Air Quality and Climate Connections

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Acknowledgments:
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Vaishali Naik, Jason West (Princeton U), Allison Steiner (U Michigan)
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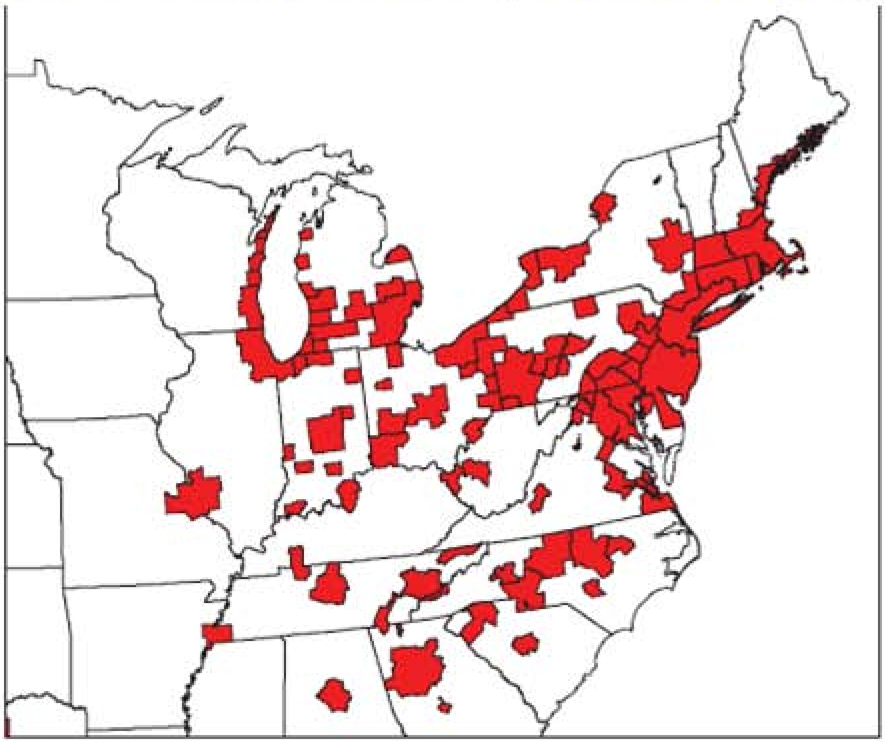
Regional and Urban Air Quality: Now and in the Future
New York Academy of Sciences, NY
February 28, 2007

The U.S. smog problem is spatially widespread, affecting >100 million people [U.S. EPA, 2004]

OZONE

Nonattainment Areas (2001-2003 data)

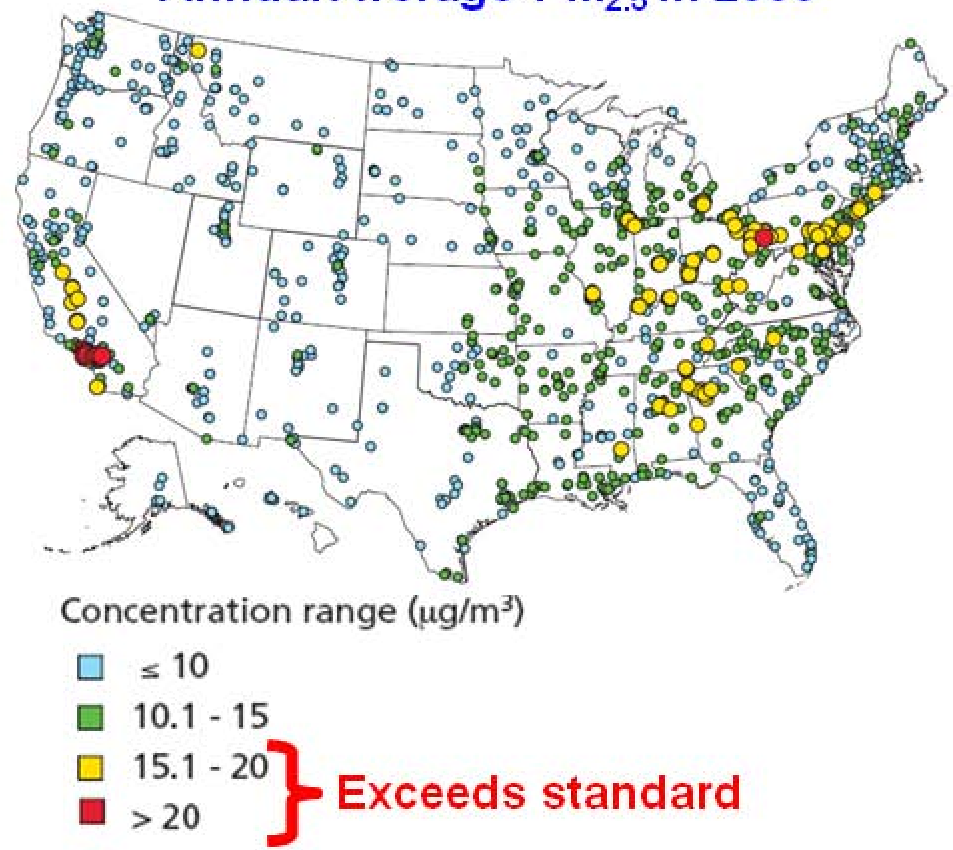


4th highest daily max 8-hr O_3 > 84 ppbv

U.S. EPA, 2006

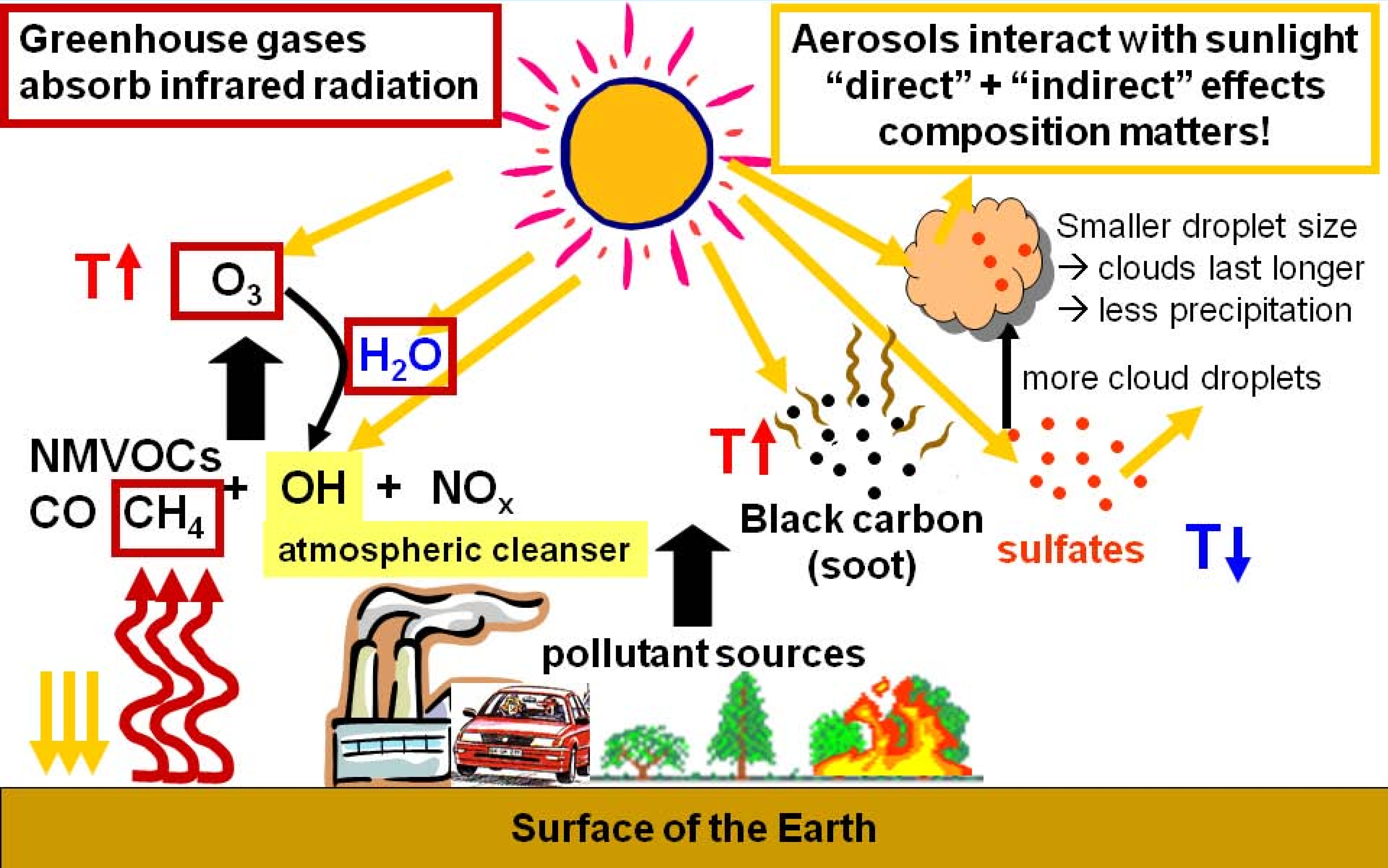
AEROSOLS (particulate matter)

