Sciamachy Level 1C Product

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The extraction and application tools may be used to transform SCIAMACHY level 1b products into 1c products, containing geo-located, calibrated spectral radiance.

Due to the high degree of flexibility, which can be achieved by a number of extraction and calibration options, this tool can do more than just calibrating a 1b product. It will be ideally suited for detailed sensitivity studies, investigating e.g. the interaction between calibration and level 2 quality.

In the following sections, various possible configurations of the extraction/application filters shall be recommended for the various applications. Of course, these will be recommendations, only. The user is free to find their optimum settings.

1.1 The level 1c Format

SCIAMACHY level 1c products are user specific products, which will have the general ENVISAT data format, i.e. it will be a binary format.

The EnviView tool can directly be used to achieve a first, basic visualisation of the results.

The general structure of the product is depicted by figure 1. As any other Envisat data product, it will contain of a main product header (MPH) and a specific product header (SPH). The remaining data sets – so called annotation and measurement data sets – all depend on the user's specifications, which will be explained more detailed in the following, starting from the left part in figure 1.

The first column of three general ADS are basically copies of the level 1b product ADS, but only containing those records (1 record per state) of the extracted states. The states of the product is of special importance because it contains mandatory information of state details, like e.g. the cluster definition, the exact duration, integration times etc.

The second column contains a "User Option" GADS. In there, all selection criteria, the user has applied to the original level 1b product, are summarised in order to trace his work easily and to distinguish between e.g. 1c products, he has derived from the same 1b input.

This is followed by the calibration GADS, which are again copies of the level 1b product. The user might decide which of the individual calibration GADS of the 1b he wants to copy into 1c (see recommendations below).

Finally, there will be in total up to 10 measurement data sets possible. Four measurement data sets (MDS) are reserved for nadir, limb, occultation or monitoring cluster, i.e. science channel data. The latter one is not yet been displayed in figure C.1, as it is such a brand new feature. Another three sets will contain integrated PMD data, again separated by nadir, limb or occultation. Finally, it is also possible to have fractional polarisation values for nadir, limb and occultation. For both groups PMD/polarisation related data sets, no monitoring pendent can be generated, because the level 1b input files do not contain the relevant information. All these data sets are selectable items, i.e. the user can decide himself whether he wants them to be in his 1c product or not.

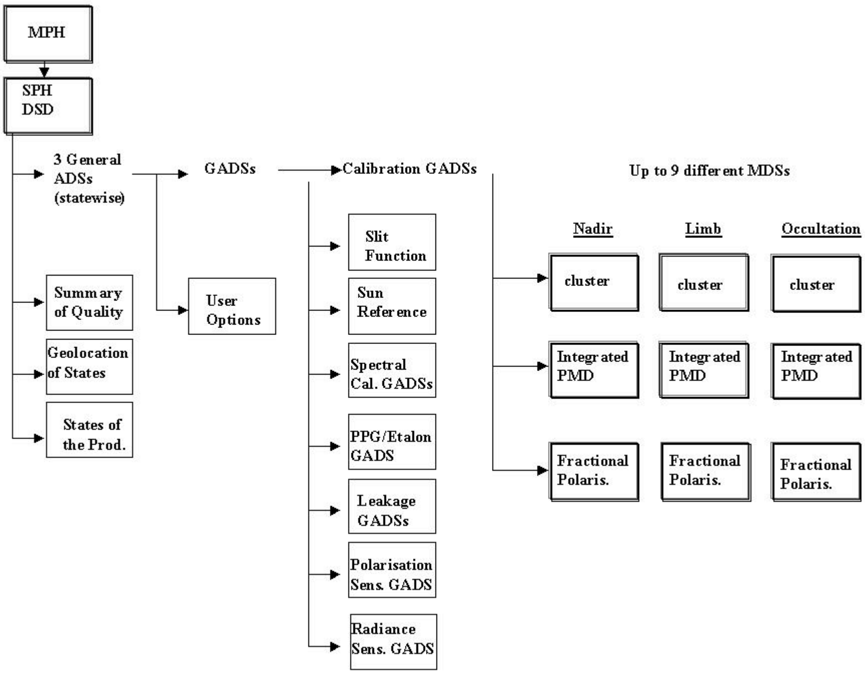

Figure C.1: The general product structure

1.1.1 The Cluster Data MDS

As mentioned before, there will be one MDS for each of the main scientific measurement categories, nadir, limb, occultation or monitoring. All MDS are organised in the same way. One record of these MDS will contain data of one cluster of one complete state data set. The individual cluster readouts (or observations) are put in chronological order. They are followed by the geolocation information for the specific observation, which is a structure of its own. Besides ground pixel co-ordinates, this structure also hosts solar zenith and azimuth angles and more.

