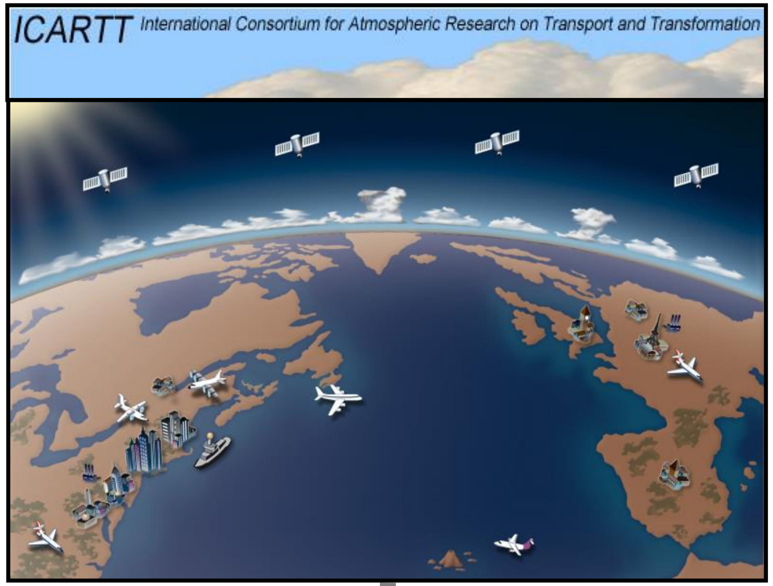
Characterizing the troposphere up and downwind of New York and New England during ICARTT 2004

Michael Trainer, NOAA



Overview: Singh et al., JGR, 2006JD007905, 2006

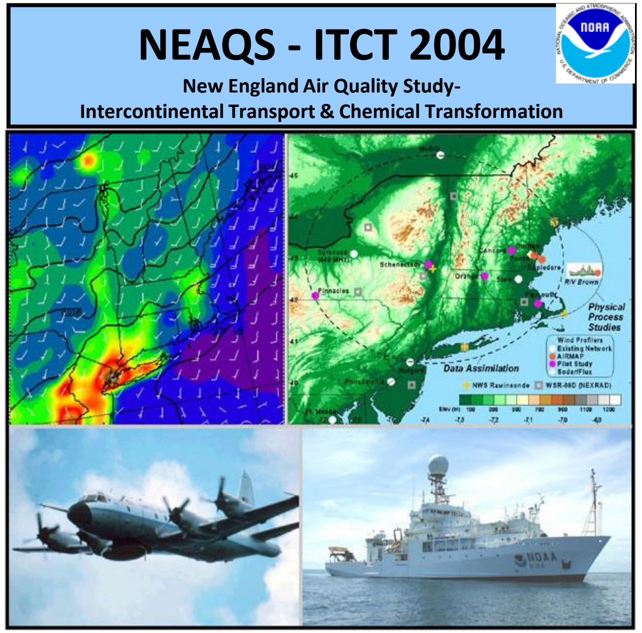
Consortium of atmospheric research

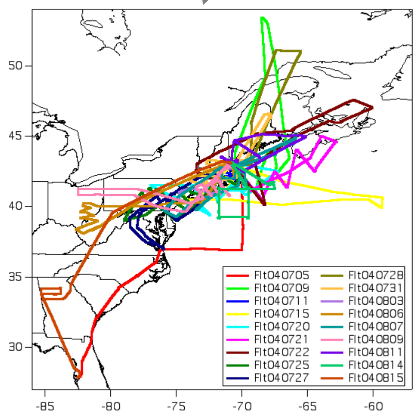
Built on the legacy of previous studies

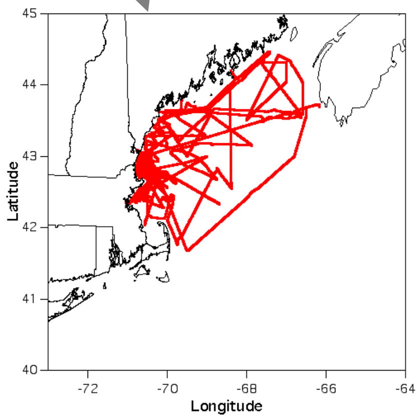
Explored and evaluated new approaches

Informed stakeholders

Provides reference point for future studies



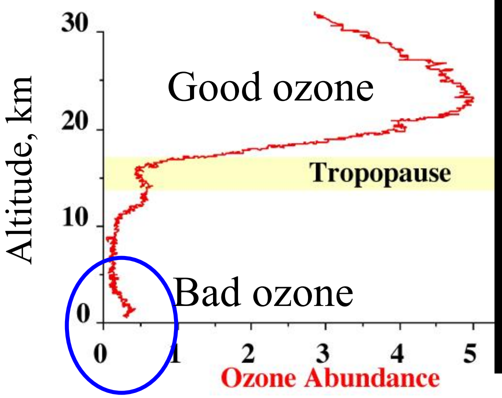


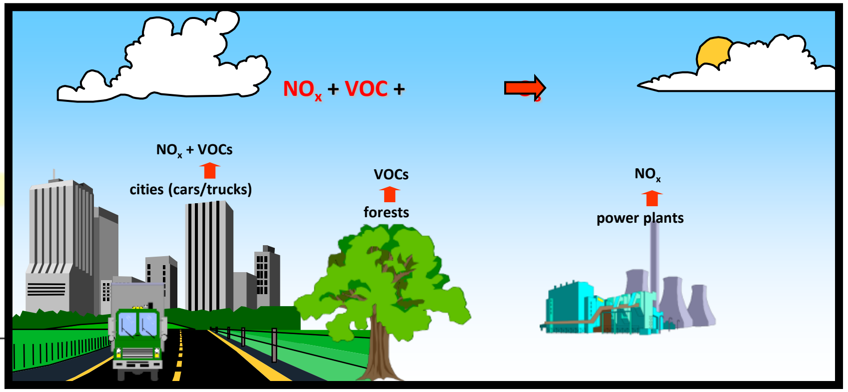


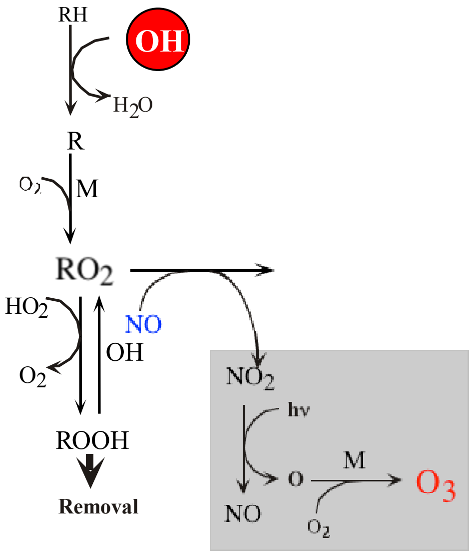
Overview: Fehsenfeld et al., JGR, 2006JD007829, 2006

Ozone: Where does it come from?

- Ozone is made in the atmosphere- not emitted into it.
- Processes that make, remove, and move ozone are complex.







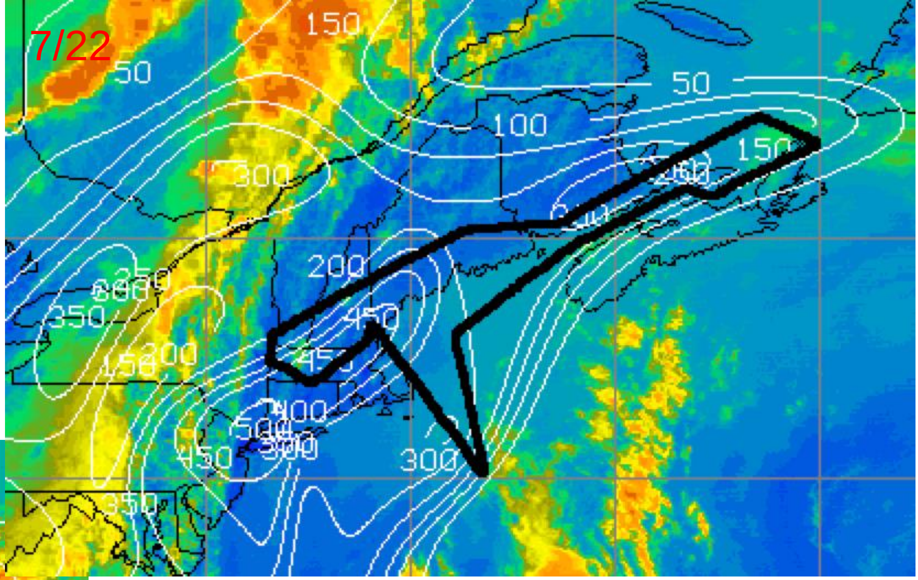
To understand and predict ozone, we need to:

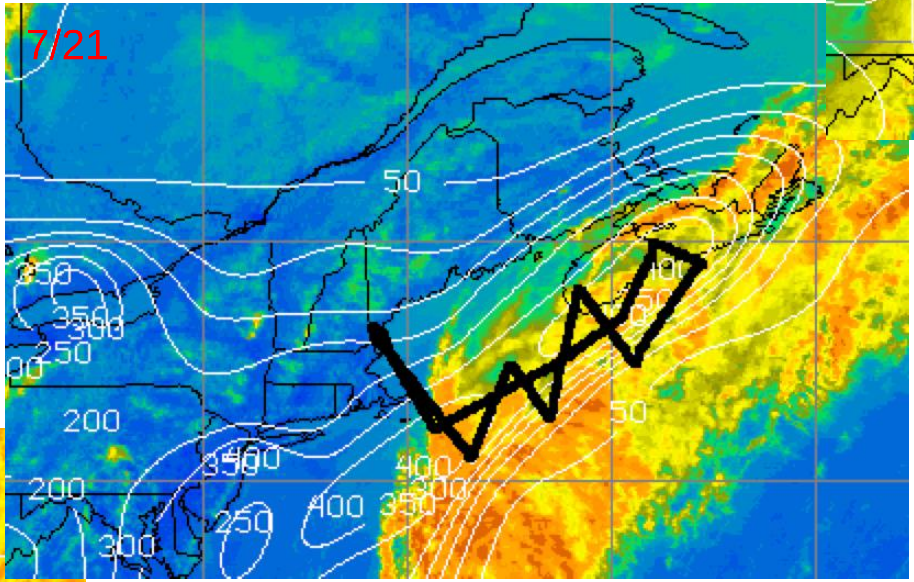
- Quantify 2 key ingredients- VOCs and NOx (amount and form)
- Understand and quantify meteorology (including deposition)
- Understand day and night chemistry (gas and particle phase)

