Lessons learned from the Aeolus DISC and Cal/Val

Oliver Reitebuch (DLR) with contribution from the Aeolus DISC and ESA colleagues

2nd ESA EarthCARE Validation Workshop

25-28 May 2021 (online)

Lessons learned from the Aeolus DISC and Cal/Val

Oliver Reitebuch[1], Isabell Krisch[1], Christian Lemmerz[1], Oliver Lux[1], Uwe Marksteiner[1], Nafiseh Masoumzadeh[1], Fabian Weiler[1], Benjamin Witschas[1], Fabio Bracci[2], Markus Meringer[2], Karsten Schmidt[2], Dorit Huber[3], Ines Nikolaus[4], Frédéric Fabre[5], Phil McGoldrick[5], Michael Vaughan[6], Katja Reissig[7], Alain Dabas[8], Thomas Flament[8], Adrien Lacour[8], J.-F. Mahfouf[8], M. Savli[8], Dimitri Trapon[8], Vivien Pourret[8], Saleh Abdalla[9], Lars Isaksen[9], Michael Rennie[9], Angela Benedetti[9], Julie Letertre-Danczak[9], Dave Donovan[10], Jos de Kloe[10], Gert-Jan Marseille[10], Ad Stoffelen[10], Gerd-Jan van Zadelhoff[10], Ping Wang[10], Gaetan Perron[11], Sebastian Jupin-Langlois[11], Joost Smeets[12], Bas Pijnacker Hordijk[12], Simone Bucci[13], Giacomo Gostinicchi[13], Sebastian Bley[14], Frithjof Ehlers[15], Thomas Kanitz[15], Anne-Grete Straume[15], Denny Wernham[15], Emilio Alvarez[15], Jonas von Bismarck[16], Peggy Fischer[16], Marta De Laurentis[16], Tommaso Parrinello[16]

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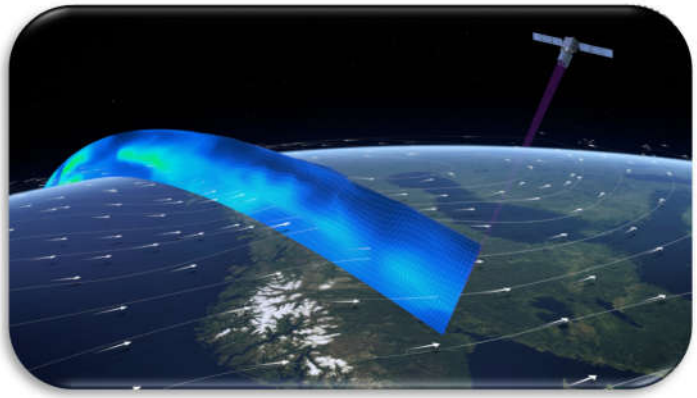
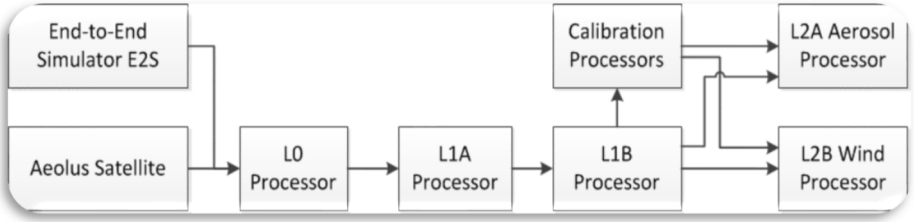
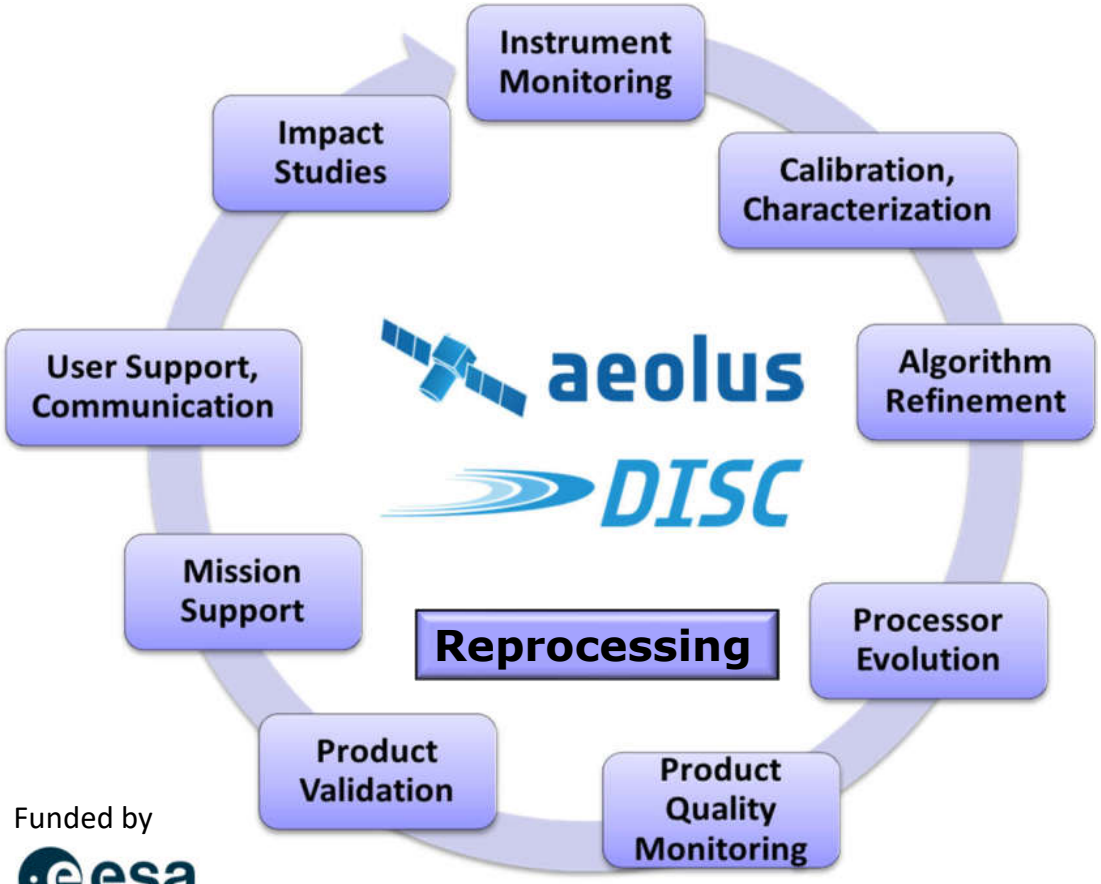
Outline of the talk

- Aeolus mission, highlights and performance
- Aeolus processor and product evolution
- Validation of Aeolus products, communication and tools

