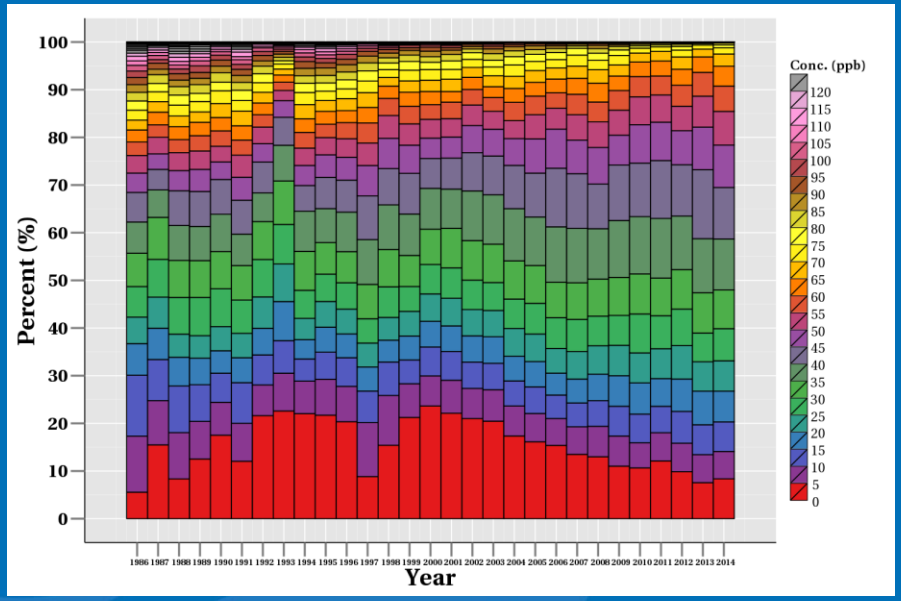
EPA
United States
Environmental Protection
Agency

Trends in Hourly Ozone and Ozone Health Metrics across the United States and the European Union

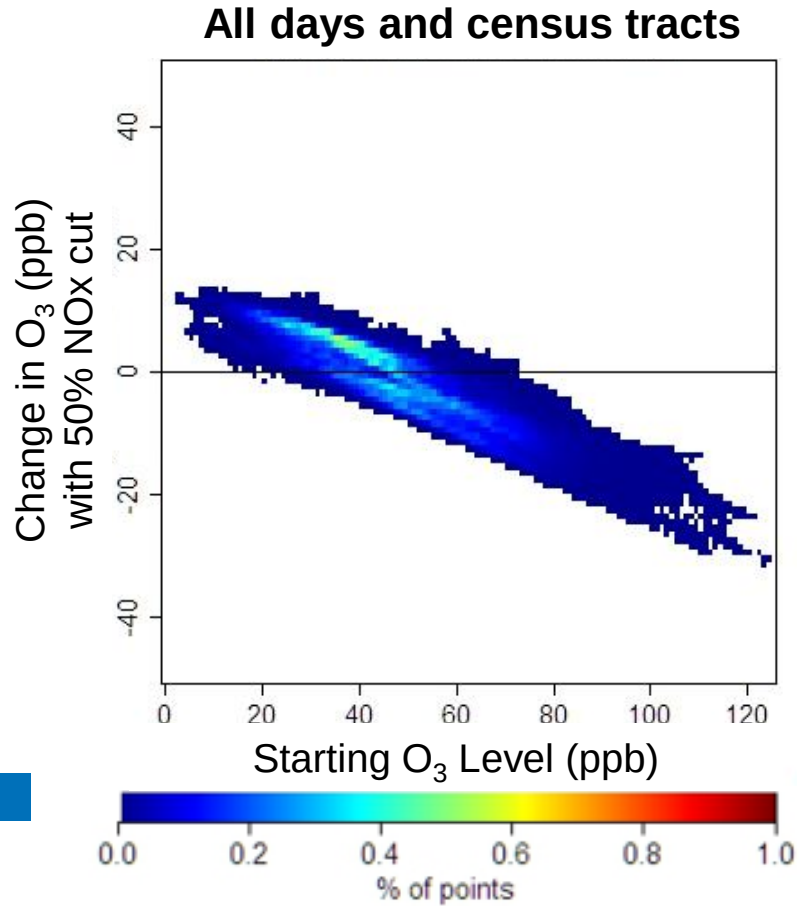
Heather Simon, Allen Lefohn, Chris Malley, Benjamin Wells, Adam Reff, Xiaobin Xu, Li Zhang, Tao Wang, Bryan Hubbell, Kirk Baker

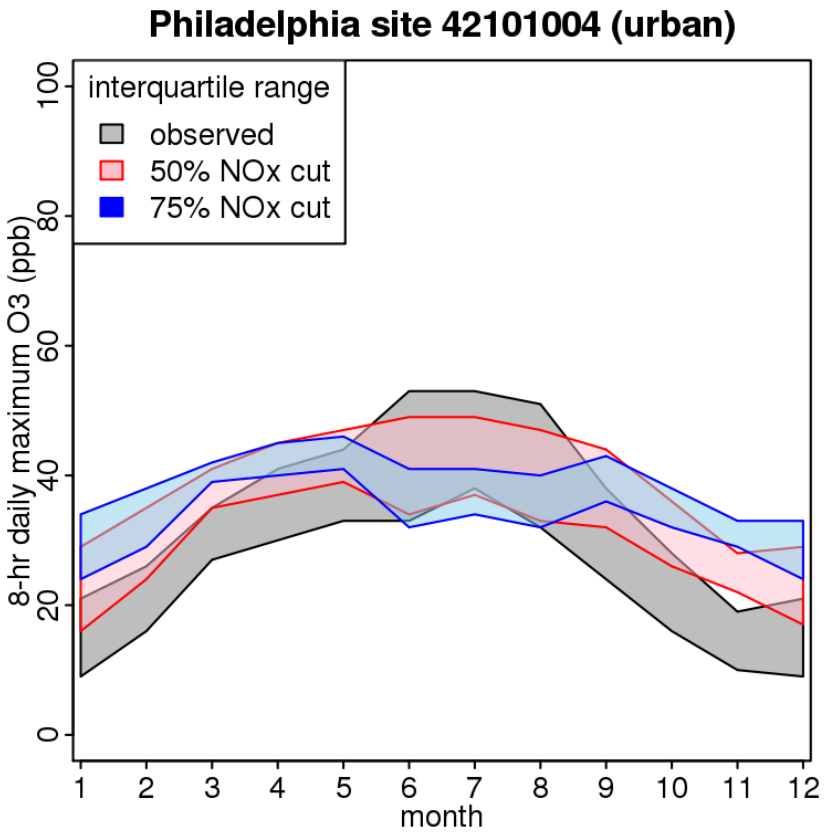


Motivation: Philadelphia Modeling Case Study

Photochemical modeling analysis predicts that future NOx reductions will lead to changes in spatial and temporal patterns of ozone

- Decreased frequency of high and low O_3 concentrations: "compression" of O_3 distribution
- Shift in seasonal pattern: peaks occur earlier in the year



