MOZART Development, Evaluation, and Applications at GFDL

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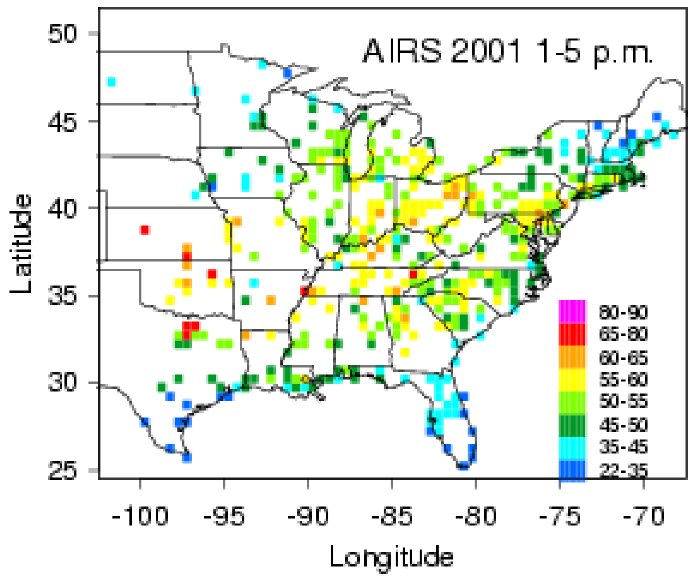
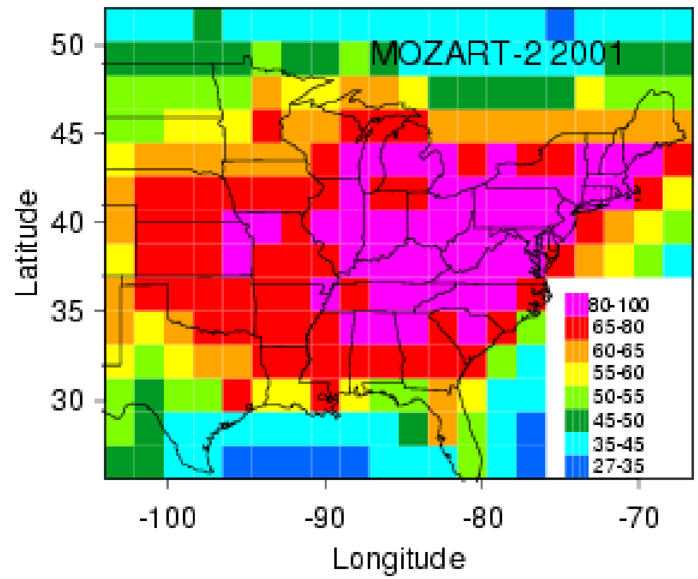
Outline: MOZART Development, Evaluation, and Applications at GFDL

- Surface Ozone Bias over the United States
  - Comparison with observations (EPA AQS; CASTNet)
  - Sensitivity
  - Policy-relevant background
- Evaluation with 2004 ICARTT observations*
- Vertically distributed biomass burning
- Trends (historical, future) in ozone and aerosols
- Methane control for climate and air quality
  - 1990-2004 CMDL CH_4*

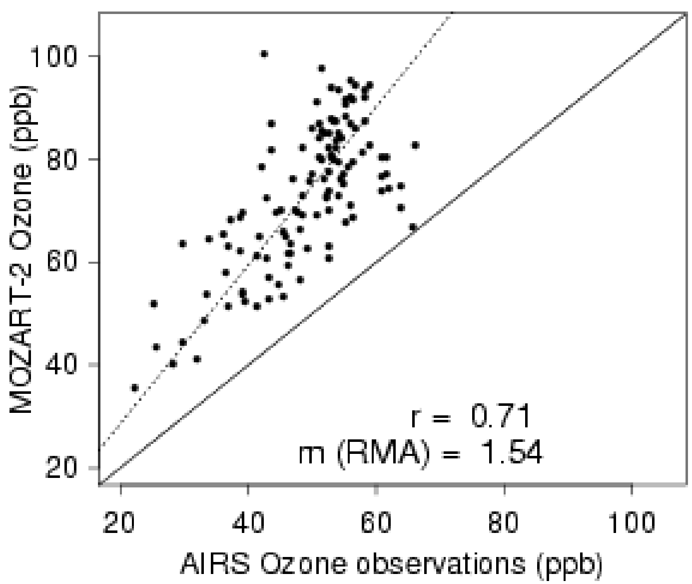
*Special thanks to George Milly, the ICARTT Science Team, CMDL

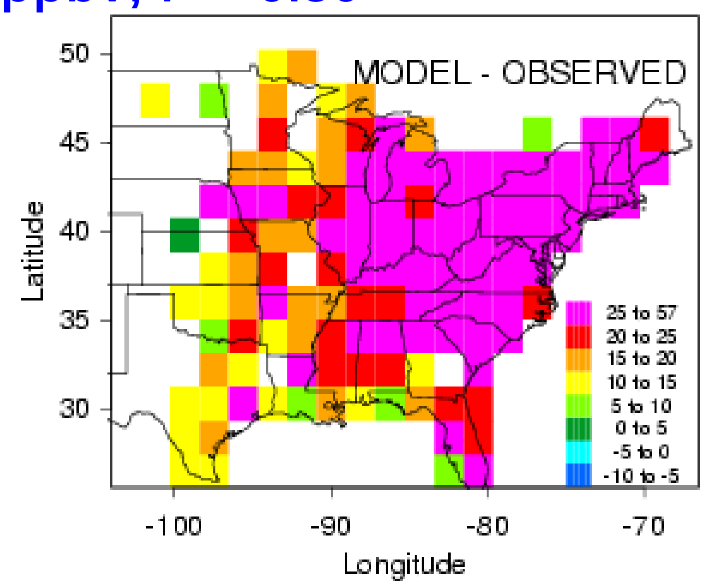
MOZART-2 Comparison with AIRS: July 2001 1-5 p.m. Surface O_3 (ppbv)



