Additional Comments on the 2019 Draft Integrated Science Assessment of the Ozone National Ambient Air Quality Standards

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Introduction

The authors provided written comments on November 26, 2019 to assist the Environmental Protection Agency's (EPA's) Clean Air Science Advisory Committee (CASAC) in their review of the EPA's 2019 Draft Integrated Science Assessment (ISA) and Policy Assessment (PA) of the Ozone National Ambient Air Quality Standards (NAAQS). Additional discussion is provided in this comment regarding the nature of stratospheric intrusions of ozone and how they affect surface ozone concentrations. Our comments discuss the general nature of these exchanges, and we mention field studies involving additional profiling of ozone concentrations aloft. These studies appear to indicate that stratospheric intrusions (SIs) into the upper troposphere are quite frequent and widespread, even if deep intrusions (to the ground within a short time) are more episodic in nature. Although the stratospheric ozone may often be mixed into the upper troposphere initially, the elevated ozone can reach the ground in somewhat diluted form during the days after the intrusion event.

Summary of Draft ISA comments on Stratospheric Intrusions

Much of the discussion of SIs is in Appendix 1, involving United States ozone background (USB). The draft ISA notes that deep SIs are "episodic" in nature and they do not typically occur during the peak summer ozone season. The draft ISA also notes that "quantifying the contribution of [stratospheric intrusions] to surface ozone remains challenging and is a source of uncertainty in estimating USB." In the additional comments that we provide below, we cite additional references and provide an example of how a stratospheric intrusion event documented with the assistance of ozonesondes may have been a contributor to a Maryland ozone NAAQS exceedance event two days later in July 2011.

Discussion of Stratospheric-Troposphere Exchanges

The tropopause separates the troposphere from the stratosphere. The stratosphere is characterized by stable temperature lapse rate conditions (where temperature does not decrease with height), low humidity, and high ozone levels. Commercial aircraft typically fly in the lower stratosphere (above 32,000 feet, or about 10 km in the mid latitudes) due to the lower levels of turbulence and lack of clouds at those levels. However, those who have flown on aircraft know very well that there can be high levels of turbulence even at those levels, that aircraft need to avoid areas of significant weather to avoid turbulence, and that spring and summer thunderstorms can penetrate to heights well above this level and cause significant air exchanges with the stratosphere.

In addition to tall cumulonimbus clouds associated thunderstorms, which are a commonplace event in the summer, there is significant mixing with the stratosphere and troposphere along the jet stream where cold or warm fronts are forming. In areas where fronts are forming, vertical turbulence at the tropopause level can lead to a distortion, or folding, of the tropopause, and mixing of stratospheric air into the troposphere. Several investigators[1,2,3,4] have studied these events, and the more extensive the upper-level measurements, the more likely the conclusion by these investigators that SI events are relatively frequent. However, the most common SI event is a shallow intrusion into the troposphere, rather than a deep intrusion.

While the shallow stratospheric intrusion events are much more frequent than deep intrusions, the elevated ozone remains in the troposphere and can still provide elevated levels of ozone to the ground after a day or so by the diurnal pattern of strong convective mixing within the troposphere, especially in the summer on days with clear skies. Typically, the very dry air of the stratosphere that is mixed into the troposphere will be seen in balloon soundings as contributing to a subsidence inversion, which is an elevated deep temperature inversion capped by a very dry layer of air. When the inversion breaks, the stratospheric air with its elevated ozone lying in a tropospheric reservoir aloft can be mixed to the ground. This can often happen with the passage of a high pressure system, which is also associated with relatively clear skies and strong photochemical activity. As investigators Singh et al. have noted, "under turbulent (windy) weather conditions, and under conditions of afternoon heating and convection of the boundary layer, ozone from the tropospheric reservoir is brought down to the ground almost intact." Therefore, high ozone concentrations at the ground can be a combination of ozone transported from the stratosphere and ozone generated from anthropogenic emissions.

Example of an SI Event Possibly Contributing to an Ozone NAAQS Exceedance

Due to the presence of ozonesondes (instruments that provide vertical atmospheric sampling of ozone concentrations) and aircraft ozone measurements during a research study in July 2011 (the 2011 DISCOVER AQ campaign[1]), the presence of specific SIs was able to be detected. One of these SI events occurred on July 14, 2011. These (and other) summertime SIs likely did not immediately transport ozone to ground level, but the ozone transported to the troposphere was then available for mixing to the ground on subsequent days when the enhanced contribution could potentially contribute to NAAQS exceedances.

Figure 1 (from the Ott et al. 2016 paper) shows areas of high SI-based ozone modeled on July 1, 2011. Figure 2 shows a backward trajectory using NOAA's HYSPLIT model[5] of air parcel movement (6-hour increments going 72 hours back in time) from a Maryland ozone monitor location (Aldino) that

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[1] Ott, L. E., et al. 2016. Frequency and impact of summertime stratospheric intrusions over Maryland during DISCOVER-AQ (2011): New evidence from NASA's GEOS-5 simulations, J. Geophys. Res. Atmos., 121, 3687–3706, doi:10.1002/2015JD024052. https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2015JD024052.
[2] Singh, H. B., W. Viezee , W. B. Johnson, and F. L. Ludwig, 1980. The Impact of Stratospheric Ozone on Tropospheric Air Quality, *Journal of the Air Pollution Control Association*, 30:9, 1009-1017, DOI: 10.1080/00022470.1980.10465139. https://www.tandfonline.com/doi/pdf/10.1080/00022470.1980.10465139.
[3] Škerlak, B., M. Sprenger, S. Pfahl, E. Tyrlis, and H. Wernli , 2015. Tropopause folds in ERA-Interim: Global climatology and relation to extreme weather events. *J. Geophys. Res. Atmos*., 120, 4860–4877, doi:10.1002/2014JD022787. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2014JD022787.
[4] Holton, J. R., P. H. Haynes, M. E. McIntyre, A. R. Douglass, R. B. Rood, and L. Pfister, 1995. Stratosphere-Troposphere Exchange*. Reviews of Geophysics*, 33-4, 403-439. Available at https://acd-ext.gsfc.nasa.gov/People/Douglass/95RG02097.pdf.
[5] NOAA Air Resources Laboratory website documents HYSPLIT, available at https://www.ready.noaa.gov/HYSPLIT.php.

