ESA-MOST Dragon Cooperation 中国科技部-欧洲空间局“龙计划”合作

2014 DRAGON 3 MID-TERM RESULTS SYMPOSIUM

2014年“龙计划”三期中期成果学术研讨会

DRAGON 3 Project ID 10532 Cal/Val

Studying Atmospheric Dynamics – Validation of ADM-Aeolus Wind Lidar Observations

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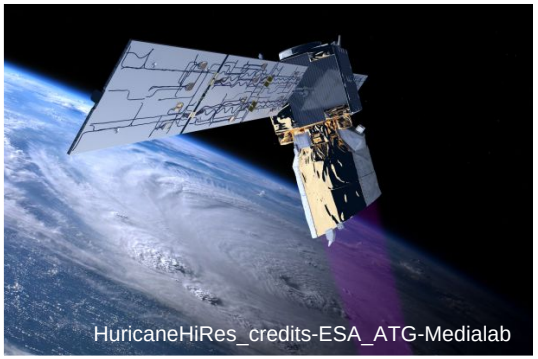


Project Objectives

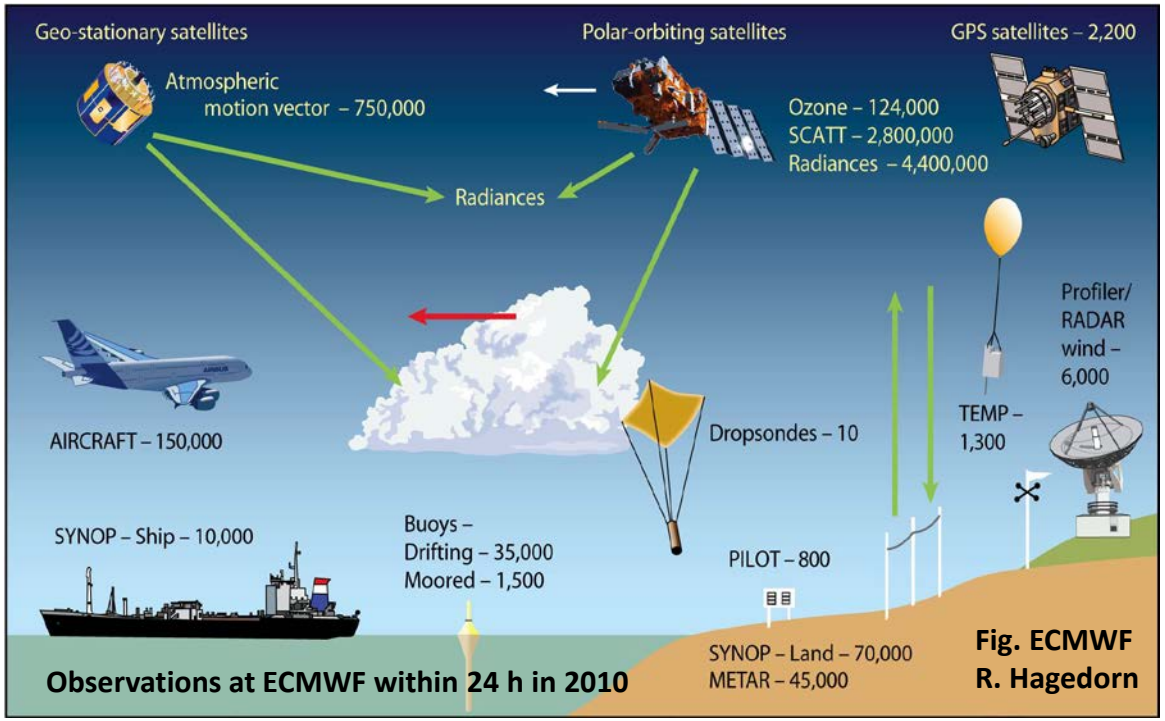
Wind Lidar Observations from ADM-Aeolus launch currently foreseen by end 2015

- Validation with ground-based and airborne campaigns in Europe and China (DLR, OUC, SIOM)
- Study of atmospheric dynamics and assimilation of wind lidar observations (DLR, CMA)
- Derivation of high-resolution land-surface albedo observations in the UV (DLR, MSSL)
- Derivation of cloud motion winds from multi-angle imaging spectro-radiometer and comparison of wind and cloud height with ADM-Aeolus (MSSL)
- Development and test of new retrieval algorithms for wind and land surface observations (Young Scientist)

Outline of the talk

- ADM-Aeolus – the 1st wind lidar in space
- Airborne Pre-Launch Campaigns for ADM-Aeolus
- Future Airborne Campaigns

Wind profiles have highest priority for NWP



WMO Expert Team on Observational Data Requirements and Redesign of the Global Observing System

Statement of Guidance for Global NWP (May 2012) and High-Resolution Numerical Weather Prediction (May 2012):
"The critical atmospheric variables that are not adequately measured by current or planned systems are (in order of priority): …"

1. wind profiles at all levels

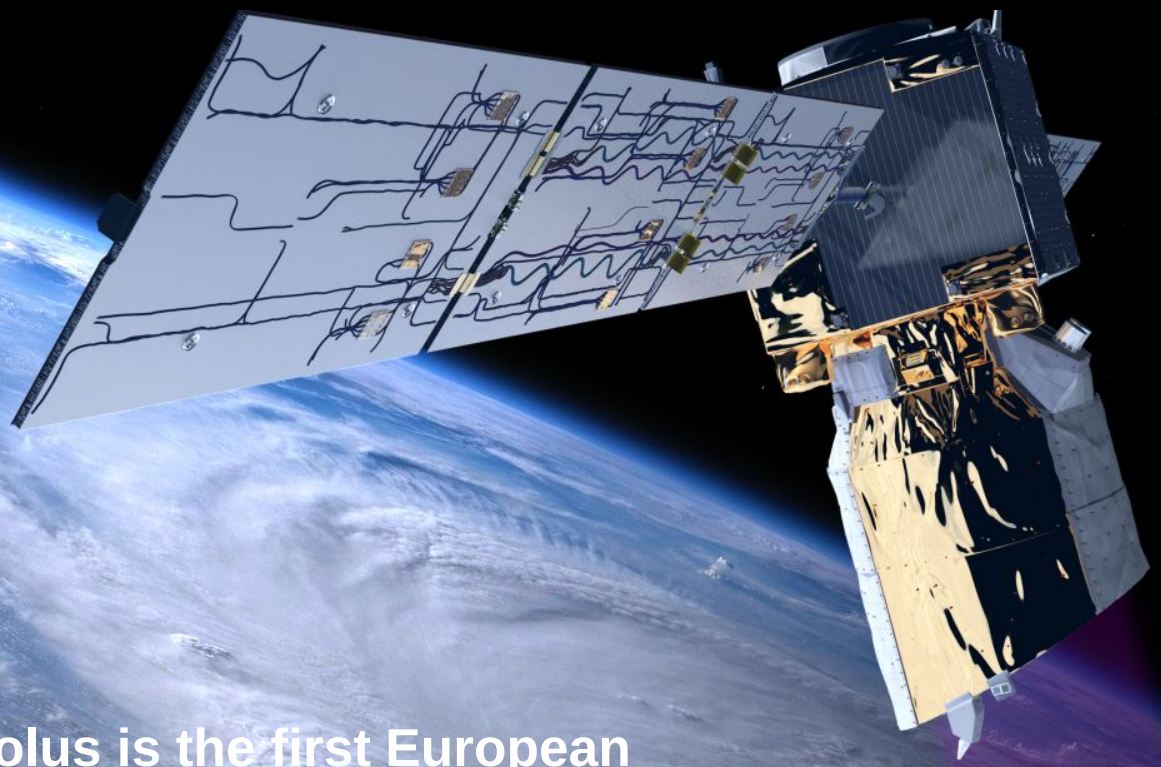
"Development of satellite-based wind profiling systems remains a priority for the future global observing system." (5th WMO NWP Impact Workshop Final Report, Sedona May 2012)