Note: In the 1c product, the cluster geolocation is matched to the observation time grid, i.e. for each cluster observation, there is one geolocation.

1.1.2 The integrated PMD MDS

Integrated PMD data are, in difference to raw PMD data, synchronised with the science detectors. For that purpose they are linked to the shortest possible integration time in a science channel, which is 0.03125 seconds, this corresponds to 32 Hz. These integrated values are used e.g. in the virtual sum algorithm to determine the atmospheric degree of polarisation. Extraction of these values may therefore allow investigation of the quality of the polarisation correction, especially when comparing it to fractional polarisation values (see below).

Another application of integrated PMD data could be – if normalised to the PMD values of the sun mean reference GADS – some broadband albedo plots.

As opposed to the cluster MDS, the geolocation attached to these data sets, is not broken down to the 32 Hz of the integrated PMD data, but repeated with the shortest integration time in the state (to be taken from the states of the product ADS).

There will be one MDS record (MDSR) per state.

1.1.3 The fractional polarisation MDS

Fractional polarisation values are the atmospheric Stokes parameters itself, which are determined by level 0 to 1b processing for each individual integration time of a state. Values themselves are hidden in the level 1b defined “POLV” structure, which are copied in the corresponding MDS records. All fractional polarisation values, belonging to one integration time, are put in chronological order, starting with the longest integration time in the state.

Geolocation will be handled identically to the integrated PMD value MDS. There will be one MDSR per state.

1.2 Selectable Options

In this section all those items, which can be specified by the user, will be described. In general we can distinguish between extraction, calibration GADS, cluster and application filters.

1.2.1 Extraction filters

Extraction filters are meant to filter the geophysical content of the 1b input product. This can be done by either time, geolocation or measurement type respectively category.

Extraction Filter	**To be specified**
Time	Start and Stop Time for area of interest
Geolocation	Latitude and Longitude for top right/bottom left corner for area of interest. By choosing the right corner coordinates, extraction of data for zonal or meridional applications is possible.
Measurement Type	Selects a certain type of level 1b data sets, i.e. all data of the Nadir MDS.
Measurement Category	Selects a certain class of instrument states, e.g. all nadir states which are performed in pointing mode. This filter is handy to be combined with Time or Geolocation.

If a user does not know from the very beginning, which filters to use in order to reduce his 1b input set, he is advised to use EnviView in record view, displaying the “States of the product ADS” of the 1b product itself. This annotation data set contains all necessary information about the processed states in the current 1b product. Additionally, the Geolocation per State ADS may be analysed in the same way in order to define an orbital region of interest.

Code	Measurement Category	Function
1	Nadir	Scientific Measurement
2	Limb	Scientific Measurement
3	Nadir_pointing	Scientific Measurement
4	Solar Occultation, Scanning and Pointing at end of state	Scientific Measurement/Calibration
5	Solar Occultation, Pointing	Scientific Measurement/Calibration
6	Moon Occultation, Pointing	Scientific Measurement/Calibration
7	Moon Scanning	Scientific Measurement/Calibration
8	Sun over Diffuser, Neutral Density Filter out	Calibration
9	Sub Solar Calibration/Pointing	Calibration
10	Spectral Lamp Calibration	Calibration
11	White Lamp Calibration	Calibration
12	Dark current Calibration	Calibration
13	Nadir/Elevation Mirror Calibration, Pointing using the sun	Calibration
14	Nadir/Elevation Mirror Calibration, Scanning, using the moon	Calibration
15	ADC Calibration/ Scanner Maintenance	Calibration/Maintenance
16	Sun over Diffuser, Neutral Density Filter in	Calibration
17	Nadir Eclipse, pointing	Scientific Measurement
18	Nadir Eclipse, scanning	Scientific Measurement
19	White Lamp over Diffuser	Calibration/Monitoring

Table : Coding of Measurement Categories. Shaded fields – the scientific states - are those, which are currently supported by the extraction/application s/w.

1.2.2 Level 1b calibration GADS

Basically, all calibration relevant GADS can be copied from the 1b product into the 1c product. Table gives recommendations, which GADS to select for which applications.

