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Nitrogen dioxide DOAS measurements from ground and space: comparison of zenith scattered sunlight ground-based measurements and OMI data in Central Mexico

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RESUMEN

El uso de datos satelitales en combinación con mediciones realizadas en superficie puede proporcionar información valiosa acerca de la química atmosférica y la calidad del aire. En este estudio se comparan mediciones en superficie de dióxido de nitrógeno (NO_2) realizadas mediante la técnica de espectroscopia óptica de absorción diferencial (DOAS, por sus siglas en inglés) con mediciones del instrumento satelital para la medición de ozono (OMI, por sus siglas en inglés) realizadas de 2006 a 2011. Las mediciones realizadas desde la superficie presentaron grandes variaciones diarias y fueron en promedio tres veces más altas que las columnas medidas desde el espacio. La diferencia se atribuye a una fuerte heterogeneidad horizontal presente en la capa inferior de las columnas de NO_2, las cuales fueron muestreadas por el instrumento satelital a partir de un área extensa; de igual manera, esta discrepancia se atribuye a la sensibilidad reducida del satélite cerca de la superficie, donde se encuentran las mayores concentraciones. A partir de los datos del OMI analizados se reconstruyeron mapas de distribución de NO_2 sobre el centro de México, y se identificaron tres áreas principales de interés: la zona metropolitana de la Ciudad de México, que fue el área predominante; la zona altamente industrializada de Tula, al norte, y el valle de Cuernavaca, al sur. En este análisis se detectaron de igual forma variaciones estacionales de columnas de NO_2 sobre el centro de México: se encontraron columnas más altas durante la estación fría y seca, seguidas por las de la estación caliente y seca; las columnas más bajas se encontraron durante la época de lluvias. Este conjunto de datos evidencia el transporte de contaminación de este gas desde Tula hasta la Ciudad de México, así como al Valle de Cuernavaca.

ABSTRACT

The use of satellite data in combination with ground-based measurements can provide valuable information about atmospheric chemistry and air quality. In this study, ground-based Differential Optical Absorption Spectroscopy (DOAS) measurements of nitrogen dioxide (NO_2) conducted in central Mexico are compared with the space-borne Ozone Monitoring Instrument (OMI) dataset of 2006-2011. Ground-based measurements exhibited large day-to-day variations and were on average three times higher than the space-borne derived average over the observation site. This difference is attributed to strong horizontal inhomogeneity of the lower layer of the measured NO_2 columns, sampled over a large footprint from the satellite instrument. Also, a reduced sensitivity of the satellite observation near the surface, where the largest concentrations are expected, could be responsible for this large discrepancy. From the analyzed OMI dataset, distribution maps of NO_2 above central Mexico were reconstructed, allowing to identify three main areas with increased NO_2 column densities: The dominating metropolitan area of Mexico City, the heavily industrialized region of Tula to the north and the Cuernavaca valley to the south. In this analysis, seasonal variability of NO_2 columns over central Mexico was detected, finding higher NO_2 columns during the dry and cold season, followed by the dry and warm period, and finally the lowest NO_2 columns were found during the rainy season. Pollution transport of this gas from Tula into Mexico City, as well as towards the Cuernavaca valley, is evident from this dataset.

Keywords: DOAS, OMI, nitrogen dioxide, ground-based, space-borne, central Mexico.

1. Introduction

Mexico City is the third largest city of the world, with more than 20 million inhabitants (UN, 2012). It is located at 19.4º N latitude and approximately at an elevation of 2200 m above sea level (masl). For several years Mexico City has experienced severe air quality problems, which have been addressed by authorities trough the implementation of various programs. While the countermeasures and technological improvements have effectively decreased the amount of some pollutants, the city continues to experience pollution episodes resulting on the frequent violation of air quality standards.

Nitrogen dioxide (NO_2) plays a major role in tropospheric and stratospheric chemistry (Crutzen, 1979). In polluted regions such as Mexico City, tropospheric NO_2 concentrations can be highly variable in time and space and are influenced by both natural and anthropogenic emissions. In Mexico City, most of the NO_2 present in the atmosphere comes from fossil fuel combustion from transportation and partly from industrial activities. NO_2 levels in Mexico City have decreased by 30% between 1990 and 2008, and the average surface concentration registered in 2008 by four stations around the Universidad Nacional Autónoma de México (UNAM) campus in Mexico City—where the ground-based measurements presented in this study were conducted—was 56.8 ppb (SMA-GDF, 2010).

Satellites provide global observations, allowing to retrieve information from nearly every region in the globe (Rees, 2001). There are a number of instruments measuring from space, covering a wide range of wavelengths, with different spatial resolution and viewing geometries. In this work we have focused on the Ozone Monitoring Instrument (OMI) (Levelt *et al.* 2006a, b), a UV-VIS spectrometer on board NASA's Earth Observing System-Aura satellite, able to provide a daily global coverage.

Data from the OMI instrument have been used in an extensive number of studies involving different atmospheric gases as NO_2, O_3, SO_2, HCHO, among others (Bhartia, 2002; Chance, 2002). The NO_2 data products provide information about total and tropospheric NO_2 columns. The NO_2 dataset in particular, has been validated in different studies. Celarier *et al.* (2006) compared NO_2 columns from OMI with NO_2 columns measured by the Système d'Analyse par Observation Zénithale (SAOZ) network, finding good agreement between the two of them although the measurements were not done at the same time. As a continuation, the different measurements and validation activities for OMI NO_2 stratospheric, tropospheric and total columns using ground- and aircraft-based measurements were summarized by Celarier *et al.* (2008). Good agreement was reported between OMI and nearby instruments, finding correlations higher than 0.6 with ground-based instruments, whereas OMI NO_2 stratospheric and total columns were found to be underestimated by 14 and 15-30%, respectively.

During the Dutch Aerosol and Nitrogen Dioxide Experiments for Validation of OMI and SCIAMACHY (DANDELIONS) 2005 and 2006 field experiments in the Netherlands, Brinksma *et al.* (2008) found good agreement between tropospheric NO_2 from OMI and MAX-DOAS (Multi-AXis), as well as between total NO_2 from OMI and direct sun observations. Boersma *et al.* (2008) compared OMI NO_2 tropospheric columns with *in situ* aircraft measurements during the INTEX-B campaign, the results showed good correlation with no significant bias between the two data sets. Irie *et al.* (2008) used MAX-DOAS measurements to validate OMI NO_2 columns during the Mount Tai Experiment 2006 finding that OMI data may have a positive bias of 20% over the North China Plain. Gruzdev and Elokhov (2010) found that tropospheric OMI NO_2 columns measured over Zvenigorod, Russia were approximately 40% lower than ground-based twilight measurements. Vlemmix *et al.* (2010) compared tropospheric ground-based measured NO_2 columns with OMI-satellite tropospheric NO_2 data finding no significant difference and a correlation of 0.88.