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The Analysis of the Correlations Between NO_2 Column, O_3 Column and UV Radiation at Global Level Using Space Observations

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Abstract. A well known relationship between nitrogen dioxide (NO_2), ozone (O_3) and ultra-violet radiation (UV) exists. In this work several correlations between NO_2 column, O_3 column, and UV radiation for several worldwide urban agglomerations or stations during 2004-2015 are presented. For the both NO_2 and O_3 columns we used the Ozone Monitoring Observations (OMI) instrument, which is a space sun-synchronous polar orbit space instrument. UV parameter has been determined using the clear-sky UV index which is the effective UV irradiance which reaches the surface of the Earth. The UV station data utilized satellite data acquired by SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) and GOME-2 (Global Ozone Monitoring Experiment) instruments. The time or local dependencies of the evolution of the NO_2 column, O_3 column and UV index above the selected cities or stations are analyzed and presented.

INTRODUCTION

In the last 30 years the satellite platforms used for measuring atmospheric components have widely developed. One of the main techniques used for atmospheric remote sensing from space is UV-Vis spectroscopy that operates based on DOAS (Differential Optical Absorption Spectroscopy) method [1, 2]. The main atmospheric trace gases determined from space by the UV-Vis instruments are O_3 (ozone), NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide), HCHO (formaldehyde), H_2O (water vapour) and others. A major advantage of the developments of the satellite observations is provided by global coverage of inaccessible areas (desert, ocean) where measurements made at ground level are not possible. The measurements made from space provide daily information about different atmospheric components at different spatial scales in correlation with the technical characteristics of the used instruments. The main UV-Vis space instruments which are used nowadays are: GOME-1(Global Ozone Monitoring Experiment-1) [3], SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) [4], OMI (Ozone Monitoring Observations) [5] and GOME-2 (Global Ozone Monitoring Experiment-2) [6]. These space instruments use spectrometers that can measure the back-scattered radiance of the Earth irradiation spectra directly from the Sun. The satellites platforms, that carry the space born instruments, fly on the heliosincron polar orbits. The GOME-1, SCIAMACHY and GOME-2 instruments have been created by the ESA and the OMI sensor by the National Aeronautics and Space Administration (NASA) in collaboration with Netherlands's Agency for Aerospace Programs (NIVR) and Finnish Meteorological Institute (FMI). Each instrument passes the equator at the same local hour and every orbit lasts approximately 100 minutes. The GOME-1 instrument was launched in space along with ERS-2 satellite in 2 April 1999. The aim of this instrument was to determine the vertical columns of O_3. Moreover, other gases such as NO_2, SO_2, H_2O, OClO, and BrO can be detected by the same instrument. GOME-1 scans the atmosphere using its four spectral channels which cover the following wave lengths intervals 240-295 nm, 296-405 nm, 400-605 nm and 590-790 nm. The spectral resolution is from 0.2 to 0.4 nm. The SCIAMACHY instrument is a sensor found on the ENVISAT satellite since July 2002. This instrument uses eight spectral channels which cover wave lengths from 0.2 to 0.4 nm. Unlike GOME-1, the SCIAMACHY instrument can detect other

