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中国科技部-欧洲空间局“龙计划”合作

2017 DRAGON 4 SYMPOSIUM

2017年“龙计划”四期学术研讨会

26–30 June 2017 | Copenhagen, Denmark

2017年6月26-30日，丹麦 哥本哈根

PREPARATION OF THE CALIBRATION – VALIDATION PHASE WITH THE AIRBORNE DEMONSTRATOR FOR THE ESA AEOLUS WIND-LIDAR MISSION

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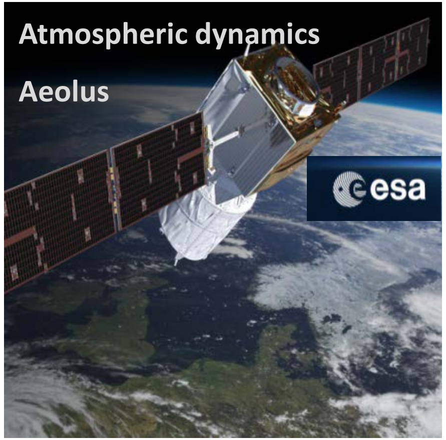
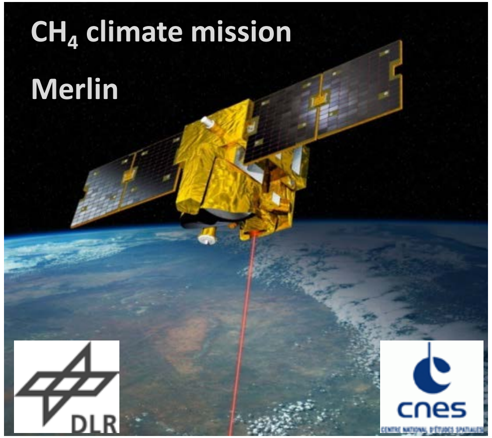
Reitebuch Oliver (LI), Witschas Benjamin
DLR (Deutsches Zentrum für Luft- und Raumfahrt),
Institute of Atmospheric Physics, Oberpfaffenhofen,
Germany

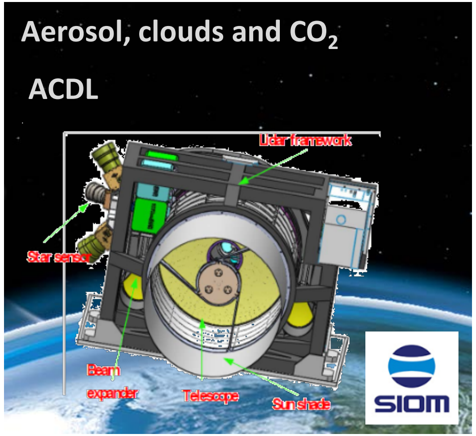
WEDNESDAY 28 JUNE 2017; A3-ID32296: LIDAR Studies and Validation

Lidar Observations from ADM-Aeolus and EarthCARE - Validation, study of long-range transport of aerosol and preparation of a future Chinese CO2 lidar mission

➔ Proposal objectives cover calibration and validation aspects relevant for four lidar missions addressing major focus topics atmosphere, climate & carbon cycle







Begin 2018 | 2019 | 2021 | 2020+

expected launch dates

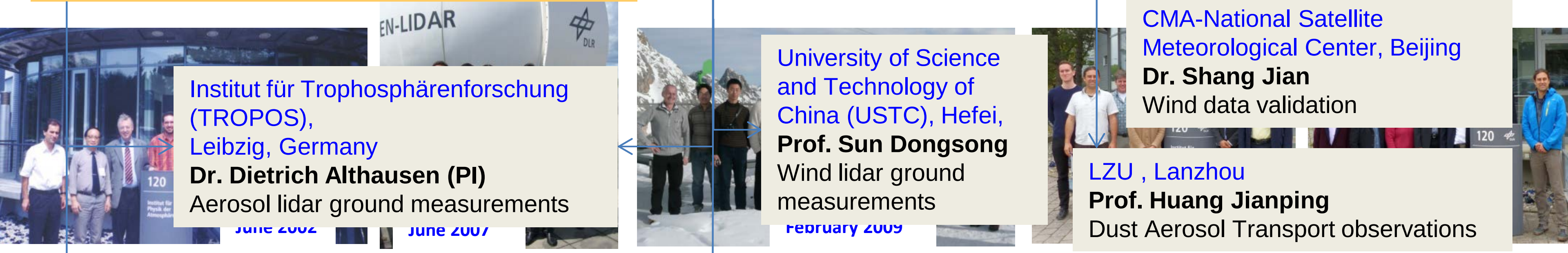
Outline of the talk

- Project architecture & objectives
- Aeolus – the 1st wind lidar in space – latest status
- Airborne campaigns - results and planning

Project Architecture and Partners

Deutsches Zentrum für Luft- und Raumfahrt (DLR), German Aerospace Center, Institute of Atmospheric Physics (IPA), Oberpfaffenhofen, Germany
European Lead Investigator
Dr. Oliver Reitebuch (LI, PI), et al.
Wind lidar, ADM Cal/Val, CO_2/CH_4 lidar

Ocean University of China (OUC), Ocean Remote Sensing Institute ORSI, Qingdao
Chinese Lead Investigator
Prof. Wu Songhua (LI, PI) et al.
Wind lidar , ADM Cal/Val, aerosol transport, CO_2 lidar



Institut für Trophosphärenforschung (TROPOS), Leibzig, Germany
Dr. Dietrich Althausen (PI)
Aerosol lidar ground measurements

University of Science and Technology of China (USTC), Hefei,
Prof. Sun Dongsong
Wind lidar ground measurements

CMA-National Satellite Meteorological Center, Beijing
Dr. Shang Jian
Wind data validation

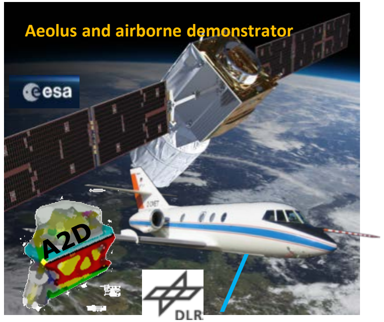
LZU , Lanzhou
Prof. Huang Jianping
Dust Aerosol Transport observations

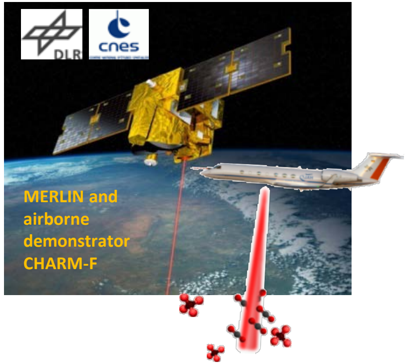
IPA
Dr. Gerhard Ehret, Dr. Andreas Fix
CO_2/CH_4 lidar Merlin and CHARM-F

Shanghai Institute of Optics and Mechanics (SIOM), Chinese Academy of Sciences
Prof. Chen Weibiao (PI), Dr. Liu Jiqiao
ACDL Chinese CO_2 - Mission

Anhui Institute of Optics and Fine Mechanics, CAS-AIOFM, Hefei
Dr. Liu Dong
ACDL

Project Objectives





1. Wind Lidar Observations from Aeolus

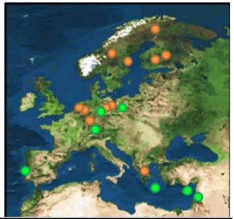
- Validation of the wind, cloud and aerosol data products with ground-based and airborne campaigns in Europe and China (**DLR**, OUC, SIOM), the ALADIN Airborne Demonstrator (A2D) data will be analyzed with particular attention to zero-wind calibrations and the retrieval of surface albedo using ground returns.
- Development and test of new retrieval algorithms for wind and land surface observations (Young Scientist)

