Generation and update of AUX_CSR

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1. Table of content

2. Log

Date	Version	Author	Comment
11/12/2007	0.1	A. Dabas	Draft version
12/02/2008	1.0	A. Dabas	New version after comments from ESA: - §6.3: the way AUX_MET data are read is clarified. - §6.3: the reference to the number of observations and measurements per observation in IRC L1A files is given. - §6.3: the reading of the AUX_RRC file is clarified, as well as the content of the `rrc` structure. - §6.3.1: inclusion of an equation for the Rayleigh spectrum. - Processor settings in a separate file which content is described in §10.3.
04/04/2008	1.1	A. Dabas	- Remove AUX_IRC from input and mention data currently missing un AUX_RRC. - Add AUX_PRR_1B in output files with a file format defined in §10.4.
29/07/2008	1.2	A. Dabas D. Huber	- Minor corrections following DH review. - Detailed processing model for AUX_PRR data (see §9).
04/11/2008	1.3	A. Dabas	- References are updated. - Validity of RRC frequency step results is checked, invalid steps are excluded. A minimum number of steps is required to complete the CSR update. - RRC observations and AUX_MET profiles are matched. - The matching criteria for predicted versus observed RRC are revised.
08/12/2009	1.4	A. Dabas D. Huber	- Addition of list of Applicable documents - Name of parameter setting file changed to AUX_PAR_CS to comply with ESA standards. - All tags start with a capital letter. - Units corrected. - Completion of file description. - Correction of eq. (9) and (20).
15/10/2010	1.5	A. Dabas	- Minimization of the distance between RRC and RRC prediction based on Downhill Simplex. - Étendue model extended to tilted top-hat (2 parameter). - Output of second top-hat parameter in AUX_CSR.
30/11/2010	1.6	A. Dabas	- Opened points in IPF 34 and IPF 35
25/11/2011	1.7	A. Dabas	- Addition of Mie peaks to Rayleigh spectra. - Output of AUX_PRR consistent with CM version of AUX_RRC_1B. **This version is hybrid: it reads BM L1B data and outputs a CM AUX_PRR file.The next version will be fully compliant with the CM mode. It will be numbered 2.0**
12/12/2011	1.8	A. Dabas D. Huber	AE-IPF-35.
17/01/2012	2.0	A. Dabas	Minor modifications, but **first version fully compatible with the CM mode**. Modifications concern - Update of reference documents: L1B-IODD, RBC-DPM, E2S-DPM, L2BC-IODD. - Clarification in section 6: if it is found the current CSR is not representative of the double FP as revealed by the last IRC, then the updating procedure goes back to the last ISR and applies the top-hat model until it finds a good match with the IRC. If no good match is found, a new ISR is recommended.
10/08/2012	2.1	A. Dabas	– Scattering ratios for Mie contamination are now searched in the right Mie bin (used to be in Mie bin of index the current Rayleigh bin -1. See section 8.3.3. – The ValidRespCurve module has been modified. This module determines whether a predicted RRC can be considered equivalent to the actual RRC or not. See section 8.3.4.
23/04/2013	2.2	A. Dabas	– Modification of the “distance” between the predicted and observed RRC. The distance now takes a very large value when the top-hat width or tilt takes “impossible” values ($\Delta < 0$ or $\|x\| > 2$). This prevents the down-hill simplex to look for a minimum distance $dist(\Delta, x)$ around impossible settings. – Correction of a bug in the prediction of the Rayleigh response curve. – Inclusion of the ISR in the CSR file (required by the RBC generator). – Update of references.
20/12/2013	2.3	A. Dabas	– Possibility to input two AUX_MET files. – Removal of calls to L1A products. The information that was searched in L1A products has been moved to L1B products.
25/09/2014	3.0	A. Dabas	– Resample of ISR data by interpolation is replaced by a fit of DLR model.
10/03/2015	3.1	A. Dabas	– IPF 195, 198.

			– Check compatibility between IODD val type and content of AUX_PAR_CS. Cleaning of AUX_PAR_CS IODD (removal of parameters not used anymore). Fraction of RRC frequency steps used for the comparison with RR prediction based on CSR now passed as a parameter setting. – Update reference documents.
20/03/2015	3.1.1	A. Dabas	– Inclusion of Fizeau transmission in AUX_CSR.
15/12/2015	3.2	A. Dabas	– IPF 217 – Detection of a potential laser frequency drift between ISR and IRC. – Altitudes corrected from WGS84 / geoid separation. – Two sets of tolerance and max iterations for the two implementations of the down-hill simplex (ISR fit and estimation of étendue effect). – Attenuation by upper clouds or aerosol layers taken into account in the estimation of the beam étendue effect. – Update PRR format so that it matches RRC_1B (IPF 250) – Update of AUX_CSR and AUX_PRR IODD. – Update references.
30/06/2016	3.3	A. Dabas	– Correction of meaning of IRC (I in IRC stands for Instrument and not Internal as previously written). – The goeid/ellipsoid altitude shift is not read from AUX_MET files anymore but from the RRC_1B product where it has been added. – The scattering ratio threshold applied by the L1B while computing the Rayleigh response Curve is read from the RRC product. A thresholding of the SR value was also applied in the CSR updating procedure but the threshold value was hard coded. – Baseline information in Main Product Header in IODD (where there used to be Spare_2) – see Table 7. – Addition of Frequency_Drift_Reference in AUX_PAR_CS (see Table 25). – Update of AUX_CSR and AUX_PRR IODDs.
10/07/2017	4.0	A. Dabas	Update of documents after the delivery of patch 3 of the 30 June 2016 delivery. Note this version has been tested on version 4.01 of the E2S and 7.00 of the L1B. – Modification of Tenti_Spectrum function: the shear viscosity is now a function of the temperature. – Modification of Rayleigh_Spectrum: the width is now a function of the wavelength (declared in the function). – The geoid separation read in the RRC 1B file is the middle one and not necessarily the second one. – Correction of bugs in the handling of invalid frequency steps.

3. Applicable documents

	Reference	Title	Version	Date
[EE_FFS]	PE-TN-ESA-GS-0001	Earth Explorer Ground Segment File Format Standard	1/4	13/06/03

4. Reference documents

	Reference	Title	Version	Date
[L2_CAL_GEN]	AE-TN-MFG-L2P-CAL-002	Generation / update of L2 calibration data at ACMF	3.0	10/03/15
[OPMODES]	AE-TN-ASF-AL-00044	Aladin Instrument Operation Definition	3.0	29/10/04
[L2BC-IODD]	AE-IF-ECMWF-L2BP-001	ADM-Aeolus Level-2B/C Processor Input/Output Data Definitions Interface Control Document	2.20	15/03/15
[L1B-IODD]	ADM-IC-52-1666	Aeolus Level 1B Processor and End-to-End Simulator: Input / Output Data Definitions Interface Control Document	4.07	21/07/17
[RBC-DPM]	AE-TN-MFG-GS-0001	Generation of the RBC Auxiliary file: Detailed Processing Model	4.0	24/07/17
[RBC-IODD]	AE-TN-MFG-GS-0003	ADM-Aeolus Rayleigh-Brillouin Correction Look-up Tables GeneratorInput/Output Data Definitions (IODD) ICD	3.3	30/06/16
[E2S-DPM]	ADM-MA-52-1801	End-to-end simulator detailed processing model	4.00	02/05/17
[REC-MOD]		Witschas, B., Ch. Lemmerz, O. Reitebuch (2012): Horizontal lidar measurements for the		

	proof of spontaneous Rayleigh-Brillouin scattering in the atmosphere. *Appl. Opt.*, **51**, 6207-6219.	
[RBS-MOD]	B. Witschas: Analytical model for Rayleigh-Brillouin line shapes in air. *Appl. Opt.*, **50**, 267-270.	20/01/11

5. Acronyms

ACMF	Aeolus Calibration & Monitoring Facility
BRC	Basic Repeat Cycle
CSR	Corrected Spectral Registration
DSD	Data Set Descriptor
DSR	Data Set Record
ECMWF	European Centre for Medium Range Weather Forecast
E2S	End to end simulator of AEOLUS mission.
FPA	Fabry Perot Channel A
FPB	Fabry Perot Channel B
FSR	Free Spectral Range
GADS	Global Annotation Data Set
ISR	Instrument Spectral Registration
IRC	Instrument Response Calibration
RBC	Rayleigh-Brillouin Correction
RRC	Rayleigh Response Calibration
USR	Useful Spectral Range

6. Introduction

The present document explains and details the processors that generate and update the AUX_CSR_1B auxiliary file.

The AUX_CSR_1B is defined in [L2_CAL_GEN]. It shall contain the transmission characteristics of the Fabry-Perot A and B of the Rayleigh receiver for the atmospheric channel. We remind here that these characteristics are different from the transmission curves registered on the internal reference during the Instrument Spectral Registration (ISR, see [OPMODES]) because the *étendue* of the beams in the atmospheric and the internal reference paths are different.

Two processors are presented in this document, one for the initial generation of the AUX_CSR file, and the other for its updating. An update is attempted whenever an Instrument Response Calibration (IRC – see [OPMODES]) is carried out.

The triggering mechanisms of the generation and updating of the AUX_CSR file are explained in [L2_CAL_GEN].

The generation of the AUX_CSR is simple. It consists in fitting a model to the transmission curves contained in the AUX_ISR (ISR output file). The model is based on DLR work on the Aladin-Airborne-Demonstrator.

The updating procedure is more complex. It is based on an IRC from which two level 1B products are derived: the Rayleigh Response calibration (RRC) and Mie Response Calibration (MRC). It consists in predicting the Rayleigh response curve measured by the atmospheric channel during the IRC and reported in the RRC 1B output product. The prediction uses the MRC 1B product in order to include the impact of aerosols or clouds in the predicted Rayleigh responses. During an IRC, the line-of-sight is pointed vertically to the Earth, and the laser frequency is swept across the Useful Spectral Range (USR). The Rayleigh responses from the atmosphere are predicted on the basis of the atmospheric parameters contained in the AUX_MET data file(s) (see [L2BC-IODD]) provided by the L2_Met_12 generator operated at the European Centre for Medium Range Weather Forecast (ECMWF). Most of the times, a single AUX_MET file should contain all the necessary meteorological information. It may occasionally happen that the information is split into two different AUX_MET files. Therefore, the AUX_CSR updater offers the possibility to input two AUX_MET files. The predicted Rayleigh responses are compared to those in AUX_RRC file. If both match, it is concluded that the FP transmission characteristics contained in the current CSR are representative of the actual sensitivity of the Rayleigh receiver. If not, another iteration of modification is brought to the transmission curves of the two FPs of the latest ISR and a new response prediction is computed. The process is repeated until the predicted and the actual responses coincide or until a limit is reached. In this latter case, the updater recommends that a new ISR shall be carried out.

The modification of the transmission curves consists of the convolution by a tilted top-hat function defined by

$$\Pi_{\Delta,x}(\mathrm{f}) = \begin{cases} 0 \text{ if } |\mathrm{f}| \geq \dfrac{\Delta}{2} \\ \dfrac{1}{\Delta} + \dfrac{\mathrm{f}x}{\Delta^2} \text{ otherwise} \end{cases} \tag{1}$$

The parameter Δ sets the width of the top-hat (see Figure 1) while x sets its tilt. It must be noted that x must not be less than -2 nor greater than +2.

The updating of the AUX_CSR seeks the values of Δ and x that produce an RRC response prediction as close as possible from the actual one.

It is to be noted that the present modification scheme could easily be changed if a better *étendue* model is found in the future. This has been made possible by writing a modular code with the modification of the transmission curves accomplished in a separate sub-routine.

In addition to the AUX_CSR file, the generation and updating tools output the AUX_PRR file. This file contains predicted Rayleigh responses for standard atmospheric conditions. These conditions are prescribed in the parameter setting file AUX_PAR_CS with a unique vertical profile, possibly restricted to a single pressure – temperature (for a pressure and a temperature constant with the altitude). The purpose of the AUX_PRR is to provide an easy tool for monitoring a potential drift of the Rayleigh receiver of Aeolus. The way it is computed is described in §9.

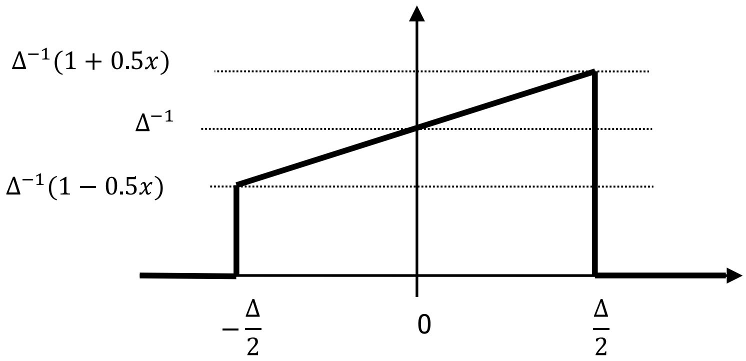

Figure 1 : Shape of the tilted top-hat that the AUX_CSR updater convolves with the ISR transmission curves in order match the RRC.

7. Generation of the AUX_CSR

7.1 Input files

The generation of the AUX_CSR requires two input files, the AUX_PAR_CS and the AUX_ISR_1B. The former contains the processor settings, the latter the results of the ISR. The content of the AUX_PAR_CS file is described in §10.3. The precise content of the AUX_ISR is described in [L1B-IODD].

The parameter settings for the AUX_CSR generation are listed in Table 1 below.

Variable	Unit	Tag name	Comment
$\boldsymbol{FP.FSR}$	GHz	Fabry_Perot.FSR	The Free Spectral Range of the FPs that shall be characterized at ground before launch and should henceforth remain stable
$\boldsymbol{FP.FWHM}$	MHz	Fabry_Perot.FWHM	A first-guess value $FP.FWHM$ (in MHz) for the Full-Width-Half-Max of the two Fabry-Perot interferometer transmissions. The same value is used for both. It is the initial value that DLR model fitting procedure uses.
$\boldsymbol{Fiz.FSR}$	GHz	Fizeau.FSR	The Free Spectral Range of the Fizeau interferometer. As for the Fabry-Perot interferometers, this value shall be characterized at ground before launch and remain stable throughout AEOLUS mission lifetime.
$\boldsymbol{Fiz.Fiz\_Reflec\_Model}$		Fizeau. Fiz_Reflec_Model	The model used for fitting the reflection on the Fizeau (see §7.4.1 below). Its value is either "DLR" or "E2S".
$\boldsymbol{Df}$	MHz	Df	The spectral resolution of the CSR output transmission curves.
$\boldsymbol{zrefmin}$	m	Ref_Grid.Zref_Min	The minimum and maximum altitudes and $Ref\_Grid.$ and the altitude resolution $Ref_Grid.$used for computing Rayleigh responses (see Table 28)
$\boldsymbol{zrefmax}$	m	Ref_Grid.Zref_Max	
$\boldsymbol{dzref}$	m	Ref_Grid.Dz_Ref	
$\boldsymbol{specMod}$		RBC_Spec_Model	The model used for simulating spectra backscattered by air molecules. It can be either GAUSS (pure Rayleigh) or TENTI (Rayleigh Brillouin)
$\boldsymbol{Gen.iterMax}$		Simplex_Fit.Generate. Max_Iterations	The maximum number of iterations and termination tolerance for the optimization procedure (Down-hill simplex) used for fitting the ISR (see §7.4.3).
$\boldsymbol{Gen.Tol}$		Simplex_Fit.Generate. Tolerance	
$\boldsymbol{atm.altitude}$	m	Atm_Profile.Altitude	The standard atmospheric conditions (see Table 35) used for

$\boldsymbol{atm.pressure}$	Pa	Atm_Profile.Pressure	the computation of the AUX_PPR
$\boldsymbol{atm.temperature}$	$°C$	Atm_Profile.Temperature	
$\boldsymbol{prr.satAlt}$	m	PRR_Params.Sat_Alt	The standard satellite altitude used for the computation of the AUX_PRR
$\boldsymbol{prr.zmin}$	m	PRR_Params.Zmin	The minimum and maximum altitudes defining the boundaries of the interval over which the Rayleigh signals from FPs A & B are integrated (computation of the AUX_PRR).
$\boldsymbol{prr.zmax}$	m	PRR_Params.Zmax	
$\boldsymbol{prr.foffset}$	GHz	PRR_Params. Freq_Offset	The frequency offsets for which the PRR is computed.