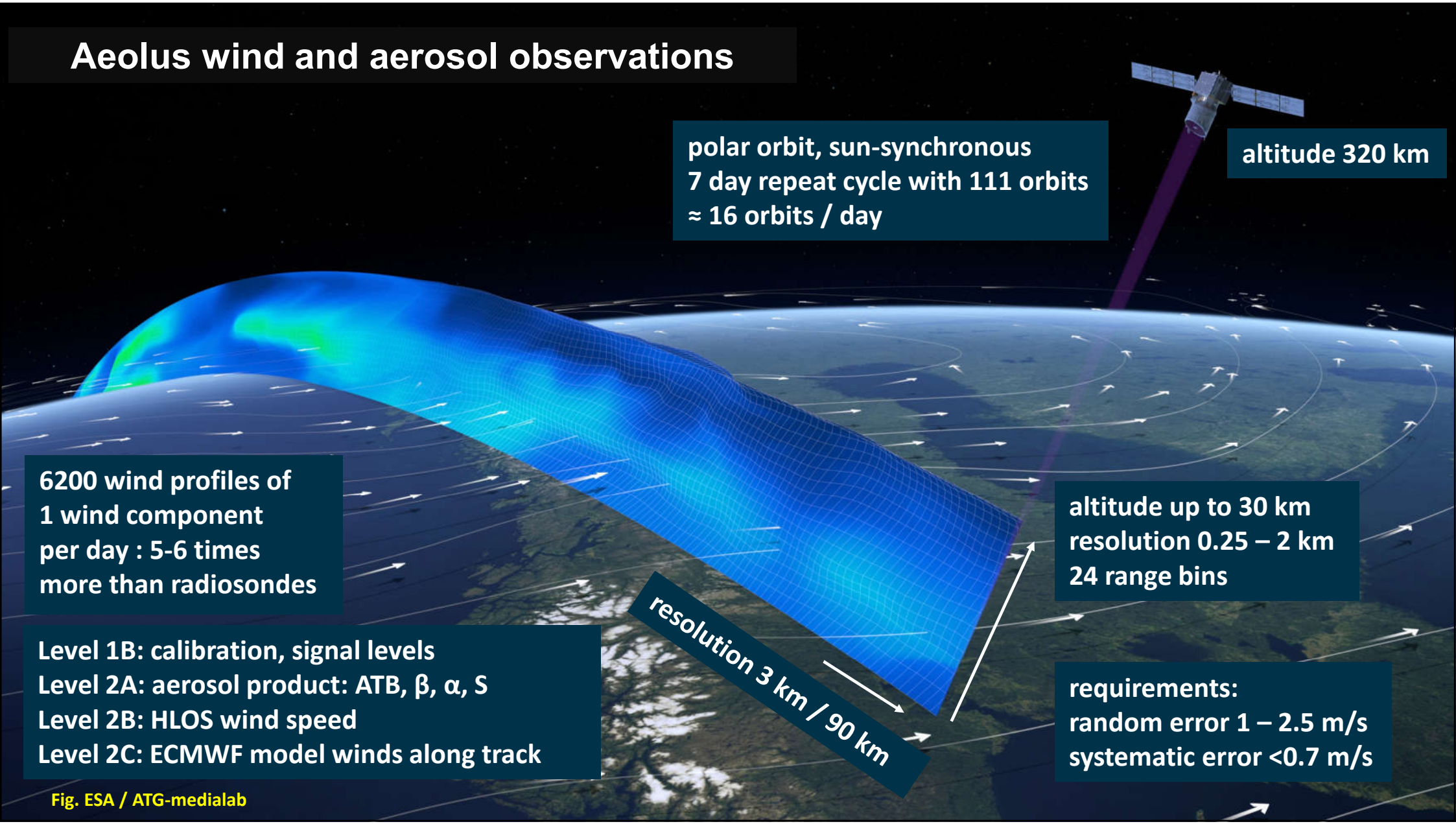




Aeolus Data Innovation and Science Cluster (DISC)

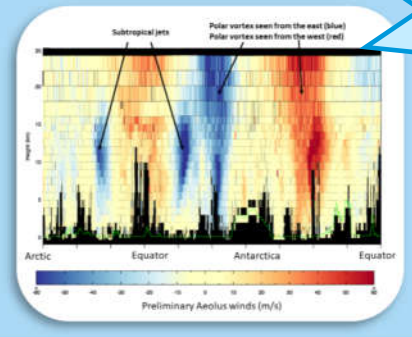


Funded by


Aeolus wind and aerosol observations
polar orbit, sun-synchronous
7 day repeat cycle with 111 orbits
≈ 16 orbits / day
altitude 320 km
6200 wind profiles of
1 wind component
per day : 5-6 times
more than radiosondes
altitude up to 30 km
resolution 0.25 – 2 km
24 range bins
resolution 3 km / 90 km
Level 1B: calibration, signal levels
Level 2A: aerosol product: ATB, β, α, S
Level 2B: HLOS wind speed
Level 2C: ECMWF model winds along track
requirements:
random error 1 – 2.5 m/s
systematic error <0.7 m/s
Fig. ESA / ATG-medialab

Aeolus highlights during first 33 months in orbit

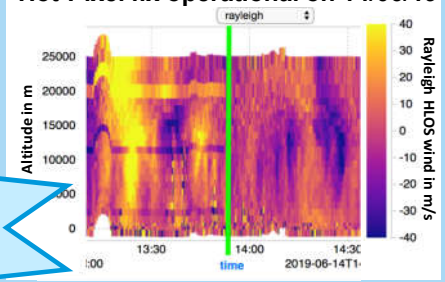
First wind on 12 Sept 2018

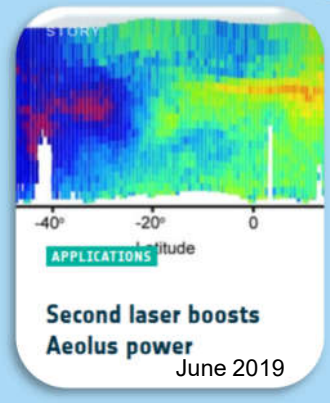


Data release to Cal/Val teams on 18/12/2018

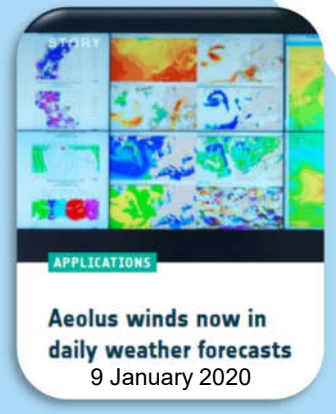
Commis-sioning Phase E1 Review January 2019

Hot-Pixel fix operational on 14/06/19





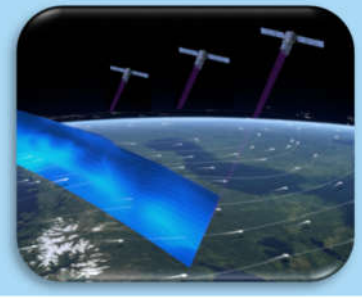
June 2019



9 January 2020

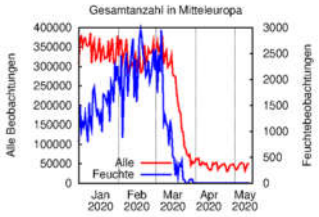
Public release of L2A product in June 2021

Preparation of Aeolus Follow-On started in 2020



May/June 2020:

Aeolus winds are used by national weather services (DWD, Météo France) for daily weather forecasts (also caused by the decline in aircraft data)



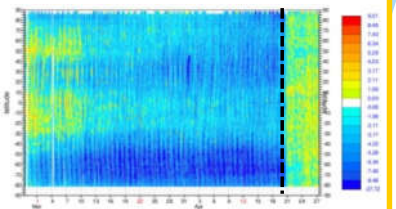
Reduction in meteorological observations from aircraft in Europe © DWD

12 May 2020:

Public release of wind products

20 April 2020:

M1 temperature correction activated in Aeolus processor

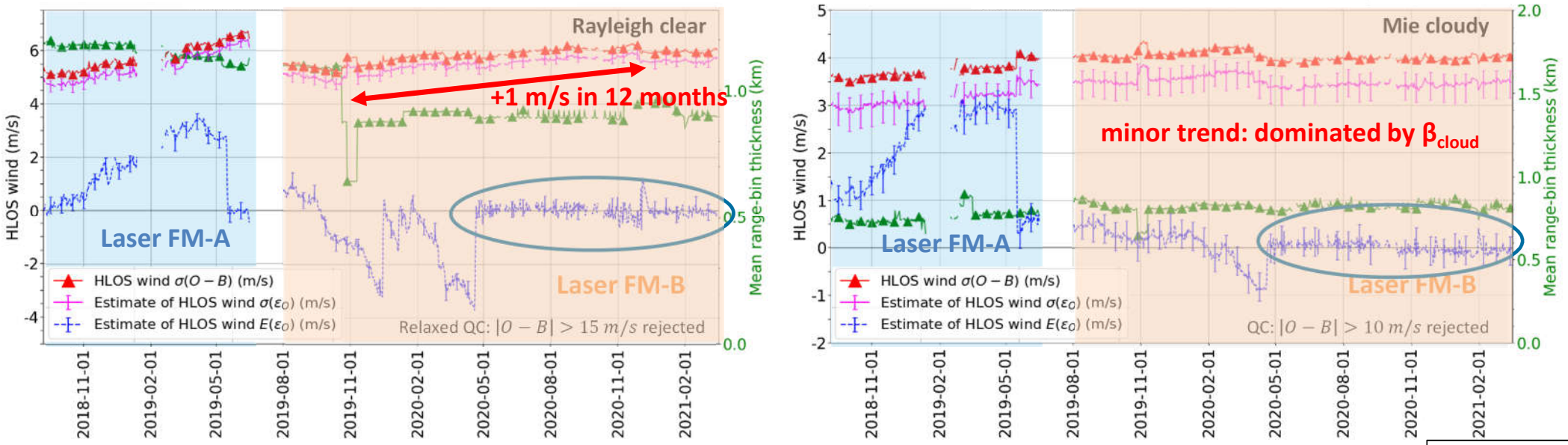


Wind bias before and after implementation of the M1 temperature correction © ECMWF

