ADM-Aeolus, VAMP

Vertical Aeolus Measurement Positioning
Technical note TN1
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Authors: **Jos de Kloe**, Gert-Jan Marseille, Ad Stoffelen, KNMI

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		updated the range bin scenarios to reflect the requirement of a maximum size of 2 km added several items to the terminology section and some other smal textual changes
1.0	28-Mar-2008	added ESA comments dated 23-Nov-2007

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1 Introduction

This document gives an overview of the constraints and possible choices to be made on the settings for the vertical sampling of the ADM-Aeolus mission. The instrument has been designed to be adjustable, but in order not to waste valuable measurement time an overview of the possible settings, and their expected effect on the measurement quality is needed before launch.

First, the terminology used within the ADM-Aeolus mission is summarised in section 3. Then the operational cencept and instrument characteristics, relevant for the current study are given in section 4. The constraints will be summarised to which the mission is bound in section 5. Then a reference scenario and possible alternative scenarios are described in section 6. The choices following from the choosen terrain model are summarised in 7. In section 8 the types of errors are summarised which influence the end product. The tools needed to perform the simulations are summarised in section 9. Finally this technical note is concluded with an overview of the findings in section 10.

2 Documents and acronyms

2.1 Applicable documents

[AD1] "Mission Operations Concept Document", AE-TN-ESA-GS-006, issue 1.

[AD2] Contract # 18366/04/NL/MM Change Request: "Aeolus Level 1B/2A Processor Refinement & Pre-Launch Validation", AE-SW-ESA-GS-025, issue 1, dated 20060519.

[AD3] "ADM-Aeolus Level-1B Products, Algorith Theoretical baseline Document (ATBD)", AE-RP-DLR-L1B-001, issue 3.0, dated 20061130.

[AD4] "ADM-Aeolus Level-2B, Algorith Theoretical baseline Document (ATBD)", AE-TN-ECMWF-L2P-0023, issue 2.1, dated 20070223.

[AD5] "ADM-Aeolus L1B Master Algorithm Document (MAD)", AE-SW-ASU-GS-023, issue 4, dated 20060626.

[AD6] "Aeolus Flight Operation Manual Volume 7: ALADIN Instrument", issue 2, rev. 0, Dec.2006, ref: AE.OM.ASF.AL.00003.

[AD7] "ADM-Aeolus Level-2A, Algorith Theoretical baseline Document (ATBD)", AE-TN-IPSL-GS-001, issue 3.3, dated 31-May-2006

2.2 Reference documents

[RD1] Merci executive summary, Measurement Error and Correlation impact on the Atmospheric Dynamics Mission, by: Ad Stoffelen, Pierre Flamant, Måns Håkansson, Erland Källén, Gert-Jan Marseille, Jean Pailleux, Harald Schyberg, Michael Vaughan.

[RD2] "L1B PM10, Action Item 9, update of E2S default input parameter files", by O. LeRille, issued 20070629.

[RD3] "ADM Terrain model correction: processing model", by: Matthias Renard, PE-TN-ESA-SY-0177, version 2.1, issue date 18 april 2007

[RD4] "ADM-AEOLUS Commanding enhancement using a DEM", by: Matthias Renard, PE-TN-ESA-SY-0176, version 2.0, issue date 30 march 2007

[RD5] "TN 2.1, Sensitivity Analysis", by: Jürgen Streicher, Dorit Huber, Ulrike Paffrath, Oliver Reitebuch and Ines Leike, AE-TN-DLR-L1B-002, (or AE-TN-DLR-GS-TN2.1-SENSITIVITY-ANALYSIS ??), version 3.4, issue date 29 september 2006.

[RD6] "Harmonic Bias Estimation Application Prototype", by J. Marshall, ae-asu-gs-0137-2-harmonic-estimator, version 2, issue date 29 march 2007.

[RD7] "Aeolus Level 1b Processor and End-to-End Simulator, End-to-End Simulator Detailed Processing Model", by: P. Saeedi, ADM-MA-52-1801-E2S-DPM, version 2.4, issued 12 april 2007.

[RD8] "ADM-Aeolus, Ocean Albedo", TN on ocean albedo and calibration, AE-TN-KNMI-L1B-001, by J. de Kloe and A. Stoffelen, KNMI, 11-Jan-2007, version 0.4.

[RD9] Establishment of a backscatter coefficient and atmospheric database, DERA/EL/ISET-/CR980139/1.0, june 1998, by: J.M. Vaughan, N.J. Geddes, Pierre H. Flamant and C. Flesia.

[RD10] "Aeolus Mission Performance Budget Document", AE.RP.ASU.SY.128, version ???, p.56.

[RD11] "L2A Algorithm Theoretical Basis Document", Version 3.4m 25-Oct-2006, AE-TN-IPSL-GS-001.

2.3 Literature

[LR1] Tan, D., Andersson, E., 2005, "Simulation of the yield and accuracy of wind profile measurements from the Atmospheric Dynamics Mission (ADM-Aeolus)", Q.J.R. Meteorol. Soc., 131, 1737-1757.

[LR2] G.J. Marseille and A. Stoffelen, "Simulation of Wind Profiles from a Space-borne Doppler Wind Lidar", Q. J. R. Meteorol. Soc. (2003), 129, pp. 30793098.

[LR3] "Using GLAS/ICESAT Data To Derive CFLOS Statistics For The Design Of Future Space-Based Active Optical Remote Sensors; Final Report to the Earth Science Technology Office (ESTO)", by Simpson Weather Associates, G.D. Emmitt, sept. 2006. As presented on the SPIE Europe Remote Sensing Conference, 11-14-september 2006, Stockholm, Sweden.

[LR4] "Summary of Global Results from the GLAS Satellite Lidar.", by Spinhirne, Proc. 23rd ILRC, 24-28 July 2006, Nara (Japan), 9O-2.

[LR5] "Winds, shear and turbulence in atmospheric observations and models", thesis by Måns Håkansson, Department of meteorology, Stockholm University, 2002, chapter IV: "Determination of Atmospheric Wind Statistics", also published as DM Report, No. 87/ESA Contract No. 14659/00/NL/SF, pp.19, 2001.

[LR6] "Observations of Antarctic polar stratospheric clouds by the Geoscience Laser Altimeter System (GLAS)", by Stephen P. Palm, Michael Fromm and James Spinhirne, GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L22S04, doi:10.1029/2005GL023524, 2005.

[LR7] "Sand Transport by Wind on Complex Rough Surfaces: Field Studies in the McMurdo Dry Valleys, Antarctica", by: N. Lancaster, W.G. Nickling, J.A. Gillies and K. Cupp, American Geophysical Union, Fall Meeting 2004, abstract #P21B-02, dec.2004. See: http://adsabs.harvard.edu/abs/2004AGUFM.P21B..02L

[LR8] "Threshold wind velocity for snow particle movement and its variation with snow surface condition", by: Sato Kengo, Takahashi Shuhei, Tanifuji Takashi, Journal Title: Seppyo, 2003, see: http://sciencelinks.jp/j-east/article/200313/000020031303A0412040.php

[LR9] "Preadvies Stuifzanden", by: Theo Bakker, Henk Everts, Pim Jungerius, Rita KetnerOostra, Annemieke Kooijman, Chris van Turnhout, Hans Esselink, Expertisecentrum LNV, report EC-LNV nr. 2003/228-O, Ede/Wageningen, sep.2003, see: dt.natuurkennis.nl/uploads/228_OBN_preadvies_stuifzanden_bos.pdf

[LR10] "An introduction to dynamic meteorology", by: J. R. Holton, book, 4th edition, published 2004 by: Elsevier Academic press.

2.4 Acronyms

ACCD	Accumulation Charge Coupled Device
AD	Applicable Document (see section 2.1)
ADM	Atmospheric Dynamics Mission
ANX	Ascending Node Crossing
BRC	Basic Repeat Cycle (covering a 200 km orbit section)
DCC	Dark Current Calibration
DEM	Digital Elevation Model
E2S	End-to-End Simulator
ESA	European Space Agency
FP	Fabry-Perot (spectrometer)
Fz	Fizeau (spectrometer)
GLAS	Geoscience Laser Altimeter System
HLOS	Horizontal projection of the Line-Of-Sight (of the wind component)
HSRL	High spectral resolution Lidar
IAT	Instrument Auto Test
IDC	Instrument De-focus Characterization
IDL	Interactive Data Language (a commercial software package sold by CreaSo for plotting and data analyse)
IRC	Instrument Reponse Calibration
ISR	Instrument Spectral Registration
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Dutch Meteorological Institue)
L1Bp/L2Ap/L2Bp	Level 1B/2A/2B processor
L2CAL	Level 2 related Calibration tasks
LCPA	Laser-Chopper-Phase-Adjustment
LDTA	Laser Diode Temperature Adjustment
LOS	Line-Of-Sight
LOSCAL	LOS calibration/in-flight mispointing characterisation
LR	Literature Reference (see section 2.3)
LTAN	Local Time Ascending Node
MERCI	Measurement Error and Correlation Impact on ADM (ESA project)
MLST	Mean Local Solar Time
MRC	Mie Response Calibration
NWP	Numerical Weather Prediction
OCKA	???
OWVM	Offline WVM
PBL	Planetary Boundary Layer
PDF	Probability Density Function
PSC	Polar Stratospheric Cloud
RD	Reference Document (see section 2.2)
RRC	Rayleigh Response Calibration
SNR	Signal to Noise Ratio
SP_VS_R	Starting Point Vertical Sampling Rayleigh
Td	Time delay
TMC	Time period of the high frequency Master Clock (it uses a frequency of 48 [MHz], so the cycle period is 1./48e6 [s], see [AD5], section 19, Annex 5 auxiliary data, p.85.)
WGS84	World Geoid System 84 ???
WVM	Wind Vector Mode or Wind Velocity Measurement
ZWC	Zero-Wind-Calibration

2.5 Document preparation

This document was written using the LaTeX typesetting system. The range bin graphics have been produced using the IDL software package.

3 Terminology

This section defines for all project participants which terminology is used, and may be used as a reference by them. If possible the same terminology will be used as is in use for the algorithm development work (L1B,L2A, L2B). Since at the beginning of this study we may not be able to foresee all needed definitions, this list will be updated during the course of the study. If other definitions are needed please request them. (todo: fill these definitions.)

Definition of the terminology used (in alphabetical order):

- Ascending Node Crossing (ANX): The Aeolus Ascending Node Crossing point is the location of the intersection point between the spacecraft's ground track and the equator. Accordingly, the ANX time is the UTC time of the ANX passage.
- assimilation: the process of objectively adapting the model state to observations in a statistical optimal way taking into account model and observation errors.
- attenuation (a): a measure for the signal loss in a volume. Also known as local optical depth (see optical depth for more details). It has no unit. Often attenuation is also expressed in dB, which differs only in the multiplicative factor 10/log(10) with the expression just given.
- backscatter (β): the amount of radiation at a given wavelength (355 nm in our case) that is reflected in a given direction from an atmospheric volume V, relative to the incident radiation on the surface area facing the incident radiation of this volume. Its unit is [1/(m.sr)].
- BRC: in measurement mode the instrument will use a Basic Repeat Cycle (sometimes also called Burst Repeat Cycle) as follows: it takes lidar measurements over 50 km, then it waits for 150 km. The timing is as follows. The total 200 km BRC takes 28 seconds. Taking the measurements over 50 km takes 7 seconds. During these 7 seconds the lidar fires laserpulses at a rate of 100 Hz, so 700 individual laser pulses are fired. During the 21 second interval between measuring, the laser amplifiers are switched of during 15 seconds. The remaining 6 seconds are used for warming up the laser. The last 305 pulses of the warm-up period may also be used as measurement, but the quality of the results is still uncertain. Therefore we assume in this study that these warm-up pulses cannot be used. (see [AD3], sec. 4.2.1, page 20.)
- calibration parameters: (to be filled)
- classification: the L2BP tries to sort the lidar result at measurement level into different classes. At the moment 2 classes have been implemented: cloud or no-cloud. Results in each class are then accumulated into an observation for this BRC.
- cross talk between the 2 channels: when detecting the broad Rayleigh scattered light, it is inavoidable to also detect the small Mie peak. This Mie peak will be present in the tail of both FP response curves, but on different sides of the top of the response curves. Therefore the Mie signal in both the A and B channel changes with windspeed, and a correction is needed to perform accurate wind inversion.
- cross talk between subsequent range bins: it takes a finite time to read all datalines from the ACCD chip. This has as consequence that light is still being detected for some time after the ACCD read-out started. This seems to lead to an overlap in signals for two adjecent range bins (a more clear explanation would be welcome here).
- extinction (α): a measure for the signal loss at a given position. It is defined as the natural logarithm of the radiation leaving a given atmospheric volume of infinitesemal thickness, relative to the amount of radiation entering this volume, devided by the layers thickness. Its unit in [1/m]. Extinction relates to local optical depth or attenuation, by the integration: $d = \int_z^{z+dz} \alpha(z)dz)$. Note that if α is constant

over a given volume, this can be written as: $d = \alpha dz$ The extinction may be used by the L2BP to classify the atmosphere by applying a threshold to it. The other implemented method is to apply a threshold to the scattering ratio.

