Atmospheric Composition Constellation Meeting (ACC-11)
2015-4-29, ESA/ESRIN, Frascati, Italy

Pandonia ground based network

Alexander Cede, Bojan Bojkov

What is Pandonia?

Pandonia is a planned ground-based remote sensing network for air pollution monitoring and satellite validation.

MOTIVATION:

Long, uninterrupted, well-maintained, homogeneously calibrated time-series of ground-based remote sensing atmospheric ozone measurements have been and still are the **backbone for the validation** of ozone columns measured from satellite (e.g. TOMS, OMI). There is no comparable network for other satellite-derived trace gas measurements (e.g. NO_2).

GOAL:

Start building such a self-standing calibrated network for satellite validation using Pandora-2S and Pandora as core instruments for

- O_3 and NO_2, total and tropospheric columns, profiles
- Spectral AOD from 340 to 900nm
- SO_2, HCHO, H_2O, and BrO total columns
- Effective O_3 and NO_2 temperature

Why does ESA fund Pandonia?

ESA wants Pandonia to be a key element in the validation of the existing and upcoming satellite missions listed in the table.

Mission	Launch	Instrument	Products (gray=not measured by Pandonia)
Upcoming ESA missions			
EarthCARE	2015	MSI	Aerosol, Clouds
ADM-Aeolus	2015	ALADIN	Aerosol, Clouds
Sentinel 3A	Late 2015	MWR, OLCIS, LSTR	Aerosol, H_2O
Sentinel 5P	2016	TROPOMI	O_3, NO_2, SO_2, HCHO, Aerosol, Clouds, CO, CH_4
Sentinel 3B	Early 2017	MWR, OLCIS, LSTR	Aerosol, H_2O
Sentinel 4	2021?	UVN	O_3, NO_2, SO_2, HCHO, Aerosol
Sentinel 5	2021?	UVNS	O_3, NO_2, SO_2, HCHO, Aerosol, Clouds, CO, CH_4
Third party missions in orbit			
AQUA	1999	MODIS	Aerosol
TERRA	2002	MODIS	Aerosol
AURA	2004	OMI	O_3, NO_2, SO_2, HCHO, BrO, Aerosol

What is Pandora?

Spectrometer system for direct sun, sky radiance and direct moon measurements with standard wavelength range: 270-530nm, 0.6nm resolution

Why direct sun?

→ Measuring direct sun is much harder than measuring sky radiance (pointing, effects of quasi-parallel beam).
→ More than 90% of the development time for Pandora was "consumed by direct sun"

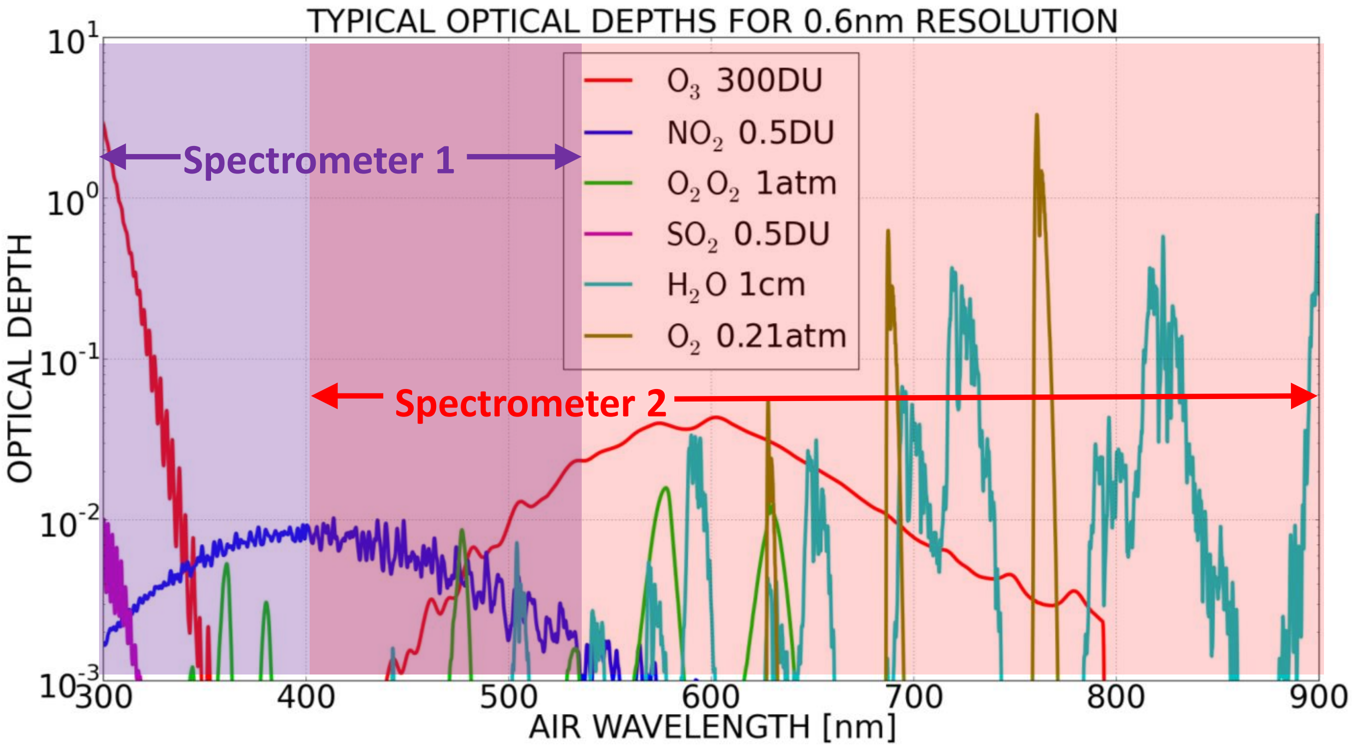
However we think that these benefits are worth it:

