TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Topics in Texas Air Quality Science

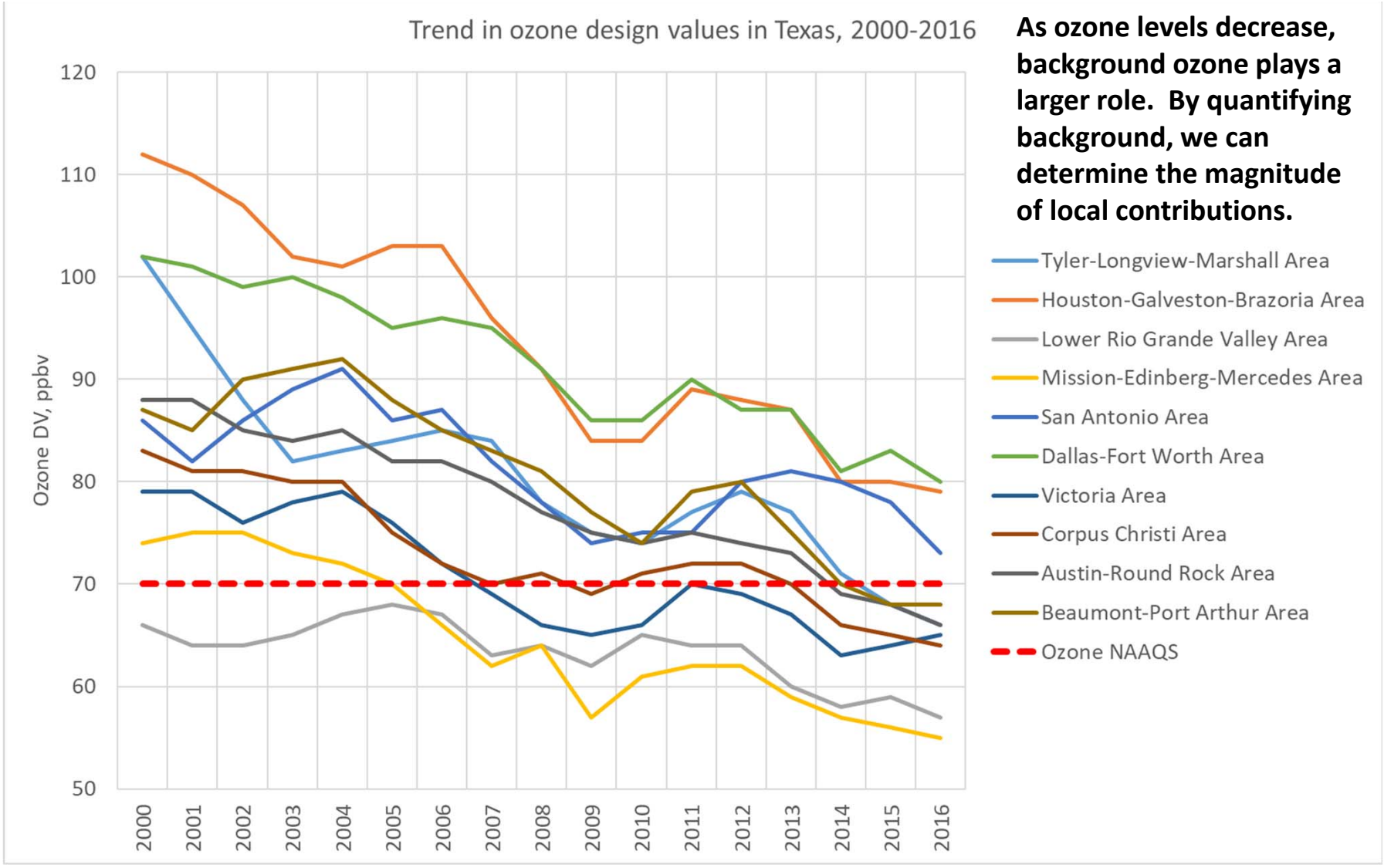
Mark J. Estes

Senior Air Quality Scientist, Texas Commission on Environmental Quality

Mark.Estes@tceq.texas.gov

Outline

- Background ozone and international emissions, and their effects upon ozone in Texas. Discussion of the upcoming review article by panel of experts.
- Effects of the emissions from oil and gas development on ozone in Texas



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Upcoming review article by experts on background ozone and international contributions

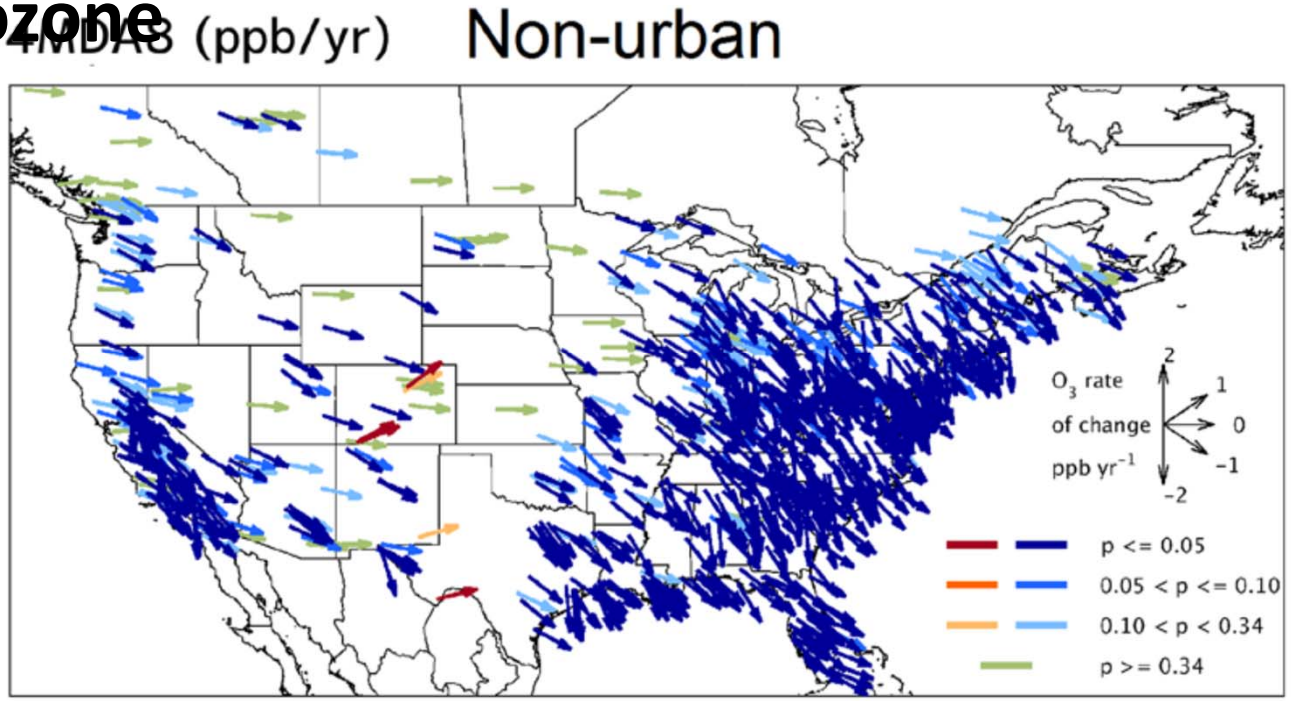
D. Jaffe's American Meteorological Society background ozone presentation: Definitions

- U.S. background (USB) O_3 or North American background (NAB) O_3 : O_3 formed from all natural sources plus anthropogenic sources in countries outside the U.S. (N.A.), plus methane.
- ***USB and NAB must be determined using chemical transport models or statistical models that yield source apportionment. Both of these methods have notable uncertainties.***
- Baseline O_3 : O_3 measured at relatively remote sites that have little or no recent influence from US domestic emissions.
- Non-Controllable O_3 sources (NCOS): These are sources of O_3, or its precursors, that could not be reasonably controlled by domestic legislation, e.g., stratospheric intrusions or wildfire contributions.

