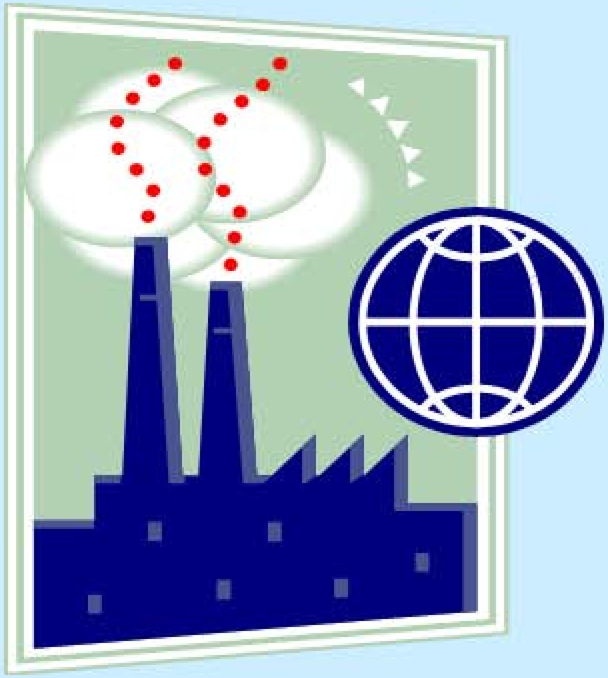

Background Ozone in Surface Air: Origin, Variability, and Policy Implications

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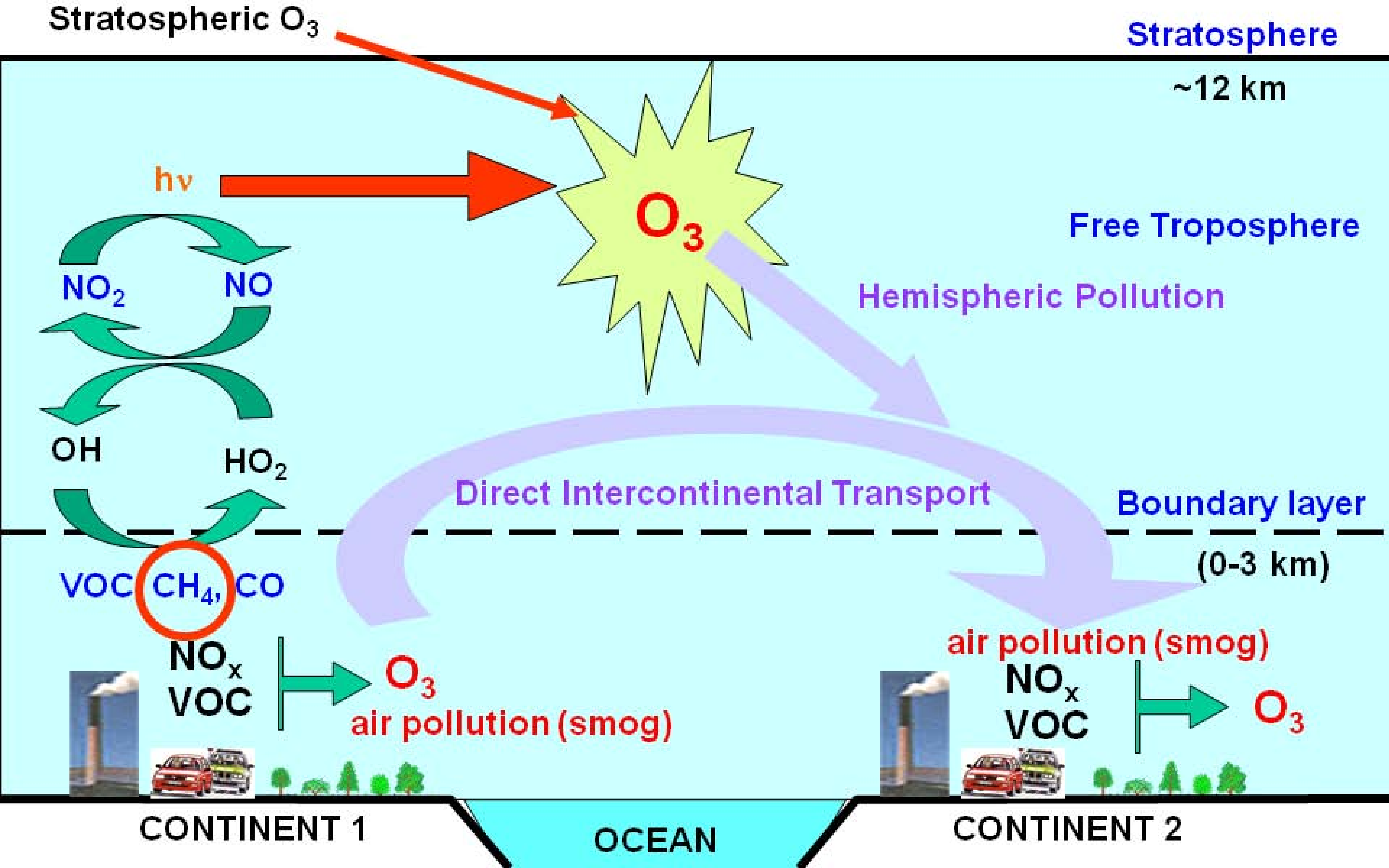
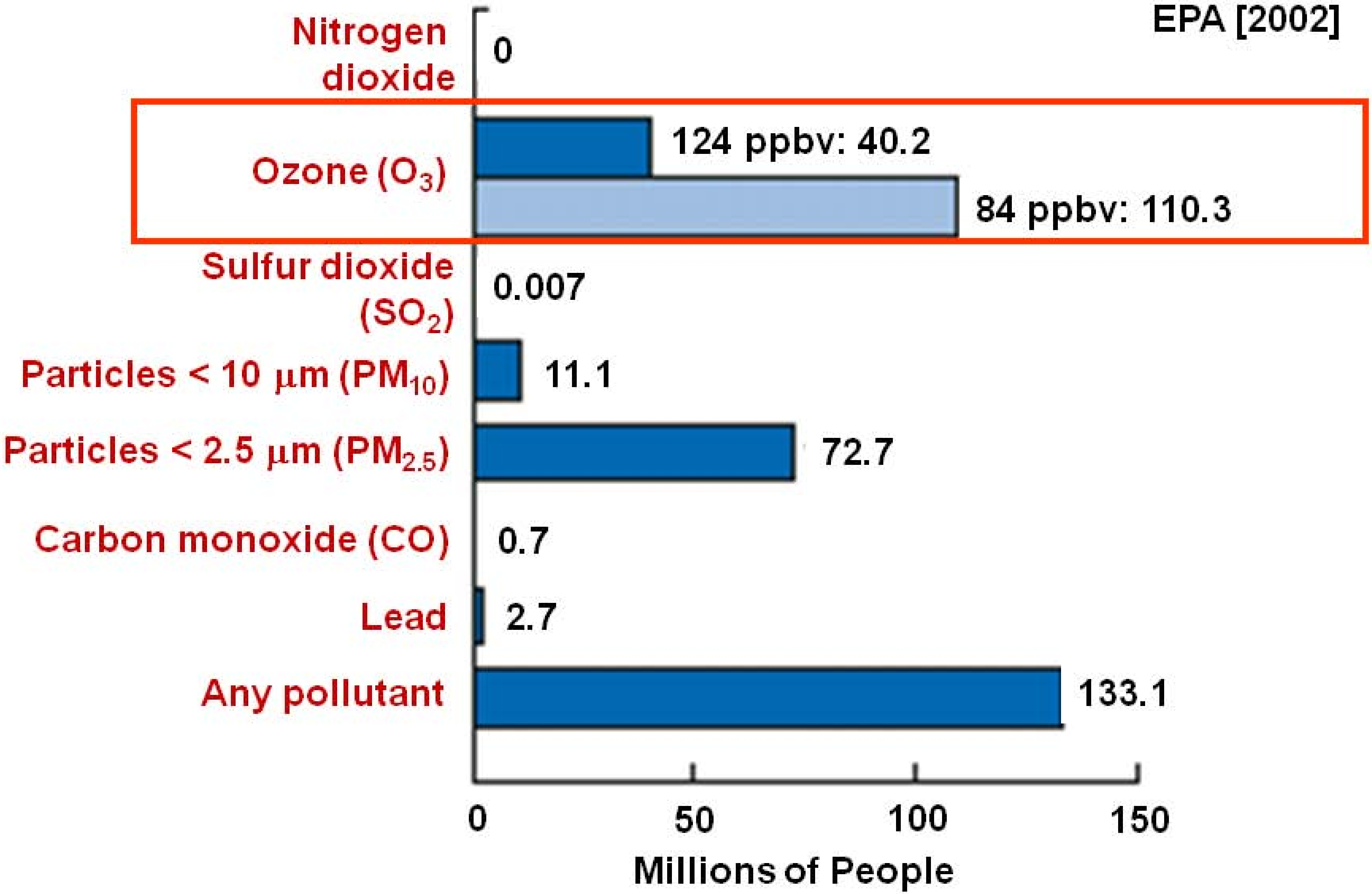
Argonne National Laboratory: David Streets, Suneeta Fernandes

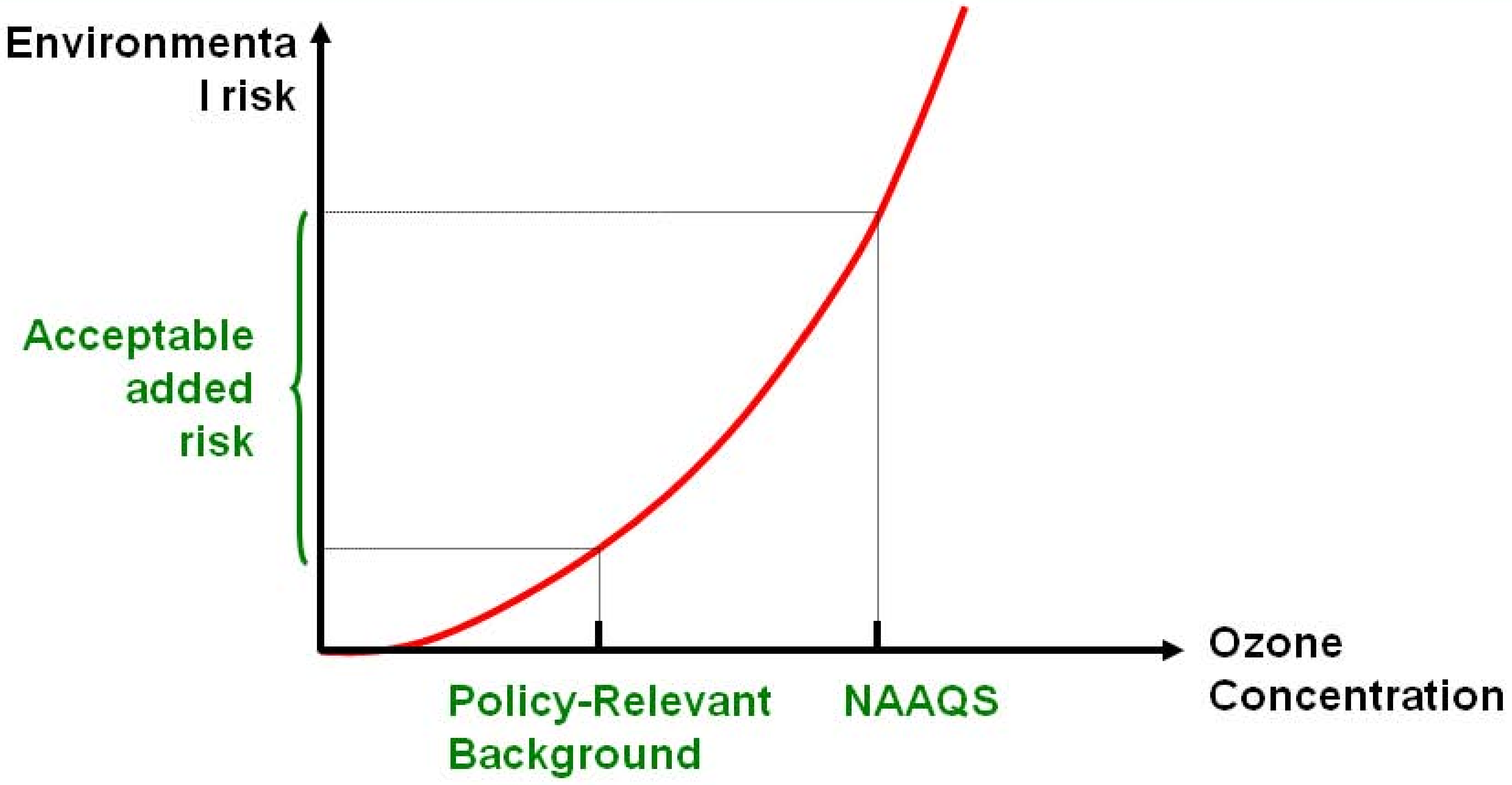
What is the origin of tropospheric ozone?