→ Doppler wind lidar technology can fill this gap

Aeolus

The first wind lidar in space with launch in 2015

2013-10 - Aeolus Video.mp4



- Aeolus is the first European lidar mission from ESA and first wind lidar mission worldwide
- Objective is to improve weather forecasting by providing global wind-profile observations
- Polar orbiting satellite at 400 km with single payload instrument - the Doppler lidar ALADIN

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The Atmospheric Dynamics Mission ADM-Aeolus

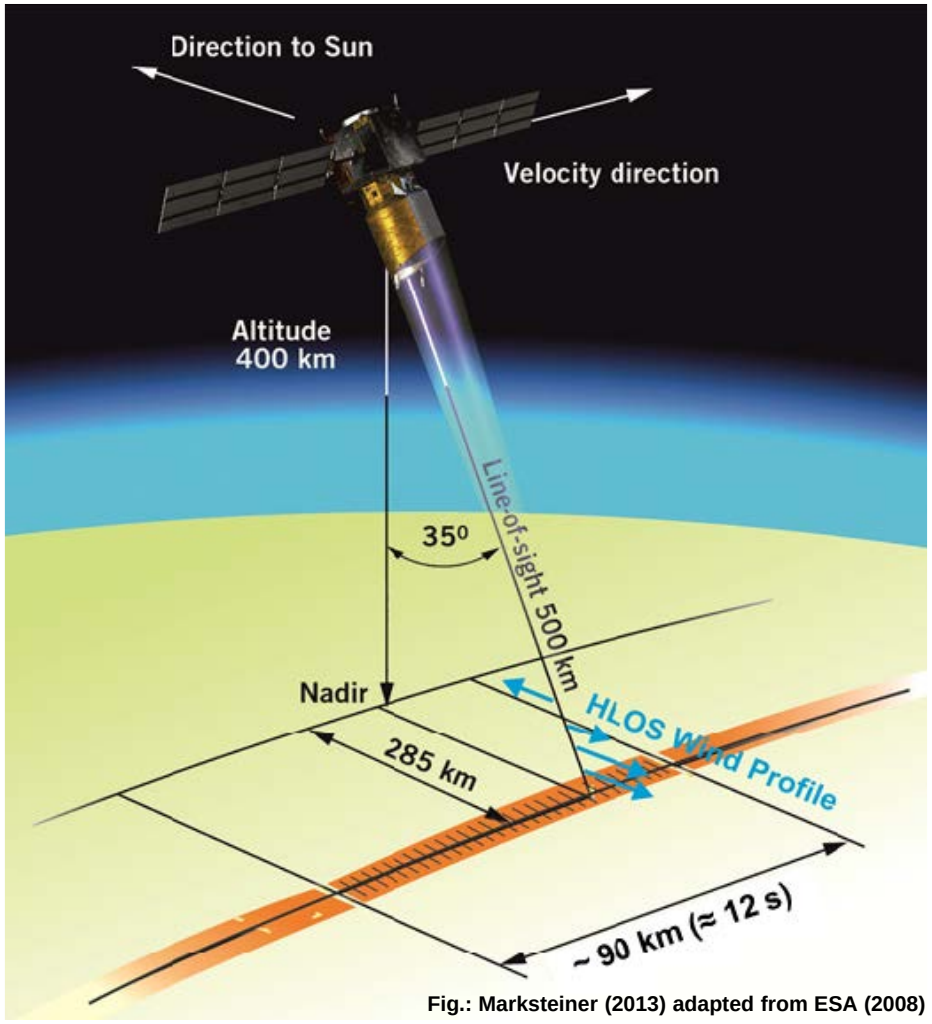


Fig.: Marksteiner (2013) adapted from ESA (2008)

ADM-Aeolus with single payload
Atmospheric LAser Doppler INstrument
ALADIN

- First **wind lidar** and a High Spectral Resolution Lidar **HSRL** in space to obtain aerosol/cloud optical properties, e.g. cloud height, extinction coefficients
- Measures **profiles of wind in line-of-sight direction** from ground up to 20-30 km with a vertical resolution of 250-2000 m averaged over 90 km
- **High requirements on wind error**
  - random error: < 1-2 m/s
  - systematic error: < 0.4 m/s
    0.7% of wind speed

Perspectives for Earth Observation

ADM-Aeolus

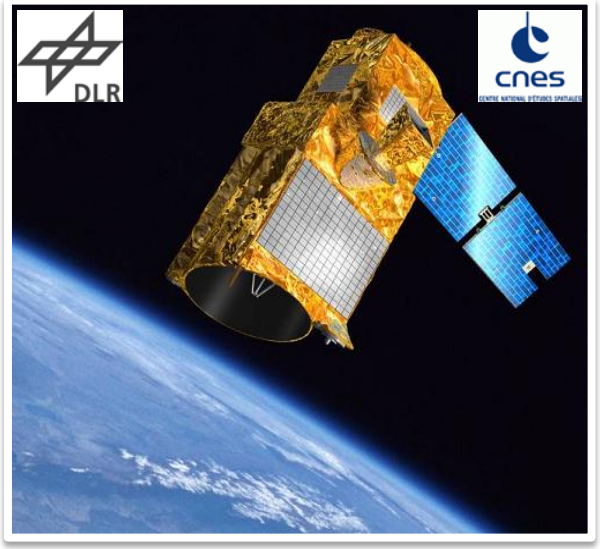
The first Doppler lidar in space for wind

EarthCARE

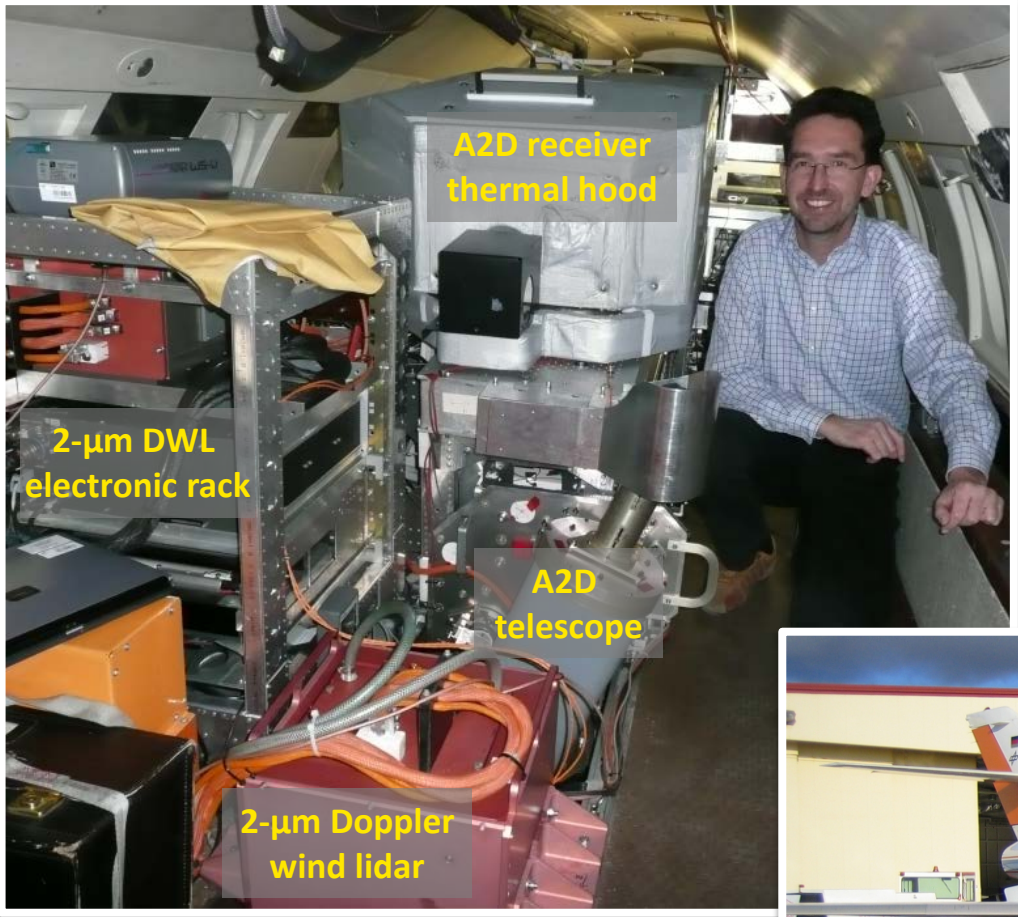
The first high spectral resolution lidar in space for aerosol and clouds

