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title

SCanning Imaging Absorption spectroMeter for Atmospheric ChartograpHY

Error budget for SCIAMACHY calibration

summary

This document describes the errors on the SCIAMACHY key data and data products that result from individual measurements errors. This third issue incorporates all error sources as discussed during the Final Result Review of the SCIAMACHY calibration held on March 5 1999 and numerous dedicated meetings thereafter. The method chosen to propagate individual errors on measurements to final errors on keydata and level 1 data products is the Monte Carlo approach.

The present error analysis is applicable to the situation during the OPTEC-5 measurements which resulted in the keydata issue 2. This keydata set is based on the (H/W) modified instrument w.r.t. straylight in channel 1 and on the calibration approach with correction for the straylight in channel 1 and the other channels. However, this error budget describes not the new Mueller matrix appraoch with the new Nadir keydata. The errors as calculated in this report are to be regarded as the errors as we would have experienced when the original TPD approach (i.e. not the Mueller matrix approach) is taken to come to the data products. As it is assumed that the alternative approach with correction for the polarization shift will yield better results, the reported errors can be regarded as “worst case” figures.

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CHANGE RECORD

issue	Date	total pages	authorisation	Pages affected	brief description of change
1	19/2/1999	41	T. Watts	All	
2	3/2/2000	50	T. Watts	All	1) new error propagation approach (Monte Carlo) 2) additional wavelengths 3) Comments from several meetings and discussions implemented
3	13/12/00				1) Straylight modification and correction taken into account 2) More wavelengths added (one in each channel)

TABLE OF CONTENTS

1. SCOPE

This document describes the errors on the individual calibration keydata parameters and the propagation of these errors in the final relative and absolute data products. The error discussion focusses mainly on the pre-launch calibration measurements. Errors that originate from changes , uncertainties and unforeseen characteristics of the instrument once in orbit (e.g. pointing accuracy, in-orbit operational temperature differing from the temperature during calibration, etc) are addressed but not accounted for in the final budget. For ease of reading a summary of the errors on the individual keyparameters and the data products is given in last section of this document.

2. Document List

2.1 Applicable Documents

AD01 SCIAMACHY PFM calibration key data TN-SCIA-0000TP/168

2.2 Reference Documents

RD01 SCIAMACHY PFM Calibration Implementation plan PL-SCIA-0000TP/110

3. Error sources

Table 3.1.1 Error sources and their impact on the SCIAMACHY calibration key data

Error source	**Effect**	**Possible impact on**	**Remark**
Ambient calibration			
Intensity fluctuations test beam	Noise, drift	All measurements	Largely eliminated by reference detector
S/N ratio	Noise	All measurements	Using Si detector typically less than 0.1%.
Wrong polarization component (imperfect polarizer, angular setting)	Erroneous reflectivity	All measurements where input beam is linearly polarized	
“Unpolarized” light has rest polarization	Erroneous reflectivity for applicable measurements	*anaunp, anauns, alaulp, alauls, ac_ucp, ac_ucs, al0ucp, al0ucs*	Rest polarization measured to be < 1%..
Polarization dependent intensity	Erroneous ratios		Largely eliminated by reference detector
Polarization dependence of main and reference detector	Erroneous compensation for beam intensity at different polarization states.	All measurements	However, due to the fact that we only use ratios this polarization dependence is eliminated for all measurements except for those used in the calculation of h_{limb}.
Absorption by water vapor	Decreased IR spectrum	All measurements	If water amount (column density) varies between measurements this yields erroneous ratios. The SCIAMACHY maesurements have been performed in a controlled environment having a more or less constant relative humidity
Extinction ratio analyzer (polarizer main detector)	Erroneous reflectivity	All measurements in which input beam is linearly polarized	Impact can be assessed from numerical simulation. Extinction ratio Glan-Thompson polarizer is less than $1x10^{-5}$
Setting accuracy analyzer	Erroneous reflectivity	All measurements where analyzer is used	

Error source	Effect	Possible impact on	Remark
Wavelength dependent transmission analyzer	Erroneous reflectivity	All measurements	Due to the fact that we only use ratios the effect of wavelength dependent transmission is eliminated.
Non-uniformity test beam	Erroneous reflectivity/ BRDF when mirrors/ diffu-ser are non-homogeneous	All measurements	Largest effects expected for measurements involving diffuser
Misalignment scan mirror axes/trolley axes	Erroneous angle dependence of the reflectivities		In combination with non-uniform test beams the varying beam area which is viewed while changing the angulare setting will cause erroneous angulare dependencies.
IFOV detector different from SCIAMACHY IFOV	Erroneous reflectivity/ BRDF when mirrors/ diffuser are non-homogeneous	All measurements	Largest effects expected for measurements involving diffuser
Monochromator wavelength	Wavelength shift	All measurements	Significant impact only when wavelength dependence is high and wavelength error is large. This is not expected
Limited number of wavelengths and angles	Interpolation errors	All measurements	Expected to be less than 0.5-1%.
Monochromator bandwidth	Smearing out of wavelength dependence	All measurements	Significant impact only in regions where wavelength dependence has strong second order derivative.
Monochromator out of band stray light	Erroneous reflectivity/ BRDF	All measurements	
Errors in angles	Erroneous reflectivity/ BRDF	All measurements	Erroneous correction OPTEC measurements for scan angle dependence.
Temperature dependence main / reference detector	Erroneous correction for varying beam intensity	All measurements when temperature varies and both detectors have a different temperature dependence	Measurements performed in temperature-stabilized clean room
Responsivity main vs reference detectors		All measurements	Due to the fact that we only use ratios the effect of different responsivities is eliminated.

Error source	**Effect**	**Possible impact on**	**Remark**
OPTEC calibration			
Intensity fluctuations test beam	Noise, drift	*wn0snd, wn0pnd mn0pnd, mn0pnq, mn0pnx*	The measurements *wn0snd* and *wn0pnd* will be corrected using the reference monitor. The measurements employing the monochromator do not have to be corrected using the reference monitor, since ratios are taken of SCIA detector signals which are obtained simultaneously.
S/N ratio	Noise	All measurements	May be assessed from SRON instrument model with input concerning radiance levels measured during stimuli commissioning
Wrong polarization component (imperfect polarizer, angular setting)	Erroneous signals for polarization dependent detectors channels (all)	*wn0snd, wn0pnd mn0pnd, mn0pnq, mn0pnx, mn0snd, mn04nd*	For a discussion of the resulting errors see below.
“Unpolarized” light has rest polarization			No measurements are performed using an unpolarized beam from the White Light Source with or without the monochromator.
Polarization dependent intensity	Erroneous ratio *wn0snd/wn0pnd*	*tmp* and h_{nadir} one to one. The key data h_{limb}, z, w, k, x_{limb}, s, y, and t are indirectly affected (by *tmp*).	Since only the measurements employing the White Light Source without monochromator are affected the error can be decreased by using the reference detector signals. However, remaining error due to polarization dependence of reference detector.
Polarization dependence of reference detector	Erroneous compensation for varying beam intensity between S and P polarization	*wn0snd* and *wn0pnd* and all related key data given above	See previous point.
Absorption by water vapor	Decreased IR spectrum	*wn0snd*/*wn0pnd rn0und, rl0uld, il0ucd*	If water amount (column density) would vary between measurement *wn0snd* and *wn0pnd*

Error source	Effect	Possible impact on	Remark
			this would yield erroneous *tmp* and h_{nadir}. However, stimuli will be flushed with dry N_2. All measurements in which absolute light sources are employed (*rn0und, rl0uld, il0ucd*) are strongly affected. Provision for keeping water vapor out of the light path is essential.
Non-uniformity test beam	Erroneous key data when SCIA response depends on fill factor aperture/ FOV		In principle all measurements *wn0snd, wn0pnd, mn0pnd, mn0pnq, mn0pnx, mn0snd, mn04nd* as well as the wavelength calibration may be affected.
Monochromator wavelength			Only ratios of SCIA detector signals are obtained. SCIA itself acts as the wavelength meter.
Monochromator bandwidth			
Monochromator stray light		Spectral stray light measurements	
Irradiance error FEL lamp	Absolute errors	*rn0und, rl0uld, il0ucd*	This error is documented in the NIST calibration handbook
Wrong distance between lamp and Spectralon diffuser	Absolute errors	*rn0und, rl0uld*	An error of 1 mm yields a 0.4% error.
BRDF of Spectralon diffuser	Absolute errors	*rn0und, rl0uld*	The absolute accuracy is estimated to be better than 1% for the visible and NIR
Spectralon diffuser at wrong angle to ILOS	Absolute errors	*rn0und, rl0uld*	Since the BRDF of Spectralon only shows a minor scatter angle dependence for normal incidence (~0.3%/°) impact of this error is small.
Beam reflected off 50 cm spherical mirror not perfectly collimated	Absolute error	*il0ucd*	Due to the fact that the lamp filament is not a point source, the beam cannot be perfectly collimated. As a result the irradiance will vary with distance to the mirror.
Reflectivity spherical mirror Calibrated Irradiance Source.	Absolute error	*il0ucd*	This reflectivity has been measured by CZ. Accuracy ±0.5% (RP-SCIA-011-CZ/96, ADP Calibrated Rad./Irr. Source)

Error source	**Effect**	**Possible impact on**	**Remark**
Absorption Suprasil windows	Absolute errors	*rn0und, rl0uld, il0ucd*	Reflection of one surface measured by CZ. Bulk absorption is measured by TPD
<u>SCIAMACHY</u>			
Scan mirror angle accuracy			
Temperature dependence OBM			All measurements (including wavelength calibration) are probably affected.
Temperature dependence detectors			All measurements (including wavelength calibration) are probably affected
Temperature/humidity dependence dichroic filters			All measurements are probably affected.
Temperature/humidity dependence additional optics			
Etalon effect			On-board white light source can be used to monitor etalon effect.