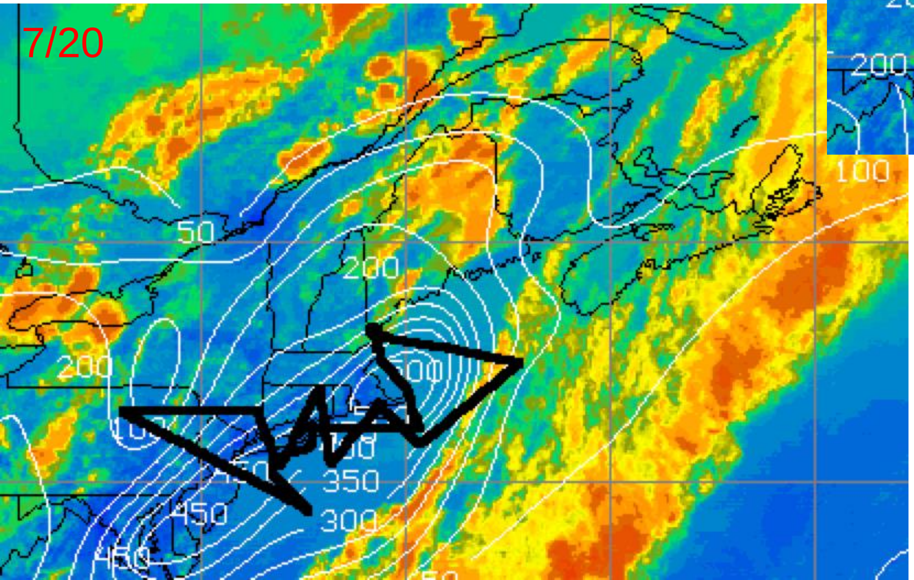
ESRL's expertise

Export of the New York City plume
to the North Atlantic,
20-22 July 2004

The start of a Lagrangian experiment of
transport across the North Atlantic



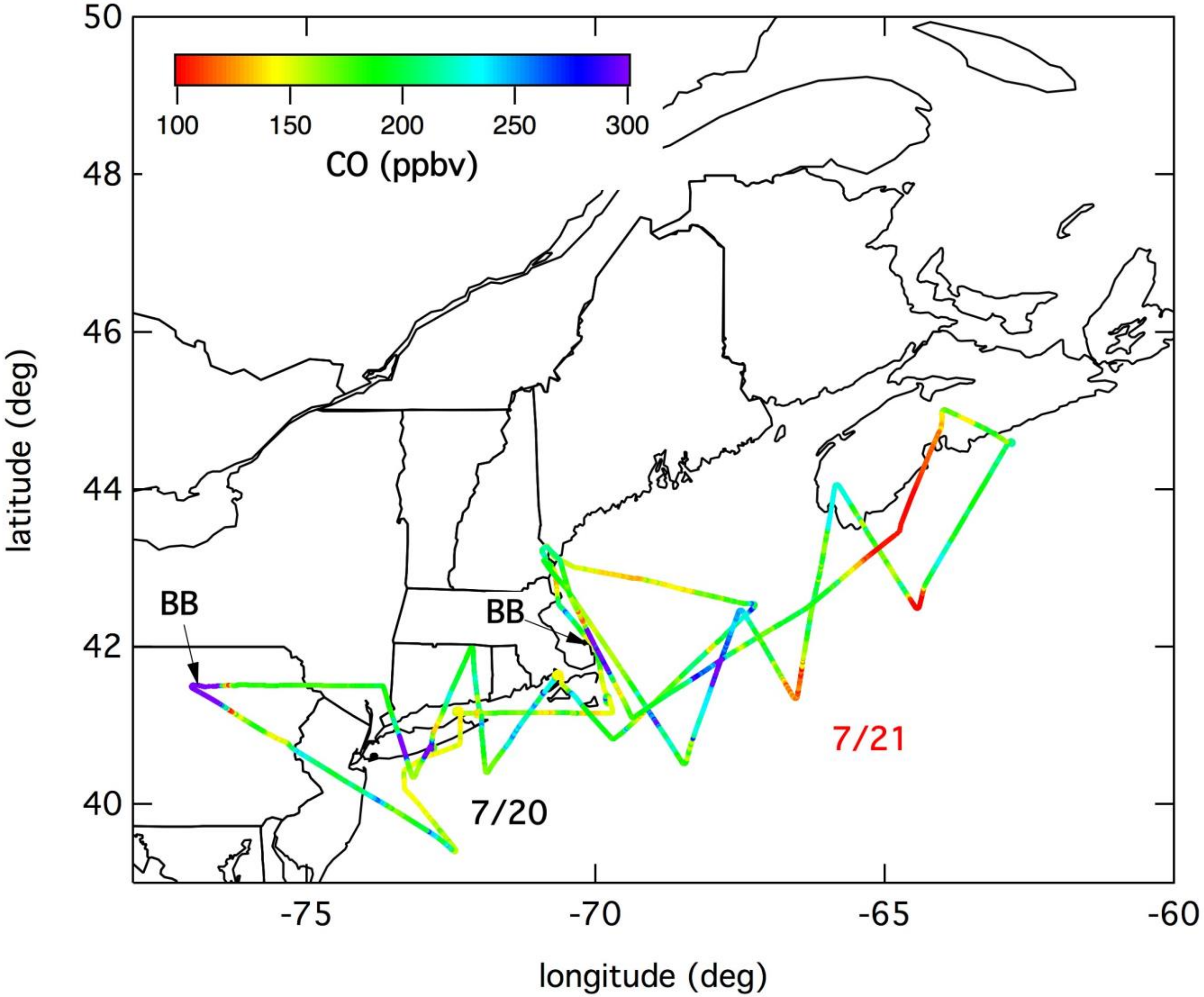


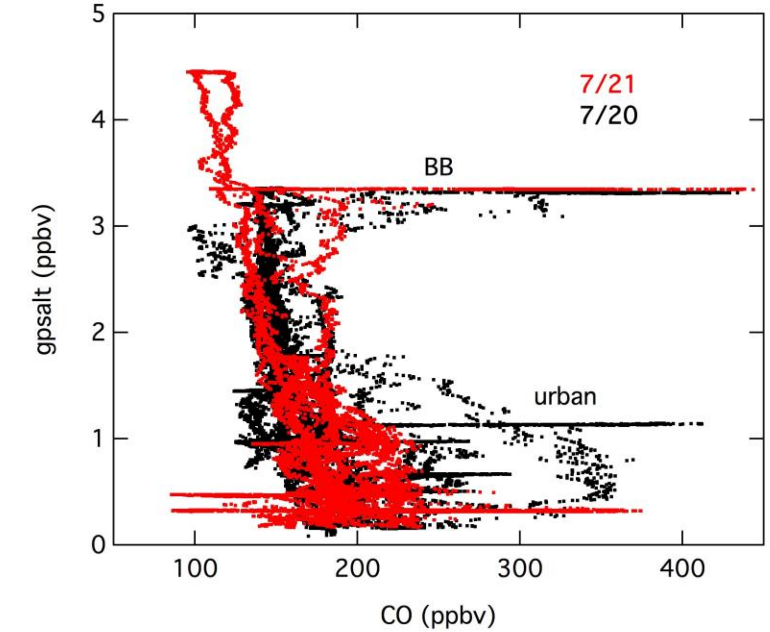


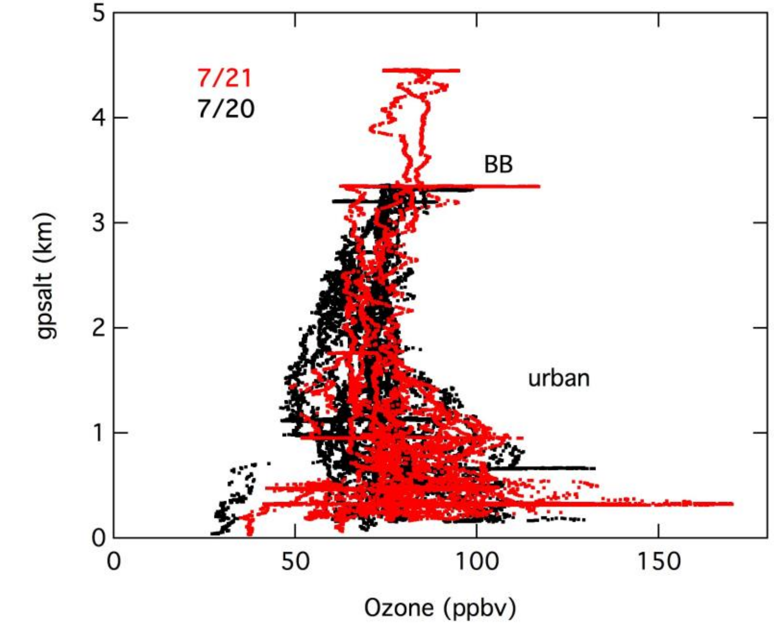
Flight Planning guided by Lagrangian transport model
FLEXPART CO tracer overlaid on GOES IR image
using MCIDAS, Owen Cooper and Andreas Stohl