- height bin thickness (dZ): also called range bin thickness, is the vertical thickness of the atmospheric layer observed by a single rangebin by applying the range gating technique on the observed signal. (basically switching the detector on for a very short time only, which determines, together with the speed of light and the pointing of the laser, what the location was of the scattering particles or molecules)
- Horizontal Line Of Sight (HLOS): The horizontal line of sight (HLOS) is the horizontal component of the LOS, as projected to the local tangential plane above the WGS84 ellipsoid.
- Line Of Sight (LOS): The line of sight (LOS) is defined as the path of propagation of an emitted laser pulse. It follows a straight line between the Aladin instrument and the intersection point with an atmospheric target in case refraction effects are neglected (which will be assumed in this study).
- measurement length: the integration length user for 1 measurement. See measurement versus observation for more details.
- measurement modes: the ADM-Aeolus/ALADIN instrument can be operated in the following active modes (see [AD1]):
  - Measurement mode, this includes WVM (Wind Vector Mode/Wind Velocity Measurement), but also others like OWVM (Offline WVM), DCC (Dark Current Calibration), IDC (Instrument Defocus Characterization), LCPA (Laser-Chopper-Phase-Adjustment), LDTA (Laser Diode Temperature Adjustment), OCKA (???), LOSCAL (LOS calibration/in-flight mispointing characterisation), and L2CAL (Level 2 related Calibration tasks)
  - slow calibration: IAT (Instrument Auto Test) and RRC (Rayleigh Response Calibration)
  - fast calibration: MRC (Mie Response Calibration), IAT (Instrument Auto Test), and ISR (Instrument Spectral Registration).
- measurement versus observation: the lidar measurements are composed of an accumulation (in the accd hardware) of p pulses. This typically covers 1 to 3.5 km of orbit. The amount of measurements n in a BRC ranges from 15 to 50 (depending on p). The product $n \times p$ may never be larger than 1005. An observation is an accumulation in the L2BP software of some or all measurements within a given BRC.
- Mie versus Rayleigh channel: two types of backscatter are present for the 355 nm UV radiation. Scattering on air molecules (Rayleigh), and scattering on particles and droplets (Mie). Scattering on air molecules results in a broadening of the spectrum of the returned light due to the termal motion of the molecules. Scattering on aerosol particles, cloud droplets and ice crystals do not show any additional broadening, and will have a spectral width equal to the spectral width of the emitted laser light. This difference in spectral properties of the backscattered light is used to split it in 2 mostly independent channels.
- observation: see explanation for: measurement versus observation
- off-nadir geometry: the measurement mode used for wind-vector-measurements, using an incidence angle of 37°
- off-nadir zero wind ground calibration: due to mispointing of the lidar it is possible that a small component of the satellite velocity is projected on to the line of sight. By measuring ground reflections this component is measured routinely during WVM operation. This calibration data will then be fitted to some model and used to correct the retrieved winds from this effect.
- operational parameters: (to be filled)

- (local) optical depth (d), or attenuation: a measure for the signal loss in a volume. It is defined as one minus the radiation leaving a given atmospheric volume, relative to the amount of radiation entering this volume, and equals $a = 1 - \tau$. It has no unit. It can be calculated from the extinction profile by integration: $d = \int_z^{z+dz} \exp(-\alpha dz)$.

- optical properties parameters: (to be filled)

- orbit: ADM-Aeolus will be flying in a sun-synchronous down-dusk polar orbit at a mean altitude of 408 km.

- range bin: the smalles vertical atmospheric layer that can be resolved by the instrument. The light resulting fromr eflection in a range bin is selected by applying a time window on the received signal. The smallest possible range bin for ADM-Aeolus is 250 [m] (for incidence angle of 37°). Larger values upto 2 [km] are possible, provided that they are integer multiples of 250 [m].

- Rayleigh channel: see explanation for: Mie versus Rayleigh channel

- Reference orbit: The Aeolus reference orbit is defined in terms of a set of orbit parameters (eccentricity, sun-synchronous inclination), an orbit repeat cycle and a set of nominal longitude values defining the ascending node crossing positions for all orbits within an orbit repeat cycle. Margins are specified for the tolerable deviations of the actual cross-track position and the mean local solar time (MLST) of the ANX crossings from the reference track.

- scattering ratio (ρ): the scattering ratio is the amount of particle backscatter, devided by the total molecular and particle backscatter. This means that a value of exactly 1 means that only molercular backscatter is present. Note that scattering ratio may be used by the L2BP to classify the atmosphere by applying a threshold to it. The other implemented method is to apply a threshold to the extinction.

- shear: see explanation for: wind vector versus wind shear

- SP_VS_R: defines the top of the highest Rayleigh range bin along the LOS in [km].

- Terrain Model: A terrain model will be stored on board Aeolus for use in adjusting the vertical offset of sampling grids in the two receiver channels. The model will reflect the actual topography at the line-of-sight intersection point with the Earth and will be stored as a discrete look up table covering all orbits within an orbit repeat cycle.

- transmission (τ): a measure for the amount of signal that traverses a given atmospheric volume. It is defined as the radiation leaving a given atmospheric volume, relative to the amount of radiation entering this volume, normalised by the thickness of the volume. Its has no unit. the relation to the optical depth d is: $\tau = exp(-d)$, which can for small d be approximated with: $\tau = 1 - d$. Note that the 2-way transmission through this volume is τ^2. Note also that when tau is assumed constant in a rangebin, then the transmission to the middle of the rangebin is $\sqrt{\tau}$. If the light is reflected in the middle of a rangebin by a cloud, the 2-way transmission to the middle of the rangebin is thus $(\sqrt{\tau})^2 = \tau$.

- WGS84: is an ellipsoid representing the global shape of the earth[1] and is used as reference for the coordinate system used by the reported measurements. Note that the actual shape of the globe will differ from the WGS84 value from location to location. For this reason the difference named Geoid_Separation is added to the geolocation parameters of the L1B product file. Note that this difference is based on a Digital-Elevation-Model (DEM) which has its own inaccuracies, so this number will contain errors.

- wind parameters: (to be filled)

- wind vector versus wind shear: when measurement data is used in a Numerical Weather Prediction (NWP) model, a "pseudo" measurement is extracted from the model data and compared to the real measurement. The difference between real and pseude measurement is used to adapt the model state

[1] see: http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.html

to the real atmospheric conditions. Constructing such a “pseude” measurement is equally simple when the measurement is a wind vector, or when it is a difference between two vectors at different altitude (i.e. shear). Therefore there is no technical constraint in favor of one over the other as far as NWP models are concerned. Because shear is a difference between 2 values, the 24 measured winds are reduced to 23 shear values. This seems a drawback. However, it may be possible in this case to skip the zero-wind-calibration as a constraint from constructing the range bin scenarios, which on average will lead to more than 1 rangebin to be below the surface (so without any valid wind result). Therefore the possibility exists that the use of wind shear is favorable, and this will be examined in this study. Note also that the stability of the instrument is an important factor here. If the stability turns out to be insufficient zero-wind-calibration may not be feasable at all.

- WVM: Wind Vector Mode/Wind Velocity Measurement (see also “measurement modes”)
- zero wind ground calibration (ZWC): see explanation for: off-nadir zero wind ground calibration

See [AD3], [AD4] and [AD7] for more definitions of the used terminology.

4 Operational concept and instrument characteristics

This section will summarise the relevant characteristics for the operational concept, the orbit and the instrument, as far as needed in the context of this project. Only items are described that may have influence on the choice of range bin definitions, it is not intended to be a complete list. If other definitions are needed please request them.
(todo: fill these definitions.)

4.1 Instrument characteristics

The instrument characteristics are:

- Laser: the laser will operate at 355 nm, which corresponds to 845 THz, with a repetition rate of 100 Hz. Beam divergence is 12.18 μrad, leading to an illuminated spot on the surface with a diameter in the order of 10 m. The average laser pulse energy is designed to be 120 mJ, and the laser pulse length will be 30 ns, which corresponds to 9 m.
- Pointing: the laser will be pointed with a slant angle of 35° off nadir. The satellite is steered in such a way that earth rotation and systematic orbit height variations are compensated. Due to the curvature of the earth, the incidence angle at the surface is close to 37....°.
- Telescope: has a diameter of 1.5 m, and a Field-of-View (FOV) for background light of 15 μrad.
- Mie channel: this channel consists of a Fizeau spectrometer and ACCD detector, and is mainly sensitive to the backscatter on aerosol and cloud particles/droplets.
- Rayleigh channel: this channel consists of a Fabry-Perot (FP) spectrometer and ACCD detector, and is mainly sensitive to the molecular backscatter.
- Horizontal sampling: measurements are collected over a 50 km orbit section. Each measurement is formed by collecting the signal for a configurable number of laser pulses. The L2BP approach is then to classify these measurements into different classes (at the moment cloudy and clear sky are discriminated), and the accumulate each class to form an observation representing (part of) the 50 km measurement track. Horizontal separation of profiles is between 150 and 250 km, depending on which measurements where used in the accumulation to construct the observations[2].

[2]For example L2B processing for one BRC might produce an observation based on only the first measurement, while the processing of the next BRC might produce an observation based on the last measurement. The distance between these 2 observations will then be almost 250 km. The other way around will yield observations much closer to each other, only separated by about 150 km.

- Vertical sampling: the signal is split at the detector in 25 range gates. 24 range gates are used for atmospheric return signals, and one range gate is used to characterize the background solar light contribution due to surface or cloud albedo. Range bin definitions can be set from ground level up to 30 km.
- The SP_VS_R value defines the top of the highest Rayleigh range bin along the LOS in [km]. The abbreviation stands for "Starting Point Vertical Sampling Rayleigh".
- The Td_Ray_Mie value defines the separation between the highest Rayleigh range bin and the highest Mie range bin in units of the TMC clock.
- For each range bin the top and bottom altitude are also determined by TMC values in clock cycles. Note that the TMC unit is also used to program the E2S. These TMC values can only be changed 8 times per orbit. The SP_VS_R can be used to shift both channels up and down, and may have a different value for each BRC. This will be controlled by the on board terrain model.
- others?

4.2 Operation characteristics

The operation characteristics (for measurement mode) are:

- WVM mode is used
- the on board ground model Look-up-table for setting SP_VS_R can be updated only once a week. This concerns the so-called terrain-model, which is used to update the lowest vertical sampling height for every observation (thus every 200 km).
- on average the range bin definition may be switched 8 times per orbit. Actually for 107 orbits available in a week for WVM (assume 2 will be used for calibration purposes) 8*107 = 856 times for switching may be pre-defined. The planning is done for 3 weeks at a time, and this switching table will only be updated once a week (see [AD1] for details).
- others?

Note that the other operational modes, especially the dedicated calibration modes like ISR, MRC, RRC, etc. are not relevant for this study, and will not be discussed.

4.3 Orbit characteristics

The orbit characteristics are:

- mean altitude of 408 km
- mean orbital speed of 7664 m/s.
- inclination
- repeat cycle
- orbit prediction accuracy
- LTAN, Local Time Ascending Node (relevant for considerations on atmospheric mixing, PBL height, clouds, etc.)
- others?

4.4 Calibration characteristics

The calibration characteristics are:

- characteristic 1

4.5 Processing characteristics

The processing characteristics are:

- characteristic 1

4.6 Atmospheric characteristics

The atmospheric characteristics are:

- the altitude at which the tropopause and jet winds occur differ with altitude/climate zone and season. A similar dependency exists for the altitude at which cirrus clouds may occur.
- The Planetary Boundary Layer (PBL) may have a strong vertical variation in wind speed and wind direction.
- others

5 Constraints

Several constraints exist on the range bin definition that may be used for ADM-Aeolus measurements. First technical constraints, due to the choosen hardware, will be discussed. Then the needs for calibration, processing and assimilation are given.

5.1 Instrument constraints

These constraints are technical, due to the design of the hardware. They follow from the instrument characteristics mentioned in section 4.1.

- we are limited to 24 vertical range bins for both the Fabry-Perot (FP) and the Fizeau (Fz) spectrometer.
- the range bins typically will have a size of 250 m, 500 m, 1 km, 2 km[3] The technical constraint is that they should be multiples of 250 m, so the values 250 m, 500 m, 750 m, 1000 m, 1250 m, 1500 m, 1750 m and 2000 m are allowed. Currently there is a constraint in the on-board software that limits the range bin size to 2 km, and in the current stage of preparation it is not possible to change this. Therefore it is requested for a follow-on mission to relax this requirement to higher values and allow a Mie Range bin size upto 16 km.
- The maximum allowed altitude for the upper rangebin is defined by the difference between the T_max (= 16160 TMC = 40 km) and the On_Ground (= km) variables, and is thus 37 km.
- The range bin definition can be altered on average 8 times per orbit (preprogrammed)
- The range bin definition can be shifted upwards or downwards following the local terrain. For this an optimal ground level determined for a 50x50 km box will be used[4]. This ground level is precalculated for all 109 orbits (having each 200 BRC's) in an orbit repeat cycle of one week, and stored on board of the satellite (see [AD1], section 4., p.30). Details on how this is calculated are given in [RD3] and [RD4]. The purpose of using a terrain model, is to ensure that not too many Mie and Rayleigh bins are lost below the surface. From [RD4], sec. 5.2.2, fig. 12 on p.19, it can be seen that the improvement is significant[5]

[3]Note that in [AD6], the vertical resolution is given as 0.5 km to 2 km. However, from the default scenarios created for use with the E2S by Oliver Le Rille it is clear that 250 m resolution is also possible. From remarks made at the ADMAG it is clear that 3 km resolution is desired in the stratosphere. It would also be very usefull to have the possibility to create Mie range bins of 10 or 12 km, to be used to check the upper Rayleigh range bins for possible cross-talk.

[4]a square box is used, rather than the line along the predicted orbit, because of uncertainties in the orbit prediction. This uncertainty would lead to a maximum across-track deviation of the expected orbit after one week, of 50 km.

[5]This study used a range bin definition consisting of only 250 m bins, which is a bit unrealistic. When only looking at the bottom 4 bins (which is a scenario more likely to be used) it can be seen that only 50 % of the rangebins are (partly) above the surface in case no terrain model is used. When allowing 8 steps in SP_VS_R per orbit this is already increased to 65 %, and for 200 steps in SP_VS_R a value of better than 90 % can be reached.

