Summary
Day 1 – L2B product quality

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Summary Aeolus mission and DISC presentation

- Aeolus has exceeded its nominal lifetime of 3 years (+ 3 months commissioning) at the end of November 2021.
- The data quality has been slowly decreasing over time, amongst others due to instrument misalignments. Highest so far Rayleigh wind random errors were reached recently. The L2B wind product error estimates are based on the signal-to-noise ratio calculation and are hence very representative for all mission phases. Recommendations on how to use them are posted on the CAL/VAL Confluence site.
- The laser output energy was increased to a record level >80mJ in November 2021. This lead to lower L2B product random errors. The horizontal averaging on measurement scale will be increased soon to improve the scene classification resulting in more valid winds
- Participants were encouraged to submit abstracts to
  - The Aeolus 3rd Anniversary Conference in Taormina, Italy, 28 March – 1 April 2022. Deadline: 17 December
  - 2022 ESA Living Planet Symposium, sessions: A1.05, A1.07, A1.08, A1.11, B5.01
- The many gaps in the dataset this year were due to special instrument operations, attempting to mitigate the slow signal loss trend, and due to the instrument going to safe-mode two times. Gaps due to GPS receiver degradations occur twice a month.
- The altitude-dependent bias in the Rayleigh winds probably caused by imperfect Rayleigh-Brillouin scattering correction using AUX_MET data.
- An NWP model based Mie response calibration has been implemented by the DISC, and is being validated a.o. with Mode-S data.
- It would be interesting to validate the latter with collocated observations to assess if Aeolus high winds are biased.
- Ascending and descending orbit biases are probably caused by remaining uncorrected M1 telescope temperature variability. A measurement geolocation error was recently corrected (bringing geolocation from 5 km to 1 km accuracy, operational in Baseline 14).
- Statistical comparisons of Aeolus and ECMWF model winds show higher Aeolus winds for high wind speeds as compared to the model.
- Rayleigh cloudy winds are rather biased, but should be improved soon.
- The latest reprocessed dataset contains an increased number of L2B winds and reduced random errors.

Reporting by Aeolus L2B product CAL/VAL teams

- Wind quality during JATAC was impacted by high atmospheric return signal loss. In the presence of cirrus clouds at higher altitudes, the Rayleigh-clear winds below are affected by signal attenuation causing even higher random errors. High attenuation within the SAL layer was also seen. The provided error estimates are found to be significantly underestimated in these regions. (M. Borne)
- Bias reduction of Rayleigh clear winds was found for latest baseline. Results from CADDIWA campaign indicate possible orbit- and speed-dependent biases for Mie winds. Classification and horizontal integration could be improved as Aeolus is missing Mie cloudy winds in SAL. (Q. Cazenave)
- Mean random error increases from 4.6 m/s to 7.6 m/s between AboVE-1 (Oct2019) and AboVE-2 campaign (Jun2021): strongly enhanced random error (larger than estimated error) for the uppermost bin (special RBS to high altitudes above La Reunion) for both asc and dsc phases. Aggregation of 2 or more Aeolus profiles reduces the error. (M. Ratynski)
- Mie cloudy and Rayleigh clear winds were compared to ground-based radar wind profiles in Cochin, India from July 2019 to September 2021. Rayleigh clear wind random errors were 5.9 m/s (July 2019) to 7 m/s (September 2021), and Mie cloudy wind random errors 3.4 m/s (July 2019) to 3.8 m/s (September 2021). Biases were well below 1 m/s. Gross errors were removed by using prior information on wind speed. The team plans to do apply further quality control using the L2B product error quantifiers in the near future. (A. Kottayil)
- Comparisons of Aeolus winds with AMVs suggest that the correlation of the datasets is generally high, but varying with height and latitude region. Lower correlations were found at upper and middle layers for 15S-EQ, and for lower layers from 15S-30S. The latter region is known from earlier studies to be challenging for the low level cloud height assignment. (H. Shin). It was suggested to also look at the special AMV range bin setting period (end October to early October 2019) for further analysis of this issue.
- A three years Aeolus validation campaign in Punta Arenas have just been concluded. The dataset contains observations of very strong wind at higher altitudes (~25km) which are well captured by Aeolus. Gravity waves sometimes create large discrepancies between neighboring wind profiles and ground-based observations. The spatial representativeness has to be questioned under such conditions. Doppler cloud radar profiles are very promising for the validation of Aeolus Mie winds. (H. Baars)