- The retrieval uncertainty for total columns is greatly reduced due to the accurate calculation of the air mass factor. This also allows to use an external reference spectrum (which is done for Pandora ozone retrievals!).

- The direct sun mode gives you an absolute positioning reference frame and therefore high pointing accuracy ($2\sigma<0.1°$).

From Pandora to Pandora-2S

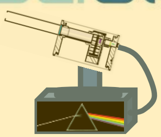
- One tracker, one head sensor (with two separate optics), two optical fibers, two spectrometers in one large temperature controller
- Spectrometer 1: 270 to 530nm , 0.12nm step, 0.6nm resolution
- Spectrometer 2: 400 to 900nm , 0.24nm step, 1.1nm resolution
- This evolution model is based on ESA-requirements for EarthCARE as well as the atmospheric products from the Sentinels 5P, 4, and 5



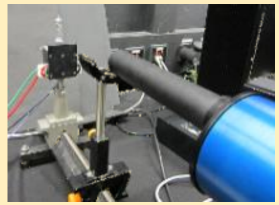
Pandonia calibration method

GOAL: Network instruments should not have data interruptions!

New instrument
SciGlob

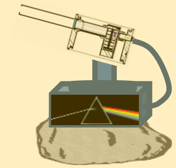


Or existing instrument



Laboratories
Innsbruck
SciGlob (Ellicott City)
NASA/GSFC (?)

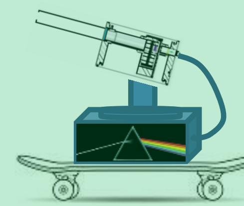
Permanent network location



Langley extrapolations; Comparisons with other instrumentations and models

Stationary references
Izaña, Tenerife
Brewer triad (O_3 auxil)
Pandora triad

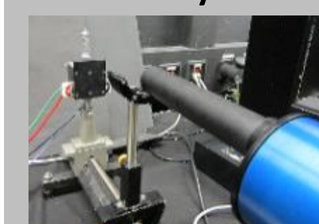
Mobile references



Transport calibration to network Pandoras; at least 1 mobile reference unit per 25 monitoring sites

Field calibration tool

Laboratory Izaña



Pandonia calibration method

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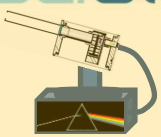

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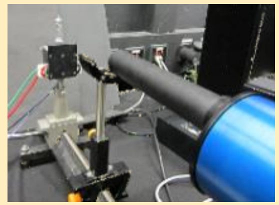

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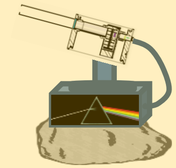

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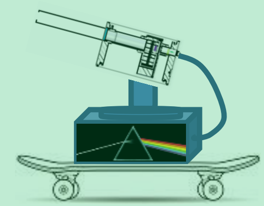

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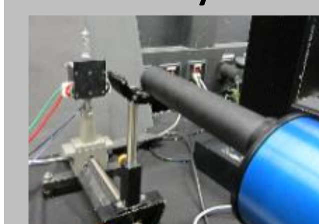


Working towards traceability to NMIs!

