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Ozone concentrations in air flowing into New York State

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HIGHLIGHTS

- New York State receives high regional inflow of ozone.
- We provide conservative estimate of inflows.
- Inflows limit New York ability to comply with ozone standards.

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ABSTRACT

Ozone (O_3) concentrations measured at Pinnacle State Park (PSPNY), very close to the southern border of New York State, are used to estimate concentrations in air flowing into New York. On 20% of the ozone season (April–September) afternoons from 2004 to 2015, mid-afternoon 500-m back trajectories calculated from PSPNY cross New York border from the south and spend less than three hours in New York State, in this area of negligible local pollution emissions. One-hour (2p.m.–3p.m.) O_3 concentrations during these inflowing conditions were 46 ± 13 ppb, and ranged from a minimum of 15 ppb to a maximum of 84 ppb. On average during 2004–2015, each year experienced 11.8 days with inflowing 1-hr O_3 concentrations exceeding 50 ppb, 4.3 days with $O_3 > 60$ ppb, and 1.5 days had $O_3 > 70$ ppb. During the same period, 8-hr average concentrations (10a.m. to 6p.m.) exceeded 50 ppb on 10.0 days per season, while 3.9 days exceeded 60 ppb, and 70 ppb was exceeded 1.2 days per season. Two afternoons of minimal in-state emission influences with high ozone concentrations were analyzed in more detail. Synoptic and back trajectory analysis, including comparison with upwind ozone concentrations, indicated that the two periods were characterized as photo-chemically aged air containing high inflowing O_3 concentrations most likely heavily influenced by pollution emissions from states upwind of New York including Pennsylvania, Tennessee, West Virginia, and Ohio. These results suggest that New York state-level attempts to comply with National Ambient Air Quality Standards by regulating in-state O_3 precursor NO_x and organic emissions would be very difficult, since air frequently enters New York State very close to or in excess of Federal Air Quality Standards.

1. Introduction

Ozone pollution measured at any location can form from precursor NO_x (= NO + NO_2) and organic emissions at various distances upwind of the measurement site. The contributions of in-state emissions relative to contributions from out-of-state emissions will heavily influence any state-level strategy that might be considered to mitigate O_3 concentrations in excess of accepted federal health standards.

Ozone that is photochemically produced in the lower troposphere has a relatively long atmospheric residence time: several days in the planetary boundary layer, and up to several weeks in the free troposphere. Numerous studies have shown that elevated and harmful ozone concentrations can be formed from pollution emitted far upwind and transported long distances to a measurement location (Reid et al., 2008; Chan and Vet, 2010; McDonald-Buller et al., 2011 and references therein).

Lindskog et al. (2007) studied an extreme ozone episode at remote Scandinavian sites located north of the Arctic Circle. On 19–20 April 2003, they noted that two sites measured ozone concentrations of about 85 ppb, along with higher concentrations of nitrate, suggesting an anthropogenic pollution origin.

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Source–receptor analysis connected this episode to a pollution plume originating over southern continental Europe and United Kingdom.

Parrish et al. (2010) analyzed ozone sonde measurements launched from Trinidad Head, California to estimate background O_3 in air flowing into North America on the west coast. They found that inflowing background O_3 exceeds 75 ppb under many conditions.

Transport of elevated ozone concentrations over considerable distances also occurs on subcontinental and regional scales. For example, Angevine et al. (2004) document cases where overwater transport from primarily Boston, but also the entire New York - Washington D. C. urban corridor contributes to ozone concentrations in Maine exceeding 100 ppb.

Ozone transport from outside of state is of great concern to New York State policymakers. On October 1, 2015, the United States Environmental Protection Agency (EPA) revised the primary and secondary national ambient air quality standard (NAAQS) for ozone to provide protection of public health and welfare (80 FR 65292, October 26, 2015). EPA revised the levels of both standards to 70 ppb averaged over an eight hour period, and retained their indicator as the fourth-highest daily maximum, averaged over three consecutive years. As a result of how compliance with the NAAQS is calculated, even a small number of days with elevated levels of ozone produced from out-of-state precursor emissions can negate the effects of emission reduction control measures implemented within New York State.

