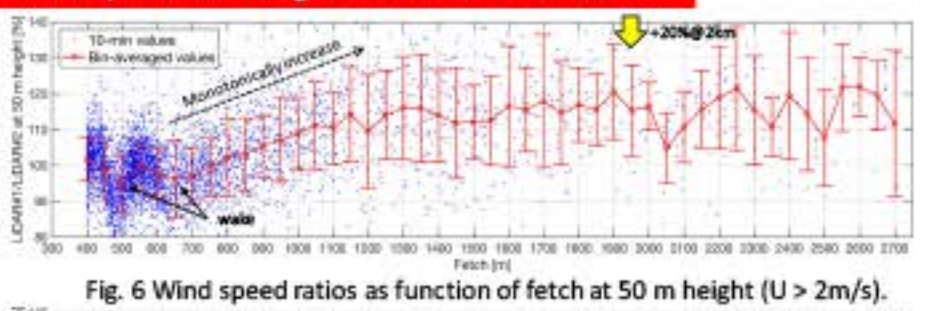

Fig. 6 Wind speed ratios as function of fetch at 50 m height (U > 2m/s).

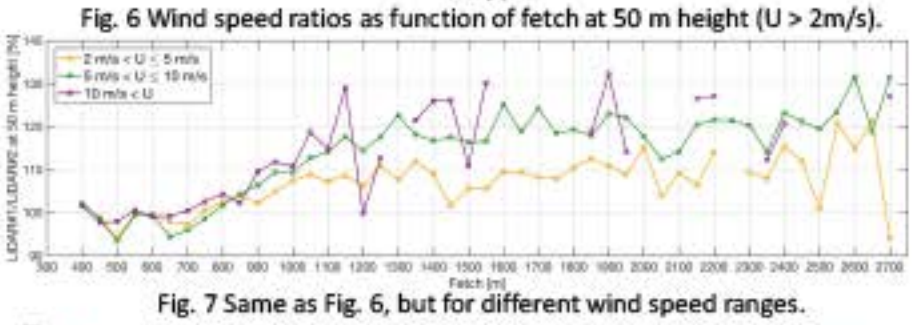

Fig. 7 Same as Fig. 6, but for different wind speed ranges.

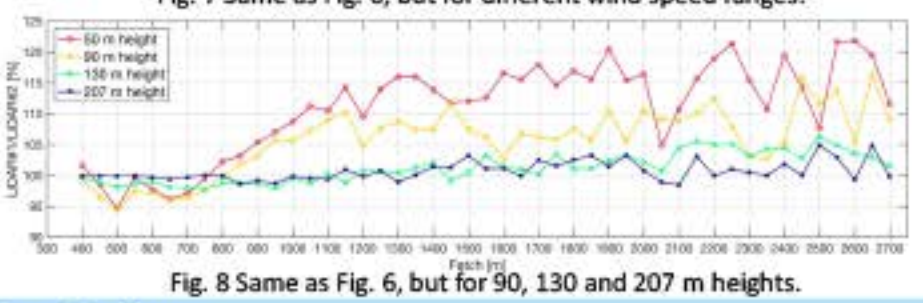

Fig. 8 Same as Fig. 6, but for 90, 130 and 207 m heights.

Conclusions

The observations at the top of the pier were found to be strongly influenced by the onshore turbines which are located more than 10D away. Moreover, they also showed that the onshore wind at 40 m height gradually increases for 600 to 2,000 m fetches. It was increased up to **approximately 20% with a fetch of 2 km**. A similar relationship can be found in Barthelmie et al. (1996)[1]. Therefore, these results may indicate that approximately 2 km from the coast is a reasonable distance to employ offshore winds sufficiently enhanced by the fetch effect for nearshore wind farm development.

References

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