Annual Average $PM_{2.5}$ in 2003

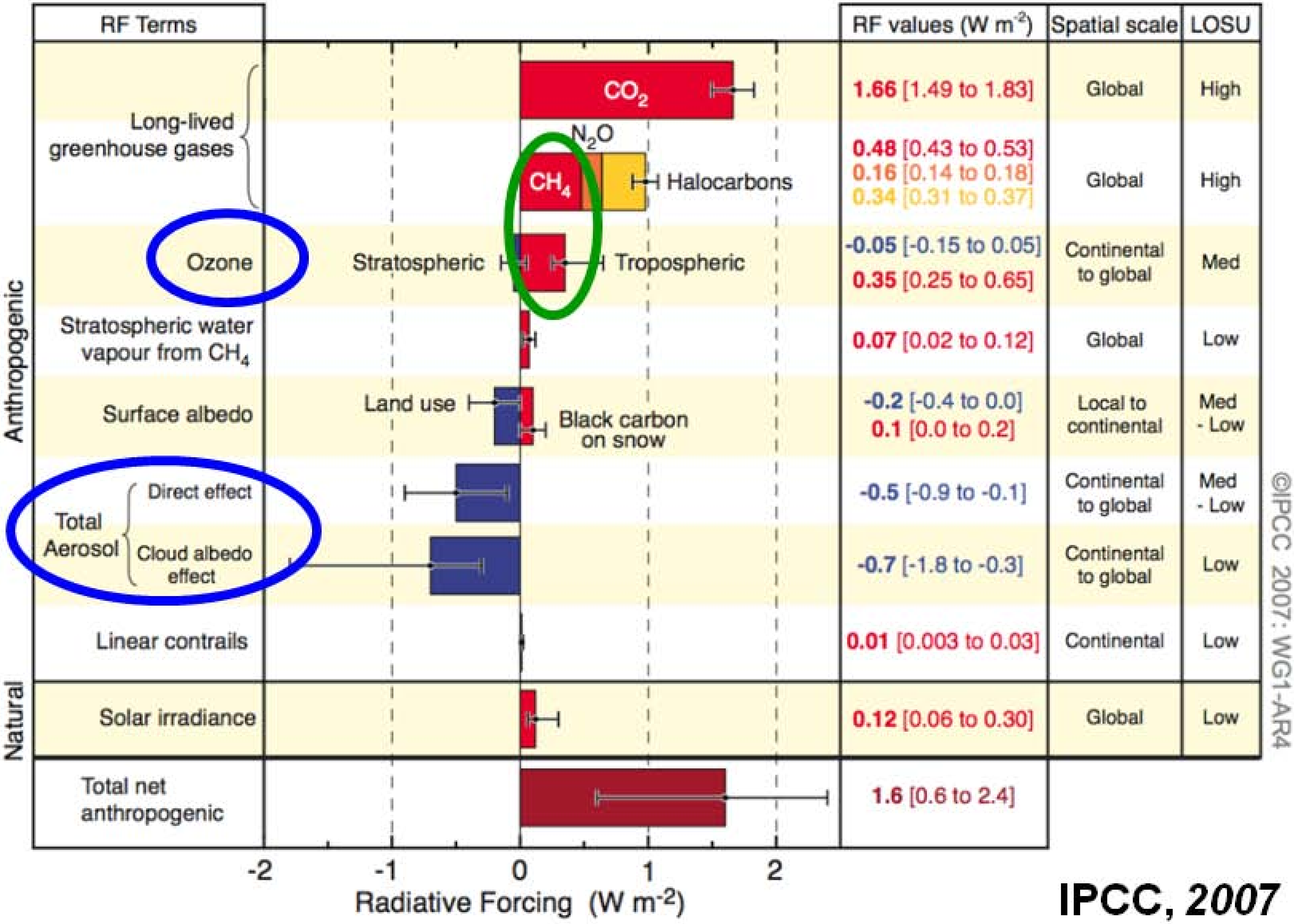


U.S. EPA, 2004

Air pollutants affect climate by absorbing or scattering radiation



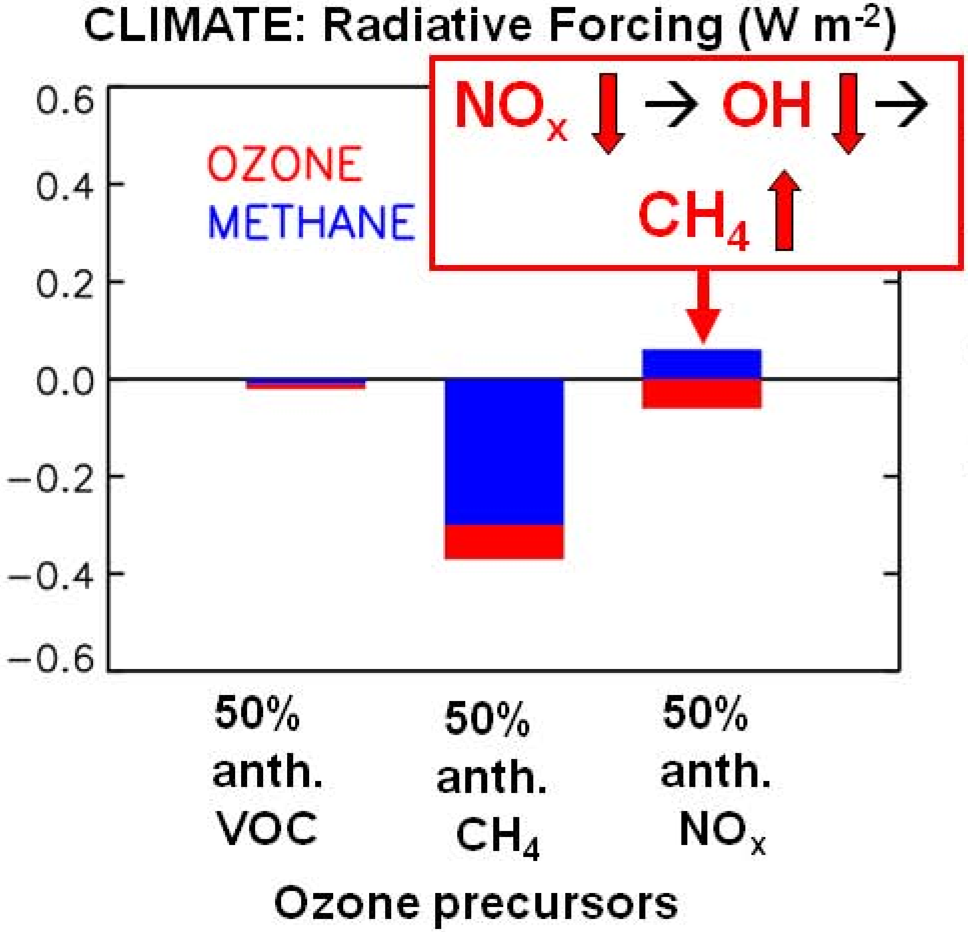
Radiative forcing of climate (1750 to present): Important contributions from air pollutants

