First results from two airborne campaigns over Europe in order to calibrate and validate ESA's Aeolus Wind Lidar mission

Working group Meeting for Space Lidar Winds - 10-11 July 2019

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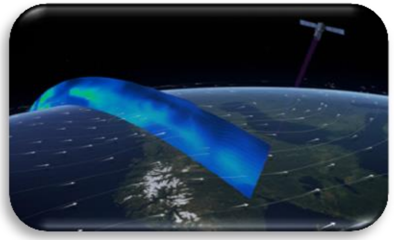
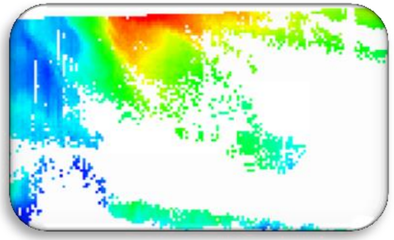
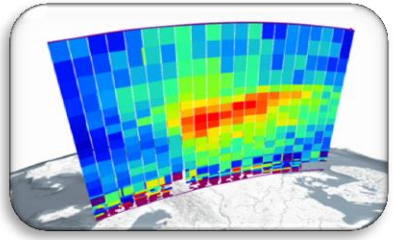
The support by S. Henderson, D. Bruns and C. Hale from Beyond Photonics is highly appreciated and saved the AVATARE campaign.

Outline



Introduction

- Aeolus Cal/Val activities at DLR
- The airborne Aeolus Cal/Val payload at DLR

The WindVal III campaign, Nov/Dec 2018, Germany

- Overview
- First results and comparison to the Aeolus wind product

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- Short overview

Summary and Outlook

Fig. credits ESA

Introduction

Airborne campaigns for Aeolus validation at DLR supported by ESA (Th. Fehr)

Post-Launch Calibration campaign WindVal III
- Nov/Dec 2018, Europe
- Still commissioning phase

Post-Launch Calibration campaign AVATARE
- May/June 2019
- Central Europe, (DLR)

Tropical Validation campaign
- Q2 2020
- Cape Verde

2018 | 2019 | 2020 | 2021

Aeolus Launch
- 22. August 2018

Artic Calibration campaign AVATARI
- September 2019
- Keflavik, Iceland

Artic Calibration campaign
- 2021
- Tbd

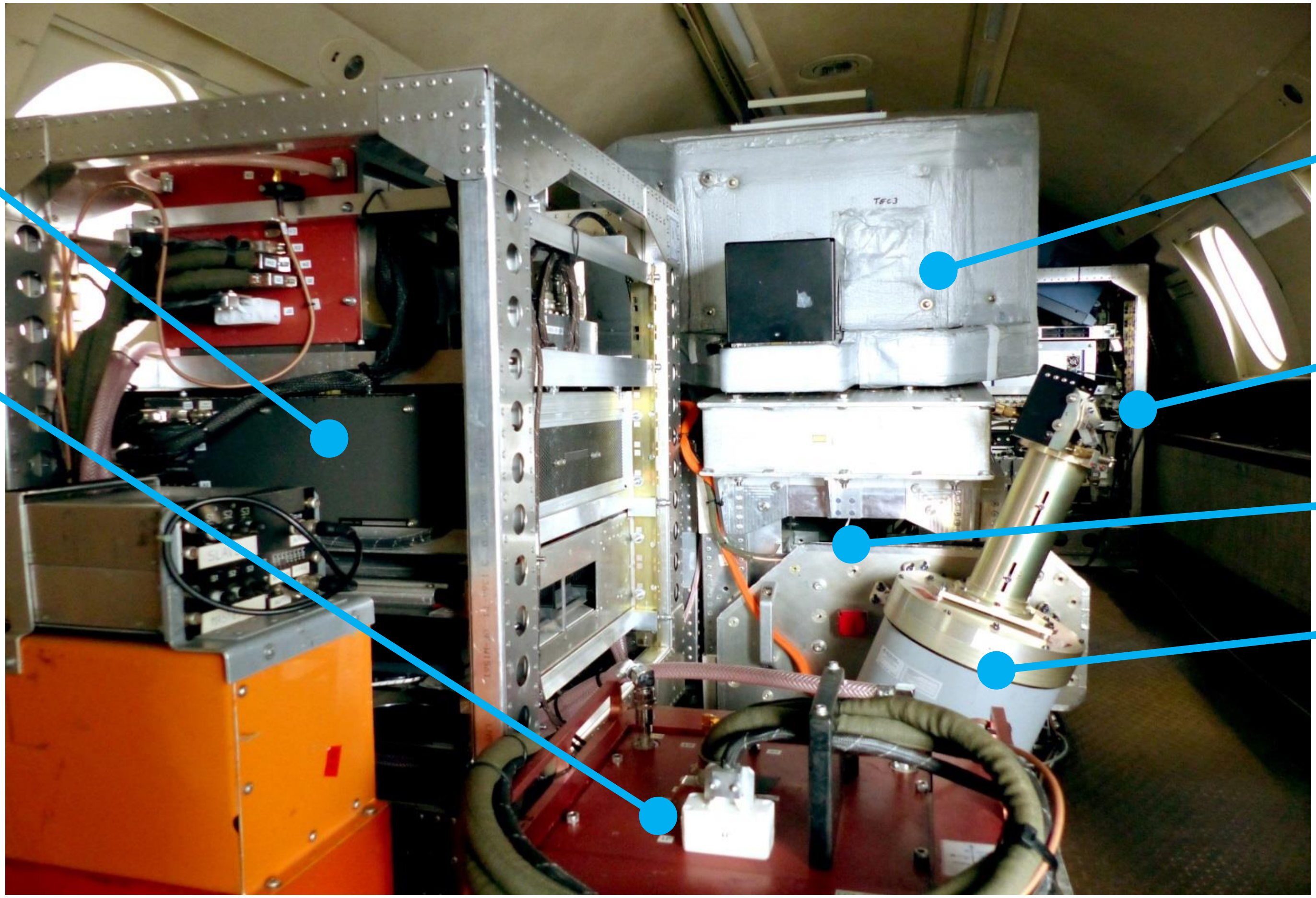
The airborne Aeolus Cal/Val payload at DLR