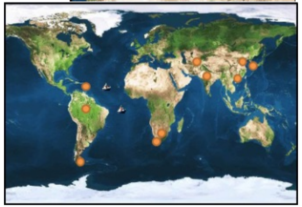
2. Support of Chinese ACDL - Mission

- Validation with ground-based and airborne sounding instruments for aerosol and CO_2 in Europe and China (**DLR**, SIOM)
- Scientific support in definition of mission requirements

3. Dust transport and validation with lidar

- Determine the dust source region, the main transport route and the main deposition areas (OUC, TROPOS)
- Validate the ADM-Aeolus and EarthCARE wind, cloud and aerosol data products (**DLR**, TROPOS, OUC)





Past and present locations of the TROPOS Portable Raman lidar systems (Polly)

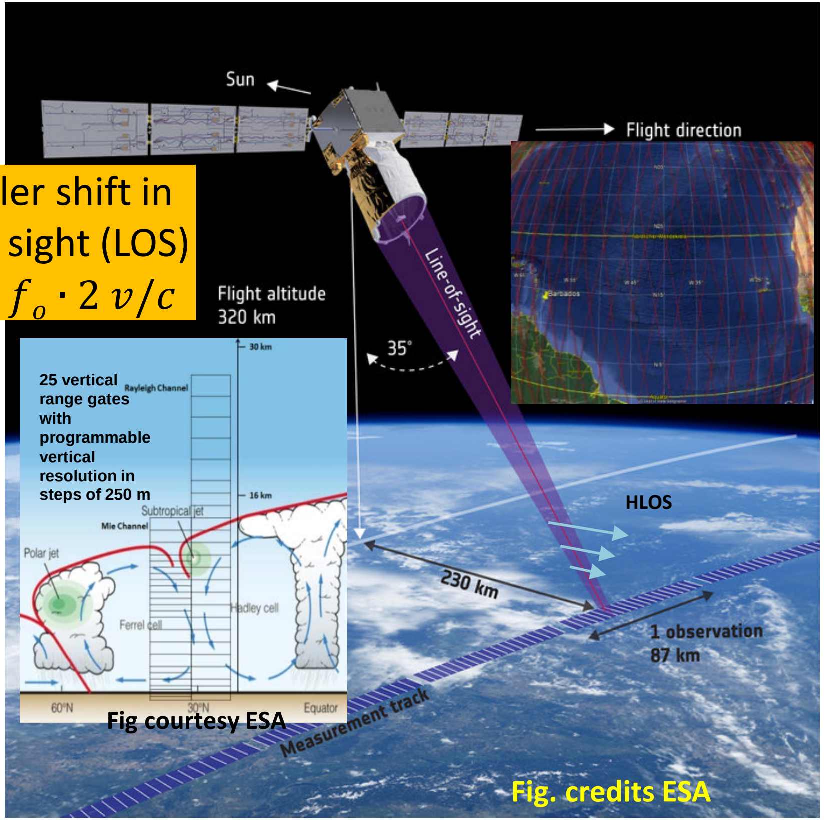
Aeolus: First wind lidar in space

Aeolus
with single payload
Atmospheric LAser Doppler INstrument
ALADIN

- First **wind lidar** in space with molecular and aerosol/cloud channel: **wind+aerosol products**
- **Profiles of wind in line-of-sight LOS direction (mainly zonal wind)** from ground up to 20-30 km averaged over 100/140 km
- **Error requirements on horizontally projected LOS (HLOS) random:**
  - < 1 m/s (z=0-2 km, Δz=0.5 km)
  - < 2.5 m/s (z=2-16 km, Δz=1.0 km)
- **systematic error:** < 0.7 m/s HLOS (0.5 m/s + 0.7% slope error)

Doppler shift in line of sight (LOS)

$$\Delta f = f_o \cdot 2\, v/c$$

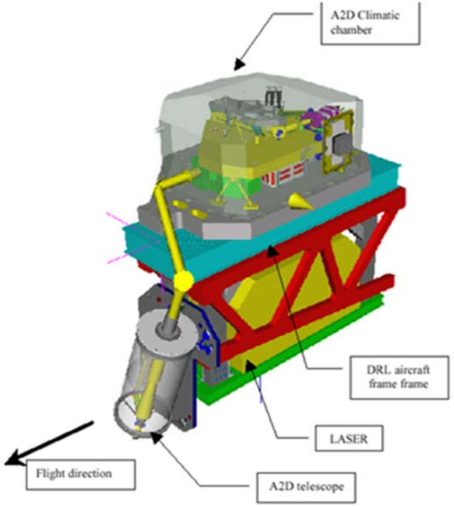


AEOLUS status

- Satellite fully integrated and tested in ambient
- Aeolus CAL/VAL Rehearsal Workshop was held in Toulouse, France on 28-30 March (http://aeolus-calval-2017.org/)
- Thermal vacuum test of the satellite is ongoing until mid-July.
- Next steps: Qualification and Acceptance Review completion in October 2017; Launch Jan. 2018

Fig. credits ESA

The ALADIN Airborne Demonstrator – A2D



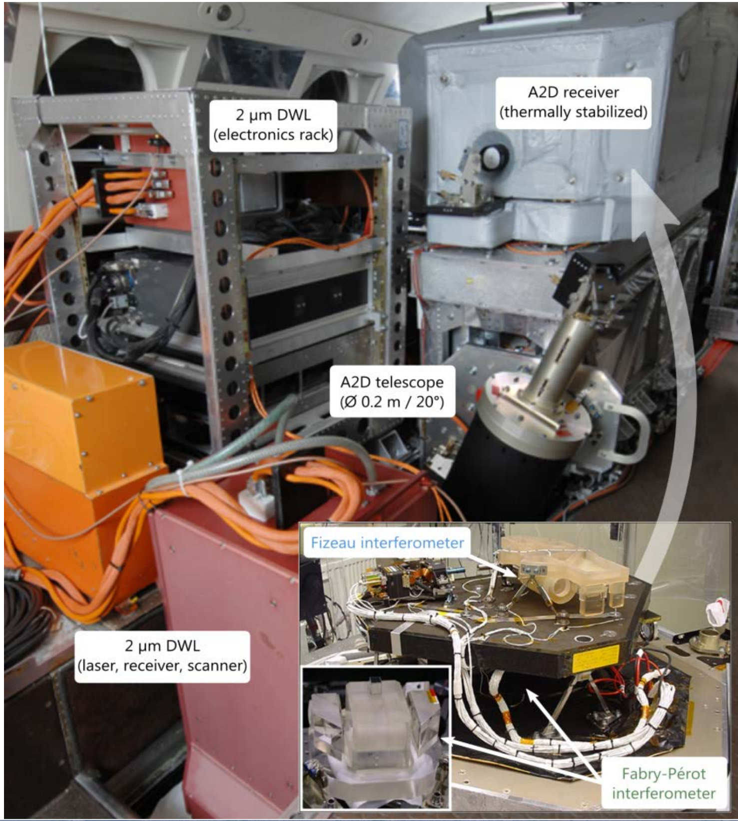
A2D first direct-detection airborne wind lidar in 2005

First flights of coherent 2-µm and direct-detection wind lidars on-board same aircraft in 2007

