Using WRF-STILT to Determine Relative Contributions of US and Mexican Emissions to High Ozone Events in El Paso, Texas

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Introduction

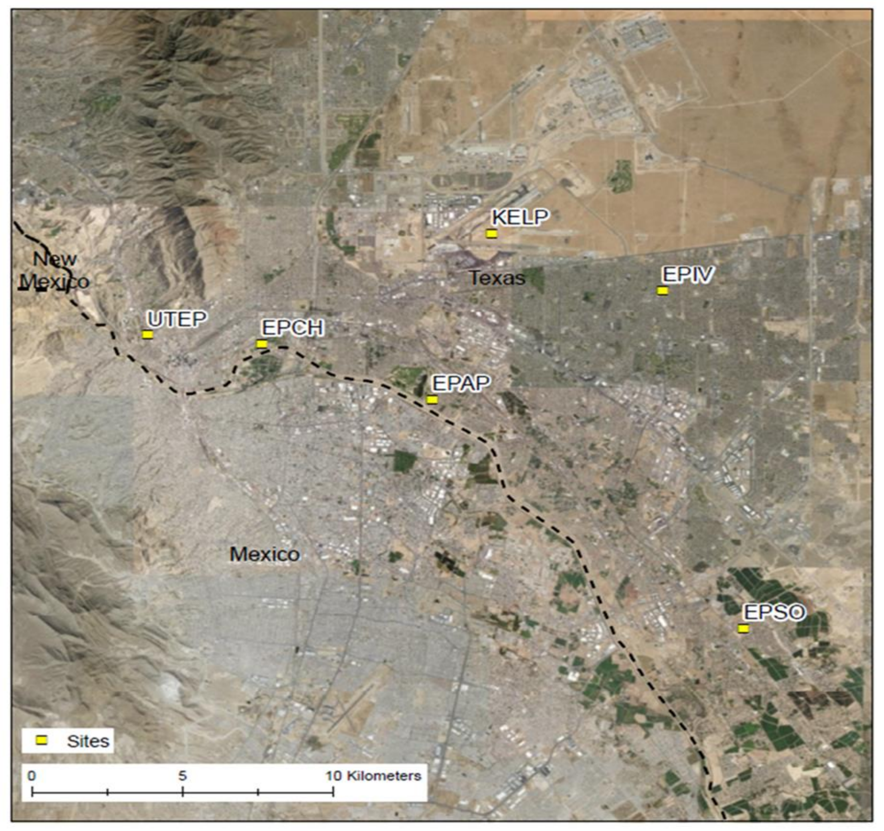
The U.S. Environmental Protection Agency (EPA) has set increasingly stringent National Ambient Air Quality Standards for ozone (O_3), and many O_3 observations for El Paso in recent years have been close to the latest standard. Because El Paso is on the border between the US and Mexico and directly borders Ciudad Juárez, the air quality in El Paso is influenced by emissions from both the US and Mexico. For compliance with the Clean Air Act, it would be useful for the Texas Commission on Environmental Quality (TCEQ) to separate days where El Paso had high O_3 primarily due to Mexican emissions of O_3 precursors from days where the high O_3 is primarily due to US emissions.

The WRF-STILT atmospheric transport and dispersion modeling framework has been used in several studies to determine the emission sources impacting observations of pollutants at a given monitoring location (e.g., Nehrkorn et al., 2010, *Meteor. Atmos. Phys.*). The WRF-STILT framework calculates emissions "footprints" for each measurement that can be combined with bottom-up emission inventories to estimate the relative impacts of sources from different geographic regions. In this study, WRF-STILT footprints for recent poor air quality events in El Paso, Texas were combined with emission inventories to quantify the relative influence of US (inside and outside of Texas) and Mexican emissions sources on Volatile Organic Compounds (VOCs) and oxides of nitrogen (NOx) during the events.