MERLIN

The first differential absorption lidar in space for methane



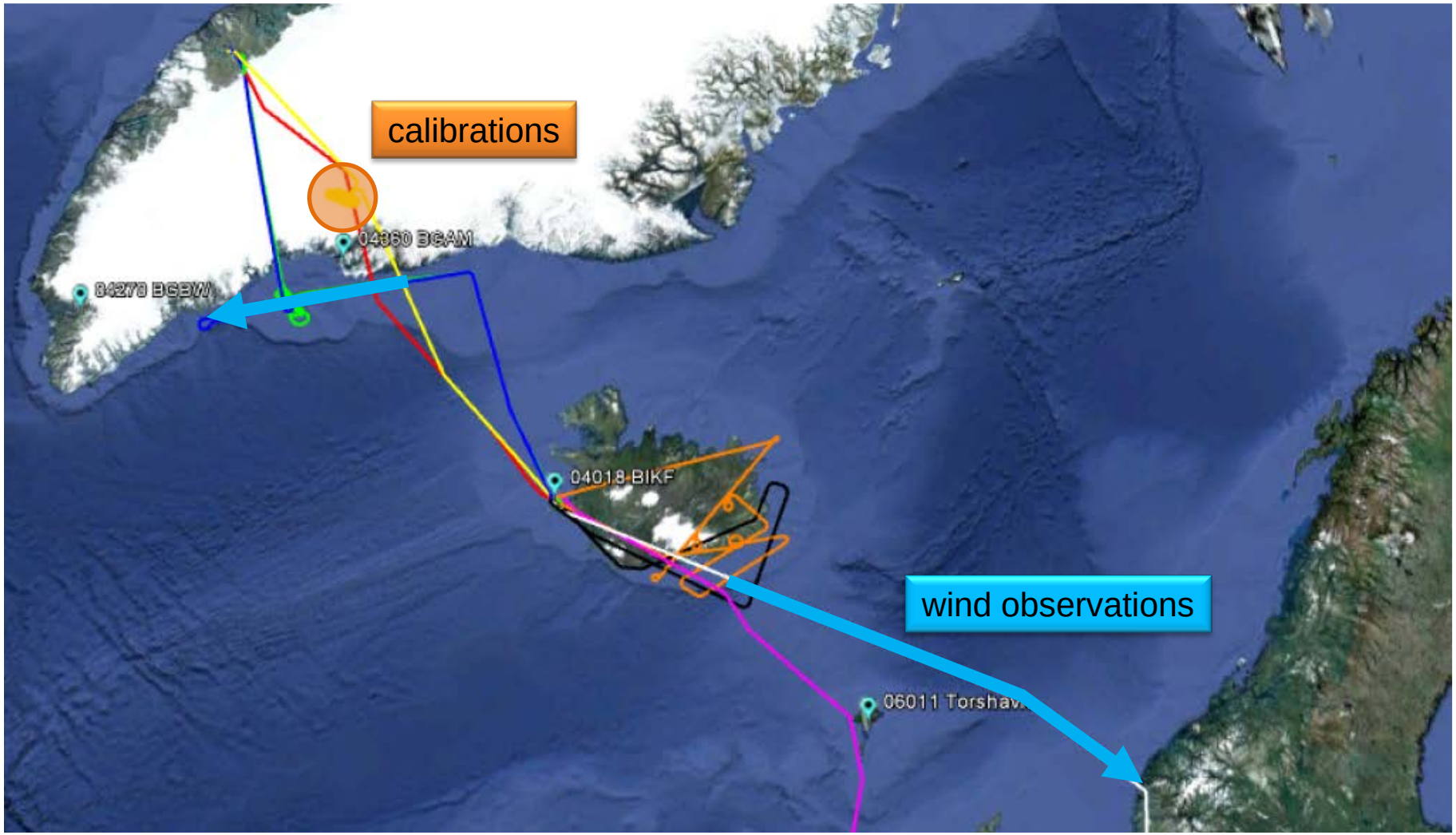
The ALADIN airborne demonstrator



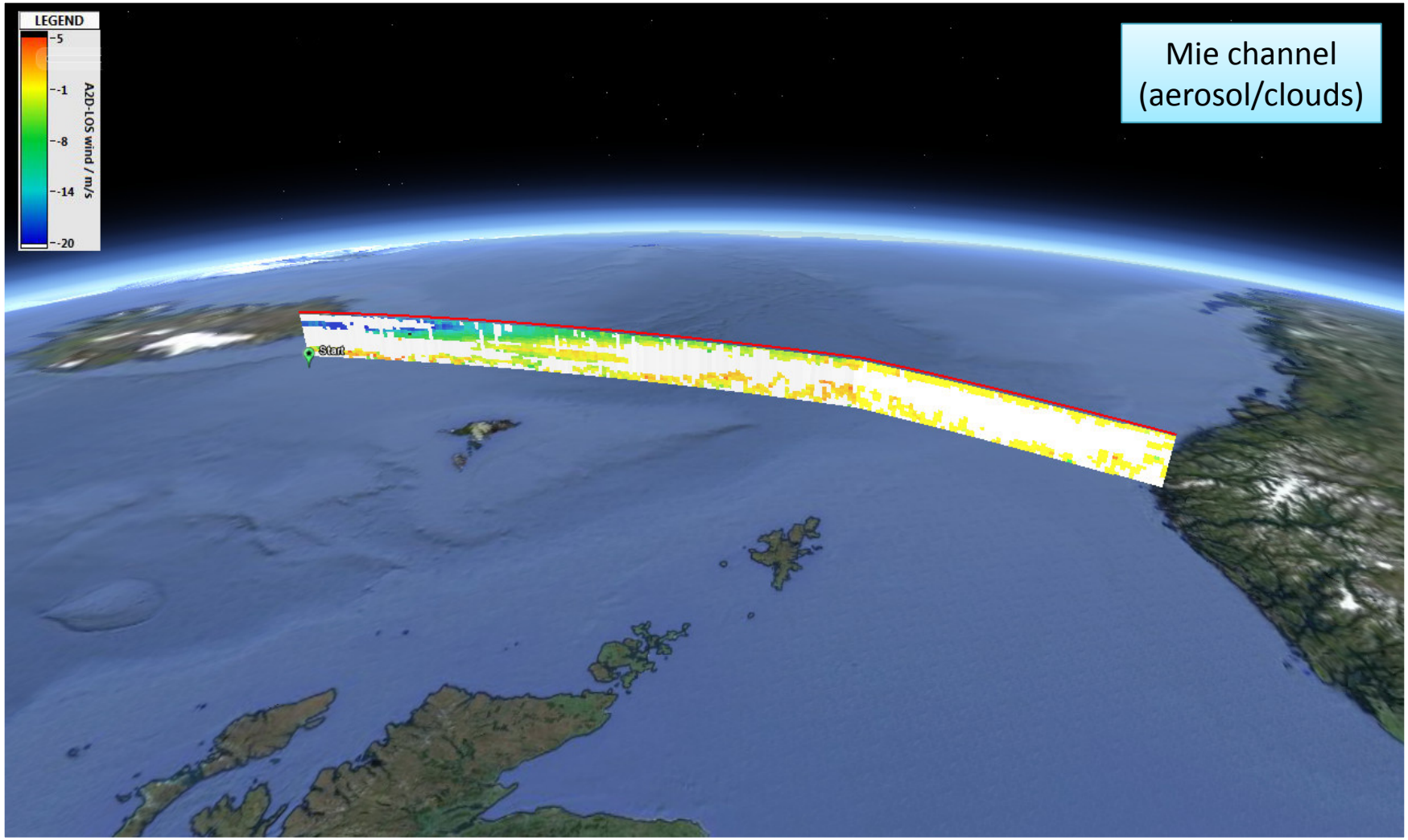
- Development of the airborne demonstrator with the optical receiver and laser breadboard from ESA´s Pre-Development Programme
- First flights of a direct-detection Doppler lidar worldwide in October 2005
- First flights of coherent and direct-detection wind lidar on-board same aircraft in 2007