A coherent [1,2,3] and a direct detection [4,5] Doppler wind lidar on-board Falcon

2-µm DWL power supply and cooling unit

2-µm DWL transceiver

A2D data acquisition unit, power supply and cooling unit are mounted behind (not visible)



Temperature stabilized A2D receiver

2-µm DWL data acquisition unit

A2D laser

A2D telescope

[1] Chouza et al., 2016, ACP, [2] Weissmann et al., 2005, J-TECH, [3] Witschas et al., 2017, J-TECH
[4] Lux et al., 2018, Atmos. Meas. Technol. (2018), [5] Marksteiner et al., 2018, Remote Sensing 10.12 (2018)

The airborne Aeolus Cal/Val payload at DLR

Specifications

Parameter	Demonstrator: DLR A2D [1,2]	Reference: DLR 2-µm DWL [3]
Detection principle	**Direct detection**	**Coherent detection**
Scanning	Fixed line-of-sight	Double-wedge scanner
Wavelength	354.89 nm	2022.54 nm
Laser energy	50-60 mJ	1-2 mJ
Pulse repetition rate	50 Hz	500 Hz
Pulse length	20 ns (FWHM)	400-500 ns (FWHM)
Telescope diameter	20 cm	10.8 cm
Vertical resolution	300 m to 2.4 km	100 m
Temporal averaging raw data (horizontal)	20 shots = 400 ms	single shot = 2 ms
Temporal averaging product (horizontal)	14 s (+4 s data gap)	1 s per LOS (500 shots), 42 s scan (21 LOS)
Horizontal resolution	3.6 km (18 s)	0.2 km LOS, 8.4 km scan
Precision (random error)	1.5 m/s (Mie) 2.5 m/s (Rayleigh)	< 1 m/s

Parameter	DLR Falcon
Max. Range	3700 km
Max. Altitude	12800 m
Max. Endurance	4-5 h (dep. on altitude)
Take-off distance	2000 m
Pressurized Cabin	Yes
Long Range Speed	245 m/s

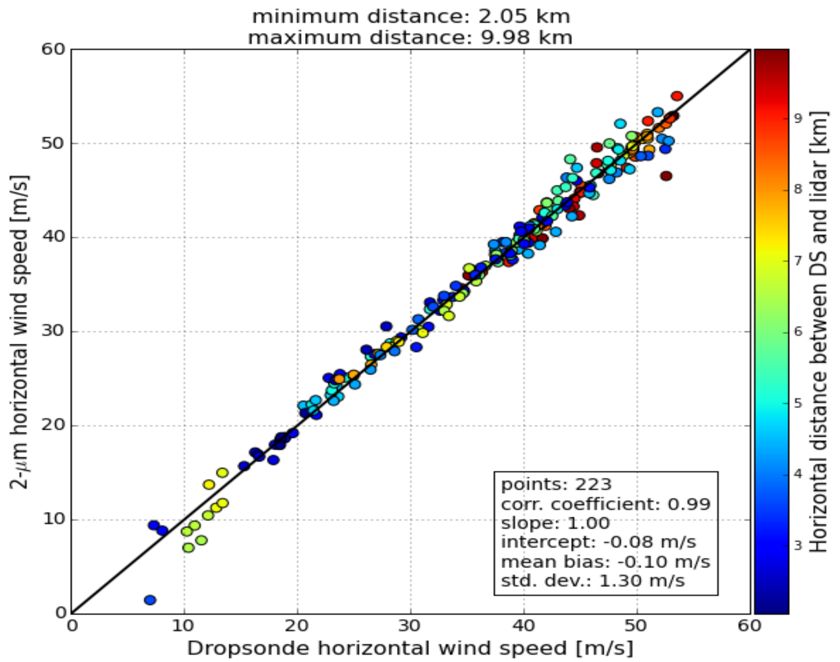
[1] Lux et al., 2018, Atmos. Meas. Technol. (2018), [2] Marksteiner et al., 2018, Remote Sensing 10.12 (2018)
[3] Witschas et al., 2017, Journal of Atmospheric and Oceanic Technology 34.6 (2017)

The 2-µm DWL
The reference lidar

The accuracy (and the precision) of the 2-µm DWL and corresponding retrieval algorithms was verified during several campaigns within the last years by means of comparison to dropsonde measurements.

- Bias: **0.00 m/s**; STD*: 1.20 m/s [1] – hor. wind
- Bias: **0.08 m/s**; STD*: 0.92 m/s [2] – hor. wind
- Bias: **0.05 m/s**, STD*: 0.20 m/s [3] – vert. wind
- Bias: **0.08 m/s**, STD*: 1.30 m/s [4] – hor. wind

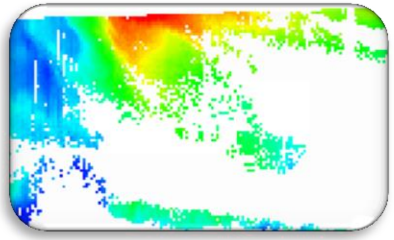
  (from NAWDEX – comparison to Halo dropsondes)



* STD considers the uncertainty of dropsonde and lidar measurements

[1] Weißmann et al., 2005, Journal of Atmospheric and Oceanic Technology, Vol. 22.
[2] Chouza et al., 2016, Atmospheric Chemistry and Physics, Vol. 16.
[3] Witschas et al., 2017, Journal of Atmospheric and Oceanic Technology Vol. 34.
[4] Schäfler et. al, 2018, Bulletin of the American Meteorological Society 99.8 (2018)