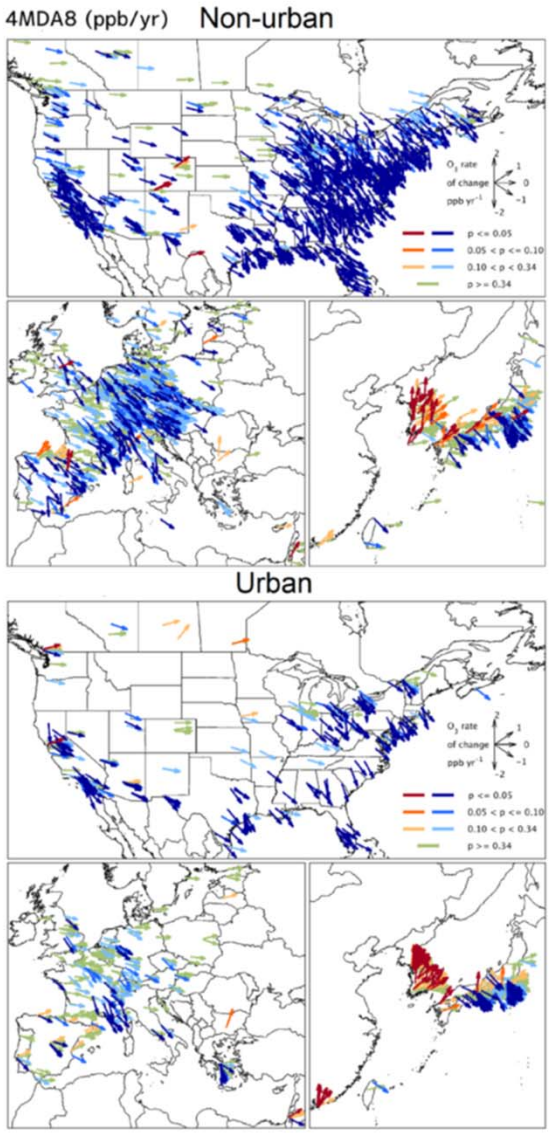
What are consistent patterns for observed O_3? (Jaffe AMS 2018)

- Highest Maximum Daily eight-hour Average (MDA8) values are seen in urban areas of the U.S. **Most of these areas show significant downward trends in the 4th highest MDA8 values**.
- **At high elevation sites in the western U.S., the 4th highest MDA8 values are close to 70 ppb.**
- Inter-annual variations can be very important in calculating design values. These variations occur due to El Niño/Southern Oscillation (ENSO) and other large-scale weather oscillations, wildfire influence, and/or temperature influence.
- Trends at high elevation sites are more flat or increasing (e.g., Mt. Bachelor in Washington state). Some urban sites in the west are not showing significant reductions in the 4th highest MDA8.

Nationwide ozone trends, 4th highest annual daily maximum eight-hour ozone



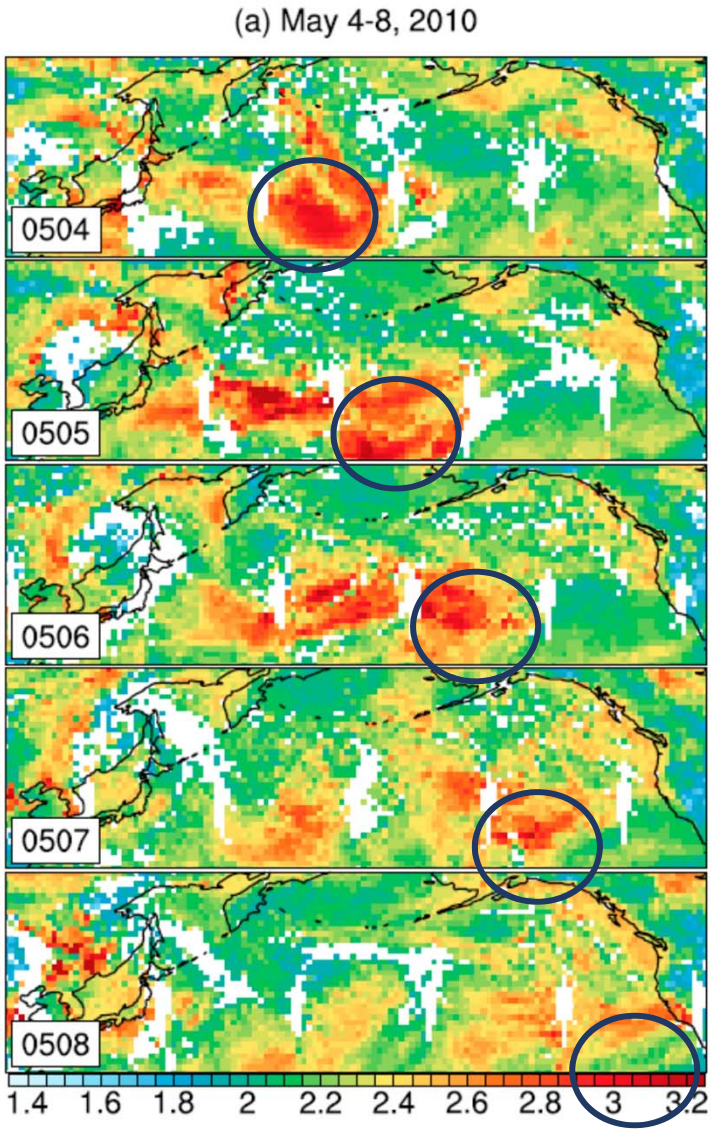
Fleming, ZL, et al. (2018), Tropospheric Ozone Assessment Report: Present-day ozone distribution and trends relevant to human health. *Elem Sci Anth*, doi: 10.1525/elementa.273.