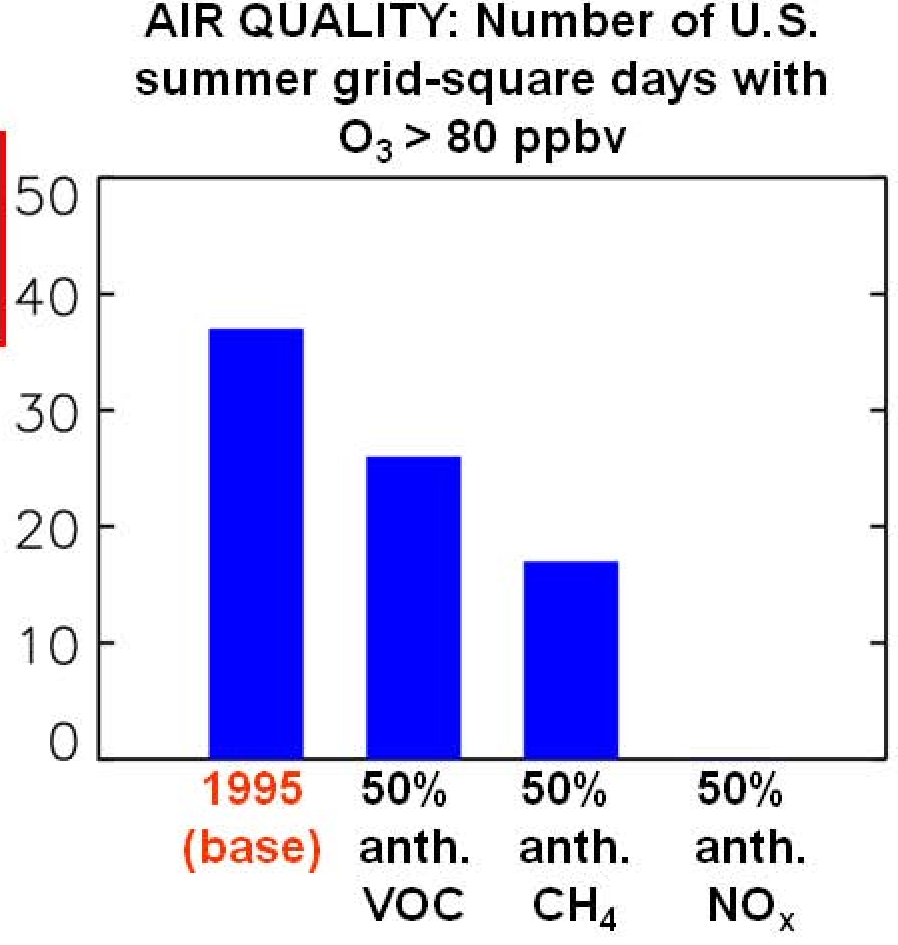


IPCC, *2007*

Double dividend of Methane Controls: Decreased greenhouse warming and improved air quality

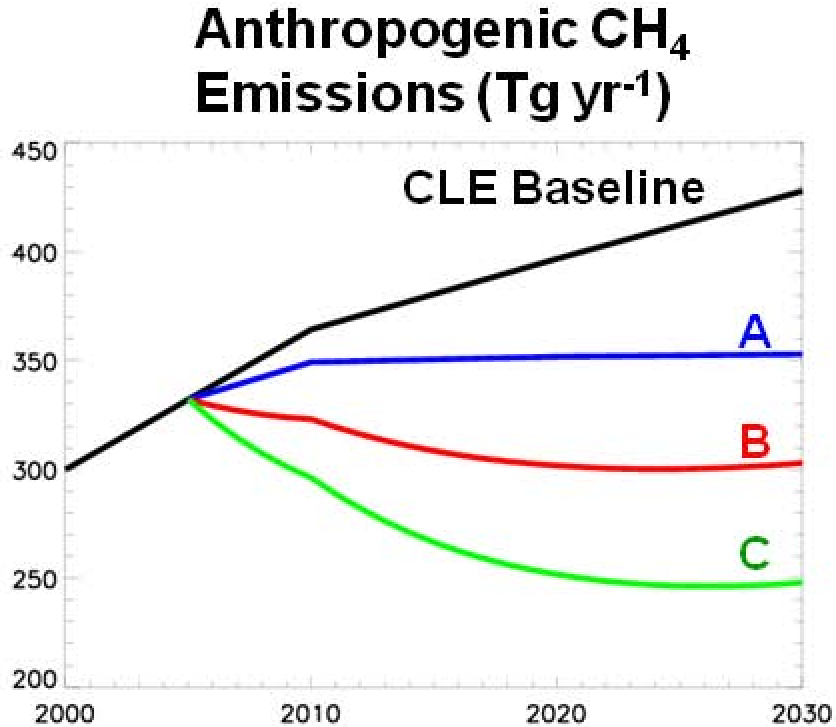
Results from GEOS-Chem global tropospheric chemistry model (4°x5°)

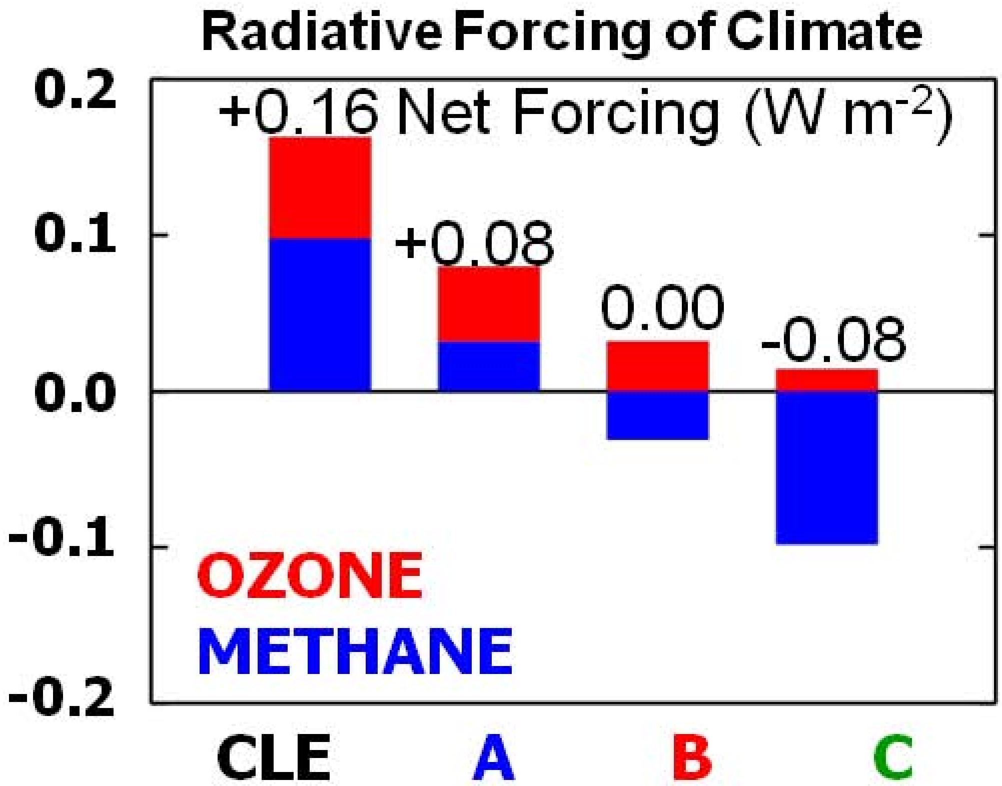




Fiore *et al.*, *GRL*, 2002

Reducing tropospheric ozone via methane controls decreases radiative forcing (2030-2005)





Control scenarios reduce 2030 emissions relative to CLE by:

A) -75 Tg (18%) – cost-effective now

B) -125 Tg (29%) – possible with current technologies

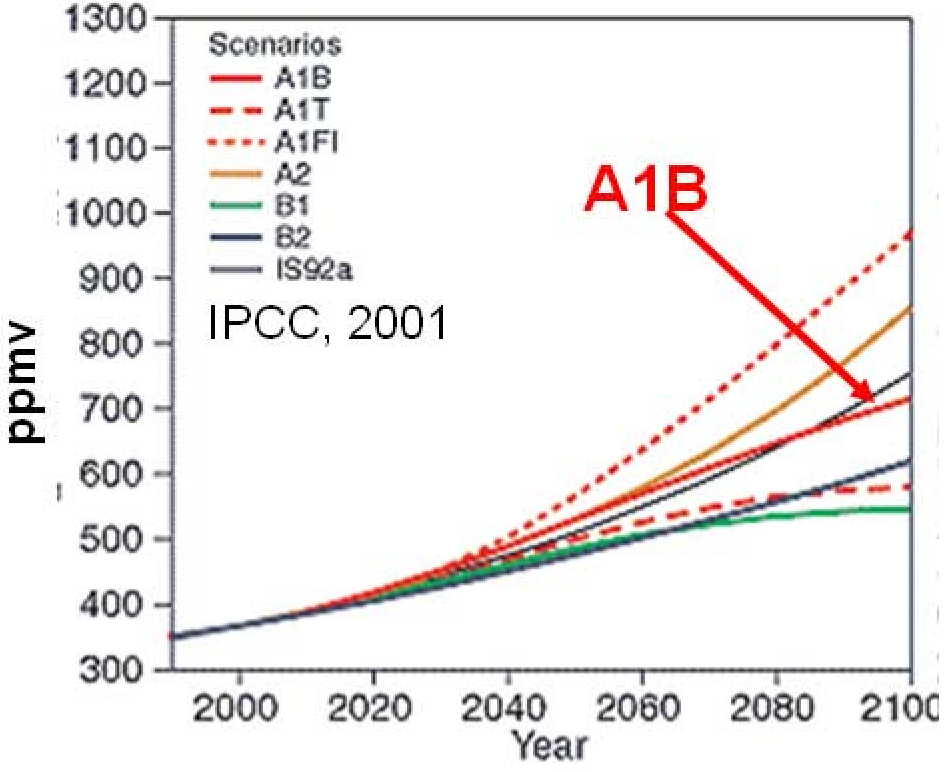
C) -180 Tg (42%) – requires new technologies