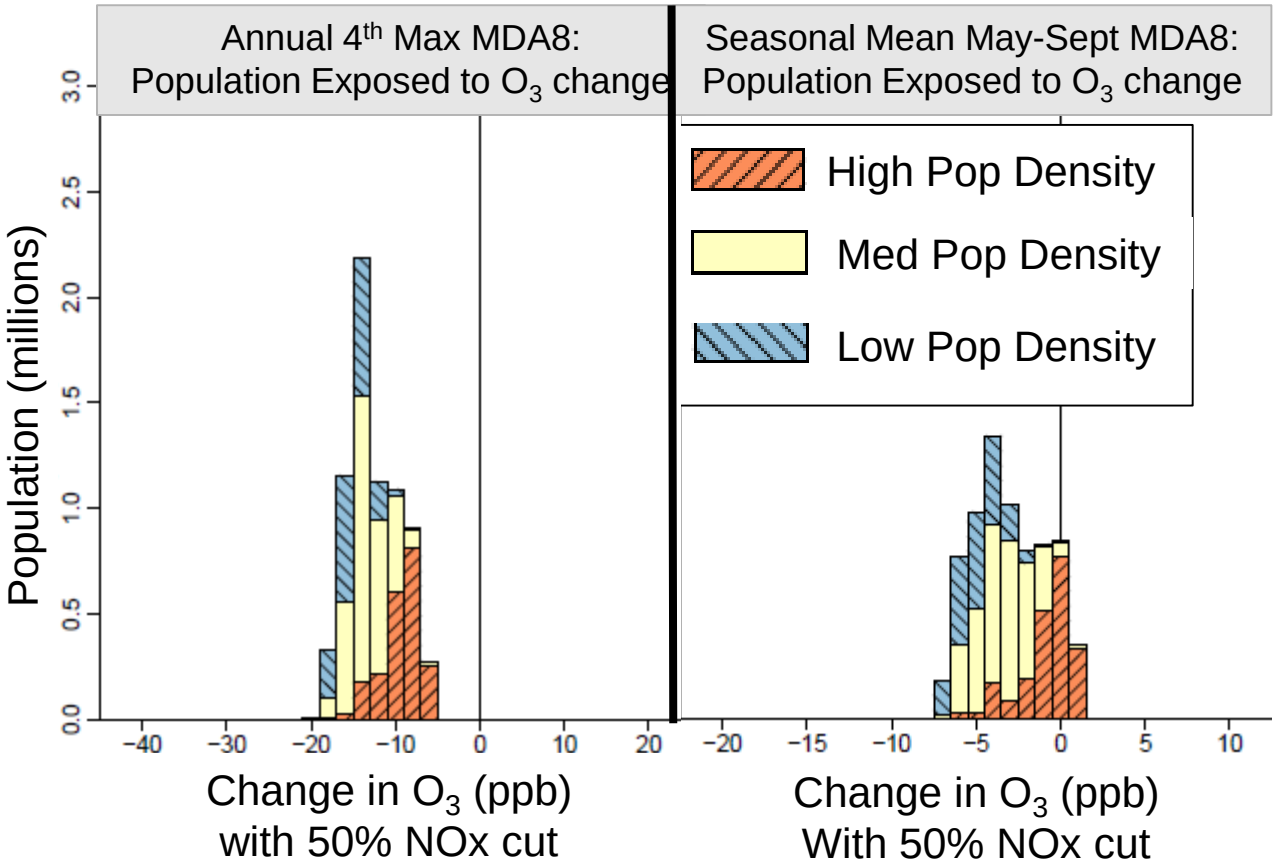


Simon et al., 2016 *Environmental Health Perspectives*

Motivation: Philadelphia Modeling Case Study

Photochemical modeling analysis predicts that future NOx reductions will lead to changes in spatial and temporal patterns of ozone

- Annual 4th high MDA8 decreases at in all Philadelphia census tracts
  - Highest pop density areas (low starting O_3) see less benefit
- Most of population lives in areas with decreasing 5-month seasonal mean
  - A small portion of the population in the highest pop density areas see a small O_3 increase



Simon et al., 2016 *Environmental Health Perspectives*

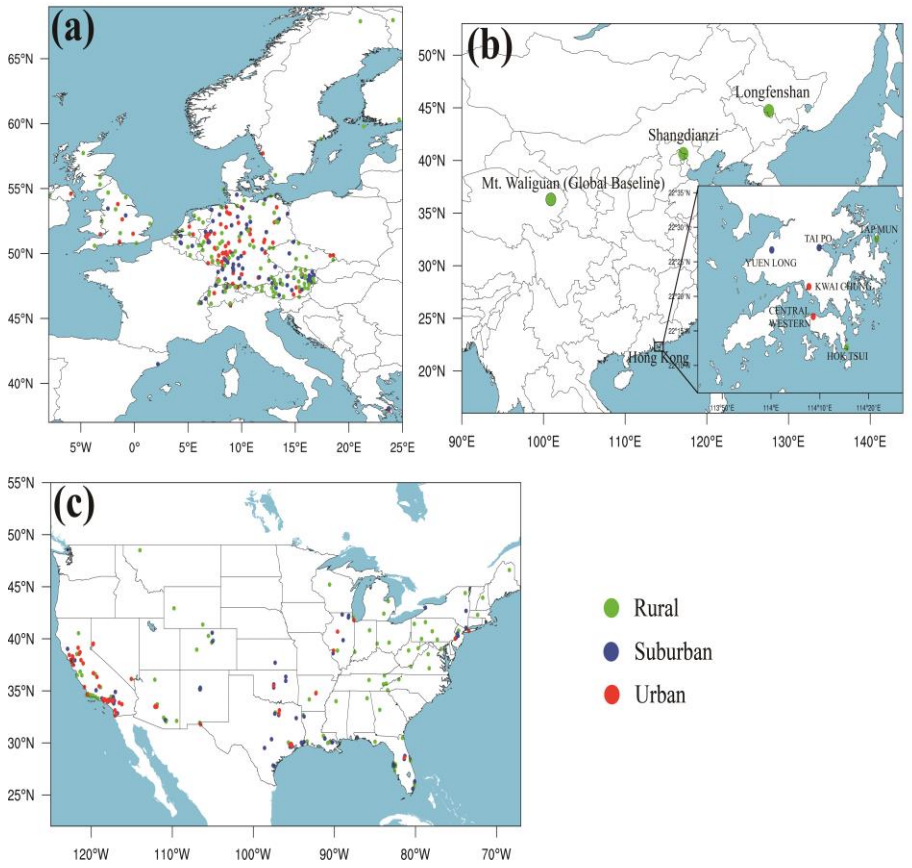
Ozone Metrics Explored

Emissions changes impact the ozone distribution and these changes can in turn be related to changes in important ozone regulatory and health metrics

- **Hourly O_3**
- **8-hour daily maximum O_3 (MDA8) - human health**
  - **Seasonal MDA8 mean (May-September)**
  - **Annual 4th high MDA8**
  - **MDA8 Percentiles: 5th, 25th, 50th, 75th, 95th**
  - **Annual SOMO35 – MDA8 sum for days ≥ 35 ppb**
  - **Annual SOMO10 – MDA8 sum for days ≥ 10 ppb**
- W126 - vegetation
- AOT40 - vegetation
- 6-month average of 12-hr (0800-1959h) O_3 concentrations - vegetation and climate and global atmospheric chemistry model evaluation

What Can Ambient Data Tell Us About These Trends?

