AirWaterGas

Sustainability Research Network

Assessing the Impacts of Emissions from Oil and Gas Extraction on Urban Ozone and Associated Health Risks

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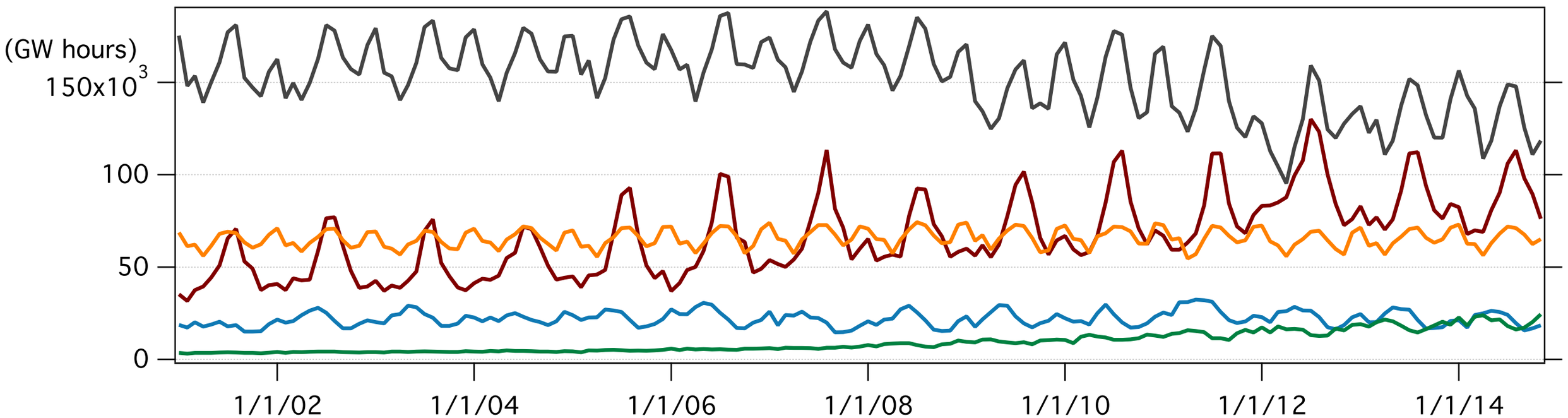
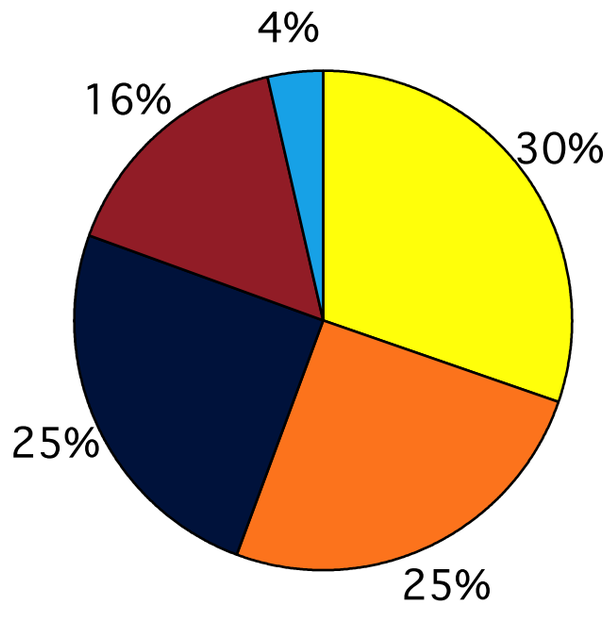
U.S. Energy Sector Shifts & Emissions



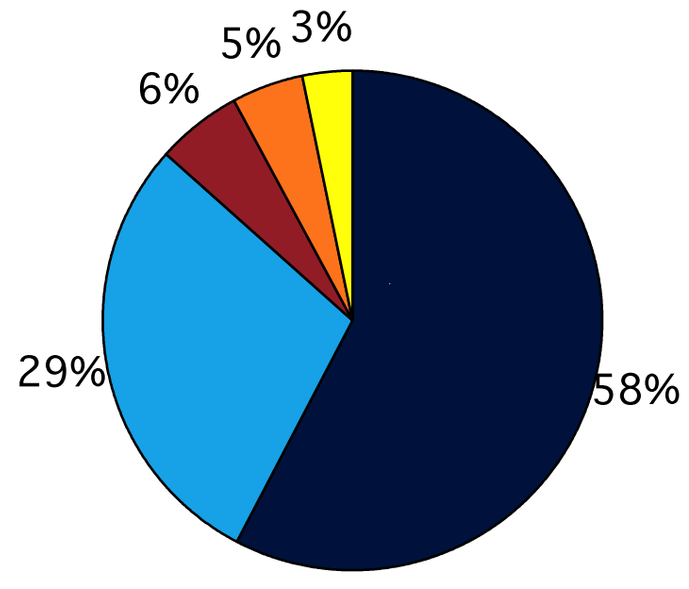
(U.S. EIA www.eia.gov/electricity/data/browser)

Oil and gas production emits NO_x and VOCs at least through engines powering drilling rigs & compressors, condensate storage tanks, and pneumatic devices.

volatile organic compounds (VOCs)

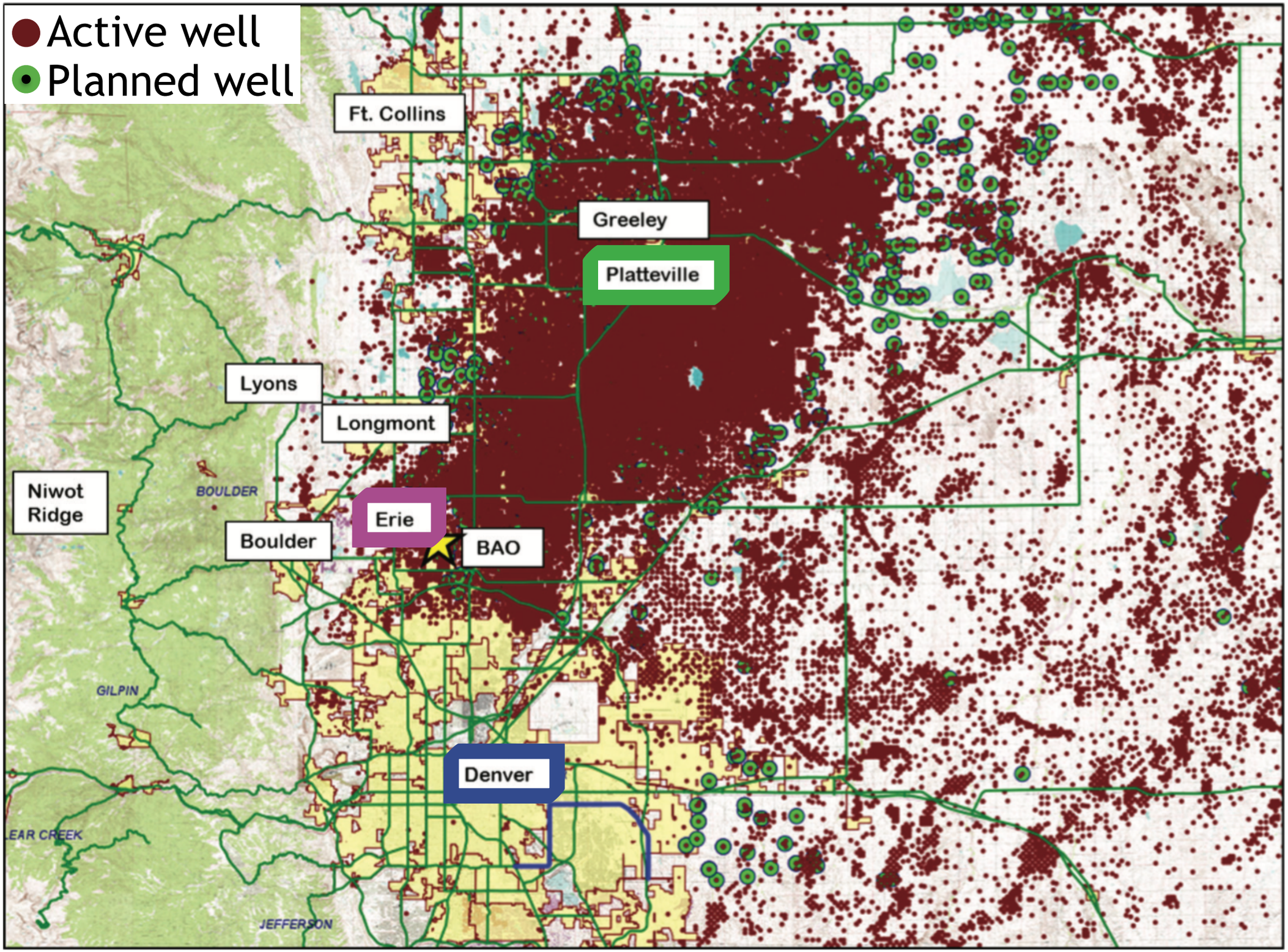


oxides of nitrogen (NOx)



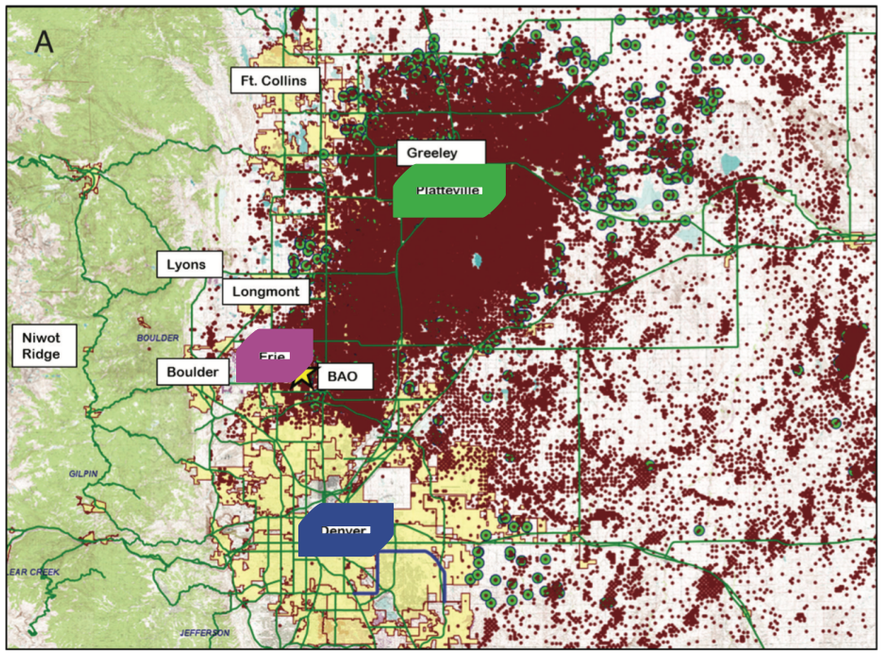
(U.S. EPA, 2011 NEI)

