Data Set Description:
PI: Sergey Khaykin
Instrument: Rayleigh-Mie Doppler Lidar
Site(s): Maido observatory, Reunion island (21.0º S, 55.5 º E, 2158 m)
Measurement Quantities: Horizontal wind components (5-70 km)

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Instrument Description

The design of LiWind lidar is largely similar to that of LIOvent wind lidar at OHP (Souprayen et al., 1999; Khaykin et al., 2020), except for the telescope. Both lidars feature a transmitter based on a Quanta-Ray Pro290 Q-switched, injection-seeded Nd:YAG laser emitting at 532 nm with a repetition rate of 30 Hz and 800 mJ per pulse energy. The sensing of wind velocity is done using a double-edge Fabry-Perot interferometer for detection of the Doppler shift of Rayleigh-backscattered light.

The key difference between LIOvent and LiWind instruments regards the telescope design and the commutation of the emitted and received light between the different lines of sight. While the OHP LIOvent lidar is based on three fixed mosaic telescope assemblies comprising four 50 cm parabolic mirrors each (which translates to the total collective area for each telescope of 0.78 m^2), the LiWind instrument makes use of a rotating 60 cm mirror (collective area 0.28 m^2), which serves for both emission and reception of the light from the off-zenith lines of sight. An additional pair of mirrors serves for commuting the laser beam to the zenith line of sight.

The backscattered light is collected by means of a multimode optical fiber located at the focal point of the mirror after a 0.3 nm-wide interference filter and linked to an optical commutation chamber, which transfers the collected light to the entrance of the FPI (Fabry-Perot Interferometer) etalon in a thermally-stabilized pressure-controlled chamber.

The detection of the spectrally-processed light is done with two pairs of cooled ultra-bialkali Hamamatsu R9880-210 photomultipliers (PMTs), receiving respectively 95% and 5% of the flux (high- and low-gain channels). The high-gain PMTs are electronically gated at 30 µs, i.e. 5 km radial distance. The acquisition is done using a four-channel Licel transient recorder featuring 8190 gates of 100 ns width (i.e. 15 m radial resolution) and 200 ns (i.e. 30 m radial resolution) for the low-gain and high-gain channels respectively. The low-gain channels provide analog counting option.

Algorithm Description

Complete description of the wind retrieval algorithm, which is identical to the OHP wind lidar, can be found by Khaykin et al. (2020). An absolute measurement of the wind velocity requires a careful determination of the null Doppler shift reference, which is done through 1-minute zenith-pointing acquisition within each 12-minute cycle. The measurement cadence is such that the zenith, south and east lines of sight are alternated in a cycle of 1-5-5 minutes respectively. A typical acquisition lasts 5 hours during nighttime, which ensures signal-to-noise ratio better than 2 all the way up to about 70 km altitude a.s.l provided clear-sky conditions.

The lidar returns are aggregated over 5-minute intervals and downsampled to 1 μs bins (300 m radial resolution). The off-line signal pre-processing includes subtraction of background due to sky light and PMT thermal noise as well as dead-time correction, after which the response profiles are calculated for each line-of-sight using eq. 1 in Khaykin et al. (2020). Then, the Doppler shift is computed using the instrument calibration function with account for atmospheric temperature profile, provided by ECMWF analysis. Finally, the zonal and meridional wind components are obtained by comparing the tilted East and South pointings to the corresponding zenith pointing (see eq. 2) in (Khaykin et al., 2020).

Expected Precision/Accuracy of Instrument

For a typical lidar acquisition lasting 5 hours (i.e. ~2.1 hours of a given tilted pointing acquisition, the statistical (photon counting) error is less than 3 m/s below 33 km and does not exceed 9 m/s throughout the stratosphere. In the mesosphere, the error increases from 10 m/s at 50 km to 25 m/s at 70 km.

The evaluation of the LiWind instrument performance has been done using a series of 39 time-coordinated radiosoundings conducted at Maido within various measurement campaigns between 2015 - 2021. A point-by-point intercomparison showed a remarkably small average bias of 0.1 m/s between the lidar and the radiosonde wind profiles with a standard deviation of 3.7 m/s.

LiWind lidar has been used for validation of the space-borne Aeolus ALADIN Doppler wind lidar within AboVE-Maido campaigns in 2019 and 2021, which altogether included 21 time-coordinated lidar and radiosonde measurements during the satellite overpasses (Ratynski et al., 2023). On average, we found a systematic error (bias) of −0.92 and −0.79 m s^{-1} and a random error (scaled MAD) for the Aeolus measurements of 6.49 and 5.37 m s^{-1} using the LiWind lidar and radiosondes, respectively.

Instrument history and perspectives

The OPAR wind lidar represents a successor of the NDACC-affiliated OHP LIOvent lidar featuring a more compact telescope design. LiWind has been deployed at Maido observatory of La Reunion in 2013, shortly after the station inauguration (Baray et al., 2013). A series of technical campaigns aimed at the evaluation and improvement of the instrument capacities has been carried out in November 2014 (Lideole-I), October 2015 (Lideole-II), June 2016 (ARISE2), June 2017 (Lideole-III), September 2019 (AboVE-1) and June 2021 (AboVE-2). Initially, LiWind lidar did not have the vertical pointing and the absolute calibration was made using ECMWF meteorological analysis. A replacement of the PMT detectors and installation of the PMT cooling system has been carried out prior to Lideole-II. During Lideole-II, the vertical pointing has been successfully implemented. Prior to the AboVE-I Aeolus cal/val campaign in September 2019, a new advanced spectral processing box has been installed and the wind lidar's performance has been brought to the current level in terms of its altitude coverage. Since that time, the lidar has been operated quasi-continuously together with all the other OPAR lidars. In 2022, LiWind took part in a two-month intensive Hunga Tonga measurement campaign spanning January-March.

LiWind instrument makes part of the CNRS-INSU funded GON lidar project (2023-2025), aiming at a major upgrade and automation of the OHP and OPAR lidar parks. As the outcome of the project, all the lidars will be automated or semi-automated, which will enable remote operation of the lidars and therefore a significant increase in the measurement frequency.

Reference Articles

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