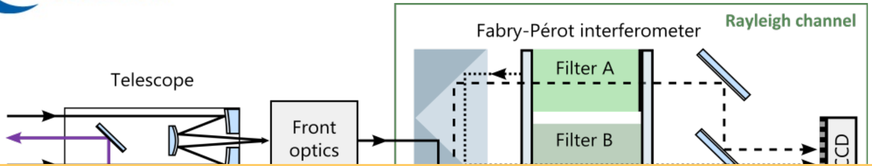
A2D – Tasks at DLR

➔ Instrument improvements of A2D

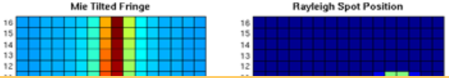
➔ Refined operational and analysis methods relevant for Aeolus satellite mission



A2D/Aeolus measurement principle

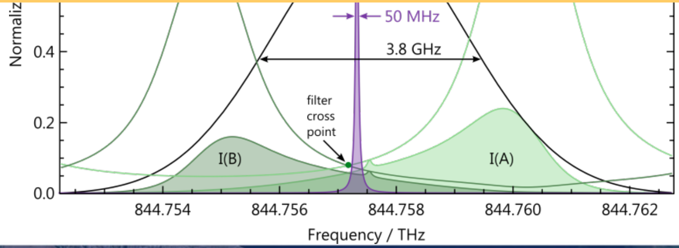


Vertical bin overlap incl. imperfections for Rayleigh spots and Mie fringe

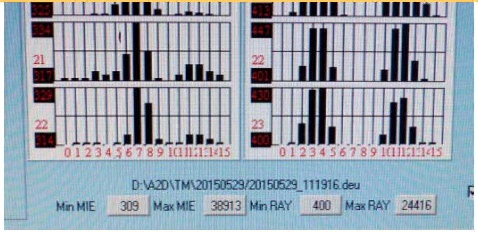


- Intensive calibration and validation by ground based instruments, other satellite data and airborne lidars planned during commissioning phase

- Continuous performance assessment during mission



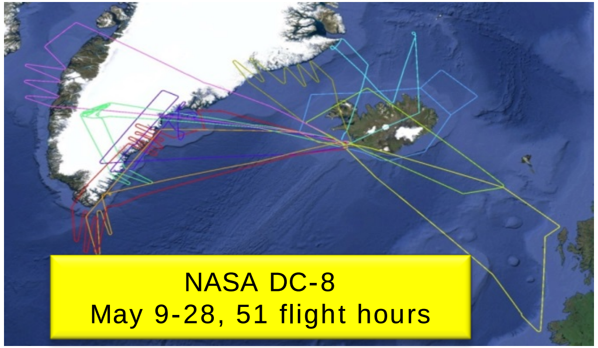
Signal (Mie) ~ N(aerosol/cloud)

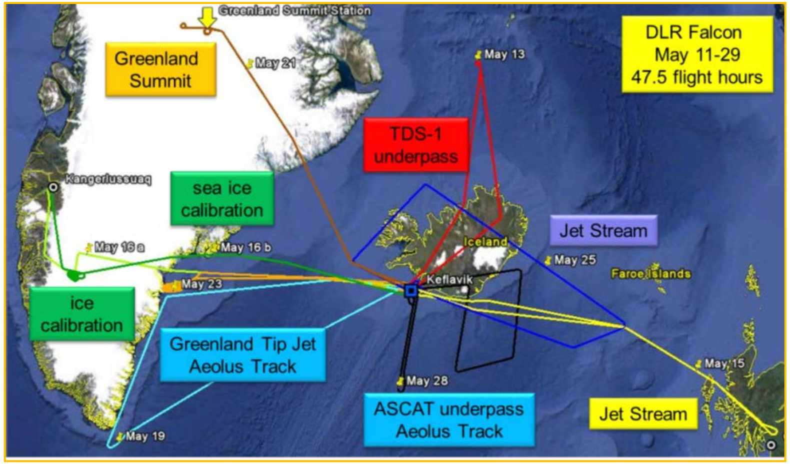


reference)

Ground return

Airborne campaign 2015 overview

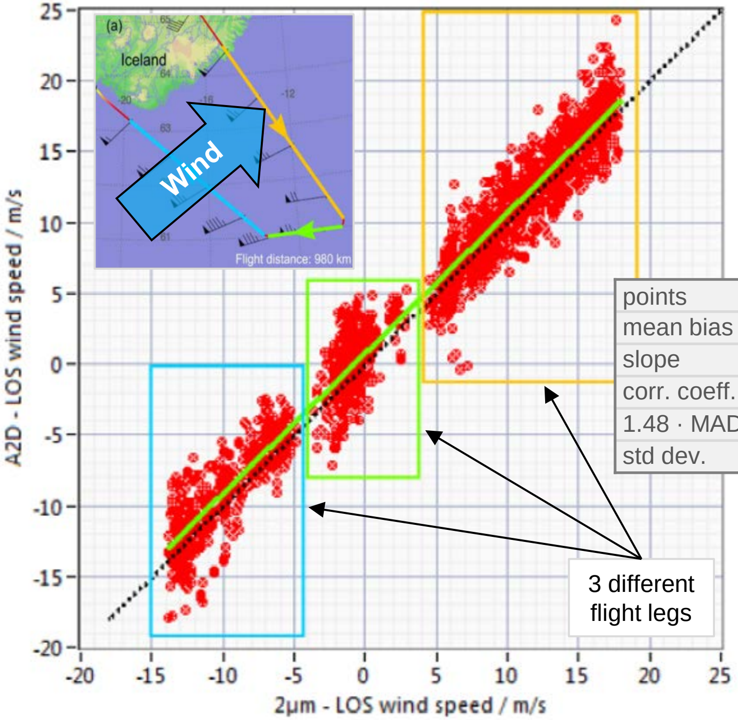




First time 4 Wind Lidars and dropsondes on 2 aircrafts

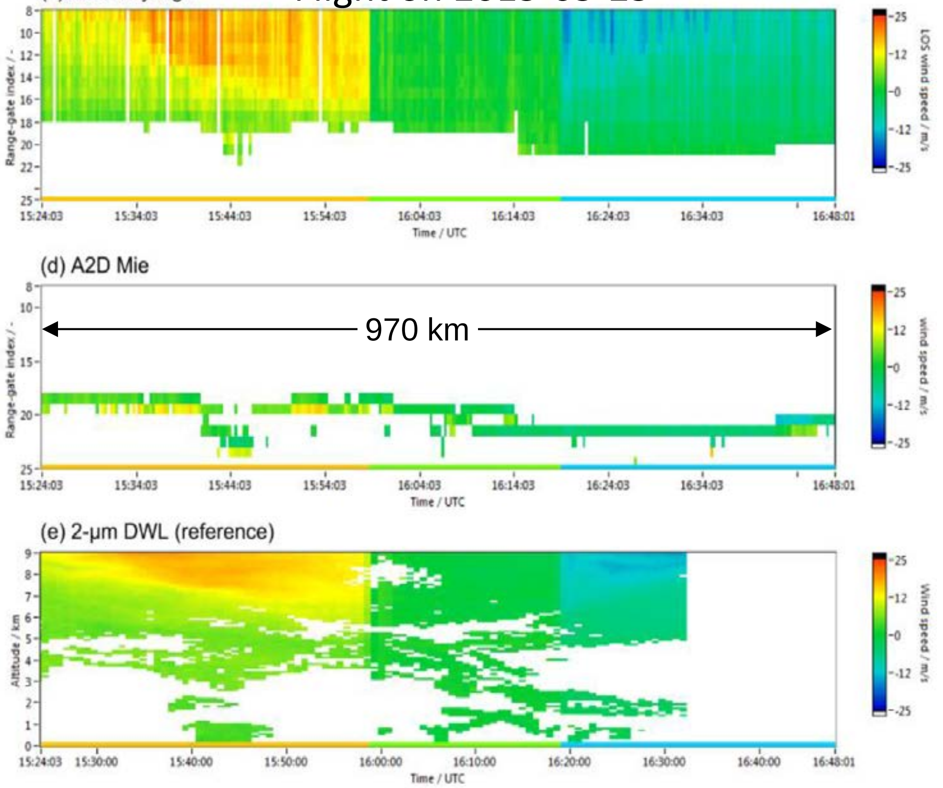
WindVal 2015 results (selected)