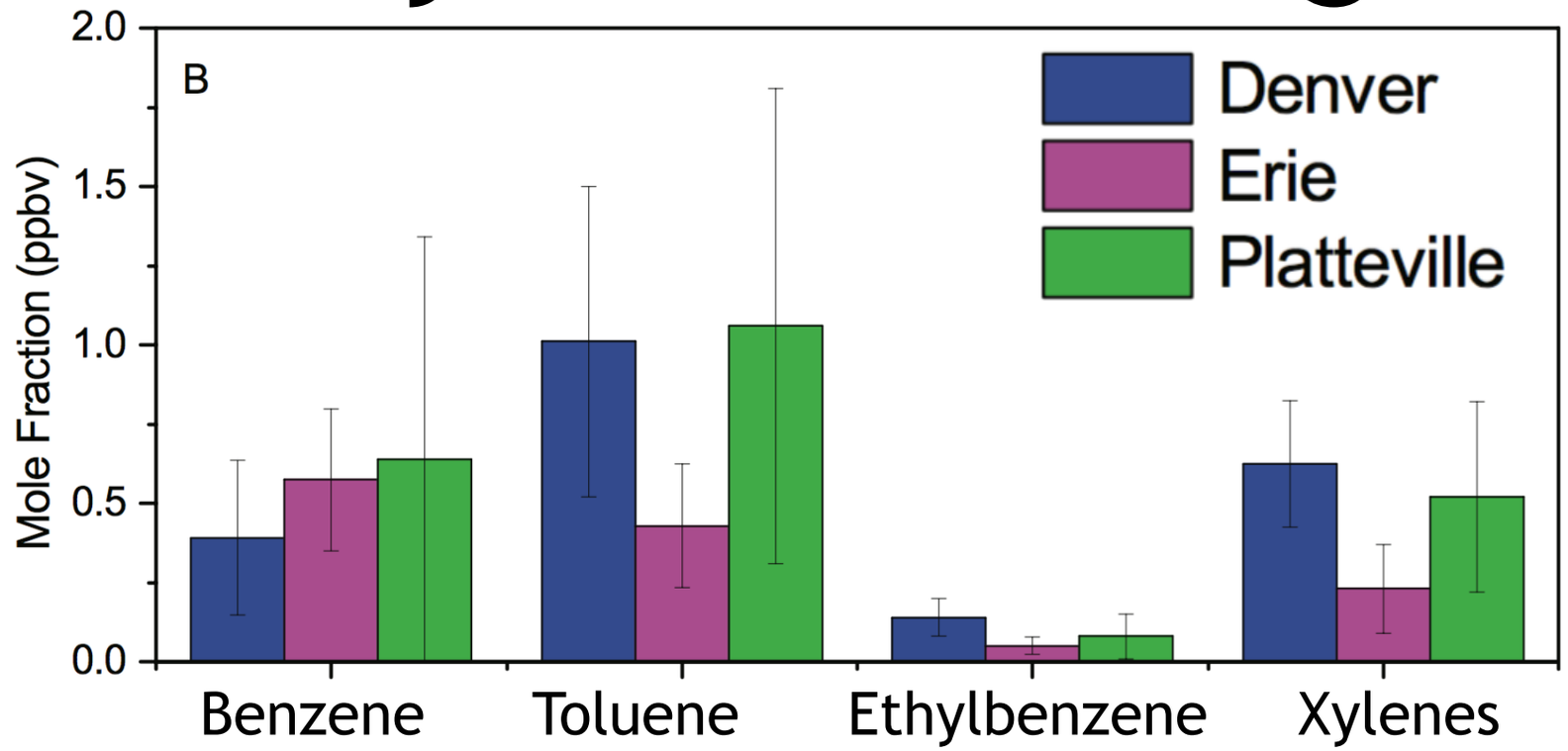
Oil & Gas in the Rocky Mountain region



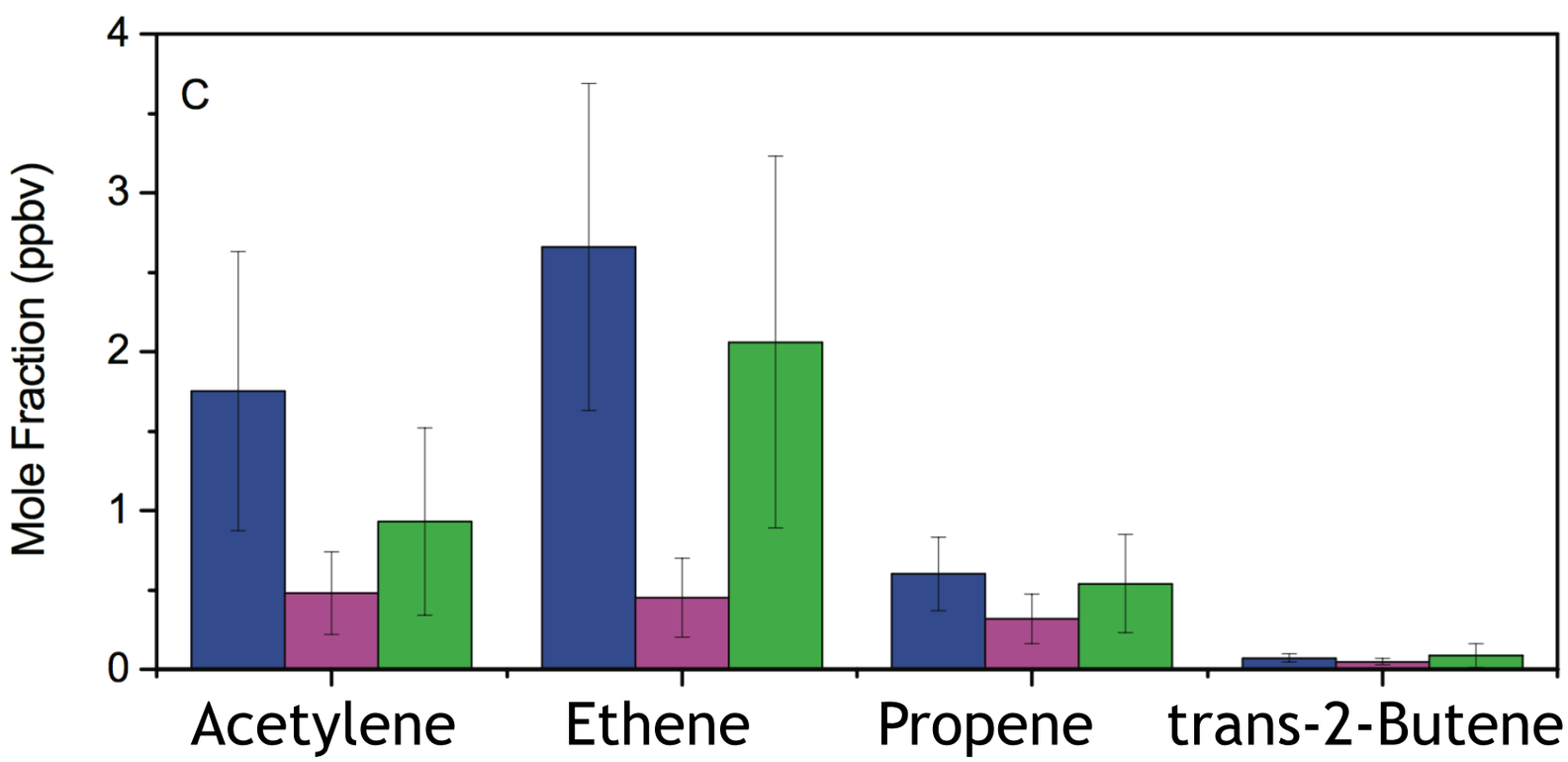
(Thompson et al., 2014)

Oil & Gas in the Rocky Mountain region





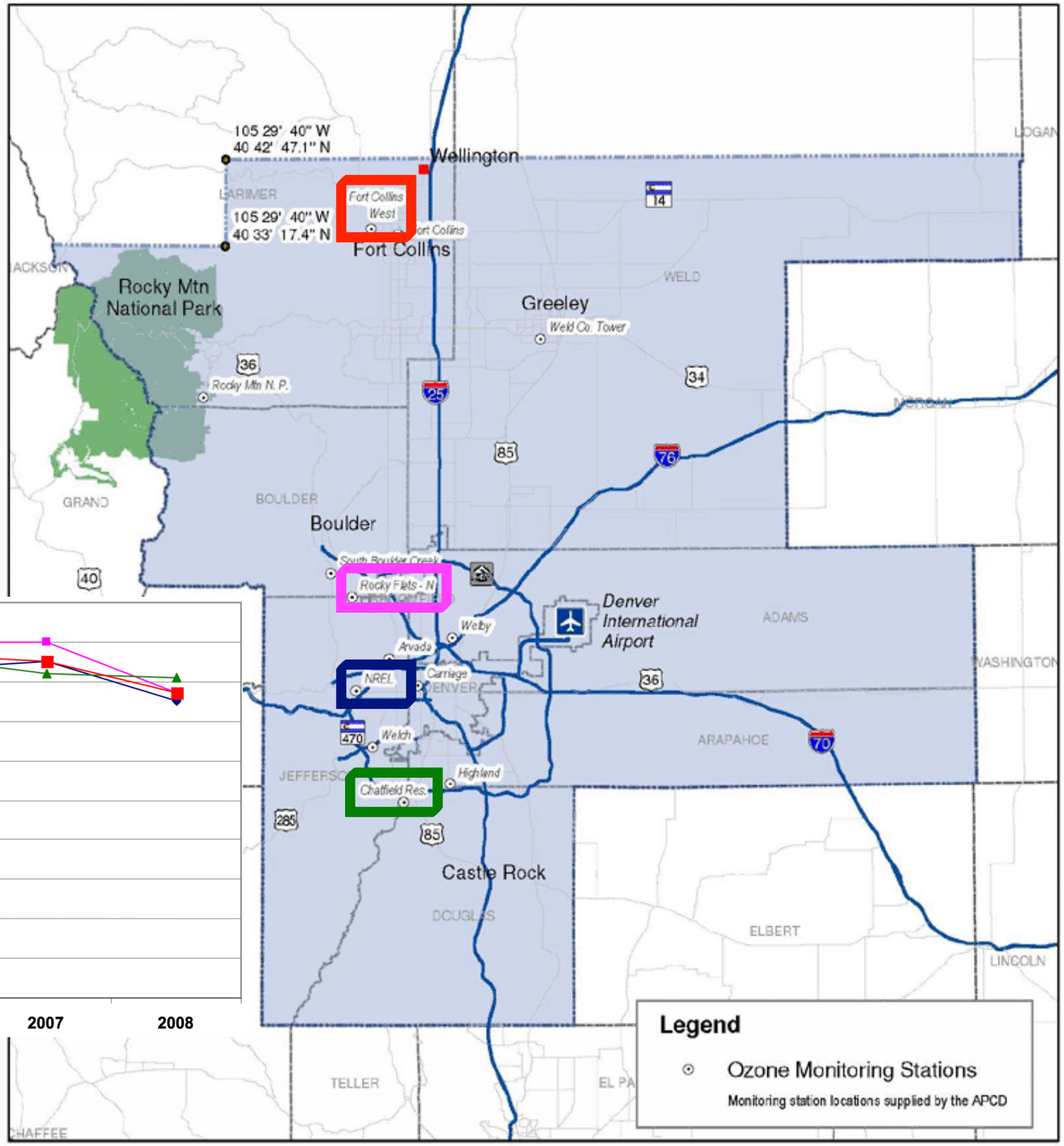
- Ambient VOC concentrations from flask canister observations
- March - May 2013
- Colorado Department of Public Health and Environment (Denver, Platteville) and Thompson et al. (Erie) measurements



