CEOS Intercalibration of Ground-Based Spectrometers and Lidars

Minispectrometer Intercalibration and Satellite Validation

Report 2:
Recommendations for Inter-Calibration of minispectrometer networks

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Contents

Document Change Record

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1	2013-08-06	All	First draft version without section 3
2	2013-08-27	3, 7 - 10	Added section 3
3	2013-08-30	All	A few modifications to version 2
4	2013-9-16	All	Slightly modified figures, added more detailed analysis of validation uncertainty criteria
5	2013-9-26	All	A few modifications to version 4

1 Introduction

This report is deliverable D2 of the project [RD1, RD2]. In section 2, we discuss key questions needing to be addressed when making a network calibration plan. We answer the questions for a network made up of 'Pandora-like'-minispectrometers, of which the primary focus is to perform satellite validation. Section 3 gives an overview of the uncertainties involved in a minispectrometer network. Section 4 draws conclusions and gives specific recommendations for a network calibration plan.

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	Holben, B.N., et al., An emerging ground-based aerosol climatology: Aerosol Optical Depth from AERONET, J. Geophys. Res., 106, 12067-12097, 2001.
RD4	Fioletov, V. E., G. Labow, R. Evans, E.W. Hare, U. Köhler, C.T. McElroy, K. Miyagawa, A. Redondas, V. Savastiouk, and A.M. Shalamyansky, Performance of the ground-based total ozone network assessed using satellite data. Journal of Geophysical Research, 113, 2008.
RD5	Bhartia, P. K., OMI Algorithm Theoretical Basis Document, Volume II, OMI Ozone Product, ATBD-OMI-02, Version 2.0, 2002.
RD6	Tzortziou, M., J.R. Herman, A. Cede, and N. Abuhassan, High precision, absolute total column ozone measurements from the Pandora spectrometer system: Comparisons with data from a Brewer double monochromator and Aura OMI, J. Geophys. Res., 117 (D16303), doi:10.1029/2012JD017814, 2012.
RD7	Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation, Report 3: Mid-term progress report, 26 September 2013
RD8	Cede, A., J. Herman, A. Richter, N. Krotkov, and J. Burrows, Measurements of nitrogen dioxide total column amounts using a Brewer double spectrometer in direct Sun mode, J. Geophys. Res., 111, D05304, doi:10.1029/2005JD006585, 2006.

1.2 Definitions, Acronyms, and Abbreviations

No	Description
AERONET	Aerosol Robotic Network
AOD	Aerosol Optical Depth
CIAI	Izaña Atmospheric Research Center of the National Meteorology Agency of Spain
DU	Dobson Units
GSFC	Goddard Space Flight Center
MobREFI	Mobile reference instrument
MONI	Monitoring instrument
NO2	Nitrogen Dioxide
O3	Ozone
OMI	Ozone Monitoring Instrument
StatREFI	Stationary reference instrument
SZA	Solar zenith angle
UV	Ultraviolet

2 Key questions

We (Luftblick) claim that the general guidelines for the inter-calibration of minispectrometer networks do not differ from guidelines for networks made of 'regular sized' spectrometers. However, compared to regular spectrometers, minispectrometers are smaller, lighter and often have fewer moving parts, thus simplifying their transportation and reducing the risk of calibration changes during travel. This is a significant advantage for network operations.

A typical spectrometer network consists of these groups:

- **Monitoring instruments** (MONIs) are distributed at different locations in order to obtain extended time series of atmospheric parameters.
- **Stationary reference instruments** (StatREFIs) determine the absolute calibration of the network. All network observations should be traceable to them.
- **Mobile reference instruments** (MobREFIs) transfer the calibration from the StatREFIs to the MONIs.

Ideally, StatREFIs are located at a pristine site in order to perform field calibration methods such as the Langley method or to compare with other (external) instrumentation. MobREFIs are transported periodically from the location of the StatREFIs to the locations of the MONIs. A network calibration plan should define how to obtain and maintain the absolute calibration of the StatREFIs, how to transfer it to the MobREFIs, and how to transfer it from the MobREFIs to the MONIs. Key questions should be answered in order to make this plan:

- What are the uncertainty requirements of the network?
- How affected are the instruments by transport?
- How stable are the instruments when installed at a fixed location?

In the following sections, we give background information for each of the key questions, as well as, answer them for the Pandora minispectrometer data analyzed in this project.

