Lessons learnt for Aeolus from the pre-launch validation campaigns with the A2D

Uwe Marksteiner, Oliver Reitebuch, Benjamin Witschas, Christian Lemmerz, Stephan Rahm

DLR German Aerospace Center, Institute of Atmospheric Physics, Oberpfaffenhofen, Germany
Objectives of A2D (ALADIN Airborne Demonstrator)

- Validation of ALADIN instrument with atmospheric signals before launch
- Derivation of conclusions for:
  - retrieval algorithms
  - on-ground and in-orbit tests
  - verification and calibration of satellite instrument

Acknowledgement:
Funding for the development of the ALADIN Airborne Demonstrator A2D and performance of campaigns was provided by ESA and DLR.
A2D (ALADIN Airborne Demonstrator):

- “twin instrument” (receiver, detector, …)
- space industry performs test and characterisation in laboratory
- DLR performs also atmospheric measurements
- viewing geometry comparable to Aeolus
- possibility of ground detection

→ A2D is particularly suited to verify the wind measurement & calibration strategy of Aeolus
The ALADIN airborne demonstrator

- Development of the A2D with the optical receiver and laser breadboard from ESA’s Pre-Development Programme
- Delivery of A2D and first flights of a direct-detection Doppler lidar worldwide in 2005
- Ground campaigns in 2006 and 2007
- First flights of coherent and direct-detection wind lidar on-board the same aircraft in 2007

⇒ 10 years of experience with A2D

Payload in DLR Falcon aircraft during campaigns in 2007, 2008 & 2009
The optical receivers of the airborne demonstrator from DLR (A2D) and the satellite instrument (ALADIN) are based on almost identical design.

1. combined arrangement of two different spectrometers
2. Fizeau spectrometer for Mie channel
3. sequential implementation of Fabry Perot interferometers
4. custom-built ADM specific ACCD chip
3rd Aeolus campaign in Sept. 2009

10 flights with a duration of 33 hours including transfer and test flight

Reasons for choice of Iceland/Greenland

- low aerosol load → pure Ray. scatter
- jet-stream → high wind speeds
- ice albedo → calibration as Aeolus
- ocean → change of reflexion
3rd Aeolus campaign in Sept. 2009

2 calibrations

wind observations

26 km → 6 min
Instrument Response Calibrations of A2D

⇒ Apparently very consistent calibrations. However, resulting in differences in wind speeds of up to ≈4 m/s.
Ground calibration ⇒ summation of signal

- Ground echo signal distributed over 2 "range-gates"

- Deviations depending on non-perfect location of Rayleigh spots and Mie fringe on ACCD and range-gate overlap

- In this case calibration curves of single "range-gates" are partly deviating by ≈120 m/s

⇒ preceding summation of signal yields a useful calibration curve
Comparison of detected ground height:
A2D ↔ Digital Elevation Model

1 µs ≈ 150 m

100 ratio in %

detector

ground
**Line-Of-Sight wind and corrections**

\[ \nu_{\text{LOS,wind}} = (\Delta f_A - \Delta f_I) \cdot \frac{\lambda_0}{2} - \nu_{\text{LOS,A/C}} + \nu_{\text{ZWC}} \]

Additionally induced „virtual“ wind speed, e.g. due to:

1. component of aircraft velocity in direction of LOS (know)
2. Instrumental error or error in flight attitude (unknown)

**Diagram:**
- **v\_A/C:** Aircraft velocity.
- **v\_LOS,A/C:** Line-Of-Sight velocity.
- **v\_ZWC:** Zero-Wind Correction.

Ground does not move \( \Rightarrow \) signal must yield 0 m/s \( \Rightarrow \) Zero-Wind Correction
1st airborne measurements of 2 different lidars in 2009

A2D (Rayleigh)

2-µm lidar
cloud
jet-stream

A2D (Mie)

368 km

30 min wind measurement

30 min wind measurement
Airborne lidar observations and ECMWF model

MODIS, Oct. 1st, 2009

ECMWF

2-µm

Mie

Rayleigh

ECMWF

Flight distance / km

s/u (km) / Pass plane SOT
Statistical comparison for ALADIN airborne demonstrator against 2-µm lidar

Rayleigh

slope: 1.04
std. dev.: 2.5 m/s
# of points: 596

Mie

slope: 1.14
std. dev.: 1.5 m/s
# of points: 932
Ongoing study on A2D instrumental noise sources

- An ideal (photon) counting process obeys Poisson statistics
- For Aeolus it is expected, that all instrumental noise sources are so small that Poisson Noise is the largest contributor ("shot noise limited detection")

Noise study for A2D to investigate instrumental errors:

- A2D is Poisson noise limited in regarding the background signal intensity ⇒ no increased electronic noise
- signal intensity of the Internal Reference Poisson noise limited up to 40 s

\[
\text{BKG}_{\text{mean}} = 4464 \text{ LSB} \\
\sigma_{\text{Poisson}} = 38.4 \text{ LSB} \\
\sigma_{\text{BKG}} = 42.3 \text{ LSB}
\]
Experience of more than 10 years with operation of the unique A2D instrument

New methods & new wind retrieval algorithms were developed using A2D data from airborne and ground measurements

High quality wind measurements

Principle of calibration and wind retrieval for Aeolus was validated with airborne demonstrator A2D at DLR during several ground and airborne campaigns

The A2D will be used after launch for validation of Aeolus wind measurement and calibration strategy
Thank you very much!