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DOCUMENT

Aeolus

Scientific Calibration and Validation Requirements

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1 INTRODUCTION AND OBJECTIVES

The mission objective of Aeolus [R2] is to provide global observations of wind profiles with a vertical resolution satisfying requirements of the World Meteorological Organisation (WMO), as described in detail in the Mission Requirements Document [A2]. Accurate global wind profiles will eliminate one of the main deficiencies in the Global Observing System (GOS) [R28]. The Aeolus mission will demonstrate the impact of these data on operational weather forecasting and on climate research [R3]. It can be considered a prototype for future operational wind satellites. Secondary data products are profiles of atmospheric optical properties such as cloud parameters (e.g. scene classification (cloud vs. no cloud), cloud top height, optical thickness, structure (if semi-transparent)) and aerosol backscatter and extinction coefficient profiles.

Aeolus shall measure wind profiles with an accuracy of 1 m/s in the PBL (0-2 km), 2-3 m/s in the free troposphere and around the tropopause (2-16 km) and 3 m/s in the lower stratosphere (16-30 km) [A2]. The precision and accuracy of the wind products is amongst others dependent on the instrument stability, instrument calibration, algorithm performance, auxiliary data, atmospheric scene, geographical region observed as outlined in [A1]. It is, furthermore, also dependent on a proper atmospheric scene classification, which will be done through the use of an appropriate algorithm for cloud and aerosol retrieval and through quality control [R4]. An overview of the Aeolus scientific validation needs is given in [R2].

The objective of this document is to define the scientific calibration and validation requirements for the Aeolus mission phases E1 (commissioning phase) and E2 (operational phase). It shall, furthermore, provide guidelines for the selection process of the Phase E1 and E2 CAL/VAL Announcement of Opportunity (AO) proposals. The scientific objectives that need to be addressed by CAL/VAL activities are listed in this document to identify areas that have not been covered to a satisfactory extent at the end of the CAL/VAL proposal review process. Recommendations shall be made either to adapt CAL/VAL proposals or to initiate additional validation activities. The proposal review shall identify whether the proposed validation techniques are appropriate for the purpose of validation of the space-based data products. The major part of these guidelines will also be applicable to the planning and selection process for potential routine CAL/VAL activities during Phase E1 and E2 performed in the frame of the ESA Aeolus data Quality control and campaign activities.

The statistical methods for establishing the product accuracies (focusing primarily on the L2A and L2B products, but also assessing the L1B product) during Phase E1 and E2 shall be outlined in this document together with specific instrumentation and model needs. L2C product, which is the ECMWF model winds at the location of the Aeolus observations, after assimilation of Aeolus observations, may also be validated through comparison with in-situ measurements. However, in order to assess the impact of Aeolus observations on the forecast, Observing System Experiments (OSE, e.g. including a reference run, a run adding Aeolus observations to the assimilation, and a run with radiosonde data denial) would be needed.

Below, the document has been divided into the following sections: Chapter 6: Wind profile validation, Chapter 7: Validation of cloud and aerosol products, Chapter 8: Other products, Chapter 9: Needs for dedicated campaigns, Chapter 10: Conclusions.

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2 DOCUMENTS

2.1 Applicable documents

	Document	Issue	Title
[A1]	EOP-SM/2945/AGS-ags	1.0	Aeolus Scientific Calibration and Validation Implementation Plan
[A2]	AE-RP-ESA-SY-001	2.0	ADM-Aeolus Project Mission Requirements Document for Phases B, C/D, E1
[A3]	AE-RS-ESA-SY-001	3.1	ADM-Aeolus System Requirements Document

2.2 Reference documents

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[R4] ADM-Aeolus Level-2B Algorithm Theoretical Baseline Document (Mathematical Description of the Aeolus L2B Processor), *AE-TN-ECMWF-L2P-0023*, v3.2. Available on https://earth.esa.int/aos/AeolusCalVal.

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[R6] Mission Operations Concept Document, *AE-TN-ESA-GS-006*, v1.0.

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[R16] Horanyi, A., et al. (2013) Impact of Aeolus Continuous Mode Operation on Numerical Weather Prediction, Document Reference AE-TN-ECMWF-Impact-Study-005, Issue 2.1. Final Report of ESA contract 4000104080. Available from ESA.

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[R28] World Meteorological Organisation (WMO), 2004: Proceedings of the 'Third WMO Workshop on the Impact of various observing systems on Numerical Weather Prediction', WMO/TD No. 1228, pp 329.

[R29] Chanin, M. L., A. Garnier, A. Hauchecorne, J. Porteneuve, 1989, A Doppler lidar for measuring winds in the middle atmosphere, Geophysical Research Letters, Volume 16, Issue 11, https://doi.org/10.1029/GL016i011p01273.

[R30] ADM-Aeolus Algorithm Theoretical Basis Document (ATBD) Level 1B Products, Document reference AE-RP-DLR-L1B-001, issue 4.4, available on https://earth.esa.int/aos/AeolusCalVal

3 LIST OF ACRONYMS AND ABBREVIATIONS

A2D	ALADIN Airborne Demonstrator
ADM-Aeolus	Atmospheric Dynamics Mission - Aeolus
AERONET	AErosol RObotic NETwork
AMV	Atmospheric Motion Vectors
AO	Announcement of Opportunity
ASCVT	Aeolus Scientific Calibration and Validation Team
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CAL/VAL	Calibration and Validation
Campaigns_DQO-#	Aeolus campaigns Data Quality Objective number #
Campaigns_SO-#	Aeolus campaigns Science Objective number #
Campaigns_PER-#	Campaigns Planning and Execution Requirements number #
CEOS	The Committee on Earth Observation Satellites
CI	Cirrus
CloudSat	Cloud Satellite
DREAM	Dust REgional Atmospheric Model
EARLINET	European Aerosol Research LIdar NETwork
ECMWF	European Centre for Medium-range Weather Forecasts
ESA	European Space Agency
EVDC	ESA Atmospheric Validation Data Centre (https://evdc.esa.int/)
FT	Free Troposphere
GOS	Global Observing System
HBE	Harmonic Bias Estimator
HLOS	Horizontal Line of Sight
HSRL	High Spectral Resolution Lidar
ICA	Iterative Correct Algorithm (part of the Aeolus L2A retrieval)
IRC	Instrument Response Calibration
L1B	Level 1B
L2A	Level 2A
L2B	Level 2B

lidar	Light Detection and Ranging
LITE	Lidar-In-space Technology Experiment
LOS	Line-of-Sight
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MODIS	MODerate resolution Imaging Spectroradiometer
NWP	Numerical Weather Prediction
OD	Optical Depth
OMI	Ozone Monitoring Instrument
OptP	Atmospheric Optical Properties product (L2A)
PBL	Planetary Boundary Layer
PI	Principal Investigator
PREVIEW	PREVention Information and Early Warning
PSC	Polar Stratospheric Cloud
RDB	Range Dependent Bias
RBS	Rayleigh-Brillouin Scattering
S	Stratosphere
SA	Stratospheric Aerosols
SCA	Standard Correct Algorithm (part of the Aeolus L2A retrieval)
SCVR_xxxx-#	Scientific calibration and validation requirement for xxxx product (e.g. wind, OptP), number #
SCVR_xxxx-# CAL/VAL techniques	CAL/VAL Techniques for xxxx product (e.g. wind, OptP) number #
SCVR_xxxx-# communication needs	communication needs for xxxx product (e.g. wind, OptP) number #
SCVR_xxxx-# coordination/planning needs	coordination/planning needs for xxxx product (e.g. wind, OptP) number #
SCVR_xxxx-# proposal evaluation	proposal evaluation for xxxx product (e.g. wind, OptP) number #
TROPOS	Institute for Tropospheric Research
WGCV	Working Group on Calibration and Validation
wind	Wind product (L2B / L2C)
WMO	World meteorological Organisation

w.r.t.	With respect to

4 DEFINITIONS AND CONVENTIONS

4.1 Definitions

In-line with [R1] and [A2], the following definitions are applicable to this document. The first four definitions are based on ISO standard 3534-1 (ISO, 1993).

Accuracy:

The closeness of agreement between a measurement and the accepted reference value. The term accuracy, when applied to a set of measurements, involves a combination of random components and a common systematic error or bias component, and can be expressed as follows:

$$Accuracy = \sqrt{(Precision^2 + Bias^2)} \qquad \text{(Eq. 1)}$$

Bias:

The difference between the expectation of measurements and the accepted reference value. The bias is the total **systematic error**. There may be one or more systematic error components contributing to the bias.

Free Troposphere:

The Earth atmosphere between 2 km above the surface and 16 km. Please note that this definition is specific to this document and not fully in-line with the exact definition of the free troposphere in meteorology (e.g. Wallace and Hobbs, 1977).

Instrument related observation error:

The root of the sum of the observation precision squared and the observation systematic error squared.

Level 0:

Instrument source packet (ISP) data with raw Aladin measurement data, instrument housekeeping data and Aeolus platform housekeeping data, vertical sampling grid information, calibrated housekeeping data and instrument health parameters.

Level 1:

Geolocated measurement data including processed ground echo data, preliminary HLOS wind measurements and observations (zero wind correction applied), viewing geometry & scene geolocation data, and annotation data including processed calibration data, product confidence data and calibrated housekeeping data

Level 2A:

Optical properties profile data, fully processed error information and product confidence data.

Level 2B:

Geo-located consolidated HLOS wind observations, after applying tmospheric corrections to Rayleigh channel data.

Level 2C:

ECMWF forecast model winds on the location of the Aeolus L2B observations after assimilation of Aeolus L2B data, L2B data.

Measurement:

Horizontal average of the atmospheric backscattered signals from a number of laser pulses from a vertical bin. The horizontal averaging laser pulses from Aeolus takes place on-board the spacecraft to reduce the data size before data downlink.

Medium-range forecast:

Forecast for the following 72 to 240 hours, see http://www.wmo.int/pages/prog/www/DPS/GDPS-Supplement5-AppI-4.html

Observation:

In order to achieve sufficient signal-to-noise levels, Aeolus measurements are further horizontally averaged by the on-ground Level 1 and Level 2 data processors within a vertical bin. The resulting product is called an observation. Adjacent observations in the vertical form an observation profile.

Observation profile:

An observation profile is a collection of adjacent observations along the lidar line-of-sight from the surface up to the highest vertical bin.

Observation representativeness error:

When observations are assimilated into numerical weather prediction models, the associated observation error is increased adding the so-called observation representativeness error to the instrument-related error. This is done to compensate for the introduction of an observation with a given geographical representativeness in a discretized numerical representation of the atmosphere by the forecast models. The total associated observation error is mostly defined through the use of statistics, comparing the observations with the model first guess and analysis.

Phase E1:

The satellite, instrument and ground segment commissioning phase. For Aeolus, this is defined as the first 3 months after launch. Within this period the instrument will be switched on and the platform, instrument and ground segment operation and performance is calibrated and/or validated.

Phase E2:

The operational phase of the Aeolus satellite. In this phase, the platform and instrument is assumed to operate in a stable measuring mode. Routine instrument calibration and product validation is performed. Only minor changes to the instrument settings, measurement modes, and algorithm updates are expected.

Planetary Boundary Layer (PBL):

Earth atmosphere between the surface and 2 km above the surface. Please note that this definition is specific to this document, and not fully in-line with the exact definition of the planetary boundary layer in meteorology (e.g. Wallace and Hobbs, 1977).

Precision:

The closeness of agreement between independent test results obtained under stipulated conditions. It depends only on the distribution of the **random errors**. It is computed as the standard deviation of the measurements.

Precision of a lidar observation:

The random part of the wind-speed estimation error. It is defined as the standard deviation of the estimates (σ_{LOS}) (good estimates) falling under the bell shape part of the Probability Density Function (PDF) described below, and is hence the calculated precision after the removal of gross errors.

Probability Density Function (PDF) of a line-of-sight wind speed:

For wind observation by Doppler Wind Lidars in the low-backscatter regime, the number of events (photons) per measurement interval, detected at receiver level, can be close to the number of 'noise' events. The retrieved wind speeds from measurements with a low signal-to-noise ratio (SNR) are less accurate, especially for cases where the noise resembles the measured signal characteristics. A PDF of the Line-Of-Sight wind speed (V_{LOS}) can be estimated by retrieving the wind speed from a synthetic measurement applying the estimated error distribution. The resulting wind speed distribution looks like a cluster of localised good estimates (bell shape) around the defined true mean speed (V_{true}), as shown in Figure 1.

An approximate model of the estimated PDF for any observing system – here with terminology appropriate for Aeolus-type line-of-sight winds – is as follows:

$$PDF(V_{LOS}) = \frac{P_{ge}}{V_S} + \frac{1-P_{ge}}{(2\pi)^{\frac{1}{2}}\sigma_{LOS}} \exp\left[\frac{-(V_{LOS}-V_{true})^2}{2\sigma_{LOS}^{\ 2}}\right] \qquad \text{(Eq. 2)}$$

where σ_{LOS} is the random part of the wind-speed estimated error (precision of a lidar observation), P_{ge} is the probability of gross error of a lidar observation, and V_s is the wind search window (horizontal axis in Figure 1).

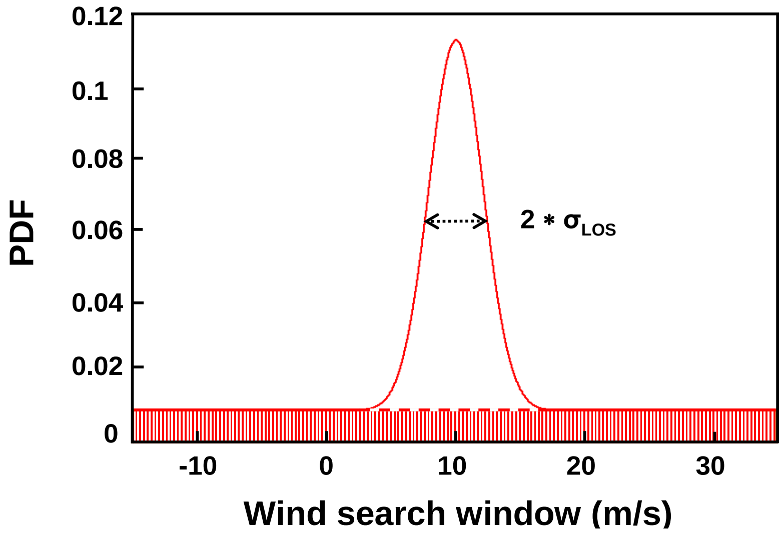


Figure 4-1: *The PDF of wind estimates looks like a cluster of localised good estimates (bell shape) around the true mean speed (here 10 m/s) sitting on a pedestal of uniformly distributed bad estimates (shaded zone), or gross errors, extending over the wind search window. Here the systematic error equals 0. The wind search window is linked to the LOS dynamic range (± 90 m/s).*

Probability of gross error (P_{ge}) of a lidar observation:

The complement to unity of the percentage of estimates (bad estimates) contained in the pedestal of uniform distribution over the 'search window' wind speed range (V_S). This is shown by the shaded area in Figure 1. Estimates outside the search window should always be considered 'bad' and thus rejected. It is expected that the on-ground data processing will be able to remove most gross-errors through quality control (QC). The requirement in this document refers to the maximum amount of gross errors not being detected by the data processing and QC.

Short-range forecast:

Forecast for the following 12 – 72 hours (see http://www.wmo.int/pages/prog/www/DPS/GDPS-Supplement5-AppI-4.html

Stratosphere:

The Earth atmosphere between about 10 and 50 km. Please note that this definition is specific to this document and not fully in-line with the exact definition of the range of the stratosphere in meteorology (e.g. Wallace and Hobbs, 1977).

Systematic error of a lidar observation:

Originated from the instrument and platform characterization, calibration and data processing. In the case of Aeolus, this will include **biases** due to undetected/uncorrected instrument misalignments, platform miss-pointing and errors in the instrument response calibration.

Trueness:

The closeness of agreement between the average value obtained from a large series of measurements and an accepted reference value. The measure of trueness is in the document expressed in terms of bias.

Vertical bin:

The return signal from an emitted laser pulse can be averaged over time on the detector, resulting in an atmospheric return signal representative of an atmospheric layer with a thickness equal to the speed of light divided on the averaging time.

4.2 Conventions

Scientific CAL/VAL requirements have been defined for the Aeolus wind, atmospheric optical properties (aerosol and cloud), and other products according to the following definitions:

- **SCVR_wind-#:** Scientific calibration and validation requirement for wind, number #
- **SCVR_OptP-#:** Scientific calibration and validation requirement for atmospheric optical properties, number #
- **SCVR_xxx-#:** Scientific calibration and validation requirement for xxx product (new products to be developed in phase E2), number #

In addition to the requirements, associated

- CAL/VAL Techniques (**SCVR_wind-# CAL/VAL techniques**),
- communication needs (**SCVR_wind-# communication needs**),
- coordination/planning needs (**SCVR_wind-# coordination/planning needs**)
- proposal evaluation (**SCVR_wind-# proposal evaluation**)

are listed.