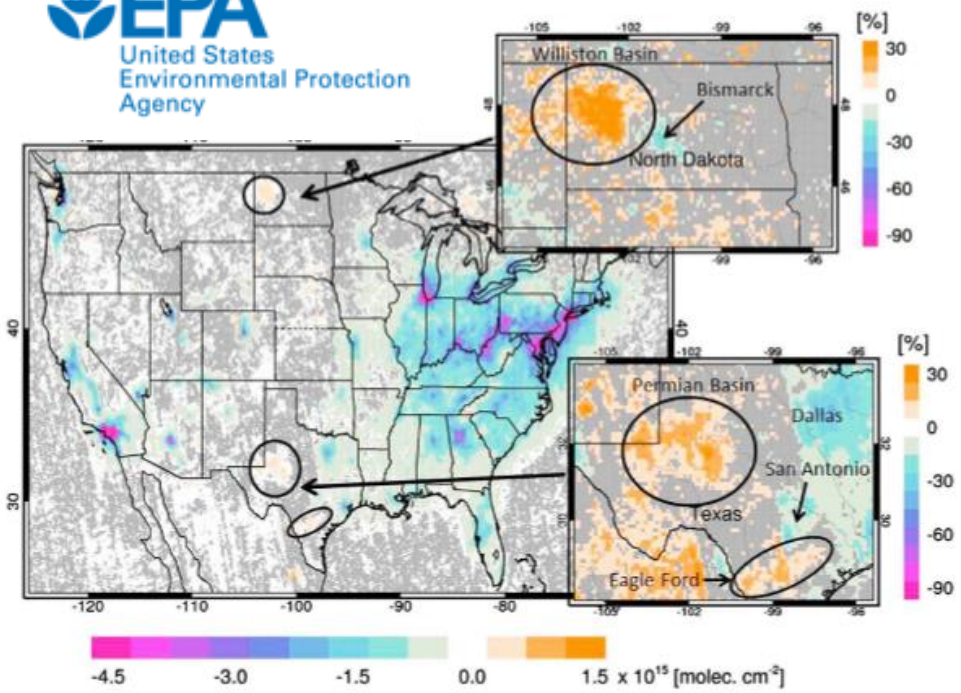
- Extensive ground-based ozone monitoring network with data dating back at least 20 years in the EU and US
- Long-term data from Chinese monitoring sites are more limited
  - Not discussed today
- The past ~25 years provide a “natural experiment” to look at ambient ozone trends over a period of dramatically changing NOx and VOC emissions
  - U.S. NOx emissions dropped by 52% from 1990 to 2015
  - EU NOx emissions dropped by 54% from 1990-2013

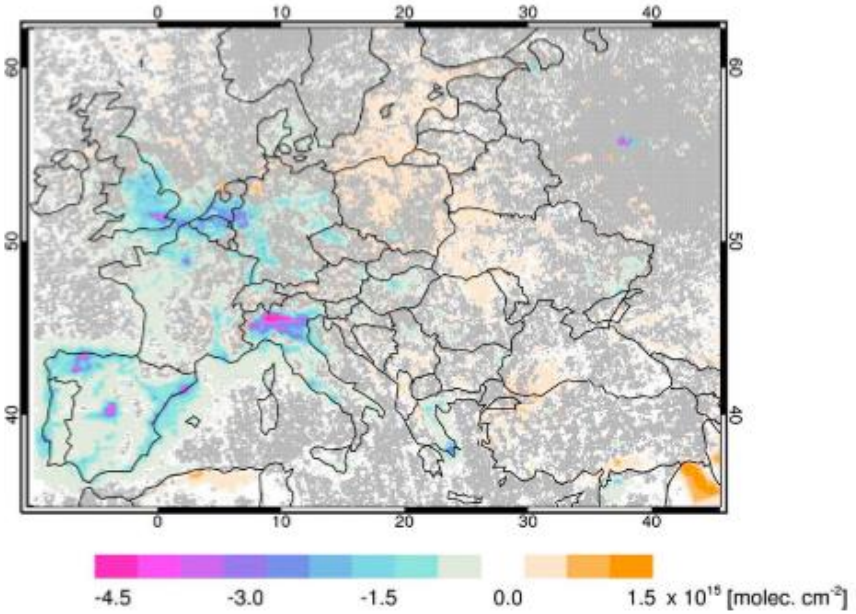


Lefohn et al., 2017, *Atmos. Environ.*

Satellite-Derived NO_2 Trends

EPA United States Environmental Protection Agency

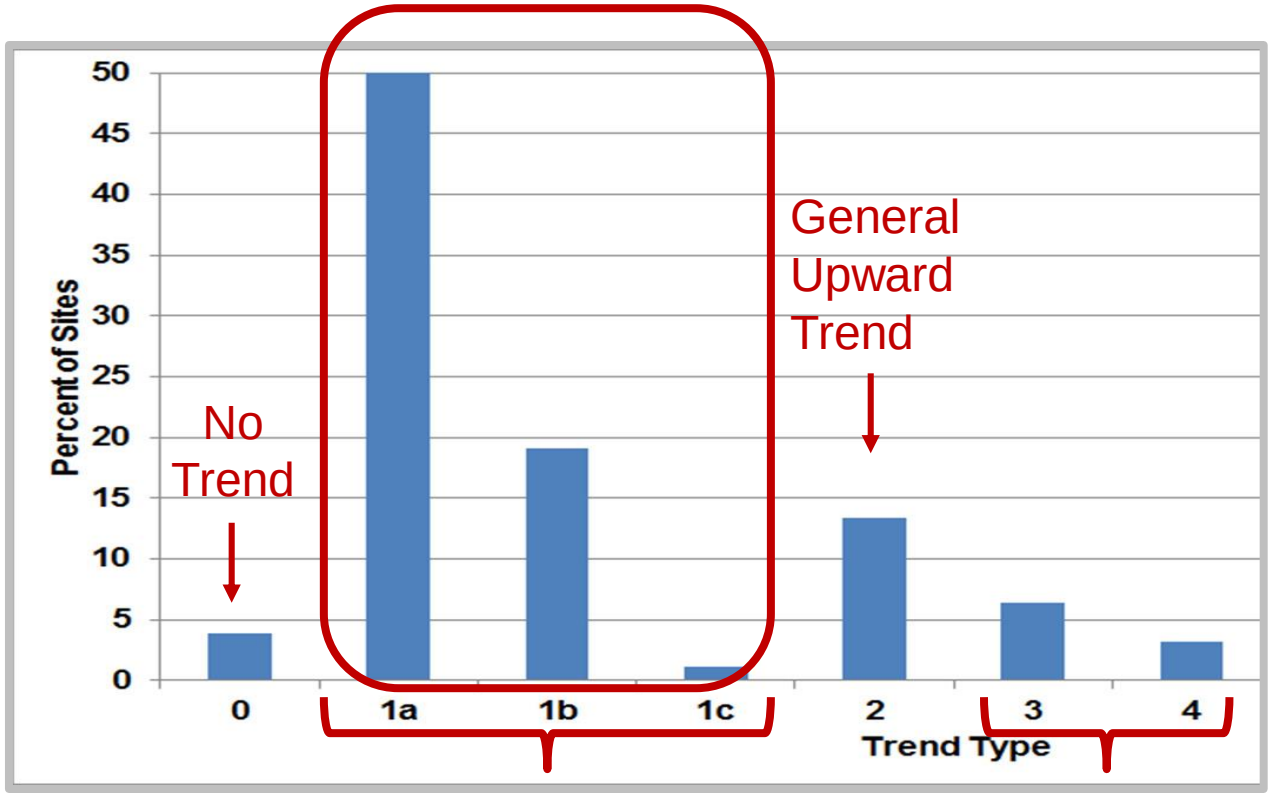




- Duncan et al (2016) show OMI satellite column NO_2 changes from 2005-2014 for different regions
- Broad NO_2 decreases across US and W. Europe are consistent with reported decreases in NOx emissions