July 20 & 21, 2004
Biomass Burning Plumes over the NE US at 3 km

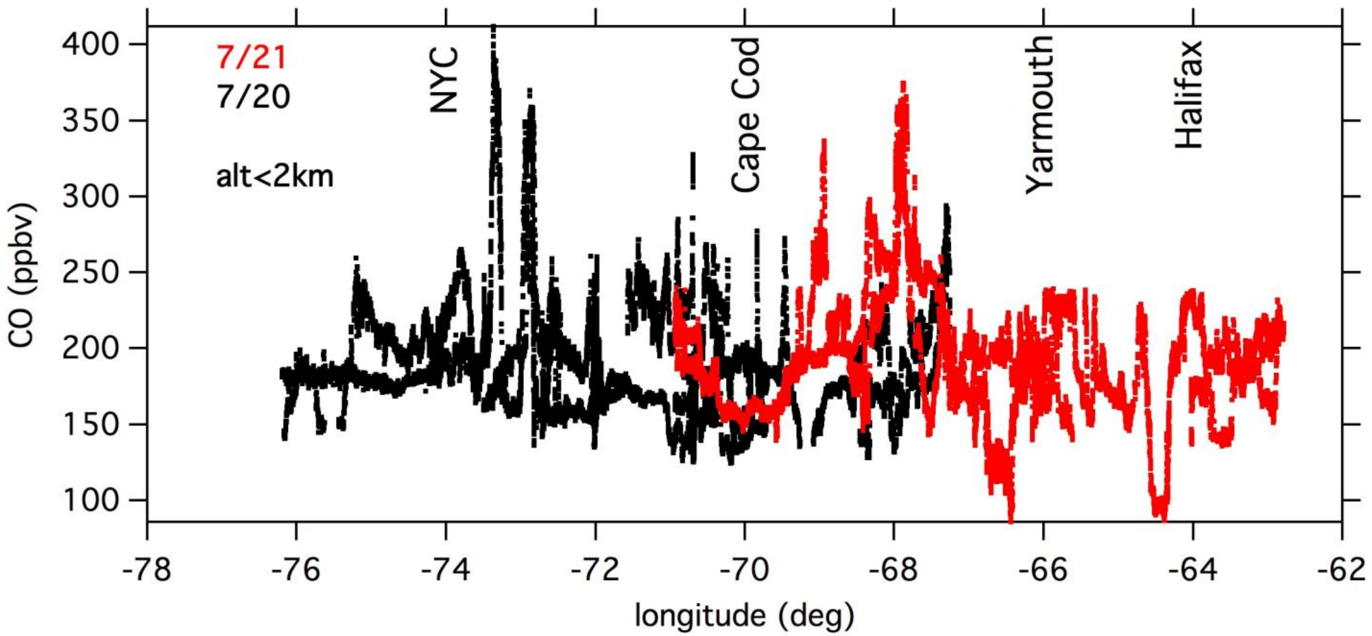
Export of pollution from New York City and the US East Coast to the Atlantic below 2km

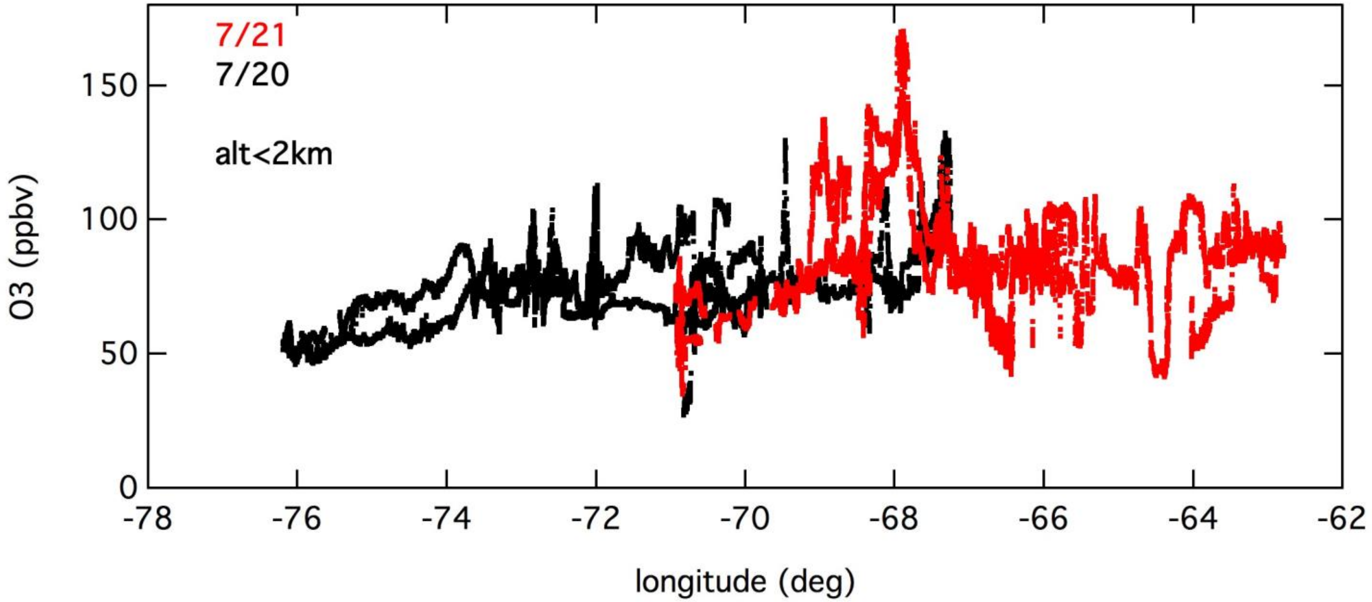






Transport and Photochemistry in urban plumes over the North Atlantic Ocean

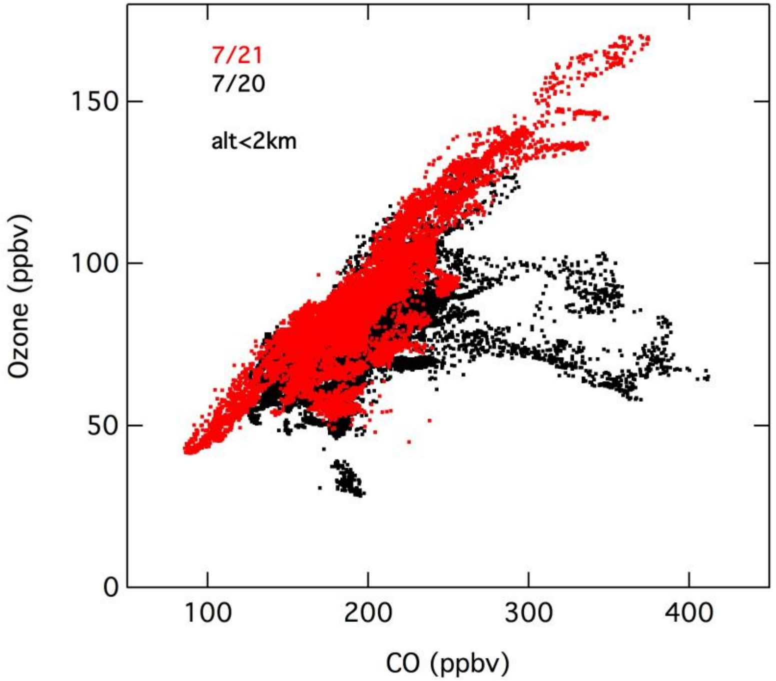




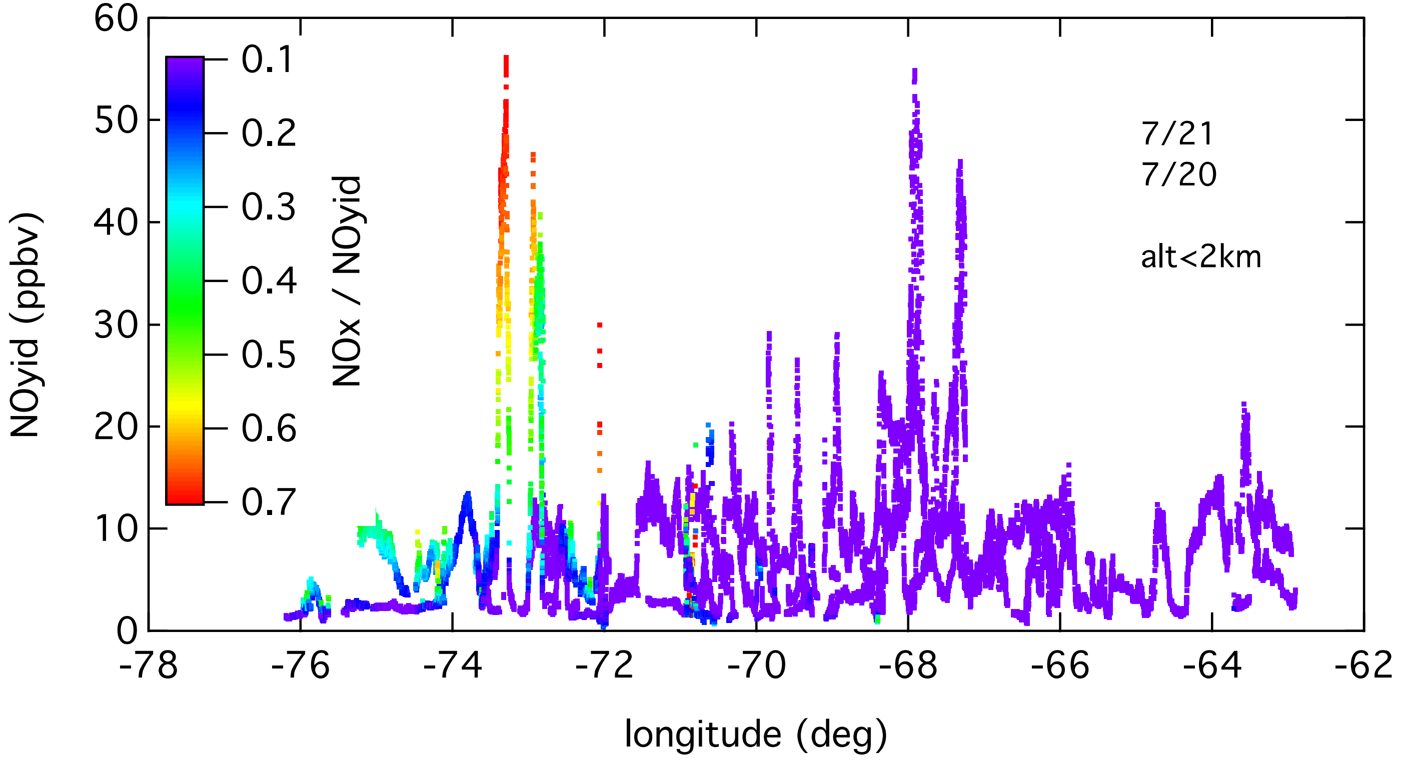
On 7/20 and 21 maximum Ozone
Seen > 500 km downwind of New York City

