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Regional climate feedbacks in Central Chile and their effect on air quality episodes and meteorology

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A B S T R A C T

Santiago, an emerging megacity of 7 million plus inhabitants has shown great improvement in its air quality reducing $PM_{2.5}$ concentrations from 69 μg/m^3 in 1989 to 24 μg/m^3 in 2013 with a comprehensive air quality management strategy. An operational air quality forecasting model that has shown great potential in predicting air quality episodes is used to establish how the climate A1B scenario can impact the frequency of bad air days. In comparison to 2011, in 2050 extreme air quality episodes will be reduced in 20%. WRF-Chem is used to evaluate the effect of anthropogenic emissions on the regional climate including aerosol radiative feedbacks for October–November 2008. Anthropogenic emissions of sulfur and black carbon show different geographical patterns which result in local cooling (0.2–1 °C) in coastal Chile, due to large sources of SO_2. Central Chile, where most of the population of the country lives, shows transportation of black carbon emissions into the Andes mountain range, resulting in local warming of 0.4 °C.

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While global forcings may cause regional heating for 2050, reducing current black carbon emissions in Central Chile can reduce anthropogenic warming with immediate benefits to the regional climate, and simultaneously reducing local air pollution.

1. Introduction

Rural urban migration is driven by many factors, including the search for better economic opportunities (Henderson, 2002). Cities are very efficient in delivering goods and services to the population (Gordon and Richardson, 1997), and densification thwarts increased emissions associated to sprawl (Glaeser and Kahn, 2010). But when population reaches a certain level, megacities can be very unsustainable in their demand for water resources and solid waste management (Niemczynowicz and Iwra, 1996). Megacities also cause a high density of population and emissions, which are ideal conditions for increased exposure to atmospheric pollutants (Parrish and Zhu, 2009), ultimately linked to (Dockery and Stone, 2007; Seaton et al., 1995; Miller et al., 2007), alongside with premature mortality (Samet et al., 2000; Pope et al., 2004).

Megacities have been shown to have large regional impacts on air quality, increasing concentrations of particulate matter, ozone (O_3), carbon monoxide (CO) and nitrogen oxides (NO_x). Anthropogenic sources of pollution have been traced at long distances. Chinese megacity emissions have been detected in aircraft measurements in the northern Pacific, thousands of kilometers from their origin (Jacob et al., 2003). Mexico City's emissions have been shown to increase regional concentrations of ozone by exporting large amounts of precursors almost 1000 km NE of the city, and aerosol sources were shown to decrease photochemical activity nearby, through the direct effects of aerosols scattering and absorbing sunlight (Le Quesne et al., 2009; Mena-Carrasco et al., 2009). Santiago's anthropogenic black carbon, and ozone precursors have been detected some 3000 km northwest of the city, over the southeast Pacific Ocean (Mena-Carrasco et al., 2010; Yang et al., 2011; Saide et al., 2012a). Anthropogenic black carbon can deposit on glaciers and mountain snowpack, contributing to melting (Ramanathan and Carmichael, 2008).

Central Chile's Metropolitan Region, which includes Santiago, has a total population of 7,007,620, representing 40% of the nation's population. The urban area is located entirely in a basin between two mountain ranges, the Cordillera de Los Andes to the east and the Cordillera de la Costa to the west, which limit horizontal dispersion. Successive air pollution attainment plans have successfully reduced annual average $PM_{2.5}$ concentrations from 69 $\mu g/m^3$ in 1989 to 24 $\mu g/m^3$ in 2013 (Fig. 1). Among the most important measures contributing to this reduction were banning open burning during the winter months, establishing standards and permanent restrictions on passenger and fleet motor vehicle emissions, overhauling the public transportation system, and importing cleaner fuels for industrial processes. Also, diesel fuel in Santiago currently has a limit of 30 ppm sulfur, making it among the cleanest in the world, and supporting the deployment of clean diesel technology (Jhun et al., 2013).

During the winter, $PM_{2.5}$ and PM_{10} standards are routinely exceeded, and for those reasons there are bad air day measures in place to reduce emissions from industry and motor vehicles when an exceedance is predicted. Colder winters are associated to increased frequency of bad air days due to both lower dispersion conditions and increased emissions (Mena-Carrasco et al., 2012).

Little has been done on regional climate modeling in Chile (Cortes et al., 2012), much less the effect of climate forcings on future air quality episodes, nor the effect of aerosols on regional meteorology. This study identifies the potential effects of current criteria pollutant emissions and future climate on air quality episodes in Santiago using a regional coupled chemistry-climate model, independently quantifying impacts of synoptic conditions that cause low dispersion conditions as well as the effect