Outline



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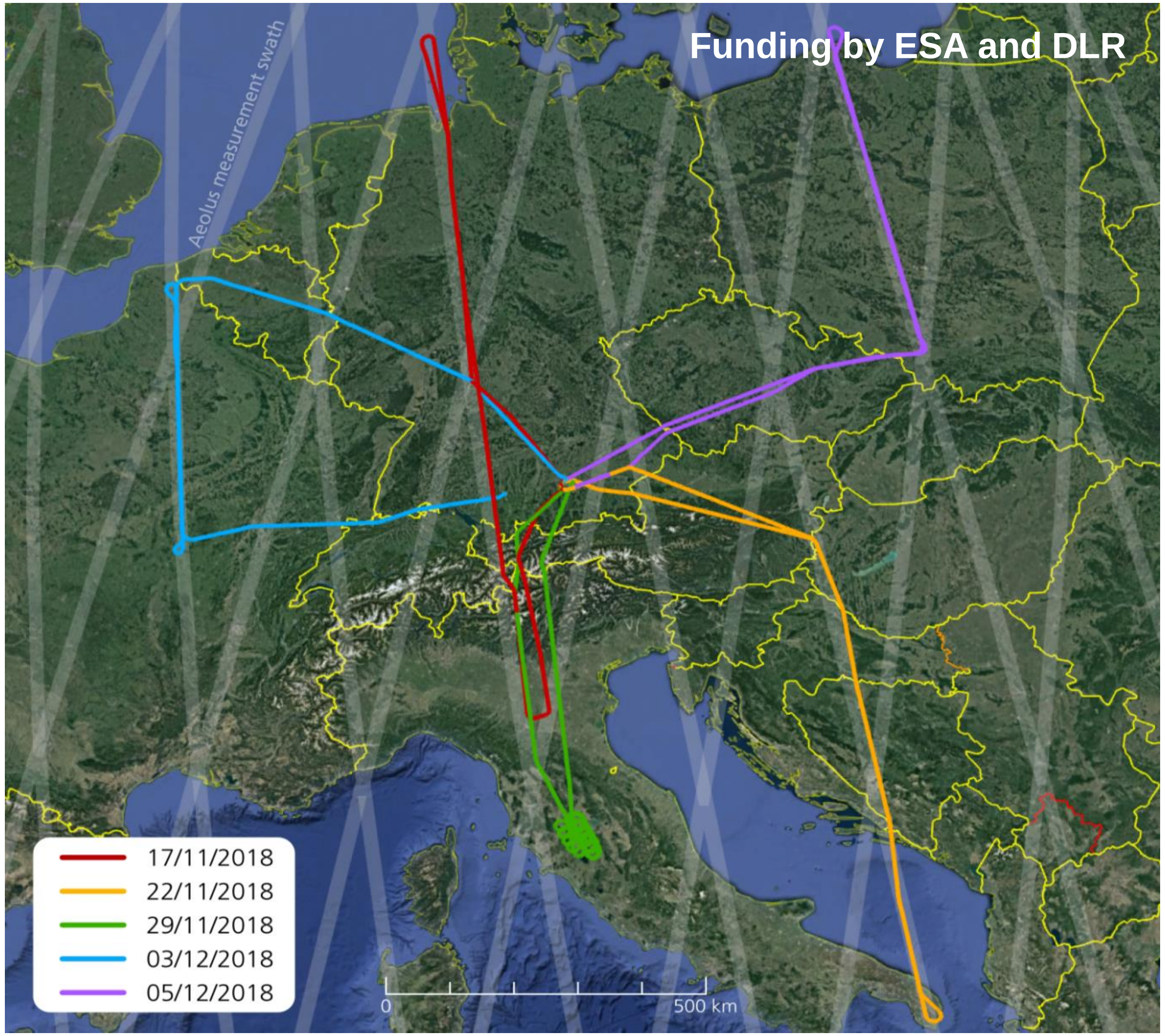
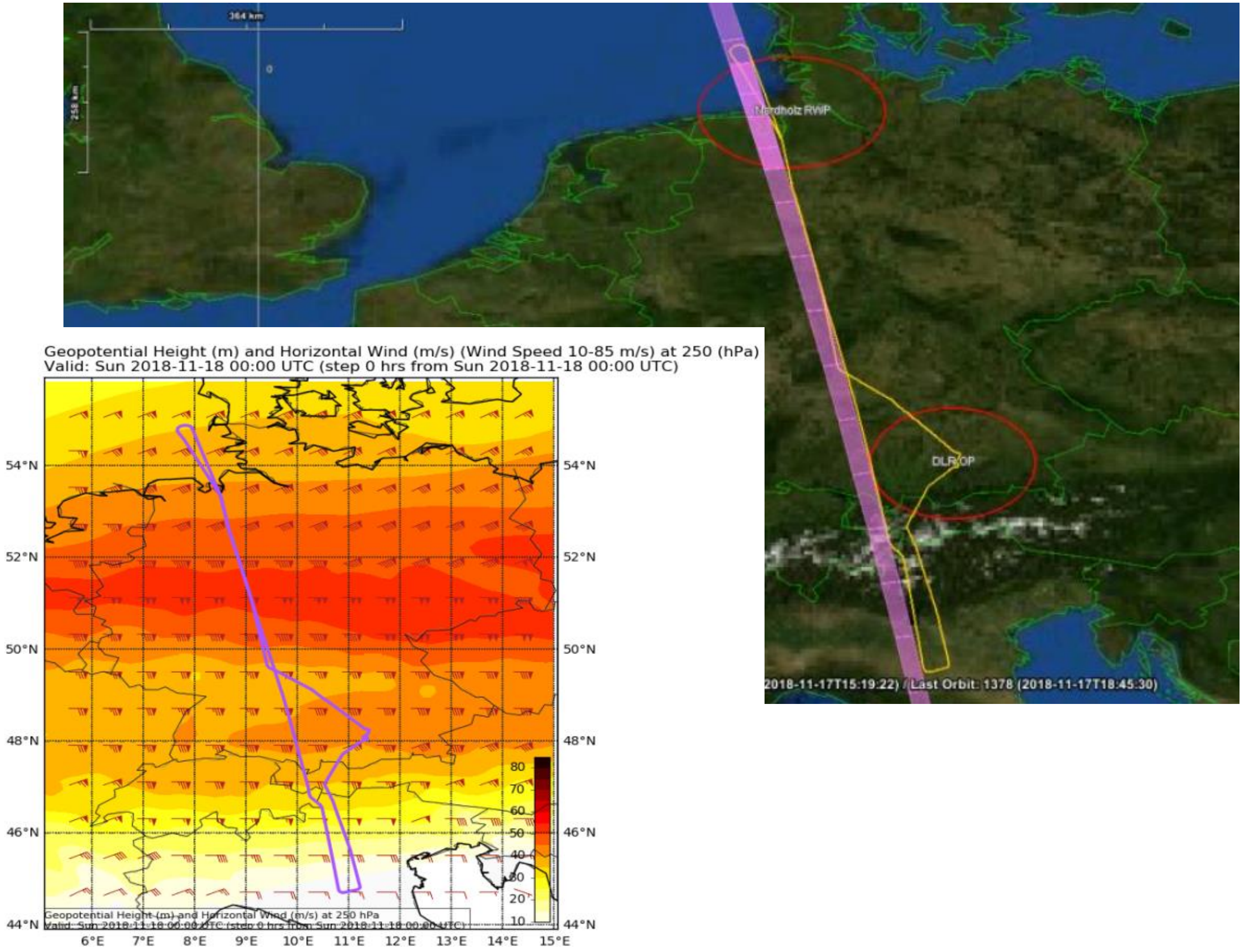
The WindVal III campaign
Overview