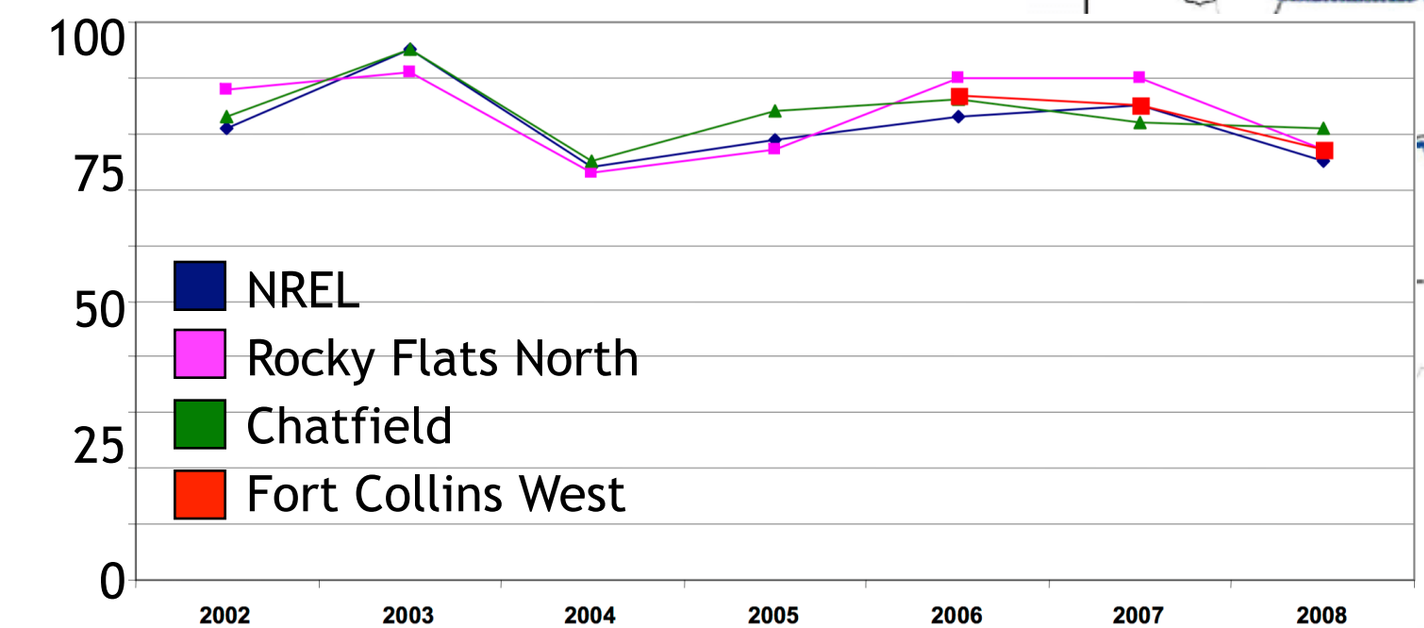
(Thompson et al., 2014)

Importance of Ozone Precursors in Front Range

- History of challenge to achieve attainment, including current status of ***marginal nonattainment***.
- Efforts to comply with National Ambient Air Quality Standards
- DISCOVER-AQ and FRAPPE missions to help understand challenges

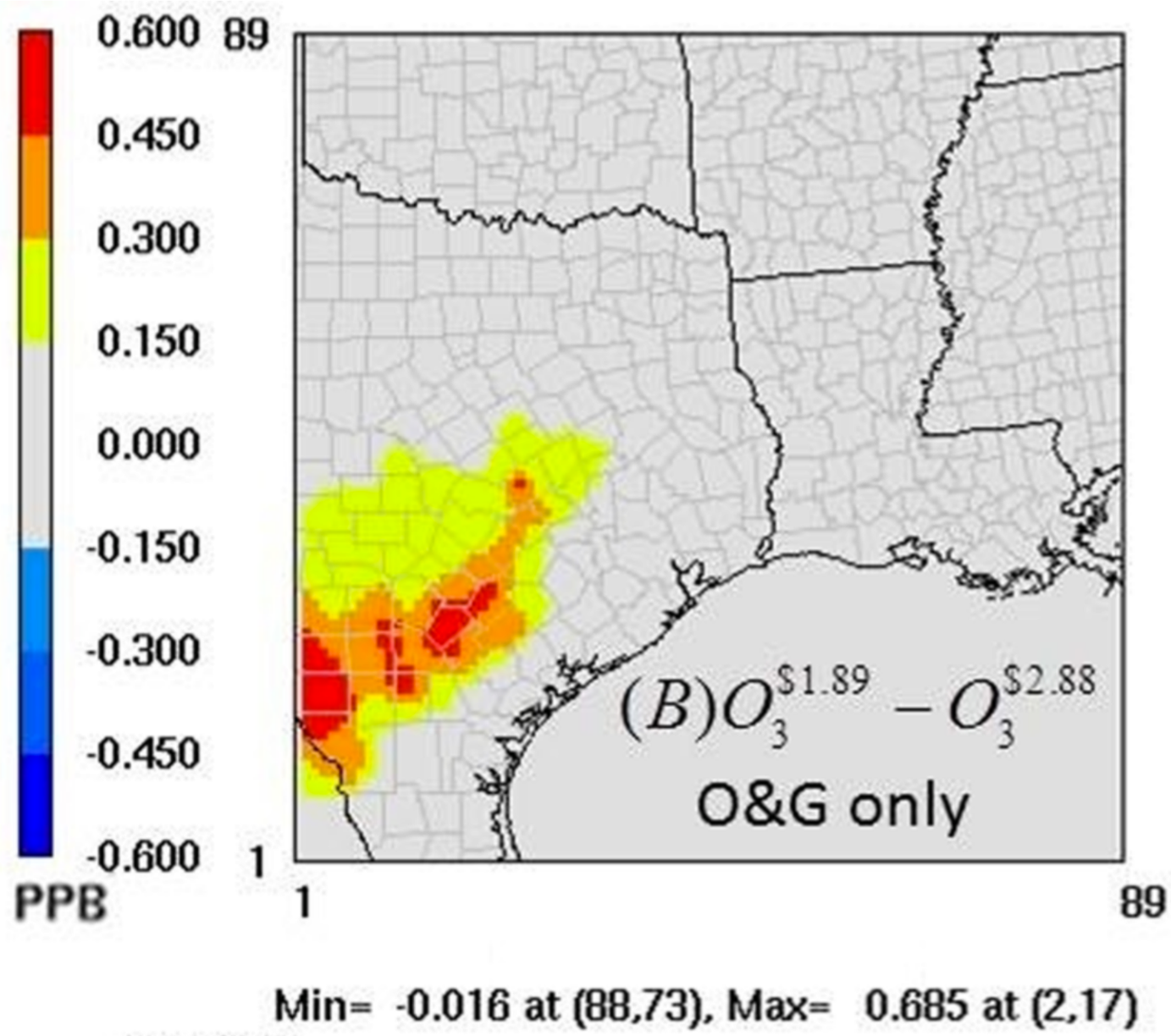


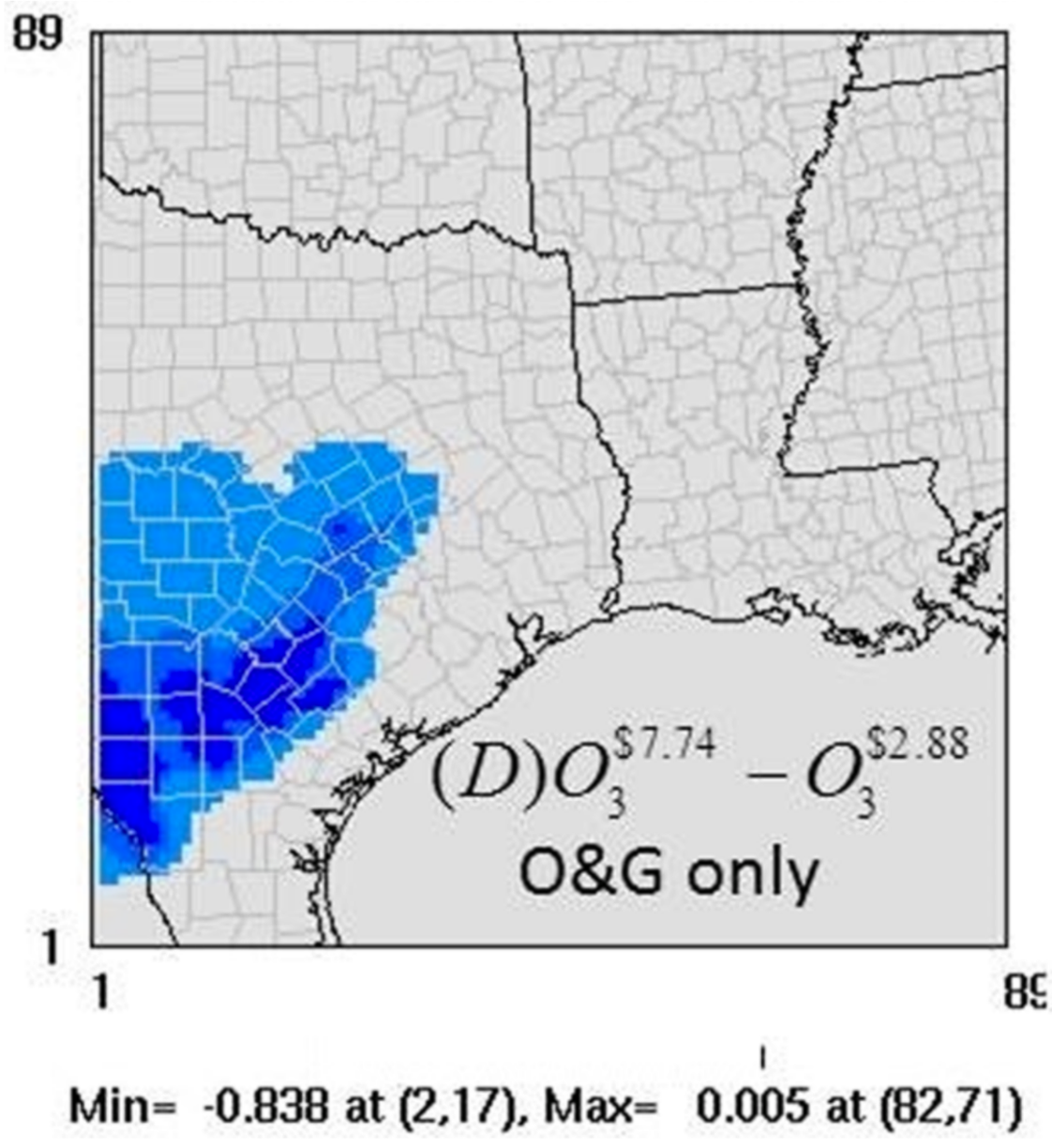
Time Series of Monitored 4th Maximum 8-Hour Ozone Values



(Colorado Dept. of Public Health & Environment)

Evaluation of Oil & Gas Contributions to MDA8 Ozone





Influence of ***Eagle Ford shale emissions*** on daily maximum 8-hr average (MDA8) ozone concentrations in eastern Texas explored through ***natural gas pricing*** for 33 day episode.