Methods

Case Selection

The 10 days with the highest maximum daily 8 - hour average ozone (MDA8) at the TCEQ El Paso Chamizal monitoring location (shown as EPCH in the image to the right) from 2012 – 2018 were selected for analysis. A total of 70 episodes were analyzed. The EPCH location was selected because it included VOC measurements over the time period that were used in a companion cluster analysis study. The MDA8 at EPCH were compared with MDA8 at other TCEQ monitoring locations in El Paso (shown as yellow dots in the image) including the El Paso International Airport (KELP) and the University of Texas El Paso (UTEP) and were found to be consistent in terms of the timing and intensity of the high O_3 episodes. The dashed line in the image represents the US-Mexican border with Ciudad Juárez located just south of the border in the center of the image.

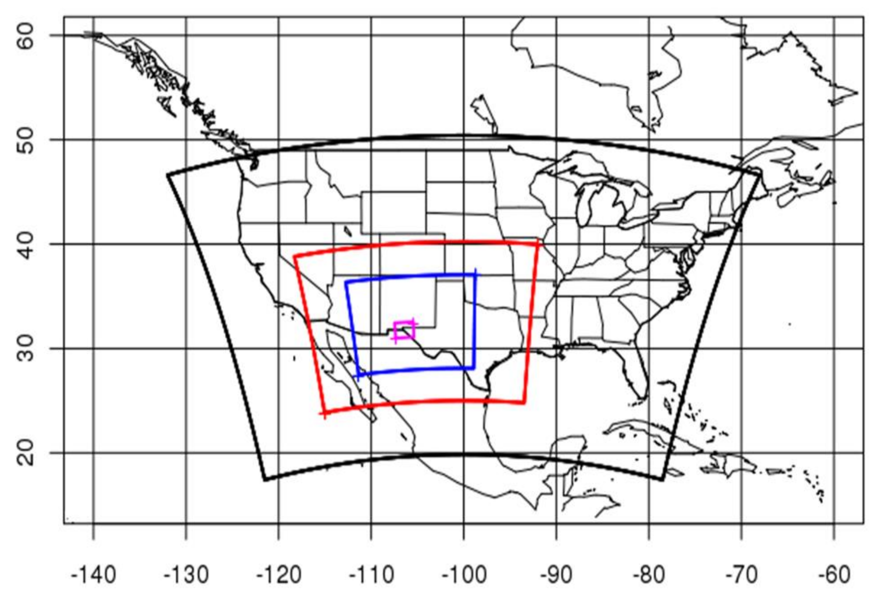


Google Earth Image of El Paso, TX

WRF Simulations

WRF simulations were run starting 3-days before each high O_3 episodes to provided gridded meteorological data to STILT. The details of the WRF simulations are provided below.

