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DLR - Doppler Lidar Activities

(from ground-based to airborne and space-borne Doppler lidars)

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Abstract

A report is given on DLR-Doppler lidar development and appication. The DLR-ground-based system is in operation since 10 years, the airborne system ADOLAR is just tested , the pulsed airborne system WIND is under development with CNRS-France, and the spaceborne system ALADIN is in a pre-phase A study at ESA. Results of ground-based and airborne systems are presented with respect to global wind observations from space.

1. Introduction

The last ten years have seen a significant improvement in our ability to forecast the weather and simulate the general circulation of the atmosphere. This success has served to expose and underline the need for a significant improvement in the global and regional observing system. In this connection special mention should be made of observations of wind fields in three dimensions as these are of special importance to both operational weather forecast and studies of the Earth´s climate. The estimation of energy convergence and divergence asks for the precise measurement of wind with the accuracy and resolution shown in table 1.

Table 1 Requirements for a spaceborne lidar by German Weather Service

	Stratosphere	Troposphere
horizontal resolution	100 km (50 km)	100 km (50 km)
vertical resolution	3 km	1 km between 2 - 15 km 0.5 km below 2 km
accuracy	2 - 3 m/s	1 - 2 m/s
frequency per day	4	4

2. Doppler lidar technique

One measures the backscattered, Doppler shifted radiation. Backscattering depends on the size and number density of the aerosol particles available in the volume of interest. The backscattered Doppler frequency directly determines the line-of-sight (LOS) component (V_{LOS}) of the wind vector. At CO_2 laser (wavelengths $\lambda = 10.6\ \mu m$) a velocity component of 1 m/s corresponds to a frequency shift, Δf_D of 189 kHz. This is obtained from the equation

$$\Delta f_D = 2 \frac{V_{LOS}}{c} \cdot f_0$$

where c is the speed of light and V_{LOS} is the line-of-sight component.

By scanning the transceiver with a conical scan pattern (VAD) one reaches different azimuth and elevation angles to combine the single LOS-components to a wind vector (sine-wave-fitting). Conical scans performed from the airborne system WIND need a sector data handling and the spaceborne systems only LOS-components can be used.

It is accepted worldwide that ground-based Doppler lidars can measure wind profiles in the atmosphere. Various field experiments have been carried out where balloon wind-sondes were launched simultaneously with wind profile measurements made by Doppler lidar (Hall et al., 1984; Köpp et al., 1984).

If one uses the laser Doppler system on board an aircraft or in space, the speed of the aircraft (spacecraft) modifies of the Doppler shift with $v_{LOS} = v_{LOS}(\text{wind}) + v_{LOS}(\text{carrier})$,where $v_{LOS}(\text{carrier})$ is the carrier speed with respect to the laser line-of-sight.

3. Ground based system (LDA Container)

The continuous wave CO_2 laser Doppler anemometer exists since 1983. It is installed in a standard container for mobil operations.Table 2 gives the system parameters.

Table 2 LDA system parameters

laser:	CO_2 laser from Marconi (U. K.)
laser power:	4 W cw
transceiver:	primary mirror 30 cm diameter
range resolution:	at 100 m approximatly 6 m
detector:	MCT at 77 K (SAT)
SAW spectrum analyser:	accuracy 0.2 m/s
installation:	20" container, weight 5350 kg
power required	4 kVA

A surface-acustic dispersive-delay-line spectrum analyser (SAW) is used to process the Doppler shifted data.

4. Airborne cw-Doppler lidar (ADOLAR)

Based on the experiences with the compact - LDA (Werner et al. 1992) an airborne cw-Doppler lidar was developed. The main part of the compact LDA is the optics. It consists of the three parts: Laser,transceiver optics and interferometer. The laser is a four Watt Laser Ecosse Ltd. CM 1000 waveguide laser (former Ferranti). It is a dc-driven laser which needs a Freon cooling system. The system ADOLAR was tested in 1994. Figure 1 shows the installation in the Falcon 20 aircraft.