(Pacsi et al., 2015)

Attributing Ozone Effects to Emissions with CMAQ adjoint

$$\frac{\partial(\text{cost function})}{\partial(\text{emissions})}$$

∂(emissions)

∂(Ethene Emissions)

∂(NOx Emissions)

∂(Isoprene Emissions)

∂(Toluene Emissions)

∂(Chlorine Emissions)

∂(cost function)

∂(local MDA8)

or

∂(health risks associated with ozone exposure)

$$\partial\vec{x}=(F')^{T}(x,\partial y)$$

Emissions influences are spatially resolved at the grid scale.

(Hakami et al., 2007)

Modeling Episode & Approach

May-September 2007

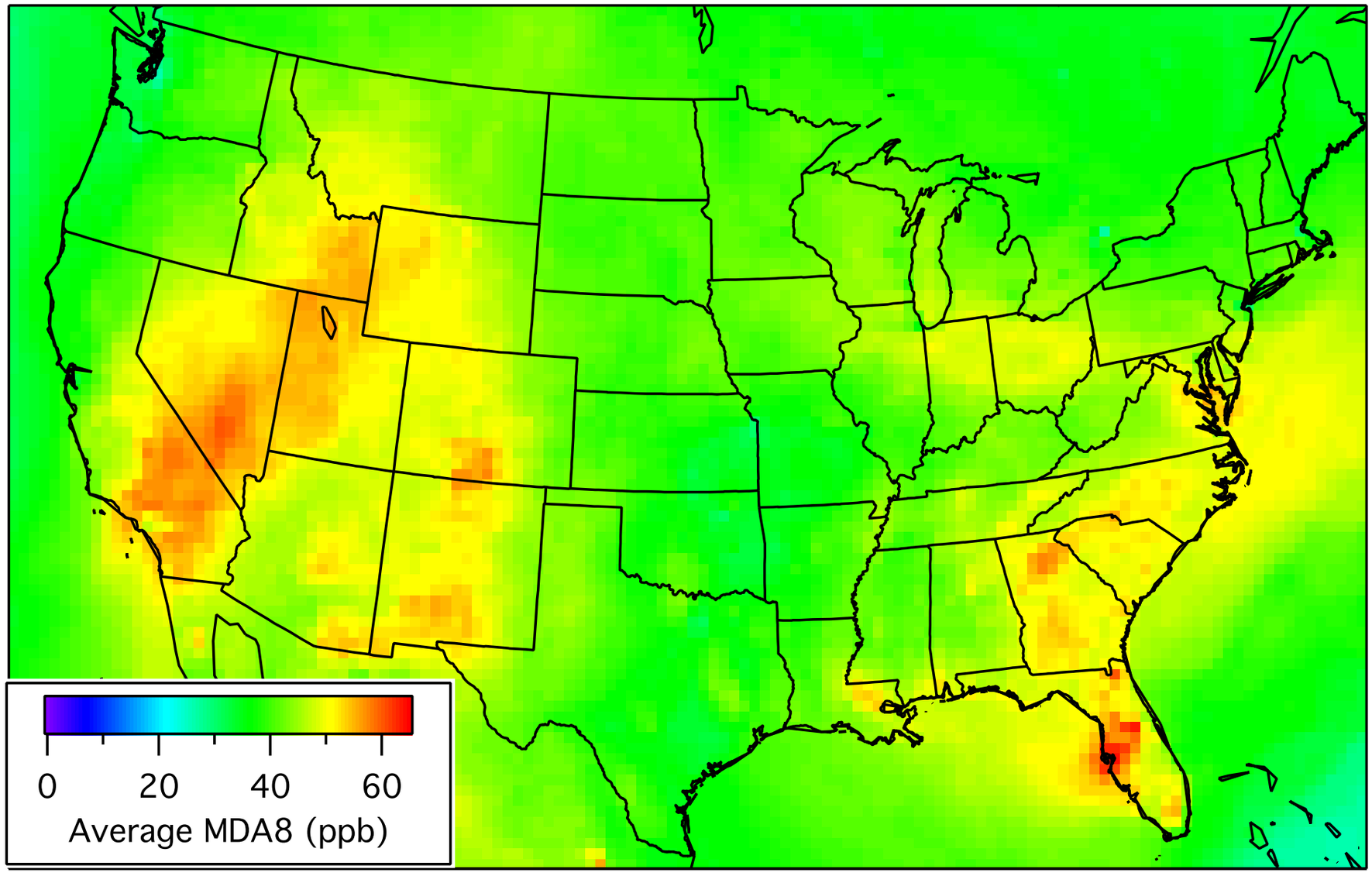
Emissions
EPA NEI 2008v2
with BEIS 3.14

Chemistry
Carbon Bond 05

Meteorology
WRF v3.1

Resolution
24 layers | 36x36 km^2

Model
CMAQ adjoint

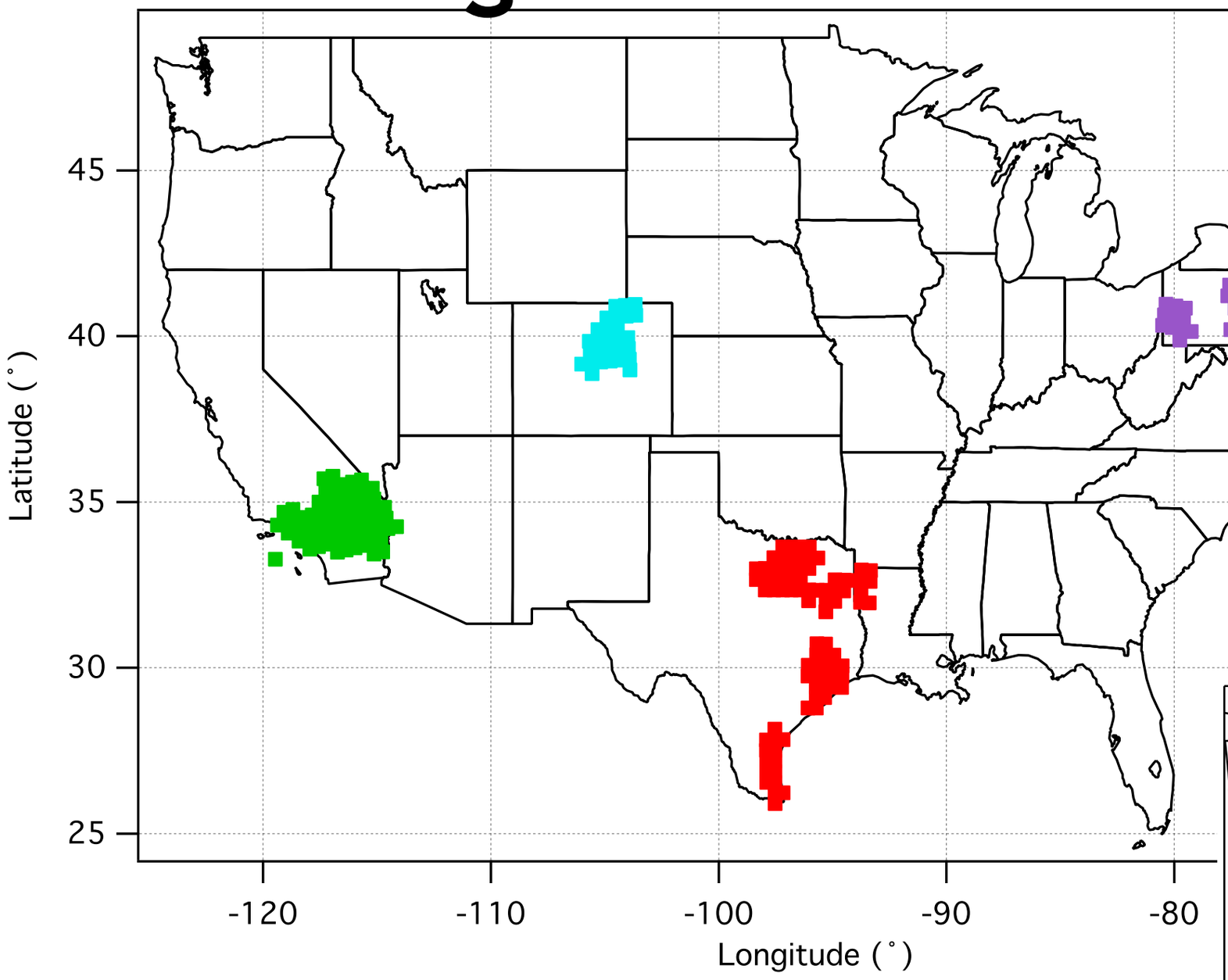


Example mean MDA8 O_3 from week long run in May 2007

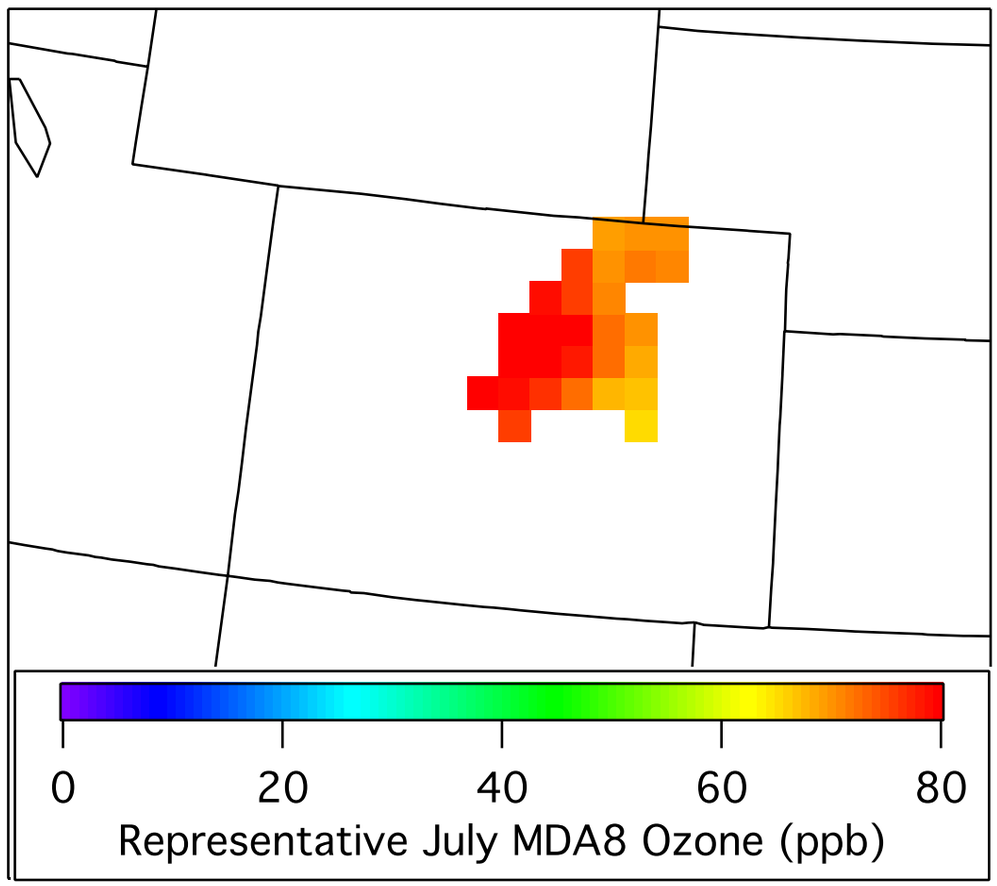
Cost Functions
MDA8 | ozone-related health risks
in urban areas adjacent to oil and gas development