Fig. compiled by I. Krisch (DLR)

Monitoring of wind data quality at ECMWF

ECMWF operational monitoring of Aeolus Rayleigh and Mie winds



- **random error** is currently in the order of **5.5-6.5 m/s for Rayleigh winds and 3.5-4.5 m/s for Mie winds** (mostly clouds): random errors in both channels increased since launch and show some decrease due to L2B processor improvements
- **systematic errors (bias) for both Mie and Rayleigh winds (several m/s)** showed **strong slow drifts, orbital variations, differences for ascending and descending orbits**, and **occurrence in some range-gates**
  - **Since 20 April 2020 global mean bias** for both channels **around 0 m/s**

O-B: Difference between Aeolus observation and ECMWF forecasted HLOS wind

Data quality reports available online: https://earth.esa.int/eogateway/instruments/aladin/quality-control-reports

Figures M. Rennie (ECMWF) et al., 2021, QJRMS, revised

Evolution of ALADIN laser energy and signal levels

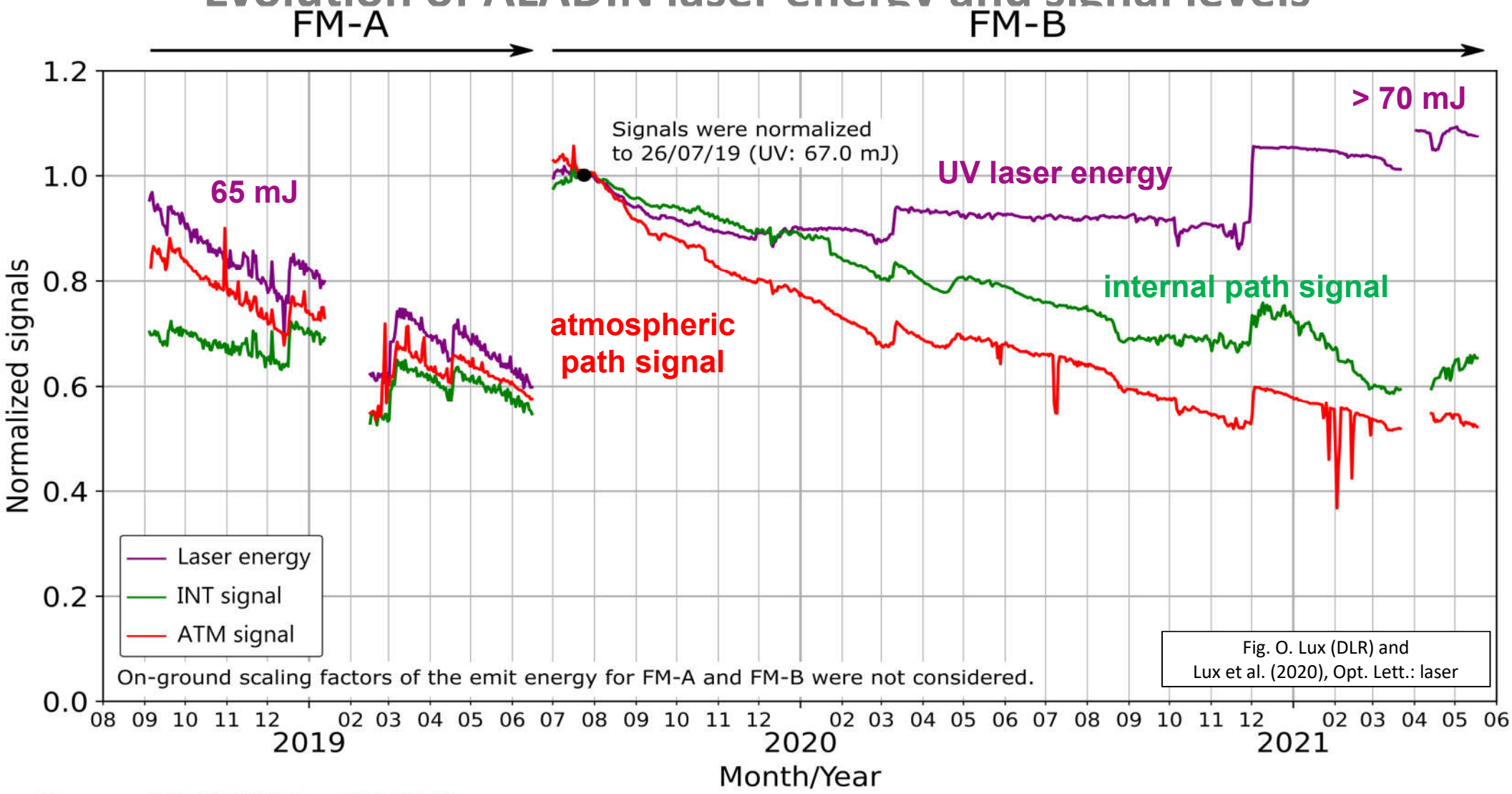


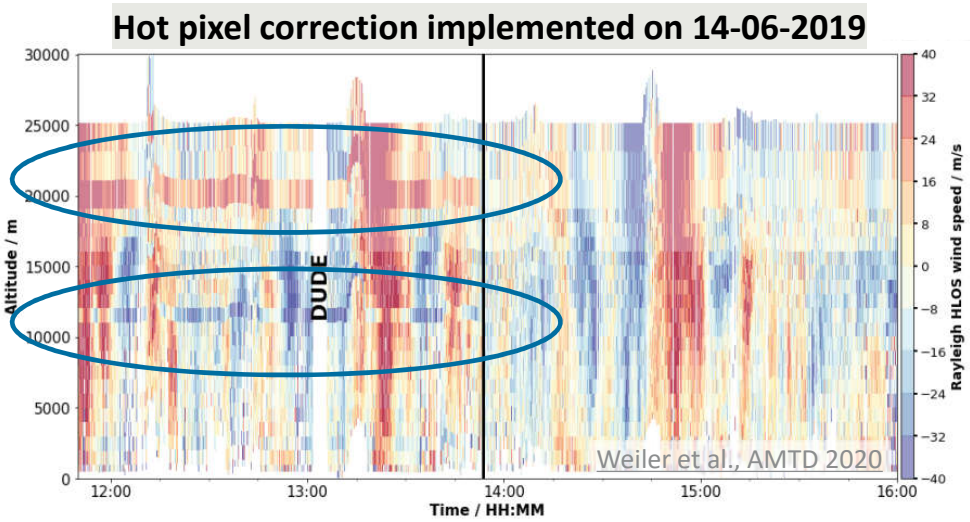
Fig. O. Lux (DLR) and
Lux et al. (2020), Opt. Lett.: laser

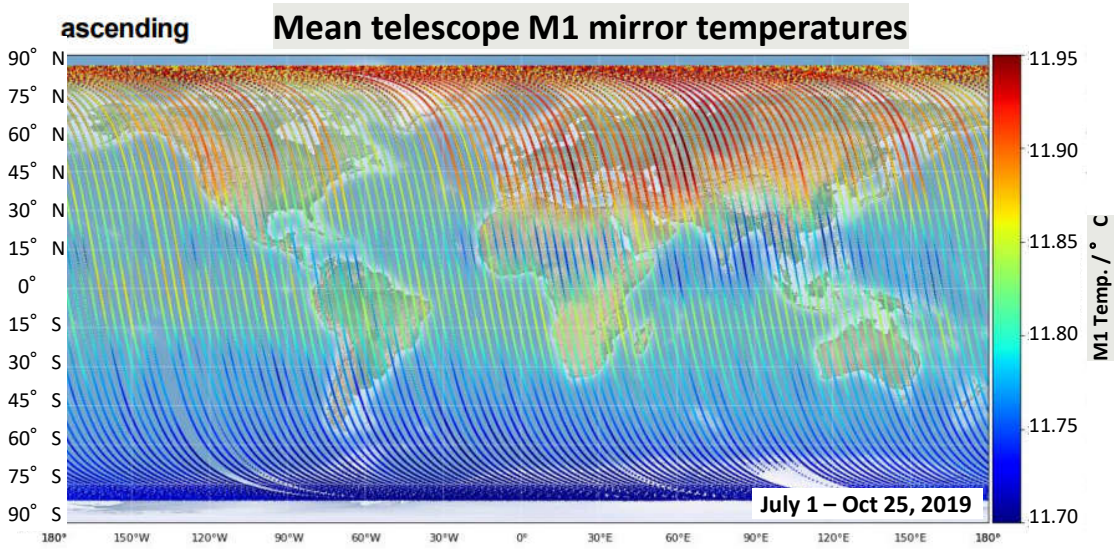
4 major causes for wind bias identified and corrected