- The time needed to transfer charges on the CCD is $\approx 1\mu s$ corresponding to 300 m 2-way LOS path[6]. This induces a vertical range of overlap between subsequent range bins of 120 m in the Mie channel. Since the FP CCD illumination is in two limited-size spots, the Rayleigh channel signal overlap between range gates is smaller, and is about 50 m. (todo: check numbers with Oliver's presentation, and refer to it). This introduces additional crosstalk between subsequent range bins in the same channel, and makes it harder to combine information between the 2 channels at the same level. It also causes the ground reflection to be smeared over 120 m, making it more likely to have the ground reflection in 2 range bins. The only wat to prevent this would be when the ground level can be placed very close to the center of the 250 m range bin used to detect the ground. This would limit the possibility to obtain usefull ground reflection signals to very flat terrain only. Unfortunately the ground level can only be predicted to an accuracy of 200 to 300 meters, even over flat terrain, due to pointing accuracy. Therefore the smearing of the signal cannot be prevented.
- the horizontal sampling, defined by n (number of measurements per BRC) and p (number of laser pulses per measurement) have effect on the expected signals. The PDF for cloud cover is different when sampled with a different resolution. Also the SNR for the measurements will differ, which have an effect on the quality of the classification result of the L2BP.
- the instrument will operate in burst mode, measuring for 50/70 km, followed by the 150/130 km pause. The exact length of the burst depends on whether warm-up shots are used or not. The exact start time/location of the burst cannot be predicted very accurately within the 200 km stretch. The uncertainty will be in the order of 100 km.
- it was recently discovered that the transmission in the Mie spectrometer throughput is now 47% (in stead of the previously estimated 66%). This may have as consequence that the instrument will not fullfill the requirement in the PBL of acquiring winds with 1 m/s accuracy.
- others ?

todo: find the proper pages in [AD1] and refer to them for each constraint.

5.2 Operation constraints

From the operational characteristics, mentioned in section 4.2 the following constraints are extracted:

- there are 8 switching moments on average per orbit. Since we have 109 orbits per week, this leads to 8*109 = 872 switching moments that may be preprogrammed along the orbits of one week. This table holds the switching definition for 3 weeks, will be uploaded once a week, and must be available 1 week before the actual upload takes place.
- this study focusses on WVM mode only. However, also the other operational modes (like RRC, MRC, ISR etc.) have an influence on the data, since they cost time to be performed, and thus lead to less data for WVM measurements. This has to be taken into account especially for the zero-wind-calibration opportunities. An additional constraint may be present if 2 switching moments are used by these calibration modes, since they will need customised range bin settings. This means that the amount of 872 switching moments per week is reduced, depending on the frequency of these calibration measurements.
- others?

5.3 Orbit constraints

From the orbit characteristics, mentioned in section 4.3 the following constraints are extracted:

- the accuracy of the orbit prediction is limited. This leads to inaccuracies in the on board terrain model which is used to position the range bin definition with respect to the expected surface level. This uncertainty is estimated to be 50 km across and along track.

[6]These numbers for rangebin overlap are based on A2D results. As far as we know now, this will be very similar for the flight model, but this needs to be confirmed.

- The Local Time Ascending Node (LTAN) defines that the satellite will pass at 6 h and 18 h local time at the equator. Since the expected atmospheric properties at 6 h may have different characteristics compared to 18 h, when looking at for example atmospheric mixing (which determines PBL height), development of convection and presence of clouds, this is important for this study.
- others?

5.4 Calibration constraints

The calibration constraints follow from the calibration characteristics mentioned in section 4.4.

It is assumed that mispointing results in HLOS wind biases due to wrong Doppler compensation[7].

Because mispointing changes only slowly, and may be related to the phase of the orbit, it is hoped that this may be compensated by fitting the zero wind calibration results to a set of harmonic functions. Therefore calibration in off-nadir geometry (as used during wind vector mode) is needed.

This calibration can be combined with the wind vector measuring mode, provided that a ground echo is measured. This calibration should yield a number of results per orbit high enough to correct for the bias caused by these errors[8]. At measurement level this could yield as much as 50 ground echo's per BRC, or with 200 BRC's per orbit, 1000 ground echo's per orbit, but it will probably be much less due to cloud coverage, and terrain unsuitable to measure a proper ground echo.

The locations where this type of calibration can be performed are not yet choosen. The specific question to study the feasability of zero-wind-calibration over the oceans has been adressed in [RD8]. From this study it is clear that the possibility of obtaining a sufficient amount of unbiased surface reflections for zero wind calibration is very low above the ocean. Selecting data based on the magnitude of the backscatter will not be possible. Maybe selection based on advance knowledge from NWP models could be used to select surface reflections with cross-wind, which would probably have the smallest errors.

However, if it is decided that use of NWP data is acceptable for calibration, then other methods seem more likely to yield good results. The simplest way would then be to just select clear rayleigh hlos results, with good SNR, and compare these with NWP winds at the relevant altitude. Averaging over a large number of hlos results would then more likely give a proper zero-wind-calibration then a result based on sea-surface returns.

Results from several previous orbits maybe combined with the current result, to reach better results by fitting the data for example to harmonic functions[9] (see [RD6]).

The exact signal level is not very important for this calibration, but it must clearly be stronger than the backscatter from the remainder of the atmosphere in the range bin detecting the ground. This has been studied in [RD5], and it was concluded that this limits the possibility for calibration to highly reflective surfaces like snow and ice, and possibly water. The albedo of grass, forest and soil is too low to yield proper results for medium aerosol loading, and for these cases the signal from the aerosol layer above the surfaces confuses the result and introduces an unacceptable bias for moderate surface wind speeds. In addition, ground returns may also be confused by reflections on moving particles (sand/dust, snow/ice-crystals) close to the surface. This is a very common situation in certain types of landscape (i.e. over deserts and poles), and may already occur for moderate surface windspeeds of 5 or 6 m/s[10].

Furthermore the results for the Rayleigh channel clearly showed to be worse than for the Mie channel, leading to the recommendation to only use the Mie channel for zero-wind ground calibration. Therefore the Rayleigh range bin definitions would not need to reach the surface. Important for this calibration is that a

[7] The error in the HLOS projection caused by the mispointing is negligible. A projection error would result from an error in Roll-angle. For a typical Roll-angle error of 127 μrad (see [RD10], p.56), assuming a HLOS wind velocity of 100 m/s and an incidence angle of 37.5° = 0.654498 rad, this would lead to an error in HLOS wind velocity of only 0.017 [m/s]. The error due to wrong Doppler compensation is caused by an error in the Pitch-angle. For a typical Pitch-angle error of 446 μrad, (see [RD10], p.56) using an incidence angle of 37.5°, a HLOS wind velocity of 100 m/s and a satellite orbital velocity of 7664 m/s, this would lead to an error in the HLOS windvelocity of 4.45 m/s.

[8] The current estimation is that at least 780 good ground echo measurements are needed to determine the harmonic functions needed to perform the bias correction (see [AD5], section 14.5, p.57). These should have a proper coverage of the globe. If only certain areas are sampled, for example only the poles, then not all harmonic functions can be resolved, no matter how many calibration points are collected.

[9] Note that the harmonic functions are a plausible set, but not proven to be the optimal set of functions.

[10] A surface wind threshold value for sand transport of 6 m is mentioned in [LR7] and around 6.6 m/s (wrongly classified as beaufort scale 6 in this report, while it should be scale 4) in [LR9]. For fresh snow a value of 5 m/s is mentioned in [LR8], while the same article mentions 10 m/s for aged snow (1 to 3 days old).

ground echo is observed, and that the remaining atmosphere above the ground is as small as possible, so several 250 m Mie range bins need to be located around the surface level to achieve this.

Note that [RD5] does not consider the vertical range bin overlap due to the ACCD. This overlap effectively causes the ground level signal to be vertically smeared by more than 100m. Depending on the ground level position with respect to the vertical range bin setting, this will cause effect on the Mie ground detection. Moreover, a limitation to calibration on for example snow and ice surfaces will not provide control on orbit phase dependent biases.

Constraints:

- several 250 m Mie range bins below and above ground level, but only near the desired surfaces[11], so the possibility to switch range bin definition 8 times per orbit may be used to switch this on and off.
- Rayleigh rangbins do not need to reach the ground.
- above sea the Mie definition can be lifted upwards to prevent loosing many range bins close to the surface, because there is almost no DEM variation at sea. This can be achieved by adjusting the on-board terrain model.

5.5 Processing constraints

The processing constraints follow from the processing characteristics, as mentioned in section 4.5. The L2B processor needs to have sufficient data to convert the retrieved spectra to proper wind vector components. To correct the L1B HLOS wind results for pressure and temperature effects it will use advance knowledge from a NWP model forecast. Also it needs to be able to correct for cross-talk (for the Rayleigh channel), and to classify the measurements to discriminate between cloudy and cloud-free profiles (both channels). This leads to the following constraints:

- In order to control the representativity of the HLOS wind for the Rayleigh range bins, an over-sampling by the Mie channel is recommended, whenever possible, upto the levels where cloud and aerosol layers may occur. This depends on climate zone. This is needed to improve the vertical high assignment of the HLOS wind results.
- Ideally at the highest range bins one Mie bin could cover several Rayleigh bins to control the contamination risk, but since it is currently not possible to use rangebins larger than 2 km, this can only be recommended for future missions.
- Mie range bins should be as small as possible, to retrieve proper vertical localisation of the retrieved wind.
- Rayleigh range bins should have matching Mie range bins as high as possible, at least upto the levels where cloud and aerosol layers may occur. This will enable crosstalk correction of the Rayleigh signals.
- Mie range bins should match 1-to-1 or several-to-1 with Rayleigh range bins. this is necessary for a proper cross-talk correction and extended retrieval of atmospheric optical properties (backscatter, extinction and lidar ratio) by the L2AP.

Note that, as was noted in section 5.1, due to the ACCD vertical range bin overlap, the signals detected by the FP and Fz over identical vertical range bin settings will result from differently smeared vertical atmospheric slabs. Therefore these signals will represent different volumes because the vertical smearing is different for the Fz and FP channel. The L2B processor does not yet take this into account.

[11]Possibly ice and or snow and or water surfaces will be suitable. This is still t.b.d. The ongoing A2D campaign may give usefull data to decide this.

5.6 Atmospheric constraints

The atmospheric constraints follow from the atmospheric characteristics, as mentioned in section 4.6.

NOTE: some of the text in this section probably should be moved to the Atmospheric Characteristics section.

Known properties of the atmosphere can be used to target the measurements to the more interesting altitude. Properties to be considered are:

- Range bins should be large enough to yield sufficient signal (so a good SNR) to enable processing to HLOS wind. For Mie range bins this leads to no extra constraints, since a sharp cloud-no cloud boundary always will give a strong reflection, no matter how small the range bin is. However, for Rayleigh rangebins this leads to the constraint that above 16 km the rangebin size needs to be at least 2 km.

- In most cases aerosol layers will be present close to the surface. This leads to extinction of the Rayleigh signal, and degradation of the results for this channel. Therefore it should be considered to have the lowest Rayleigh range bin at some altitude above ground level.

- The altitude of the highest common cloud type (cirrus) is a function of latitude. In the tropics, defined to be region between -30 and +30 degree latitude, they may occur up to 18 km. In the extra-tropics the maximum altitude is around 15 km, and drops gradually to about 12 km in the polar regions. See figure 1 for an illustration of this property. This figure was taken from [LR4].

- Recent measurements from GLAS have shown that Polar Stratospheric Clouds (PSC's) are very common, and occur frequently (almost daily) over the arctic regions during the hemispheric winter periods. PSCs may extend over several thousands of kilometers horizontally and some kilometers vertically. Two types of PSC's are discriminated (see [LR6]). The first type has very small backscatter and extinction values[12], has been reported upto 21 km altitude, and will probably not noticably affect the HLOS wind results. The second type is more similar to cirrus, and has higher backscatter and extinction[13]. This type may have a significant effect on the observed lidar signals. Unfortunately the GLAS instrument was not able to discriminate bwteen both PSC types, so it is not yet known whether type II also may occur at very high altitudes of 20 km or more.

- From impact studies we know that measurements at tropopause/jet level have maximum positive effect on the current NWP models (see [LR1]). Therefore extra measurements on this level (the altitude of which varies also with latitude) may be desirable. From [LR5] p.8, figure 3, and [LR10], p.140-142 and p.347-349, figure 6.2, it is clear that jet winds occur between altitudes 8 and 14 km and above ca. 25 km. For the higher jet, known as the polar stratospheric jet, wind velocities upto 140 m/s have been observed. For the tropopause level jets around 10 km maxima of 125 m/s do occur. These jets are also known as the polar-front-jet and the subtropical-jet, and are both located near the tropopause (which is located between 6-10 km for the polar-front-jet, and around 15 km for the subtropical-jet) (see [LR5] p.17).

- Desert dust outbreaks may cause substantial aerosol concentrations up to 6 km, above for example the Sahara and the Atlantic. Typical height has been established within several AMMA and SAMUM campaigns. However, due to the limited number of switching moments on average for an orbit, it is probably not possible to use a range bin definition with high resolution PBL sampling tuned for this case. Also the fact that rangebin definitions need to be uploaded at least a week before use, makes it unlikely that anticipation on this type of events will be possible.

- For sea salt particles no specific profiles or datasources are available yet.

[12] Reported typical values (converted to 355 nm) are: $\beta_c = 2.5 \times 10^{-7}$ [1/(m.sr)], and $\alpha_c = 2.5 \times 10^{-6}$ to 5.0×10^{-6} [1/m] (see [LR6]). This gives a maximum extinction of only 0.995 per km PSC cloud. These numbers agree well with the older estimates given in [RD9], This backscatter and extinction for PSC's is typically 2 orders of magnitude smaller than normal cirrus clouds. See for example [RD9], section 5.1.4, table 5.2. Here PSC has $\beta_c = 3.0 \times 10^{-7}$ [1/(m.sr)], and $\alpha_c = 6.0 \times 10^{-6}$ [1/m], while cirrus has $\beta_c = 1.4 \times 10^{-5}$ [1/(m.sr)], and $\alpha_c = 2.0 \times 10^{-4}$ [1/m]. Also [RD9] estimates the altitudes a bit higher, and reports that these PSC's may occur up to 25 or 30 km in the polar region. The consequence of this is that cross-talk and extinction due to PSC's will be well below the expected noise level. (todo: give some numbers for noise level)

[13] Reported typical values (converted to 355 nm) are: $\beta_c = 2.5 \times 10^{-6}$ [1/(m.sr)], and $\alpha_c = 5.0 \times 10^{-5}$ [1/m] (see [LR6]).