2.1 What are the uncertainty requirements of the network?

The answer to this question depends on the purpose of the network. Atmospheric parameters (e.g. O3 and NO2 columns) measured by the network can be used to:

A) Monitor air quality at the network locations: analyze daily, weekly, and seasonal pollution cycles and detect long term trends.

B) Inform the public about extreme atmospheric conditions: e.g. low total O3 columns causing enhanced solar UV radiation reaching the Earth's surface (causing increased sun burn induced skin cancer conditions), or pollution events (indicated by high levels of NO2 columns or surface O3 concentrations) affecting the air quality.

C) Improve the results of chemical-transport models.

D) Validate satellite data: how do ground- and satellite-data compare at the different locations? Do they show the same trend?

E) Vicarious calibration for satellites: some satellite instruments operate by continuously checking and updating their calibration against ground-based data

We think that the uncertainty requirements are similar for A, C, D, and E and less stringent for B. Reasonable requirements for a minispectrometer network for satellite validation are the following:

- The homogeneity of 10min-averaged network data of total O3 (NO2) columns from non-obstructed (i.e. no cloud in line of sight) direct sun observations for SZA<80° (SZA<85°) should be ±10DU (±0.1DU).
- The calibration drift of the network should be smaller than 2DU (0.05DU) per 10 years for total O3 (NO2) columns.

The second requirement depends on the calibration of the StatREFIs and is not discussed in this document. The term ‘homogeneity’ is explained and defined in section 3.4. Note that when specific numbers are given for an uncertainty expression (accuracy, homogeneity, noise, etc.), they represent the 1-sigma-level (or 1 standard deviation).

2.2 How affected are the instruments by transport?

The answer to this question is especially important when selecting a network instrument. MobREFIs are frequently transported, i.e. dismantled, packed, shipped, unpacked, and mounted at a new location. Each of these processes could affect the hardware, causing calibration changes. Therefore, for MobREFIs it is mandatory to be ‘good travelers’, while for MONIs it is desired. A MONI that is sensitive to transportation can in principle be kept at one site, preferably equipped with a laboratory.

There are two ways to check the calibration of the MONI. Either the MONI is brought to the location of the StatREFI and then returned to its own location, or a MobREFI is brought to the location of the MONI. The former method (i.e. transporting the MONI) is generally done for AERONET [RD3], which consists of >500 stations worldwide. In that case no MobREFIs are needed. The latter method (i.e. moving the MobREFIs) is generally done for the Brewer total ozone network [RD4] with >100 stations worldwide.

Data analysis from a cross section of Pandoras (instruments 3, 16, and 17) was made to validate whether Pandora-like instruments are good travelers, or not. In summer 2011 Pandoras 16 and 17 were participating in a campaign outside GSFC. Pandora 3 remained at GSFC for the entire time, while Pandoras 16 and 17 were transported to other sites for the duration of the campaign. This scenario can be compared to a MobREFI traveling twice to a MONI location. Therefore, we define Pandoras16 and 17 as MobREFI1 and MobREFI2, respectively, and Pandora 3 as MONI1.

The time series of total O3 for MobREFI1 and 2 (brown and green) and MONI1 (red) for selected days before the summer-campaign (02.06.2011 to 04.06.2011) and after the campaign (06.11.2011 to 08.11.2011) are displayed in **Error! Reference source not found.**]. More details are discernible in the corresponding difference plots (MobREFI minus MONI) in **Error! Reference source not found.**]. Although MobREFI2 is slightly biased to MONI (~4DU) this bias remains virtually unchanged at the 2nd visit. MobREFI1 exhibits a change in total O3 of about 2DU as a median value.

The transportation effect on total NO2 for a MobREFI is shown in **Error! Reference source not found.**] and **Error! Reference source not found.**], comparable to **Error! Reference source not found.**] and **Error! Reference source not found.**] from the O3 stability check. The mean difference in NO2 columns between MobREFI and MONI changed for less than 0.01DU between the 1st and 2nd visit.