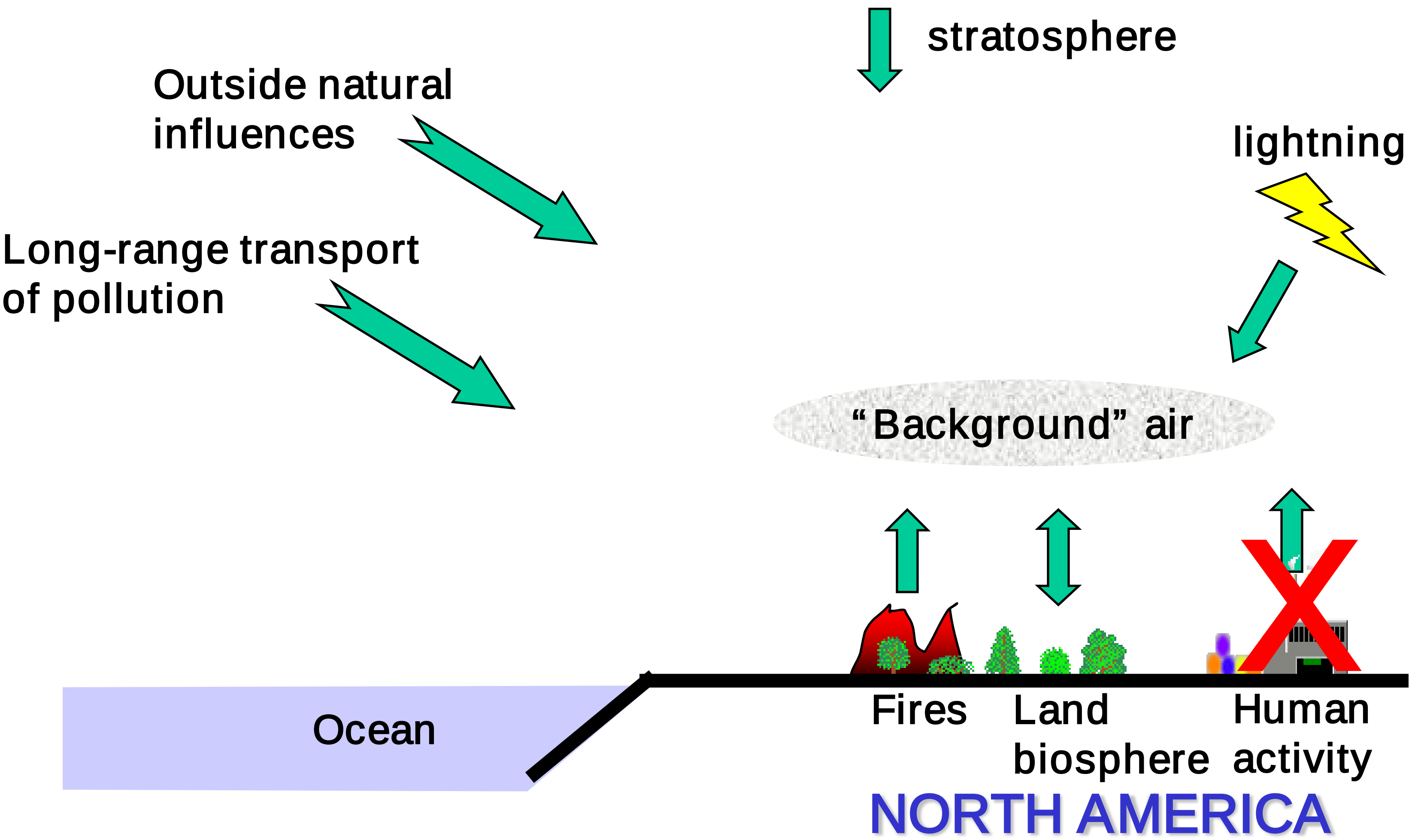


Mean Bias = 24±10 ppbv; r^2 = 0.50





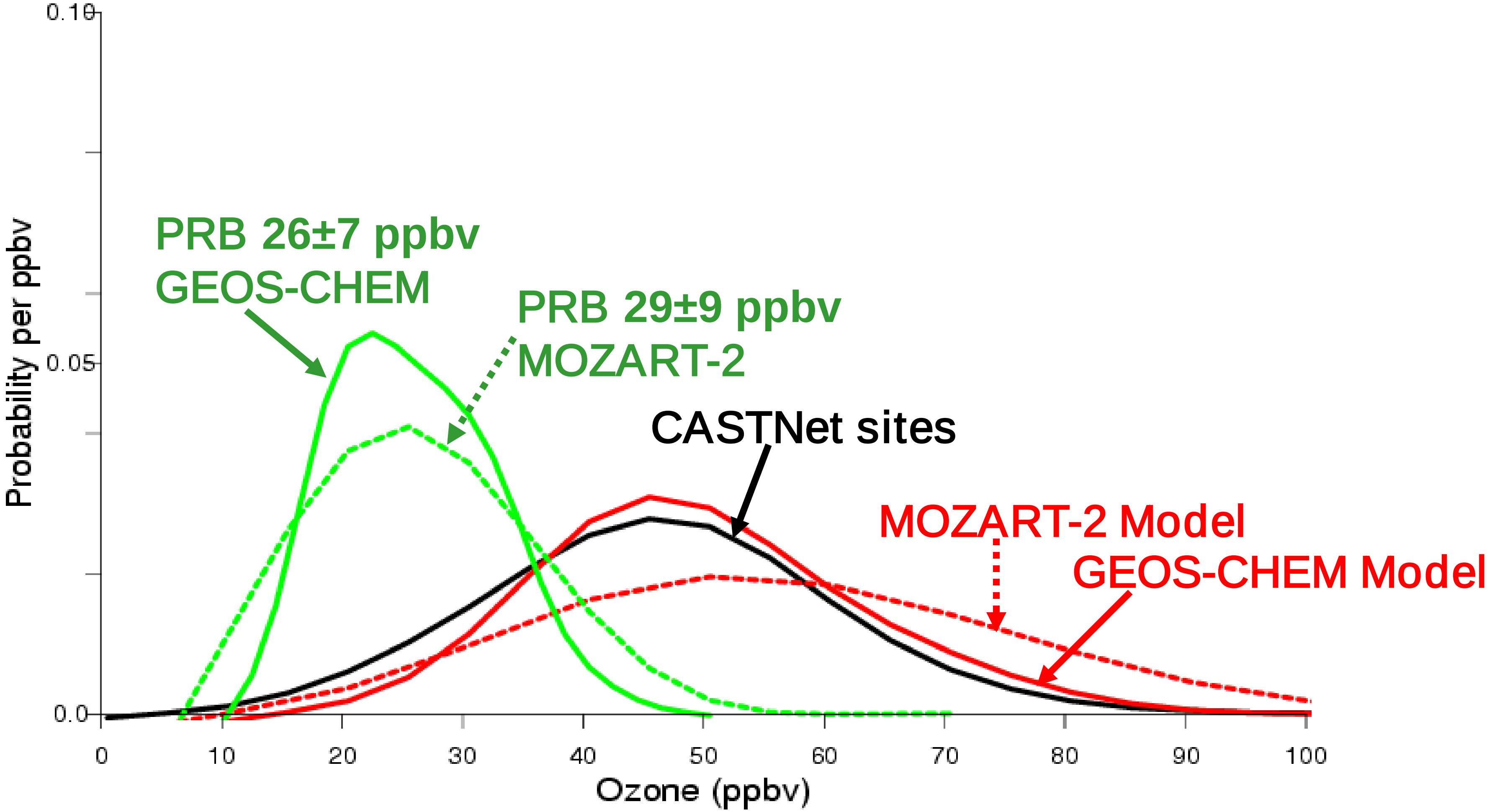
Processes Contributing to Surface Ozone over North America



"POLICY RELEVANT BACKGROUND" (PRB) OZONE:
Ozone concentrations that would exist in the absence of anthropogenic emissions from North America

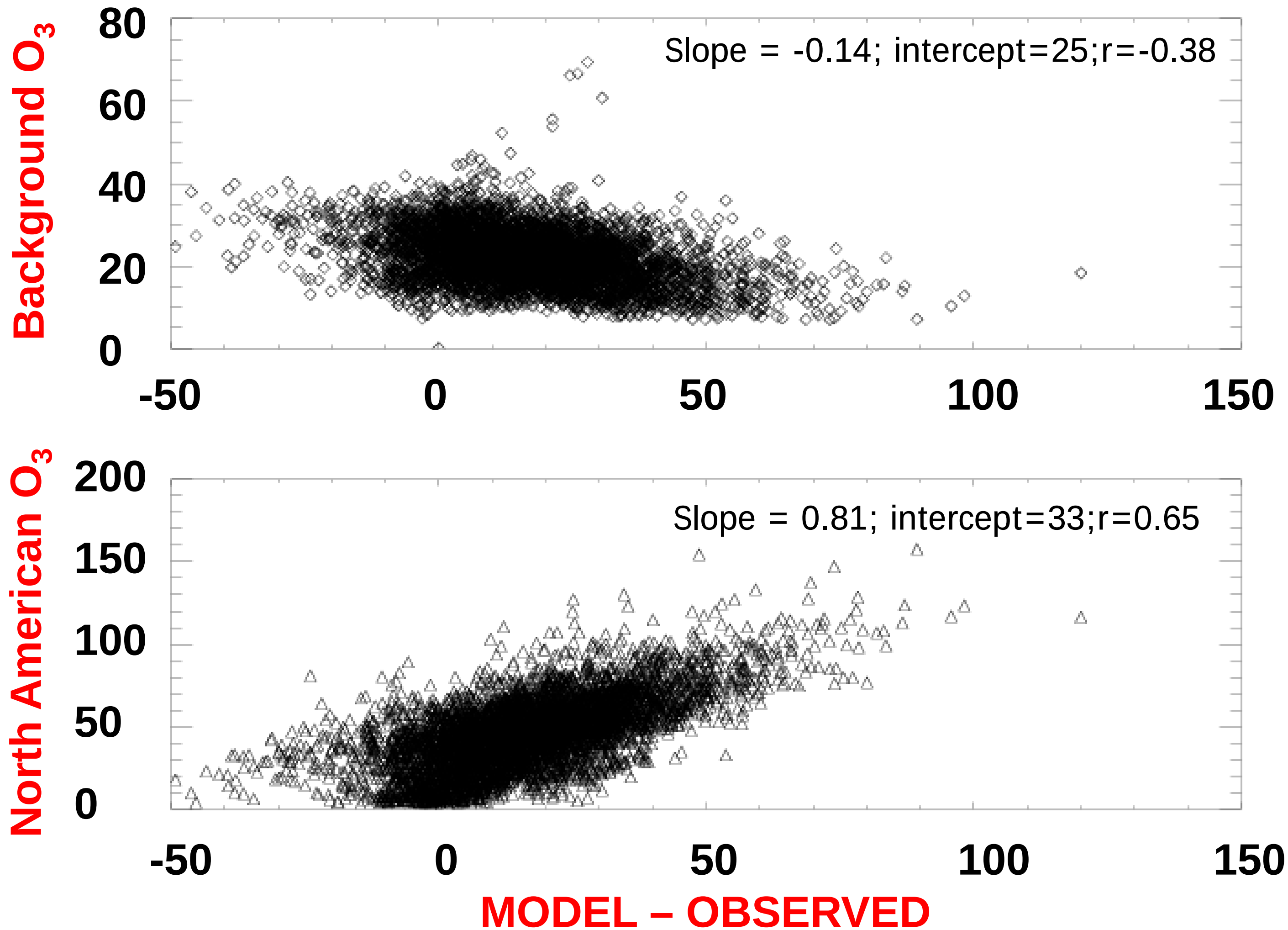
Daily afternoon (1-5 p.m. mean) surface ozone from all CASTNet sites for March-October 2001:

PRB ozone over the U.S. is typically 20-35 ppbv



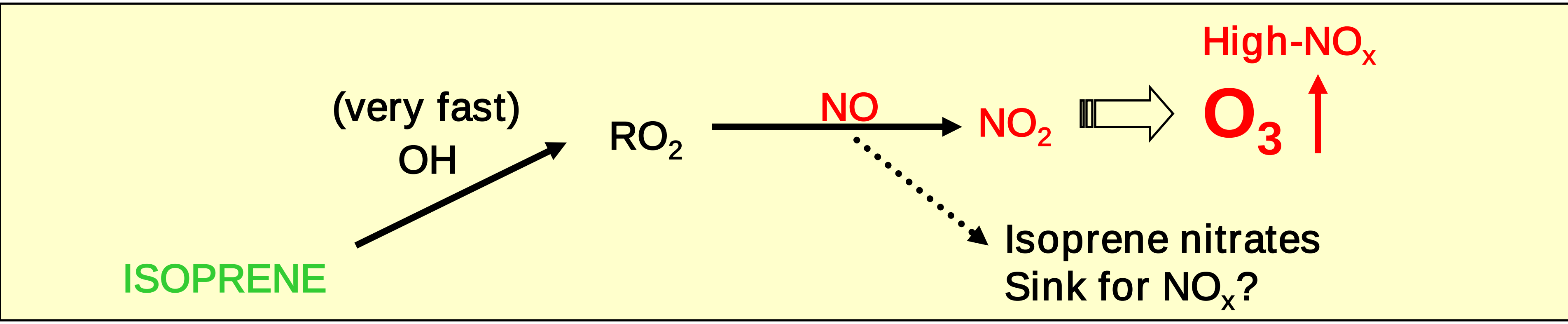
→ **Both models predict consistent PRB range despite large surface O_3 bias in MOZART-2**

MOZART-2 bias associated with domestic ozone production



Daily mean 1-5 p.m. June 1 – Aug 31 at CASTNet stations

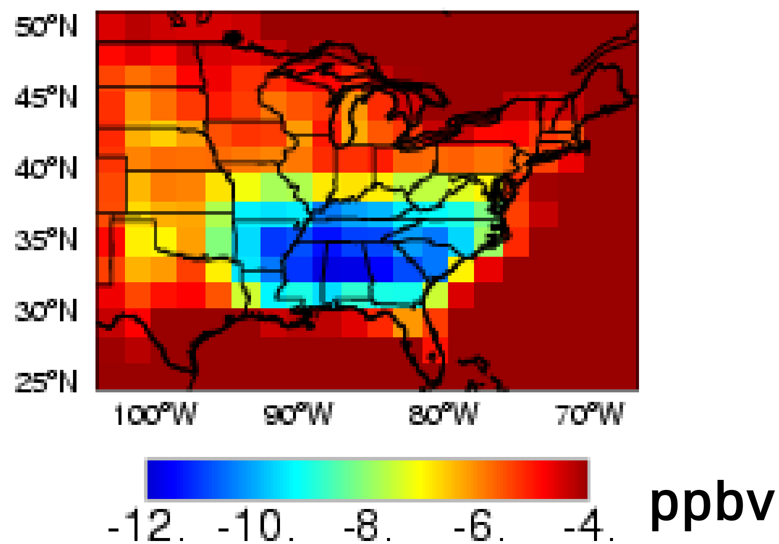
Substantial O_3 sensitivity to the uncertain fate (and yield) of organic isoprene nitrates



Change in July mean 1-5 p.m. surface O_3 when isoprene nitrates (at 12% yield) act as a NO_x sink

→ 4-12 ppbv impact!

