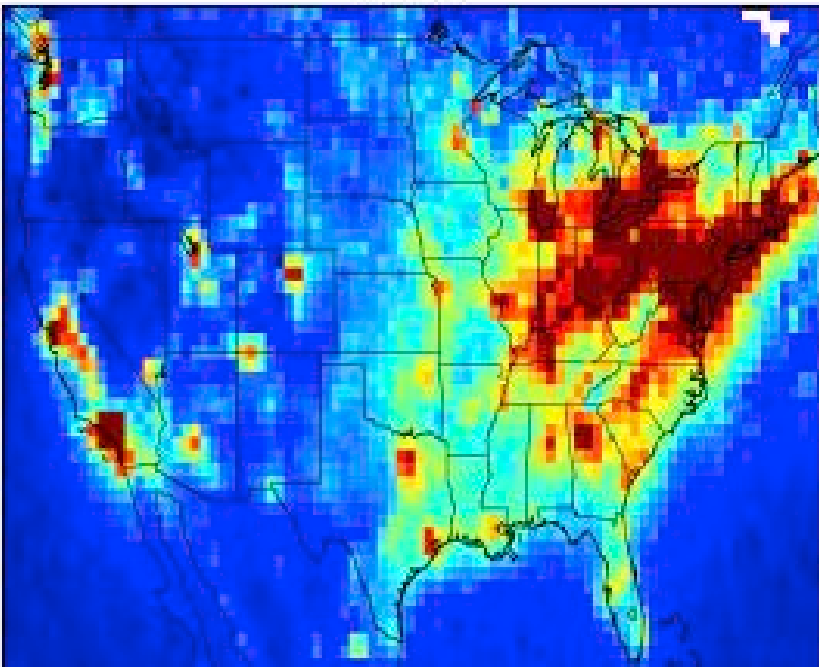
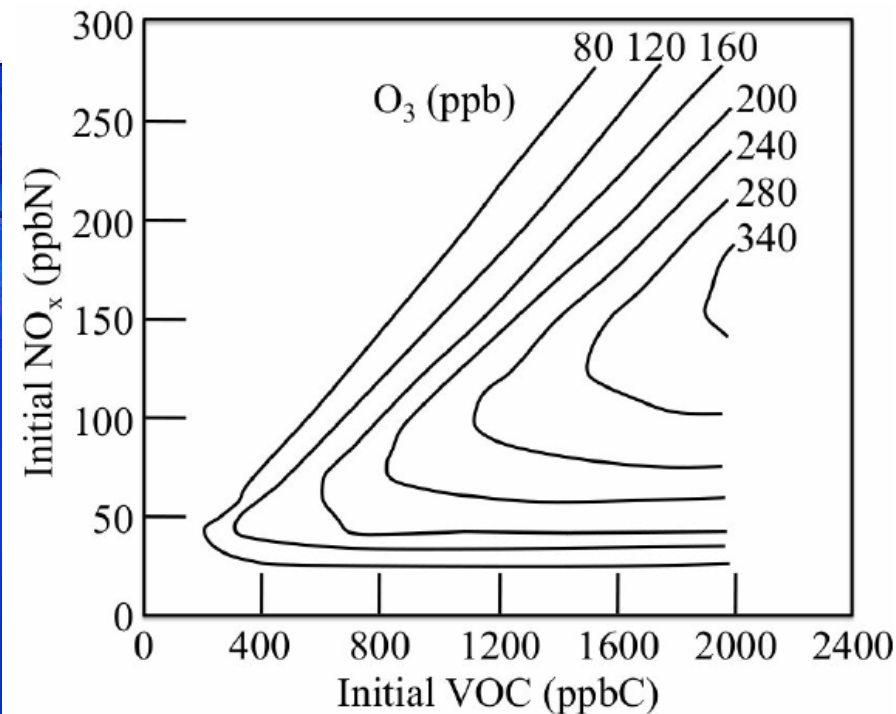
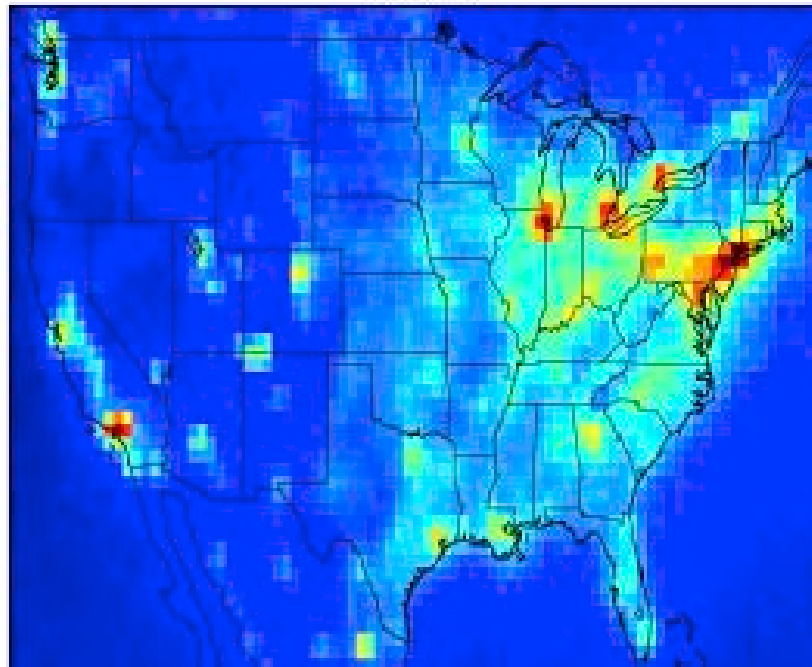