Number of People Living in U.S. Counties Violating National Ambient Air Quality Standards (NAAQS) in 2001



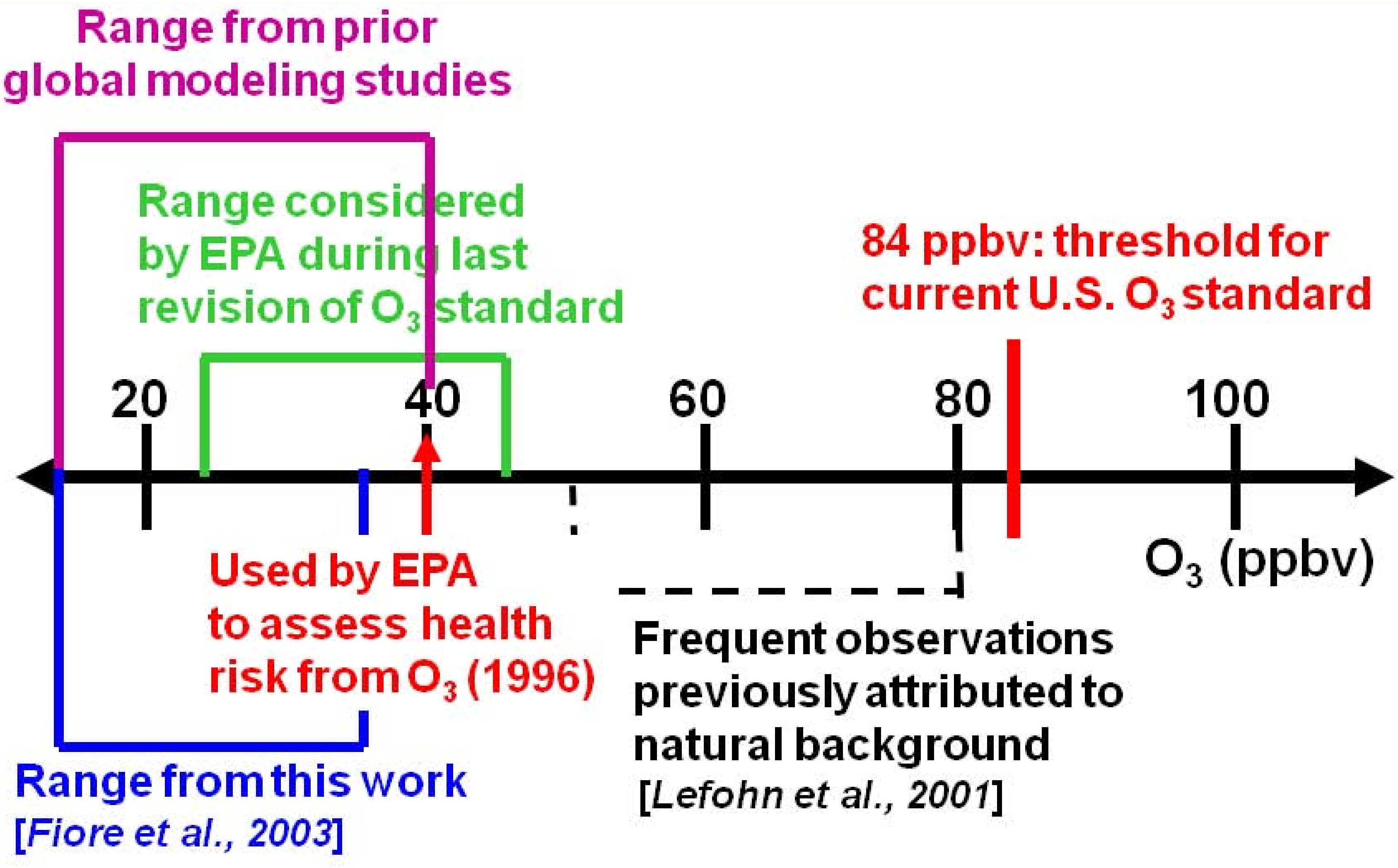
The Risk Increment Above the Background is Considered when setting the NAAQS for Ozone



→Need a quantitative estimate for background ozone

→EPA chose a constant value (40 ppbv) in previous review of O_3 standard

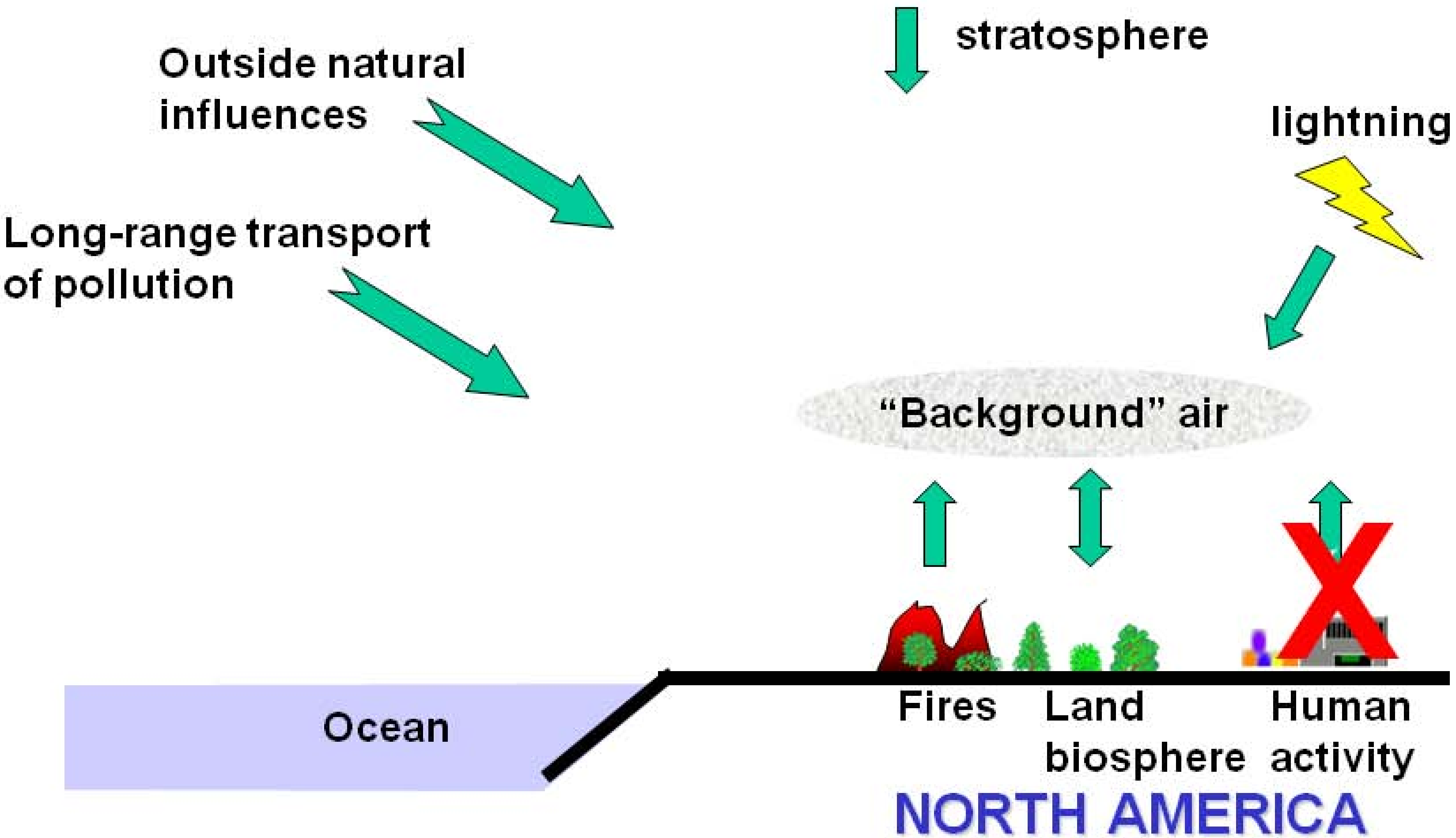
Range of "background O_3" estimates in U.S. surface air



The U.S. EPA considers background levels when setting the NAAQS

"POLICY RELEVANT BACKGROUND" OZONE:

Ozone concentrations that would exist in the absence of anthropogenic emissions from North America [*EPA CD*, 2005]



Policy Relevant Background is not directly observable
→ Must be estimated with models