Campaigns objectives and requirements are identified and numbered as follows:

- Aeolus campaigns Data Quality Objective number # (**Campaigns_DQO-#**)
- Aeolus campaigns Science Objective number # (**Campaigns_SO-#**)
- Campaigns Planning and Execution Requirements number # (**Campaigns_PER-#**)

5 MISSION AND PRODUCT DESCRIPTION

A detailed instrument description is provided in the Aeolus Science Report [R2]. A short summary of the main instrument features is provided here.
The Aeolus satellite (Figure 5-1) carries a single instrument – a Doppler wind lidar called Aladin (Figure 5-2). This sophisticated instrument is designed to probe the lowermost 30 km of the atmosphere to provide profiles of wind, aerosols and clouds along the satellite's orbital path (Figure 5-3). Comprising a powerful laser, a large telescope and a very sensitive receiver, Aladin is the first wind lidar in space.

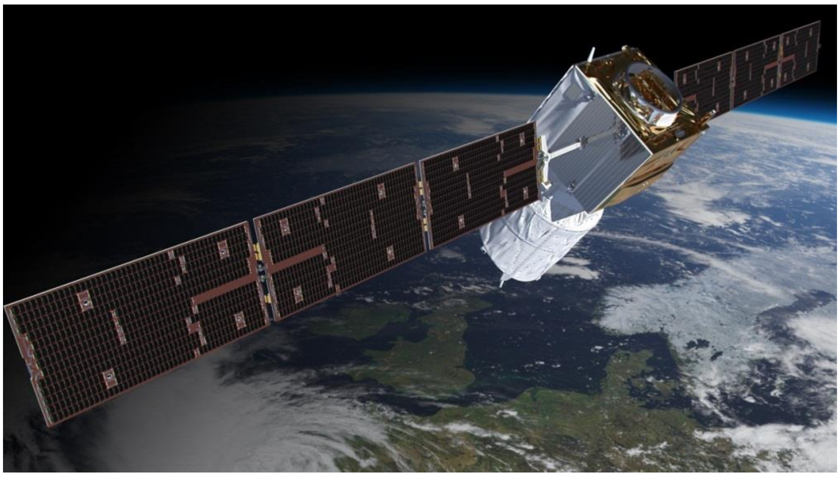
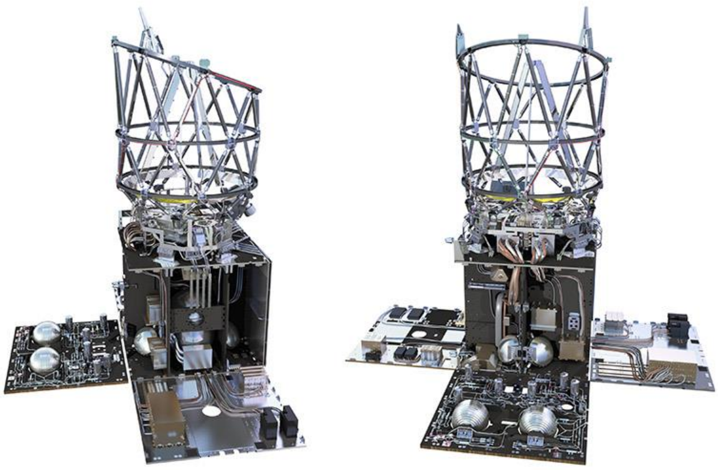


Figure 5-1: An artists' view of the Aeolus satellite in-flight, illustrating the dusk-dawn orbit configuration



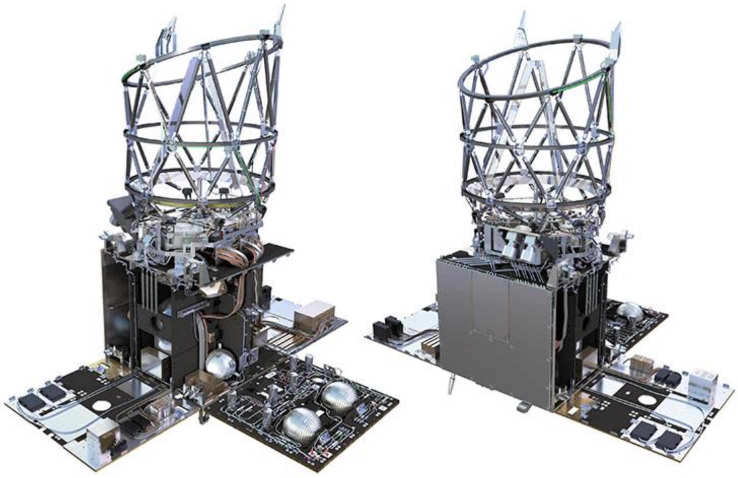


Figure 5-2: An “emploded” view of the Aeolus platform revealing the satellite interior from 4 different angles. Three of the four platform side panels are flipped down to display the platform interior. The telescope baffle (on top) is shown without its MLI and Kevlar wrappings. The Aladin instrument is situated on top of the satellite bus, directly behind the primary telescope. The upright side panel is the passive cooler.

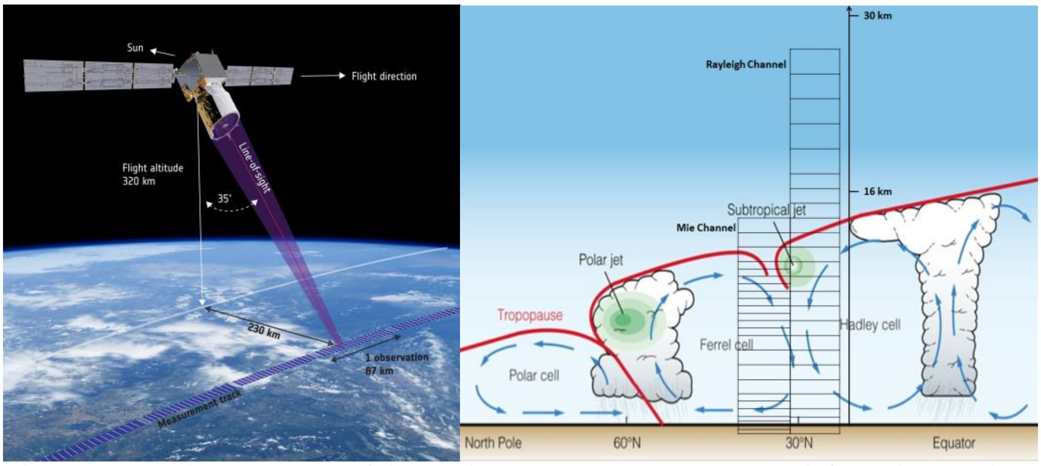


Figure 5-3: Schematic view of the Aeolus measurement geometry (left) and example vertical sampling by its molecular (Rayleigh) and particle (Mie) channels (right).

The laser system emits short powerful pulses of ultraviolet light down into the atmosphere (Figure 5-4, left panel). The telescope collects the light that is backscattered from air molecules (Rayleigh scattering), aerosol particles and hydrometeors (Mie scattering). The Mie backscattered signal is frequency narrow (Figure 5.4, right panel) and is detected by a Fizeau spectrometer receiver assembly. The frequency broadened Rayleigh backscattered signal (Figure 5.4, right panel) is detected by a double-edge Fabry-Perot interferometer receiver assembly [R 29]. The receiver analyses the Doppler shift of the backscattered signal to determine the wind speed at various altitudes below the satellite.

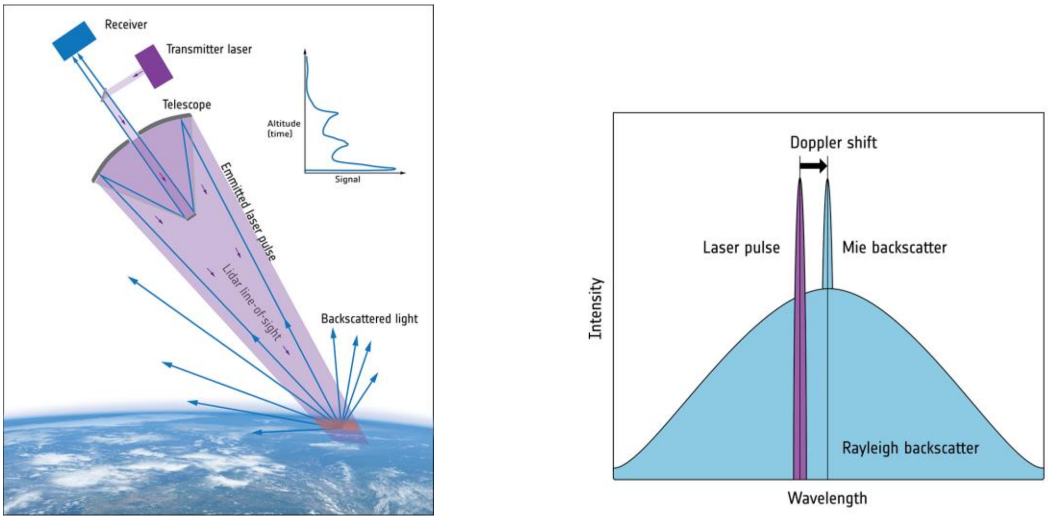


Figure 5-4: The Aladin measurement principle. Wind and atmospheric optical properties profile measurements are derived from the Doppler shifted signals that are backscattered along the lidar line-of-sight (LOS).

The satellite is flying at approximately 320 km altitude in a polar dawn-dusk orbit with an equatorial crossing time of the orbit descending node of 6 AM. The number of orbits per day is about 15, and the orbit repeat cycle is weekly, covering 111 orbits. The satellite track coverage in approximately 24 hours is illustrated in Figure 5-5.

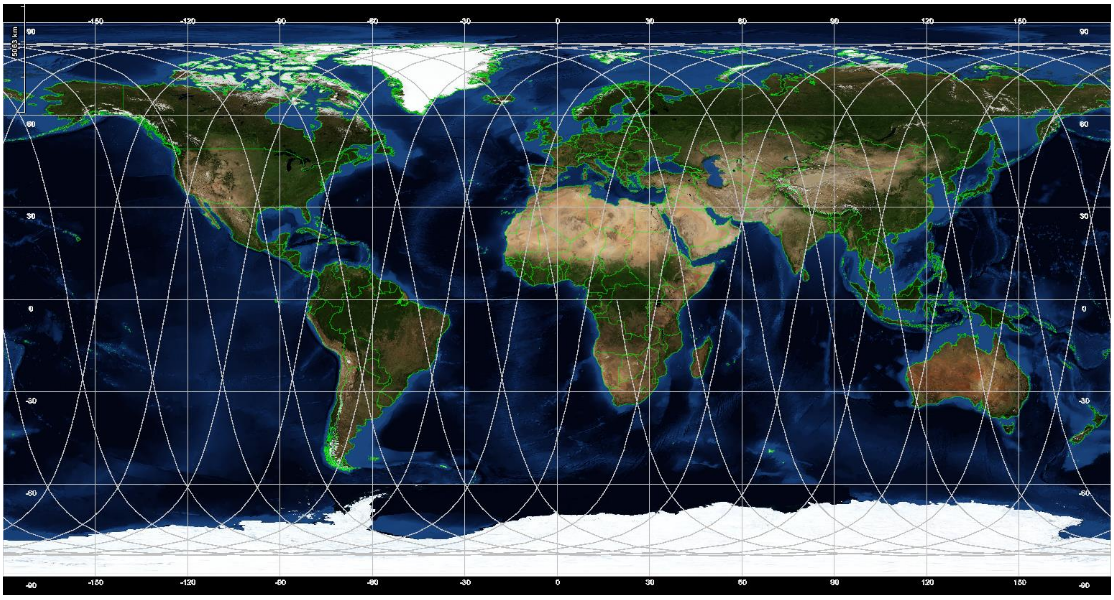


Figure 5-5: Illustration of Aeolus ground track coverage in approximately 24 hours. The number of orbits per day is approximately 16 and the orbit repeat cycle is 7 days. The actual longitudinal position of the ground tracks will be known after launch and can be optimized in-flight.

As explained in [R30], the Aladin instrument is operated in six different modes, as summarized in Table 5-1. Besides the nominal Wind Velocity Measurement (WVM) mode, five calibration, characterisation and health-check modes are implemented.

Table 5-1: Aladin Instrument operation modes. For an explanation of acronyms, see chapter 2.5.

Instrument Operation	Acronym	Purpose	Transmitter frequency (range/step)	Processed data
Instrument Spectral Registration	ISR	To centre laser transmitter frequency	[-5.5, +5.5 GHz] Step 25 MHz	Internal
Instrument Auto test	IAT	To verify Mie/Rayleigh receiver spectral transfer functions	[-5.0, -0.75 GHz] And [0.75, 5.0 GHz] With 250 MHz steps [-0.75, +0.75 GHz] with 25 MHz steps	Internal
Dark Current Calibration	DCC	to characterise detection chain in darkness	fixed	Internal
Instrument Defocus Characterization	IDC	to characterise defocus or optics by measuring Rayleigh spot size	fixed	External on RSP
Instrument (Mie, Rayleigh) Response Calibration	IRC MRC RRC	To measure MSP and RSP response with satellite in nadir, including centring of frequency	[-0.5, +0.5 GHz] Step 25 MHz	Internal and ground return on MSP and RSP, and atmosphere on RSP
Wind Velocity Measurement	WVM	nominal wind measurement mode	fixed	Internal and atmosphere and ground return on MSP and RSP

5.1 Aeolus Data Processing steps and Product Description

The Aeolus products and how they are derived are described in the product Algorithm Theoretical Basis Documents (ATBDs) [R4], [R24], [R30]. The main data processing steps for the Aeolus wind and aerosol products is illustrated in Figure 5.1-1.

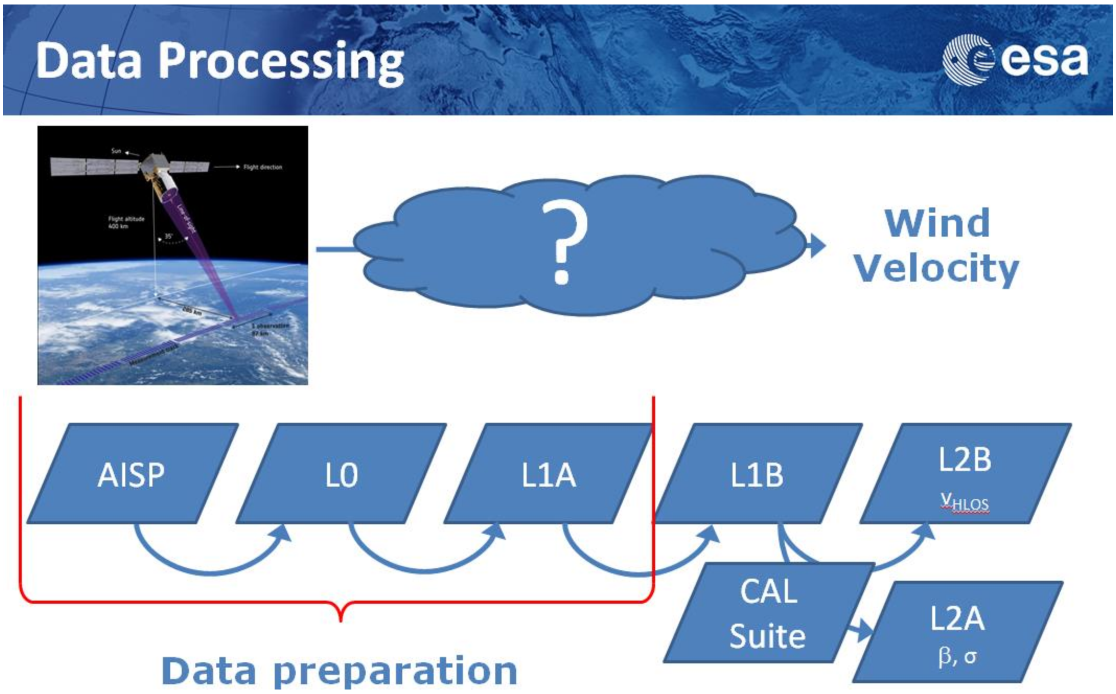


Figure 5.1-1: Schematic overview of the Aeolus data processing steps. Courtesy: T. Kanitz.

The main product from Aeolus will be horizontally projected line-of-sight (HLOS) wind observation profiles (approximately zonally oriented) from the surface up to about 30 km. The product levels and individual products are described in the product Input Output Data Definition documents (IODDs) ([R20]-[R22]) and an overview is provided in Table 5.1-1.