2005



2013



The Double Life of NO_2 : Ozone Precursor and Ambient Pollutant

-The role of NO_x in ozone formation-

Armistead Russell

Health Effects Institute Annual Conference

May 2, 2017

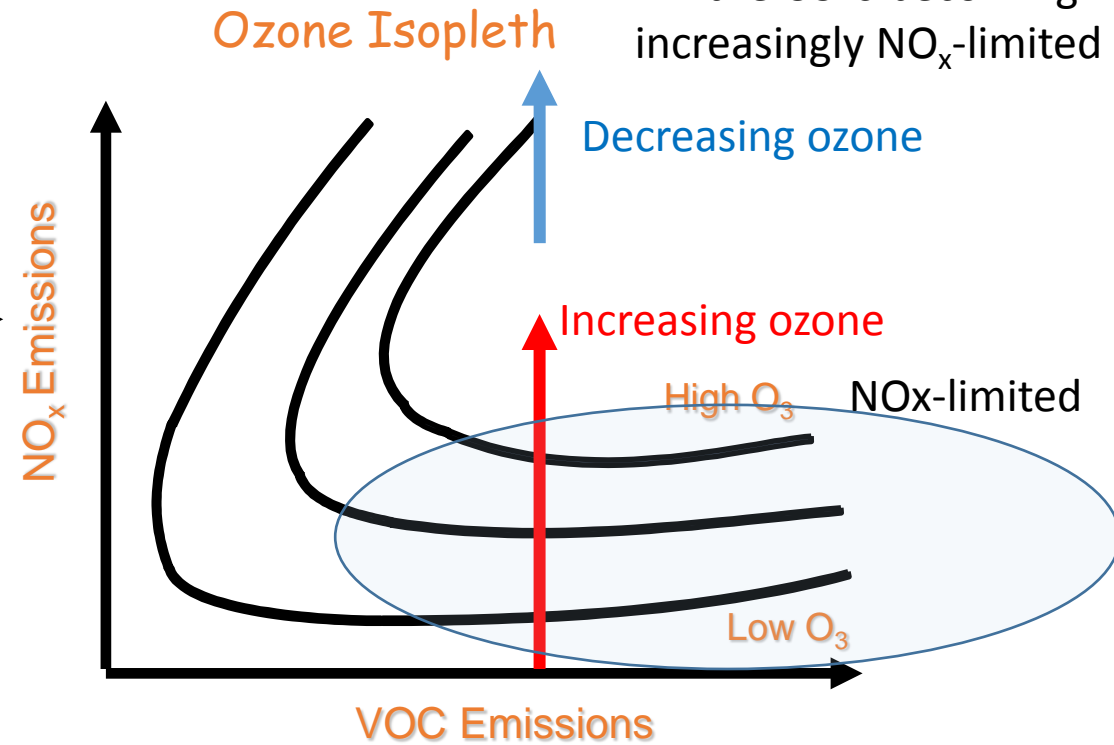
Alexandria, VA

The dual role of NO_x emissions

- NO_x emissions lead to multiple pollutants which may have adverse health impacts

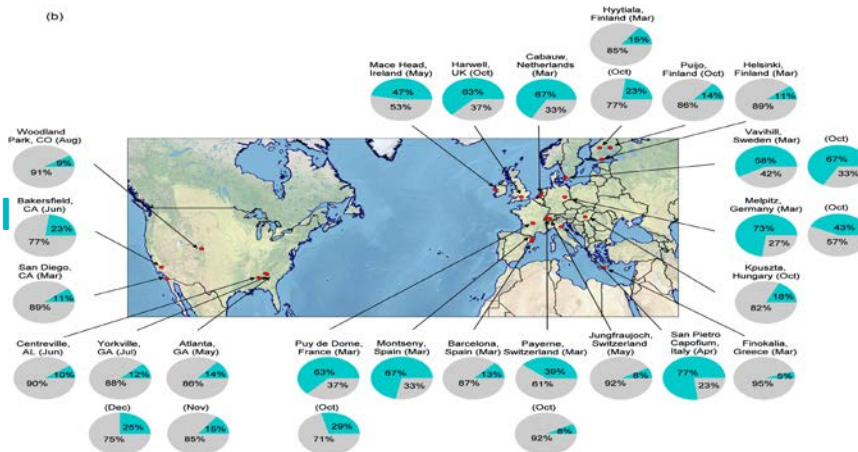
- NO₂
- **Ozone**
- Particulate matter
 - Nitrogen-containing organics