(Capps et al., *in prep*)

Evaluating Emissions Influences on MDA8



- Marcellus & Utica shale plays in Appalachian Basin
- Eagle Ford, Haynesville, & Barnett shale plays
- Niobrara play in Denver Basin
- San Joaquin, Santa Maria, Ventura, and LA basins

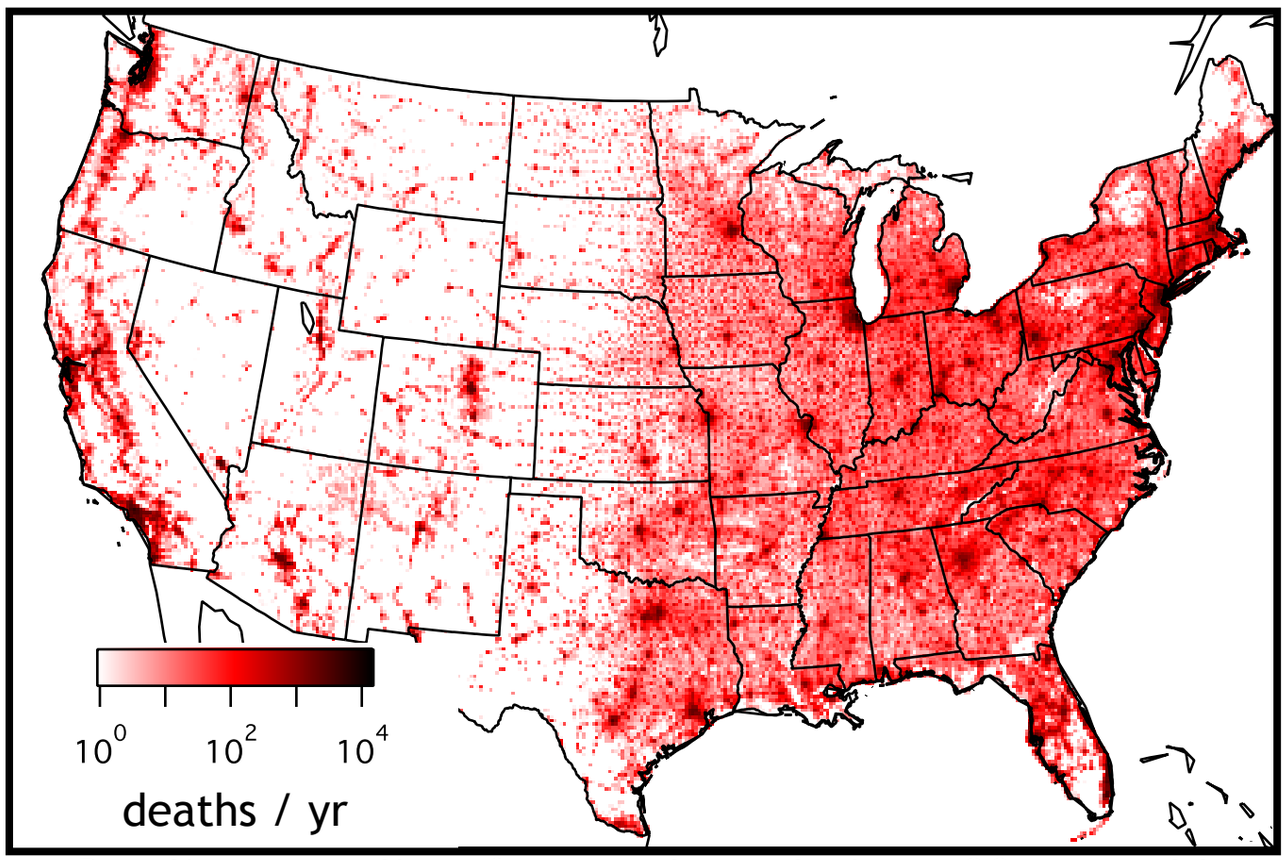


Combined statistical areas encompassing four geographically-aggregated urban areas adjacent to oil and gas development to be evaluated.

MDA8 and ***exceedances of ozone NAAQS levels*** to be assessed.

U.S. Energy Information Administration
www.eia.gov/oil_gas/rpd/shale_gas.pdf

Estimate Risk due to Ozone Exposure



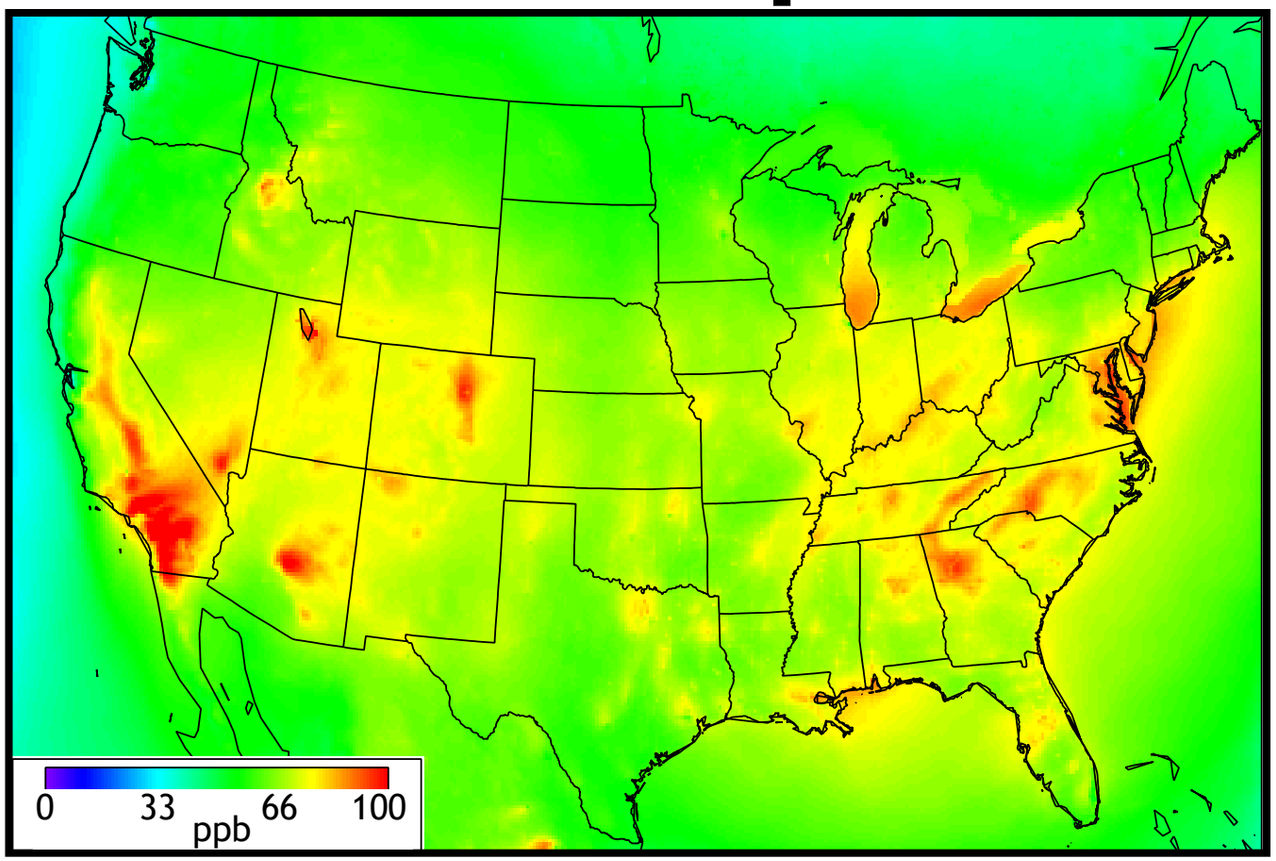
Baseline mortality of exposed population, ≥30 years old

$$\Delta M = M_0 P (1 - e^{-\beta \Delta C})$$

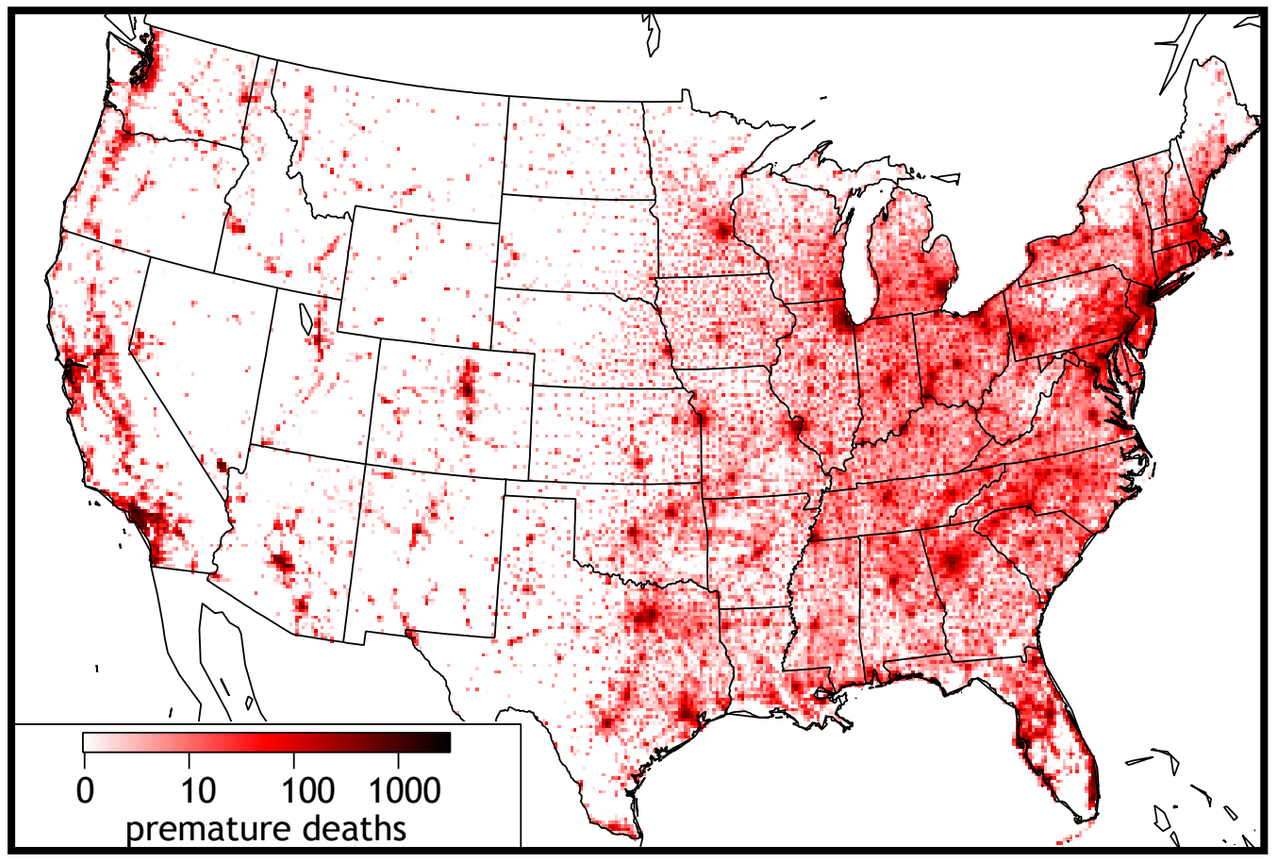
where M_0 is the baseline mortality, P is the exposed population over 30 years old, β is 0.0427% per ppb O_3, and C is the 6-month mean of maximum hourly O_3.