Ozone vs CO relation is shaped by
Ozone formation during transport

In aged plume on 7/21:
O3 to CO slope is 0.57, (R=.97)



Reactive nitrogen transport and photochemistry in urban plumes over the North Atlantic Ocean above the Marine Boundary Layer without fresh emissions and without surface removal.



HNO3 is the dominant NOx oxidation product (up to 50 ppbv)

Low level outflow above the MBL is efficient in long-range transport of HNO3

Such transport events are well predicted and have been studied in airborne experiments (NARE 1993, Buhr et al., Daum et al.)

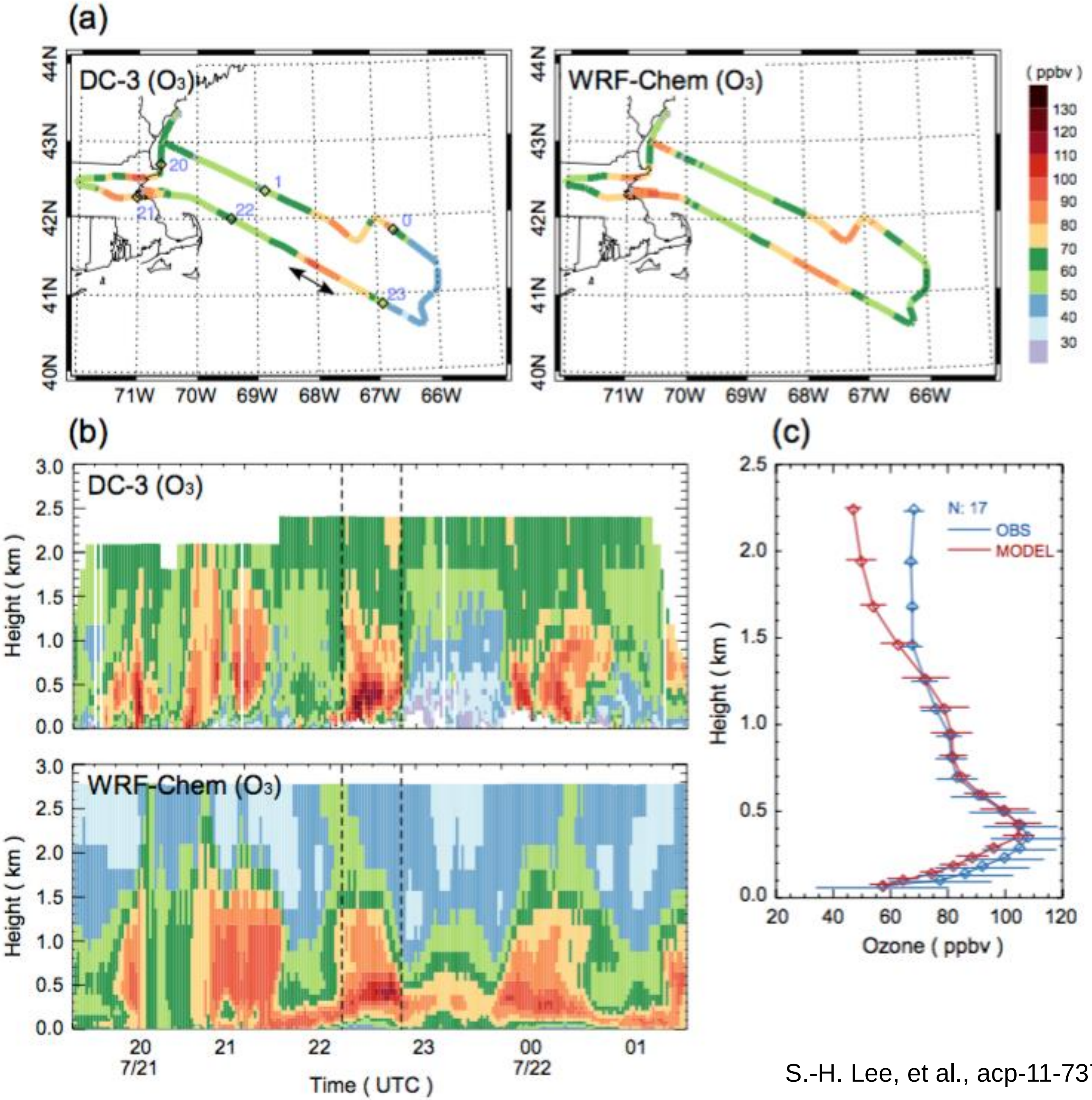
Can we start to see the change of anthropogenic emissions and its effect on the photochemistry during such continental outflow events?

NOyid = Sum (NO + NO2 + HNO3 + PANs)

Neuman et al., JGR, 2005JD00710, 2006,

(Buhr et al., JGR, 101, 29013, 1996, Daum et al. JGR, 101, 29029, 1996, Lin et al., JGR 103, 13593, 1998)

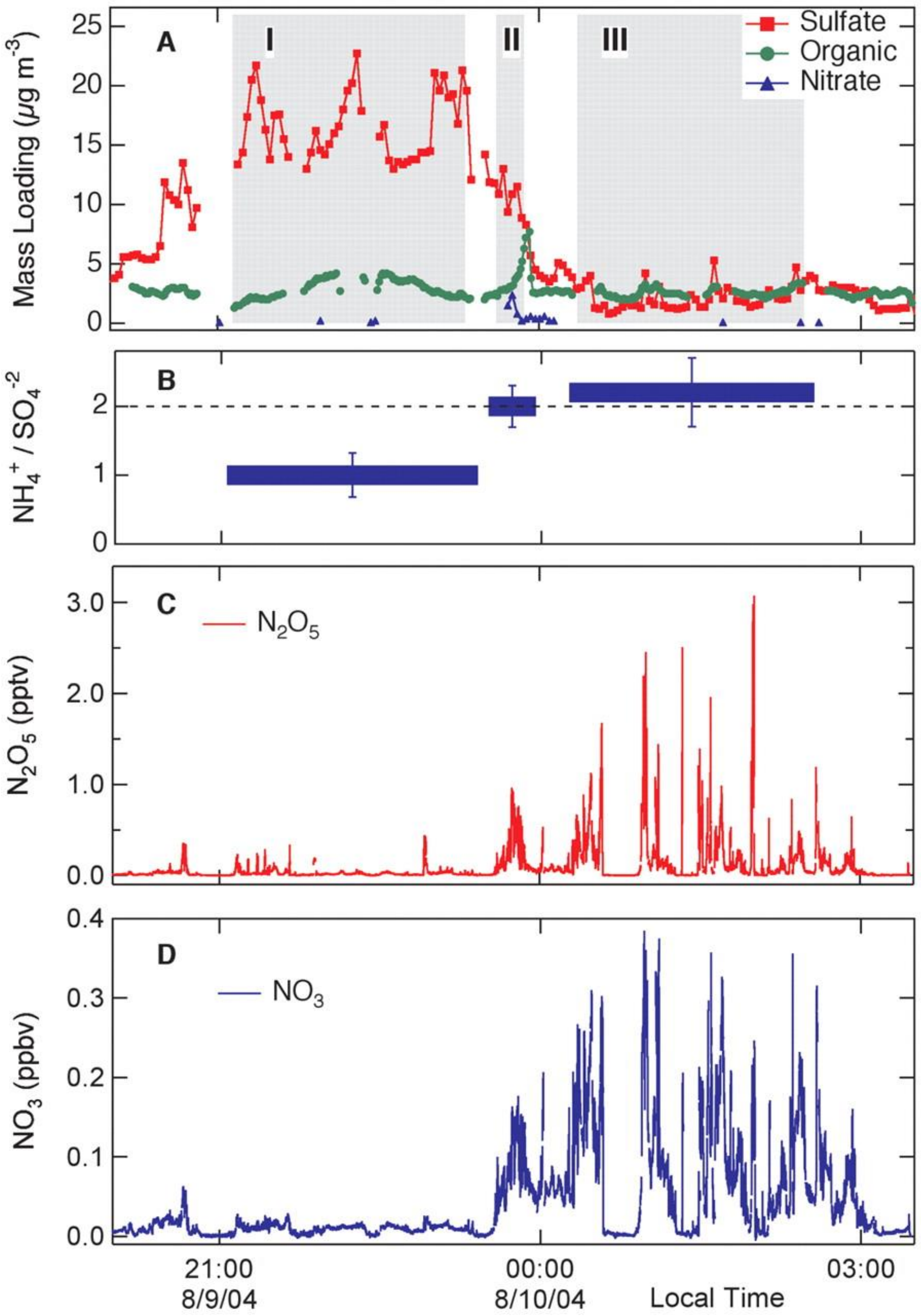
Modeling ozone plumes observed downwind of New York City over the North Atlantic

