Evolution of Aeolus Atmospheric and Solar Background Data

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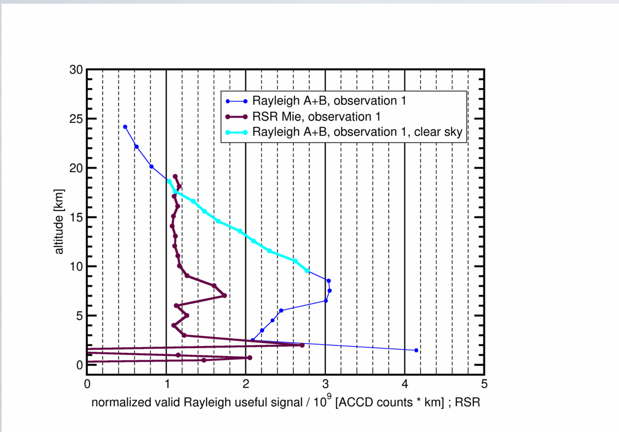
Introduction

The laser signals backscattered by air molecules are one of the system parameters which are regularly monitored to assess the performance of the ALADIN instrument including its two redundant lasers FM-A and FM-B on board the Aeolus satellite. They also determine the quality of the L2B Rayleigh channel wind velocities. To avoid interfering signals coming from cloud particles and aerosols, the latter have to be suppressed. The corresponding scheme to do so had been presented at the Aeolus 3rd Anniversary Conference, Taormina, Italy, 28.03. - 01.04.2022. It is based on the rejection of all atmospheric L1B Rayleigh useful signals on the observation level in and below height bins having a refined scattering ratio (RSR) larger than 1.3. In this way, only clear sky conditions, and correspondingly clear sky normalised valid Rayleigh useful signals (CSNVRUS), are taken into account. Note that about 45% of all Rayleigh useful signals have been rejected.

Example of CSNVRUS determination

- 01.07.2019, orbit 4952, observation 1
- Blue line: L1B normalised valid Rayleigh useful signal
- Maroon line: refined scattering ratio (RSR) Mie
- Cyan line: resulting L1B CSNVRUS
- Probably clouds at altitudes of about 7km – 8km, RSR up to about 1.8
- Clouds and/or PBL aerosols at altitudes of about 0.7km – 2km, RSR up to about 2.7

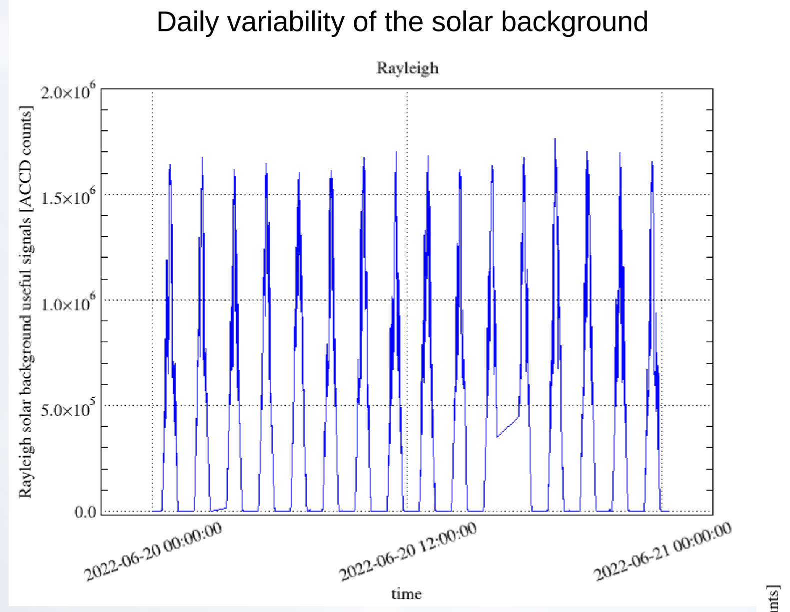


Since June 2021, larger CSNVRUS of about 1.6E9 - 7.2E9 ACCD counts * km have appeared which degrade the data validity. They are mainly present in latitude and longitude regions with special range bin settings (RBS; e.g. POLARIS RBS to investigate PSCs, TONGA RBS to investigate the Tonga eruption ash plume), and in about 5km - 10km altitude. Therefore, a quality control (QC) has been implemented to reject these large signals (see next box).

