CEOS Intercalibration of Ground-Based Spectrometers and Lidars

Minispectrometer Intercalibration and Satellite Validation

Report 3:
Mid-term progress report

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Contents

Document Change Record

Version	Date	Page	Observations
1	2013-08-06	All	First draft version
2	2013-08-29	3 - 5	Addition of sections 2 and 3
3	2013-08-30	All	A few modifications to version 2
4	2013-09-26	5+	Added figures in section 3, added section 4

1 Introduction

This report is deliverable D3 of the project [RD1, RD2]. Section 2 explains how much of the data base described in RD3 has already been re-calibrated and re-processed. Section 3 lists significant observations made during the first five months of this activity. Section 4 gives the status for each work package of the project.

1.1 Reference Documents

No	Description
RD1	Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation [Statement of Work], Issue 1, Revision 0, GMES-CLVL-EOPG-SW-13-0001, 15 January 2013
RD2	Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation [Proposal], Contract: 22202/09/I-EC, RFQ/3-12340/08/I-EC, 22 January 2013
RD3	Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation, Report 1: List of Minispectrometers considered in this activity, 10 April 2013
RD4	Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation, Report 2: Recommendations for Inter-Calibration of minispectrometer networks, 25 September 2013

1.2 Definitions, Acronyms, and Abbreviations

No	Description
CCR	Corrected Count Rates
EVDC	Envisat Validation Data Center
KO	Kick off
NO2	Nitrogen Dioxide
O3	Ozone
OMI	Ozone Monitoring Instrument
RMS	Root Mean Square
RRCal	Relative radiometric calibration
SCIAMACHY	SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY
WCal	Wavelength calibration

2 Current status of data base recalibration

Table [1]: Progress of re-calibration and re-processing of each Pandora (IN=Instrument Number); the number of available relative radiometric calibrations (RRCal) and wavelength calibrations (WCal) performed in the laboratory are shown in columns 2 and 3 respectively. Column 4 indicates what portion of lab- and field calibrations have already been analyzed. Column 5 indicates what portion of the existing data is already in its final form to be used for this project.

IN	Available laboratory calibrations		Re-calibration progress				Re-processing progress			
	RRCal	WCal	25 %	50 %	75%	100%	25 %	50 %	75%	100%
2	3	5								
3	9	6								
6	4	3								
7	3	3								
8	4	5								
9	6	4								
16	5	5								
17	3	1								
18	6	5								
19	2	2								
20	2	2								
21	3	3								
23	5	3								
24	2	2								
25	4	2								
26	5	3								
27	8	3								
28	7	2								
29	4	2								
30	2	2								
31	2	2								
32	3	3								
33	4	2								
34	2	2								
35	3	3								
36	3	3								
37	1	1								
38	2	1								
101	2	1								

3 Observations

Several observations have been made during data base recalibration and reprocessing. These observations include laboratory calibration work, instrument field stability and processed data.

3.1 Observations on laboratory calibration work

The vast majority of laboratory measurements carried out for RRCal and WCal provide high quality data. However, in a few instances an unstable laboratory setup required repetition of the RRCal. This lab-instability was attributed to the temperature dependence of a metal bracket employed in the laboratory and has since been remedied. Figure 1 shows an example of the effect of the unstable laboratory setup.