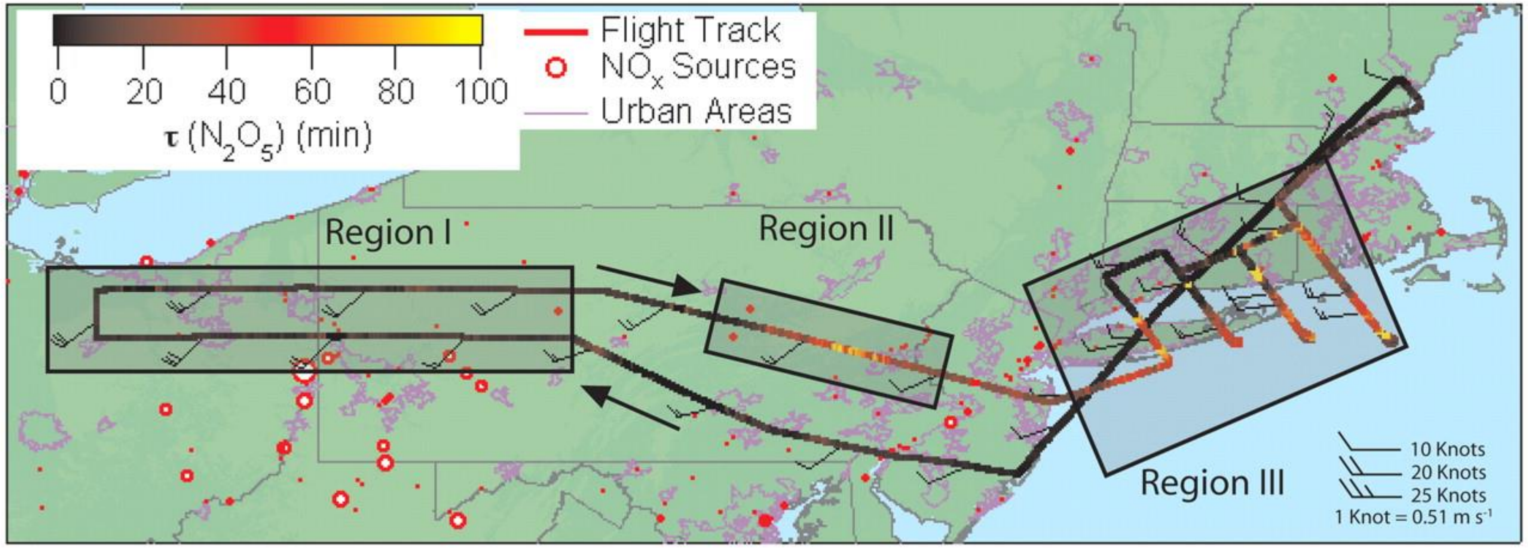


S.-H. Lee, et al., acp-11-7375-2011

Isentropic transport from the continent to the North Atlantic can lead to decoupling of urban plumes from the Marine Boundary Layer

On 21 July 2004
observed by O3-Lidar on board of DC-3 aircraft
and
modeled by fine resolution (9 km x 9km) WRF-Chem





Novel measurements give new insights: night flight of 9 to 10 August, 2004

Variability in nocturnal Nitrogen Oxide Processing

Fast uptake of N_2O_5 on acidic particles => low ambient N_2O_5 and NO_3

Slow uptake of N_2O_5 on neutral particles => high ambient N_2O_5 and NO_3

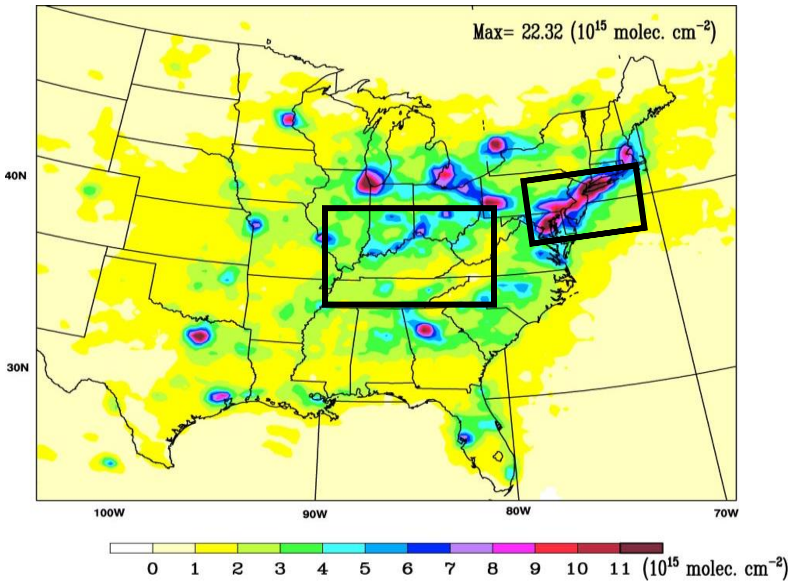
Present day:
Implications of reduction in SO_2 and NO emissions from power plants
for nighttime chemistry?

Science, 311, 67, 2006, Brown et al.

Can we detect change?

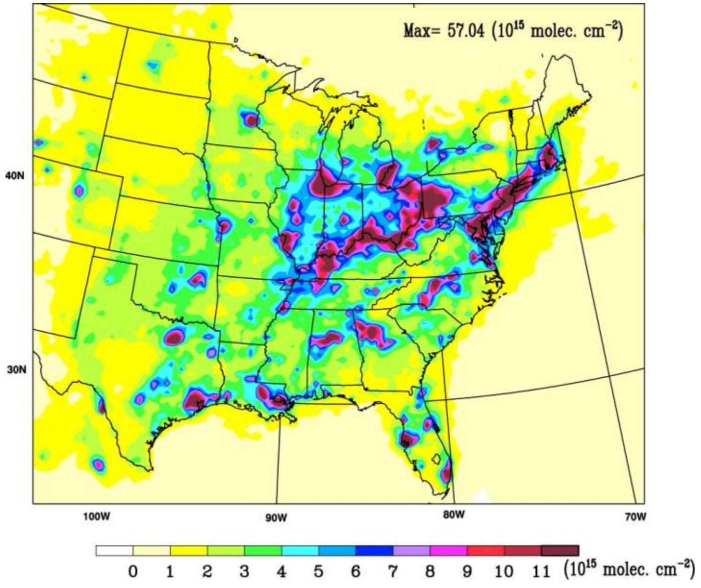
SCIAMACHY
on
ENVISAT

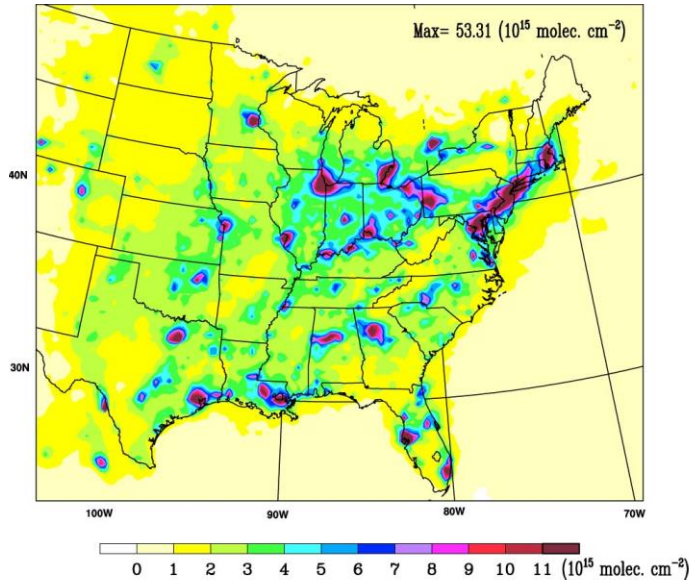
Jun-Aug 2004



Reduction of power plant
NO_x emissions,
Satellite Observations
and Analysis Model

