Airborne Wind Lidar Observations for the Validation of ESA's Wind Mission Aeolus

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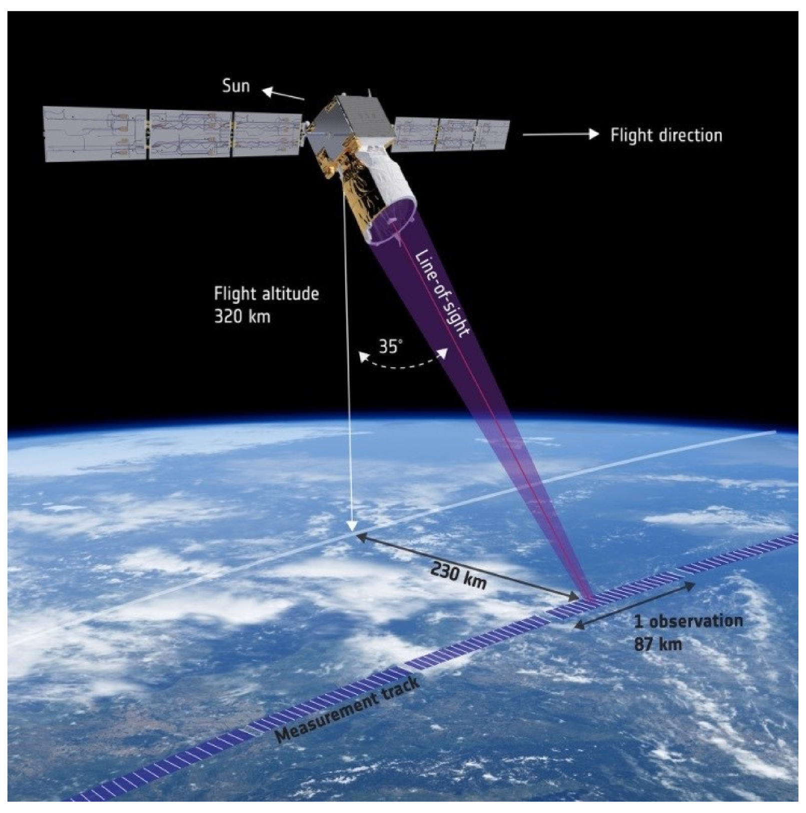
Since the successful launch of ESA's Earth Explorer mission Aeolus on 22 August 2018, atmospheric wind profiles from the ground to the lower stratosphere are being acquired on a global scale deploying the first-ever satellite-borne wind lidar system ALADIN (Atmospheric LAser Doppler INstrument). Already several years before the launch, an airborne prototype of the Aeolus payload, the ALADIN Airborne Demonstrator (A2D), was developed at DLR. Due to its representative design and operating principle, the A2D has been delivering valuable information on the wind measurement strategies of the satellite instrument and helped to optimize the wind retrieval and related quality-control algorithms. Together with DLR's high-accuracy coherent Doppler wind lidar (2-µm DWL), the A2D has been employed in several airborne campaigns in Europe before and after the launch, providing an extensive dataset under various atmospheric conditions for the validation of the Aeolus mission.

Aeolus – The First Wind Lidar in Space

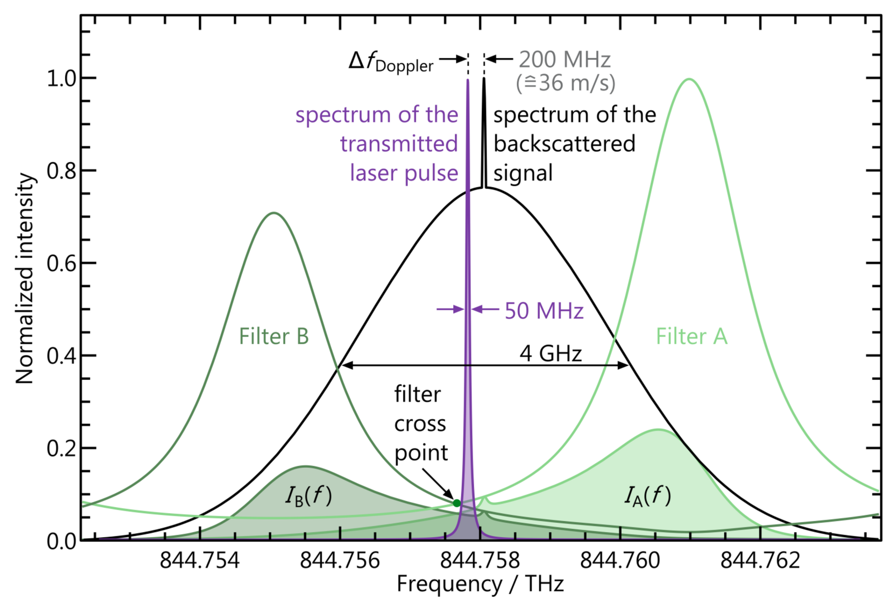


Schematic of the measurement geometry of the polar-orbiting Aeolus satellite.

