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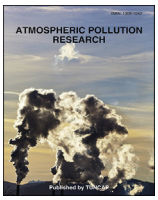

Influence of boundary conditions and anthropogenic emission inventories on simulated O_3 and $PM_{2.5}$ concentrations over Lebanon

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ABSTRACT

This study investigates the influence of boundary conditions and anthropogenic emission inventories on the simulated O_3 and $PM_{2.5}$ concentrations over a middle-eastern country – Lebanon. The Polyphemus chemical transport model (CTM) is used over Lebanon to simulate O_3 and $PM_{2.5}$ concentrations. Comparisons to measurements at a sub-urban site of Beirut between 2 and 13 July 2011 show that O_3 is largely over-estimated when concentrations from a large-scale model are used as boundary conditions, as used in Waked et al. (2013). A global anthropogenic emission inventory (EDGAR-HTAP) is used with Polyphemus, in order to provide anthropogenic emissions for the Middle-East domain. Over Lebanon, sensitivity to emissions and to boundary conditions have been investigated. The comparison of EDGAR-HTAP to Waked et al. (2012) over Lebanon highlights high discrepancies between the inventories both in terms of emission estimates and spatial distribution. However, when studying the sensitivity to boundary conditions, O_3 is well modeled when a Middle-East domain and the Lebanon domain are nested and thus achieves better statistics. The observed concentration is 48.8 μg m^{-3} and the respective concentrations for the simulation using MOZART4 and the one using the Polyphemus/Middle-East are 154.8 and 65.1 μg m^{-3}. As for $PM_{2.5}$ which is less sensitive to regional transport than O_3, the influence of the boundary conditions on the $PM_{2.5}$ concentrations at the site of comparison is low. The observed concentration is 20.7 μg m^{-3}, while the modeled concentrations are 20.7 and 20.1 μg m^{-3} respectively.

Contents

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1. Introduction

Lebanon, a developing country of the Middle East, is facing multiple challenges related to ambient air quality problems resulting from climatic conditions, high anthropogenic emissions, and persistent air pollution conditions (Afif et al., 2008, 2009; Waked et al., 2013). However, the only legislation made for ambient air quality standards dates back to 1996 (MoE, 1996), and has not been updated since then. Nowadays, this legislation is considered as outdated in comparison to the current ambient air quality standards of the European Union (EU) and the World Health Organization (WHO), as it does not define standards for $PM_{2.5}$ concentrations, and tolerates higher concentrations than in the WHO guidelines (WHO, 2006) for yearly NO_2, PM_{10}, etc. Table 1 compares the air quality standards of the Lebanese legislation to those of the European legislation and those of the WHO guidelines. Until 2013, air quality in Lebanon was assessed through initiatives conducted by universities as part of their short-term research studies and focused mainly on Beirut (Afif et al., 2008, 2009; Waked et al., 2013, 2014). In 2013, the Ministry of Environment with the support of the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP) established the first phase of the national air quality monitoring network comprising five air quality monitoring stations. Data is not public yet. The achievement of the expansion of the air quality network is planned to increase the number of stations to sixteen in 2016.

In an effort to better understand and estimate pollutant concentrations over Beirut, a summer campaign with pollutant measurements (CO, NO_x, O_3, and $PM_{2.5}$) was performed in 2011. Simultaneously, Waked et al. (2012) put together the first emission inventory for both Lebanon (with a grid resolution of 5 km) and Beirut and its suburbs (with a grid resolution of 1 km). They used it in an air-quality modeling study using the Polyphemus chemical transport model (CTM) (Mallet et al., 2007) over two nested domains (Lebanon and Beirut) (Waked et al., 2013). Over Lebanon, their simulations showed a good spatial representation of the country's hotspots such as Beirut, Chekka, and Zahle. Over Beirut, the results were satisfactory for most of the pollutant concentrations measured during the summer campaign of 2011. However, simulations showed an over-estimation of ozone concentrations over Beirut when compared to measurements. This issue was resolved by dividing the boundary conditions for ozone of their coarsest domain (Lebanon) by a factor two. These boundary conditions were obtained from a global-scale model MOZART-4 (Model for OZone And Related chemical Tracers version 4) (Emmons et al., 2010). In order to simulate accurately pollutant concentrations over Lebanon and Beirut, boundary conditions of the simulations over Lebanon need to be improved. To that end, in this paper, simulations over a larger domain than Lebanon are performed using Polyphemus and are used as boundary conditions of the Lebanon simulation. Since an emission inventory over such larger domain is not available, a global emission dataset is used: EDGAR-HTAP (Janssens-Maenhout et al., 2012). This dataset has a grid resolution of $0.1^\circ \times 0.1^\circ$ and it uses modeling to estimate emissions over regions where emissions inventories are not available. In this global dataset, modeling is also used over certain regions such as Europe to improve the spatial resolution of available gridded emission inventories. Over Lebanon in EDGAR-HTAP, modeling is used, although a gridded emission inventory exists (Waked et al., 2012).

The objective of this paper is to improve air quality simulations over Lebanon. To that end, we study the sensitivity of the concentrations simulated over Lebanon to the anthropogenic emission datasets and to the boundary conditions used. The paper is organized as follows: in Section 2, the air-quality modeling system Polyphemus used in the simulations of this paper is briefly described. Section 3 presents the global emission dataset EDGAR-HTAP and the local emission dataset used over Lebanon. The impact of emission modeling in the global emission inventory EDGAR-HTAP is studied by comparison to local inventories over Europe and Lebanon, and the impact of the emission dataset used on pollutant concentrations simulated with Polyphemus is evaluated. The potential shortcomings of the EDGAR-HTAP emission dataset over Lebanon are estimated. Finally, Section 4 presents a Middle East simulation performed with Polyphemus and the impact of using it as boundary conditions of the Lebanon simulations.

Table 1
The current Lebanese Air Quality Standards (in $\mu g\ m^{-3}$) as found in the legislation of 1996 (MoE, 1996) along with the current standards from the European Union legislation (EU, 2008) and the World Health Organization guidelines (WHO, 2006).

Pollutant	Duration of exposure	Lebanon	EU	WHO
SO_2	10 min	–	–	500
	1 h	350	350	–
	24 h	120	125	20
	1 year	80	–	–
NO_2	1 h	200	200	200
	24 h	150	–	–
	1 year	100	40	40
O_3	1 h	150	–	–
	8 h	100	120	100
CO	1 h	30,000	–	30,000
	8 h	10,000	10,000	10,000
Lead	1 year	1	0.5	0.5
Benzene	1 year	16	5	excess lifetime risk of leukemia
TSP	24 h	120	–	–
PM_{10}	24 h	80	50	50
	1 year	–	40	20
$PM_{2.5}$	24 h	–	–	25
	1 year	–	25	10

2. Modeling set-up

The Polyphemus air quality modeling platform is used in this study with the CTM Polair3d (Mallet et al., 2007). The set-up is similar to Waked et al. (2013) for the Lebanon domain. A coarser domain is added for the Middle East region and comprises the Lebanon domain. This Middle East domain is added in order to study the influence of the boundary conditions of the Lebanon domain on the concentrations. In the default set-up used in this paper, the simulation over Lebanon uses concentrations from the simulation over the Middle East as boundary conditions. The simulation domains are presented in Fig. 1. The Middle East domain covers the east Mediterranean basin and the Arab peninsula. It extends from 21°E to 46°E and from 24°N to 41.5°N with a horizontal resolution of $0.25^\circ \times 0.25^\circ$. The Lebanon domain extends

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