Pandonia data processing

LOCAL OPERATOR
Routine maintenance
Trouble shooting in coordination with network operator
Optionally local data processing

NETWORK OPERATOR
Remote trouble shooting
Trouble shooting in coordination with network operator

INSTRUMENT HOST COMPUTER
Saves raw (L0) data
Data transfer to SERVER
Initial trouble shooting

PANDONIA CENTRAL SERVICE AT LUFTBLICK
Checks/archives incoming (L0) data
Runs automated processing chain
Automated QA and remote monitoring
L0/L1/L2 data base
Data download
Data display

NASA SITE, AVDC (?)
Processing copy
Mirror and backup

Calibration data

L0 to L1
Dark correction
Non-linearity correction
Latency correction
Flat field correction
Conversion to count rates
Temperature correction
Stray light correction
Wavl. change determination
Filter correction
Conversion to (ir)radiances
Wavelength correction

L1 to L2
Spectral fitting
Total column algorithms
AOD algorithms
Profile algorithms

Pandora during DISCOVER-AQ

4 campaigns with more than 10 Pandoras deployed each time. From a "Pandora-perspective" DISCOVER-AQ had benefits and disadvantages:

BENEFITS

- We received funding!
- We improved significantly our knowledge of how to best calibrate Pandoras.
- We improved significantly our knowledge of how to operate the Pandoras remotely with very little time needed by local operators.
- We could test measurements on ship.

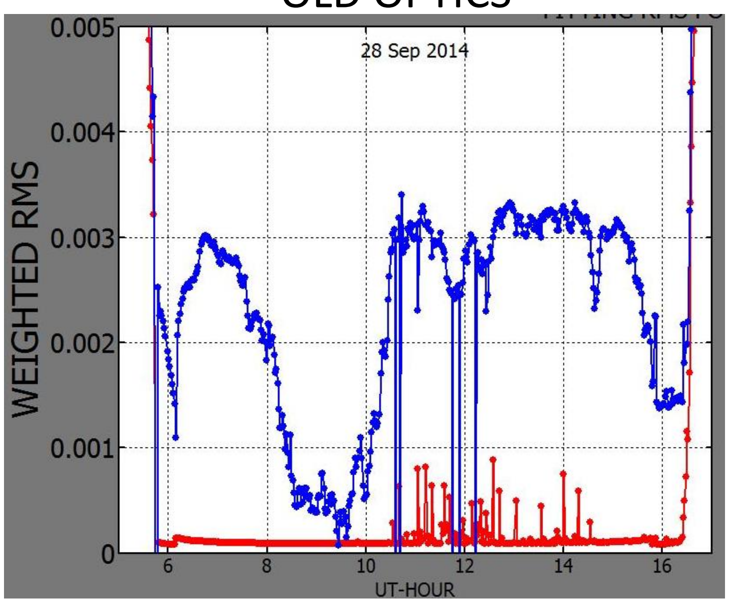
DISADVANTAGE

- We did not have any man-power and instruments left for research and could therefore not really make any hardware improvements on the instruments.

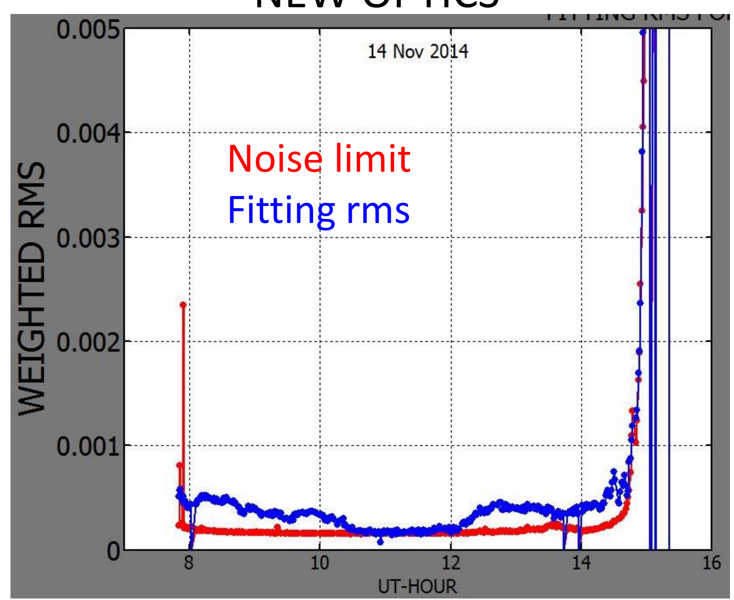
Achievements since start of Pandonia project (2014)