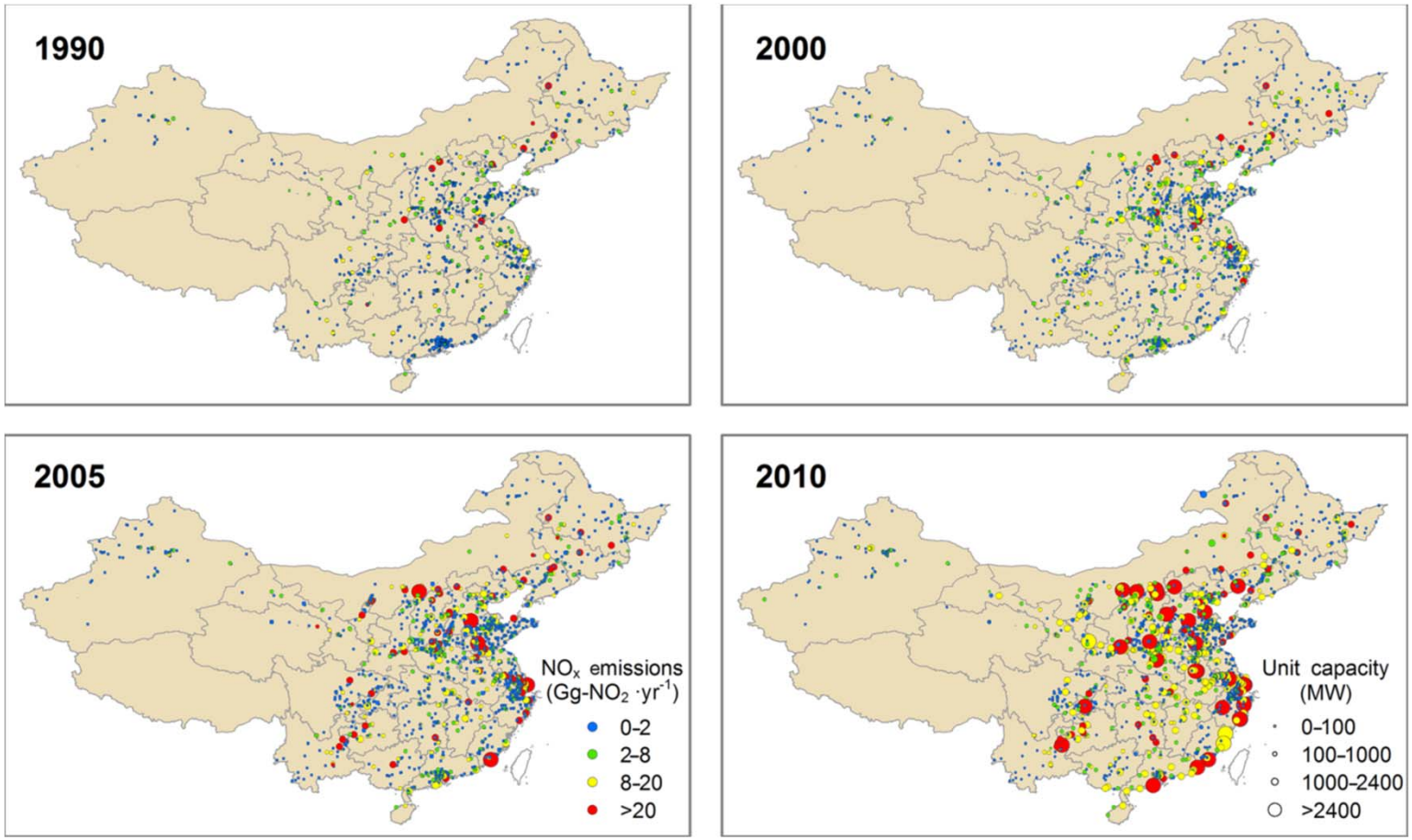


Examples of international contributions

Right: Trans-Pacific Asian pollution event in May 2010 as seen from AIRS satellite retrievals of CO total columns (10^{18} molecules per cm^2) Transport from mid-Pacific takes 5 days. Figure from Lin et al. 2012.

Left: Smoke from fires in Mexico and Central America, observed by the MODIS satellite-based spectrometer on May 9, 2003.
Note: Transported smoke may or may not contain ozone.





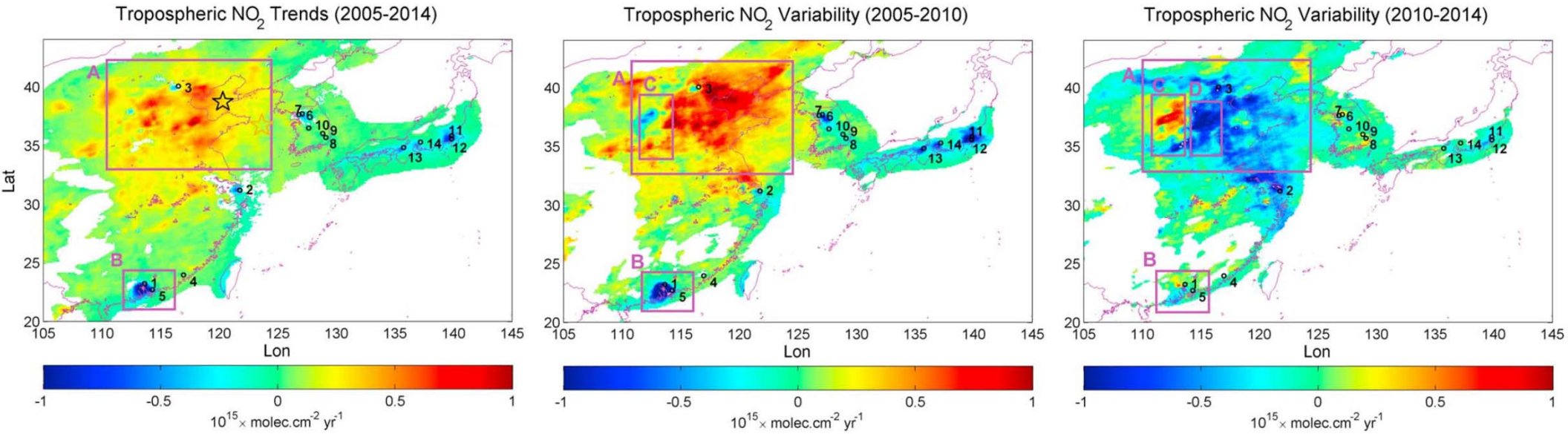
Emissions of ozone precursors in Asia are linked to higher baseline ozone on the US West Coast

Economic development occurring in China since 1990 has spurred the construction of power plants, especially in NE China and the eastern coastal areas. Consequently, NO_x emissions have greatly increased from 1990 to 2010.

Spatial distribution of NO_x emissions from China's coal-fired power plants in 1990, 2000, 2005, and 2010.

From Atmos. Chem. Phys., 15, 13299–13317, www.atmos-chem-phys.net/15/13299/2015/doi:10.5194/acp-15-13299-2015. High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. F. Liu, Q. Zhang, D. Tong, B. Zheng, M. Li, H. Huo, and K. B. He

Since 2010, however, Chinese NO_x emissions have been decreasing

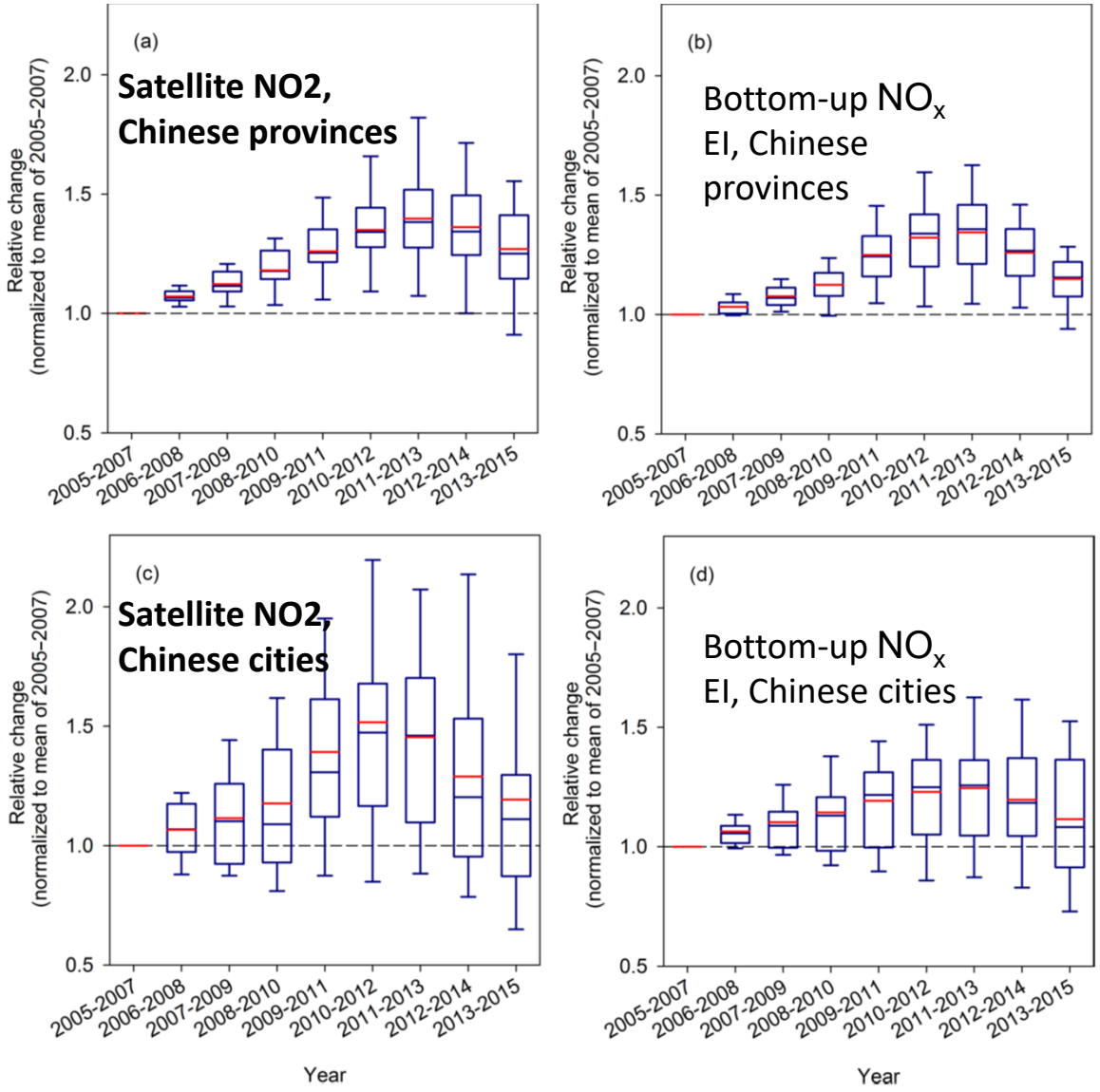


From Souri et al. JGR 2017.