- Doppler wind lidar called ALADIN (Atmospheric LAser Doppler INstrument) which is accommodated on Aeolus flying in a polar, sun-synchronous orbit at an altitude of about 320 km
- Wind profiles in line-of-sight (LOS) direction under a slant angle of 35° from ground up to 30 km with horizontal resolution of 90 km and vertical resolution of 0.25 to 2 km depending on altitude
- Accuracy for the horizontal LOS wind component: <0.7 m/s
- Precision: 2 m/s to 4 m/s depending on altitude

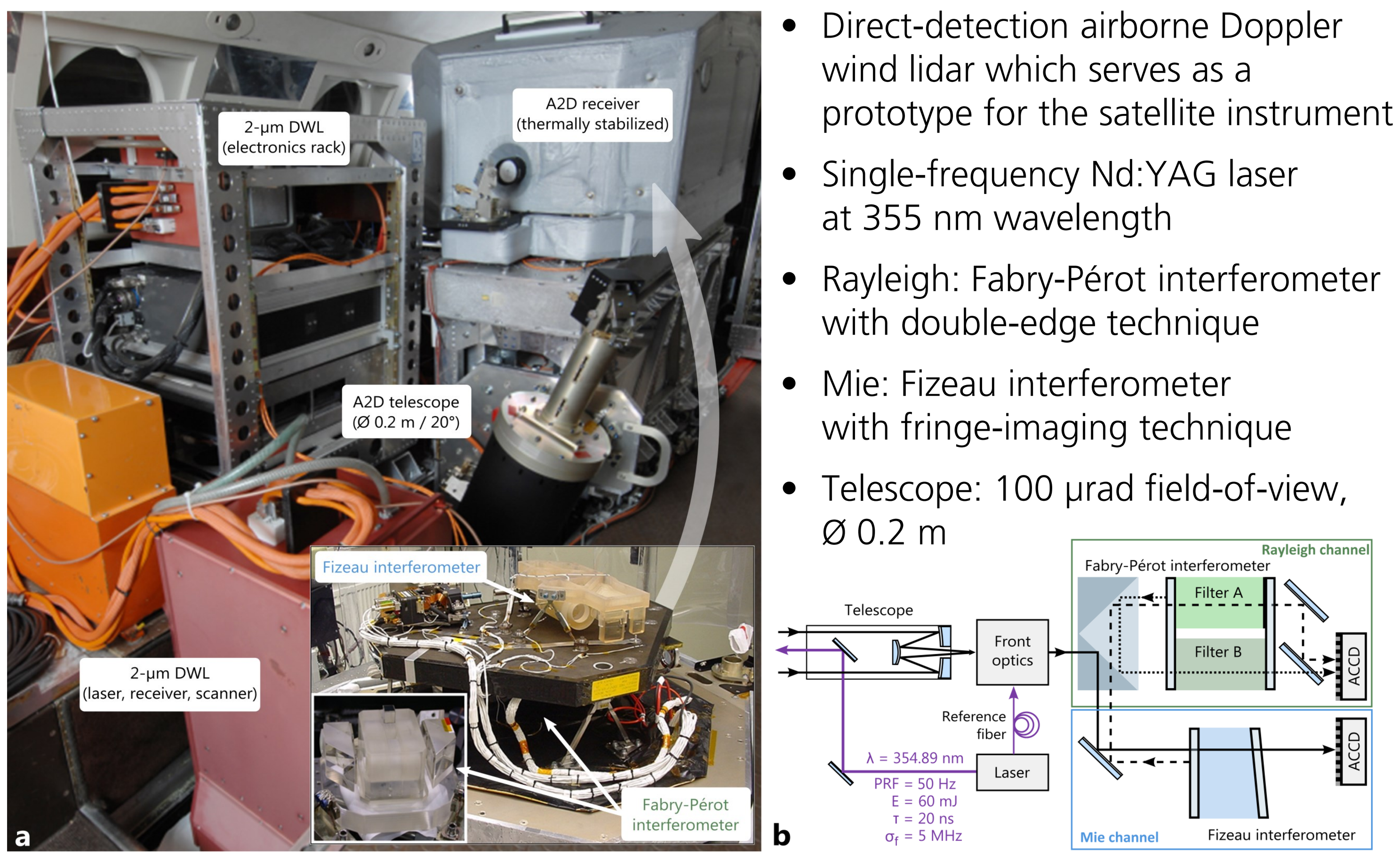
Principle of the Direct-Detection Wind Lidar