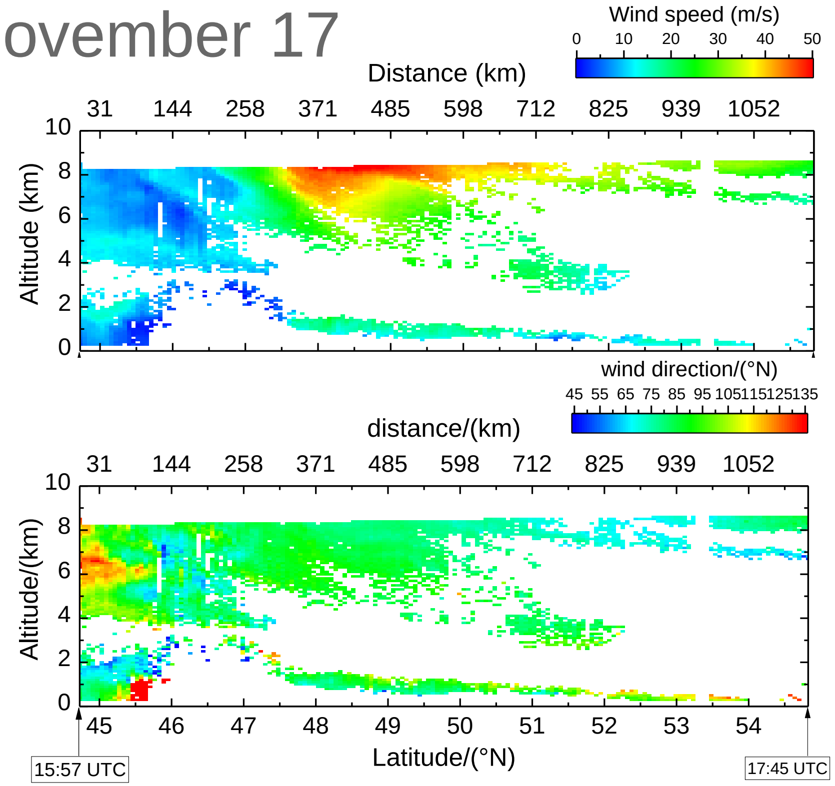


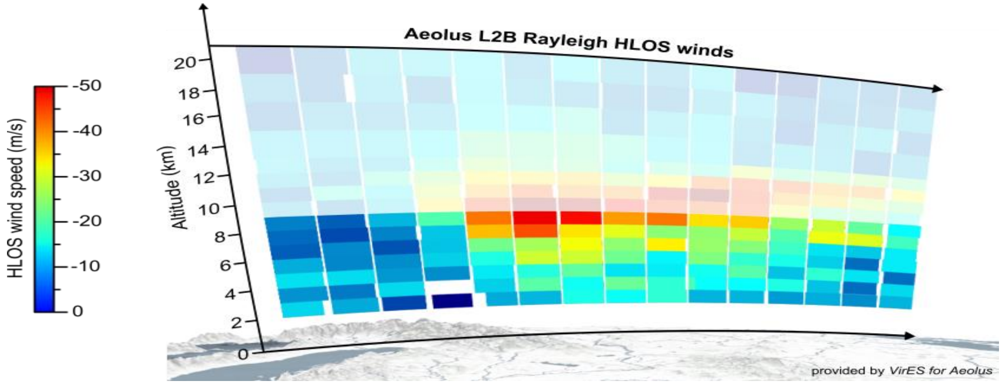
- 6 flights from Oberpfaffenhofen, Germany including a test flight and a calibration flight on 29/11/2018 (22 flight hours)
- 4 Aeolus underflights covering nearly 3000 km of the Aeolus swaths
- 1155 km long flight leg along the track from the Alps to the North Sea on 17/11