West and Fiore, 2005; Fiore *et al.*, in prep

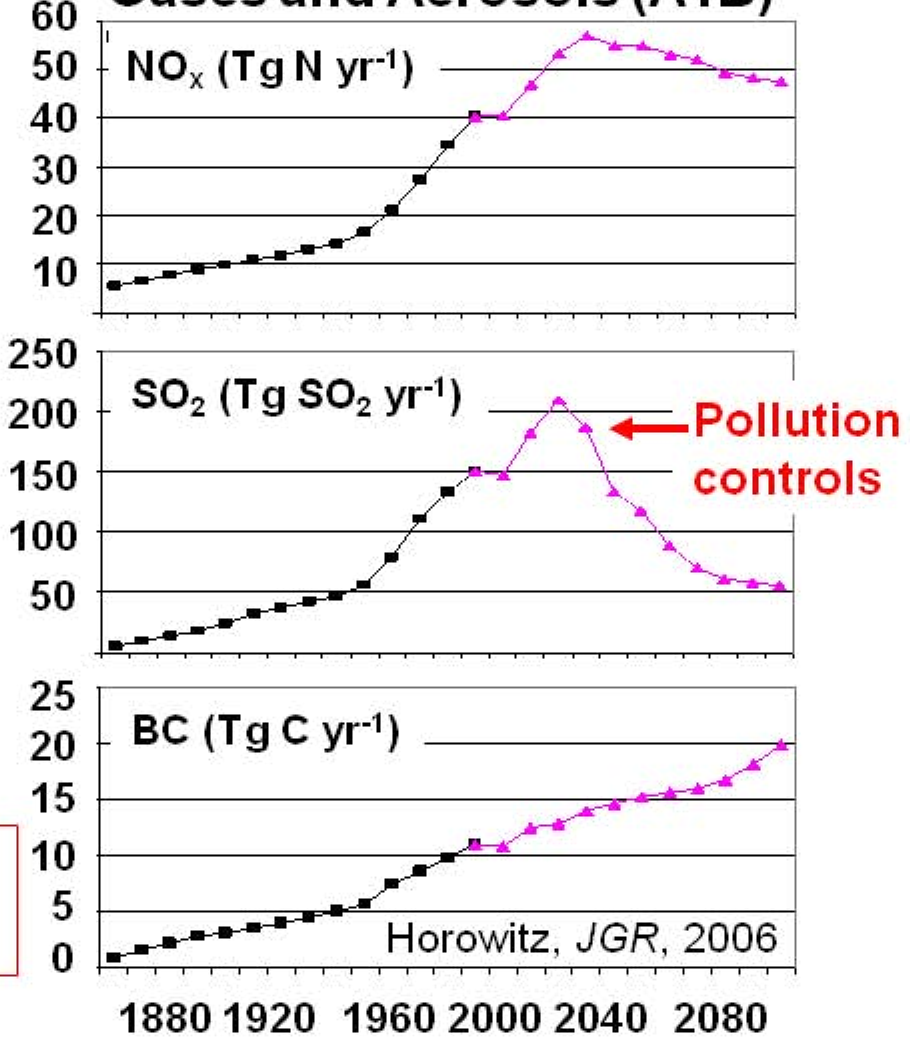
How might future changes in aerosols affect climate?

HISTORICAL and FUTURE SCENARIOS

CO_2 concentrations



Emissions of Short-lived Gases and Aerosols (A1B)



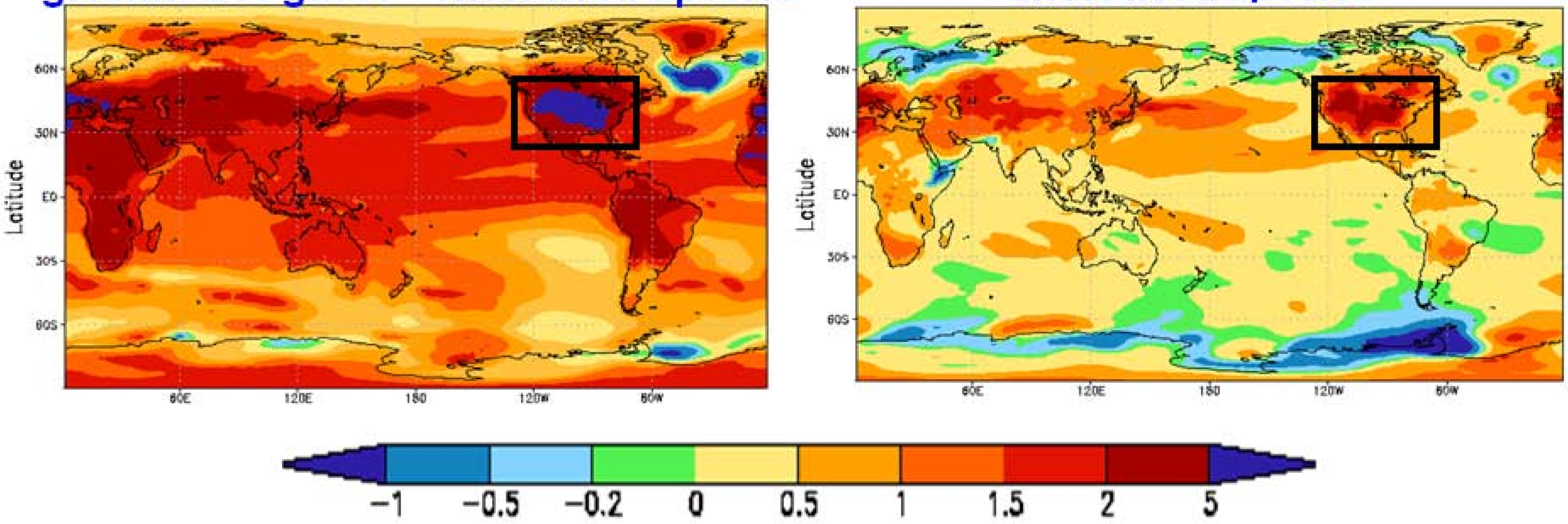
Large uncertainty in future emission trajectories for short-lived species

Up to 40% of U.S. warming in summer (2090s-2000s) from short-lived species

Results from GFDL Climate Model [Levy *et al.*, 2006]

