Status of ESA's Doppler Wind Lidar Mission Aeolus

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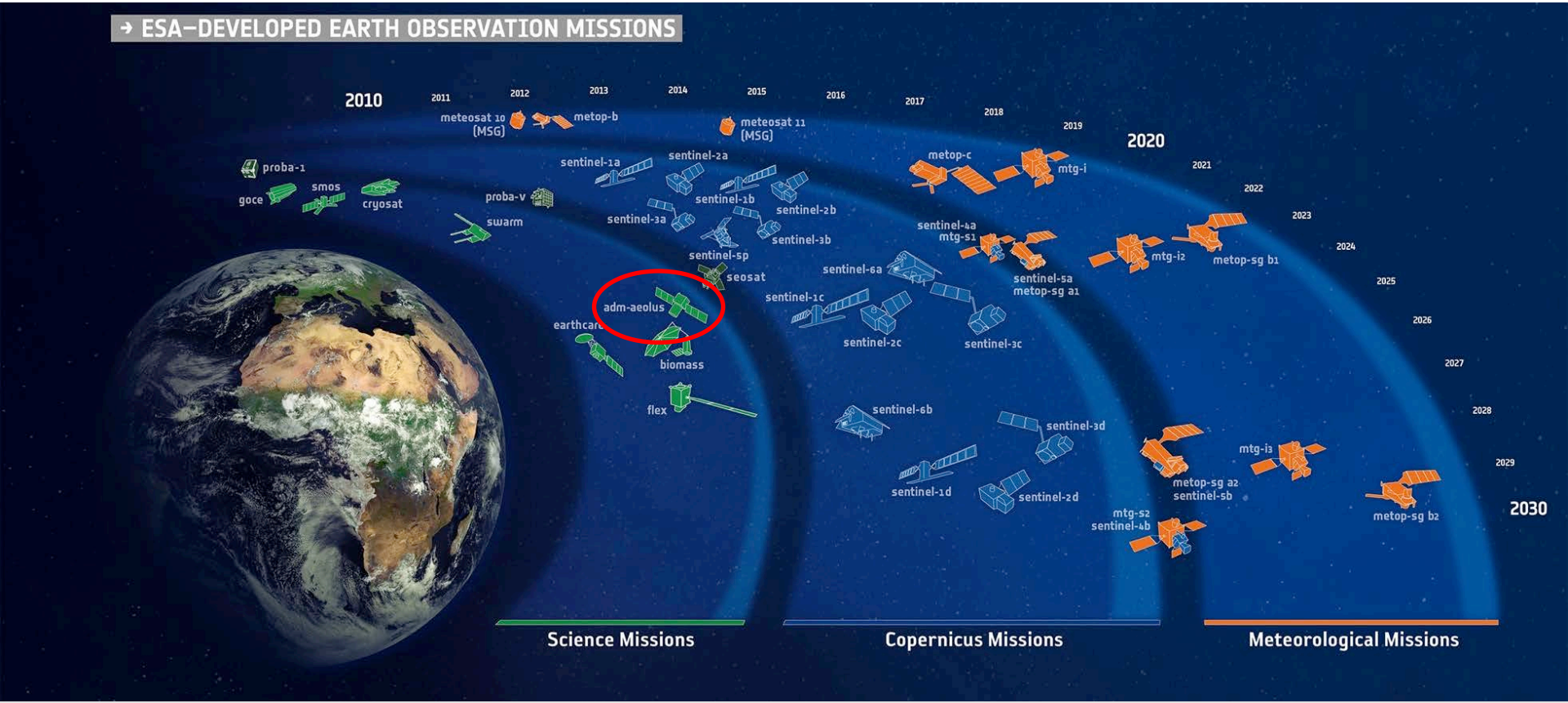
14th International Winds Workshop

Jeju City, South Korea, 23-27 April 2018

Outline

- Aeolus in ESA's Earth Observation Program
- Mission objective and measurement principle
- Data product, processing, data access and use
- Mission status and on-ground verification
- Product CAL/VAL
- Data assimilation and NWP impact assessment preparations
- Conclusions

ESA's Earth Observation Satellites



Aeolus Mission Objectives

Scientific objectives

- To improve the quality of weather forecasts
- To advance our understanding of atmospheric dynamics and climate processes

Explorer objectives

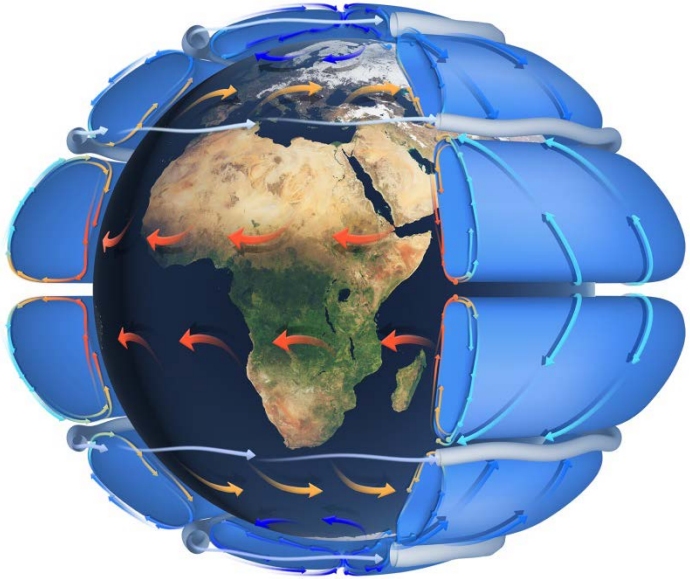
- Demonstrate space-based Doppler Wind Lidar potential for operational use

Observation means

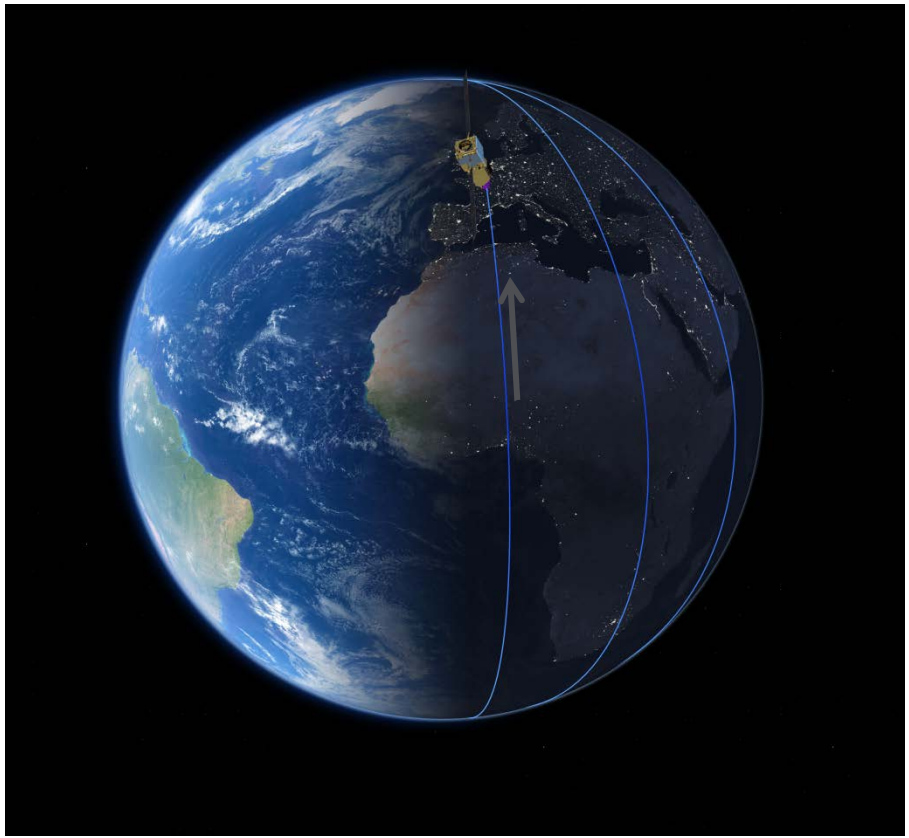
- Provide global profiles of winds in the troposphere and lower stratosphere
- Spin-off product: Atmospheric backscatter and extinction profiles