4. Error propagation

For nadir and limb keydata as well for 'end results', unpolarized sun normalized, polarized sun normalized, unpolarized sun absolute and polarized sun absolute, are calculated together with their errors. The calculations are based on the equations 3.1.3, 3.1.4, 3.1.24, 3.1.25 of PL-SCIA-0000TP/110. The equations for the 'end results' are given in table 1.

Table 1) equations for the end results

Type	Nadir	Limb
Unpolarized sun normalized	$\frac{tmp\ ac\_ucs + ac\_ucp}{tmp\ anuns + anaunp}$	$\frac{tmp\ ac\_ucs + ac\_ucp}{tmp\ aluls + alaulp}$
Polarized sun normalized	$c_{\text{nadir}} \frac{tmp\ ac\_ucs + ac\_ucp}{tmp\ anuns + anaunp}$	$c_{\text{limb}} \frac{tmp\ ac\_ucs + ac\_ucp}{tmp\ aluls + alaulp}$
Unpolarized sun absolute	$\frac{1}{RN0UND} D_{ext} e_{cal} \frac{tmpan0uns + ac0unp}{tmpanuns + anaunp}$	$\frac{1}{RL0ULD} D_{ext} e_{cal} \frac{tmpan0uls + ac0ulp}{tmpaluls + alaulp}$
Polarized sun normalized	$c_{\text{nadir}} \frac{1}{RN0UND} D_{ext} e_{cal} \frac{tmpan0uns + ac0unp}{tmpanuns + anaunp}$	$\frac{1}{RL0ULD} c_{\text{limb}} D_{ext} e_{cal} \frac{tmpan0uls + ac0ulp}{tmpaluls + alaulp}$

4.1 The method

The quantities are obtained by means of the method of Monte Carlo simulation.
Input of the simulations are expected values of the parameters al0ulp etc and the error sources
It is assumed that all error sources are normal distributed with known variance. The square root of the variance is called the standard deviation σ_i. Two type of error sources are distinguished, random errors and systematic errors. Perhaps it is better to speak about independent and dependent (correlated) errors. In chapter 5 it is discussed which error sources are random or systematic. The errors are expressed as percentiles of the parameters.
Random errors (independent errors)
The numeric values for the errors that are given in chapter 5 are the standard deviations of the normal distributions. The various random errors are for each parameter combined in 1 new random error with a standard deviation $s_t = \sum o_i^2$.
Systematic errors (dependent/correlated errors)
The sign of the numeric value of the error indicate the type of correlation between the error source and the parameters. The absolute value of the error is equal to the standard deviation of the normal distribution.
The following Monte Carlo simulations are performed.
Random errors
For each *parameter* a random number is generated from the standard normal distribution and next multiplied with the standard deviation. So there is one random error contribution for each parameter.
Systematic errors
For each *error source* a random number is generated from the standard normal distribution. This value is multiplied with the different standard deviations (inclusive the sign) of the different parameters. Next all the systematic sources are combined with each other, by adding them, into one systematic error contribution for each parameter.

Next the expected values of the parameters are combined with their random and systematic error contributions. These values are used to calculate the key data and the end results. This procedure is repeated 10 000 times resulting in 10 000 possible values for the parameters, the key data and end results. Next the mean values and the relative standard errors are calculated. These relative standard errors *100% are the errors of the error budget.

The nadir case

In order to calculate cnadir it is necessary to estimate p by solving equation 3.1.9. However the left side (ena_nq/ena_nd) of this equation is unknown. It was decided that to make use of a calculated value for ena_nq/ena_nd which is obtained by substituting p=.5 in 3.1.9. This fixed value is then used in to solve p for each simulation combination of $\eta$and ξ.

The limb case

In order to calculate climb it is necessary to estimate p and q. this can be achieved by solving equations 3.1.13 and 3.1.14 simultaneous. However the left sides (ela_nq/ela_nd) and (ela_lx/ela_ld) of these equation are unknown. It was decided to make use of calculated values for (ela_nq/ela_nd) and (ela_lx/ela_ld) which are obtained by substituting p=.5 and q=.5 in 3.1.13 an 3.1.14. These fixed values are then used to solve p and q for each simulation combination of $\eta$and ξ.

5. Discussion of error sources - Scan mirror and on-board diffuser calibration

5.1 Noise

All random errors were deduced statistically by using the 1 σ value for the average value deduced from the set of individual measurements per data point. The random error includes:

- detector and ammeter noise for measurement, dark current and reference signal during radiance and irradiance measurements.
- lamp and detector noise during the time where signal and reference detector are not synchronized.

For the measurements performed this error amounts to 0.1% in each measurement (no correlation between measurements). The number of averages (individual measurements) were chosen such that for all wavelengths this accuracy was reached.

Error type: Random

Wavelength	1σ value of error
240nm	0.1%
310nm (ch1)	0.1%
310nm (ch2)	0.1%
350nm	0.1%
500nm	0.1%
700nm	0.1%
850nm	0.1%
2350nm	0.1%

Reference of errorsource: ARCF logbook

5.2 Drift/Linearity

Systematic error due to non-linearity of the detector and the ammeter. No Keithley calibration data are available for the non linearity of the Keithley picoam-meter. Own calibration measurements indicated that this linearity is better than : 0.1 % for the silicon detectors. The linearity of the PbS detectors can be expected to be worse, typically 1%.
Drift will influence the measurement since S_m an $S_{100\%}$ are measured with considerable time differences. Only drift differences between the measuring and reference detector will influence the calibration. Ammeter drift is smaller than 0.05 % per degree Centigrade. The difference in drift between the two ammeters is expected to be insignificant.

Error type: Systematic

Wavelength	1σ value of error
240nm	0.1%
310nm (ch1)	0.1%
310nm (ch2)	0.1%
350nm	0.1%
500nm	0.1%
700nm	0.1%
850nm	0.1%
2350nm	1%

Reference of error source: Detector commissioning

5.3 Wrong polarisation component

An important contribution to the error budget of polarisation parameters originates from imperfect polarisers or polariser settings. I.e., a “wrong” polarisation component is transmitted which may be due to the fact that the polariser has a non-zero extinction ratio (i.e., p = dp_0, 1-dp_0 instead of p = 0, 1 for S, P polarised light respectively) or a rotational misalignment of the polariser (i.e., not 0° and 90°, but df and $\pi/2 + df$, respectively).
Commissioning measurements on the TPD Brewster polariser yielded $dp_0 < 0.6\%$. An angular offset of the polariser of angle df yields $dp = \sin^2 df$ » df^2, i.e, $df = 1°$ yields $dp = 0.03\%$. The total component wrong polarised light is therefore < 0.63%

The scan mirror and diffuser measurements consisted of different measurements, each with a certain polariser, analyser setting. The error due to the wrong polarisation component has therefore a different impact on the different measurements.

On the measurements anaunp, anauns, alauls, alaulp, ac_ucp, ac_ucs, al0ucs, al0ucp this error has no impact since unpolarised light was used.

For the two polarizer measurements the wrong polarisation of the beam results in the effect that the measurement of e.g. alasls contains a small portion ε of alapls. This introduces a relative error of ε x alapls/alasls on the alasls measurement.

A model od the set-up was implemented to derive the errors due to the wrong polarization component on the diferent measurements.