Peak, summertime ozone in the US is becoming increasingly NO_x-limited



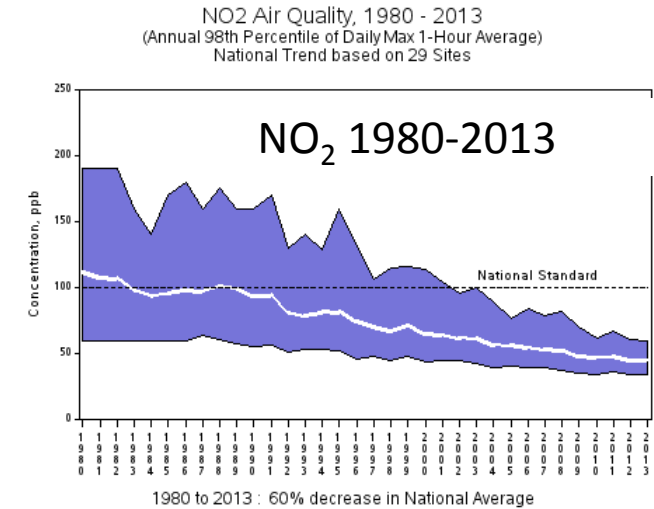
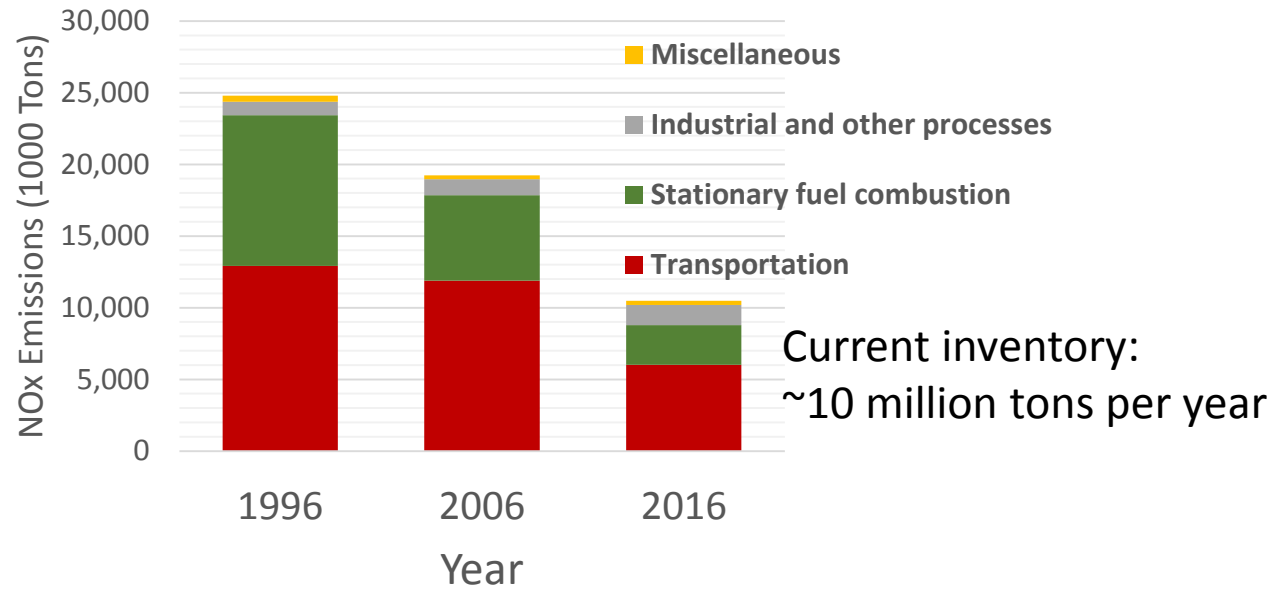
Many uncertainties:
Shape of isopleths, NO_x and VOC emissions

Percentage of organic nitrates (by mass) in ambient organic aerosol (OA) (the turquoise fraction shown)



US NO_x→₂ Emissions and Trends

- Atmospheric concentrations going down similar to mobile source NO_x:



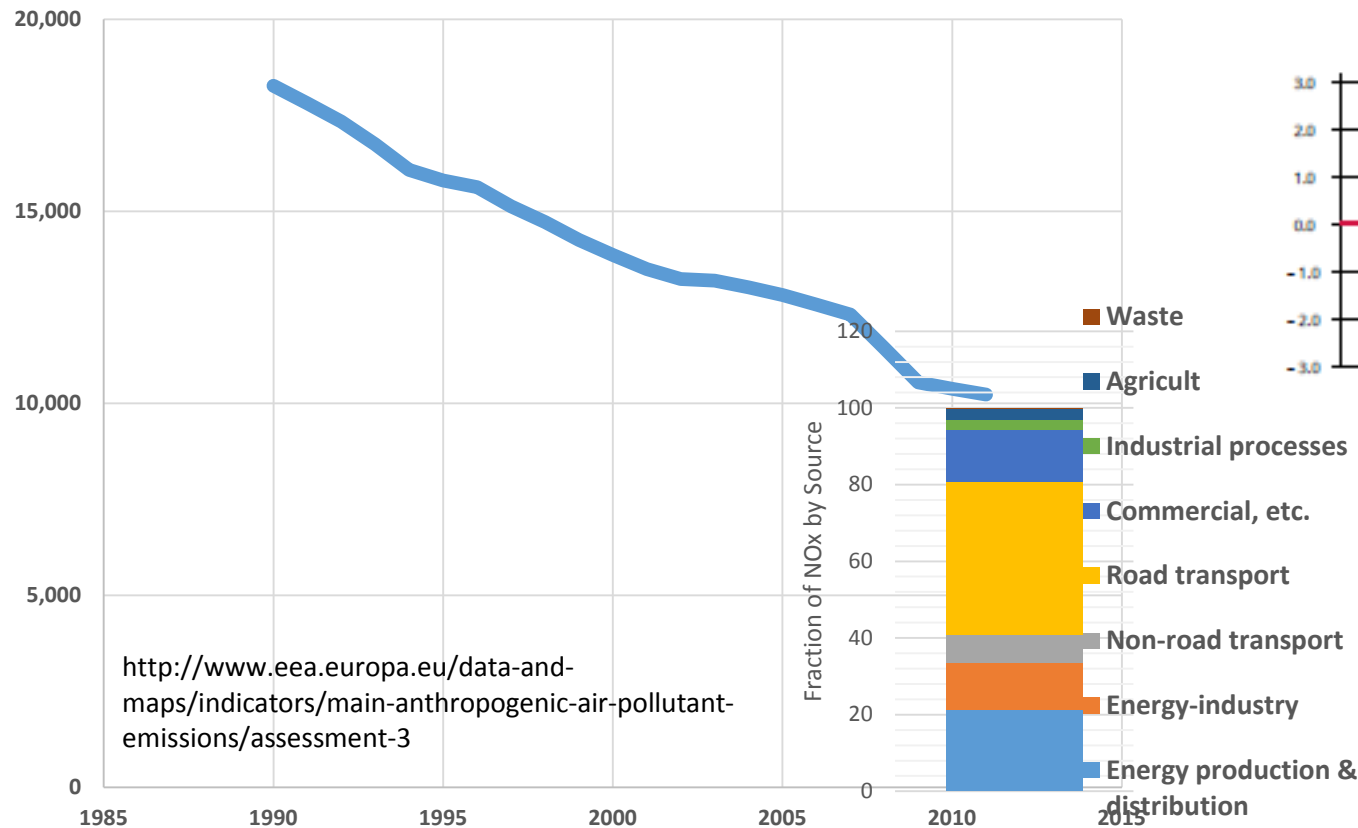
- Estimated emissions have gone down (and will continue to go down)
 - Mobile
 - Electrical generation
 - Industrial processes

- How much lower can it go and from where will the decreases come?



European NO_x Emission Trends

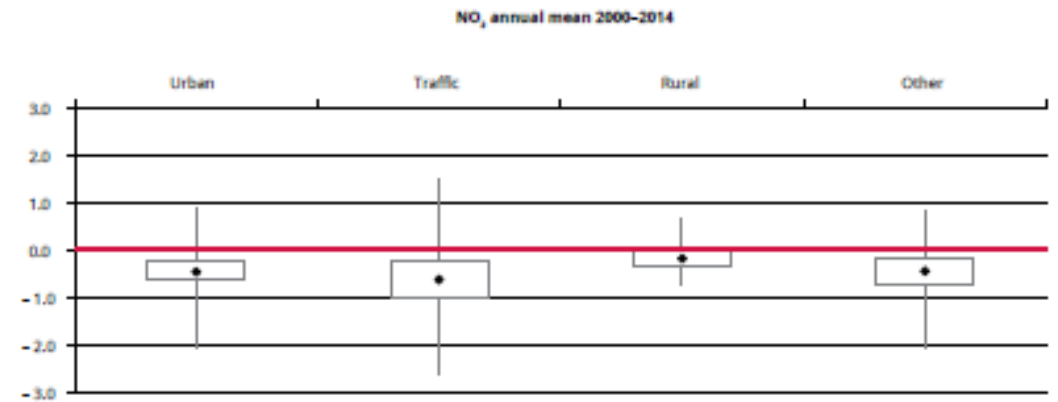
- European NO_x emission trends likewise decreasing



- Concentrations are decreasing

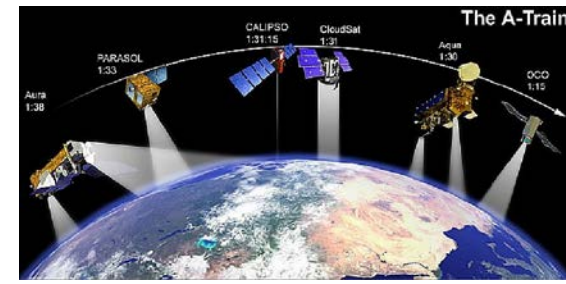
Air quality in Europe — 2016 report (EEA)