Comparison 2µm – A2D Rayleigh channel

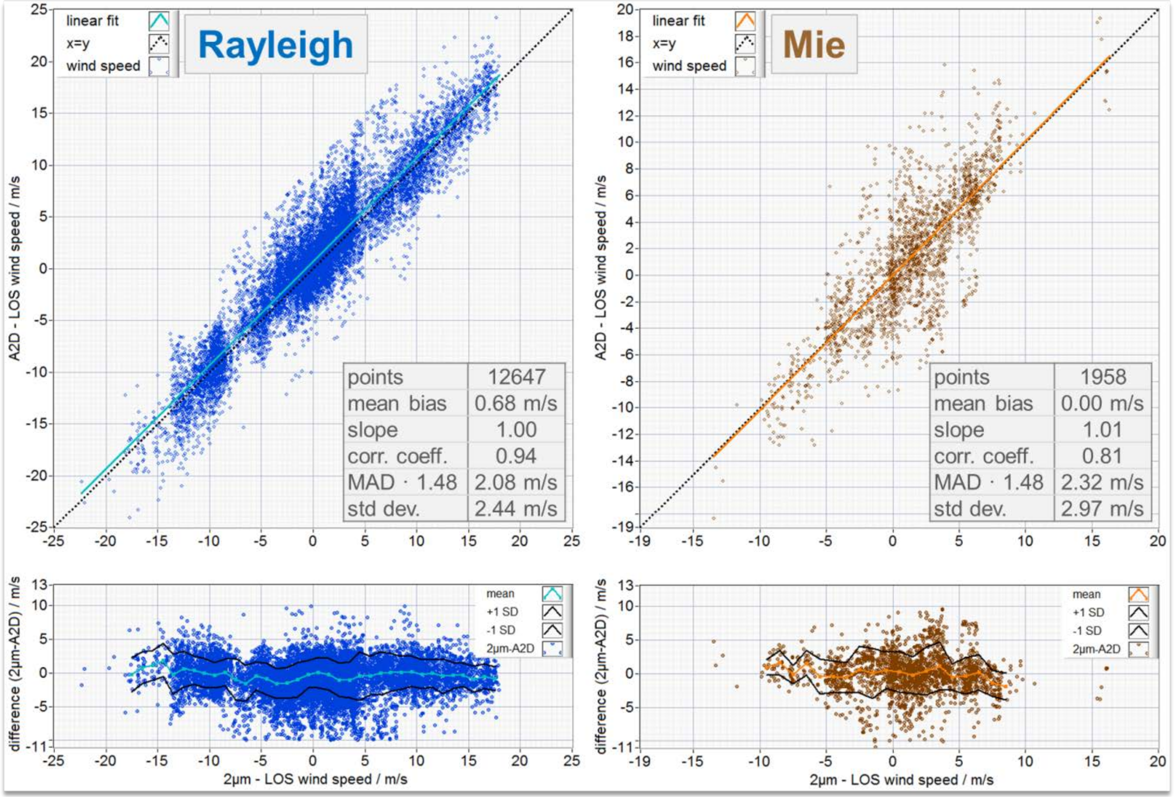


points	1996
mean bias	0.60 m/s
slope	0.99
corr. coeff. r	0.98
1.48 · MAD	1.63 m/s
std dev.	1.86 m/s

Flight on 2015-05-25



WindVal 2015: Overall LOS wind speed comparison A2D vs. 2-µm lidar

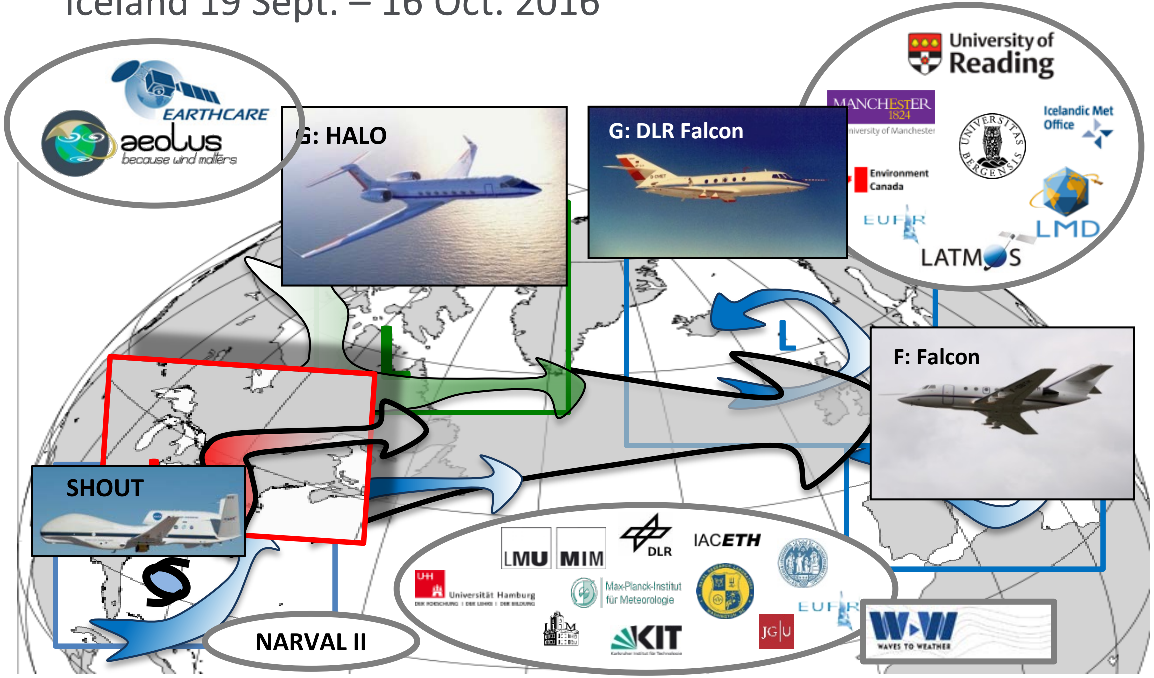


WindVal 2015 summary:

- A2D: 9 scientific and 4 transfer flights between May 11th and May 29th, 2015
- ≈ 12 h of A2D wind measurements (21 scenes between 10 – 88 min)
- 5 in-flight instrument response calibrations (≈ 2.5 h)
- Coordinated wind measurements performed during 7 flights
- Flight hours:
  NASA DC-8 = 51 h (excl. transfer)
  DLR Falcon = 48 h (incl. transfer)
- 101 dropsondes released from DC-8
- Large increase in statistical evidence for comparison A2D and 2-µm from 2 scenes in 2009 (N_{Ray}=1076, N_{Mie}=975) to 18 scenes (N_{Ray}=12647) for Rayleigh and 5 scenes (N_{Mie}=1958) for Mie; statistics in LOS with 20°
- Final meeting successful, final report delivered