Payload

- ALADIN: Atmospheric LAser Doppler INstrument

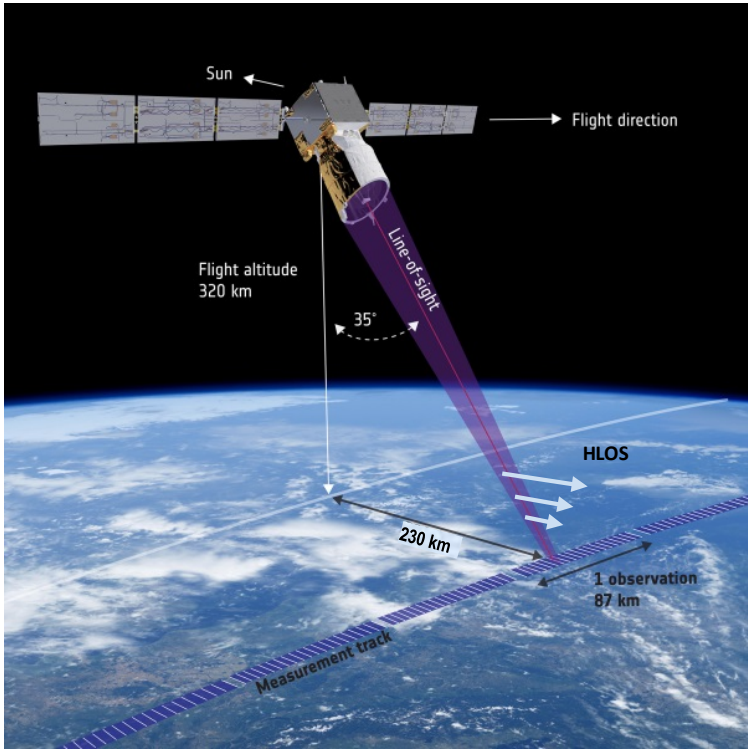


Mission characteristics



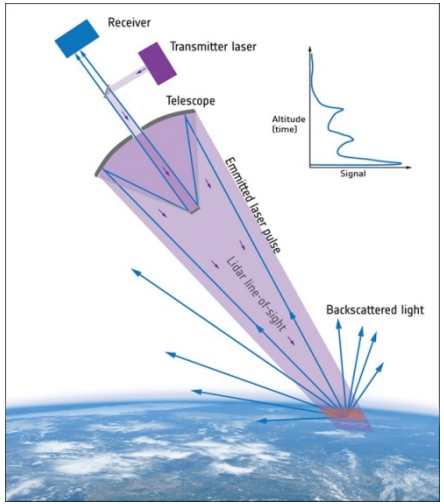
- Orbit: sun-synchronous
- Mean altitude: ~320 km
- Local time: 18:00 ascending node
- Inclination: 96.97°
- Repeat cycle: 7 days / 111 orbits
- Orbits per day: ~16
- Profiles per day: ~64000
- Mission lifetime: 3 years

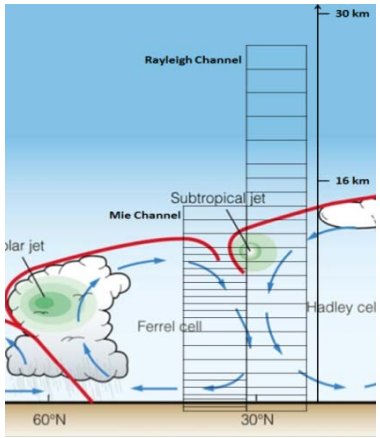
Measurement principle (1/2)

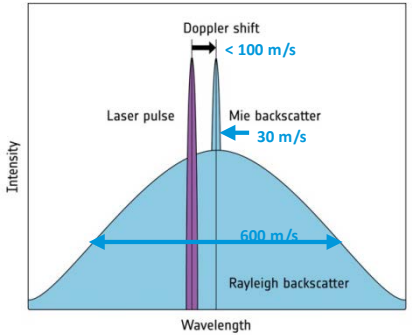


- UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in continuous mode, with 2 receiver channels (HSRL):
  - Mie receiver (aerosol & cloud backscatter)
  - Rayleigh receiver (molecular backscatter)
- The line-of-sight is pointing
  - 35° off nadir to derive horizontal wind component
  - orthogonal to ground track to avoid satellite velocity contamination
- Spacecraft regularly pointed to nadir for calibration (1/3 orbit per week)

Aeolus measurement principle (2/2)

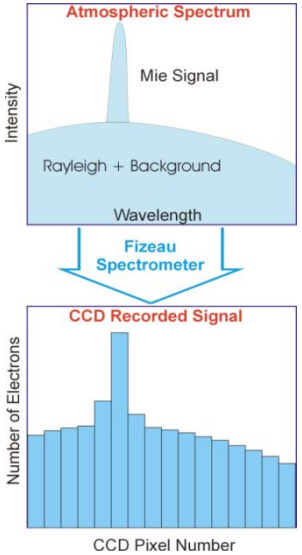


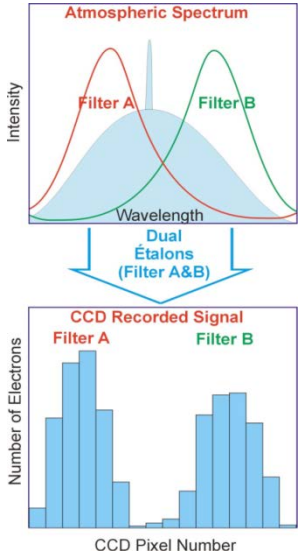




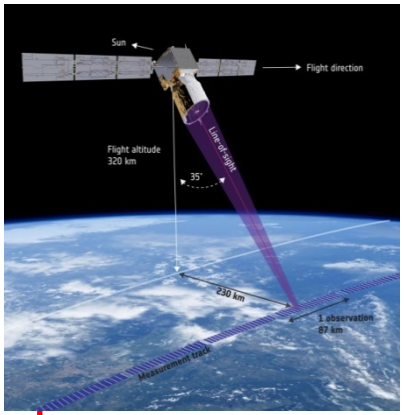
Mie channel:
- Aerosol/cloud backscatter
- Imaging technique

Rayleigh channel:
- Molecular backscatter
- Double-edge technique





Aeolus data processing and distribution (1/2)



?

Wind Velocity

AISP → L0 → L1A → L1B → L2B v_{HLOS} → ECMWF, Met Centres, Science

L2C $\vec{v}$

L1B → T & p, calibration → L2A β, σ → Air quality, Forecasts, Science

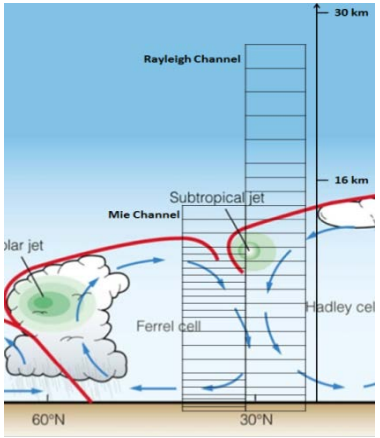
Data preparation

Aeolus data products

1. Primary product (L2b):

Horizontally projected LOS (HLOS) wind profiles (no vector)

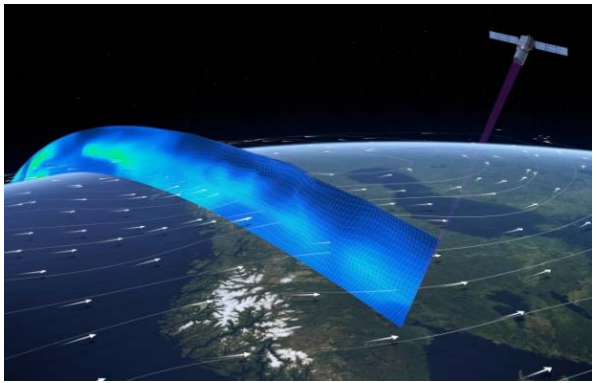
- Approximately zonal at dawn/dusk (6 am/pm)
- 87 km observation from 3 km subsamples – scene classified
- 0-30 km altitude in 24 vertical layers
- Random errors: < 1-2(PBL), 2(Trop), 3-5 (Strat) m/s
- Bias: < 0.7 m/s
- ***L2c product**: ECMWF forecast wind vectors after assimilation of Aeolus L2B winds, not to be used for assimilation!!)*