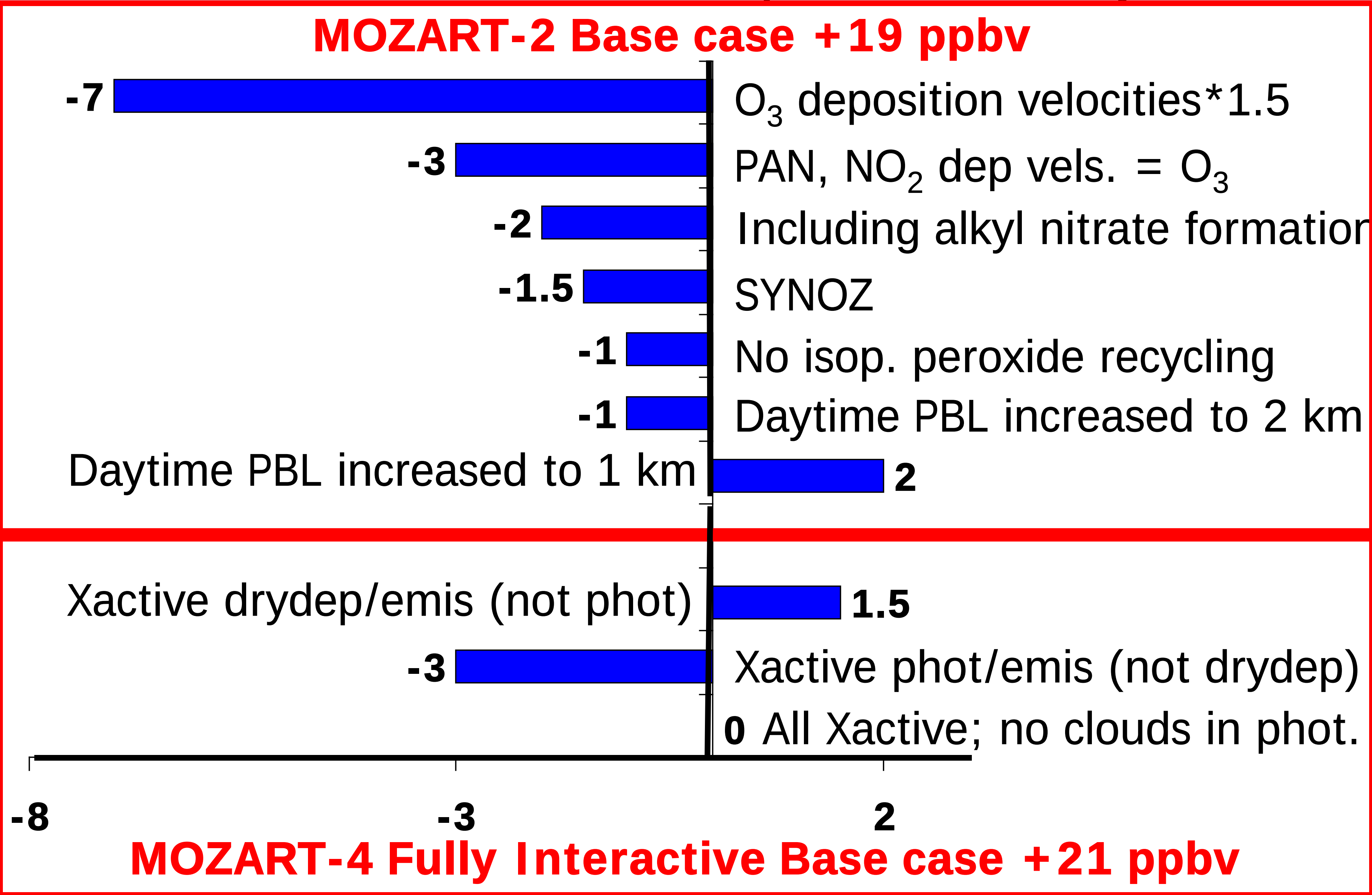
MOZART-2



Fiore et al., *JGR*, 2005

Change in eastern U.S. surface ozone bias due to sensitivity simulations

Base case = simulation with isop. nitrates as a NO_x sink



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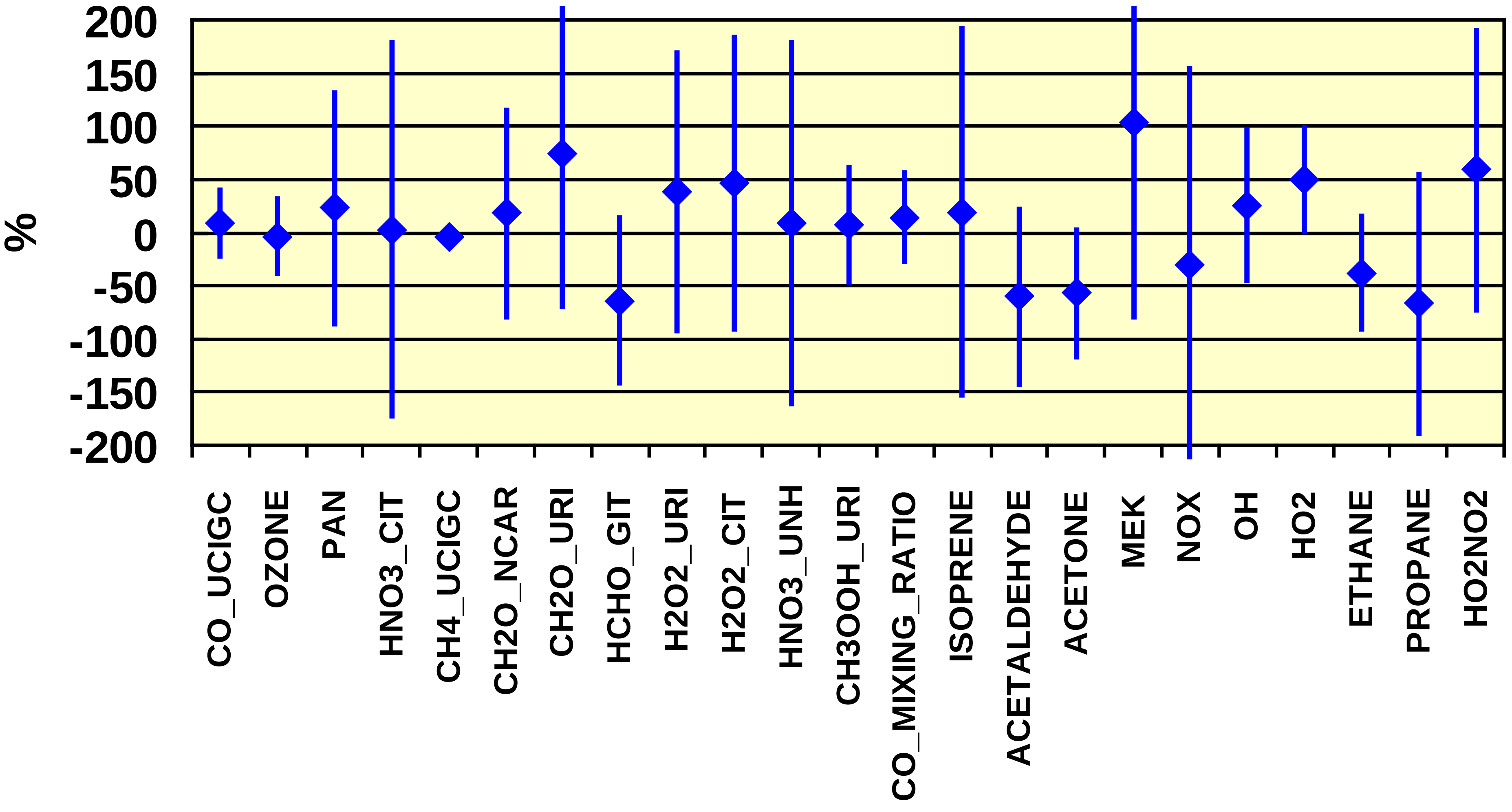
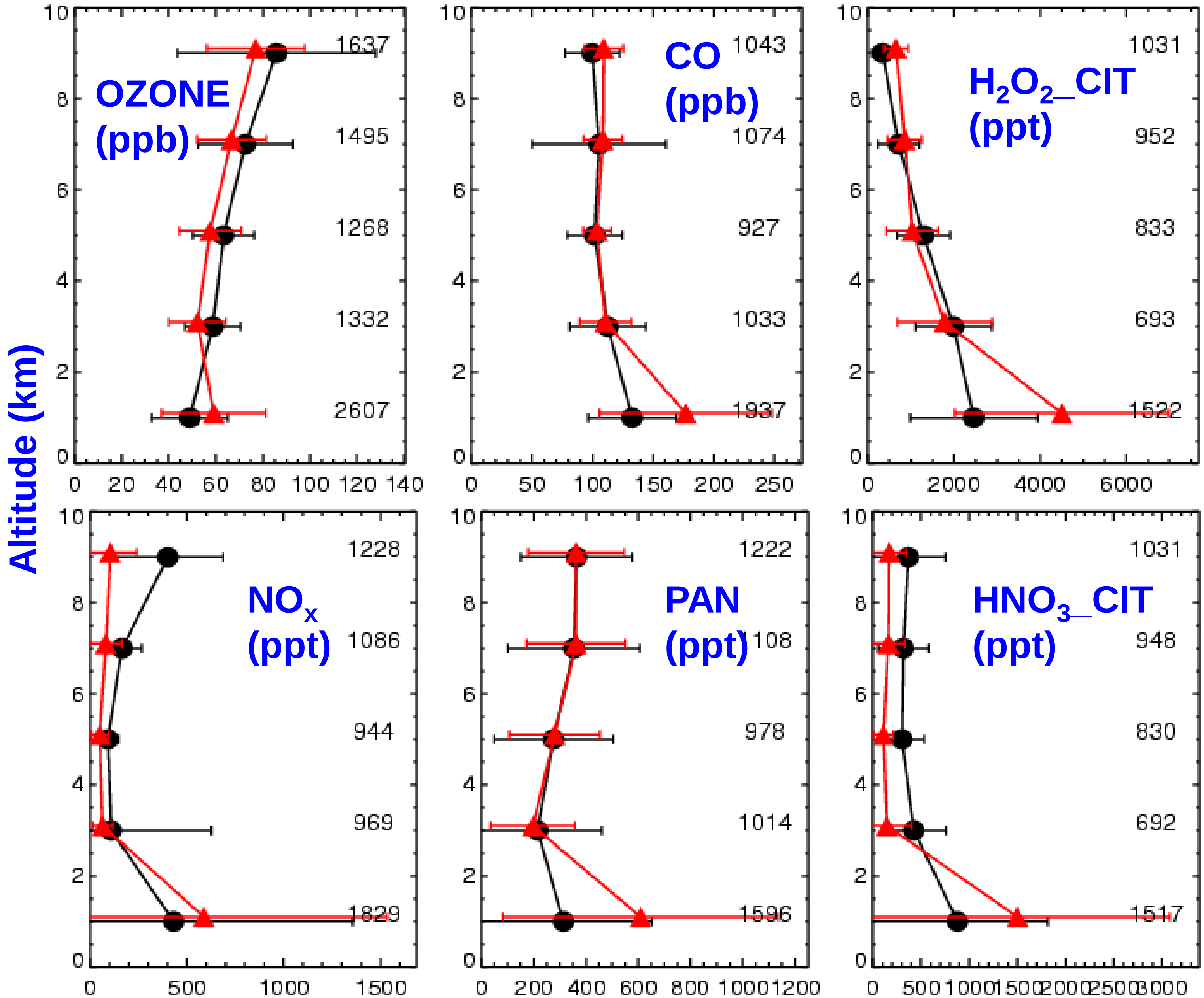
COMPARISON WITH ICARTT : Mean % Bias

