LuftBlick Report 2014003

ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study

Instrument System Requirements Document
Network System Requirements Document
Instrument Locations and Validation Strategy plan

	Name	Company	Date
prepared by	Alexander Cede	LuftBlick	9 Sep 2014
checked by	Katherine Cede	LuftBlick	9 Sep 2014
approved by			

Contents

Document Change Record

Issue	Date	Page	Observations
0.1	5 May 2014	All	First draft version
1.0	15 May 2014	All	Correct typos
1.1	9 Sep 2014	All	Apply modifications based on ESA-review

Acronyms and Abbreviations

NO_2	Nitrogen dioxide
O_3	Ozone
DU	Dobson Units
EarthCARE	ESA's Cloud, Aerosol and Radiation Mission
ESA	European Space Agency
FOV	Field of view
HTTP	Hypertext Transfer Protocol
OMI	Ozone Monitoring Instrument
Pandonia	ESA Ground-Based Air-Quality Spectrometer Validation Network
Pandora	Pandora spectrometer system
Pandora-2S	Pandora dual spectrometer system
S5P	Sentinel 5 Precursor Mission
SFTP	SSH File Transfer Protocol
SNI	Selected network instrument
SoW	Statement of Work
SpecAOD	Spectral aerosol optical depth over the entire range 300-900nm
SSH	Secure shell
TC	Temperature controller
$TotNO_2$	Total nitrogen dioxide column
$TotO_3$	Total ozone column
$TropNO_2$	Tropospheric nitrogen dioxide column
$TropO_3$	Tropospheric ozone column
VAT	Value Added Tax

1 Introduction

This report is combining deliverables D02 (section 2), D04 (section 3), and D05 (section 4) of the ESA Ground-Based Air-Quality Spectrometer Validation Network (Pandonia) project [2, 1]. Many parts of this report were already addressed in the project proposal [1]. Here we summarize, update, and complete these findings.

1.1 Applicable Documents

[1] Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study [Proposal], LuftBlick Proposal 201309A, Issue 2, 2013.

[2] ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study [Statement of Work], ENVI-SPPA-EOPG-SW-13-0003, Issue 1, Revision 3, 2013.

1.2 Reference Documents

[3] A. Cede and M. Tiefengraber. Inter-calibration of ground-based spectrometers and Lidars – Minispectrometer Intercalibration and Satellite Validation, LuftBlick Report 2013002: Recommendations for Inter-Calibration of minispectrometer networks, 2013.

[4] A. Cede and M. Tiefengraber. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2014008: Network Design - Development Document, 2014.

[5] G. Pinardi et al. MAX-DOAS formaldehyde slant column measurements during CINDI: intercomparison and analysis improvement. *Atmospheric Measurement Techniques*, 6(1), 2013.

[6] A. J. Reed, A. M. Thompson, D. E. Kollonige, D. K. Martins, M. A. Tzortziou, J. R. Herman, T. A. Berkoff, N. K. Abuhassan, and A. Cede. Effects of local meteorology and aerosols on ozone and nitrogen dioxide retrievals from OMI and pandora spectrometers in Maryland, USA during DISCOVER-AQ 2011. *Journal of Atmospheric Chemistry*, pages 1–28, 2013.

[7] H. K. Roscoe et al. Intercomparison of slant column measurements of NO_2 and O_4 by MAX-DOAS and zenith-sky UV and visible spectrometers. *Atmospheric Measurement Techniques Discussions*, 3(4): 3383–3423, 2010.

[8] M. Schwärz and A. Cede. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2014002: Pandonia Network Web Site Technical Baseline and Architectural Design Document (ADD), 2014.

[9] M. Tzortziou, 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. *Journal of Geophysical Research (Atmospheres)*, 117:D16303, August 2012. doi: 10.1029/2012JD017814.

[10] M. Tzortziou, J. R. Herman, A. Cede, C. P. Loughner, N. Abuhassan, and S. Naik. Spatial and temporal variability of ozone and nitrogen dioxide over a major urban estuarine ecosystem. *Journal of Atmospheric Chemistry*, pages 1–23, 2013. ISSN 0167-7764. doi: 10.1007/s10874-013-9255-8. URL `http://dx.doi.org/10.1007/s10874-013-9255-8`.