2. Spin-off product (L2a):

Optical properties profiles

- co-polar β, σ, lidar ratio
- <85 km observation averages from 3 km subsamples

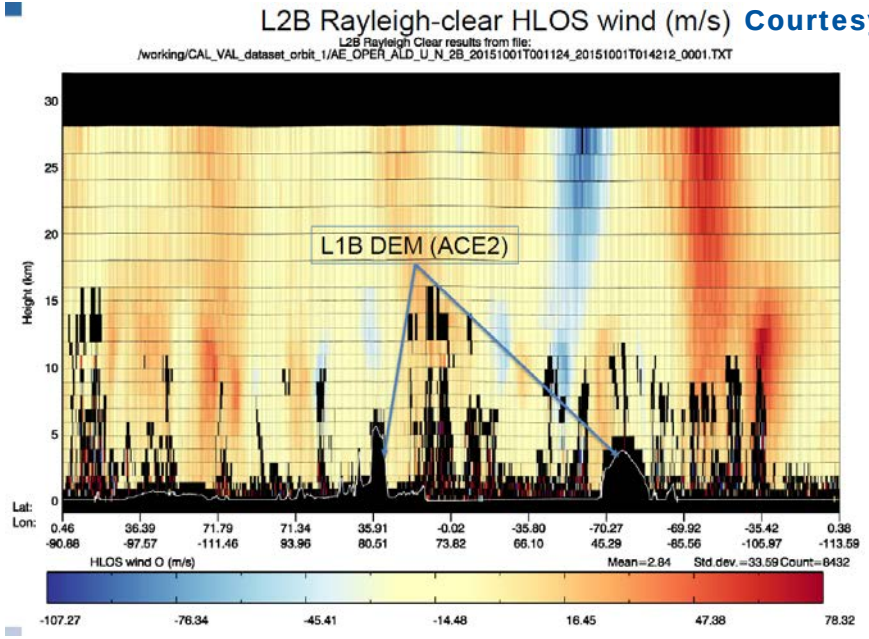


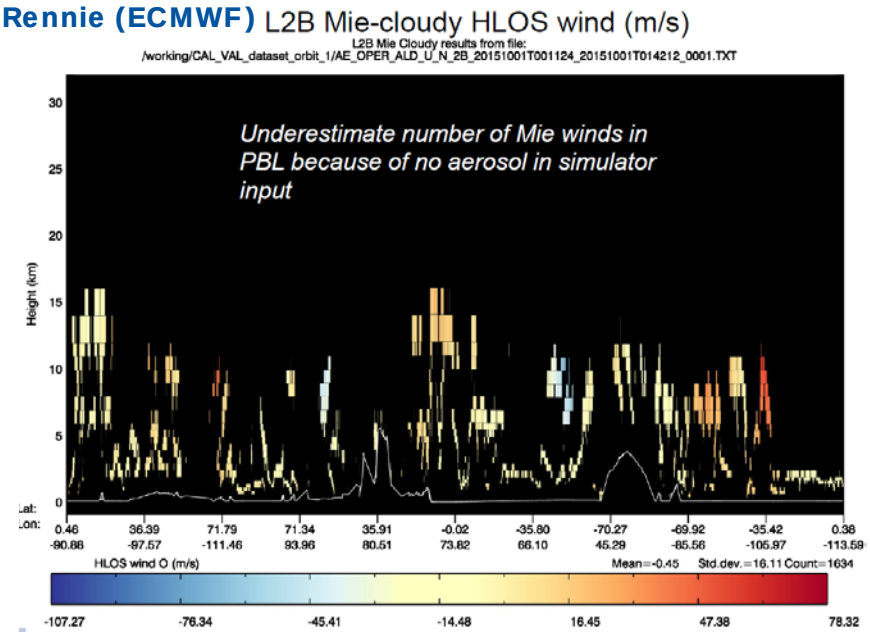
Aeolus L2B winds, test dataset 1 Oct. 2015

Molecular (Rayleigh) winds

Particle backscatter (Mie) winds

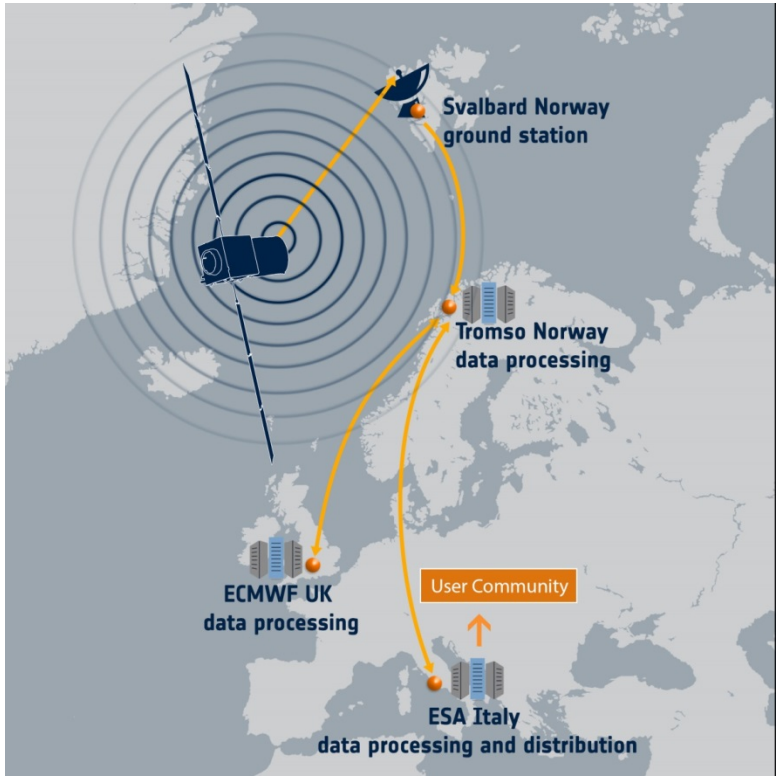
Courtesy M. Rennie (ECMWF)





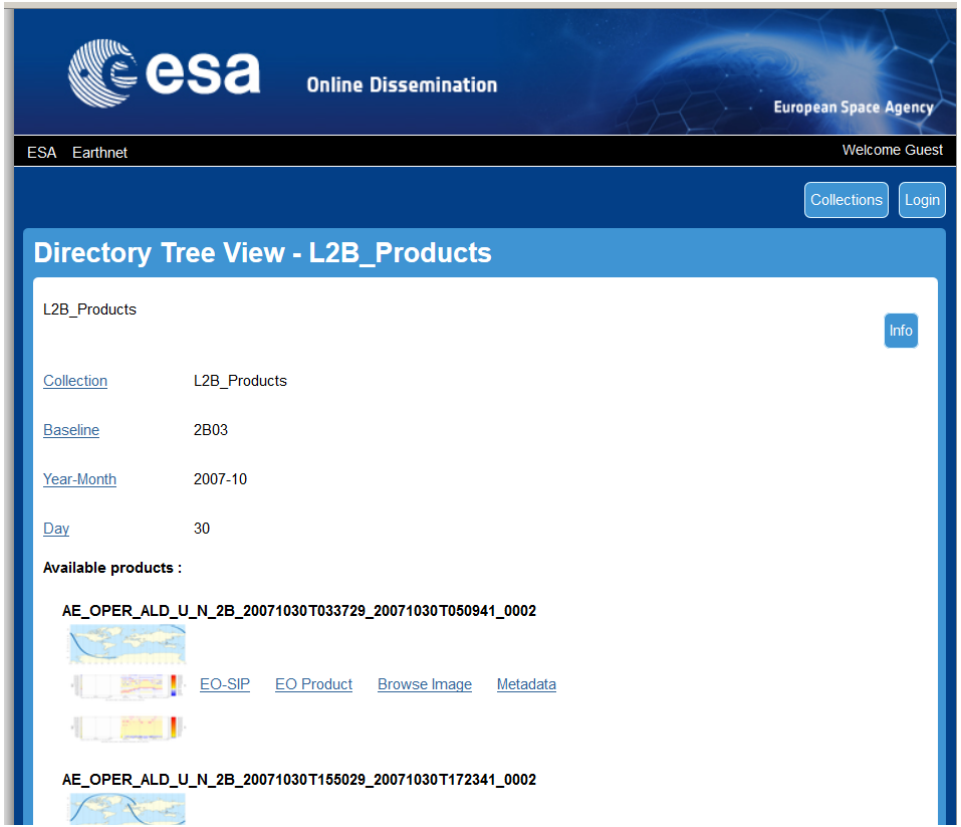
L2B algorithm development: J. de Kloe (KNMI), M. Rennie (ECMWF), G.J. Marseille (KNMI)

Data processing and distribution (2 / 2)



- Data processing from L1-L2 at ECMWF
- **Users get Aeolus L2B winds in NRT (for use in assimilation)** from
  - ESA Data Dissemination Server in ESA Earth Explorer (EE) binary format + BUFR convertor
  - EUMETSAT in BUFR format (still to be implemented)
- Data quality monitoring at ECMWF
- ECMWF assimilates Aeolus L2B winds,
  - **model forecast wind vectors at Aeolus measurement location -> L2C product**

