AEROSOL FIELD INFLUENCE ON THE RETRIEVAL OF THE OZONE VERTICAL COLUMN DENSITIES FROM PANDORA 2S MEASUREMENTS

Alexandru Dandocsi[1,2], Anca Nemuc[1*], Doina Nicolae[1], Livio Belegante[1], Alexander Cede[3], Martin Tiefengraber[3,4]

[1]National Institute of Research and Development for Optoelectronics INOE 2000, Remote Sensing Dept., Magurele-Bucharest, Romania
[2]University Politehnica of Bucharest, Faculty of Applied Sciences, Bucharest, Romania
[3]LuftBlick, Kreith 39A, 6162 Mutters, Austria
[4]Institute of Atmospheric and Cryospheric Sciences, University of Innsbruck, Innsbruck, Austria Romania
**Email: anca@inoe.ro*

ABSTRACT

Total ozone and other trace gases are measured and reported regularly due to the increased interest started with the ozone hole discovery but the new satellites dedicated to worldwide observations of these species need both short-and long-term well calibrated ground based observation for validation procedures.

The ESA/NASA *Pandora* network established a sophisticated, automatic calibration procedure that utilizes a variety of narrow-line and broadband emission lamps with temperature control for their UV-Vis-NIR spectroradiometers. In this study, we describe additional calibration efforts for ozone retrievals.

In this paper we explore the local aerosol field influence on the retrieval of the ozone spectra from PANDORA 2S measurements using collocated lidar and sunphotometer measurements and proposed a methodology to be implemented in the calibration procedure of the instruments.

INTRODUCTION

Observations of ozone and trace gases during the last decades proved that anthropogenic activities do affect the environment on large scales and that the consequences are potentially very harmful to humans. But atmospheric processes are still far from being entirely understood and therefore there is a need for better, continuous and worldwide spread of both satellite and ground based observations.

Pandora instruments are field grade spectroscopic UV–Vis systems (Herman et al., 2009). They are part of the European Space Agency-sponsored Pandonia Global Network but also NASA (USA) sponsored network. The main goal of Pandonia is to provide consistent ground-based total O_3, NO_2, and HCHO columns for satellite validation, overlapping significantly with the spectral ranges of the S5p instrument as well as the MSI and ATLID on-board EarthCARE. The major advantages of networking are uniform instrument design and calibration, and centralized data monitoring, processing, and distribution. Direct-sun-observation geometry eliminates the need for atmospheric radiative transfer modeling and simplifies data interpretation (Tzourtiu, 2012). Pandonia currently operates 75 instruments and is expected to have about 300 instruments in the next 5 years. The quality assurance procedures are extremely important for satellite validation.

One issue not tackled by the comprehensive approach (Cede et al.) in the calibration fitting procedures is the influence of the aerosol local fields. Radiative effects of UV-absorbing aerosols produce spurious ozone column reductions. The magnitude of the total ozone underestimation depends on the aerosol type, optical depth, and aerosol layer height. The error is produced by complex interactions between ozone absorption (both stratospheric and tropospheric), aerosol scattering, and aerosol absorption. Tropospheric UV-absorbing aerosols such as dust and carbonaceous aerosols from biomass burning have been found to affect the retrieved ozone from radiance spectra.

At RADO (Romanian 3D Atmospheric Observatory) in Magurele, near Bucharest, Romania (26.029◦E, 44.048◦N, 93 m above sea level) several instruments for aerosol observations along with PANDORA 2S have been implemented during the last years and are performing regular measurements (Nicolae et al,2010). Therefore we took this opportunity and use lidar and sunphotometer measurements characterizing the vertical distribution and optical properties of aerosols.

In this paper we investigate how the retrieved ozone spectra from Pandora 2S measurements are influenced by the local aerosol fields and we propose a methodology for routinely using this by the stations from PANDONIA with collocated lidar and /or sunphotometer.