After each laser shot, the atmospheric background signal level is also measured. It is used to correct the laser return signals and determines their signal-to-noise ratio. Consequently, this background level has an influence on the winds and wind errors derived from the backscattered laser signals. Thus, the so-called solar background (SBG) signals have been regularly monitored since the launch of Aeolus, too.

Evolution of L1B Rayleigh Useful Signals for Solar Background

Daily variability of the solar background



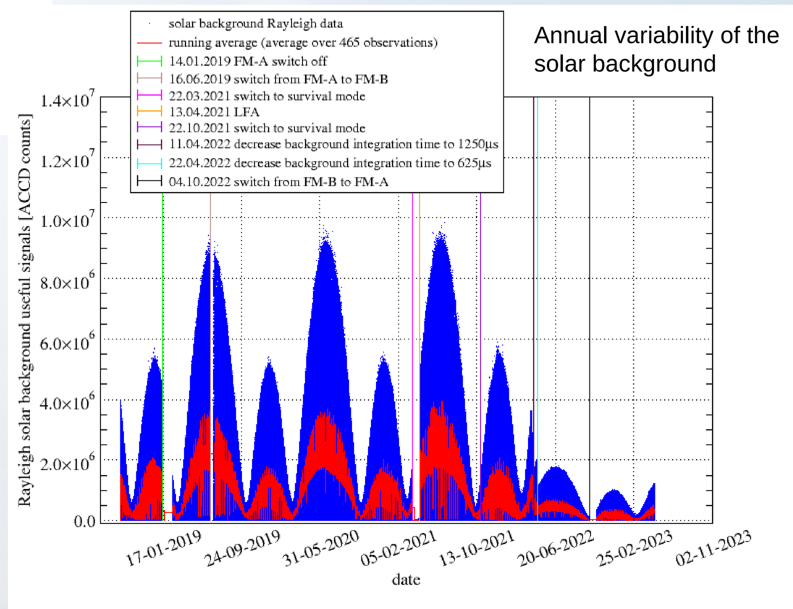
Example: Daily cycle of the L1B Rayleigh channel SBG useful signals on the observation level on 20.06.2022 (15 orbits), measured by Aeolus. The signals show a periodic behaviour along the orbits. This is caused by the changing sun illumination and Earth albedo. The maxima were measured in the Arctic, while the minima originated from the southern hemisphere (see next box).

The L1B Mie channel SBG useful signals show a similar behaviour. The ratio of the Rayleigh to Mie SBG signals behave also periodically.

The maxima of the Rayleigh (and Mie) SBG signals show also an oscillating behaviour in time with a primary maximum in June and a secondary maximum in December, and minima in March and October of every year. This is caused by the Earth's orbit around the sun, the inclination of the Earth's axis, and the polar orbit of Aeolus.