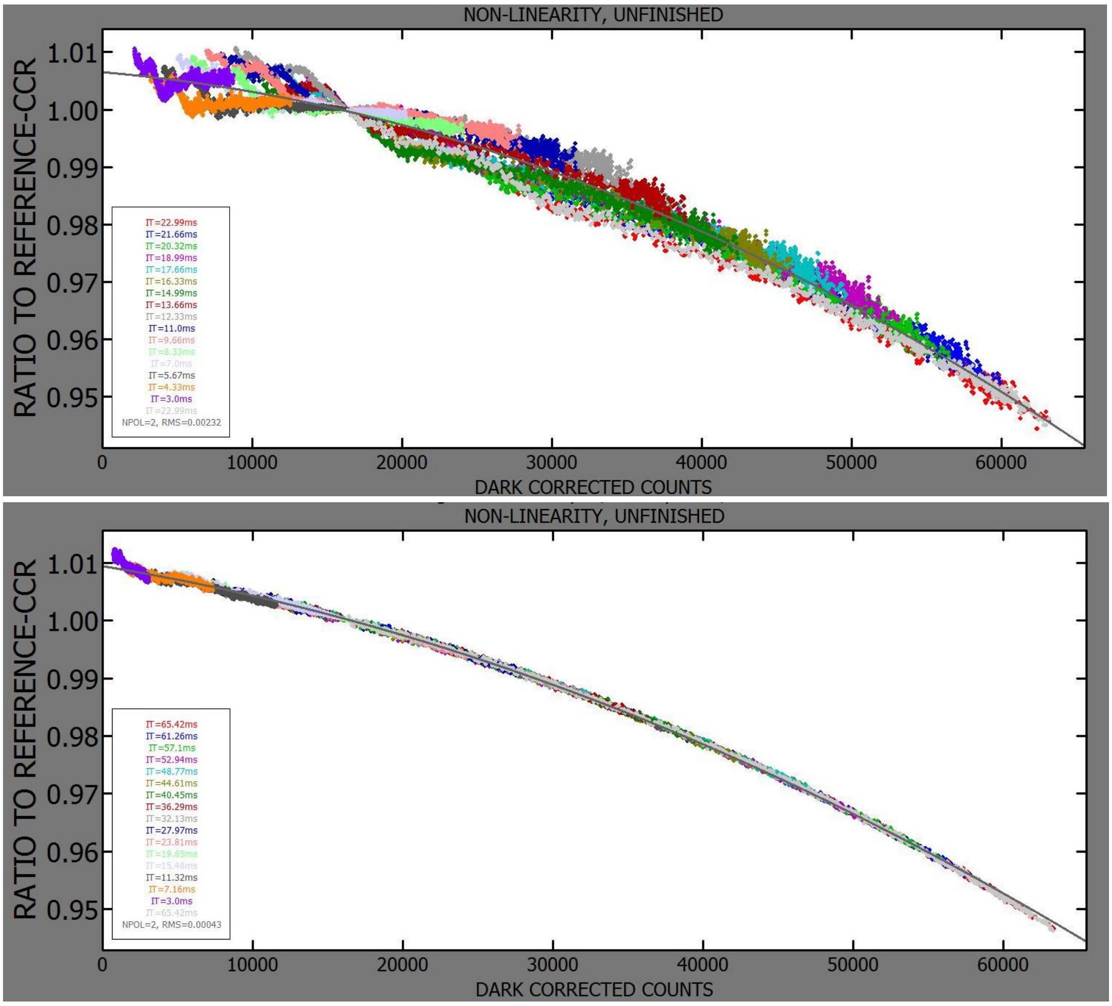

Figure 1: Ratio of CCR to the reference value (CCR=16384) as a function of the dark corrected counts for different integration times (IT). Data are from Pandora 34. Gray line is 2^{nd} order polynomial in the data and is used as linearity correction in the data processing. Unstable laboratory setup causes scatter in the data and a bias in the linearity function (top panel). With stable laboratory setup the scatter is small, as is the uncertainty in retrieved linearity function (bottom panel).

3.2 Observations on instrument field stability

The long-term and travel stability of Pandora instruments was addressed in [RD4]. From there we conclude that a well-maintained Pandora is capable of measuring reliable O3 and NO2 data for >2 years between calibrations. In addition, the instruments do not loose calibration during travel, under normal circumstances. These characteristics make Pandora an excellent network instrument.

3.3 Observations on processed data

The following paragraphs list the main limitations observed on the Pandora data products.

Enhanced scatter: Total NO2 data sometimes exhibit enhanced scatter. This happens usually around noon (see figure 2), only affects some instruments and only during specific periods and at some locations. We noticed this effect for 4 of the 29 Pandoras listed in table 1 (numbers 6, 7, 26, and 101). It impacts less than 10% of their data, except for Pandora 101, where it happens more often. The cause is not understood at this time. We suspect an external noise source modifying the data. We do not know at present, whether the increased scatter is random noise, in which case the data could be averaged and are still useful, or if it includes a systematic error, which would render the data unusable. Figure 2 seems to suggest the latter is happening. Nevertheless, we know that the effect does not change the instrument’s calibration, i.e. the data compare well with other units once the increased scatter is gone. We are able to detect periods of increased scatter, as these values are characterized by strongly fluctuating RMS of the residuals in the spectral fitting process. We are currently working on a method to flag these periods.