Comparison of 2-µm DWL and Aeolus Data

Procedure by an example of the first underflight on November 17







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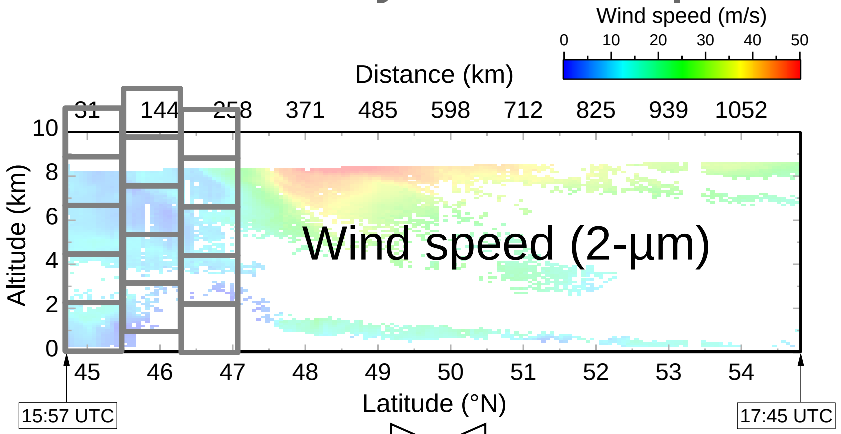
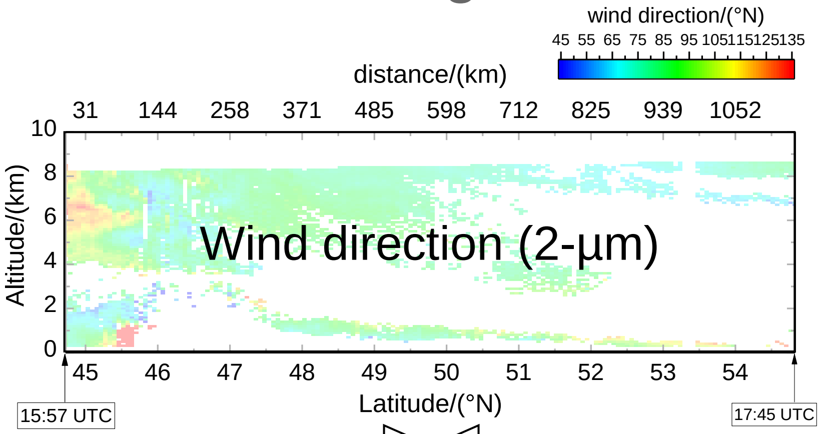
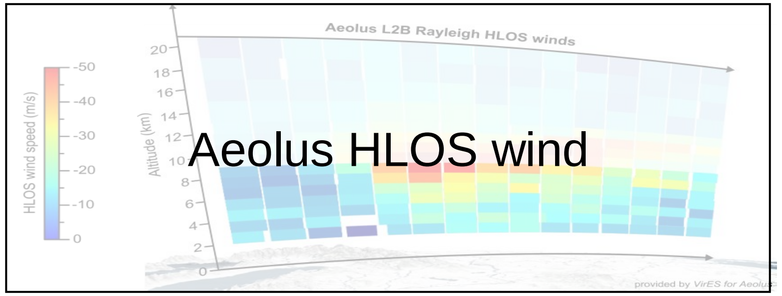
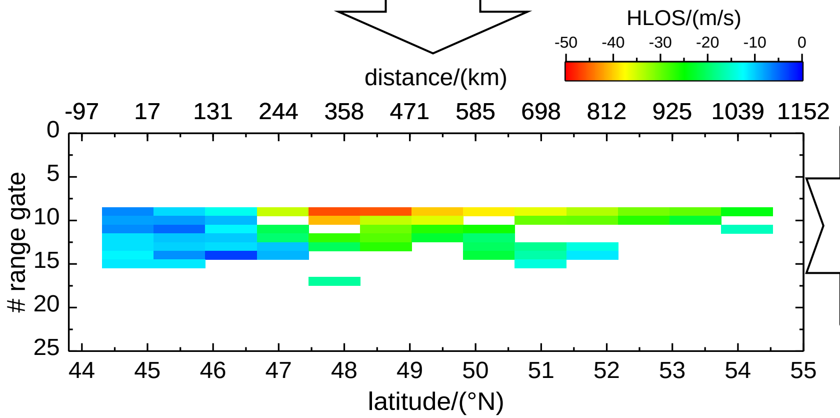




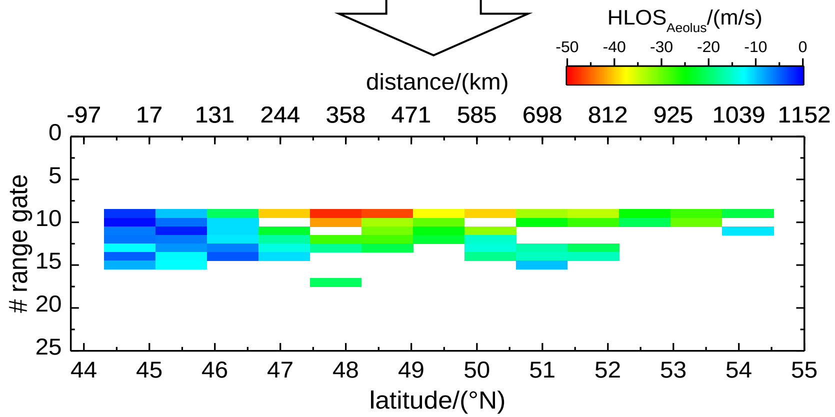


1. Averaging to Aeolus grid (**10%** data coverage as threshold)
2. projection onto the horizontal LOS

Extracting points with valid 2-µm winds (+ est. error filter **8 m/s**)