1b GADS	**Content (Summary)**	**Recommendation/Comments**
Sun Mean Reference	Sun mean reference spectra 1 record per different ref. Spectrum Includes also PMD solar reference values	Mandatory for DOAS type trace gas retrieval
PPG/Etalon	PPG correction factor Etalon correction factor Dead/bad pixel mask	Mandatory for DOAS type trace gas retrieval
Slit Function (large Aperture)	Slit function to be applied for further processing of all nadir and limb and lunar occultation type measurements	Mandatory for DOAS type trace gas retrieval
Slit Function (small Aperture)	Slit function to be applied for further processing of all solar occultation measurements	Mandatory (but only) necessary in case of further processing of solar occultation measurements
Radiance Sensitivity Nadir		In case a certain calibration application has not been selected, it is always recommended to extract associated 1b GADS as references.
Radiance Sensitivity Limb – Aperture large, ND filter out		
Radiance Sensitivity Limb – Aperture small, ND filter in (for Occultation)		
Polarisation Sensitivity Nadir	Full spectrum of μ_2=(1-□/1+□) Full spectrum of μ_3=(1-□/1+□) For different elevation mirror positions	
Polarisation Sensitivity Limb Aperture large, ND filter out	Full spectrum of μ_2=(1-□/1+□) Full spectrum of μ_3=(1-□/1+□) For different elevation and azimuth scan mirror positions	
Polarisation Sensitivity Limb – Aperture small, ND filter in (for Occultation)	Full spectrum of μ_2=(1-□/1+□) Full spectrum of μ_3=(1-□/1+□) For different elevation and azimuth scan mirror positions, ND filter in.	
Wavelength Calibration I (polynomial parameters)		
Wavelength Calibration II (standard calibration)		
Leakage current (constant fraction)		
Leakage current (variable fraction)		

Table : The level 1b calibration GADS. *Details are given in EnviView product Formats.*

1.2.3 Clusters

The extraction/application S/W allows addressing of individual clusters. Clusters have to be addressed via their cluster identifiers, which are specified for nadir and limb (and occultation). In these tables, the identifier, its approximate wavelength range and its purpose are listed.

It is strongly recommended to take advantage of this filter, especially when thinking about further trace gas retrieval. Relevant information is obtained from relatively small spectral windows, anyway.

Start Pixel	**End Pixel**	**Approximate Wavelength [nm]**	**Purpose**
0	4	-	Blinded pixel
216	743	240.00 – 305.99	Virtual channel 1a
744	767	306.11 – 308.99	Virtual channel 1b
768	807	309.12 – 314.00	Overlap region
1019	1023	-	Blinded pixel
1024	1028	-	Blinded pixel
1119	1215	405.00 – 394.06	Overlap region
1215	1857	319.94 – 314.06	Virtual channel 2b
1858	1909	313.95 – 309.00	Virtual channel 2a
1910	1953	-	Overlap region
2043	2047	-	Blinded pixel
2048	2052	-	Blinded pixel
2094	2139	394.00 – 404.95	Overlap region
2140	2221	405.19 – 424.90	-
2222	2324	425.14 – 449.95	NO2
2325	2529	450.20 – 499.82	O3
2530	2735	500.07 – 549.94	-
2736	2776	550.18 – 559.91	Aerosol
2777	2957	560.16 – 603.94	-
2958	3023	604.19 – 620.00	Overlap region
3067	3071	-	Blinded pixel
3072	3076	-	Blinded pixel
3118	3192	604.00 – 619.99	Overlap region
3193	3349	620.21 – 653.93	-
3350	3395	654.14 – 663.87	Aerosol
3396	3816	664.08 – 754.86	-
3817	3932	755.07 – 779.93	Clouds
3933	3955	780.15 – 784.90	-
3956	4047	785.12 – 804.78	Overlap region

Start Pixel	End Pixel	Approximate Wavelength [nm]	Purpose
4091	4095	-	Blinded pixel
4096	4100		Blinded pixel
4150	4218	785.00 – 804.74	Overlap region
4219	4409	805.03 – 860.18	-
4410	4442	860.47 – 869.75	Aerosol
4443	4856	870.04 – 989.92	-
4857	4890	990.21 – 999.79	Aerosol
4891	4925	1000.08 – 1009.95	-
4926	5063	1010.24 – 1050.00	Overlap region
5115	5119	-	Blinded pixel
5120	5129	-	Blinded pixel
5177	5227	1009.66 – 1049.89	Overlap region
5228	5457	1050.70 – 1234.98	-
5458	5481	1235.78 – 1254.29	Aerosol
5482	5649	1255.10 – 1389.48	-
5650	5674	1390.29 – 1409.60	Water vapour
5675	5848	1410.41 – 1549.62	-
5849	5910	1550.43 – 1599.52	Water/Ice
5911	6034	1600.32 – 1699.30	Water/Ice
6035	6097	1700.11 – 1750.00	Water/Ice
6134	6143	-	Blinded pixel
6144	6153	-	Blinded pixel
6217	7093	1940.00 – 2040.00	-
7158	7167	-	Blinded pixel
7168	7177	-	Blinded pixel
7241	8118	2265.00 – 2380.00	
8182	8191	-	Blinded pixel