Approach: Insights from two chemical transport models

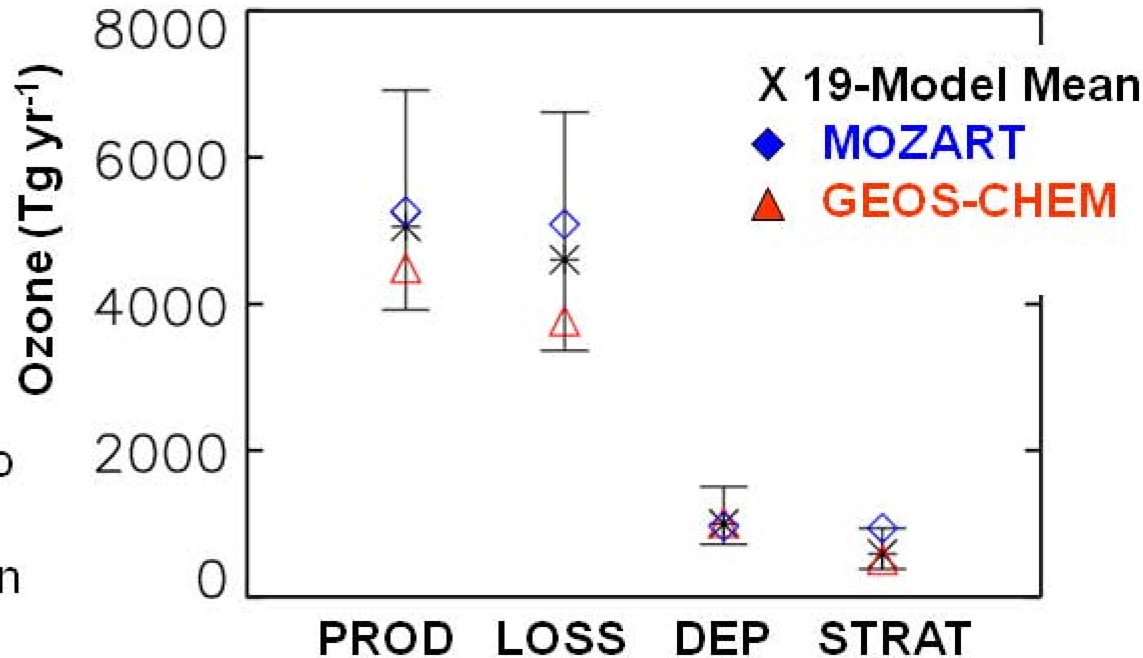
GEOS-CHEM
[*Bey et al.*, 2001]

- GEOS-3 GMAO met
- 2°x2.5°; 30 σ-levels
- Synoz upper boundary

MOZART-2
[*Horowitz et al.*, 2003]

- NCEP meteorology
- T62 (1.9°) ; 28 σ-levels
- Strat O_3 relaxed to climatology

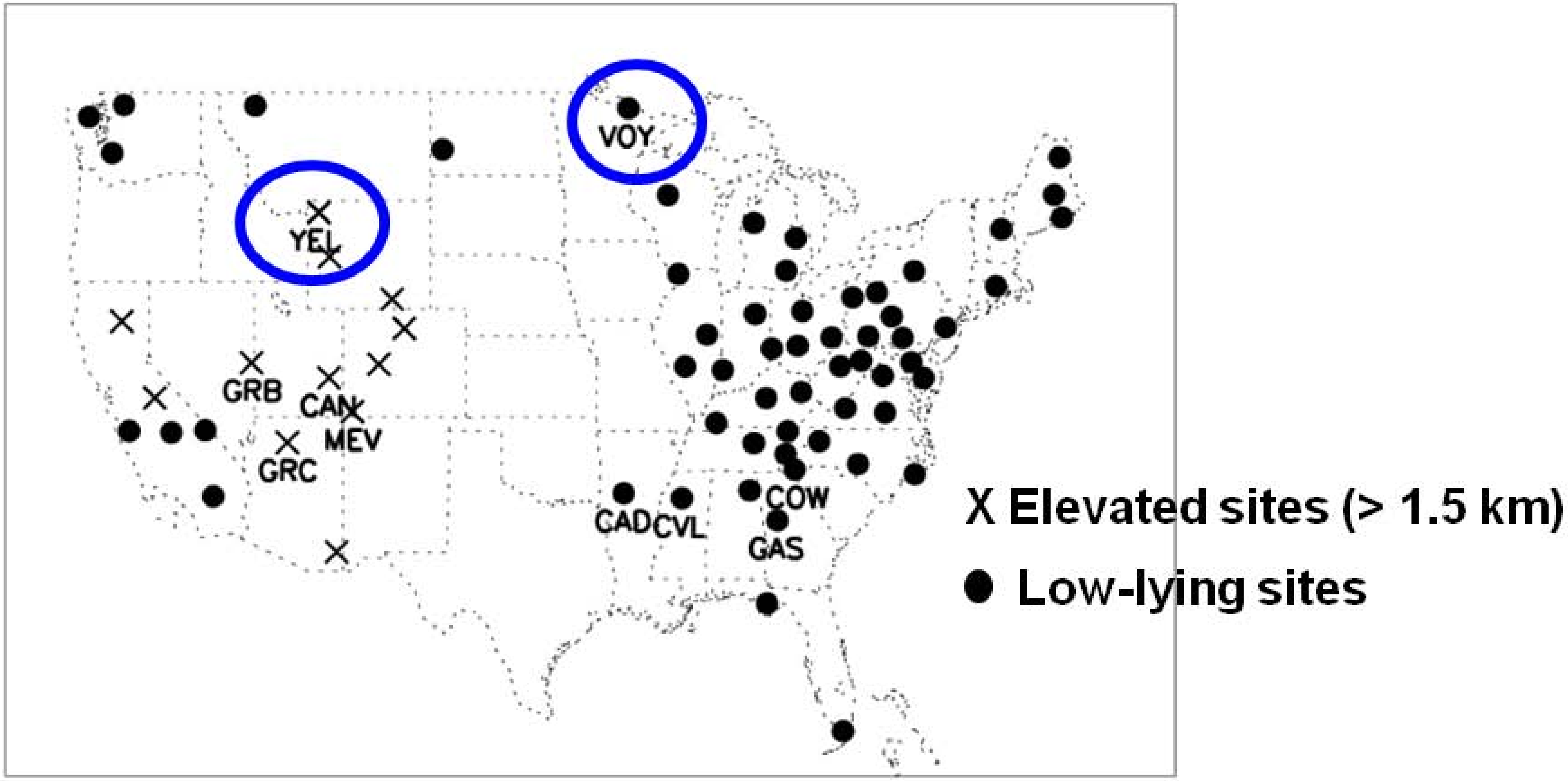
Ozone Budgets in IPCC-AR4 Tropospheric Chemistry Models



- CHASER_CTM
- CHASER_GCM
- FRSGC
- GEOS-CHEM
- GFDL
- GMICCM
- GMIDAO
- gmigis
- LLNL-IMPACT
- LMDzINCA
- LMDzINCAc
- NCAR
- STOCHEM_HadAM3
- TM4
- TM5
- UM_CAM
- MOZECH
- STOCHEM_HadGEM
- ULAQ

AR4 budgets c/o
Jérôme Drevet
David Stevenson
Frank Dentener

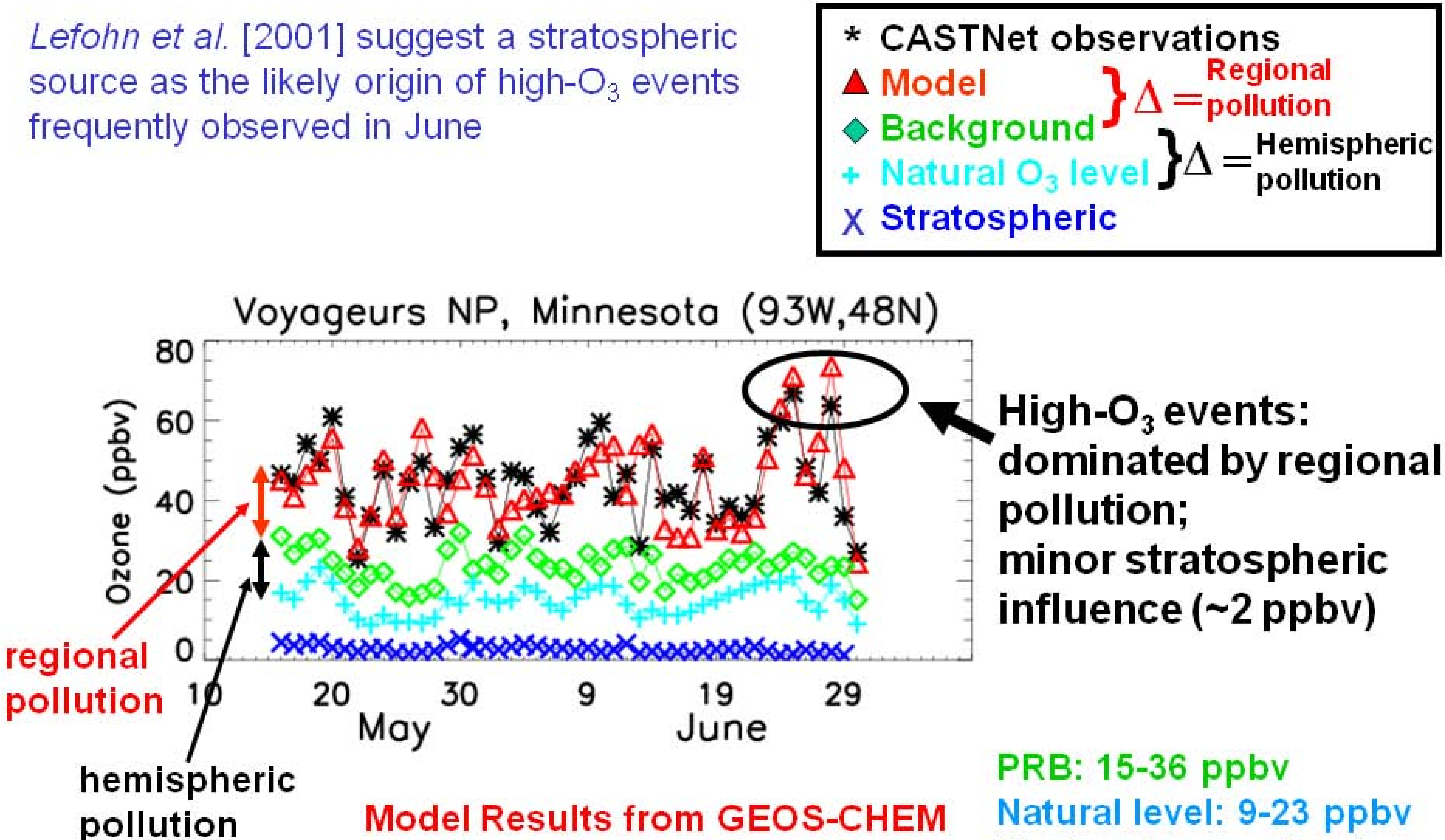
Approach: 2001 CASTNet Observations (EPA, NPS)



1. quantify PRB O_3 and its various sources
2. diagnose origin of springtime high-O_3 events at remote U.S. sites, previously attributed to natural, stratospheric influence

Case Study #1: Voyageurs National Park, Minnesota (May-June 2001)

Lefohn et al. [2001] suggest a stratospheric source as the likely origin of high-O_3 events frequently observed in June



High-O_3 events: dominated by regional pollution; minor stratospheric influence (~2 ppbv)

