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3D WIND MEASUREMENTS WITH THE FIBERED AIRBORNE COHERENT DOPPLER WIND LIDAR “LIVE”

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ABSTRACT

A 3D wind profiling lidar based on the latest high power 1.5 μm fiber laser development at ONERA, has been successfully flown on-board a SAFIRE ATR42 aircraft. The lidar called LIVE is designed to measure wind profiles from the aircraft down to the ground, with a horizontal resolution of 3km, a vertical resolution of 100 m and an accuracy on each 3 wind vector components better than 0.5 m/s.

1. INTRODUCTION

Since the late 80's, several onboard coherent wind lidars have been developed, tested and exploited, based on various laser technologies: at 10,6 μm with gas laser [1][2][3], at 2 μm with solid state laser [4][5][6]. Recent progress in fiber laser technology at 1.5 μm have enabled new lidar technology development [7][8][9][10]. More robust and compact, fiber technology paves the way for a simple and standard use of coherent Doppler lidar from an airplane. The 1.5 μm lidar called LIVE has been developed at ONERA in order to measure 3D wind fields under an airplane. It was installed and tested on SAFIRE ATR42. LIVE wind lidar is based on a LEOSPHERE lidar that has been extensively modified to meet the constraints of real-time wind measurement from an aircraft. In particular, it incorporates an innovative laser amplifier designed and developed by ONERA which, thanks to its high peak power pulses, makes it possible to perform wind profiling from the aircraft altitude down to the ground.

2. LIDAR SPECIFICATIONS AND ONBOARD INSTALLATION.

The LIVE lidar is designed for 3D wind profiling from an aircraft for meteorological applications. The wind measurements requirements are a horizontal resolution of 3km, a vertical resolution of 100 m and an accuracy on each 3 wind vector components better than 0.5 m/s. To achieve those accuracies, the 1.5 μm laser energy is 350 μJ , with a 14 kHz pulse repetition rate. For a flight level of 5000 m, and an aircraft speed of 100 m/s, the 3km horizontal resolution is obtained with a conical scanning of 30° total opening angle and one round in 17 s. After each lap, the lidar points in the nadir direction during 2s, in order to achieve good accuracy on vertical wind. The 1.5 μm lidar detailed design will be the object of a specific publication.

The lidar is installed inside the SAFIRE ATR42 looking through a trapdoor in the floor of the plane in nadir pointing (Figure 1 & Figure 2).

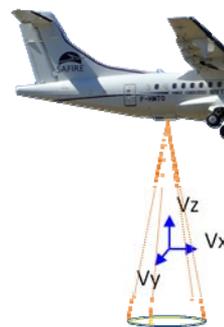


Figure 1: ATR42 aircraft, with trapdoor localization and lidar scanning representation

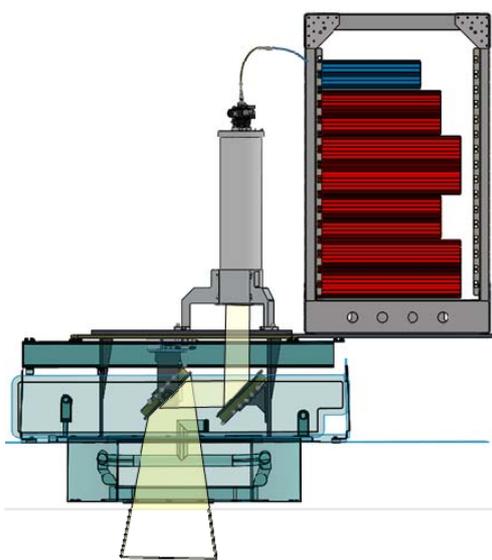


Figure 2: Drawing of the LIVE lidar installation inside the airplane.

3. FLIGHT TEST CAMPAIGN

The objectives of the test campaign were to evaluate LIVE behavior in aeronautical environment, to validate its performance (range, velocity measurements), and to validate LIVE 3D wind field measurements by comparisons with wind measurements from other ground based wind profilers (UHF Radar, ground based lidar).