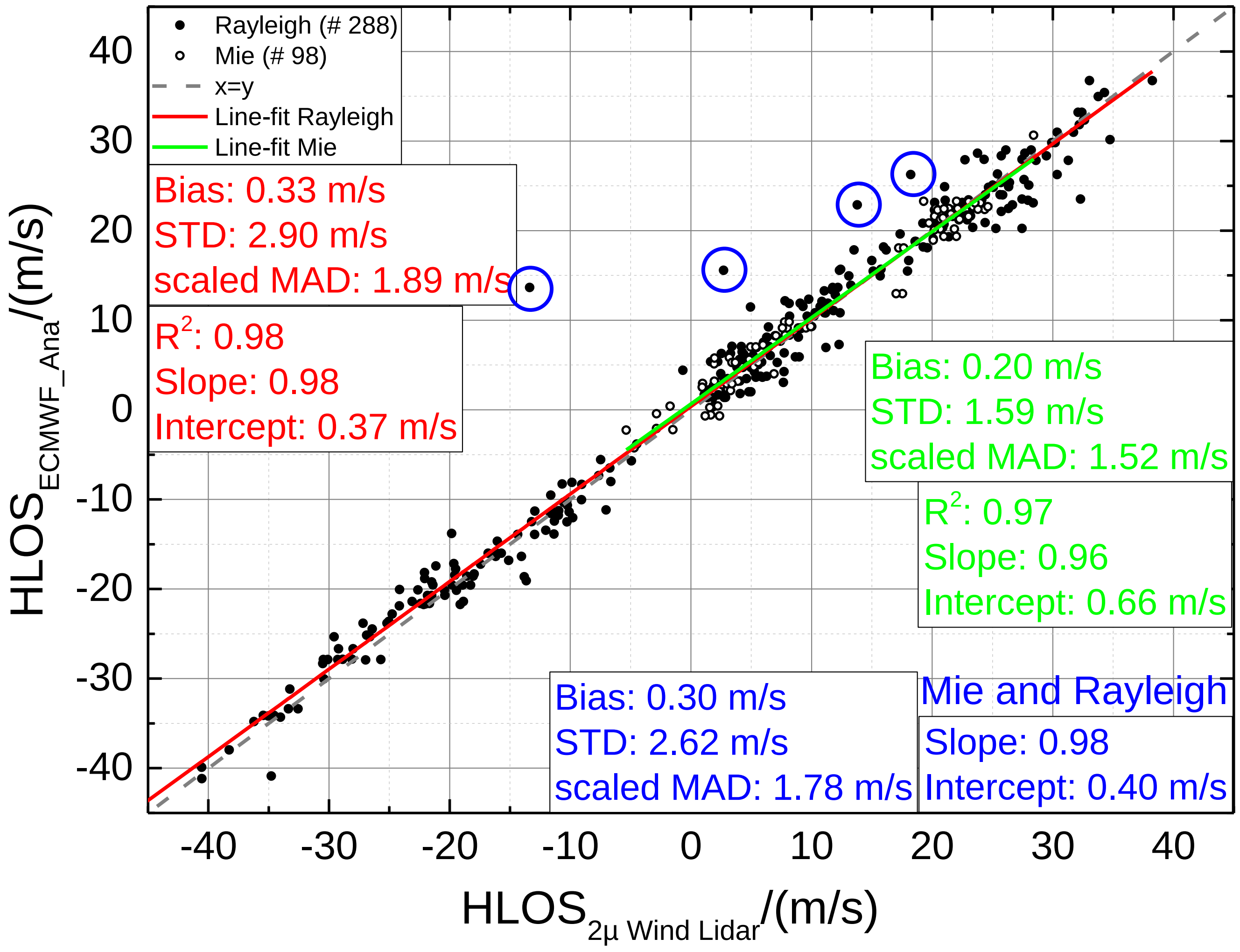


Investigate the difference



Statistical comparison

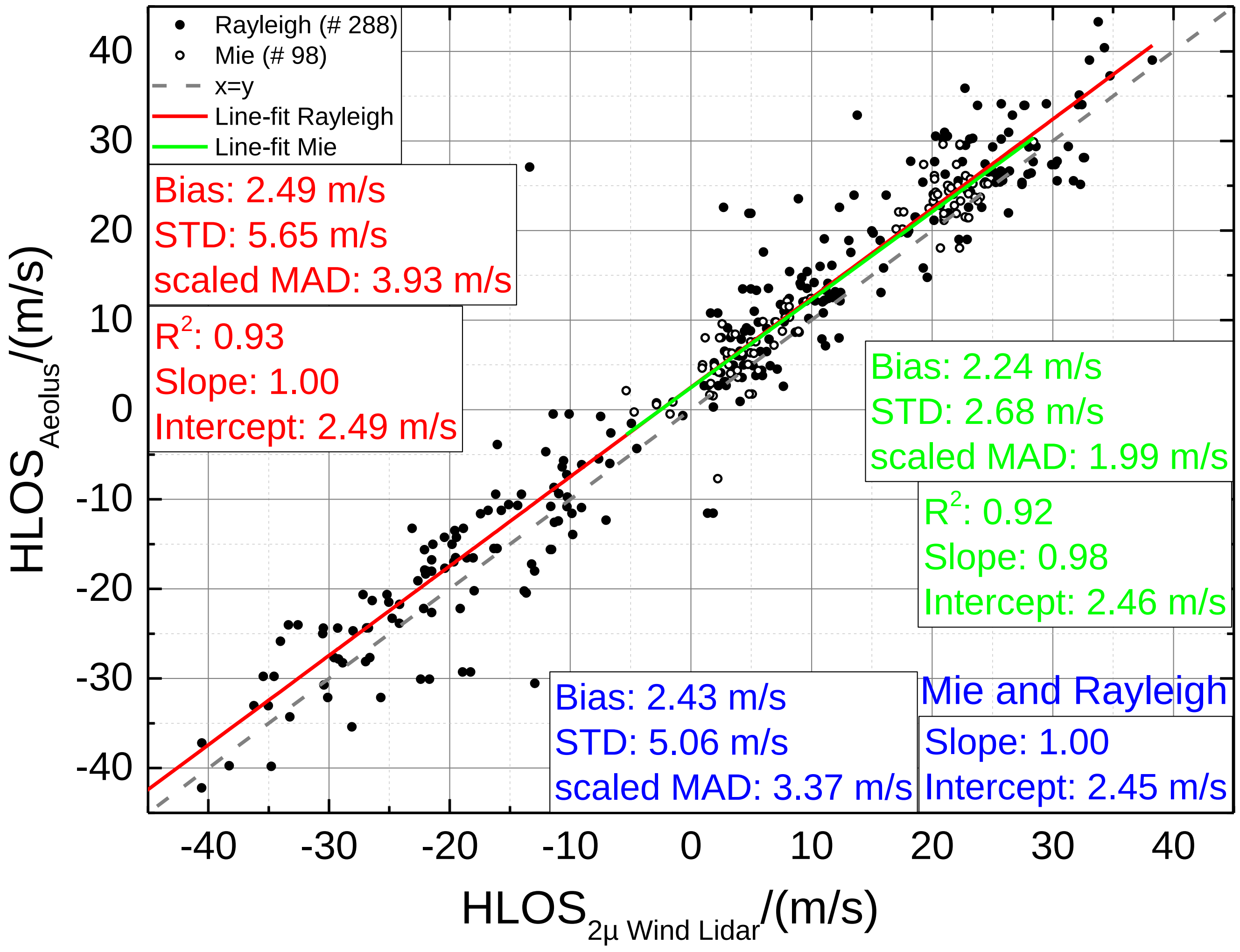
2-µm DWL measurements to ECMWF analysis



- ECMWF analysis data and 2-µm wind speed data are in good accordance (slope close to **1.0** and a bias of **0.3 m/s**).
  → ECMWF is already doing a great job (central Europe)
  → 2-µm DWL data provides a reliable reference for Aeolus cal/val
- A few remaining outliers may arise from undetected "noise" in the 2-µm DWL data
  → Data filtering is currently improved