Product/ Data Set	Contents	Approx. Size [Mbytes/ orbit]	Remarks
AISP ("Raw Data")	**Header Data** FH **Measurement data** Instrument source packet data with raw Aladin measurement data and platform housekeeping/AOCS data (CDMU)	50	Actual sensing period will typically cover 1 orbit but may vary in the range ~ 0.5 ... 1.5 orbits, depending on actual X-band downlink scenario

Product/ Data Set	Contents	Approx. Size [Mbytes/ orbit]	Remarks
Level 0	**Header Data** FH, VH (MPH + SPH) **Measurement data** Instrument source packet (ISP) data with - Raw Aladin measurement data (DEU output) - Instrument housekeeping data (ACDM) - Aeolus platform housekeeping/AOCS data (CDMU) **Annotation data** - Vertical sampling grid information - Calibrated housekeeping data (ACDM + CDMU) - Instrument health parameters	55	
Level 1A	**Header Data** FH, VH (MPH + SPH) **Measurement data** - Reconstructed Aladin measurement data (DEU output data, no processing performed) - Pre-processed AOCS and orbit geometry data **Annotation data** - Vertical sampling grid information - Calibrated housekeeping data (ACDM + CDMU) - Instrument health parameters	70	

Product/ Data Set	Contents	Approx. Size [Mbytes/ orbit]	Remarks
Level 1B	**Header Data** FH, VH (MPH + SPH) **Measurement data** - Processed ground echo data - Preliminary HLOS wind observations with calibrations applied (zero wind correction, receiver response calibration, harmonic and range dependent bias corrections) - Viewing geometry & scene geolocation data **Annotation data** - Processed calibration data - Product confidence data (PCD) - Calibrated housekeeping data (ACDM+CDMU)	90	Preliminary HLOS data for Rayleigh channel based on standard (default) atmospheric corrections
Level 2A	**Header Data** FH, VH (MPH + SPH) **Measurement data** - Geo-located consolidated backscatter and extinction profiles, backscatter-to-extinction (BER) ratio per observation - Scene classified backscatter, extinction and BER profiles - Error information **Annotation data** - Product confidence data (PCD) - Others	20	
Level 2B	**Header Data** FH, VH (MPH + SPH) **Measurement data** - Geo-located consolidated HLOS wind observations, after applying actual atmospheric corrections to Rayleigh channel data - Error information **Annotation data** - Product confidence data (PCD) - Others	22	

Product/ Data Set	Contents	Approx. Size [Mbytes/ orbit]	Remarks
Level 2C	**Header Data** FH, VH (MPH + SPH) **Measurement data** - Vertical profiles of wind vectors (horizontal components, u and v) - Supplementary geophysical parameters - Fully processed error information **Annotation data** - NWP model settings - Definition of non-Aeolus model input data - Product confidence data (PCD) - Others	25	Aeolus assisted wind fields, resulting from NWP assimilation processing. Data co-located in time and space with Aeolus wind observations
Higher level data products	No processing, dissemination of higher level data products by the PDGS envisaged	-/-	
Auxiliary data	**Header Data** FH, VH (MPH + SPH) **Data blocks** - Instrument characterisation data (AUX_CHAR) - Miss-pointing / geometry correction data (AUX_HBE, AUX_RDB) - In-flight calibration data (AUX_RRC, AUX_MRC, AUX_HBE, AUX_CAL, AUX_RBC, …) - Algorithm configuration parameters, settings (AUX_PAR) - Information on atmospheric state (e.g. pressure, temperature, humidity etc. from a forecast model) (AUX_MET) and an atmospheric backscatter-to-extinction ratio climatology (AUX_CLM) - Validation thresholds / templates - Others	40	Examples of Aeolus auxiliary files: AUX_PAR_1B AUX_PAR_2A AUX_PAR_2B AUX_PAR_CL AUX_RRC_1B AUX_MRC_1B AUX_HBE_1B AUX_RDB_1B AUX_MET_12 AUX_RBC_L2 AUX_CAL_L2 AUX_CLM_L2 For further details, see section 4.3.6 below

Table 5.1-1: Aeolus data products and product levels. For an explanation of acronyms and abbreviations, see chapter 3.

5.1.1 Data down-link and data preparation (L0 and L2A)

The data that is sent from the satellite to the ground station in Svalbard is called Annotated Instrument Source Packets (AISP). These "raw data" contain instrument, platform, orbit and measurement related information. The scientific data contains the averaged detector signal from each altitude bin together with information on the frequency of the individual outgoing laser pulses. In addition, instrument calibration data (mainly spectral calibration) will be obtained from on-board calibration measurements. These calibration data will be used on ground for the L1B processing. The atmospheric returns from individual laser pulses (shots) are averaged on-board the spacecraft to a so-called measurement. The current instrument baseline is a measurement size of 3 km (average over 0.4 s or 20 shots). The instrument also measures the laser frequency for every laser shot via the so-called "instrument internal path" (internal reference). These measurements are not averaged on-board.

The AISP is further processed to Level 0 (L0) and to Level 1A (L1A) at the Aeolus Processing Facility (APF) in Tromsø, Norway. This processing is in preparation of the Level 1B (L1B) processing, and consists of "cleaning" and time-ordering of the raw data (L0), and measurement geo-location and full processing of satellite house-keeping data (L1A).

5.1.2 Data processing to Level 1B

At the APF the further L1B processing results in the L1B data product, which contains preliminary horizontally projected line-of-sight (HLOS) winds, processed calibration files (including instrument characterization, instrument settings and calibration processor output), product confidence data (e.g. random and systematic errors and product quality flags), and Mie and Rayleigh useful signal profiles. The Aeolus L1B product is calibrated using information on instrument offsets, atmospheric background and the instrument responses in both channels. The data are further corrected with information on the satellite pointing both from the satellite attitude information and through the use of a so-called Harmonic Bias Estimator. The Harmonic Bias Estimator collects valid ground returns over a number of orbits to characterize the instrument pointing, altitude and thermal effects as a function of orbit position. The output of this tool is used to correct the retrieved wind Doppler shifts for these effects. Also, range-dependent errors in the instrument responses are corrected by a range-dependent bias correction algorithm after a dedicated instrument characterization observation campaign.

5.1.3 Dedicated calibration for Level 2 retrieval (CAL Suite)

A dedicated chain of calibration processors for the further Level 2A (L2A) and Level 2B (L2B) processing (the so-called Calibration Suite) is run in the Aeolus Calibration and Monitoring Facility (ACMF) in ESA-ESRIN. The Calibration Suite produces auxiliary data files used in the L2 processing described in the sections below.

One of the files produced by the Calibration Suite allows for a Rayleigh-Brillouin scattering correction of the atmospheric backscatter. The monochromatic Aladin emitted laser light that is backscattered by molecules undergoes a frequency broadening which is both temperature (Rayleigh) and pressure (Brillouin) dependent. The atmospheric temperature and pressure along the lidar line-of-sight is in general unknown during the time of the L1B processing. Thus the output from the molecular channel will be given for a standard temperature and pressure profile. This simplification is corrected during the Level 2 processing, making use of NWP 6-h forecast information (AUX_MET, see section 5.1.6 below) on the local temperature and pressure throughout the measurement volume. The effectiveness of the correction is strongly dependent on the provision of a well-characterized instrument spectral response. The Calibration Suite prepares a look-up table for the instrument Rayleigh responses as a function of atmospheric temperature and pressure (AUX_RBC, see section 5.1.6 below).

The Calibration Suite further calculates instrument performance information (transmissions and calibration coefficients), which is used in the L2A processing. This information is stored in the AUX_CAL file (see section 5.1.6 below).

5.1.4 Data processing to Level 2B and Level 2C (wind products)

The L1B product is then further processed to

- Level 2B (L2B), pressure and temperature corrected HLOS wind profile product, and
- Level 2C (L2C), ECMWF forecast model wind profiles at the Aeolus observation location after assimilation of Aeolus Level 2B wind,

at the European Centre for Medium-Range Weather Forecasts (ECMWF). The L2B and L2C are the primary data products from Aeolus.

The main L2B processing steps concern the correction of the Rayleigh wind processing for atmospheric temperature and pressure broadening effects (using the so-called AUX_RBC look-up table). This is done using a priori temperature and pressure information, collocated to the wind observations, from the weather forecast model (AUX_MET). Particle (aerosols or hydrometeors) detection is performed using the so-called scattering ratio provided by the L1B processing (called scene classification). The wind observations are then classified into cloudy and cloud free, as illustrated in Figure 5.1.4-1. Finally, the data are averaged to form a representation of the actual wind observation over the 87 km long pixels (illustrated for Rayleigh winds in Figure 5.1.4-2). The processor also performs L1B and L2B data quality control and estimates error quantifiers.

The Aeolus L2B wind observations are then assimilated in the ECMWF model. The output assimilated winds (zonal and meridional wind component profiles at the location of the L2B wind profiles) are then used to populate the L2C product. The L2C product also contains the L2B winds.

The vertical resolution of the layer-average winds vary from 0.25 to 2 km, and can be adapted as a function of the under-laying topography and/or climate zone. An example of terrain following sampling is clearly visible in the upper panel of Figure 5.1.4-2. The required wind accuracies (a combination of bias and precision, as defined in section 3) are 2 m/s in the planetary boundary layer (PBL), 2-3 m/s in the free troposphere, and 3-5 m/s in the stratosphere. A detailed description of the Aeolus wind retrievals can be found in [R23].

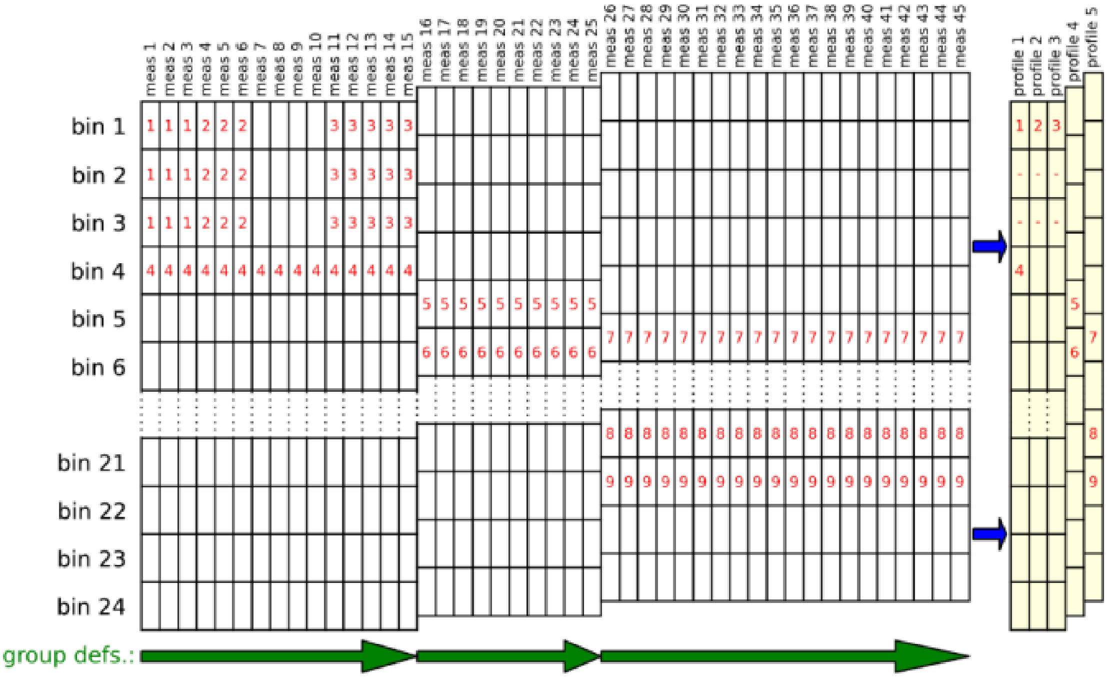


Figure 1.5.4-1: Schematic view of the Aeolus L2B wind observation processing. The numbers indicate different scene classifications (clouds versus no clouds), resulting in a number of wind profiles for an observation. These are partial or full wind profiles for the Rayleigh (cloud free) and Mie (cloud or aerosol layer winds) channels. Courtesy: J. de Kloe (KNMI).

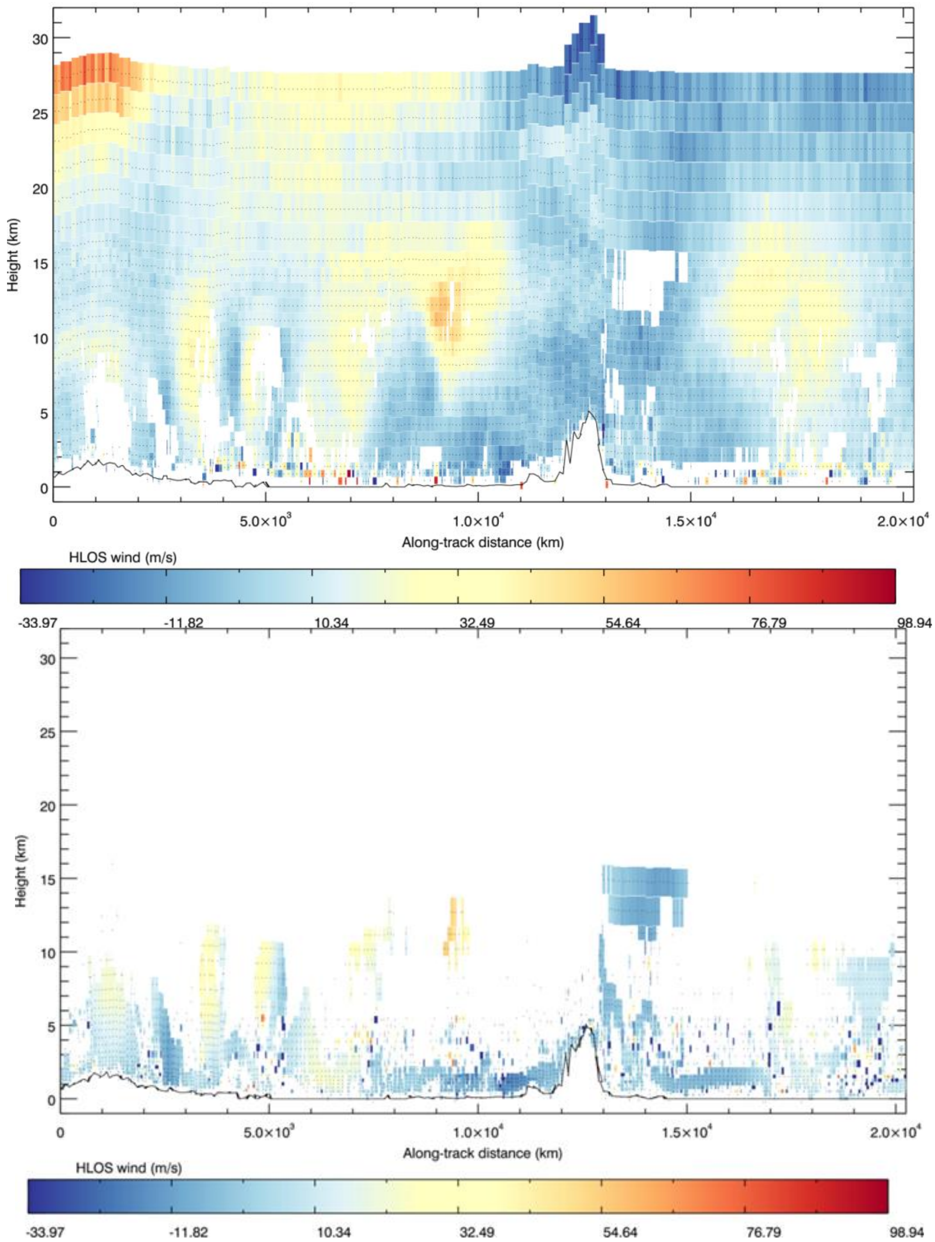


Figure 5.1.4-2: Example of simulated Aeolus L2B Rayleigh clear air wind observations (ms^{-1}) (upper panel) and Mie cloud/aerosol wind observations (ms^{-1}) (lower panel). Courtesy: M. Rennie (ECMWF).

5.1.5 Data processing to Level 2A (atmospheric backscatter and extinction coefficient products)

At the APF, the L1B product is also further processed to Level 2A (atmospheric optical properties product). The Level 2A product is defined as an Aeolus spin-off product.
The L2A product contains height profiles of Mie and Rayleigh co-polarized backscatter and extinction coefficients, scattering ratios and lidar ratios ([R13], [R24]) along the lidar line-of-sight. From this dataset the user can derive cloud and aerosol information such as layer height, multi-layer cloud and aerosol stratification, cloud and aerosol optical depths (integrated light-extinction profiles), and some information on cloud/aerosol type (lidar ratio).

The profiles will be provided both on observation scale (87 km averages) and on smaller scales after applying scene classification. An example of simulated Aeolus backscatter and extinction profiles on observation scale is given in Figure 5.1.5-1.

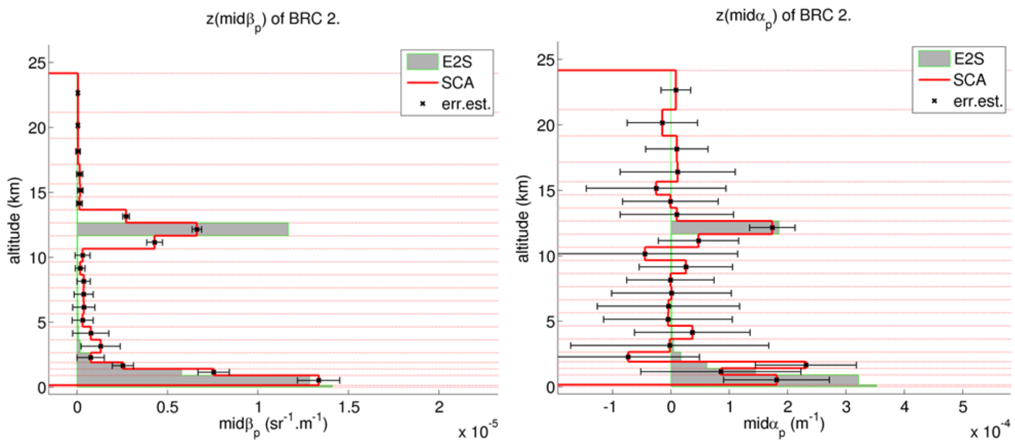


Figure 5.1.5-1: Examples of simulated Aeolus L2A co-polar backscatter (left) and extinction profiles, retrieved from a scene measured by the NASA LITE mission. E2S: The original backscatter profile used to feed the end-to-end simulator, SCA: results from the so-called Standard Correct Algorithm (SCA), Err.est.: Retrieved error estimate. Courtesy: P. Martinet (MeteoFrance).