Combination of several unexpected error sources with different temporal characteristics

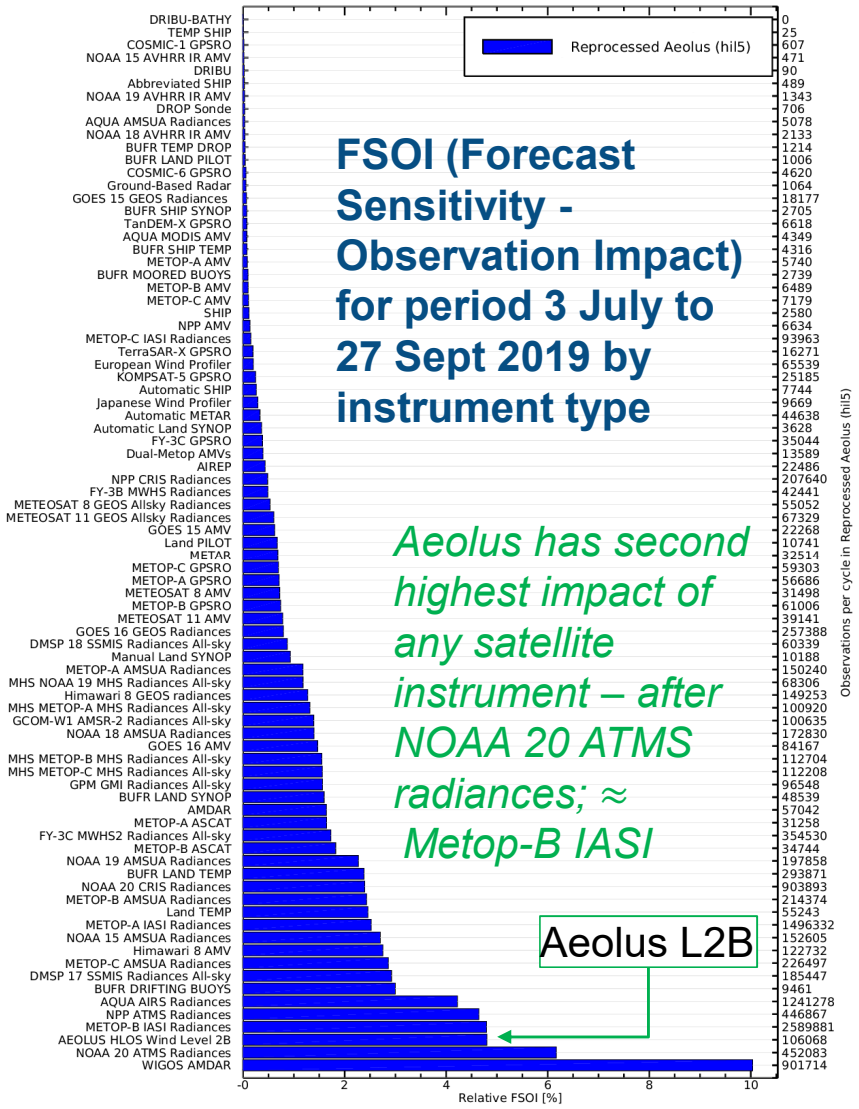
1. Higher dark current rates for some **"hot pixels"**
   - ⇨ Corrected on 14 June 2019
2. Error in the on-board software in calculation of residual projection of the **satellite ground speed on the line-of-sight LOS**
   - ⇨ Corrected with Baseline 11 (08 October 2020)
3. **Slow drifts** in the illumination of the Rayleigh/Mie spectrometers causing a **slowly, linear drifting constant bias**
   - ⇨ Corrected with Baseline 09 (20 April 2020)
4. Thermal variations of the **M1 telescope mirror**
   - ⇨ Corrected with Baseline 09 (20 April 2020)

2 remaining causes for Rayleigh/Mie winds identified





Figures by **F. Weiler (DLR) et al., 2020, AMTD, Weiler et al (2021), under preparation**



Aeolus mission objective to demonstrate positive impact on NWP is achieved

- ***For this period*** with ***good atmospheric signal*** with **reprocessed L2B**, Aeolus provides **4.8% relative FSOI** Aeolus ≈ radiosondes, > scatterometer & GPSRO
- **Shows the importance of wind profile observations in NWP** even with higher random errors than requirements => impact could be even significantly higher for mission requirements

Fig. M. Rennie (ECMWF) et al., 2021, QJRMS, revised

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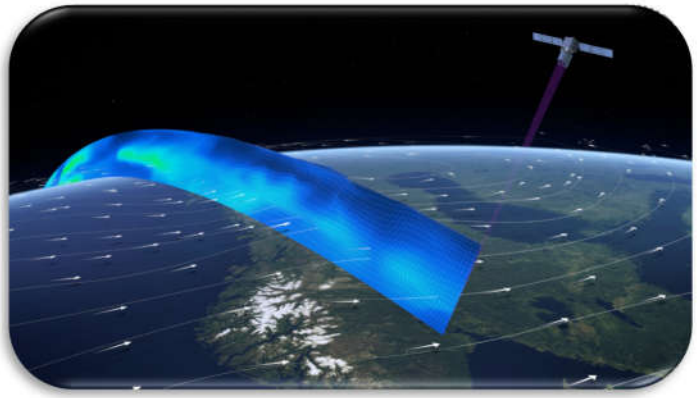
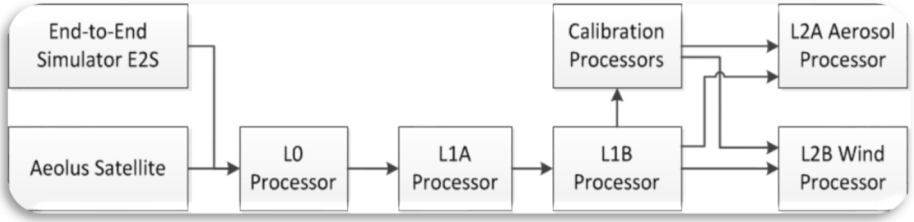
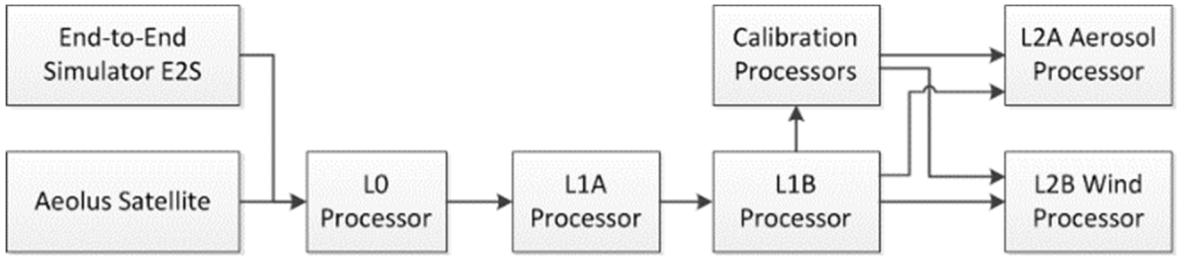




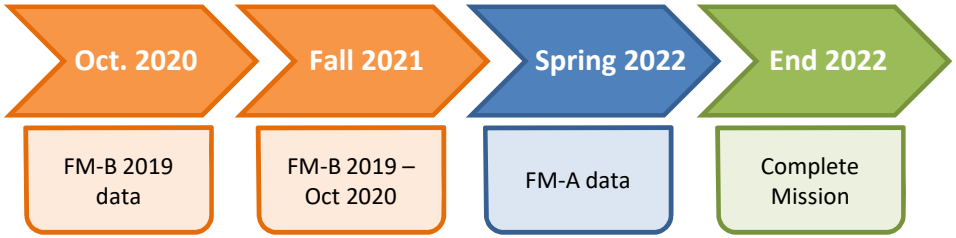
Aeolus operational processors and data product baseline updates every 6 months