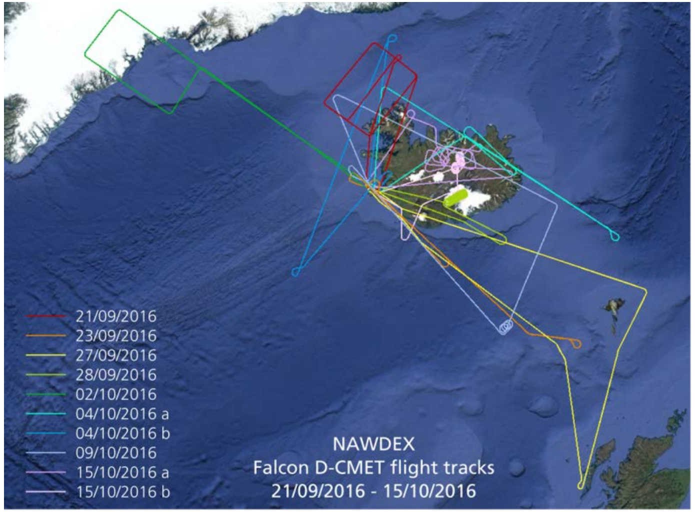
WindVal II during NAWDEX 2016

North Atlantic Waveguide and Downstream Impact Experiment
Iceland 19 Sept. – 16 Oct. 2016