DLR Falcon aircraft payload during campaigns in 2007, 2008 and 2009

3rd Aeolus campaign in Sept. 2009



Airborne observations in cloudy conditions over the North Atlantic



Airborne observations and ECMWF model

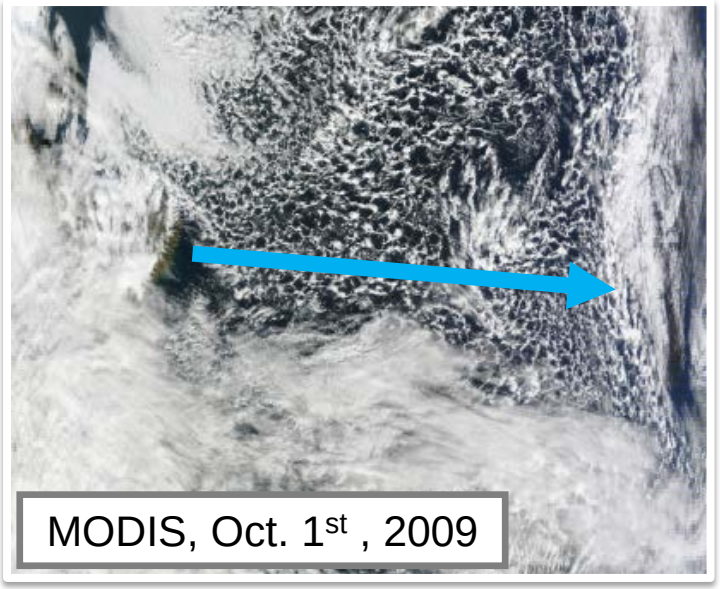
LOS wind observations on 2009/10/01

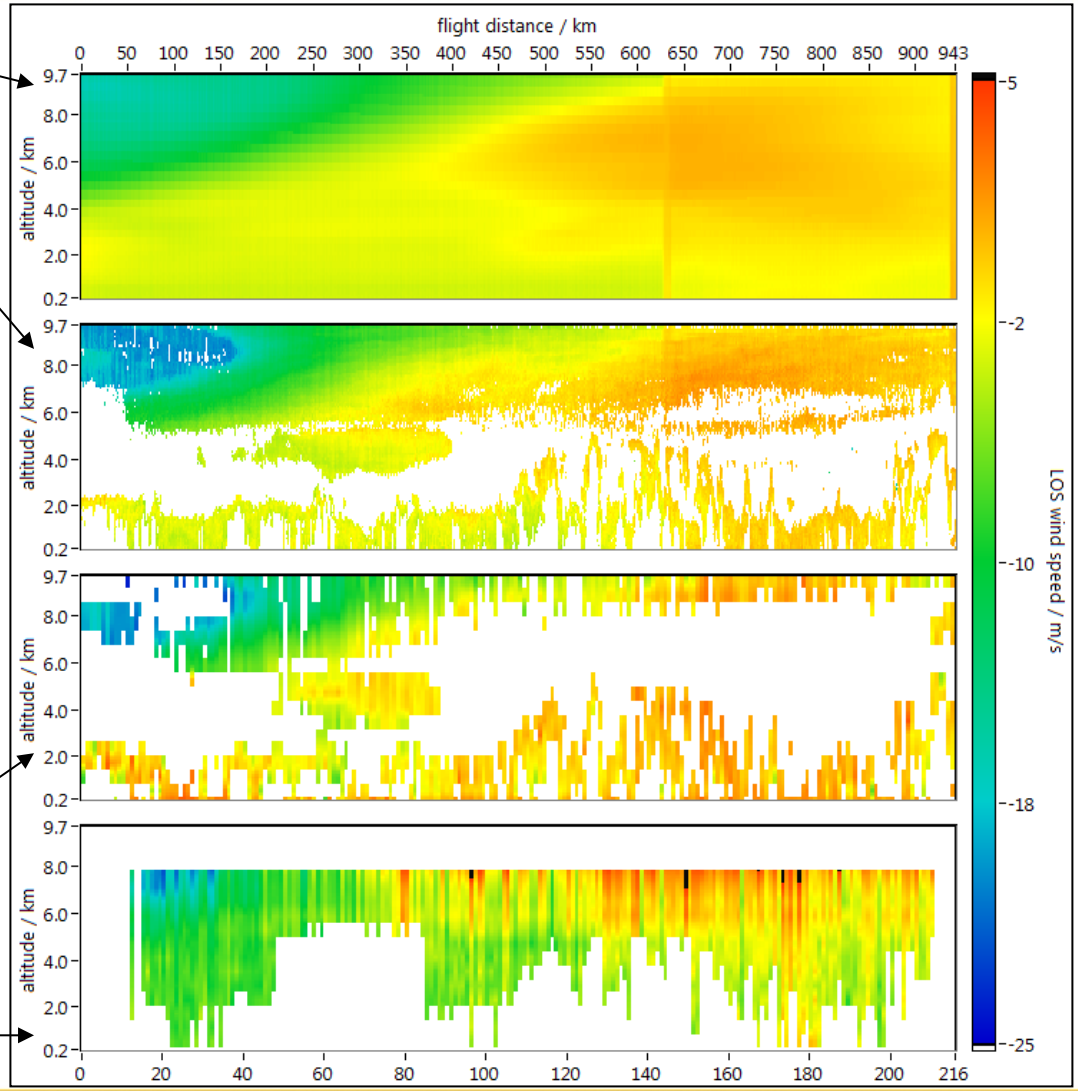
ECMWF

2-µm

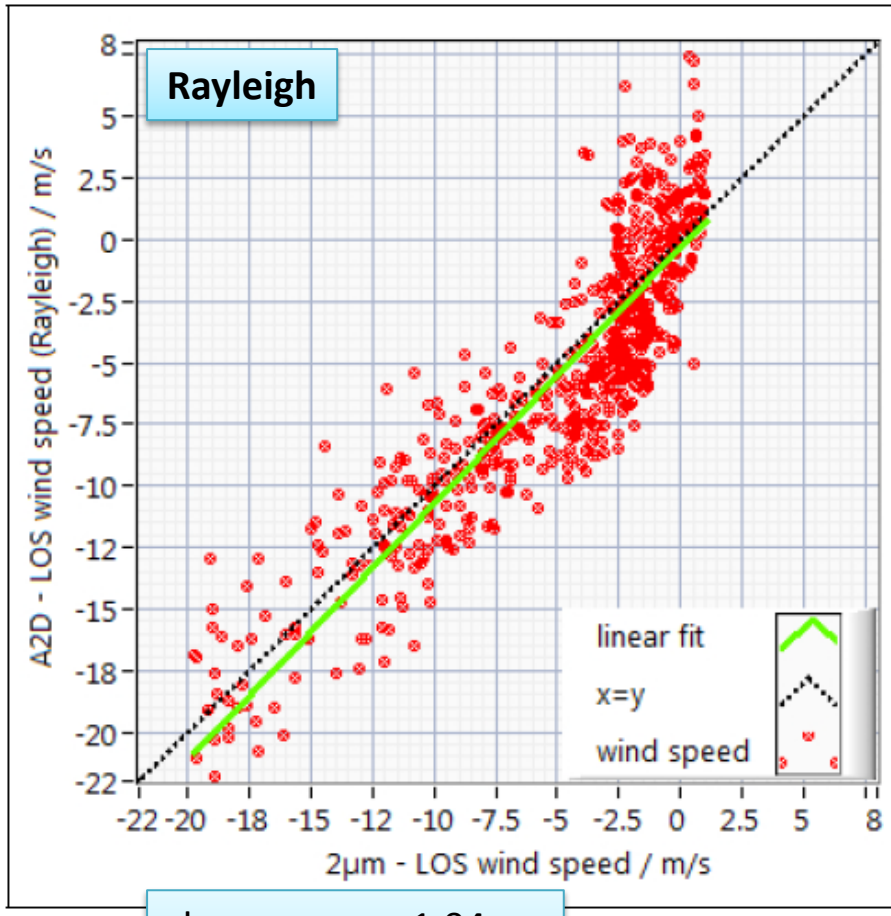
Mie

Rayleigh

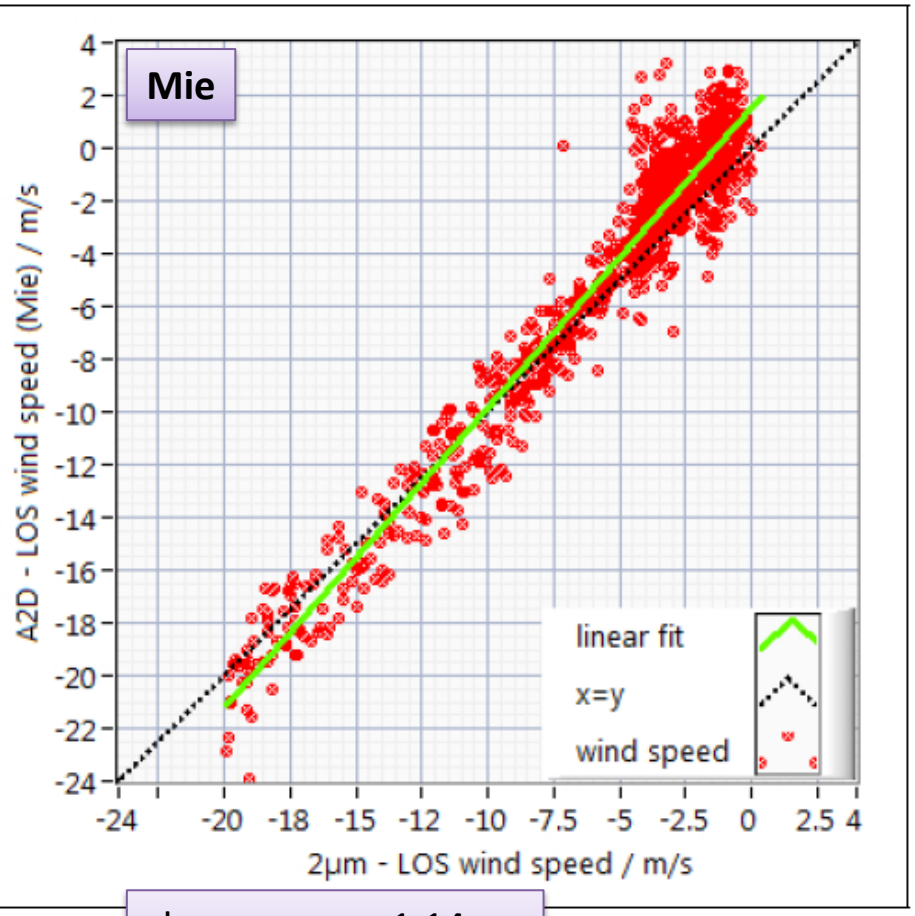




Statistical Comparison for ALADIN airborne demonstrator



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