[11] S. Wang, T. J. Pongetti, S. P. Sander, E. Spinei, G. H. Mount, A. Cede, and J. Herman. Direct Sun measurements of NO_2 column abundances from Table Mountain, California: Intercomparison of low-and high-resolution spectrometers. *Journal of Geophysical Research (Atmospheres)*, 115(D13), 2010.

2 Instrument system requirements

This section is a summary and update of sections 2.3 to 2.5 of the proposal [1] in response to the requirements outlined in the statement of work (SoW) [2].

2.1 Instrument requirements from the SoW

The selected network instrument (SNI) must be capable to measure the following atmospheric parameters below given uncertainty limits.

- Total ozone column ($TotO_3$) within ±3 %
- Tropospheric ozone column ($TropO_3$) within ±25 %
- Total nitrogen dioxide column ($TotNO_2$) within ±0.05 DU
- Tropospheric nitrogen dioxide column ($TropNO_2$) within ±0.05 DU
- Spectral aerosol optical depth over the entire range 300-900nm (SpecAOD) within ±0.05

In addition to the measurement requirements, the SNI shall meet the following cost criteria.

- The costs for one unit shall not exceed 40.000 Euro (excluding VAT).
- The costs for operation, maintenance, and calibration of one unit within the network (excluding the costs for a local operator) shall not exceed 5.000 Euro per year.

2.2 Pandora-2S capabilities

The Pandora spectrometer system (Pandora) has proven to be able to provide accurate $TotO_3$ and $TotNO_2$ [9, 10, 6, 11] and meets the uncertainty goals listed in section 2.1 for these products. As explained by *Cede and Tiefengraber* [3], the uncertainty in derived $TropO_3$ and $TropNO_2$ depends on both, the uncertainty in the slant columns from the sky radiance measurements and the uncertainty in the profile algorithm. Pandora has also proven, that it is not limited in the uncertainty of the derived slant columns [7, 5].

This means that the only data product not entirely covered by Pandora is SpecAOD. Therefore the Pandora dual spectrometer system (Pandora-2S) is being developed within this project, as an evolution of the existing Pandora. Pandora-2S will contain two spectrometers, capable of covering the full wavelength range up to 900 nm. In order to stay below the limits for the instrument costs, LuftBlick will use only one telescope and tracking system for both spectrometers.

To achieve the low costs for operation, maintenance, and calibration, LuftBlick plans on operating all network instruments from a central server by a Pandonia central network operator. Routine maintenance (checking of the instrument, cleaning of the optics, plus responding to tasks given by the central network operator) is performed by local operators. Routine calibration, based on the instrument's own data, is also done remotely by the central network operator. Special calibration, e.g. intercomparisons, visits by reference instruments, laboratory calibration, and maintenance of damaged hardware will be done by LuftBlick personnel.

3 Network system requirements

This section lists the logistical requirements for a network location. Topographic considerations are discussed in section 4.

3.1 Space requirements

Figure 1 shows images of a Pandora installed on an observation platform. The head sensor with the collimator is fixed on a tracker, which is on top of a metal shaft coming from a base plate. The dimensions are:

- Diameter of base plate: 24 cm
- Distance from bottom of base plate to top of collimator, when instrument is looking to the zenith (horizon): 66 cm (41 cm)
- Radius of circle drawn by the head sensor when looking at zenith (horizon): 13 cm (33 cm)

One can say that Pandora's (or Pandora-2S's) outside pieces (head sensor and tracker) need about 1 m^2 space. The instrument base plate must be mounted on a stable surface. Soft surfaces (e.g. grass) or surfaces that change with temperature (like some metallic roofs) cannot be used.

Figure 1: Images of Pandora from the side (left panel) and from top (right panel).

A fiber optics cable connects the outside part of Pandora to the Pandora box, which is shown in figure 2. The Pandora box contains the spectrometer box, interfaces, temperature controller, etc. and will be the same one for Pandora-2S.