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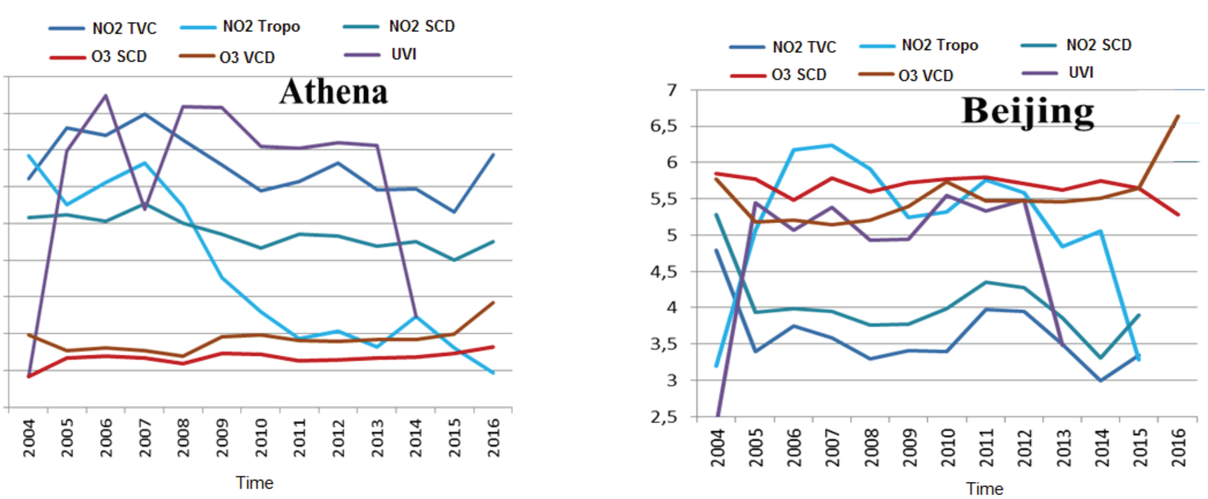
gases such as CH_4, CO, CO_2 and N_2O, thanks to its eight spectral channels which use infrared technology. The OMI instrument was launched in space in July 2004 along with the EOS-Aura satellite. OMI is a UV-Vis spectrometer which operates using nadir geometry. The main objective of this instrument is the detection of O_3. It also detects other gases like NO_2, SO_2, HCHO, BrO and OClO. Mainly the GOME-2 instrument is similar to GOME but it has some better features of the optical design. In this work we present the analysis of the correlations between NO_2 column, O_3 column and UV radiation at global level using space observations; the novelty of this paper consists of several cases which are presented and analyzed.

METHODOLOGY

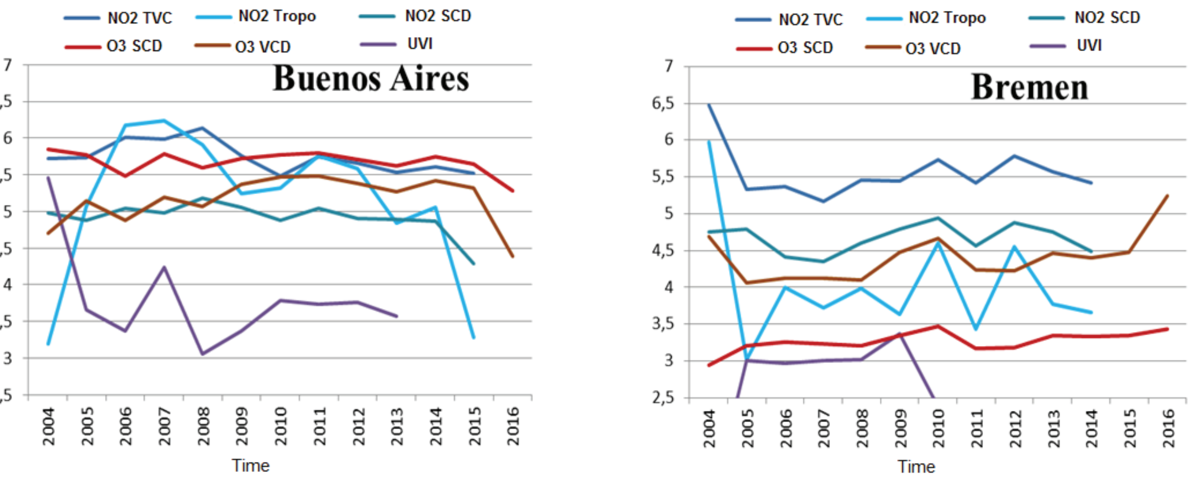
This study is based on NO_2 and O_3 space observations collected from the OMI space instrument. The UV station data are based on satellite data collected from SCIAMACHY and GOME-2. Pearson's correlation coefficients which show the linear relationship between two sets of data are calculated for each two atmospheric parameters introduced in this study. Five important locations worldwide such as Athens (23.73°E, 37.98°N), Buenos Aires (58.48°W, 34.58°S), Bremen (8.85°E, 53.10°N), Beijing (116.32°E, 39.95°N), and Eureka (86.41°W, 80.05°N) are considered. For each location were generated plots that present variations of the TVC (Total Vertical Column NO_2), Tropo VC (Tropospheric Vertical Column), SC NO_2 (Slant Column NO_2), UVI (UV Index), O_3 VCD (Vertical Column Density), and O_3 SCD (Slant Column Density).