5.1.6 Auxiliary files

As described in sections 5.1.4 and 5.1.5, the L2A and L2B data processors make further corrections w.r.t.

- instrument transmission, responses and channel crosstalk (AUX_CAL),
- the Rayleigh-Brillouin scattering broadening of the backscattered signal (AUX_RBC) using a priori temperature and pressure information (AUX_MET) and
- a priori lidar ratio information (AUX_CLM).

These corrections require a set of auxiliary files produced by the ECMWF NWP model, a dedicated calibration processor called the Calibration Suite running in the Aeolus Calibration and Monitoring Facility (ACMF) in ESA-ESRIN, and forward model simulations. The Aeolus auxiliary files used during the L2 processing are listed in Table 5.1.6-1.

AUX file name	Generated by	Comment
AUX_PAR_2A	PDGS	Generated with input from Aeolus Algorithm Core Team
AUX_PAR_2B	PDGS/ECMWF	Generated with input from Aeolus Algorithm Core Team
AUX_MET_12	Aeolus AUX_MET processor within the ECMWF Integrated Forecast System (IFT)	Forecasted temperature and pressure information at the (predicted) location of the Aeolus L1B observations. Predicted locations are used in the case of late L1B arrival at the Aeolus L2B processing facility at ECMWF
AUX_RBC_L2	Aeolus AUX_CSR processor at the ACMF	Look-up-table of Rayleigh responses corresponding to atmospheric temperature and pressure combinations
AUX_CAL_L2	Aeolus AUX_CSR processor at the ACMF	Calibration coefficients defining the instrument transmissions for the Mie and Rayleigh channels (K_{Ray}, K_{Mie}) Calibration coefficients defining the atmospheric Mie and Rayleigh backscatter contributions to the measured Rayleigh and Mie signals (C_1, C_2, C_3, C_4) Spectral transmission characteristics of the Fabry-Perot and Fizeau interferometers (T_A, T_B)
AUX_CLM_L2	Forward model simulations performed by Aeolus L2B algorithm team, KNMI	Global map of extinction-to-backscatter ratios based on climatological information

Table 5.1.6-1: Auxiliary files used in the Aeolus L2A and L2B processing together with the L1B product.

5.2 Data downlink, processing and distribution

The raw measurement data is received by the ground stations and submitted to the Aeolus data processing centres. These are located in Tromsø (Norway), Reading (United Kingdom) and Frascati (Italy). Data processing up to L1B is done in Tromsø. Processing up to L2B and L2C is done by ECMWF, and further data monitoring, calibration and the data distribution (all product levels) is done by ESA-ESRIN in Frascati, Italy (see Figure 5.2-1). The Level 2A is being processed in the APF at Tromsø.

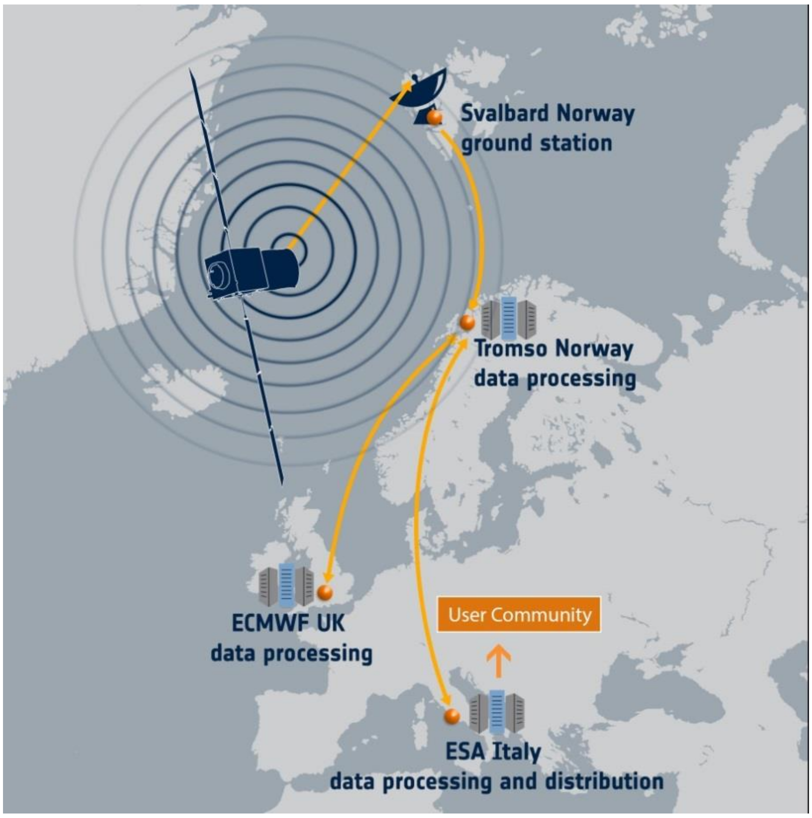


Figure 5.2-1: Illustration of the Aeolus data downlink and data processing facilities

The data are made available to the users via the "ESA Earth Online" web site, http://aeolus-ds.eo.esa.int. The Aeolus data user interface is illustrated in Figure 5.2-2.

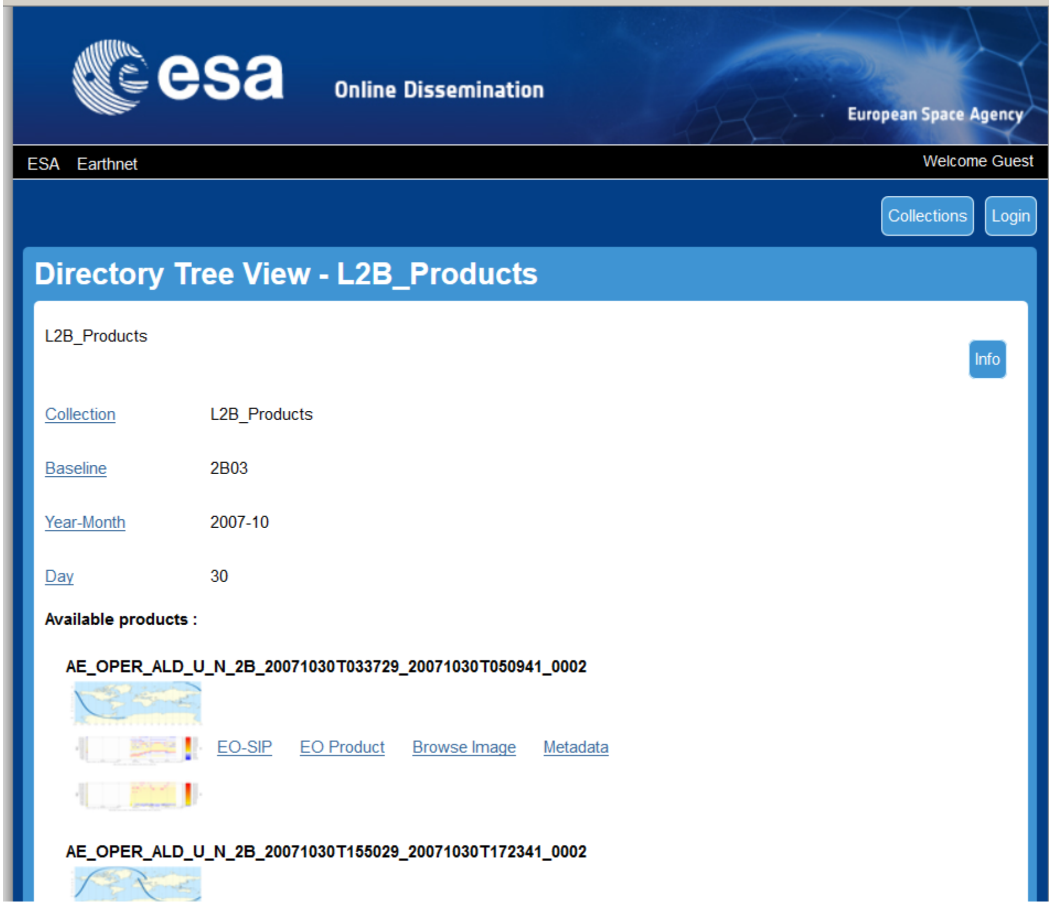


Figure 5.2-2: Illustration of the ESA web site for the ordering of Aeolus data.

6 THE VALIDATION OF AEOLUS WIND PROFILES

6.1 The understanding of the product properties and quality

As described in chapter 5, the L1B (not temperature and pressure corrected) and the L2B temperature and pressure corrected wind profiles are provided at measurement level (3 km averages) as well as per observation (86 km averages) along the Aeolus dawn/dusk orbit. An averaging of the measurements to an observation is necessary in order to achieve the required measurement accuracy.

In the L2B processor, the measurements within 86 km are sorted in cloud/aerosol and cloud/aerosol-free measurements, and these are then averaged over 86 km into Mie (cloud and aerosol backscatter) and Rayleigh (molecular backscatter) wind observations (see chapter 5.4.1).

Note that Rayleigh winds from cloud/aerosol scenes are reported, as well as Mie winds from clear scenes. These two products are of less good quality and should not be used for scientific research without strict quality control.

The vertical profiles are slant (tilted by 35° w.r.t. nadir) as depicted in Figure 5.3. Measurements at/near the surface are thus displaced by about 285 km w.r.t. the satellite ground track (Figure 5.3). The displacement will be either west or east of the ground track, depending on the orbit phase (descending vs. ascending). **The sign of the horizontally projected line of sight winds (negative or positive) will hence vary for a westerly wind depending whether they are sampled in a descending or ascending leg of the orbit.**
The winds will be averaged over layers with a thickness from 250 m (minimum) to 2 km. The vertical sampling may vary along an orbit according to climate zone and topography [R7].

Aeolus product quality is dependent on satellite, instrument and data processing errors. Examples of Aeolus mission related observation errors are:

1. **Instrument errors**
    a. Instrument alignment and transmission
    b. Spectrometer imperfections
    c. Instrument degradation and laser stability
    d. Channel cross-talk
2. **Satellite / orbit related errors**
    a. Harmonic biases from thermal variability
    b. Range dependent biases
    c. Pointing stability (accuracy of AOCS, also impacted by 2a…)
3. **L1 (and lower) processing errors**

   a. Instrument calibration (Rayleigh and Mie response calibration)
   b. Non-corrected instrument and satellite related errors from bullet 1 and 2
   c. Signal processing and product quality control
4. **L2 processing errors**
   a. Accuracy of *a-priori* temperature and pressure (ECMWF model forecast)
   b. Instrument calibration, signal processing and quality control
      1. Mie and Rayleigh channel cross-talk correction
      2. Signal classification
      3. Mie core processing
      4. Rayleigh signal height assignment,
      5. …

Spatially varying errors from bullet 2 above can be further explained as follows:

2.a **Orbit phase dependent wind biases**:

1. **Thermo-elastic** - solar aspect angle (see figure 6.1-1a)
2. **Thermo-elastic** - effects of Earth solar reflected and thermal fluxes (see figure 6.1-1b)
3. **Satellite altitude** (harmonic range-dependent biases) (see figure 6.1-1c)

A Harmonic Bias Estimation (HBE) correction scheme has been implemented using ground returns and error fitting through harmonic functions to remove this during the L1B processing [R26].

2.b **Range-dependent wind bias (RDB)**

1. This bias is caused by varying backscatter angle on telescope as function of range because the satellite is moving along a circular path during the time it takes from the light to scatter back from the atmosphere at different ranges (see Figure 6.1-2).

A range-dependent bias correction scheme has been implemented using ground returns at different ranges from the satellite to characterize and remove this in the L1 and L2 data processing [R26].

Spatially varying errors from bullet 4 above:

4.a **Regional T and p accuracy variations.** During the L2B processing

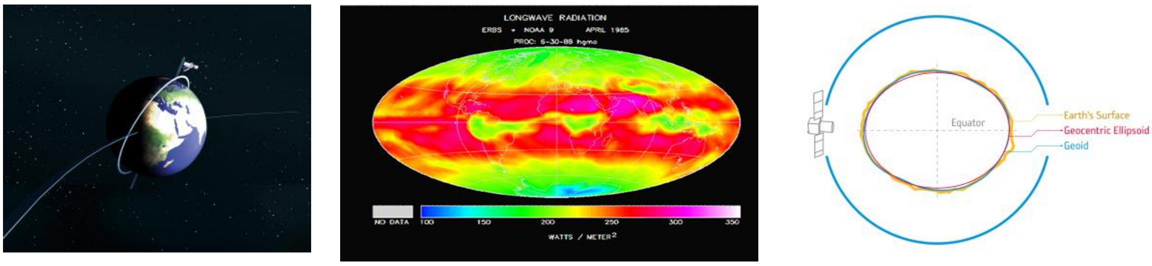


Figure 6.1-1: *a) Illustration of the change in solar aspect angle around the Aeolus orbit, b) Illustration of the varying thermal radiation from the Earth as a function of latitude, c) illustration of the varying altitude of the satellite above the Earth surface along the satellite orbit.*

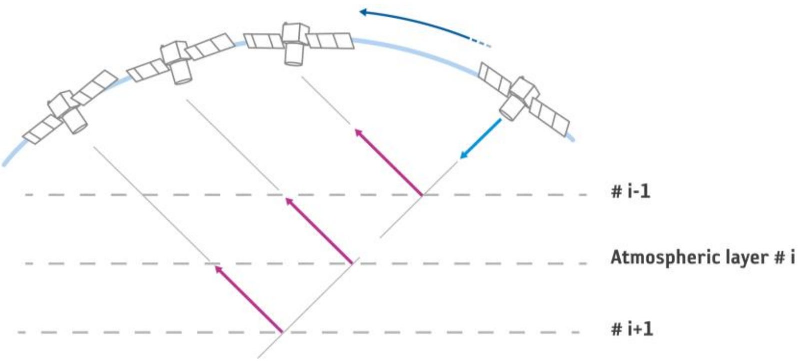


Figure 6.1-2: *Illustration of the varying angle of incidence of the backscattered light from the atmosphere on the Aeolus telescope during flight.*

Aeolus SCVR_wind-0 proposal evaluation:
Aeolus AO proposals shall be evaluate according to whether the product information content and quality are clearly understood and taken into account.

Further related product quality requirements are given in the sections 6.3 below.

6.2 Product Requirements

The Aeolus Mission requirements are listed in [A2], and are summarized in Table 6.2-1. A number of these requirements shall be addressed and evaluated with pass/fail criteria in the Aeolus CAL/VAL work. **The requirements to be addressed by the ASCVT are MR-50, MR-90, MR-95, MR-100, MR-110, MR-120 and MR-130, MR-140 and MR-150**. **ASCVT are also asked to assess the observation coverage according to MR-85, MR-60 and MR-80.**

Requirement ID	Observation Requirements		PBL	Troposphere	Stratosphere
MR-85	Vertical Domain	[km]	0-2	2-16	16-20 (30)*
MR-60	Vertical Resolution	[km]	0.5	1.0	2.0
MR-80	Horizontal Domain		Global		
MR-70	Number of Profiles (sampling)	[hour^{-1}]	>100		
MR-150	Minimum horizontal track data availability	[%]	95		
MR-75	Temporal sampling	[hour]	12		
MR-50	Horizontal observation size (L1 and L2)	[km]	15 (goal) – 100 (threshold)		
MR-50	Horizontal measurement size	[km]	3 km		
MR-110	Precision (HLOS Component, L2)	[m/s]	1	2.5	3* (3-5)*
MR-100	Systematic error (HLOS component, L2)	[m/s]	0.7		
MR-90&95	Dynamic Range, HLOS	[m/s]	±100 (150)**		
MR-120	Error Correlation (per 100 km and between adjacent vertical bins, L2)		< 0.1		
MR-130	Probability of Gross Error (L2)	[%]	5		
MR-140	Timeliness (L1)	[hour]	3		
MR-160	Length of Observation Dataset	[yr]	3		

Table 6.2-1: Observational requirements of the Atmospheric Dynamics Mission Aeolus for a realistic (heterogeneous) atmosphere. ()*: Desirable, (i) atmospheric sampling from the surface up to 20 km altitude is required whereas sampling up to 30 km is highly desirable, (ii) above 16 km there is no formal requirement on the HLOS precision, but a precision of 3 m/s between 16 and 20 km and 3-5 m/s between 20 and 30 km is desirable. ()**:Wind observation performance requirements are linked to a dynamic range of +/-100 m/s, wind observations shall not saturate up to +/-150 m/s.