Figure 6.2 Trends in NO₂ annual mean concentrations by station type, 2000-2014



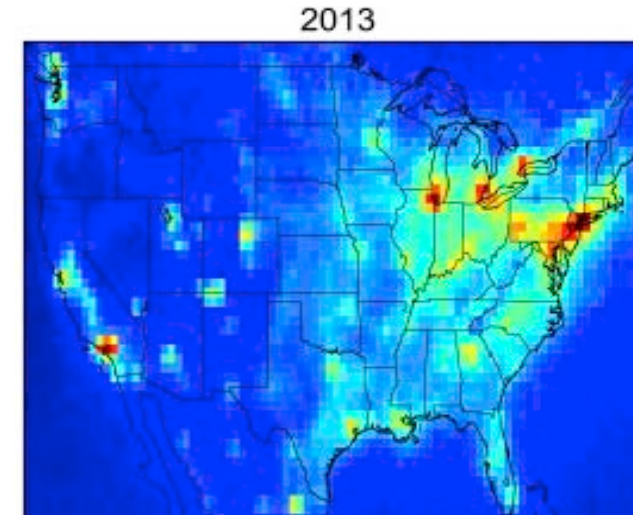
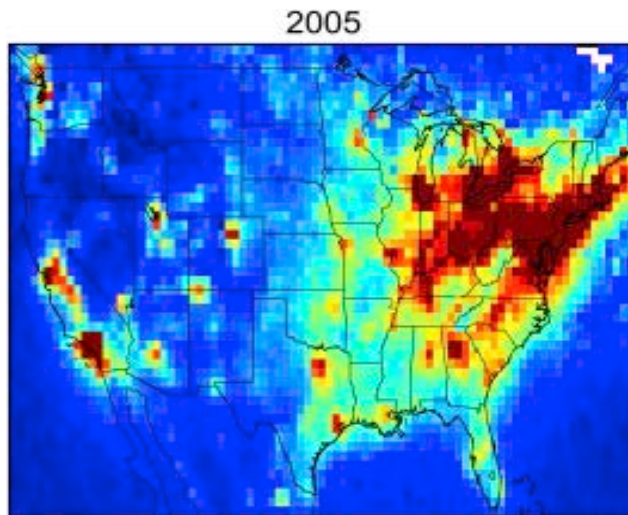
Annual Rate of Change of Mean NO₂

Oh wow! Big reductions... Maybe bigger than we think!



- Some analyses suggest that the emissions estimates from mobile sources are biased substantially high (more on that from our speakers).

OMI Satellite images of NO₂ columns



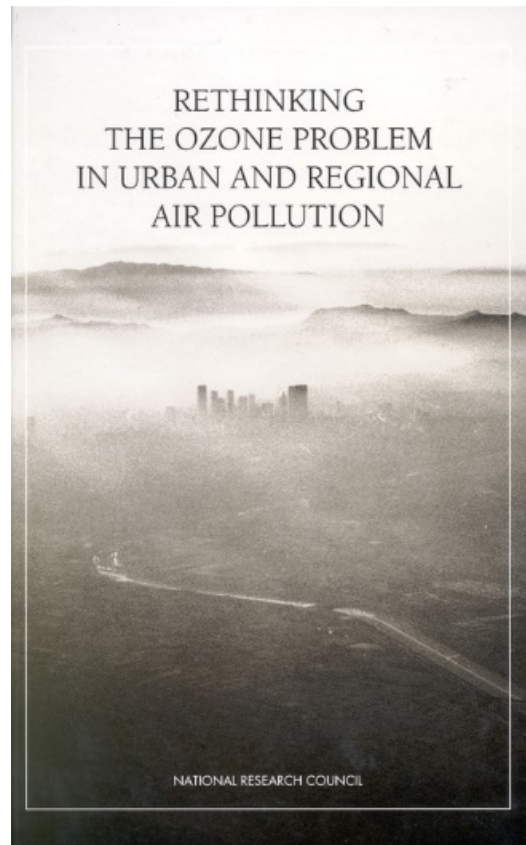
Substantial NO₂ reductions :
More than expected, especially over cities?

Why is it so important to have an accurate estimate of emissions (emissions inventory)?