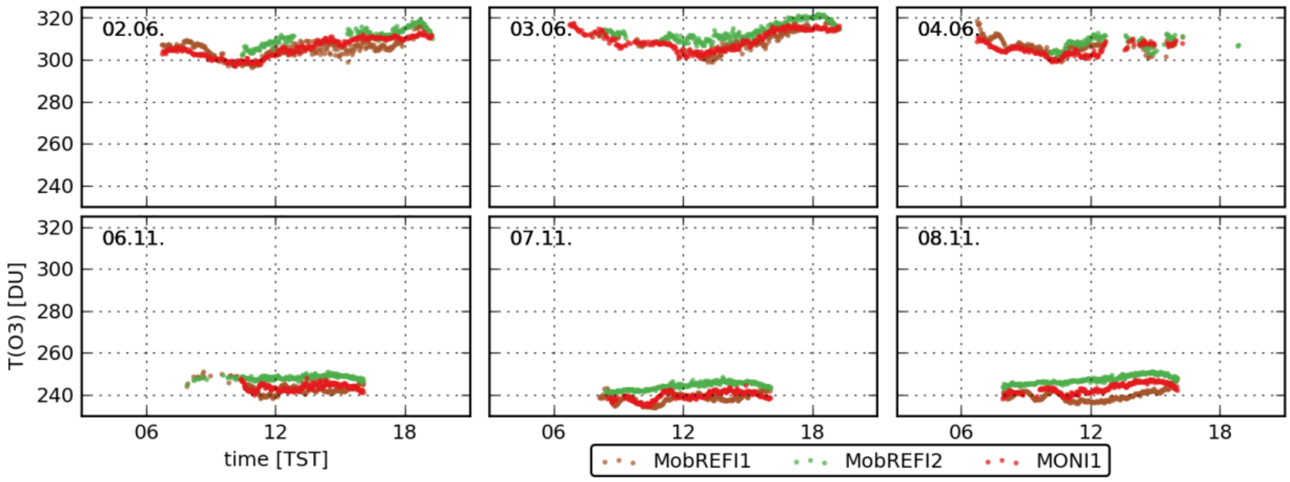

Figure [1]: Total O3 [T(O3)] time series for MONI1 (red), MobREFI1 (brown) and MobREFI2 (green). The top row shows the period before the campaign and the bottom row the period after the campaign.

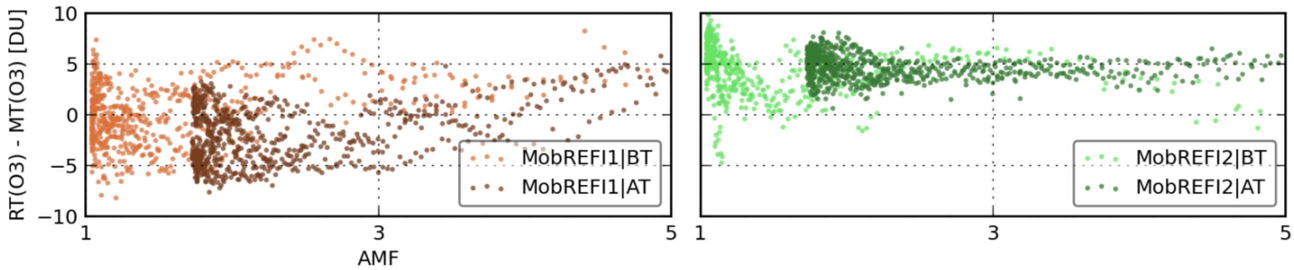

Figure [2]: Total O3 differences MobREFI minus MONI for the period before the campaign (shaded lighter) and after the campaign (shaded darker), as a function of the direct sun air mass factor (AMF). Shown are MobREFI1 (left) and MobREFI2 (right).