6.3 Areas deserving special attention by CAL/VAL

6.3.1 Sampling

The relationship between errors in the Aeolus wind measurements and the horizontal and vertical sampling was studied in detail in [R5]. The horizontal and vertical sampling by Aeolus is programmable during flight, and can be reset once per week. The vertical sampling can be programmed to vary up to 8 times along the orbit [R6]. Strategies for the horizontal and vertical sampling will be optimized prior to launch based on global statistics on the occurrence of wind shear in combination with cloud and aerosol layers [R7]. The influence of the alternative sampling scenarios has been evaluated by impact studies focusing on NWP and stratospheric analysis (e.g. [R7-8], [R15-16]). As mentioned above, this can lead to a variable vertical sampling along the orbit. The proposed sampling strategy should be validated during and after the commissioning phase (long-term activity). Dedicated impact studies focusing on the Aeolus sampling strategy are expected to be proposed by science teams during the Aeolus operational phase. In support of this, there is a need to request periods of dedicated Aeolus operations during Phase E1 and E2 for a subset of the proposed vertical sampling scenarios.

Aeolus SCVR_wind-1:
Validation of the vertical sampling strategy to optimize the scientific exploitation or validation technique

Aeolus SCVR_wind-1 CAL/VAL techniques:
1. comparison of Aeolus wind observations with well collocated observations oversampling the Aeolus observations in the horizontal and/or vertical
2. comparison with well-established, verified NWP models providing wind together with quality information
3. comparison of Aeolus wind observations with oversampled collocated observations covering
   3.1. the full vertical range
   3.2. different geographical regions
   3.3. position along orbit
   3.4. all seasons

Aeolus SCVR_wind-1 communication needs:
Communication of vertical sampling strategy and planning (Mission Planning cycle) via Aeolus wiki page

Aeolus SCVR_wind-1 coordination/planning needs:
ESA to perform Mission Planning of vertical bin sampling in wind mode with input from algorithm core team, CAL/VAL teams, campaigns and scientific exploitation studies under ESA contract.

Aeolus SCVR_wind-1 proposal evaluation:

The proposals shall be evaluate whether (i) the AO PIs have understood the vertical sampling strategy and that (ii) the vertical sampling is validated/optimized in corporation with the CAL/VAL core team [A1] and/or by AO CAL/VAL teams.

6.3.2 *Wind quality as a function of atmospheric scene/condition*

As mentioned in chapter 5, the L2B wind profiles will be sorted into categories per observation, e.g. averaging over cloudy and clear measurements separately [R4]. This is the so-called scene classification. Since the winds and aerosol and cloud loadings are varying both vertically and along the orbit as a function of space and time, it is of great importance to **establish the quality of the retrieved Mie and Rayleigh wind products under the various atmospheric conditions.** The a**mount and location of clouds within a height bin, potential vertical motion biases** on top of convective clouds, and the Mie **cross-talk** on the Rayleigh winds (see section 5.1.4) affect the wind velocity estimates (e.g. [R5], [R9]). Furthermore, the quality of the retrieved L2B Rayleigh winds is dependent on the accuracy of the **a-priori temperature and pressure profiles** and, if applied, the accuracy of the a-priori lidar ratio etc. [R9]. The quality of the **applied scene classification** influences the representativity of the retrieved L2B winds. These effects need to be statistically quantified through validation. **This should include not only independent wind observations, but also independent scene classifications** through co-located satellite, air-borne, or ground-based aerosol and cloud observations.

Aeolus SCVR_wind-2:
Aeolus wind profiles must be validated for a full range of atmospheric conditions assessing the impact of algorithm settings. This shall lead to an assessment of the product systematic and random errors as a function of:
1. clear or (partially) cloudy conditions within a measurement and observation
2. location of cloud and aerosol layers within a vertical bin
3. vertical wind shear within a bin
4. vertical wind velocity within the vertical and horizontal averaging space
5. algorithm scene classification technique applied (scattering ratio classification, optical properties code, …)
6. effectiveness of the algorithm channel cross-talk correction applied (aerosol scattering contribution to molecular observations and vice versa)
7. AUX-MET data used for L2B Rayleigh wind retrieval

Aeolus SCVR_wind-2 CAL/VAL techniques:
1. Comparison of Aeolus winds with collocated observations for a wide range of atmospheric conditions
2. Provision of scene classified statistics
3. Comparison with well collocated observations (flight campaigns under-flying the satellite for different conditions and in different geographical areas, well collocated ground-based observations sampling over a long time period)
4. Comparison with (less well) collocated observations over a long time period to produce seasonal and geographical statistics

Aeolus SCVR_wind-2 coordination/planning needs:
The completeness of the activities covering SCVR_wind-2 shall be assessed and gaps identified. Mitigating activities shall be launched to stimulate more or other CAL/VAL activities.

Aeolus SCVR_wind-2 proposal evaluation:
The planned and proposed CAL/VAL activities (including core and AO CAL/VAL activities) shall cover all relevant atmospheric conditions, and the proposed validation techniques shall be appropriate and complete for the validation of measurements of inhomogeneous scenes.

6.3.3 Instrument and atmospheric "artefacts"

Examples of instrument and mission related random and systematic errors sources have been identified in section 6.1. CAL/VAL activities shall aim at validating and quantifying possible systematic errors remaining after the implemented instrument self-calibration mentioned in section 6.1.
Further instrument-related error sources are Mie cross-talk contribution to the retrieved Rayleigh wind products and its correction [R9].

Aeolus SCVR_wind-3:

1. Validation of instrument, platform and processing related systematic and random errors in the L1 and L2 products after calibration and data processing (e.g. quality of IRC, HBE, RDB, AUX_RDB data processing and quality control as listed in section 6.1 of the Aeolus Scientific CAL/VAL Requirements).
2. Validation of the systematic and random errors (L1 and L2) as function of
   - 2.1. Geographical region
   - 2.2. Orbit position
   - 2.3. Altitude
   - 2.4. Time
   - 2.5. Atmospheric scene

Aeolus SCVR_wind-3 CAL/VAL techniques:

1. comparison of Aeolus wind observations with well collocated observations oversampling the Aeolus observations
2. comparison with NWP models with a well-established quality and quality information
3. comparison of Aeolus wind observations with oversampled collocated observations covering
   - 3.1. the full vertical range
   - 3.2. different geographical regions
   - 3.3. all seasons

Aeolus SCVR_wind-3 communication needs:
Communication of the status of the Aeolus product quality (known uncorrected biases, random errors, etc. as reported by the Industry, ESA, the Aeolus algorithm core team or ASCVT) via Aeolus wiki page.

Aeolus SCVR_wind-3 coordination/planning needs:
ESA to perform regular instrument calibration as recommended by industry at the end of phase E1, by the Aeolus algorithm core team, or ASCVT.

Aeolus SCVR_wind-3 proposal evaluation:
Assure that the Aeolus product systematic and random errors are addressed applying appropriate statistical methods, globally and over time by the Aeolus algorithm core team and ASCVT.

6.3.4 Suggestions for the grouping of the validation activities

It is suggested that the proposed validation activities are grouped in order to form smaller validation teams that will exchange comparable validation results on a more frequent basis. This will also facilitate the overall evaluation of the validation results. Below is a list of suggested grouping criteria:

- Vertical extent: Planetary Boundary Layer (PBL), the Free Troposphere (FT), the Stratosphere (S), total column phenomena, etc.
- Geographical region: global, tropics, mid-latitude (e.g. storm-track regions, jet-streams), polar regions, etc.
- Time range: Season, yearly, bi-annual, etc.
- Scientific focus, e.g. atmospheric rivers, jets, fronts, Brewer Dobson Circulation, gravity waves, stratospheric-tropospheric exchange, cloud-dynamics interactions, tropical dynamics, QBO, MJO, El Niño, etc.
- Observation principle and/or platform

Aeolus SCVR_wind-4:
When beneficial, Aeolus CAL/VAL team sub-groups should be established/organized according to CAL/VAL focus (e.g. PBL, free troposphere or stratosphere, Polar CAL/VAL activities, Tropical activities, etc.)

Aeolus SCVR_wind-4 communication needs:
Announcement of Aeolus CAL/VAL teams / groups at the Aeolus wiki page (e.g. Aeolus Polar validation efforts, tropical campaign activities, etc.).

Aeolus SCVR_wind-4 coordination/planning needs:
ESA to identify partners and to coordinate joint Aeolus CAL/VAL campaigns. ESA to stimulate topical CAL/VAL activities.

Aeolus SCVR_wind-4 proposal evaluation:
Recommendations for useful grouping of ASCVT activities shall be given by ESA based on the CAL/VAL proposal evaluation and discussions on Aeolus Cal/Val workshops.

6.4 Cal/Val Instrumentation and modelling needs

Before the launch of a satellite mission, it is important to develop appropriate instrument simulators and retrieval algorithms up to level 2, and to fly instrument prototypes, e.g. on balloon platforms or aircraft, to validate the technical and scientific readiness of the space-borne system. The following CAL/VAL activities need to be performed in the different project/mission phases for Aeolus:

Pre-launch (phases pre-phase 0 to phase D):

1. Airborne demonstrator flights to test the instrument measurement capabilities (including expected precisions), viewing geometry, calibration needs, and retrieval algorithms [R11].
2. Airborne demonstrator flights over ground-based stations and in conjunction with (airborne) measurements by other instruments to optimize the data processing (including speed) and practice validation.
3. End-to-end simulations of the Aeolus product quality for theoretical and realistic scenes using atmospheric input from state-of-the-art atmospheric models, a representative instrument end-to-end simulator, L1, calibration and L2 retrieval software to check the compliance of the SRD (L1) with the MRD (L2).

Post-launch (Phase E1 and E2):

1. Airborne validation (e.g. A2D, Doppler lidars, radars, dropsondes, backscatter lidars, etc.) underflying the satellite, probing the same volume (best way of performing campaign activities). These must cover both different geographical regions and seasons. The maximum altitude of the aircrafts will be on the order of 12 (e.g. Falcon-20) to 15 km (e.g. HALO) as opposed to 30 km probed by Aeolus. In order to probe the atmosphere above an upward-viewing port must be used. The latter is not possible/implemented for the A2D.
2. Ground-based validation, which requires strict co-location criteria in space and time [R2]. When comparing the observations it is important to take the wind direction and horizontal and vertical extent of an atmospheric feature into account. The differences in representativity due the sampling of slightly different volumes may also be averaged out when analysing a sufficiently long data series covering a large variety of atmospheric conditions. This assumption is not correct e.g. in the case of prevailing wind conditions and systematic effects due to the Aeolus weekly repeat cycle. Within the EU project PREVIEW, the capability of launching radiosondes on demand was built in order to take part in campaign activities. This may be an option for dedicated Aeolus CAL/VAL campaigns. Another option is to make use of mobile systems.
3. Comparison with other satellite-based measurements (ATOVS (mass), scatterometers, AMVs from geostationary and polar orbiting satellites, CALIPSO (if still operational, for cross-talk validation), etc.)
4. NWP monitoring. The first comparisons to be made will focus on comparing Aeolus data with the forecast and analysis. The model error distribution is relatively well known. NWP monitoring will have to be performed over a certain time-span. The first NWP validation may be on a case-study basis and run off-line.

5. Aeolus measurements can be compared with other GOS measurements either directly using the specified collocation criteria, or by the use of the triple collocation technique. The statistics (e.g. monthly) will reveal the magnitude of random errors and identify gross errors [R2].
6. Intercomparison with retrievals using different retrieval algorithms and/or auxiliary parameter files (e.g. assumed extinction-to-backscatter ratios, calibration, Rayleigh-Brillouin scattering correction etc.)

Aeolus SCVR_wind-5:
A wide range of instrument types with collocated observations as well as model and retrieval comparisons shall be used to validate all aspects of the Aeolus data quality and to assure a correct understanding of the data quality.

Aeolus SCVR_wind-5 CAL/VAL techniques:
CAL/VAL techniques shall include comparisons with:

1. on-ground instruments allowing collocated observations and airborne instrument under-flying the satellite,
2. comparison with collocated satellite observations (e.g. AMVs, scatterometer winds, ...)
3. NWP monitoring
4. other GOS observations (e.g. radiosondes, AIREPS, wind profilers, ...)
5. alternative calibration and L2 retrieval schemes

Aeolus SCVR_wind-5 communication needs:
Industry, Algorithm core team and ASCVT CAL/Val results shall be reported, presented at Aeolus CAL/Val Workshops and shared at the Aeolus wiki page.

Aeolus SCVR_wind-5 coordination/planning needs:
The errors will be a function of the CAL/VAL technique used. The validation results from all ASCVT activities shall feed-back into improvements of the processing chain.

Aeolus SCVR_wind-5 proposal evaluation:
ESA shall make sure that the CAL/VAL techniques listed in section 6.4 of the “Aeolus Scientific CAL/VAL Requirements” document are covered either within the ESA core validation activities (industry, Algorithm Core team) or by the ASCVT.

6.5 Requirements for the comparison of non-collocated measurements from differing instrumentation

When comparing measurements that are taken by different instruments that were operated at slightly different locations and times, the differences in observation information content and atmospheric conditions have to be taken into consideration.

6.5.1 Representation Error

The Aeolus observations will be representative for 86 km averages (base-line observation size in the L2b product) or less along the satellite track, depending on the atmospheric scene (presence of aerosols or clouds). An example of sampling inhomogeneity during campaigns is given in figure 6.5.1-1. If one assumes that the horizontal variability along track is representative for the across-track variability, the ideally co-located measurements would be located within 43 km of the centre of the observation. This strict co-location requirement can be relaxed in conditions with large-scale flow, such as in the middle and high parts of the troposphere and in the stratosphere ([R12], [R5]). Non-collocated measurements could also be used to validate models, which would again be used to evaluate Aeolus wind measurements. In the lower troposphere and in regions with complex terrain, and in regions with strong wind-shears, the co-location requirement will have to be stricter. Furthermore, the Aeolus sampling geometry (slant path) makes the measurements at some heights more co-located with ground-based or air-borne measurement than at other heights, unless a parallel measurement path is used.

It is proposed that a set of common co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc.) is created for each validation category, e.g. during the pre-launch CAL/VAL preparatory workshops. This should be done in order to assure that the various teams deliver a minimum set of comparable statistics. This is for example practiced by the NWP-SAF community. The teams should however be free to do additional validations applying co-location criteria of their own choice.

Aeolus SCVR_wind-6:
A set of common time and space co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc.) shall be defined for the wind product, and all ASCVT teams are invited to produce results using these common criteria. The ASCVT are also invited to define further own collocation criteria and results as appropriate. In this case, the ASCVTs shall assess and document their representation error resulting from the spatial and temporal distance between the satellite and correlative observation

Aeolus SCVR_wind-6 CAL/VAL techniques:
CAL/VAL teams shall create statistics for the Aeolus product quality based on the agreed time and space collocation criteria, according to Aeolus SCVR_wind-6

Aeolus SCVR_wind-6 communication needs:
ESA shall document the common time and space collocation criteria established for the Aeolus wind product validation in [A1].

Aeolus SCVR_wind-6 coordination/planning needs:
A set of common co-location criteria shall be created for each validation category during the pre-launch CAL/VAL preparatory workshops. These can be evaluated and adapted based on experience during Phase E2. Such updates must be reflected in updates of [A1].

Aeolus SCVR_wind-6 proposal evaluation:
ESA shall assess whether the CAL/VAL proposals address the need for co-location and the proposed comparison technique and apply the agreed collocation criteria listed in "SCVR_wind-6 CAL/VAL Techniques".

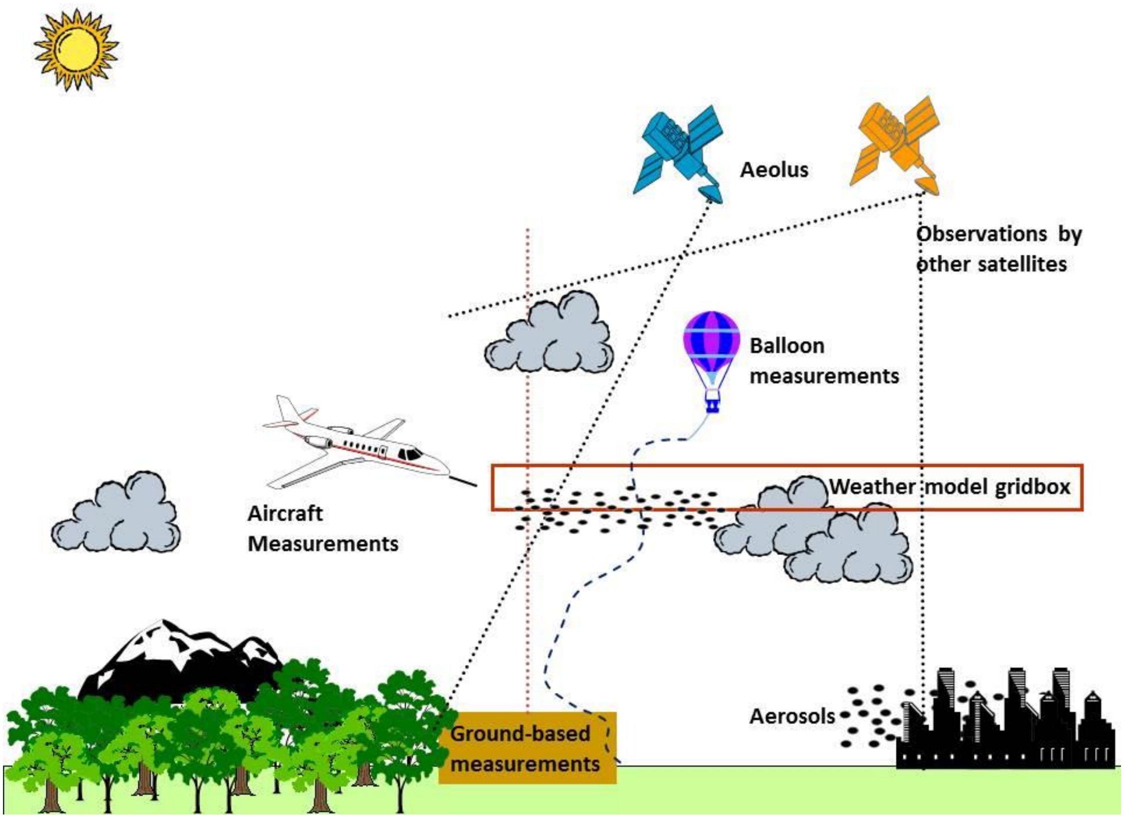


Figure 6.5.1-1: An example of sampling inhomogeneity during campaigns

6.5.2 Instrument and measurement errors

Wind products from space-based lidars, ground-based instrumentation (wind profilers, lidars) and air-borne sensors (balloons, airborne lidars, dropsondes, etc.) all have different viewing geometries, instrument error characteristics, and vertical and horizontal resolution. The winds can furthermore be measured at different wavelengths, may be sensitive to the presence and motion of different atmospheric constituents and varying surface reflectance. It is therefore important that this is taken into account in the process of establishing the Aeolus product quality through CAL/Val. To achieve this, instrument and product errors as well as observation representativity must be calculated and reported. This must then be taken into account when performing the comparison of the satellite and collocated observations.