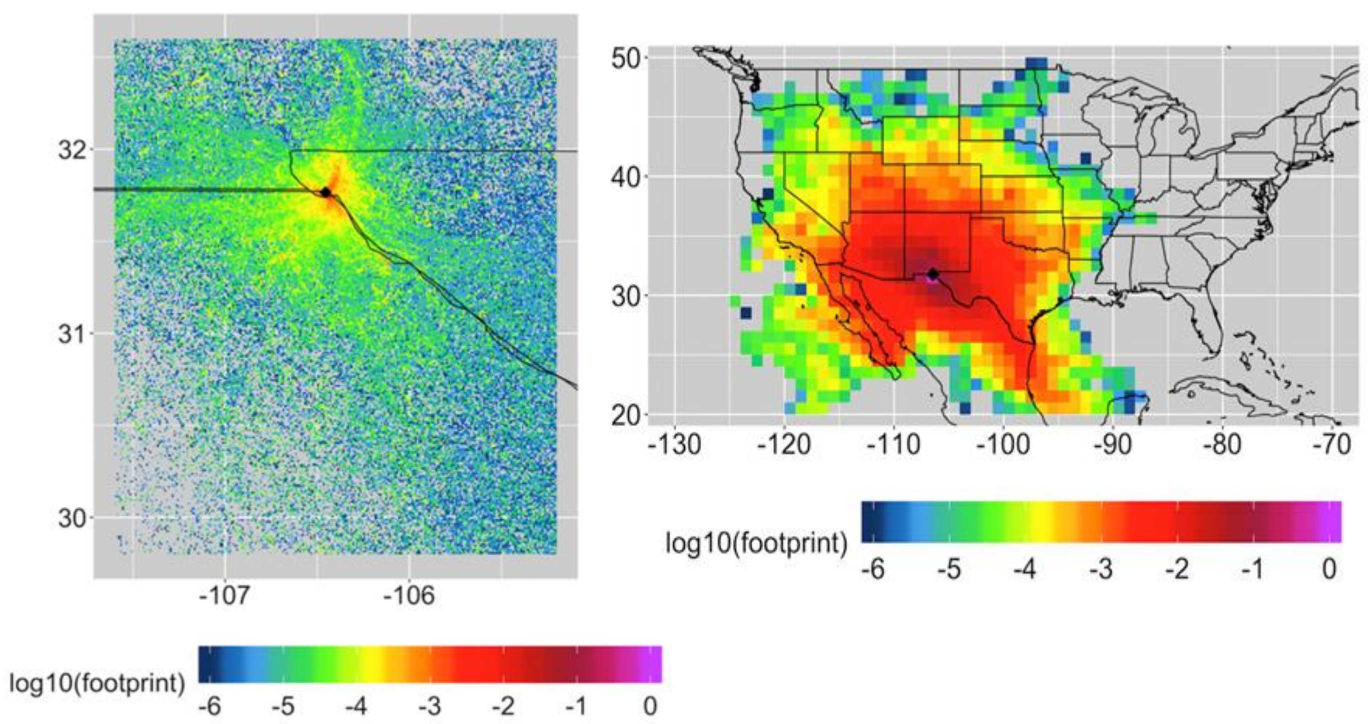
- Advanced Research WRF Version 3.8.1 with 4 nest levels of 27, 9, 3, and 1 km
- 43 vertical levels from surface to 100 hPa
- Shin-Hong (SH) PBL schemes
- Revised MM5 surface layers
- Grell Freitas (GF) cumulus parameterization
- Noah land surface model (Noah)
- Single-layer urban canopy model (UCM)
- Initial and boundary conditions from North American Regional Reanalysis (NARR)
- Daily re-initialization and grid nudging above PBL