WRF-Chem
&
National
Emissions
Inventory
19**99**

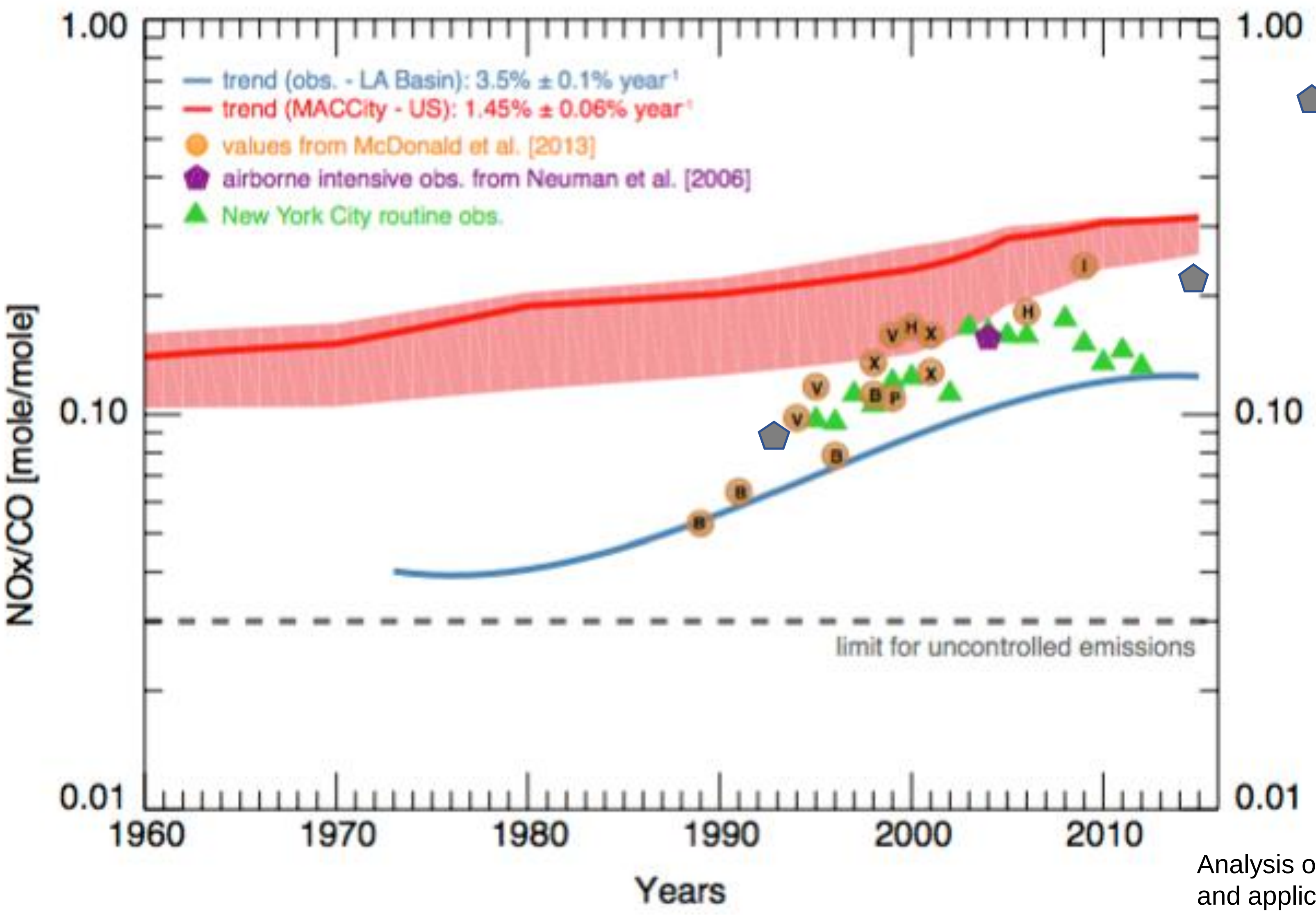




WRF-Chem
&
2004
Power
Plant
Emissions

Kim et al., GRL, 2006GL027749, 2006
building on
Richter et al., Nature, 437, 129, 2005

Long-term atmospheric NO_x/CO enhancement ratios in megacities provide evaluations of emission inventories



NO_x / CO enhancement ratios:

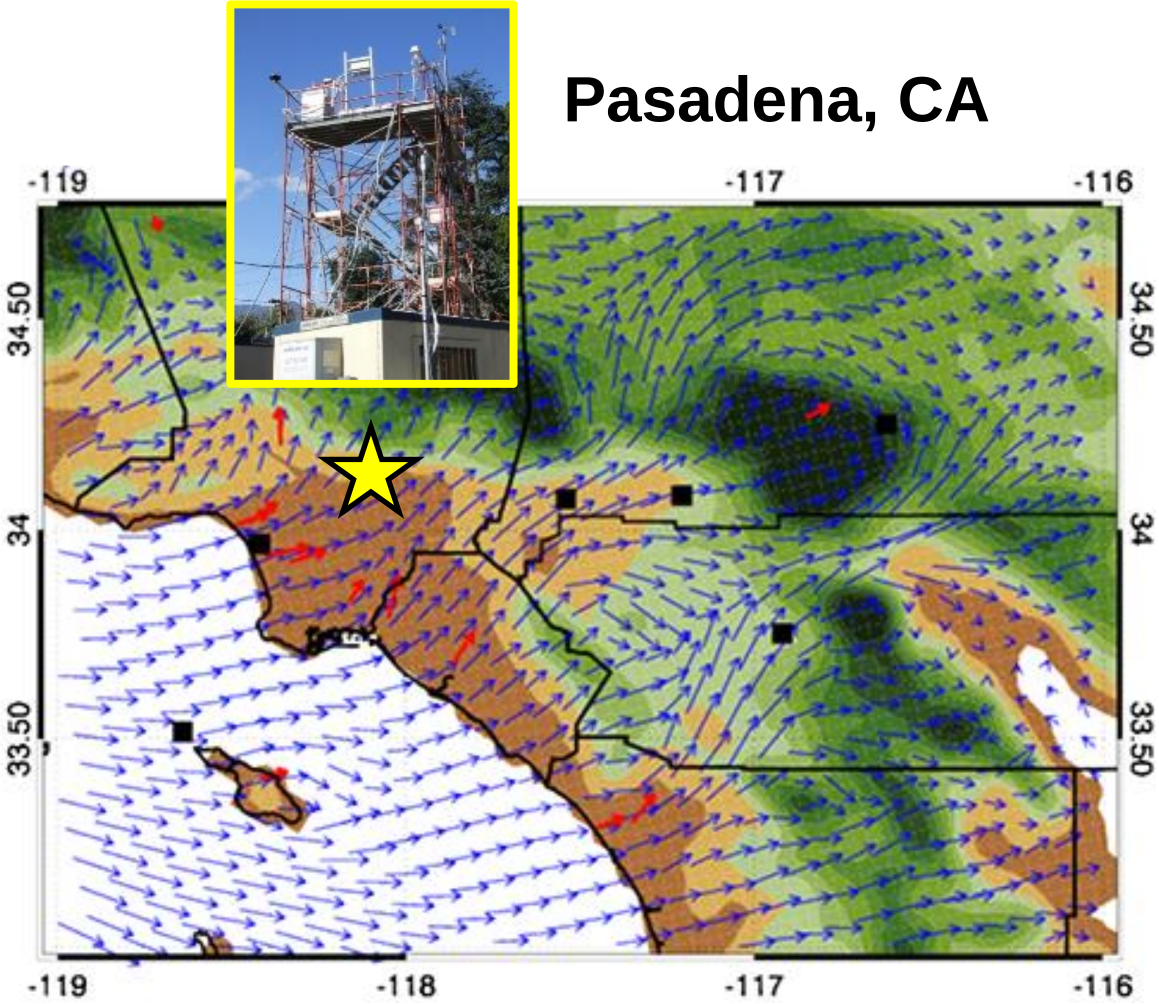
Airborne intensives downwind of NYC and Boston
2015 Winter intensive, PI: J. Thornton
2004 ICARTT, Neuman et al., 2006
1993 NARE, Lin et al., 1998

In comparison to urban ground based observations and a global emission inventory

Analysis of long-term observations of NO_x and CO in megacities and application to constraining emission inventories
Hassler et al., GRL 2016

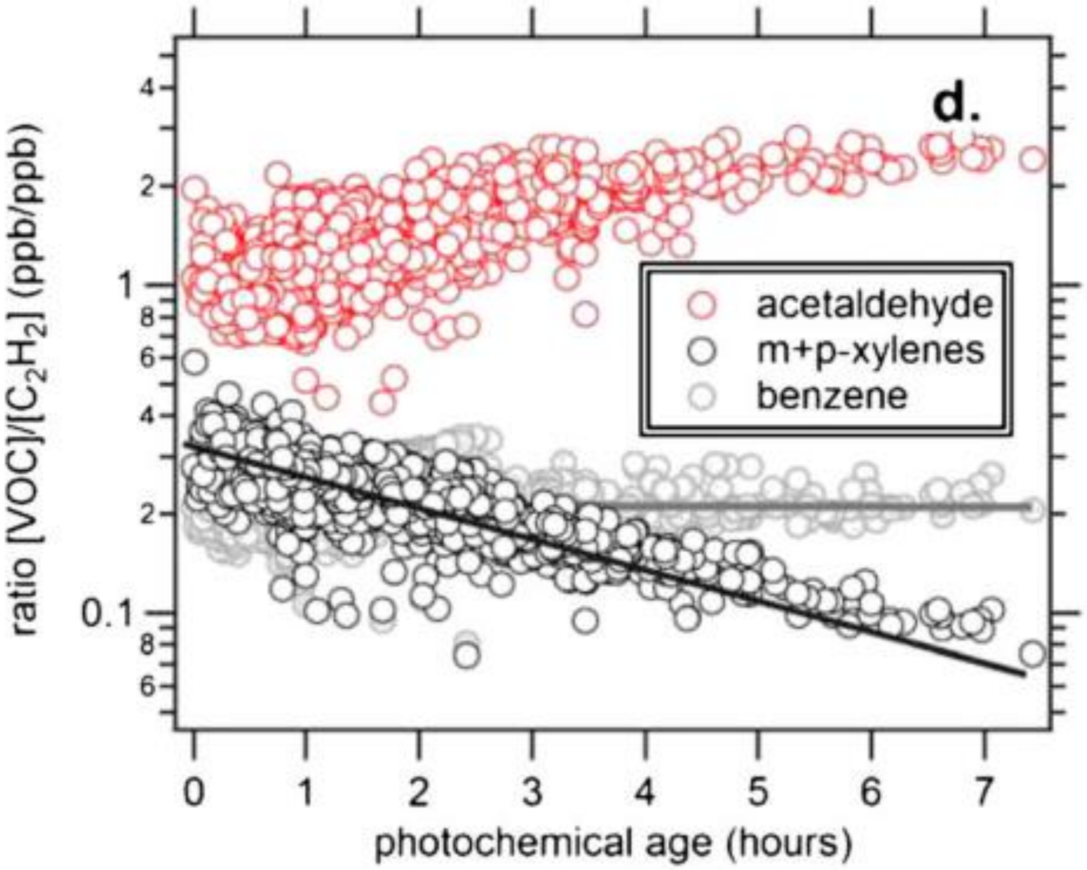
Evaluate Inventory using VOC Measurements from CalNex (2010)