Aeolus SCVR_wind-7:
It shall be assessed what the satellite and collocated observation information content and errors are, and these shall be taken into account for the data product comparison.

Aeolus SCVR_wind-7 CAL/VAL techniques:
The satellite and collocated observation datasets shall be delivered with product quality (systematic and random error estimates), and the information content and representativity shall be assessed.

Aeolus SCVR_wind-7 communication needs:
The Aeolus systematic and random errors shall be established and reported and the data error estimates shall be validated. The systematic and random errors for the collocated observations shall be reported by the CAL/VAL PIs in the validation reports, at workshops and in the datasets when delivered to the ESA Atmospheric Validation Data Centre (EVDC, https://evdc.esa.int/).

Aeolus SCVR_wind-7 coordination/planning needs:
Aeolus campaigns shall address observation information content, errors and representativity.

Aeolus SCVR_wind-7 proposal evaluation:
It shall be assess whether the AO proposals propose adequate techniques to deal with the difference in satellite and collocated observation information content, errors and representativity.

7 THE VALIDATION OF ATMOSPHERIC OPTICAL PROPERTIES PRODUCT (L2A)

7.1 The understanding of the product properties

The L2A atmospheric optical properties products will be given both per per observation (87 km horizontal resolution) and on the scale of atmospheric features (minimum of 3 km horizontal resolution) along the Aeolus dawn/dusk orbit. These atmospheric optical properties products will include atmospheric backscatter and extinction coefficient profiles, lidar ration profile and limited scene classification. The vertical profiles are slant (tilted by 37° w.r.t. nadir). Measurements at/near the surface are thus displaced by about 285 km w.r.t. the satellite ground track. The displacement will be either left or right of the ground track (in the east/west direction during most of the orbit), depending on the orbit phase (descending vs. ascending). The optical properties products are representative for layers with a thickness from 250 m (minimum) to 2 km. The vertical sampling may vary along an orbit according to climate zone and topography.

Aeolus SCVR_OptP-0 proposal evaluation:
Aeolus AO proposals shall be evaluate according to whether the product information content and quality are clearly understood and taken into account.

7.2 Product characteristics and expected accuracies

There are no product requirements for the Aeolus L2A products because they are categorized as additional to the primary wind profile products. Table 2 lists the main characteristics of the Aeolus L2A product.

The contribution of Aeolus to a long-term aerosol and cloud optical properties database was addressed by the Institute for Tropospheric Research (TROPOS) in Leipzig, Germany [R10]. The objective of the study was to demonstrate the potential of Aeolus to measure optical properties of aerosol and clouds based on end-to-end simulation studies. The study concluded that Aeolus is able to provide global sets of trustworthy height-profiles of backscatter and extinction coefficients, and extinction-to-backscatter (lidar) ratios. Table 3 presents simulated uncertainties in the Aeolus optical properties observations taking into account statistics (random) and input-parameter-related systematic uncertainties, and uncertainties due to polarization and multiple scattering.

		PBL	Troposphere	Stratosphere
Vertical Domain	**[km]**	0-2	2-16	16-20 (30)
Vertical Resolution	**[km]**	0.5	1.0	2.0
Horizontal Domain		global		
Number of Profiles	**[$hour^{-1}$]**	>100		
Horizontal Integration Length	**[km]**	<100		
Horizontal Sub-sample Length	**[km]**	≤3 km		
Length Observational Data Set	**[yr]**	3		

Table 2: Aeolus L2A product geographical coverage and sampling characteristics.

Layer (ext. value)	$\delta\beta_a/\beta_a$ Backscatter	$\Delta\sigma_a/\sigma_a$ Extinction	$\delta OD/OD$ Optical Depth	$\delta S_a/S_a$ lidar ratio	$\delta S_{col}/S_{col}$ Column lidar ratio
PBL (σ_a = 200 Mm^{-1})	10%	15%	10%	20%	15%
FT (σ_a = 50 Mm^{-1})	15%	30%	20%	35%	25%
DUST (σ_a = 100 Mm^{-1})	15%	20%	15%	25%	20%
CI (σ_a = 200 Mm^{-1})	25%	-	25%	-	35%
SA (σ_a = 10 Mm^{-1})	15%	-	-	-	-
PSC (σ_a = 20 Mm^{-1})	30%	-	-	-	-

Table 3: Expected overall uncertainties in the retrievable quantities considering input uncertainties, statistical errors, depolarization, and multiple scattering effects, and that cirrus cloud depth is typically <3 km. Only uncertainties < 50% are listed. PBL: planetary boundary layer, FT: free troposphere, CI: Cirrus, SA: volcanic stratospheric aerosols, PSC: polar stratospheric clouds. From [R10].

This table may be taken as a guideline for the expected L2A product accuracies/requirements when preparing the validation activities.

7.3 Areas deserving special CAL/VAL attention

7.3.1 Sampling

The horizontal and vertical sampling by Aeolus is programmable during flight, and can be reset once per week. The vertical sampling can be programmed to vary up to 8 times along the orbit [R6]. The vertical sampling will be optimized prior to launch based on databases of wind shear and backscatter/extinction data (e.g. from CALIPSO) together with impact studies [R7]. The sampling will be optimized w.r.t. the primary wind profile product. This can lead to a varying sampling along the orbit. This proposed sampling strategy should be validated during and after commissioning (long-term activity). In support of this, there is a need for requesting dedicated Aeolus operations during Phase E1 and/or E2 for a subset of the proposed vertical sampling scenarios. Needs for the measuring of ground returns (calibration) also influences the choice for the vertical sampling.

Aeolus SCVR_OptP-1:
Validation/optimization of the vertical sampling strategy to achieve the required L2A observation accuracy and sampling

Aeolus SCVR_OptP-1 CAL/VAL techniques:
1. comparison of Aeolus L2A observations with well collocated observations oversampling the Aeolus observations in the horizontal and/or vertical
2. comparison with well established, verified air quality models providing aerosol and cloud information together with quality information
3. comparison of Aeolus L2A observations with oversampled collocated observations covering
   3.1. the full vertical range
   3.2. different geographical regions
   3.3. position along the orbit

3.4. all seasons

Aeolus SCVR_OptP-1 communication needs:
Communication of vertical sampling strategy and planning (Mission Planning cycle) via Aeolus wiki page

Aeolus SCVR_OptP-1 coordination/planning needs:
ESA to perform Mission Planning of vertical bin sampling in "wind mode" (35 degrees off nadir) with input from algorithm core team, CAL/VAL teams, campaigns and scientific exploitation studies under ESA contract.

Aeolus SCVR_OptP-1 proposal evaluation:
The proposals shall be evaluate whether (i) the AO PIs have understood the vertical sampling strategy and that (ii) the vertical sampling is validated/optimized in corporation with the CAL/VAL core team [A1] and/or by AO CAL/VAL teams.

7.3.2 Quality of optical properties products as a function of atmospheric scene/condition

The cloud and aerosol layers vary both geographically (horizontally and vertically) and as a function of time. Within a vertical height bin, both thin and / or multiple aerosol and cloud layers may occur. This may lead to an artificial vertical smearing of the backscattered signal over a height bin, depending on the applied L2A retrieval algorithm [R13]. The importance of the applied cross-talk correction is also dependent on the aerosol and cloud loading. If an a-priori lidar ratio is used in the L2A algorithm, its validity and impact on the L2A products must be validated.
It is therefore very important to establish the quality of the retrieved optical properties products under a complete range of different atmospheric conditions.

Aeolus SCVR_OptP-2:
Aeolus Optical Properties product (L2A, feature mask, backscatter and extinction coefficient profiles, lidar ratio, etc.) must be validated for a full range of atmospheric conditions assessing the impact of algorithm and settings. This shall lead to an assessment of the product accuracy as a function of:

1. clear or (partially) cloudy conditions within a measurement and observation
2. location of cloud and aerosol layers within a vertical bin
3. scene dependence of algorithm feature finder technique used
4. degree of polarization (and hence signal loss as seen by Aeolus) within scene (e.g. desert dust, cirrus, ...)
5. effectiveness of the algorithm channel cross-talk correction applied (aerosol scattering contribution to molecular observations and vice versa)
6. AUX_MET data used for calibration

Aeolus SCVR_OptP-2 CAL/VAL techniques:

1. Comparison of Aeolus L2A products with collocated observations for a wide range of atmospheric conditions

2. Provision of scene classified statistics
3. Comparison with well collocated observations (flight campaigns under-flying the satellite for different conditions and in different geographical areas, well collocated ground-based observations sampling over a long time period)
4. Comparison with (less well) collocated observations over a long time period to produce seasonal and geographical statistics

Aeolus SCVR_OptP-2 coordination/planning needs:
The completeness of the activities covering SCVR_OptP-2 shall be assessed and gaps identified. Mitigating activities shall be launched to stimulate more or other CAL/VAL activities.

Aeolus SCVR_OptP-2 proposal evaluation:
The planned and proposed CAL/VAL activities (including core and AO CAL/VAL activities) shall cover all relevant atmospheric conditions, and the proposed validation techniques shall be appropriate and complete for the validation of measurements of inhomogeneous scenes.

7.3.3 Instrument and atmospheric "artefacts"

Examples of instrument and mission related random and systematic errors sources have been identified in section 6.1. These also affect the Aeolus optical Properties product (L2A) quality. CAL/VAL activities shall aim at validating and quantifying possible systematic errors remaining after the implemented instrument self-calibration mentioned in section 6.1.
Furthermore, the effect of channel cross-talk (and the effectiveness of its correction), depolarization and multiple scattering on the products (systematic biases) should be quantified.

Aeolus SCVR_OptP-3:

1. Validation of instrument, platform and processing related systematic and random errors in the L1 and L2 products after calibration and data processing (e.g. quality of IRC, HBE, RDB, AUX_CAL data processing and quality control as listed in section 6.1 of the Aeolus Scientific CAL/VAL Requirements).
2. Validation of the systematic and random errors (L1 and L2) as function of
   2.1. Geographical region
   2.2. Orbit position
   2.3. Altitude
   2.4. Time
   2.5. Atmospheric scene

Aeolus SCVR_OptP-3 CAL/VAL techniques:

1. comparison of Aeolus L2A observations with well collocated observations oversampling the Aeolus observations
2. comparison with air quality prediction models with a well-established quality and quality information
3. comparison of Aeolus L2A observations with oversampled collocated observations covering
   3.1. the full vertical range
   3.2. different geographical regions
   3.3. all seasons

Aeolus SCVR_OptP-3 communication needs:

Communication of the status of the Aeolus L2A product quality (known uncorrected biases, random errors, etc. as reported by the Industry, ESA, the Aeolus algorithm core team or ASCVT) via Aeolus wiki page.

Aeolus SCVR_OptP-3 coordination/planning needs:

ESA to perform regular instrument calibration as recommended by industry at the end of phase E1, by the Aeolus algorithm core team, or ASCVT.

Aeolus SCVR_OptP-3 proposal evaluation:
Assure that the Aeolus L2A product systematic and random errors are addressed applying appropriate statistical methods, globally and over time by the Aeolus algorithm core team and ASCVT.

7.3.4 Suggestions for the grouping of the validation activities

It is suggested that the proposed validation activities are grouped in order to form smaller validation teams that will exchange comparable validation results on a more frequent basis. This will also facilitate the overall evaluation of the validation results. Below is a list of suggested grouping criteria:

- Vertical extent: Planetary Boundary Layer (PBL), the Free Troposphere (FT), the Upper Troposphere and lower Stratosphere (UTLS), Stratosphere (S), total column phenomena, etc.
- Geographical region: global, deserts, polluted continental, biomass burning, remote regions, etc.
- Time range: Season, yearly, bi-annual, etc.
- Scientific focus, e.g aerosol scene classification, polarization, aerosol processes, improvements of air quality models, …
- Observation principle (instrumentation) and/or platform

Aeolus SCVR_OptP-4:
When beneficial, Aeolus CAL/VAL team sub-groups should be established/organized according to CAL/VAL focus (e.g. vertical extent, geographical region, time range, science focus, instrumentation etc.)

Aeolus SCVR_OptP-4 communication needs:
Announcement of Aeolus CAL/VAL teams / groups at the Aeolus wiki page (e.g. Aeolus Polar validation efforts, tropical campaign activities, etc.).

Aeolus SCVR_OptP-4 coordination/planning needs:
ESA to identify partners and to coordinate joint Aeolus CAL/VAL campaigns. ESA to stimulate topical CAL/VAL activities.

Aeolus SCVR_OptP-4 proposal evaluation:
Recommendations for useful grouping of ASCVT activities shall be given by ESA based on the CAL/VAL proposal evaluation and discussions on Aeolus Cal/Val workshops.

7.4 CAL/VAL instrumentation and modelling needs

Before the launch of a satellite mission, it is important to develop appropriate instrument simulators and retrieval algorithms up to level 2, and to fly instrument prototypes e.g. on balloon platforms or aircraft to validate the technical and scientific readiness of the space-borne system. The following CAL/VAL activities should be performed in the different project/mission phases for Aeolus:

Pre-launch:

1. Airborne Demonstrator flights to test the instrument measurement capabilities (including expected precisions), viewing geometry, and calibration needs, and retrieval algorithms [R11].

Post-launch (Phase E1 and E2):

1. Airborne validation (e.g. A2D, backscatter lidars, radars, in-situ instrumentation, sun photometers, multi-angle polarimeter, etc.) under-flying the satellite and probing the same volume (best way of performing campaign activities). These must cover both different geographical regions and seasons. The maximum altitude of the aircrafts will be on the order of 12 km (e.g. Falcon) to 15 km (e.g. HALO), which will not cover (or only a small part of) the stratosphere. In order to probe the atmosphere above an upward-viewing port must be used.
2. Ground-based lidar vertical profile measurements of atmospheric optical properties (e.g. EARLINET). When comparing the observations it is important to take the wind direction and horizontal and vertical extent of an atmospheric feature into account. The differences in representativity due the sampling of slightly different volumes may also be averaged out when analysing a sufficiently long data series covering a large variety of atmospheric conditions. This assumption is not correct e.g. in the case of prevailing wind conditions and systematic effects due to the Aeolus weekly repeat cycle. Another option is to make use of mobile systems.
3. Ground-based sun photometer measurements of Optical Depths (OD) (e.g. AERONET). These will be of limited use because of strict co-location criteria [R2]. However, a large number of observations can help average out the lack of representativity due to the sampling of slightly different volumes. Again, mobile systems are preferred.
4. Ground-based radar profiling of cloud base and top pressure, etc. (e.g. Cloudnet). These measurements are again of limited use because of strict co-location criteria [R2].
5. Comparison with aerosol transport models and parameters such as radiances assimilated by NWP models.
6. Observations from other space-based sensors (e.g. CALIPSO, CloudSat, MODIS, VIIRS, other imagers, OMI, etc.)
7. Verification of aerosol elevated layers (long-range transport) using back trajectories. Great care has to be taken when using back-trajectory models, initiating enough trajectories at and around the validation point in order to get a statistically correct representation of the transport probability function. The results (the identified source

region) are very sensitive to the trajectory initialization. A representative estimate can only be given when a sufficiently large number of trajectories, perturbed around the starting height (ensemble), is used.
8. Intercomparison with retrievals using different retrieval algorithms and auxiliary parameter files (e.g. assumed lidar ratio, calibration, Rayleigh-Brillouin scattering correction, etc.).

The errors will be a function of the instrument and processing chain. The validation results should feed-back into improvements of the processing chain.

Aeolus SCVR_OptP-5:
A wide range of instrument types with collocated observations as well as model and retrieval comparisons shall be used to validate all aspects of the Aeolus data quality and to assure a correct understanding of the data quality.