WRF 27, 9, 3 and 1 km domains

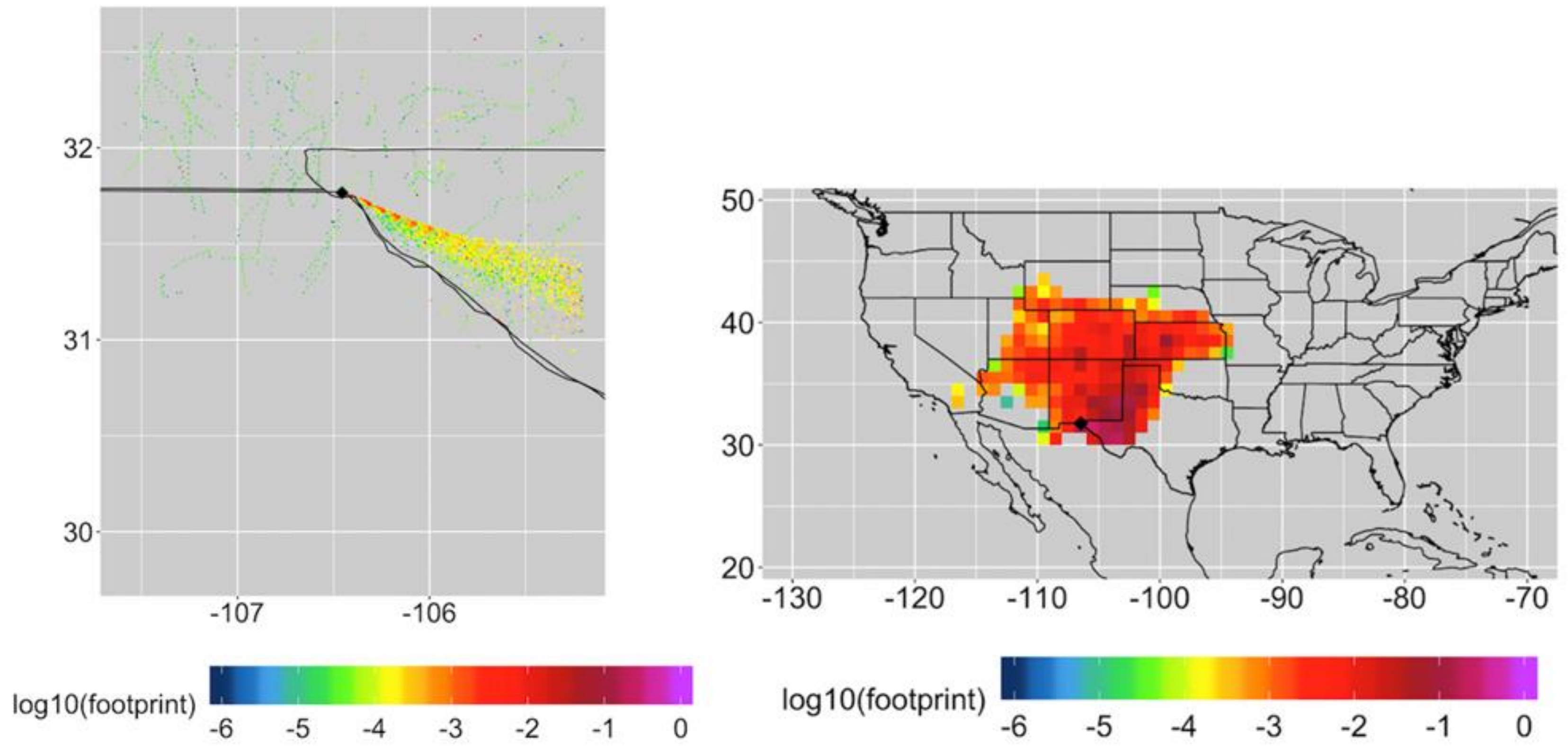
STILT

The Stochastic Time-Inverted Lagrangian Transport (STILT) model (Lin et al., 2003, *J. Geophys. Res.*) driven by WRF meteorological fields was used to calculate surface footprints for each of the high O_3 days. The footprint represents how sensitive a receptor concentration is to the influence of upwind surface fluxes, where a receptor is defined as a specific point in space and time. On the high O_3 days STILT released 500 particles at the El Paso Chamizal site at 1800 UTC from 2, 25 and 50 m agl and simulated the particle trajectories for 72 hours backwards in time. using the WRF fields The footprints were computed over this time period by counting the number of particles that interact with the surface or that are in a surface-influenced volume. The footprint is expressed in units of volume mixing ratio per unit flux, ppm/(μmol m^{-2} s^{-1}), a species-agnostic quantity. When surface fluxes are known and chemical production and loss along the particle trajectory is negligible for a particular species, the footprint convolved with surface fluxes yields an incremental concentration change, Δvmr, at a receptor, which can be directly attributed to surface fluxes upwind of that receptor. For this study, the surface fluxes were derived from the Emission Database for Global Atmospheric Research (EDGAR).