From changing well-mixed greenhouse gases +short-lived species

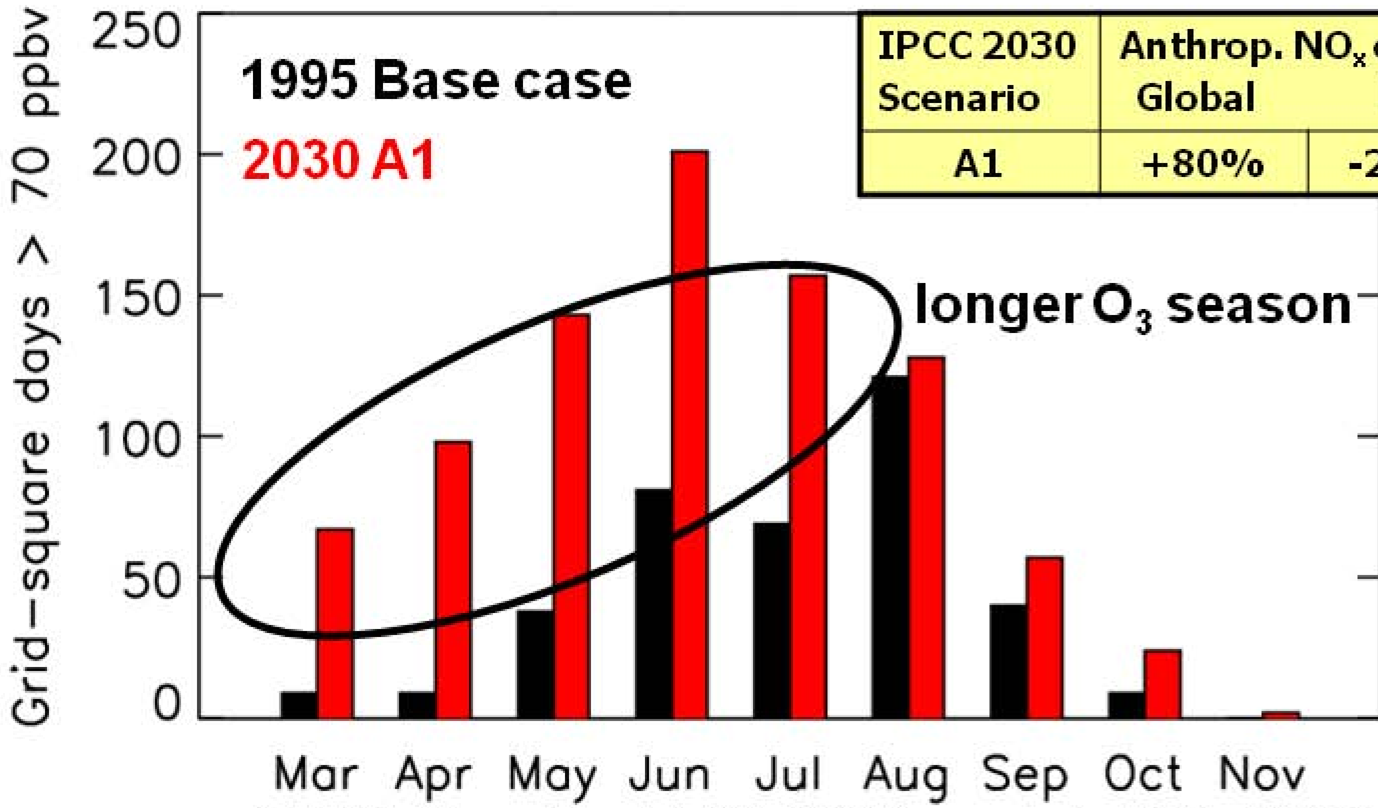
From changing only short-lived species



Change in Summer Temperature 2090s-2000s (°C)

Warming from increases in BC + decreases in sulfate; depends critically on highly uncertain future emission trajectories

Changes in global anthropogenic emissions affect regional air quality



IPCC 2030 Scenario	Anthrop. NO_x emis. Global	U.S.	Methane emis.
A1	+80%	-20%	+30%

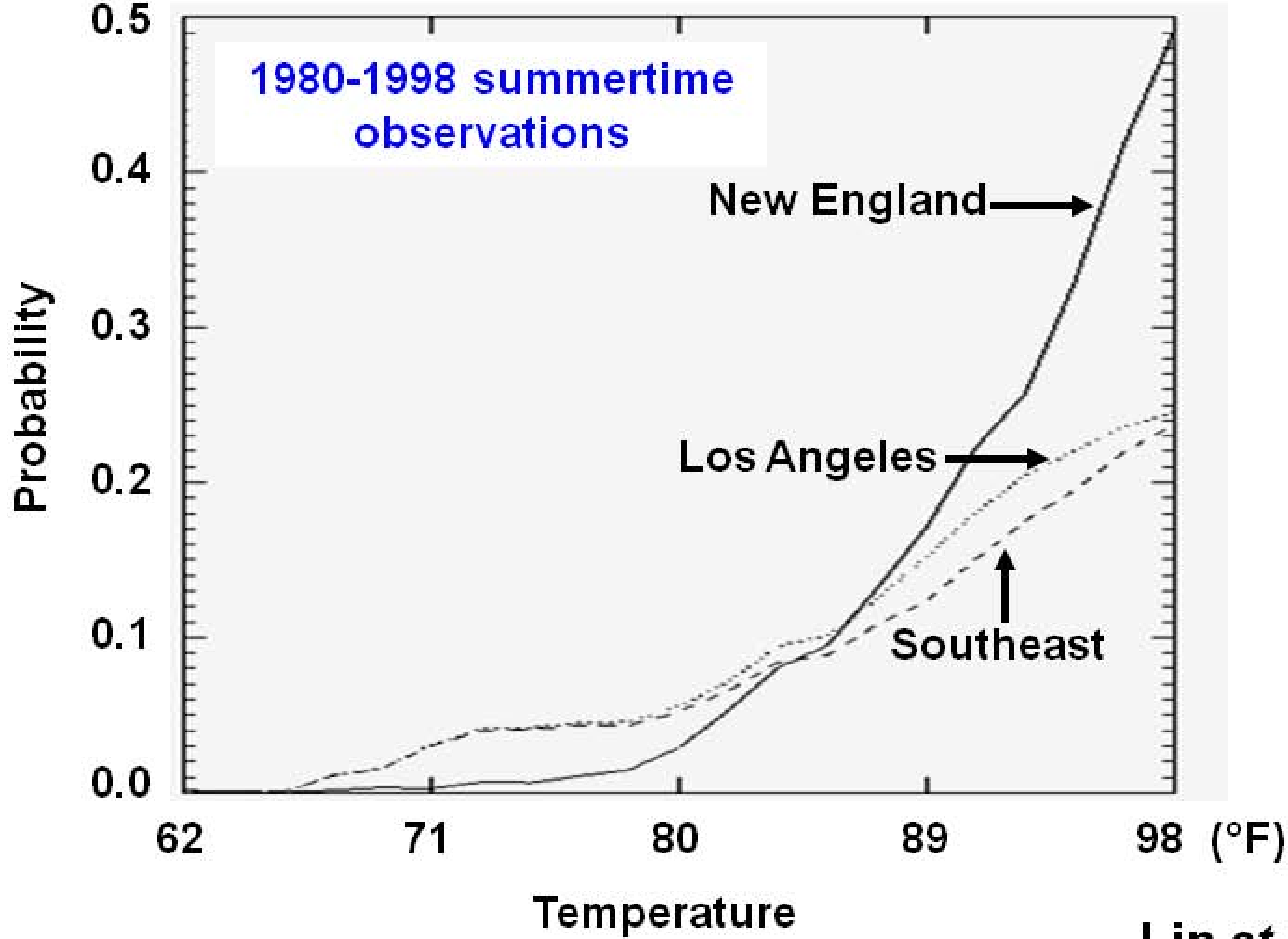
GEOS-Chem Model (4°x5°) [Fiore *et al.*, *GRL*, 2002]

Rising global emissions may offset U.S. efforts to reduce pollution

How will changes in climate influence regional air quality?

Observed surface ozone over the U.S. correlates strongly with temperature

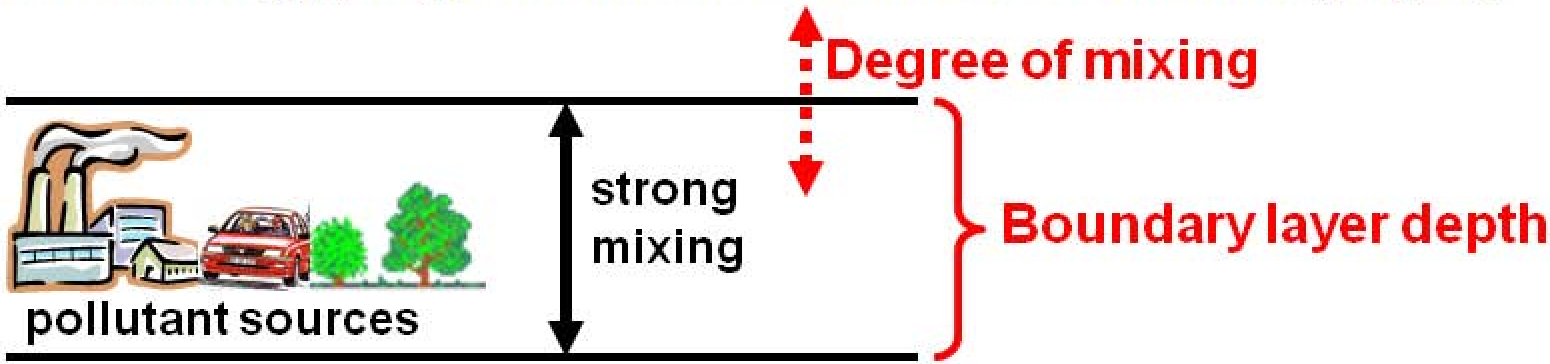
Probability of daily max 8-h O_3 > 84 ppbv vs. daily max. temperature