- Some history
- Responsiveness of ozone to further reductions and where to seek those reductions

Some history: Those who do not learn history are doomed to repeat it

1992



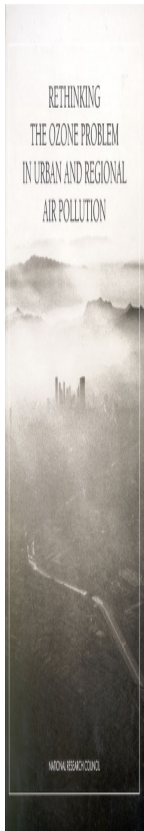
- Executive Summary
- Introduction
- The Charge to the Committee
- The Committee's Approach to its Charge
- Ozone in the United States
- Ozone Trends
- State Implementation Planning
- Anthropogenic VOC Emissions
- Biogenic VOC Emissions
- Ambient Air Quality Measurements
- Air Quality Models
- VOC Versus NO_x Control**
- Alternative Fuels For Motor Vehicles
- A Research Program on Tropospheric Ozone
- What Is the Problem?
- Natural Atmospheric Ozone
- Understanding Tropospheric Ozone and Photochemical Air Pollution
- Ozone and Air-Quality Regulations
- National Trends in Ozone
- Detrimental Effects of Ozone
- Purpose of This Report



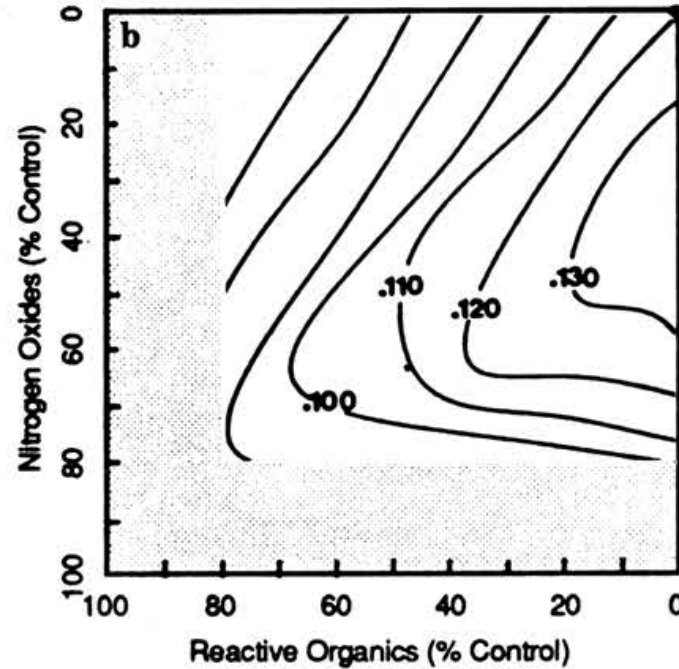
VOC Versus NO_x Control

Some history:

1992



- Executive Summary
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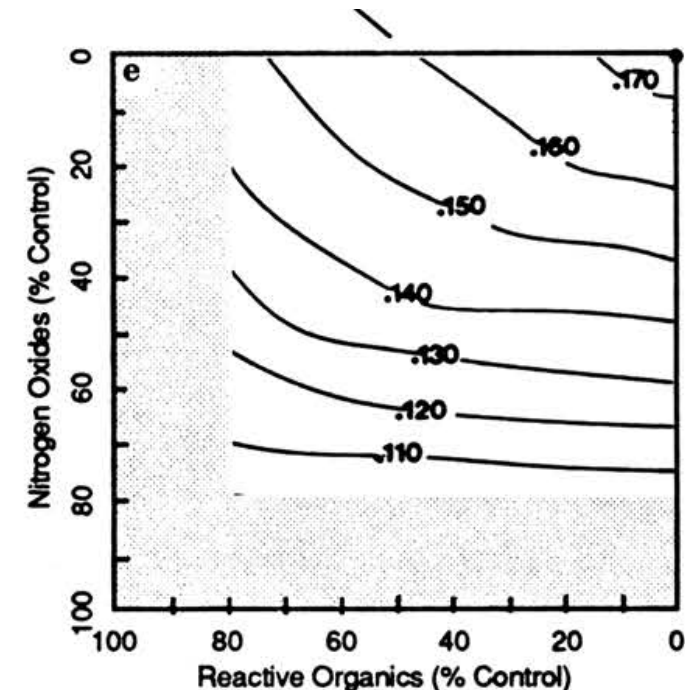
Downwind, NO_x reductions decrease highest ozone levels with increasing effectiveness, and VOC controls begin having less impact

- Significant ozone reductions now tied to NO_x controls

From Milford et al., (1989)

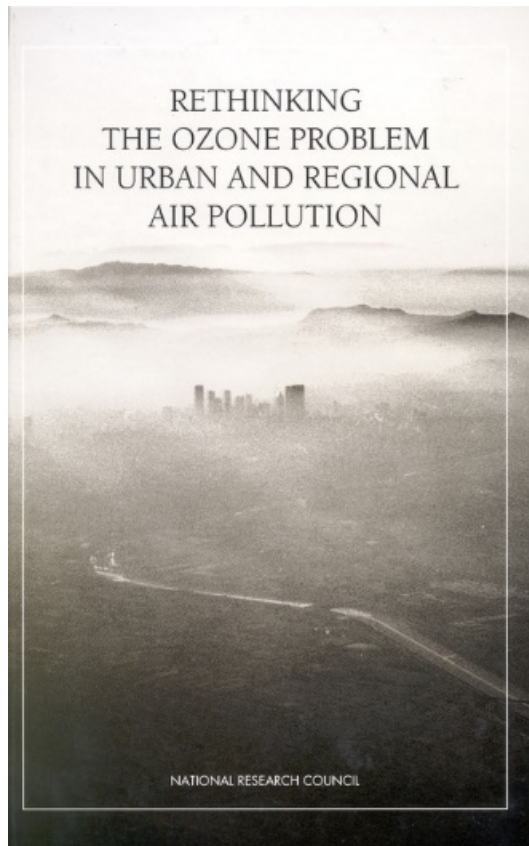
In more heavily populated areas (with higher emissions) VOC controls reduce ozone, NO_x reductions (at that time, with a wrong VOC emissions inventory) increase ozone