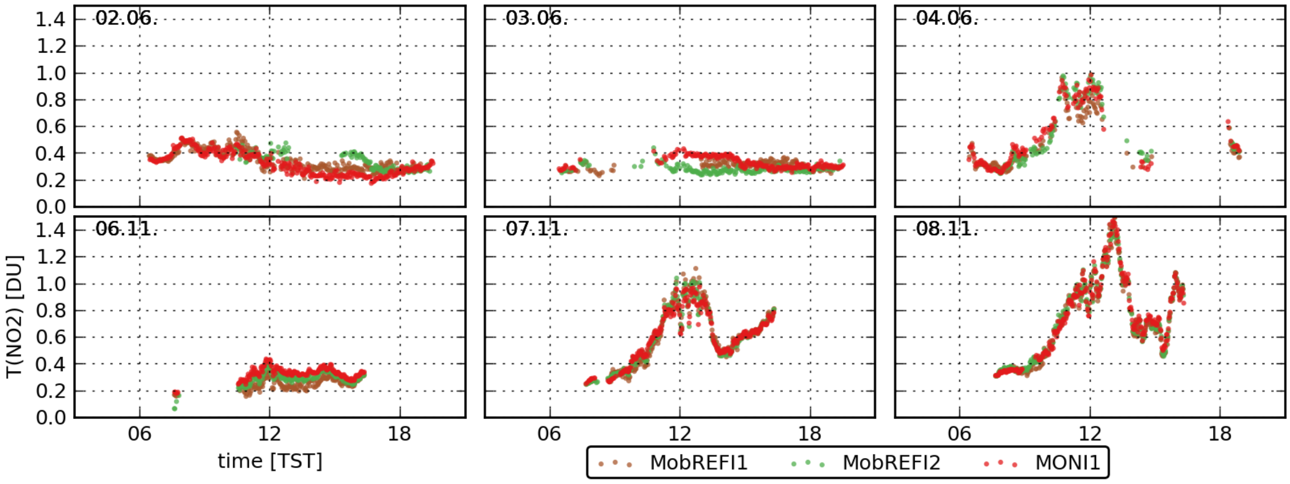

*Figure [3]: Total NO2 time series (compare **Error! Reference source not found.**]).*

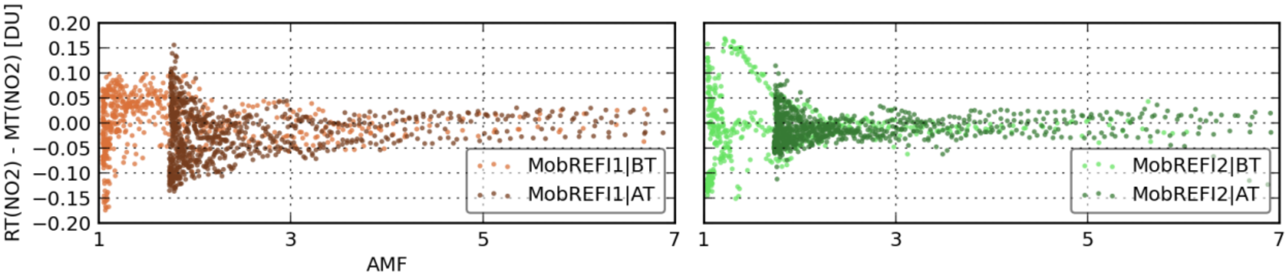

*Figure [4]: Total NO2 differences MobREFI minus MONI (compare **Error! Reference source not found.**]).*

2.3 How stable are the instruments when installed at a fixed location?

The better the stability of a MONI, the less it requires calibration by a MobREFI. Calibration changes in an instrument can occur over time or suddenly. E.g. the transmission of a filter can be altered by chemical processes happening inside the filter material. This process is typically proportional to the accumulated exposure time of the filter, therefore, a gradual change over time. On the other hand, a crack in the fiber optics can produce a sudden change of the instrument's sensitivity.

It is important to note, that a calibration change in an instrument has different consequences for different data products. E.g. a spectrometer might change its radiometric sensitivity, therefore, the retrieved AOD is affected. However, this change might not affect the retrieved trace gas columns, since their algorithm is based on the differential structure of the measured spectra, which has not necessarily changed. Table 1 summarizes possible calibration changes of a spectrometer, how they can be detected, and what should be done once they are detected.

Table 1: Possible instrument calibration changes

Type of calibration change	How to detect it	What needs to be done
Wavelength calibration change	In laboratory or by comparison with solar spectrum	New laboratory calibration & new comparison to MobREFI
Sudden radiometric calibration change	Checking (direct sun) irradiance or AOD for a sudden change	New comparison to MobREFI
Slow radiometric calibration change	In laboratory or by comparison with reference instrument	New comparison to MobREFI

We performed a stability check on three Pandora time series:

1) Pandora 3; GSFC, Maryland, USA; urban site (polluted)
   Feb. 2011 to Oct. 2012; defined as MONI1
2) Pandora 6; Langley, Virginia, USA; rural site (less polluted)
   Jun. 2010 to Apr. 2013; defined as MONI2
3) Pandora 101, CIAI, Spain; remote site (pristine)
   Oct. 2011 to Mar. 2013; defined as MONI3

Following laboratory calibration at GSFC the instruments (MONI2 and MONI3) were transported to their data collection sites. No further calibration was applied thereafter. In order to detect possible drift in Pandora data products, we compared them to an independent, continuous, well-maintained data series. Due to a lack of ground-based reference data, we have chosen OMI as the independent reference as it provides a wider range of temporal and spatial coincidences than other satellite data products considered. Note that in this exercise our goal is to detect a possible change over time between the two different data products, meaning that a constant offset in the data is allowed.