MOZART-4 (preliminary version) NCEP T62, 1999 NEI vs. All INTEX DC-8 observations June-Aug 2004



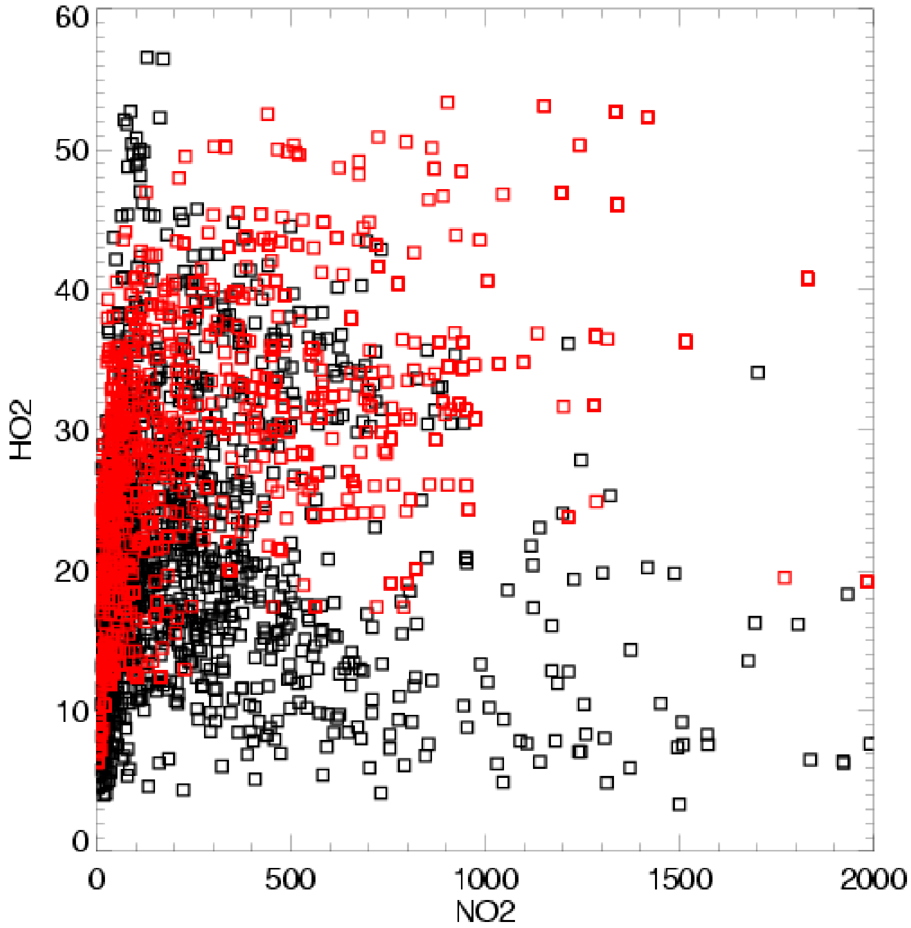
Campaign Mean Vertical Profiles
Model vs. INTEX DC-8 Observations



Ozone Chemical Regime

Model vs. INTEX DC-8 Observations (day; <2km; east of 100 °W)

HO_2 vs. NO_2



Model more HOx-rich (i.e., NO_x-sensitive) and shows a stronger HO_x-NO_x correlation than observed.

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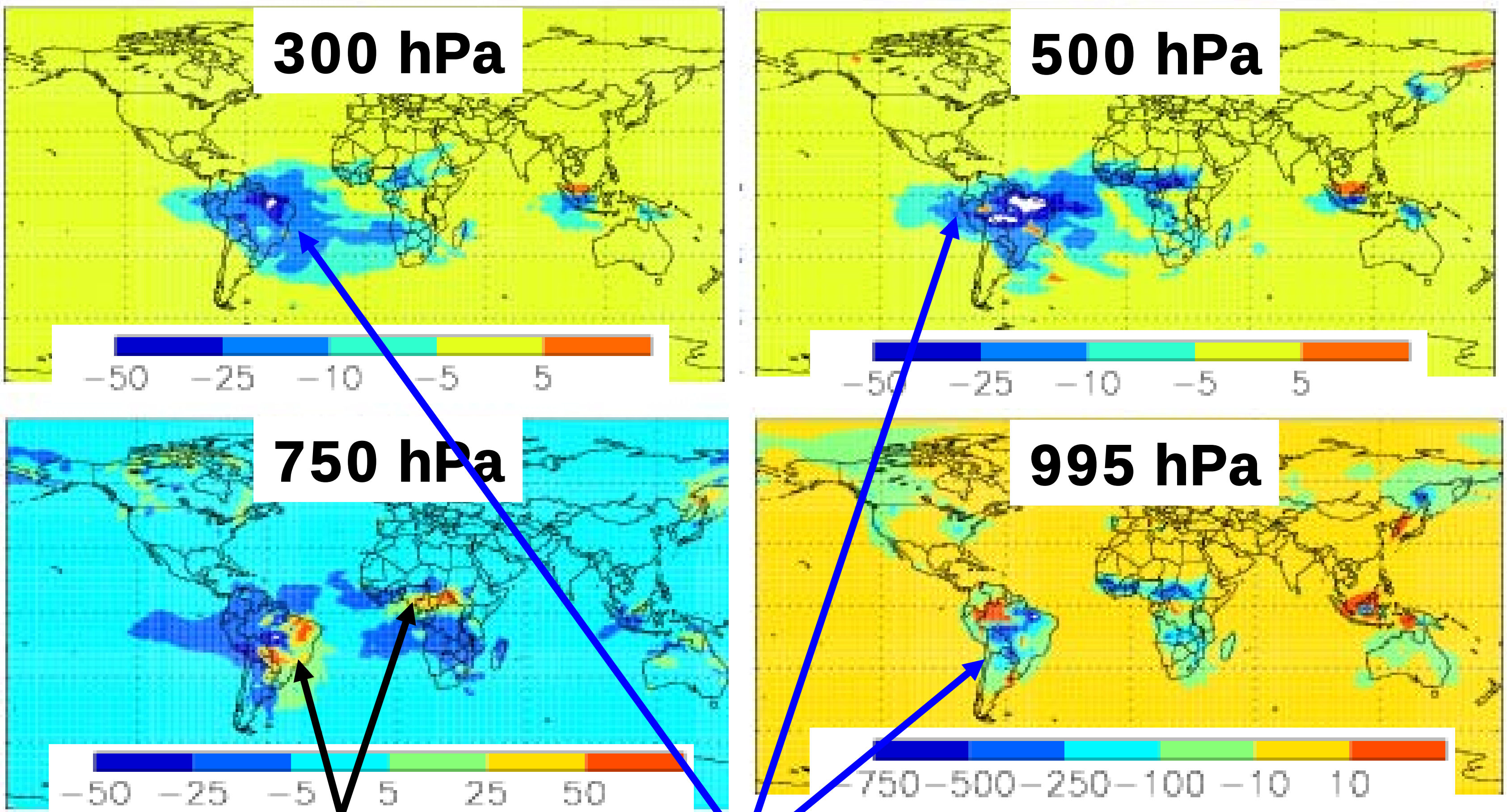
Vertically Distributed Biomass Burning (BMB) Emissions

