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Atmospheric transport of ozone between Southern and Eastern Asia

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HIGHLIGHTS

- Maximum effect of East Asian pollution over South Asia happens in post-monsoon.
- Maximum effect of South Asian pollution over East Asia occurs in pre-monsoon.
- Most densely populated parts of South Asia are affected by East Asian emission.
- South Asia is largely affected by the East Asian emission change from 2000 to 2010.

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ABSTRACT

This study describes the effect of pollution transport between East Asia and South Asia on tropospheric ozone (O_3) using model results from the Task Force on Hemispheric Transport of Air Pollution (TF HTAP). Ensemble mean O_3 concentrations are evaluated against satellite-data and ground observations of surface O_3 at four stations in India. Although modeled surface O_3 concentrations are 1020 ppb higher than those observed, the relative magnitude of the seasonal cycle of O_3 is reproduced well. Using 20% reductions in regional anthropogenic emissions, we quantify the seasonal variations in pollution transport between East Asia and South Asia. While there is only a difference of 0.05 to 0.1 ppb in the magnitudes of the regional contributions from one region to the other, O_3 from East Asian sources affects the most densely populated parts of South Asia while Southern Asian sources only partly affect the populated parts of East Asia. We show that emission changes over East Asia between 2000 and 2010 had a larger impact on populated parts of South Asia than vice versa. This study will help inform future decisions on emission control policy over these regions.

1. Introduction

Intercontinental transport of air pollution is a global issue as the air quality of a region can be highly influenced by long range transport from remote continents (HTAP, 2010). Pollutants with longer atmospheric life times are important when assessing the impacts of long range transport, but shorter lived air pollutants that produce secondary pollutants are also important. Tropospheric ozone (O_3) is a secondary pollutant produced through a sequence of photochemical reactions involving nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs) and CH_4. Due to the long lifetime of CH_4, the O_3 produced from its oxidation is largely independent of the location of the CH_4 emissions (Fiore et al., 2008). The spatial pattern of the O_3 formed is controlled by the distribution of OH and NO_x, which have much shorter lifetimes and can affect both the location of CH_4 oxidation and the amount of O_3 production per CH_4 molecule oxidized (Fiore et al., 2008). Increases in atmospheric CH_4 contribute to all regions relatively uniformly, averaging 1.5–1.9 ppb O_3 since 1960, and this contributes about one third of the O_3 increase seen over Europe (EU) and North America (NA) over this period (Wild et al., 2012). From a series of future (2005–2030) transient simulations, it has been demonstrated that cost-effective CH_4 controls could offset the positive climate forcing from CH_4 and O_3 and improve air quality (Fiore et al., 2008).

Measurements from remote regions consistently indicate that long-range transport exerts a strong influence on observed concentrations of aerosols, O_3 and its important precursors (HTAP, 2007). For example, dust of Asian origin has been observed throughout the North Pacific region (Duce et al., 1980; Prospero, 1979). Studies over the west coast of NA identified the influence of Asian emissions on the sulfur budget (Andreae et al., 1988) and on the concentrations of O_3, hydrocarbons and peroxyacetyl nitrate (Parrish et al., 1992). Several observation and model-based studies have shown the impact of foreign emissions on countries at Northern mid-latitudes. For example, EU and NA respectively contribute 3.5 ± 1.1 and 2.2 ± 0.5 ppb to the annual mean surface O_3 over Japan (Yoshitomi et al., 2011). The annual mean magnitude of

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NA and EU contributions to surface O_3 over East China is 1.2 ppbv and 1.5 ppbv respectively. EU experiences the greatest intercontinental import of O_3 due to rapid short-distance transport from NA (Wild and Akimoto, 2001). A widely used technique to study the contribution of upwind emissions to a region downwind is the calculation of source–receptor relationships, which evaluate the impact of a relatively small emission perturbation over a specific source region (Derwent et al., 2001; Fiore et al., 2002; Wild and Akimoto, 2001). Source–receptor relationships depend on various factors including the emission strength, size of the source region, the transport pathway, and the extent of pollutant transformation and loss during transport.

This study quantify the source–receptor relationship for surface O_3 between East Asia (EA, 15–55°N, 95–160°E) and South Asia (SA, 5°–35°N, 50°–95°E) using the Task Force on Hemispheric Transport of Air Pollution (HTAP) Phase 1 source–receptor model experiments (www.htap.org). EA and SA are two major developing industrial regions that are also the most heavily populated regions in the world. Development in each of these regions not only affects air quality in the region itself, but also air quality in the other region through the transport of air pollutants from one region to the other. There is widespread scientific agreement that the observed increase in O_3 concentrations is the consequence of human activities around the globe. Among anthropogenic factors, the principal one is increasing population (Dietz and Rosa, 1997). A population density map for the year 2000 (Fig. 1) shows that India, Central and Eastern China, Japan, Bangladesh and Korea are the most densely populated regions. Bangladesh and the Indo-Gangetic plain of India are the most densely populated parts of southern Asia.