The comparisons of total O3 for MONI1 (red), MONI2 (green), and MONI3 (orange) to OMI are shown in **Error! Reference source not found.**]. Displayed are the differences in total O3 from MONI [MT(O3)] to OMI [OMIT(O3)] over the period August 2010 to May 2013. After proper cloud filtering (MONI retrieval noise <5 DU, OMI cloud fraction <0.2) 60 minute averages of total O3 are interpolated in time to corresponding OMI overpass time. The time-averaging improves the comparison, since it reduces 'instantaneous effects', e.g. a cloud or a localized plume affecting only the ground measurement exactly at the overpass time. Thus we compare the spatially averaged satellite data with temporally averaged ground data.

Characteristic sinusoidal distribution observable in the data course is attributed to O3 effective temperatures used in each retrieval algorithm. The OMI algorithm corrects for seasonal and latitudinal variations in atmospheric temperatures [RD5], whereas, Pandora utilizes a constant effective O3 temperature [RD6]. Apart from the slightly biased MONI3 (median deviation of approximately 9 DU), the overall agreement to OMI is excellent, showing no obvious drift between data sets for more than two and a half years. Without making a detailed quantitative trend analysis, which would include removing the seasonal difference in the data sets, we claim conservatively that a possible drift in the Pandora O3 columns is <3DU per 2 years.

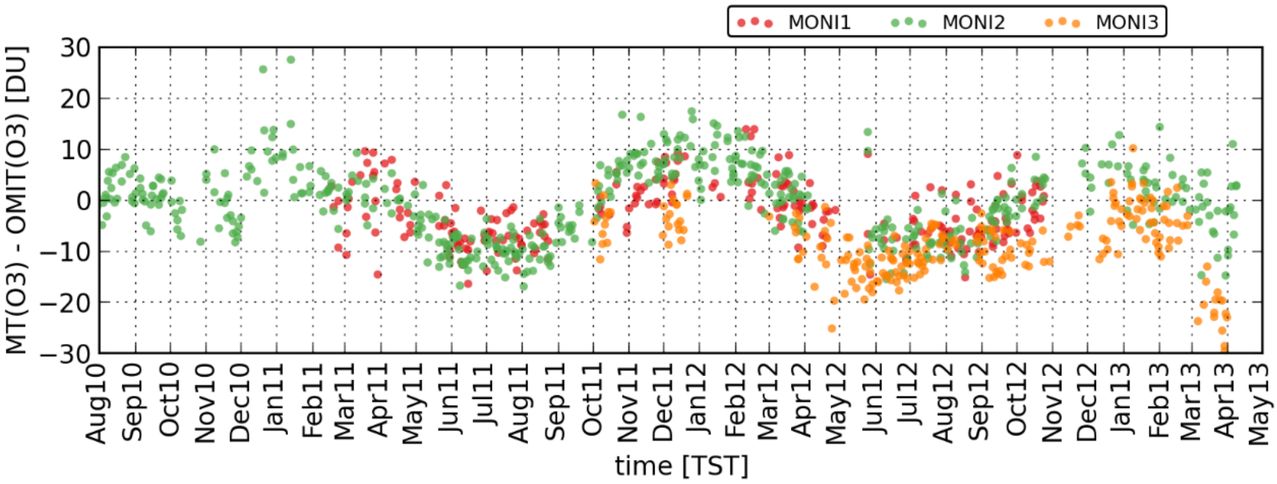

Figure [5]: Total O3 differences for (stationary, un-interrupted, one-time calibrated) MONI 1 (red), MONI2 (green) and MONI3 (orange) [MT(O3)] to the satellite product retrieved from OMI [OMIT(O3)].

The comparison for total NO2 is carried out in a similar manner as for total O3 (using cloud filtering of <0.005 DU retrieval noise for MONIs). Due to higher spatiotemporal variability of NO2, 20 minute averages of Pandora total NO2 data are used. As shown in f**Error! Reference source not found.**] (color mapping as in **Error! Reference source not found.**]) data stability is reasonably good. Except for MONI1 the deviations to OMI are <±0.2 DU over the entire period. Increased disagreement for MONI1 can be explained knowing that GSFC is located in an urban environment. This causes the 'point-measurements' from the ground-based instruments to often substantially exceed the satellite product, which is an average over an extended region.

We did not make a detailed quantitative trend analysis for the data in figure 6. We claim conservatively that a possible drift in the Pandora NO2 columns is <0.05DU per 2 years.