Table 1: Parameters defined in the AUX_PAR_CS file that are used for tuning the generation of the AUX_CSR. The first column designates the name of the variable in the present document while the third column gives the tag name in the AUX_PAR_CS. The names in the first column were shortened for convenience.

7.2 Output files

The output files are the AUX_CSR and AUX_PRR.

The format of the AUX_CSR is detailed in §10.2 below.

The format of the AUX_PRR is detailed in §10.4 below, it is similar to the AUX_RRC so that it can be input to the L1B processor instead of the AUX_RRC.

7.3 General Architecture

The general architecture of the generation of the AUX_CSR is depicted in Figure 2. It consists in:

1. fitting the information contained in the AUX_ISR with a model of ALADIN receiver (see §7.4.1);
2. predicting the Rayleigh Response expected for the standard atmospheric conditions specified by the $Atm\_Profile$ structure (see §7.6).

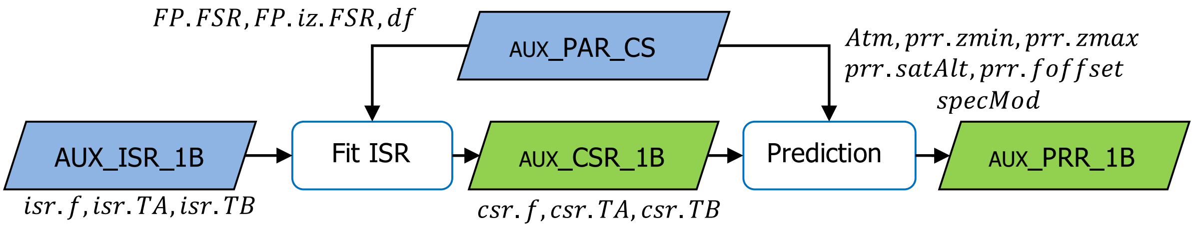

Figure 2: High-level architecture of the processor generating the AUX_CSR. The input products are in blue, the output products in green. The Fit ISR function is explained in §7.4 below, and the prediction of PRR in §9.

7.4 Fitting of AUX_ISR_1B data.

7.4.1 ALADIN receiver model

The model fitted to AUX_ISR_1B data is fully described in [REC-MOD]. It was derived in the frame of the studies realized at DLR on the ALADIN Airborne Demonstrator (A2D) which implements a receiver nearly identical to ALADIN.

ALADIN receiver is composed of three interferometers illuminated sequentially by either the laser emission (in the internal reference path) or the light captured by the telescope (in the atmospheric path). The circulation of the light is depicted in Figure 3. The Fizeau is illuminated at first. The light it reflects is directed to the first Fabry-Perot – the so-called direct FP – and the reflection on it is then sent to the second FP – the so-called reflected FP.

Let us denote $P_0(f)$ the power of a monochromatic light at frequency f input to the receiver. The amount $P_0(f)$ that passes through the direct FP is

$$T_A(f) = P_0(f)R_{Fiz}(f)T_{dir}(f) \tag{2A}$$

where $R_{Fiz}(f)$ is the reflection on the Fizeau and $T_{dir}(f)$ the transmission through the direct FP. It is denoted $T_A(f)$ as it shall be detected by the section A of the Rayleigh receiver CCD (CCD columns 3 to 10).

The light passing through the reflected FP is

$$T_B(f) = P_0(f)R_{Fiz}(f)\big(1 - QT_{dir}(f)\big)T_{ref}(f) \tag{2B}$$

where $T_{ref}(f)$ is the transmission through the reflected FP, and $\big(1 - QT_{dir}(f)\big)$ models the reflection on the direct FP with Q a factor accounting for losses. It is denoted $T_B(f)$ as it shall be detected by the section B of the Rayleigh receiver CCD (CCD columns 11 to 18).

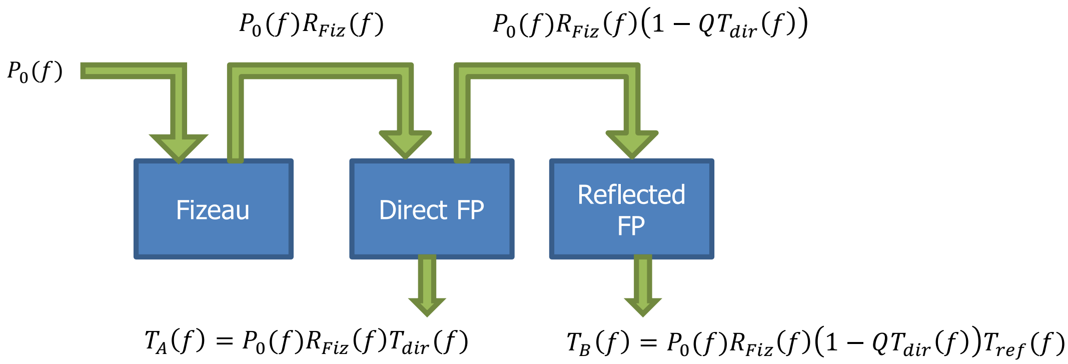

Figure 3: Circulation of the light in ALADIN receiver.

With $Fiz.RefModel$ set to DLR in the AUX_PAR_CS file, the reflection on the Fizeau is modeled by

$$R_{Fiz}(f) = 1 - \frac{1}{T_{Fiz}}\left|cos\left(\frac{\pi(f - f_{Fiz}^0)}{Fiz.FSR}\right)\right| \tag{3a}$$

The shape of this function is shown in Figure 4. It is periodical with a periodicity set by the parameter $Fiz.FSR$. This parameter is assumed known and is passed to the CSR generator via the AUX_PAR_CS. The reflection achieves its minimal value T_{Fiz}^{-1} at the frequencies $f_{Fiz}^0 + k\,Fiz.FSR$ where $k \in \mathbb{Z}$. The parameters T_{Fiz} and f_{Fiz}^0 are unknown and will have to be determined by the CSR generator. T_{Fiz} must be greater than 1. Its typical value is of the order of 10.

The model above was determined by DLR from registrations of Fizeau reflections in the ALADIN Airborne Demonstrator. As this instrument implements a receiver very close to ALADIN, it should be applicable to real ISR data. However, the reflection model used by the end-to-end simulator E2S of AEOLUS is slightly different. For this reason, the CSR generator proposes a second model. It is selected by settting $Fiz.RefModel$ to E2S in the AUX_PAR_CS file. It consists of an interpolation of a normalized, reference curve saved in a file (called FizRef.mat). The E2S model is parametrized by the parameters T_{Fiz} and f_{Fiz}^0. The former modulates the ripple size of the transmission curve and the latter moves the curve on the frequency axis.

$$R_{Fiz}(f) = 1 - T_{Fiz}\, interp(FizRef.f, FizRef.reflection, f - f_{Fiz}^0) \tag{3b}$$

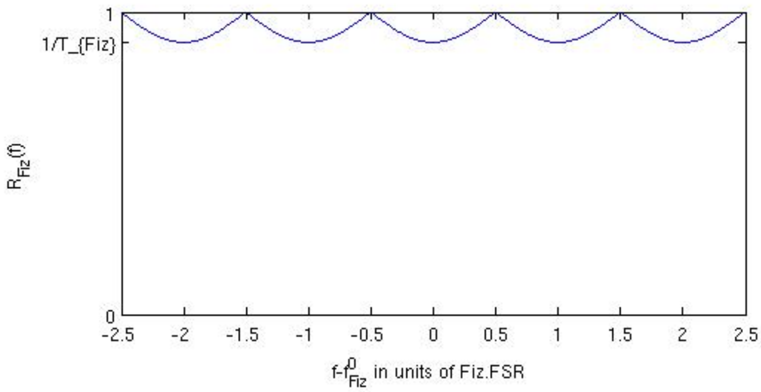

Figure 4: Shape of the reflection on the Fizeau.

The transmission through the direct and reflected FPs can be modeled by the convolution of an Airy and a Gaussian function:

$$T_{dir,ref}(f) = T_{dir,ref}^{peak}\mathcal{T}_{dir,ref}(f) \tag{4}$$

Where

$$\mathcal{T}_{dir,ref}(f) = (A \otimes G)(f) \tag{5}$$

$$A_{dir,ref}(f) = \frac{1}{1 + F_{dir,ref} sin^2\left(\frac{\pi\left(f - f_{dir,ref}^{peak}\right)}{FP.FSR_{dir,ref}}\right)} \tag{6}$$

$$G_{dir,ref}(f) = \frac{1}{\sqrt{2\pi}\sigma_{dir,ref}} \exp\left(-\frac{1}{2}\frac{f^2}{\sigma_{dir,ref}^2}\right) \tag{7}$$

In (4), $T_{dir,ref}^{peak}$ sets the peak transmission of $T_{dir}(f)$ and $T_{ref}(f)$. It must be greater than 1.

In (5), the symbol ⊗ denotes a convolution product.

The Airy function in (6) is a common expression for the transmission of a Fabry-Perot. It assumes the plates of the interferometer are perfect, which is not true in reality. This is why the convolution with the Gaussian function in (7) is introduced. It models the impact of plate defects on the transmission characteristics of the Fabry-Perot. The parameters σ_{dir} and σ_{ref} set the width of the Gaussian functions. The larger they are, the larger is the impact of plate defects on FP responses.

The parameters F_{dir} and F_{ref} are the finesse of the direct and reflected FP. They are related to the Full-Width-Half-Maximum of $A_{dir}(f)$ and $A_{ref}(f)$ through the relationship

$$\sin^2\left(\frac{\pi}{2}\frac{FWHM_{dir,ref}}{FSR_{dir,ref}}\right) = \frac{1}{F_{dir,ref}} \tag{8}$$

To summarize, the overall transmission from the receiver entrance to section A (or B) of the Rayleigh receiver CCD can be modeled by

$$T_A\left(f, \theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, \sigma_{dir}\right) = T_{dir}^{peak} R_{Fiz}(f, \theta_{Fiz}) \mathcal{T}_{dir}(f, \theta_{dir}) \tag{9A}$$

and

$$\begin{aligned} &T_B\left(f, \theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, \sigma_{dir}, T_{ref}^{peak}, \theta_{ref}, \sigma_{ref}, Q\right) \\ &\quad = T_{ref}^{peak} R_{Fiz}(f, \theta_{Fiz}) \left[1 - Q T_{dir}^{peak} \mathcal{T}_{dir}(f, \theta_{dir})\right] \mathcal{T}_{ref}(f, \theta_{ref}) \end{aligned} \tag{9B}$$

with

$$\theta_{Fiz} = (T_{Fiz}, f_{Fiz}^{0}) \tag{9D}$$

$$\theta_{dir} = (FWHM_{dir}, f_{dir}^{peak}, \sigma_{dir}) \tag{9E}$$

$$\theta_{ref} = (FWHM_{ref}, f_{ref}^{peak}, \sigma_{ref}) \tag{9F}$$

7.4.2 Fitting procedure

The generation of the AUX_CSR consists in minimizing the cost functions

$$CostFuncDir\left(\theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}\right) = \sum_{n=1}^{N_{ISR}} \left| isr.TA(n) - T_A\left(isr.f(n), \theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}\right)\right|^2 \tag{10A}$$

and

$$\begin{aligned} &CostFuncRef\left(\theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, T_{ref}^{peak}, \theta_{ref}, Q\right) \\ &\quad = \sum_{n=1}^{N_{ISR}} \left| isr.TB(n) - T_B\left(f, \theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, T_{ref}^{peak}, \theta_{ref}, Q\right)\right|^2 \end{aligned} \tag{10B}$$

The sums are on the frequency steps reported in the AUX_ISR_1B file. The nominal value for N_{ISR} is 40.

In practice, the minimization of the cost functions is done in two sequential steps:

Step 1: Minimization of $CostFuncDir\left(\theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, \sigma_{dir}\right)$ with respect to $\theta_{Fiz}, T_{dir}^{peak}$, θ_{dir} and σ_{dir};

Step 2: Minimization of $CostFuncRef\left(\hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, \hat{\sigma}_{dir}, T_{ref}^{peak}, \theta_{ref}, \sigma_{ref}, Q\right)$ with respect to θ_{ref}, σ_{ref}, and Q, with $\hat{\theta}_{Fiz}$, $\hat{\theta}_{dir}$ and $\hat{\sigma}_{dir}$ the values of θ_{Fiz}, θ_{dir} and σ_{dir} that minimize $CostFuncDir(\theta_{Fiz}, \theta_{dir}, \sigma_{dir})$

The whole process is summarized in Figure 5.

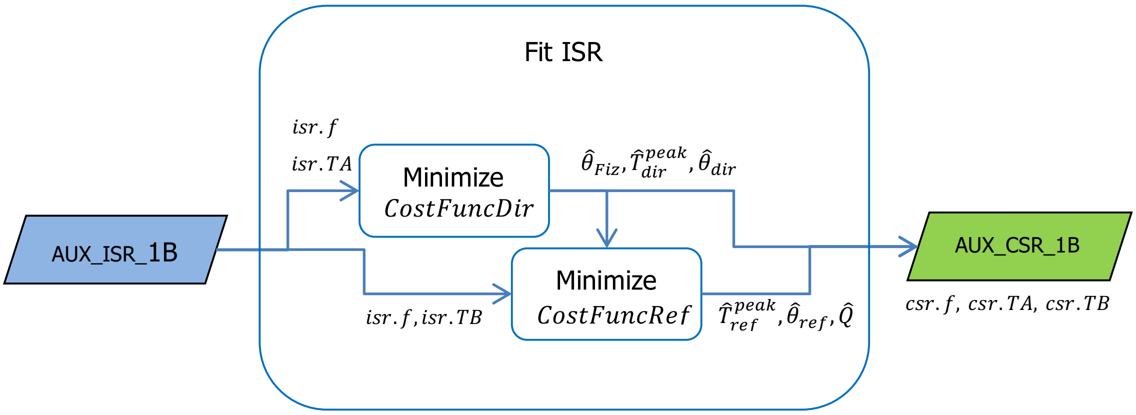

Figure 5: Diagram showing how the Fit ISR function is operating.

