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An overview of the 2013 Las Vegas Ozone Study (LVOS): Impact of stratospheric intrusions and long-range transport on surface air quality

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HIGHLIGHTS

- Stratosphere-to-troposphere transport (STT) significantly impacts surface O_3 in the intermountain west.
- STT can directly lead to exceedances of the 2008 ozone NAAQS during springtime.
- STT influences background surface O_3 more than long-range transport from Asia.
- With a 65 ppbv standard, exceedances may be too frequent to treat as “exceptional events” in the intermountain west during springtime.

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ABSTRACT

The 2013 Las Vegas Ozone Study (LVOS) was conducted in the late spring and early summer of 2013 to assess the seasonal contribution of stratosphere-to-troposphere transport (STT) and long-range transport to surface ozone in Clark County, Nevada and determine if these processes directly contribute to exceedances of the National Ambient Air Quality Standard (NAAQS) in this area. Secondary goals included the characterization of local ozone production, regional transport from the Los Angeles Basin, and impacts from wildfires. The LVOS measurement campaign took place at a former U.S. Air Force radar station ~45 km northwest of Las Vegas on Angel Peak (~2.7 km above mean sea level, asl) in the Spring Mountains. The study consisted of two extended periods (May 19–June 4 and June 22–28, 2013) with near daily 5-min averaged lidar measurements of ozone and backscatter profiles from the surface to ~2.5 km above ground level (~5.2 km asl), and continuous in situ measurements (May 20–June 28) of O_3, CO, (1-min) and meteorological parameters (5-min) at the surface. These activities were guided by forecasts and analyses from the FLEXPART (FLEXible PARTticle) dispersion model and the Real Time Air Quality Modeling System (RAQMS), and the NOAA Geophysical Research Laboratory (NOAA GFDL) AM3 chemistry-climate model. In this paper, we describe the LVOS measurements and present an overview of the results. The combined measurements and model analyses show that STT directly contributed to each of the three O_3 exceedances that occurred in Clark County during LVOS, with contributions to 8-h surface concentrations in excess of 30 ppbv on each of these days. The analyses show that long-range transport from Asia made smaller contributions (<10 ppbv) to surface O_3 during two of those exceedances. The contribution of regional wildfires to surface O_3 during the three LVOS exceedance events was found to be negligible, but wildfires were found to be a major factor during exceedance events that occurred before and after the LVOS

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campaign. Our analyses also shows that ozone exceedances would have occurred on more than 50% of the days during the six-week LVOS campaign if the 8-h ozone NAAQS had been 65 ppbv instead of 75 ppbv.

1. Introduction

Surface ozone (O_3) has decreased dramatically across much of the eastern United States over the last two decades (Lefohn et al., 2010; He et al., 2013), largely as a result of stricter emission controls on stationary and mobile NO_x sources (Butler et al., 2011; EPA, 2012). More than 65% of the rural eastern U.S. sites surveyed in a recent study by Cooper et al. (2012) showed statistically significant decreases in median ozone during the summer with 43% also exhibiting significant decreases in the spring. In contrast, only 8% of the western U.S. rural sites examined showed similar summertime decreases, and more than 50% had significant springtime increases. These east–west differences have been partially attributed to increasing emissions of NO_x and other ozone precursors from industrial activities and development in East Asia (Jacob et al., 1999; Jaffe et al., 1999; Brown-Steiner and Hess, 2011; Zhang et al., 2011) and to a higher fraction of background ozone in the western U.S. compared to the east due to both long-range transport and stratospheric influences (Lefohn et al., 2012; Lin et al., 2012a, 2012b; Lefohn et al., 2014). The absence of clear trends in the west may reflect the cancellation of local emission controls by increasing background concentrations (Jaffe et al., 2003; Oltmans et al., 2008).

Much of the pollution emitted in East Asia is carried eastward across the North Pacific Ocean by the prevailing winds. The fastest transport occurs in the mid-and upper troposphere, often associated with Asian boundary layer pollution being entrained into the warm conveyer belts (WCB) of midlatitude cyclones, and these plumes can descend to the surface of western North America (Stohl, 2001; Cooper et al., 2004b; Liang et al., 2005; Brown-Steiner and Hess, 2011; Lin et al., 2012b). The high average elevation and deep boundary layers of the intermountain west increase the likelihood that some of this pollution may reach the surface as the plumes move inland and the transported pollution descends isentropically behind cold fronts (Liang et al., 2004). Asian pollution can also be transported to western North America at low altitude but only has a significant impact in summer (Holzer and Hall, 2007).

