Retrieval of tropospheric columns from ground-based MAX-DOAS measurements performed in the greater area of Thessaloniki and comparison with satellite products

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Introduction

Phaethon is a ground-based mini MAX-DOAS system (Kouremeti et al., 2013) that performs both direct solar irradiance and sky radiance (zenith and off-axis) spectrally resolved measurements in the region 300-450nm for the retrieval of total and tropospheric column densities of trace gases using QDOAS software. It is portable, thus it can be deployed at different sites to address specific air quality problems and to support satellite validation at locations of particular scientific interest. It comprises a cooled miniature CCD spectrograph (AvaSpec-ULS2048LTEC) operating at 5°C. In regular operation the system samples a sequence of 20 radiance spectra at 2, 3, 4, 5, 8, 10, 12, 15, 30, 45 and 90° elevation angles at different azimuth angles, as well as direct irradiance spectra, with adjustable integration times depending on signal level. A 2-axis tracker developed at AUTH is used to direct with high precision the fore optics towards the specific elevation and azimuth angles or the Sun.

	Phaethon #1	Phaethon #2, #3
Spectrograph	AvaSpec-ULS-TEC Avantes	
Detector	Sony- ILX511 Cooled	
Entrance slit	25μm	50μm
Pixels	2048x1	
Wavelength Range	300-450nm	
Spectral Resolution	0.20-0.29nm	0.34-0.42nm
Signal/Noise	300:1	

LAP-AUTH: urban conditions

Epanomi: rural conditions

ATEITH: suburban conditions

Three almost identical systems have been built and operated for several months in the greater area of Thessaloniki, Greece. A similar system has been deployed in the Guangzhou region in China in the framework of MarcoPolo project in April 2015. Phaethon #1 operates continuously at the center of Thessaloniki (LAP-AUTH on the map) while the other two were deployed at Epanomi (Phaethon #2) and ATEITH (Phaethon #3) (fig 1) representing rural and suburban conditions respectively. The time series of tropospheric vertical column densities (VCD) of NO_2, HCHO and SO_2 obtained with the Phaethon systems at these three locations are presented and compared with satellite products. Prior to the relocation of the systems, they performed parallel measurements at LAP-AUTh, revealing an agreement in NO_2 and HCHO tropospheric VCDs of $1.32x10^{15}$, $4.97x10^{15}$ molec/cm2 respectively.

Ground-based Dataset

NO_2, HCHO and SO_2 tropospheric columns are retrieved from radiance spectra at 15° elevation angle using the geometric approximation for the airmass factor. Each radiance spectrum is analyzed with the QDOAS 2.108 algorithm (Dackaert, Fayt & van Roozendael, 2014) to derive the Differential Slant Column Density (DSCD) from a reference spectrum recorded at the zenith for each sequence of sky radiance measurements (e.g. Pinardi et al 2013). Comparison of co-located pyranometer measurements with SZA- and time-dependent threshold values based on radiative transfer model calculations for low and high aerosol loading is currently used for the cloud flagging of the Phaethon data.
For the comparison with the satellite retrievals the ground-based columns were averaged for ±30 min around the satellite overpass time.