- Determination of the LOS wind speed from the Doppler frequency shift $\Delta f = 2 f_0 \cdot \frac{v}{c}$ imposed on ultra-violet laser pulses that are transmitted into the atmosphere from a high-power and frequency-stabilized laser operating at 355 nm wavelength
- Analysis of backscatter signals using a complementary dual-channel receiver
- Rayleigh and Mie channel for sensing the Doppler shift from molecules as well as particles (aerosols, clouds)
- Measurement of the Doppler frequency shift with accuracy of 10^{-8} in order to achieve wind speed accuracy of 1 m/s



Measurement principle of the Rayleigh channel based on the double-edge technique.

ALADIN Airborne Demonstrator (A2D) Wind Lidar

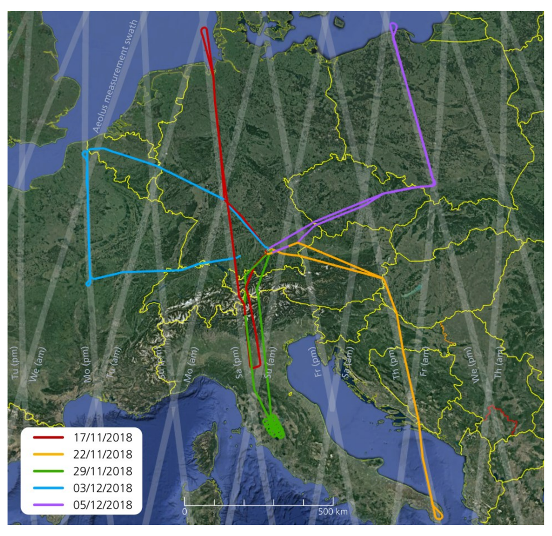


a Instrumentation of the Falcon aircraft comprising the A2D and the 2-µm DWL as a reference. **b** Schematic of the A2D Doppler wind lidar.

- Direct-detection airborne Doppler wind lidar which serves as a prototype for the satellite instrument
- Single-frequency Nd:YAG laser at 355 nm wavelength
- Rayleigh: Fabry-Pérot interferometer with double-edge technique
- Mie: Fizeau interferometer with fringe-imaging technique
- Telescope: 100 µrad field-of-view, Ø 0.2 m

Validation Campaign in Central Europe in 2018

- Six research flights including one test flight and one calibration flight (22 flight hours)
- Four Aeolus underflights covering nearly 3000 km of the Aeolus measurement swaths
- 1155 km long flight leg along the track from the Alps to the North Sea on 17 November 2018
- Additional ground studies with the A2D for calibration and alignment purposes