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- Long-term analysis over Germany show increasing random errors to the end of the mission due to slowly evolving loss of atmospheric return signal. After the implementation of the M1 temperature bias correction scheme, some temporally varying biases are still present and need to be analyzed further. The number of available Mie measurements is decreasing due to decreasing signal levels and resulting challenges for the scene classification. Reprocessed dataset drastically improve the data quality, especially concerning the bias correction. An altitude/temperature dependent bias in Rayleigh clear winds was found. (A. Geiss)
- Triple collocation of Aeolus winds with ERA5 and ground-based wind profilers in Australia from October 2020 to March 2021 showed constant wind biases below 0.6 m/s and slope errors around 1 m/s. Comparable results were found with direct comparison between Aeolus and the wind profilers. Rayleigh clear random errors were found to be 5.43 m/s and Mie cloudy wind random errors 4.42 m/s. (H. Zuo).
- Both Rayleigh-clear and Mie-cloudy L2B HLOS winds were compared to 3D wind observations by accurate inter-calibrated ground-based coherent Doppler lidars (CDLs), between 30 and 6000m altitude. Amongst others PBL turbulence introduces a significant vertical wind component as measured by the CDLs. It was shown that a vertical velocity correction is necessary in the wind retrieval and the validation process. Aeolus L2B Rayleigh clear winds were still shown to be of quite good quality for B11, except from the lowest atmospheric bin. Vertical velocity variability in the range of ±0.3 m/s lead to HLOS errors of ±0.4 m/s. Random errors of 3.15 (Mie) and 7 (Rayleigh) m/s and biases of -0.25 m/s (Mie), -0,16 (Rayleigh ascending) and 2 (Rayleigh descending) m/s were found (S. Wu)
- L2B Rayleigh wind retrievals show sensitivity up to 0.5-1 m/s when using NOAA FV3GFS temperature and pressure information for the L1B-L2B Rayleigh-Brillouin scattering correction as compared to ECMWF model information in the operational Aeolus L2B product (H. Liu)
- Validation results from several Cal/Val teams show consistent results for the Rayleigh-clear wind systematic bias and random error, also in-line with NWP monitoring. Long-term global reference datasets (e.g. radiosondes, wind profilers and super pressure balloons) allow to quantify NWP model uncertainties. While NWP O-B results show a positive systematic Rayleigh clear wind bias in the tropics in the upper troposphere and lower stratosphere, super pressure balloon observations indicate that this systematic bias is due to model uncertainties. (S. Bley).

Plenary discussion (1/3)

- Did you recognize differences in the L2B data quality (systematic and random errors) throughout the mission lifetime (FM-A, FM-B)? Does your analysis indicate improvements after M1 bias correction (all datasets after B09, including reprocessed)?
  - After M1 bias correction, the systematic errors are close to zero. The random errors increased for Rayleigh clear over the mission lifetime due to decreasing signal levels. The random errors for Mie cloudy remained constant, but the number of Mie cloudy observations drastically decreased.
- Did you assess the quality of the reprocessed dataset B11 from June 2019 – October 2020?
  - With the reprocessed dataset and its implementation of the M1 bias correction for the period before April 2020, the bias significantly improved especially for Rayleigh-clear winds. The number of available wind measurements increased from B10 to B11 reprocessing, and random errors also decreased. The negative bias (ascending) and positive bias (descending) in Oct-Nov 2019 is still visible.
- Have you noticed range-bin dependent, orbital phase, geographical, temporal wind biases?
  - La Reunion observations show larger biases in range-bins above 22km.
  - In comparison to wind profilers at India (Tropics), the low wind bias and random errors are robust and do not change over range-bin, wind speed, or season.
  - Range-bin thickness (Mie and Rayleigh) and altitude dependent (Rayleigh) biases are observed above Germany.
  - Enhanced orbital dependent biases found in March & October (likely due to increased solar background noise). This was observed over Germany, China, and La Reunion for Oct-Nov 2019.

Plenary discussion (2/3)

- What is the spatial representativeness of Aeolus Rayleigh/Mie winds?
  - Problematic in gravity wave areas (e.g. Punta Arenas).
  - On La Reunion the distance did not play a crucial role (comparison to ascending & descending path)
  - Temporal representativeness error can be well assessed by Wind Profilers which measure at higher temporal variability. Using Taylors Hypothesis the temporal representativeness can easily be transferred to a spatial representativeness for strong winds (>7m/s).
  - Triple colocation is a good tool to asses the representativeness by using ERA5 or ECMWF model data and an independent accurate observation dataset such as wind profilers. However, the three datasets have to be independent, hence care must be taken when Aeolus observations are assimilated. Information assimilated into a model gets lost after a couple of days. Aeolus observations are not used in ERA-5 yet.
- Which QC filters have you used and did you change them during the mission?
  - 4 m/s error estimates threshold for Mie and 8 m/s for Rayleigh is used by most, but some teams used different values. Validation results in terms of statistical parameters (bias, scaled MAD, SD) are very sensitive to the applied QC filter criteria (error estimate threshold)
  - Aeolus mission requirements for random errors are defined as the standard deviation of a Gaussian distribution
    → error estimate thresholds should ideally be chosen to yield a Gaussian distribution of the Aeolus wind differences with respect to the reference validation instrument
  - Gaussian distribution could be checked with so-called Q-Q plots (quantile-quantile plots) for different error estimate thresholds
  - A statistical tool for outlier removal is the modified z-score (threshold of 3.5)
  - Aeolus performance is not constant over time and as a result different percentages of data are removed during the mission if a too tight error estimate threshold is applied. This also applies to different altitudes. → compare results with different thresholds
  - More results and information will be presented by the DLR team at the Aeolus 3rd Anniversary Conference in 2022

Plenary discussion (3/3)

Recommendations for the future:

- Have you compared the HLOS estimated error, provided in the product, to random errors (scaled MAD) found in your cal/val comparisons?
  - AboVE-2 (Reunion): Random errors 2-3 higher than the estimated errors for the uppermost bins (22+ km altitude)
  - See presentation by S. Bley: Temporal evolution is very well captured, random errors usually slightly higher.
- Comparison to AMVs: Did you compare L2B Mie cloudy winds to AMVs for the special RBS period (November 2019)?
  - This was not shown. It is recommended to use this special period to assess the altitude assignment issue.

A Cal/Val Confluence Page will be set-up to discuss the following questions:

- Do you have recommendations for future operations (for upcoming reprocessing campaigns, scene classification in clear, cloudy)?
- Do you have recommendations for special range bin settings?
- Are there any ideas/needs/potential for L3 products (different grids, global maps/statistics)?
- Recommendations for Aeolus follow-on mission?

Aeolus follow-on discussion on confluence: https://www.aeolus.esa.int/confluence/display/CALVAL/Aeolus+follow-on%2C+ideas+for+future+operations%2C+products