Left: Satellite-observed NO2 trends in China are upward from 2005-2014, indicating large increases in NO_x emissions. Increases are largest in NE China.

Center: Most of the NO2 increases, however, occurred between 2005-2010. The Pearl River Delta and cities in Japan had substantial decreases in NO_x during the same period.

Right: From 2010-2014, the trend has reversed in NE China, so that large decreases in NO_x emissions have occurred. Although emissions are still higher than they were in 2005, control measures by China have proven effective in reducing NO_x . The increase of NO2 in western China (i.e., Shaanxi province) is probably due to efforts to increase economic development in the western provinces.



Trends are reversing in OMI satellite NO_2 observations and NO_x emissions inventories

The box plots show the relative changes in (a) the average OMI tropospheric NO2 column densities for provinces in China; (b) the anthropogenic NO_x emissions for provinces in China; (c) the fitted NO_x emissions for cities investigated in this study; and (d) the anthropogenic NO_x emissions for the corresponding cities.

The blue horizontal line is the median of the relative differences; the red horizontal line is the mean of the relative differences; the box denotes the 25 and 75% percentiles; and the whiskers denote the 10 and 90% percentiles. The bottom-up emission data are derived from the MEIC model.

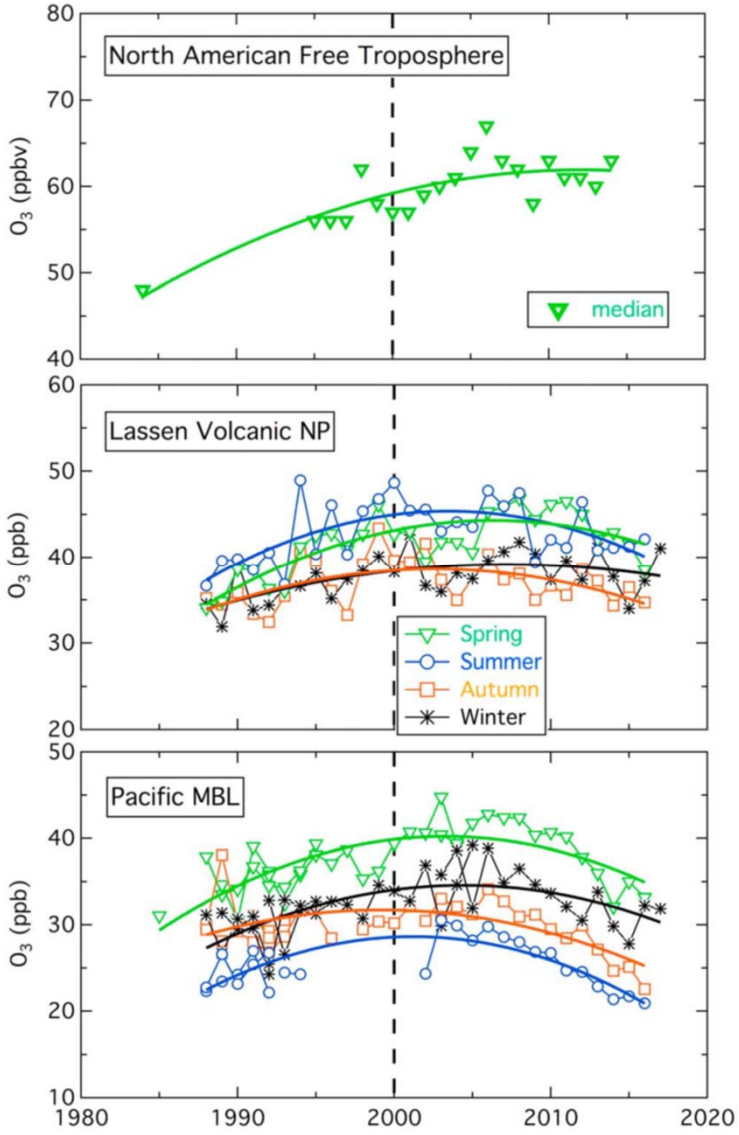
Liu, Fei et al. (2017), NO_x emission trends over Chinese cities estimated from OMI observations during 2005 to 2015, Atmos. Chem. Phys., 17, 9261–9275, doi: 10.5194/acp-17-9261-2017.

Reversal of Long-Term Trend in Baseline Ozone Concentrations at the North American West Coast

D. D. Parrish[1,2] , I. Petropavlovskikh[1,3] , and S. J. Oltmans[1,3]
[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO, USA, [2]NOAA ESRL Chemical Sciences Division, Boulder, CO, USA, [3]NOAA ESRL Global Monitoring Division, Boulder, CO, USA

Plain Language Summary **In U.S. urban and rural areas, ozone transported into the country from the Pacific (i.e., baseline ozone) makes substantial contributions to exceedances of the ozone National Ambient Air Quality Standard.** Over past decades, baseline ozone concentrations increased, which made achievement of ozone air quality goals increasingly difficult. **However, that increase ended in the early to mid-2000s, and the baseline concentrations have begun to decrease, thus easing this particular difficulty.** Global modes are relied upon to quantify the influence of this ozone transport, but they poorly reproduce
observed baseline ozone concentrations.

Parrish, D. D., Petropavlovskikh, I., & Oltmans, S. J. (2017). Reversal of long-term trend in baseline ozone concentrations at the North American West Coast. *Geophysical Research Letters*, 44. https://doi.org/10.1002/2017GL074960