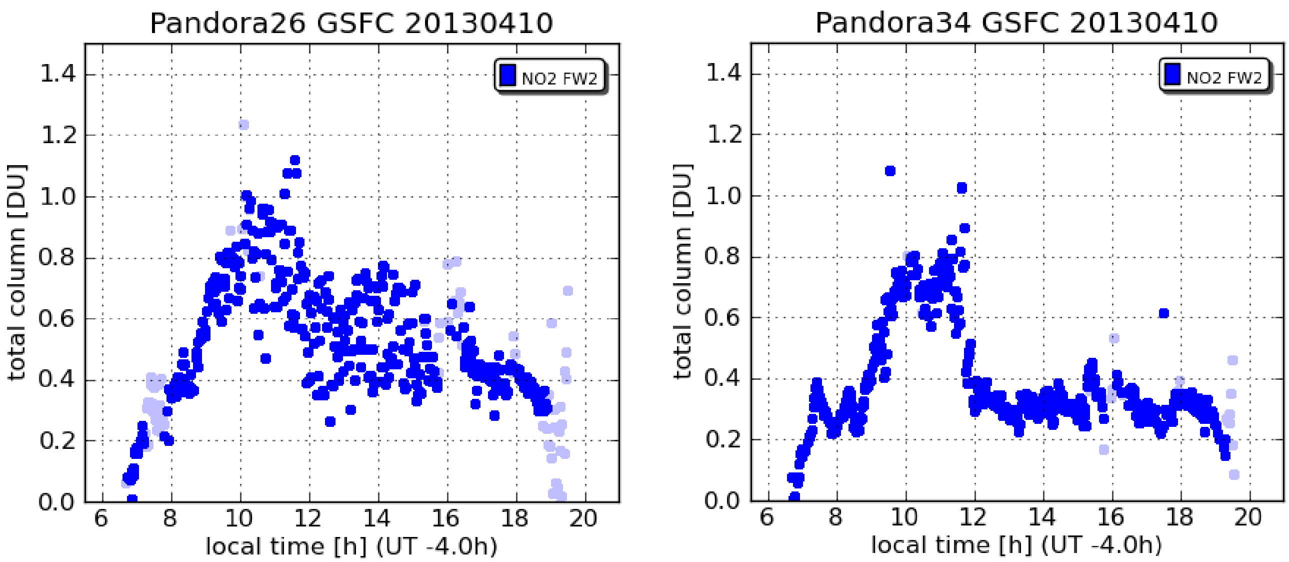

Figure 2: Total NO2 columns from Pandoras 26 and 34 at Goddard Space Flight Center (GSFC) on 10 April 2013 as a function of local time. Dark blue dots have passed the cloud filter. Light blue dots have not passed it. Pandora 26 data show rather large instrumental scatter from approximately 10:00 to 16:00, while Pandora 34 data show the natural variability only.

Additional spectral signal: We frequently observe an additional spectral signal in the data (see figures 3 and 4). We have just started to characterize this effect. It seems to affect basically all instruments, but to different extent. The cause is not understood at this time. Since the reference spectrum used in the standard Pandora data processing is an average over many measured spectra, this effect does not impact the calibration. I.e. the final data are correct on average. However, first tests indicate that this spectral signal with an RMS of up to 0.002 potentially impacts the derived O3 (NO2) columns by about ±5DU (±0.07DU). We believe that this temporary systematic error has an even greater impact on the retrieval of weaker atmospheric absorbers such as formaldehyde, sulfate dioxide, etc. We are working on a method to detect and eliminate this effect. Thus, reducing the uncertainty in the O3 and NO2 columns, as well as, significantly improve the capability to retrieve column amounts of weaker atmospheric absorbers. We do not expect this correction method to be finished within the time of this project, which means the effect will impact the uncertainty of the data in its full extent. Nevertheless, this contribution to the total uncertainty is minor compared to the expected point-to-point differences between NO2 columns from ground and space.