7.4.3 Minimization of cost function

$CostFuncDir\left(\theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, \sigma_{dir}\right)$ is a second order polynomial of the parameter T_{dir}^{peak}. For a given set of parameters $(\theta_{Fiz}, \theta_{dir}, \sigma_{dir})$, it achieves a minimum for

$$\hat{T}_{dir}^{peak}(\theta_{Fiz}, \theta_{dir}) = \frac{\sum_{n=0}^{N_{ISR}} isr.TA(n) T_A(isr.f(n), \theta_{Fiz}, 1, \theta_{dir})}{\sum_{n=1}^{N_{ISR}} T_A^2(isr.f(n), \theta_{Fiz}, 1, \theta_{dir})} \tag{11A}$$

It follows that the parameters $\hat{\theta}_{Fiz}$ and $\hat{\theta}_{dir}$ which minimize $CostFuncDir\left(\theta_{Fiz}, T_{dir}^{peak}, \theta_{dir}, \sigma_{dir}\right)$ can be found by minimizing $CostFuncDir\left(\theta_{Fiz}, \hat{T}_{dir}^{peak}(\theta_{Fiz}, \theta_{dir}), \theta_{dir}\right)$ instead, with the benefit that the minimization now bears on 5 parameters instead of 6.

The minimization of $CostFuncDir\left(\theta_{Fiz}, \hat{T}_{dir}^{peak}(\theta_{Fiz}, \theta_{dir}), \theta_{dir}\right)$ is done with a Downhill Simplex algorithm. The initial value for θ_{Fiz} is $(10{,}0GHz)$, and initial steps are $(1{,}0.1GHz)$. For θ_{dir}, the initial value is $(FP.FWHM, 0GHz, 0GHz)$ and the initial steps are $(5MHz, 5MHz, 10MHz)$.

Likewise, $CostFuncRef\left(\hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, T_{ref}^{peak}, \theta_{ref}, Q\right)$ is a second order polynomial of the variable T_{ref}^{peak}, so the parameters $\hat{\theta}_{ref}$ and $\hat{Q}$ that achieves the minimum of $CostFuncRef\left(\hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, T_{ref}^{peak}, \theta_{ref}, Q\right)$ can be found by minimizing the function $CostFuncRef\left(\hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, \hat{T}_{ref}^{peak}(\theta_{ref}, Q), \theta_{ref}, Q\right)$ with

$$\hat{T}_{ref}^{peak}(\theta_{ref}, Q) = \frac{\sum_{n=0}^{N_{ISR}} isr.TB(n) T_B\left(f, \hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, 1, \theta_{ref}, Q\right)}{\sum_{n=1}^{N_{ISR}} T_B^2\left(f, \hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, 1, \theta_{ref}, Q\right)} \tag{11B}$$

The minimization of $CostFuncRef\left(\hat{\theta}_{Fiz}, \hat{T}_{dir}^{peak}, \hat{\theta}_{dir}, \hat{T}_{ref}^{peak}(\theta_{ref}, Q), \theta_{ref}, Q\right)$ is done with a Downhill Simplex algorithm. The initial value for θ_{ref} is $(FP.FWHM, 0GHz, 0GHz)$, and initial steps are $(5MHz, 5MHz, 5MHz)$. For Q, the initial value is 0.8 and the initial step is 0.01.

For both cost functions, a maximum number of iterations $Gen.iterMax$ is authorized and the minimization stops when the cost functions vary less than $Gen.tol$.

7.5 Validity period of generated AUX_CSR

The validity period of the output product AUX_CSR product is equal to the validity period of the input ISR_1B product. This period is determined by the dates included in the ISR_1B file names. These dates are decoded by the $UpdateValidityDates$ function.

7.6 Computing the AUX_PRR

The algorithm for the computation of the AUX_PRR is described in §9 below.

8. AUX_CSR Update

8.1 Input files

The updating of the AUX_CSR needs 5 or 6 input files:

- The AUX_PAR_CS file where the settings of the processor are given (see §10.3).
- The currently valid AUX_CSR_1B file. Note that the AUX_CSR_1B file contains a copy of the ISR from which it was derived. If the current CSR is found unrepresentative of the double FP, the updating processor goes back to this ISR and tries to modify it until it matches the RRC.
- The AUX_RRC_1B file where the results of the last Rayleigh Response Calibration are stored (see [L1B-IODD]).
- The AUX_MRC_1B file where the results of the last Mie Response Calibration are stored (see [L1B-IODD]). This file must originate from the same IRC_1A product as the AUX_RRC_1B above. This condition is partially checked by the processor that verifies the dates and position of AUX_RRC_1B and AUX_MRC_1B frequency steps are identical.
- One or two AUX_MET_12 files. The AUX_MET_12 file contains the characteristics of the atmospheric volumes probed by the lidar. They are produced by the L2_Met_12 generator. They contain vertical profiles of atmospheric variables (pressure, temperature, humidity…) along the lidar track. As the lidar beam is looking at nadir during an RRC, the atmospheric information is to be found in MET_DS2 of AUX_MET. The meteorological information for an ISR is usually contained in a single AUX_MET_12 file. It may however happen that it is split into two of them (ISR extending across two downloaded orbits for instance).

The processor settings relevant for the AUX_CSR update are all those required for the AUX_CSR generator (see §7.1), plus those listed in Table 2 below.

8.2 OUTPUT FILES

The output files are the AUX_CSR and AUX_PRR.

The format of the AUX_CSR is detailed in section 10.2 below.

The format of the AUX_PRR is close to that of the AUX_RRC, it is detailed in section 10.4 below.

Variable	Unit	Tag name	Comment
$\boldsymbol{driftRef}$		Frequency_Drift_Reference	Switch selecting the receiver used for the estimation of a potential laser frequency drift. It can be "RRC" or "MRC". See §8.3.1.
$\boldsymbol{matchup.range\_max}$	km	Matchup.Range_Max	Parameters setting the maximum horizontal distance and time permissible between a RRC frequency step and an AUX_MET profile. If none of the atmospheric profiles in an AUX_MET file is closer in time and space from a given RRC BRC, than the matchup algorithm (see §8.3.2) returns a missing indicator. Since there is no atmospheric profile available for the corresponding RRC frequency step, the BRC is tagged invalid and excluded from the AUX_CSR updating process.
$\boldsymbol{matchup.time\_max}$	s	Matchup.Time_Max	
$\boldsymbol{up.iterMax}$		Simplex_Fit.Update. Max_Iterations	The maximum number of iterations and tolerance defining the termination criteria of the optimization procedure used for estimating the beam étendue effect parameters (width Δ and with of the tilted top-hat, see equation (1)).
$\boldsymbol{up.tol}$		Simplex_Fit.Update. Tolerance	
$\boldsymbol{maxtophattilt}$		Max_TopHat_Tilt_Range	Sets the maximum absolute value the tilt parameter of the étendue model can take (see equation 1). Set to 2 by default. This value is presently unused.
$\boldsymbol{thresholds.minFreqStepsValid}$		Thresholds. Min_Freq_Steps_Valid	Minimum number of valid RRC frequency step requested for carrying out the updating of the AUX_CSR (see Table 32)
$\boldsymbol{thresholds.FractionValidCSR}$	%	Thresholds. Fraction_Valid_CSR	Fraction of RRC frequency steps considered for the validation of the current CSR (see §8.3.4 and Table 32).
$\boldsymbol{thresholds.slope}$		Thresholds. Slope	Used to determine whether the difference between the predicted and observed Rayleigh responses is meaningful or not (see §8.3.4 and Table 32).
$\boldsymbol{thresholds.offset}$	m/s	Thresholds.Offset	
$\boldsymbol{thresholds.minUsefulSignal}$		Thresholds. Min_Useful_Signal	The threshold below which the useful signal recorded in a height-bin by the Rayleigh receiver is discarded from the estimation procedure of the aerosol or cloud attenuation in the prediction of Rayleigh responses (see Table 32).

Table 2: Parameters used for setting the updating procedure of the AUX_CSR. These parameters come in addition to those listed in Table 1.

8.3 ALGORITHM.

The high level architecture of the processor is depicted in Figure 6.

The algorithm starts by reading the configuration file AUX_PAR_CS, the currently valid AUX_CSR, then the AUX_RRC and AUX_MRC derived from the latest IRC, and at last the AUX_MET files.

The content of the AUX_PAR_CS is read by a dedicated function $ReadCSRParams$ that returns its content in the structure $param$.

From the AUX_CSR, the processor reads the current transmission characteristics TA and TB of the two Fabry-Perot as well as the ISR from which it was derived. The result is stored in the structure ref with fields $ref.csr.f$, $ref.csr.TA$ (transmission of FPA), $ref.csr.TB$ (transmission of FP B), $ref.isr.TA$ (transmission of FPA in ISR), $ref.isr.TB$ (transmission of FPB in ISR), $ref.isr.MieResp$ (internal Mie response in pixel index), and $ref.isr.Fiz$ (transmission of the Fizeau).

The useful information read from the AUX_RRC file is the geolocation $date$, alt, lon and lat, and $range$ of the Rayleigh height-bins (table 7-91 in [L1B-IODD]), the height $goeid$ of the goeid above the WGS84 ellipsoid at DEM intersection[1], the frequency offsets $f$and the corresponding Rayleigh measurement and internal reference pulse responses (Measurement_Response and Reference_Pulse_Response in table 7-75 in [L1B-IODD]) $resp$ and int, the normalized useful signals $signal$ (Rayleigh useful signal divided by the emitted laser energy; Normalized_Useful_Signal in table 7-75 in [L1B-IODD]), the mean slope $mean\_sensitivity$ and zero-frequency $zero\_freq$ of the best linear fit to the actual response curve (Measurement_Mean_Sensitivity and Measurement_Zero_Frequency in table 7-78 in [L1B-IODD]), the minimum and maximum altitudes $zmin$ and $zmax$ of the altitude range considered for the computation of the RRC (Lower_Altitude_Limit and Upper_Altitude_Limit in table 7-85 in [L1B-IODD]), the minimum and maximum frequencies $fmin$ and $fmax$ of the range across which the best linear fit to the actual response curve is computed (Rayleigh_Fit_Lower_Frequency_Range and Rayleigh_Fit_Upper_Frequency_Range in table 7-86 in [L1B-IODD]), and the scattering ratio threshold $maxScatRatio$ used by the L1B for discarding useful signals contaminated by particle backscatter from the computation of the Rayleigh Response Curve. All these information are stored in the structure rrc.

From AUX_MRC, the processor extracts geolocation ($mrc.date$, $mrc.alt$, $mrc.lon$ and $mrc.lat$ and $mrc.range$ of the Mie height-bins, the normalized useful signal $mrc.signal$, the scattering ratios $mrc.scatratio$ computed by the L1b processor within Mie height-bins, and the frequency steps $mrc.f$, Mie and internal responses $mrc.resp$ and $mrc.int$, and the mean sensitivity $mrc.intSlope$ of the Mie internal reponse.

Note that since AUX_RRC and AUX_MRC are derived from the same IRC_1A product, the geolocation information $date$, lat, lon should be the same for the frequency steps in both products. This is verified by the AUX_CSR updater. If a difference is found for these fields in mrc and rrc structures, the updater issues an error and aborts.

For each Rayleigh height-bin of the IRC, the values of the $mie.scatratio$ of any Mie height-height-bin intersecting the height-bin is checked. If any of them exceeds the threshold $rrc.maxScatRatio$ the Rayleigh height-bin is tagged invalid. The validity information is stored in the $rrc.ValidSignal$ matrix (24 lines, as many columns as there are frequency steps in the RRC product under consideration). This quality control is done as it is also done by the L1B processor.

[1] Three goeid heights are reported for each frequency step in the AUX_RRC product. The middle one is read.

The algorithm first detects a potential frequency laser drift between the CSR and the IRC. This offset is afterwards added to all MRC and RRC frequency step offsets so that they all become relative to the baseline laser frequency of the CSR. The detection is explained in §8.3.1. It is based on a comparison of the internal responses of either the Rayleigh or Mie receiver derived (or contained) in the CSR and the RRC (resp. MRC). The choice between the Rayleigh or Mie receiver is controlled by the setting $param.driftRef$.

Then it applies the match-up functionality that searches among the AUX_MET profiles which match the MRC/RRC frequency steps. If two AUX_MET_12 files are read, their contents are concatenated. The matching procedure is described in §8.3.2, it is based on the RRC geolocation information contained in table 7-91 in [L1B-IODD] (Start_of_Oservation_Time_Last_BRC, Latitude_of_DEM_Intersection and Longitude_of_DEM_Intersection). The output is a structure array met. The array has as many elements as there are frequency steps in the RRC file. Each element contains three fields: $altitude$, $pressure$ and $temperature$. All of them are vectors of same length, they characterize the pressure and the temperature profiles at the location of the RRC frequency step.

It must be noted here that the altitudes in AUX_MET files are relative to the goeid rather than the WGS84 ellipsoid.

The match-up algorithm returns empty fields if no meteorological profile is found that satisfies the time and space proximity criteria. Empty met fields invalidate the RRC frequency step which is then discarded from the AUX_CSR updating procedure.

The third step consists in predicting the Rayleigh response from the AUX_CSR and AUX_MET data. It is then compared to the actual response contained in the AUX_RRC. If both match, it is concluded the current AUX_CSR characterizes properly the Fabry-Perot interferometers. Otherwise a new CSR is generated from the ISR data (noise filtered by the application of the fitting procedure described in §7.4) contained in the AUX_CSR product, and beam étendue effect parameters are estimated. The estimation process is explained in §8.3.5. It returns estimates for Δ and x. It may happen that estimation process fails in which case a warning is issued.

8.3.1 Estimation of laser frequency drift between ISR and IRC

The response of the Mie or Rayleigh receivers through the internal reference paths can be found in (or derived from) both the ISR and the RRC/MRC products:

- Internal path Rayleigh response:
    - the response can be derived from CSR data with the equation:

$$ref.isr.int = \frac{ref.isr.TA - ref.isr.TB}{ref.isr.TA + ref.isr.TB} \tag{12}$$

   - the response $rrc.int$ is to be found in Frequency step section of the AUX_RRC_1B file (see element Reference_Pulse_Response in table 7-75 of [L1B-IODD]).
- Internal path Mie response:
   - the ISR response $ref.isr.MieResp$ is to be found in the ISR Frequency Step section of the CSR product (see Table 15).
   - the MRC response $mrc.int$ is in the section Reference_Pulse_Response of Frequency Step Results (see Table 7-62 in [L1B-IODD]).