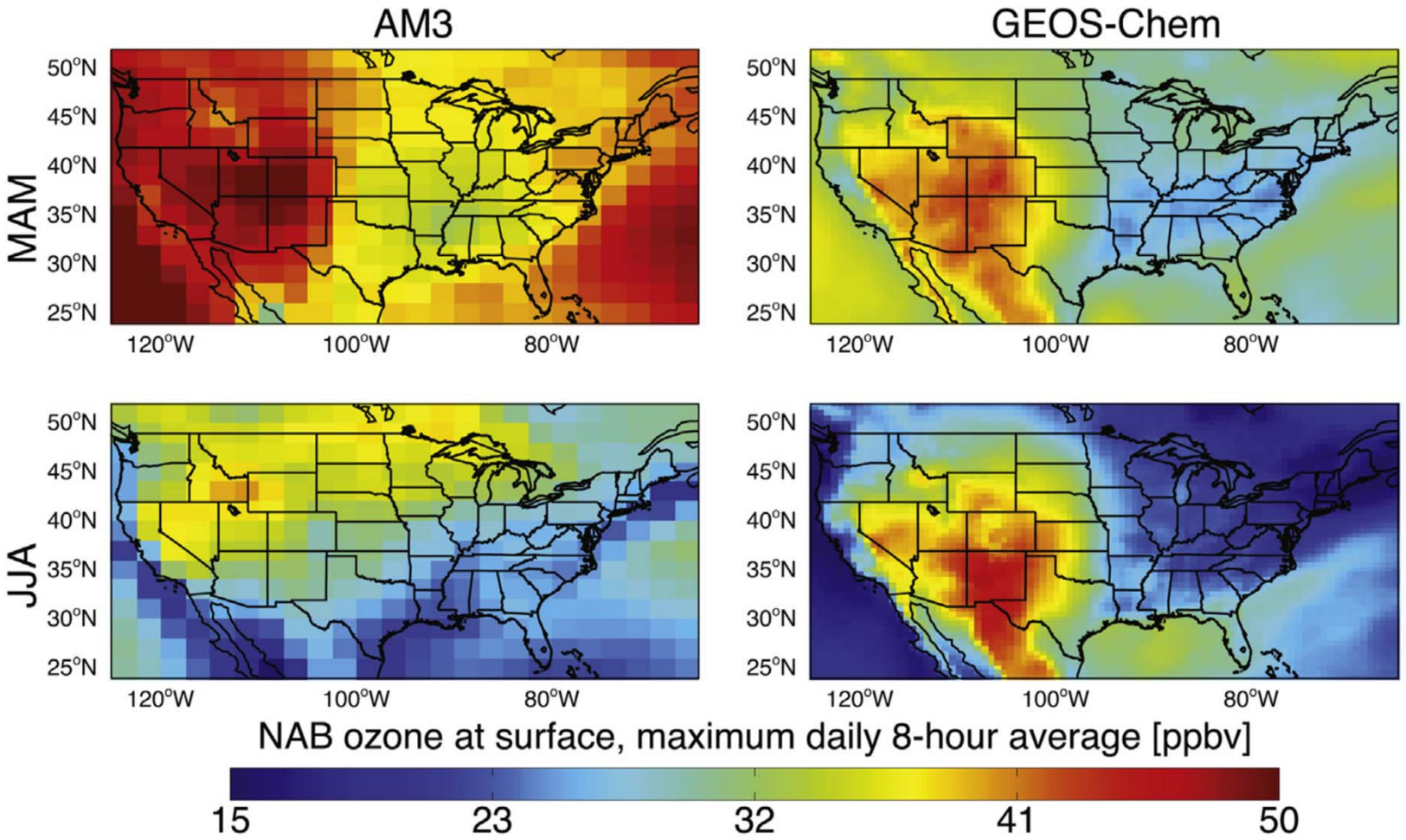


Non-controllable O_3 Sources (NCOS) (Jaffe AMS 2018)

- **Stratospheric transport, wildfires, lightning, biogenic emissions and international sources all contribute to USB O_3.**
- **Daily variations in stratospheric transport and wildfires can be large and on some days make significant contributions to O_3 MDA8s above 70 ppb.**
- **At present, the tools to identify and quantify these contributions to O_3 are limited.**
- **Numerous research campaigns have successfully quantified these contributions, but doing so often depends on advanced tools, not available in routine monitoring networks. *Identifying an NCOS is easier for a large O_3 contribution, harder for smaller contributions.***

What are consistent and robust patterns in modeled US background O_3 or North American background O_3? (Jaffe AMS 2018)

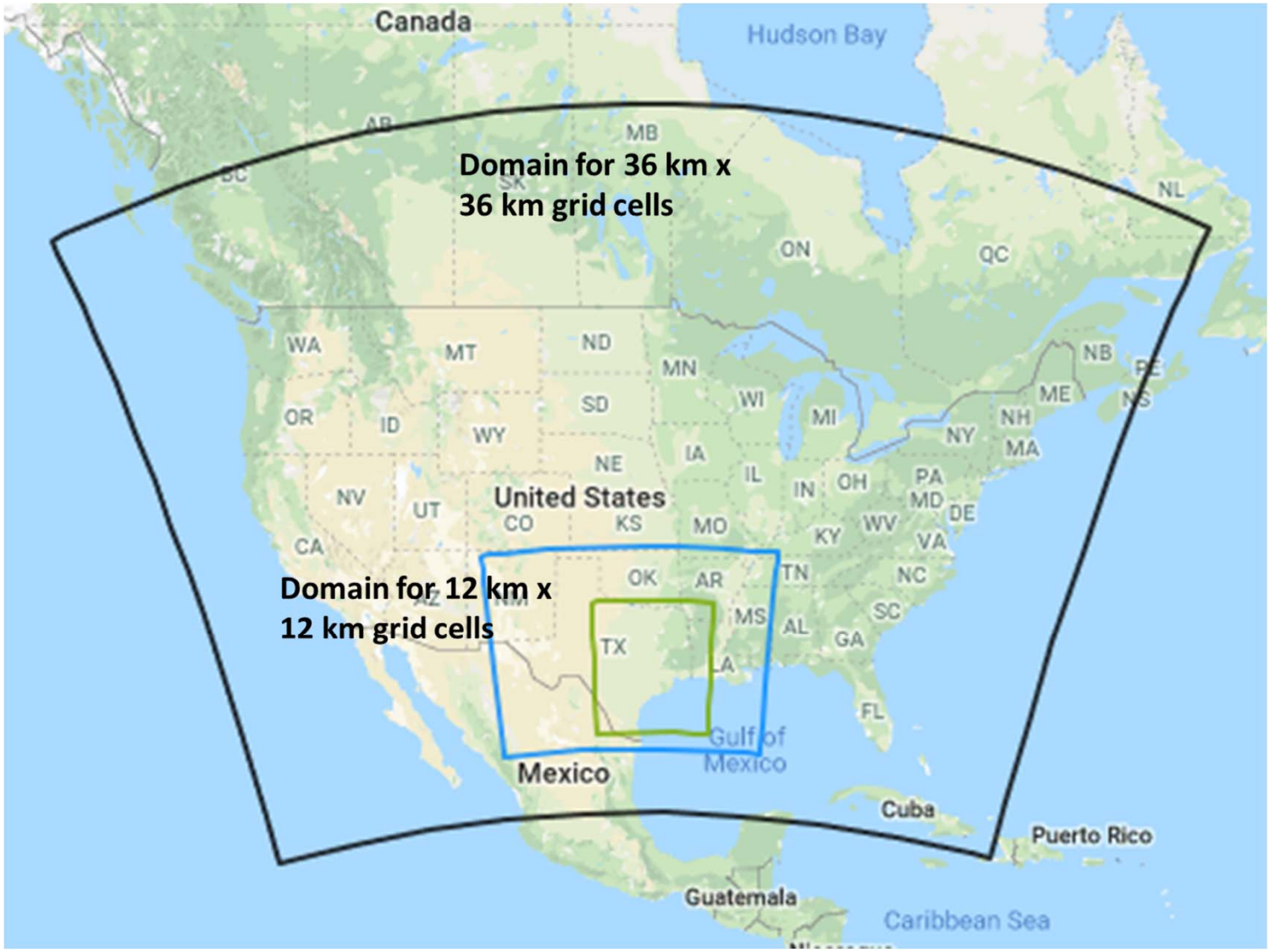
- Models consistently show that highest seasonal mean USB O_3 is in the spring in intermountain west and at highest elevations.
- Models estimate the seasonal mean USB O_3 at 20-40 ppb for low elevation sites (e.g. east and west coast of U.S.) and over 50 ppb at some high elevation sites.
- Significant model differences due to boundary conditions, resolution, treatment of stratosphere, wildfires, etc.
- Difficult to compare across studies due to different reported metrics, years, definitions, etc.
- ***How well do we really know USB and NAB O_3 ? How well do different models agree on USB/NAB? How accurate are the models compared to observations?***
- **Key conclusion: Our best estimate of *uncertainty* in *seasonal mean US background O_3* is ± 10 ppb. Uncertainty is even larger for individual days, or time periods shorter than 3 months.**



From Fiore et al. 2014: Modeled estimates of 2006 North American background (NAB) ozone from two different global models, AM3 and GEOS-Chem. Models give NAB values differing by 10 ppb or more in many locations. North American anthropogenic emissions are set to zero in both models.

