Investigation of the fetch effect using onshore and offshore vertical LiDARs

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1. Introduction

A coastal wind measurement campaign using a LiDAR (Light Detection and Ranging) system is being conducted at the Hazaki Oceanographic Research Station (HORS), which has been operated by the Port and Airport Research Institute since October 2015 (Fig. 1), in order to obtain hub height wind speeds for a new Japanese offshore wind atlas project. Recently, an additional LiDAR has been installed at the research platform to examine the structure of coastal winds in detail. The purpose of this study is to observe and analyze the variations between onshore and offshore winds, which seem to be related to the distance over water that a wind has blown (the fetch affect), using LiDARs installed both onshore and offshore. The results obtained from this study are expected to assist in the determination of the optimal distance from land for nearshore wind farm development from a meteorological perspective. In this abstract, an overview of the results obtained so far is presented.

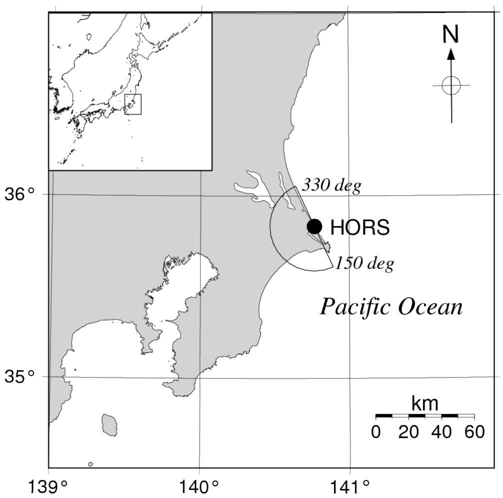

Fig. 1 Location and orientation (left) and photograph (right) of the HORS research platform.

2. Approach

The measurement setup is illustrated in Fig. 2. There is a 427 m long pier at a height of 7 m above sea level at the HORS station. Vertical wind speed profiles from 40 to 200 m in height at intervals of 20 m are measured with two WINDCUBE WLS7s. One WINDCUBE (hereafter referred to as LiDAR#1) is installed at the top of the pier, and the other (LiDAR#2) is located at the foot of the pier. A sonic anemometer is also used for surface wind and atmospheric stability measurements. Since the region has a rectilinear coastline and is surrounded by flat terrain, this research platform is an ideal site to investigate variations in wind speed related to the fetch effect. Some winds observed by both LiDARs, blowing from between 165° and 215°, were influenced by a nearby wind turbine. Measurements using the two LiDARs began in March 2016. Prior to this, LiDAR#2 was located at the top of the pier for two weeks in order to investigate differences between the two instruments, which were found to be negligibly small.