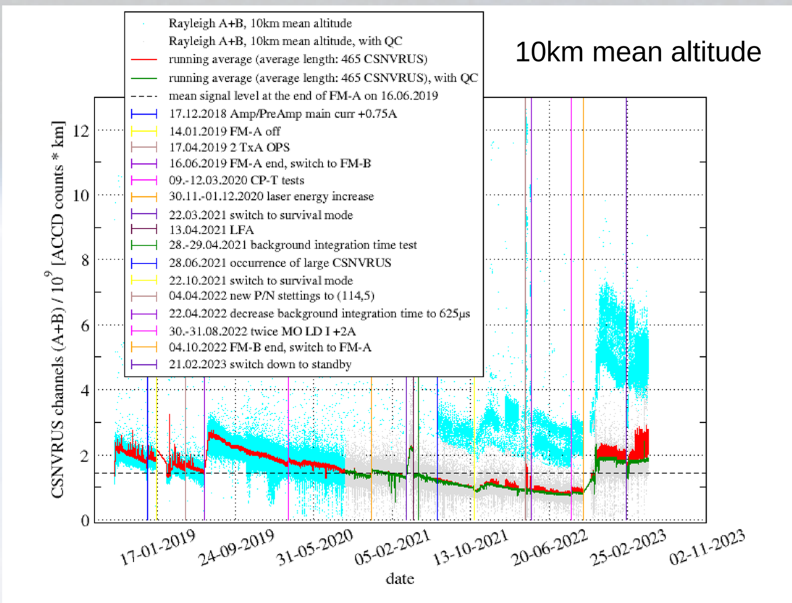
In April 2022, the background integration time was stepwise decreased from 3750µs via 1250µs to 625µs to avoid saturation of the background pixels due to a P/N setting change to (114,5) on 04.04.2022. A decrease of the SBG signal level resulted.

Annual variability of the solar background



Evolution of L1B Rayleigh Useful Signals for Clear Sky Conditions at 10km and 15km Mean Altitude in 03.09.2018 – 30.04.2023

10km mean altitude



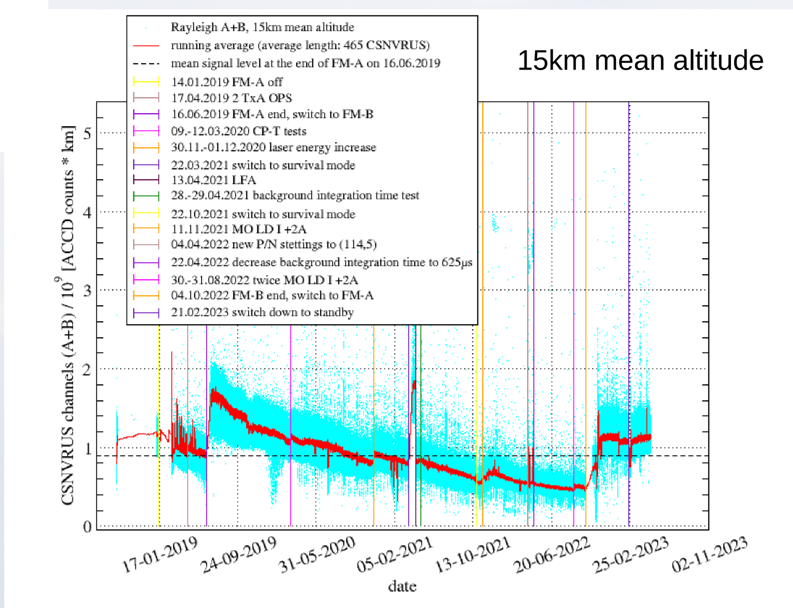
Three different periods can be seen in the atmospheric Rayleigh signal evolution:

1. laser FM-A from 03.09.2018 – 16.06.2019
2. laser FM-B from 28.06.2019 – 04.10.2022
3. laser FM-A from 29.10.2022 – 30.04.2023