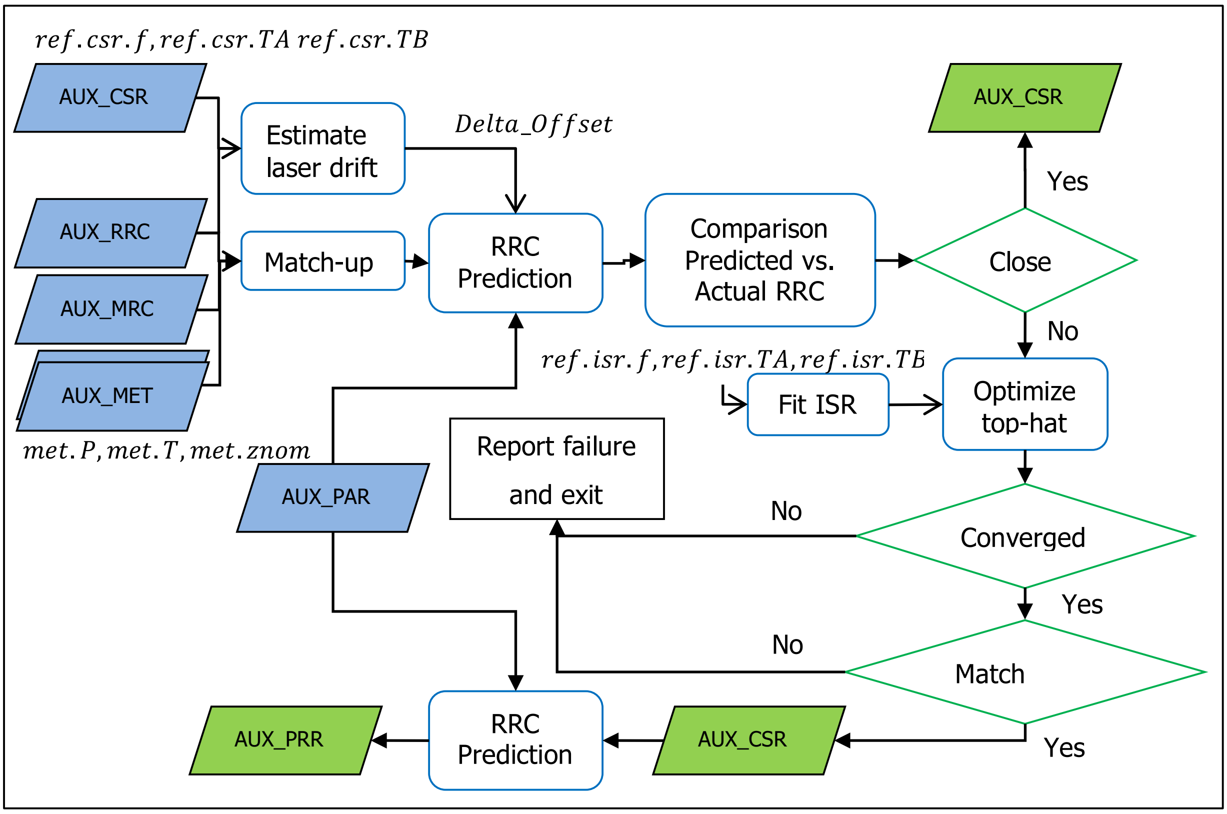

Figure 6 : High-level architcture of the AUX_CSR updating algorithm. Input products are in blue, output products are in green.

Let us assume here the AUX_PAR_CS commands the estimation shall be done on the Rayleigh receiver ($driftRef = RRC$). The ISR response $ref.isr.int$ is interpolated to $rrc.freq$ frequencies:

$$temp = interp1(ref.isr.f, ref.isr.int, rrc.freq) \tag{13}$$

The result is stored in a temporary vector $temp$. The frequency laser drift is then estimated by

$$Delta\_offset = mean(rrc.int - temp)/rrc.intSlope \tag{14}$$

That is, the estimate is equal to the average difference between the responses in RRC and the one derived from the ISR divided by the slope of the RRC response $rrc.intSlope$. The last step consists in verifying that the RRC and ISR derived responses are matching once the laser frequency drift is taken into account. For this, $Delta\_offset$ is added to all $rrc.freq$ values, $ref.isr.int$ is interpolated to the new $rrc.freq$ values using equation (13) above, and the matching between $temp$ and $rrc.int$ is checked by the function $ValidRespCurve$ (see §8.3.4).

In case $driftRef = MRC$, the same procedure is applied but $ref.isr.int$ must be replaced by $ref.isr.MieResp$ in equation (13) and rrc by mrc in equations (13) and (14).

8.3.2 Match-up

The match-up algorithm consists in finding the closest MET profile within a specified time-window. This is done iteratively for all the RRC frequency steps.

For any given RRC frequency step of index $kobs$, the algorithm computes the absolute time difference with all the MET profiles in the MET_DS2 section of the AUX_MET file. The time differences are stored in a vector. All the MET profiles for which the time difference exceeds the threshold $Match\_up.Time\_Max$ are discarded. For all the remaining MET profiles, the distance to the RRC frequency step is computed and the profile with the minimum distance is selected and associated to the RRC frequency step in the output met structure as long as it does not exceed $Match\_up.Range\_Max$.

The distance between the RRC frequency step and the MET profile is computed the following way:

$$dist = 6378.1[km]\cos^{-1}\left(x_{prof}x_{obs} + y_{prof}y_{obs} + z_{prof}z_{obs}\right)$$

where $[x_{prof}, y_{prof}, z_{prof}]$ (resp. $[x_{obs}, y_{obs}, z_{obs}]$) are the cartesian coordinates of the MET profile and RRC frequency step respectively. They are computed from the latitude and longitude $[lat_{prof}, lon_{prof}]$ (resp. $[lat_{obs}, lon_{obs}]$) of the profile (resp. frequency step) by :

$$\begin{cases} x_{prof,obs} = \cos\left(lon_{prof,obs}\right)\cos\left(lat_{prof,obs}\right) \\ y_{prof,obs} = \sin\left(lon_{prof,obs}\right)\cos\left(lat_{prof,obs}\right) \\ z_{prof,obs} = \sin\left(lat_{prof,obs}\right) \end{cases}$$

8.3.3 Prediction of the RRC

The prediction of the RRC output (response versus laser frequency) is based on a prediction of the Rayleigh useful signal in FPs A & B of the Rayleigh receiver. It is carried out as long as there are enough valid RRC profiles. The minimum number of valid profiles is set by $Min\_Freq\_Steps\_Valid$.

The initial processing step is the definition of a fine resolution, vertical grid:

$$zref = zrefmax{:}-dzref{:}zrefmin \tag{15}$$

The vertical resolution $dzref$ is defined in the AUX_PAR_CS file, it is currently set to $dzref = 25m$. It must be noted that altitudes must be sorted in a descending order in $zref$ (from top to bottom). The parameters $zrefmax$ and $zrefmin$ (both in meters) are parameter settings. The interval $[zrefmin, zrefmax]$ must encompass the altitude range over which the RRC is performed (reported in $rrc.zmin$ and $rrc.zmax$). The processor checks this condition is met and aborts if it is not.

Then, for each valid RRC frequency step (index $iobs = 1, \dots, nobs$), the vertical pressure and temperature AUX_MET profiles are interpolated to the altitudes $zref$:

$$Tref(:,iobs) = interp(met.altitude(:,iobs) + rrc.geoid(iobs), met.temperature(:,iobs), zref)$$
$$Pref(:,iobs) = interp(met.altitude(:,iobs) + rrc.geoid(iobs), met.pressure(:,iobs), zref)$$

Note the geoid height $rrc.geoid$ is added to the altitudes of the meteorological profiles are these are referenced to the geoid while RRC altitudes are referenced to the WGS84 ellipsoid. With this correction, all altitudes are now relative to the ellipsoid reference.

A RRC frequency step is valid when the two following conditions are met :

1. The Frequency_Valid field in the corresponding Frequency_Step_Result structure (see table 7-75 in [L1B-IODD]) is equal to « TRUE »,
2. The corresponding Mie frequency step in the MRC product is valid (see field Calibration_Valid in table 7-53 in [L1B-IODD]).
3. The matchup algorithm has been able to return a pressure and temperature profile (see §8.3.2).

The arrays $Tref$ and $Pref$ are used in order to predict the molecular backscatter $bmol$ and extinction $amol$ coefficients along the lidar line-of-sight:

$$\begin{gathered} bmol = 2.351319\ 10^{-6}\ Pref/Tref \\ amol = 8\pi\ bmol/3 \end{gathered} \tag{16}$$

This prediction is done in the separate function `molOptProp`.

Based on these coefficients, the processor computes the expected strength of the Rayleigh return according to the standard lidar equation :

$$rayStrength(izref, iobs) = \frac{bmol(izref, iobs)}{range(izref)^2} \exp\left(-2 \sum_{k=1}^{izref} amol(k, iobs) dr(k)\right)$$

Here, $izref$ is the index of the current altitude, $range(izref)$ is the distance along the line-of-sight from the lidar to $zref(izref)$, and dr is defined by $dr(1) = 0$ and for $k > 1$, $dr(k) = range(k) - range(k-1)$. The vector $range$ is obtained by interpolating $rrc.range$ to the altitudes $zref$:

$$range = interp(rrc.alt(:,iobs), rrc.range(:,iobs), zref)$$

The shape of the spectrum of the received light is computed as the sum a broad Rayleigh-Brillouin return (scattering from molecules) and a narrow Mie peak (scattering from particles). The broad Rayleigh-Brillouin return is generated by a call to the $Tenti\_Spectrum$ function. It implements the algorithm described in [RBS-MOD].

$$\begin{aligned} &spectrum(:, izref, iobs) \\ &\quad = Tenti\_Spectrum\big(ref.csr.f, rrc.f, Tref(izref, iobs), Pref(izref, iobs)\big) \end{aligned} \tag{17A}$$

Then the Mie peak is added. It is modeled as a Dirac centered about the frequency in $csr.f$ that is closest to laser frequency $rrc.freq(iobs)$. The index of this frequency is denoted $jfreq$.

$$spectrum(jfreq, izref, iobs) = spectrum(jfreq, izref, iobs) + (mrc.scatratio(ibin, iobs) - 1)/df \quad (17B)$$

The parameter $mrc.scatratio(ibin, iobs)$ is the scattering ratio estimated by the L1B processor from the Mie spectrum registered in Mie bin $ibin$ of the frequency step $iobs$. To get an estimate of the scattering ratio at altitude $zref(izref)$ (and for the frequency step $iobs$), we look for the Mie bin $ibin$ that contains this altitude:

$$ibin = \min\left(find\big(mrc.alt(:, iobs) < zref(izref)\big)\right)$$

Scattering ratios below 1 are set to 1.

Based on $rayStrength$ and the spectra in $spectrum$ the expected useful signals in Rayleigh channels A and B are computed by integrating over the RRC height bins the products

$$nA(izref, iobs) = rayStrength(izref, iobs) * \sum_{ifreq} ref.csr.TA(ifreq) * spectrum(ifreq, izref, iobs)$$
$$nB(izref, iobs) = rayStrength(izref, iobs) * \sum_{ifreq} ref.csr.TB(ifreq) * spectrum(ifreq, izref, iobs)$$

The summation is on the frequencies in $csr.f$ (index $ifreq$). The matrices nA and nB have as many lines as there are altitudes in $zref$. They are proportional to the number of photons that should be detected by the FP CCDs at the altitude $zref(izref)$ if there was no aerosol extinction.

The integration of nA and nB over RRC height-bins is done the following way :

$$NA(:, iobs) = diff\left(interp\big(zref, cumsum(nA), rrc.alt(:, iobs)\big)\right)$$
$$NB(:, iobs) = diff\left(interp\big(zref, cumsum(nB), rrc.alt(:, iobs)\big)\right)$$

where the function $diff$ computes the differences between successive elements of its vector argument ($diff(x) = [x(2) - x(1), x(3) - x(2), \dots]$).

The extinction by aerosols is estimated by forming the ratio between $rrc.signal$ and the $NA + NB$

$$T2aer = rrc.signal/(NA + NB)$$

The last step consists in selecting and adding the RRC height bins that are comprised in the altitude range $[rrc.zmin, rrc.zmax]$, and forming the ratio

$$R(iobs) = \frac{\sum_{ibin} T2aer(ibin, iobs) * NA(ibin, iobs) - \sum_{ibin} T2aer(ibin, iobs) * NB(ibin, iobs)}{\sum_{ibin} T2aer(ibin, iobs) * NA(ibin, iobs) + \sum_{ibin} T2aer(ibin, iobs) * NB(ibin, iobs)}$$

In the current version of the processor, the last three equations (from $N_{A,B}$ to $R(iobs)$) are carried out in a separate sub-routine called $ResponseCalculation$.

Note that a second option can be commanded with the swith $specMod$ concerning the simulation of the molecular spectrum. In $specMod = GAUSS$ instead of $TENTI$, a pure Gaussian spectrum is generated. Equation (17A) becomes

$$spectrum(:, izref, iobs) = Rayleigh\_Spectrum\big(ref.csr.f, rrc.f, Tref(izref, iobs), Pref(izref, iobs)\big) \tag{17B}$$

8.3.4 COMPARISON OF PREDICTED VERSUS OBSERVED RRC

The predicted Rayleigh response is compared to the current RRC. The purpose is to determine whether both can be assumed equivalent or not. In the first alternative, it will be concluded that the current CSR is representative of the Rayleigh receiver. In the latter one, it be concluded on the contrary that the Rayleigh receiver must be corrected.

Since signals are contaminated by noise (in particular photo-counting noise), one cannot expect the predicted and RRC frequency step Rayleigh responses perfectly match. The differences between them may simply arise from the noise. The difficulty is thus to determine whether these differences are significant or not.

The way it is done in the AUX_CSR generator and updater is as follows. First of all, the x% of the frequency steps yielding the largest differences between the RRC and the Rayleigh response prediction are discarded. The value of x is specified in the AUX_PAR_CS file with the field $Fraction\_Valid\_CSR$ in the section $Thresholds$ (see Table 32). This is done in order to discard from the process frequency steps that may be contaminated by ground or cloud echoes and aerosols. Let us denote ind the vector of the frequency steps indices that are left after this selection, and N_{ind} its length.