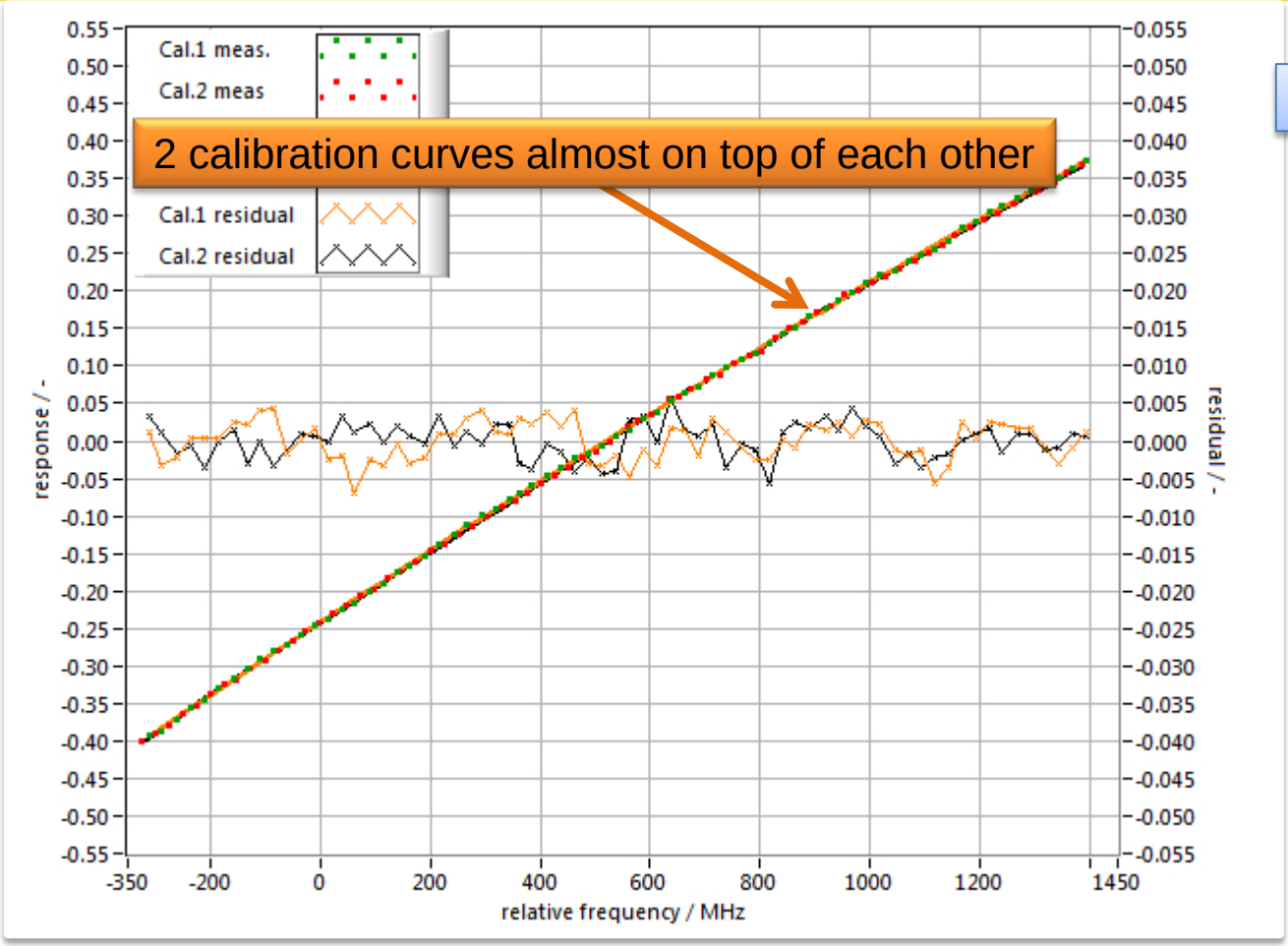


slope:	1.14
std. dev.:	1.5 m/s
# of points:	932

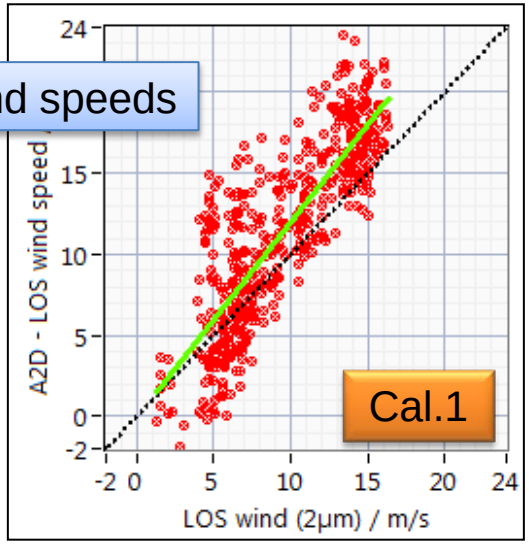
Poisson noise limitation for A2D intensity measurements

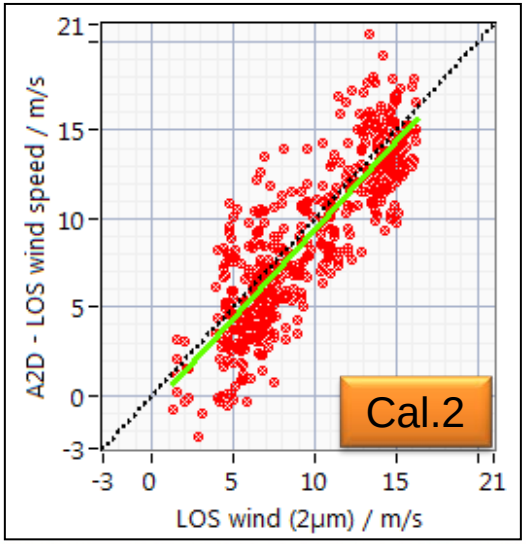
- An ideal (photon) counting process obeys Poisson statistics
- Poisson statistics are the statistical description of Shot Noise, which constitutes the lower limit
- $\sigma \sim \sqrt{n}$ → n = number of counts
  - 10000 counts → 100 counts expected from Poisson noise → 1%
  - 100 counts → 10 counts expected from Poisson noise → 10%