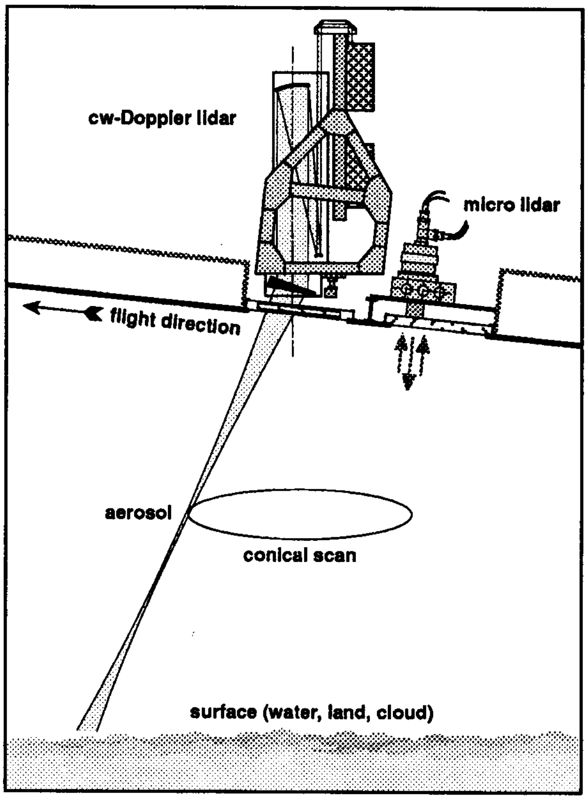

Figure 1 Installation of two lidars in the Falcon 20 aircraft

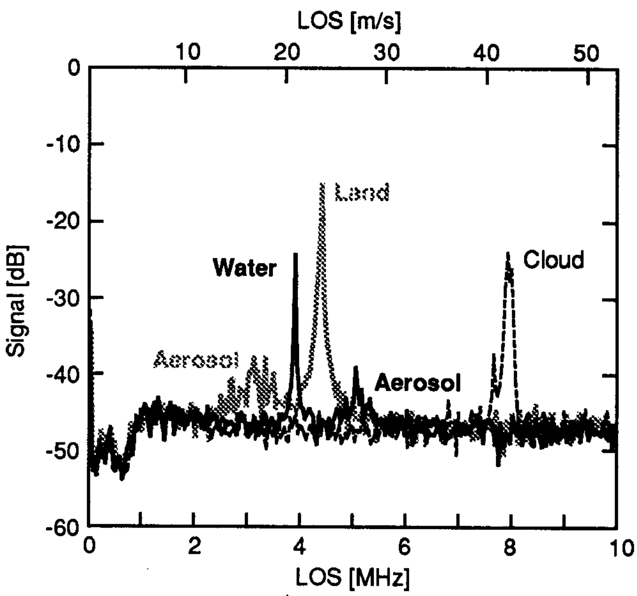

Figure 2 Doppler lidar signals for different targets

The Doppler lidar can perform a conical scan using a Gemanium wedge scanner into the nadir direction. The aircraft position versus nadir was corrected by the construction of the mounting frame. A simple backscatter lidar was installed adjacent to get range resolved information on the scatterers .

A first flight test was performed on May 18, 1994. Received beat frequencies were digitized and analyzed. Figure 2 shows 3 single measurements at different scan direction and different time (flight altitude) for an first overview. There is a land and sea surface return each together with an aerosol (wind) signal. This is caused by the focal distance of 200 m and the stronger return of land and sea surface from outside the focal volume (figure 1). The wind signal is left from the land signal and right from the sea signal caused by the scanning and the aircraft velocity. The LOS difference is in the order of 8 m/s. The third signature comes from a cloud. As shown in figure 2 there is different signal strength from water and land. Because this signal can be used from a spaceborne Doppler lidar to correct the pointing and laser parameters, its variation is importand.

5. Representativity

For extrapolation to a spaceborne system, the main question to be answered was: How representative is a single line-of-sight component ? A study was performed where it was assumed that a measured Doppler lidar wind profile (ground-based) from the sine-wave fitting was the true wind profile. A single LOS component out of this data set is the spaceborne lidar simulation value. The errors in measuring the LOS components with the Doppler lidar are mainly caused by speckle noise.

To improve the accuracy or probability for the estimation of the error, averaging is possible in various ways:

- integration of a few shots (by hardware before or by software after the signal processing)
- summing up some height levels (gates).

Data sets from a ground based system (M. Hardesty et al.) were available as single shots and as averages of three pulses (averages performed by hardware). Thus it was possible to compare both methods of averaging.

The results of the representativity study are (Werner et al.(1992)): The representativity depends mainly on the atmospheric aerosol loading and the laser stability. Sufficient aerosols and laser pulse power produce a processable signal. Averaging or/and selection of useful information out of a speckle signal is necessary.

6. References:

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