Then we fit a line to the differences $\epsilon_R\big(ind(i)\big) = rrc.resp\big(ind(i)\big) - R\big(ind(i)\big)$ as a function of the frequency steps $rrc.freq\big(ind(i)\big)$. The line fit is done by the function$Linear_Fit$ that returns a slope and an intercept:

$$slope = \frac{N_{ind}\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)\epsilon_R\big(ind(i)\big) - \sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)\sum_{i=1}^{N_{ind}} \epsilon_R\big(ind(i)\big)}{N_{ind}\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)^2 - \Big(\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)\Big)^2} \tag{18A}$$

$$offset = \frac{1}{N_{ind}}\sum_{i=1}^{N_{ind}} \epsilon_R\big(ind(i)\big) - slope\ \frac{1}{N_{ind}}\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big) \tag{18B}$$

If the predicted response and the RRC match, the line should be close to the horizontal and pass close to the (0,0) point. This is what is now tested. For this, we estimate the uncertainty associated to the estimates $slope$ and $offset$:

$$\sigma_R^2 = \frac{1}{N_{ind} - 2} \sum_{i=1}^{N_{ind}} \left(\epsilon_R\big(ind(i)\big) - slope\ rrc.freq\big(ind(i)\big) - offset\right)^2$$

$$\sigma_{slope}^2 = \frac{\sigma_R^2}{\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)^2 - N_{ind}^{-1}\left(\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)\right)^2}$$

$$\sigma_{offset}^2 = \frac{\sigma_R^2 \sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)^2}{N_{ind} \sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)^2 - \left(\sum_{i=1}^{N_{ind}} rrc.freq\big(ind(i)\big)\right)^2}$$

Then we set the maximum admissible departure of the slope and intercept from (0,0) by combining the tolerance set in the AUX_PAR_CS with the uncertainty above

$$maxSlope = Thresholds.Slope + \sigma_{slope}$$

$$maxOffset = Thresholds.Offset/\lambda + \sigma_{offset}$$

where $\lambda = 354.8nm$ is the laser wavelength. Note this value is used to convert a tolerance expressed in wind speed in ms^{-1} into a tolerance in frequency in GHz. It does not need to be precise.

The conclusion about the validity is now straightforward. The current CSR is declared valid if

$$|slope| \leq maxSlope$$

$$|offset| \leq maxOffset$$

If one of these two conditions is not met, it is declared invalid.

The comparison of the RRC with the predicted Rayleigh response is done by a separate function called $validRespCurve$.

8.3.5 Optimization of the tilted top-hat.

The optimization of the tilted top-hat consists in finding the two parameters Δ and x (see equation (1)) that produce the RRC prediction closest to the actual one. It is based on a Down-hill simplex algorithm. The Down-hill simplex minimizes a distance between the RRC prediction and frequency step. The distance is defined by a function called $Dist\_ObsRRC\_PredRRC$ coded in a function:

$$dist(\Delta, x) = \begin{cases} \dfrac{sum\left(\left(R(jobs, \Delta, x) - rrc.resp(jobs)\right)^2\right)}{length(jobs)} & if\ \Delta \geq 0\ and\ |x| \leq 2 \\ 100\ otherwise & \end{cases}$$

Here, $rrc.resp$ is the RRC response read in the RRC file, $jobs$ is the vector of all the valid RRC frequency steps ($length(jobs)$ is the number of valid frequency steps), and $R(jobs, \Delta, x)$ is the vector of RRC responses predicted for the frequency steps $jobs$ with ISR transmission functions for Fabry-Perot interferometers A and B convoluted by the titled top-hat $\Pi_{\Delta,x}(f)$. The prediction is done as described in §8.3.3. The tilted top-hat convolution is made in a separate function detailed in §8.3.6 below.

The Down-hill simplex was coded in Matlab after chapter 10.4 of *Numerical Recipes in Fortran 77*, second edition (1997), by W. H. Press, S. A. Teutolsky, W. T. Vetterling and B. P. Flannery (Cambridge University Press). We send the reader to this book (available on-line at http://www.nrbook.com/fortran/) for details. The algorithm starts by computing the distance $dist$ (see equation above) for 3 different sets of tilted top-hat settings (Δ=0.0, x=0), (Δ=0.25, x=0) and (Δ=0.0, x=1) forming the initial simplex.

When searching for the minimum of $dist(\Delta, x)$, it may happen that the down-hill simplex test top-hat settings outside their admissible ranges (for instance, a negative width or a tilt above 2 in absolute value). To ensure a good convergence of the minimization, $dist(\Delta, x)$ is set to 100 when this happens. A $dist(\Delta, x) = 100$ is indeed well above any possible distance for admissible Δ and x, so it indicates to the down-hill simplex it is getting away from the optimal tilted top-hat.

8.3.6 CONVOLUTION OF TA AND TB BY THE TILTED TOP-HAT

Mathematically, the convolution of the transmission curves $T_A(f)$ and $T_B(f)$ by the titled top-hat is written

$$\tilde{T}_{A,B}(f) = \int_{f-0.5\Delta}^{f-0.5\Delta} T_{A,B}(f)\Pi_{\Delta,x}(u-f)du \tag{19}$$

Considering the expression of $\Pi_{\Delta,x}$ in equation (1), this equation can be re-written

$$\tilde{T}_{A,B}(f) = \frac{\Delta - fx}{\Delta^2}\left[\Sigma^0_{A,B}\left(f+\frac{\Delta}{2}\right) - \Sigma^0_{A,B}\left(f-\frac{\Delta}{2}\right)\right] + \frac{x}{\Delta^2}\left[\Sigma^1_{A,B}\left(f+\frac{\Delta}{2}\right) - \Sigma^1_{A,B}\left(f-\frac{\Delta}{2}\right)\right] \tag{20}$$

where

$$\Sigma^0_{A,B}(f) = \int_{-FSR}^{f} T_{A,B}(u)du \qquad \Sigma^1_{A,B}(f) = \int_{-FSR}^{f} uT_{A,B}(u)du$$

The zero-th $\Sigma^0_{A,B}$ and first $\Sigma^1_{A,B}$ order moments of $T_A$and T_B are computed by a centered, finite-difference scheme

$$S^0_{A,B} = Df * cumsum\big([0{,}0.5 * T_{A,B}(1{:}end-1) + 0.5 * T_{A,B}(2{:}end)]\big)$$

and

$$S^1_{A,B} = Df * cumsum\big([0{,}0.5 * f_{csr}(1{:}end-1).* T_{A,B}(1{:}end-1) + 0.5 * f_{csr}(2{:}end).* T_{A,B}(2{:}end)]\big)$$

Here, f_{csr} and $T_{A,B}$ designate the vectors defining the resampled ISR transmission curves. For any frequency f, the values $\Sigma^0_{A,B}(f)$ and $\Sigma^1_{A,B}(f)$ is obtained by interpolating the vectors $S^0_{A,B}$ and $S^1_{A,B}$

$$\Sigma^{0,1}_{A,B} \approx interp\left(f_{csr}, S^{0,1}_{A,B}\right)$$

In practice, a linear interpolation is used.

The function $TransferFunction$ forces the top-hat width to be greater than 10MHz in order to avoid divisions by zero in equation (17). A top-hat width of 10MHz produces a negligible effect on the transmission curves. Likewise, the function also makes sure the tilt parameter does not exceed 2 in absolute value. If a tilt greater than 2 in absolute value is passed to the function, it is automatically set to 2 (if positive) or -2 (if negative).

8.4 Validity period

The validity period of the updated AUX_CSR is determined from the validity dates of the input products AUX_RRC_1B, AUX_MRC_1B, initial AUX_CSR, and ISR_1B. The start of validity date is the earliest validity date of all this products and the stop of validity date is the oldest of their end of validity dates. They are determined by calls to the $UpdateValidityDates$ function done when the input products are read.

9. Generation of AUX_PRR

9.1 Algorithm.

The AUX_PRR file contains a prediction of the Rayleigh response based on the latest CSR and a standard atmosphere defined in the AUX_PAR_CS file (see Table 33).

The first step consists in interpolating the standard pressure and temperature profiles contained in the $Atm\_Profile$ structure (read from the AUX_PAR_CS) to the reference altitudes in the vector $zref$:

$$Tatm = interp(Atm\_Profile.Altitude, Atm\_Profile.Temperature, zref)$$
$$Patm = interp(Atm\_Profile.Altitude, Atm\_Profile.Pressure, zref)$$

Then the vertical profiles of the molecular backscatter $bmol$ and extinction $amol$ are computed using equation (16) and a Rayleigh return strength is predicted by:

$$rayStrength(izref) = \frac{bmol(izref)}{range^2(izref)} \exp\left(-2 \sum_{k=1}^{izref} amol(k)dr(k)\right)$$

where $range(izref) = satalt - zref(izref)$ with $satalt$ the satellite altitude specified in the AUX_PAR_CS file.

From the profiles $Tatm$ and $Patm$, the processor computes the shape of the Rayleigh return spectrum for all the altitudes in $zref$. It does so by applying the same spectral model as for the prediction of the RRC (see §8.3.2 for a discussion on this model):

$$spectrum(:, izref, ioffset) = Tenti\_Spectrum\big(csr.csr.f, Freq\_Offset(ioffset), Tatm(izref), Patm(izref)\big)$$

or

$$spectrum(:, izref, ioffset) = Rayleigh\_Spectrum\big(csr.csr.f, Freq\_Offset(ioffset), Tatm(izref), Patm(izref)\big)$$

depending on the value of the swith $specMod$. Here, $csr.f$ is the vector of the AUX_CSR frequency offsets (see equation (2)).

The spectra are convolved by the transmission curves of FPs A & B and multiplied by the return strengths $rayStrength$ in order to obtain the relative strength of the signals detected by the FP detectors as a function of the altitude:

$$nA(izref, ioffset) = rayStrength(izref, ioffset) * \sum_{ifreq} csr.TA(ifreq) * spectrum(ifreq, izref, ioffset)$$

$$nB(izref, ioffset) = rayStrength(izref, ioffset) * \sum_{ifreq} csr.TB(ifreq) * spectrum(ifreq, izref, ioffset)$$

It then remains to integrate nA and nB over the altitude interval $[zmin, zmax]$ to obtain a relative prediction of the number of photons counted on FPs A & B during a standard RRC:

$$NA(ioffset) = diff\left(interp\big(zref, cumsum\big(nA(:, ioffset)\big), [zmin, zmax]\big)\right)$$

$$NB(ioffset) = diff\left(interp\big(zref, cumsum\big(nB(:, ioffset)\big), [zmin, zmax]\big)\right)$$

and form the ratio

$$R(ioffset) = (NA(ioffset) - NB(ioffset))/(NA(ioffset) + NB(ioffset))$$

in order to get the Predicted Rayleigh Response to be stored in the AUX_PRR file.

9.2 Validity period

The validity period of the AUX_PRR is the same as for the AUX_CSR (see §7.5 or §8.4).

10. File formats

10.1 General product structure

All the Aeolus files comply with the Earth Explorer Ground Segment File Format Standard Document [EE_FFS], including auxiliary and non-product files.

The Aeolus files follow a generalised structure containing:

- A Fixed Header (FH) written using the XML standard. This header is identical for all files and is described in Section 10.1.1.
- A Variable Header (VH), which varies from one file type to another and consists of:

- A Main Product Header (MPH) written using the XML standard. This header is identical for all files and is described in Section 10.1.2.
- A Specific Product Header (SPH) written using the XML standard. This header varies for each product type, and the SPH for each product type is described in the applicable product type sections. All SPH structures will include one or more Data Set Descriptors (DSD) which describe the format/structure of individual Data Sets in the Data Block portion of the product. The DSD structure is described in Section 10.1.4.

- A Data Block (DB) containing one or more Data Sets (DS), each consisting of one or more Data Set Records (DSR). Each product will contain different types of DSs, which are described in the various product type sections. Data sets in the Data Block can be of three different types: Measurement Data Sets (MDS), Annotation Data Sets (ADS), or Global Annotation Data Sets (GADS)

For small data volumes a single XML files contain all three components separated with the following top level tags. The FH, VH and DB structures described throughout this document assume this top level structure.

- "Earth_Explorer_File" delimiting the file contents
- "Earth_Explorer_Header" delimiting the header section (fixed and variable header)
- "Data_Block" delimiting the data block

.

The high level layout of these files is shown below:

```
<?xml version="1.0" encoding="utf-8"?>
<Earth_Explorer_File xmlns="xml namespace" schemaversion="schema version number">
        <Earth_Explorer_Header>
                <Fixed_Header>
                        Fixed Header contents
                </Fixed_Header>
                <Variable_Header>
                        Variable Header contents
                </Variable_Header>
        </Earth_Explorer_Header>
        <Data_Block type="xml">
                <data_set_1_root_tag>
                        <List_of_Data_Set_Records count="N">
                                <Data_Set_Record>
                                        Data Set 1 Record Contents
                                </Data_Set_Record>
                                ...
                        </List_of_Data_Set_Records>
                </data_set_1_root_tag>
                <data_set_2_root_tag>
                        <List_of_Data_Set_Records count="N">
                                <Data_Set_Record>
                                        Data Set 2 Record Contents
                                </Data_Set_Record>
                                ...
                        </List_of_Data_Set_Records>
                </data_set_2_root_tag>
                ...
                <data_set_N_root_tag>
                        <List_of_Data_Set_Records count="N">
```

```
                        <Data_Set_Record>
                                Data Set N Contents
                        </Data_Set_Record>
                        ...
                  </List_of_Data_Set_Records>
            </data_set_N_root_tag>
      </Data_Block>
</Earth_Explorer_File>
```

10.1.1 FIXED HEADER

The content and size of the Fixed Header is detailed in tables 1 to 3 below.

Tag Name	Content Description	Unit	Type	Size (XML)		
Fixed_Header	Root tag.		Structure	14	0	15
File_Name	Logical file name without the extension		String	11	62	13
File_Description	One line description of the file		String	18	32	20
Notes	Multi-lines free text		String	7	32	9
Mission	String representing the mission name ('Aeolus' for the ADM-Aeolus mission). Note that, in the File_Name, the Mission ID is a two character string ('AE' for the ADM-Aeolus mission)		String	9	6	11
File_Class	OPER or TEST (file type as indicated in the file name)		String	12	4	14
File_Type	The part of the file name that gives the file type.		String	11	10	13
Validity_Period	SeeTable 4 for structure description		Structure	18	112	19
File_Version	The vvvv part of the file name		Integer	14	4	16
Source	See Table 5 for structure description		Structure	9	157	10
Total size for XML FH in bytes:				**682**		

Table 3 Structure of the Fixed Header

Tag Name	Content Description	Unit	Type	Size (XML)		
Validity_Start	Validity start time as specified in the file name.		DateTime	16	23	18
Validity Stop	Validity stop time as specified in the file name.		DateTime	15	23	17
Total size in bytes				**112**		

Table 4: Structure of the Validity_Period field of the Fixed Header.

Tag Name	Content Description	Unit	Type	Size (XML)		
System	Name of facility in charge of running the calibration processors = ACMF		String	8	4	10
Creator	Official name of AUX_CSR processor		String	9	12	11
Creator_Version	Version of AUX_CSR Generation processor		String	17	12	19
Creation_Date	Date/time of creation.		DateTime	15	23	17
Total size in bytes:				**157**		

Table 5: Structure of Source field of the Fixed Header.

