Airborne wind lidar observations over the North Atlantic in preparation for the ADM-Aeolus validation

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Abstract: The first space-borne wind lidar mission ADM-Aeolus from ESA is currently scheduled for launch by mid-2017. Aeolus carries the direct-detection Doppler lidar ALADIN that operates at an ultraviolet wavelength of 355 nm and makes use of two types of spectrometers to measure frequency shifts from molecular and aerosol backscatter. For the preparation of the Aeolus validation, an airborne field experiment was performed during 3 weeks in May 2015 with the DLR Falcon and the NASA DC-8 aircraft. For the first time 4 wind lidars were deployed during an airborne campaign including two coherent and two direct-detection wind lidars at a wavelength of 2-µm and 355 nm. A total of 7 coordinated flights of the Falcon and DC-8 yielded an extensive dataset of wind lidar observations in the North Atlantic region around Iceland and Greenland.

Keywords: ADM-Aeolus, Airborne Wind Lidar, Coherent Detection, Direct Detection

1. Introduction

Measurements of winds throughout the atmosphere are crucial for both numerical weather prediction (NWP) and climate studies. Nevertheless observations of height profiles of the global wind field are still pending and profile measurements of wind are prioritized by World Meteorological Organization (WMO) expert teams for global NWP. The European Space Agency (ESA) is currently implementing a Doppler wind lidar mission named Atmospheric Dynamics Mission ADM-Aeolus [1]. It is considered as a technology demonstrator for future operational wind lidar missions. Aeolus will provide profiles of one component of the horizontal wind vector along the laser line-of-sight (LOS) from ground up to the lower stratosphere (20-30 km) with 0.25 km to 2 km vertical resolution and a precision of 1 m/s to 3 m/s depending on altitude. A wind profile will be obtained from horizontal averaging over 90 km along track. The launch of the satellite is currently planned for mid-2017.

The lidar ALADIN (Atmospheric LAser Doppler INstrument) is based on a direct-detection Doppler wind lidar (DWL) operating at 354.9 nm [2]. The optical receiver consists of two spectrometers to determine the Doppler shift from the spectrally broad Rayleigh-Brillouin molecular backscatter and the spectrally narrow Mie backscatter from aerosols and cloud particles.

In order to assess the performance of the Doppler lidar ALADIN and to optimize the retrieval algorithms with atmospheric signals, an airborne prototype – the ALADIN Airborne Demonstrator A2D – was developed [3,4]. The A2D was the first airborne direct-detection Doppler lidar with its maiden flight on the DLR Falcon aircraft in 2005. Three airborne campaigns with a coherent-detection wind lidar and the direct-detection wind lidar A2D were performed for pre-launch validation of Aeolus from 2007-2009 [5-7].

In preparation for the Aeolus validation, an airborne field experiment was performed during 3 weeks in May 2015 with the DLR Falcon and the NASA DC-8 aircraft. For the first time 4 wind lidars were deployed during an airborne campaign including two coherent and two direct-detection wind lidars at wavelengths of 2-µm and 355 nm. A total of 7 coordinated flights of the Falcon and DC-8 yielded an extensive dataset of wind lidar observations in the North Atlantic region around Iceland and Greenland.

2. Objectives for the airborne campaign from 2015

The objectives for this campaign in 2015 were derived from results, experience and lessons learnt from the previous ADM pre-launch airborne campaign from 2009:

1. Confirm and document the technical performance of the A2D lidar and its suitability for the foreseen calibration/validation (Cal/Val) of ADM-Aeolus.
2. Extend datasets on response calibrations over favourable areas for Aeolus calibrations, e.g. ice or land with high surface albedo in nadir-pointing mode.
3. Extend datasets on Rayleigh and Mie wind observations. This shall include measurements in highly variable atmospheric conditions (vert./hor.) w.r.t. wind and clouds
4. Rehearsal for airborne Cal/Val activity after launch with focus on coordination with other aircrafts and ground validation sites.
5. Extend datasets on Rayleigh and Mie wind observations for variable aerosol conditions, e.g. low to high backscatter and different depolarization characteristics from aerosol.
6. Extend datasets on response calibration during less favourable conditions (cloud contamination or strongly varying ground albedo conditions, PBL snow drift conditions).
7. Demonstrate the ADM-Aeolus capabilities in resolving the vertical structure of the atmosphere and compare measurements to output from numerical weather prediction models.
8. Perform satellite underpasses for CALIPSO, ASCAT, TDS-1, or other existing satellite sensors.

3. Airborne and ground-based wind lidar instruments

Both the DLR Falcon and NASA DC-8 aircraft were equipped with a coherent and direct-detection wind lidar operating at wavelengths of 2-µm resp. 355 nm. The payload of the DLR Falcon aircraft consisted of the A2D [2-4] and the 2-µm Doppler wind lidar (DWL) [8-11]. The NASA DC-8 was equipped with the DAWN (Doppler Aerosol Wind) [12], TWiLiTE (Tropospheric Wind Lidar Technology Experiment) [13] and a dropsonde unit from Yankee Environmental Systems [14]. The main properties of the 4 different wind lidars A2D, 2-µm DWL, DAWN and TWiLiTE are summarized in Table 1.