Error type: systematic

Model input:

SCIAMACHY CALIBRATION ERROR ANALYSIS; AMBIENT MEASUREMENTS

MODEL PARAMETERS Wpol / 12-10-1999

OPTICAL INPUT

residual polarization: Psrc = 0

BREWSTER

rotation error (deg): Rbwe = 1

s/p ratio (<1): Lbw = .006

GLAN-THOMSON

rotation error (deg): Rgte = 0

s/p ratio (<1): Lgt = 0

BEAMSPLITTER

tilt angle (deg): Tbs = 8

MAIN DETECTOR

main detector s/p ratio (<1): Mdsp = 1

main detector rotation (deg): Rmd = 0

REFERENCE DETECTOR

reference detector s/p ratio (<1): Rdsp = 1

reference detector rotation (deg): Rrd = 0

SCANNER ANGLES

azimuth pointing angle (deg, nadir mode: >90)): Alph = 0

nadir pointing angle (deg): Betan = 0

elevation pointing angle (deg): Betae = 25.4

WRONG POLARIZATION COMPONENT

BREWSTER LEAKAGE: 0.6%; BREWSTER ROTATION ERROR: 1ø

Mideal/Merror: IRRADIANCE CORRECTED MEAS.MNT RESULTS WITHOUT/WITH SET-UP ERRORS

RELATIVE ERRORS IN PERCENT: 100 x (Merror-Mideal)/Mideal

	240 nm	*310 nm*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2,350 nm*
anaunp	0	0	0	0	0	0	0
anauns	0	0	0	0	0	0	0
anopnp	0	0	0	0	0	0	0
anopnx	-6.177	-6.345	-6.399	-6.495	-6.509	-6.514	-6.623
alauls	0	0	0	0	0	0	0
alaulp	0	0	0	0	0	0	0
alasls	0.269	0.179	0.15	0.1	0.099	0.097	0.023
alaplp	0.185	0.092	0.064	0.007	-0.036	-0.045	-0.014
alaslp	7.478	15.02	20.043	43.612	74.277	88.009	518.259
alapls	6.337	13.15	17.732	38.838	63.381	74.606	494.877
alamls	0.597	0.4	0.332	0.203	0.172	0.163	0.038
alamlp	0.597	0.4	0.332	0.203	0.172	0.163	0.038
ala4ls	0.252	0.197	0.178	0.154	0.199	0.206	0.051
ala4lp	0.538	0.322	0.248	0.098	0.009	-0.011	-0.011
ala4lx	-0.093	-0.04	-0.024	0.01	0.042	0.048	0.014

alaslx	0.166	0.12	0.104	0.081	0.095	0.097	0.024
alaplx	-0.551	-0.311	-0.231	-0.065	0.053	0.078	0.028
aloucp	0	0	0	0	0	0	0
aloucs	0	0	0	0	0	0	0

5.4 Residual polarisation of "non-polarised" beam

The monochromator used for the present measurements has a typical residual polarisation of 1%. This results in the effect that the measurement of e.g. alauls contains a small portion γ of alasls. This introduces a relative error of γx alauls/alasls on the alauls measurement. The portion γ is the residual polarisation (1%). The following graphs show the impact of the rest polarisation component on the different measurements.

Model input:

SCIAMACHY CALIBRATION ERROR ANALYSIS; AMBIENT MEASUREMENTS

MODEL PARAMETERS Respol / 12-10-1999

OPTICAL INPUT

residual polarization: Psrc = .01

BREWSTER

rotation error (deg): Rbwe = 0

s/p ratio (<1): Lbw = 0

GLAN-THOMSON

rotation error (deg): Rgte = 0

s/p ratio (<1): Lgt = 0

BEAMSPLITTER

tilt angle (deg): Tbs = 8

MAIN DETECTOR

main detector s/p ratio (<1): Mdsp = 1

main detector rotation (deg): Rmd = 0

REFERENCE DETECTOR

reference detector s/p ratio (<1): Rdsp = 1

reference detector rotation (deg): Rrd = 0

SCANNER ANGLES

azimuth pointing angle (deg, nadir mode: >90)): Alph = 0

nadir pointing angle (deg): Betan = 0

elevation pointing angle (deg): Betae = 25.4

RESIDUAL POLARIZATION

DEGREE OF POLARIZATION OF SOURCE: 1%

Mideal/Merror: IRRADIANCE CORRECTED MEAS.MNT RESULTS WITHOUT/WITH SET-UP ERRORS

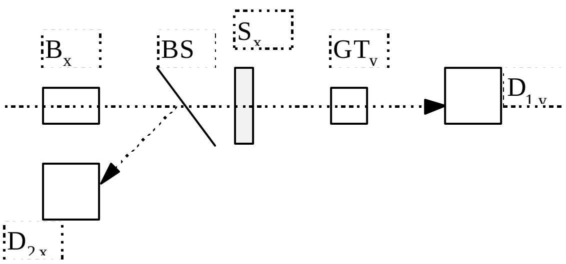
RELATIVE ERRORS IN PERCENT: 100 x (Merror-Mideal)/Mideal

Error type: Systematic

	240 nm	*310 nm*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2,350 nm*
Anaunp	0	0	0	0	0	0	0
Anauns	0	0	0	0	0	0	0
Anopnp	0	0	0	0	0	0	0
Anopnx	0	0	0	0	0	0	0
Alauls	0.108	0.067	0.053	0.027	0.017	0.014	0.002
Alaulp	-0.111	-0.068	-0.054	-0.028	-0.017	-0.015	-0.002
Alasls	0	0	0	0	0	0	0
Alaplp	0	0	0	0	0	0	0
Alaslp	0	0	0	0	0	0	0
Alapls	0	0	0	0	0	0	0
Alamls	0	0	0	0	0	0	0
Alamlp	0	0	0	0	0	0	0
ala4ls	0	0	0	0	0	0	0
ala4lp	0	0	0	0	0	0	0
ala4lx	0	0	0	0	0	0	0
Alaslx	0	0	0	0	0	0	0
Alaplx	0	0	0	0	0	0	0
Aloucp	-0.111	-0.068	-0.054	-0.028	-0.017	-0.015	-0.002
Aloucs	0.108	0.067	0.053	0.027	0.017	0.014	0.002

5.5 Polarisation dependence of main and reference detectors

a typical mirror measurement consists of a reflectance/radiance (sample in test beam) and irradiance (no sample in beam) measurement. The ratio of these two is the mirror reflectivity or diffuser BRDF. One such a measurement consists of the simultaneous measurement of a main detector and a reference detector.



B= Brewster polarizer (x denotes polarisation)

BS_T = Beam splitter (Quartz plate under 8° angle) in transmission. BS_R similar reflectance.

S = Sample (either mirror or diffuser)

GT = Glan Thomson analyser (y denotes polarisation)

D1 = main detector

D2 = reference detector

Model input:

SCIAMACHY CALIBRATION ERROR ANALYSIS; AMBIENT MEASUREMENTS

MODEL PARAMETERS Detpol / 12-10-1999

OPTICAL INPUT

residual polarization: Psrc = 0

BREWSTER

rotation error (deg): Rbwe = 0

s/p ratio (<1): Lbw = 0

GLAN-THOMSON

rotation error (deg): Rgte = 0

s/p ratio (<1): Lgt = 0

BEAMSPLITTER

tilt angle (deg): Tbs = 8

MAIN DETECTOR

main detector s/p ratio (<1): Mdsp = .957

main detector rotation (deg): Rmd = 0

REFERENCE DETECTOR

reference detector s/p ratio (<1): Rdsp = .957

reference detector rotation (deg): Rrd = 0

SCANNER ANGLES

azimuth pointing angle (deg, nadir mode: >90)): Alph = 0

nadir pointing angle (deg): Betan = 0

elevation pointing angle (deg): Betae = 25.4

DETECTORS POLARIZATION

S/P POLARIZATION RATIO: 0.957

Mideal/Merror: IRRADIANCE CORRECTED MEAS.MNT RESULTS WITHOUT/WITH SET-UP ERRORS

RELATIVE ERRORS IN PERCENT: 100 x (Merror-Mideal)/Mideal

Error type: systematic

	240 nm	*310 nm*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2,350 nm*
Anaunp	0	0	0	0	0	0	0
Anauns	0	0	0	0	0	0	0
Anopnp	0	0	0	0	0	0	0
Anopnx	0	0	0	0	0	0	0
Alauls	0	0	0	0	0	0	0
Alaulp	0	0	0	0	0	0	0
Alasls	0	0	0	0	0	0	0
Alaplp	0	0	0	0	0	0	0
Alaslp	4.493	4.493	4.493	4.493	4.493	4.493	4.493
Alapls	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3	-4.3

Alamls	0	0	0	0	0	0	0
Alamlp	0	0	0	0	0	0	0
ala4ls	0	0	0	0	0	0	0
ala4lp	0	0	0	0	0	0	0
ala4lx	0	0	0	0	0	0	0
Alaslx	0	0	0	0	0	0	0
Alaplx	0	0	0	0	0	0	0
Aloucp	0	0	0	0	0	0	0
Aloucs	0	0	0	0	0	0	0

5.6 extinction ratio analyser >0

The detector that is used for the present measurements is equipped with a Glan-Thompson analyzer to select the polarisation of the detected light. The extinction ratio of the used Glan-Thompson analyzer is excellent ($<1x10^{-5}$). Compared to the error of the wrong angular setting this error is negligible (see section 4.7).