Trends in Hourly O_3 Concentrations in EU & US

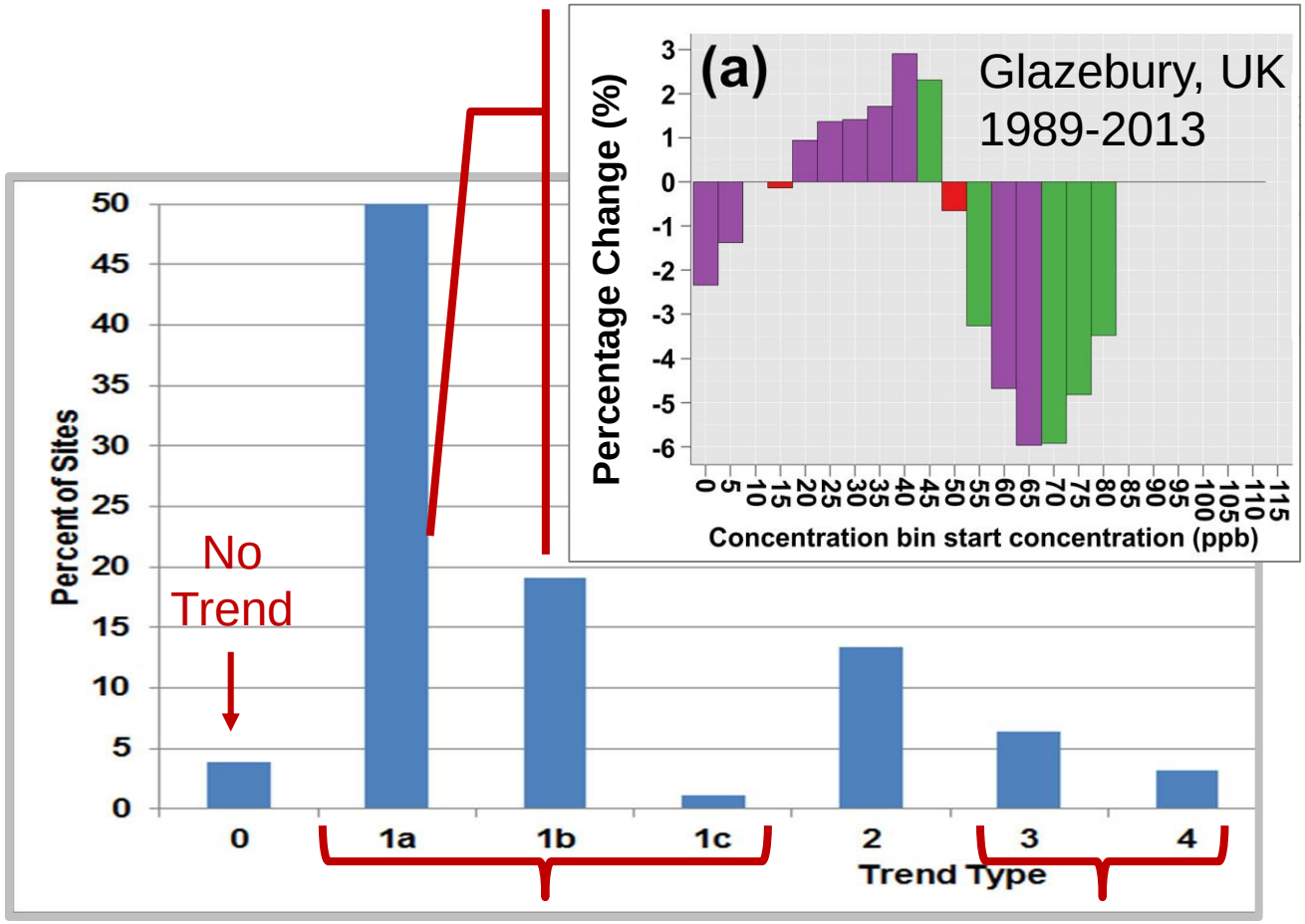
- Changes in hourly O_3 distributions at US and EU sites categorized into trend types
- By far the most common trend was a compression of the O_3 distribution – shift of high and low O_3 values towards mid-range



Lefohn et al., 2018, *in review*

Trends in Hourly O_3 Concentrations in EU & US

- Changes in hourly O_3 distributions at US and EU sites categorized into trend types
- By far the most common trend was a compression of the O_3 distribution – shift of high and low O_3 values towards mid-range

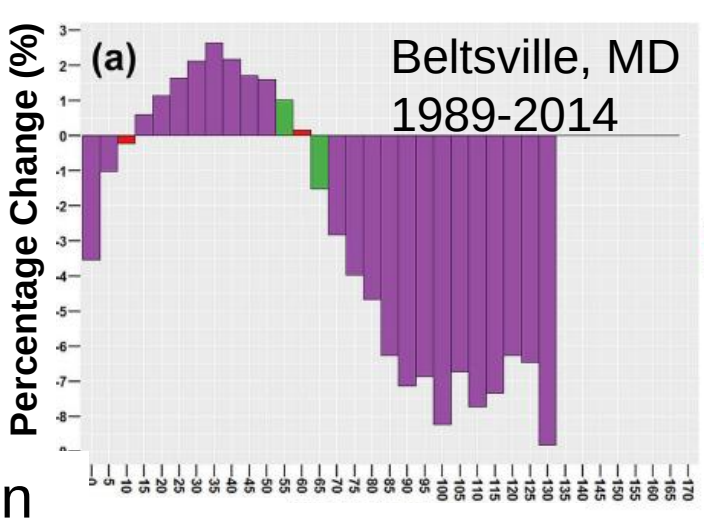


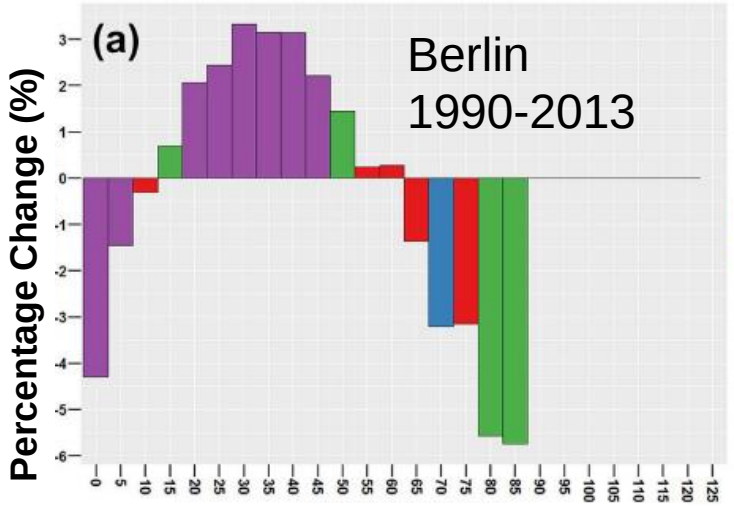
Lefohn et al., 2018, *in review*

Relationship between Hourly O_3 Trends and Trends in O_3 Health and Vegetation Metrics

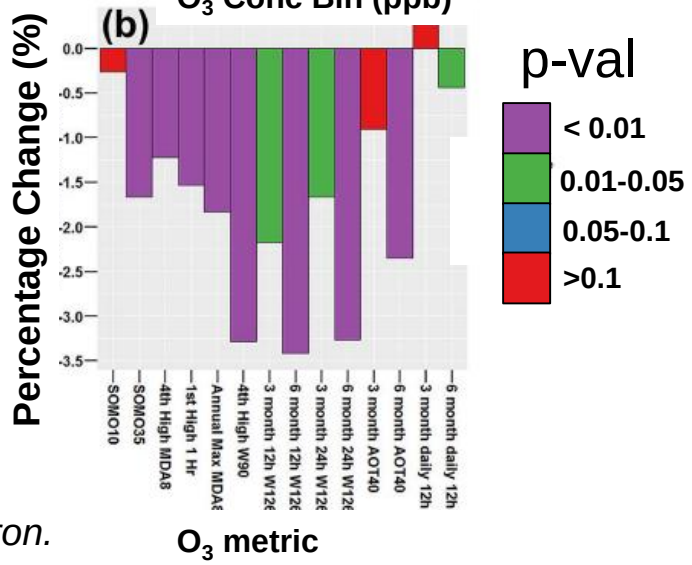
United States Environmental Protection Agency

