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A NEW GENERATION OF DOPPLER RAYLEIGH LIDAR FOR ABSOLUTE WIND MEASUREMENTS

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INTRODUCTION

A few years ago, our laboratory developed a first Doppler Rayleigh LIDAR to measure the mean wind in the stratosphere. The feasibility of the new method employed was demonstrated in 1989 (Chanin et al., 1989). After the eruption of the Pinatubo volcano, in June 1991, we adapted the characteristics of the spectral analysis to obtain a wind measurement trouble-free of the presence of aerosols (Garnier and Chanin, 1992).

The first prototype version, the scope of which was to validate the new method employed, had a simplified design. Though, it did not provide simultaneously both horizontal components of the wind ; this restriction is a main limitation for the geophysical studies specifically those concerning short temporal scale phenomena. Furthermore, due to the spectral drift of the experiment, a radiosonde profile of reference was required to perform absolute wind profile.

The aim of this presentation is to describe a new wind lidar recently installed at the Observatory of Haute-Provence, in France (44°N, 6°E) and to present the first wind measurements. This new system has been designed to give an absolute and quasi-simultaneous determination of both horizontal components of the mean wind in the stratosphere and low mesosphere. It is more powerfull than the first one and more automated for an easier utilization by an operator.

LIDAR DESCRIPTION

Emission

We use the second harmonic of a pulsed (repetition rate = 30 Hz), single mode Nd:YAG laser. The output energy per pulse is typically 330 mJ at 532 nm.

Transmitter/receiver

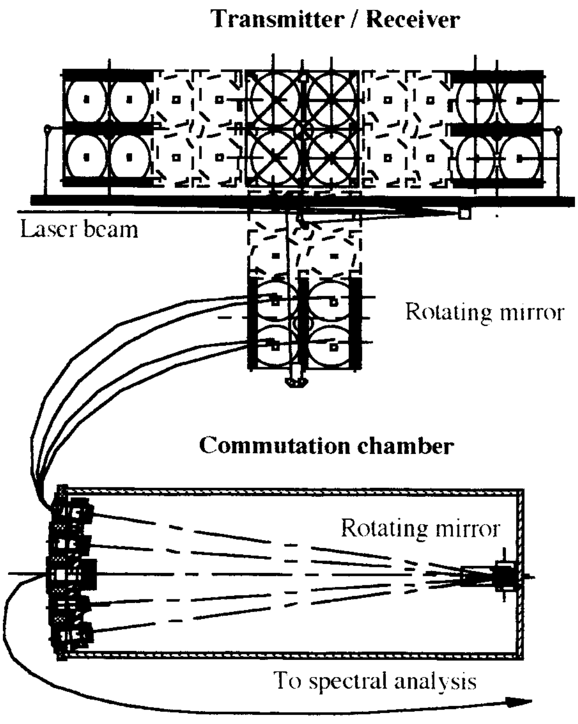
The apparatus includes 4 sub-assemblies : one points to the zenith and the 3 others are tilted at 40° from the zenith with an azimuth corresponding to a cardinal point (except for the South). The meridional component is obtained from the North and vertical lines of sight. The zonal component is obtained from 2 of the 3 following line of sight : East, West and zenith. For safety reasons towards the aerial traffic, the West pointing cannot be used very offen.

Each sub-assembly is composed of a central afocal transmitter and 4 receiving parabolic mirrors (diameter : 500 mm ; focale length : 1,5 m). The total collective area is 0.78 m^2. After the transmitter, the full divergence of the laser beam emited in the sky is 0.1 mrad. The photons are collected by the mean of 4 multimode optical fibers located at each focus point. The 4 fiber outputs are disposed together as close as possible in a unique cylindrical ferrule. The 4 cores of 200 µm diameter each are included in a 580 µm diameter circle. The 4 fibers have to be considered hereafter as a unique large optical fiber. This large extremity is fixed as input on a commutation chamber that receives each large fiber from each sub-assembly by the same manner ; the output is a unique 600 µm diameter optical fiber. The commutation chamber includes a rotating mirror and suitable optics to make the image of one of the 4 input fibers on the output fiber whose other extremity is fixed on an optical box for spectral analysis.

The 4 sub-assemblies, i.e. the 4 lines of sight, are never used at the same time but successively. The unique laser beam is sent on a second rotating mirror with 4 predefined positions. Each position induces a beam transfer up to the chosen afocal transmitter. Simultaneously, the rotating mirror in the commutation chamber is positioned in order to obtain the image of the adequate input fiber on the output fiber. The photons received are then spectrally analyzed in the optical box to extract the information on the wind.

Spectral analysis

The radial velocity along the line of sight is determined through the Doppler shift of the laser line after backscattering on the air particles. To measure the Doppler shift, we use a monolithic Fabry-Perot interferometer (FPI) with two slightly different thicknesses corresponding to two bandpasses A and B. The FPI is placed in the optical box that is thermally controled (± 0.1 °C). As the FPI has to be adjusted in order to center the laser wavelength between the two bandpasses, the optical thickness is adaptable by pressure scanning. The number of photons NA and NB transmitted respectively through the bandpasses A and B are detected with cooled Hamamatsu phomultipliers (PMTs) using the photon counting mode.



OPTICAL DESIGN

Data acquisition

The system includes 4 electronics channels with 2048 gates of 1 μs width. The computer used is a Hewlett-Packard's HP9000/400S. The software is based on multi-tasks concepts. It drives the electronics, controls the lidar and stores the data. It provides a real time calculation of the scientific parameters that are also plotted on a graphic window.

Automatic change of line of sight

One of the most important improvement on this new wind LIDAR is the automatic and fast change of line of sight, which is driven and controled by the computer. The operator fixes the change of lines of sight progress (choice of the directions, frequency of change) at the beginning of the experiment. For each change request, the software orders the laser light interruption, drives the simultaneous rotation of both mirrors and, after status control, authorizes again the laser emission. The data acquisition begins then immediately. As the computer needs about 1 second for the change, it is possible to change the line of sight for example every minute, pointing successively to the East, the Vertical, the North, this sequence being repeated for one to a few hours. This kind of configuration has just been tested successfully at O.H.P. As the wind is deduced from 2 measurements temporally spaced from only 1 minute, we obtain an absolute determination of the velocity, with a residual systematic error due to the spectral drift for 1 minute. The signal to noise ratio is improved by increasing the number of sequences, or the integration time. Such frequent change of line of sight allows a quasi-simultaneous determination of both horizontal wind components.

CONCLUSION

The first wind measurements will be able in the next month and will be presented for the 17th International Laser Radar Conference. The preliminary results obtained recently shown the feasibility of the frequent change of sight, without any problem of alignment due to the rotation of the mirrors. The new system is expected to give the absolute wind profile without needing any external reference as a radiosonde. The wind profiles should extend typically from 15 to 60 km for about 2 hour integration time and 2 km height resolution, with a statistical error of ±15 m/s in the upper part of the profile. Depending upon the temporal and spatial resolution chosen for the analysis, this new wind lidar system allows geophysical studies on both large scales (i. e. mean wind, planetary waves) and mesoscale (i.e. gravity waves) phenomena, and on coupling effects. As far as the new lidar provides absolute wind measurements, validation of on board satellite systems is possible (HRDI experiment on UARS satellite).

REFERENCES

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