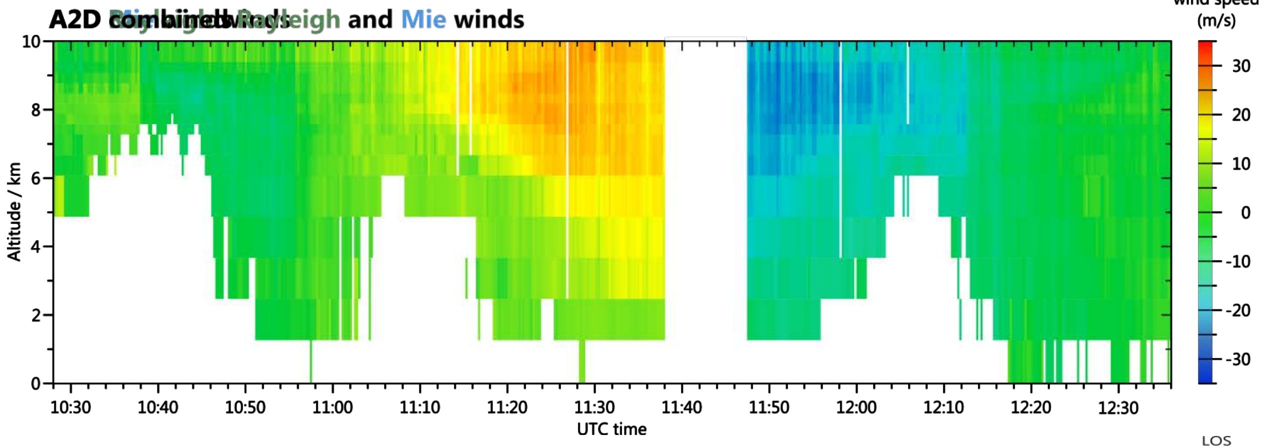


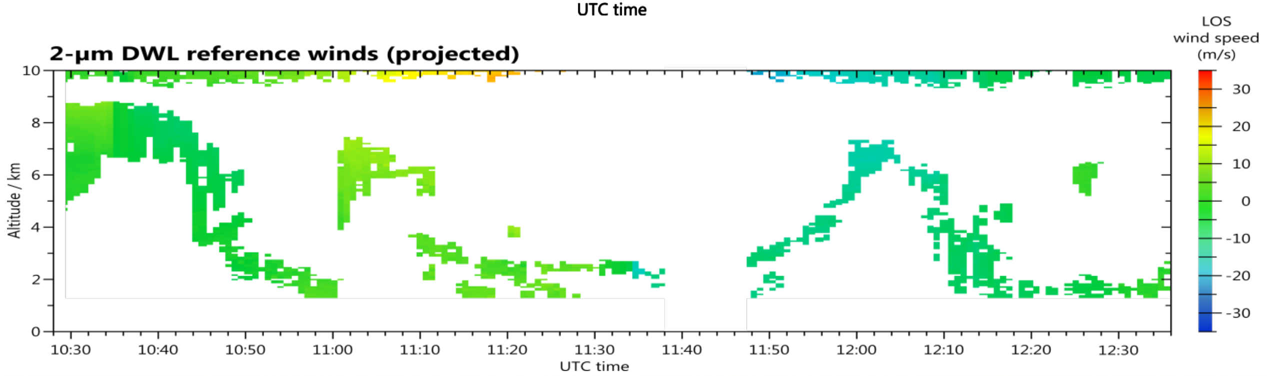
German DLR - Falcon flight tracks

Aeolus Cal-Val payload
A2D & 2-µm Doppler wind lidars

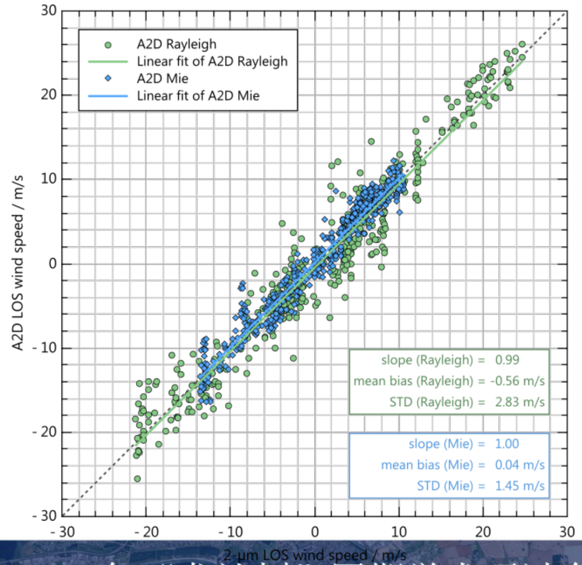


Sampling of the jet stream on 27/09/2016



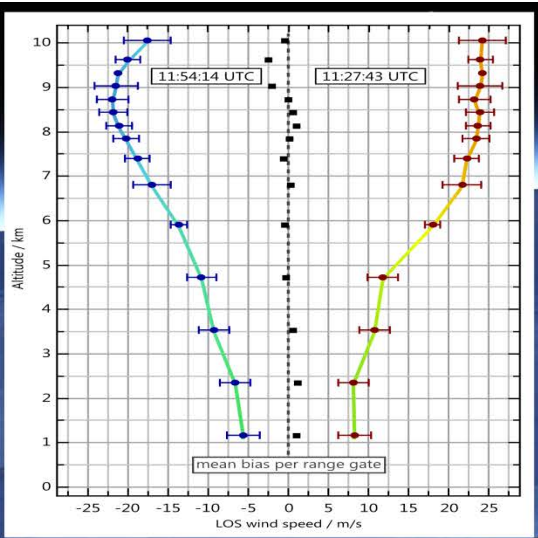


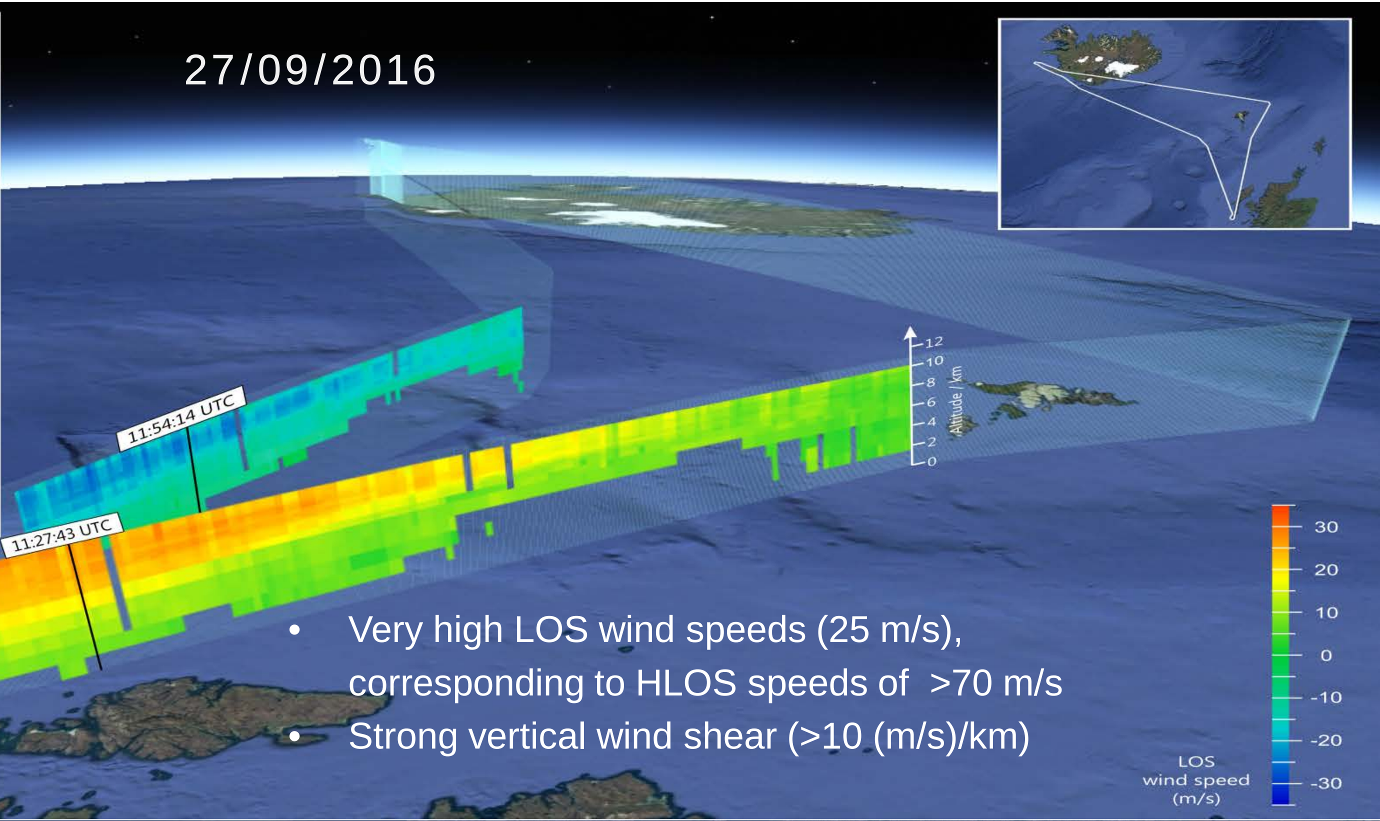
- Jet stream crossing near the Outer Hebrides
- High LOS wind speeds above 25 m/s (HLOS > 70 m/s)
- Broad coverage, good agreement with 2-µm DWL data



Sampling of the jet stream with A2D - 3D

27/09/2016





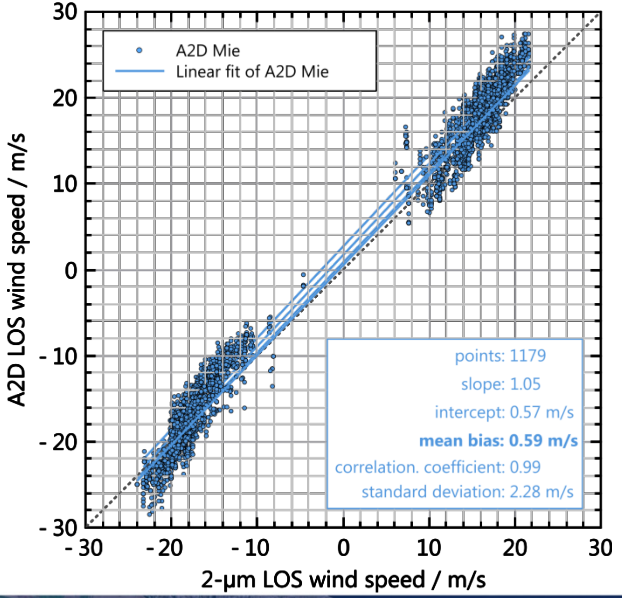
- Very high LOS wind speeds (25 m/s), corresponding to HLOS speeds of >70 m/s
- Strong vertical wind shear (>10 (m/s)/km)

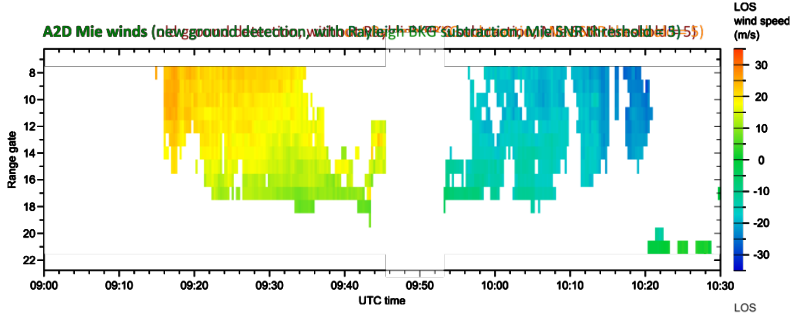
Correction of Mie winds (mean bias reduction)

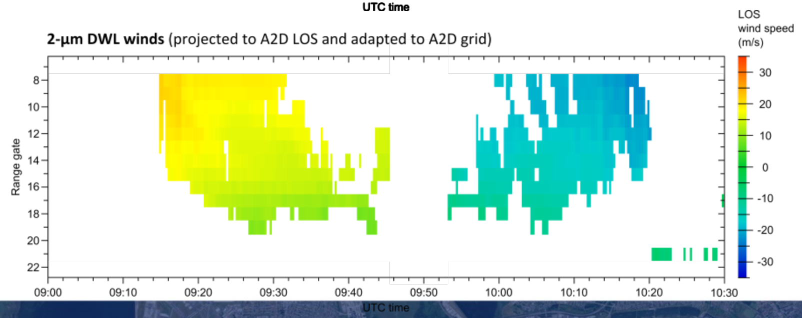
Reduction of mean bias of Mie winds (for the flight on 04/10/2016) by:

- Applying calibration with new ground detection (-1 m/s)
- Subtraction of Rayleigh background signal on Mie channel (-0.9 m/s)
- Lowering of SNR threshold from 5 to 3 (-0.3 m/s)
- *Further corrections possible (e.g. taking account of different altitudes/pressure levels)*

Calibration with new ground detection
Subtraction of Rayleigh background
Mie SNR threshold = 5





