DIVA2

Demonstration of an Integrated approach for the Validation and exploitation of Atmospheric missions

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D4 Pandora products optimised for DIVA (Technical Note)

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1 Introduction

1.1 Purpose

The purpose of this document is to describe how the Pandora data products can be used as input for the GRASP aerosol retrieval framework. Especially synergistic input with AERONET data has the potential of improving existing standard data products. Here, required data formats are described in detail and aspects regarding calibration are discussed.

1.2 Definitions, acronyms and abbreviations

AERONET – Aerosol Robotic Network

AOD – Aerosol optical depth

BSS – Blick software suite

EVDC – ESA Atmospheric Validation Data Centre

FOV – field-of-view

GEOMS – Generic Earth Observation Metadata Standard

GRASP – Generalized Retrieval of Aerosol and Surface Properties

L1/2 – Pandora data level1/2

PGN – Pandonia Global Network

1.3 Applicable Documents

Contract number: 4000121773/17/I-EF

Project proposal: Demonstration of an Integrated approach for the Validation and exploitation of Atmospheric missions – DIVA2

DIVA_TD_D2_v01, D2 Standard DIVA data formats descriptions, Issue 1, revision 01, June 28, 2018

1.4 Reference Documents

Dubovik, O., T. Lapyonok, P. Litvinov, M. Herman, D. Fuertes, F. Ducos, A. Lopatin, A. Chaikovsky, B. Torres, Y. Derimian, X. Huang, M. Aspetsberger, and C. Federspiel: *GRASP: a versatile algorithm for characterizing the atmosphere*, SPIE: Newsroom, Published Online: September 19, 2014. doi:10.1117/2.1201408.005558

Dubovik, O., Herman, M., Holdak, A., Lapyonok, T., Tanré, D., Deuzé, J. L., Ducos, F., Sinyuk, A., and Lopatin, A.: *Statistically optimized inversion algorithm for enhanced retrieval of aerosol properties from spectral multi-angle polarimetric satellite observations*, Atmos. Meas. Tech., 4, 975-1018, 2011. doi:10.5194/amt-4-975-2011

Blick software suite manual, https://www.pandonia-global-network.org/home/documents/manuals/

2 Pandora data and use cases for GRASP

2.1 Data for GRASP

Within the PGN, the Pandora spectrometer system measures spectral direct sun irradiance and sky radiance, optimized to retrieve trace gas total and tropospheric columns.

The Cimel filter radiometer operated within AERONET also measures solar and sky radiation, for a few wavelengths only, but with high absolute accuracy, optimized for the retrieval of aerosol properties.

The aim is to prepare the Pandora data for use within the highly versatile GRASP retrieval algorithm [Dubovik, 2011 and Dubovik, 2014] which then also allows synergetic use with Cimel radiometer data. This scheme is sketched below:

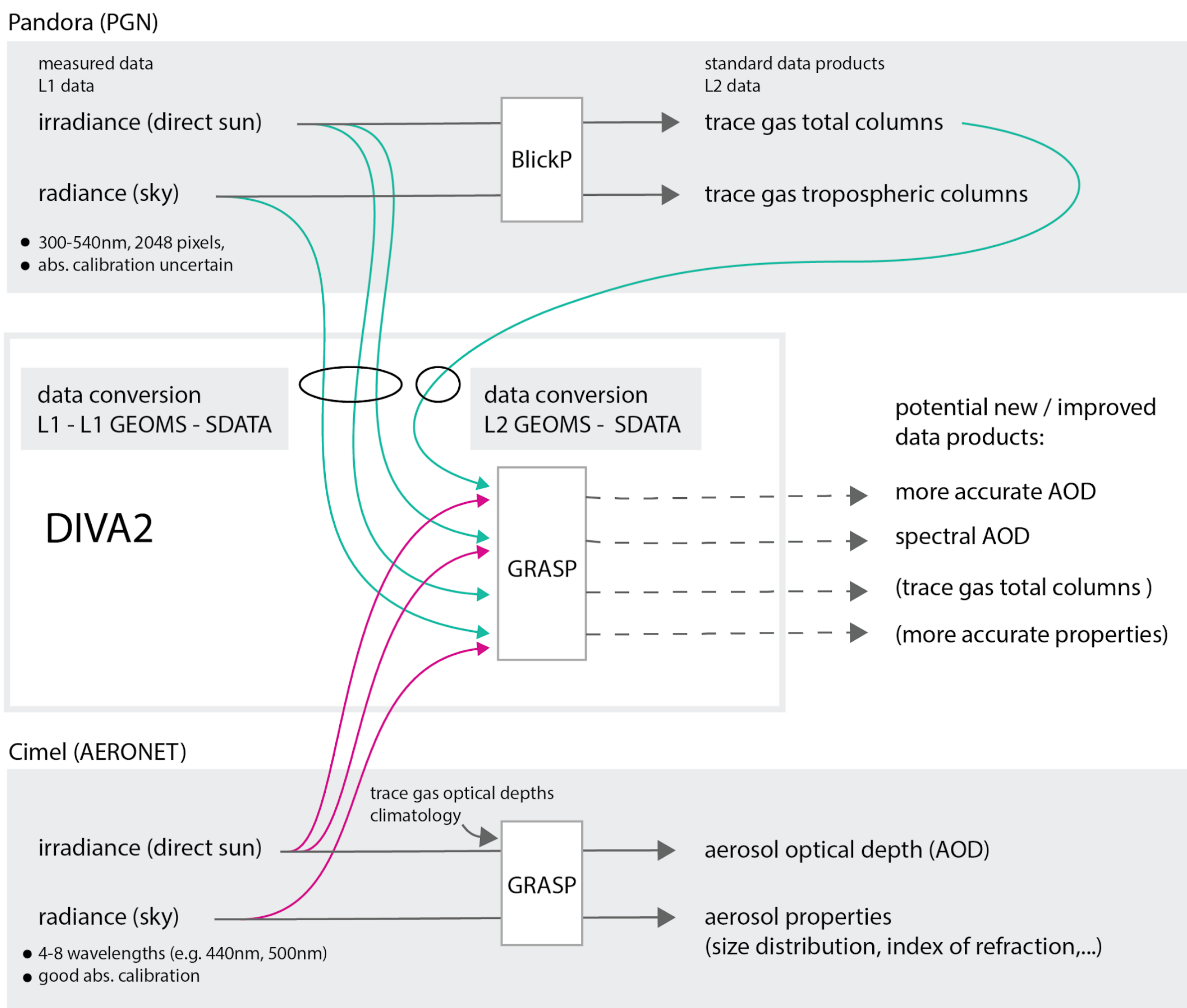

Figure 1 standard data products of Pandora and Cimel instruments and synergetic use with GRASP.

Two data format conversions from Pandora data to a GRASP compatible format have been developed:

L1 direct sun irradiance and sky radiance spectra

L2 total columns

Note that regarding the Pandora wavelength range, there are two types of instruments, 1S (spectral range 300 nm - 540 nm) and 2S, with a second spectrometer of spectral range 400 nm - 950 nm. Relevant for DIVA, Pandora 110 (Innsbruck), 138 (Rome-SAP) and 111 (Bucharest) are 2S instruments, Pandora 101 (Izana) is a 1S type.

2.2 Use cases and potential data products

The use of Pandora data in combination with Cimel data within GRASP suggests four use cases, with associated potentially improved data products:

1) Use of the Pandora L2 trace gas total columns to improve the Cimel AOD, which currently only bases the corrections on climatologies
2) Use of the Cimel superior absolute calibration at single wavelengths to correct the Pandora direct sun irradiance and hence determine the spectral AOD
3) Use of the Pandora L1 direct sun spectra to determine trace gas total columns from GRASP directly
4) Combination of Pandora and Cimel sky radiance data in the GRASP retrieval to increase the accuracy of aerosol optical properties

3 Data format description

3.1 Level 1 GEOMS format

Pandora L1 data contain spectra of direct sun irradiance and sky radiance measurements of one instrument for one day. The native L1 text files have been converted to GEOMS format with the following data fields:

Column name	dimension	unit	description
DATA.QUALITY	Ndata x 1	-	Quality flags: 1(0)=high,1(1)=medium,1(2)=low
DATETIME.START	Ndata x 1	-	Time, fractional days since 1.1.2000
DURATION	Ndata x 1	s	Duration of measurement
FILTERWHEEL.ONE	Ndata x 1	-	Filterwheel position 1, 1-9, see instrument's operation file.
FILTERWHEEL.TWO	Ndata x 1	-	Filterwheel position 2, 1-9, see instrument's operation file.
INTEGRATION.TIME	Ndata x 1	ms	Integration time
LEVEL1.DATA	Ndata x Npix	see below	Data in units below
LEVEL1.DATA.TYPE	Ndata x 1	-	Type: 1=corrected count rate [s-1], 2=radiance [W/m2/nm/sr], 3=irradiance [W/m2/nm]
LEVEL1.UNCERTAINTY	Ndata x Npix		Measurement uncertainty derived from the number of measurement cycles within one measurement routine
LEVEL1.UNCERTAINTY.INSTRUMENT	Ndata x Npix		Expected uncertainty from instrument parameters
POINTING.AZIMUTH.ANGLE	Ndata x 1	deg	Azimuth pointing angle
POINTING.AZIMUTH.MODE	Ndata x 1	deg	Mode: 0=absolute, 1=relative to sun, 2=relative to moon
POINTING.ZENITH.ANGLE	Ndata x 1	deg	Zenith pointing angle
POINTING.ZENITH.MODE	Ndata x 1	deg	Same as for azimuth mode
ROUTINE	Ndata x 1	-	Routine count

WAVELENGTH	Npix x 1	nm	Nominal wavelength

Table 1 Description of L1 GEOMS format for Pandora data

Ndata and *Npix* are the number of measurements (data points) and number of pixels (wavelengths), respectively. The measurement and instrument uncertainty are described in more detail in the Blick software suite manual. The actual wavelength is determined in the trace gas slant column fit and may be shifted slightly (typically less than 0.05 nm) from the nominal wavelength.