TCEQ measures to improve estimates of background ozone and international contributions

- Expand the modeling domain. CAMx model is used to simulate ozone at high resolution within the US and state of Texas; GEOS-Chem global model is used to simulate ozone outside the CAMx modeling domain, that is, to set the boundary conditions. By expanding the domain, we can include Canadian and Mexican emissions within the higher-resolution domain, and improve our estimates of their contributions to Texas background ozone. Also, a larger domain pushes the boundaries further from the cities of interest.
- Run GEOS-Chem at TCEQ. By running the global model in-house, we can run it for the exact times that we are interested in simulating, rather than having to rely upon someone else's runs, or upon monthly averages.
- Improve our understanding of the weather patterns that transport background air into Texas during ozone season: Bermuda High, Great Plains low-level jet, frontal passages, El Niño/Southern Oscillation. Better knowledge of transport patterns helps us understand when international transport is likely (or unlikely), helps us interpret our modeling results, and can identify exceptional events.



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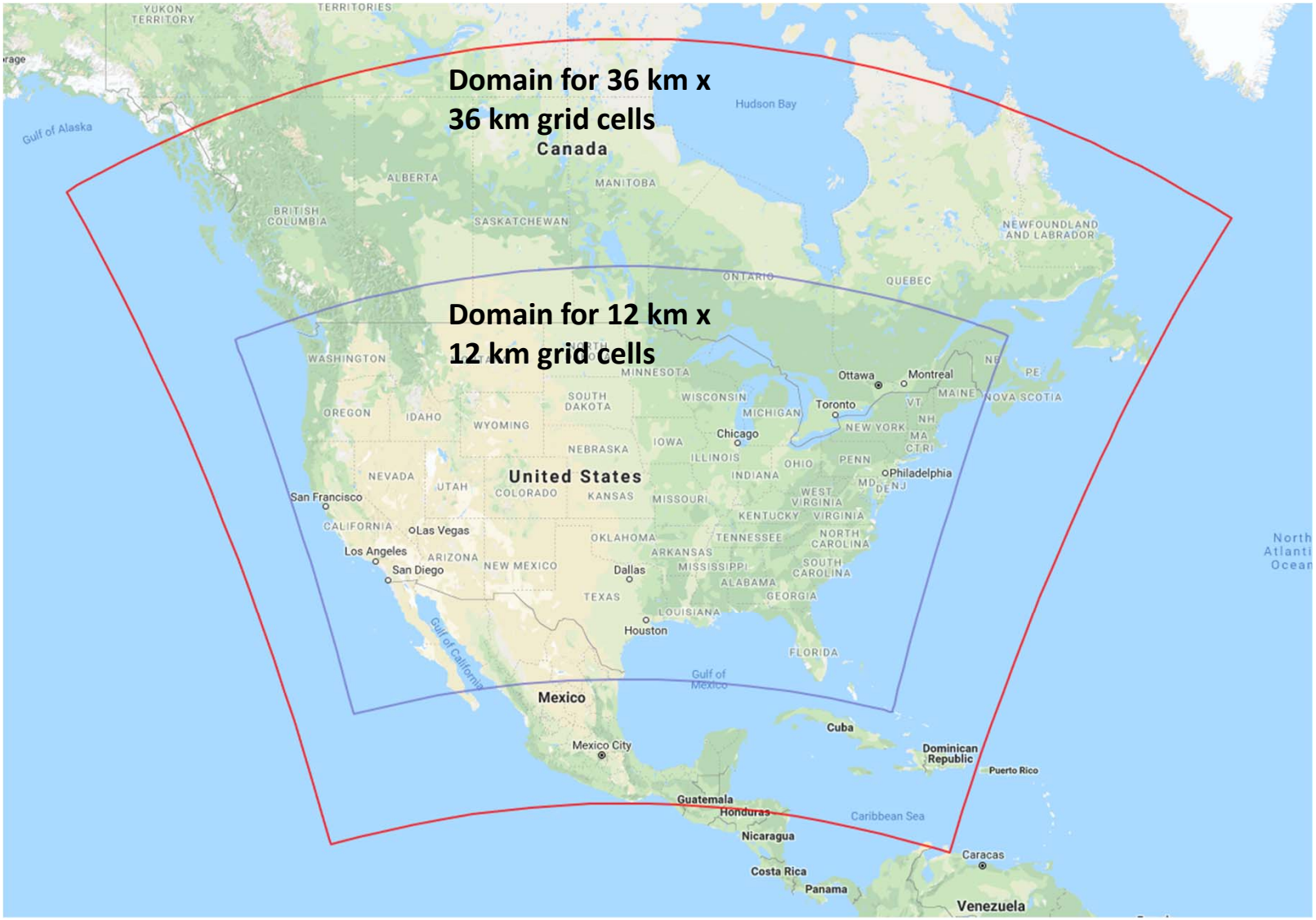

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AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL076150

Effects of El Niño on Summertime Ozone Air Quality in the Eastern United States

Lu Shen[1] and Loretta J. Mickley[1]

[1]John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA

Key Points:
- Summertime ozone air quality in the eastern United States is related to sea surface temperature anomalies mainly in the eastern Pacific
- El Niño can increase ozone in the middle and south Atlantic states but decrease ozone in the south central by altering atmospheric circulation
- Niño 1 + 2 can be used to predict the summertime ozone air quality in the eastern U.S. by as much as 4 months in advance

Supporting Information:
- Supporting Information S1

Abstract We investigate the effect of El Niño on maximum daily 8 h average surface ozone over the eastern United States in summer during 1980–2016. El Niño can influence the extratropical climate through the propagation of stationary waves, leading to (1) reduced transport of moist, clean air into the middle and southern Atlantic states and greater subsidence, reduced precipitation, and increased surface solar radiation in this region, as well as (2) intensified southerly flow into the south central states, which here enhances flux of moist and clean air. As a result, each standard deviation increase in the Niño 1 + 2 index is associated with an increase of 1–2 ppbv ozone in the Atlantic states and a decrease of 0.5–2 ppbv ozone in the south central states. These influences can be predicted 4 months in advance. We show that U.S. summertime ozone responds differently to eastern-type El Niño events compared to central-type events.

Atmos. Chem. Phys., 16, 15265–15276, 2016
www.atmos-chem-phys.net/16/15265/2016/
doi:10.5194/acp-16-15265-2016
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Atmospheric Chemistry and Physics
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Influence of the Bermuda High on interannual variability of summertime ozone in the Houston–Galveston–Brazoria region

Yuxuan Wang[1,2], Beixi Jia[2], Sing-Chun Wang[1], Mark Estes[3], Lu Shen[4], and Yuanyu Xie[2]

PNAS

Seasonal prediction of US summertime ozone using statistical analysis of large scale climate patterns

Lu Shen[a,1] and Loretta J. Mickley[a]

[a]John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138

Edited by Guy Brasseur, Max Planck Institute of Meteorology, Hamburg, Germany, and accepted by Editorial Board Member A. R. Ravishankara January 10, 2017 (received for review June 30, 2016)

We develop a statistical model to predict June–July–August (JJA) daily maximum 8-h average (MDA8) ozone concentrations in the eastern United States based on large-scale climate patterns during the previous spring. We find that anomalously high JJA ozone in the East is correlated with these springtime patterns: warm tropical Atlantic and cold northeast Pacific sea surface temperatures (SSTs), as well as positive sea level pressure (SLP) anomalies over Hawaii and negative SLP anomalies over the Atlantic and North America.