Aeolus SCVR_OptP-5 CAL/VAL techniques:
CAL/VAL techniques shall include comparisons with:
1. Ground-based instruments allowing collocated observations and airborne instruments under-flying the satellite,
2. comparison with collocated satellite observations (e.g. MODIS, Sentinel 2, Sentinel 3, Sentinel 5p, CALIPSO, EarthCARE, ...)
3. air quality model product monitoring
4. other GOS observations (e.g. sun photometers, ceilometers, ground-based lidars, PANDORA, ...)
5. alternative calibration and L2 retrieval schemes

Aeolus SCVR_OptP-5 communication needs:
Industry, Algorithm core team and ASCVT CAL/Val results shall be reported, presented at Aeolus CAL/Val Workshops and shared at the Aeolus wiki page.

Aeolus SCVR_OptP-5 coordination/planning needs:
The errors will be a function of the CAL/VAL technique used. The validation results from all ASCVT activities shall feed-back into improvements of the processing chain.

Aeolus SCVR_OptP-5 proposal evaluation:
ESA shall make sure that the CAL/VAL techniques listed in section 6.4 of the “Aeolus Scientific CAL/VAL Requirements” document are covered either within the ESA core validation activities (industry, Algorithm Core team) or by the ASCVT.

7.5 Requirements for the comparison of non-collocated measurements from differing instrumentation

When comparing measurements that are taken by different instruments that were operated at slightly different locations, the following has to be taken into consideration.

7.5.1 Representation Error

The Aeolus observations will be representative for 86 km averages or less along the satellite track. An example of sampling inhomogeneity during campaigns is given in figure 6.5.1-1. If one assumes that the horizontal variability along track is representative for the across-track variability, the ideally co-located measurements would have to lie within 43 km of the centre of the observation. This strict co-location requirement can be softened in conditions with uniform cloud cover (e.g. uniform stratus), PBL background aerosols in regions with no strong aerosol sources and long-range aerosol transport in the free troposphere (e.g. forest fire plumes and desert dust outbreaks). Non-collocated measurements could also be used to validate models (e.g. regional dust transport models or ECMWF radiances), which would again be used to evaluate Aeolus measurements. Furthermore, the Aeolus sampling geometry (slant path) makes the measurements at some heights more co-located with ground-based or air-borne measurement than at other heights, unless a parallel measurement path is used. The proposals should be evaluated on how well they address the need for co-location and the proposed comparison technique.

It is proposed that a set of common co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc., see e.g. [R18]) is created for each validation category, e.g. during the pre-launch CAL/VAL preparatory workshops. This should be done in order to assure that the various teams deliver a minimum set of comparable statistics. This is for example practiced by the EARLINET community. The teams should however be free to do additional validations applying co-location criteria of their own choice.

Aeolus SCVR_OptP-6:
A set of common time and space co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc.) shall be defined for the atmospheric optical properties product (L2A).

Aeolus SCVR_OptP-6 CAL/VAL techniques:
CAL/VAL teams shall create statistics for the Aeolus product quality based on the agreed time and space collocation criteria, according to Aeolus SCVR_OptP-6

Aeolus SCVR_OptP-6 communication needs:
ESA shall document the common time and space collocation criteria established for the Aeolus atmospheric optical properties (L2A) product validation in [A1].

Aeolus SCVR_OptP-6 coordination/planning needs:
A set of common co-location criteria shall be created for each validation category during the pre-launch CAL/VAL preparatory workshops. These can be evaluated and adapted based on experience during Phase E2. Such updates must be reflected in updates of [A1].

Aeolus SCVR_OptP-6 proposal evaluation:

ESA shall assess whether the CAL/VAL proposals address the need for co-location and the proposed comparison technique and apply the agreed collocation criteria listed in "SCVR_OptP-6 CAL/VAL Techniques".

7.5.2 Instrument and measurement errors

Aerosol products from space-based lidars or passive instruments, ground-based lidar, sun photometers, air-borne lidars, etc. all have different viewing geometries, instrument error characteristics, averaging kernels, measure at different wavelengths (approximate conversion laws from 2 μm and/or 532 nm to 355 nm – if possible, measure at 355 nm), and varying surface reflectance (see e.g. [R19]). The instrumentation with the largest potential for aerosol validation is mobile equipment with HSRLs and Raman lidars at 355 nm.

Aeolus SCVR_OptP-7:
It shall be assessed what the satellite and collocated observation information content and errors are, and these shall be taken into account for the data product comparison.

Aeolus SCVR_OptP-7 CAL/VAL techniques:
The satellite and collocated observation datasets shall be delivered with product quality (systematic and random error estimates), and the information content and representativity shall be assessed.

Aeolus SCVR_OptP-7 communication needs:
The Aeolus systematic and random errors shall be established and reported and the data error estimates shall be validated. The systematic and random errors for the collocated observations shall be reported by the CAL/VAL PIs in the validation reports, at workshops and in the datasets when delivered to the ESA Atmospheric Validation Data Centre (EVDC, https://evdc.esa.int/).

Aeolus SCVR_OptP-7 coordination/planning needs:
Aeolus campaigns shall address observation information content, errors and representativity.

Aeolus SCVR_OptP-7 proposal evaluation:
It shall be assess whether the AO proposals propose adequate techniques to deal with the difference in satellite and collocated observation information content, errors and representativity.

8 VALIDATION OF OTHER POTENTIAL PRODUCTS

Proposals for validation of other products from Aeolus (e.g. surface reflectivity, etc.) should not necessarily be discarded simply because they are not belonging to the present list of official Aeolus products. On a case-by-case basis, it shall be decided whether the proposed validation activities are feasible, useful and relevant for the Aeolus mission.

9 DEDICATED AEOLUS MISSION CAMPAIGNS

Campaigns are needed to address mission/instrument, product and scientific maturity and exploitation both during the mission development and commissioning phases (phase 0 to E1) and during the operational and post operational phases (phase E2 and F).
ESA organizes and manages campaigns in all phases of a mission, and examples of objectives and results from Aeolus campaigns during phases C/D are provided in [R11] and [R25-26].
ESA sets up a campaigns plan for the phases E2 (mission operational phase) and sometimes also in phase F (post-operational phase concerning data pre-processing), based on the mission requirements, advice from the Mission Advisory Group, and based on the feedback from the Aeolus AO CAL/VAL calls. The campaign planning is provided on the Aeolus CAL/VAL wiki page (https://www.aeolus.esa.int/confluence/index.action).
The objectives and instrument requirements for Aeolus campaigns are listed in the section below.

9.1 Campaigns Objectives for Data Quality

Dedicated Aeolus campaigns in phases C/D/E1 and E2 shall address the following **data quality objectives:**

Campaigns_DQO-1:

Verification of instrument performance w.r.t. laser energy and instrument transmission (including short- and long-term drifts) and ACCD characteristics (including memory effects).

Campaigns_DQO-2:

Verify that the precision, unknown bias and response slope error of the wind observations and the atmospheric Mie and Rayleigh backscatter and extinction products are within the expected range and stable. This also includes validation of the cross-talk correction of the Rayleigh signal.

Campaigns_DQO-3:

Establish the precision of the Mie and Rayleigh Response calibration and of the zero-wind calibration, including the effect of the atmosphere on the ground return bin.

Campaigns_DQO-4:

Establish the accuracy and precision estimates of the wind, aerosol and cloud products during different atmospheric conditions and over different locations and seasons.

Campaigns_DQO-5:

Confirm the instrument performance, including the operational L1b, L2A and L2B algorithms, for homogenous atmospheres.

Campaigns_DQO-6:

Establish the influence of heterogeneous atmospheric conditions (clouds, wind shear and aerosol) on the instrument performance including operational L1b, L2A and L2B algorithms.

Campaigns_DQO-7:

Verify the temperature and pressure correction of the L2A Rayleigh backscatter, including L2B Rayleigh winds, (Rayleigh-Brillouin scattering correction) by comparison of the input NWP temperature and pressure data to independent pressure and temperature measurements.

9.2 Scientific Campaigns Objectives

Dedicated Aeolus campaigns in phases C/D/E1 and E2 shall address. the following **scientific objectives:**

Campaigns_SO-1:
Aeolus campaigns shall address dynamical processes in connection with **extratropical storms** including front developments. This should include processes linked to the total atmospheric energy budget.

Campaigns_SO-2:
Aeolus campaigns shall address **dynamically and optically strongly variable regions** such as **jet streams**, the upper troposphere and lower stratosphere (**UTLS**) and their exchange of energy and composition, in- and out-flow of **deep convective systems**, …

Campaigns_SO-3:
Aeolus campaigns shall address the understanding of **tropical dynamics,** including Kelvin and gravity waves, intensive storm development (e.g. hurricanes), heat exchange with the ocean and how that impacts tropical weather and intense storm development, …

Campaigns_SO-4:
Aeolus campaigns shall address atmospheric processes linked to **topography** such as katabatic winds, gravity waves, PSC formation and their impact on stratospheric processes, …

Campaigns_SO-5:
Aeolus campaigns shall address the **vertical distribution of aerosol** and their impact on **air quality modelling** and the earth radiation budget (including cloud formation).

Campaigns_SO-6:
Aeolus campaigns shall address **physical processes for different aerosol types and their interaction of the Aeolus lidar backscatter**. This shall include the studying of the Aeolus L2A product and information content and further evolution.

Campaigns_SO-7:
Aeolus campaigns shall contribute to the **understanding of large-scale circulations and their variations** such as the Brewer Dobson Circulation (impacting meridional transport in the stratosphere including stratospheric ozone distribution), the Monsoon, El

Niño, quasi-bi-annual oscillation and its variability (QBO), Madden-Julian Oscillation (MJO), Tropical Kelvin waves and their impact on climate and climate change, …

9.3 Requirements for Aeolus campaign planning and execution

The analysis of Aeolus wind and optical properties products will require the measurement of other parameters such as the vertical profiles of temperature and pressure (e.g., by using radiosondes or dropsondes). For the validation of the wind profile product, it is important to establish whether there are layers that are heavily loaded with aerosols. The interpretation of results from the campaigns would be greatly aided by the inclusion of a backscatter lidar and observations of cloud type. For campaigns over sea, it is important to try to include measurements of the surface wind speed, since this is decisive for the establishing of the surface reflectance and possible wind-speed biases due to waves [R14].

Correlated observation needs during campaigns:

1) Collocated wind observations with a reference (high quality) instrument probing a similar air volume and range (e.g. high quality Doppler wind lidar, Doppler wind radar, dropsondes, radiosoundings, …)
2) Collocated temperature soundings (e.g. from satellites, dropsondes, radiosondes, temperature lidars, …)
3) Collocated measurements of cloud and aerosol content (e.g. by the use of imagers (cameras), aerosol lidar systems, cloud radars, ceilometers, sun photometers, in-situ aerosol observation (profiles), …)
4) Collocated air pressure observations (for testing of Rayleigh-Brillouin correction, for checking (cabin) air pressure stability when operating lidars on airplanes or on ground)
5) Humidity observations (e.g. radiosondes, dropsondes,) in case cloud formation processes are investigated
6) Wavemeter (for A2D performance monitoring)
7) …

The campaigns should also focus on providing the most direct comparison possible, e.g. by performing co-located measurements in clear conditions, using comparable viewing geometries.
If possible, related campaign activities should be coordinated in order to ensure compatibility of the results from various campaigns. The campaign activities should also cover different geographical regions and seasons. This is needed for the construction of global statistics.
The Phase E2 Validation Plans will evaluate the results and effectiveness of pre-launch and Phase E1 campaigns.

Campaigns_PER-1:
ESA shall compile a campaigns plan, assessing the ASCVT campaigns and their contribution to the overall Aeolus campaign objectives.

Campaigns_PER-2:
Dedicated ESA supported campaigns shall secure core data quality and science campaign activities, deploying the necessary instrumentation.

Campaigns_PER-3:
The campaigns shall be coordinated by ESA and if applicable also in synergy with campaigns for other ESA missions or (inter)national scientific campaigns.

10 SUMMARY AND ONCLUSIONS

The objective of this document is to define the scientific calibration and validation requirements focussing on the Aeolus mission phases E1 and E2. It shall, furthermore, provide guidelines for the selection process of the Phase E1 CAL/VAL Announcement of Opportunity proposals. The major part of these guidelines will also be applicable to the planning and selection process for the routine CAL/VAL activities during Phase E2. The Scientific issues that need to be tackled by CAL/VAL activities are listed in order to identify areas that have not been covered to a satisfactory extent at the end of the CAL/VAL proposal review process. This includes the products to be validated and their specific characteristics, product requirements, instrument and atmospheric "artefacts", validation strategies, instrument and modelling needs and needs for dedicated campaigns during Phase E1 and Phase E2. Recommendations shall then be made either to adapt some of the CAL/VAL proposals or to initiate additional validation activities. The AO proposal review team is, furthermore, asked to check that the proposed validation techniques are appropriate for the purpose of validation of the space-based data products.

Summary of [Aeolus CAL/VAL Requirements] and [Campaigns Objectives and Requirements]:

#	Requirement identifier	Description
	Wind Products (L2B and L2C)	
1	**Aeolus SCVR_wind-0 Proposal evaluation**	Aeolus AO proposals shall be evaluate according to whether the product information content and quality are clearly understood and taken into account.
2	**Aeolus SCVR_wind-1 Vertical Sampling Strategy**	Validation/optimization of the vertical sampling strategy to achieve the required wind observation accuracy and sampling
3	Aeolus SCVR_wind-1 CAL/VAL techniques	1. Comparison of Aeolus wind observations with well collocated observations oversampling the Aeolus observations 2. Comparison with NWP models with a well-established quality and quality information 3. Comparison of Aeolus wind observations with oversampled collocated observations covering 3.1. The full vertical range 3.2. Different geographical regions 3.3. All seasons
4	Aeolus SCVR_wind-1 Communication needs	Communication of vertical sampling strategy and planning (Mission Planning cycle) via Aeolus wiki page
5	Aeolus SCVR_wind-1 Coordination/planning needs	ESA to perform Mission Planning of vertical bin sampling in wind mode with input from algorithm core team, CAL/VAL teams, campaigns and scientific exploitation studies under ESA contract

6	Aeolus SCVR_wind-1 Proposal evaluation	The proposals shall be evaluate whether (i) the AO PIs have understood the vertical sampling strategy and that (ii) the vertical sampling is validated/optimized in corporation with the CAL/VAL core team [A1] and/or by AO CAL/VAL teams
7	**Aeolus SCVR_wind-2** **Atmospheric conditions**	Aeolus wind profiles must be validated for a full range of atmospheric conditions assessing the impact of algorithm settings. This shall lead to an assessment of the product accuracy as a function of: 1. clear or (partially) cloudy conditions within a measurement and observation 2. location of cloud and aerosol layers within a vertical bin 3. vertical wind shear within a bin 4. vertical wind velocity within the vertical and horizontal averaging space 5. algorithm scene classification technique applied (scattering ratio classification, optical properties code, …) 6. effectiveness of the algorithm channel cross-talk correction applied (aerosol scattering contribution to molecular observations and vice versa) 7. AUX-MET data used for L2B Rayleigh wind retrieval
8	Aeolus SCVR_wind-2 CAL/VAL techniques	1. Comparison of Aeolus winds with collocated observations for a wide range of atmospheric conditions 2. Provision of scene classified statistics 3. Comparison with well collocated observations (flight campaigns under-flying the satellite for different conditions and in different geographical areas, well collocated ground-based observations sampling over a long time period) 4. Comparison with (less well) collocated observations over a long time period to produce seasonal and geographical statistics
9	Aeolus SCVR_wind-2 Coordination/planning needs	The completeness of the activities covering SCVR_wind-2 shall be assessed and gaps identified. Mitigating activities shall be launched to stimulate more or other CAL/VAL activities
10	Aeolus SCVR_wind-2 Proposal evaluation	The planned and proposed CAL/VAL activities (including core and AO CAL/VAL activities) shall cover all relevant atmospheric conditions, and the proposed validation techniques shall be appropriate and complete for the validation of measurements of inhomogeneous scenes