Aeolus Data Dissemination Server



http://aeolus-ref-addf.eo.esa.int/addf/

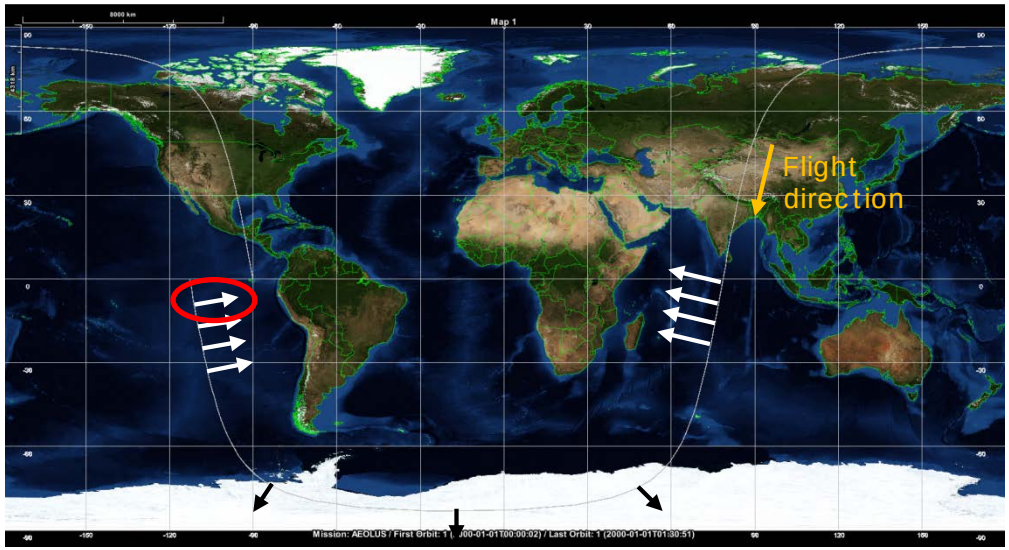
Automatic download of data can be set up with scripts (see help pages)

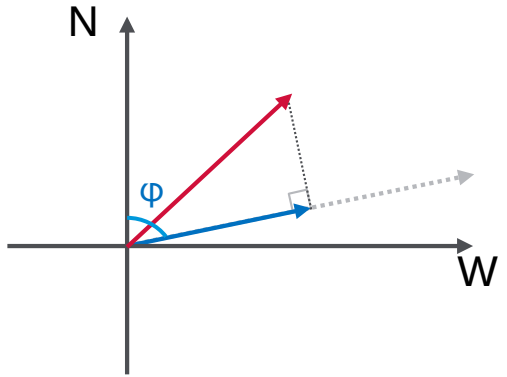
Aeolus wiki's:

ESA: https://wiki.services.eoportal.org/tiki-index.php?page=Aeolus%20Wiki (coming soon)

ECMWF: https://software.ecmwf.int/wiki/display/AEOL/

Aeolus data use





AMV vector wind
AMV wind projected on Aeolus HLOS
Aeolus horizontal line-of-sight

- For comparing AMV vector winds and Aeolus HLOS winds, a projection to Aeolus HLOS using L2B “LOS_Azimuth” (φ) is needed
- A westerly wind will be negative in descending and positive for ascending orbits in the Aeolus L2B wind product

Expected Aeolus impact

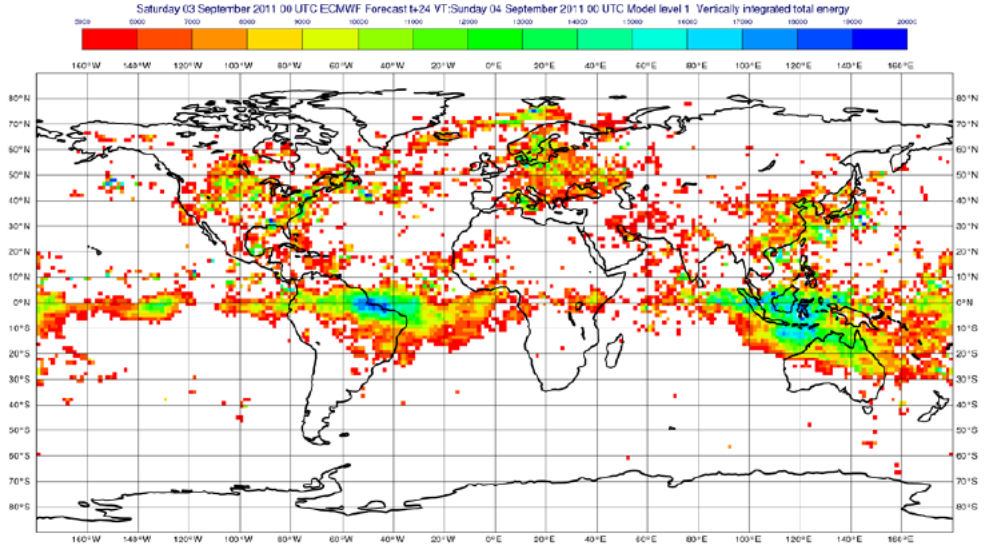


Figure 4: The reduction of mean total energy of the 24h forecast error (TEFE), when HLOS (zonal wind) data are assimilated. Only the contours of the largest values are displayed.

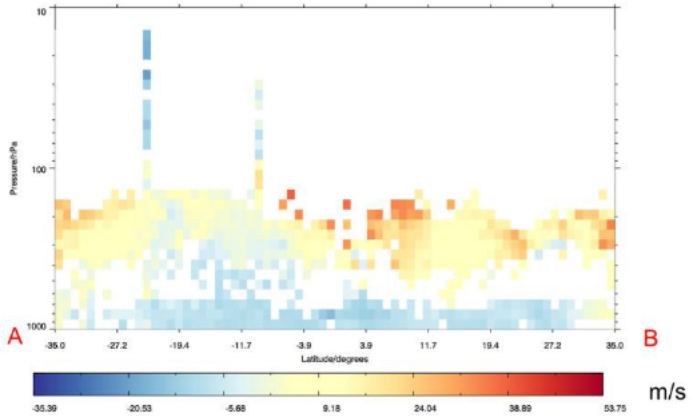
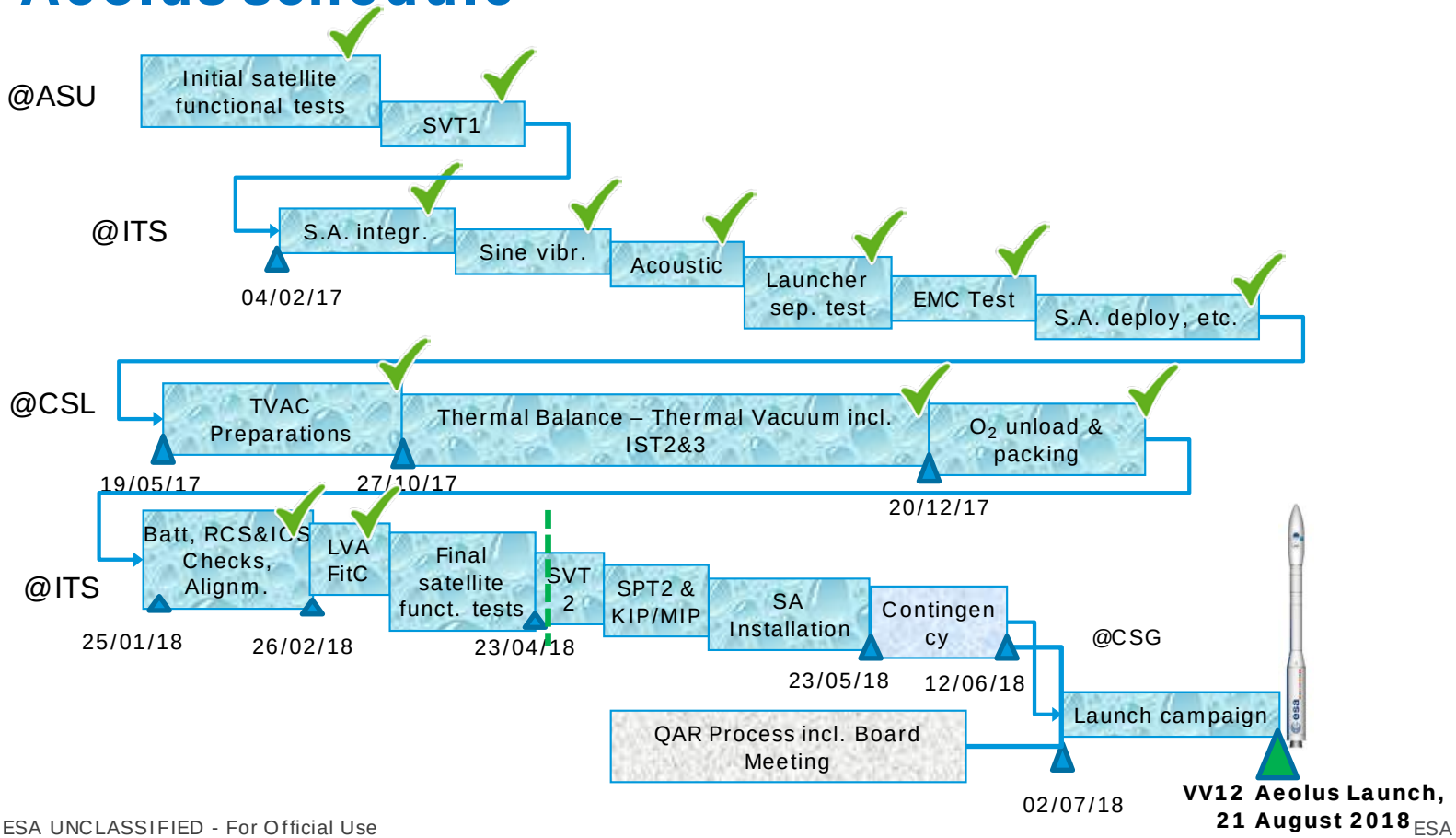