Model input:

SCIAMACHY CALIBRATION ERROR ANALYSIS; AMBIENT MEASUREMENTS

MODEL PARAMETERS Anext / 12-10-1999

OPTICAL INPUT

residual polarization: Psrc = 0

BREWSTER

rotation error (deg): Rbwe = 0

s/p ratio (<1): Lbw = 0

GLAN-THOMSON

rotation error (deg): Rgte = 0

s/p ratio (<1): Lgt = .00001

BEAMSPLITTER

tilt angle (deg): Tbs = 8

MAIN DETECTOR

main detector s/p ratio (<1): Mdsp = 1

main detector rotation (deg): Rmd = 0

REFERENCE DETECTOR

reference detector s/p ratio (<1): Rdsp = 1

reference detector rotation (deg): Rrd = 0

SCANNER ANGLES

azimuth pointing angle (deg, nadir mode: >90)): Alph = 0

nadir pointing angle (deg): Betan = 0

elevation pointing angle (deg): Betae = 25.4

ANALYZER SPURIOUS TRANSMISSION

EXTINCTION RATIO: 0.00001

Mideal/Merror: IRRADIANCE CORRECTED MEAS.MNT RESULTS WITHOUT/WITH SET-UP ERRORS

RELATIVE ERRORS IN PERCENT: 100 x (Merror-Mideal)/Mideal

Error type: systematic

	240 nm	*310 nm*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2,350 nm*
Anaunp	0	0	0	0	0	0	0
Anauns	0	0	0	0	0	0	0
Anopnp	0	0	0	0	0	0	0
Anopnx	0	0	0	0	0	0	0
Alauls	0	0	0	0	0	0	0
Alaulp	0	0	0	0	0	0	0
Alasls	0	0	0	0	0	0	0
Alaplp	0	0	0	0	0	0	0
Alaslp	0.018	0.029	0.037	0.074	0.12	0.141	0.822
Alapls	0.017	0.028	0.036	0.07	0.112	0.131	0.808
Alamls	0	0	0	0	0	0	0
Alamlp	0	0	0	0	0	0	0
ala4ls	0	0	0	0	0	0	0
ala4lp	0	0	0	0	0	0	0
ala4lx	0	0	0	0	0	0	0
Alaslx	0	0	0	0	0	0	0
Alaplx	0	0	0	0	0	0	0
Aloucp	0	0	0	0	0	0	0
Aloucs	0	0	0	0	0	0	0

5.7 setting accuracy of analyser

We estimate that the wrong polarization component is of the order of 0.03% ($df = 1°$, see above). Furthermore, we assume that the wrong polarization component is constant throughout all measurements.

Model input:

SCIAMACHY CALIBRATION ERROR ANALYSIS; AMBIENT MEASUREMENTS

MODEL PARAMETERS Anset / 12-10-1999

OPTICAL INPUT

residual polarization: Psrc = 0

BREWSTER

rotation error (deg): Rbwe = 0

s/p ratio (<1): Lbw = 0

GLAN-THOMSON

rotation error (deg): Rgte = 1

s/p ratio (<1): Lgt = 0

BEAMSPLITTER

tilt angle (deg): Tbs = 8

MAIN DETECTOR

main detector s/p ratio (<1): Mdsp = 1

main detector rotation (deg): Rmd = 0

REFERENCE DETECTOR

reference detector s/p ratio (<1): Rdsp = 1

reference detector rotation (deg): Rrd = 0

SCANNER ANGLES

azimuth pointing angle (deg, nadir mode: >90)): Alph = 0

nadir pointing angle (deg): Betan = 0

elevation pointing angle (deg): Betae = 25.4

ANALYZER ROTATION SETTING

ANGULAR ERROR: 1ø

Mideal/Merror: IRRADIANCE CORRECTED MEAS.MNT RESULTS WITHOUT/WITH SET-UP ERRORS

RELATIVE ERRORS IN PERCENT: 100 x (Merror-Mideal)/Mideal

Error type: systematic

	240 nm	*310 nm*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2,350 nm*
Anaunp	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.001
Anauns	0.002	0.002	0.002	0.002	0.003	0.003	0.001
Anopnp	0	0	0	0	0	0	0
Anopnx	0	0	0	0	0	0	0
Alauls	0.086	0.087	0.085	0.09	0.13	0.137	0.037
Alaulp	-0.09	-0.091	-0.089	-0.094	-0.139	-0.147	-0.037
Alasls	0.206	0.142	0.121	0.085	0.091	0.09	0.022
Alaplp	0.118	0.053	0.033	-0.008	-0.046	-0.054	-0.015
Alaslp	-3.091	-3.267	-3.346	-4.015	-7.186	-8.422	6.919
Alapls	-1.483	-0.629	-0.089	2.742	8.591	11.039	37.044
Alamls	-0.624	-0.425	-0.355	-0.225	-0.2	-0.192	-0.046
Alamlp	-0.624	-0.425	-0.355	-0.225	-0.2	-0.192	-0.046
ala4ls	0.013	0.042	0.049	0.069	0.115	0.123	0.032
ala4lp	-0.531	-0.31	-0.235	-0.081	0.019	0.041	0.018
ala4lx	-0.152	-0.075	-0.052	-0.004	0.033	0.041	0.013
Alaslx	0.02	0.049	0.056	0.077	0.127	0.135	0.035
Alaplx	0.591	0.34	0.256	0.084	-0.03	-0.056	-0.023

Aloucp	-0.09	-0.091	-0.089	-0.094	-0.139	-0.147	-0.037
Aloucs	0.086	0.087	0.085	0.09	0.13	0.137	0.037

5.8 Absorbtion by water vapour

The water absorption bands may introduce an error in two ways. Firstly the measured signal may drop due to the absorption causing a deteriorated S/N. Secondly if the water content in the measurement set-up changes in between the reflected (or scattered) light measurement and the irradiance measurement changes, the difference in absorption may result in absorption features in the mirror or diffuser characteristics. Note however that the test environment was well controlled with a constant relative air humidity. Moreover, the discrete data points are chosen such that the main water absorption bands are avoided. Therefore this error is estimated to be negligible.

Error type: Random

Wavelength	1σ value of error
240nm	0%
310nm (ch1)	0%
310nm (ch2)	0%
350nm	0%
500nm	0%
700nm	0%
850nm	0%
2350nm	0%

Reference of error source: ARCF commissioning log

5.9 Non-uniformity of test beam

The non uniformity of the test beam introduces an error in the measured reflectance/BRDF when the part of the beam that is measured in the irradiance measurement differs from the part of the beam that contributes to the reflectance / BRDF signal.

Wavelength	1σ value of error
240nm	0.5%
310nm (ch1)	0.5%
310nm (ch2)	0.5%
350nm	0.5%

500nm	0.5%
700nm	0.5%
850nm	0.5%
2350nm	0.5%

5.10 Misalignment of scan-mirror axes and trolley axes

anaunp, anauns
The maximum change occurs when going from ESM angle -29° to -61° around 820 nm. There the change is of the order of 0.5% per degree ESM scan angle change. For an angle accuracy of 0.2° the contribution to the error budget is 0.1%. In other wavelength regions the errors is <0.05%.

Error type: Random

wavelength	1σ value of error
240nm	0.05%
310nm (ch1)	0.05%
310nm (ch2)	0.05%
350nm	0.05%
500nm	0.05%
700nm	0.05%
850nm	0.2%
2350nm	0.05%

5.11 Monochromator wavelength setting

The monochromator wavelength setting was found to be < 2nm during commissioning. Due to anomalies during the measurements the actual wavelength setting was found to be worse and therefore the error is estimated to be larger.

Refrence of error source: ARCF commissioning log, ARCF measurements log.

