Summary of Quality of Aeolus Data Products from 2nd Reprocessing Campaign covering June 2019 to October 2020

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Aeolus data products were reprocessed from June 24, 2019 to October 10, 2020 covering the operation period of the second Flight Model laser (FM-B). This second reprocessing was based on processor versions deployed in October 2020 (L1bP 7.09.1, L2aP 3.11.1, L2bP 3.40.2), used for near-real time (NRT) generation of baseline 11 (B11) data products. The second reprocessing campaign covers a longer FM-B period with a later processor baseline version (B11 instead of B10) compared to the first reprocessing campaign. The reprocessing covered L1A, L1B, L2A and L2B data products as well as the respective auxiliary files and provides a more homogenous data product quality for the whole period. In combination with the NRT products, B11 now covers the period from June 24, 2019 to May 26, 2021 (day of deployment of B12 for NRT production). This 2nd reprocessing ensures for the first-time seamless data availability of low wind bias data for the whole time period of FM-B operation. The next reprocessing campaign will cover the FM-A period from September 2018 to June 2019 with the baseline 13 processor version, which will come in NRT-operation soon.

What is the main improvement with respect to the original processing baseline?

- Correction of orbit phase dependent wind bias in L2B product using daily updates of the correlation between ECMWF O-B (observation-background) statistics and temperatures from the telescope primary mirror M1. This is especially important to correct the the large wind biases for January until April 2020, which was not covered by the first re-processing campaign. This correction is applied to Rayleigh and Mie L2B winds and includes also the correction of constant bias drifts. The correction for day d was applied with correlations from day d (which is even more accurate than the previous day, d-1, correlations used for B10 and B11 NRT products), which should slightly improve the bias as well.
- Radiometric coefficients K_{ray} and K_{mie} are calculated along the orbit for L2A products (B11) using a multiple linear regression based on M1 temperatures. The first estimates are calculated from signal prediction in particle-free regions of the atmosphere for mid-altitudes from 6 to 16 km and then fitted using the regression coefficients to provide both K_{ray}, and K_{mie} per observation for the whole orbit. This is an improvement compared to the constant values taken from calibration file for the first reprocessing campaign (B10); in addition, the parameter attenuated backscatter is now provided for the complete FM-B period.

What are further improvements with respect to NRT data products?

- Correction of hot pixel fluctuations in time periods between dark signal measurements (DUDE) for the L1B product, in contrast to updating the hot-pixel correction only 4 times per day after DUDE for the NRT data products; improvement of the hot-pixel correction for the uppermost Rayleigh range bin for some DUDE calibrations of the NRT product up to October 21, 2019.
- L2B wind products were flagged invalid for periods of known instrument tests or degraded data quality, which eases the automatic use of L2B products (see below).

- The L2B wind bias correction using M1 temperatures was applied for day d with correlations from the same day d. This is more slightly accurate than using the correlations from the previous day, d-1, as applied during NRT processing for 10 and B11 products, and should slightly improve the wind bias.

What is the quality of the data products?

- Better quality of signal levels (Rayleigh, Mie) in the L1B product wrt hot-pixel dark current levels, which also improves L2A and L2B products which use L1B signal levels as input.
- Improvement of the radiometric calibration of the L2A products by considering orbital variations; this leads to lower systematic errors for the backscatter and extinction profiles, with slightly lower values than the NRT products; this results in a lower number of unrealistic, negative values for the backscatter and extinction coefficient; moreover, the accurate radiometric calibration now allows the monitoring of the signal loss in the atmospheric path over time.
- The Rayleigh (clear) wind bias wrt to the ECMWF model shows global averages of around 0 m/s; also, most of the orbit phase dependent wind bias in NRT products has been removed, resulting in a bias within ±0.4 m/s for most orbits except for the October 2019 and March 2020 period (see below); this is a large improvement wrt NRT products, which showed temporal variations of the Rayleigh bias between -4 m/s to +1 m/s during this period.
- The Mie (cloudy) wind bias wrt the ECMWF model shows global averages around -0.25 m/s (underestimation), with most orbits showing a bias within ±0.4 m/s; this is a slight improvement wrt NRT products, which showed temporal variations of the Mie bias between 0 m/s to +0.6 m/s during this period.
- The Rayleigh and Mie wind random errors show a similar level and evolution as for the NRT products, with a period of 2 weeks (2019/10/28 – 2019/11/10) with enhanced values due to a special range-bin setting (250-500 m bins globally) for the purpose of comparison to Atmospheric Motion Vectors AMVs.
- The scaled median absolute deviation MAD (1.4826*MAD) as a measure of the random error shows values of around 3.5 m/s (Mie) with a small increase in time and an increasing value of 4.3 m/s to 6.2 m/s (Rayleigh) from July 2019 to October 2020.
- The Mie random error shows a linear increase with altitude up to 16 km, while the Rayleigh random error shows a C-shape with lowest values (scaled MAD of 4.5 m/s) around 5 km and linearly increasing values for altitudes higher than 12 km (scaled MAD of 5.0 m/s at 12 km).
- The number of valid winds for a given time period has slightly increased from the first to the second reprocessing campaign for the Mie cloudy and Rayleigh clear winds, thanks to an improved classification algorithm and improved tuning of screening thresholds for the incoming L1B data.