surface ozone air quality (e.g., ref. 6), the interannual variability in weather is much greater than that in anthropogenic emissions (7). Here, we exploit the dependence of surface ozone on weather in an effort to predict summertime ozone one season in advance. Achieving our goal depends on how much memory the ocean–atmosphere system can retain from spring to summer. Sea heat content, as quantified by SSTs, has a relatively long inertial memory of months to years, and SST anomalies may excite large-

atmosphere
MDPI

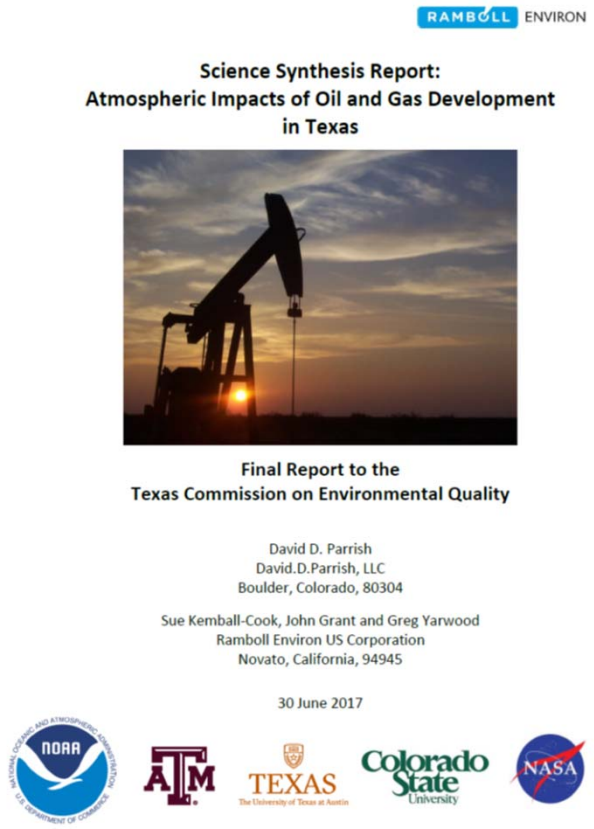
Article

Influence of Cold Fronts on Variability of Daily Surface O_3 over the Houston-Galveston-Brazoria Area in Texas USA during 2003–2016

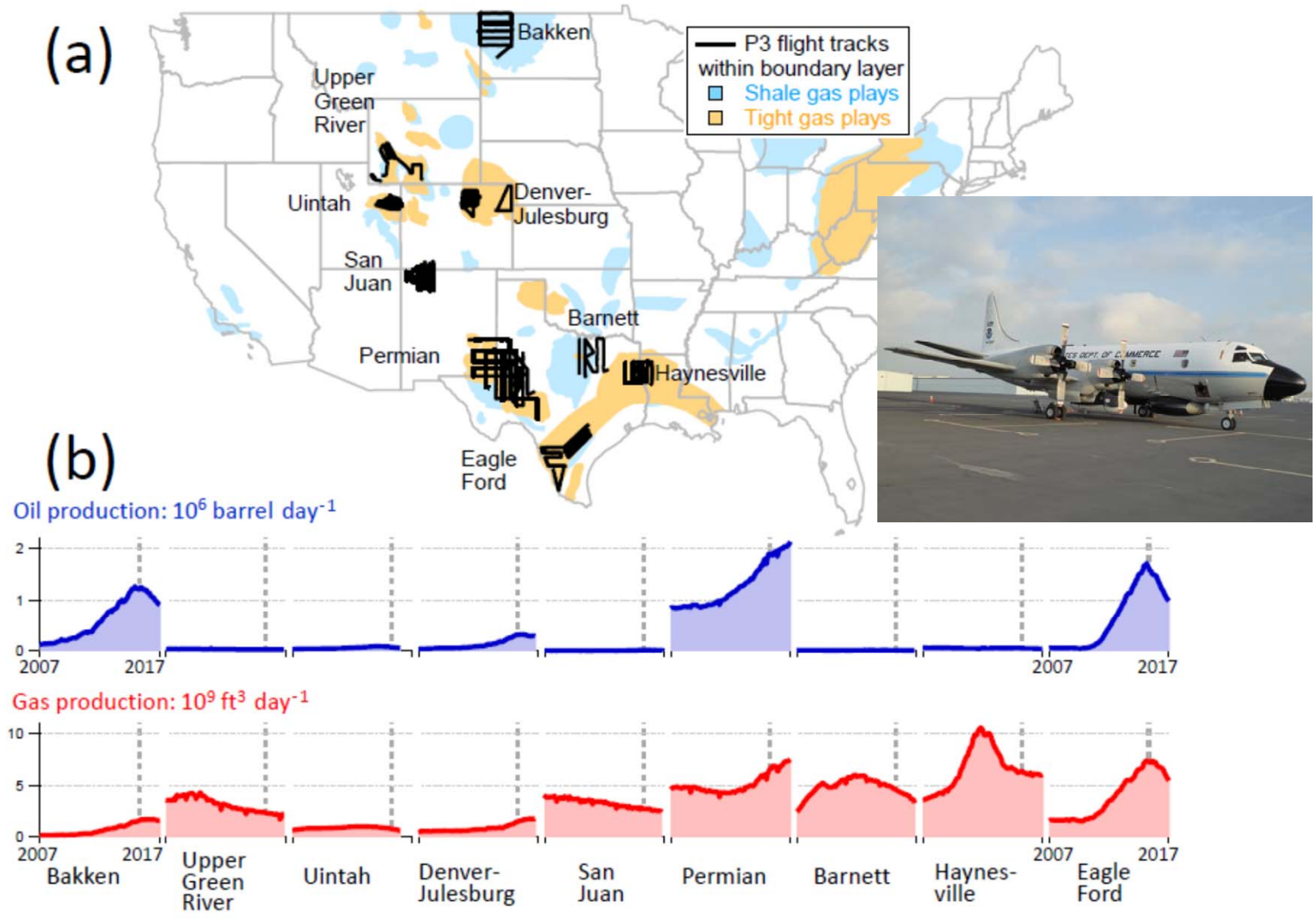
Ruixue Lei [1,2,*], Robert Talbot [1,2], Yuxuan Wang [1,2,3], Sing-Chun Wang [1,2] and Mark Estes [4]

Effects of oil and gas development on ozone

- The TCEQ commissioned a review and synthesis study of recent research that examined how oil and gas emissions affect air quality.