Figure 6. ECMWF actively assimilated u-component wind observations, available in the longitude range 140°W -120°W, for the 12 hour data assimilation cycle at ECMWF on 14th March 2014. Showing that large parts of the equatorial wave feature are not observed.

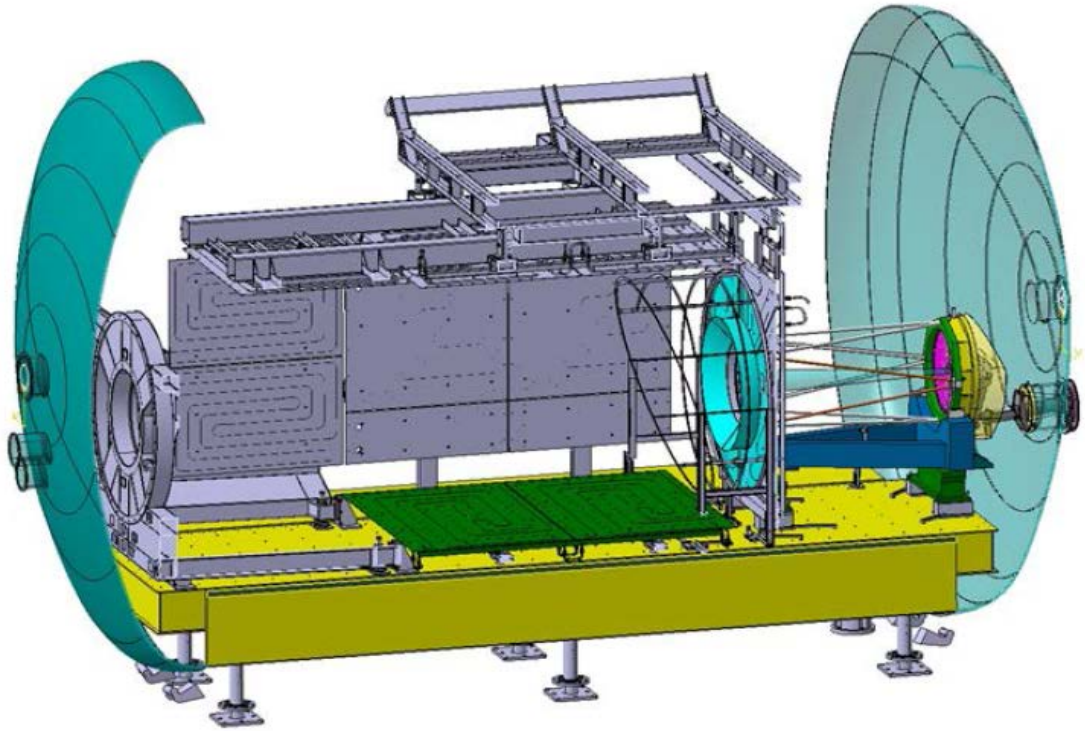
Horanyi et al, 2014, IFS total energy error reduction based on thinned u observations from aircraft. Impact shown is limited to aircraft coverage areas

From Rennie 2018, https://www.epj-conferences.org/articles/epjconf/pdf/2018/11/epjconf_ilrc28_02015.pdf

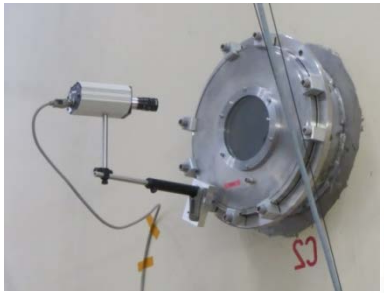
Aeolus schedule

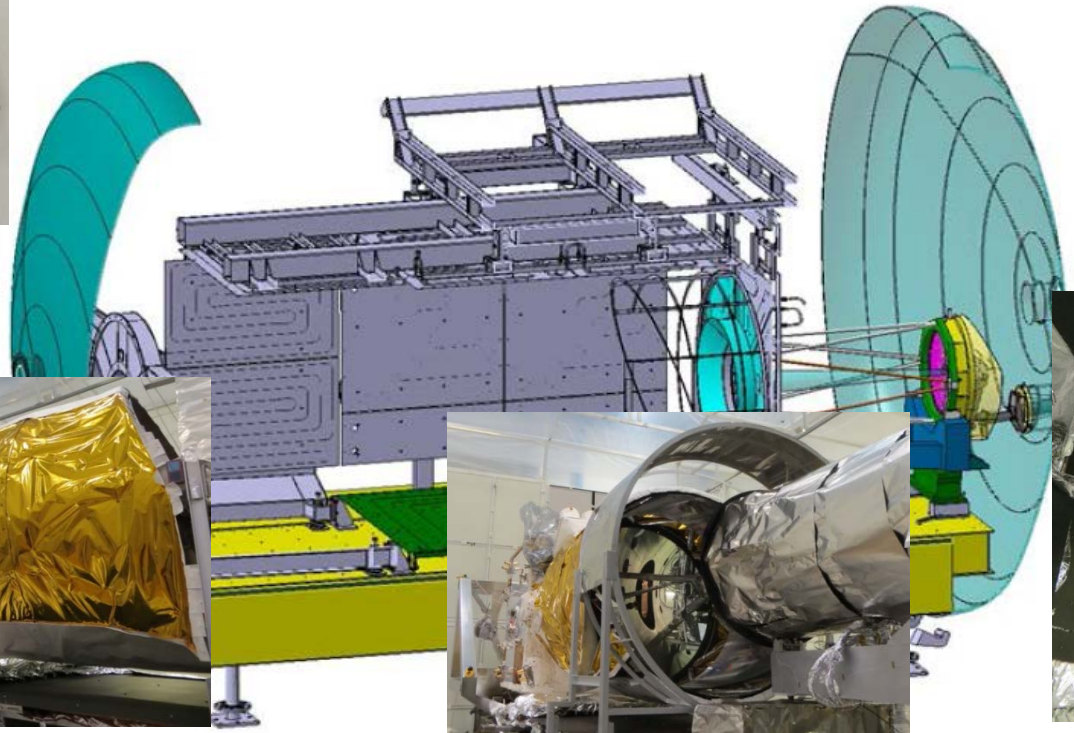


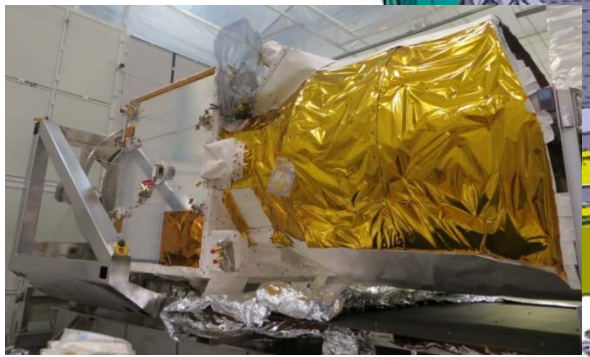
Aeolus on-ground performance testing in Thermal Vacuum (1/3)