$$\Delta \text{Risk} = 1 - e^{-\beta \Delta C}$$

(BenMAP | Jerrett et al., 2009)



2007 6-month mean of maximum hourly O_3



Enabling Emissions Scaling Factor and Absolute Emissions Sensitivities

- Added sensitivities with respect to ***absolute emissions*** and ***emissions scaling factors*** at each layer (with Matt Turner).
  - Each array is are propagated through the ACM2 continuous adjoint of vertical diffusion.

$$\left\{ \frac{\Delta \sum_{i=1}^{6\ \text{days}} \left[\text{MDA8 Denver} \right]}{\Delta \sigma_{\text{emis, ethene}}} \right\} \overset{?}{=} \left\{ \frac{\partial \sum_{i=1}^{6\ \text{days}} \left[\text{MDA8 Denver} \right]}{\partial \sigma_{\text{emis, ethene}}} \right\}$$

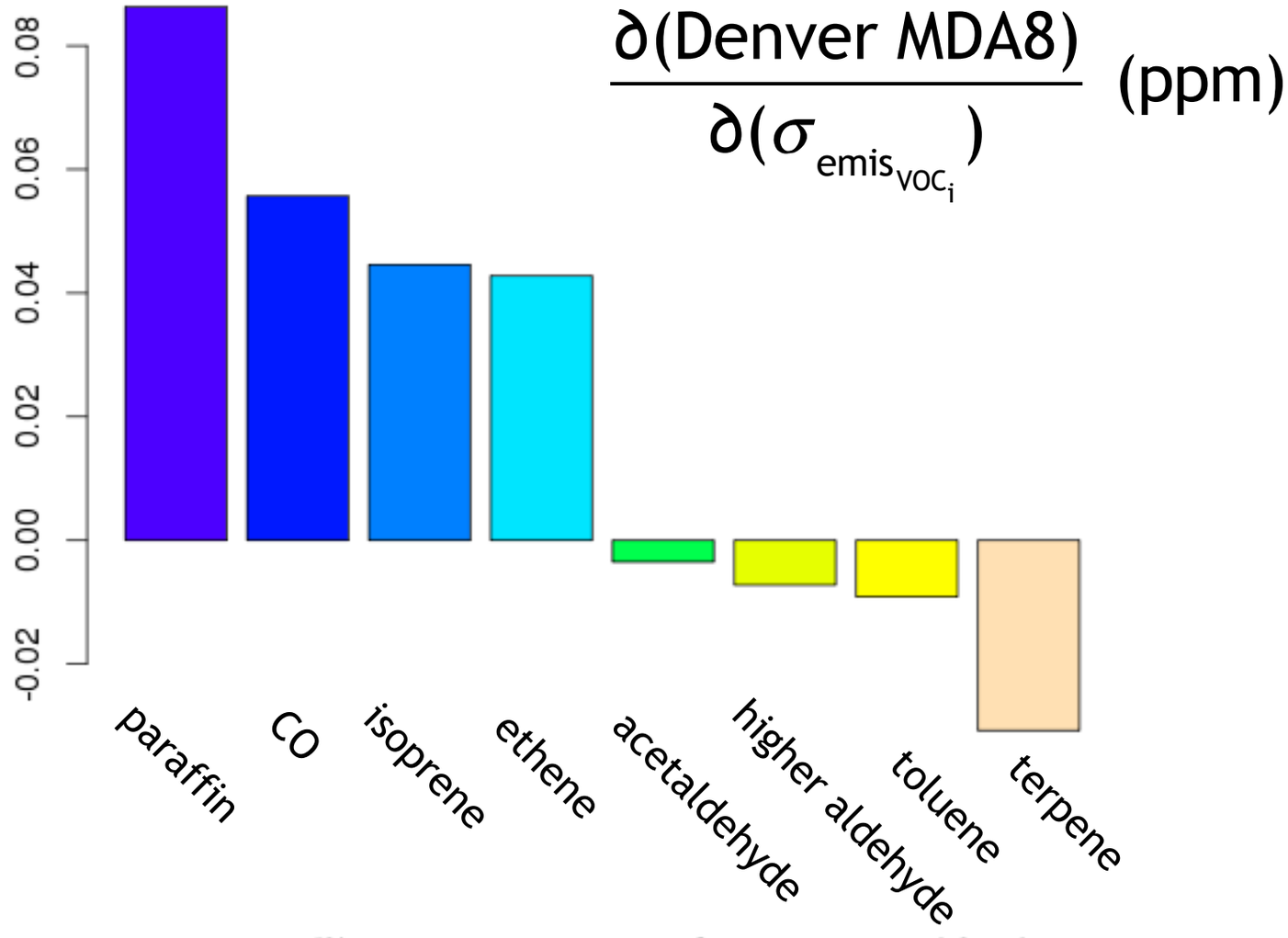
- ***Adjoint-based influence*** of ethene on sum of June 1-7 average MDA8 for the Denver CSA ***within 25% of finite difference*** value (10% perturbation).

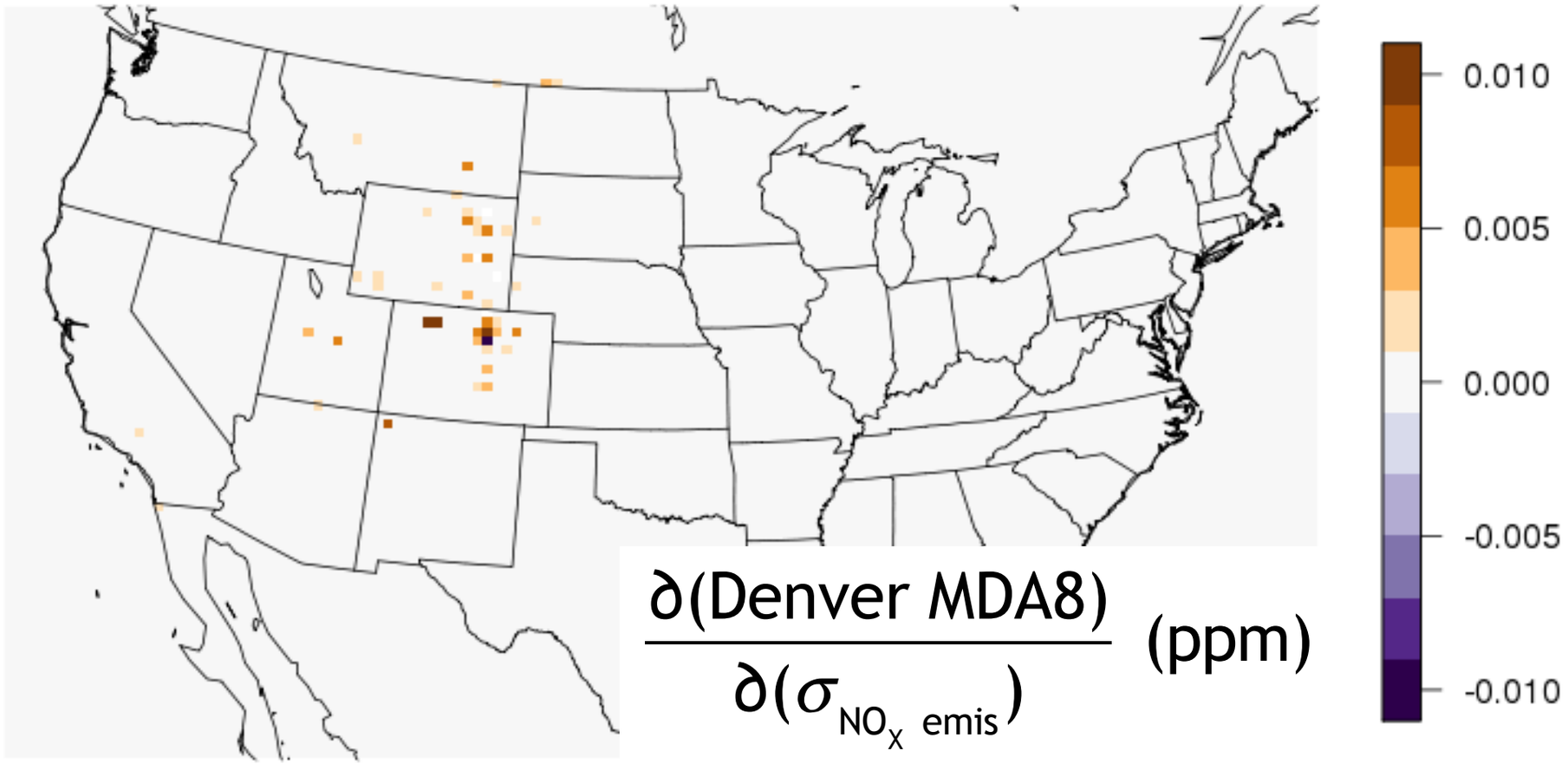
Denver MDA8 Sensitivities June 1-7

$$\frac{\partial(\text{Denver MDA8})}{\partial(\sigma_{\text{emis}_i})}$$

Ranking ***sensitivities to surface VOC emissions*** shows the relative importance of each species to MDA8 ozone formation.

Spatially-refined sensitivities allow investigation of efficient emissions control strategies.