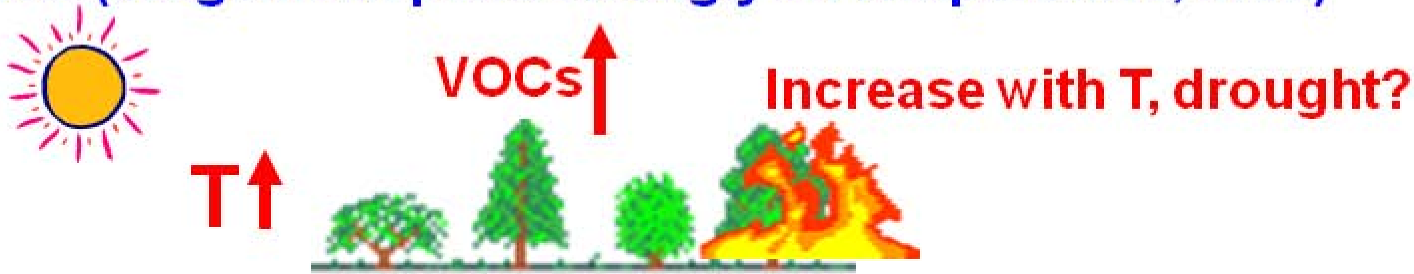
Lin *et al.*, 2001

How does climate affect air quality?

(1) Meteorology (stagnation vs. well-ventilated boundary layer)



(2) Emissions (biogenic depend strongly on temperature; fires)



(3) Chemistry responds to changes in temperature, humidity

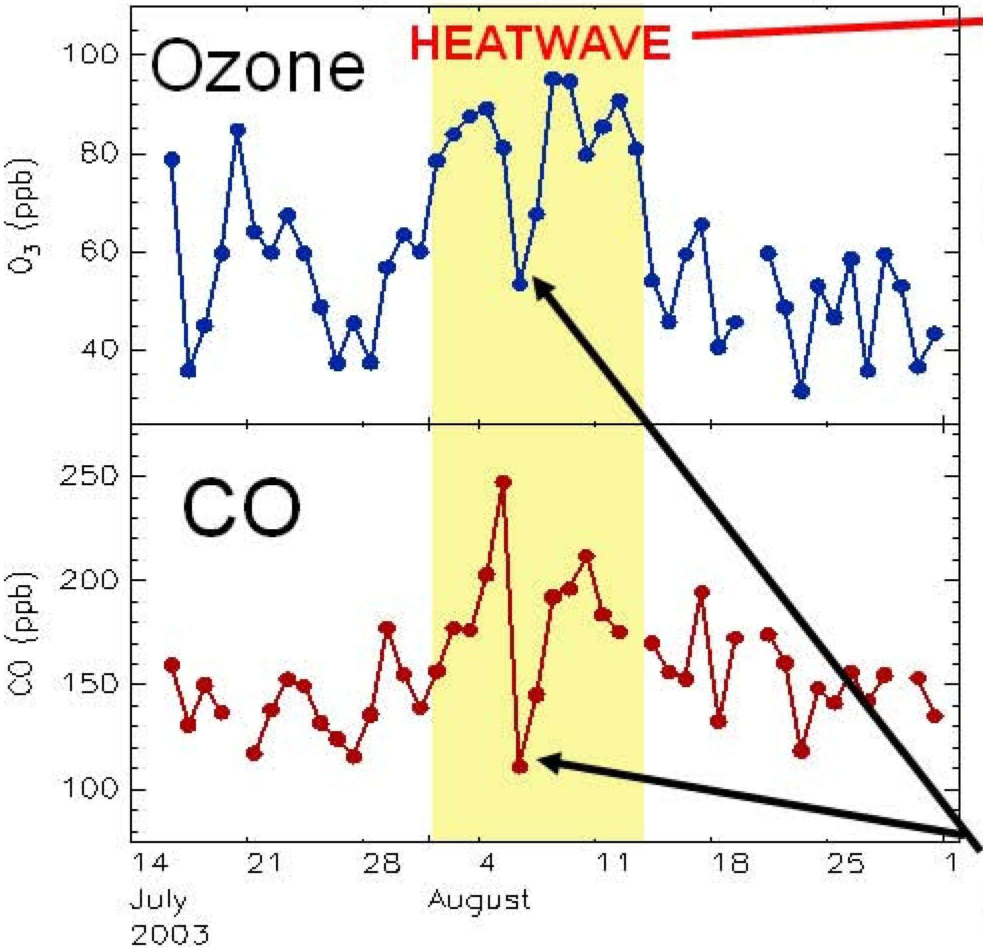
T↑ generally faster reaction rates

NMVOCs, CO, CH_4 + NO_x + OH → O_3 → H_2O → OH

Pollution build-up during 2003 European heatwave

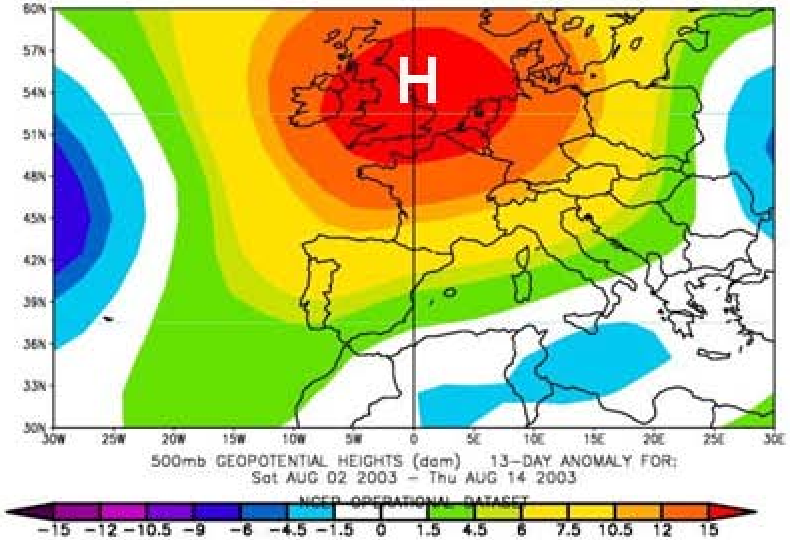
CO and O_3 from airborne observations (MOZAIC)