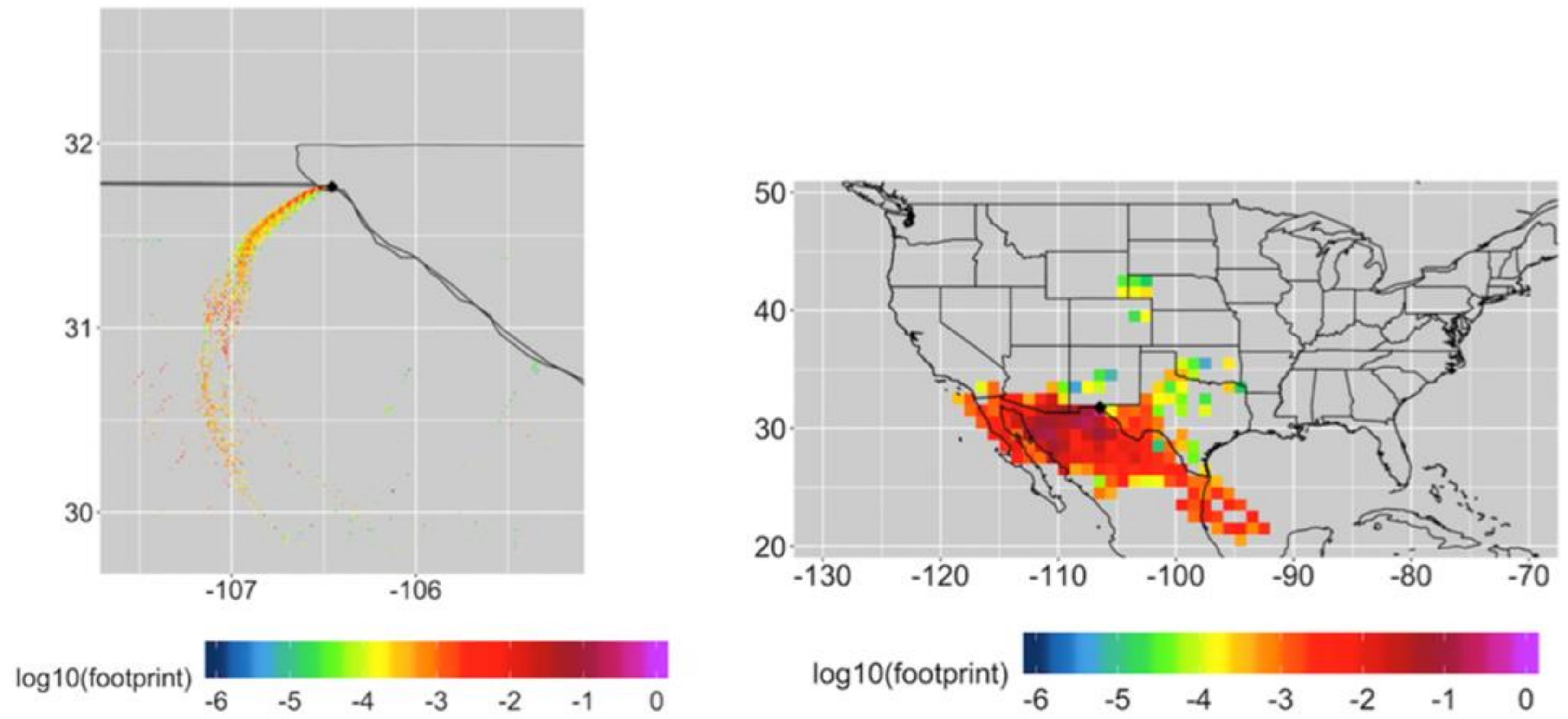


The 3-day summed footprints aggregated to 0.01° (left) and 1.0° (right) grids averaged across all 70 high ozone days, for a receptor height of 25 m agl. Units in ppm/(μmol m^{-2} s^{-1}). The footprint gridding is done to visualize the transport patterns and source regions, but the convolution with emissions is done on the particle footprints

Results



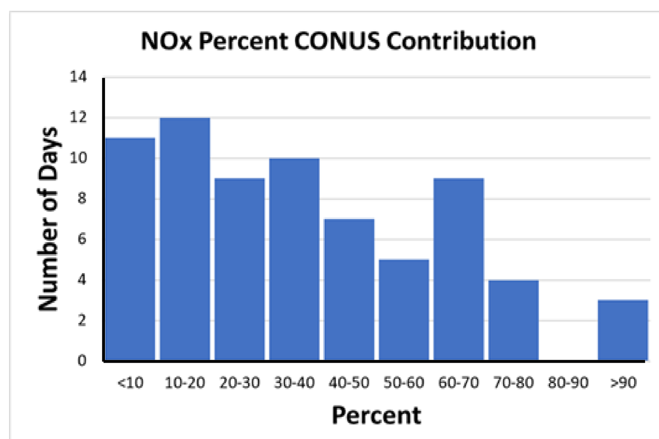
The 0.01° (left) and 1.0° (right) 3-day summed footprints for June 6, 2017 18UTC at the Chamizal El Paso station. Units in ppm/(μmol m^{-2} s^{-1}). This date has Δvmr values dominated by CONUS.