Model Results from GEOS-CHEM

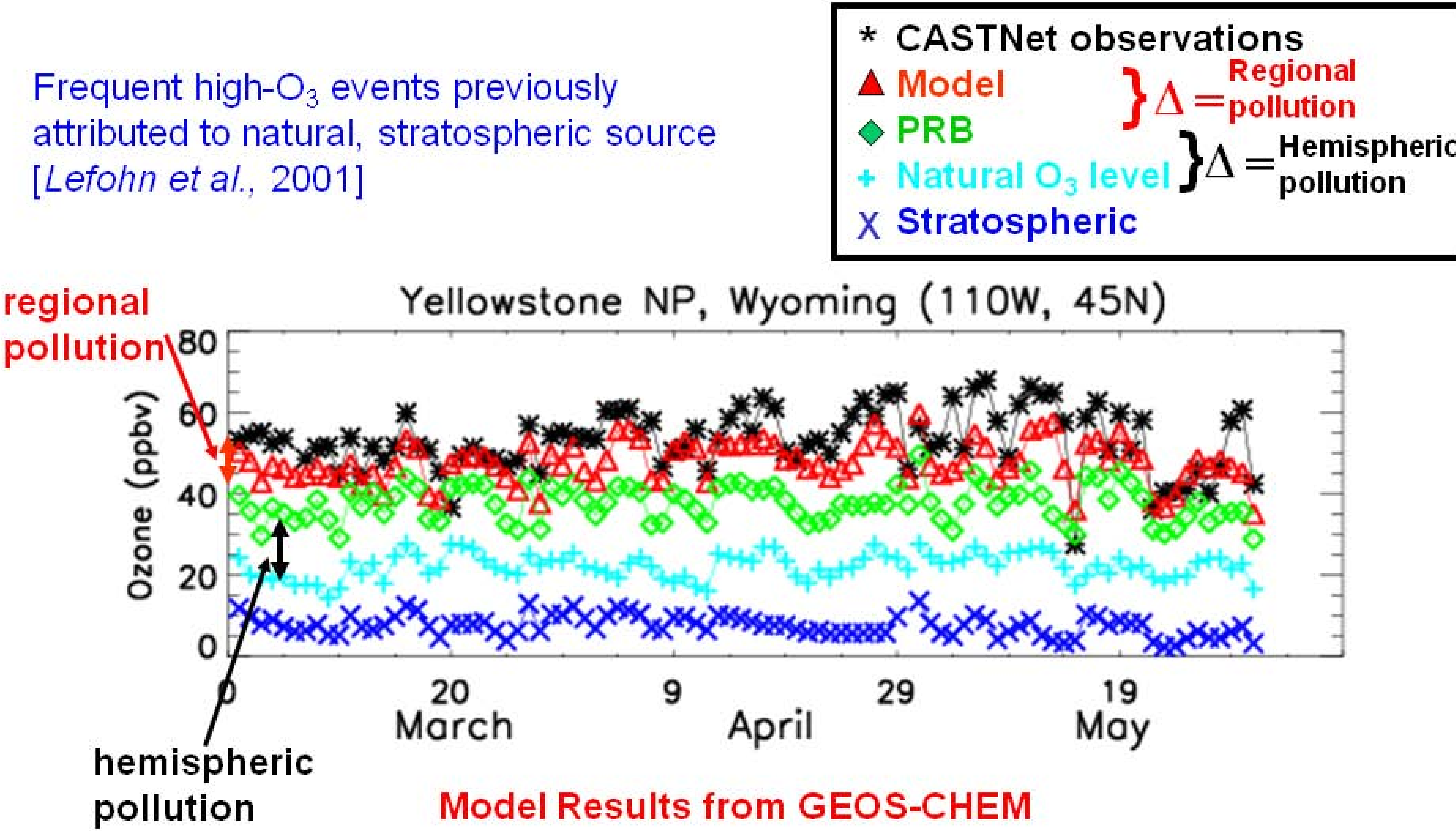
PRB: 15-36 ppbv

Natural level: 9-23 ppbv

Stratosphere: < 7 ppbv

Case Study #2: Yellowstone National Park, Wyoming (March-May 2001)

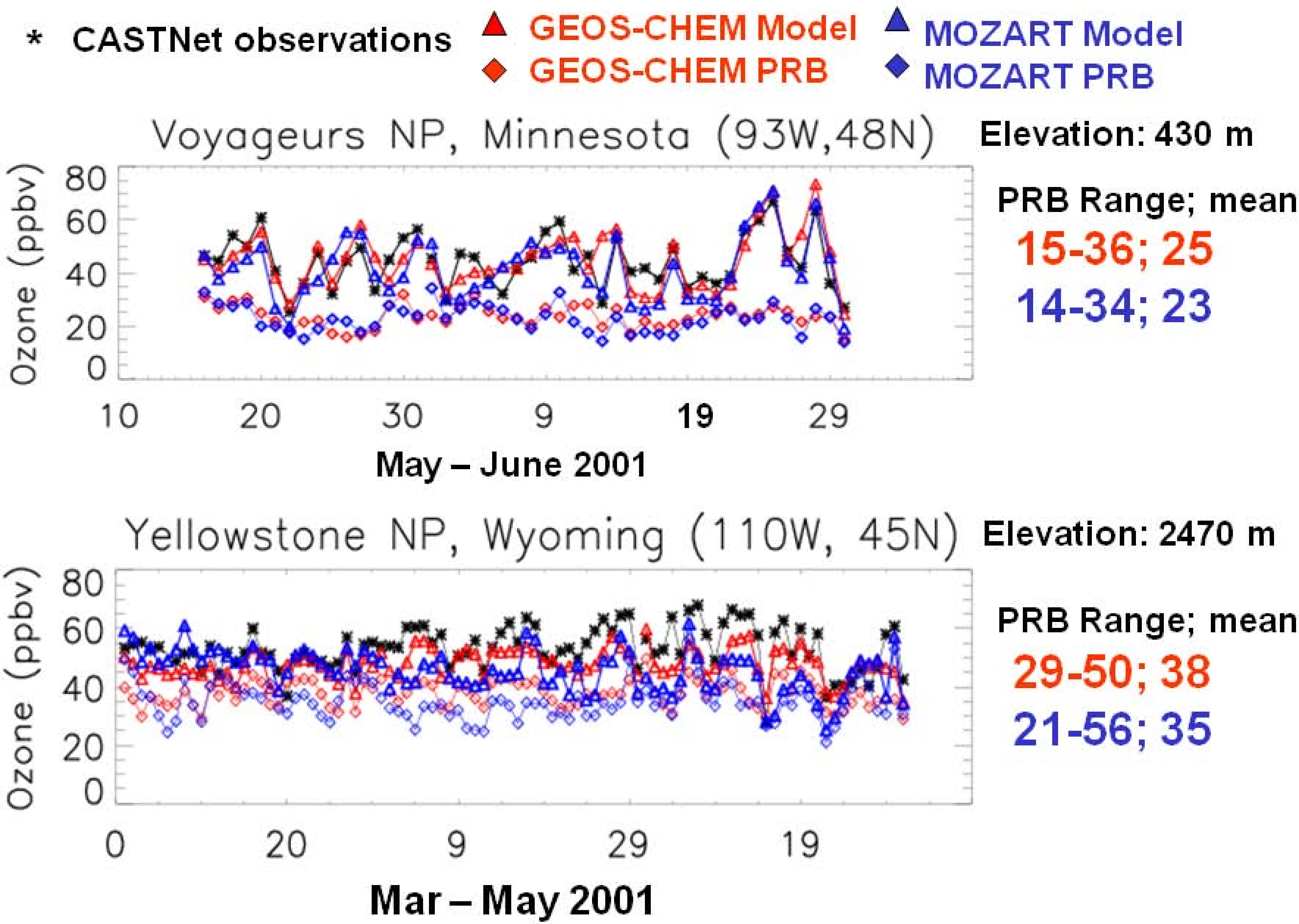
Frequent high-O_3 events previously attributed to natural, stratospheric source [*Lefohn et al.*, 2001]



Model Results from GEOS-CHEM

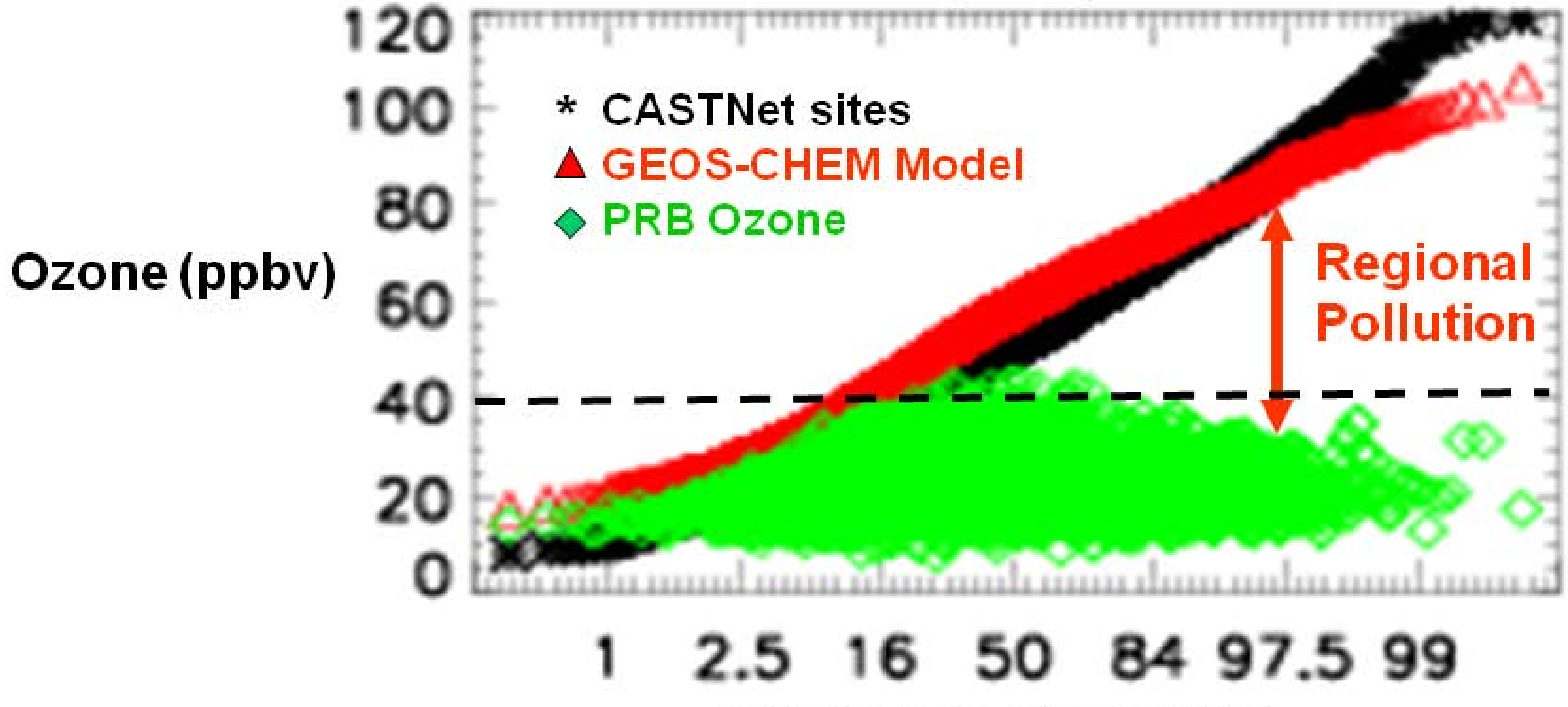
Background at high-altitude site (2.5 km) not necessarily representative of background contribution at low-lying sites