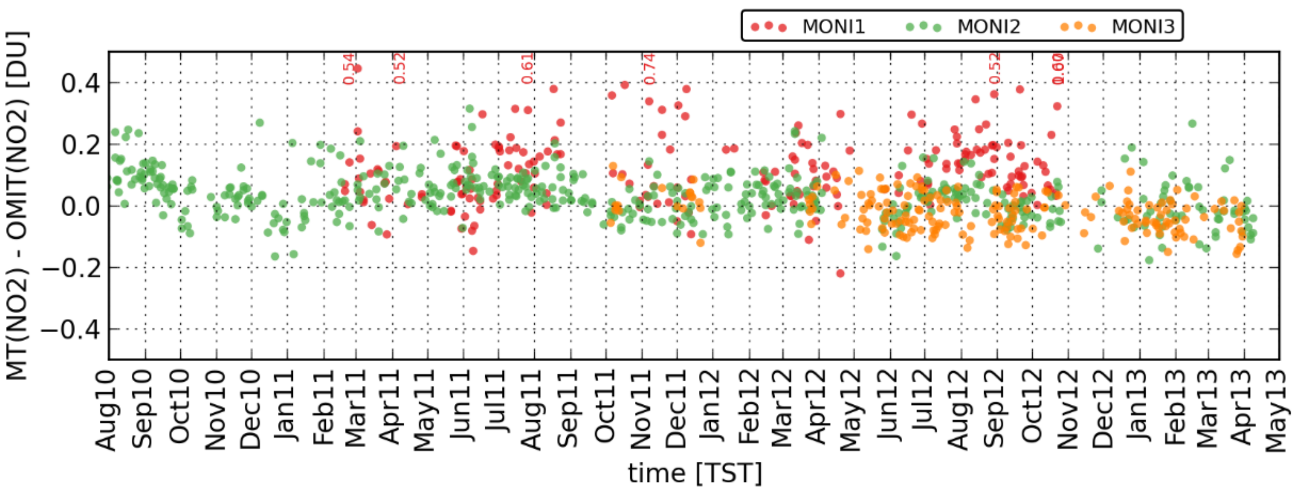

Figure [6]: Total NO2 differences for MONIs to OMI (compare **Error! Reference source**

not found.*]). Outliers are written out in the corresponding color.*

3 Uncertainties of minispectrometer network data

Here we give an overview of the uncertainties involved in a minispectrometer network, again applied to Pandora-like minispectrometers. We assume the network focuses on producing total O3 and total NO2 columns for satellite validation with uncertainty requirements as listed in section 2.1. The numbers given in this section refer to total O3 and NO2 columns with the number for NO2 in parenthesis.

To estimate the uncertainty of a measurement is one of the most difficult tasks in science. The total uncertainty of a data product is made up of different contributions. The following sections group these uncertainty contributions in a convenient way for our case, i.e. remote sensing measurements of atmospheric parameters by minispectrometers.

3.1 Noise

We define noise as the purely statistical measurement-to-measurement variation of the spectrometer-signal around a mean value. In our case the noise is a combination of photon noise and read noise. At high light intensity (e.g. direct sun observations) the photon noise is dominant. As light intensity drops, the contribution of the read noise increases, becoming dominant in low light intensity situations (e.g. direct sun observations in the UV at high SZA; sky radiance measurements at high SZA or with cloud cover). Since minispectrometers have smaller optical components than regular spectrometers, they capture less light, thus increasing photon noise. In addition, they are often equipped with non-cooled detectors thus enhancing the read noise. Therefore, minispectrometers have reduced capability for low light observations, compared to regular spectrometers. E.g. minispectrometers are in general not useful for zenith sky observations during twilight.

For satellite validation of O3 and NO2 columns noise is usually not a limiting factor. First, most satellites have a near-noontime overpass (so low SZA in most cases). Second, the ground-data can be (and should be, see section 2.3) averaged over a certain time period around the overpass time, which reduces noise. An exception is for high latitude and/or winter time observations, where the SZA at the satellite overpass time can be large.

The noise of Pandora (non-obstructed) direct sun observations in the required SZA-range is well below 1DU (0.01DU) for single measurements of 40s duration. For 10min averages, it can basically be neglected in the total uncertainty budget.

3.2 Permanent systematic effects

Every measurement ‘suffers’ from systematic effects, which produce results deviating from those taken by an ‘ideal’ instrument. Those systematic effects present for each measurement at any time and any location are defined as ‘permanent systematic effects’. If it is possible to fully characterize the effect, it should be corrected in the data processing. In that case, the uncertainty associated with this effect is greatly reduced, leaving a ‘residual’ uncertainty due to imperfections in the correction process. E.g. a spectrometer might have a non-linear response that underestimates the measured signal by 5% whenever the counts are close to the saturation point (see e.g. figure 1 of [RD7]). Therefore, a non-linearity correction is applied. This correction is usually determined in the laboratory to better than 0.1% 'residual uncertainty' in the measured signal. Furthermore, proper field calibration reduces the impact of these effects even more, rendering the uncertainty in the retrieved O3 and NO2 column minimal.