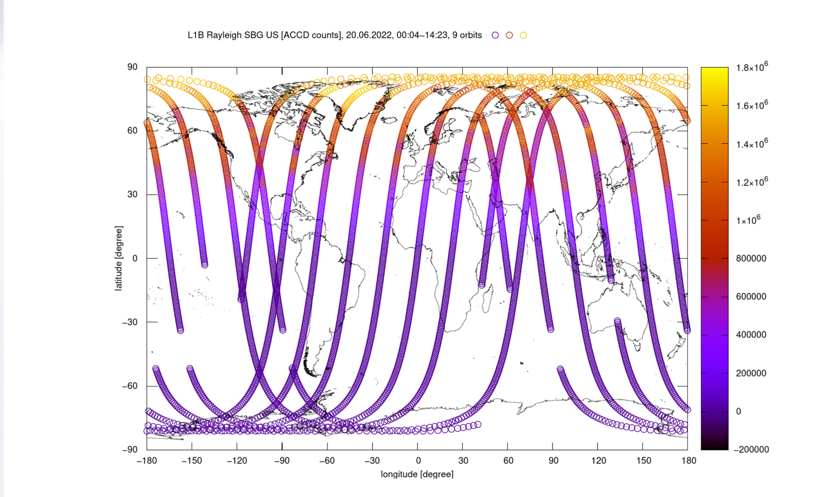
The first two periods are characterized by a decreasing signal level, in general. In the last period, the signal level is relatively constant.

Several special operations and settings changes (see insets) were performed to achieve a larger atmospheric signal gain, in particular in the first two periods. The largest signal level has been obtained after the switch from FM-A to FM-B in July 2019 (signal increase by about 77% at 10km, and 78% at 15km). The mean signal level at the end of operations on 30.04.2023 is at about 70% (10km, green line) and 67% (15km, red line), respectively, of the FM-B maximum signal level in July 2019.

15km mean altitude

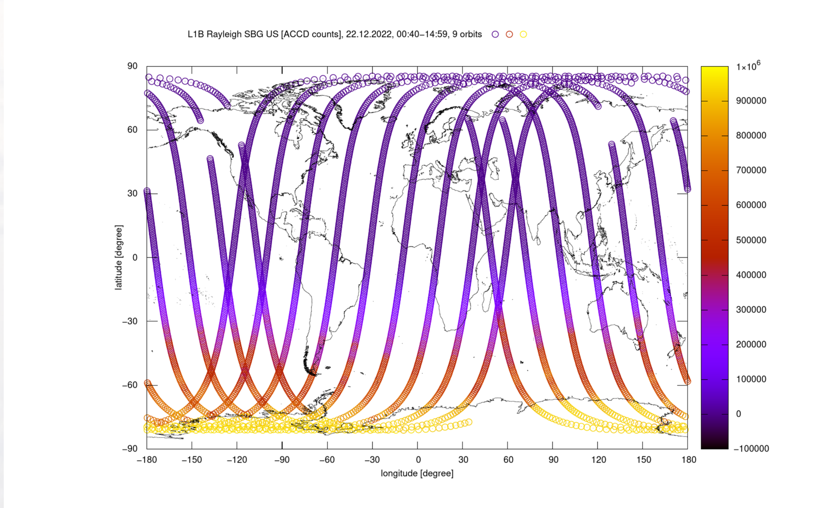


L1B Rayleigh Useful Signals for Solar Background during the Primary and Secondary Maximum in 2022