Both models show that PRB ozone is higher at high-altitude site



PRB ozone is lower under polluted conditions: typically below 25 ppbv

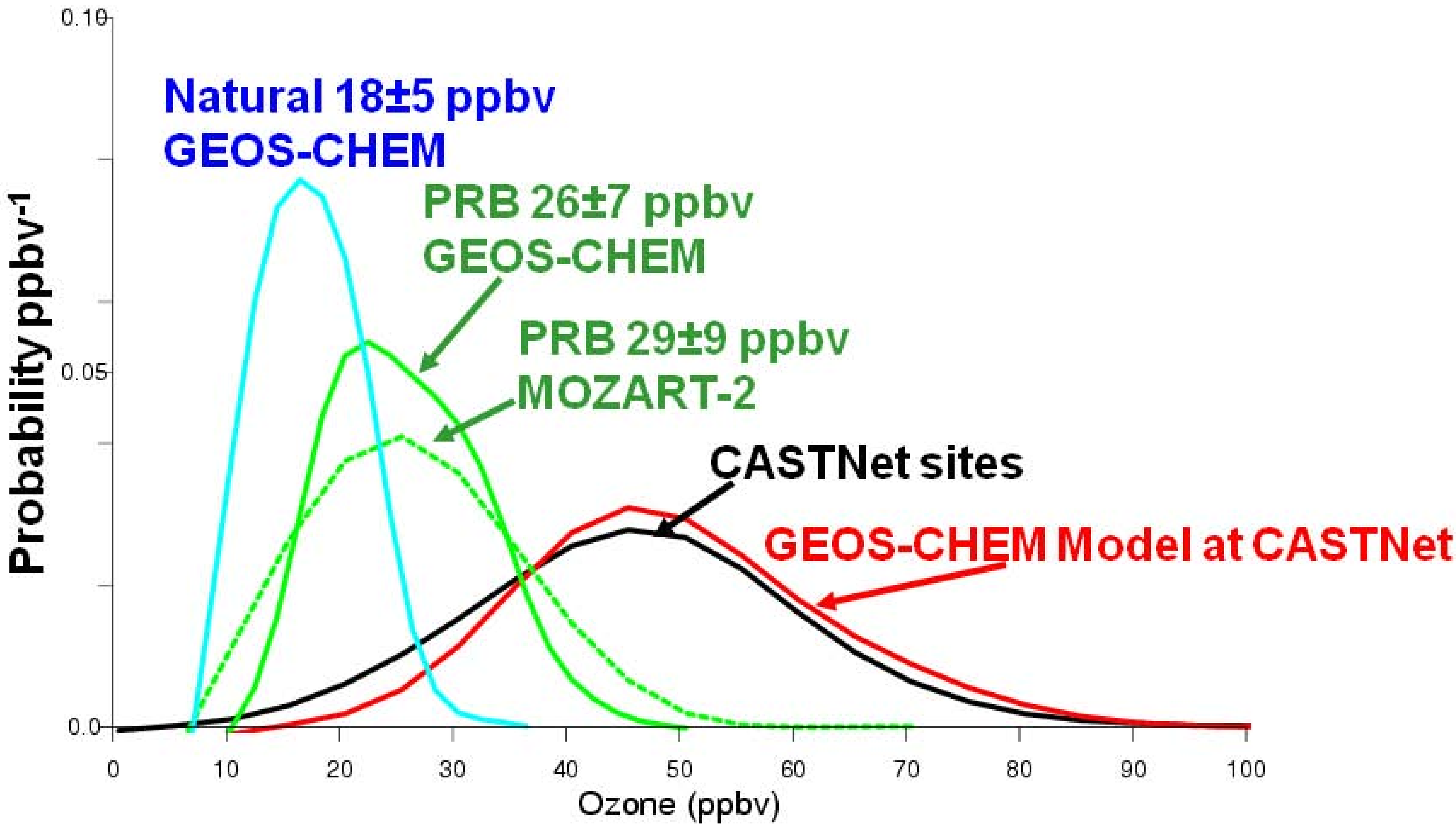
Daily mean afternoon O_3 at 58 low-elevation U.S. CASTNet sites
June-July-August



→ Assuming constant 40 ppbv background underestimates health risks on most polluted days

Compiling daily afternoon (1-5 p.m. mean) surface ozone from all CASTNet sites for March-October 2001:

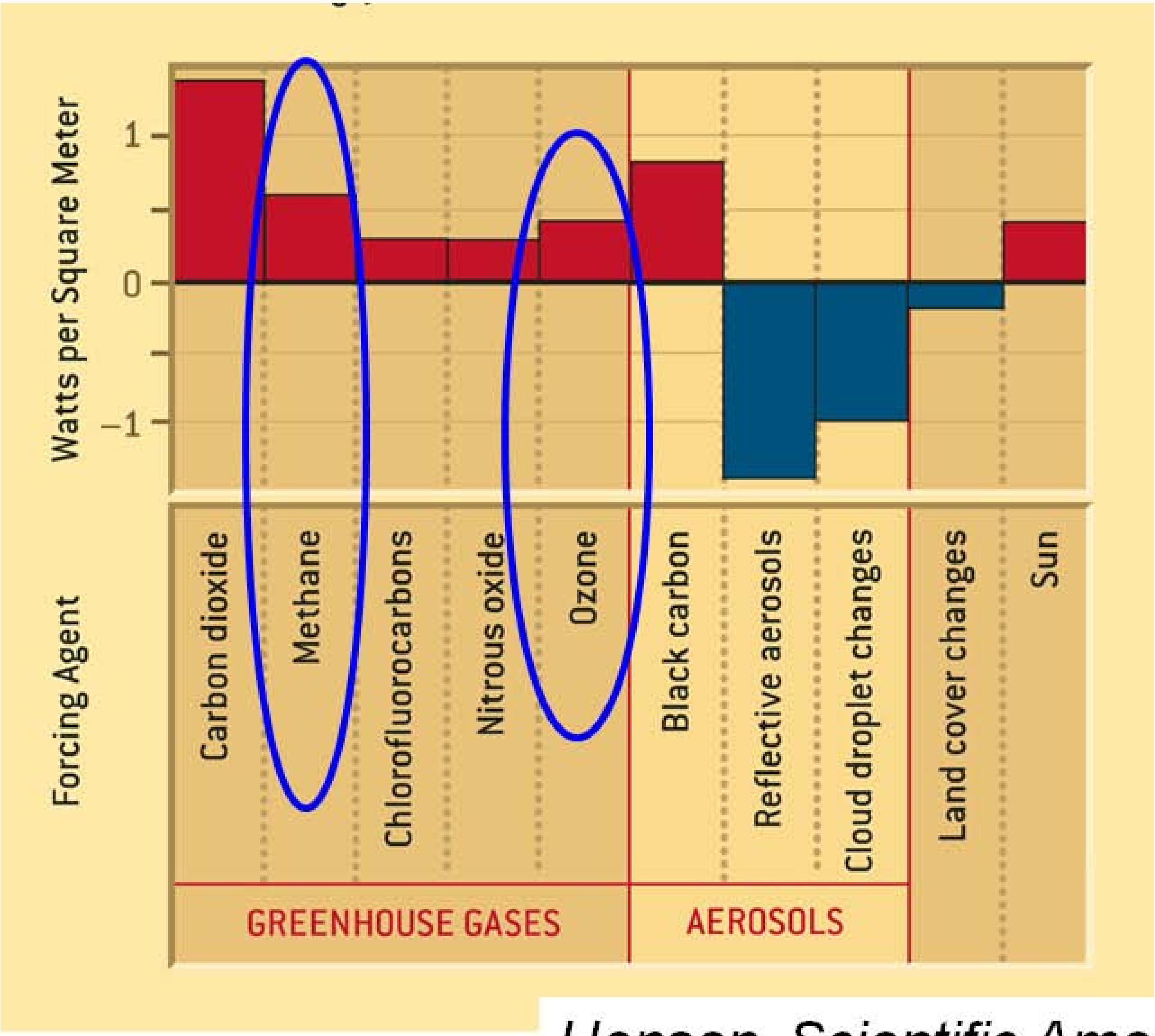
PRB ozone is typically 20-35 ppbv



→Hemispheric Pollution enhances U.S. PRB by 8±4 ppbv

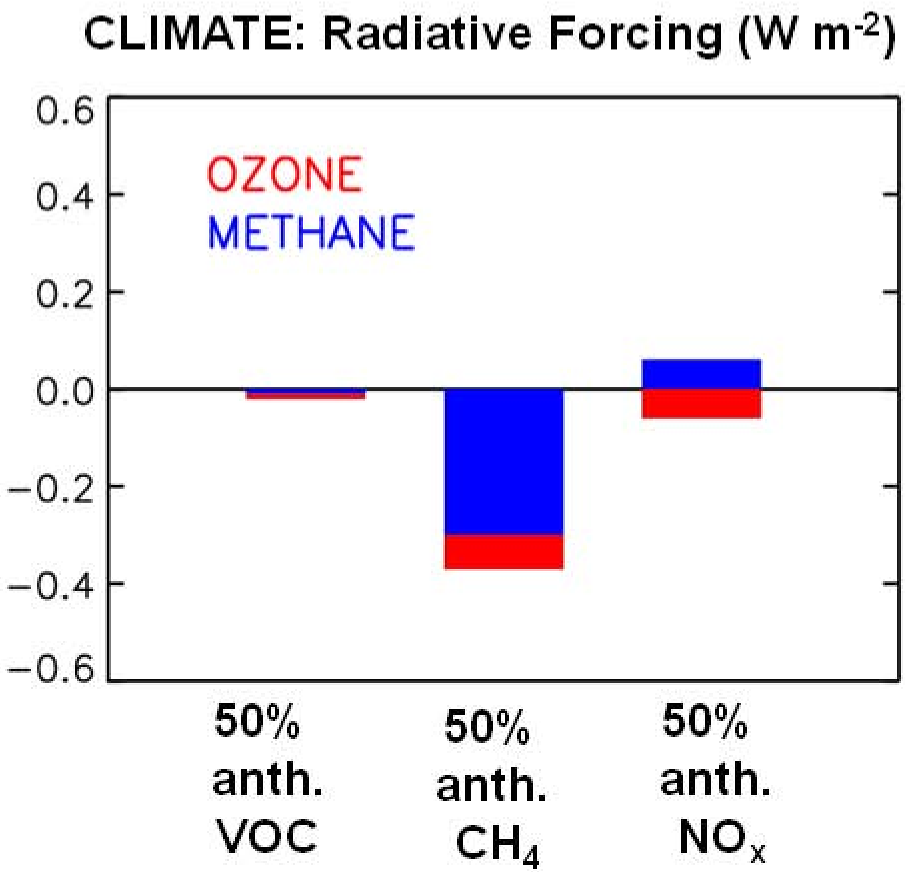
→Prior work suggests 6 ppbv from anthrop. CH_4 on average