Table: Cluster definitions for Nadir measurements.

Start Pixel	End pixel	Approximate Wavelength [nm]	Purpose
0	4	-	Blinded pixel
5	14	-	Straylight
216	743	240.00 – 305.99	Virtual channel 1a
744	807	306.11 – 314.00	Virtual channel 1b
1009	1018	-	Straylight
1019	1023	-	Blinded pixel
1024	1028	-	Blinded pixel
1119	1857	405.00 – 320.05	Virtual channel 2b
1858	1953	319.94 – 309.00	Virtual channel 2a
2033	2042	-	Straylight
2043	2047	-	Blinded pixel
2048	2052	-	Blinded pixel
2094	3024	394.00 – 620.00	Channel 3
3067	3071	-	Blinded pixel
3072	3076	-	Blinded pixel
3118	4048	604.00 – 805.00	Channel 4
4091	4095	-	Blinded pixel
4096	4100	-	Blinded pixel
4150	5063	785.00 – 1050.00	Channel 5
5115	5119	-	Blinded pixel
5120	5129	-	Blinded pixel
5165	6097	1000.00 – 1750.00	Channel 6
6134	6143	-	Blinded pixel
6144	6153	-	Blinded pixel
6217	7093	1940.00 – 2040.00	Channel 7
7158	7167	-	Blinded pixel
7168	7177	-	Blinded pixel
7241	8091	2265.00 – 2380.00	Channel 8
8182	8191	-	Blinded pixel

Cluster Definitions for limb and occultation measurements.

NOTE:

1. It is not possible to select by wavelength, directly.

2. Cluster definitions are those in line with the sample products and may change in the future with respect to the number of defined cluster as well as their pixel and wavelength boundaries.

1.2.3 Applications

The different possible calibration applications are given below.

1. Memory Effect
2. Leakage Current
3. Pixel to Pixel Gain
4. Etalon
5. Straylight
6. Wavelength
7. Polarisation
8. Radiometric Calibration

Similar as for the extraction filters, the user shall have the choice between options like

1. No calibration applied – the data is just transferred into 1c format.
2. Partly calibration applied – basically all combinations are allowed. This mode is of special interest for processor verification (see below, user type 2 and 3).
3. Full calibration applied – yields geo-located, calibrated spectral radiance. This shall be the baseline for further trace gas retrieval.

Some important notes:

- Without wavelength calibration, neither polarisation nor radiance calibration can be applied – because they depend on the spectral calibration.
- Without applying polarisation correction, radiance calibration could still be applied, yielding a result in radiance units. But the absolute values do not reflect the instrument's true radiance response, which requires un-polarised respectively polarisation corrected input. On the other hand, assuming the polarisation correction to be smooth in wavelength, the impact on DOAS type retrieval might not be that dramatic.
- Polarisation correction cannot be applied to monitoring data, because the required fractional polarisation values are not calculated for the level 1b monitoring data sets.

1.3 Configuration examples

In the following, some typical configurations for the extraction/applications will be discussed. Three general classes of users can be identified.

User profile 1:

This user wants to do his own trace gas retrieval. The input he requires is geo-located spectral radiance, resulting from either nadir, limb or occultation measurements. requiring geo-located, spectrally calibrated radiance, belonging to either nadir, limb or occultation measurements. He may want to do his analysis over the full orbit, considering all measurements of one category, e.g. all nadir states. As he wants to do a retrieval for a specific trace gas, he only needs limited spectral information, i.e. he will probably specify only one or a few spectral clusters.

For his purpose he needs fully calibrated data. This means that he has to apply all calibrations. Associated level 1b GADS have not to be extracted. But he has to extract the Sun Mean Reference GADS, the PPG/Etalon GADS, containing the dead and bad pixel mask, and finally the Slit function GADS. This information he needs for further processing .