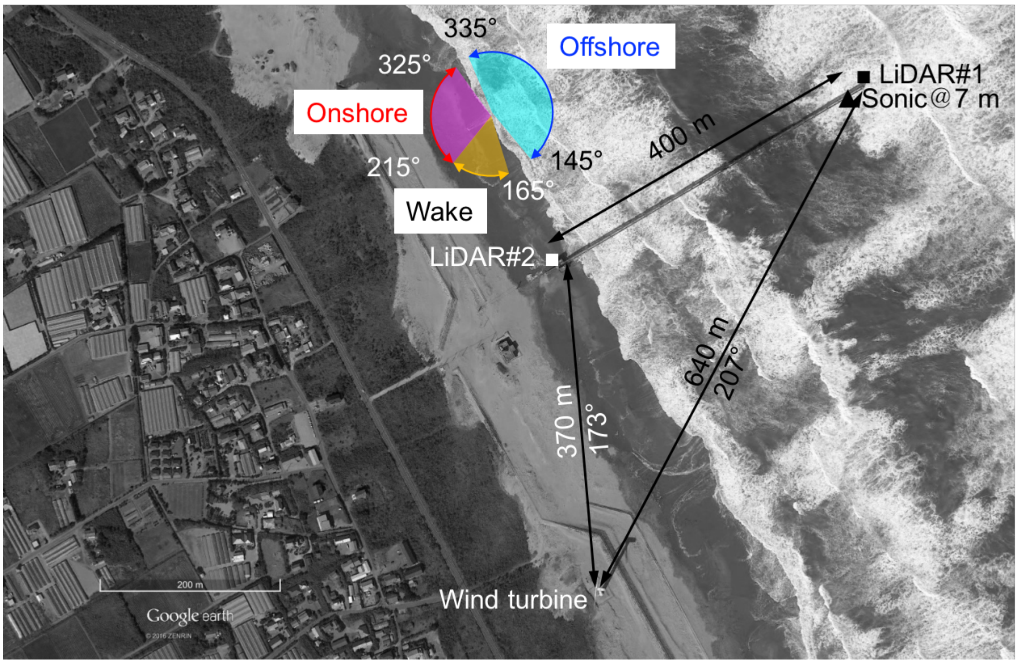

Fig. 2 Experimental setup

3. Main body of abstract

Figure 3 shows the time series of wind speeds and directions at 80 m height, obtained with the LiDARs during the period from March 22 to April 10, 2016. The data availability for both LiDARs exceeded 98%. For this period, the mean wind speed at 80 m height was 7.1 m/s and the prevailing winds were north-northwesterly. From Fig. 3, a large difference cannot be seen between the observations by the two LiDARs. The wind speed ratio for LiDAR#1 to LiDAR#2 as a function of wind direction is shown in Fig. 4. The bin-averaged values within 10° intervals were calculated, and are plotted in red on 10-minute observations. Two peaks with ratios of about 1.1 in bin-average can be seen around wind directions of 150° and 330°, which correspond to the directions of the coast. The winds measured by LiDAR#1 on the top of the pier for these directions had a long marine fetch, while those measured by LiDAR#2 were entirely onshore. Hence, this result suggests that the fetch effect can result in an increase in offshore wind speeds of up to 1.1 times, while travelling over water for a long distance. On the other hand, the trough at about 200° in Fig. 4 might be attributable to the wake from a nearby wind turbine, which has a hub height of 64.5 m and a rotor diameter of 62 m. The same figure, but for 200 m height is depicted in Fig. 5. The variations dependent on the wind directions found in Fig. 4 cannot be seen at 200 m height. Therefore, the difference between Figs. 4 and 5 indicates that the variations dependent on the wind directions reflect the fetch and wake effects near the surface. Unfortunately, the number of observations is currently insufficient to consider the influence of the turbine in detail. Thus, a more detailed analysis will be conducted after more data are collected over the coming months.

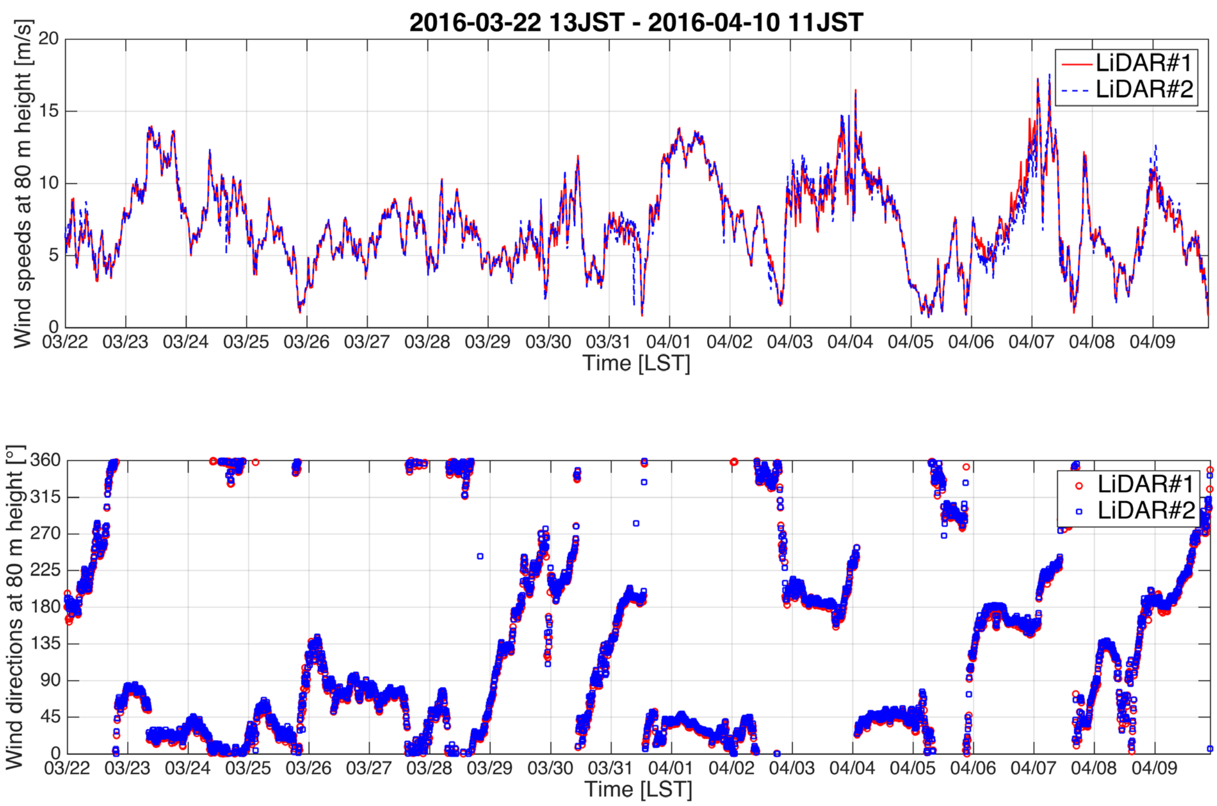

Fig. 3 Time series of wind speed (top) and direction (bottom) at 80 m height, observed by two LiDARs.