The Instruments' operation files can be found at http://data.pandonia-global-network.org/operationfiles/ .

It is further noted that the Pandora L1 GEOMS format is based on a customized template and is not complete with all fields according to the official EVDC GEOMS definition, since it is not a stand alone data product within DIVA but only a preliminary step in the conversion to the GRASP compatible SDATA format.

For this deliverable, the following example GEOMS files have been created to demonstrate the compatibility of the format:

L1 sky radiance spectra for one day for Pandora 106 in Innsbruck, which has been running a sky radiance test measurement schedule along the principal plane

L1 direct sun spectra for one day for Pandora 106 in Innsbruck

L1 direct sun spectra for one day for Pandora 111 in Bucharest

3.2 Level 2 GEOMS Format

Pandora L2 GEOMS files are a final PGN data product and contain trace gas total and tropospheric columns (for Blick SW version 1.7). Relevant trace gases for DIVA are NO2 and O3, with further options in the future. The Pandora L2 GEOMS data are formatted according to the official EVDC template and can be downloaded at http://data.pandonia-global-network.org/ .

For input to GRASP, the total columns have to be converted to optical depths for each GRASP input wavelength, i.e. scaled with the corresponding gas cross-section. The Python module pydiva_geoms_LB.py contains all required functions to read trace gas total columns from a L2 GEOMS file, *read_geoms_h5(fn_geoms , gas),* and compute optical depths, *tc2od(df_tc, gas, wl).*

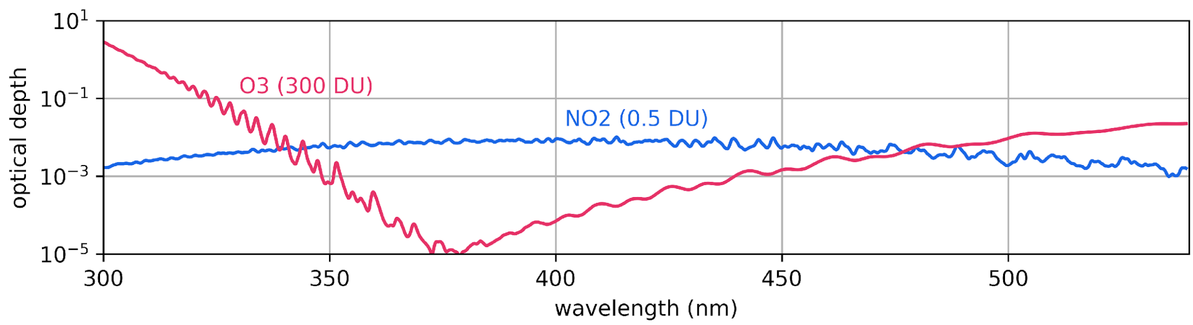

Figure 2 Optical depths for NO2 and O3, scaled to 0.5 DU and 300 DU, respectively.

The specific gas cross-sections used in the Blick software are: NO2 from Vandaele at an effective temperature of 254,5K and for O3, Harmonics_H2012 at 225K. More details and references are found in the BSS manual. Of course also any other reference for the cross-section can be implemented.

4 Pandora calibration

4.1 L1 data, direct sun irradiance

The Pandora instruments are routinely calibrated in absolute radiometric irradiance units in the laboratory before being deployed within the PGN.

This is an important step to determine the instruments spectral response, which cannot be adequately captured by a background polynomial (of order ~4) in the fitting process of the trace gas slant columns. However, for trace gas retrieval, the relative spectral response is crucial rather than an accurate absolute calibration, which has been found to be insufficient for the determination of the AOD in standard instrument operation.

Regarding the absolute radiometric irradiance of the Pandora instruments, there are four separate issues:

- transfer of the absolute calibration in the laboratory to the field measurement with solar input
- radiometric stability after shipment or movement of the instrument
- radiometric stability over time in standard operation mode
- non uniform transmission within the FOV

which may lead to an uncertainty of the absolute radiometric irradiance of typically <10% but possibly up to 30%. For further details about the analysis of radiometric stability with respect to AOD retrieval, refer to the corresponding LuftBlick reports:

LuftBlick_Pandonia_TN_cindiAOD_RP_2017006_v1.0.pdf
LuftBlick_Pandonia_TN_RecOperationalAOD_RP_2018003_v1.0.pdf

at https://www.pandonia-global-network.org/home/documents/reports/ .

4.2 L1 data, sky radiance

The LuftBlick laboratory is not yet equipped for Pandora radiance calibration, which requires a radiance standard (integrating sphere). Simply applying the irradiance calibration to the sky radiance measurements already fulfils the above requirement of including the relative spectral response in the trace gas retrieval.

The above issues of radiometric stability also apply to a potential radiance calibration. The non uniform transmission within the FOV should not affect the radiance measurements in homogeneous parts of the sky but may affect measurements with small relative angles to the sun with high radiance gradients within the FOV. This issue will have to be investigated separately.

Here, we propose to first attempt to use radiances normalized to the zenith as input data for GRASP. Another possibility is to use the calibrated Cimel radiances, where the different FOVs of the two instruments will have to be taken into account.