STT also contributes to the relatively high background ozone in boundary layer air transported ashore from the north Pacific during spring and can likewise lead to episodic increases at the surface (Langford et al., 2009; Ambrose et al., 2011; Lefohn et al., 2011). Direct transport of undiluted stratospheric air to the surface is uncommon, but some exchange of air between the upper troposphere and lower stratosphere occurs with all midlatitude cyclones (Johnson and Viezee, 1981) and a fraction of the ozone-rich air descending in the dry airstream (DA) may be entrained into the deep springtime boundary layers of the intermountain west. This descending air can also become interleaved with long-range transport layers in the WCB (Stohl and Trickl, 1999; Cooper et al., 2004a, 2004b).

Several climatologies (Wernli and Bourqui, 2002; James et al., 2003; Sprenger and Wernli, 2003) suggest that deep stratospheric intrusions (i.e. those penetrating to within ~3 km of the surface) are most likely to form near the exit of the east Pacific storm track above the Pacific Northwest with the deepest descent of stratospheric air near the coast of Southern California. These conclusions are consistent with measurements (Langford et al., 2012) made during the 2010 California Research at the Nexus of Air Quality and Climate Change (CalNex) field study, and with analyses from the NOAA/GFDL AM3 global-high resolution (~50 × 50 km) chemistry–climate model. Fig. 1 displays the mean contributions of (a) STT (Lin et al., 2012a), and (b) transport from Asia (Lin et al., 2012b) to the daily maximum 8-h average (MDA8) surface O_3 in the United States during May and June of 2010. These plots show the greatest impact of both transport processes to be in the Intermountain West with minimal contributions along the Gulf Coast and in the Southeastern U.S. The striking similarity between the two plots reflects the primary role of midlatitude cyclones in both transport processes. The AM3 model shows the stratospheric contribution to surface ozone during May and June of 2010 to be roughly 4–5 times that of long-range transport from Asia.

Since the higher background concentrations and episodic increases associated with STT and Asian pollution are unaffected by local control strategies, these processes pose a serious challenge for air quality managers tasked with meeting the NAAQS in the western United States. This is especially true in late spring when the contribution from local and regional photochemistry is also rapidly

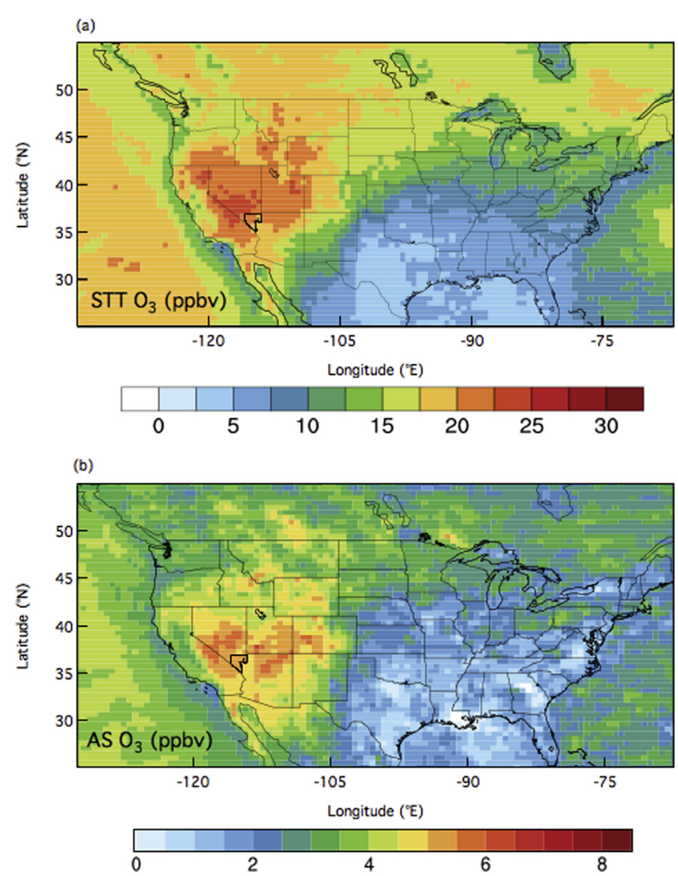

Fig. 1. NOAA GFDL AM3 model mean contributions of (a) STT, and (b) Asian pollution, to MDA8 surface O_3 during May and June of 2010. The resolution is 50 km × 50 km. Note the different color scales. Clark County, NV is outlined in black. Adapted from Lin et al. (2012a, 2012b). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)