RESULTS AND DISCUSSIONS

Figures 1, 2 and 3 present the time series of NO_2 column, O_3 column and UV Index for Athens (Greece), Buenos Aires (Argentina), Bremen (Germany), Beijing (China), and Eureka (Canada). To figure in the same plot the different parameters, all the data sets were normalized. For all locations taken into consideration a descending trend for the NO_2 columns has been found. Figure 1 shows the most important NO_2 descending trend is visible for Beijing (China). The ozone columns have a low ascending trend which is correlated with the UV Index. Table 1 storages the Pearson's correlation coefficients calculated between the atmospheric parameters show small correlation coefficients (< 0.2). The best correlation between O_3 VCD and UV Index was calculated in the case of China, where an important amount of NO_2 is released in the atmosphere by industry; similar correlation coefficients were found for Bremen in Germany.



FIGURES 1. Time series of NO_2 column, O_3 column and UV Index for Athena (left) and Beijing (right)



FIGURES 2. Time series of NO_2 column, O_3 column and UV Index for Buenos Aires (left) and Bremen (right)

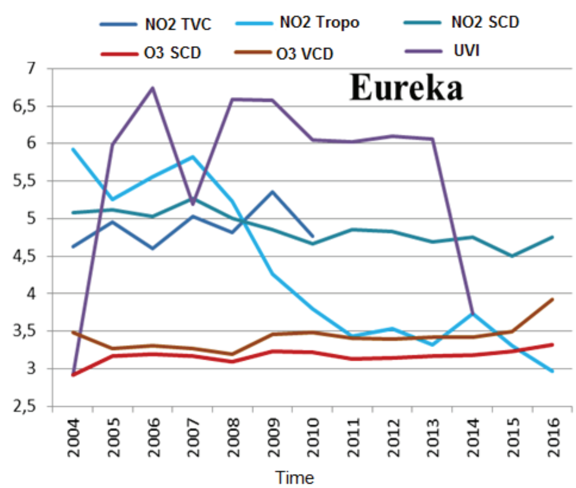


FIGURE 3. Time series of NO_2 column, O_3 column and UV Index for Eureka

TABLE 1. Correlation coefficients

Location	**Beijing**	**Buenos Aires**	**Bremen**	**Athens**	**Eureka**
Atmospheric parameter	*Pearson correlation*				
VCD_O_3-TropoVC_NO_2	0.038	-0.002	0.077	-0.31	0.047
VCD_O_3-TVC_NO_2	0.066	0.02	-0.101	-0.14	0.01
VCD_O_3-UVI	0.184	0.093	0.105	-0.19	0.012
SCD_O_3-TropoVC_NO_2	0.066	0.027	0.122	0.036	0.006
SCD_O_3-TVC_NO_2	0.111	-0.003	-0.03	-0.173	0.005
SCD_O_3-UVI	0.184	-0.15	-0.076	0.106	0.027
TropoVC_NO_2- UVI	0.073	0.093	-0.049	-0.12	0.043
TVC_NO_2-UVI	0.089	-0.037	-0.078	0.024	-0.062

CONCLUSIONS

In this work we have presented a correlation exercise between NO_2 column, O_3 column and UV index data sets collected from the satellite space instruments OMI, SCIAMACHI and GOME-2. The study was performed for the time period 2002-2015 for several locations in different places around the Earth: Athens (Greece), Buenos Aires (Argentina), Bremen (Germany), Beijing (China), and Eureka (Canada). For each pair of parameters presented in this study the Pearson's correlation coefficients were computed. Overall, we found small correlation coefficients (<0.2), but the best correlation between O_3 VCD and UV Index was calculated for China where an important amount of NO_2 is released in the atmosphere by industry. Similar correlation coefficients were found for Bremen in Germany. The small correlation coefficients could be related to the fact that the total ozone column is influenced by many other parameters, e.g. winds and trace gases. For the other locations no important correlation coefficients was found. However, this investigation needs further works.

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