If no correction for a permanent systematic effect has yet been developed, the data will be flagged or filtered accordingly. E.g. spectral stray light occurring in all single monochromators (such as Pandora) reduces the retrieved total O3 columns for high SZA (see e.g. figure 5 of [RD7]). Therefore, Pandora O3 columns taken at SZA>80° will be flagged. All other systematic effects of Pandora are corrected in the processing algorithm, based on characterization in laboratory and field.

3.3 Temporary systematic effects

In contrast to the previous group, these effects are not present for each measurement at any time and any location. They 'come and go' and are most likely triggered by an external event. It is usually rather difficult to correct for these temporary systematic effects, since it is hard to reproduce and characterize them. E.g. the readout electronics of minispectrometers (and also Pandora) often do not produce a constant dark count over time. Therefore, periodic dark count measurements have to be made, possibly a dark count measurement together with each 'light measurement' at the same exposure time. Even then it is possible that the measured dark count and the dark count included in the light measurement differ. This difference is minimal overall, however, becomes important at low light observations (i.e. can produce a systematic effect). For required direct sun observations in the given SZA range this dark variation is negligible.

Pandoras also frequently show a spectral signal in the data, which impacts retrievals (see section 3.3 of [RD7]). The influence of this effect on 10min averaged data is estimated to ±5DU (±0.07DU). Especially for NO2 this is a major contribution to the uncertainty budget. The characteristic time of this effect is minutes to hours, i.e. the spectral signal appears for a few minutes or even up to 3 hours before it disappears again. Since it is not permanent, the impact of this effect is greatly reduced in daily or multi-day averages. We are currently characterizing this effect, in an effort to reduce its impact through changes in both hardware and software.

Another temporary systematic effect seen in Pandora is enhanced scatter in the measured total NO2 columns for some instrument's data in a few occasions (see section 3.3 of [RD7]). We are currently developing a method to flag these data.

3.4 Accuracy

In principle, accuracy reflects the difference between the measured value and the true value. One part of this 'difference to the truth' comes from measurement uncertainties like those listed above. Another part comes from 'algorithm deficiencies'. Assume we have several network instruments located at the same site. They will all retrieve somewhat different data, since the instrumental uncertainties are individual for each spectrometer. However, even if all of them were ideal instruments, free of uncertainties, and all give basically the same value, it still does not mean that this is the true amount. Errors in the cross sections, effective gas temperature, etc. are still included and affect all units in approximately the same way.

In order to produce homogeneous data in the network, we do not really have to focus on the algorithm deficiencies. What we want is that all MONIs measure in the same way, i.e. if they were installed at the same place, they should all produce the same data. We call this ‘homogeneity’. Of course the closer the data are to the true value the better. The accuracy of the network is determined by the StatREFIs. Therefore, great care has to be taken to maintain their calibration over time. This is done through periodic checks of the StatREFIs in both field and laboratory settings.

Note that the data analyzed in this project are not calibrated in the way recommended in this document. Instead, so-called ‘Modified Langley Extrapolation’ is used for each individual instrument [RD8]. Therefore, the data will be less homogeneous than in a proper network operation.

It is beyond the scope of this report to define how the absolute calibration of a StatREFI should be obtained and maintained, nor to estimate the accuracy of the retrieved trace gas columns. Here we assume that the data from the StatREFIs are the absolute reference for the network.

3.5 Calibration transfer uncertainty

While the above uncertainty groups refer to uncertainties in measurement and algorithm, the ‘calibration transfer uncertainty’ and all remaining groups reference post-processing of the data.

During regular network operation, calibration is transferred from the StatREFI to a MobREFI. In principle this could be done with one simultaneously measured column amount. Note that in order to reduce noise and the impact of temporary systematic effects, inter-comparisons of StatREFIs and MobREFIs should include at least five clear sky days. The same is true for the calibration transfer from a MobREFI to a MONI.

We claim that if calibration transfers (StatREFI to MobREFI and MobREFI to MONI) are performed utilizing the recommended methodology over several clear sky days, the estimated ‘transfer uncertainty’ is not more than ±0.5DU (±0.005DU). Given that calibration transfers are done twice, total calibration transfer uncertainty rises to ±0.7DU (±0.007DU).