Above Frankfurt (850 hPa; ~160 vertical profiles



Stagnant high pressure system over Europe

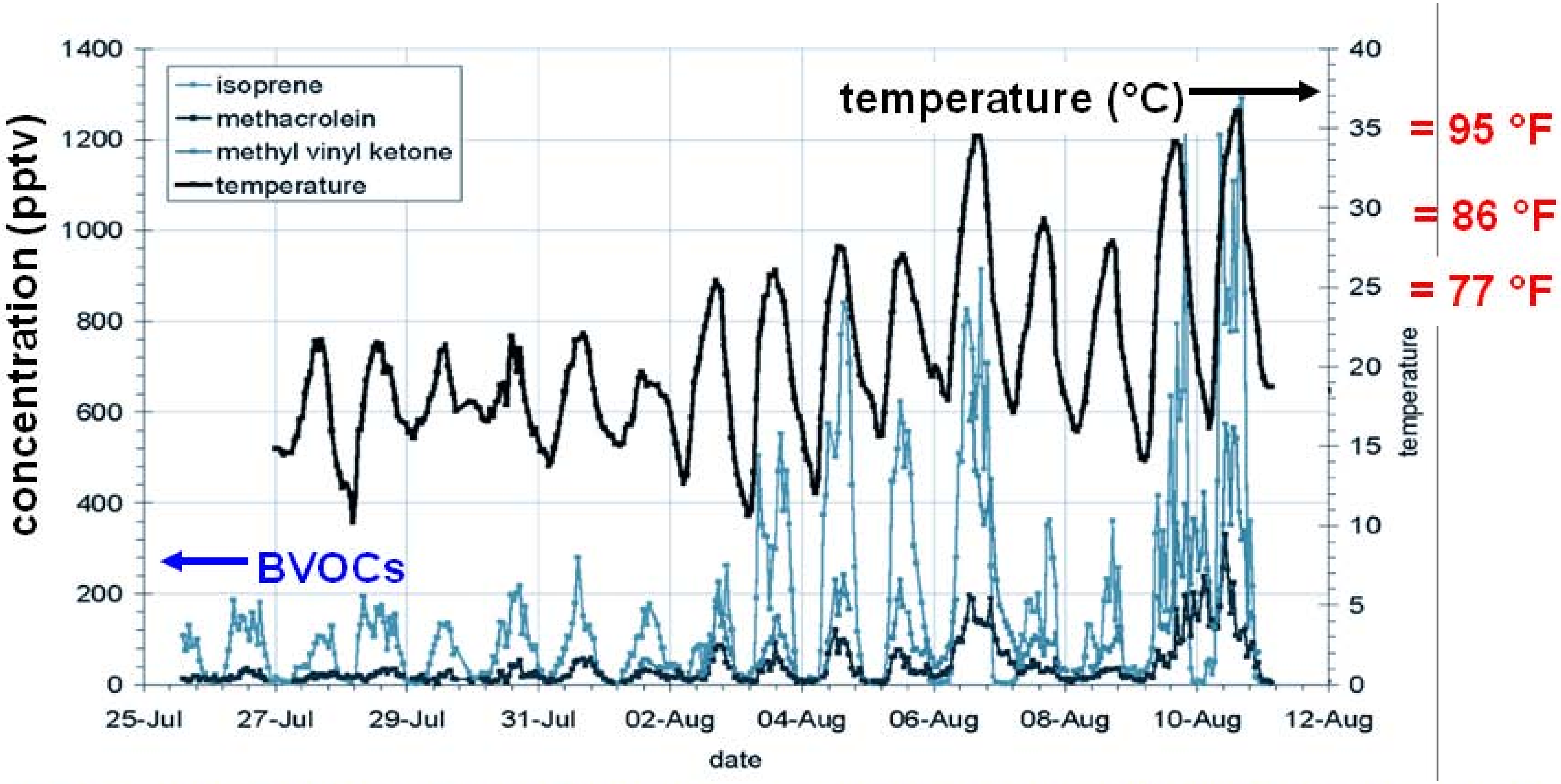
(500 hPa geopotential anomaly relative to 1979-1995 for 2-14 August, NCEP)



Ventilation (low-pressure system)

Carlos Ordóñez ordc@aero.obs-mip.fr Laboratoire d'Aérologie Toulouse, France
Contribution to GEMS, Integrated Project of the 6th EC Framework Programme
GEMS-GRG subproject coordinated by Martin Schultz (m.schultz@fz-juelich.de)

Observations during 2003 European heatwave show enhanced biogenic VOC concentrations



Measurements from August 2003 Tropospheric Organic Chemistry Experiment (TORCH) in Essex, UK, during hottest conditions ever observed in the UK
c/o Dr. Alistair Lewis, University of York, UK

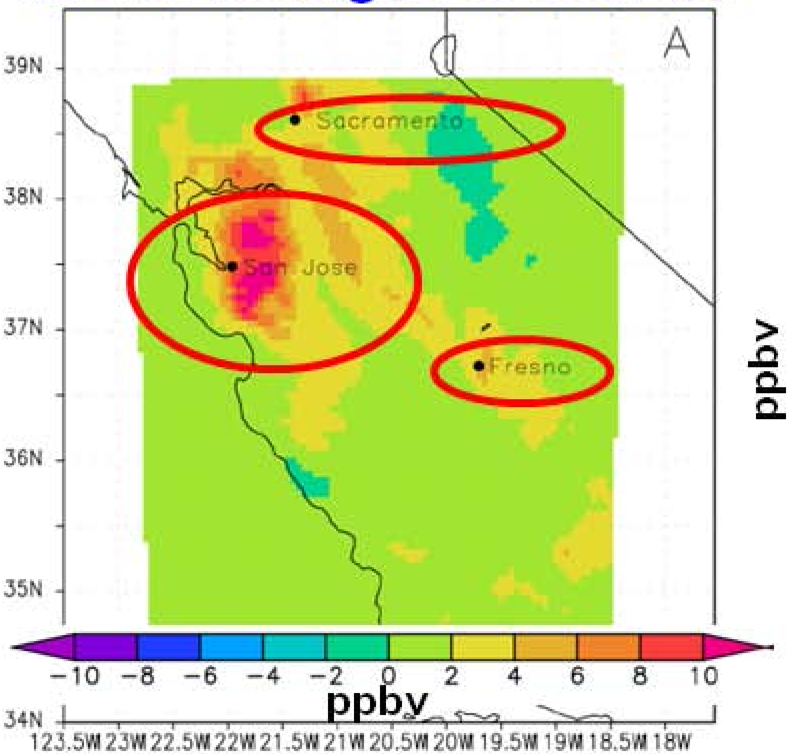
Hogrefe *et al.*, *EM*, 2005

Impacts on surface O_3 from T-driven increases in reaction rates, humidity, and BVOC emissions

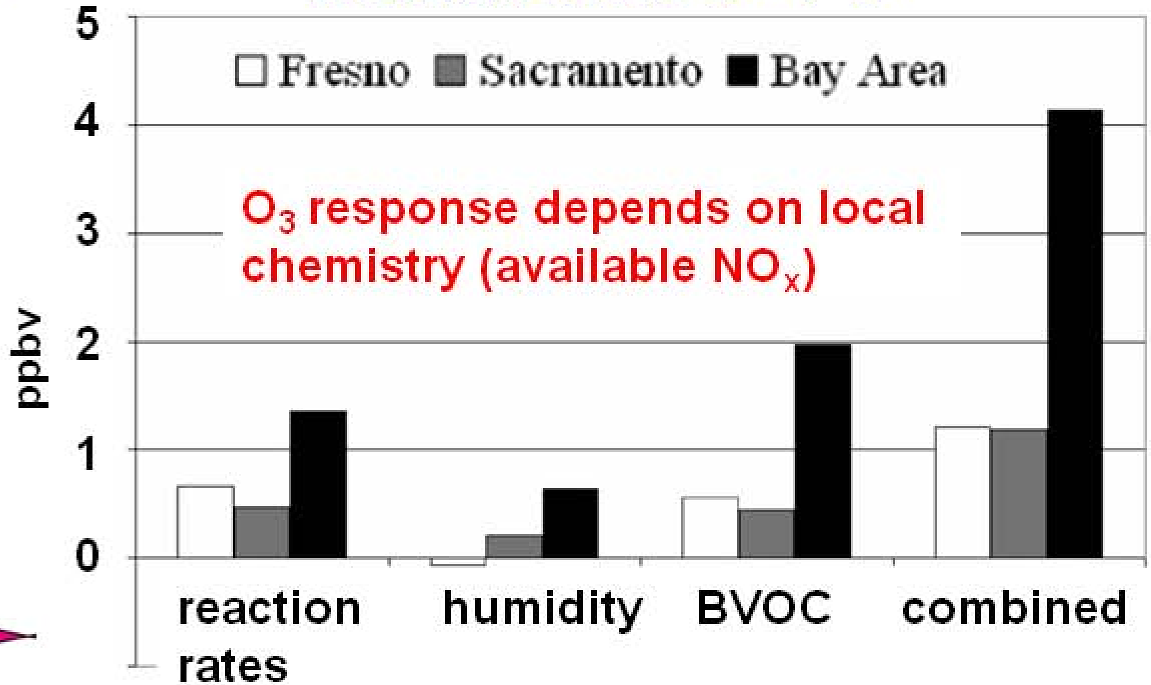
3 p.m. O_3 change (ppbv)

in 3-day O_3 episode with CMAQ model (4x4 km^2), applying T change from $2xCO_2$ climate (changes in meteorology not considered) [Steiner *et al.*, *JGR*, 2006]

due to changes in climate



normalized to a +1°C

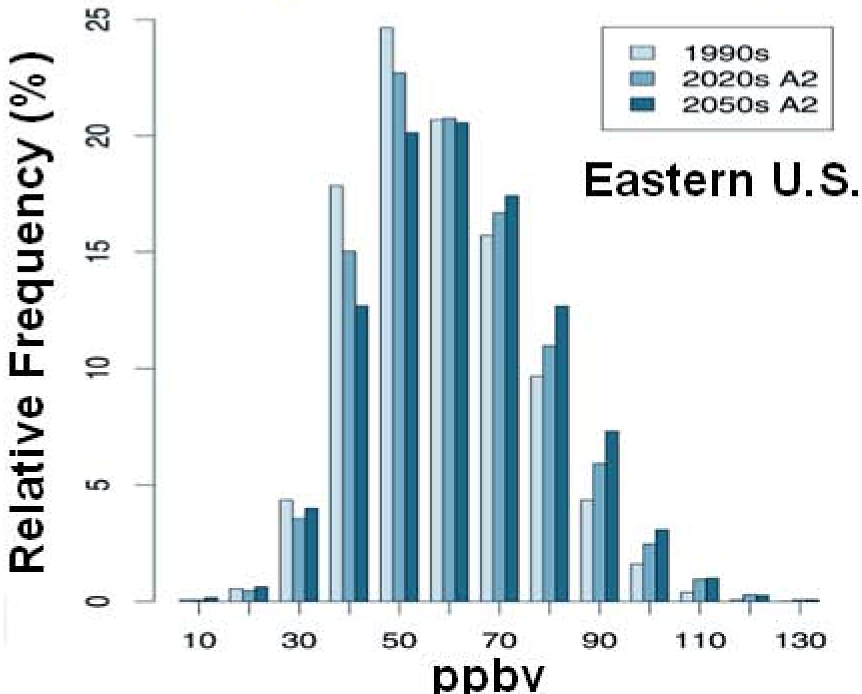


Climate-driven O_3 increases may counteract air quality improvements achieved via local anthropogenic emission reductions