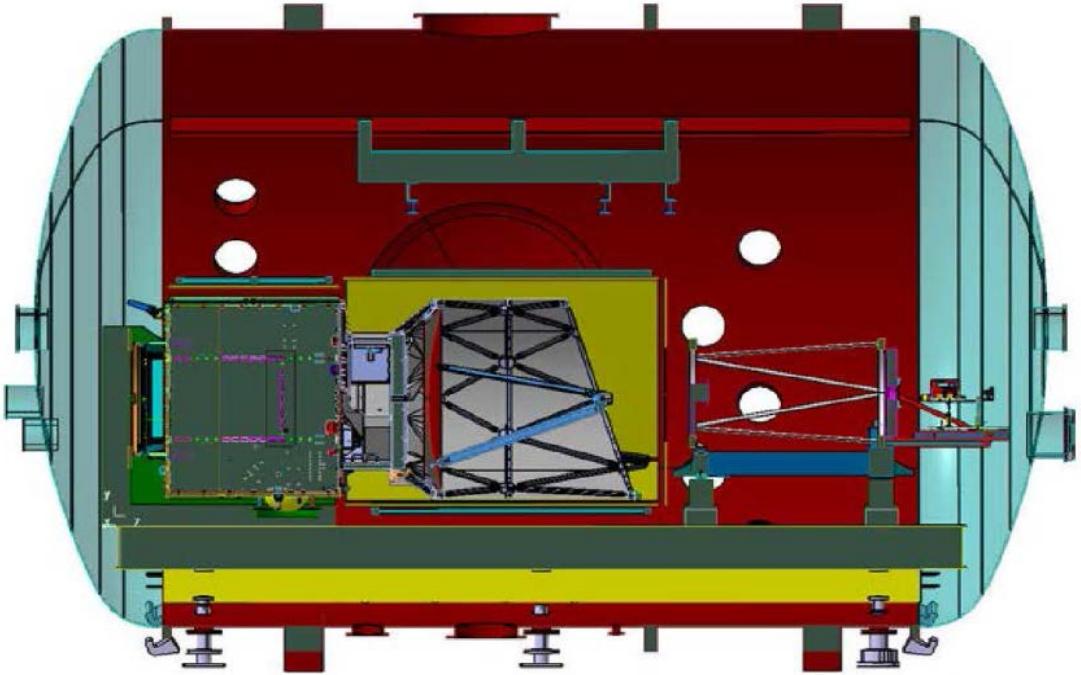
Aeolus on-ground performance testing in Thermal Vacuum (2/3)







Aeolus on-ground performance testing in Thermal Vacuum (3/3)



High-level questions before on-ground test

- Are the **lasers** still **operational?** (1st time after mechanical tests)
  - Both lasers turned On

- How do the laser function with the **satellite cooling system?** (1st time ever)
  - Both lasers were operated at high energy, stable

- Are the lasers still **aligned**? (1st time after mechanical tests)
  - Light received through internal and emission path

- Are the spectrometers still function? (1st time after mechanical tests)
  - Spectral measurements performed with both channels

- Can on-ground characterization equipment be aligned to Aladin for all test cases?

Non-conformance still under investigation

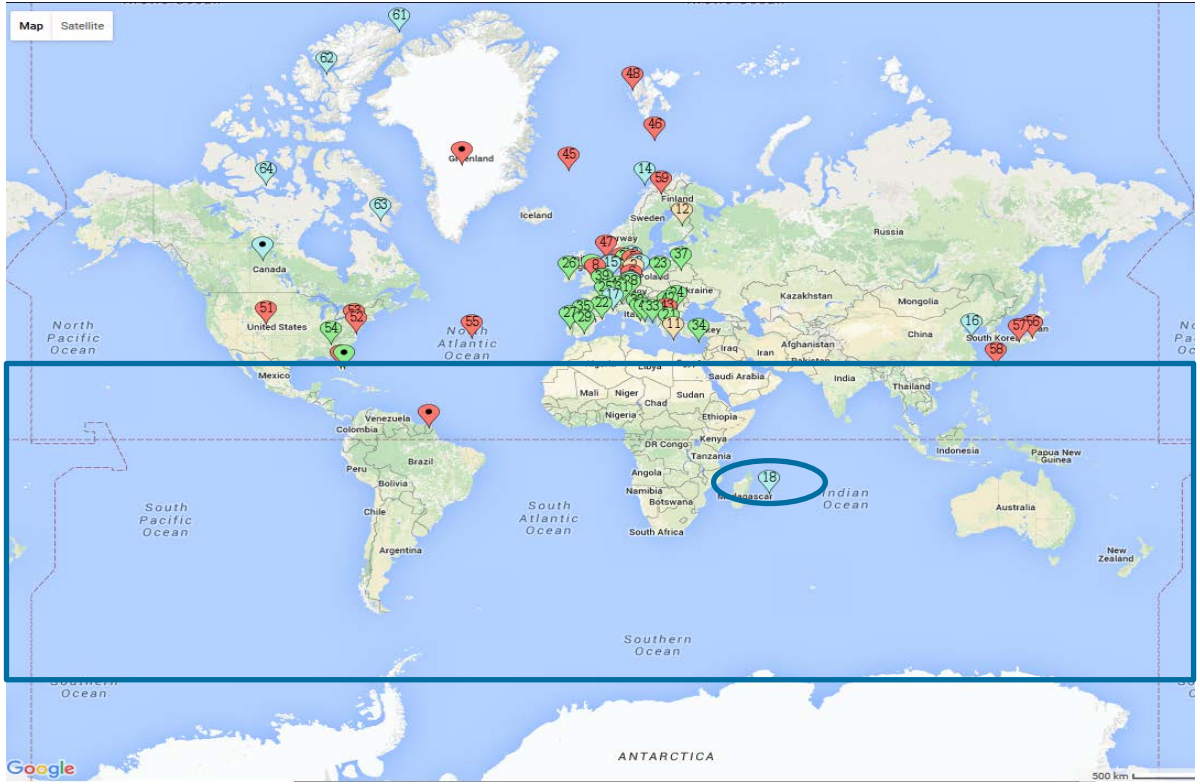
- Emit transmission increased for both Laser transmitters

- Receive transmission decreased
  - Current hypothesis “losses caused by on-ground characterization equipment”, not yet proven. Tiger Team assessing test outcome and re-characterizing on-ground test set-up.

- Frequency stability more noisy than expected

- Conclusions expected in May
  - intermediate results show system requirements still met in most cases (random error slightly above 2 m/s at some altitudes)

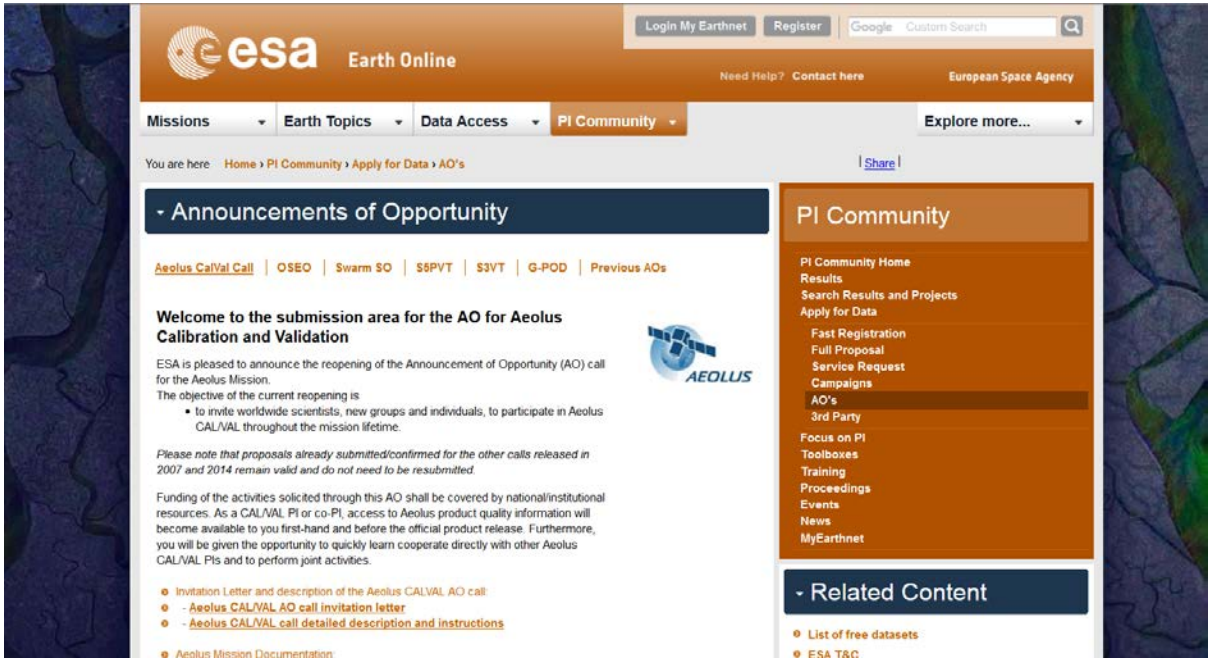
Aeolus CAL / VAL teams



- Data calibration and validation will be performed by teams world wide using:
  - Correlative ground-based (remote sensing) wind and aerosol observations
  - Airborne observations
  - Comparison to models
- Gaps:
  - Tropics and SH