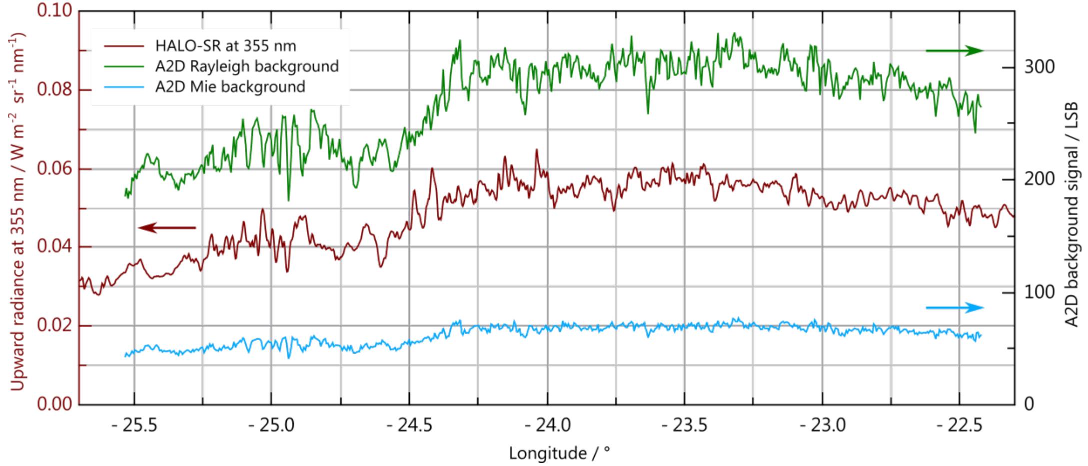


A2D background data and solar radiance 21/09/2016

Comparison with solar radiance data obtained with SMART-HALO during coordinated flight over dense clouds

➔ Potential for Aeolus relevant albedo data

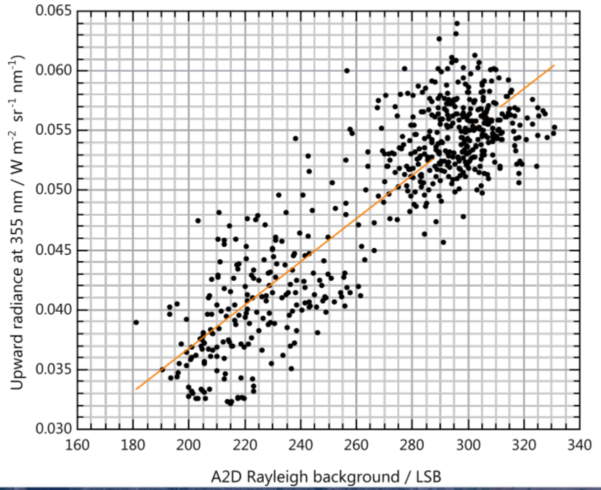
Background and solar radiance:



Slope: $1.81 \cdot 10^{-4}$ $Wm^{-2}sr^{-1}nm^{-1}LSB^{-1}$

Intercept: $5.7 \cdot 10^{-4}$ $Wm^{-2}sr^{-1}nm^{-1}$

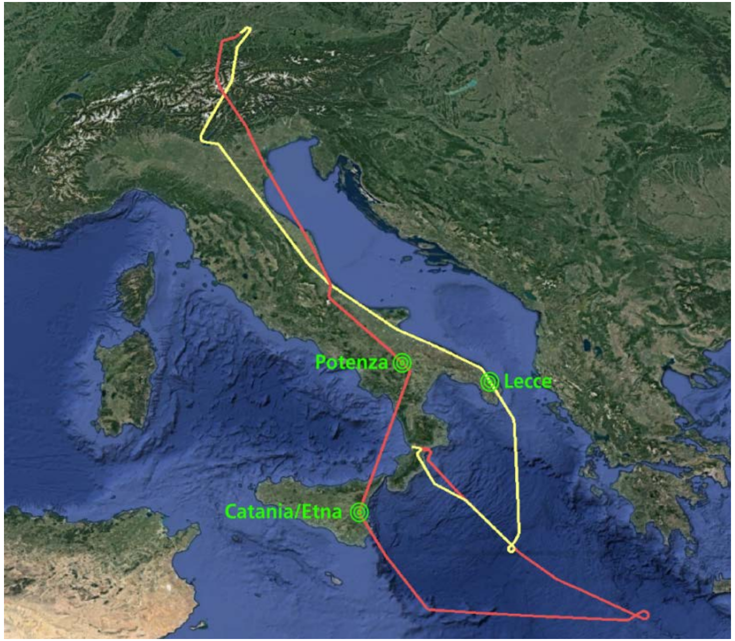
Correlation coefficient R^2: 0.78



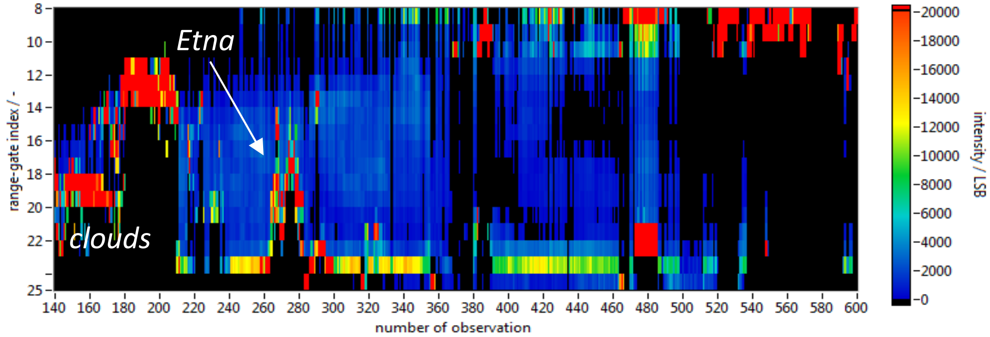
Smart – Halo data Courtesy Kevin Wolf, University Leipzig

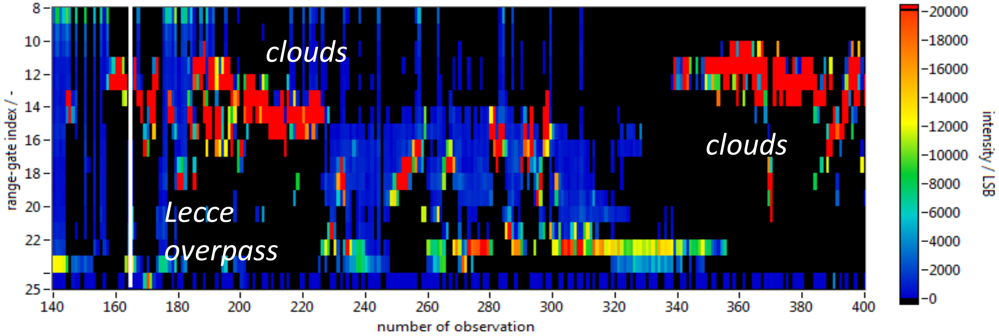
A2D - aerosol flights on 22/10/2016

A2D Mie-signal analysis for comparison with ground lidars and Calipso spaceborne lidar