10.1.2 VARIABLE HEADER

The Variable header is composed of the Main product Header (see table 4)

Tag Name	Content Description	Unit	Type	Size (XML)		
Variable_Header	Root tag.		Structure	17	0	19
Main_Product_Header	Structure containing the Main Product Header (see Table 6)		Structure	1522		
Specific_Product_Header	Structure containing the Specific Product Header (see Table 9)		Structure	2974		
Total size in bytes				**4532**		

Table 6 : Structure of the Variable Header

10.1.3 Main Product Header

The structure of the Main Product Header of the AUX_CSR file is the same as for all other ADM files. It is reminded below in table 4 for the sake of clarity.

Tag Name	Content Description	Unit	Type	Size (XML)		
Main_Product_Header	Root tag.		Structure	21	0	23
Product	Logical file name, extension i.e., file name excluding the		String	9	62	11
Proc_Stage	Processing stage flag: 'N' for nominal processing (quasi-or close to real-time), 'T' for test product, 'R' for reprocessed.		Enum	12	1	14
Ref_Doc	Reference document describing the product		String	9	23	11
Spare_1			Spare	9	0	11
Acquisition_Station	Acquisition station ID		String	21	20	23
Proc_Center	Processing centre ID		String	13	6	15
Proc_Time	Time of processing		DateTime	11	23	13
Software_Ver	Sersion number of processing software. Format: name of processor (up to 10 characters)/version number(4 characters)		String	14	14	16
Baseline	Baseline identifier (as provided by the Job Order File)		IntAus	10	4	12
Sensing_Start	Start time of sensing		DateTime	15	23	17
Sensing_Stop	Stop time of sensing		DateTime	14	23	16
Spare_3			Spare	9	0	11
Phase	Phase number. If not used set to 'X'		Enum	7	1	9
Cycle	Cycle number		IntAuc	7	4	9
Rel_Orbit	Start relative orbit number		IntAs	11	6	13
Abs_Orbit	Start absolute orbit number		IntAs	11	6	13
State_Vector_Time	Time of state vector		DateTime	19	23	21
Delta_UT1	Delta_UT1 = UT1-UTC	s	FAdo06	11	8	13
X_Position	X position in Earth-fixed reference	m	FAdo73	12	12	14
Y_Position	Y position in Earth-fixed reference	m	FAdo73	12	12	14
Z_Position	Z position in Earth-fixed reference	m	FAdo73	12	12	14
X_Velocity	X velocity in Earth-fixed reference	m/s	FAdo46	12	12	14
Y_Velocity	Y velocity in Earth-fixed reference	m/s	FAdo46	12	12	14
Z_Velocity	Z velocity in Earth-fixed reference	m/s	FAdo46	12	12	14
Vector_Source	Source of orbit vectors (not used by ADM-Aeolus)		String	15	2	17
Spare_4			Spare	9	0	11
Utc_Sbt_Time	Time corresponding to SBT below (not used by ADM-Aeolus)		DateTime	14	23	16
Sat_Binary_Time	Satellite Binary Time (not used by ADM-Aeolus)		IntAul	17	11	19
Clock_Step	Clock step size (not used by ADM-Aeolus)	ps	IntAul	12	11	14
Spare_5			Spare	9	0	11
Leap_Utc	Time of occurrence of the leap second		DateTime	10	23	12
Leap_Sign	Leap second sign (+001 if positive leap second, -001 if negative)		IntAc		11	
Leap_Err	Leap second error. 'TRUE' if leap second error occurs during processing segment, 'FALSE' otherwise		Boolean	10	5	12
Spare_6			Spare	9	0	11
Product_Err	'TRUE' or 'FALSE'. If 'TRUE', errors have been reported in the product. User should then refer to the SPH or Quality ADS of the product for details of the error condition. '0' otherwise.		Boolean	13	5	15
Tot_Size	Total size of product (#bytes DSR+SPH+MPH)		IntAd	10	21	12
Sph_Size	Length of SPH (#bytes in SPH)		IntAl	10	11	12
Num_Dsd	Number of DSDs		IntAl	9	11	11
Dsd_Size	Length of each DSDs (#bytes for each DSD, all DSDs shall have the same length		IntAl	10	11	12
Num_Data_Sets	Number of DSs attached (not all DSDs have a DS attached)		IntAl	15	11	17
Spare_7			Spare	9	0	11
Total size in bytes					**961**	

Table 7: Structure of the Main Product Header

10.1.4 Data Set Descriptors

Name	Description / Comment	Unit	Type	Size (XML)		
Dsd	Root tag for XML format only.		Structure	5	0	7
DS_Name	DS descriptor ASCII string describing the data set		String	9	28	11
DS_Type	Type of DS. 'M' if Measurement DS, 'A' if Annotation DS, 'G' if Global ADS and 'R' if Reference DS (no DS attached)		Enum	9	1	11
Filename	If Ds_Type='R', this field contains the name of external file used to process the current product. Otherwise, this field is left blank or has the value "unused"			10	6	12
Ds_Offset	Offset in bytes from beginning of file		IntAd	11	2	13
Ds_Size	Size of Data Set		IntAl	9	2	11
Num_Dsr	Number of Data Set Records in Data Set		IntAl	9	1	11
Dsr_Size	Size of Data Set Record, -1 if DSRs have variable sizes.		IntAl	10	2	12
Byte_Order	"3210" for binary DS's to designate byte order is most significant byte first.		String	12	4	14
Spare_1			Spare	9	0	11
Total size in bytes				**286**		

Table 8: Structure of the Data Set Descriptor

10.2 AUX_CSR_1B file.

10.2.1 File Name

The AUX_CSR file is in XML. The headers and the data block are in a single file. The name of the file is

AE_cccc_AUX_CSR_1B_yyyymmddThh:mm:ss_yyymmddThh:mm:ss_vvvv.EEF

where cccc can be either TEST or OPER, the groups yyyymmddThh:mm:ss are the start and end of validity dates for the file, and vvvv is a version number.

10.2.2 Specific Product Header

Name	Description / Comment	Unit	Type	Size (XML)		
Specific_Product_Header	Root tag.		Structure	25	0	27
Sph_Descriptor	Specific Product Header descriptor: ASCII string describing the product. Equal to AEOLUS_CSR_SPECIFIC_HEADER in the present case.		String	16	26	18
Spare_1			Spare	10	0	0
Base_Laser_Frequency	Base laser frequency.	GHz	FAdo6.6	33	13	24
Num_Freq_ISR	Number of frequency steps reported in the ISR GADS of the file.		IntAus	14	4	16
Num_Freq_CSR	Number of frequency steps for which the transmission of FPs A and B are characterized in the CSR GADS. The number depends on the frequency resolution and the value of the Free Spectral Range. With $FSR = 10938 MHz$ and $Df = 25 MHz$, we have Num_Freq=875.		IntAus	14	4	16
Checked_Against_RRC	This field is TRUE or FALSE. It is false if the current AUX_CSR has been obtained directly from the AUX_ISR without comparison to an RRC. It is true if a comparison with an RRC has been made.		Boolean	21	5	23
Width	Width in MHz of the top-hat function that has been applied to the currently valid ISR in order to modify the transmission curves TA and TB of FPs A and B so that they match the last RRC_1B. If no correction has been applied (that is the case when the AUX_CSR is computed directly from the ISR, or if a comparison has been carried out with a RRC that has shown no modification is necessary), it is equal to 0.	MHz	FAdo4.1	18	6	8
Tilt	Tilt of the top-hat function hat has been applied to the currently valid ISR in order to modify the transmission curves TA and TB of FPs A and B. If no correction has been		FAdo3.2	6	6	8

	applied (that is the case when the AUX_CSR is computed directly from the ISR, or if a comparison has been carried out with a RRC that has shown no modification is necessary), it is equal to 0.			
List_of_Dsds	See Table 10 for list of Data Sets in product. The structure of the Dsd is defined in Table 8 above.		A	24 2574 15
Total size in bytes				**2974**

Table 9: Structure of the Specific Product Header

Name	Description / Comment	Unit	Type	Size (XML)
ISR_GADS	DSD for the ISR		G	286
CSR_GADS	DSD for the result of the AUX_CSR		G	286
AUX_PAR_CS	DSD for processor settings		R	286
AUX_ISR_1B	DSD referencing the AUX_ISR data file used for the generation of this AUX_CSR		R	286
AUX_MRC_1B	DSD indicating the AUX_MRC_1B file that was used for updating the AUX_CSR file. If no MRC file was used (this happens when the initial CSR is derived from the ISR), the DSD points to nothing.		R	286
AUX_RRC_1B	DSD indicating the AUX_RRC_1B file that was used for updating the AUX_CSR file. If no RRC file was used (this happens when the initial CSR is derived from the ISR), the DSD points to nothing.		R	286
AUX_MET_1	DSD referencing the AUX_MET data file used for the generation of this AUX_CSR		R	286
AUX_MET_2	DSD referencing the second AUX_MET data file used for the generation of this AUX_CSR. If a single AUX_MET was considered, this DSD points to nothing.		R	286
AUX_CSR_1B	DSD referencing the AUX_CSR data file used for the generation of this AUX_CSR		R	286
Total size in bytes				**2574**

Table 10: List_of_Dsds

10.2.3 DATA BLOCK

Name	Description / Comment	Unit	Type	Size (XML)
Data_Block	Root tag			13 0 14
Internal_Spectral_Registration	Structure containg the ISR_GADS (copy of the current ISR). See Table 13.		Structure	32 142592 33
Corrected_Spectral_Registration	Structure containing the CSR. See Table 18.		Structure	33 191292 34
Total size				**334043**

10.2.4 ISR_GADS

The ISR_GADS contains a copy of the ISR results used for generating the CSR. It is representative of the transmission of the two FPs in the internal path. The number of Data Set Records is given by the Num_Freq_ISR field in the SPH. The root tag is Internal_Spectral_Registration.

Name	Description / Comment	Unit	Type	Size (XML)
List_of_Data_Set_Records	List of data set records (one for this data set). See		Structure	34 142535 23
Total size				**142592**

Table 11: Structure of the list of data set records in ISR_GADS.

Name	Description / Comment	Unit	Type	Size (XML)
Data_Set_Record	Structure of the data set record in the ISR_GADS. See Table 13.		Structure	17 142500 18
Total size				**142535**

Table 12: Structure of the data set record in ISR_GADS.

Name	Description / Comment	Unit	Type	Size (XML)
List_of_ISR_Results	List of ISR results. See Table 14 for the description of an ISR result.		Structure	34 142443[2] 23
Total size				**142500**

Table 13: Structure of DSRs in the ISR_GADS.

Name	Description / Comment	Unit	Type	Size (XML)
ISR_Result	Frequency step results. See Table 15 for a description of the structure.		Structure	13 296 14
Total size				**323**

Table 14: Structure of List_of_ISR_Results.

Name	Description / Comment	Unit	Type	Size (XML)
Laser_Freq_Offset	Laser frequency offset	GHz	FAdo3.6	30 10 21
Fizeau_Transmission	Transmission through the Fizeau		FAdo6.6	21 13 23
Rayleigh_A_Response	Response of FPA.		FAdo6.6	21 13 23
Rayleigh_B_Response	Response of FPB.		FAdo6.6	21 13 23
Mie_Response	Response of the Fizeau	PixelIndex	FAdo6.6	32 16 16
Total size				**296**

Table 15: Structure of Frequency_Step_Results for ISR.

10.2.5 CSR_GADS

The CSR_GADS contains the transmission curves of FPs A and B as a result of the CSR procedure. The number of Data Set Records is given by the Num_Freq_CSR field in the SPH as the results are stored by frequency offsets. The root tag for this data set is Corrected_Spectral_Registration.

Name	Description / Comment	Unit	Type	Size (XML)
List_of_Data_Set_Records	List of data set records (one for this data set). See		Structure	34 191292 23
Total size				**191349**

Table 16: Structure of the list of data set records in CSR_GADS.

Name	Description / Comment	Unit	Type	Size (XML)
Data_Set_Record	Structure of the data set record in the ISR_GADS. See Table 13.		Structure	17 191257 18
Total size				**191292**

Table 17: Structure of the data set record in CSR_GADS.

Name	Description / Comment	Unit	Type	Size (XML)
List_of_CSR_Frequency_Steps	List of frequency step results. See Table 19		Structure	41 191186[3] 30
Total size				**191257**

Table 18: Structure of the list of CSR frequency steps.

Name	Description / Comment	Unit	Type	Size (XML)
CSR_Frequency_Step	CSR frequency step results. See structure in Table 20.		Structure	21 175 22
Total size				**218**

Table 19: Structure of List_of_CSR_Frequency_Steps.

Name	Description / Comment	Unit	Type	Size (XML)
Laser_Freq_Offset	Laser frequency offset	GHz	FAdo3.6	30 10 21
Rayleigh_A_Response	Response of FPA.		FAdo6.6	21 13 23
Rayleigh_B_Response	Response of FPB.		FAdo6.6	21 13 23
Total size				**175**

Table 20: Structure of CSR_Frequency_Step.

[2] Assuming there are 441 frequency steps.

[3] Assuming there are 877 frequency steps.

10.2.6 OVERALL SIZE

Assuming there are 441 DSRs in the ISR_GADS and 875 in CSR_GADS ($FSR = 10938MHz, df = 25MHz$), the overall size of the AUX_CSR_1B file is 682 + 961 + 2974 + 441*323 + 875*218 = ~330kBytes.

10.3 AUX_PAR_CS

10.3.1 FILE NAME

The AUX_PAR_CS file is in XML. The headers and the data block are in a single file. The name of the file is

AE_cccc_AUX_PAR_CS_yyyymmddThh:mm:ss_99991231T23:59:59_vvvv.EEF

where cccc can be either TEST or OPER, yyyymmddThh:mm:ss is the date and time of start of validity for the file, and vvvv is a version number. Note that the date of end of validity is 31 December 9999 at 23:59:59 by default since the AUX_PAR_CS is valid as long as no new settings are prescribed.

10.3.2 FIXED HEADER

See 10.1.1.

10.3.3 VARIABLE PRODUCT HEADER

See 10.1.2

10.3.4 MAIN PRODUCT HEADER

See 10.1.3

10.3.5 SPECIFIC PRODUCT HEADER

Name	Description / Comment	Unit	Type	Size (XML)		
Specific_Product_Header	Root tag.		String	26	0	27
Sph_Descriptor	Specific Product Header descriptor: AUX_PAR_CSR_SPECIFIC_HEADER		String	16	27	18
Num_Alt_Prof	Number of altitudes of the reference atmospheric profile in structure refProfile (see below)		IntAus	14	3	16
Spare_1			Spare	11	0	0
List_of_Dsds	The AUX_PAR_CS file has only one DS (see name in Table 22 below. The structure of a Dsd is detailed in Table 8.		List of structures	25	286	16
Total size in bytes				**485**		

Table 21: Structure of the Specific Product Header

Name	Description / Comment	Unit	Type	Size (XML)
CSR_PAR_GADS	DSD for the processing parameters of the AUX_CSR		G	**286**
Total size in bytes				**286**

Table 22: Structure of List_of_Dsds

10.3.6 CSR_PAR_GADS

Name	Description / Comment	Unit	Type	Size (XML)		
CSR_Parameters	Root tag of CSR_PAR_GADS		String	17	0	18
List_of_Data_Set_Records	Tag opening the list of data set records in the product. The data block of the AUX_PAR_CS file contains a single DSR. See		List of structures	36	3409	28
Total size in bytes				**3508**		

Table 23 : Structure of the CSR_PAR_GADS

Name	Description / Comment	Unit	Type	Size (XML)		
Data_Set_Record	Single data set record of the AUX_PAR_CS. See Table 25 for a description.		Structure	18	3372	19
Total size in bytes				**3409**		

Table 24 : Structure of the List_of_ Data_Set_Records.