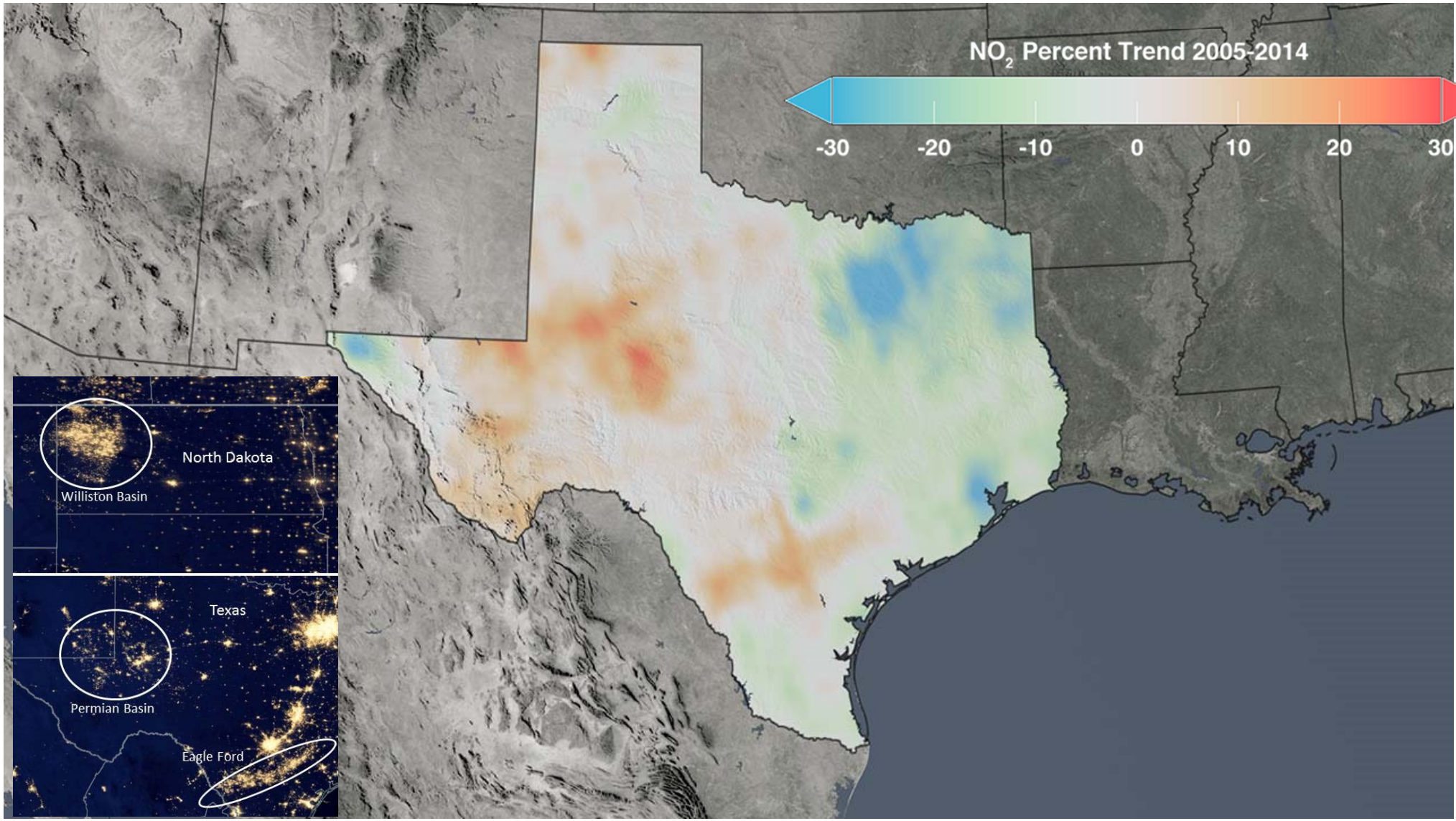


Study of oil and gas emissions by airborne sampling



SONGNEX study took place in 2015 https://www.esrl.noaa.gov/csd/projects/songnex/

Koss, A. et al. (2017) Observations of VOC emissions and photochemical products over US oil- and gas-producing regions using high-resolution H3O+ CIMS (PTR-ToF-MS), *Atmos. Meas. Tech.*, doi:10.5194/amt-10-2941-2017.



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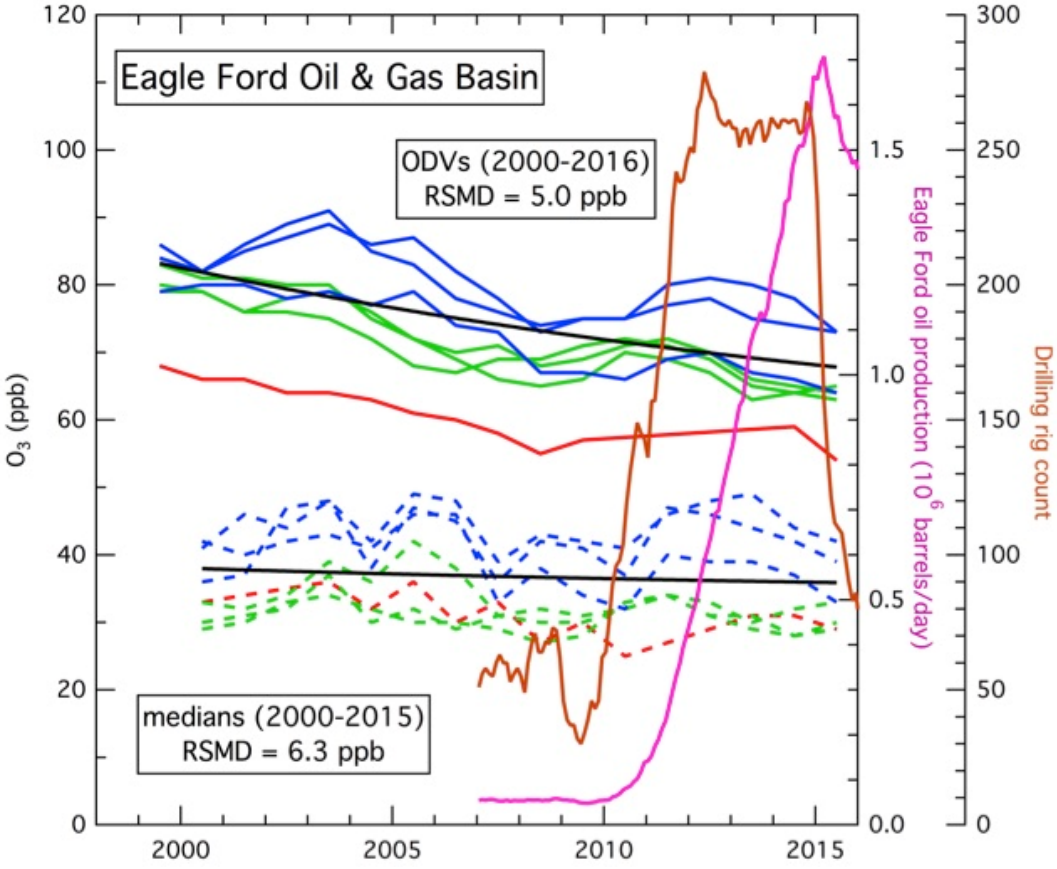
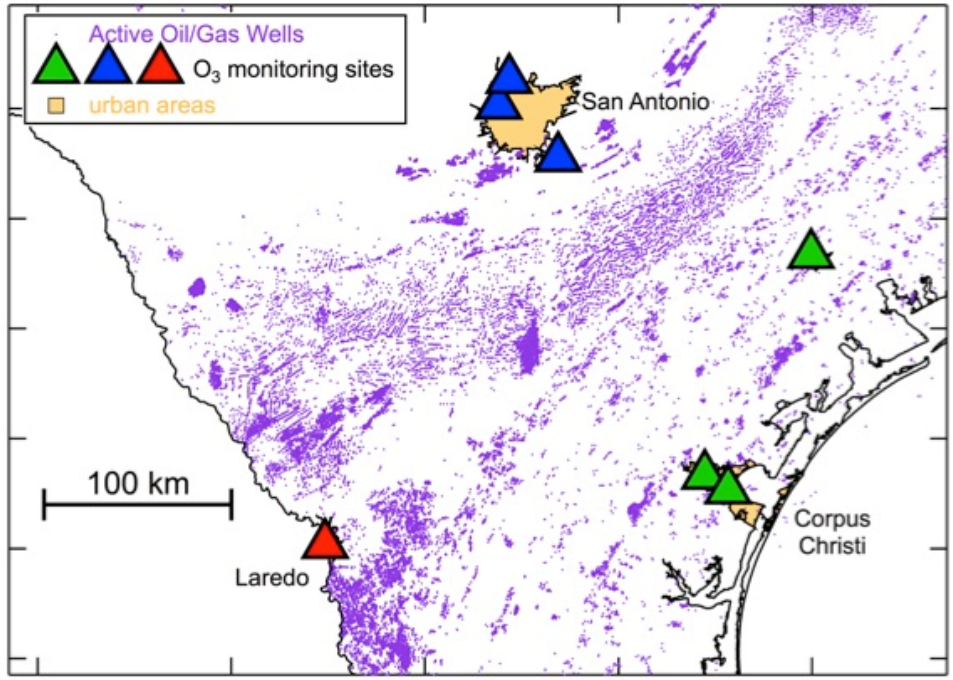
What are the contributions of emissions from oil and gas development to ambient O_3 concentrations at regulatory monitors in Texas?

Emerging Hypothesis: O&G impacts on summertime O_3 concentrations in Texas are small





Ozone concentrations are not very sensitive to immense increases in oil and gas activity or emissions

- From Parrish 2017: "**What are the contributions of emissions from O&G development to ambient ozone concentrations at regulatory monitors in Texas?**
- An observationally based analysis could discern no impact of O&G activity on ozone concentrations within or near Texas O&G basins. The smallest discernable impact is estimated as < 5 ppb, but could not be more quantitatively defined."

For further information

- Parrish et al., 2017. Report to TCEQ, completed in 2017. https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/oth/582166321516-20170629-environ-oilgas_impact_aq_synthesis.pdf