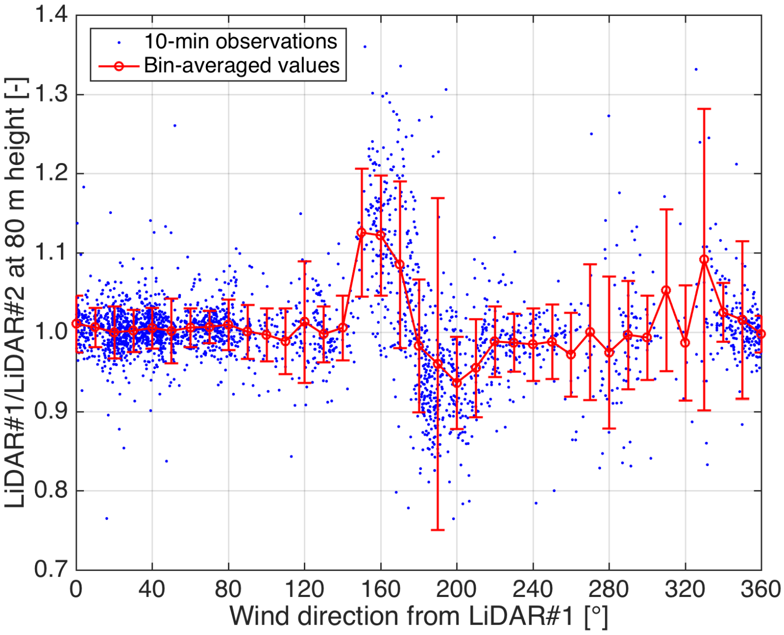

Fig. 4 LiDAR#1 to LiDAR#2 wind speed ratio at 80 m height as function of wind direction.

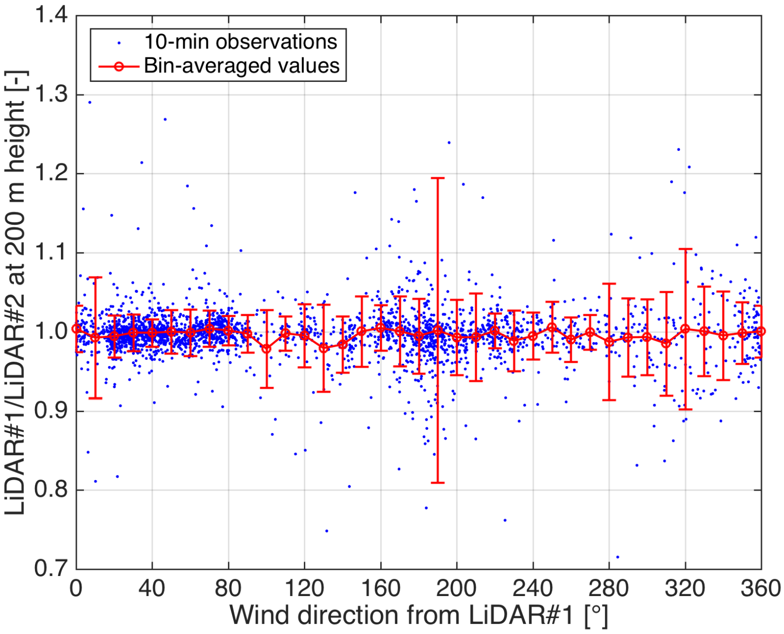

Fig. 5 Same as Fig.4, but for 200 m height.

4. Conclusion

A coastal wind measurement campaign has been conducted using two vertical LiDARs at a coastal research station, HORS, to investigate the increase in wind speed with distance from the coast. The experimental setup and initial results for the first three weeks were described. The results showed that the 80 m height wind speed in this region increased by a factor of up to 1.1 times when travelling over a long marine fetch. In addition, the wind speed measured at the top of a peer were influenced by a nearby wind turbine which was located 640 m southeast of the LiDAR. Theoretically, offshore winds with fetches ranging from 400 to 6,000 m can be observed at the top of the pier. The relation between the wind speed ratio and fetch are being quantitatively examined using LiDAR and sonic observations, with the intention of presenting results at the conference. Moreover, the difference between onshore and offshore vertical wind speed profiles are also presented.

5. Learning objectives

The object of this study is to examine the changes in coastal winds when transitioning from onshore to offshore using LiDAR measurements. It was unclear how much more effective it is to develop wind farms in the sea near the shore than on land, since the difference of onshore and offshore wind speeds was yet to be well examined. The difference in wind speeds over the land and sea might be of interest not only to scientists, but also to engineers working in the renewable energy industry, since it is highly relevant for effective offshore wind farm development. Moreover, the results of this study will also be beneficial to researchers who are assessing wind resources using numerical simulations, as high-quality observations are necessary for developing and validating numerical models.