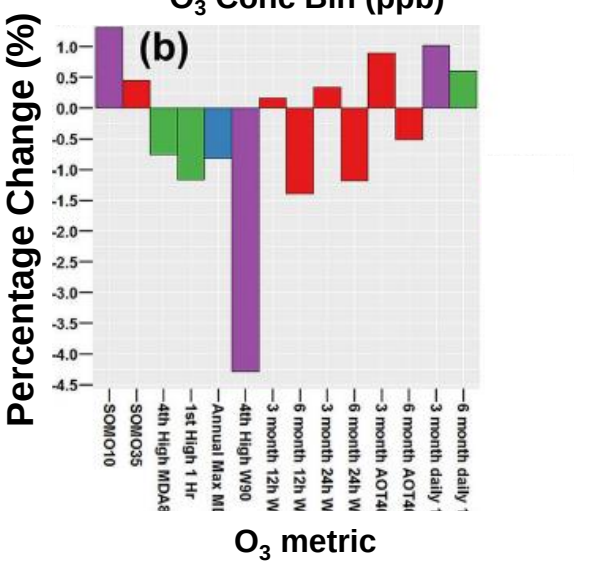
Common Trend Pattern in US and EU





The same pattern of change in hourly O_3 distributions can result in different trend directions for various health metrics



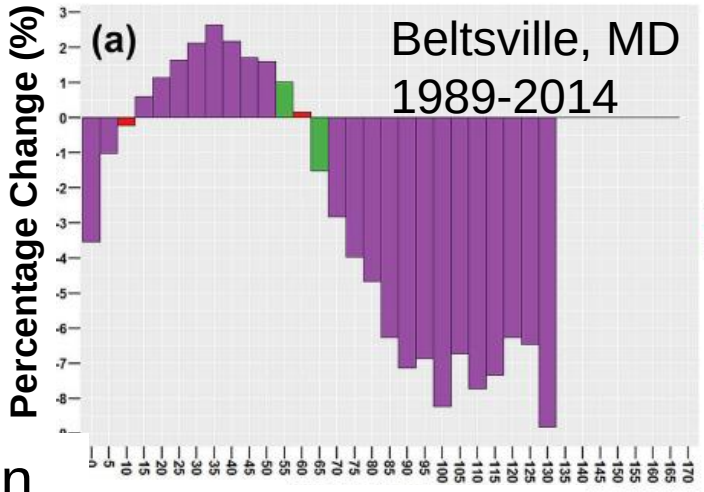


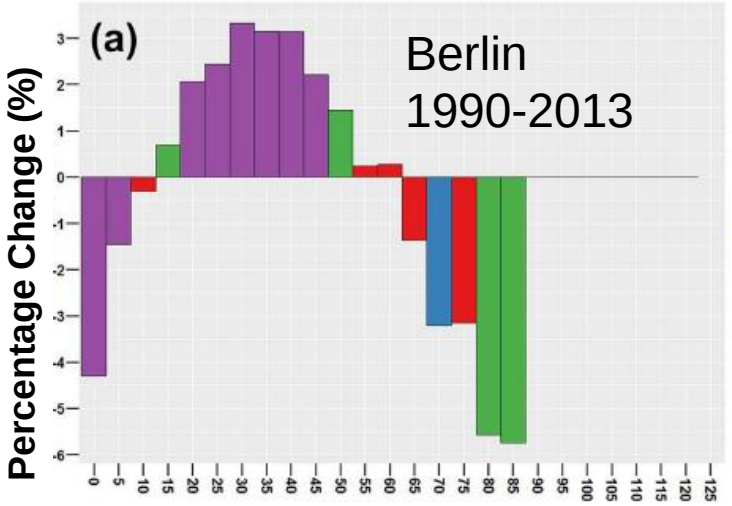
Lefohn et al., 2017, *Atmos. Environ.*

Relationship between Hourly O_3 Trends and Trends in O_3 Health and Vegetation Metrics

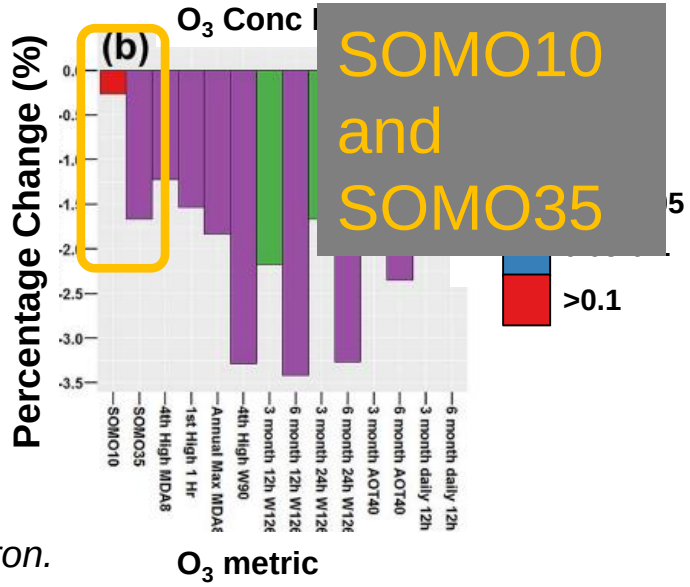
United States Environmental Protection Agency

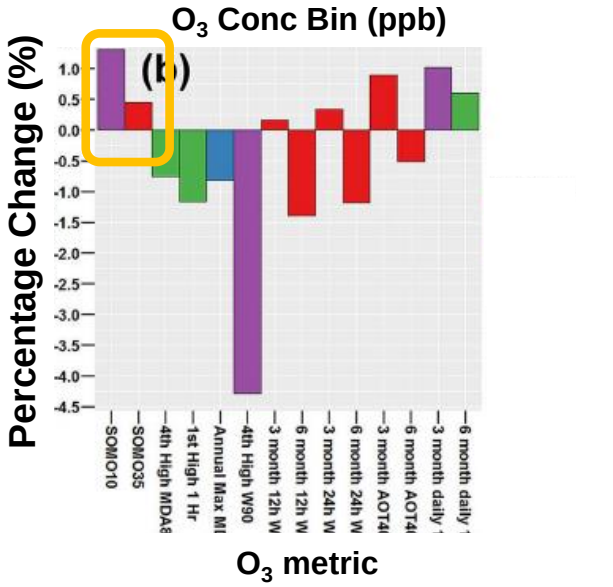
Common Trend Pattern in US and EU





The same pattern of change in hourly O_3 distributions can result in different trend directions for various health metrics