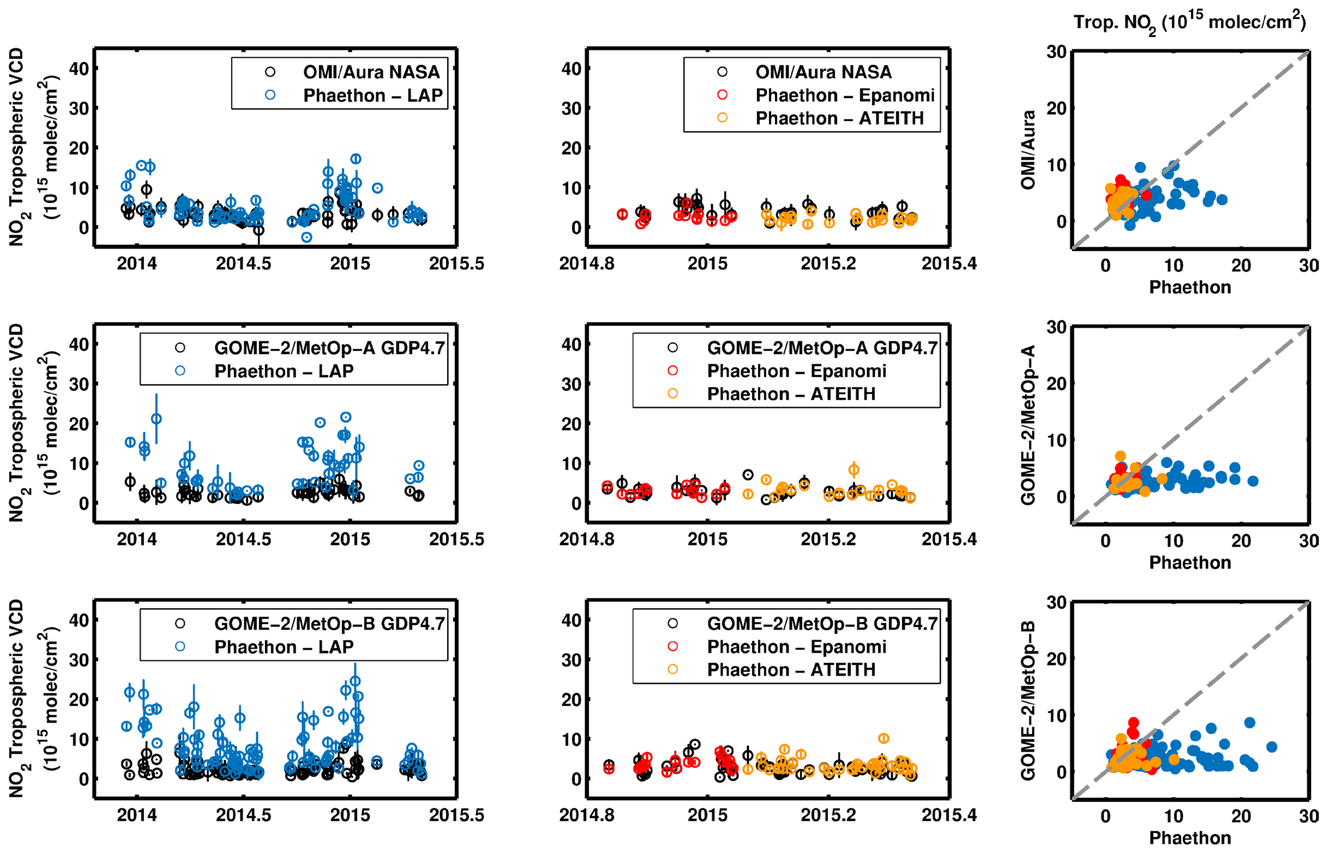
Satellite Dataset

The operational GOME-2 total NO_2, HCHO and SO_2 columns from MetOp-A are generated at the German Aerospace Center (DLR) using the UPAS (Universal Processor for UV/VIS Atmospheric Spectrometers) environment version 1.3.9, implementing the level-1-to-2 GDP 4.7 algorithm. The data processing is commissioned by EUMETSAT within the auspices of the *Satellite Application Facility for Atmospheric composition and UV radiation*, O3MAF, project, http://o3msaf.fmi.fi/.
This GOME2/MetopA dataset was downloaded from http://atmos.eoc.dlr.de/gome2/

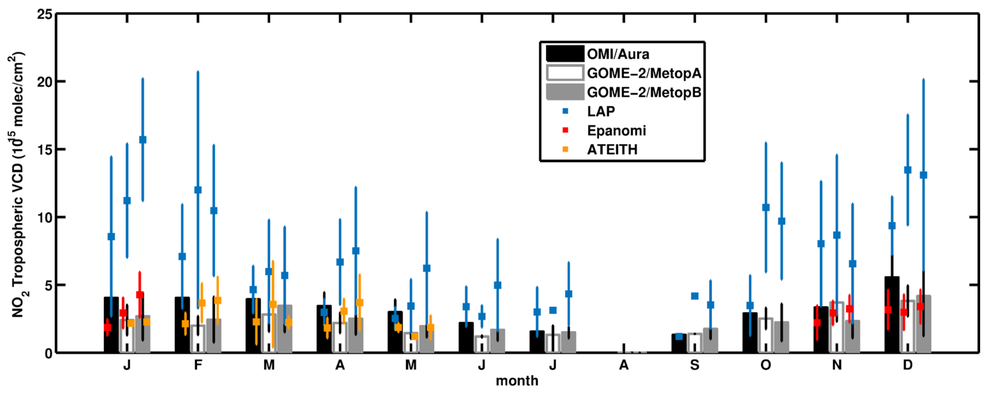
The operational OMI total NO_2, HCHO and SO_2 columns from AURA are generated by NASA and distributed by the Aura Validation Data Center. The Aura Validation Data Center (AVDC) is a centralized, long-term, archive for validation data hosted by the Atmospheric Chemistry and Dynamics Branch at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) in Greenbelt, Maryland.
This OMI/Aura dataset was downloaded from http://avdc.gsfc.nasa.gov.

Satellite retrievals within 50 km from measurements site with cloud fraction ≤ 20% and SZA ≤ 75° were used for the comparisons.

NO_2 Tropospheric VCD



- The retrieved NO_2 trop. VCD at the rural site location (Epanomi) is much lower than in the urban site (LAP).
- NO_2 concentrations at the rural and suburban site (ATEITH) show significant similarities. At the ATEITH occasionally higher NO_2 levels are encountered which can be attributed to air pollution transport due to its proximity to the city.
- The comparison of ground-based and satellite NO_2 trop. VCD at the urban site (LAP) showed an average agreement of $1.33x10^{15}$, $1.78x10^{15}$, $3.07x10^{15}$ with OMI, GOME-2A and GOME-2B during the summer months, when the anthropogenic emissions in the city center are lower, while in winter the offset increases to $3.69x10^{15}$, $9.96x10^{15}$, $9.75x10^{15}$ molec/cm^2 respectively. Larger deviations have been observed for the GOME-2 sensors, due to their larger pixel size which includes areas without significant anthropogenic activities, as well as due to the earlier overpass times when higher NO_2 concentrations prevail in the city.
- The comparison results for the GOME-2 sensors improve significantly for the suburban and rural sites (on average $0.66x10^{15}$). In contrary the OMI/Aura sensor seems to be less sensitive to these areas showing higher NO_2 values.
- Averaging the Phaethon NO_2 trop. VCD of the urban and suburban and/or rural site would lead to an improvement of the comparison results for OMI.



Preliminary HCHO and SO_2 VCDs

The tropospheric columns derived by the three Phaethon systems are in good agreement with the OMI and GOME-2A/2B data as far as it concerns the HCHO concentration (on average $2.02x10^{16}$, $1.04x10^{16}$, $0.65x10^{16}$ molec/cm^2 respectively), which doesn't show significant seasonal variations and seems to be independent of the monitoring location in the greater area of Thessaloniki. However, some overestimations are observed in the measurements of Phaethon #3 (ATEITH), which have not been explained yet.

Preliminary comparisons of SO_2 tropospheric columns are inconclusive, particularly because the satellite data are often negative, owing mainly to the limited strong SO_2 sources in the area, as it can be seen also from the small columns reported by Phaethon.

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