- **New processor versions** from DISC **and baseline update** for NRT and reprocessing **every 6 months** with improvements in data quality for all products from L0-L1A-L1B-L2A-L2B and calibration processors
- **Next baseline update** to baseline 12 product's will take place **on May 26, 2021 => public data release of L2A aerosol products in June 2021**
- **First re-processed data** set FM-B period 2019 was made publicly available in October 2020
- **Currently second re-processing campaign** is on-going covering FM-B period until October 2020: will be available in September 2021



L2C Wind processor: ECMWF model analysis, background

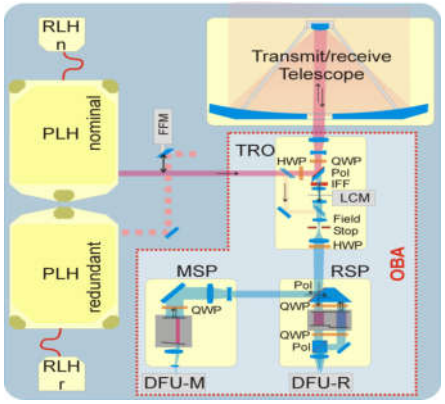
Reprocessing further enhances data quality



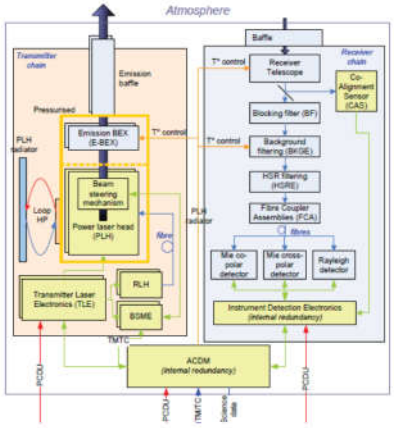
L1B+L2A processor by **D. Huber (DoRIT)**
L2B processor by **J. de Kloe (KNMI)**
ACMF calibration processors by **ABB+S&T**

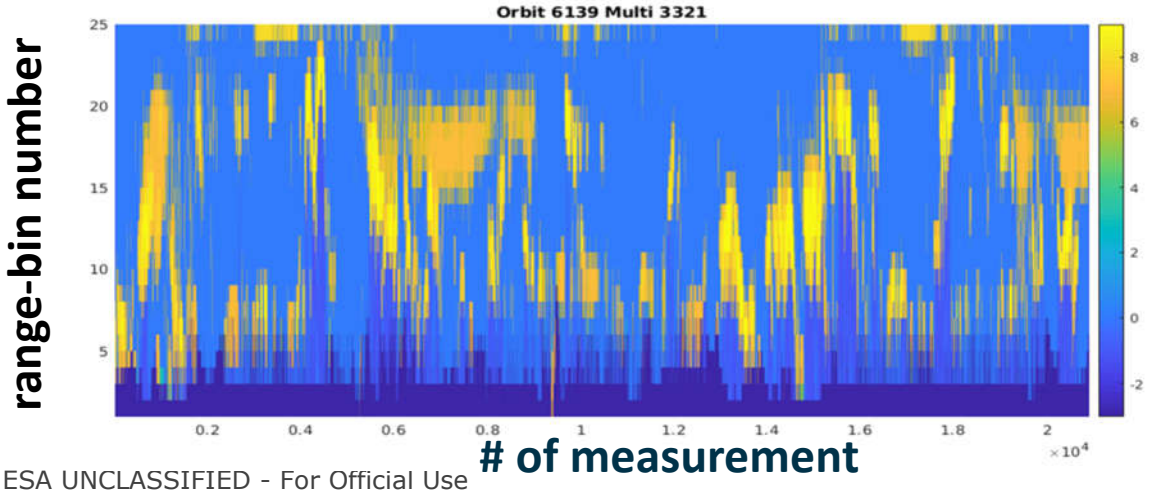
Exploitation of synergies between Aeolus and EarthCARE for the first High-Spectral Resolution Lidars in Space

ALADIN (ESA 2008)



ATLID (Heliere et al. 2012)





Operational L2A Aeolus Feature Mask FM probabilities

Figure by **D. Huber (DoRIT)**

- EarthCARE Feature Mask was adapted and refined by KNMI (DD, GJvZ) to Aeolus needs using and re-coded for operational L2A processor V. 3.12 by DoRIT/Reissig (February 2021); is available in L2A products for baseline 12
- Currently Aeolus version of the ATLID Optimal Estimation algorithm (DD) is implemented in operational code for summer delivery of L2A V3.13: will be available for baseline 13 in Sept. 2021

Aeolus Level 2a product backscatter coefficient

available in L2A product

L2A SCA

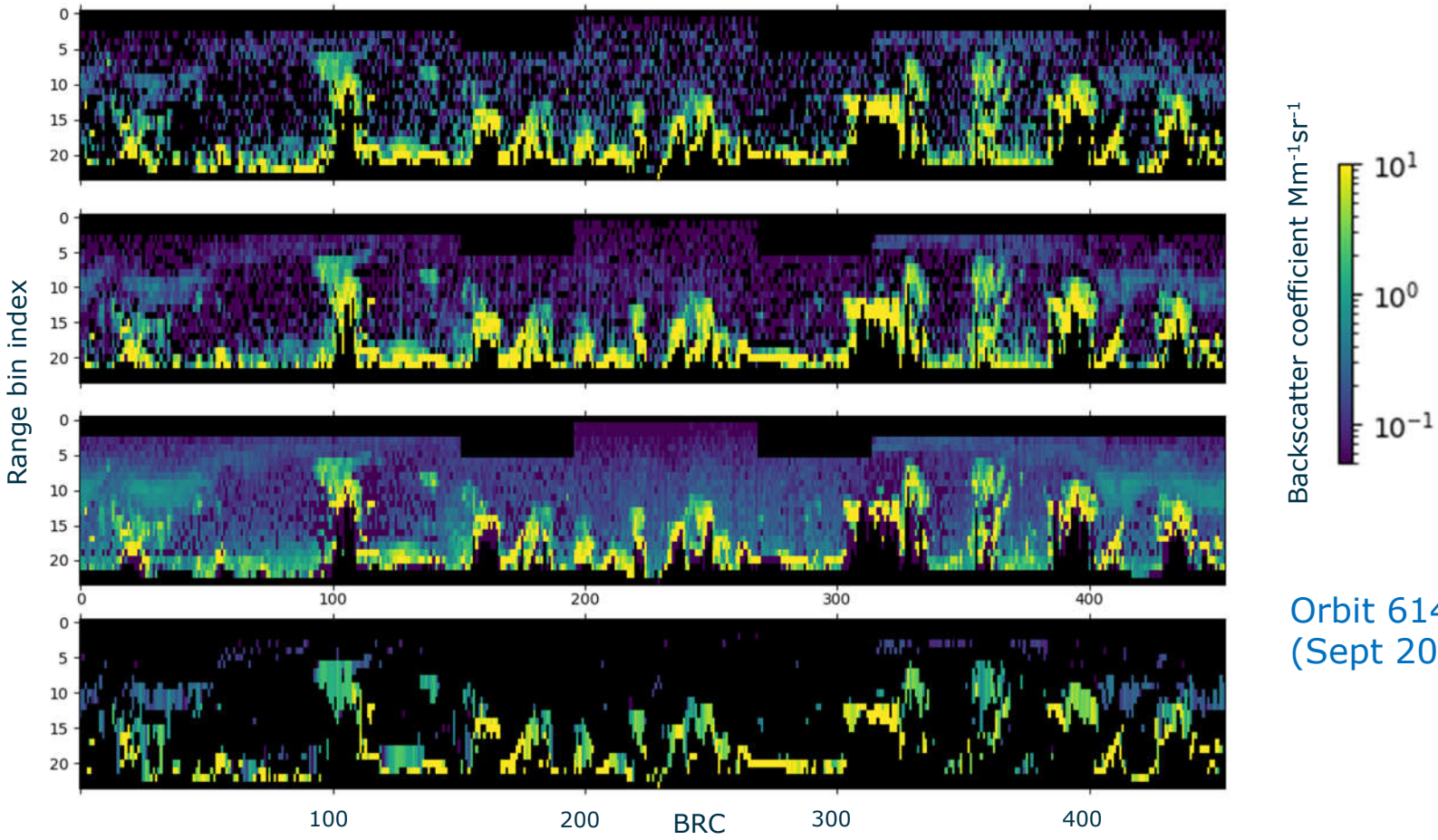
MLE

available in Sept 2021 in L2A products

AEL PRO

Level 2B wind processor optical properties code

L2B OPC



Orbit 6142 (Sept 2019)