Name	Description / Comment	Unit	Type	Size (XML)		
Frequency_Drift_Reference	Indicates which internal reference is considered for estimating the laser frequency drift. Can be either RRC or MRC.		String	27	3	29
Fabry_Perot	Structure containing information relevant for the Fabry-Perot interferometers. See Table 26.		Structure	14	59	15
Fizeau	Structure containing information relevant for the Fizeau interferometer. See Table 27.		Structure	9	70	10
Df	Frequency resolution of CSR computation	MHz	IntAuc	15	2	6
Ref_Grid	Structure containing the parameters of the high-resolution vertical grid used for predicting the RRC curve. See Table 28.		Structure	10	95	11
Matchup	Parameters for the AUX_MET versus BRC match-up (see Table 29)		Structure	11	72	12
RBC_Spec_Model	Name of the spectral model for molecular return. Can take the value “TENTI” or “GAUSS”		String	16	5	18
Simplex_Fit	Structure containing the termination criteria for the down-hill simplex algorithm. See Table 30: Context of Simplex_Fit structure		Structure	14	186	15
Max_Top_Hat_Tilt_Range	Maximum of the absolute value of the tilt parameter of the top-hat used for simulating the beam étendue effect on the transmission of the Fabry-Perot interferometers		FAdo1.1	23	3	25
Thresholds	Structure containing the thresholds for the modification of the transmission characteristics of the FPs and for the comparison between the predicted and observed Rayleigh response (see Table 32).		Structure	13	201	14
Ref_Profile	Structure defining the reference atmospheric profile use for the computation of the Predicted Rayleigh Response. See Table 33.		Structure	13	369	14
PRR_Params	Parameter settings for the computation of the AUX_PRR. See Table 36.		Structure	13	1946	14
Total size in bytes				**3372**		

Table 25: Structure of the single DSR in the AUX_PAR_CS

Name	Description / Comment	Unit	Type	Size (XML)		
FSR	Free Spectral Range FSR of the two Fabry-Perot interferometers forming the Rayleigh receiver. The FSR will be characterized at ground and shall remain stable throughout the mission lifetime.	GHz	Fado2.3	16	6	7
FWHM	Initial value for the estimation of the Full-Width-Half-Max of the T_A and T_B. See §7.4.3.	MHz	IntAus	18	4	8
Total size in bytes				**59**		

Table 26: Structure of the Fabry_Perot structure in the single DSR of AUX_PAR_CS.

Name	Description / Comment	Unit	Type	Size (XML)

FSR	Initial value for the estimation of the FSR of the Fizeau. See §7.4.3.	GHz	Fado1.3	17	5	7
Fiz_Reflec_Model	Takes the value "E2S" or "DLR". Sets the model used for the reflection on the Fizeau in the ISR fitting procedure.		String	18	3	20
Total size in bytes				**70**		

Table 27: Structure of the Fizeau structure in the single DSR of AUX_PAR_CS.

Name	Description / Comment	Unit	Type	Size (XML)		
Dz_Ref	Vertical resolution	m	IntAus	16	2	9
Zref_Min	Minimum altitude (above WGS84 geoid)	m	IntAus	18	5	11
Zref_Max	Maximum altitude	m	IntAus	18	5	11
Total size in bytes				**95**		

Table 28: Content of structure Ref_Grid

Name	Description / Comment	Unit	Type	Size (XML)		
Range_Max	Maximum distance between an AUX_MET profile and a RRC frequency step.	km	IntAus	21	3	13
Time_Max	Maximum time difference between an AUX_MET profile and a RRC frequency step.	s	IntAus	19	4	12
Total size in bytes				**72**		

Table 29 : Content of the Matchup structure

Name	Description / Comment	Unit	Type	Size (XML)		
Generate	Termination criteria for the down-hill simplex used for fitting the ISR. See Table 31.		Structure	11	73	12
Update	Termination criteria for the down-hill simplex used estimating the beam étendue parameters. See Table 31.		Structure	8	73	9
Total size in bytes				**186**		

Table 30: Context of Simplex_Fit structure

Name	Description / Comment	Unit	Type	Size (XML)		
Max_Iterations	Maximum distance between an AUX_MET profile and a RRC frequency step.		IntAus	16	5	18
Tolerance	Maximum time difference between an AUX_MET profile and a RRC frequency step.		FAdo18	11	10	13
Total size in bytes				**73**		

Table 31: Content of the Simplex_Fit Generate and Update structure.

Name	Description / Comment	Unit	Type	Size (XML)		
Min_Freq_Steps_Valid	Minimum number of valid frequency steps (valid RRC data and valid AUX_MET profile) required for the update of the CSR to be carried out.		IntAuc	22	2	24
Fraction_Valid_CSR	Fraction of RRC frequency steps closest to CSR-based Rayleigh response prediction considered for validating the CSR.	%	IntAuc	29	2	22
Offset	Parameter setting the max difference between the offsets of the predicted and observed Rayleigh response.	m/s	FAdo1.3	19	5	10
Slope	Maximum of the relative error on the Rayleigh response slope.		Fado1.3	7	5	9
Min_Useful_Signal	Value the height-bin useful signals of a RRC frequency step must exceed in order to keep this frequency step in the CSR updating procedure.		IntAus	19	5	21
Total size in bytes				**201**		

Table 32 : Content of the Thresholds structure

Name	Description / Comment	Unit	Type	Size (XML)
List_of_Atm_Profiles	List of Atm_Profile structure defining the state of the atmosphere at various altitudes (minimum 2 altitudes). See Table 35.		Structure	35 308[4] 26
Total size in bytes				**369**

Table 33: Content of structure Ref_Profile

Name	Description / Comment	Unit	Type	Size (XML)
Atm_Profile	Structure giving the pressure and temperature at a given altitude. See Table 35.		Structure	17 119 18
Total size in bytes				**154**

Table 34 : Content of the List_of_Atm_Profiles structure.

Name	Description / Comment	Unit	Type	Size (XML)
Altitude	Altitude (WGS84)	m	Fadoxy5.1	19 7 12
Pressure	Pressure	Pa	Fadoxy4.1	21 6 12
Temperature	Temperature	C	Fadoxy3.1	22 5 15
Total size in bytes				**119**

Table 35: Content of structure Atm_Profile

Name	Description / Comment	Unit	Type	Size (XML)
Sat_Alt	Satellite altitude	m	IntAul	17 6 10
Zmin	Minimum altitude of PRR computation	m	Int	15 4 8
Zmax	Maximum altitude of PRR computation	m	Int	15 5 8
List_of_Freq_Offsets	Structure containing the list of frequency offsets for PRR.		Structure	34 1800[5] 24
Total size in bytes				**1946**

Table 36: Content of structure PRR_Params.

Name	Description / Comment	Unit	Type	Size (XML)
Freq_Offset	Frequency Offset	GHz	Fado2.3	24 6 15
Total size in bytes				**45**

Table 37: Content of List_of_Freq_Offsets

10.3.7 OVERALL SIZE

Assuming the reference profile (see Ref_Profile in Table 25) is characterized by two sets of atmospheric characteristics (see Table 35), the overall size of the AUX_PAR_CS file is ~8.2kBytes.

10.4 AUX_PRR

The AUX_PRR product has a format similar to the AUX_RRC for it is required that it can be used by the L1B processor instead of the AUX_RRC. The consequence is many fields are added in the product

[4] Assuming num_Alt_Prof=2.

[5] Assuming there are 40 frequency steps as for the RRC.

for the sole purpose of compatibility. These fields are signaled in the tables below by the indication NA (=Not Applicable) followed by their default value.

10.4.1 File Name

The AUX_PRR_1B file is in XML. The headers and the data block are in a single file. The name of the file is

AE_cccc_AUX_PRR_1B_yyyymmddThh:mm:ss_yyymmddThh:mm:ss_vvvv.EEF

where cccc can be either TEST or OPER, the groups yyyymmddThh:mm:ss are the start and end of validity dates for the file, and vvvv is a version number.

10.4.2 Fixed Header

See 10.1.1.

10.4.3 Variable Header

See 10.1.2

10.4.4 Main Product Header

See 10.1.3.

10.4.5 Specific Product Header

Tag Name	Content Description	Unit	Type	Size
Specific_Product_Header	Root tag.			53
Sph_Descriptor	AEOLUS_PRR_SPECIFIC_HEADER		String	60
Total_Num_of_Observations	Number of observations used for the derivation of the Rayleigh Response Curve (NA, set to 0)		IntAl	57
Total_Num_of_Measurements	Number of total measurements (NA set to 0).		IntAl	57
Total_Num_of_Reference_Pulses	Number of total reference pulses (NA, set to 0)		IntAl	65
Base_Laser_Frequency	Base Laser Transmit Frequency (copied from the AUX_RRC file)	GHz	FAdoxy	70
Spare_1			Spare	11
Num_of_Mie_Observations_Used	Number of Mie frequency steps used (NA, set to 0)		IntAl	63
Num_of_Rayleigh_Observations_Used	Number of Rayleigh frequency steps used (NA, set to 0)		IntAl	73
Num_of_Mie_Measurements_Used	Number of Mie measurements used (NA, set to 0)		IntAl	63
Num_of_Rayleigh_Measurements_Used	Number of Rayleigh measurements used (NA, set to 0)		IntAl	73
Num_of_Mie_Reference_Pulses_Used	Number of Mie reference pulses used (NA, set to 0)		IntAl	71
Num_of_Rayleigh_Reference_Pulses_Used	Number of Rayleigh reference pulses used (NA, set to 00000).		IntAl	81
Num_of_Valid_Mie_Calibration_Results	Number of valid Mie calibration results (NA, set to 0)		IntAl	79
Num_of_Valid_Rayleigh_Calibration_Results	Number of valid Rayleigh calibration results (NA, set to 0)		IntAl	89
Spare_2			Spare	11
Total_Num_of_Measurement_Invalid	Total number of invalid measurements.		IntAl	71
Total_Num_of_Pulse_Validity_Status_Flag_False	Total number of reference pulses with validity flag false		IntAl	97
Total_Num_of_Sat_Not_on_Target_Measurements	Total number of measurements with satellite not on target status (NA, set to 0)		IntAl	93
Total_Num_of_Corrupt_Mie_Measurement_Bins	Total number of corrupt Mie measurements (NA, set to 0).		IntAl	89
Total_Num_of_Corrupt_Rayleigh_Measurement_Bins	Total number of corrupt Rayleigh measurements (NA, set to 0).		IntAl	99

Tag Name	Content Description	Unit	Type	Size
Total_Num_of_Corrupt_Mie_Reference_Pulses	Total number of corrupt Mie reference pulses (NA, set to 0)		IntAl	89
Total_Num_of_Corrupt_Rayleigh_Reference_Pulses	Total number of corrupt Rayleigh reference pulses (NA, set to 0)		IntAl	99
Spare_3			Spare	11
List_of_Dsds	List of Data Set Descriptors. There are 3 DSDs in the AUX_PRR file, one attached, two referenced. See Table 39.			910
Total size for XML structure in bytes:				**2534**

Table 38 : Specific product header of the AUX_PRR file.

Num.	DSD Name	Content Description	Data Set Type	Update Frequency	Size
1	PRR_GADS	DSD structure for AUX_PRR GADS	G	1 DSR	263
2	AUX_PAR_CS	DSD for AUX_PAR parameter settings	R	No DS	292
3	AUX_CSR_1B	DSD for the AUX_CSR 1B file	R	No DS	314
Total size					**869**

Table 39 : Data Set Descriptors

10.4.6 PRR_GADS

Tag Name	Content Description	Unit	Type	Size
Auxiliary_Calibration_PRR	Root tag		Structure	57
List_of_Data_Set_Records	List of data set records. This list contains a single DSR. See Table 41.		Structure	208054
Total size for XML structure in bytes:				**208111**

Table 40: Structure of PRR_GADS

Tag Name	Content Description	Unit	Type	Size
Data_Set_Record	Data set record of Auxiliary_Calibration_PRR . See content in Table 42.		Structure	208054
Total size for XML structure in bytes:				**208054**

Table 41; Structure of the data set record in Auxiliary_Calibration_PRR.

Tag Name	Content Description	Unit	Type	Size
First_Start_of_Observation_Time	Date and time of the first observation used for deriving the AUX_CSR with which the PRR is computed.	UTC	DateTime	91
Last_Start_of_Observation_Time	Same for the last observation of the AUX_CSR.	UTC	DateTime	89
Calibration_Valid	NA, set to TRUE		Boolean	44
Ground_Calibration_Valid	NA, set to TRUE		Boolean	58
List_of_Frequency_Step_Results	List of channel response per frequency step. See Table 43 for structure description		List of 60 Structures	108498
List_of_Frequency_Step_Temperatures	List of Etalon, RSPT, and Optical Baseplate average temperatures per frequency step. See Table 46 for structure description		List of 60 Structures	59608
Measurement_Response_Calibration	See Table 50 for structure description		Structure	1156
Ground_Measurement_Response_Calibration	See Table 52 for structure description		Structure	1155
Reference_Pulse_Response_Calibration	See Table 54 for structure description		Structure	1138
Calibration_Validity_Indicators	Calibration validity indicators for each category. See Table 56 for structure description		Structure	1305
Rayleigh_Response_Calibration_Thresholds	See Table 58 for structure description		Structure	2951
Diff_Offset_Freq_Ref_Meas	NA. Set to 0	GHz	FAdoxy	91
Diff_Offset_Freq_Ref_Ground_Meas	NA. Set to 0	GHz	FAdoxy	105
Min_Aht_9_Rsp_Etalon	Minimum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	54
Max_Aht_9_Rsp_Etalon	Maximum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	54
Min_Aht_10_Rsp_Etalon	Minimum Etalon temperature for current sensor, over		FAdoxy	56

	all BRCs and all 10 time samples per BRC. NA, set to 0.000000.			
Max_Aht_10_Rsp_Etalon	Maximum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	56
Min_Aht_11_Rsp_Etalon	Minimum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	56
Max_Aht_11_Rsp_Etalon	Maximum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	56
Min_Aht_12_Rsp_Etalon	Minimum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	56
Max_Aht_12_Rsp_Etalon	Maximum Etalon temperature for current sensor, over all BRCs and all 10 time samples per BRC. NA, set to 0.000000.		FAdoxy	56
Data_Is_Valid	NA, set to TRUE.		Boolean	36
List_of_Frequency_Step_Geolocations	List of geolocation information for all BRCs. See Table 60 for structure description.		List of 40 Structures	31248
Total size for XML structure in bytes:				**208017**

Table 42 : PRR GADS.