1 INSTRUMENTS AND METHODOLOGY

1.1 The lidar and sunphotometer

Advanced Lidar system with elastic and inelastic channels – such as our Multiwavelength Raman Lidar instrument -RALI– can be used into the inversion procedure to obtain all optical parameters of the aerosols. It emits and receives light at 1064, 532, and 355 nm. (Nicolae et al. 2010, Nemuc et al 2013)

Extinction profiles retrieved from the 355 nm and 532 nm channels (Figure 1) of the Lidar system are used to compute the aerosol optical depths by integrating the profile.

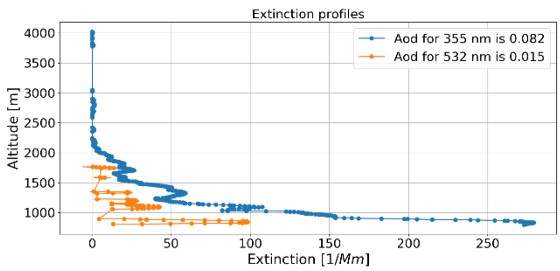

Figure 1 Extinction profiles from Lidar system

Column Aerosol properties are retrieved from automatic sun-photometer measurements (AERONET) at our site since 2007 (Carstea et al 2019). Standard measurements performed by the CIMEL CE-318 sun photometer are composed of solar spectral irradiance used to derive accurate spectral extinction AOD (±0.01) within the range 340 to 1640 nm as well as downward sky spectral radiances (440 to 1020 nm) in the solar principal plane and in the almucantar geometries. The instrument measures direct Sun with a 1.2° FOV at discrete channels from UV to NIR (i.e., 340, 380, 440, 500, 675, 870, 940, 1,020, and 1,640 nm). The direct-Sun measurements take about 10 s to scan all filter wheels in front of the detector for each wavelength. Data products used in this study were collected in cloud-free conditions, provided by the AERONET web site as "aerosol optical depth (V3) - solar" using the Smirnov et al. (2000) cloud-screening algorithm.

1.2 Pandora

A detailed description of the instrument has been provided by Herman et al. (2009). Pandora is a sun-viewing spectrometer that was initially developed for validation of the Ozone Monitoring Instrument (OMI) aboard the Aura satellite (Herman et al., 2009).

The instrument consists of a small Avantes low-stray-light spectrometer (280–525 nm with 0.6 nm spectral resolution with 5 times oversampling) and the second one (400-900 nm, 0.24nm step, 1.1nm resolution) connected to an optical head by 400 µm core diameter single-strand fiber optic cables. The optical head is attached to a small two-axis positioner, capable of accurate pointing to track the sun's center (±0.2∘). A diffuser is included in the optical path to minimize the effect of small pointing errors. Direct-sun spectra are taken at variable integration times (2.5 ms to 4 s) with a total measurement duration of 40 s. Pandora measures unscattered solar photons in a narrow cone (2.1∘ field of view (FOV) full width at half maximum with a diffuser and 1.6∘ FOV without the diffuser) at a specific solar azimuth and zenith direction that changes from east in the morning to west in the evening.

Pandora spectra are automatically collected and submitted to LuftBlick servers for centralized uniform processing by the Blick Software Suite (Cede, 2018). All standard operational Pandora (instrument #111) data products are available live at http://live.pandonia.net/ and archived at http://pandonia.net/data (INOE site). (last access: 13 March 2019).

To achieve wavelength and radiometric calibration stability, the spectrometer is temperature stabilized inside an insulated enclosure using an actively coupled thermo-electric cooler and heater.

Total vertical column of O_3 is retrieved using direct sun measurements. As the reference spectrum, in this case, it is used an extraterrestrial spectrum from another source (i.e. not measured by the Pandora system), convoluted with the Pandora filter function. The reference spectrum is obtained in a similar way as described in Bernhard et al., 2004.

Algorithm and calibration related to Pandora Total Ozone Spectral Fitting Algorithm have been described in details by Tzortziou et.al. 2012.

Spectral fitting-data presented in this paper are from a 310 to 330 nm fitting window.