- measuring above 30 km will probably not be necessary (Ad and Heiner will motivate why this is the case).
- others ?

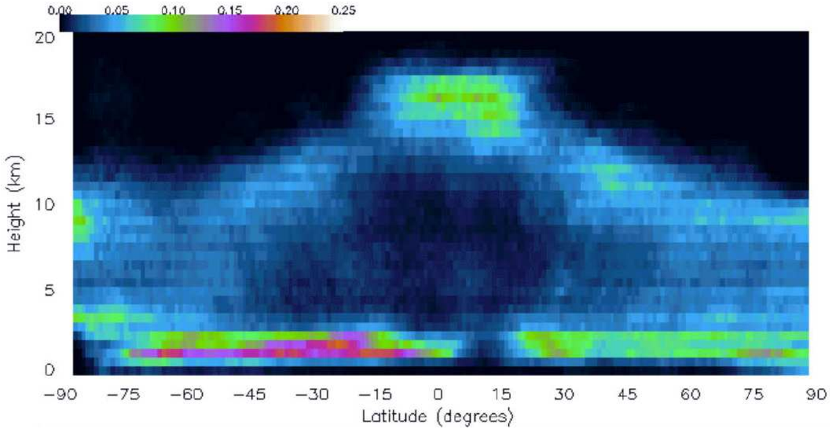

Figure 1: *The zonal average frequency distribution of cloud height detection for GLAS data from October 2003. This clearly shows that in tropical regions (-30 to 30 deg. latitude) clouds reach up to 18 km, while in the remainder of the world 15 km is a safe upper estimate.*

5.7 Shear observation operator

In order to assimilate the HLOS wind data in a NWP model an observation operator is needed[14]. The observation operator includes the projection of the model state to the observed information. For Aeolus the observation could be regarded as both a HLOS wind component profile and a HLOS wind shear profile. Shear does not depend on the zero wind calibration[15] and thus no Mie range bins are needed at ground level for calibration (see first constraint in section 5.4). The benefits of shear assimilation as compared to HLOS wind assimilation will be elaborated in VAMP.

6 Sampling scenarios

This section discusses the currently defined reference scenarios and the possible alternative scenarios that could be used for the different measuring modes The orbital switching between these different scenarios has not yet been defined, and will be addressed later in this study. It must be noted that the table defining this switching has to be ready 1 week before the actual uploading takes place, and will cover a 3 week period. Therefore it is not possible to adapt the scenario switching to the actual whether situation using some NWP model. Also adaptation to sudden events like volcanic eruptions will not be possible on a short term. Only climatological considerations can be taken into account.

6.1 Reference scenarios

Two reference scenarios for the wind vector measurement mode have currently been defined, see [RD2]:

- WVM1, see section 6.1.1
- WVM2, see section 6.1.2

[14]Note that the HLOS wind observation operator is already available at ECMWF, but the HLOS wind shear observation operator is not.

[15]The effect of calibration errors on the Mie hlos result will be identical for all rangebins in a given observation. Therefore they will disappear when the difference between hlos values at different altitudes is calculated before assimilatiing the result in the NWP model.

6.1.1 Wind vector mode scenario1

This scenario has been designed to have maximum 1-to-1 overlap between the Rayleigh and Mie channel, as well as ground returns for both channels.

This overlap is usefull to easily combine measured optical information between both channels. Ground returns are used to obtain zero-wind-calibration results.

The parameter settings for this scenario are given in table 1 on page 35. For each range bin the top and bottom altitude is given in [km], as well as the corresponding TMC value in clock cycles. In addition the SP_VS_R value is given, defining the top of the highest Rayleigh range bin in [km] along the LOS. Finally the Td_Ray_Mie value is given, in [km] and the corresponding TMC value in clock cycles, defining the separation between the highest Rayleigh range bin and the highest Mie range bin. Note that the TMC unit is used to program the E2S. These TMC values can only be changed 8 times per orbit. The SP_VS_R can be used to shift both channels up and down, and may have a different value for each BRC. This will be controlled by the on board terrain model.

A graphical representation of the range bin definition for this scenario is given in figure 2.

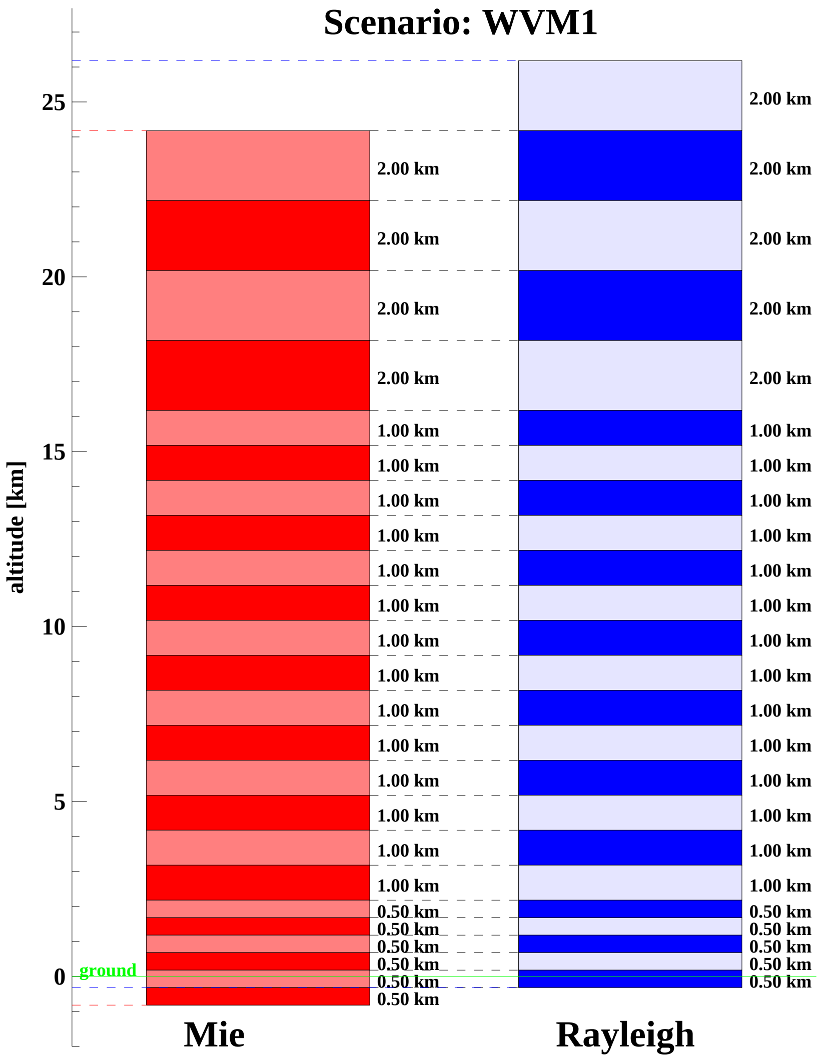

Figure 2: *Range bin definition for wvm1.*

6.1.2 Wind vector mode scenario2

This scenario has been designed to have optimal zero-wind-calibration results for the Mie channel, and puts many range bins in the PBL. The lowest Rayleigh bins may often not be useful due to low SNR. The Rayleigh channel has been tuned to obtain a number of upper atmosphere measurements. Consequence is that the upper 6 Rayleigh range bins have no corresponding Mie range bin, which makes processing them more difficult. Extra assumptions are needed to detect possible aerosol layers that contaminate the signal.

Also the lowest 4 Rayleigh range bins do not match 1-to-1 but 1-to-2 with the lowest 8 Mie range bins (and are thus oversampled). Multiple Mie range bins in one Rayleigh bin help identify the occurrence of optically significant layering of clouds or aerosol and the height assignment of the Aeolus winds. So in general, this is a favourable setting to have.

The parameter settings for this scenario are given in table 2 on page 36, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 3.

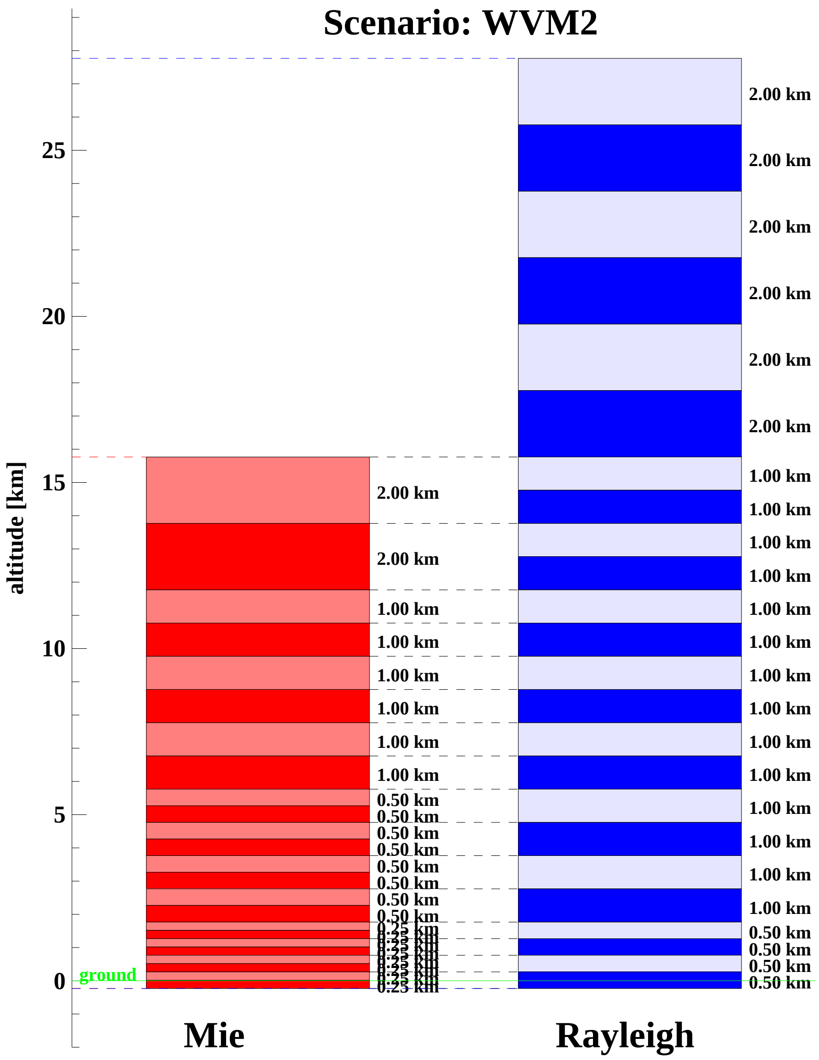

Figure 3: *Range bin definition for wvm2.*

6.2 Alternative wind vector mode scenarios

Looking at the constraints mentioned in section 5 several alternative scenarios may be used.

Since on average 8 range bin definitions per orbit can be used, this suggests definition of 3 different latitude ranges. When these would be named tropical, mid latitude, and polar, this would lead to the following sequence (going from equator to equator, so scenario 9 is identical to scenario 1, after which the sequence continues indefinitely):

1. tropical scenario [ascending]
2. midlat scenario [ascending]
3. polar scenario [ascending/descending]
4. midlat scenario [descending]
5. tropical scenario [descending]
6. midlat scenario [descending]
7. polar scenario [descending/ascending]
8. midlat scenario [ascending]
9. tropical scenario [ascending]
10. etc.

However, since from figure 1 on page 19 in section 5.6, it can clearly be seen that the main difference is between the tropics and extra-tropics, we suggest to use only 2 latitude zones:

- tropical, between -30 and 30 degrees latitude
- extra-tropical, the remainder of the globe

By doing this, we introduce the possibility to add 4 additional switching moments per orbit, so on average two extra alternative scenarios per orbit.

It is proposed to use this possibility to switch between scenarios intended for performing zero-wind-calibration ("zwc"), and scenarios not intended to perform zero-wind-calibration ("nozwc"). The "zwc" scenarios would be defined to have at least 3 range bins of 250 m, around the expected surface level. The "nozwc" will not have rangebins that aim at measuring a ground echo, and may start at some distance above the ground (or even above the PBL when it is decided that this would be a less interesting region). The exact location for this extra scenario switch possibility is to be defined later, and may be based on the landscape type, or the land-sea boundaries[16]. Remember that for 109 orbits 8*109=872 switching moments may be preprogrammed along the predicted orbits for one week.

This leads to the following 4 scenarios.

- tropics-zwc, see section 6.2.1
- tropics-nozwc, see section 6.2.2
- extra-tropics-zwc, see section 6.2.3
- extra-tropics-nozwc, see section 6.2.4

An example of how the instrument might be switched between these scenarios along a single orbit is:

1. tropics-nozwc [ascending]

[16] As an example, suppose it is concluded later in this study that calibration above the ocean is not very accurate. In that case using the predicted orbit it is known in advance whether a reasonable amount of land will be present in the measurement track. In case very little or no land is present, a switch to a nozwc scenario may be in order, while in case a significant amount of land is covered, a zwc scenario may be used.

2. extra-tropics-nozwc [ascending]
3. extra-tropics-zwc [descending]
4. tropics-zwc [descending]
5. extra-tropics-nozwc [descending]
6. extra-tropics-zwc [ascending]
7. extra-tropics-nozwc [ascending]
8. tropics-nozwc [ascending]
9. tropics-zwc [ascending]
10. etc.

Since the altitude of occurrence of the jets is correlated to the altitude of the tropopause, and als with the occurrence of high cirrus clouds, these phenomena would all be covered in this way. Adaptation of the scenarios to shear or aerosol layers at other altitudes is not yet foreseen.