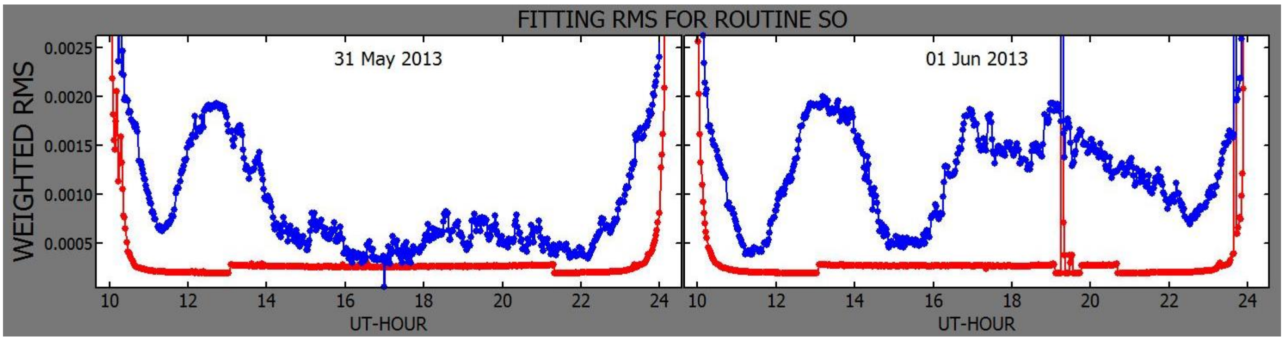

Figure 3: RMS of residuals from NO2 spectral fitting for Pandora 23 on 2013-5-31 and 2013-6-1. Red data show RMS-level expected from instrumental noise only. Blue data show RMS for a reference spectrum taken at 16:59 on 2013-5-31. Ideally the RMS should be at a level below 0.001 from 11:00 to 23:00. However both days show a hump in the RMS around 13:00, and there is also increased RMS on 2013-6-1 from 17:00 to 22:00. The times of elevated RMS are characterized by a spectral signal as shown in figure 4.

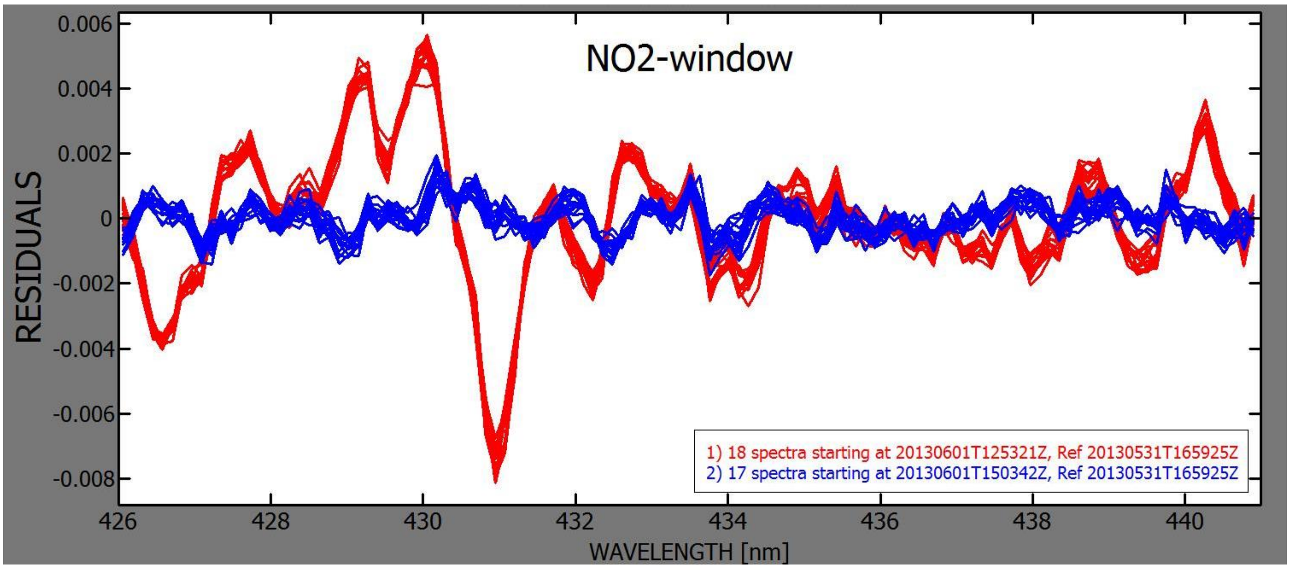

Figure 4: Residuals from NO2 spectral fitting for Pandora 23 for groups of spectra on 2013-6-1 as a function of wavelength for the range 426 to 441nm. Blue lines are spectra taken around 15:00 with RMS around 5e-4, i.e. the expected value. Red lines are spectra taken around 13:00 with RMS around 2e-3. The additional spectral signal for other spectra with elevated RMS seen in figure 3 also looks like the red lines.

