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LiDAR measurements of downslope winds in the Liguria region: Wind development from the mountains to the coast

Ivana Ivančić[a], Alessio Ricci[a], Massimiliano Burlando[b], Djordje Romanic[c], Branko Grisogono[d], Hrvoje Kozmar[d]

[a]*School for Advanced Studies, IUSS, Pavia, Lombardia, Italy, ivana.ivancic@iusspavia.it, alessio.ricci@iusspavia.it*
[b]*University of Genoa, Genoa, Liguria, Italy, massimiliano.burlando@unige.it*
[c]*McGill University, Montreal, Quebec, Canada, djordje.romanic@mcgill.ca*
[d]*University of Zagreb, Zagreb, Croatia,branko.grisogono@gfz.hr, hrvoje.kozmar@fsb.unizg.hr*

SUMMARY:
Downslope winds (DWs) frequently occur along the Ligurian coast in northwest Italy when cold air descends from the Maritime Alps and Apennines toward the Mediterranean Sea. Despite their frequent occurrence, especially in winter, Ligurian DWs are insufficiently documented. This study presents field measurements carried out during winter 2024/2025 using a WindCube 400s scanning LiDAR installed in the Port of Genoa. Preliminary results from a representative event that occurred on 19–20 February 2025 are presented. The results reveal the characteristic nose shape vertical profile expected in bora-like winds, as well as mean velocities exceeding 17 ms^{-1}. This findings indicate that Ligurian DWs may be as vigorous as severe bora.

Keywords: downslope winds, LiDAR measurements, Ligurian coast, wind field evolution

1. INTRODUCTION

Downslope winds (DWs) are considered non-synoptic winds in the wind engineering community. They often develop when cold air blows over a mountain along the lee slope (Durran, 2003). The study of DWs dates back to the 19th century, beginning with cloud observations with the aim of understanding the effects of upper air currents on the near-surface flows (Grubišić and Orlić, 2007). DWs develop due to mountain waves, hydraulic dynamics and atmospheric stability (e.g. Klemp and Lily, 1975, Clark and Farley, 1984, Smith, 1987).
DW-type winds occur in many parts of the world where they have local names. For example, similar winds occur near Hokkaido, Japan (Takimoto, 2022), Boulder, Colorado, United States (Klemp and Lily, 1975), over the Alps, Europe (Kuettner and O'Neill, 1981), to name a few. One of the most investigated DWs is the Mediterranean Bora, which blows over the Dinaric Alps in north-eastern Italy and Croatia (e.g., Grisogono and Belušić, 2009, Belušić et al., 2013, Bervida et al., 2019). Numerous field campaigns documented the mesoscale and microscale characteristics of bora (e.g., Ivančan-Picek et al., 2004, Grubišić, 2004, Belušić and Klaić, 2006, Večenaj et al., 2010).
In contrast, studies of similar bora-like DWs in other coastal Mediterranean regions are rather sparse. One of such regions is the Ligurian coast in Italy, where specific type of DW develops when the wind blows down the lee slope from the Maritime Alps and Apennines mountains towards the Mediterranean Sea (Burlando et al., 2017). In the western part of Genoa, at the end of the Turchino Valley, DWs events are frequent, especially during the winter season. However, they have not been studied in detail. To address this gap, field measurements were performed using Light Detection and Ranging (LiDAR) scanner during the winter of 2024/2025 as part of the 'ERIES-LIDAR' transnational access project, supported by the Engineering Research

Infrastructures for European Synergies (ERIES).

2. DATA AND METHODOLOGY

Measurements were performed between December 2024 and March 2025 using a WindCube 400S (version 2018) operated by the University of Genoa. The scanning LiDAR operates over a maximum distance of 14 km. It is installed at the end of a long quay, 5 m above the sea level (Fig. 1). Since the Turchino valley is to the north-west of the Port of Genoa, LiDAR is positioned to assess the DWs coming from azimuthal directions between 270° and 360° (Fig. 1b).

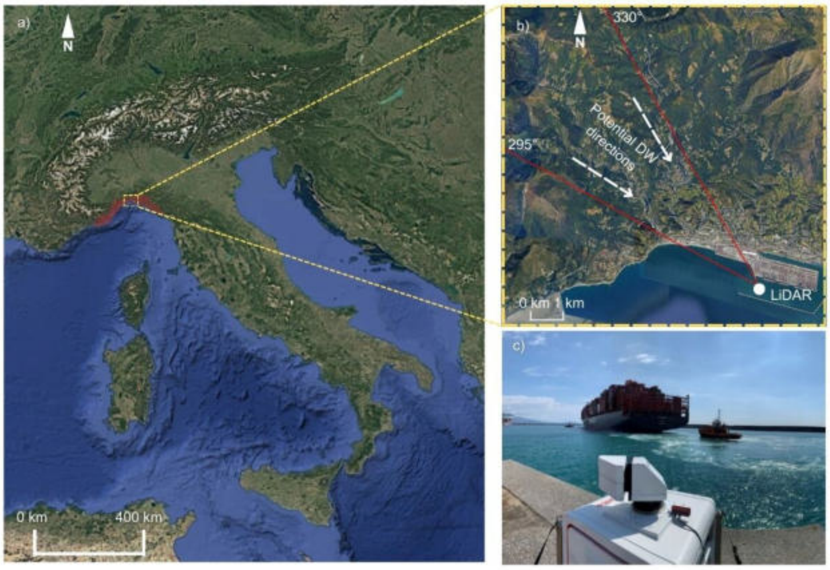

Figure 1. a) City of Genoa in the north-west of Italy, with the Liguria region indicated in red; b) position of the scanning LiDAR in the Port of Genoa, potential directions of DWs and the scanning path of the LiDAR during the measurement campaign; c) scanning LIDAR at the end of the quay.