6.2.1 Tropical zwc wind vector mode scenario

The tropics "zwc" scenario is proposed between latitudes of -30 and +30 degrees, in case usefull zero-wind-calibration results are expected.

This scenario has been designed to have zero-wind-calibration results for the Mie channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few 500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto about 18 km.

Consequence is that the upper 6 Rayleigh range bins have no corresponding Mie range bin, which makes processing them more difficult. Extra assumptions are needed to detect possible aerosol layers that contaminate the signal.

Just 2 Rayleigh range bins are oversampled by the Mie channel in this scenario. Possible improvements by choosing different locations for this oversampling are proposed in section 6.3.

Finally the lowest 4 Mie bins have no corresponding Rayleigh range bin. Since these bins are intended to be used mainly for ground detection anyway, this should not be a problem.

The parameter settings for this scenario are given in table 3 on page 37, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 4 on page 24.

6.2.2 Tropical nozwc wind vector mode scenario

The tropics "nozwc" scenario is proposed between latitudes of -30 and +30 degrees, in case no usefull zero-wind-calibration results are expected.

This scenario has been designed to have no zero-wind-calibration results for the Mie or Rayleigh channel. The Rayleigh channel is extended to 30 km. The Mie channel has been tuned to enable measuring clouds upto about 18 km.

Consequence is that the upper 6 Rayleigh range bins have no corresponding Mie range bin, which makes processing them more difficult. Extra assumptions are needed to detect possible aerosol layers that may contaminate the signal in these upper layers.

In this scenario 6 Rayleigh bins are oversampled by the Mie channel. Possible improvements by choosing different locations for this oversampling are proposed in section 6.3.

The parameter settings for this scenario are given in table 4 on page 38, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 5 on page 25.

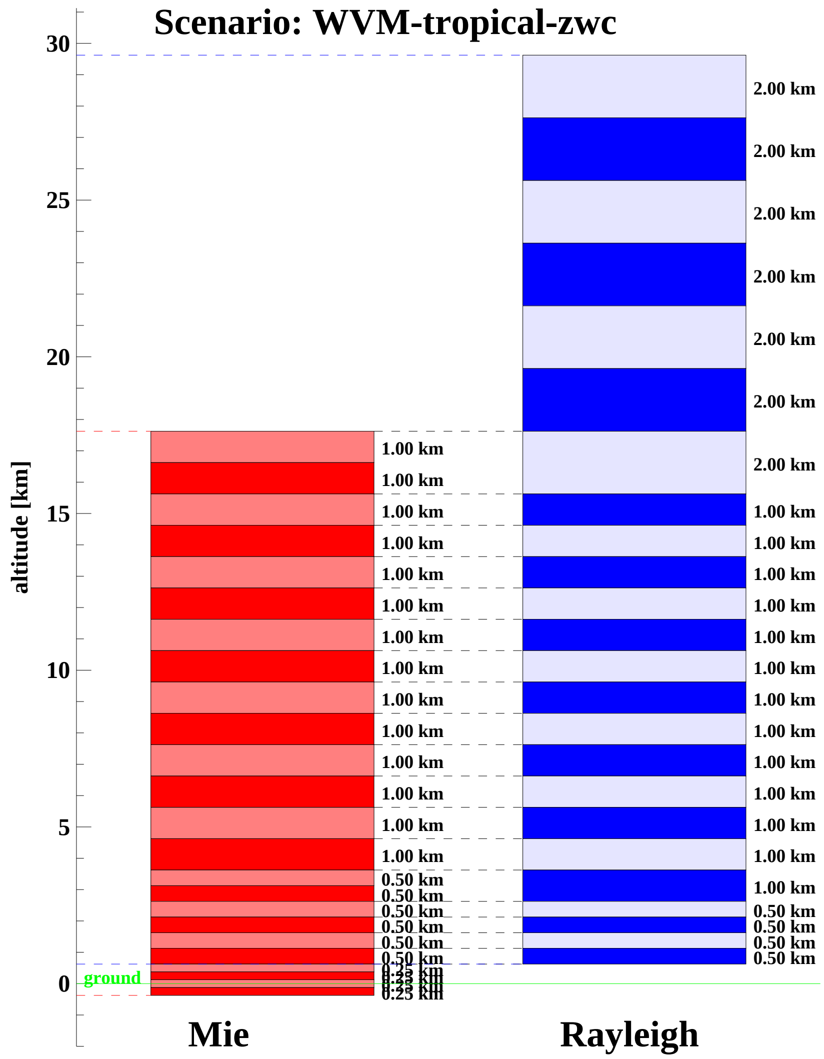

Figure 4: *Range bin definition for wvm-tropical-zwc.*

6.2.3 Extra-tropical zwc wind vector mode scenario

The extra-tropical "zwc" scenario is proposed between latitudes of 30 and 90 degrees, on both sides of the equator, in case no usefull zero-wind-calibration results are expected.

This scenario has been designed to have zero-wind-calibration results for the Mie channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few 500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto at least 15 km.

Consequence is that the upper 7 Rayleigh range bins have no corresponding Mie range bin, which makes processing them more difficult. Extra assumptions are needed to detect possible aerosol layers that contaminate the signal.

Just 3 Rayleigh range bins are oversampled by the Mie channel in this scenario. Possible improvements by choosing different locations for this oversampling are proposed in section 6.3.

Finally the lowest 4 Mie bins have no corresponding Rayleigh range bin. Since these bins are intended to be used mainly for ground detection anyway, this should not be a problem.

The parameter settings for this scenario are given in table 5 on page 39, and have been explained in

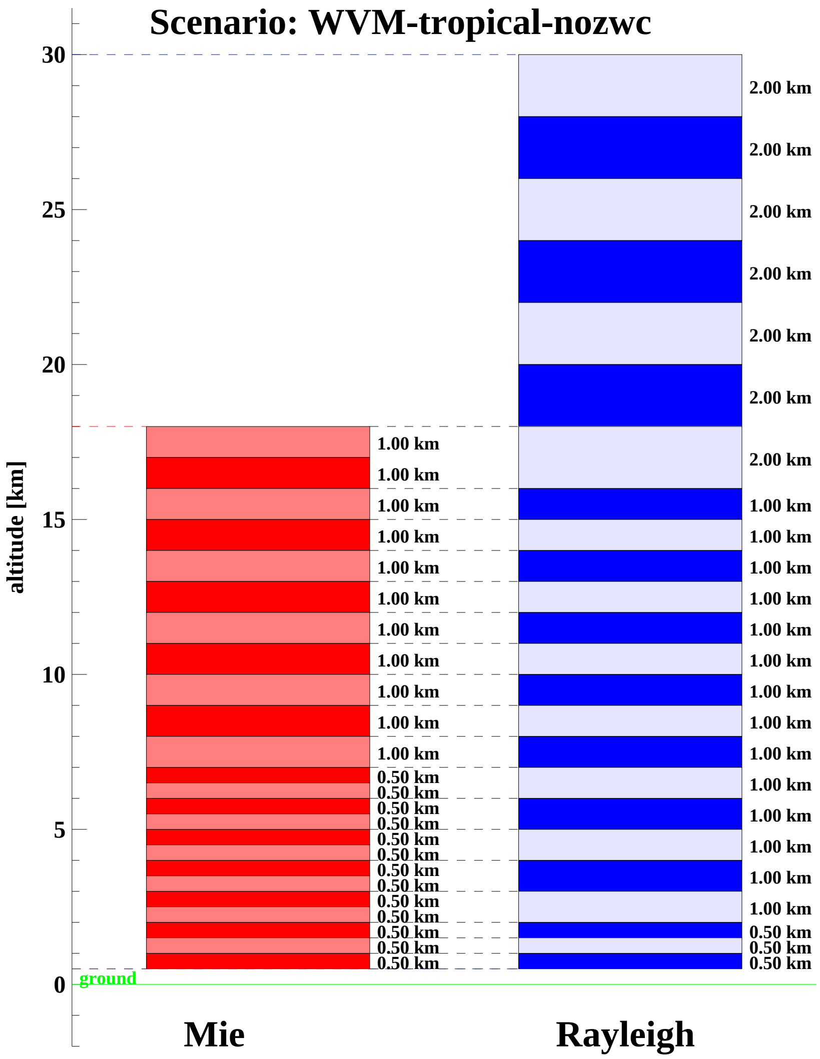

Figure 5: *Range bin definition for wvm-tropical-nozwc.*

section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 6 on page 26.

6.2.4 Extra-tropical nozwc wind vector mode scenario

The extra-tropical "nozwc" scenario is proposed between latitudes of 30 and 90 degrees, on both side of the equator, in case no usefull zero-wind-calibration results are expected.

This scenario has been designed to have no zero-wind-calibration results for the Mie or Rayleigh channel. The Rayleigh channel is extended to 30 km. The Mie channel has been tuned to enable measuring clouds upto about 15 km.

Consequence is that the upper 8 Rayleigh range bins have no corresponding Mie range bin, which makes processing them more difficult. Extra assumptions are needed to detect possible aerosol layers that may contaminate the signal in these upper layers.

In this scenario 8 Rayleigh bins are oversampled by the Mie channel. Possible improvements by choosing different locations for this oversampling are proposed in section 6.3.

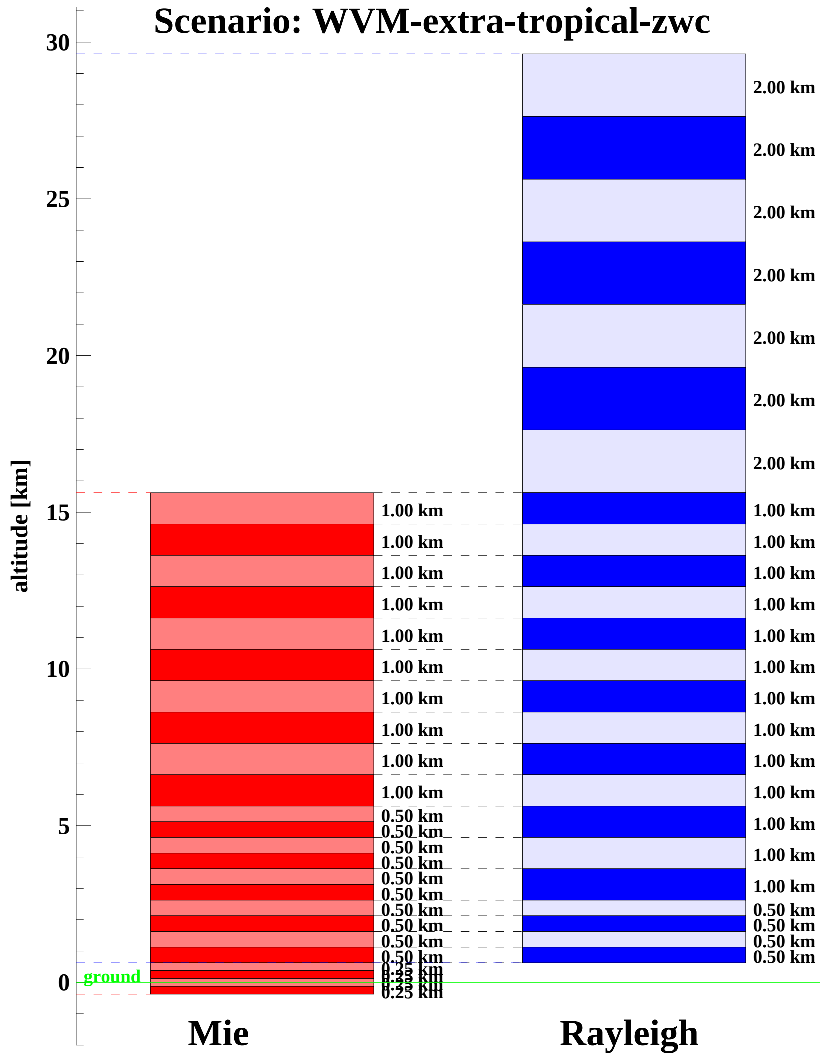

Figure 6: *Range bin definition for wvm-extra-tropical-zwc.*

The parameter settings for this scenario are given in table 6 on page 40, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 7 on page 27.

6.3 Additional wvm scenarios using oversampling

An additional set of scenarios based on oversampling is defined in this section.

The jet level varies with latitude and season, and is expected between 6-10 km for the polar-front-jet, and around 15 km for the subtropical-jet (see [LR10], p.140-142 and p.347-349, figure 6.2). The sampling scenarios are adapted to reflect this.

For the Rayleigh channel, the available oversampling possibilities by the Mie channel have been moved to the expected tropopause/jet level. We hope this will give more optimal wind results, and better height assignment compared to the scenarios without optimised oversampling. A reason for this is that at this level strong wind shear is expected (see [RD1]) which will lead to height assignment errors. Mie "oversampling" of the Rayleigh channel may reduce this problem.