High summertime ozone levels becoming increasingly NO_x-limited



Some history

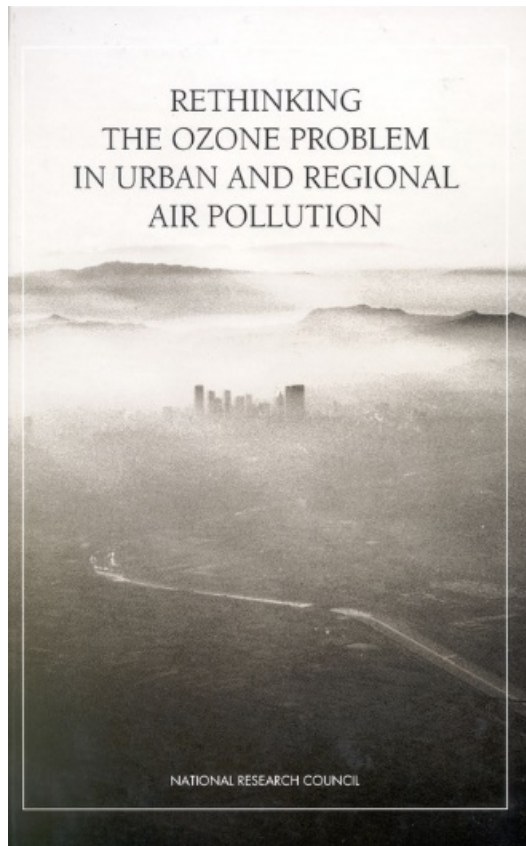
1992



Recommendation: To substantially reduce ozone concentrations in many urban, suburban and rural areas in the United States, the control of NO_x emissions will **probably** be necessary in addition to, or instead of, the control of VOCs.

Some history

1992



Also in there: “According to the SCAQS [Southern California Air Quality Study] tunnel study, measured CO and VOC emissions rates were a factor of 1.7+/-0.7 and 3.8 +/-1.5 higher, respectively than predicted by CARB’s EMFAC7C [California Air Resources Board mobile source emissions model] model... NO_x emissions rates agreed reasonably well” (citing Ingalls et al., 1989)

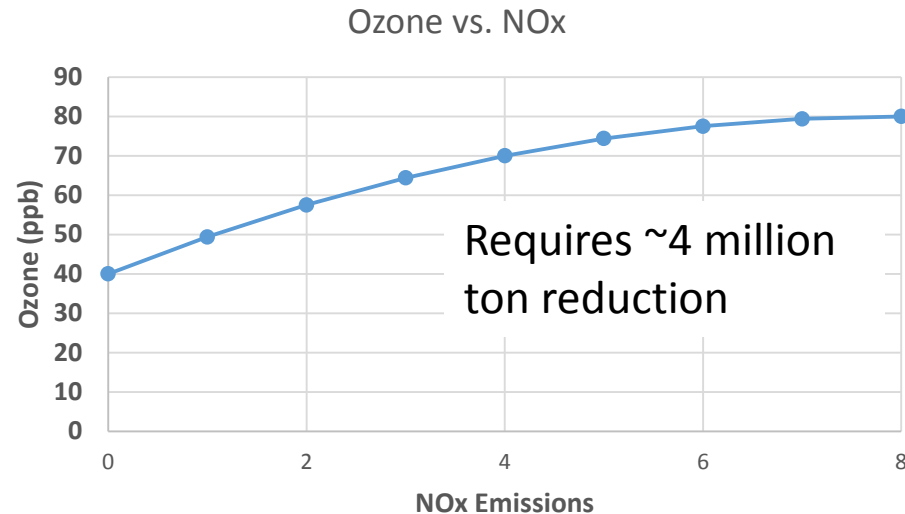
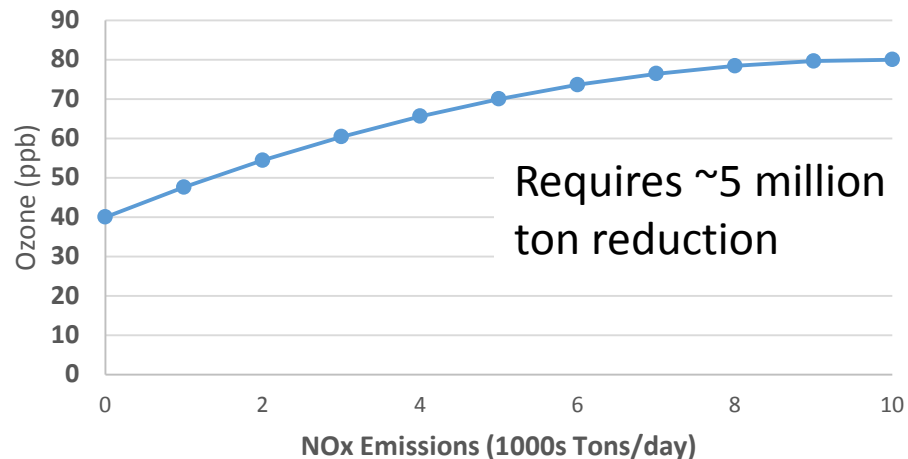
This would mean:

- NO_x controls would likely be even more effective and VOC controls less, and
- Emissions estimates have, historically, been uncertain and potentially biased to a level that can significantly affect air quality management decisions

Those who do not learn history are doomed to repeat it.

Back to the present...

- Potential NO_x emissions overestimate has multiple ramifications
 - Each ton of NO_x emissions may be more effective at reducing ozone than currently modeled using typical chemical transport model, but
 - Fewer tons to reduce
 - Model response will be wrong
 - Example: Say you are in a city at 80 ppb O₃, how much NO_x reduction is required to get to 70 ppb?
 - Hypothetical ozone-NO_x response curves (current/reduced mobile NO_x emissions)... more nonlinear, more controls required

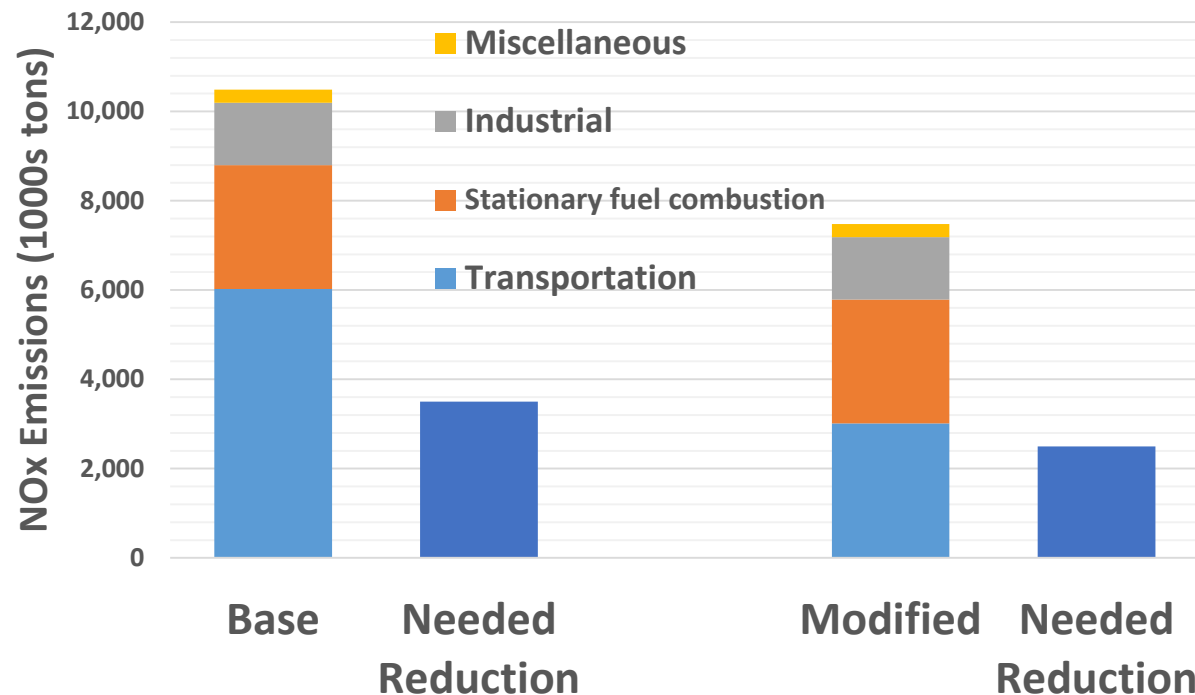


Mobile source NO_x emissions reduced by 50% in both hypothetical cases

- Current inventory: ~10 million tons per year

The problem...

- Where do you get those reductions?
- Current estimates vs. 50% reduced mobile NO_x
 - Necessary reductions a much bigger piece of the pie



Also... many uncertainties:
how ozone will respond to NO_x,
concurrent VOC reductions,
background ozone...

Bottom line: accurate
emissions are critical to
making the correct
management decisions

To the experts

- Russ Dickerson, University of Maryland
 - NO_x emission inventories and approaches to evaluate them
- Greg Yarwood, Environ-Ramboll
 - Ozone photochemistry and how air quality models perform at low levels of NO_x and the implications of reducing NO_x emissions