Briefly, spectral fitting is performed using laboratory measured absorption cross sections and implement shift squeeze functions to fit the observed spectra with the solar reference spectrum's Fraunhofer line structure (Figure 2) and spectrum from Ring effect is also considered. The fourth-order polynomial is applied for removal of aerosol and Rayleigh scattering effects.

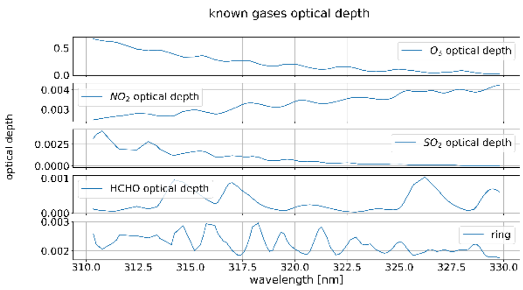

Figure 2 Known optical depths of species fitted for the retrieval of total vertical column of O_3

1.3 Methodology

During the first step of our proposed procedure the daily mean values of aerosol optical depths from Lidar and sunphotometer systems are evaluated. The Angstrom exponent is calculated from the 532 and 355 or 500 and 340 channels from the Lidar and sunphotometer respectively. Using the Lambert-Beer law, the aerosol optical depths for spectral range of 310 – 340 nm is extrapolated. Example of correction of the reference spectrum is shown in (Figure 3)

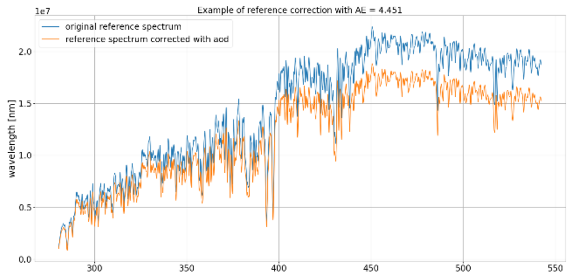

Figure 3 Reference spectrum modified based on aod from Lidar system

The vertical total column densities are evaluated using both original and corrected with the AOD spectra for several cases.

2. RESULTS

All analyzed cases were choose to be under cloud free conditions. Differences between total column densities retrieved using the original and modified reference spectrum ranges from 0.5% for lower values of AOD up to 5% for the cases where the calculated Angstrom exponent was higher.

An example of time series using both reference spectra is shown in Figure 4.

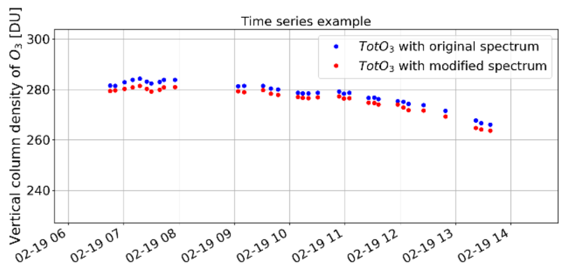

Figure 4 Example of vertical column density of O3 retrieved with original and modified reference spectrum

In this case the differences vary between 0.8% and 1.4%. Data points in Figure 4 are considered measurements with high confidence based on spectral fitting and measured spectra.

3. CONCLUSION

Aerosol information can be implemented in the retrieval of vertical column densities of trace gases based on differential optical absorption spectroscopy method.

In this paper the authors have implemented in the processing chain of the measured spectra from direct sun measurements the possibility of correcting the reference spectrum used in the retrieval of column density of O_3. Collocated in space and time measurements of AOD have been considered.

For the analysed cases, differences using the Angstrom exponent to correct the reference spectrum ranges from 0.5% to 5% in the final product, the vertical column of O_3 expressed in Dobson Units.

Next steps will be dedicated to long term comparisons and also implementation and evaluation at other PANDONIA sites.

Through the implementation of this type of methodologies the well-calibrated ground-based PANDORA 2S will comprehensively complement spaceborne measurements in spectral and temporal domains.

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