The Pandora box can be located outside (as in figure 3) or inside a room. In the former case the box must be covered with reflective material so that the temperature in the box does not raise too high. The space needed for the Pandora box is also about 1 m^2.

The attenuation of the fiber at 300 nm is about 100 dB/km, which means the signal is reduced by about 20 % for each 10 m of fiber length. For larger wavelengths the attenuation is smaller. Therefore we recommend to use fiber lengths above 10 m only if really necessary.

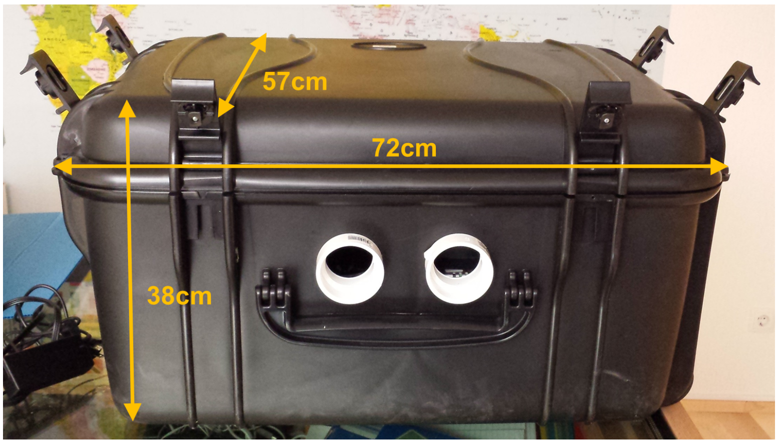

Figure 2: Dimensions of Pandora box

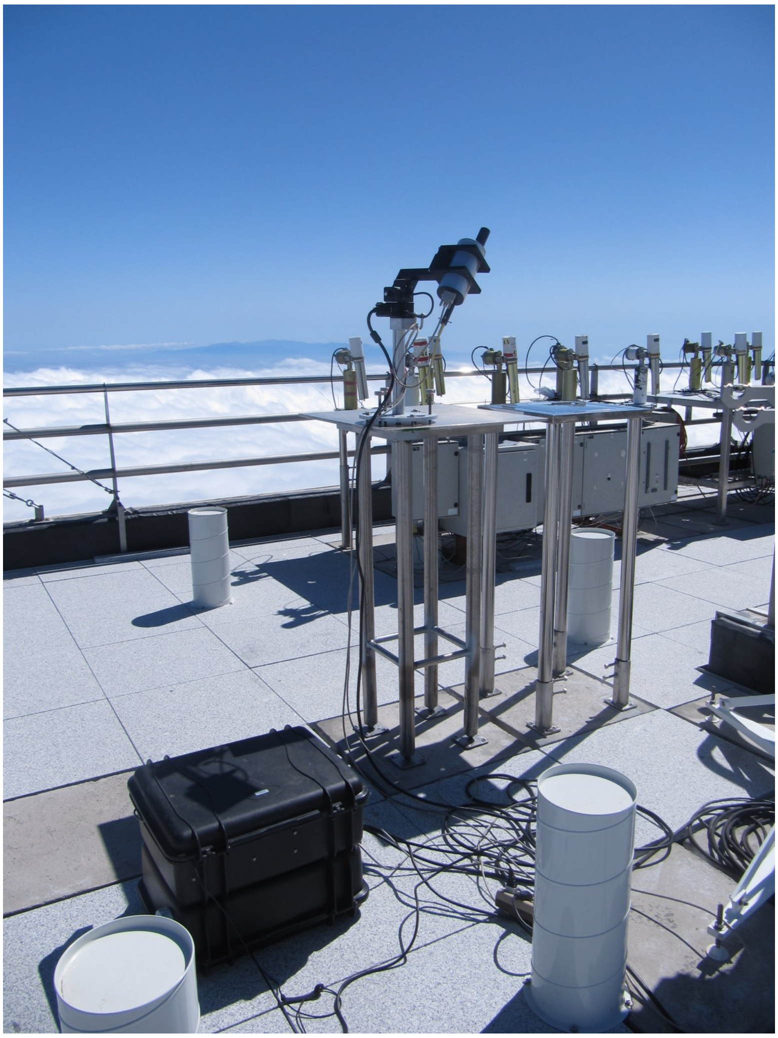

Figure 3: Image of Pandora with the spectrometer box (in black) nearby. Note that when the Pandora box is outside during monitoring, it is covered with an aluminum foil blanket (or space blanket), which is not shown here.