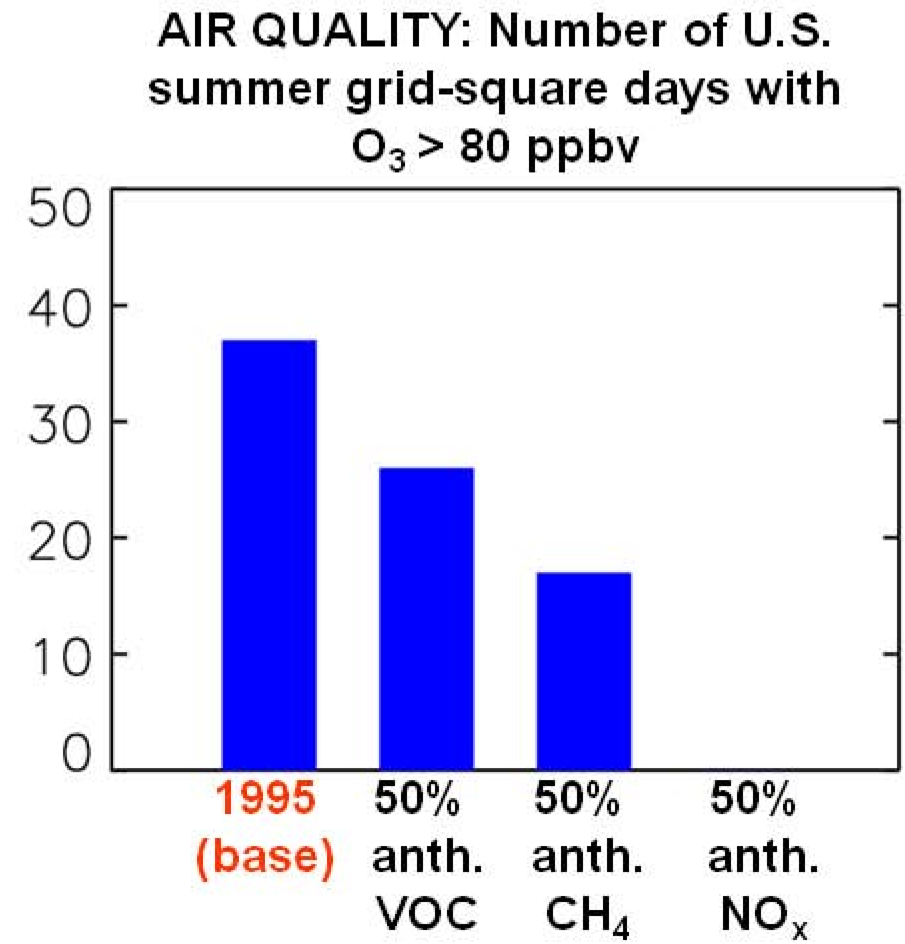
Radiative Forcing of Climate from Preindustrial to Present: Important Contributions from Methane and Ozone



Hansen, *Scientific American*, 2004

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

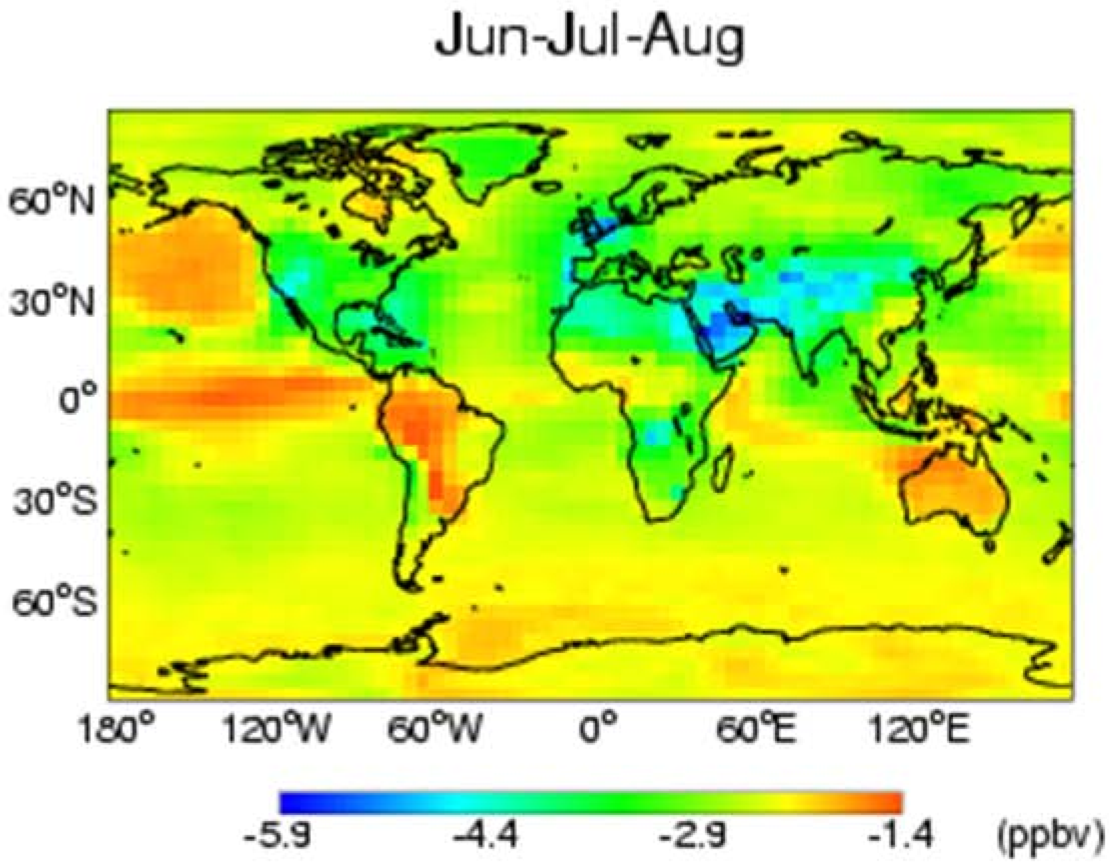




→ Methane links air quality and climate via background ozone

Fiore et al., GRL, 2002

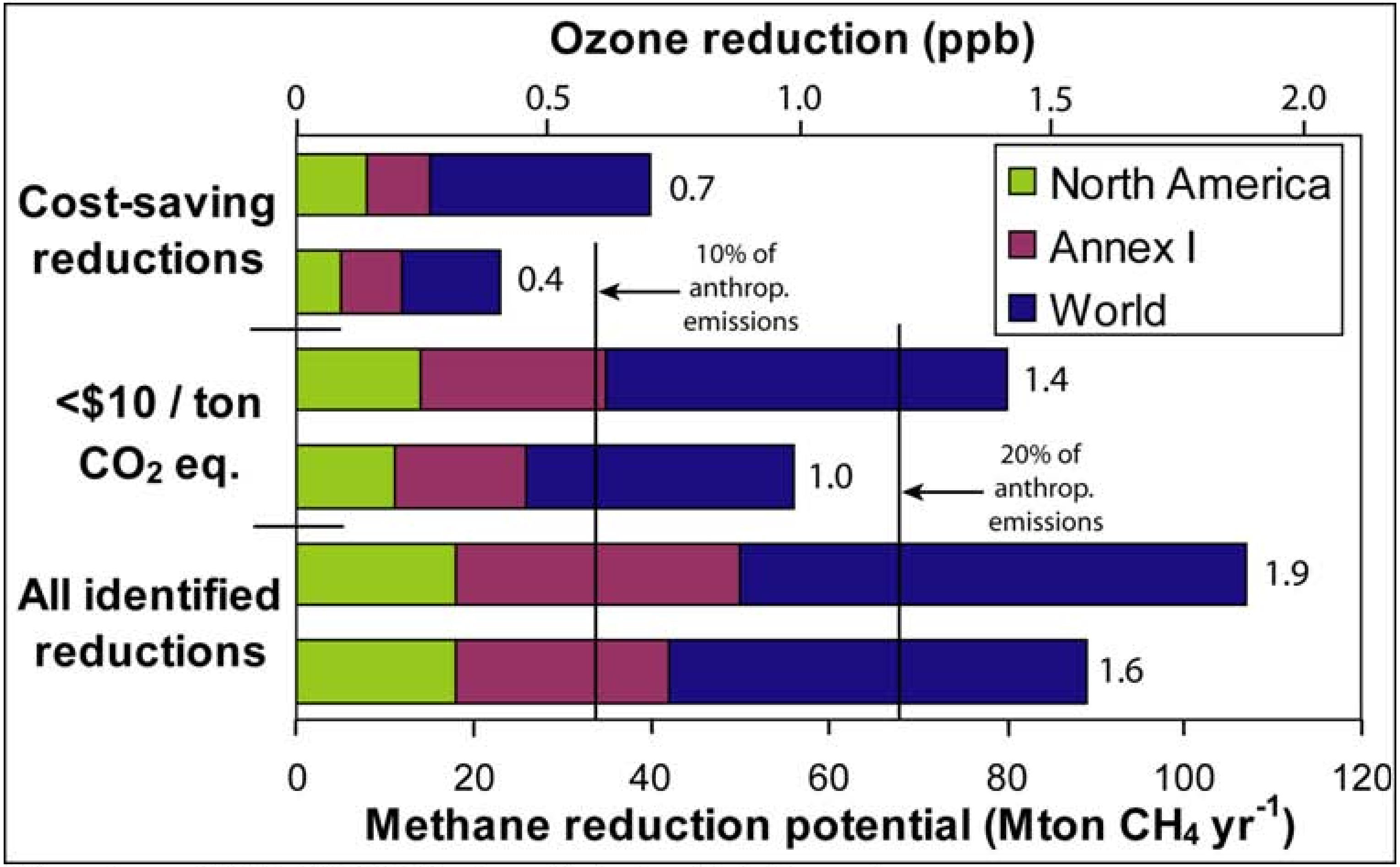
Response of Global Surface Ozone to 50% decrease in global methane emissions (actually changing uniform concentration from 1700 to 1000 ppbv)



- Ozone decreases by 1-6 ppb
- ~3 ppb over land in US summer

** ~60% of reduction in 10 yr; ~80% in 20 yr.

How Much Methane Can Be Reduced?