Aeolus CAL / VAL Announcement of Opportunity call reopened 15 March 2018

https://earth.esa.int/aos/AeolusCalVal



“Aeolus Exploitation for NWP and Future Needs for Satellite Wind Observations”

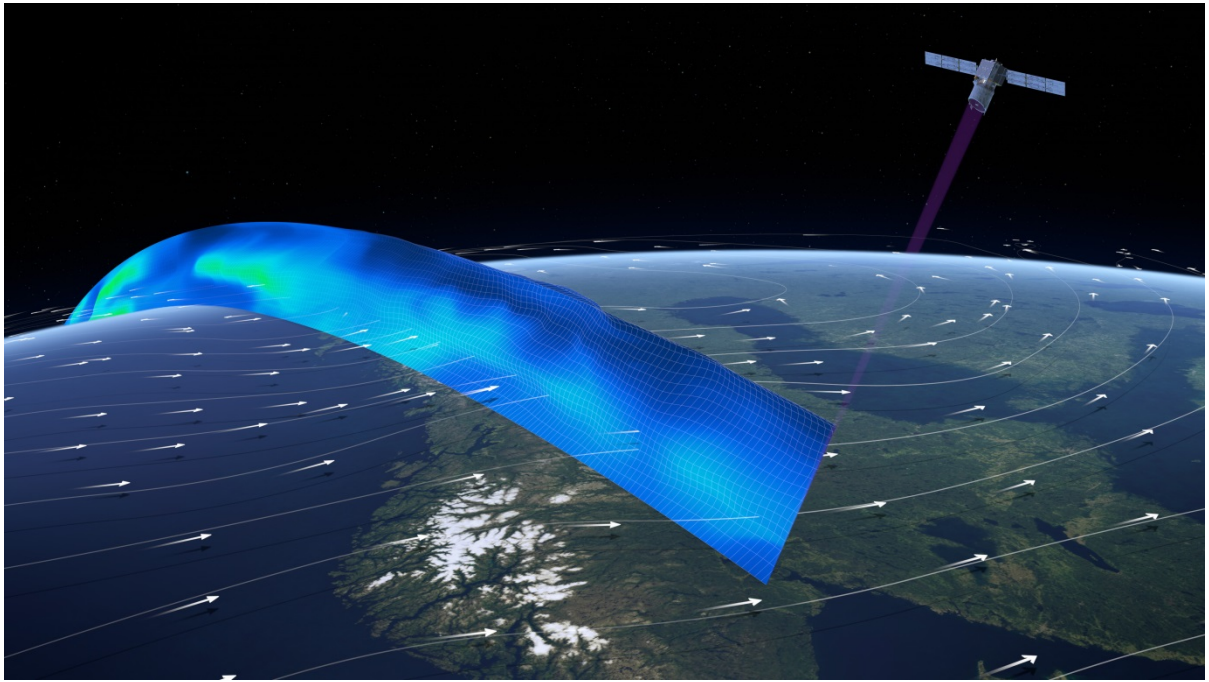
- Joint ESA and EUMETSAT Workshop
- 29 May 2019 at EUMETSAT
- Programme:
  - Aeolus mission and products
  - Expected impact of Aeolus in global models
  - Expected impact of Aeolus in limited area models
  - Preparations for assimilation and impact analysis of Aeolus at ECMWF, KNMI, MetOffice, DWD, MeteoFrance, Norwegian Meteorological Institute
  - Aeolus lessons learnt
  - Follow-on concepts
  - Plenary discussion on impact assessment coordination in Europe, future satellite winds, synergies and gaps, possible Aeolus-2

Conclusions

- **Aeolus will be the first Doppler Wind lidar in space**
- **Aeolus is scheduled for launch on 21 August 2018**
- Commissioning phase: 3 months, first data for CAL/VAL teams ~L+2 months
- Aeolus data release is expected around L+6 months
- Mission lifetime: 3 years (lifetime beyond 4 years not expected)
- Aeolus L2B product will be delivered within 3 hours of sensing in
  - ESA Earth Explorer binary format from ESA (NRT)
  - BUFR format by EUMETSAT (NRT to be confirmed)
- NWP monitoring, assimilation and impact experiments will be done at ECMWF under ESA funding
- The potential for an Aeolus follow-on will be followed up by Aeolus Mission Manager via an Aeolus Mission Advisory Committee

Anne.Straume@esa.int

https://aeolusweb.wordpress.com/

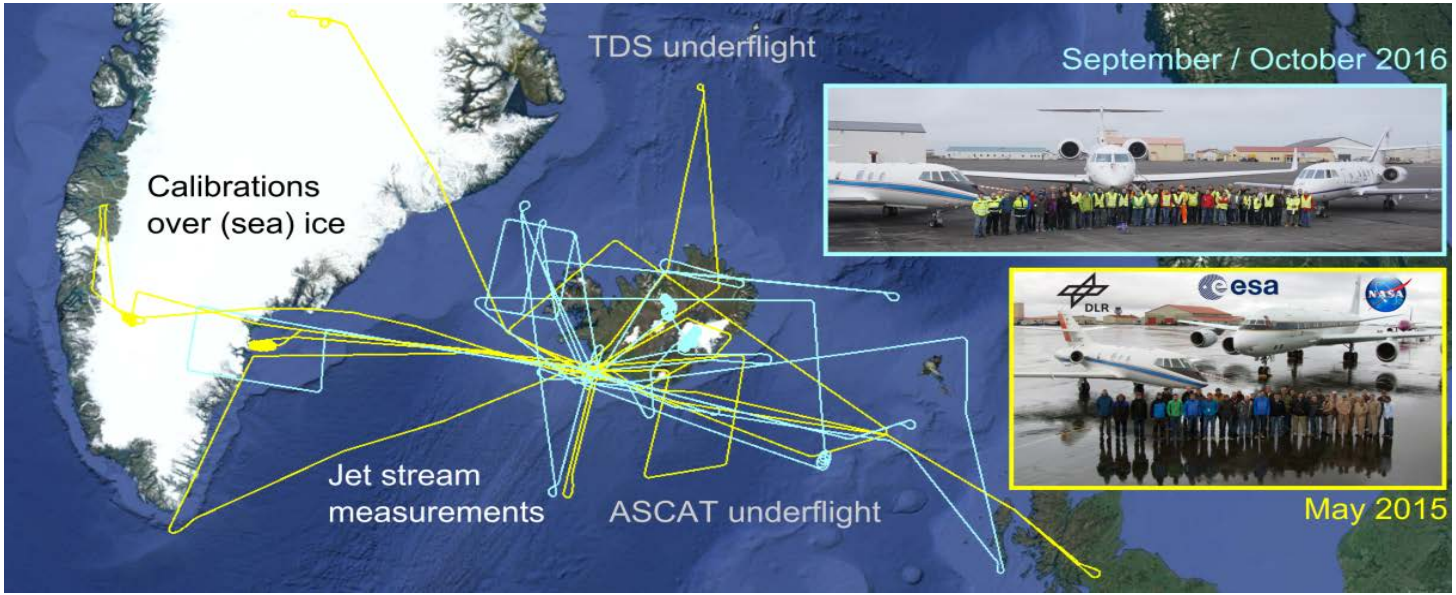


http://www.esa.int/esaLP/LPadmaeolus.html
https://wiki.services.eoportal.org/tiki-index.php?page=Aeolus%20Wiki (coming soon)