- Development of Pandora-2S system
- New software suite “Blick”
- Periodic data upload (e.g. 10min)
- Inclusion of blind pixels in the detector, which allows stray light characterization
- Creation of Pandora data simulator for algorithm development
- Several optical improvements, especially the elimination of the “unwanted spectral signal” we saw in direct sun data (see figure below showing rms of residuals in NO_2 fitting)

OLD OPTICS



NEW OPTICS

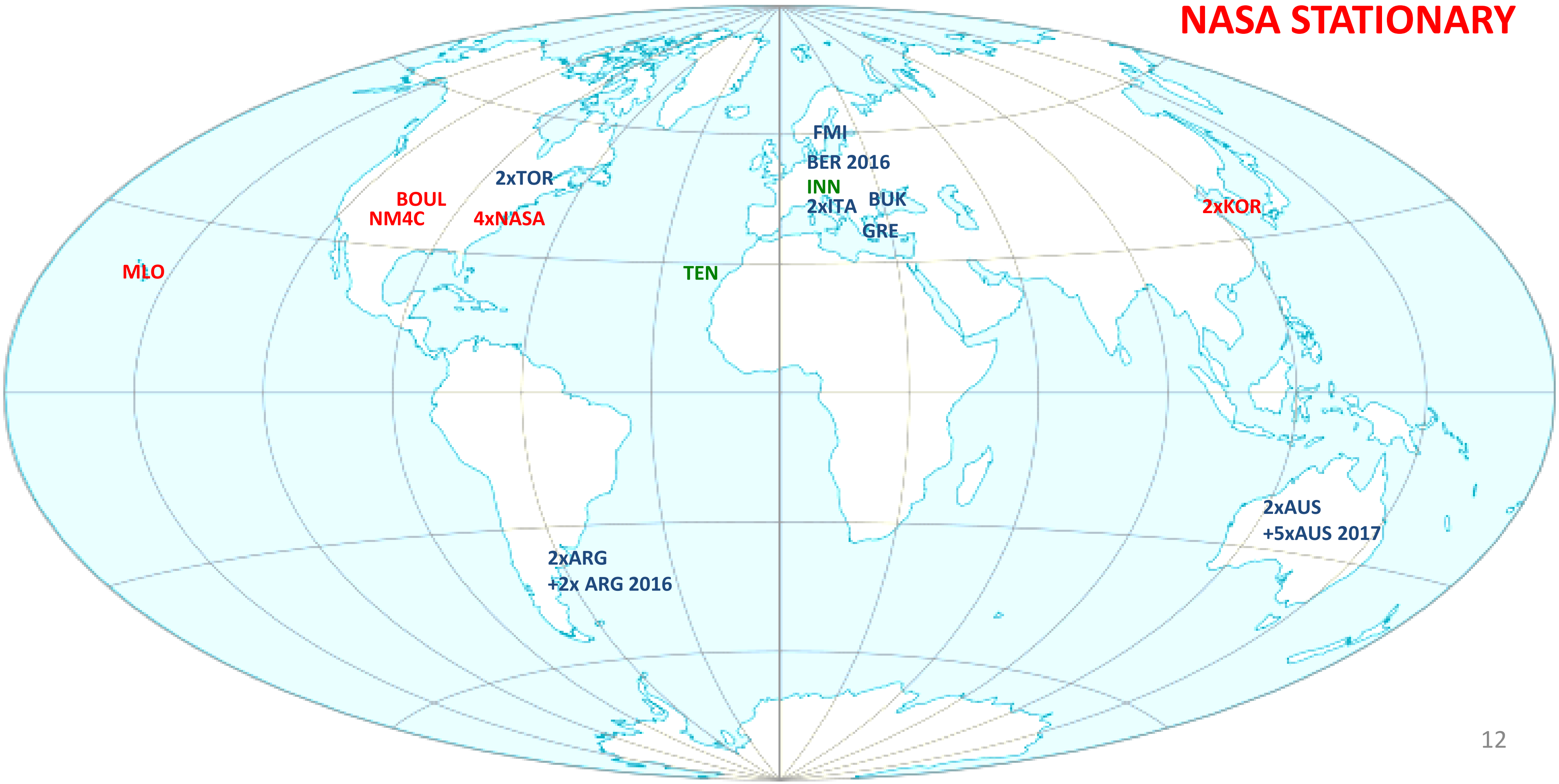


Pandonia/Pandora planned milestones-timeline

Time	Milestone
Jun 2015	Suggest upgrading all NASA Pandoras to improved optics
Sept 2015	Pandora-2S prototype and operation software debugged. SciGlob/LuftBlick (both SMEs) starts selling Pandora-2S.
Dec 2015	Complete optimization of direct sun algorithms (O_3 and NO_2) and feasibility-study to retrieve HCHO, SO_2, BrO, and effective temperature of O_3 and NO_2
Jan 2016	Start using Pandonia data portal and incorporating existing units into network
In 2016	• At least 10 network instruments fully operational • Finished calibration infrastructure set up: laboratories ready, at least one network operator and network technician trained, at least one stationary and mobile reference instrument ready • Finished network infrastructure set up: full software suite ready (operating software, processing software, web-display software, etc.) → Ready to operate/maintain/expand network

Existing and planned Pandonia stations

PANDONIA EXISTING
PANDONIA PLANNED
NASA STATIONARY



History of Pandora-related funding from NASA and ESA

- Continuous NASA funding since Oct 2006 with varying amounts
- Secured funding until end of 2015
- 2016 not secured yet (end of DISCOVER-AQ; may be picked up by KorUS)

- ESA funding started March 2013, starting with 1FTE (CEOS Ground-based intercomparison), and increasing funding level over time
- Pandonia project started Jan 2014
- IDEAS+ software development funding starts May 2015
- Ground-based PreDISK combining Lidars, sunphotometers and spectrometers starting Nov 2015

→ At the current and projected funding level, NASA and ESA will have contributed by about the same amount to Pandora-related research at the end of 2016.

Pandonia vision for the future

Institutions at the network sites…

- Acquire instruments (currently there is large demand)
- Provide local support for operation and maintenance

Pandonia project funds everything else…