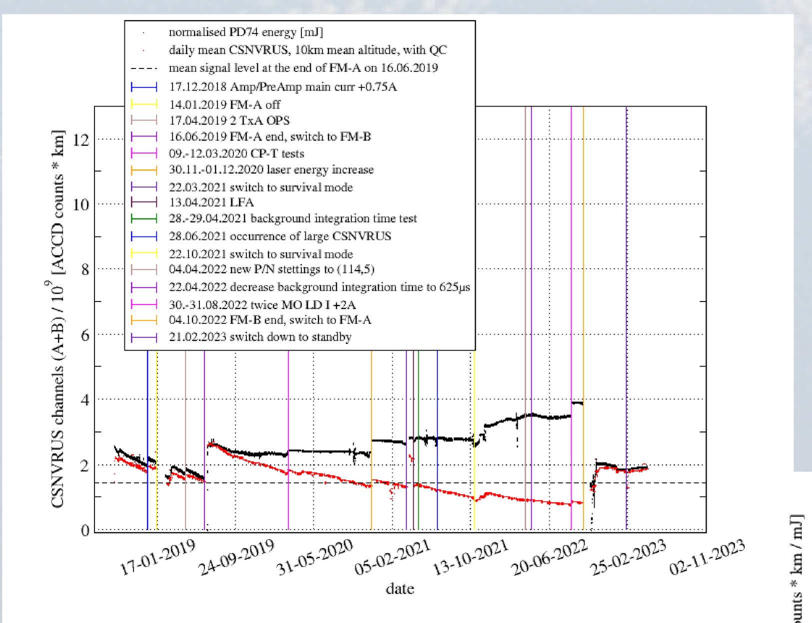
20.06.2022

Aeolus measured the largest L1B Rayleigh SBG signals of about 1.6E6 ACCD counts during the primary SBG maximum (20.06.2022) in the Arctic (upper figure). During the secondary maximum (22.12.2022), the largest Rayleigh SBG signals of about 0.9E6 ACCD counts were obtained in the Antarctic (lower figure). This signal level is smaller than that one in the Arctic during the primary maximum (compare the scales of the color bars). The same holds for the Mie SBG signals.



22.12.2022

Evolution of L1B Rayleigh Useful Signals for Clear Sky Conditions at 10km Mean Altitude and UV Laser Energy in 03.09.2018 – 30.04.2023

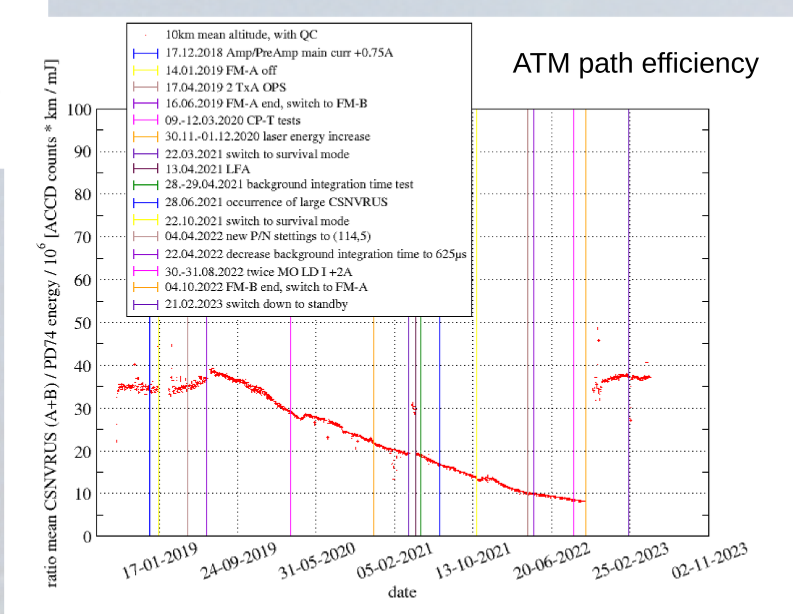


During the first FM-A period from September 2018 through June 2019, the atmospheric Rayleigh signals followed mainly the emitted laser energy. Their ratio (ATM path efficiency) is, in particular, nearly constant in the beginning of FM-A. Thus the atmospheric signal loss was mainly a consequence of the decreasing laser energy.