Error type: Random

wavelength	1σ value of error
240nm	0.5%
310nm (ch1)	0.5%
310nm (ch2)	0.5%
350nm	0.5%
500nm	0.5%
700nm	0.5%
850nm	0.5%
2350nm	0.5%

5.12 Wavelength interpolation error

The wavelength interpolation error is dependent on the change per wavelength observed in the individual measurements. This change is largest around the aluminum dip (820nm) Typically the change per wavelength is <0.01%/nm for wavelengths <600nm, <0.1%/nm 600<λ<1100nm, and <0.01%/nm >1100nm. The interpolation error is assumed to be an order of magnitude better then the change per nm.

Error type: Random

Reference of error source: ARCF measurement log

Wavelength	1σ value of error
240nm	0.001%
310nm (ch1)	0.001%
310nm (ch2)	0.001%
350nm	0.001%
500nm	0.001%
700nm	0.001%
850nm	0.01%
2350nm	0.001%

5.13 Angle interpolation error

The angle interpolation error is dependent on the change per degree observed in the individual measurements. This change is largest around the aluminum dip (820nm) Typically the change per degree is <0.01%/deg for wavelengths <600nm, <0.1%/deg 600<λ<1100nm, and <0.01%/deg >1100nm. The interpolation error is assumed to be an order of magnitude better then the change per degree.

Error type: Random

wavelength	1σ value of error
240nm	0.001%
310nm (ch1)	0.001%
310nm (ch2)	0.001%
350nm	0.001%
500nm	0.001%
700nm	0.001%
850nm	0.01%
2350nm	0.001%

5.14 non-zero monochromator bandwidth

This error will contribute mainly in the wavelength regions where the wavelength dependence differs from a straight line, e.g. around 820nm where the error is estimated to be 0.2%. At other wavelengths this error is estimated to be <0.05%

Error type: Random

wavelength	1σ value of error
240nm	0.05%
310nm (ch1)	0.05%
310nm (ch2)	0.05%
350nm	0.05%
500nm	0.05%
700nm	0.05%
850nm	0.2%
2350nm	0.05%

5.15 Monochromator out of band straylight

This error is negligible based on the commissioning measurements.

Error type: Random

wavelength	1σ value of error
240nm	0
310nm (ch1)	0
310nm (ch2)	0
350nm	0
500nm	0
700nm	0
850nm	0
2350nm	0

5.16 wrong angles scan mirrors and diffuser

The angles of the scanmirror units are set with an accuracy/reproducibility after initial alignment (see 5.10) of better then 0.01deg, resulting in a negligible error.

Error type: Random

Wavelength	1σ value of error
240nm	0
310nm (ch1)	0
310nm (ch2)	0
350nm	0
500nm	0
700nm	0
850nm	0
2350nm	0

5.17 temperature dependence main and reference detector

The two detectors are made of the same material and are operated in a temperature controlled room. Since the ratio of the two detecors is always used in the calculations only differences in behaviour are relevant. Therefore the error is estimated to be negligible.

Error type: Random

wavelength	1σ value of error
240nm	0
310nm (ch1)	0
310nm (ch2)	0
350nm	0
500nm	0
700nm	0
850nm	0
2350nm	0

5.18 air to vacuum effect mirrors

The air to vacuum effect on mirrors has not been measured during calibration. Some references in literature claim to have observed something but always very close to the measurement accuracy, and mainly in the UV. This error budget will not ignore the possibility of this effect. As a rough estimate a 0.5% error is assumed in the UV (<310nm) and 0.1% error is assumed for other wavelengths.

Error type: systematic

Wavelength	1σ value of error
240nm	0.5%
310nm (ch1)	0.5%
310nm (ch2)	0.5%
350nm	0.1%
500nm	0.1%
700nm	0.1%

850nm	0.1%
2350nm	0.1%

5.19 air to vacuum effect on-board diffuser

The air to vacuum effect on diffusers has not been measured during calibration. Some references in literature claim to have observed something but always very close to the measurement accuracy, and mainly in the UV. This error budget will not ignore the possibility of this effect. As a rough estimate a 0.5% error is assumed in the UV (<310nm) and 0.1% error is assumed for other wavelengths.

Error type: systematic

Wavelength	1σ value of error
240nm	0.5%
310nm (ch1)	0.5%
310nm (ch2)	0.5%
350nm	0.1%
500nm	0.1%
700nm	0.1%
850nm	0.1%
2350nm	0.1%

5.20 stray light

The error resulting from stray light scattered off the surroundings of the sample is estimated to be less than 0.1%. Stray light generated inside the detectors (e.g., due to reflection off the detector surface) would in principle show up as a (wavelength-dependent) increase of the detector sensitivity. Since the BRDF/reflection is calculated from the ratio of radiance and irradiance, this type of stray light would not affect the calculated BRDF/reflection. However, since the detector FOV is not completely illuminated during the irradiance measurement contrary to the situation during radiance measurement, the internal stray light might be different for radiance and irradiance measurement. Therefore the error on the diffuser measurements due to straylight is estimated to be larger (0.15%).

Mirror measurements

Error type: systematic

Wavelength	1σ value of error
240nm	0.1%
310nm (ch1)	0.1%
310nm (ch2)	0.1%
350nm	0.1%
500nm	0.1%
700nm	0.1%
850nm	0.1%
2350nm	0.1%

Diffuser measurements

Error type: systematic

Wavelength	1σ value of error
240nm	0.15%
310nm (ch1)	0.15%
310nm (ch2)	0.15%
350nm	0.15%
500nm	0.15%
700nm	0.15%
850nm	0.15%
2350nm	0.15%

6. Discussion of error sources - Optical bench calibration

6.1 beam reflected by 50 cm spherical mirror not perfectly collimated

Determined from commissioning report and multiple distance measurements with the mirror.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	N/A							
rl0uld	N/A							
il0ucd	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	4.00^{E}-02	4.00E-02
e_cal	N/A							

6.2 erroneous reflectivity of spherical mirror of Cal. Irr. Source (il0ucd)

The following figures are estimated:

Wavelength	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	N/A							
rl0uld	N/A							
il0ucd	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00^{E}-03	5.00E-03
e_cal	N/A							

6.3 wrong angle spectralon diffuser w.r.t. ILOS

A rough estimate: alignment accuracy of 1 degree, difference due to changes in the cosine effect, averaged for the extremes of a foot-print of 20 cm.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04
rl0uld	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04
il0ucd	N/A							
e_cal	N/A							

6.4 wrong polarisation component/residual polarisation

The m* measurements were performed with an extra Glan-Thompson polariser at the monochromator, in addition to the Brewster polariser. Instrumental polarisation effects are taken into account for the impact on the measurements.

For the Brewster polariser a polarisation purity of 99 % is assumed (RP-SCIA-1000TP/238).

Restpolarisation of radiance and irradiance beam are not known. Worst case of 1% restpolarisation assumed. Restpolarisation of e_cal not known, 0.1% restpolarisation assumed.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	<0.0006 %	all wavelengths						
mn0pnq	<0.0006 %	all wavelengths						
mn0pnx	<0.0006 %	all wavelengths						
wn0snd	0.00%	0.46%	0.04%	0.46%	0.29%	0.26%	0.13%	0.09%
wn0pnd	0.00%	0.46%	0.04%	0.46%	0.29%	0.26%	0.13%	0.09%
rn0und	0.00%	0.46%	0.04%	0.46%	0.29%	0.26%	0.13%	0.09%
rl0uld	0.00%	0.46%	0.04%	0.46%	0.29%	0.26%	0.13%	0.09%
il0ucd	0.00%	0.46%	0.04%	0.46%	0.29%	0.26%	0.13%	0.09%
e_cal	0.00%	0.05%	0.00%	0.05%	0.03%	0.03%	0.01%	0.01%

6.5 wrong distance between lamp and spectralon diffuser

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00^{E}-04	4.00E-04
rl0uld	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00^{E}-04	4.00E-04
il0ucd	N/A							
e_cal	N/A							

Reference of error source: rough estimate

6.6 stray light test environment

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	NEM							
mn0pnq	NEM							
mn0pnx	NEM							
wn0snd	NEM							
wn0pnd	NEM							
rn0und	Corrected for with dark/offset measurement							
rl0uld	Corrected for with dark/offset measurement							
e_cal	N/A							

NEM: No Estimate made

Observed during OPTEC 1, and improved during OPTEC 2. All low radiance stimulator measurements were checked for this effect, and we consider the effect negligible for those measurements that were not marked suspect

during calibration.
The effect for the irradiance and radiance measurements needs a better Estimate, sofar outstanding.
The stray light is spectrally quite peaked, and easy to recognise in the peaks. The continuum level is significantly lower, and considered negligible for the wavelengths in question.