In addition to the airborne instruments, a ground-based wind lidar was deployed at the Greenland Summit Station (72.58°N, 38.48 W, 3216 m ASL) specifically for this campaign. This station releases 2 radiosondes per day and is equipped with an aerosol lidar from the MPL (micro-pulse lidar) network [15]. The NCAS (National Centre for Atmospheric Science) Doppler Aerosol lidar (manufacturer Halo Photonics) operating at a wavelength of 1.55 µm collected data continuously at the Summit station from May 1, 2015 to June 27, 2015. The objective was to characterize the backscatter and wind conditions close to the surface (e.g. blowing snow, diamond dust), which is of relevance specifically during response calibrations for the ALADIN.

Table 1. Operating parameters of the 4 airborne wind lidars in May 2015

	DLR Falcon		NASA DC-8	
parameter	**A2D**	**DWL**	**TWiLiTE**	**DAWN**
wavelength	354.9 nm	2022.5 nm	354.7 nm	2053.5 nm
pulse energy	50-60 mJ	1-2 mJ	25 mJ	100 mJ (nominal 250 mJ)
pulse length	20 ns	400 ns	15 ns	180 ns
repetition rate	50 Hz	500 Hz	200 Hz	5 Hz (nominal 10 Hz)
telescope Ø	20 cm	10.8 cm	32 cm	15 cm
vertical resolution	300 m - 2.4 km	100 m	200 m	156 m
temporal resolution	14 s (+4s data transfer) per LOS	1 s per LOS	30 s per LOS	4 s per LOS
scanning	no, fixed LOS with 20°	double wedge with conical scan and fixed LOS (vertical)	conical scan with 45°	single wedge with 30.1 °
precision	1.5 m/s (Mie) 2.5 m/s (Rayleigh)	< 1 m/s (speed)	2 m/s	< 1 m/s (speed)

4. Flight Tracks

Both aircrafts were operated from Keflavik, Iceland from May 11 to May 28, 2015 with a total of about 35 flight hours for the DLR Falcon aircraft and 50 flight hours for the NASA DC-8 (Fig. 1). A number of 7 coordinated flights could be achieved. As the endurance of the Falcon aircraft is limited to about 4 hours, the DC-8 could fly more extended tracks up to 8 hours. A total of 101 dropsondes were deployed from the DC-8 measuring profiles of the horizontal wind vector, pressure, temperature and humidity. With a coordinated flight pattern the DC-8 could provide valuable information for the A2D calibration in nadir-viewing geometry with additional wind, temperature and pressures soundings. One flight of the DLR Falcon was targeted towards the Greenland summit with overpasses of the ground-based wind lidar.

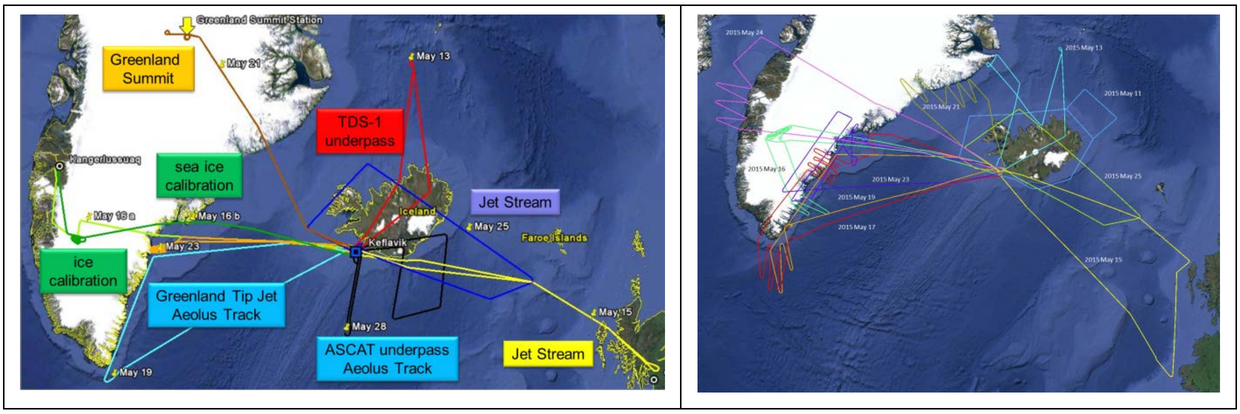

Figure 1. Flight tracks of the DLR Falcon from Keflavik, Iceland in May 2015 with the corresponding objective of the flight (left) and the track of the NASA DC-8 (right).

5. Conclusion and Outlook

The extensive dataset from 4 wind lidars, dropsondes, ground-based instruments including the wind lidar on the Greenland Summit Station and numerical weather prediction model results are currently analyzed. The objectives of the airborne campaign could be met and strategies for coordinated flights with 2 aircrafts were successfully proven. This forms the basis for future coordinated airborne validation campaigns for ADM-Aeolus after its launch.

6. Acknowledgements

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