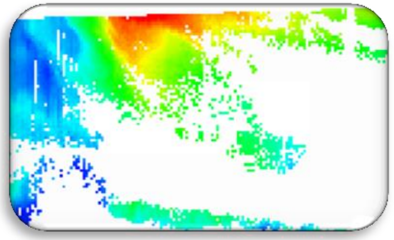
Statistical comparison

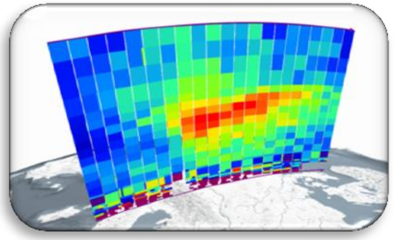
2-µm DWL measurements to Aeolus data



- Aeolus data and 2-µm data are in good accordance (slope ~ 1.00)
  → Aeolus is measuring real winds!
- The bias of about **2.5 m/s (Ray) / 2.2 m/s (Mie)** can be explained by a not-updated calibration file used for processing + instrumental drifts
  → principally solvable
- The enhanced scaled median absolute deviation (MAD) **3.9 m/s (Ray) / 2.0 m/s (Mie)** is explained by the low laser energy and a signal loss in the receiver (see also Wernham and Reitebuch)
  → may improve for second laser

Outline





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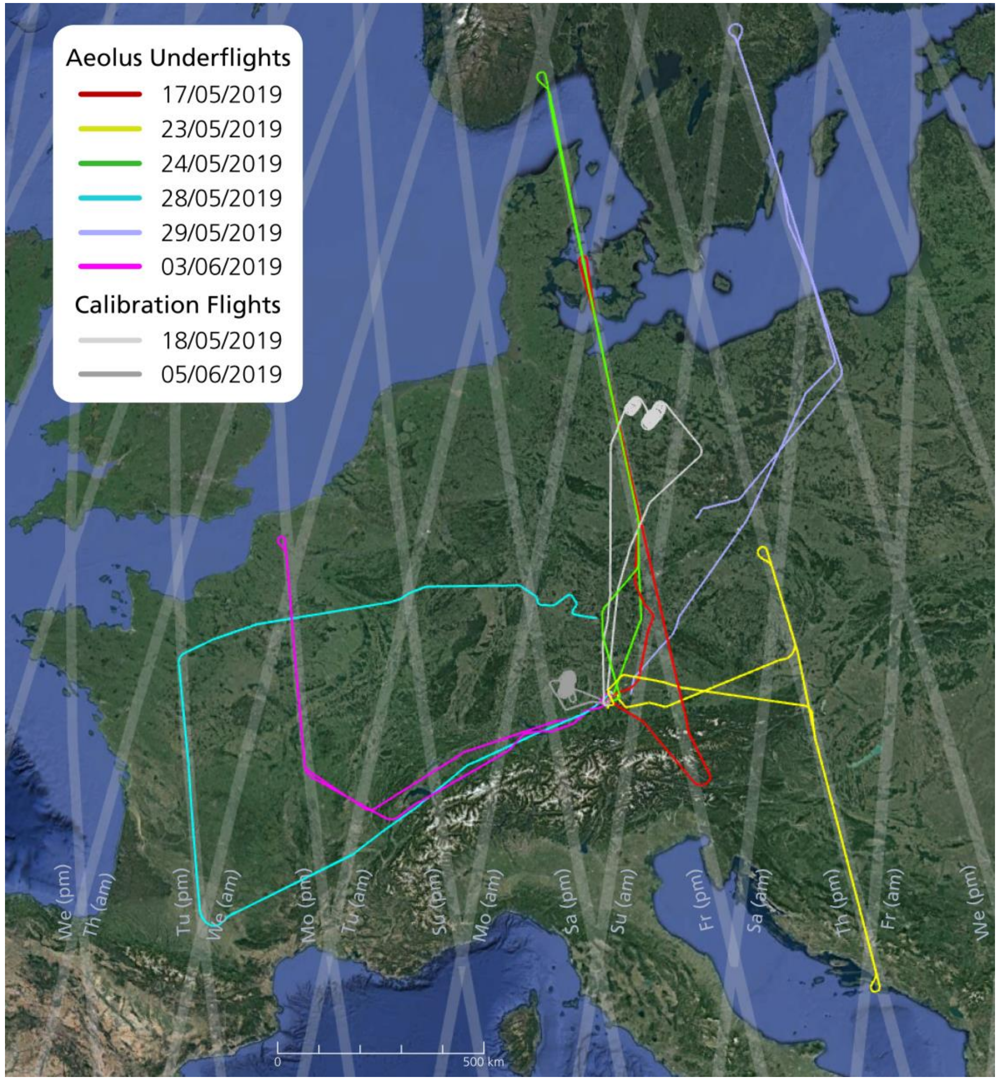
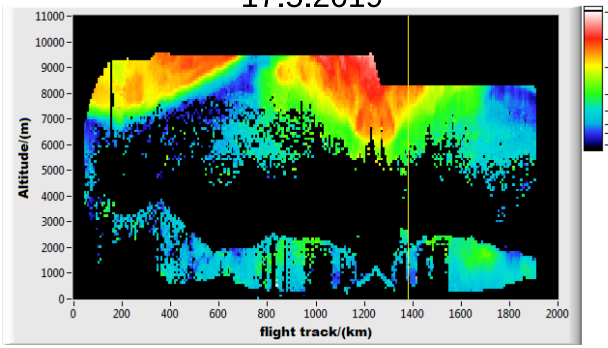
2-µm DWL wind speed measurements during AVATARE