6.7 etalon effect

No change of detector etalon was seen during instrument operation under a two month period in thermal vacuum. Estimated upper limit for any effect, derived from plots in TN-SCIA-1000TP/193: 5e-4, lower in higher channels

In addition to the detector etalon, there are some other etalons, which are visisble for certain instrument changes. These effects are not considere here, and may be covered by other error sources.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	<<1e-3	<<5e-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
mn0pnq	not invest	igated						
mn0pnx	not invest	igated						
wn0snd	<<1e-3	<<5e-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
wn0pnd	<<1e-3	<<5e-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
rn0und	<<1e-3	<<5^{e}-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
rl0uld	<<1e-3	<<5^{e}-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
il0ucd	<<1e-3	<<5^{e}-4	<<5e-4	<<1e-4	<<1e-4	<<1e-4	<<1^{e}-4	<<1e-4
e_cal	N/A							

6.8 Monochromator stray light

This error source is estimated to be not an issue for anything but the spectral ghost characterisation, which is a small correction in itself. The combination of monochromator and SCIAMACHY results in a quadruple monochromator, all optimised for straylight suppression

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	NEM							
mn0pnq	NEM							
mn0pnx	NEM							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	N/A							
rl0uld	N/A							
il0ucd	N/A							
e_cal	N/A							

NEM: No Estimate Made

6.9 noise and drift test beam

Analysis of all m* measurements determines ratios of instantaneously measured intensities, therefore any beam fluctuations that are relevant are those that are either spectral fluctuations (for straylight analysis) or polarisation fluctuations (for ksi measurements). These are considered negligible with respect to other error sources.

(from RP-SCIA-1000TP/236,SE-SCIA-0150FO/96):
Xe-lamp: 0.81 % in 5 minutes
QTH-lamp: 0.09 % in 5 minutes

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	2.00E-04	4.00E-04	2.00E-04	3.00E-04	2.00E-04	2.00E-04	1.00E-04	5.00E-05
wn0pnd	2.00E-04	4.00E-04	2.00E-04	3.00E-04	2.00E-04	2.00E-04	1.00E-04	5.00E-05
rn0und	1.00E-03	9.00E-04	9.00E-04	5.00E-04	3.00E-04	2.00E-04	7.00E-04	5.00E-04
rl0uld	1.00E-03	9.00E-04	9.00E-04	5.00E-04	3.00E-04	2.00E-04	7.00E-04	5.00E-04
il0ucd	1.00E-03	9.00E-04	9.00E-04	5.00E-04	3.00E-04	2.00E-04	7.00E-04	5.00E-04
e_cal	N/A							

6.10 Non-uniformity of test-beam

In RP-SCIA-1000TP/236 values are given. However, all low radiance stimulator measurements are performed with fixed beam position.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	0.02%	0.02%	0.02%	0.01%	0.01%	0.03%	0.10%	0.05%
wn0pnd	0.02%	0.02%	0.02%	0.01%	0.01%	0.03%	0.10%	0.05%
rn0und	NEM							
rl0uld	NEM							
il0ucd	2%	3%	2%	2%	4%	3%	2%	2%
e_cal	N/A							

6.11 phase shift predisperser prism

The phase shift problem is a serious one, and quite in-depth investigations have been performed to estimate the errors. The figures estimated here are rough estimates for the case where no correction is applied. Although in the current keydata set an correction is applied we calculate the error without correction as a worst case figure in view of the complex nature of an error budget based on the Mueller matrix approach.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	0.06	0.02	0.02	0.01	3.00E-03	8.00E-04	4.00^{E}-04	7.00E-06
mn0pnq	0.06	0.02	0.02	0.01	3.00E-03	8.00E-04	4.00^{E}-04	7.00E-06
mn0pnx	N/A	N/A	N/A	N/A	N/A	N/A	0.03	N/A
wn0snd	0.34	0.21	0.21	0.16	0.08	0.04	0.03	3.00E-03
wn0pnd	0.06	0.02	0.02	0.01	3.00E-03	8.00E-04	4.00^{E}-04	7.00E-06
rn0und	6.00E-03	2.00E-03	2.00E-03	1.00E-03	3.00E-04	8.00E-05	4.00^{E}-05	7.00E-07
rl0uld	6.00E-03	2.00E-03	2.00E-03	1.00E-03	3.00E-04	8.00E-05	4.00^{E}-05	7.00E-07
il0ucd	6.00E-03	2.00E-03	2.00E-03	1.00E-03	3.00E-04	8.00E-05	4.00^{E}-05	7.00E-07
e_cal	N/A							

6.12 pixel to pixel gain/fast etalon

Rough estimate, which needs more attention if it turnst out to be relevant. Not polarisation sensitive.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
wn0pnd	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
rn0und	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
rl0uld	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
il0ucd	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
e_cal	N/A							

6.13 scan mirror angle accuracy

Estimates for 1 degree mis-aligment. This is the difference seen between SCOE and EGSE encoder readings.

Calculated from the ambient scanner calibration values, for a systematic error.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
mn0pnq	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
mn0pnx	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
wn0snd	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
wn0pnd	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
rn0und	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
rl0uld	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
il0ucd	1.00E-03	1.00E-03	1.00E-03	2.00E-03	2.00E-03	3.00E-03	4.00E-03	5.00E-04
e_cal	N/A							

6.14 Inter/intra channel stray light

The OPTEC 5 measuremements where performed after the SCIAMACHY instrument had been refurbished w.r.t. straylight.

In the table below it is assumed that the refurbishment and the straylight correction improved the situation in channels 1 and 2 with a factor 10.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	0							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	0.001	0.001	0.01	<<1e-3	<<1e-3	<<1e-3	<<1e-3	<<1e-3
wn0pnd	0.001	0.001	0.01	<<1e-3	<<1e-3	<<1e-3	<<1e-3	<<1e-3
rn0und	0.04	0.01	0.05	<<1e-3	<<1e-3	<<1e-3	<<1e-3	<<1e-3
rl0uld	0.04	0.01	0.05	<<1e-3	<<1e-3	<<1e-3	<<1e-3	<<1e-3
il0ucd	0.04	0.01	0.05	<<1e-3	<<1e-3	<<1e-3	<<1e-3	<<1e-3
e_cal	N/A							

6.15 absorption of suprasil windows/window contamination

Estimated from calibration results package, correction factor for window contamination.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	7.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
wn0pnd	7.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
rn0und	7.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
rl0uld	7.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
il0ucd	7.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
e_cal	N/A							

6.16 temperature dependence detectors

Estimated for 0.1 K temperature difference, scales linearly

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
mn0pnq	not estim	Ated, assume	d small					
mn0pnx	not estim	Ated, assume	d small					
wn0snd	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
wn0pnd	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
rn0und	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
rl0uld	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
il0ucd	1.00E-04	5.00E-05	1.00E-04	1.00E-04	3.00E-05	4.00E-05	2.00E-04	2.00E-03
e_cal	N/A							

6.17 temperature dependence OBM

Determined from AIT measurements, for a temperature change of 0.1 K, scales linearly with temperature difference.

Wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
Pixel number:	200	800	950	600	450	450	250	600
mn0pnd	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
mn0pnq								
mn0pnx								
wn0snd	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
wn0pnd	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
rn0und	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
rl0uld	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
il0ucd	-5.00E-03	4.00E-03	7.00E-03	3.00E-03	-4.00E-03	-1.70E-03	1.00E-03	-5.00E-03
e_cal	N/A							

6.18 temperature/humidity dependence dichroic filters

Temperature effect is incorporated in OBM temperature dependence.
Humidity (or air-vacuum) effect is not visible in the calibration data for the relevant wavelengths. Some effect is visible in some of the channel overlaps.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	Beyond detection limit in measurements investigated							
mn0pnq	Idem							
mn0pnx	Idem							
wn0snd	Idem							
wn0pnd	Idem							
rn0und	Idem							
rl0uld	Idem							
il0ucd	Idem							
e_cal	N/A							

6.19 temperature/humidity other optics

Temperature effect is incorporated in OBM temperature dependence.
Humidity (or air-vacuum) effect is not visible in the calibration data for the relevant wavelengths. Some effect is visible in some of the channel overlaps. This effect is ascribed to dichroics, though strictly spoken this can not be confirmed with the measurements analysed.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	Beyond detection limit in measurements investigated							
mn0pnq	Idem							
mn0pnx	Idem							
wn0snd	Idem							

wn0pnd	Idem
rn0und	Idem
rl0uld	Idem
il0ucd	Idem
e_cal	N/A

6.20 *absorption by water vapour*

Water absorption features fall outside the selected wavelengths. The impact for all m* and w* measurements is assumed negligible, since the optical stimulus was flushed with nitrogen, and relative measurements were used. The r* and i* measurements were corrected for water absorption. Estimate for residual error in strongest absorption band, from fig 28 of TN-SCIA-1000TP/190: less than 0.04 %.