Acquisitions of LIVE took place on February 20 and 21 2019, during 2 flights over 2 geographical areas of interest, a mountainous area (Lannemezan) and a plain area (Fauga). In the Lannemezan region stands the Atmospheric Research Center (CRA) where 2 wind profilers (UHF and VHF radar) were in action (it will enable Lidar measurements to be validated at high altitudes), while in the Fauga area stands an ONERA center where a WindCube 100S (commercial Lidar) was operated to compare ground based Lidar and airborne lidar measurements in the boundary layer. Flight altitudes of 3km, 5 km and 7 km were performed during those flight tests.

Real time displays for short time averaging (0.3s) of CNR and velocity along the line of sight were available onboard thanks to GPU computing

(Figure 4). For those flight tests, 3D wind vectors retrieval from a whole conical scan pattern will be post-processed using the VAD sine-wave fitting procedure [11] after aircraft attitude and speed correction.



Figure 3 : picture of the LIVE lidar installed inside the ATR42

Figure 4 show an example of onboard real time display. In top Figure 4 (CNR real time display), the horizontal axis is the line of sight number (2 complete conical scanning patterns); the vertical axis is the range from the lidar. The blind zone is followed by a low CNR area (in blue) due to low aerosols density at high altitude, then the laser pulse reaches the top of the boundary layer around 1.5 km, and high signal level is obtained up to the ground, where the laser reflects on the ground. The distance from which ground reflection is obtained varies because of aircraft attitude variation and because of steady nadir pointing for 2s. The bottom figure 5 (real time line of sight velocity display), shows a rainbow pallet mainly due to aircraft speed projection on the conical scan of the line of sight. The larger green area for very low vertical velocity is obtained during the nadir pointing in a steady horizontal flight path.

3D wind maps will be post processed after aircraft speed has been subtracted from the signal, and attitude angle has been taken into account to correct the scanning angle, before applying the sine wave fitting process. The aircraft speed and attitude have been recorded. The aircraft speed

can also be obtained from the Doppler signature of the ground echo.

An area from 700m to 1200m from the lidar contains many ‘outliers’ velocity values, due to low CNR. Those outliers will hopefully not compromise the sine wave fitting process.

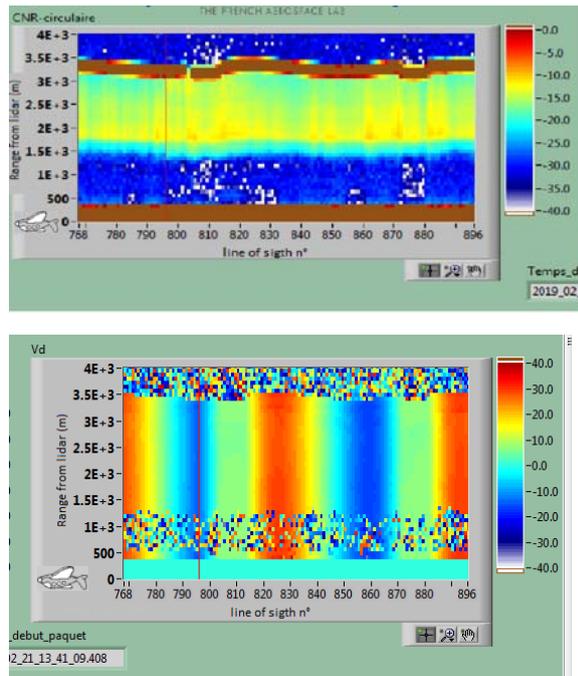


Figure 4 : Top: line of sight CNR real time display, Bottom : line of sight velocity real time display for the conical scan. Range zero is the aircraft altitude while range 3500 m is the ground echo.

4. CONCLUSIONS

A 3D wind profiling lidar based on the latest 1.5 μm fiber laser development at ONERA, has been successfully flown on-board a SAFIRE ATR42 aircraft. The LIVE lidar includes a VAD scanner. The horizontal resolution is 3km for a flight level of 5000m, the vertical resolution is 100 m and an accuracy on each 3 wind vector components better than 0.5 m/s. CNR and line of sight velocity are real time displayed onboard.

3D wind maps are being post processed. Examples of measured 3D wind maps and comparison with other ground wind profilers measurements (Radars and lidar) will be presented.

This airborne wind fibered lidar will be available for meteorological and atmosphere dynamics scientific studies.

ACKNOWLEDGEMENTS

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