Atmospheric Pollution Research 6 (2015) 230-238

Atmospheric Pollution Research

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Spatial distribution and transport patterns of NO_2 in the Tijuana – San Diego area

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ABSTRACT

The atmospheric composition of the San Diego – Tijuana border is affected by transport of air pollutants between both regions and in both directions. In this study we show NO_2 transport events identified during Cal–Mex 2010 field experiment at two different ground sites, located one downwind of the other. This field campaign was designed to overlap with the closing weeks of CalNex project to observe trans–boundary pollution transport in this area. The measurements showed a clear dispersion pattern of NO_2 towards the east–southeast on several occasions during the field experiment. Additionally, the NO_2 column distribution above the Tijuana – San Diego region was reconstructed from the OMI satellite data product, and a cluster analysis with the corresponding meteorological data was performed to identify four distinct wind patterns yielding different NO_2 distribution maps and detecting dominant wind patterns in this region, either towards the E–SE or E–NE approximately 86% of the time.

Keywords: *NO_2, transport, OMI, cluster, dispersion*

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Article History:
Received: 23 May 2014
Revised: 22 August 2014
Accepted: 18 September 2014

doi: 10.5094/APR.2015.027

1. Introduction

The Cal–Mex 2010 field experiment, coordinated by the Molina Center for Strategic Studies on Energy and the Environment, was conducted with the specific focus of characterizing emissions along the California–Mexico border as well as assessing the impact of these emissions on local and regional air quality (Molina et al., 2014). The field campaign was carried out from May 15th to June 30th 2010 and comprised a series of ground sites established along the San Diego – Tijuana border. It was designed to catch and overlap the closing weeks of the CalNex project (ARB, 2008; ARB, 2014). The metropolitan areas share the same air basin, which is basically a coastal plain open to the west and north but closed to the east and south. In general, the terrain increases from sea level along the coast to over 1 200 m a.s.l. (above sea level) inland from the west to east with isolated peaks of about 2 100 m a.s.l. Because of the geographical situation of the region in the Southern California coast, the meteorology and air quality are influenced by the semi–permanent Pacific high and by effects of the coastal marine environment (Bigler–Engler and Brown, 1995).

On the scope of this field experiment, several studies were made during May–June 2010. Based on a review of 10 years of data, Bei et al. (2013) found that between May and June the prevailing wind along the coast is weak and variable between southerly and northerly winds. From sunrise to afternoon, the surface prevailing wind directions along the coast are mainly onshore (southwest to northwest). Toward the nighttime, prevailing winds are weak and diverse, which are similar to the early morning conditions. Zheng et al. (2013a) conducted measurements of formaldehyde, finding that the early onset of the daily maximum was found around 3 h before solar noon, indicating the presence of primary formaldehyde sources and a fast loss due to photolysis in the Tijuana area. The formaldehyde emissions during early morning rush hours were expected to originate from anthropogenic activities, especially from the transportation sector. Shores et al. (2013) characterized the spatial and temporal variability of black carbon in order to identify potential source areas and assess the cross–border transport, finding occurrences of black carbon peaks around midnight. They proposed that black carbon in Tijuana was usually of local origin and that trans–boundary transport from Tijuana into the US was common. Takahama et al. (2013) studied submicron organic aerosols in Tijuana, finding contributions from anthropogenic combustion, biomass burning and marine sources. This study also found that the more oxygenated fraction of the submicron organic aerosol mass was likely to be aged aerosol transported to Tijuana from pollution advected to sea by a sub–grid scale land–sea breeze circulation off the coast of Southern California. Rivera et al. (2013a) quantified nitrogen dioxide (NO_2) fluxes from Tijuana and the Rosarito power plant during Cal–Mex 2010 finding high variability in fluxes and good agreement between modeled and measured plumes. Zheng et al. (2013b) studied volatile organic compounds (VOCs) in Tijuana, attributing them to solvent usage, gas/diesel vehicle

exhausts and aged plumes. Both gasoline and diesel engine emissions were associated with air masses passing through San Ysidro and Otay Mesa, two important cross–border ports. In addition, aged plumes consisting mainly of NO_2 (92%) and long–lived oxygenated VOCs such as methanol and acetone were associated with north–westerly winds, likely from air masses of the San Diego area.

This work focuses on NO_2, one of the most important air pollutants in the troposphere. Nitrogen oxides (NO_X=NO+NO_2) can be emitted from high–temperature combustion processes, such as those occurring in trucks, cars and power plants. However, much of the NO_2 present in the atmosphere is produced through reactions of NO with ozone (O_3) close to the NO_X emissions site, and organic radicals present along the trajectory path where urban plumes are dispersing (Finlayson–Pitts and Pitts, 2000). Nitrogen dioxide has a relatively short lifetime and is a key precursor of O_3 production in the lower atmosphere. Over the Tijuana – San Diego region, anthropogenic emissions from fossil fuel combustion of automobiles, power plants, or industries constitute the main source of nitrogen oxides (NO_X).