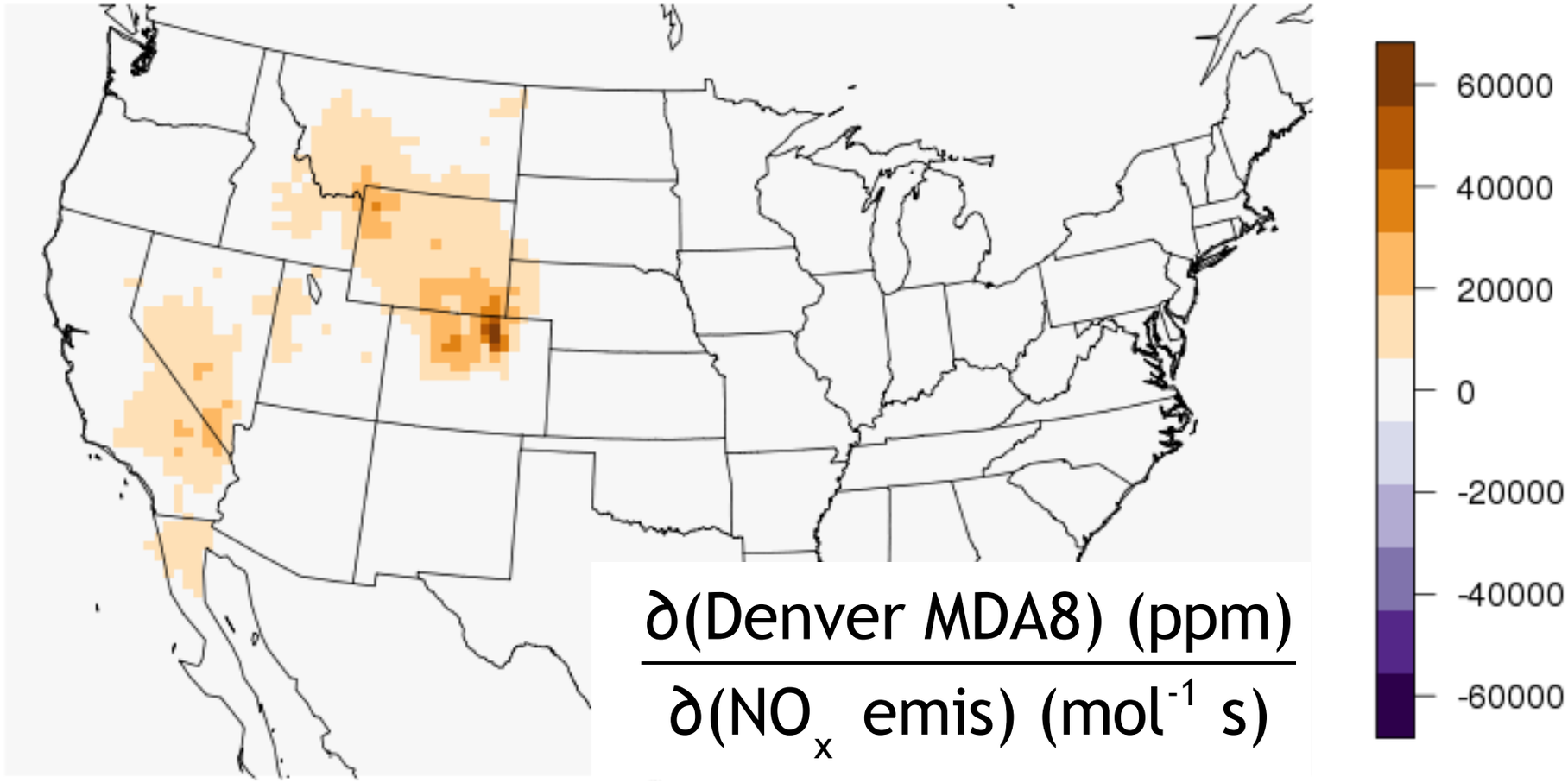


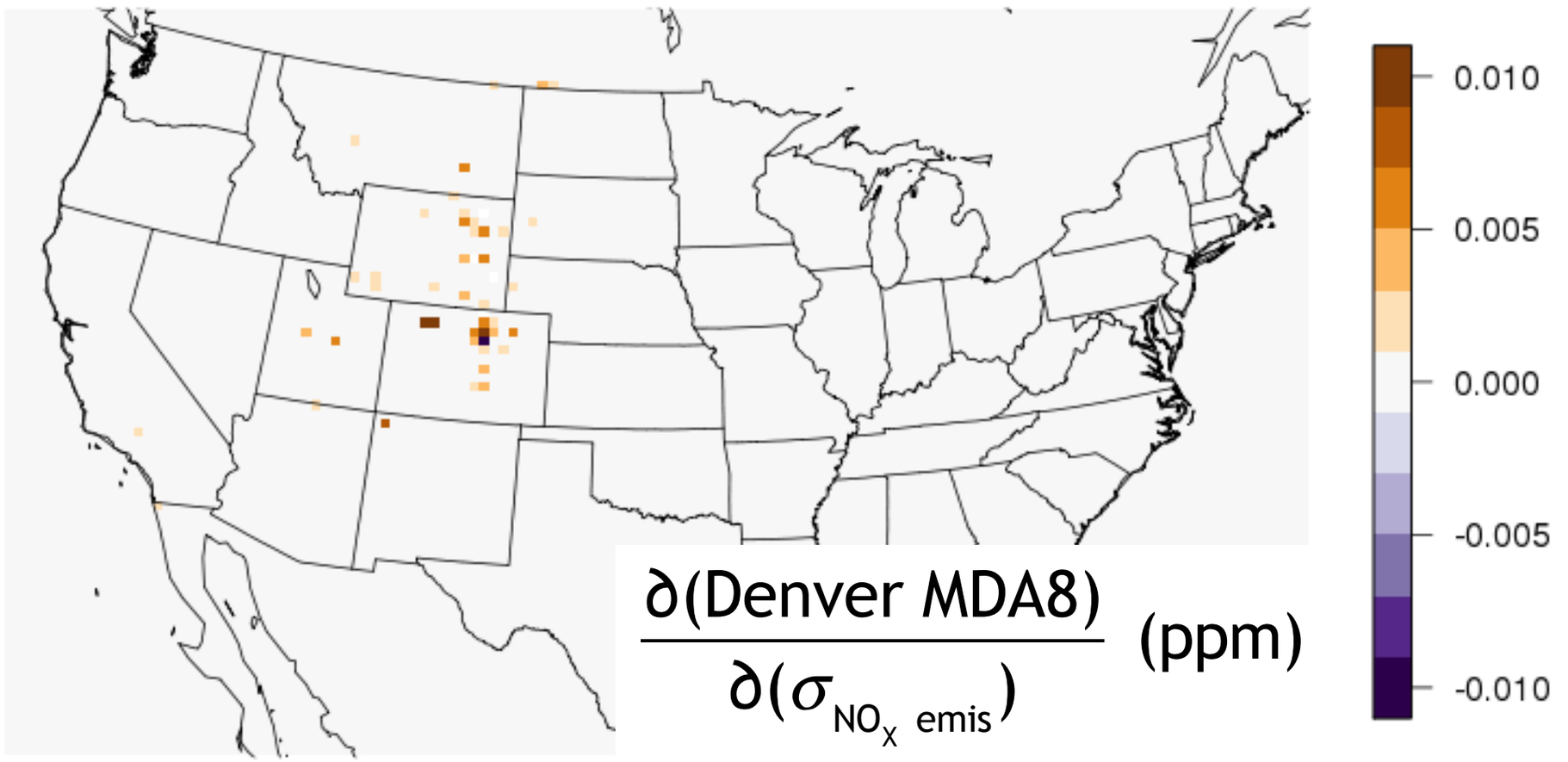


Information for Emissions Control Strategy Development

Sensitivities to ***absolute emissions*** inform which emissions were responsible for formation of the ozone present.

Sensitivities with respect to ***emissions scaling factors*** convey the extent to which a change in emissions of a species (e.g., NO_x) in a location would impact Denver MDA8.