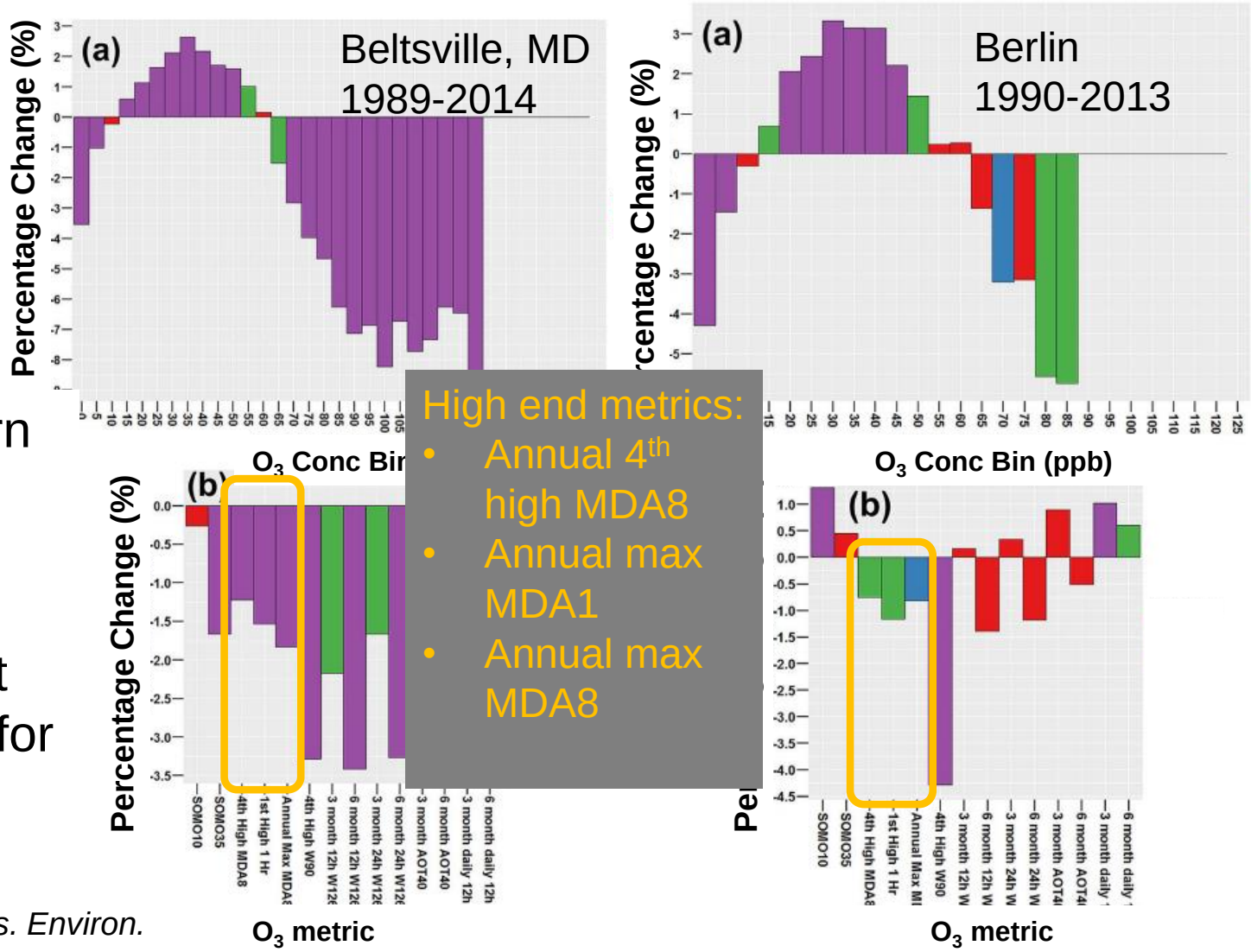


Lefohn et al., 2017, *Atmos. Environ.*

Relationship between Hourly O_3 Trends and Trends in O_3 Health and Vegetation Metrics

United States Environmental Protection Agency

Common Trend Pattern in US and EU



High end metrics:

- Annual 4th high MDA8
- Annual max MDA1
- Annual max MDA8

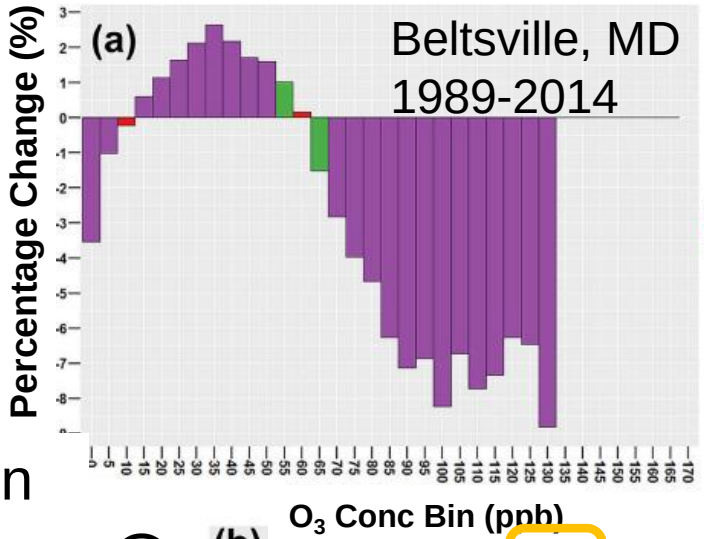
The same pattern of change in hourly O_3 distributions can result in different trend directions for various health metrics

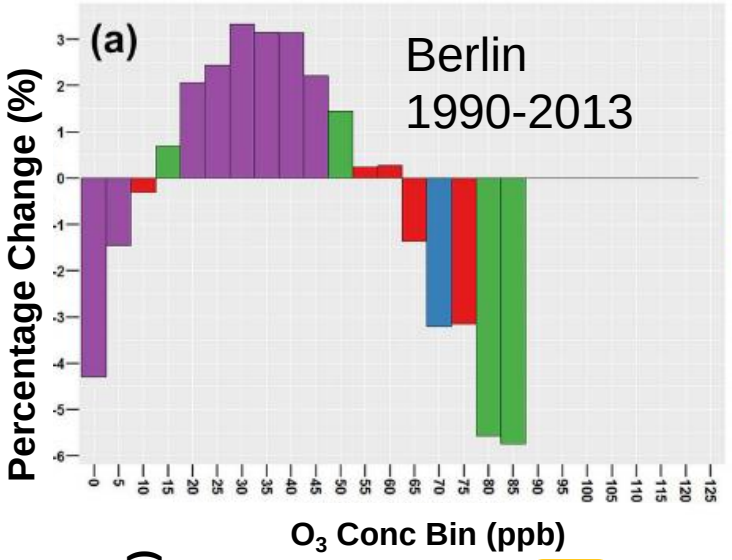
Lefohn et al., 2017, *Atmos. Environ.*

Relationship between Hourly O_3 Trends and Trends in O_3 Health and Vegetation Metrics

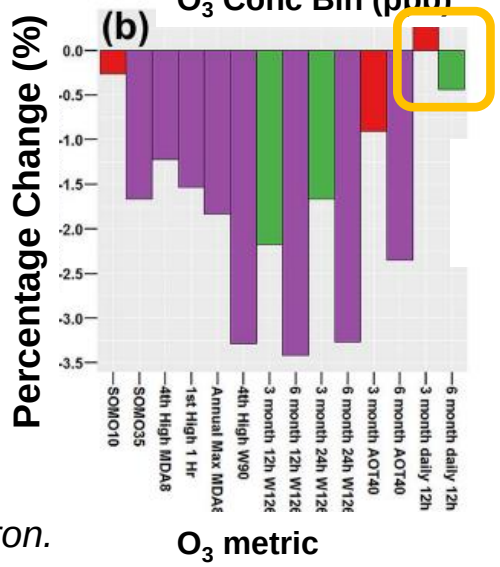
United States Environmental Protection Agency

Common Trend Pattern in US and EU



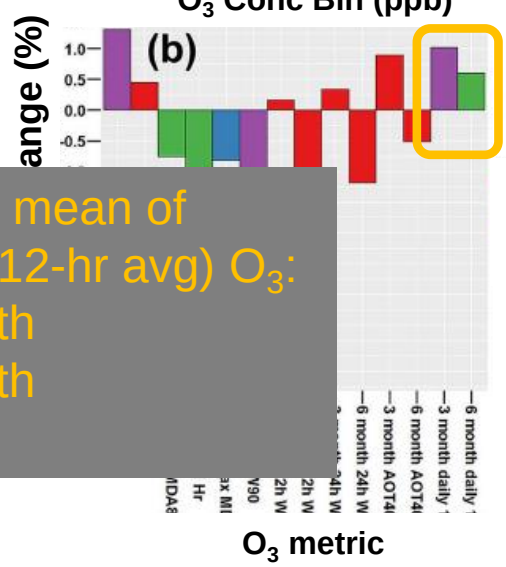


The same pattern of change in hourly O_3 distributions can result in different trend directions for various health metrics