According to the most recent emission inventory for the Tijuana Metropolitan Area in 2010, which corresponds to the base year 2005, the NO_X emission was 22.9 kT yr^{-1} (LT Consulting, 2010). On the other hand, the estimated NO_X emissions for the San Diego air basin for the year 2010 are 43.8 kT yr^{-1} (CARB, 2014a). In general, the hourly levels of NO_2 in Tijuana have been below 50 ppb since 2005, although occasional peaks of around 200 ppb are still observed (SPA, 2011). NO_2 hourly average peaks of around 120 ppb have been occasionally observed in San Diego since 2005 (CARB, 2014b).

This paper focuses on NO_2 events (from ground–based measurements) of abnormally large enhancements with respect to the typical levels observed during the Cal–Mex 2010 field experiment. It is of special interest to identify specific days and associate them with prevailing wind schemes to generate maps for the area of interest of the NO_2 vertical–column distribution. For this, data from the Ozone Monitoring Instrument (OMI) onboard the Aura satellite (NASA) was used. Four distinctive maps associated to different wind patterns resulted from a cluster analysis of historic meteorological data.

2. Methodology

2.1. Measurement sites

From May 17th to June 30th 2010 ground–based NO_2 DOAS (Differential Optical Absorption Spectroscopy), NO–NO_2–NO_X concentration and meteorological measurements were conducted at the Parque Morelos (PQM) site which was considered as the super–site for the Cal–Mex 2010 field experiment. The PQM site is located near the urban center of Tijuana (Baja California, Mexico) at 32.50°N, 116.94°W and has an elevation of 47 m a.s.l. (Figure 1). It is about 5.6 km to the south of the Mexico–California border and about 16 km to the western coastline. The site is located in the east of the city, 50 m north of a main avenue and about 300 m to the south of a small hill range. Additional ground–based concentration measurements of NO_X and meteorological parameters were conducted at the Universidad Tecnologica de Tijuana (UTT) located at 32.46°N, 116.82°W at an elevation of 173 m a.s.l. in the western piedmont of the La Gloria mountain range. UTT is about 12 km to the southeast of PQM in the edge of the Tijuana city and about 11 km to the south of the border. Meteorological data from nine stations located in and around the Tijuana and San Diego areas were used to investigate the historic wind patterns of the region. Figure 1 shows the location of all the sites. The period of meteorological data analyzed ranges from 1993 to 2010.

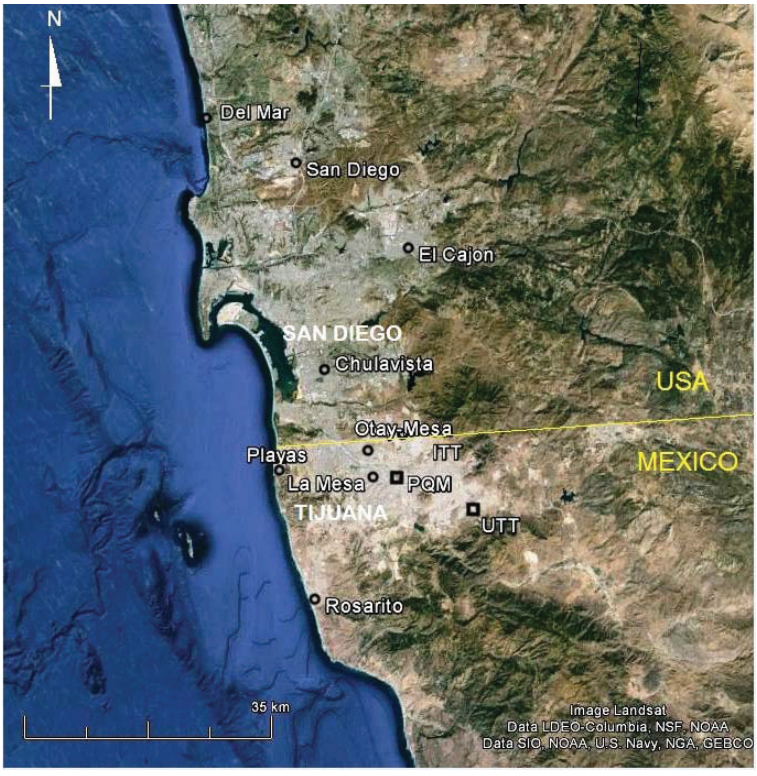

Figure 1. *Spatial distribution of ground–based measurement sites (◘ Cal–Mex 2010 monitoring sites, ○ meteorological stations).*