While multiple DW events were observed during the field campaign, this study focused on a single DW episode. During the event on 19 and 20 February 2025, DWs were driven by a high pressure system over the northern and central Europe and a spacious pressure low over the Atlantic ocean. This synoptic situation is similar to the configuration that frequently occurs during bora events in Croatia, which blows over the Dinaric Alps towards the Adriatic sea (Grisogono and Belušić, 2009). This DW event was measured using a single Range Height Indicator (RHI) scan at an azimuthal angle of 320°.

3. RESULTS AND CONCLUDING REMARKS

Figure 2a shows the development of the characteristic vertical profile of the wind speed calculated over a 30-minute long window. In Fig. 2b, we showcase the 30-minute averaged mean velocity measured at the distance of 5900 m away from the scanning LiDAR. Furthermore, Fig. 2c and d display the time series for two different time windows. The first one from 00:40 to 01:10 UTC, when the mean velocity was 17.38 ms^{-1} (peak of the event), and the second one from 06:42 to 07:12 UTC. According to (Bajić, 1989), bora is classified as severe when the mean velocity exceeds 17 ms^{-1}. This condition is satisfied in the present event near Genoa. Further investigation of gustiness and certain turbulence characteristics is ongoing and will be presented during the conference.

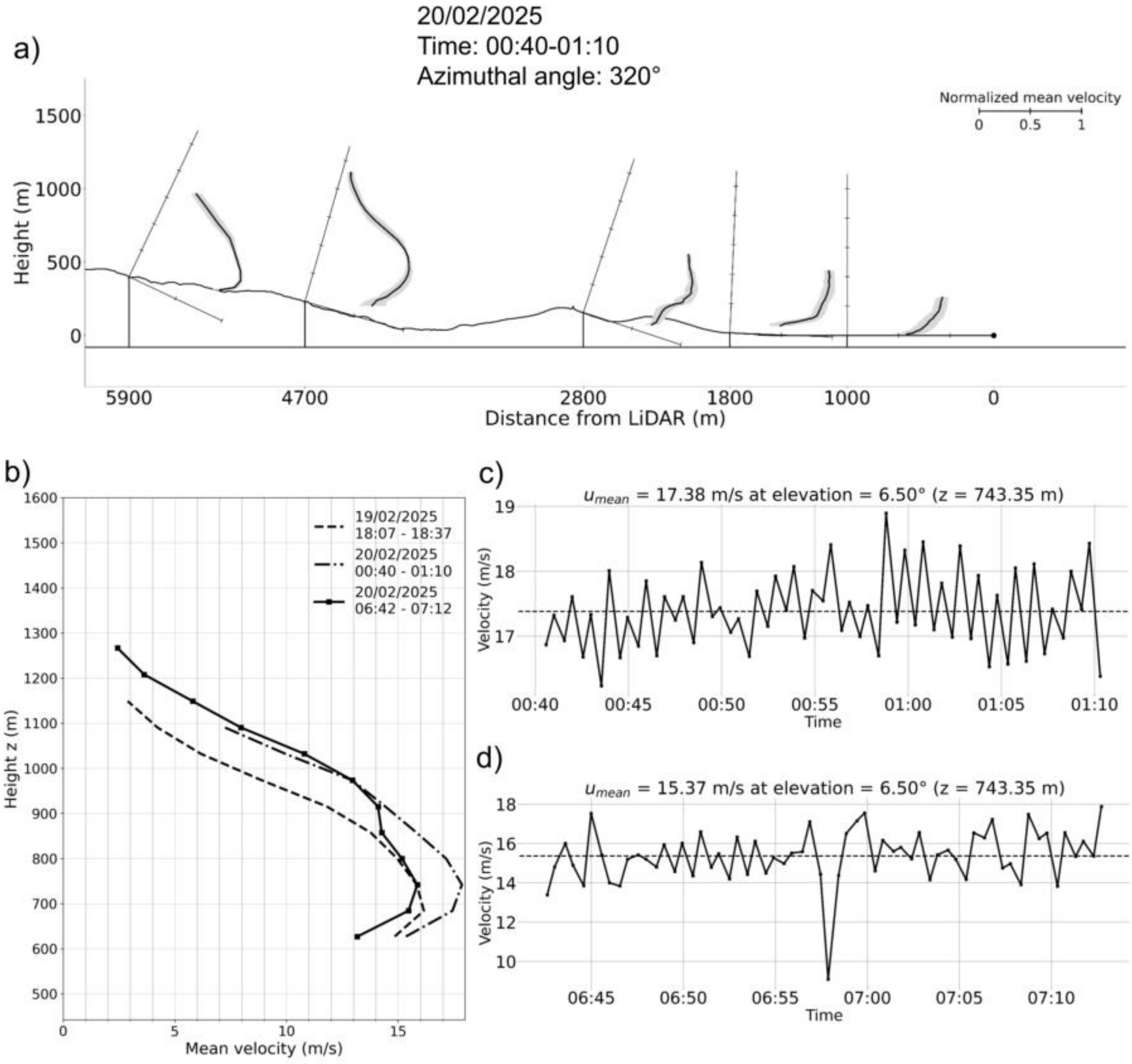

Figure 2. a) Development of the wind profile along the lee side of the orography; b) Mean 30-min velocity at 5900 m from the scanning LiDAR; c) time series at the height of 743.35 m from 00:40 - 01:10 UTC; d) time series at the height of 743.35 m from 06:42 - 07:12 UTC.

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