1. IPCC AR-4 BASE CASE (met year 2000)
-- monthly 1997-2002 mean van der Werf emissions
-- levels with tops at 0.1, 0.5, 1, 2, 3, and 6 km

2. ICARTT Summer 2004
-- daily emissions from Rynda Hudman & Solene Turquety, Harvard
-- distributed up to 4 km, with 50% below 1 km

Change in SON composite max* CO concentrations (ppb) (Vertically distributed) – (All at surface)

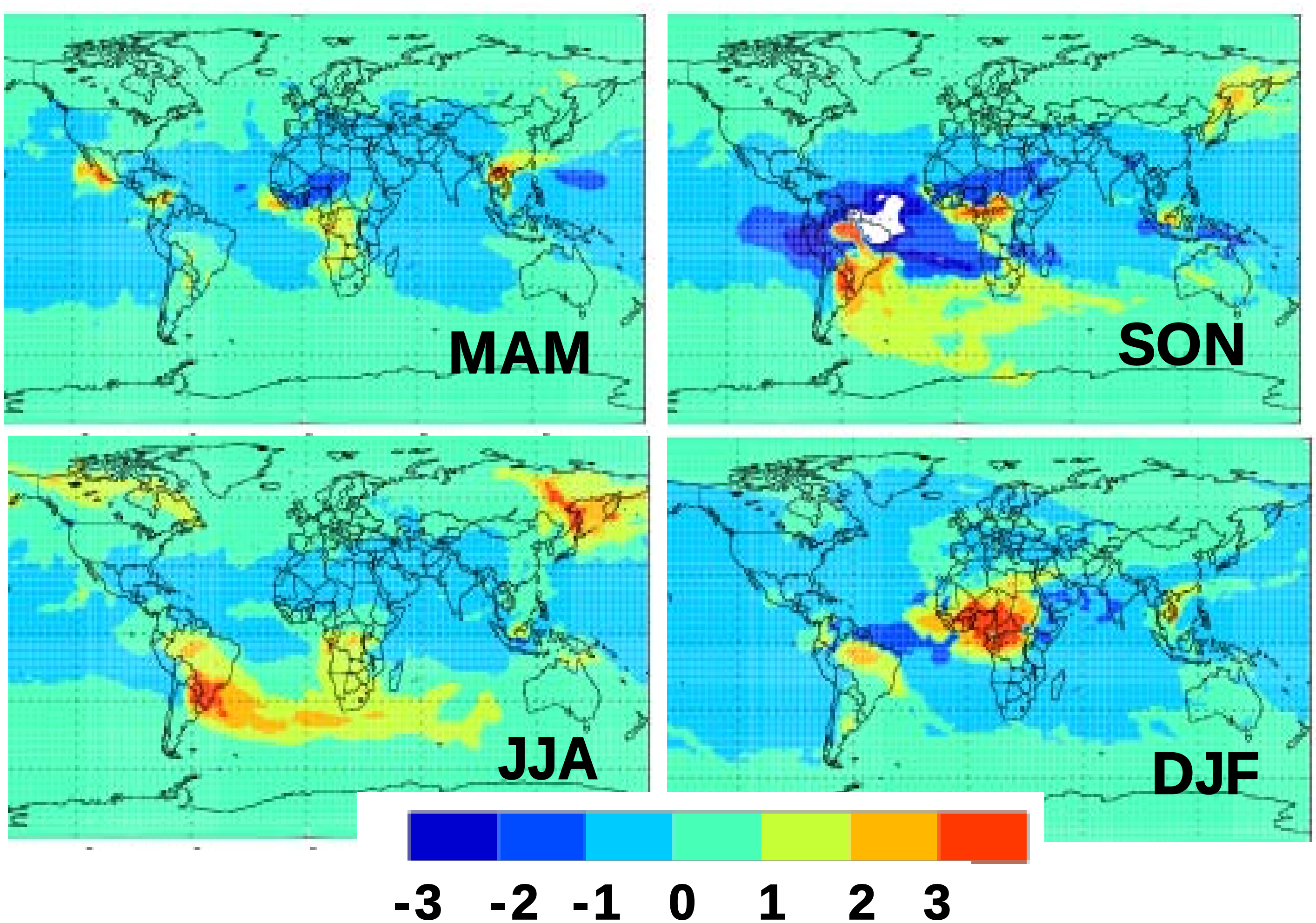


increases just above the boundary layer

decreases at surface and higher altitudes; interplay btw emissions and convection?

***Composite max = daily max per grid point**

Change in Tropospheric O_3 Columns (DU)
Composite Seasonal Maxima*
(Vertically distributed) - (All BMB emissions at surface)



Maximum impact ~10% near source region

*Composite max = daily max per grid point

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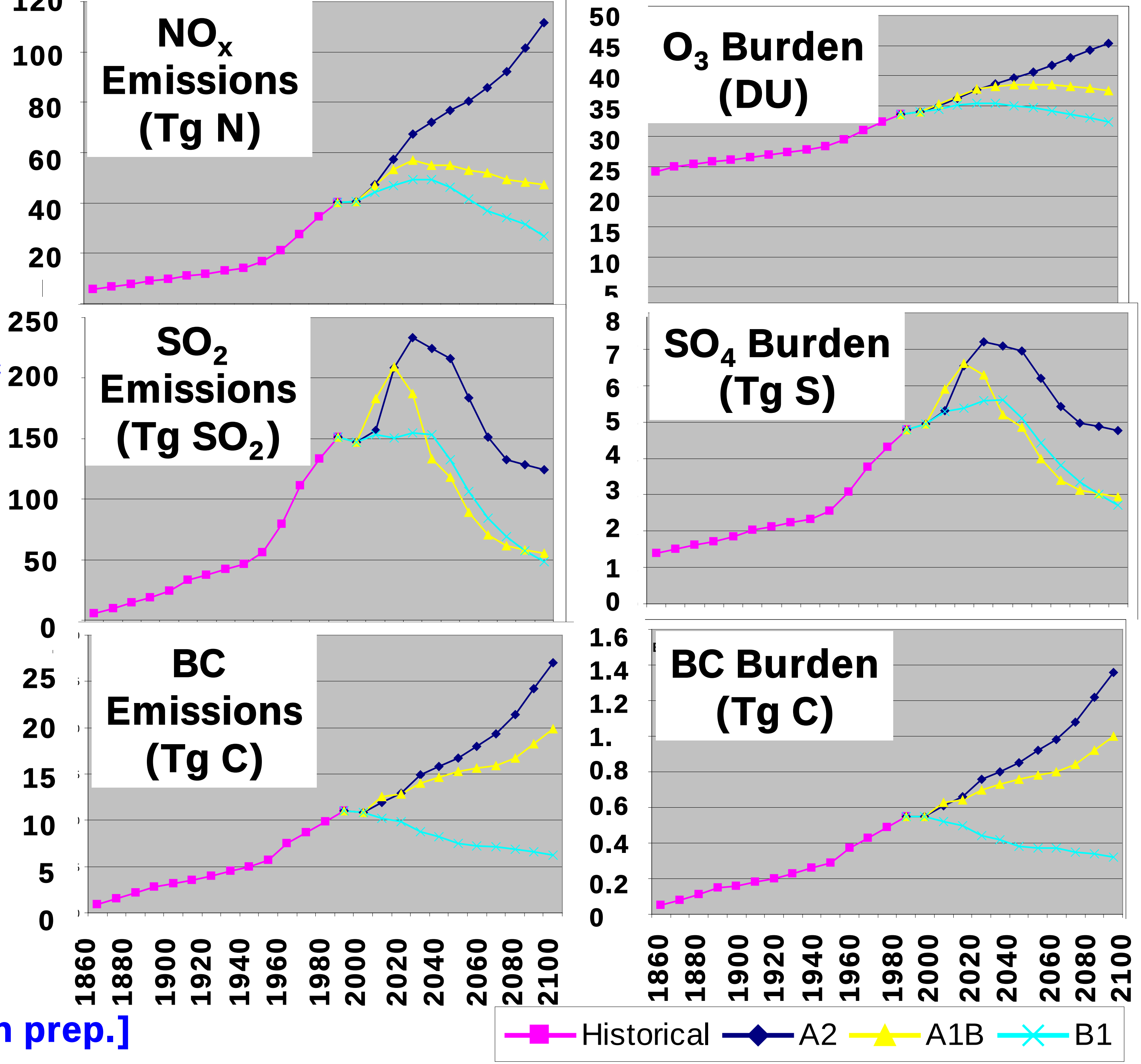
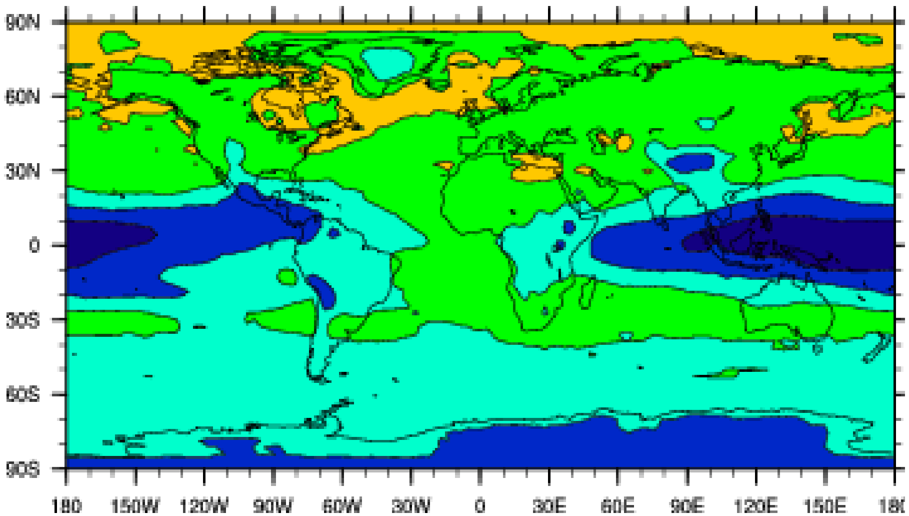
Emission trends in MOZART-2 and resulting tropospheric burdens, used to drive GFDL climate model simulations for IPCC