Figure F. Ehlers (ESA), Ehlers et al., AMTD, in preparation
Th. Flament (Météo-France) et al. AMTD, in preparation

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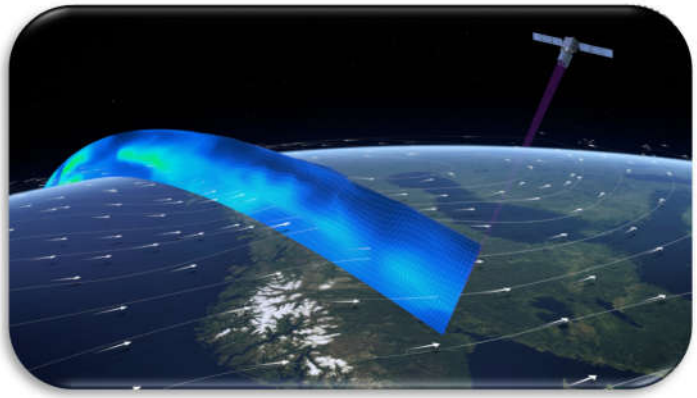
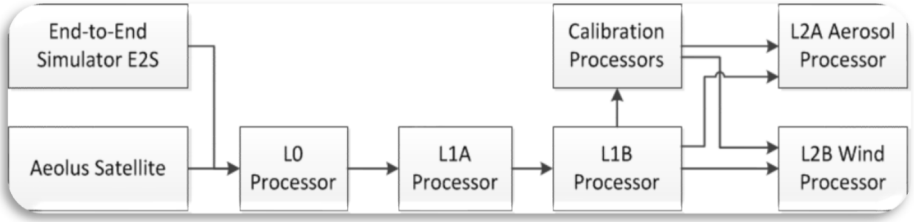
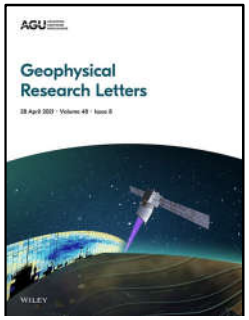




Validation of Aeolus aerosol product with ground based lidar



Geophysical Research Letters

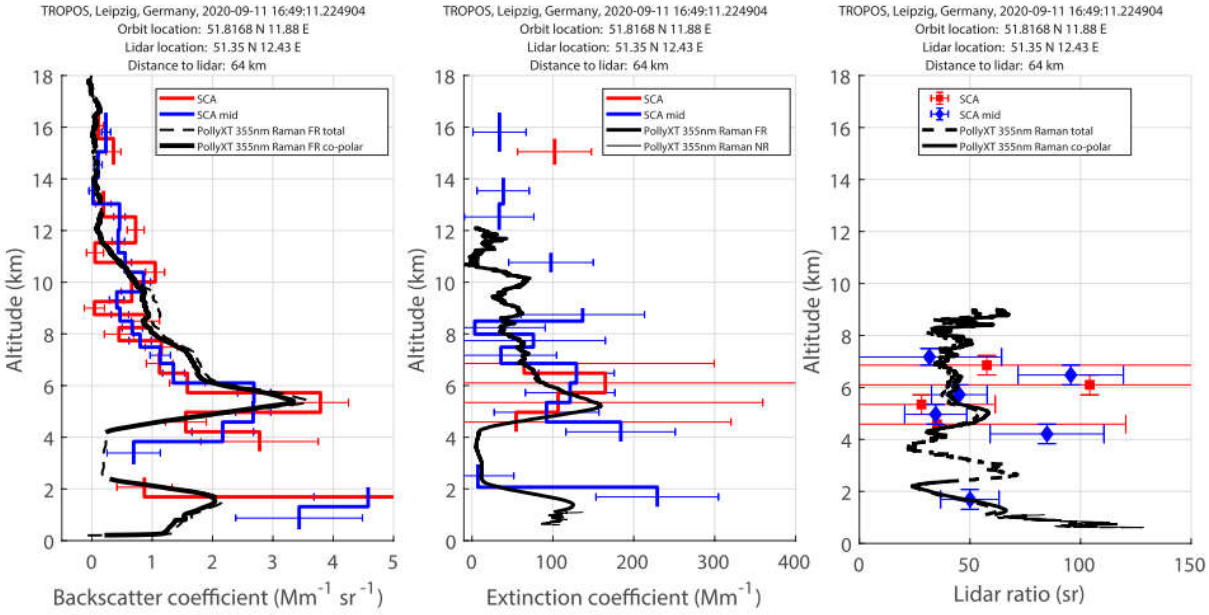
RESEARCH LETTER
10.1029/2020GL092194

Californian Wildfire Smoke Over Europe: A First Example of the Aerosol Observing Capabilities of Aeolus Compared to Ground-Based Lidar

Holger Baars[1], Martin Radenz[1], Athena Augusta Floutsi[1], Ronny Engelmann[1], Dietrich Althausen[1], Birgit Heese[1], Albert Ansmann[1], Thomas Flament[2], Alain Dabas[2], Dimitri Trapon[2], Oliver Reitebuch[3], Sebastian Bley[4], and Ulla Wandinger[1]

[1]Leibniz Institute for Tropospheric Research (TROPOS), Leipzig, Germany, [2]CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France, [3]DLR, Institute of Atmospheric Physics, Oberpfaffenhofen, Germany, [4]European Space Agency (ESA) ESRIN, Frascati, Italy

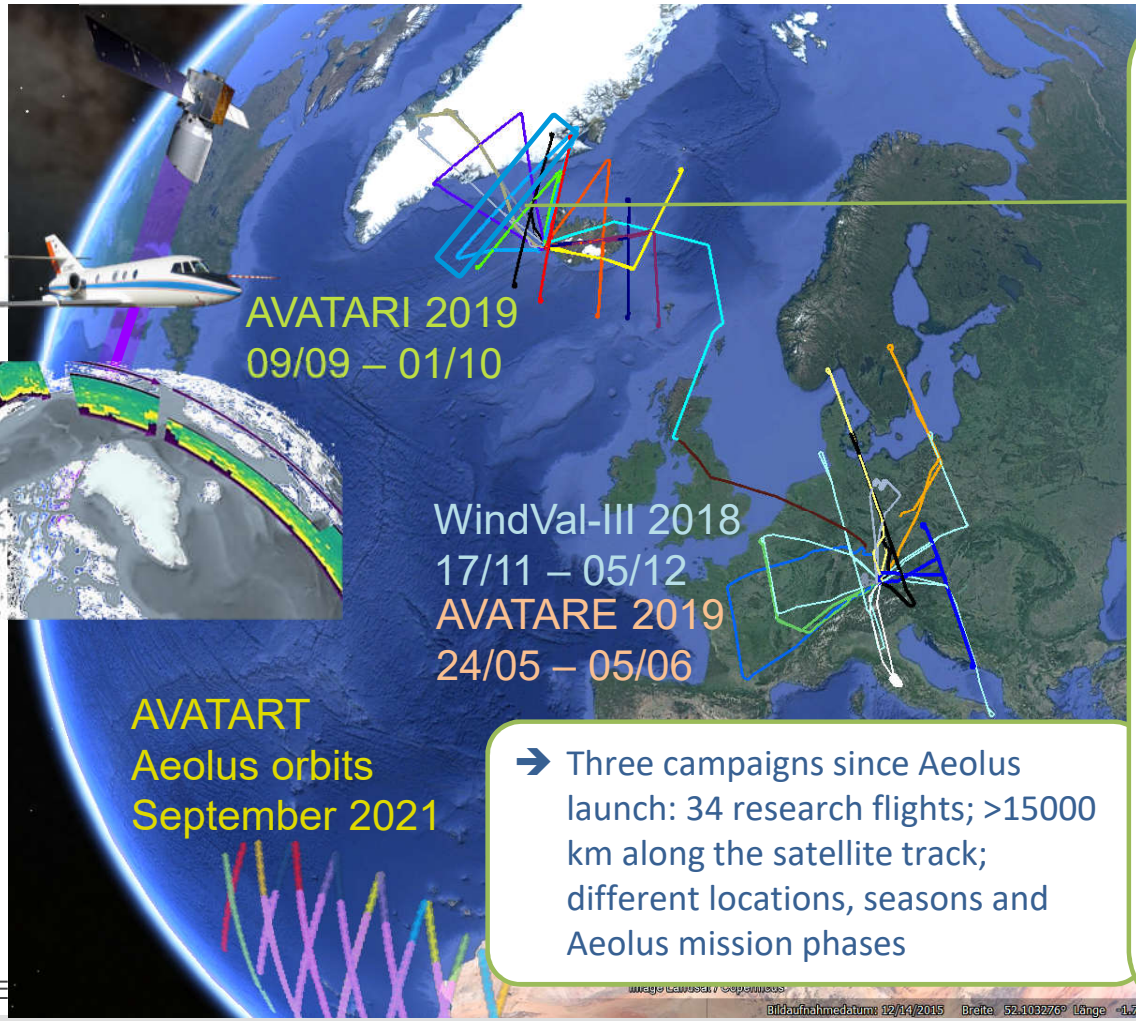
Key Points:
- Smoke from the extraordinary 2020 Californian wild fires traveled within 3–4 days toward Europe
- Highest Aerosol Optical Thickness ever measured in the free troposphere over Leipzig, Germany, Central Europe, with ground-based lidar
- Unique opportunity for a first