- Theoretically, for Aeolus all noise sources are so small that Poisson Noise is the largest contributor and must be taken into account („shot noise limited detection“)
- In practice, for the Airborne Demonstrator we detected a much higher noise level than expected from Poisson

Poisson noise limitation for A2D intensity measurements



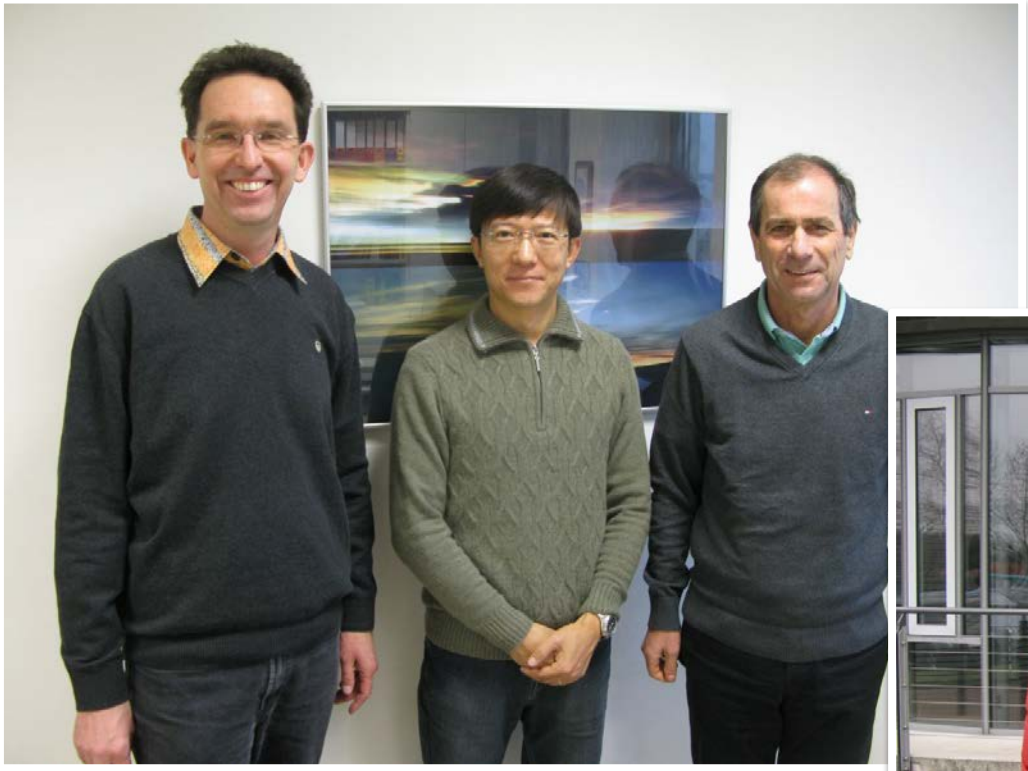
wind speeds





Apparently very consistent calibrations, however, resulting in big differences in wind speeds → future work / **POSTER**