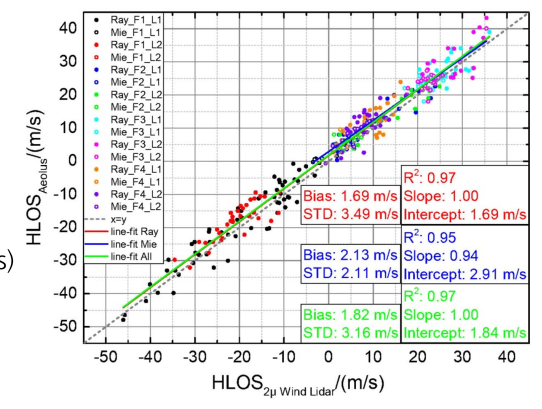


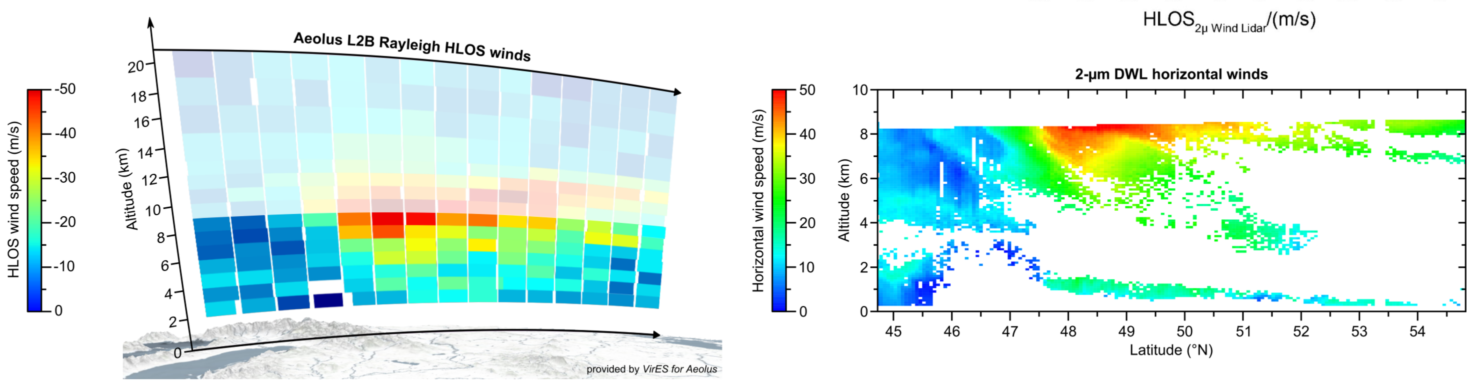
Funding by ESA and DLR

Flight tracks of the Falcon aircraft during the Cal/Val campaign in 2018 and photo of DLR Falcon aircraft in Oberpfaffenhofen.

Comparison of Aeolus with 2-µm DWL Winds

- Collocated wind observations of Aeolus and the 2-µm DWL during the DLR Falcon underflight of the satellite from the Alps to the North Sea on 17 November 2018
- Good data coverage in the southern part of the track
- Averaging of 2-µm winds to the Aeolus grid and projection of the wind vector onto the Aeolus LOS
- Mean bias of Aeolus: 1.8 m/s (R: 1.7 m/s, M: 2.1 m/s)
  (based on preliminary Aeolus data without correction of known instrument bias)
- Standard deviation: 3.2 m/s (R: 3.5 m/s, M: 2.1 m/s)

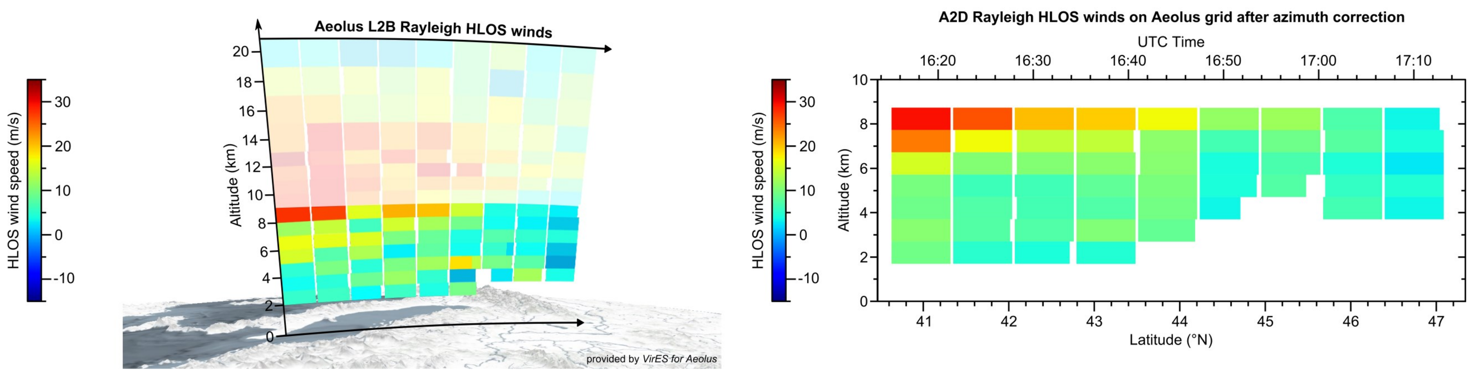




Horizontal line-of-sight (HLOS) wind speed measured by the Aeolus Rayleigh channel (left) and horizontal wind speed measured with the 2-µm coherent DWL (right) during the Aeolus underflight in Central Europe on 17 November 2018 (track length: 1155 km).

Comparison of Aeolus with A2D Winds

- Collocated wind observations of Aeolus and the A2D during the satellite underflight from Apulia to the Austrian-Hungarian border on 22 November 2018
- Averaging of A2D winds to the Aeolus grid and consideration of different azimuth angles of the LOS for the satellite and airborne instrument
- Comparison of wind data sets allows assessment of error sources, optimization of Aeolus retrieval algorithms, e.g. implementation of new quality control parameters
- Additional airborne campaign was performed in May 2019, future campaigns are planned for September 2019 (Iceland) and June/July 2020 (Cape Verde)



Horizontal line-of-sight (HLOS) wind speed measured by the Aeolus Rayleigh channel (left) and the A2D Rayleigh channel after grid adaptation and azimuth correction (right) during the Aeolus underflight in Europe on 22 November 2018 (track length: 790 km).