Tag Name	Content Description	Unit	Type	Size
Frequency_Step_Result	See Table 44 for structure description		Structure	1234

Table 43 : List_of_Frequency_Step_Results

Tag Name	Content Description	Unit	Type	Size
Frequency_Offset	Frequency offset	GHz	FAdoxy	58
Frequency_Valid	NA, set to TRUE		Boolean	40
Ground_Frequency_Valid	NA, set to TRUE		Boolean	55
Measurement_Response_Valid	NA, set to TRUE		Boolean	62
Ground_Measurement_Response_Valid	NA, set to TRUE		Boolean	76
Reference_Pulse_Response_Valid	NA, set to TRUE		Boolean	70
Measurement_Response	Measurement channel response	AU	FAdo2.6	65
Measurement_Error_Rayleigh_Response	Measurement Error_Rayleigh_Response	AU	FAdo2.6	96
Ground_Measurement_Response	Ground measurement response	AU	FAdo2.6	78
Ground_Measurement_Error_Rayleigh_Response	Ground measurement error Rayleigh response	AU		109
Reference_Pulse_Response	Reference pulse channel response	AU	FAdo2.6	73
Reference_Pulse_Error_Rayleigh_Response	Reference pulse Error_Rayleigh_Response	AU	FAdo2.6	104
Normalized_Useful_Signal	NA. 24 times the value 0.000000	AU	24*FAdo1.6	269
Frequency_Step_Data_Statistics	Frequency step product confidence data. See Table 45 for structure description		Structure	652
Total size for XML structure in bytes:				**1807**

Table 44 :Frequency_Step_Result

Tag Name	Content Description	Unit	Type	Size
Num_Valid_Measurements	Number of measurements in which ground wind bin is found. NA, set to 0.		IntAl	51
Num_Measurements_Usable	Number of measurements usable. The measurement is usable if the spacecraft attitude is on target; the number of corresponding valid pulses is over Meas_Cavity_Lock_Status_Thresh; and Rayleigh measurement is not corrupted. NA, set to 0.		IntAl	53
Num_Measurements_Valid_Ground	Number of valid measurements made at ground. NA, set to 0.		IntAl	65
Num_Reference_Pulses_Usable	Number reference pulses usable. Reference pulse is usable if the pulse is valid and the data is not corrupted. NA, set to 0.		IntAl	61
Num_Measurement_Invalid	Number of measurements for which ; the number of corresponding valid pulses is over Meas_Cavity_Lock_Status_Thresh. NA, set to 0.		IntAl	77
Num_Pulse_Validity_Status_Flag_False	Number of invalid reference pulses. NA, set to 0.		IntAl	85
Num_Sat_Not_on_Target_Measurements	Number of measurements with satellite not on target status. NA, set to 0.		IntAl	75

Tag Name	Content Description	Unit	Type	Size
Num_Corrupt_Measurements_Bins	Total number of corrupt measurements. NA, set to 0.		IntAl	55
Num_Corrupt_Reference_Pulses	Total number of corrupt reference pulses. NA, set to 0.		IntAl	63
Total size for XML structure in bytes				**585**

Table 45 : Frequency_Step_Data_Statistics.

Tag Name	Content Description	Unit	Type	Size
Frequency_Step_Temperature	See Table 47 for structure description		Structure	992

Table 46 :List_of_Frequency_Step_Temperatures

Tag Name	Content Description	Unit	Type	Size
Etalon_Average_Temperature	See Table 48 for structure definition		Structure	341
RSPT_Average_Temperature	See Table 49 for structure definition		Structure	519
Optical_Baseplate_Average	NA, set to 0.000000	C	FAdo1.6	73
Total size for XML structure in bytes:				**933**

Table 47 : Frequency_Step_Temperature

Tag Name	Content Description	Unit	Type	Size
Ray_Spectrometer_Temp_9	NA, set to 0.000000	C	FAdo1.6	69
Ray_Spectrometer_Temp_10	NA, set to 0.000000	C	FAdo1.6	71
Ray_Spectrometer_Temp_11	NA, set to 0.000000	C	FAdo1.6	71
Ray_Spectrometer_Temp_12	NA, set to 0.000000	C	FAdo1.6	71
Total size for XML structure in bytes:				**282**

Table 48 : Etalon_Average_Temperature

Tag Name	Content Description	Unit	Type	Size
Thermocouple_8_Ray_Spectrometer_Thermal_Hood_1	NA, set to 0.000000e	C	FAdo1.6	115
Thermocouple_9_Ray_Spectrometer_Thermal_Hood_2	NA, set to 0.000000	C	FAdo1.6	115
Thermocouple_10_Ray_Spectrometer_Thermal_Hood_3	NA, set to 0.000000	C	FAdo1.6	117
Thermocouple_11_Ray_Spectrometer_Thermal_Hood_4	NA, set to 0.000000	C	FAdo1.6	117
Total size for XML structure in bytes:				**464**

Table 49 : RSPT_Average_Temperature

Tag Name	Content Description	Unit	Type	Size
Measurement_Mean_Sensitivity	Measurement mean sensitivity	1/GHz	FAdo2.6	85
Measurement_Zero_Frequency	Measurement zero frequency response		FAdo2.6	77
Measurement_Error_Rayleigh_Response_Std_Dev	Measurement Error_Rayleigh_Response standard deviation		FAdo1.6	110
Measurement_Offset_Frequency	Measurement offset frequency	GHz	FAdo2.6	82
List_of_Measurement_Error_Fit_Coefficients	List of 6 measurement error fit coefficients. See Table 51 for a description.		Structure	581
Total size for XML structure in bytes:				**935**

Table 50 : Measurement_Response_Calibration

Tag Name	Content Description	Unit	Type	Size
Measurement_Error_Fit_Coefficient	NA, set to 0.		FAdo2.6	80
Total size for XML structure in bytes:				**80**

Table 51: List_of_Measurement_Error_Fit_Coefficient

Tag Name	Content Description	Unit	Type	Size
Ground_Measurement_Mean_Sensitivity	Measurement mean sensitivity. NA, set to 0.000000.	1/GHz	FAdo2.6	98
Ground_Measurement_Zero_Frequency	Measurement zero frequency response. NA, set to 0.000000.		FAdo2.6	89
Ground_Measurement_Error_Rayleigh_Response_Std_Dev	Measurement Error_Rayleigh_Response standard deviation. NA, set to 0.000000.		FAdo1.6	124
Ground_Measurement_Offset_Frequency	Measurement offset frequency. NA, set to 0.000000.	GHz	FAdo2.6	95

Tag Name	Content Description	Unit	Type	Size
List_of_Ground_Measurement_Error_Fit_Coefficients	List of six measurement error fit coeficients. See Table 53: Ground_Measurement_Error_Fit_Coefficient for a description.		Structure	679
Total size for XML structure in bytes:				**1085**

Table 52: Ground Measurement Response Calibration

Tag Name	Content Description	Unit	Type	Size
Ground_Measurement_Error_Fit_Coefficient	NA, set to 0.000000.		FAdo2.6	94
Total size for XML structure in bytes:				**94**

Table 53: Ground_Measurement_Error_Fit_Coefficient

Tag Name	Content Description	Unit	Type	Size
Reference_Pulse_Mean_Sensitivity	Reference pulse mean sensitivity	1/GHz	FAdo2.6	93
Reference_Pulse_Zero_Frequency	Reference pulse zero frequency response		FAdo2.6	85
Reference_Pulse_Error_Rayleigh_Response_Std_Dev	Reference pulse Error_Rayleigh_Response standard deviation		FAdo1.6	118
Reference_Pulse_Offset_Frequency	Frequency of the intersect between the best blinear fit ot the reference pulse response and the x-axis.	GHz	FAdo2.6	90
List_of_Reference_Pulse_Error_Fit_Coefficients	List of 6 coefficients. See Table 55.		Structure	673
Total size for XML structure in bytes:				**1059**

Table 54 : Reference_Pulse_Response_Calibration

Tag Name	Content Description	Unit	Type	Size
Reference_Pulse_Error_Fit_Coefficient	Coefficient of best polynomial fit to fit errors. NA, set to 0.		FAdo2.6	88
Total size for XML structure in bytes:				**94**

Table 55: Reference Pulse Error Fit Coefficient

Tag Name	Content Description	Unit	Type	Size
Satisfied_Min_Valid_Freq_Per_Cal	NA, set to TRUE		Boolean	74
Satisfied_Min_Valid_Ground_Freq_Per_Cal	NA, set to TRUE		Boolean	88
Freq_Offset_Data_Monotonic	NA, set to TRUE		Boolean	62
Num_Valid_Frequency_Steps	Number of valid frequency steps in the current calibration. Set to 60.		IntAul	58
Num_Valid_Ground_Frequency_Steps	NA, set to 0.		IntAl	71
Measurement_Calibration_Validity	See Table 57 for structure description		Structure	287
Ground_Measurement_Calibration_Validity			Structure	301
Reference_Pulse_Calibration_Validity			Structure	295
Total size for XML structure in bytes:				**1236**

Table 56 : Calibration_Validity_Indicators

Tag Name	Content Description	Unit	Type	Size
Mean_Sensitivity_Valid	NA, set to TRUE for Measurement_Calibration_Validity and Reference_Pulse_Calibration_Validity and FALSE for Ground_Measurement_Calibration_Response.		Boolean	54
Error_Response_Std_Dev_Valid			Boolean	66
Zero_Freq_Response_Valid			Boolean	58
Data_Monotonic			Boolean	38
Total size for XML structure in bytes:				**216**

Table 57 : Measurement_Calibration_Validity, Ground_Measurement_Calibration_Validity, Reference_Pulse_Calibration_Validity.

Tag Name	Content Description	Unit	Type	Size
Min_Valid_Freq_Per_Cal	NA, set to 0.		IntAul	51
Min_Valid_Ground_Freq_Per_Cal	NA, set to 0.		IntAul	65
Min_Valid_Measurements_Per_Freq	NA, set to 0.		IntAul	69
Min_Valid_Ground_Measurements_Per_Freq	NA, set to 0.		IntAul	84
Rayleigh_Response_Calibration_Ranges	See Table 59 for structure description		Structure	1970
Lower_Altitude_Limit	PRR lower altitude limit	m	FAdo5.6	67
Upper_Altitude_Limit	PRR upper altitude limit	m	FAdo5.6	67
Maximum_Upper_DEM_Offset	For compatibility purposes with the RRC. All values set to 0.	m	FAdo1.4	69
Maximum_Lower_DEM_Offset		m	FAdo1.4	69
Min_Rayleigh_Ground_Detection_Signal_Derivative			FAdo1.6	108
Max_Rayleigh_Ground_Detection_Response_Shift			FAdo1.6	102

Tag Name	Content Description	Unit	Type	Size
Etalon_Temp_Range_Threshold		C	FAdo1.6	77
Scattering_Ratio_Threshold			FAdo1.6	66
Total size for XML structure in bytes:				**2864**

Table 58 : Rayleigh_Response_Calibration _Thresholds

Tag Name	Content Description	Unit	Type	Size
Min_Rayleigh_Measurement_Mean_Sensitivity	NA, set to -0.600000.	1/GHz	FAdo2.6	110
Min_Rayleigh_Measurement_Zero_Freq_Response	NA, set to -0.200000.		FAdo2.6	101
Max_Rayleigh_Measurement_Mean_Sensitivity	NA, set to 0.600000.	1/GHz	FAdo1.6	109
Max_Rayleigh_Measurement_Zero_Freq_Response	NA, set to 0.200000.		FAdo1.6	100
Max_Rayleigh_Measurement_Error_Response_Std_Dev	NA, set to 10.000000.		FAdo2.6	109
Min_Rayleigh_Ground_Measurement_Mean_Sensitivity	NA, set to 0.000000.	1/GHz	FAdo2.6	123
Min_Rayleigh_Ground_Measurement_Zero_Freq_Response	NA, set to 0.000000.		FAdo2.6	114
Max_Rayleigh_Ground_Measurement_Mean_Sensitivity	NA, set to 0.000000.	1/GHz	FAdo2.6	123
Max_Rayleigh_Ground_Measurement_Zero_Freq_Respons e	NA, set to 0.000000.		FAdo2.6	114
Max_Rayleigh_Ground_Measurement_Error_Response_Std _Dev	NA, set to 10.000000.		FAdo2.6	123
Min_Rayleigh_Reference_Pulse_Mean_Sensitivity	NA, set to -0.600000.	1/GHz	FAdo2.6	118
Min_Rayleigh_Reference_Pulse_Zero_Freq_Response	NA, set to -0.200000.		FAdo2.6	109
Max_Rayleigh_Reference_Pulse_Mean_Sensitivity	NA, set to 0.600000.	1/GHz	FAdo1.6	117
Max_Rayleigh_Reference_Pulse_Zero_Freq_Response	NA, set to 0.200000.		FAdo2.6	108
Max_Rayleigh_Reference_Pulse_Error_Response_Std_Dev	NA, set to 10.000000.		FAdo2.6	117
Rayleigh_Fit_Upper_Frequency_Range	Upper frequency range when computing the best fit	GHz	FAdo2.6	94
Rayleigh_Fit_Lower_Frequency_Range	Lower frequency range when computing the best fit	GHz	FAdo2.6	94
Total size for XML structure in bytes:				**1883**

Table 59 : Rayleigh_Response_Calibration_Ranges.

Tag Name	Content Description	Unit	Type	Size
Frequency_Step_Geolocation	See Table 61 for structure description		Structure	838

Table 60 : List_of_Frequency step_Geolocations

Tag Name	Content Description	Unit	Type	Size
Start_of_Observation_Time_Last_BRC	Frequency step centroid time. NA, Set to UTC=0000-00-00T00:00:00.	UTC	DateTime	97
Latitude_of_DEM_Intersection	Latitude of the intersection of DEM and the line-of-sight. Set to 0000000.	10-6DegN	IntAl	85
Longitude_of_DEM_Intersection	Longitude of the intersection of DEM and the line-of-sight. Set to 0000000.	10-6DegE	IntAl	87
Altitude	This list contains 25 values, separated by blanks. The first item contains the height of the upper edge of the top-most bin. The remaining 24 items contain the height of the lower edge of each height bin. All are set to 0.0.	m	FAdo1.1	132
Satellite_Range	This list contains 25 values, separated by blanks. The first item contains the distance along LOS of the upper edge of the top-most bin. The remaining 24 items contain the distance along LOS of the lower edge of each height bin. All are set to 0.0.	m	FAdo1.1	146
List_of_Geoid_Separations	Structure containing three geoid separations. See Table 62.		Structure	232
Total size for XML structure in bytes				**779**

Table 61: Frequency step_Geolocation

Tag Name	Content Description	Unit	Type	Size
Geoid_Separation	Height of goeid above WGS84. NA, Set to 0.000000	m	FAdoxy	55
Total size for XML structure in bytes				**55**

Table 62: Geoid separation.

10.4.7 Overall size

~205 kbytes.