What are the known limitations of the data products?

- Due to laser instrument sensitivity tests, the data products should be only used from June 28, 2019 onwards, within the period there are small gaps in data coverage due to satellite downlink problems, orbital manoeuvres or performed calibrations; for the L2B product data was flagged invalid during periods of degraded data quality (mostly due to dedicated instrument test periods), for L1B and L2A products please check the data exclusion periods and data unavailability periods are available at:
  https://earth.esa.int/eogateway/instruments/aladin/quality-control-reports

- As the hot-pixel corrections are applied only for the following orbit file, hot pixel fluctuations cannot be corrected within one orbit product, but it should be noted that the L2B processing has a dedicated check for strong biases caused by an uncorrected hot-pixel and will flag winds invalid if they occur; also, 4 Rayleigh hot pixels within the Rayleigh spots can only be corrected with the period of DUDE measurements (4 times per day); it is expected that this will improve with a new hot pixel detection scheme for the next reprocessing.
- The L2B Mie cloudy winds show a constant bias of -0.25 m/s (underestimation). This is a known issue and related to the choice of the Mie estimated error threshold which will be further investigated; in addition, the Mie winds show an almost constant bias with altitude.
- The L2B Rayleigh clear winds show an altitude dependent bias of about 1 m/s over 20 km with an underestimation at lower altitudes and overestimation at higher altitudes; this is related to an imperfect Rayleigh response calibration using the atmospheric temperature profile.
- As the L2B bias correction is based on global O-B statistics, there could be higher regional biases; a small difference in bias is observed for ascending and descending paths, with the ascending paths showing a lower bias.
- Both the L2B Mie and Rayleigh winds show an increase for the bias starting end September 2019 until begin November 2019 with a maximum in mid-October 2019 for the ascending and descending paths; maximum values in mid-October are about -0.4 m/s to 0.4 m/s (Rayleigh) and -0.4 m/s to 0.1 m/s (Mie); this is also present again with lower maximum amplitudes in March 2020 for both Mie and Rayleigh winds; the cause of this behaviour is related to a seasonal issue for the correction of the solar background; the cause will be further investigated and hopefully lead to improved bias correction for the next reprocessing campaign.
- L2B winds show higher random error during the period with AMV range-bin settings from October 28 to November 10, 2019; this is as expected, since random error is a function of altitude and range-bin size, so a globally changed altitude sampling leads automatically to a change in random error for both channels; during that period also the L2A product shows limitations: the Mie Core Algorithm (MCA) can be used, but the Standard Correct Algorithm (SCA) cannot be fully exploited, i.e. the AMV range bin settings are not being properly handled for mid-altitudes where several Rayleigh bins match one single Mie bin. As a result, SCA products are only partially valid during this period.
- L2B Rayleigh cloudy winds still show significant bias (0.5 m/s to 2 m/s) and significant higher random error than Rayleigh clear winds at the beginning of the period (5 m/s to 6 m/s) although the random error for both cloudy and clear was almost the same (6.3 m/s) during the last 7 weeks of the period. A dedicated correction algorithm for these winds has been prepared and we hope this can be improved upon for a future reprocessing.