Pasadena, CA



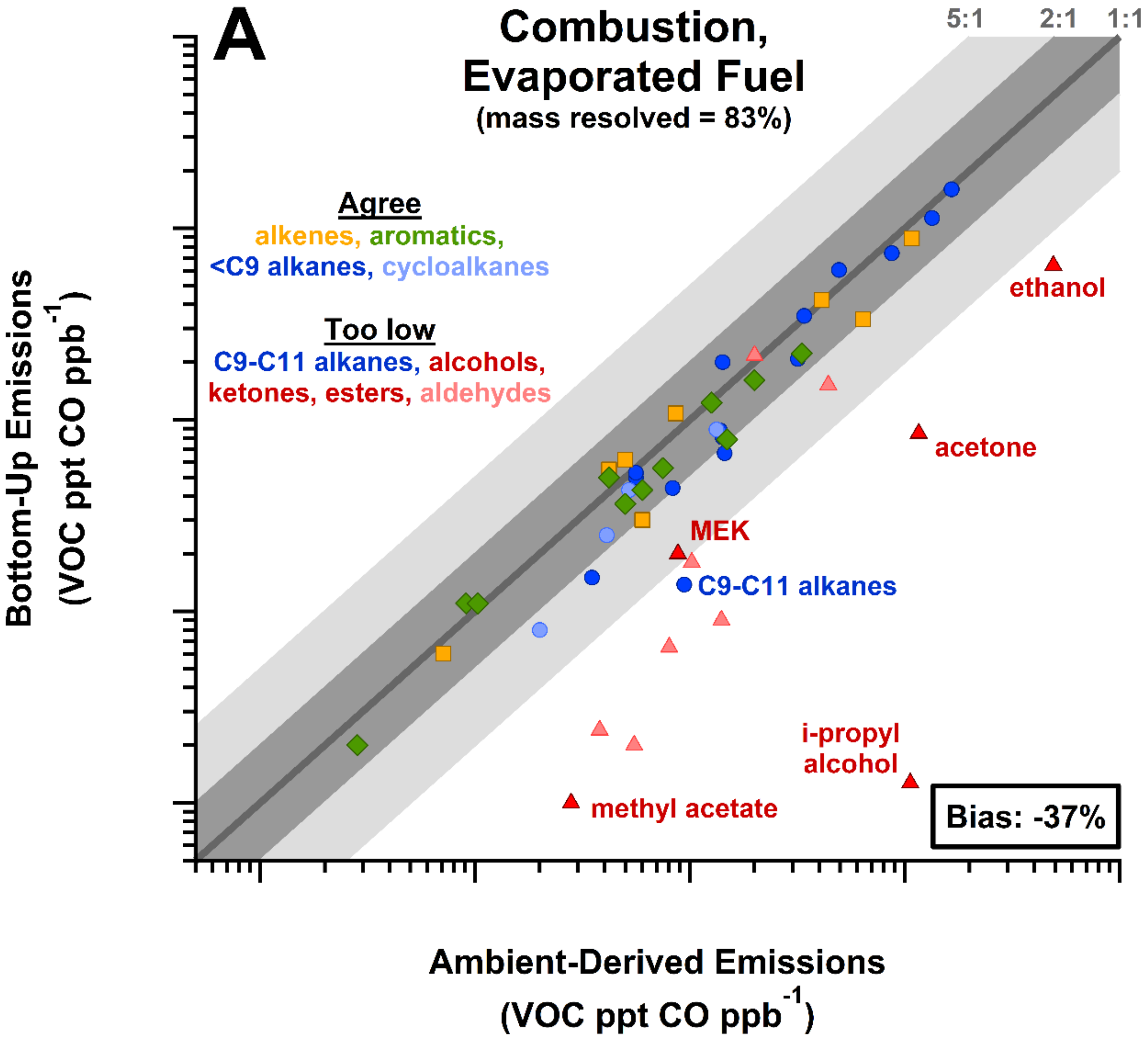
Ground site measures downtown LA emissions (Kim et al., J. Geophys. Res. 2016)

Equipped with on-line GC-MS
~80 species measured

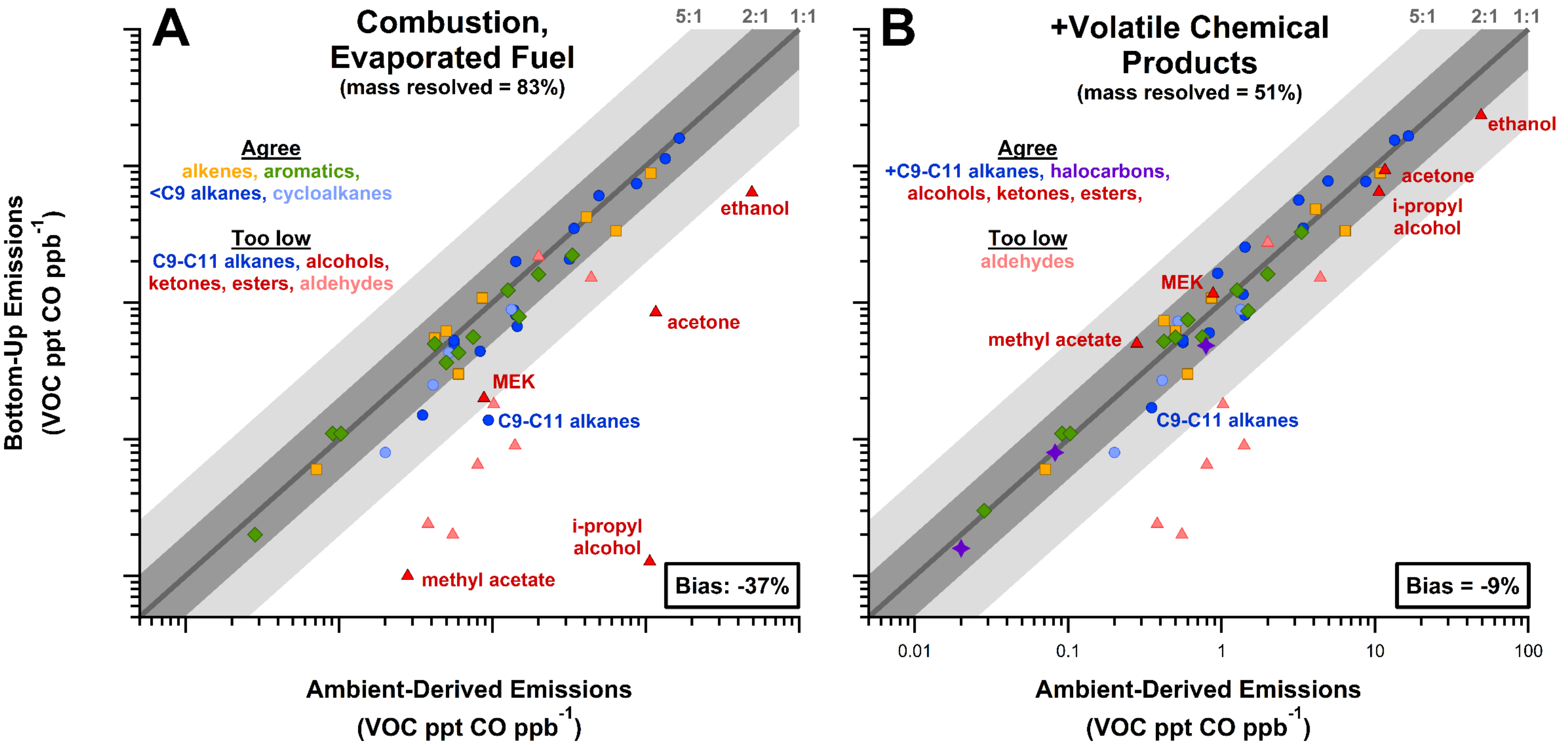


Data able to directly evaluate emission inventories (Borbon et al., J. Geophys. Res. 2012)

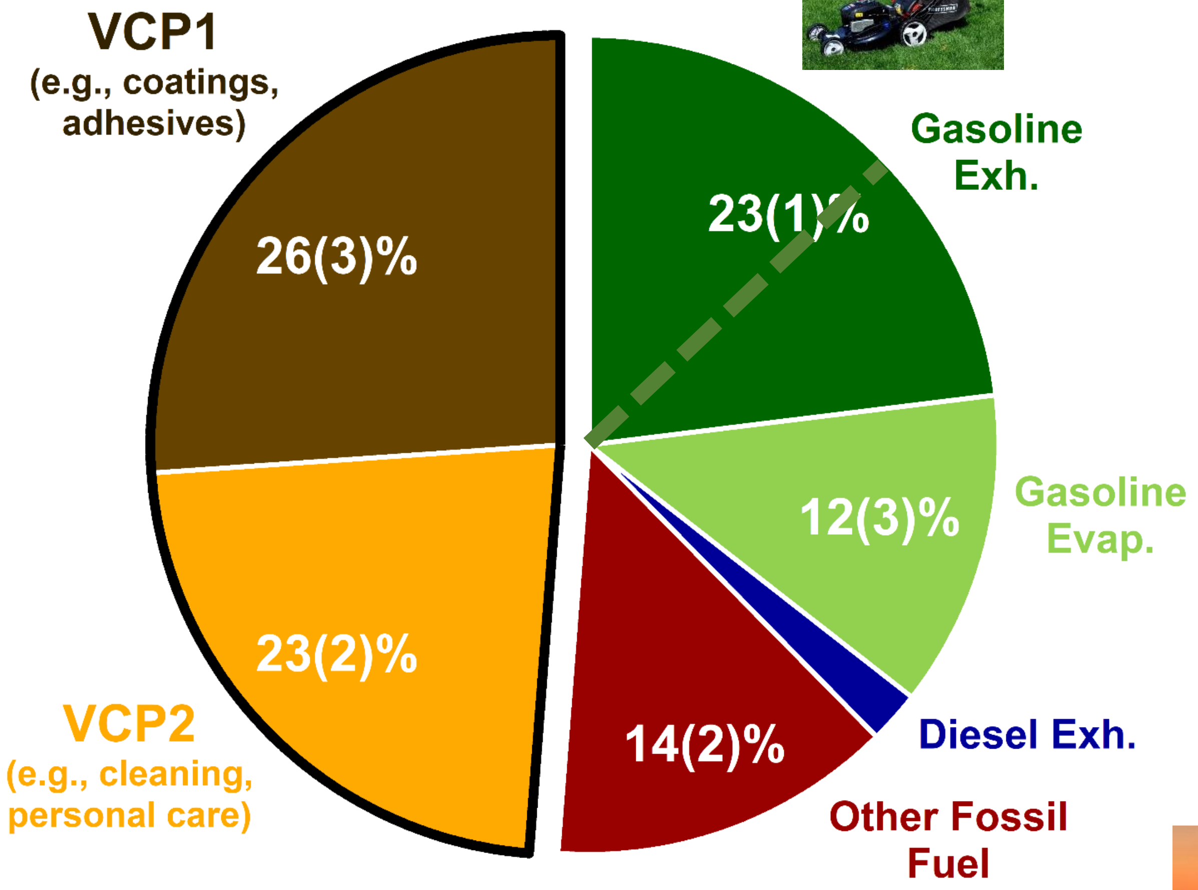
Energy-Related Emissions Alone Do not Explain Urban VOCs