measured an ozone NAAQS exceedance July 16, 2011. It is clear that the backward trajectory passes through the high ozone stratospheric region identified by Ott et al. as a region with very low humidity in Figure 1. The air trajectory indicates flow from the northwest into a high pressure area, and a subsequent migration of the high to the east of the monitor, resulting in a stagnant air mass followed by a weak southerly wind flow in advance of the high surface ozone measurements.

Conclusions

We point out that the draft 2019 ozone ISA focuses upon relatively infrequent deep SI events, while the more common case is a shallow SI event. Many exchanges between the troposphere and stratosphere can occur with spring and summer thunderstorms. The shallow SI events can still potentially contribute to a monitored ozone NAAQS exceedance after a day or two of diurnal convective mixing cycles that can act to mix the elevated stratospheric ozone to the ground.

Figure 1: Elevated dry relative humidity areas from SI Event on July 14, 2011 (from Ott et al. Figure 1)

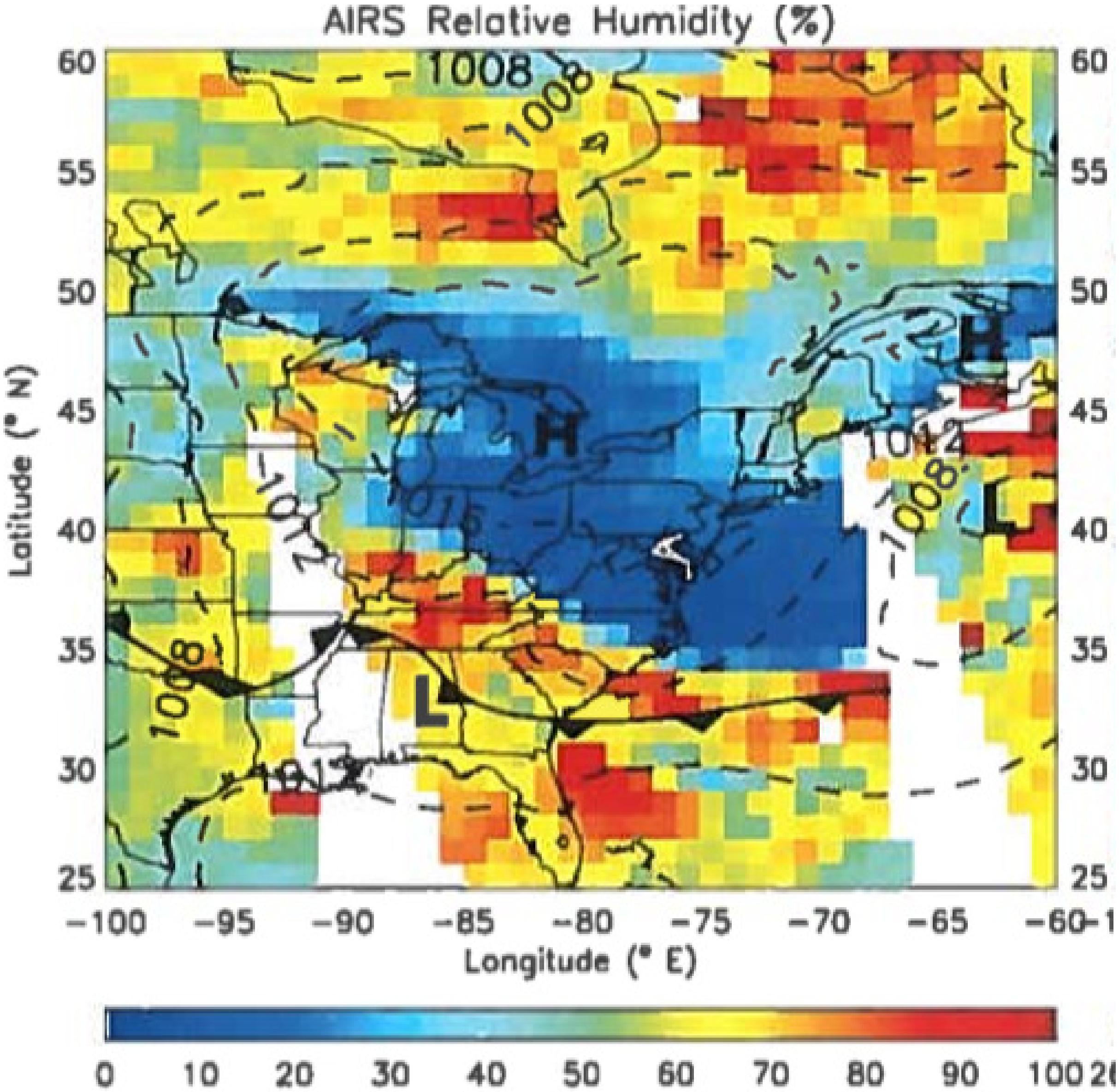

Figure 2: HYSPLIT Back Trajectory (72 hours; 6-hour increments) from a Maryland Monitor (Aldino) That Measured an Ozone NAAQS Exceedance on July 16, 2011