Changing climate may increase pollution events over the eastern U.S.

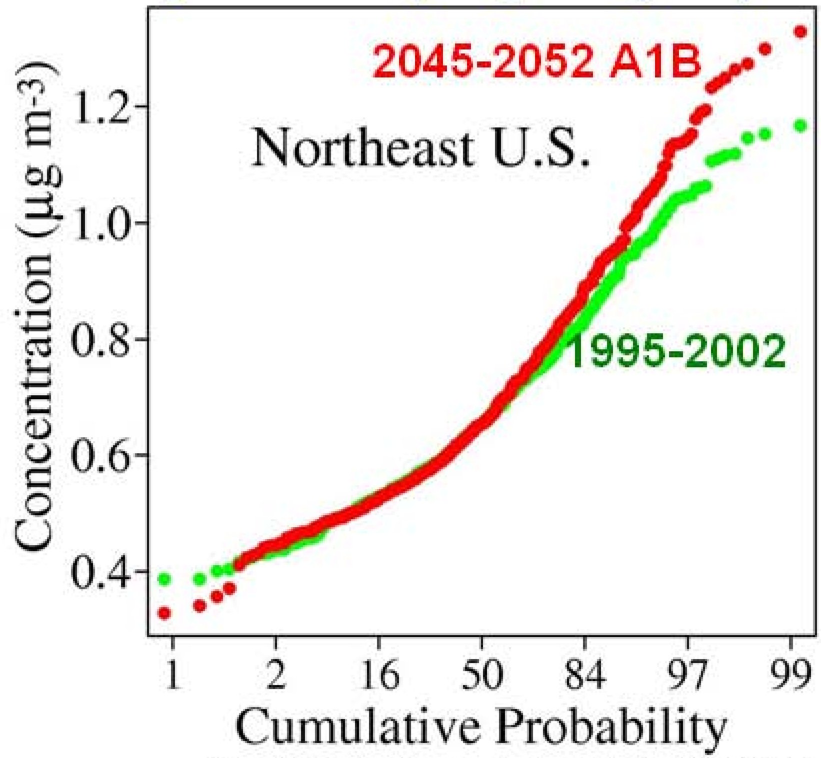
Simulations using present-day emissions with future climates

Daily max 8-hr O_3 (5-year summer mean)



Regional CMAQ model (36 km^2)
with GISS boundary conditions
Hogrefe *et al.*, *JGR* 2004; *EM* 2005

Tracer of anthropogenic pollution (July-August)

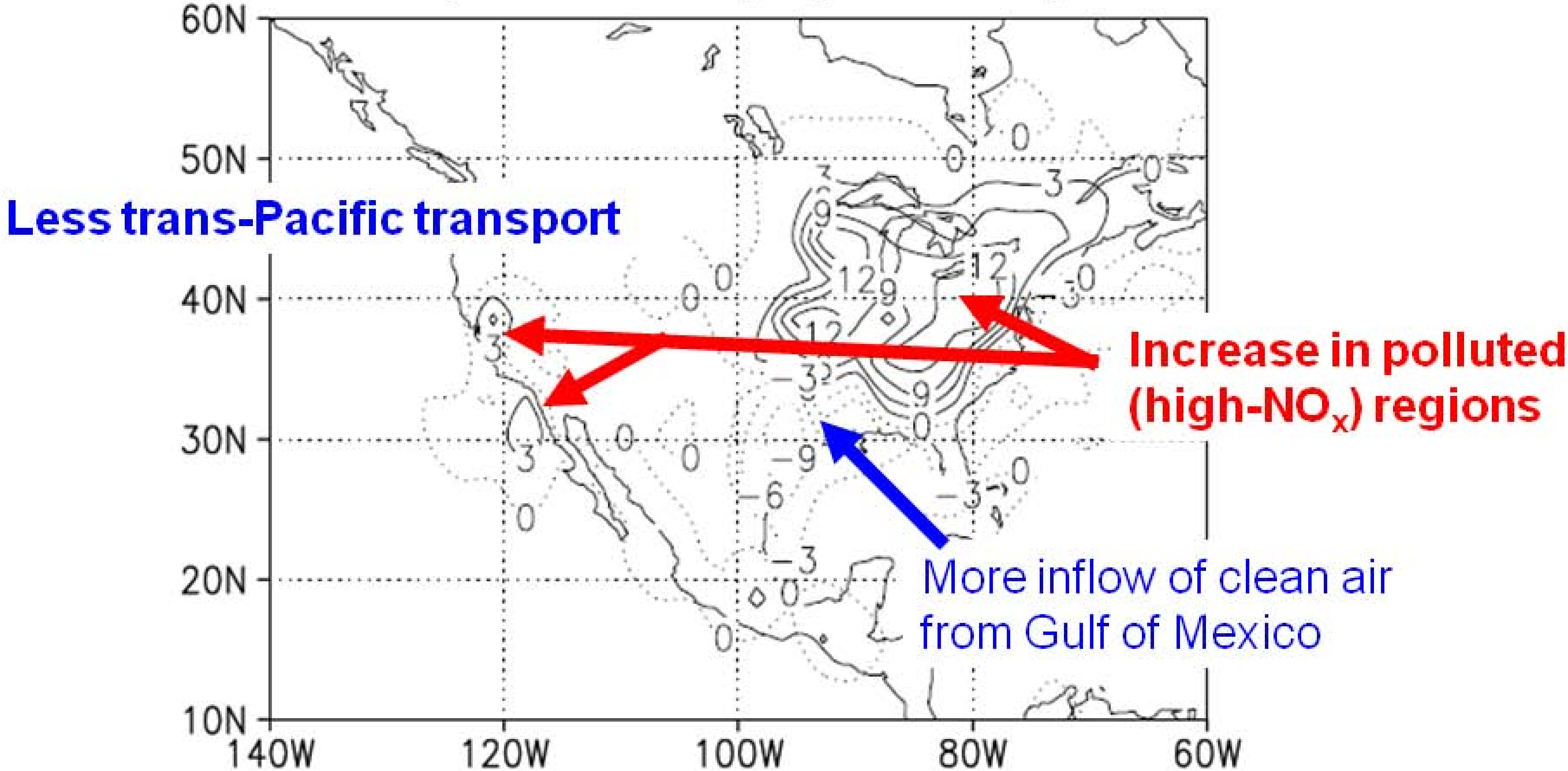


in GISS global model (4°x5°)
[Mickley *et al.*, *GRL*, 2004]

Increase in frequency and duration of pollution events due to decrease in frequency of mid-latitude storms

Surface O_3 change under future climate varies: increases in polluted regions; decreases in “background”

Mean annual change in number of days where daily max 8-hr O_3 > 80 ppbv (2090-2100 A1) – (1990-2000)



MOZART-2 global tropospheric chemistry model with meteorology from NCAR climate model [Murazaki and Hess, *J. Geophys. Res.*, 2006]

Air Quality and Climate Connections: Research Focal Points

- Costs and benefits of "win-win" (*e.g.* BC, CH_4) and "win-lose" (*e.g.* sulfate) strategies for joint mitigation of air pollution and climate forcing
- Aerosol feedbacks on climate, globally and regionally
- Response of biogenic emissions and fires to changes in climate and land-use
- Evolution of air quality with global change (climate + anthropogenic and "natural" emissions)