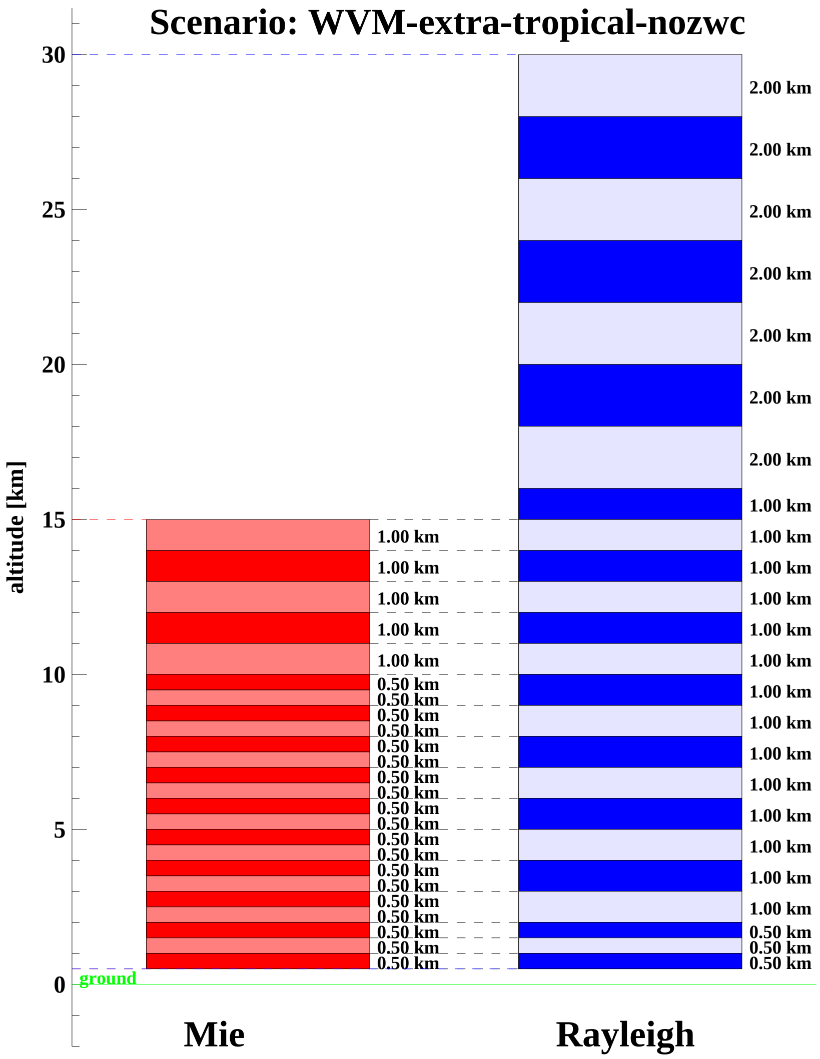

Figure 7: *Range bin definition for wvm-extra-tropical-nozwc.*

This leads to another set of 4 scenarios:

- tropics-zwc2, see section 6.3.1
- tropics-nozwc2, see section 6.3.2
- extra-tropics-zwc2, see section 6.3.3
- extra-tropics-nozwc2, see section 6.3.4

6.3.1 Tropical zwc wind vector mode scenario 2

The tropics "zwc2" scenario is proposed between latitudes of -30 and +30 degrees, in case usefull zero-wind-calibration results are expected. This scenario anticipates the presence of strong wind shear and possibly cirrus clouds around the tropical tropopause level of 15 km.

This scenario has been designed to have zero-wind-calibration results for the Mie channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few

500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto about 18 km. The available 500 m range bins for the Mie channel have been placed between 10 and 18 km.

7 Rayleigh range bins are oversampled by the Mie channel in this scenario, between 10 and 18 km, which contains the expected tropopause/jet-level.

Finally the lowest 3 Mie bins have no corresponding Rayleigh range bin. Since these bins are intended to be used mainly for ground detection anyway, this should not be a problem.

The parameter settings for this scenario are given in table 7 on page 41, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 8.

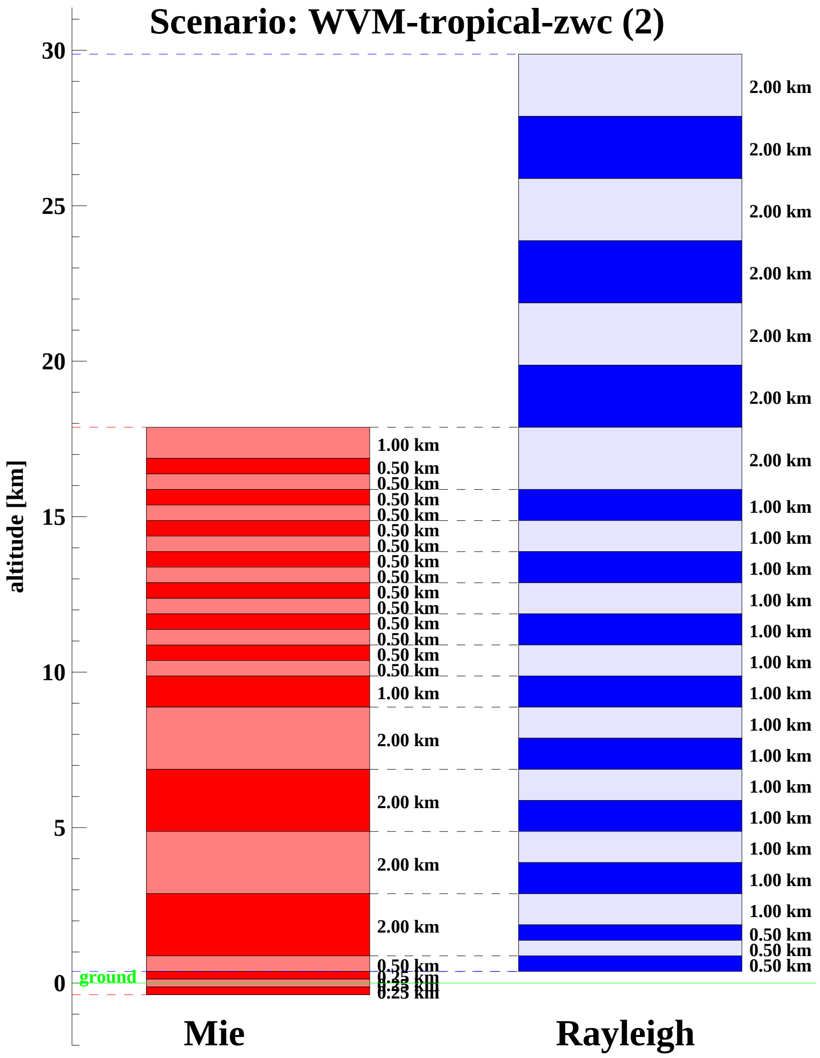

Figure 8: *Range bin definition for wvm-tropical-zwc2.*

6.3.2 Tropical nozwc wind vector mode scenario 2

The tropics "nozwc2" scenario is proposed between latitudes of -30 and +30 degrees, in case no usefull zero-wind-calibration results are expected.

This scenario has been designed to have no zero-wind-calibration results for the Mie or Rayleigh channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few 500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto about 20 km. The available 500 m range bins for the Mie channel have been placed between 10 and 18 km.

8 Rayleigh range bins are oversampled by the Mie channel in this scenario, between 10 and 18 km, which contains the expected tropopause/jet-level. An additional at 1 km oversampled 2 km Rayleigh range bin layer is present between 18 and 20 km.

The parameter settings for this scenario are given in table 8 on page 42, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 9.

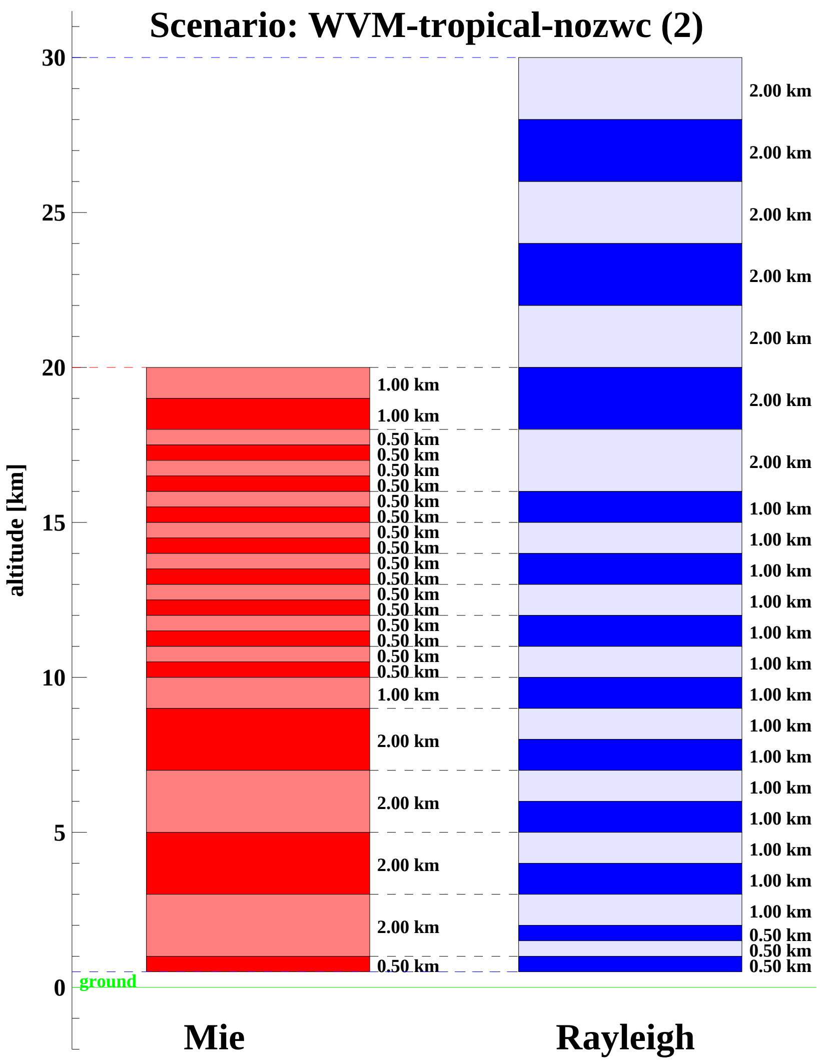

Figure 9: *Range bin definition for wvm-tropical-nozwc2.*

6.3.3 Extra-tropical zwc wind vector mode scenario 2

The extra-tropical "zwc2" scenario is proposed between latitudes of 30 and 90 degrees, on both sides of the equator, in case usefull zero-wind-calibration results are expected.

This scenario has been designed to have zero-wind-calibration results for the Mie channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few 500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto about 15 km. The available 500 m range bins for the Mie channel have been placed between 6 and 11 km.

6 Rayleigh range bins are oversampled by the Mie channel in this scenario, between 6 and 11 km, which contains the expected tropopause/jet-level.

Finally the lowest 4 Mie bins have no corresponding Rayleigh range bin. Since these bins are intended to be used mainly for ground detection anyway, this should not be a problem.

The parameter settings for this scenario are given in table 9 on page 43, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 10.

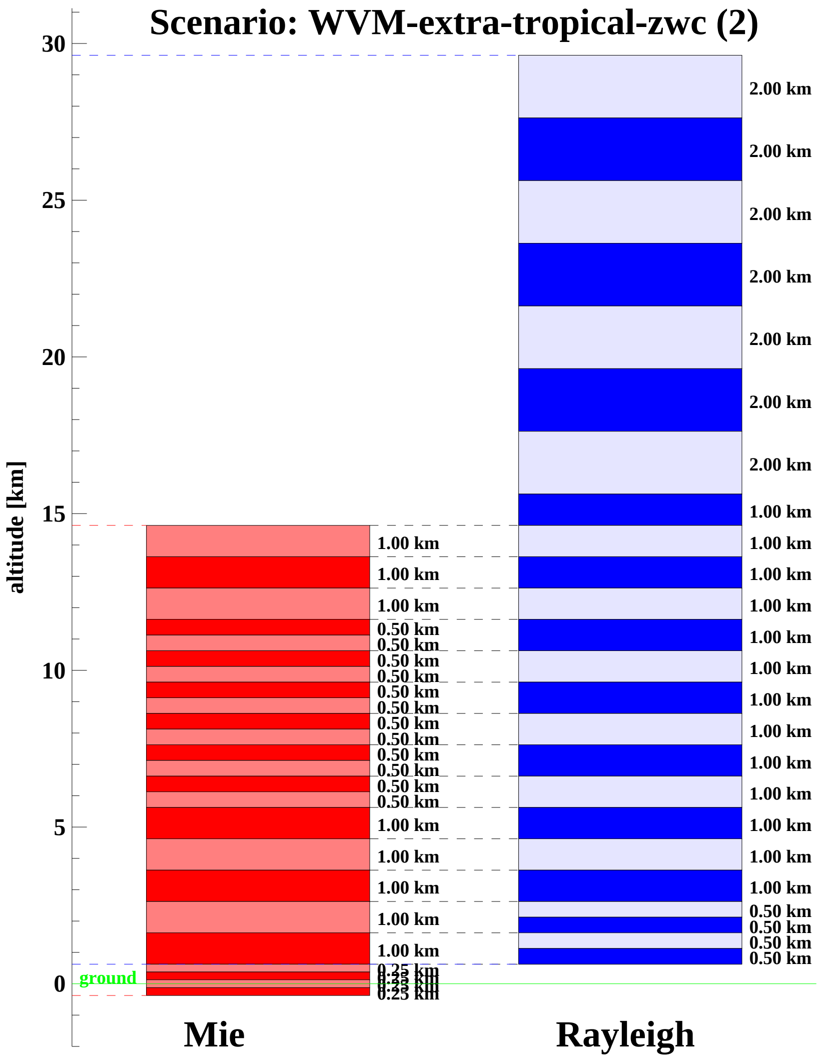

Figure 10: *Range bin definition for wvm-extra-tropical-zwc2.*

6.3.4 Extra-tropical nozwc wind vector mode scenario 2

The extra-tropical "nozwc2" scenario is proposed between latitudes of 30 and 90 degrees, on both side of the equator, in case no usefull zero-wind-calibration results are expected.

This scenario has been designed to have no zero-wind-calibration results for the Mie or Rayleigh channel. The Rayleigh channel is extended to 30 km, with 2 km rangebins above 16 km, and 1 km range bins below 16 km. A few 500 m range bins have been added to reach the total of 24 range bins. The Mie channel has been tuned to enable measuring clouds upto about 15 km. The available 500 m range bins for the Mie channel have been placed between 3 and 12 km.

9 Rayleigh range bins are oversampled by the Mie channel in this scenario, between 3 and 12 km, which includes the expected tropopause/jet-level.

The parameter settings for this scenario are given in table 10 on page 44, and have been explained in section 6.1.1 above.

A graphical representation of the range bin definition for this scenario is given in figure 11.