Stray light: For total O3 data we observed internal stray light to be a limiting factor in gaining unbiased results for direct sun air mass factors >5 (solar zenith angles >79°, see figure 5). This is a known problem affecting all single monochromator systems. Further sophistication of the stray light correction method should reduce this effect, allowing us to extent the reliable O3 measurements beyond air mass factor 5.

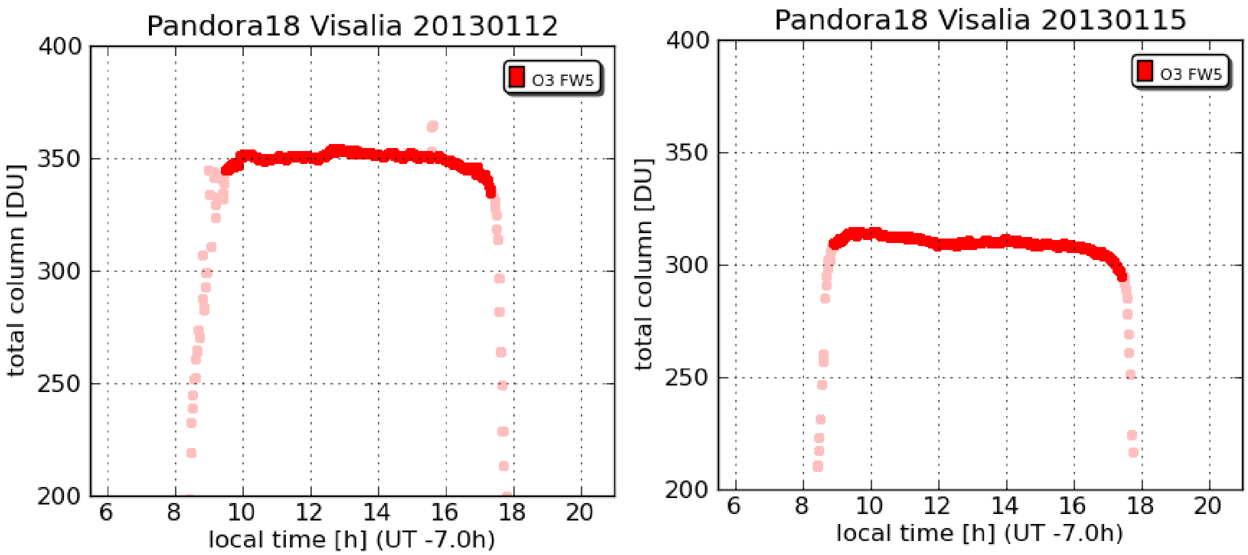

Figure 5: Total O3 column derived by Pandora 18 at Visalia, California, USA, on 12 and 15 of January 2013 as a function of local time. Dark red dots have passed the cloud filter; light red dots have not passed it. For air mass factor >5 (data before 9:15 and after 17:00) the instrumental stray light produces a negative bias in the derived O3 columns.

4 Status for each work package

4.1 [WP1] Data collection

- ***Status:*** Finished

4.2 [WP2] Data reprocessing

- ***Status:*** We have determined the best way to recalibrate the collected Pandora data. This includes assigning 'validity dates', which decide what laboratory- and field-calibration is to be used for which time period of measured data. The Pandora calibration software has been updated to speed up the calibration analysis. More than 50% of laboratory calibration data has been evaluated and nearly 50% of the data have been reprocessed (see table 1). A first version of quality flags has been given to the data.
- ***Pending:*** Finish the re-calibration and re-processing of the data. Make a final version of quality flags and submit the data to EVDC.
- ***Risks:*** This work package and deliverable D4 will probably not be finished by KO+7months. We will finish it by KO+8months instead.

4.3 [WP3] Validation protocol

- ***Status:*** As an initial study, we have compared the re-processed O3 and NO2 data series of Pandoras 3, 6, and 18 to observations from OMI [RD4].
- ***Pending:*** We will compare the same ground-based data series of Pandoras 3, 6, and 101 to observations from SCIAMACHY and then suggest a validation strategy to ESA (deliverable D6).
- ***Risks:*** This work package and deliverables D5 and D6 will probably not be finished by KO+7months. We will finish it by KO+8months instead.

4.4 [WP4] Satellite validation

- ***Status:*** Not started yet.
- ***Risks:*** At this point we do not expect any delays in finishing the work package.