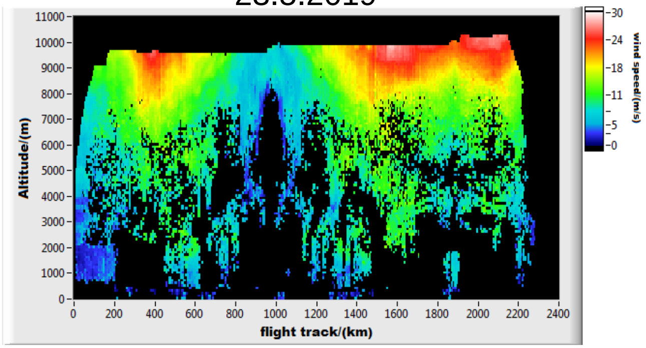
6 Aeolus underflights performed in May/June 2019 – under analysis



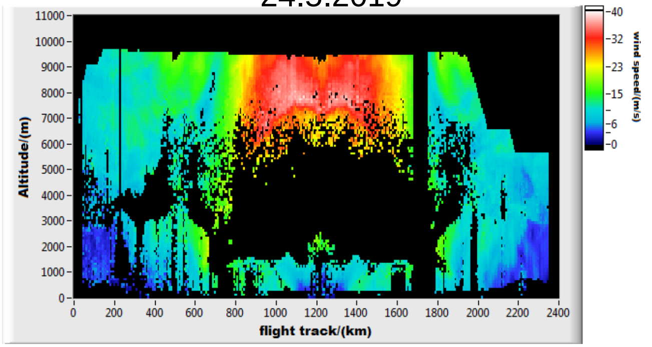
17.5.2019



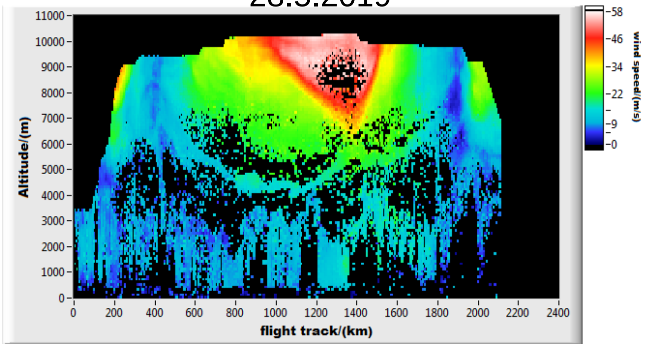
23.5.2019



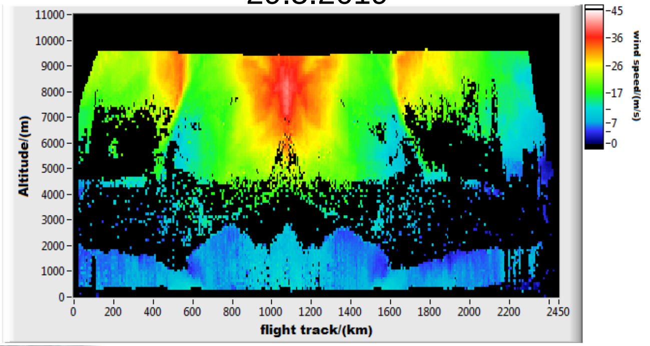
24.5.2019



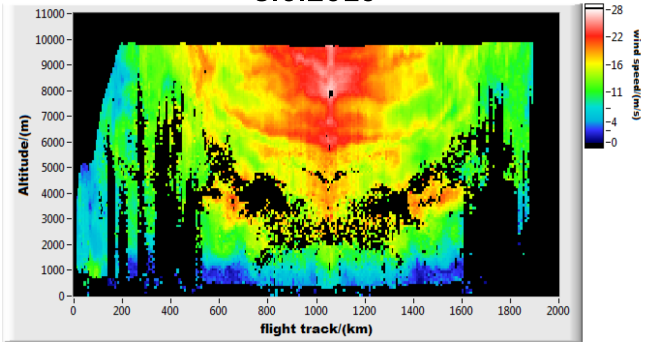
28.5.2019



29.5.2019



3.6.2019



Summary and Outlook

- **Two airborne Aeolus Cal/Val campaigns were performed** in Autumn 2018 and Spring 2019 in central Europe
- **10 successful underflights** below the satellite track were performed
- The **2-µm DWL is demonstrated to be a reliable reference** by means of comparison to **dropsonde** and **ECMWF** analysis data
- The first statistical comparison of Aeolus data to 2-µm DWL data looks promising
  - Rayleigh: **Bias: 2.49 m/s**, STD = 5.65 m/s, **scaled MAD = 3.93 m/s**
  - Mie : **Bias: 2.24 m/s**, STD = 2.68 m/s, **scaled MAD = 1.99 m/s**
  - The **enhanced MAD** for the Rayleigh winds are **due to the lower laser power** and **signal loss in the receiver**
  - The bias of Mie and Rayleigh winds is explained by a **not-updated receiver calibration** file together with **instrumental alignment drifts** that require continuous calibration (known and ongoing work)

Outlook

- Finish the analysis of the recent CalVal campaigns data
- Investigate the performance of Aeolus winds for detailed scenes as for instance
  - **wind quality in respective areas**,
  - **wind quality for respective backscatter ratios**,
  - **wind quality in cloudy regions**,

  and provide suggestions to improve the Aeolus processor
- Further refine the flight strategy for upcoming CalVal campaigns
- Install the Aeolus CalVal payload to the aircraft in August 2019 in order to head to Iceland in September 2019


AVATARE
esa
DLR
Aeolus Validation Through Airborne Lidars in Europe