- Group of engineers/technicians, trained to calibrate, trouble-shoot, repair instruments remotely and on-site. Key person is Nader Abuhassan (GSFC), who is the architect behind hardware development.
- Acquisition, operation, maintenance, calibration of reference instruments (stationary and mobile) including visiting each network location on a 2 years rhythm.

Pandonia could be for trace gases what Aeronet is for Aerosol properties!

ESA would like to cooperate with NASA on Pandonia. Ideally there is a collaborative project between NASA and ESA (and others?) that is funding the remote operation, maintenance, and calibration of the network, optionally also hardware, software and science improvements.


Thank you!
First Pandonia meeting, 8 Jan 2015, Mutters & Innsbruck, Austria

Appendix: Pandora related publications

- Knepp, T. et al., Estimating surface NO_2 and SO_2 mixing ratios from fast-response total column observations and potential application to geostationary missions, J. Atmos. Chem., DOI 10.1007/s10874-013-9257-6, 2013.
- Tzortziou M., 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, J. Atmos. Chem., DOI 10.1007/s10874-013-9255-8, 2013.
- Reed, A.J., et al., Effects of local meteorology and aerosols on ozone and nitrogen dioxide retrievals from OMI and pandora spectrometers in Maryland, USA during DISCOVER-AQ 2011, J Atmos Chem, DOI 10.1007/s10874-013-9254-9, 2013.
- Pinardi, G., et al., MAX-DOAS formaldehyde slant column measurements during CINDI: intercomparison and analysis improvement, Atmos. Meas. Tech., 6, 167-185, doi:10.5194/amt-6-167-2013, 2013.
- 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.
- Pieters, A.J.M., et al., The Cabauw Intercomparison campaign for Nitrogen Dioxide Measuring Instruments (CINDI): design, execution, and early results, Atm. Meas. Tech. 5, 457-485, 2012.
- Roscoe, H.K. et al., Intercomparison of slant column measurements of NO2 and O4 by MaxDOAS and zenith-sky UV and visible spectrometers, Atm. Meas. Tech. 3, 1629-1646, 2010.
- Wang, S., T. J. Pongetti, S. P. Sander, E. Spinei, G. H. Mount, A. Cede, and J. Herman, Direct Sun measurements of NO2 column abundances from Table Mountain, California: Intercomparison of low- and high-resolution spectrometers, J. Geophys. Res., 115, D13305, doi:10.1029/2009JD013503, 2010.
- Herman, J., A. Cede, E. Spinei, G. Mount, M. Tzortziou, and N. Abuhassan, NO2 column amounts from ground-based Pandora and MFDOAS spectrometers using the direct-sun DOAS technique: Intercomparisons and application to OMI validation, J. Geophys. Res., 114 (D13307), 10.1029/2009JD011848, 2009.