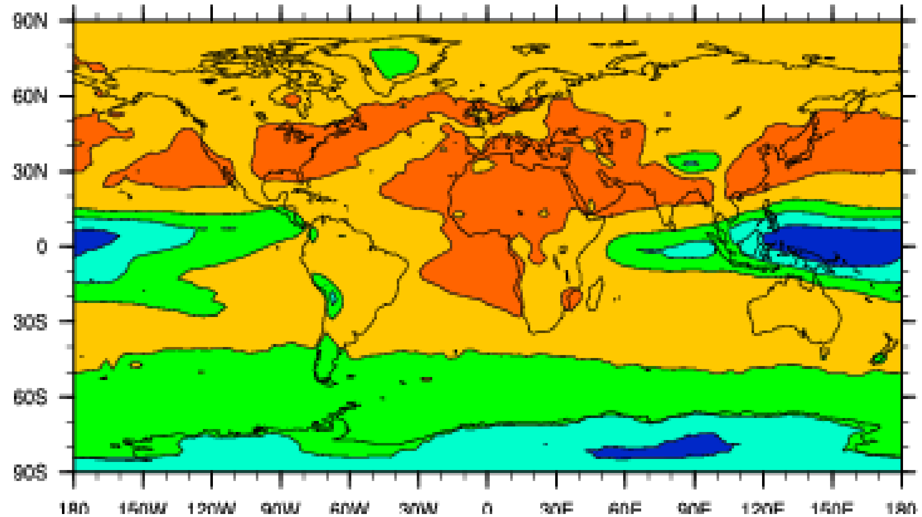
[*Horowitz*, in prep.]

Trends in Tropospheric O_3 Columns

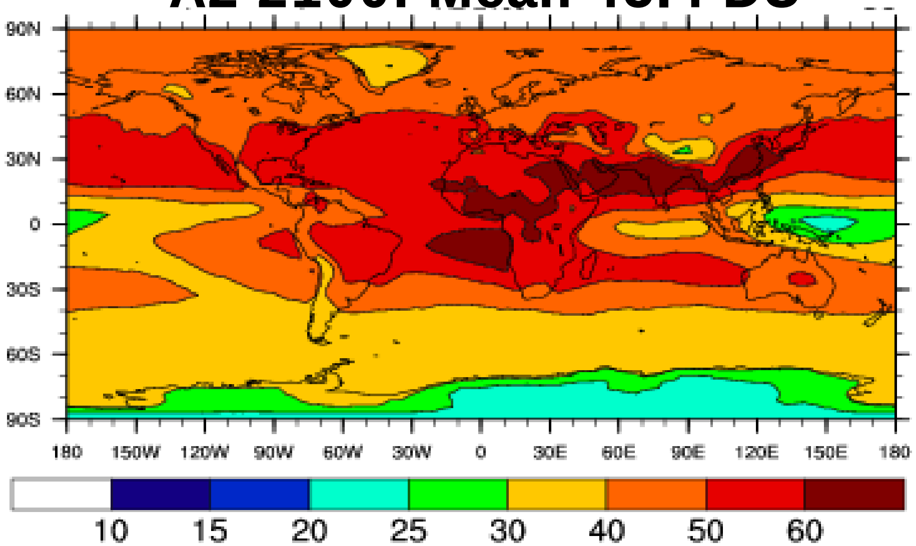
1860: Mean=24.1 DU



2000: Mean= 34.0 DU



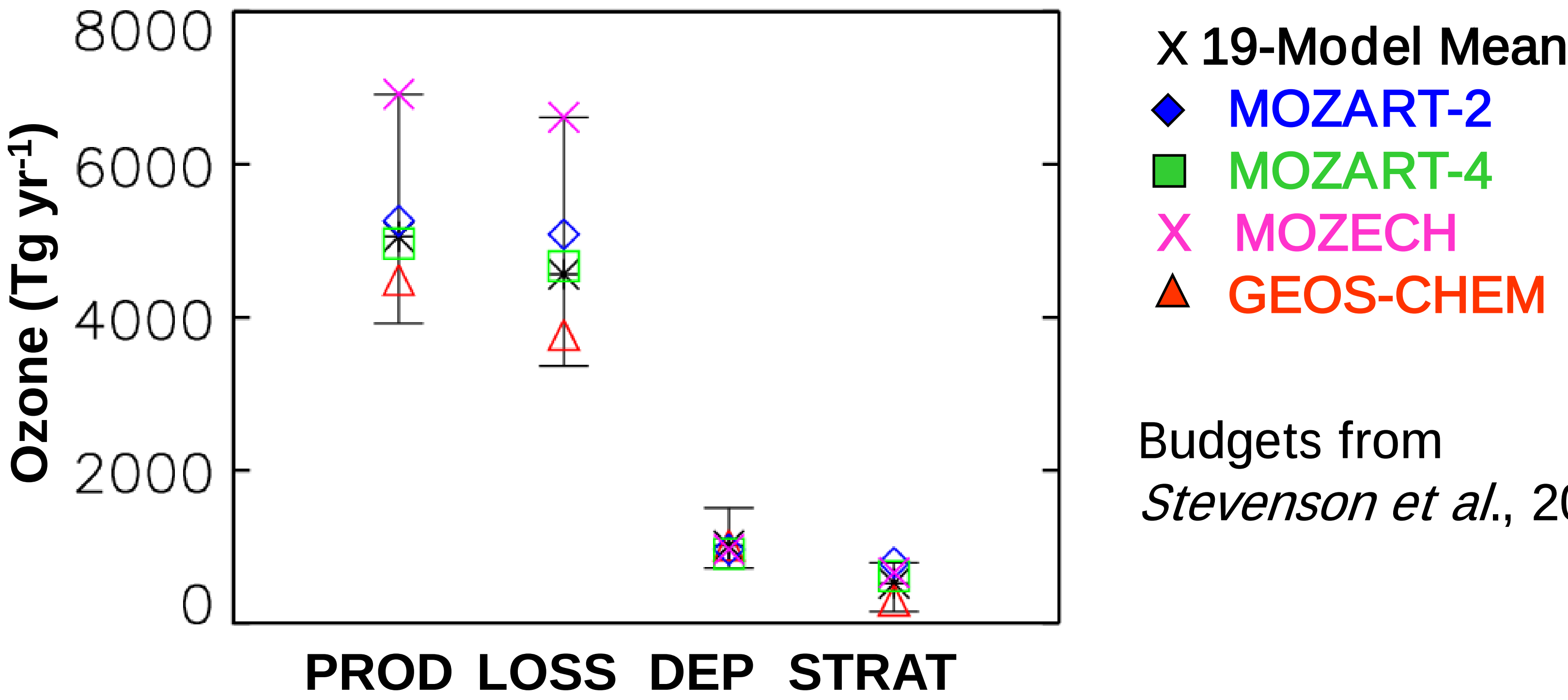
A2 2100: Mean 45.4 DU



First step; next we'll examine climate impacts on chemistry with GFDL chemistry-climate model

[*Horowitz*, in prep.]

Ozone Budgets in IPCC-AR4 from 19 Tropospheric Chemistry Models for Base Year 2000



Budgets from *Stevenson et al.*, 2005

Emissions for 2000:

- EDGAR 3.2
- GFED 1997-2002 mean for biomass burning

Scenarios for 2030:

- Current Legislation (CLE)
- Maximum Feasible Reductions
- SRES A2
- Climate change (CLE emissions)

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MOZART-2 Methane Study

Motivation: **Methane controls benefit global air quality and climate by lowering background tropospheric O_3**

Question: **Are prior results from steady-state simulations with uniform, fixed CH_4 concentrations directly relevant to real-world emission controls?**

Approach: **Multi-decadal transient simulations**

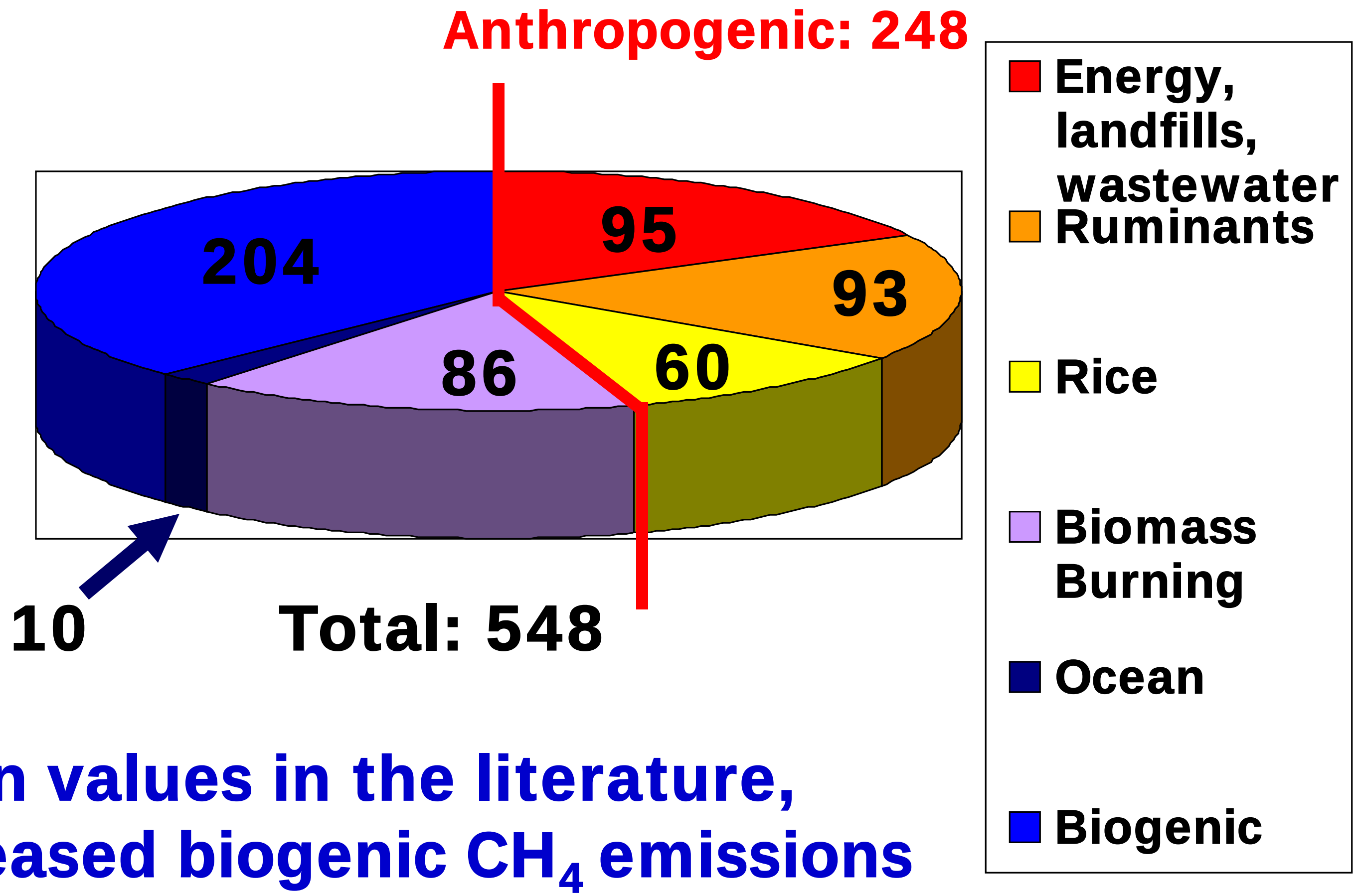
Reduce global anthrop. CH_4 emissions by 40%:

(1) All in Asia

(2) Everywhere in the globe

(All simulations use 1990-2004 T62 NCEP winds, recycled as needed)

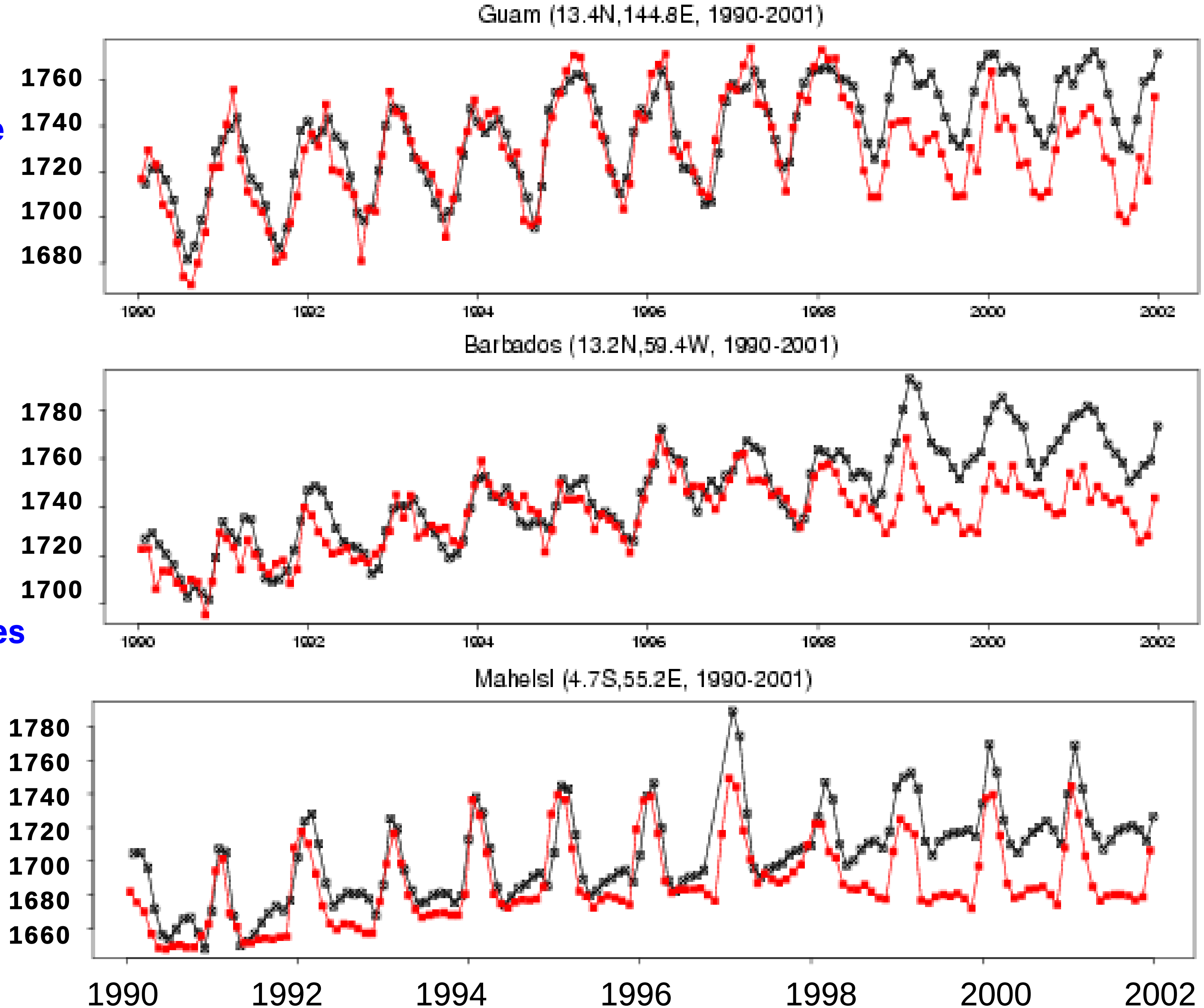
Methane Emissions in EDGAR inventory: early 1990s (Tg CH_4 yr^{-1})



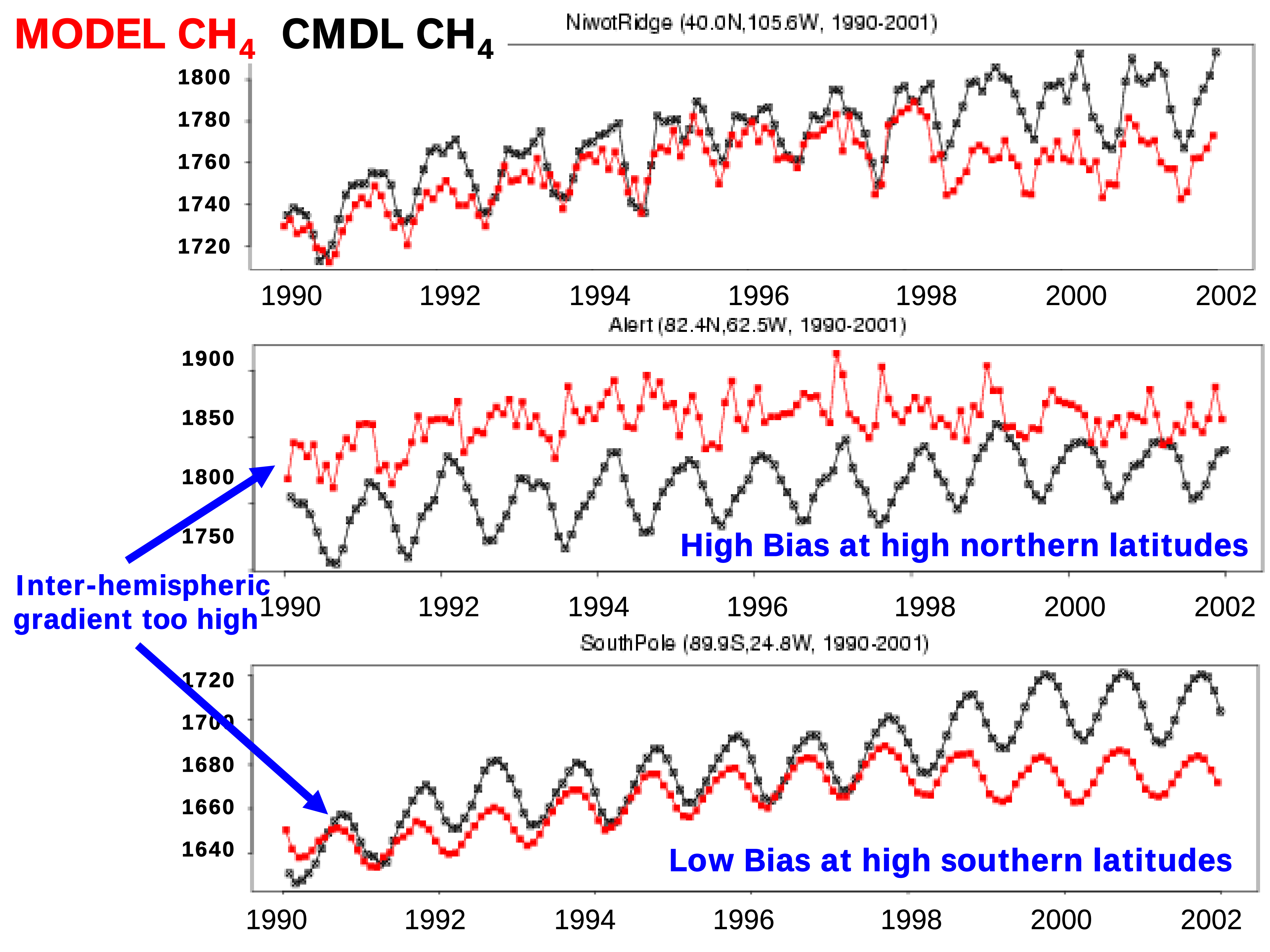
Based on values in the literature, we increased biogenic CH_4 emissions by 60 Tg

MODEL CH_4 CMDL CH_4

Seasonal cycle inter-annual variability, increasing trend largely captured at remote sites