Integrated PMD data as well as fractional polarisation values are not necessarily needed for his retrieval and might therefore not be considered for extraction.

Following table shows the 1c configuration for a user who wants to do retrieval of ozone vertical columns from all nadir measurements in a 1b product.

Extraction	Cal. GADS	Cluster	Applications	MDS
Measurement Category Filter, category [1] or measurement type [1]	Sun mean Ref. Slit function PPG/Etalon	Nadir clusters [3],[4],[9],[16]	Full calibration	Nadir cluster MDS [yes] Integrated PMD [no] Fractional Pol. [no]

Table: Possible settings for further ozone column retrieval from nadir data

User profile 2:

This user wants to investigate the general quality of the level 1b product and its associated calibration GADS.

He most probably will restrict on data of one measurement (i.e. one state of either nadir, limb or occultation), selected via either time or geolocation of the measurement. The measurement he decides to take either corresponds to a certain atmospheric scenario he has references for. Another opportunity would be to take data with „known“ radiance targets like e.g. deserts.

In difference to user 1, he most probably will not narrow the spectral range. Calibrations he wants to apply step by step, starting from „no calibration“ applied to „full calibration“ , so that in the end he will derive different level 1c products from one and the same 1b input data, in order to estimate the different calibration impacts. In this case he might find it helpful to extract the 1b calibration GADS completely, in order to check their correct application.

For additional verification, he will not only investigate the science channels, but also the PMD channels – both, integrated values as well as atmospheric polarisation might be relevant.

No.	**Extraction**	**Cal. GADS**	**Cluster**	**Applications**	**MDS**
1	Measurement category [1] & Geolocation (matching e.g. Sahara desert)	All	All	none	cluster Int. PMD Fractional Pol
2				Memory effect only	
3				Memory effect & Leakage	
4				Memory effect, leakage & ppg	
5				Memory effect, leakage, pgg & etalon	
6				Memory effect, leakage, ppg/etalon & straylight	
7				Memory effect, leakage, ppg/etalon, straylight & wavelength	
8				Memory effect, leakage, ppg/etalon, straylight, wavelength & polarisation	
9				Full calibration	

Table : Step by Step verification of calibrations applied to identical nadir level 1b input.

In this example, a nadir state over the Sahara desert has been selected. By comparison of the various level 1c MDS the correctness of the different applications, especially the order of magnitude of the various corrections, can be investigated and verified. In case of full calibration, 1c MDS might be used for comparison with e.g. GOME radiance of the same geophysical target.

User profile 3:

This user wants to investigate the impact of the various calibrations on the quality of a trace gas retrieval. Motivation of this exercise might result from validation activities. E.g. he tries to validate a SCIAMACHY ozone vertical column against a ground based value. In case he finds systematic deviations between the two columns he has to find out step by step, what might have gone wrong with the Sciamachy product – presuming of course his validation reference being the „truth“.

Therefore his demands will be very similar to those of user type 2, except that he will most probably limit his investigations on a small spectral window, which is relevant for his trace gas retrieval.

Calibrations he wants to apply in different combinations, so that in the end he will derive different level 1c products from one and the same 1b input data. These will be the input for his further trace gas retrieval, where he can investigate the impact of different calibrations on the trace gas product quality.

No.	Extraction	Cal. GADS	Cluster	Applications	MDS
1	Measurement category [1] & Geolocation or time (matching a reference target)	Sun mean Ref. Slit function PPG/Etalon Remaining GADS are optional	Nadir clusters [3],[4],[9],[16]	Full	cluster Int. PMD (optional) Fractional Pol (optional)
2				Memory, Leakage, Wavelength, Radiance	
3				Memory, Leakage, Wavelength, Polarisation, Radiance	
4				Memory, Leakage, Straylight, Wavelength, Radiance	
5				Memory, Leakage, Straylight, Wavelength, Polarisation, Radiance	
6				Memory, Leakage, Straylight, PPG/Etalon, Wavelength, Radiance	
7				Memory, Leakage, PPG/Etalon, Wavelength, Radiance	
8				Memory, Leakage, PPG/Etalon, Wavelength, Polarisation, Radiance	

Table: Investigation of calibration impact on level 2 like products.

In this example, a nadir state matching a certain reference target, was selected by combination of the measurement category filter and geolocation/time filter. The different level 1c products, based on the same level 1b input data set, can now be used to systematically trace the impact of a certain calibrations on the trace gas retrieval.