11	**Aeolus SCVR_wind-3** **Instrument and atmospheric variability**	1. Validation of instrument, platform and processing related systematic and random errors in the L1 and L2 products after calibration and data processing (e.g. quality of IRC, HBE, RDB, data processing and quality control as listed in section 6.1 of the Aeolus Scientific CAL/VAL Requirements). 2. Validation of the systematic and random errors (L1 and L2) as function of 2.1. Geographical region 2.2. Altitude 2.3. Time 2.4. Atmospheric scene
12	Aeolus SCVR_wind-3 CAL/VAL techniques	1. comparison of Aeolus wind observations with well collocated observations oversampling the Aeolus observations 2. comparison with NWP models with a well-established quality and quality information 3. comparison of Aeolus wind observations with oversampled collocated observations covering 3.1. the full vertical range 3.2. different geographical regions 3.3. all seasons
13	Aeolus SCVR_wind-3 Communication needs	Communication of the status of the Aeolus product quality (known uncorrected biases, random errors, etc. as reported by the Industry, ESA, the Aeolus algorithm core team or ASCVT) via Aeolus wiki page
14	Aeolus SCVR_wind-3 Coordination/planning needs	ESA to perform regular instrument calibration as recommended by industry at the end of phase E1, by the Aeolus algorithm core team, or ASCVT
15	Aeolus SCVR_wind-3 Proposal evaluation	Assure that the Aeolus product systematic and random errors are addressed applying appropriate statistical methods, globally and over time by the Aeolus algorithm core team and ASCVT
16	**Aeolus SCVR_wind-4** **Grouping**	When beneficial, Aeolus CAL/VAL activities can be organized according to CAL/VAL focus (e.g. PBL, free troposphere or stratosphere, Polar CAL/VAL activities, Tropical activities, etc.)
17	Aeolus SCVR_wind-4 Communication needs	Announcement of Aeolus CAL/VAL teams / groups at the Aeolus wiki page (e.g. Aeolus Polar validation efforts, tropical campaign activities, etc.)
18	Aeolus SCVR_wind-4 Coordination/planning needs	ESA to identify partners and to coordinate joint Aeolus CAL/VAL campaigns. ESA to stimulate topical CAL/VAL activities
19	Aeolus SCVR_wind-4 Proposal evaluation	Recommendations for useful grouping of ASCVT activities shall be given by ESA based on the CAL/VAL proposal evaluation and discussions on Aeolus Cal/Val workshops
20	**Aeolus SCVR_wind-5** **Instrument and modelling needs**	A wide range of collocated observations and model and retrieval comparisons shall be used to validate all aspects of the Aeolus data quality and to assure a correct understanding of the data quality

21	Aeolus SCVR_wind-5 CAL/VAL techniques	CAL/VAL techniques shall include comparisons with: 1. collocated instruments on ground and under-flying the satellite, 2. comparison with collocated satellite observations (e.g. AMVs, scatterometer winds, …) 3. NWP monitoring 4. other GOS observations (e.g. radiosondes, AIREPS, wind profilers, …) 5. alternative calibration and L2 retrieval schemes
22	Aeolus SCVR_wind-5 Communication needs	Industry, Algorithm core team and ASCVT CAL/Val results shall be reported, presented at Aeolus CAL/Val Workshops and shared at the Aeolus wiki page
23	Aeolus SCVR_wind-5 Coordination/planning needs	The errors will be a function of the CAL/VAL technique used. The validation results from all ASCVT activities shall feed-back into improvements of the processing chain
24	Aeolus SCVR_wind-5 Proposal evaluation	ESA shall make sure that the CAL/VAL techniques listed in section 6.4 of the “Aeolus Scientific CAL/VAL Requirements” document are covered either within the ESA core validation activities (industry, Algorithm Core team) or by the ASCVT
25	**Aeolus SCVR_wind-6** **Comparisons of collocated observations in inhomogeneous scenes**	A set of common time and space co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc.) shall be defined for the wind product
26	Aeolus SCVR_wind-6 CAL/VAL techniques	CAL/VAL teams shall create statistics for the Aeolus product quality based on the agreed time and space collocation criteria, according to Aeolus SCVR_wind-6
27	Aeolus SCVR_wind-6 Communication needs	ESA shall document the common time and space collocation criteria established for the Aeolus wind product validation in [A1]
28	Aeolus SCVR_wind-6 Coordination/planning needs	A set of common co-location criteria shall be created for each validation category during the pre-launch CAL/VAL preparatory workshops. These can be evaluated and adapted based on experience during Phase E2. Such updates must be reflected in updates of [A1]
29	Aeolus SCVR_wind-6 Proposal evaluation	ESA shall assess whether the CAL/VAL proposals address the need for co-location and the proposed comparison technique and apply the agreed collocation criteria listed in “SCVR_wind-6 CAL/VAL Techniques”
30	**Aeolus SCVR_wind-7** **Comparing observations from different instrumentation**	It shall be assessed what the satellite and collocated observation information content, errors and representativity are, and these shall be taken into account for the data product comparison

31	Aeolus SCVR_wind-7 CAL/VAL techniques	The satellite and collocated observation datasets shall be delivered with product quality (systematic and random error estimates), and the information content and representativity shall be assessed
32	Aeolus SCVR_wind-7 Communication needs	The Aeolus systematic and random errors shall be established and reported and the data error estimates shall be validated. The systematic and random errors for the collocated observations shall be reported by the CAL/VAL PIs in the validation reports, at workshops and in the datasets when delivered to the ESA Atmospheric Validation Data Centre (EVDC, https://evdc.esa.int/)
33	Aeolus SCVR_wind-7 Coordination/planning needs	Aeolus campaigns shall address observation information content, errors and representativity
34	Aeolus SCVR_wind-7 Proposal evaluation	It shall be assess whether the AO proposals propose adequate techniques to deal with the difference in satellite and collocated observation information content, errors and representativity
	Atmospheric Optical Properties product (L2A)	
1	**Aeolus SCVR_OptP-0 Proposal Evaluation**	Aeolus AO proposals shall be evaluate according to whether the product information content and quality are clearly understood and taken into account
2	**Aeolus SCVR_OptP-1 Vertical Sampling Strategy**	Validation/optimization of the vertical sampling strategy to achieve the required L2A observation accuracy and sampling
3	Aeolus SCVR_OptP-1 CAL/VAL techniques	1. comparison of Aeolus L2A observations with well collocated observations oversampling the Aeolus observations 2. comparison with air quality models with a well-established quality and quality information 3. comparison of Aeolus L2A observations with oversampled collocated observations covering 3.1. the full vertical range 3.2. different geographical regions 3.3. all seasons
4	Aeolus SCVR_OptP-1 Communication needs	Communication of vertical sampling strategy and planning (Mission Planning cycle) via Aeolus wiki page
5	Aeolus SCVR_OptP-1 Coordination/planning needs	ESA to perform Mission Planning of vertical bin sampling in “wind mode” (35 degrees off nadir) with input from algorithm core team, CAL/VAL teams, campaigns and scientific exploitation studies under ESA contract
6	Aeolus SCVR_OptP-1 Proposal evaluation	The proposals shall be evaluate whether (i) the AO PIs have understood the vertical sampling strategy and that (ii) the vertical sampling is validated/optimized in corporation with the CAL/VAL core team [A1] and/or by AO CAL/VAL teams

7	**Aeolus SCVR_OptP-2** **Atmospheric conditions**	Aeolus Optical Properties product (L2A, feature mask, backscatter and extinction coefficient profiles, lidar ratio, etc.) must be validated for a full range of atmospheric conditions assessing the impact of algorithm and settings (SCA, MSC, ...). This shall lead to an assessment of the product accuracy as a function of: 1. clear or (partially) cloudy conditions within a measurement and observation 2. location of cloud and aerosol layers within a vertical bin 3. scene dependence of algorithm feature finder technique used 4. degree of polarization (and hence signal loss as seen by Aeolus) within scene (e.g. desert dust, cirrus, ...) 5. effectiveness of the algorithm channel cross-talk correction applied (aerosol scattering contribution to molecular observations and vice versa) 6. AUX_MET data used for calibration
8	Aeolus SCVR_OptP-2 CAL/VAL techniques	1. Comparison of Aeolus L2A products with collocated observations for a wide range of atmospheric conditions 2. Provision of scene classified statistics 3. Comparison with well collocated observations (flight campaigns under-flying the satellite for different conditions and in different geographical areas, well collocated ground-based observations sampling over a long time period) 4. Comparison with (less well) collocated observations over a long time period to produce seasonal and geographical statistics
9	Aeolus SCVR_OptP-2 Coordination/planning needs	The completeness of the activities covering SCVR_OptP-2 shall be assessed and gaps identified. Mitigating activities shall be launched to stimulate more or other CAL/VAL activities
10	Aeolus SCVR_OptP-2 Proposal evaluation	The planned and proposed CAL/VAL activities (including core and AO CAL/VAL activities) shall cover all relevant atmospheric conditions, and the proposed validation techniques shall be appropriate and complete for the validation of measurements of inhomogeneous scenes

11	**Aeolus SCVR_OptP-3** **Instrument and atmospheric variability**	1. Validation of instrument, platform and processing related systematic and random errors in the L1 and L2 products after calibration and data processing (e.g. quality of IRC, HBE, RDB, AUX_CAL data processing and quality control as listed in section 6.1 of the Aeolus Scientific CAL/VAL Requirements). 2. Validation of the systematic and random errors (L1 and L2) as function of 2.1. Geographical region 2.2. Altitude 2.3. Time 2.4. Atmospheric scene
12	Aeolus SCVR_OptP-3 CAL/VAL techniques	1. comparison of Aeolus L2A observations with well collocated observations oversampling the Aeolus observations 2. comparison with air quality prediction models with a well-established quality and quality information 3. comparison of Aeolus L2A observations with oversampled collocated observations covering 3.1. the full vertical range 3.2. different geographical regions 3.3. all seasons
13	Aeolus SCVR_OptP-3 Communication needs	Communication of the status of the Aeolus L2A product quality (known uncorrected biases, random errors, etc. as reported by the Industry, ESA, the Aeolus algorithm core team or ASCVT) via Aeolus wiki page
14	Aeolus SCVR_OptP-3 Coordination/planning needs	ESA to perform regular instrument calibration as recommended by industry at the end of phase E1, by the Aeolus algorithm core team, or ASCVT
15	Aeolus SCVR_OptP-3 Proposal evaluation	Assure that the Aeolus L2A product systematic and random errors are addressed applying appropriate statistical methods, globally and over time by the Aeolus algorithm core team and ASCVT
16	**Aeolus SCVR_OptP-4** **Grouping**	When beneficial, Aeolus CAL/VAL activities can be organized according to CAL/VAL focus (e.g. vertical extent, geographical region, time range, science focus, instrumentation etc.)
17	Aeolus SCVR_OptP-4 Communication needs	Announcement of Aeolus CAL/VAL teams / groups at the Aeolus wiki page (e.g. Aeolus Polar validation efforts, tropical campaign activities, etc.)
18	Aeolus SCVR_OptP-4 Coordination/planning needs	ESA to identify partners and to coordinate joint Aeolus CAL/VAL campaigns. ESA to stimulate topical CAL/VAL activities
19	Aeolus SCVR_OptP-4 Proposal evaluation	Recommendations for useful grouping of ASCVT activities shall be given by ESA based on the CAL/VAL proposal evaluation and discussions on Aeolus Cal/Val workshops

20	**Aeolus SCVR_OptP-5** **Instrument and modelling needs**	A wide range of collocated observations and model and retrieval comparisons shall be used to validate all aspects of the Aeolus data quality and to assure a correct understanding of the data quality
21	Aeolus SCVR_OptP-5 CAL/VAL techniques	CAL/VAL techniques shall include comparisons with: 1. collocated instruments on ground and under-flying the satellite, 2. comparison with collocated satellite observations (e.g. MODIS, Sentinel 2, Sentinel 3, Sentinel 5p, CALIPSO, EarthCARE, …) 3. air quality model product monitoring 4. other GOS observations (e.g. sun photometers, ceilometers, ground-based lidars, PANDORA, …) 5. alternative calibration and L2 retrieval schemes
22	Aeolus SCVR_OptP-5 Communication needs	Industry, Algorithm core team and ASCVT CAL/Val results shall be reported, presented at Aeolus CAL/Val Workshops and shared at the Aeolus wiki page
23	Aeolus SCVR_OptP-5 Coordination/planning needs	The errors will be a function of the CAL/VAL technique used. The validation results from all ASCVT activities shall feed-back into improvements of the processing chain
24	Aeolus SCVR_OptP-5 Proposal evaluation	ESA shall make sure that the CAL/VAL techniques listed in section 6.4 of the "Aeolus Scientific CAL/VAL Requirements" document are covered either within the ESA core validation activities (industry, Algorithm Core team) or by the ASCVT
25	**Aeolus SCVR_OptP-6** **Comparisons of collocated observations in inhomogeneous scenes**	A set of common time and space co-location criteria (e.g. co-locations within a radius of 50 km, 100 km, 200 km, etc.) shall be defined for the atmospheric optical properties product (L2A)
26	Aeolus SCVR_OptP-6 CAL/VAL techniques	CAL/VAL teams shall create statistics for the Aeolus product quality based on the agreed time and space collocation criteria, according to Aeolus SCVR_OptP-6
27	Aeolus SCVR_OptP-6 Communication needs	ESA shall document the common time and space collocation criteria established for the Aeolus atmospheric optical properties (L2A) product validation in [A1]
28	Aeolus SCVR_OptP-6 Coordination/planning needs	A set of common co-location criteria shall be created for each validation category during the pre-launch CAL/VAL preparatory workshops. These can be evaluated and adapted based on experience during Phase E2. Such updates must be reflected in updates of [A1]

29	Aeolus SCVR_OptP-6 Proposal evaluation	ESA shall assess whether the CAL/VAL proposals address the need for co-location and the proposed comparison technique and apply the agreed collocation criteria listed in "SCVR_OptP-6 CAL/VAL Techniques"
30	**Aeolus SCVR_OptP-7** **Comparing observations from different instrumentation**	It shall be assessed what the satellite and collocated observation information content, errors and representativity are, and these shall be taken into account for the data product comparison
31	Aeolus SCVR_OptP-7 CAL/VAL techniques	The satellite and collocated observation datasets shall be delivered with product quality (systematic and random error estimates), and the information content and representativity shall be assessed
32	Aeolus SCVR_OptP-7 Communication needs	The Aeolus systematic and random errors shall be established and reported and the data error estimates shall be validated. The systematic and random errors for the collocated observations shall be reported by the CAL/VAL PIs in the validation reports, at workshops and in the datasets when delivered to the ESA Atmospheric Validation Data Centre (EVDC, https://evdc.esa.int/)
33	Aeolus SCVR_OptP-7 Coordination/planning needs	Aeolus campaigns shall address observation information content, errors and representativity
34	Aeolus SCVR_OptP-7 Proposal evaluation	It shall be assess whether the AO proposals propose adequate techniques to deal with the difference in satellite and collocated observation information content, errors and representativity
	Campaigns objectives and requirements	
1	**Campaigns_DQO-1**	Verification of instrument performance w.r.t. laser energy and instrument transmission (including short- and long-term drifts) and ACCD characteristics (including memory effects).
2	**Campaigns_DQO-2**	Verify that the precision, unknown bias and response slope error of the wind observations and the atmospheric Mie and Rayleigh backscatter and extinction products are within the expected range and stable. This also includes validation of the cross-talk correction of the Rayleigh signal.
3	**Campaigns_DQO-3**	Establish the precision of the Mie and Rayleigh Response calibration and of the zero-wind calibration, including the effect of the atmosphere on the ground return bin.
4	**Campaigns_DQO-4**	Establish the accuracy and precision estimates of the wind, aerosol and cloud products during different atmospheric conditions and over different locations and seasons.
5	**Campaigns_DQO-5**	Confirm the instrument performance, including the operational L1b, L2A and L2B algorithms, for homogenous atmospheres.

6	**Campaigns_DQO-6**	Establish the influence of heterogeneous atmospheric conditions (clouds, wind shear and aerosol) on the instrument performance including operational L1b, L2A and L2B algorithms.
7	**Campaigns_DQO-7**	Verify the temperature and pressure correction of the L2A Rayleigh backscatter, including L2B Rayleigh winds, (Rayleigh-Brillouin scattering correction) by comparison of the input NWP temperature and pressure data to independent pressure and temperature measurements.
8	**Campaigns_SO-1**	Aeolus campaigns shall address dynamical processes in connection with **extratropical storms** including front developments. This should include processes linked to the total atmospheric energy budget
9	**Campaigns_SO-2**	Aeolus campaigns shall address **dynamically and optically strongly variable regions** such as **jet streams**, the upper troposphere and lower stratosphere (**UTLS**) and their exchange of energy and composition, in- and out-flow of **deep convective systems**, …
10	**Campaigns_SO-3**	Aeolus campaigns shall address the understanding of **topical dynamics** including Kelvin and gravity waves, intensive storm development (e.g. hurricanes), heat exchange with the ocean and how that impacts tropical weather and intense storm development, …
11	**Campaigns_SO-4**	Aeolus campaigns shall address atmospheric processes linked to topography such as katabatic winds, gravity waves, PSC formation and their impact on stratospheric processes, …
12	**Campaigns_SO-5**	Aeolus campaigns shall address the vertical distribution of aerosol and their impact on air quality modelling and the earth radiation budget (including cloud formation)
13	**Campaigns_SO-6**	Aeolus campaigns shall address physical processes for different aerosol types and their interaction of the Aeolus lidar backscatter. This shall include the studying of the Aeolus L2A product and information content and further evolution
14	**Campaigns_SO-7**	Aeolus campaigns shall address the understanding of large-scale circulations and their variations such as the Brewer Dobson Circulation (impacting meridional transport in the stratosphere including stratospheric ozone distribution), the Monsoon, El Niño, quasi-bi-annual oscillation and its variability (QBO), Madden-Julian Oscillation (MJO), Tropical Kelvin waves and their impact on climate and climate change, …
15	**Campaigns_PER-1**	ESA shall compile a campaigns plan, assessing the ACVT campaigns and their contribution to the overall Aeolus campaign objectives

16	**Campaigns_PER-2**	Dedicated ESA supported campaigns shall secure core data quality and science campaign activities, deploying the necessary instrumentation
17	**Campaigns_PER-3**	The campaigns shall be coordinated by ESA and if applicable also in synergy with campaigns for other ESA missions or (inter)national scientific campaigns

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