p-val

< 0.01



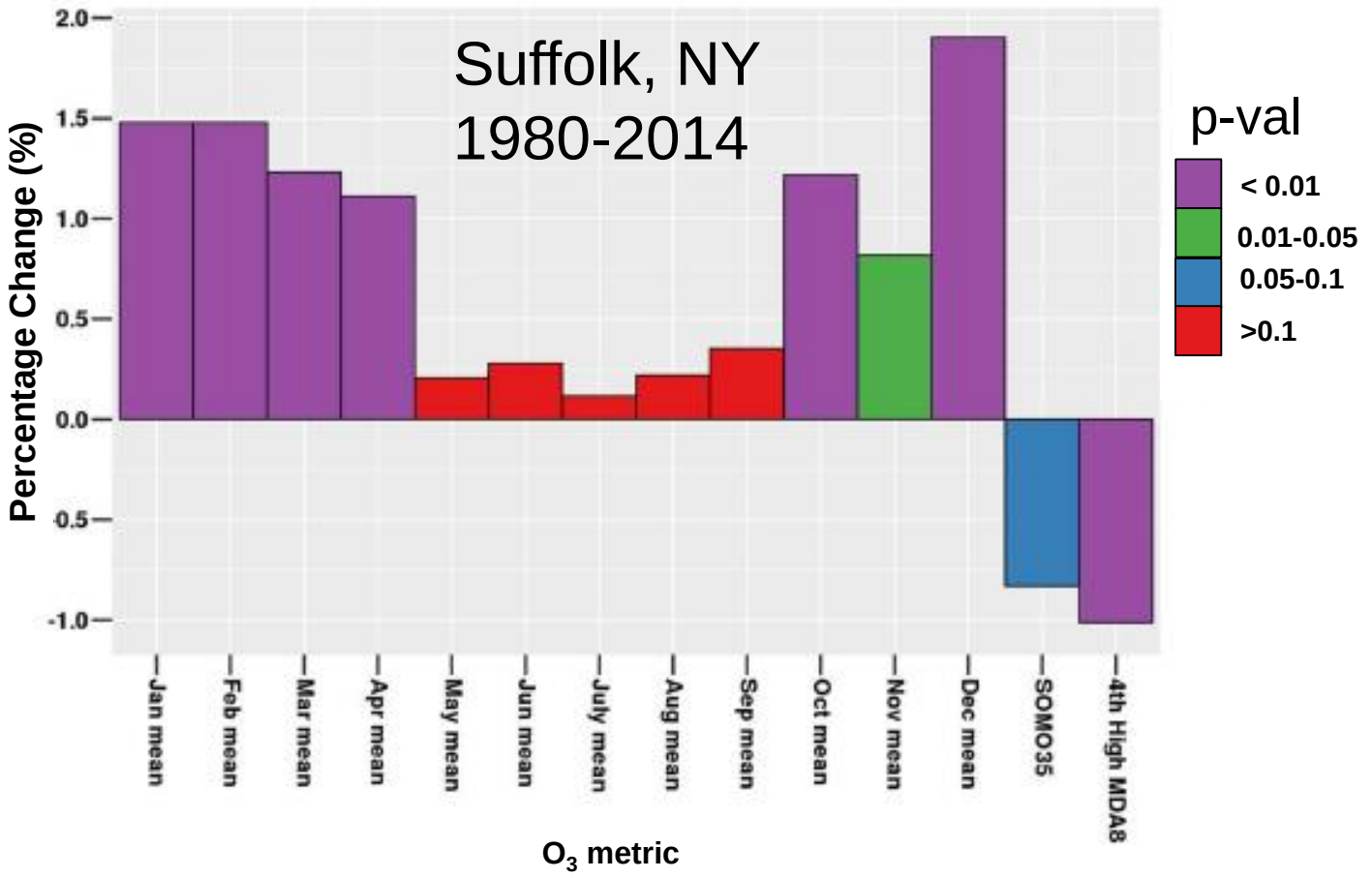
Seasonal mean of daytime (12-hr avg) O_3:

- 3-month
- 6-month

Lefohn et al., 2017, *Atmos. Environ.*

Relationship between Hourly O_3 Trends and Trends in O_3 Health and Vegetation Metrics

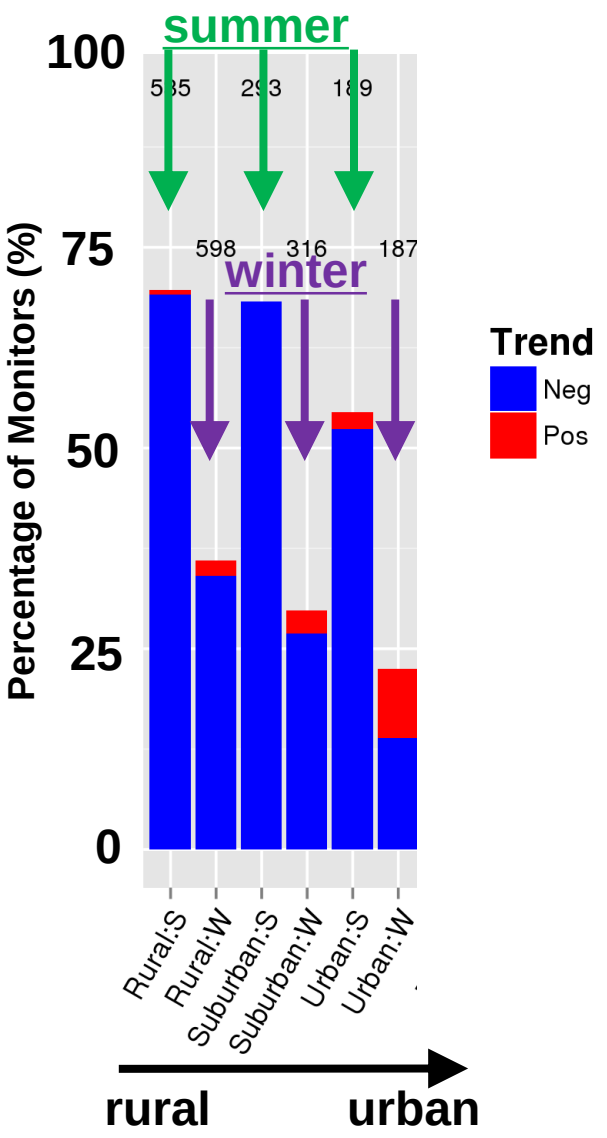
Suffolk, NY presents an example of a site where monthly mean values have increased while regulatory metrics have decreased