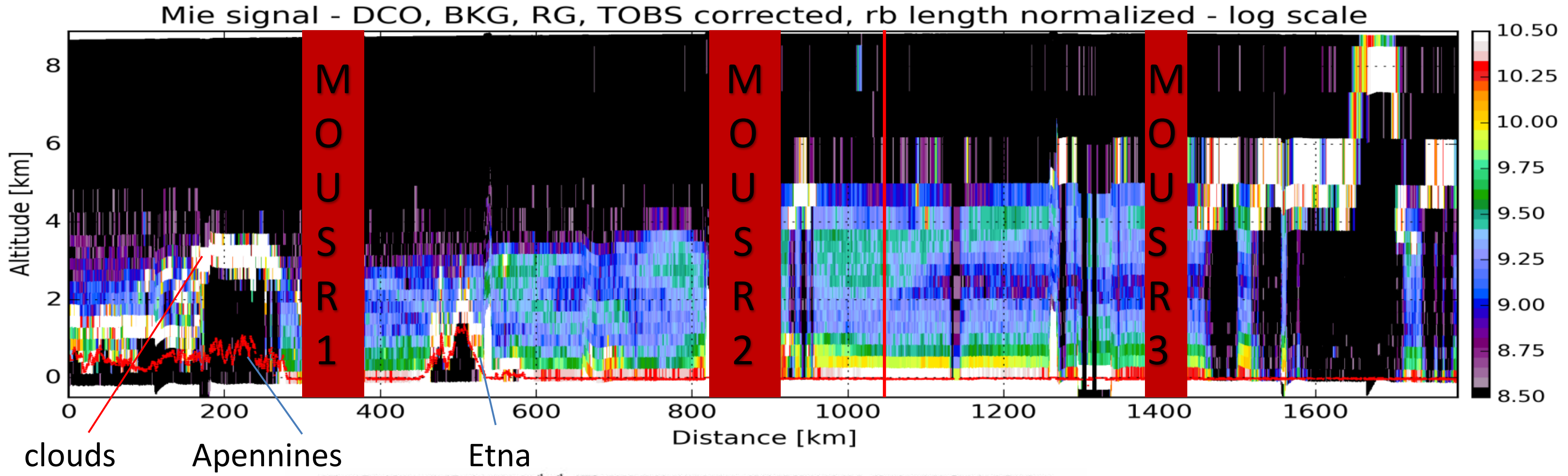


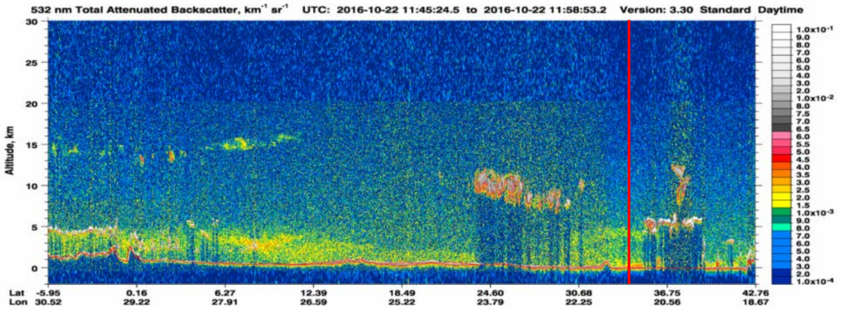
Mie signal intensities after Rayleigh background subtraction





Aerosol flights on 22/10/2016 – Mie signal





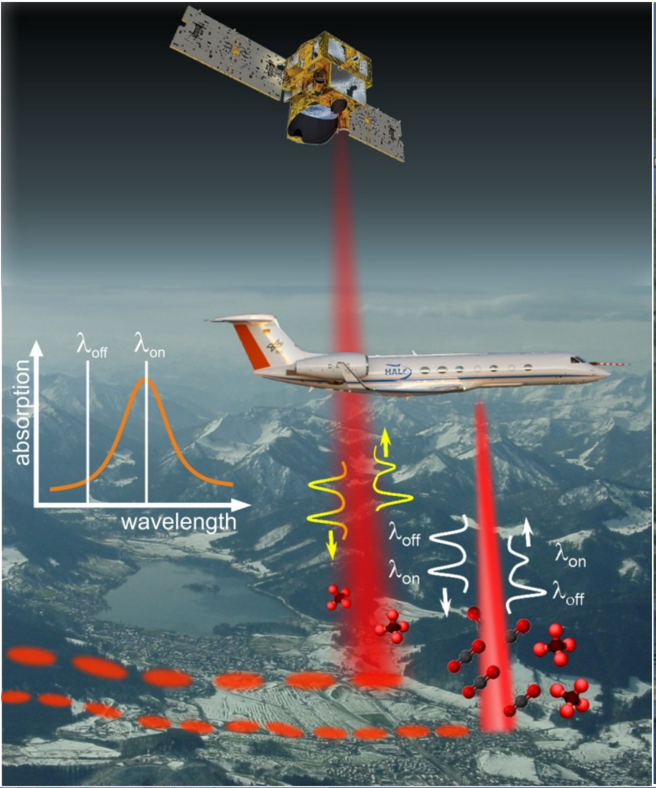
Red line marks the Calipso overpass region:
➔ Vertical aerosol extent is approximately in the same range as A2D has measured: top at ~5 km

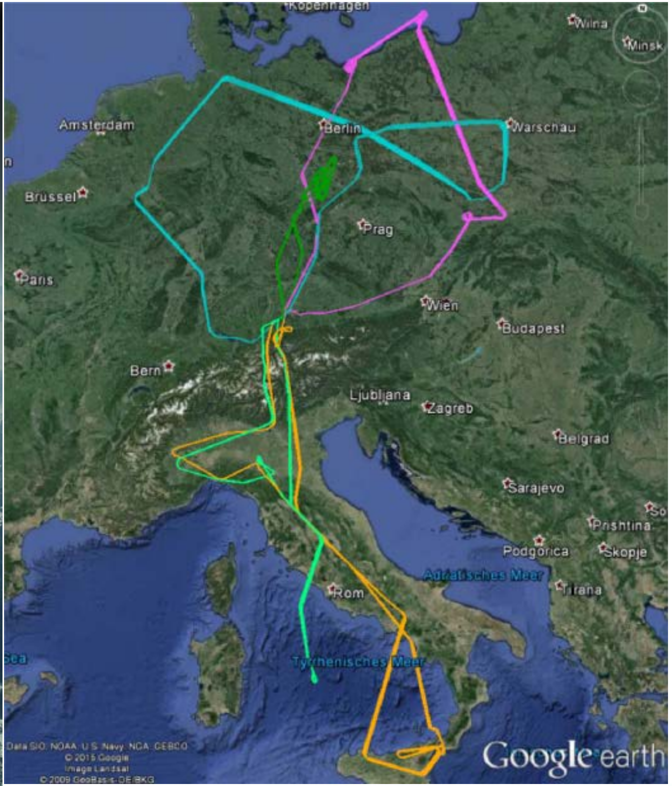
Courtesy Alexander Geiss, ESA/ESTEC

WindVal II 2016 summary

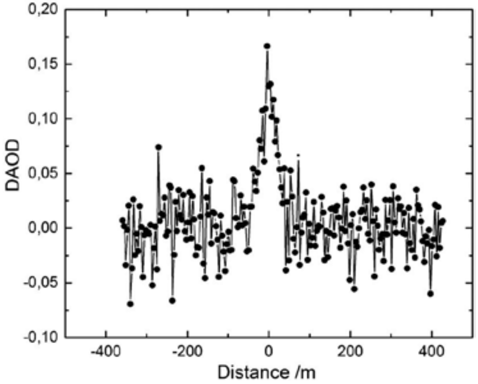
- 15 hours of wind measurements available from 12 research flights (4 additional flights were dedicated to calibrations and aerosol detection)
- Detailed analysis of Mie winds (statistical comparison with 2-µm DWL data, application of correction techniques for bias reduction, e.g. novel ground return detection algorithm)
- Correlation between A2D background signals and solar radiance data obtained from SMART-HALO was demonstrated
- Further analysis is ongoing regarding the Rayleigh wind bias, the Mie nonlinearity error and the comparison with SAFIRE data

CHARM-F CO_2 & CH_4 IPDA
➔ precursor for Merlin and ACDL





- First airborne campaign on HALO in spring 2015
- Measurement principle and data retreival algorithms demonstrated
- Second airborne campaign CoMet planned in spring 2018



CH_4 - emission from ventilation of coal mine shafts detected

Courtesy Axel Amediek, DLR
Applied Optics Amediek et al. 2017

Project summary

- Data analysis of WindVal 2015 finalized
- Airborne campaigns performed with focus on instrument specifics, algorithm refinement and satellite mission calibration and validation
- Data analysis ongoing for WindVal II 2016 and CHARM-F
- Successful tests, improvements and new developments of algorithms for all involved lidar systems.
- Contribution to L1B and L2A algorithms for Aeolus mission