[Reserved field]

Comparison between the 2D wind fields retrieved by a scanning Doppler lidar and anemometric measurements

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Introduction

In the framework of the European Project THUNDERR (Solari et al., 2020), a scanning Doppler lidar was installed in 2018 in the Port of Genoa with the aim of detecting and measuring downbursts and thunderstorm outflows that approach the Italian coast from the Ligurian Sea. As the lidar measures only the radial wind component, a procedure was needed to retrieve the two-dimensional (2D) wind fields from the raw scanning lidar data. In this work, the SingleDop software is used for the 2D wind field reconstruction and the results are compared with ultrasonic anemometric measurements. SingleDop is a software module based on the theoretical work described in Xu et al. (2006), which is intended to retrieve 2D low-level winds from either real or simulated Doppler radar data.

Instrumentation and methodology

We used the measurements of the ground-based instrumentation located at the Port of Genoa (Italy). The scanning Doppler lidar used is a WindCube 400S (Leosphere Inc.,) which scans the azimuthal range of 100º – 250º, up to a maximum distance of 14 km in the radial direction, for 4 elevations corresponding to 2.5º, 5°, 7.5° and 10º from the horizontal. The anemometer used for comparison is located about 1.3 km to the southeast of the Doppler lidar and provides the wind velocity with a sampling rate of 1 Hz. The wind speed and direction precision of the anemometer are 0.01 m/s and 1º, respectively.

The radial velocities measured by the Doppler lidar are used to retrieve 2D wind fields by the SingleDop software. The lidar dataset analyzed in this study ranges from November 2019 to July 2020. We analyzed each scan for three different de-correlation lengths (L = 1, 5 and 10 km) to evaluate the best value of L for wind field retrieval. L is a tuning parameter in the wind retrieval method. Larger values of L provide more smooth wind field, whereas the smaller values of L introduce small-scale features into the wind flow. The number of measurements available for the comparison is approximately 420 scans per day × 180 days × 4 elevations × 3 L, which results in nearly 10^6 processing cases .

Results and discussion

Figure 1 shows normalized number density plots of wind speeds retrieved by SingleDop using the lidar scans at 2.5º and compares the values to anemometer measurements. The anemometer data are averages of wind measurements over a period of ± 30 s from the lidar scanning time. Overall, the retrieved wind speeds have good correlation with anemometer measurements. The linear correlation coefficient (R) is higher than 0.9 for all values of L. The linear fit for L1 shows that SingleDop overestimates the anemometer data at high wind speeds. For L5 and L10 the linear fits are closer to 1:1 line. The RMSE for L1, L5 and L10 retrievals are 2.4, 1.6 and 1.8 m/s, respectively.

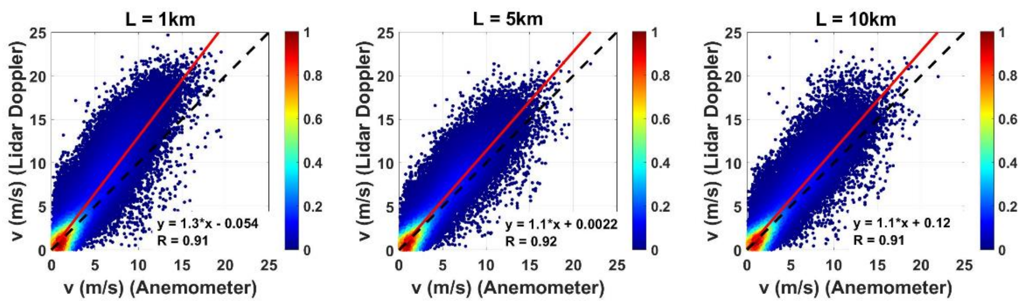

Figure 1. Wind speed retrieved by SingleDop using the Doppler lidar scans at 2.5º as a function of the anemometer measurements. Three de-correlation lengths (L) are shown: 1 km, 5 km and 10 km. The colour of points represents the relative density of points.

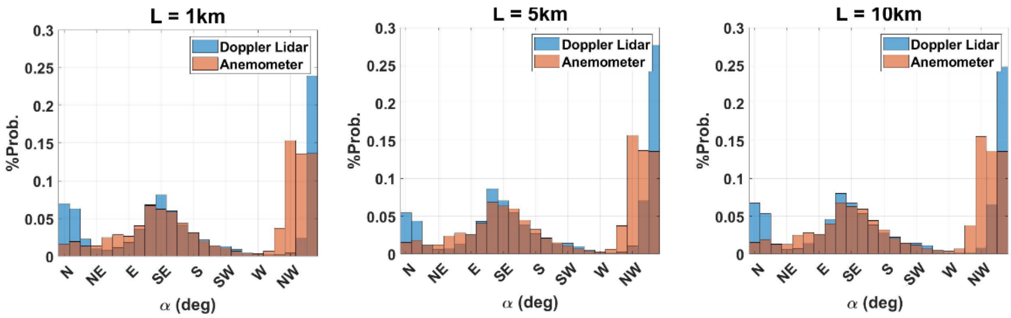

Figure 2. Distribution of wind direction measured by SingleDop and anemometer, in rectangular coordinates.

In terms of wind direction, we only considered the wind directions for which both retrieved and anemometer velocities were ≥3 m/s (~55% of data). This was done to avoid high variances in wind direction at low wind speeds. Figure 2 shows the distribution of retrieved wind direction and anemometer measurements. The circular correlation coefficient (ρ) obtained for all L's is ~0.9, thus indicating a good agreement between the retrievals and anemometer measurements. There is a predominant wind direction from NW-N with a mean value of 344 ± 12º and 330 ± 30º in both cases. The second most common wind direction was from SE (130 ± 50º).

Table 1. Regression results for wind speed and direction comparison between SingleDop L5 for 2.5°, 5°, 7.5° and 10º scans and anemometer measurements.

Wind Speed				
Elev.	**Slope**	**Offset (m/s)**	**R**	**RMSE (m/s)**
2.5º	1.1	0.002	0.92	1.6
5º	1.2	0.2	0.90	2.0
7.5	1.1	0.4	0.88	2.1
10º	1.1	0.6	0.85	2.2
Wind Direction				
Elev.	**Slope**	**Offset (º)**	**ρ**	**RMSE (º)**
2.5º	1.0	0.08	0.89	26
5º	1.0	4	0.88	29
7.5º	1.0	8	0.85	34
10º	1.0	10	0.81	37

Because the value of L5 provides the best overall correlation with anemometer measurements, Table 1 details the comparison between the L5 retrievals and anemometer data for all elevation scans The slopes are around 1 for both wind speed and direction. For wind speed, R ranges between 0.85 and 0.92, while for the wind direction ρ is higher than 0.8. The decrease of R with the elevation and the slight increase of RMSE for the values of wind speed and direction below 2.2 m/s and 37º are expected given that the difference of the altitude between the anemometer and retrievals is larger for higher scanning angles.

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