- Ground-based lidars measuring backscatter and extinction coefficient and depolarization at 355 nm are key for the validation of the Aeolus aerosol products L2A
- Ground-truth needed for assessment of Aeolus radiometric performance („photon budget“) for Mie channel (on-going)
- Routine observatations over longer period (>1 yr) needed due to only few colocations
- Active Cal/Val teams (funding!) with expertise in data product quality

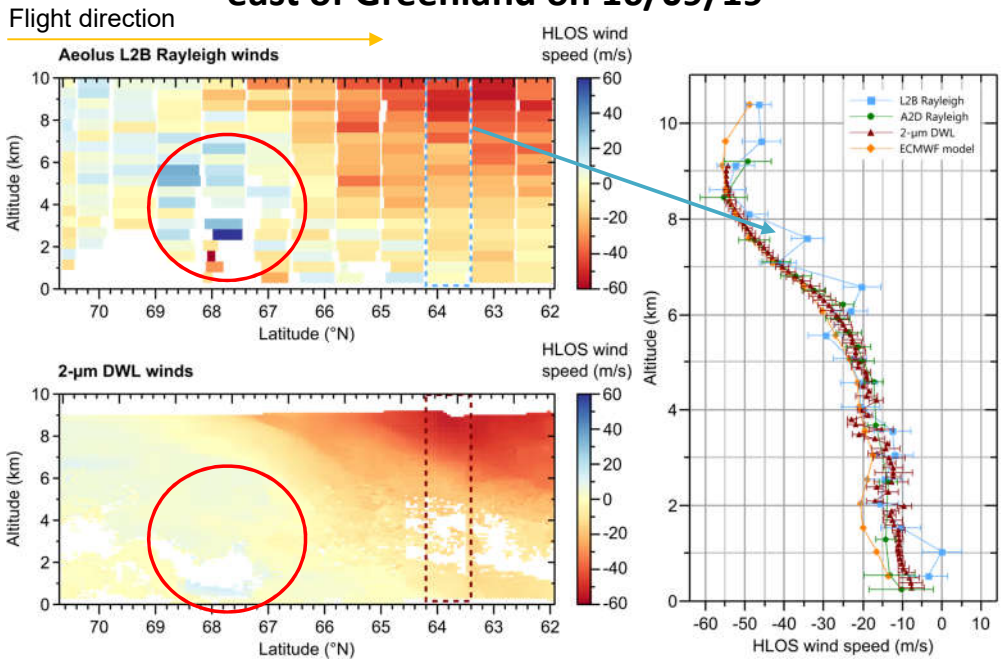
Figure H. Baars (TROPOS) et al., 2021, GRL

Airborne validation with 2 wind lidars on DLR Falcon



➔ Three campaigns since Aeolus launch: 34 research flights; >15000 km along the satellite track; different locations, seasons and Aeolus mission phases

AVATARI example: North Atlantic Jet Stream east of Greenland on 16/09/19



- Validation of wind errors and their occurence analyzed with nominal and reprocessed Aeolus data ➔ recommendations for Aeolus processor evolutions; QC advice for the Cal/Val community

Witschas et al. (2020), **AMT,** Lux et al. (2020), **AMT**

Figure: Ch. Lemmerz (DLR)

Balloon campaigns for wind validation in stratosphere

TAPAPA/ Stratéole2

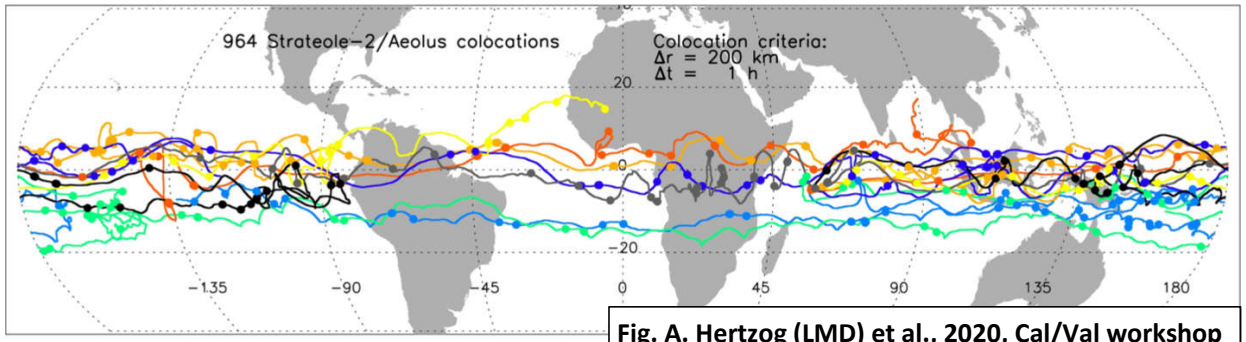
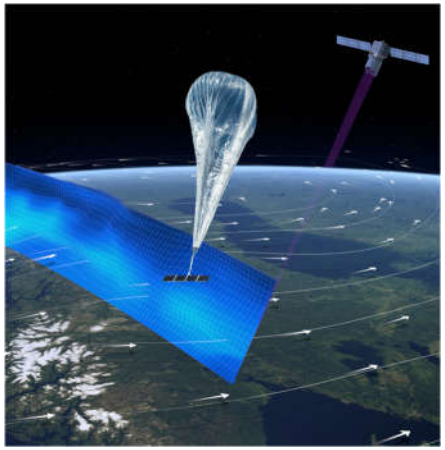