Model simulated surface O_3 over this region is quite high, ranging from 35 to 55 ppbv (Fig. 2). Surface O_3 over the most populated parts of EA (the coastal region of China, Japan, and Korea) ranges from 45 to 65 ppb.

Anthropogenic emissions over both Southern and Eastern Asia have experienced a rapid increase in recent decades (Hilboll et al., 2013; Richter et al., 2005; Zhang et al., 2007). Model based study of biomass burning over SA shows that there is enhancement of surface ozone of about 4 to10 ppb (25–50%) in the Eastern region including Burma (during March and April), 1–3 ppb (10–25%) in the Central India (during

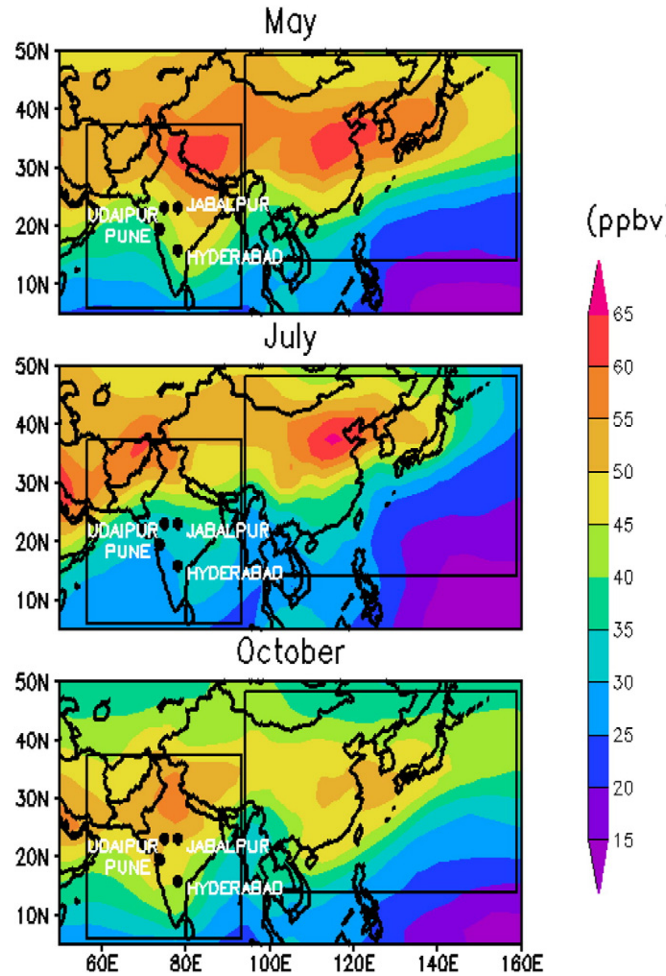

Fig. 2. Surface O_3 concentration for the months of (a) May, (b) July and (c) October, in the ensemble average of 14 models.

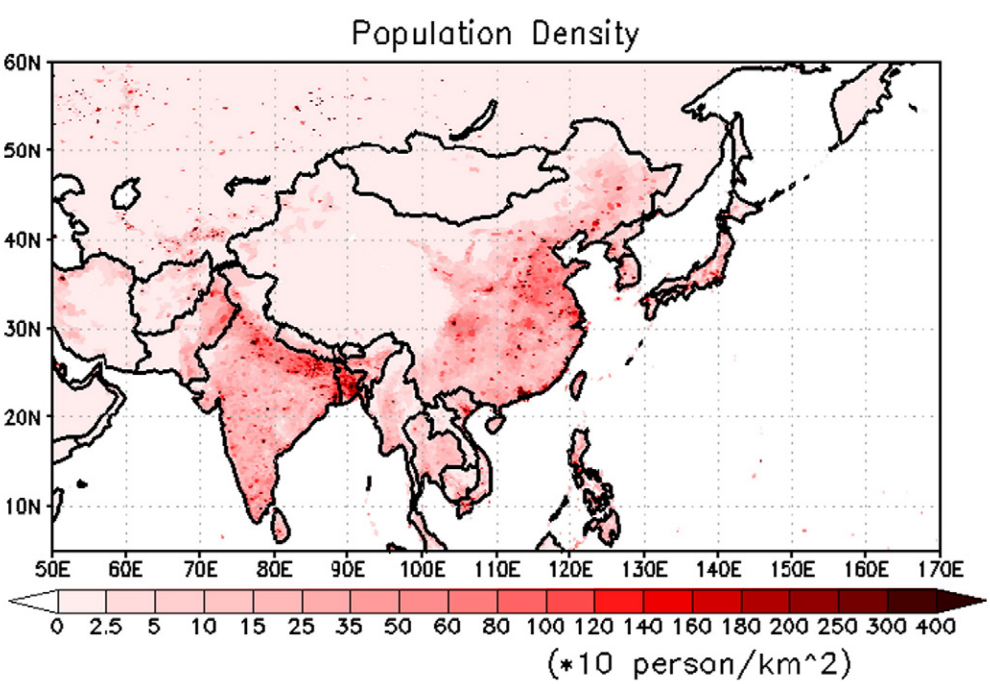

Fig. 1. The population density in Asia (http://sedac.ciesin.columbia.edu).