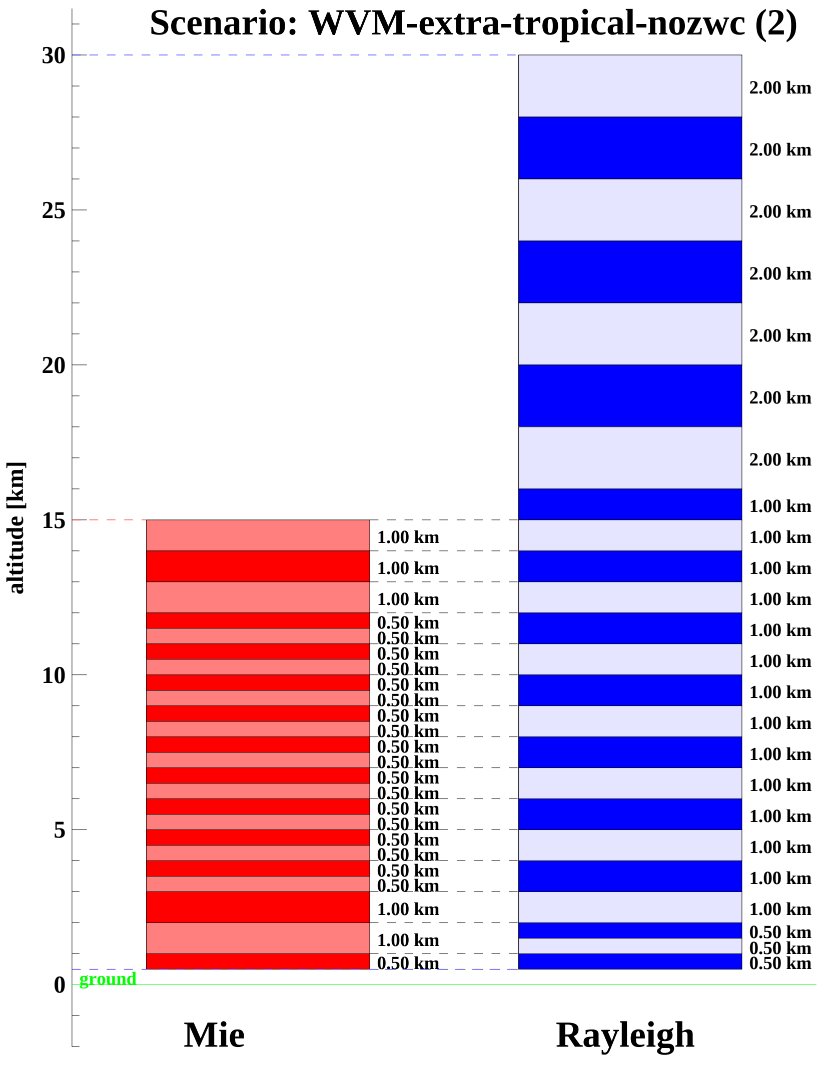

Figure 11: *Range bin definition for wvm-extra-tropical-nozwc2.*

6.4 Wind shear scenarios

To study the possible benefits of wind shear assimilation, a set of range bin definitions may be used that do not perform zero-wind-calibration. It is proposed to use the scenarios:

- tropics "nozwc" (see section 6.2.2 on page 23)
- extra-tropics "nozwc" (see section 6.2.4 on page 25)

or the oversampling scenarios:

- tropics "nozwc2" (see section 6.3.2 on page 28)
- extra-tropics "nozwc2" (see section 6.3.4 on page 31)

to do this. No dedicated range bin scenarios for wind shear assimilation will be designed.

6.5 Calibration scenarios

Still to be investigated are the errors emerging from the IRC (Instrument Reponse Calibration). An estimate of these errors should be produced by the on-going L1B activities. Depending on the final RRC (Rayleigh Response Calibration) scenario, it has to be studied whether the vertical sampling used for the RRC needs to be linked to the sampling used during the wind-measurement mode.

7 Terrain model

As was stated in section 5.1, a choice has to be made about the terrain model values to be used. This choice is related to the sampling scenario. In areas with very little variation in the model within a BRC (so at the ocean, or very flat land), this knowledge maybe used to shift the range bin definitions in such a way, that only the lowest range bin will detect the ground. On the other hand, if the terrain within a BRC has significant variation, then one or two range bins of the Mie channel may be projected below the average ground level for this BRC, in order to maximize the chance of obtaining a usefull ground echo. The result of these considrations will be stored for the predicted orbit for 1 week ahead, in a look-up-table, to be used for setting the SP_VS_R variable.

8 Errors

For each proposed scenario the expected inpact on the analysed atmospheric state will be estimated. To allow this the following is needed:

- An estimate of the signal levels for each range bin. For this an aerosol profile will be used constructed from the data retrieved from space-borne lidar or from aerosol climatological database using LIPAS [LR2], . e.g., CALIPSO and/or GLAS data will be used in combination with wavelength conversion software to estimate backscatter and extinction at 355 nm from PSCs. This will be studied in more detail in one of the upcoming work packages.
- An estimate of cloud occurence as a function of altitude and latitude on BRC and measurement level. This defines the opportunity to get wind vector measurements and zero-wind ground-calibration measurements. IceSat and Calipso data closely confirm earlier statistics obtained by LIPAS with ECMWF clouds; see: [LR2], [LR3]. This will be studied in more detail in one of the upcoming work packages.
- Estimated quality of the zero-wind-calibration, which in turn depends on the above properties, as well as on the albedo, the on-board terrain model, the presence of moving particles in the lowest range bin above the surface[17]. and the ground detection software and noise properties. [todo: find albedo average and variability values, estimate for moving surface particles (sand/snow)]

[17] Studying moving particles above the surface is part of the L1B work package. Are there already results available?

- Climatology of the observed wind, its variability, and estimated errors of the measurement of these winds by Mie and Rayleigh detection channels. Depends on available E2S, L1Bp and L2Bp qualities in simulating Aeolus in space. The package is being developed while the characterisation of ALADIN is ongoing. Some uncertainty aspects will be elaborated in VAMP and simulated by LIPAS, e.g., L2Bp Mie QC. Remaining uncertainties will be taken into account in the conclusion of VAMP. Note however, that the LIPAS simulator has its own assumptions and uncertainties as well.
- Climatology of combined optical and dynamical variability. Aspects of this will be studied in VAMP as much as feasible, but there is no climatological dataset of combined hi-resolution optical and dynamical measurements. Remaining uncertainties will be estimated.
- Climatology of the vertical wind components that confuse the LOS-to-HLOS conversion, and its variability, e.g., by inertia-gravity waves.
- A measure for the impact of the assimilated measurement results on the meteorological analyses and forecasts, as elaborated in VAMP later on for the PBL, troposphere and stratosphere.
- CALIPSO and/or GLAS data will be used in combination with wavelength conversion software to estimate backscatter and extinction at 355 nm from PSC's.
- others ...

9 Simulation tools

In order to perform this study, the following tools and data are needed:

- E2S, version 2.05, dated 22-Feb-2008: This tools needs as input:
  - the default data files and simulator settings as delivered with the software
  - the updated default data files and simulator settings, as constructed by Olivier Le Rille
  - alternative sampling scenario files as defined in section 6 of this report
  - atmospheric scenario files, from the Atmospheric Database, version 1.5, dated (to be released). A tool to convert these files to the xml format required as E2S input is available in the matlab tools mentioned below.
- L1BP, version 1.09, dated 22-Feb-2008: This tool (which in fact contains the L0, L1A and L1B processor) needs as input:
  - the default processor settings and datafiles as delivered with the software
  - the AISP files generated by the E2S.
- L2BP, version 1.33, dated 29-Feb-2008: This tool needs as input:
  - the default processor settings and datafiles as delivered with the software
  - the L1B files generated by the L1BP.
  - Auxiliary Meteo files, generated by converting the same atmospheric scenario files that where used for running the E2S. The necessary conversion tool is available in the L2BP software package.
- Matlab Tools by Meteo France, version 1.53, dated 21-Mar-2008: this package contains matlab routines to read all input and output files used and produced by the processors mentioned above, and an automatic plot generation tool for quick interpretation of the results. This tool needs as input:
  - the xml files generated by the E2S in the $scenario/instrumentData directory
  - the L1B and L2B product files

  Based on this a matlab routine needs to be written to compare input and output wind in a more automated way, to generate some sort of figure-of-merit, which allows comparing the choosen simulation and processing settings.

- the python tool by KNMI, version ... (to be released), dated ..., which takes care of running al tools mentioned above, and which collects all settings of all these tools in a single input file.
- a modified version of the LIPAS simulation tool, to match the actual implementation of the ADM instrument and processing chain. (description to be added)

10 Conclusion

to be written.
LIPAS should be mentioned here.

- end of document -

Table 1: definition of the range bins for scenario wvm1

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	24.18	26.18	2.00	808
2	22.18	24.18	2.00	808
3	20.18	22.18	2.00	808
4	18.18	20.18	2.00	808
5	16.18	18.18	2.00	808
6	15.18	16.18	1.00	404
7	14.18	15.18	1.00	404
8	13.18	14.18	1.00	404
9	12.18	13.18	1.00	404
10	11.18	12.18	1.00	404
11	10.18	11.18	1.00	404
12	9.18	10.18	1.00	404
13	8.18	9.18	1.00	404
14	7.18	8.18	1.00	404
15	6.18	7.18	1.00	404
16	5.18	6.18	1.00	404
17	4.18	5.18	1.00	404
18	3.18	4.18	1.00	404
19	2.18	3.18	1.00	404
20	1.68	2.18	0.50	202
21	1.18	1.68	0.50	202
22	0.68	1.18	0.50	202
23	0.18	0.68	0.50	202
24	-0.32	0.18	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	22.18	24.18	2.00	808
2	20.18	22.18	2.00	808
3	18.18	20.18	2.00	808
4	16.18	18.18	2.00	808
5	15.18	16.18	1.00	404
6	14.18	15.18	1.00	404
7	13.18	14.18	1.00	404
8	12.18	13.18	1.00	404
9	11.18	12.18	1.00	404
10	10.18	11.18	1.00	404
11	9.18	10.18	1.00	404
12	8.18	9.18	1.00	404
13	7.18	8.18	1.00	404
14	6.18	7.18	1.00	404
15	5.18	6.18	1.00	404
16	4.18	5.18	1.00	404
17	3.18	4.18	1.00	404
18	2.18	3.18	1.00	404
19	1.68	2.18	0.50	202
20	1.18	1.68	0.50	202
21	0.68	1.18	0.50	202
22	0.18	0.68	0.50	202
23	-0.32	0.18	0.50	202
24	-0.82	-0.32	0.50	202
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		33.00	2.00	808

Table 2: definition of the range bins for scenario wvm2

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	25.77	27.77	2.00	808
2	23.77	25.77	2.00	808
3	21.77	23.77	2.00	808
4	19.77	21.77	2.00	808
5	17.77	19.77	2.00	808
6	15.77	17.77	2.00	808
7	14.77	15.77	1.00	404
8	13.77	14.77	1.00	404
9	12.77	13.77	1.00	404
10	11.77	12.77	1.00	404
11	10.77	11.77	1.00	404
12	9.77	10.77	1.00	404
13	8.77	9.77	1.00	404
14	7.77	8.77	1.00	404
15	6.77	7.77	1.00	404
16	5.77	6.77	1.00	404
17	4.77	5.77	1.00	404
18	3.77	4.77	1.00	404
19	2.77	3.77	1.00	404
20	1.77	2.77	1.00	404
21	1.27	1.77	0.50	202
22	0.77	1.27	0.50	202
23	0.27	0.77	0.50	202
24	-0.23	0.27	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	13.77	15.77	2.00	808
2	11.77	13.77	2.00	808
3	10.77	11.77	1.00	404
4	9.77	10.77	1.00	404
5	8.77	9.77	1.00	404
6	7.77	8.77	1.00	404
7	6.77	7.77	1.00	404
8	5.77	6.77	1.00	404
9	5.27	5.77	0.50	202
10	4.77	5.27	0.50	202
11	4.27	4.77	0.50	202
12	3.77	4.27	0.50	202
13	3.27	3.77	0.50	202
14	2.77	3.27	0.50	202
15	2.27	2.77	0.50	202
16	1.77	2.27	0.50	202
17	1.52	1.77	0.25	101
18	1.27	1.52	0.25	101
19	1.02	1.27	0.25	101
20	0.77	1.02	0.25	101
21	0.52	0.77	0.25	101
22	0.27	0.52	0.25	101
23	0.02	0.27	0.25	101
24	-0.23	0.02	0.25	101
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		35.00	12.00	4848

Table 3: definition of the range bins for scenario wvm-tropical-zwc

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	27.62	29.62	2.00	808
2	25.62	27.62	2.00	808
3	23.62	25.62	2.00	808
4	21.62	23.62	2.00	808
5	19.62	21.62	2.00	808
6	17.62	19.62	2.00	808
7	15.62	17.62	2.00	808
8	14.62	15.62	1.00	404
9	13.62	14.62	1.00	404
10	12.62	13.62	1.00	404
11	11.62	12.62	1.00	404
12	10.62	11.62	1.00	404
13	9.62	10.62	1.00	404
14	8.62	9.62	1.00	404
15	7.62	8.62	1.00	404
16	6.62	7.62	1.00	404
17	5.62	6.62	1.00	404
18	4.62	5.62	1.00	404
19	3.62	4.62	1.00	404
20	2.62	3.62	1.00	404
21	2.12	2.62	0.50	202
22	1.62	2.12	0.50	202
23	1.12	1.62	0.50	202
24	0.62	1.12	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	16.62	17.62	1.00	404
2	15.62	16.62	1.00	404
3	14.62	15.62	1.00	404
4	13.62	14.62	1.00	404
5	12.62	13.62	1.00	404
6	11.62	12.62	1.00	404
7	10.62	11.62	1.00	404
8	9.62	10.62	1.00	404
9	8.62	9.62	1.00	404
10	7.62	8.62	1.00	404
11	6.62	7.62	1.00	404
12	5.62	6.62	1.00	404
13	4.62	5.62	1.00	404
14	3.62	4.62	1.00	404
15	3.12	3.62	0.50	202
16	2.62	3.12	0.50	202
17	2.12	2.62	0.50	202
18	1.62	2.12	0.50	202
19	1.12	1.62	0.50	202
20	0.62	1.12	0.50	202
21	0.38	0.62	0.25	101
22	0.12	0.38	0.25	101
23	-0.12	0.12	0.25	101
24	-0.38	-0.12	0.25	101
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.34	12.00	4848