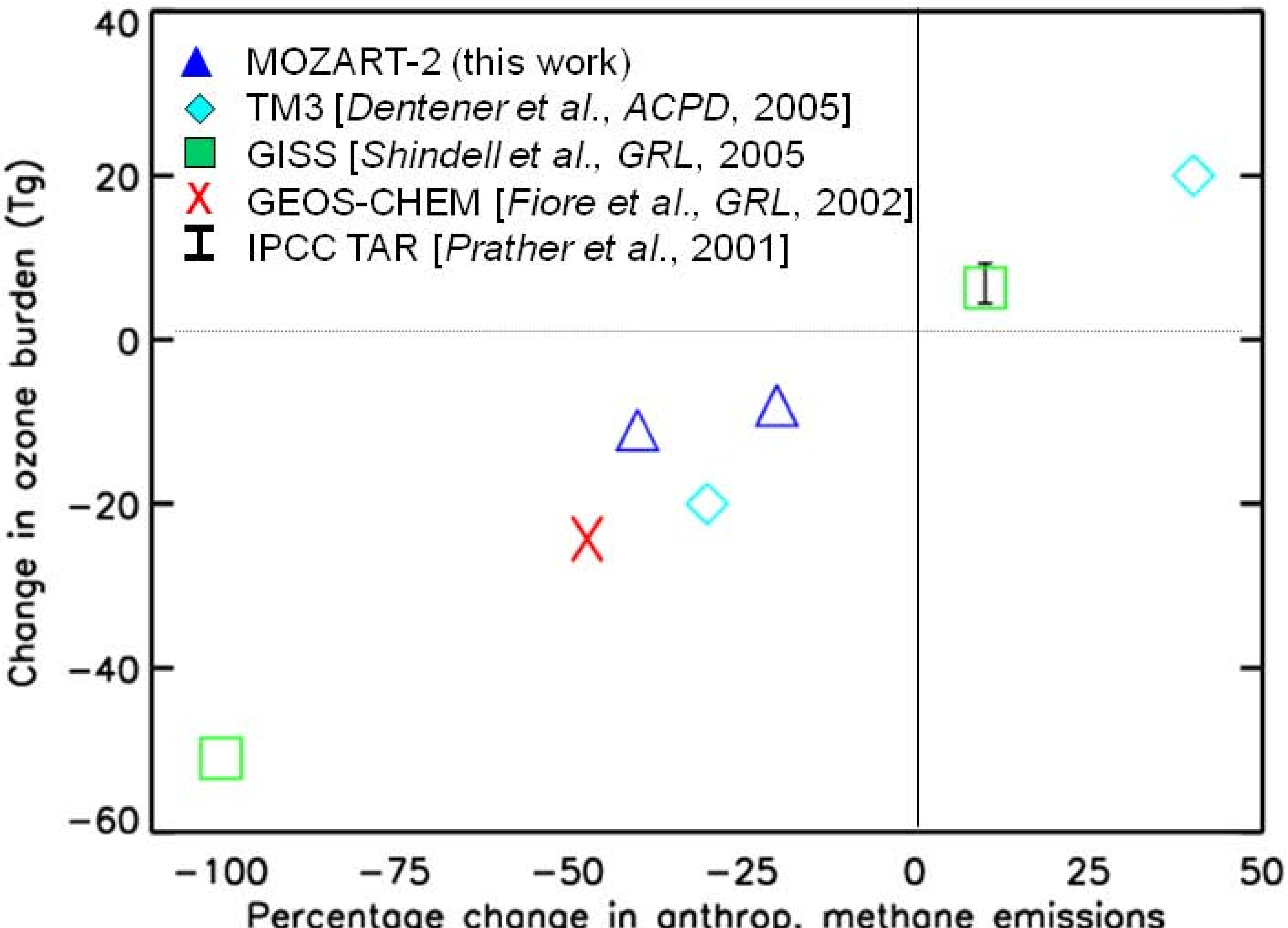


Top bar: IEA (2003), for 5 industrial sectors.
Lower bar: EPA (2003), for 4 industrial and 1 agricultural sector.

Comparison: Clean Air Interstate Rule (proposed) reduces 0.86 ppb over the eastern US, at \$0.88 billion yr^{-1}, through NO_X control.

West & Fiore, ES&T, 2005

Tropospheric ozone response to anthropogenic methane emission changes is fairly linear



Shindell et al., 2005 report that tropospheric ozone responds linearly to 10, 25, 50, 75, 100% decreases in anthropogenic CH_4

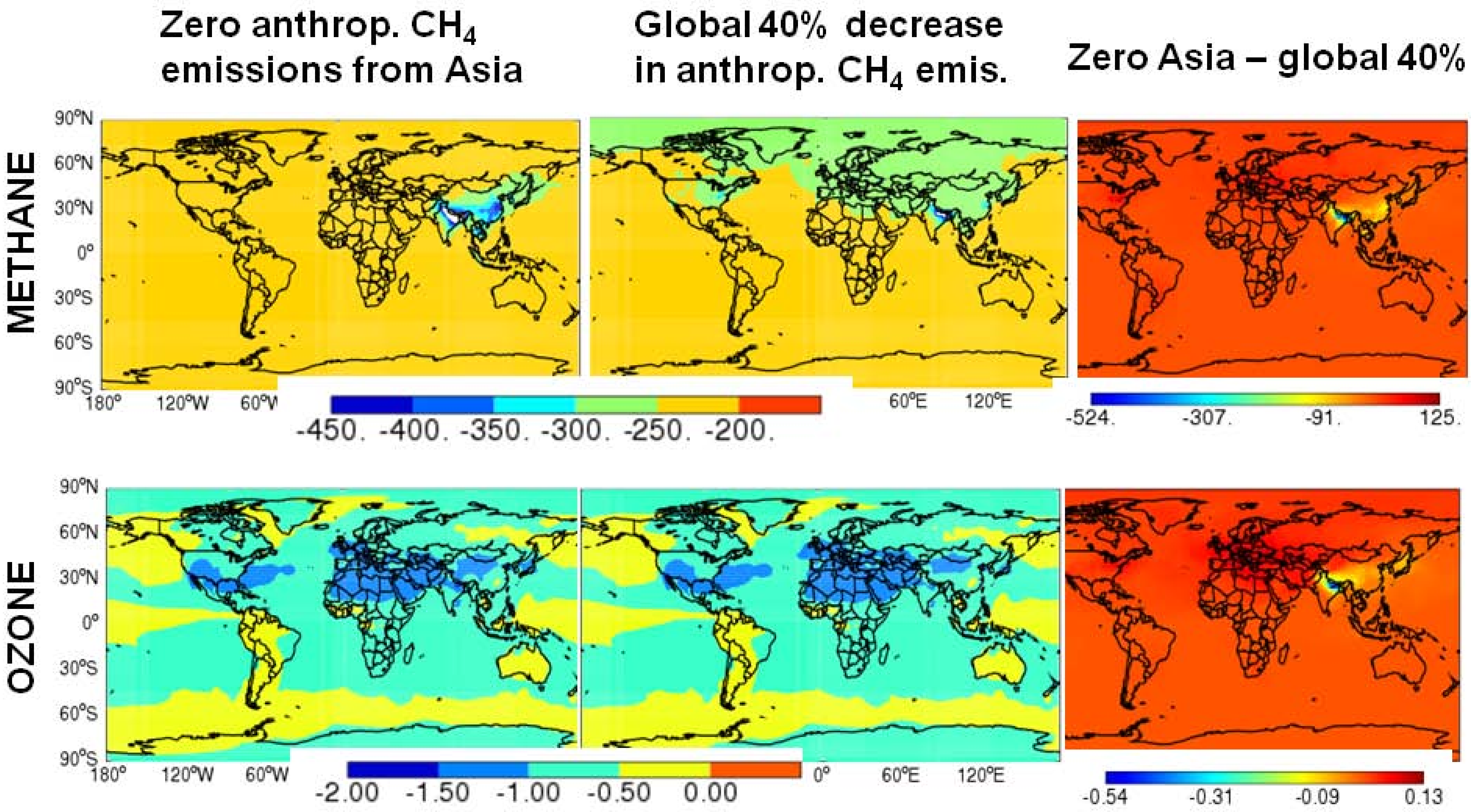
Methane Emissions in EDGAR inventory early 1990s; Tg CH_4 yr^{-1}

Anthropogenic	Energy, landfills, wastewater	95
	Ruminants	93
	Rice	60
	Biomass burning	86
Natural	Ocean	10
	Biogenic	204
	TOTAL	547

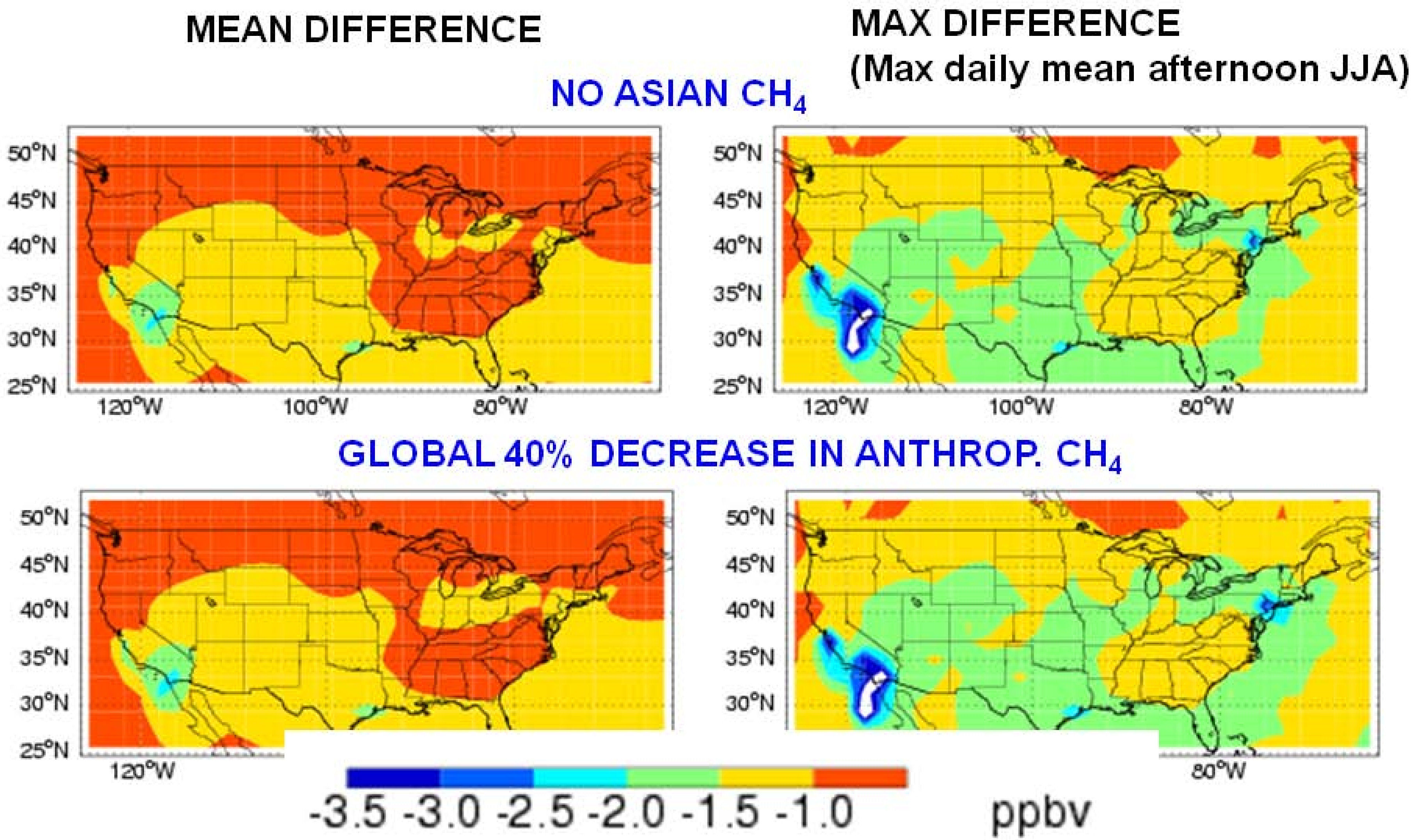
→ Are ozone decreases independent of CH_4 source location?