3.6 Transport uncertainty

The moment to detect a calibration change for a transported MobREFI is when it returns to the location of the StatREFI. In section 2.2, we saw transfer effects of 2DU (0.01DU). In this case, a ‘transport uncertainty’ should be applied to the data of the recently checked MONI. We recommend that the magnitude of the transport uncertainty should equal the change in the MobREFI, i.e. ±2DU (±0.01DU) in our case, as we do not know exactly when the change occured.

3.7 Drift correction uncertainty

In order to detect trends in the quantity of atmospheric species, the network data should not drift over time. For this reason the MONIs are periodically visited by a MobREFI which transfers the (drift-free) calibration standard, given by the StatREFIs. If a drift of a MONI is detected, its data will be post-processed and corrected. From section 2.3 we conclude that the drift of a properly maintained Pandora is <3DU (<0.05DU) over two years.

If a drift is detected, data from the previous period will be corrected accordingly, possibly in a linear way. However, the real temporal calibration change has not necessarily happened linearly, therefore, a 'drift correction uncertainty' is introduced. This uncertainty is dependent on the difference between the true evolution of the unit and the one assumed in the correction, thus significantly smaller than the drift itself. Our estimation of drift uncertainty is one fifth of the drift as one-sigma level, i.e. ±0.6DU (±0.01DU).

3.8 Uncertainty summary

Table 2 summarizes all uncertainty contributions for 10min averaged data as listed in the requirements. The accuracy is not included for reasons previously explained. The combination of all uncertainty groups is called homogeneity. We assume all uncertainty contributions to be uncorrelated. At present, homogeneity is driven by the temporary systematic effects (see row with red background), specifically by the additional spectral signal in the data. Currently our main goal is to reduce the occurrence and impact of this effect.

We can see that the drift correction uncertainty, calculated for a two years cycle of intercomparisons between the MONI and the MobREFI, is small. Thus, indicating that an even longer data period might be usable.

Table 2: Summary of all uncertainty contributions. Numbers are in DU and refer to 10min averages of un-obstructed direct sun observations for SZA<80° and SZA<85° for O3 and NO2, respectively.

Uncertainty contribution	O3	NO2	Remark
Noise	0.2	0.002	Estimated for 10min averages
Permanent systematic effects	0.3	0.001	Stray light error not included, as it applies to SZA outside the required range
Temporary systematic effects	5.0	0.07	Caused by additional spectral signal
Calibration transfer uncertainty	0.7	0.007	Includes both transfers
Transport uncertainty	2.0	0.01	Based on section 2.2
Drift correction uncertainty	0.6	0.01	Based on section 2.3
Homogeneity	5.5	0.072	= combination of all uncertainties, assuming no correlation

4 Specific recommendations for Inter-Calibration of minispectrometer networks

Based on the results of sections 2 and 3, our recommendations for a network calibration strategy for 'Pandora-like' minispectrometer networks are the following:

- Our preferred intercomparison method is that a MobREFI periodically visits a MONI, as the main goal of the network is to provide long, un-interrupted data series of atmospheric parameters.
- MONIs shall only be transported if laboratory calibration is required and no proper laboratory is present at the operation site.
- The network shall have at least one, but preferably two and ideally three StatREFIs. They shall be located at a pristine site (e.g. CIAI), where field calibration techniques can be applied with greater success than in polluted environments.
- In addition to StatREFIs, the network shall have a number of MobREFIs, dependent on the size of the network.
- In order to minimize the influence of temporary systematic effects, calibration transfers from the StatREFIs to a MobREFI and from a MobREFI to a MONI shall include at least five clear sky days. Therefore, we recommend an average time for the intercomparison between a MobREFI and a MONI of two weeks. Weather conditions can increase or reduce the number of days needed.
- Allowing for travel time and intercomparison to StatREFIs, it is possible that one MobREFI checks the calibration status of 10-15 MONIs per year.
- The results of this analysis have shown that a rotation of every two years calibration of a MONI by a MobREFI is enough for total O3 and NO2 columns. Therefore, the approximate number of MobREFIs needed for the entire network is ceil(n/25), where n is the number of MONIs.
- If the personnel at the monitoring site are well trained, a MobREFI can be sent by mail to the monitoring site, installed, operated by local operators, and then returned by mail. If the local operators are not adequately trained, the MobREFI shall be brought, installed, operated, and returned by network operators.