Table 4: definition of the range bins for scenario wvm-tropical-nozwc

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	28.00	30.00	2.00	808
2	26.00	28.00	2.00	808
3	24.00	26.00	2.00	808
4	22.00	24.00	2.00	808
5	20.00	22.00	2.00	808
6	18.00	20.00	2.00	808
7	16.00	18.00	2.00	808
8	15.00	16.00	1.00	404
9	14.00	15.00	1.00	404
10	13.00	14.00	1.00	404
11	12.00	13.00	1.00	404
12	11.00	12.00	1.00	404
13	10.00	11.00	1.00	404
14	9.00	10.00	1.00	404
15	8.00	9.00	1.00	404
16	7.00	8.00	1.00	404
17	6.00	7.00	1.00	404
18	5.00	6.00	1.00	404
19	4.00	5.00	1.00	404
20	3.00	4.00	1.00	404
21	2.00	3.00	1.00	404
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	17.00	18.00	1.00	404
2	16.00	17.00	1.00	404
3	15.00	16.00	1.00	404
4	14.00	15.00	1.00	404
5	13.00	14.00	1.00	404
6	12.00	13.00	1.00	404
7	11.00	12.00	1.00	404
8	10.00	11.00	1.00	404
9	9.00	10.00	1.00	404
10	8.00	9.00	1.00	404
11	7.00	8.00	1.00	404
12	6.50	7.00	0.50	202
13	6.00	6.50	0.50	202
14	5.50	6.00	0.50	202
15	5.00	5.50	0.50	202
16	4.50	5.00	0.50	202
17	4.00	4.50	0.50	202
18	3.50	4.00	0.50	202
19	3.00	3.50	0.50	202
20	2.50	3.00	0.50	202
21	2.00	2.50	0.50	202
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.81	12.00	4848

Table 5: definition of the range bins for scenario wvm-extra-tropical-zwc

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	27.62	29.62	2.00	808
2	25.62	27.62	2.00	808
3	23.62	25.62	2.00	808
4	21.62	23.62	2.00	808
5	19.62	21.62	2.00	808
6	17.62	19.62	2.00	808
7	15.62	17.62	2.00	808
8	14.62	15.62	1.00	404
9	13.62	14.62	1.00	404
10	12.62	13.62	1.00	404
11	11.62	12.62	1.00	404
12	10.62	11.62	1.00	404
13	9.62	10.62	1.00	404
14	8.62	9.62	1.00	404
15	7.62	8.62	1.00	404
16	6.62	7.62	1.00	404
17	5.62	6.62	1.00	404
18	4.62	5.62	1.00	404
19	3.62	4.62	1.00	404
20	2.62	3.62	1.00	404
21	2.12	2.62	0.50	202
22	1.62	2.12	0.50	202
23	1.12	1.62	0.50	202
24	0.62	1.12	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	14.62	15.62	1.00	404
2	13.62	14.62	1.00	404
3	12.62	13.62	1.00	404
4	11.62	12.62	1.00	404
5	10.62	11.62	1.00	404
6	9.62	10.62	1.00	404
7	8.62	9.62	1.00	404
8	7.62	8.62	1.00	404
9	6.62	7.62	1.00	404
10	5.62	6.62	1.00	404
11	5.12	5.62	0.50	202
12	4.62	5.12	0.50	202
13	4.12	4.62	0.50	202
14	3.62	4.12	0.50	202
15	3.12	3.62	0.50	202
16	2.62	3.12	0.50	202
17	2.12	2.62	0.50	202
18	1.62	2.12	0.50	202
19	1.12	1.62	0.50	202
20	0.62	1.12	0.50	202
21	0.38	0.62	0.25	101
22	0.12	0.38	0.25	101
23	-0.12	0.12	0.25	101
24	-0.38	-0.12	0.25	101
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.34	14.00	5656

Table 6: definition of the range bins for scenario wvm-extra-tropical-nozwc

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	28.00	30.00	2.00	808
2	26.00	28.00	2.00	808
3	24.00	26.00	2.00	808
4	22.00	24.00	2.00	808
5	20.00	22.00	2.00	808
6	18.00	20.00	2.00	808
7	16.00	18.00	2.00	808
8	15.00	16.00	1.00	404
9	14.00	15.00	1.00	404
10	13.00	14.00	1.00	404
11	12.00	13.00	1.00	404
12	11.00	12.00	1.00	404
13	10.00	11.00	1.00	404
14	9.00	10.00	1.00	404
15	8.00	9.00	1.00	404
16	7.00	8.00	1.00	404
17	6.00	7.00	1.00	404
18	5.00	6.00	1.00	404
19	4.00	5.00	1.00	404
20	3.00	4.00	1.00	404
21	2.00	3.00	1.00	404
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	14.00	15.00	1.00	404
2	13.00	14.00	1.00	404
3	12.00	13.00	1.00	404
4	11.00	12.00	1.00	404
5	10.00	11.00	1.00	404
6	9.50	10.00	0.50	202
7	9.00	9.50	0.50	202
8	8.50	9.00	0.50	202
9	8.00	8.50	0.50	202
10	7.50	8.00	0.50	202
11	7.00	7.50	0.50	202
12	6.50	7.00	0.50	202
13	6.00	6.50	0.50	202
14	5.50	6.00	0.50	202
15	5.00	5.50	0.50	202
16	4.50	5.00	0.50	202
17	4.00	4.50	0.50	202
18	3.50	4.00	0.50	202
19	3.00	3.50	0.50	202
20	2.50	3.00	0.50	202
21	2.00	2.50	0.50	202
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.81	15.00	6060

Table 7: definition of the range bins for scenario wvm-tropical-zwc2

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	27.87	29.87	2.00	808
2	25.87	27.87	2.00	808
3	23.87	25.87	2.00	808
4	21.87	23.87	2.00	808
5	19.87	21.87	2.00	808
6	17.87	19.87	2.00	808
7	15.87	17.87	2.00	808
8	14.87	15.87	1.00	404
9	13.87	14.87	1.00	404
10	12.87	13.87	1.00	404
11	11.87	12.87	1.00	404
12	10.87	11.87	1.00	404
13	9.87	10.87	1.00	404
14	8.87	9.87	1.00	404
15	7.87	8.87	1.00	404
16	6.87	7.87	1.00	404
17	5.87	6.87	1.00	404
18	4.87	5.87	1.00	404
19	3.87	4.87	1.00	404
20	2.87	3.87	1.00	404
21	1.87	2.87	1.00	404
22	1.37	1.87	0.50	202
23	0.87	1.37	0.50	202
24	0.37	0.87	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	16.87	17.87	1.00	404
2	16.37	16.87	0.50	202
3	15.87	16.37	0.50	202
4	15.37	15.87	0.50	202
5	14.87	15.37	0.50	202
6	14.37	14.87	0.50	202
7	13.87	14.37	0.50	202
8	13.37	13.87	0.50	202
9	12.87	13.37	0.50	202
10	12.37	12.87	0.50	202
11	11.87	12.37	0.50	202
12	11.37	11.87	0.50	202
13	10.87	11.37	0.50	202
14	10.37	10.87	0.50	202
15	9.87	10.37	0.50	202
16	8.87	9.87	1.00	404
17	6.87	8.87	2.00	808
18	4.87	6.87	2.00	808
19	2.87	4.87	2.00	808
20	0.87	2.87	2.00	808
21	0.37	0.87	0.50	202
22	0.12	0.37	0.25	101
23	-0.13	0.12	0.25	101
24	-0.38	-0.13	0.25	101
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.66	12.00	4848

Table 8: definition of the range bins for scenario wvm-tropical-nozwc2

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	28.00	30.00	2.00	808
2	26.00	28.00	2.00	808
3	24.00	26.00	2.00	808
4	22.00	24.00	2.00	808
5	20.00	22.00	2.00	808
6	18.00	20.00	2.00	808
7	16.00	18.00	2.00	808
8	15.00	16.00	1.00	404
9	14.00	15.00	1.00	404
10	13.00	14.00	1.00	404
11	12.00	13.00	1.00	404
12	11.00	12.00	1.00	404
13	10.00	11.00	1.00	404
14	9.00	10.00	1.00	404
15	8.00	9.00	1.00	404
16	7.00	8.00	1.00	404
17	6.00	7.00	1.00	404
18	5.00	6.00	1.00	404
19	4.00	5.00	1.00	404
20	3.00	4.00	1.00	404
21	2.00	3.00	1.00	404
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	19.00	20.00	1.00	404
2	18.00	19.00	1.00	404
3	17.50	18.00	0.50	202
4	17.00	17.50	0.50	202
5	16.50	17.00	0.50	202
6	16.00	16.50	0.50	202
7	15.50	16.00	0.50	202
8	15.00	15.50	0.50	202
9	14.50	15.00	0.50	202
10	14.00	14.50	0.50	202
11	13.50	14.00	0.50	202
12	13.00	13.50	0.50	202
13	12.50	13.00	0.50	202
14	12.00	12.50	0.50	202
15	11.50	12.00	0.50	202
16	11.00	11.50	0.50	202
17	10.50	11.00	0.50	202
18	10.00	10.50	0.50	202
19	9.00	10.00	1.00	404
20	7.00	9.00	2.00	808
21	5.00	7.00	2.00	808
22	3.00	5.00	2.00	808
23	1.00	3.00	2.00	808
24	0.50	1.00	0.50	202
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.81	10.00	4040

Table 9: definition of the range bins for scenario wvm-extra-tropical-zwc2

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	27.62	29.62	2.00	808
2	25.62	27.62	2.00	808
3	23.62	25.62	2.00	808
4	21.62	23.62	2.00	808
5	19.62	21.62	2.00	808
6	17.62	19.62	2.00	808
7	15.62	17.62	2.00	808
8	14.62	15.62	1.00	404
9	13.62	14.62	1.00	404
10	12.62	13.62	1.00	404
11	11.62	12.62	1.00	404
12	10.62	11.62	1.00	404
13	9.62	10.62	1.00	404
14	8.62	9.62	1.00	404
15	7.62	8.62	1.00	404
16	6.62	7.62	1.00	404
17	5.62	6.62	1.00	404
18	4.62	5.62	1.00	404
19	3.62	4.62	1.00	404
20	2.62	3.62	1.00	404
21	2.12	2.62	0.50	202
22	1.62	2.12	0.50	202
23	1.12	1.62	0.50	202
24	0.62	1.12	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	13.62	14.62	1.00	404
2	12.62	13.62	1.00	404
3	11.62	12.62	1.00	404
4	11.12	11.62	0.50	202
5	10.62	11.12	0.50	202
6	10.12	10.62	0.50	202
7	9.62	10.12	0.50	202
8	9.12	9.62	0.50	202
9	8.62	9.12	0.50	202
10	8.12	8.62	0.50	202
11	7.62	8.12	0.50	202
12	7.12	7.62	0.50	202
13	6.62	7.12	0.50	202
14	6.12	6.62	0.50	202
15	5.62	6.12	0.50	202
16	4.62	5.62	1.00	404
17	3.62	4.62	1.00	404
18	2.62	3.62	1.00	404
19	1.62	2.62	1.00	404
20	0.62	1.62	1.00	404
21	0.38	0.62	0.25	101
22	0.12	0.38	0.25	101
23	-0.12	0.12	0.25	101
24	-0.38	-0.12	0.25	101
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.34	15.00	6060

Table 10: definition of the range bins for scenario wvm-extra-tropical-nozwc2

Rayleigh range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	28.00	30.00	2.00	808
2	26.00	28.00	2.00	808
3	24.00	26.00	2.00	808
4	22.00	24.00	2.00	808
5	20.00	22.00	2.00	808
6	18.00	20.00	2.00	808
7	16.00	18.00	2.00	808
8	15.00	16.00	1.00	404
9	14.00	15.00	1.00	404
10	13.00	14.00	1.00	404
11	12.00	13.00	1.00	404
12	11.00	12.00	1.00	404
13	10.00	11.00	1.00	404
14	9.00	10.00	1.00	404
15	8.00	9.00	1.00	404
16	7.00	8.00	1.00	404
17	6.00	7.00	1.00	404
18	5.00	6.00	1.00	404
19	4.00	5.00	1.00	404
20	3.00	4.00	1.00	404
21	2.00	3.00	1.00	404
22	1.50	2.00	0.50	202
23	1.00	1.50	0.50	202
24	0.50	1.00	0.50	202
Mie range bin	bottom [km]	top [km]	size [km]	integration time [TMC]
1	14.00	15.00	1.00	404
2	13.00	14.00	1.00	404
3	12.00	13.00	1.00	404
4	11.50	12.00	0.50	202
5	11.00	11.50	0.50	202
6	10.50	11.00	0.50	202
7	10.00	10.50	0.50	202
8	9.50	10.00	0.50	202
9	9.00	9.50	0.50	202
10	8.50	9.00	0.50	202
11	8.00	8.50	0.50	202
12	7.50	8.00	0.50	202
13	7.00	7.50	0.50	202
14	6.50	7.00	0.50	202
15	6.00	6.50	0.50	202
16	5.50	6.00	0.50	202
17	5.00	5.50	0.50	202
18	4.50	5.00	0.50	202
19	4.00	4.50	0.50	202
20	3.50	4.00	0.50	202
21	3.00	3.50	0.50	202
22	2.00	3.00	1.00	404
23	1.00	2.00	1.00	404
24	0.50	1.00	0.50	202
		SP_VS_R [km]	Td_Ray_Mie [km]	Td_Ray_Mie [TMC]
		37.81	15.00	6060