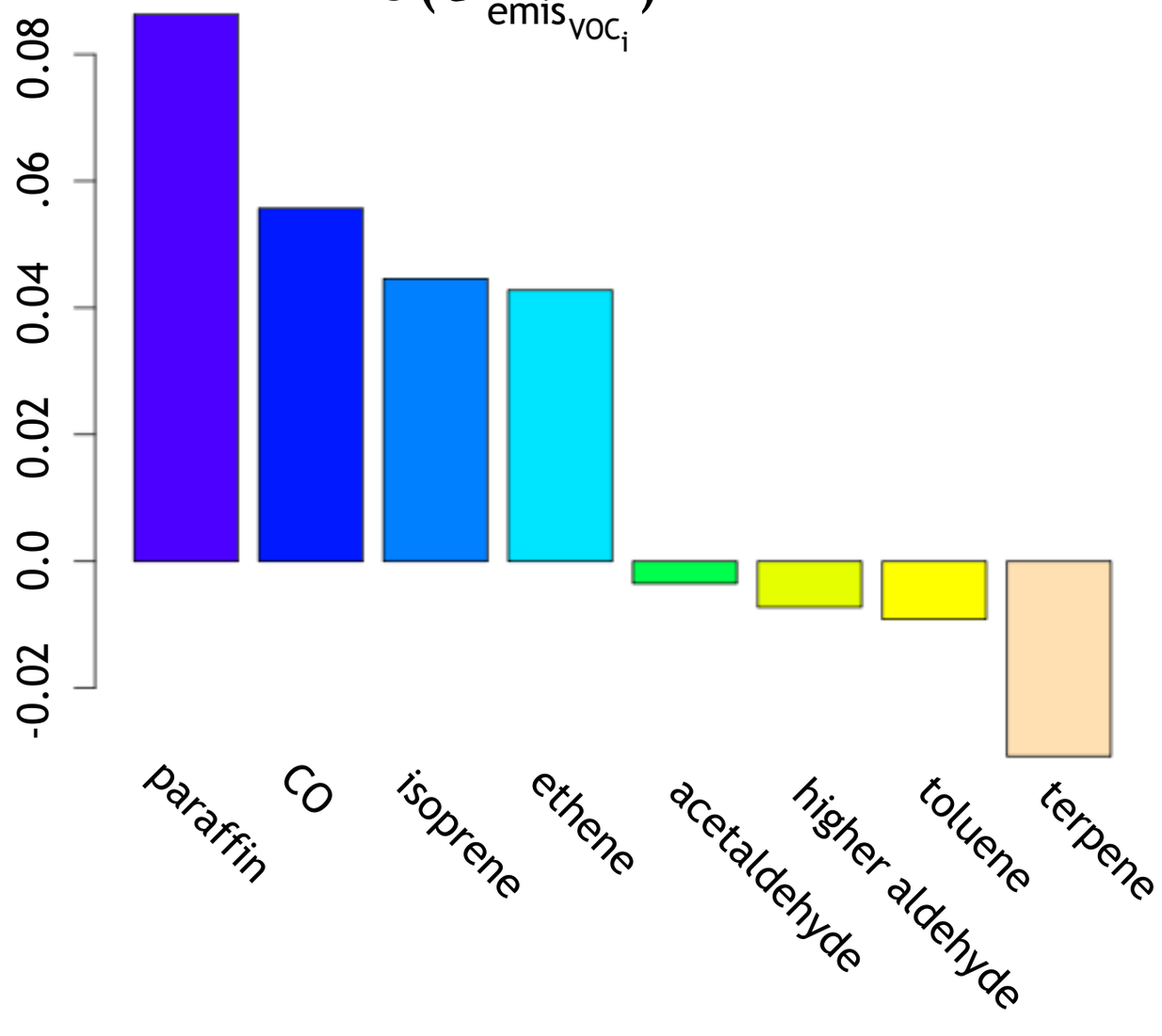




Comparison of Emissions Influences on Different Cities

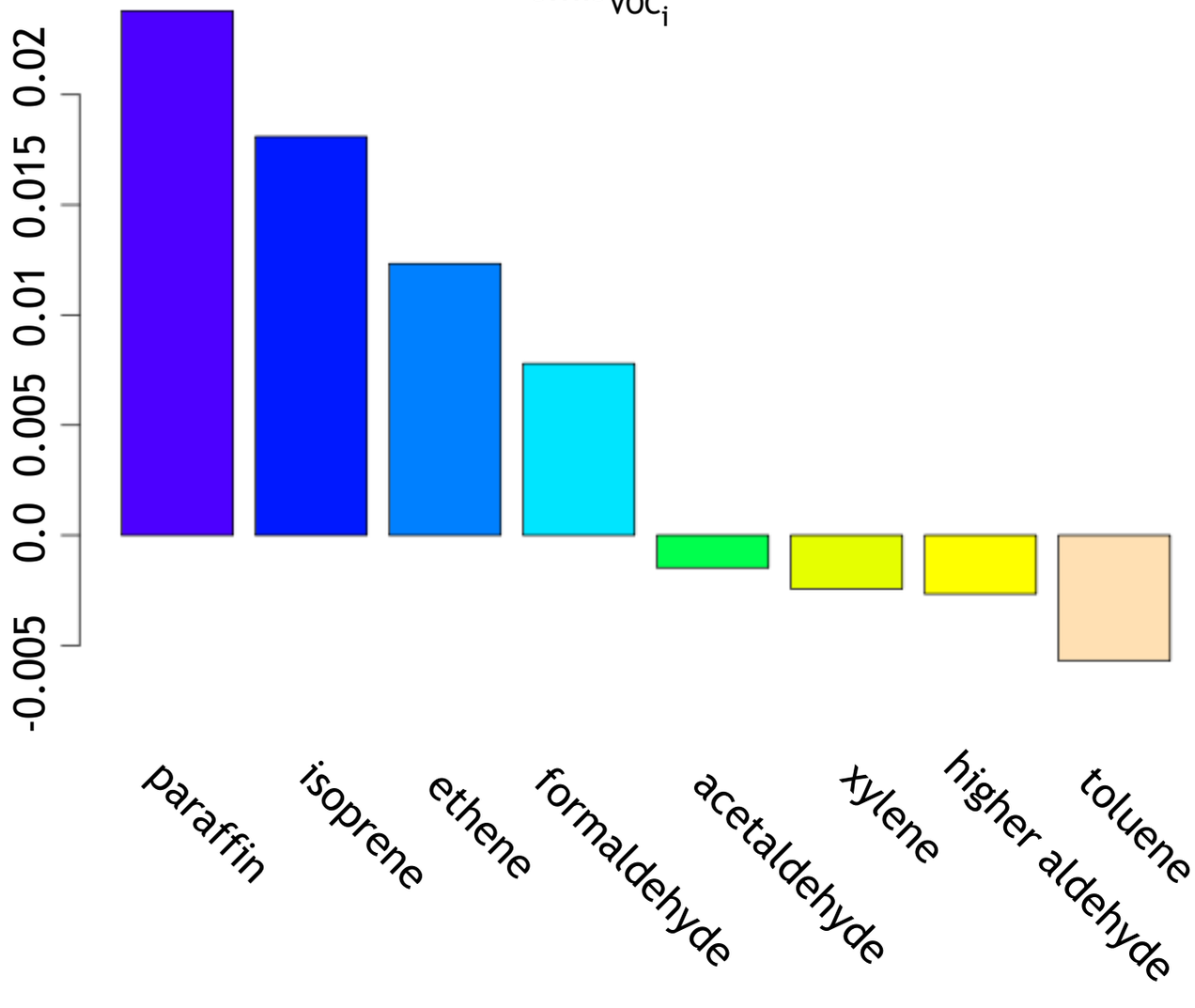
$$\frac{\partial(\text{Denver MDA8})}{\partial(\sigma_{\text{emis}_{NO_x}})} = 1.93 \text{ ppm}$$

$$\frac{\partial(\text{Denver MDA8})}{\partial(\sigma_{\text{emis}_{VOC_i}})} \text{ (ppm)}$$



$$\frac{\partial(\text{East TX MDA8})}{\partial(\sigma_{\text{emis}_{NO_x}})} = 0.95 \text{ (ppm)}$$

$$\frac{\partial(\text{East TX MDA8})}{\partial(\sigma_{\text{emis}_{VOC_i}})} \text{ (ppm)}$$



Current Progress & Next Steps

- Adjoint forcing functions have been formulated to investigate ozone impacts of oil and gas development adjacent to U.S. urban areas for 2007.

- Sensitivities with respect to emissions scaling factors and absolute emissions have been implemented.

- With CMAQ adjoint, extend the analysis to the entire summer and to other urban areas as well as MDA8 NAAQS exceedances and ozone-based health risks.

- Continue to learn from field campaign results and extrapolate revisions to ozone implications.

Extra Slides

Sample results from other region

Lower 48 states shale plays

Montana Thrust Belt
Niobrara*
Bakken***
Heath**
Cody
Williston Basin
Big Horn Basin
Powder River Basin
Three Forks
Hillard-Baxter-Mancos
Mowry
Greater Green River Basin
Niobrara*
Unita Basin
Mancos
Park Basin
Denver Basin
Piceance Basin
Manning Canyon
Hermosa
Paradox Basin
Pierre
Lewis
San Joaquin Basin
Monterey-Temblor
Monterey
Santa Maria-Ventura-Los Angeles Basins
San Juan Basin
Raton Basin
Anadarko Basin
Palo Duro Basin
Bend
Abo-Yeso****
Glorieta-Yeso****
Bone Spring****
Delaware**
Spraberry****
Permian Basin
Ft. Worth Basin
Barnett
Ardmore Basin
Woodford
Fayetteville
Arkoma Basin
Haynesville-Bossier
Eagle Ford
Western Gulf
Excello-Mulky
Cherokee Platform
Forest City Basin
Michigan Basin
Antrim
Illinois Basin
New Albany
Utica
Marcellus
Appalachian Basin
Devonian (Ohio)
Chattanooga
Black Warrior Basin
Conasauga
Floyd
Neal
Valley & Ridge Province
Tuscaloosa
TX-LA-MS Salt Basin

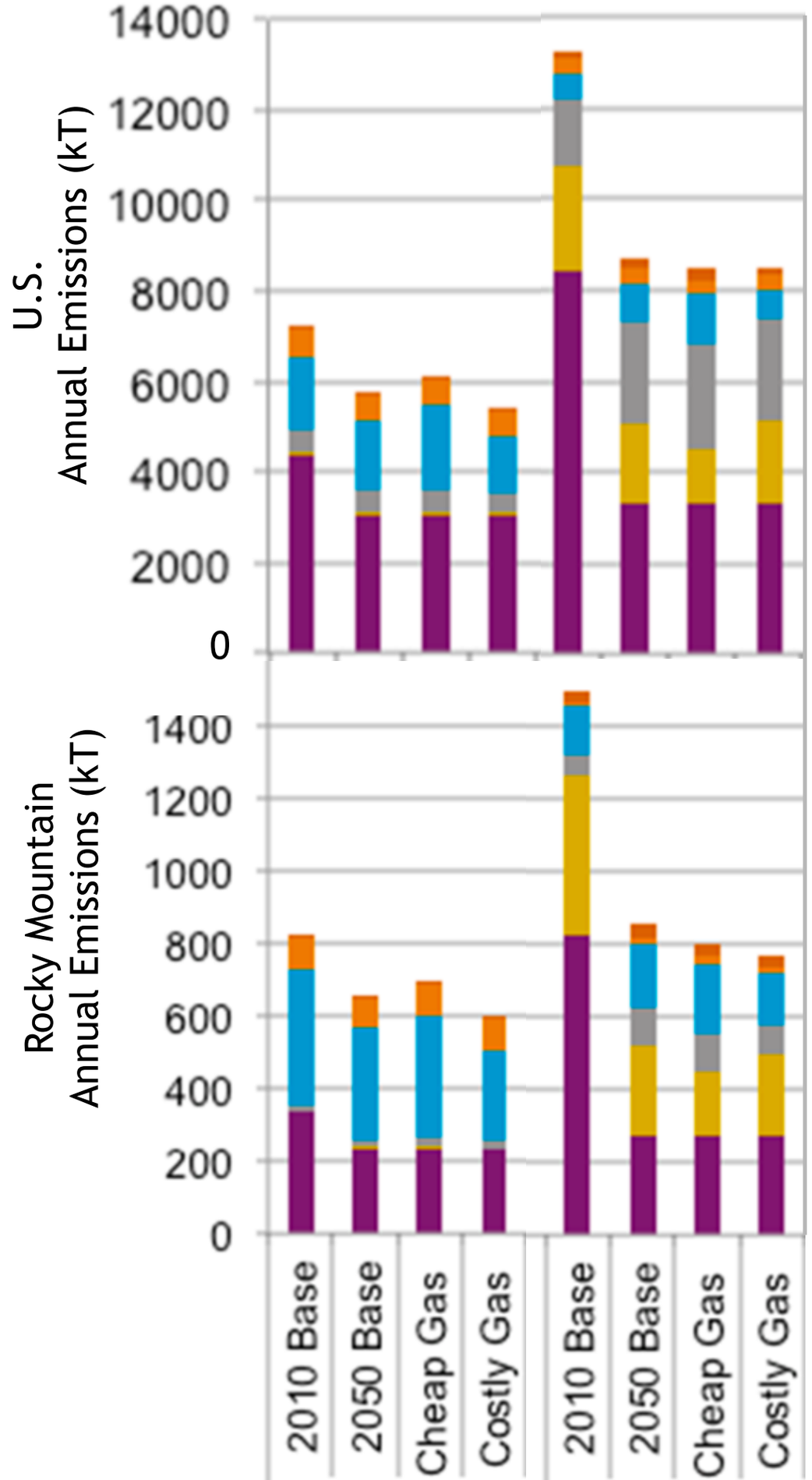
Current play - Oldest stacked play
Current play - Intermediate depth/age stacked play
Current play - Shallowest/youngest stacked play
Prospective play
Basin

*Mixed shale & chalk play
**Mixed shale & limestone play
***Mixed shale & dolostone-siltstone-sandstone play
****Mixed shale & limestone-siltstone-sandstone play

Source: U.S. Energy Information Administration based on data from various published studies.
Updated: April 13, 2015

eia

Projected Emissions Changes with Price



(McLeod et al., 2014)