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	N/A							
mn0pnq	N/A							
mn0pnx	N/A							
wn0snd	N/A							
wn0pnd	N/A							
rn0und	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<0.04%
rl0uld	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<0.04%
il0ucd	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<<0.04%	<0.04%
e_cal	N/A							

6.21 *Electronic noise/shotnoise*

The noise as observed during the measurements after averaging results in the following figures:

wavelength:	*240 nm*	*310 nm Ch1*	*310 nm Ch2*	*350 nm*	*500 nm*	*700 nm*	*850 nm*	*2350 nm*
Channel number:	1	1	2	2	3	4	5	8
pixel number:	200	800	950	600	450	450	250	600
mn0pnd	0.5%	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%
mn0pnq	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
mn0pnx	N/A						0.1%	
wn0snd	0.5%	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%
wn0pnd	0.5%	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%
rn0und	0.5%	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%
rl0uld	0.5%	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%

il0ucd e_cal	0.5% N/A	0.1%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%

7. Discussion of error sources - Spectralon diffuser calibration

In the following a description is given for the individual error sources in the BRDF calibration of the Spectralon diffuser plate that is used during the absolute calibration activities. The calibration of this Spectralon does not result in a seperate key data, but since it plays a vital role in the accuracy of the radiometric calibration of the SCIAMACHY instrument a seperate error budget for this Spectralon calibration is derived. The resulting error is input to the SCIAMACHY error budget.

Three different types of errors can be distinguished:

- direct errors: uncertainties of the variables that are directly used to calculate the BRDF value (e.g. errors in the FOV value);
- simple indirect errors: errors which do not directly influence the variables involved but do affect the final result. The magnitude of these errors can be estimated (e.g. angular precision errors);
- complex indirect errors: similar to simple indirect errors; for this type of error, however, it is hard to give an accurate estimate (e.g. stray light).

Moreover, the errors have to be categorized with respect to the statistical nature of the errors. One can distinguish between three types of error distributions (*relative* errors):

- Sign-biased (SB) errors: fixed non-zero offsets (e.g. stray light).
- Non-sign biased (NSB) errors: "top hat" uniform distributions, lying between - NSB and + NSB. The 1σ equivalent = $NSB/\sqrt{3}$.
- Random errors: Gaussian distribution, characterised by σ.

The errors are summed as follows:

$$\textbf{Total error } (1\sigma) = \left|\Sigma\, SB_i\right| + \sqrt{\left[\Sigma\, NSB_j^2/3 + \Sigma\, \sigma_k^2\right]}$$

Error sources

Field-of-view: An error in the FOV of the main detector will show up as a systematic error in all calculated BRDF values. Therefore, the FOV error does not contribute to the error in ratios of individual BRDF data points. The FOV has been measured using a setup, employing a highly collimated expanded laser beam and very accurate rotation tables. The roundness of the detector field stop has been determined using an accurate Leitz measuring microscope. The thus measured FOV is measured to have a relative error of < 0.2% (NSB).

Angular precision: All angles of the rotation tables used can be resolved with a precision of 0.01°. The orientations for perpendicular illumination of the sample are determined by mounting a reference mirror instead of the Spectralon diffuser onto the rotation/translation assembly and looking at the reflection of the beam. We estimate that by using this procedure the perpendicular orientation is accurate within 0.01°. Since during the measurements both the detector and the sample are rotated with respect to the normal position, we estimate the error in the angle of incidence to be less than 0.03°.
The error propagation of the error in the angle of incidence can be calculated as: $\partial(\cos\gamma) / \cos\gamma = |\tan\gamma|\ \partial\gamma$. Thus the relative error in the factor $\cos\gamma$ equals 0.1% (1σ) at 65° angle of incidence. In the relative spectral measurements this error contribution is eliminated.
Typically the BRDF of Spectralon changes less than 0.3% when the detector angle δ changes 1°. Therefore, the effect of the error in the angle of detection may be neglected.

Detector linearity: In the calculation of the BRDF it is assumed that both the main and the reference detector have a linear response. Deviations from linearity will lead to an erroneous BRDF. During the commissioning phase of the calibration facility, the differential linearity was measured while varying the light intensity over four orders of magnitude. For the new type of Si detector that is currently used, no trends in the measured deviations from linearity were observed as a function of wavelength or light intensity. Therefore, we conclude that the deviations from perfect linearity are smaller than the error of the commissioning measurements, i.e., we estimate the error due to non-linearity to be less than 0.1% (1σ) over the wavelength range 450nm-1000nm. For the wavelength range 1000nm to 2350nm a PbS detector is used. This type of detector has typically a higher non-linearity then the Silicon type detectors. After correction we estimate that the non linearity is better then 1%.

For the relative spatial BRDF data this error is eliminated. Since the light intensity is varying quite strongly as a function of wavelength, the detector linearity error is not eliminated for the relative spectral BRDF data.

Beam uniformity: In the calculation of the BRDF from the radiance and irradiance measurements it is assumed that the beam is uniform across its cross section. Non-uniformities of the beam will affect the calculated BRDF due to the fact that during radiance and irradiance measurements different parts of the beam are viewed. First this is due to the fact that the detector has a non-zero FOV. Furthermore, the irradiance measurement is performed with the detector aperture stop being perpendicular to the light beam, whereas during the radiance measurement both the sample normal and the detector viewing axis are at an angle to the light beam.

During the commissioning of the calibration facility, the non-uniformity of the monochromator beam was measured for different wavelength ranges. Typically the non-uniformities are of the order of a few percent. However, this does not mean that the resulting errors in the BRDF are just as large. For instance, if the beam intensity would decrease linearly from one side of the beam to the other, non-uniformity errors in the BRDF would be zero for a detector properly aligned with respect to the center of the beam. Using the calculated projected area of the detector FOV onto the diffuser, the error in the BRDF can be calculated from the commissioning data on the non-uniformity of the beam.

Based on measurements performed during the MERIS diffuser calibration we estimate that the error contribution in the absolute BRDF resulting from beam non-uniformities is estimated to be less than 0.7%. This error consists of a sign-biased contribution of -0.2% and a non-sign-biased contribution of 0.5%.

For the relative spatial dependence of the BRDF the error due to beam non-uniformity will only be eliminated partly since at different detector angles the non-uniformity will have a different impact on the BRDF value. The residual error is estimated to be 0.3% (NSB).

Since the beam uniformity is measured to be wavelength-dependent, the error due to beam non-uniformity in the relative spectral measurements is also estimated to be of the order of 0.4% (NSB).

Noise: The error due to noise on the radiance mode and irradiance mode measurements is dependent on the number of averages used for the respective measurements. The error due to noise includes:

- detector and ammeter noise during radiance and irradiance mode measurements;
- lamp and detector noise during the time in which the measurement detector and the reference detector are not gathering data simultaneously.

The measurement time was chosen such that the noise after averaging was 0.2% for all wavelengths.

Polarization: The polarization of the monochromator output (which is defined as the ratio $(T_S-T_P)/(T_S+T_P)$, where $T_{s,p}$ is the intensity transmitted by a perfect polarizer in S, P setting) amounts to less than 0.5%. The beam splitter (sending light to the reference detector), which is at an angle of 9° to the beam, adds another 0.5%, so that the polarization of the light striking the Spectralon sample is less than 1%. Since the angle of incidence at the diffuser is non-zero, there is an effect of the beam polarization on the BRDF. This effect has been investigated during commissioning of the set-up. It was found that the polarization dependence of the BRDF, defined as ($BRDF_S$-$BRDF_P$)/($BRDF_S$+$BRDF_P$) amounts to less than 5%. It can be shown that due to the rest polarization of the incident beam and the polarization dependence of the diffuser, the measured BRDF is affected by less than 0.05% (NSB). For the *relative* BRDF values the error is even less.

Stray light: The error resulting from stray light scattered off the surroundings of the sample is estimated to be less than 0.1% (SB). Stray light generated inside the detectors (e.g., due to reflection off the detector surface) would in principle show up as a (wavelength-dependent) increase of the detector sensitivity. Since the BRDF is calculated from the ratio of radiance and irradiance, this type of stray light would not affect the calculated BRDF. However, since the detector FOV is not completely illuminated during the irradiance measurement contrary to the situation during radiance measurement, the internal stray light might be different for radiance and irradiance measurement. This stray light effect, which is estimated to be less than 0.1% (NSB), cancels out for the relative measurements.