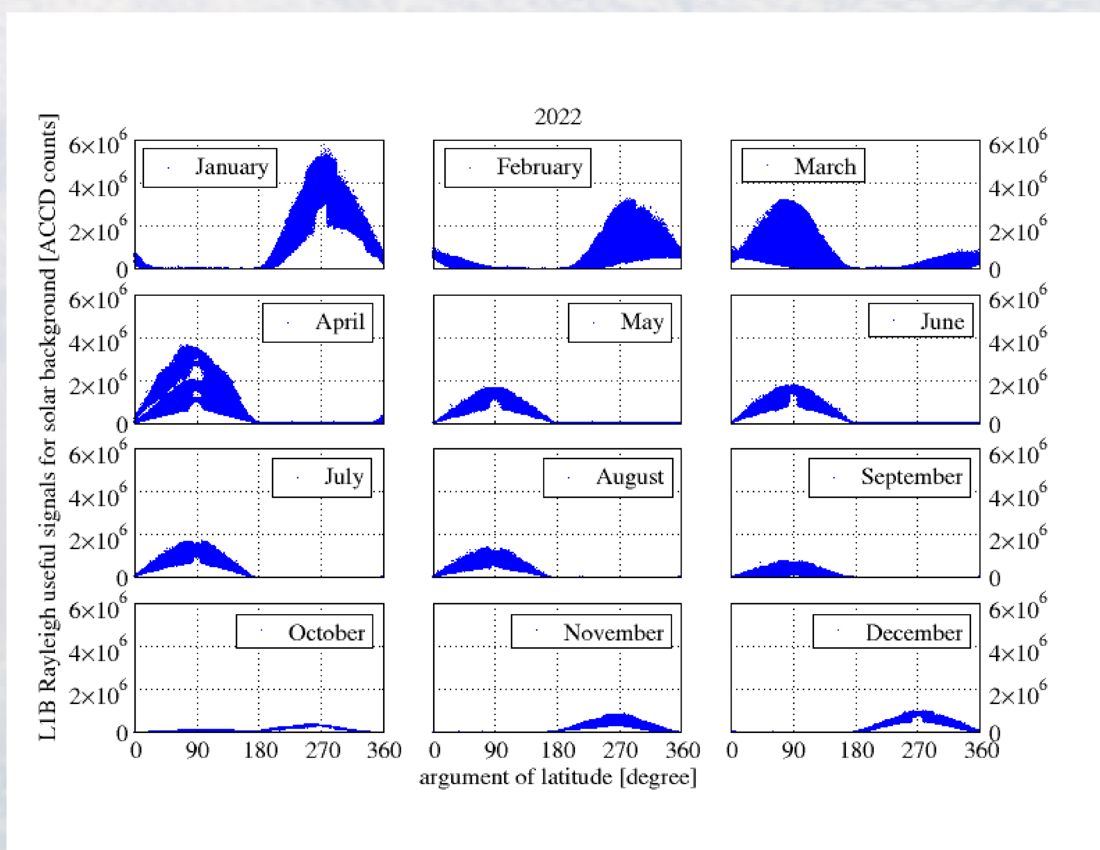
A large efficiency over a longer time has been achieved in the second FM-A period from November 2022 through April 2023. Its relative constancy shows that the atmospheric Rayleigh signals followed also here the laser energy.

After a thermalization phase of the FM-B laser in summer 2019, its output energy was stable over more than three years of operations. Moreover, several measures to increase the laser energy output have succeeded. The atmospheric Rayleigh signals, however, decreased at a nearly constant rate of -1% per week, resulting in a decreasing efficiency. The most likely cause for this was damage in a few optical elements which are only present in the optical path for the FM-B laser

ATM path efficiency



Evolution of L1B Rayleigh Useful Signals for Solar Background with Respect to the Argument of Latitude in 2022



The L1B Rayleigh (and Mie) SBG signals are maximal in the North Pole region during the primary maximum in June. They are maximal in the South Pole region during the secondaty maximum in December. During the yearly minima in March and October, the measured SBG maximum passes the equator (argument of latitude: 0° - equator, 90° - North Pole, 180° - equator, 270° - South Pole, 360° - equator).

The stepwise decrease of the background integration time from 3750µs via 1250µs to 625µs in April 2022 to avoid background pixel saturation is seen as decreasing signals. The signal levels of the following months (May – December) are correspondingly lower.

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Institut für Methodik der Fernerkundung

http://www.dlr.de/eoc

15.05.2023