Exchange: Prof. Dr. Songhua Wu
Oct. 2013 – Jan. 2014



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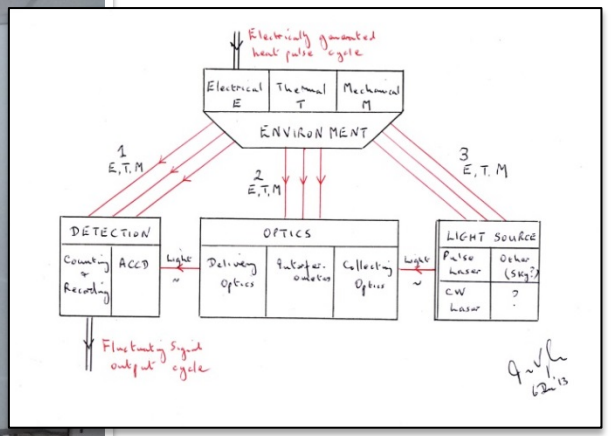
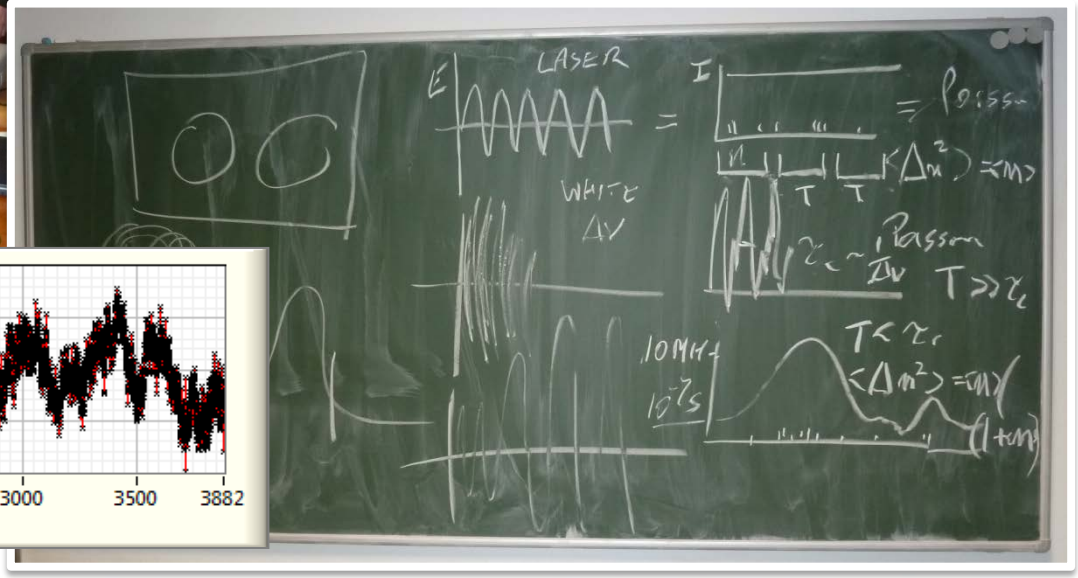
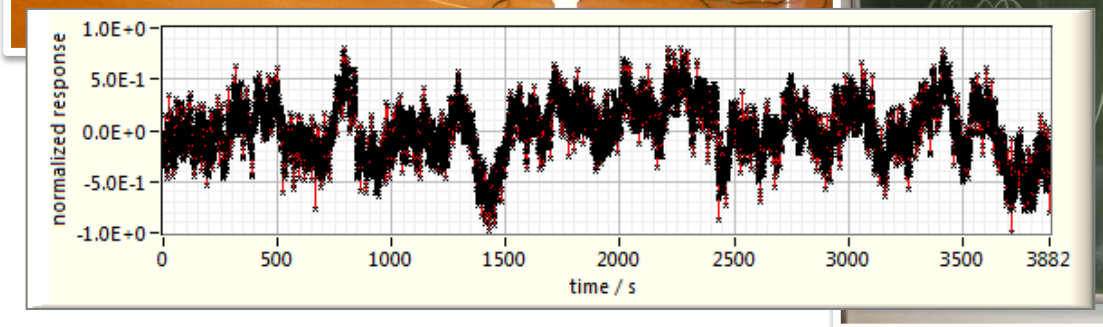


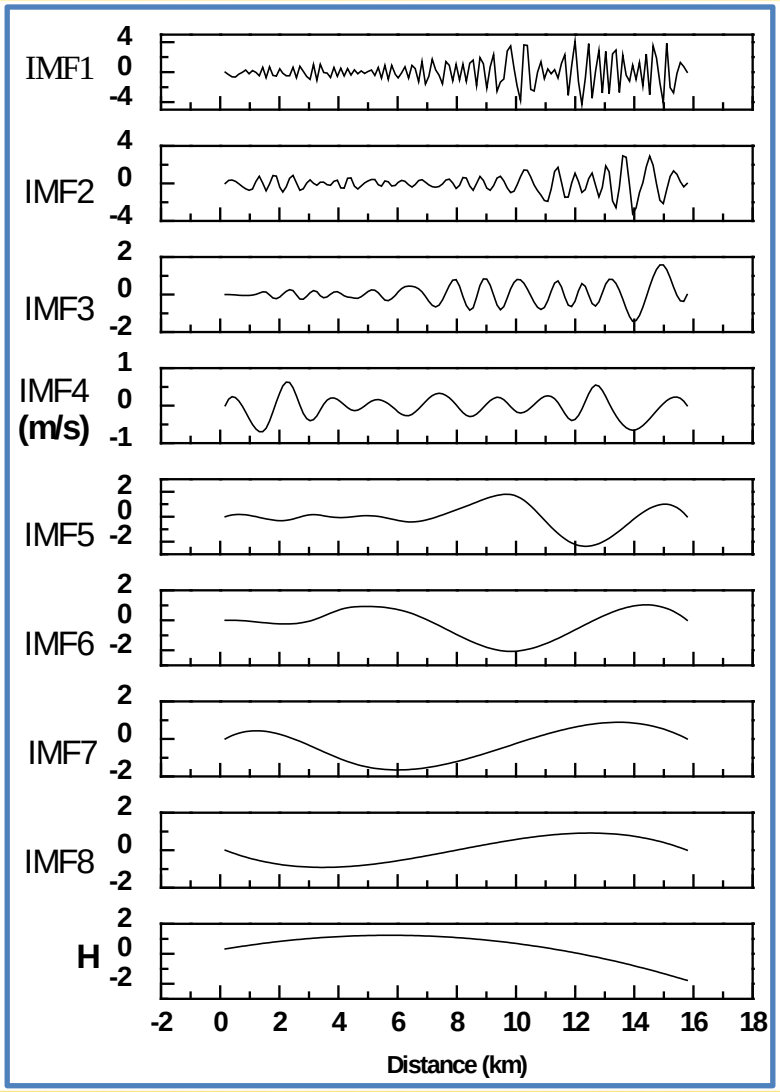




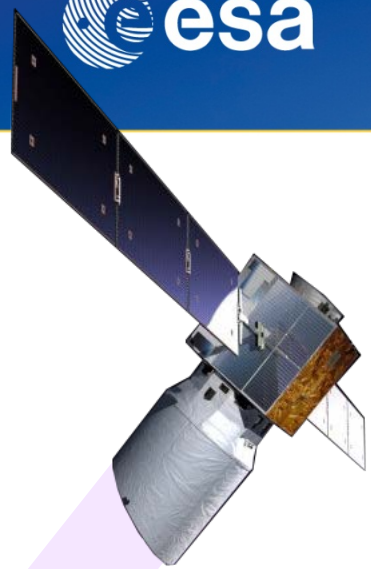
Empirical Mode Decomposition (EMD)

The EMD:

- Time domain analysis method
- Proposed by Norden Huang in 1998
- A way to decompose a signal into so called **intrinsic mode functions** (Any complicated data set can be decomposed into a finite and small number of components.)
- Designed to work well for data that are **non-stationary** and nonlinear (e.g. measured wind speed data)
- In contrast to other common transforms like the Fourier transform, the **EMD** is more like an algorithm (an **empirical** approach) that can be applied to a data set, rather than a theoretical tool.