3.2 Power and connectivity

The power needs of Pandora are driven by the Temperature controller (TC). The power consumption is typically 95 W and maximum 125 W. 'Maximum' refers to the maximum draw of the TC. 'Typical' refers to the draw for outside deployment of the Pandora box on a hot day. The power consumption on a cool day is significantly lower. For Pandora-2S there are these options:

- Pandora-2S uses the same TC as Pandora: The power consumption does not change, i.e. typical 95 W and maximum 125 W.
- Pandora-2S uses two of the same TCs: The power consumption will be typical 175 W and maximum 245 W.
- Pandora-2S uses the a bigger TC (currently being tested): The power consumption will be 180 W and maximum 220 W.

Inside the spectrometer box is the laptop operating Pandora. This computer has to be on a stable Internet connection, since the remote instrument control and the data upload are done through the web [8].

Internet connectivity must be given through either local ethernet port (preferred option) or WiFi. The local network firewall configuration must allow in/out traffic on SSH/SFTP (port 22, alternatively 115) and outgoing HTTP (port 80).

Note that if there is no Internet connection or if the Internet is temporarily unavailable, Pandora will operate just fine without data upload. All data will then be sent to the server once the connection is established.

3.3 Local support

All Pandonia locations must offer local support, which is not financially supported by the project. Local support means that local personnel acts as station operators with these duties:

- Physically check the instrument at least once per week. Look for damages and clean it if necessary.
- Make sure that power and Internet connectivity are functional.
- Communicate all observations to the network operator.
- Respond to inquiries from the network operator.
- Assist LuftBlick personnel during their visits at the stations for installation, maintenance or calibration.

4 Instrument locations and validation strategy

The logistical requirements for a network location described in section 3 are mandatory. Apart from these requirements there are also additional criteria that determine a potential station's inclusion in Pandonia. Those criteria are discussed in this section. A proposal of locations for Pandoniam which is based on the findings of this section, is given in *Cede and Tiefengraber* [4].

4.1 Satellite validation

Pandonia's main purpose is to validate data products from the Sentinel 5 Precursor Mission (S5P) and ESA's Cloud, Aerosol and Radiation Mission (EarthCARE). Both satellite missions are focused on air quality, aerosols, and clouds in the Troposphere (0-15 km height), which is different from previous European Space Agency (ESA) atmospheric chemistry missions, that had a strong focus on ozone (O_3) chemistry in the stratosphere (10-50 km height). Tropospheric O_3 and nitrogen dioxide (NO_2) are highly variable in time and space, which makes their validation even harder.

We argue that from the viewpoint of satellite validation, an optimal site would be located at a place with 'varied pollution conditions' over the year. It should have days of low or moderate pollution in the extended area ($\pm$20 km), where the difference in the field of view (FOV) between the ground- and the satellite-instrument is not so critical. On the other hand there should be days with elevated pollution, where the possibility to track 'pollution events' from the satellite can be tested. Such sites are typically at a rural place near a city. Depending on the season and wind direction, the different conditions can be given.