Although EPA did valuable work on estimating background ozone concentrations (McDonald-Buller et al., 2011; EPA, 2014), New York's concerns have not been adequately addressed because EPA defines "background" as ozone that would exist in the absence of any anthropogenic ozone precursor emitted from United States. New York's concern is with high levels of ozone produced from emissions outside of New York State (but within North America) flowing into its jurisdiction. Ozone produced from pollution emissions outside New York State can be much higher than EPA estimates of "background" ozone. This problem was acknowledged by Williams et al. (2009), who find that the margin between ozone standards and background ozone concentrations is narrow for many localities in the United States.

It is known that transport of ozone produced outside New York State can be significant, but it is difficult to quantify these out-of-state impacts in the context of the ozone NAAQS. For example, if transport of out-of-state ozone exceeds 50–60 ppb several times in one year, it may cause a nonattainment designation for the NAAQS despite minimal influences by in-state pollution emissions.

Obtaining accurate apportionment data of local, upwind and stratospheric sources of ozone over extended time periods is difficult. Cooper et al. (2015) suggest using improved numerical models in combination with enhanced ozone observations. However, the details of implementing this attribution strategy require considerable future research efforts.

The objective of this study is to quantify the frequencies of high regional ozone transport into New York using readily available tools and historical monitoring data. The results of this study will be useful for policymakers planning attainment strategies for the more stringent ozone NAAQS.

Ozone and other pollutants are transported into New York State from multiple upwind regions. These include the Chicago and Detroit-Windsor area to the west, metropolitan Toronto to the north, and the coastal urban corridor and Ohio Valley to the south. This study focuses on ozone transported into New York from the south at one location along the central portion of the southern border of New York State. This study analyzed afternoon 72-hr back trajectories from the border site over the 12-year period 2004–2015. Inflowing conditions were defined as those afternoons where back trajectories from Pinnacle spent less than three hours in New York State. Since the Pinnacle site is located in an area of low local pollution sources, ozone concentrations measured under these conditions will be negligibly influenced by pollution emissions from within New York. Here ozone observations during these inflowing periods were analyzed.

2. Data and methods

2.1. Site description

The Pinnacle State Park monitoring site (42.091°N, 77.210°W; EPA ID 36-101-0003) is located about 2 km southwest of the small rural village of Addison (2010 population: 2295) in southwest New York State (Fig. 1). The closest city is Corning (2010 population 11183), about 14 km northeast of the site. The larger city of Elmira (2010 population 29200) is located 33 km due east. The Pinnacle monitoring site is about 10 km north of the New York-Pennsylvania state border, which runs west to east along the 42°N latitude line.

The Pinnacle site is operated by Atmospheric Sciences Research Center of SUNY Albany. Ozone, oxidized nitrogen species (NO, NO_x and NO_y), carbon monoxide, sulfur dioxide, various hydrocarbons, and meteorological parameters have been monitored continuously at this site since 1995. Detailed information on the site, instrumentation, and measurement protocols are described in Schwab et al. (2009). The Pinnacle site is ideal for monitoring pollution concentrations within air entering New York State from the south, and its rural character ensures little local emissions.

2.2. Trajectory analysis

Back trajectories were calculated using the NOAA HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) model (Draxler, R.R. and Rolph, 2015; Rolph, 2015). Calculations were done on the 40 km resolution NCEP Eta Data Assimilation System (EDAS) meteorological grid, available since 2004.

72-hr back trajectories arriving 500 m above Pinnacle at 1800 UT (2 p.m. local time) were calculated daily during the April–September ozone season between 2004 and 2015. The 500 m height is representative of air within a typical mid-afternoon well-mixed planetary boundary layer.

Trajectories with less than three hour residence time in New York State before arriving at Pinnacle at 2 p.m. were then visually checked

Fig. 1. Map of New York State showing location of Pinnacle monitoring site.