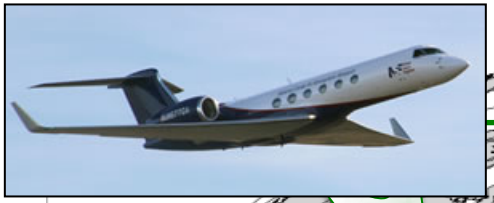


Future Validation of ADM-Aeolus with Airborne Campaigns



T-NAWDEX coordinated airborne campaign

US: GV



G: HALO

CAN: NRC Convair 580

Ideal operation period in **Sep/Oct 2016:**

- strongest storm activity
- Tropical Cyclones
- Polar Vortices

UK: BAE 146

Preparation by
A. Schäfler (DLR) and G. Craig (University Munich)

T-NAWDEX
Scientific scope

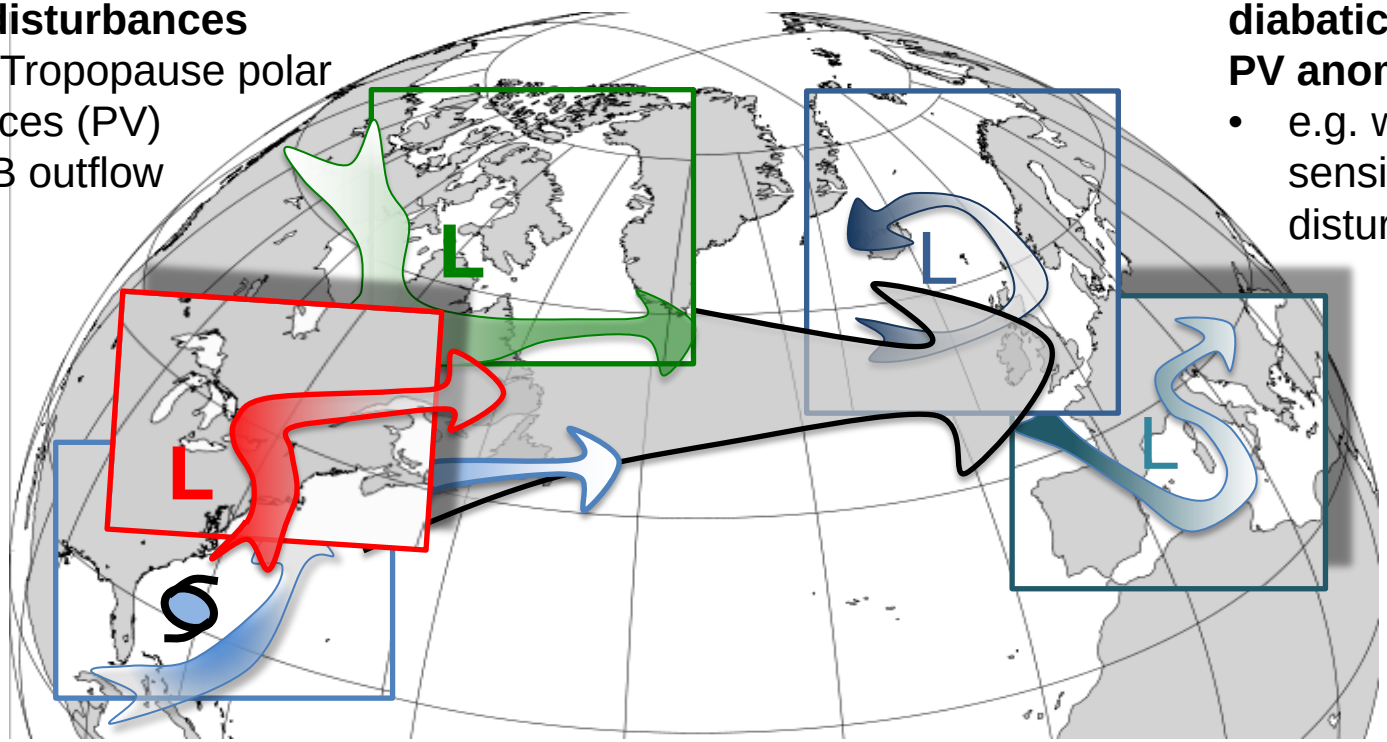
THORPEX North Atlantic Waveguide and Downstream Impact Experiment

Factors modifying wave-guide disturbances

- e.g. Tropopause polar vortices (PV)
- WCB outflow

Downstream impact of diabatically modified PV anomalies

- e.g. wave breaking sensitivity to upstream disturbances



Evolution of Rossby waves along the waveguide

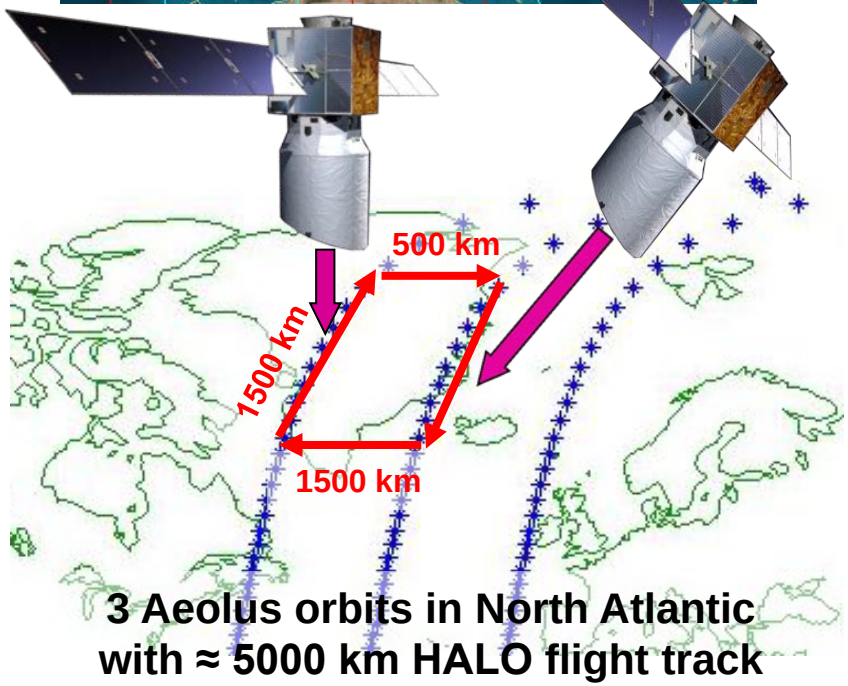
- e.g. downstream evolution of PV anomalies
- Modification from Greenland

Preparation by
A. Schäfler (DLR) and G. Craig (University Munich)

ADM-Aeolus

- Studies including Aeolus data
- Validation of Aeolus with wind lidar on HALO (2-µm or A2D2G)

ADM-Aeolus Validation in 2016



3 Aeolus orbits in North Atlantic with ≈ 5000 km HALO flight track

Central Europe Campaign in 2016, 3-6 months after launch

- 1 orbit/flight in Central Europe with overflights of radar windprofilers and lidar sites

North Atlantic in 2016, 6-12 months after launch

- North Atlantic relevant for medium range forecast and positive impact demonstrated (Weissmann und Cardinali 2007)
- Experience from previous campaigns in 2009 (Reitebuch et al. 2012)
- Jet-Stream with high speeds and gradients
- Calibration over ice with high UV albedo
- Separation of satellite tracks is closer in polar latitudes

Summary and Conclusion

May 2010

November 2013

- Wind profiles are still the missing observations with highest priority for global and regional numerical weather prediction.
- ADM-Aeolus will sense the vertical profile of wind with a vertical resolution of 250-1000 m up to the lower stratosphere (20-30 km) with high accuracy of 1-2 m/s.
- Principle of calibration and wind retrieval for ADM-Aeolus was validated with airborne demonstrator at DLR during several ground and airborne campaigns.
- Dragon 3 activities are used to prepare and coordinate a Chinese-European effort to validate ADM-Aeolus mission after launch with ground and airborne campaigns in 2016.

Xièxie!

谢谢!

Thank you very much!