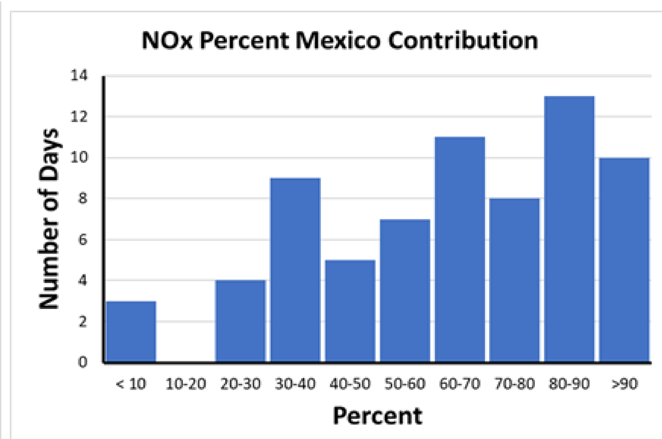


The 0.01° (left) and 1.0° (right) 3-day summed footprints for June 4, 2018 18UTC at the Chamizal El Paso station. Units in ppm/(μmol m^{-2} s^{-1}). This date has Δvmr values dominated by Mexico.

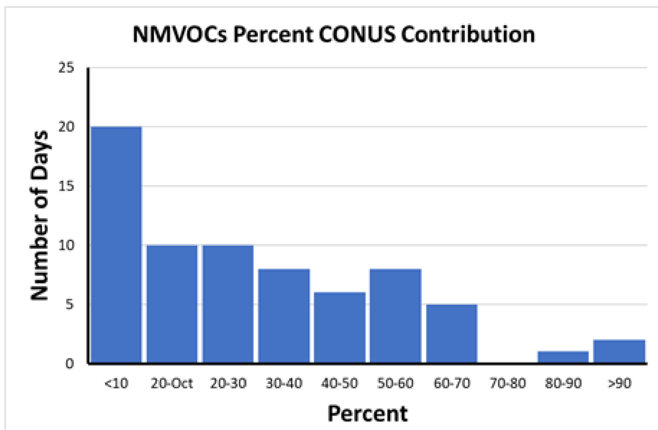
	Total Δvmr	CONUS Δvmr	Mexico Δvmr	Total Δvmr Uncertainty
NO_x	9.52	3.38	6.12	1.18
NMVOC	26.9	7.07	19.8	3.38

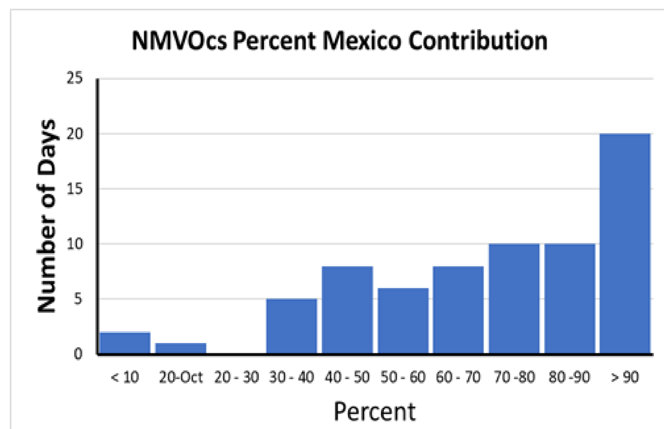
Convolution statistics for NO_x and NMVOC in terms of the average total Δvmr, average Δvmr by location, and total transport uncertainty. The total uncertainty does not factor chemical transformation or emission uncertainty. The units are ppbv.





Histogram of the number of days for each percent contribution category to NOx Δvmr at the Chamizal El Paso 25-meter agl receptor for CONUS (left) and Mexico (right).





Histogram of the number of days for each percent contribution category to NMVOC Δvmr at the Chamizal El Paso 25-meter agl receptor for CONUS (left) and Mexico (right).

Summary

1. In the context of this study in which chemical loss during 3-day transport is neglected Mexican emissions on average contributed to 62.5% of the volume mixing ratio increments (Δvmr) of NOx and 70.1% of the Δvmr for NMVOC when.

2. For both NO_x and NMVOCs the contributions from Mexican emissions was greater than 50% on most (49 of 70 for NO_x and 54 out of 70 for NMVOC) of the high O_3 days.

Acknowledgements

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