4.2 Air quality monitoring

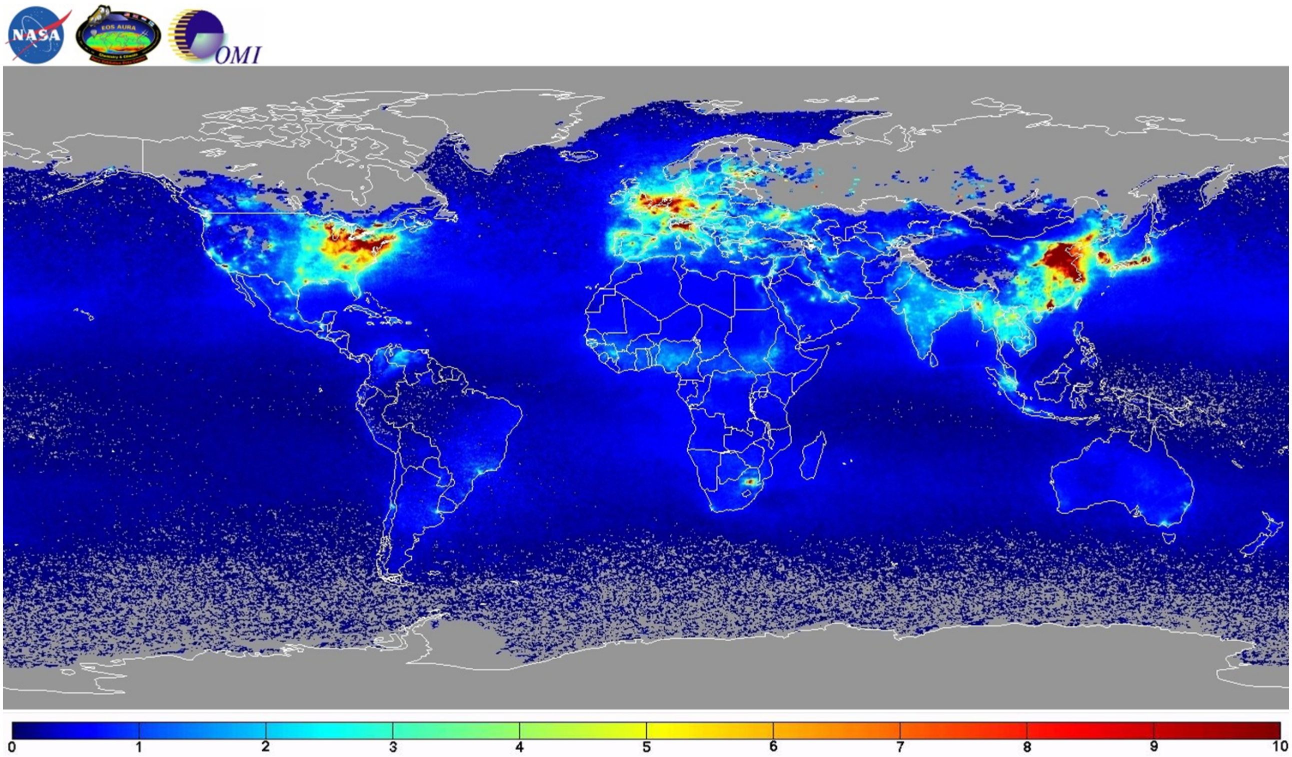

Figure 4: Average TropNO_2 for March 2014 retrieved from the Ozone Monitoring Instrument (OMI). Values are in 1e15 molecules/cm^2. Taken from `http://avdc.gsfc.nasa.gov/index.php?site=705441739`.

All Pandonia data products are directly related to air pollution (see e.g. `http://www.epa.gov/airquality/urbanair/`). TropNO_2 is often used as a general indicator of pollution. Its global distribution for March 2014 can be seen in figure 4.

From the viewpoint of air quality monitoring we consider the best locations to be in moderately or highly polluted regions. That is usually inside or nearby a city (red colors in figure 4), i.e. sites with characteristics described in section 4.1 are also suitable.

4.3 Auxiliary measurements

Another criteria for the selection of a Pandonia location is the availability of auxiliary measurements. The more data products measured at the station, as listed below, the more useful is it to have a Pandora-2S installed.

- Meteorological data such as temperature, humidity, pressure, wind speed etc.
- Similar data products as Pandonia, especially SpecAOD or AOD at selected channels inside the Pandora-2S wavelength range
- Atmospheric profiles of temperature, pressure, humidity, O_3, NO_2, aerosols, etc. from sondes, Lidars, or other remote sensing instrumentation
- Surface concentrations of O_3, NO_2, other trace gases, or aerosols