Energy-Related Emissions Alone Do not Explain Urban VOCs



Distribution of Anthropogenic VOC Emissions in Los Angeles (2010)



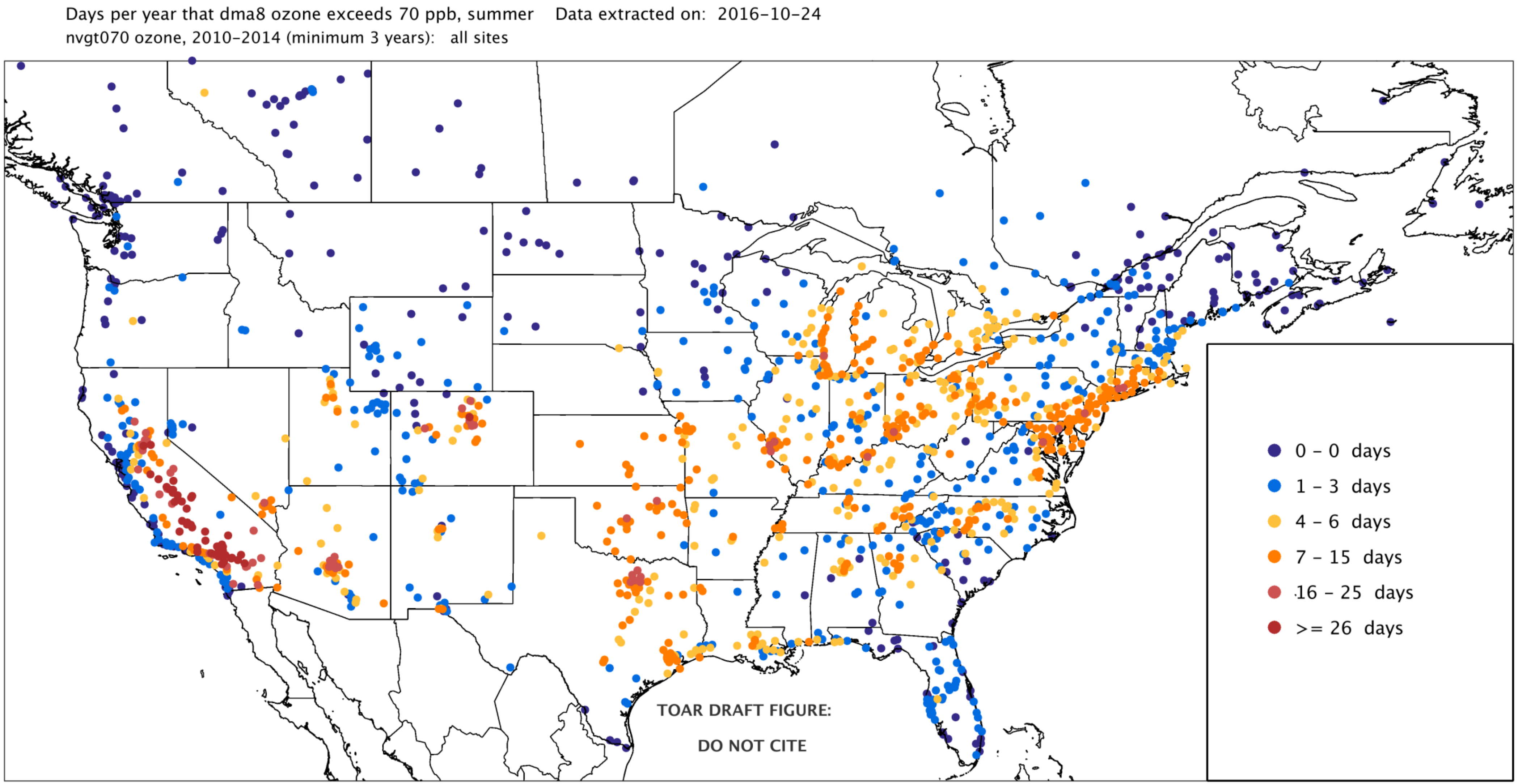
VOC Emissions = 820 ± 200 t/d

+

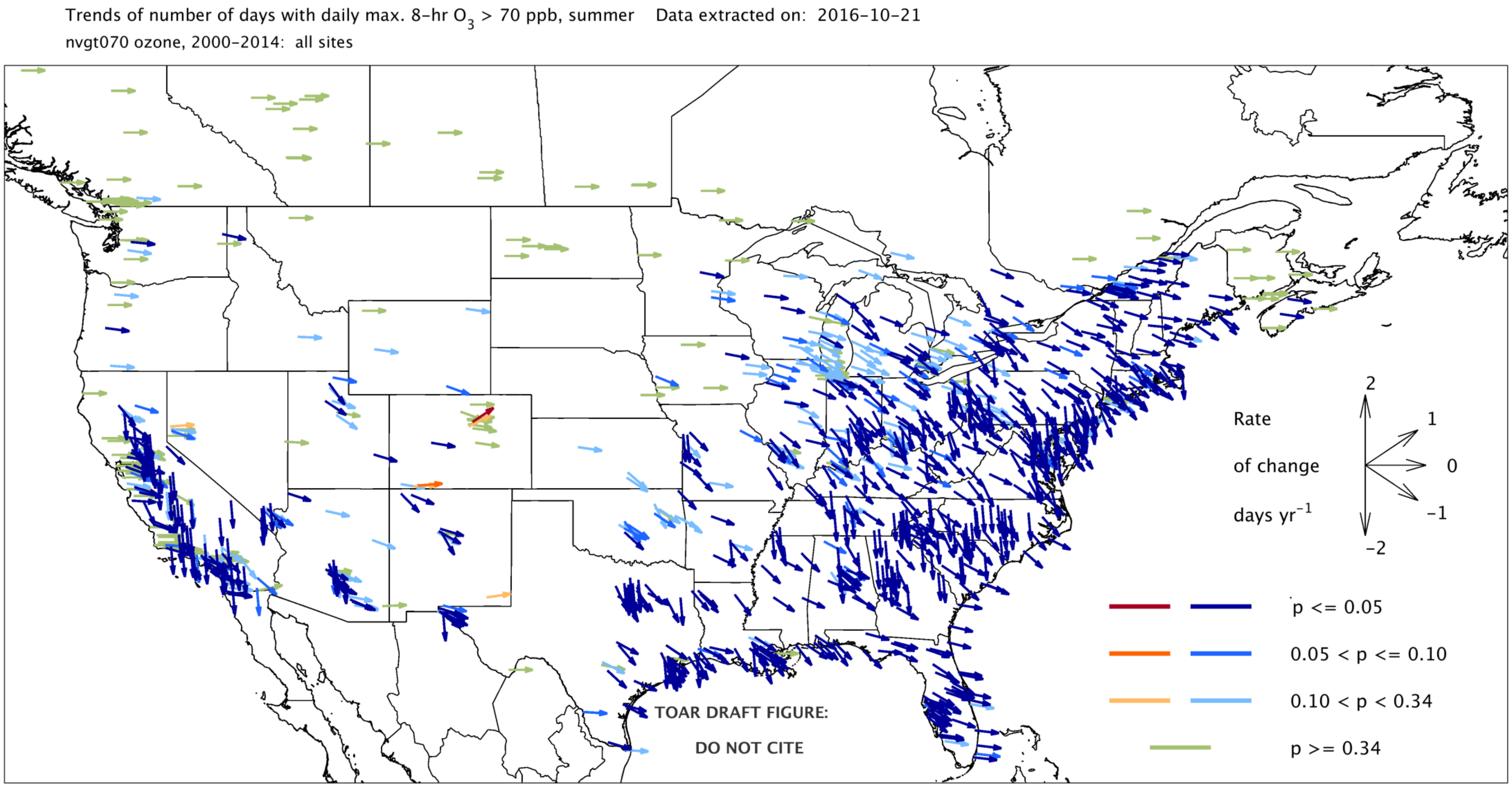
+

Volatile chemical product (a.k.a. solvent) emissions underestimated by ~2x

Number of days that Ozone exceeds the 8 hr standard of 70 ppbv, 2010 - 2014



Trend in number of Ozone exceedance days, 2000 - 2014



Emissions from power plants and traffic are changing in response to emission controls

Ambient measurements (monitors, field experiments, remote sensing) are needed to observe these changes

Ambient measurements of secondary products are critical to examine
the response of Ozone and PM to precursor emission controls