Lefohn et al., 2017, *Atmos. Environ.*

What about Urban/Rural Differences? Closer Look at MDA8 O_3 in the US 1998-2013

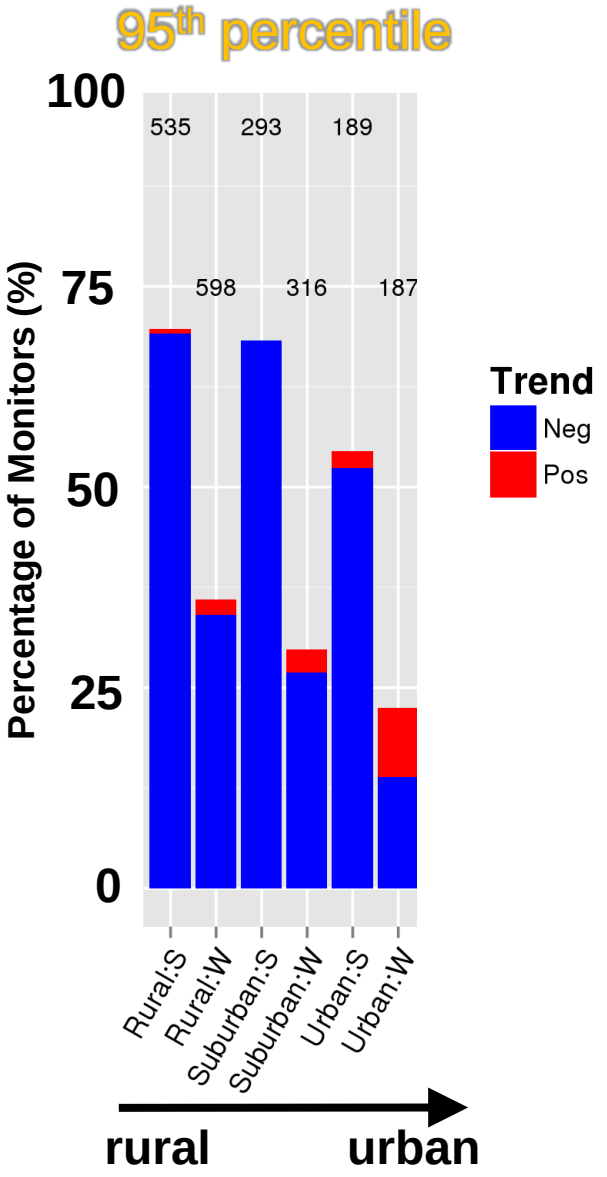
- We separated trends in MDA8 O_3 at US sites by
  - Season
  - Urban class
  - MDA8 percentile



Simon et al., 2015 *Environmental Science & Technology*

What about Urban/Rural Differences? Closer Look at MDA8 O_3 in the US 1998-2013

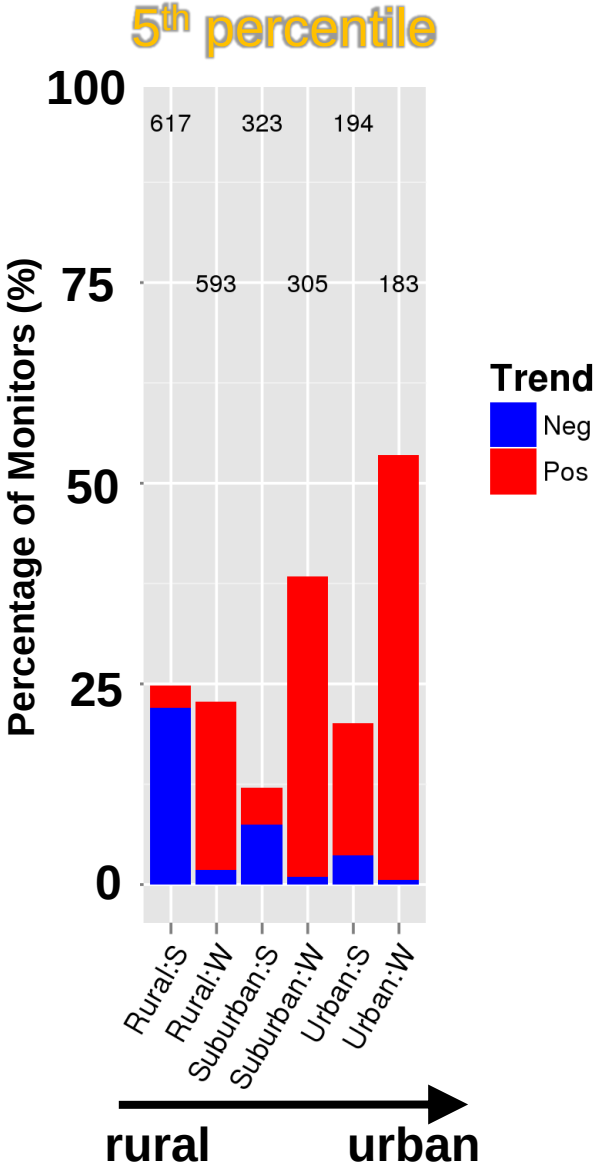
- Most sites with statistically significant trends in 95th percentile MDA8 showed **decreasing** O_3
- Decreases in 95th percentile were more frequent during summer than during winter
- Decreasing trends in 95th percentile were most common at rural sites



Simon et al., 2015 *Environmental Science & Technology*

What about Urban/Rural Differences? Closer Look at MDA8 O_3 in the US 1998-2013

- Most sites with statistically significant trends in 5th percentile MDA8 showed **increasing** O_3 except for rural sites in summer
- Increases in 5th percentile were more frequent during winter than during summer
- Increasing trends in 5th percentile were most common at urban sites



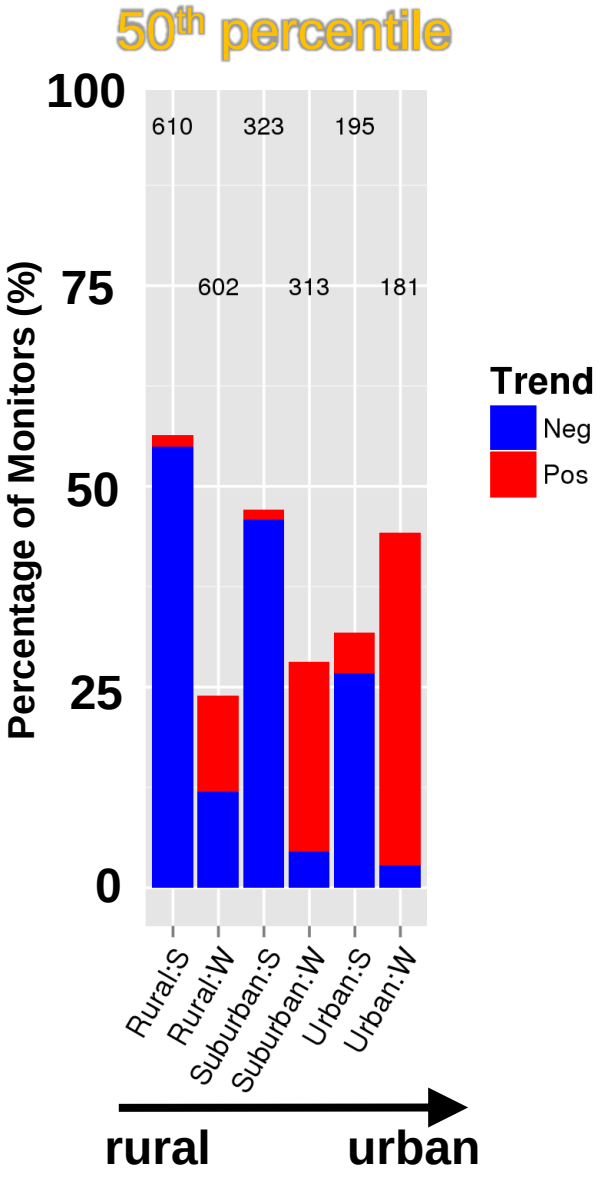
Simon et al., 2015 *Environmental Science & Technology*

What about Urban/Rural Differences? Closer Look at MDA8 O_3 in the US 1998-2013

- Most sites with statistically significant trends in 50th percentile MDA8 showed **increasing** O_3 in winter and **decreasing** O_3 in summer

- **Increasing** trends in 50th percentile were most common at urban sites

- **Decreasing** trends in 50th percentile were most common at rural sites



Simon et al., 2015 *Environmental Science & Technology*

Conclusions

- Models predict that when NOx emissions are decreased, the frequency of low and high concentrations will decrease

- Trends in observed hourly ozone across the EU and US over a period of dramatic NOx decreases shows a compression of the ozone distribution, consistent with model predictions

- A compression of the O_3 distribution can lead to some regulatory, health and vegetation metrics increasing and others decreasing
  - High-end O_3 metrics generally decrease
  - Cumulative or mid-range O_3 metrics trend direction depends on starting O_3 concentration, season & degree of urbanization

- Health and regulatory metrics must be chosen carefully
  - Response to emissions scenarios depends on metrics chosen