Spares

ESA Aeolus campaigns

WindVal I and II in 2015 and 2016

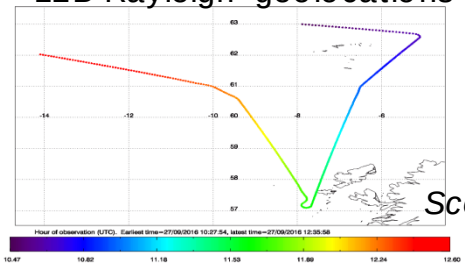


DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

WindVal II Iceland 2016

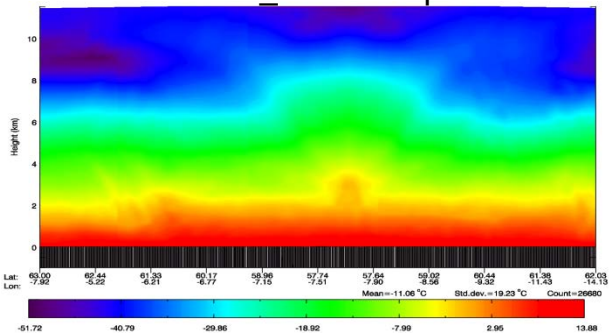
Flight through jet stream
(remnants of TC Karl, 27/9/2016)

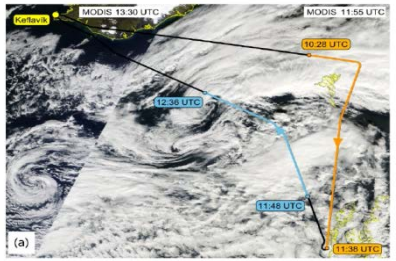
L2B Rayleigh geolocations

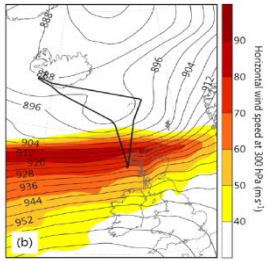


Scotland

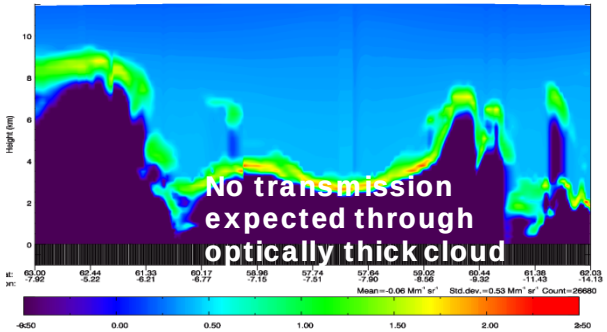
AUX_MET temperature







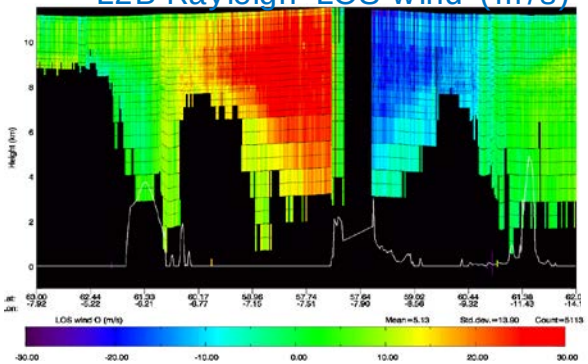
AUX_MET forward modelled
attenuated backscatter



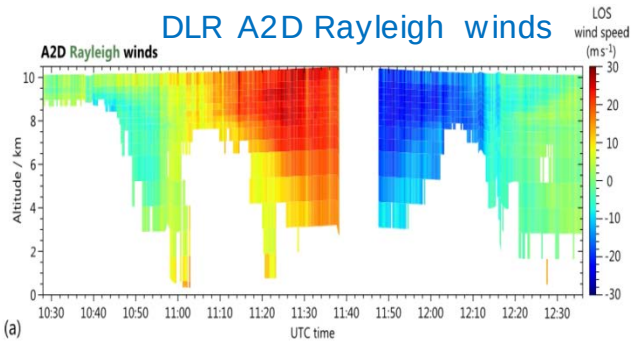
Courtesy M. Rennie (ECMWF) and U. Marksteiner and O. Reitebuch (DLR)

Aeolus campaigns data, A2D airborne demonstrator, processed with Aeolus L2B proc.

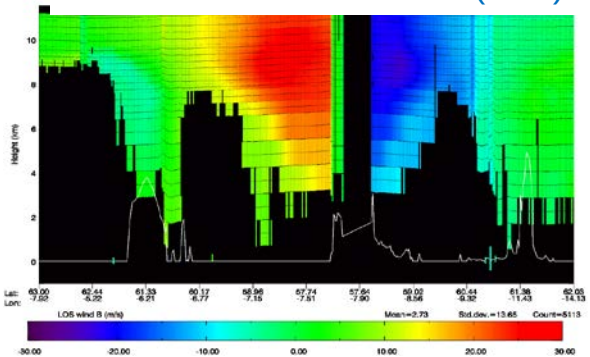
L2B Rayleigh LOS wind (m/s)



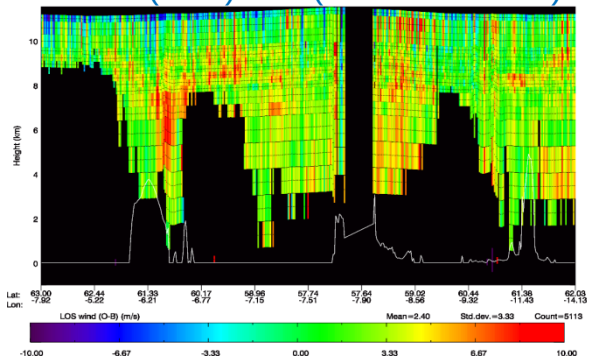
DLR A2D Rayleigh winds



ECMWF model LOS wind (m/s)



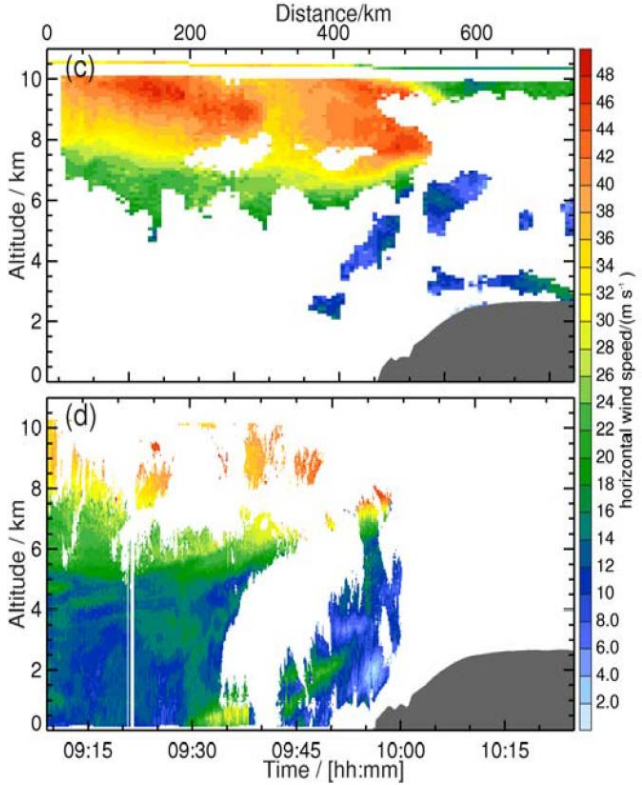
(O-B) i.e. (L2B – ECMWF)



N.B. all non-missing results shown

Courtesy M. Rennie (ECMWF) and U. Marksteiner (DLR)

Aeolus WindVal II, Iceland-Greenland, 2016



Comparison of DLR 2-µm and LATMOS / IPSL RASTA wind data over the complete common flight leg (Courtesy O. Reitebuch *et al.*, DLR)

2-µm Doppler wind lidar (2 µm wavelength, (c))

- Horizontal resolution: 8.4 km (scan mode)
- Vertical resolution: 100 m
- Sensitive to particles with µm-size (good coverage in cirrus clouds in the upper troposphere)

RASTA* (95 GHz, 3.2 mm wavelength, (d))

- Horizontal resolution: <0.2 km
- Vertical resolution: 60 m
- Sensitive to particles with mm-size (good coverage in water clouds in the mid and lower troposphere)

Data courtesy of J. Delanoë, J. Pelon and Q. Cazenave (LATMOS / IPSL / UVSQ)

* Schäfler et al., The North Atlantic Waveguide and Downstream Impact Experiment, BAMS, accepted (2018)