Summary of errors applicable to all wavelengths

	Effect on
Error source (x_i)	**Absolute BRDF**
FOV (NSB)	< 0.2 %
Angular precision (R)	0.1 %
Detector linearity (R)	0.3 %
Beam uniformity: SB NSB	-0.2 % 0.5 %
Noise (R)	0.2 %
Polarization (NSB)	<0.05 %
Stray light: SB NSB	+0.1 % 0.1 %
Total error (1 s)	**0.59 %**

Table 7/1. SB: sign-biased error; NSB: non-sign-biased error; R: random error.

8. Wavelength Calibration

Direct errors:

- S/N on pixel read-out and dark current correction error on pixel-to-pixel correction. This error is expected to be less than 0.01 pixel. For channels 5-8 this error remains to be evaluated during the calibration activities. For now it is assumed to be equal to the error for channels 1-4, i.e. 0.01 pixel.
- Precision of literature wavelength values of spectral lines. For channels 1-4 (NIST and FTS wavelength data, as well as other spectral line tables) the error is negligible. For channels 5-8 the line selection still has to take place, but as the energy levels involved are accurately known the error for these channels will also be negligible.

Indirect errors:

- Irregularity of the pixel positions on the array and non-uniformity of the sensitivity within one pixel surface. This error is assumed to be negligible.

Model errors:

- Precision of the curve fitting algorithm to localize the maxima of the selected lines. It is expected that the algorithm for finding the peak maxima will work slightly better for SCIAMACHY than for GOME because the spectral resolution of SCIAMACHY is lower (a spectral line covers more pixels).
- Precision of the 4th order polynomial (or another function) to describe the dispersion curve.This error is in general about 0.04 pixel, but may be larger for channels 7 and 8, which contain fewer lines of the internal Pt-Cr-Ne spectral lamp. The 0.04 pixel error is based on experience with GOME.

Total error is **0.04 - 0.05 pixel.**

9. SCIAMACHY error sources in flight:

Although the in-flight error sources are not within the scope of the on-gound calibration error budget, we list a number of error sources that affect the accuracy of the data products during operation. This list is not necessarily complete.

- In flight change of dichroic filters

This effect was observed in GOME. For several reasons we are in a much better position in SCIAMACHY. Firstly we have the complete instrument calibrated in TV. The instrument has been in vacuum for weeks, giving the optics time to outgas. The in-orbit situation will therefore lie much closer to the pre-flicht calibration situation then it was during GOME calibration. Secondly the dichroics have less pronounced features with sharp edges then in GOME. Finally we have the on-board WLS to correct for changes in the optics. The total error due to dichroic changes is estimated to be small.

- In flight change of additional optics

Here again we will use the WLS to correct for changes.

- (Residual) etalon effect

Here again we will use the WLS to correct for changes.

- Memory effect channel (in combination with changing intensity of the observed scenery)

This effect is very much scene dependent. A scenery where high intensities are followed by dark sceneries are most affected. The error due to this is TBD

- Spatial aliasing channel

Error TBD

- Temperature different from calibration temperature (optics and detectors)
- Pointing errors scanners
- Stability/pointing ENVISAT
- Coregistration error science detector pixels / PMD's

S/N of in-flight measurements, especiallly over ground pixels in the South Antlantic Anomaly (SAA)

10. Propagated error on individual key data

The following table gives the propagated error of the individual keydata for 10 wavelengths, with at least one wavelength in each channel. The original set of wavelengths did not cover channel 6 and 7. The wavelengths in channel 6 and 7 are copied from the calculated errors of channel 8.

PARAMETER	ch1 240nm	ch1 310nm	ch2 310nm	ch2 350nm	ch3 500nm	ch4 700nm	ch5 850nm	ch6 1400nm	ch7 2000nm	ch8 2350nm
ACUCP	0.898	0.895	0.895	0.567	0.566	0.574	0.606	1.135	1.135	1.135
ACUCS	0.898	0.894	0.894	0.568	0.567	0.574	0.606	1.135	1.135	1.135
AL0ULP	0.89	0.887	0.887	0.555	0.554	0.563	0.595	1.126	1.126	1.126
AL0ULS	0.891	0.887	0.887	0.557	0.556	0.564	0.595	1.128	1.128	1.128
ALA4L4	0.895	0.882	0.882	0.548	0.546	0.549	0.581	1.128	1.128	1.128
ALA4LP	1.158	0.985	0.985	0.642	0.559	0.546	0.578	1.127	1.127	1.127
ALA4LS	0.914	0.901	0.901	0.576	0.572	0.593	0.626	1.128	1.128	1.128
ALAMLP	1.228	1.051	1.051	0.728	0.622	0.604	0.628	1.127	1.127	1.127
ALAMLS	1.229	1.052	1.052	0.729	0.622	0.604	0.628	1.127	1.127	1.127
ALAPL4	1.198	0.995	0.995	0.647	0.556	0.549	0.585	1.128	1.128	1.128
ALAPLP	0.907	0.885	0.885	0.55	0.545	0.547	0.579	1.125	1.125	1.125
ALAPLS	7.849	13.895	13.895	18.286	39.254	64.214	75.656	494.169	494.169	494.169
ALASL4	0.895	0.889	0.889	0.559	0.558	0.57	0.602	1.129	1.129	1.129
ALASLP	9.334	16.111	16.111	20.915	44.203	75.014	88.809	516.671	516.671	516.671
ALASLS	0.942	0.908	0.908	0.579	0.561	0.562	0.591	1.127	1.127	1.127
ALAULP	0.89	0.887	0.887	0.554	0.553	0.562	0.594	1.126	1.126	1.126
ALAULS	0.89	0.887	0.887	0.557	0.556	0.564	0.595	1.128	1.128	1.128
AN0PNP	0.879	0.879	0.879	0.546	0.546	0.546	0.576	1.127	1.127	1.127
AN0PNX	6.264	6.431	6.431	6.446	6.542	6.556	6.561	6.74	6.74	6.74
AN0UNP	0.878	0.878	0.878	0.544	0.544	0.544	0.575	1.126	1.126	1.126
AN0UNS	0.877	0.877	0.877	0.543	0.543	0.543	0.574	1.125	1.125	1.125
ANAUNP	0.879	0.879	0.879	0.546	0.546	0.546	0.576	1.126	1.126	1.126
ANAUNS	0.879	0.879	0.879	0.544	0.544	0.544	0.575	1.126	1.126	1.126
MN0PND	6.062	2.067	2.255	1.084	0.545	0.369	0.43	0.717	0.717	0.717
MN0PNQ	5.913	1.974	1.974	1.007	0.367	0.322	0.41	0.505	0.505	0.505
MN0PNX	0.099	0.099	0.099	0.199	0.199	0.298	3.01	0.497	0.497	0.497
WN0SND	16.964	11.465	10.499	7.981	4.014	2.044	1.571	0.763	0.763	0.763
WN0PND	12.157	4.093	4.166	2.118	0.843	0.519	0.508	0.752	0.752	0.752
RN0UND	2.761	1.226	1.145	0.646	0.58	0.492	0.5	0.753	0.753	0.753
RL0ULD	2.74	1.21	1.13	0.636	0.577	0.486	0.495	0.75	0.75	0.75
ECAL	1.015	1.016	1.015	1.016	1.015	1.015	1.015	1.015	1.015	1.015
DEXT	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589

11. Propagated error on level 1 data products

The following table gives the propagated error of the level 1 data products for 10 wavelengths, with at least one wavelength in each channel. The original set of wavelengths did not cover channel 6 and 7. The wavelengths in channel 6 and 7 are copied from the calculated errors of channel 8.

	ch1 **240nm**	ch1 **310nm**	ch2 **310nm**	ch2 **350nm**	ch3 **500nm**	ch4 **700nm**	ch5 **850nm**	ch6 **1400nm**	ch7 **2000nm**	ch8 **2350nm**
NADIR										
Unpolarized sun normalized	0.5	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Polarized sun normalized	2.4	2.4	0.7	2.6	0.5	0.3	0.2	0.2	0.2	0.2
Unpolarized absolute	3	1.7	1.7	1.3	1.2	1.2	1.2	1.2	1.2	1.2
Polarized absolute	3.8	3.1	1.8	2.8	1.3	1.3	1.2	1.2	1.2	1.2
LIMB										
Unpolarized sun normalized	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Polarized sun normalized	2.3	2.5	0.6	2.5	0.5	0.4	0.4	0.2	0.2	0.2
Unpolarized absolute	3	1.7	1.6	1.3	1.2	1.2	1.2	1.2	1.2	1.2
Polarized absolute	3.7	3.1	1.7	2.8	1.3	1.3	1.2	1.2	1.2	1.2