Fig. A. Hertzog (LMD) et al., 2020, Cal/Val workshop

Google Loon



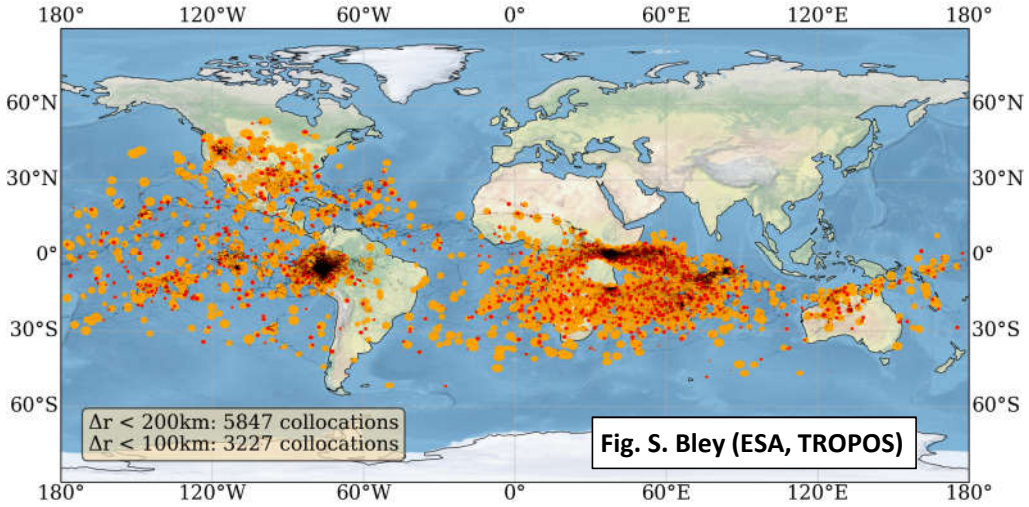
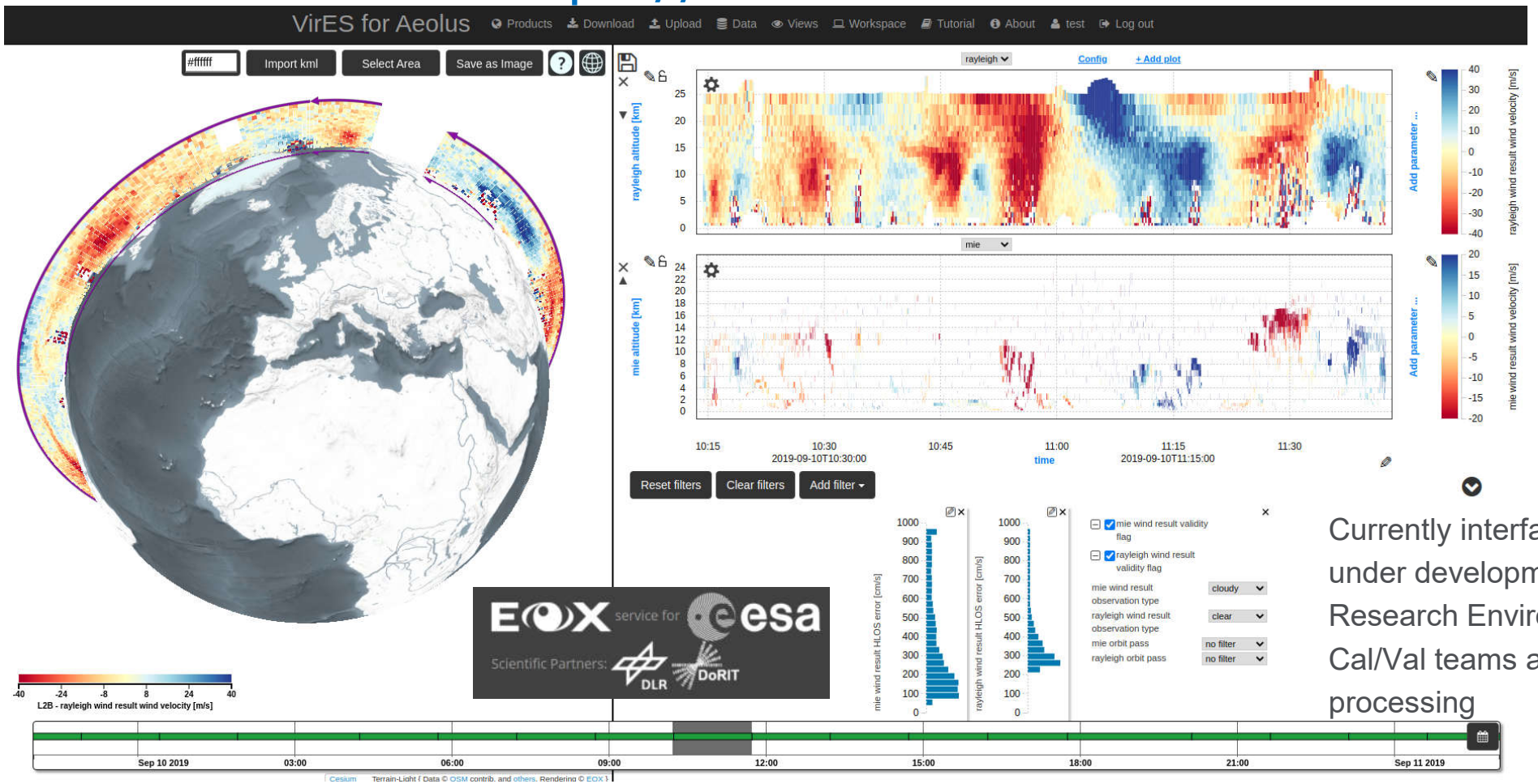


Fig. S. Bley (ESA, TROPOS)

Interactive exploitation of Aeolus via VirES https://aeolus.services



EOX service for esa

Scientific Partners: DLR DoRIT

Currently interface to Python under development (Virtual Research Environment) to support Cal/Val teams and automated processing

Communication – WIKI, workshops, papers

Latest News

- [2021-05-23] **Please be aware of temporary L2B wind date blocklistin** 05-24T19:20:00.000000 and Stop UTC=2021-05-28T23:59:59.000000.
- [2021-05-19] Take note of an **open position at ECMWF for the Aeolus A**
- [2021-05-18] **Deadline extended:** The deadline for submission of the Cal
- [2021-05-14] Get ready for a **major processor update (Baseline 12) taki** processor improvements for Baseline 12).
- [2021-05-14] **Please be aware of temporary L2B wind date blocklistin** **May 2021 23:59 UTC** due to tests which might affect data quality.
- [2021-05-10] **Please be aware of temporarty blocklisting on 11 May 2**

Cal/Val projects

Aeolus mission calibration and validation is essential in or teams will perform diverse and widespread activities, inclu intercomparisons, model and NWP impact assessment stu

- Overview of Cal/Val proposals
- Synthesis of Cal/Val activities and results
- Predicted overpasses for Cal/Val stations
- Cal/Val stations file available at the Cal/Val ftp serve
- Upload portal for Cal/Val Reference measurements:
- Overview of Cal/Val campaigns
- Half-Yearly Cal/Val reports
- Instrument and measurement status of Cal/Val mea
- EVE lidar system

Discussions

The Cal/Val confluence discussions are addressing different topics, ple heavy analysis reports are expected to kept out of this board and shou Guidelines for the discussion boards.

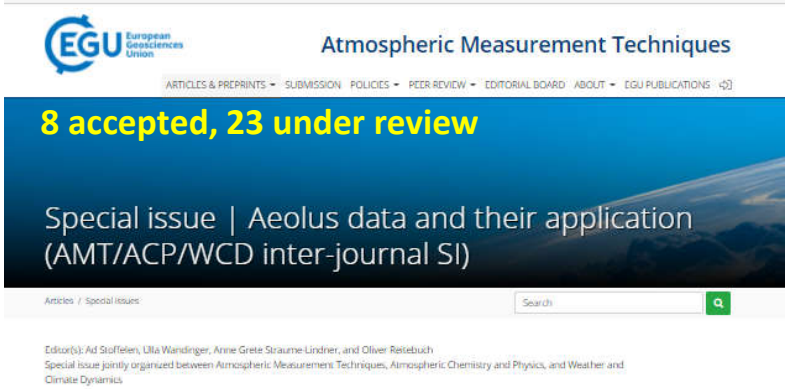
- Aeolus products L1B, Wind Product L2B/L2C, Aerosol and Clouc
- Satellite and Instrument related discussions
- NWP impact assessment
- General tools, VirES, CODA, EVDC, Data reading, etc.
- Orbit and overpass prediction, ESOV, ZoneOverpass etc.
- Overview, feedback, reports and updates on Cal/Val projects
- Cal/Val campaigns discussions
- Atmospheric sampling
- Communication and Publication
- Aeolus Cal/Val FAQ

Data quality

- Weekly data quality reports
- Data Exclusion List
- NWP monitoring of HLOS winds
- Data quality assessment
- First Aeolus performance document

Aeolus Cal/Val Wiki

https://www.aeolus.esa.int/confluence/pages/



Summary of some lessons learned

- Monitoring tools for instrument parameters (laser, temperatures, satellite), and product Level 1 and 2 are essential after launch; NRT monitoring using model output from ECMWF was key for bias correction
- Aeolus performance showed expected and unexpected behavior: laser, lidar signals, satellite, detector, thermal => we are in continuous "commissioning" phase
- Strong team of engineers/scientist with laser/lidar expertise, algorithm, operational processor development, NWP monitoring and impact within Aeolus DISC
- Strong support of cal/val teams is essential for mission success, e.g. ground, airborne, balloon, model => join Aeolus validation in preparation of EarthCARE
- Enhance cooperation between Aeolus and EarthCARE teams for the benefit of both missions and in support of an operational follow-on mission for Aeolus