Cut Global Anthropogenic by 40%: (1) All in Asia
(2) Everywhere in the globe

July 2000 surface O_3 change mainly independent of CH_4 source location, slightly larger response in source region (Transient simulations with EDGAR 1990 emissions, beginning 1990)



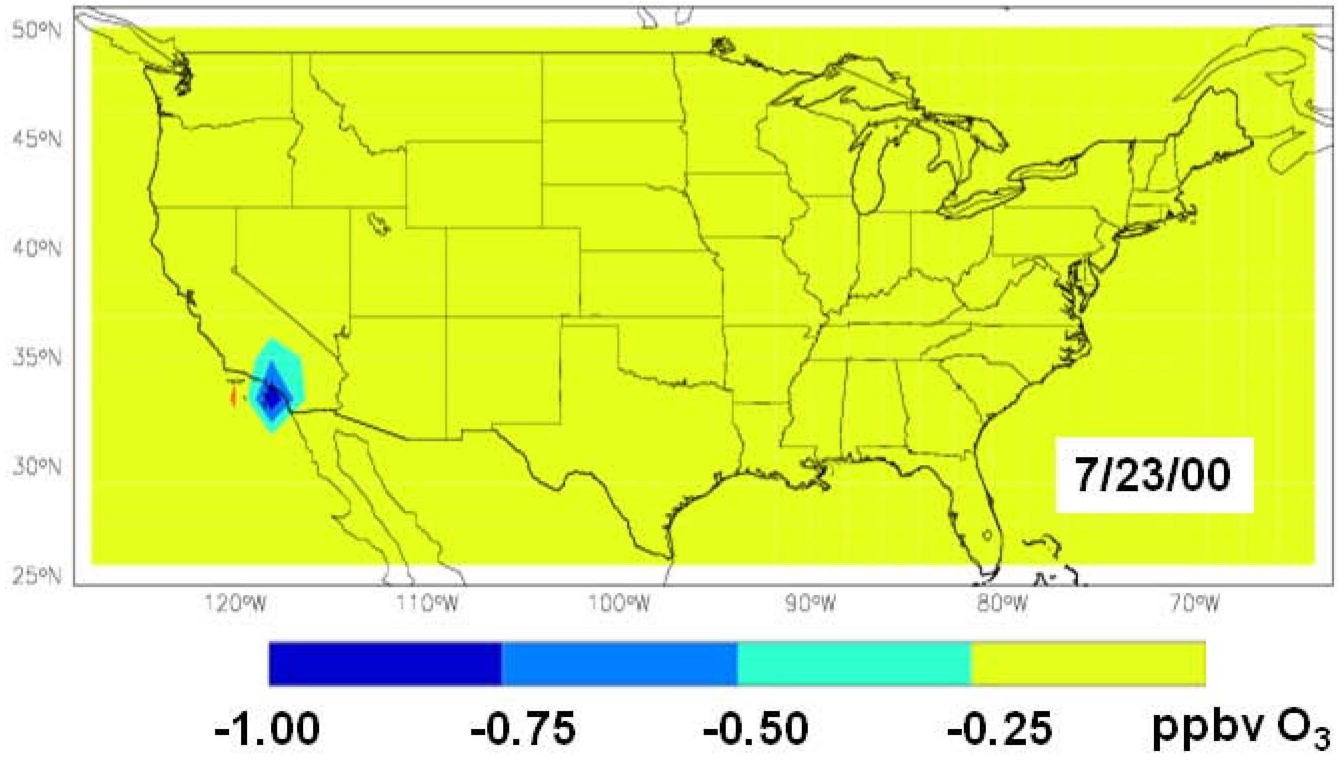
U.S. Surface Afternoon Ozone Response in Summer also independent of methane emission location



→ Stronger Sensitivity in NO_x-saturated regions (Los Angeles)

Local CH_4 oxidation contributes up to ~30% of the total decrease in surface O_3 from lowering CH_4 concentrations in a NO_x-saturated region

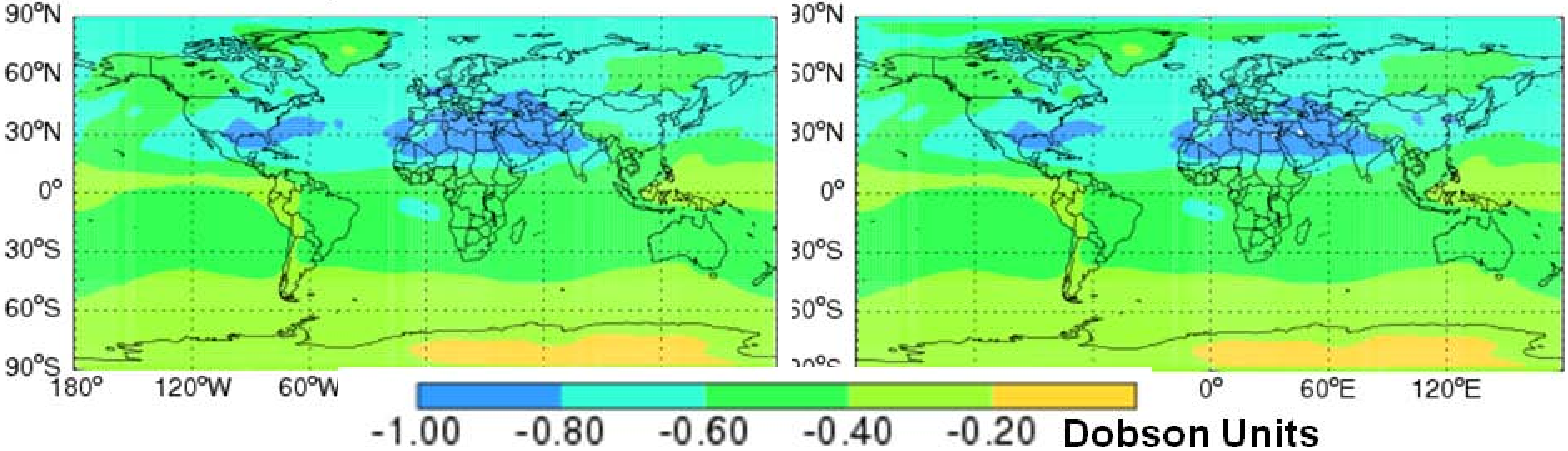
Change in MOZART-2 surface afternoon (1-5 p.m.) O_3 concentration after 1 day, when a 300 ppbv decrease in CH_4 concentrations is imposed below 800 hPa in Los Angeles



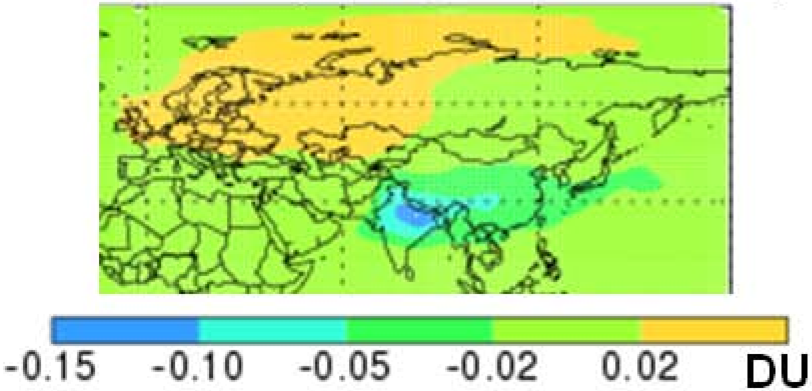
CLIMATE IMPACTS: Change in July 2000 Trop. O_3 Columns (to 200 hPa)

40% decrease in global anthrop. CH_4 emissions

Zero CH_4 emissions from Asia (= 40% decrease in global anthrop.)



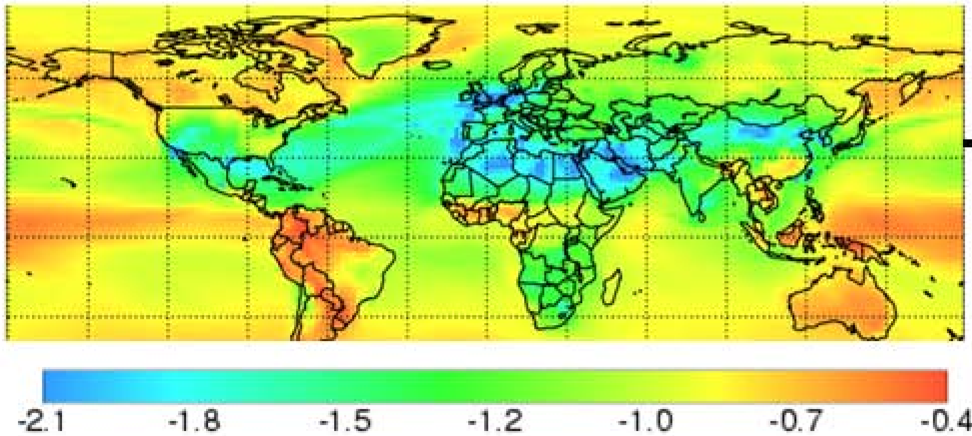
No Asia – (40% global decrease)



Tropospheric O_3 column response is independent of CH_4 emission location except for small (~10%) local changes

AIR POLLUTION IMPACTS: 2030 Avoided Premature Mortalities (A2 scenario - 65 Tg CH_4 emissions)

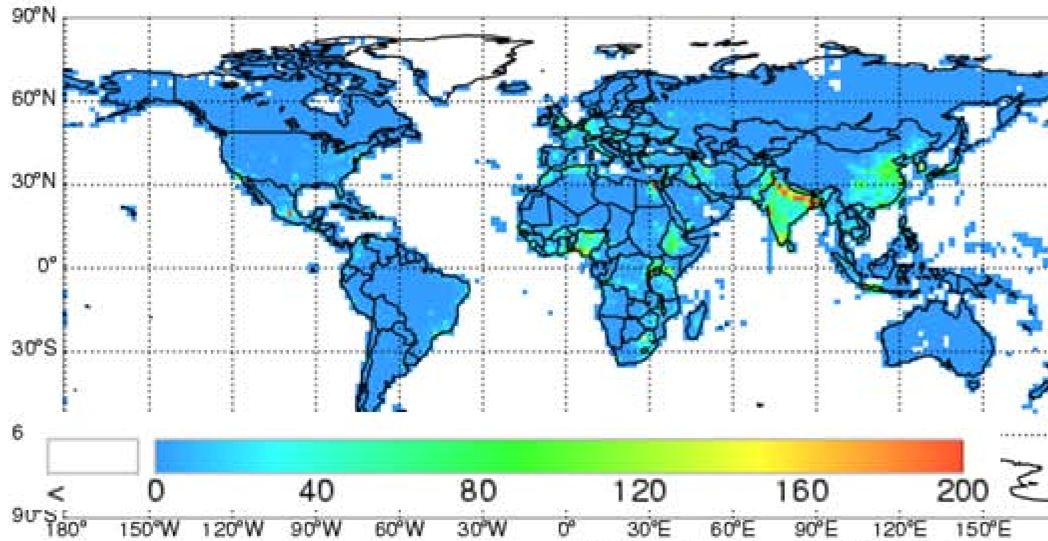
Change in 8-hr summer surface ozone from a 20% decrease in global anthrop. methane emissions



Assume 25 ppb threshold,

CH_4 reductions starting in 2000

Avoided Mortalities in 2030



West et al., 2005

Reducing anthrop. CH_4 emis. by 20% (starting in 2000):

-- decreases global surface ozone (~1 ppbv in populated areas)

-- prevents ~34,000 premature deaths in 2030

Conclusions

1. Policy-Relevant Background in surface air over the United States:
-- 25±5 ppbv at low-elevation sites in summer
-- varies with season, altitude; anti-correlated with high domestic O_3
-- 8±4 ppbv from hemispheric pollution (~5-7 ppbv from anthr. CH_4)
→40 ppbv previously used by EPA underestimates health risks
→international negotiations to reduce hemispheric background would facilitate compliance with more stringent standards

2. 20% reductions in anthrop. methane emissions possible now:
-- reduce surface ozone globally by ~1 ppbv in populated regions
-- lower global radiative forcing by ~0.13 W m^{-2}
-- avoid 34,000 premature mortalities in 2030

3. Climate and air quality benefits from controls on anthropogenic methane emissions are largely independent of source location
-- small enhancements (~10%) in source region
-- enhanced surface ozone response (up to ~30% total response) to CH_4 changes in NO_x-saturated regions