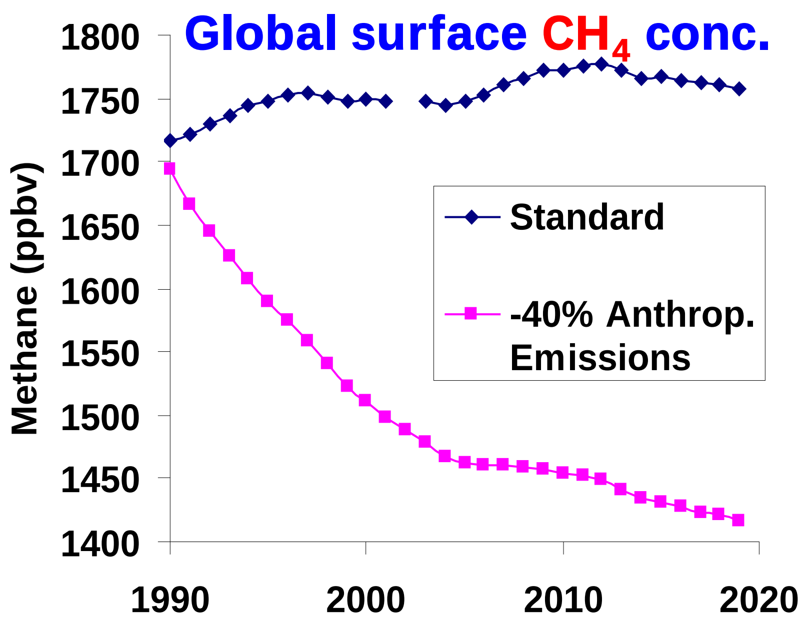


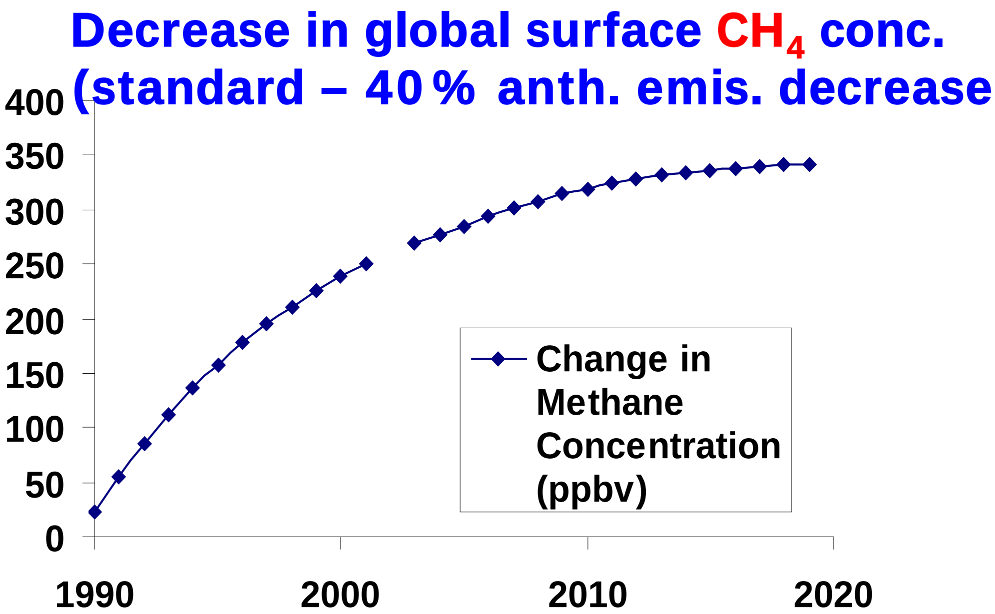
Underestimates post-1998; indicating emissions increase?

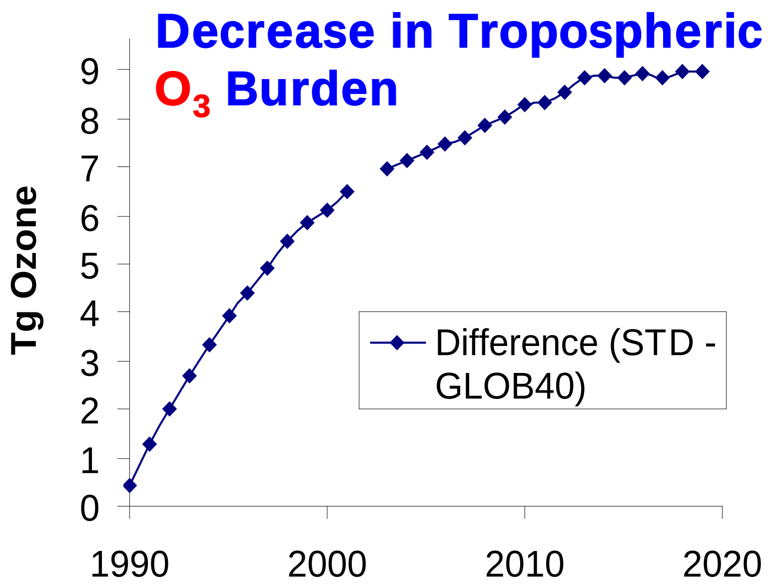


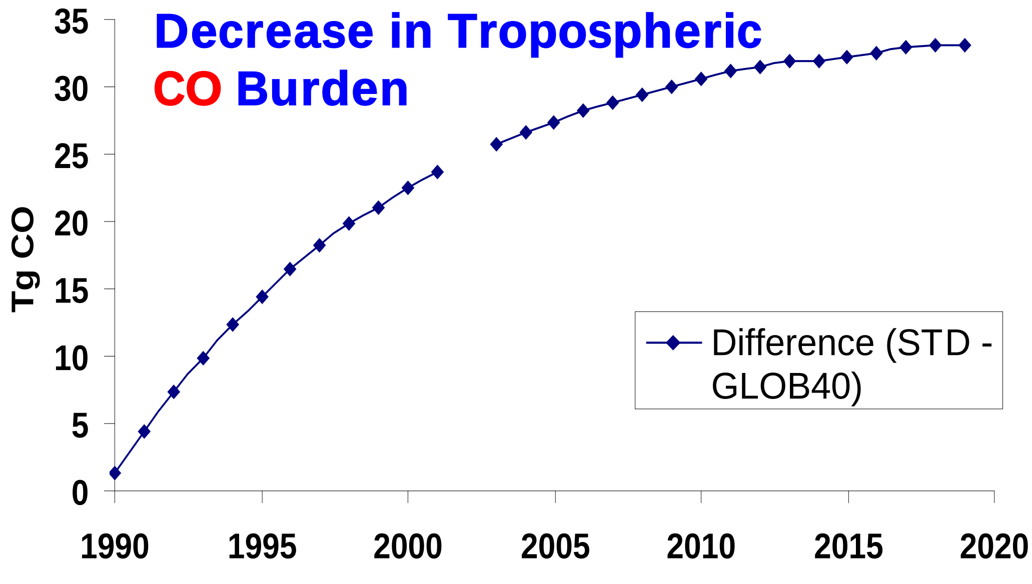
MODEL CH4
CMDL CH4
NiwotRidge (40.0N,105.6W, 1990-2001)
1800
1780
1760
1740
1720
1990
1992
1994
1996
1998
2000
2002
Alert (82.4N,62.5W, 1990-2001)
1900
1850
1800
1750
High Bias at high northern latitudes
Inter-hemispheric
gradient too high
1990
1992
1994
1996
1998
2000
2002
SouthPole (89.9S,24.8W, 1990-2001)
1720
1700
1680
1660
1640
Low Bias at high southern latitudes
1990
1992
1994
1996
1998
2000
2002

Transient simulations with EDGAR 1990 emissions, beginning 1990:
(1) Standard (2) 40 % decrease in global anthrop. emissions (18 % of total CH_4 emissions)





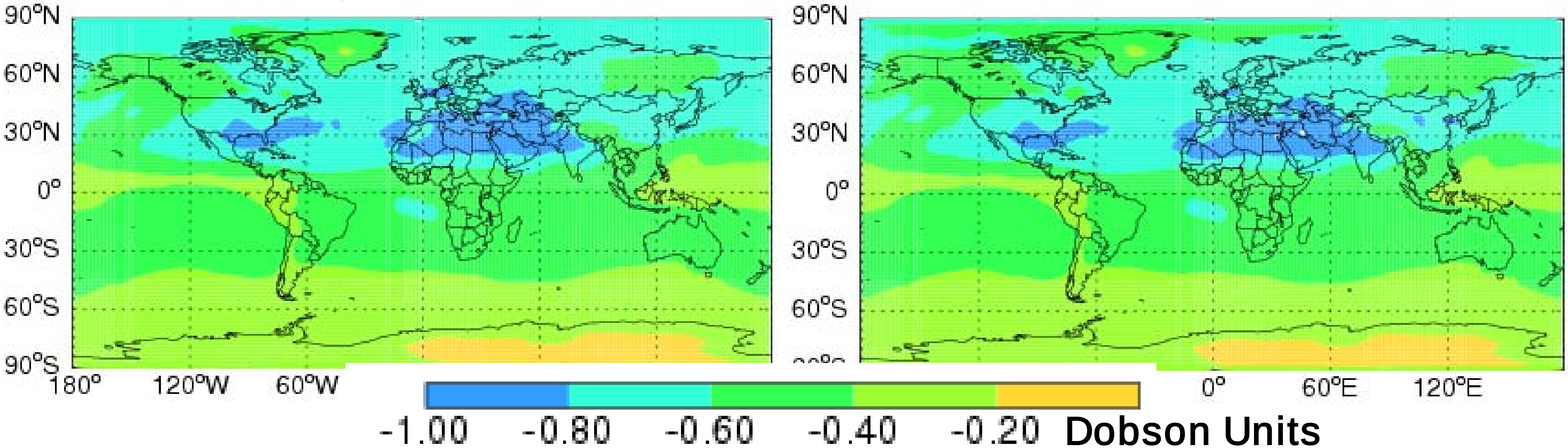




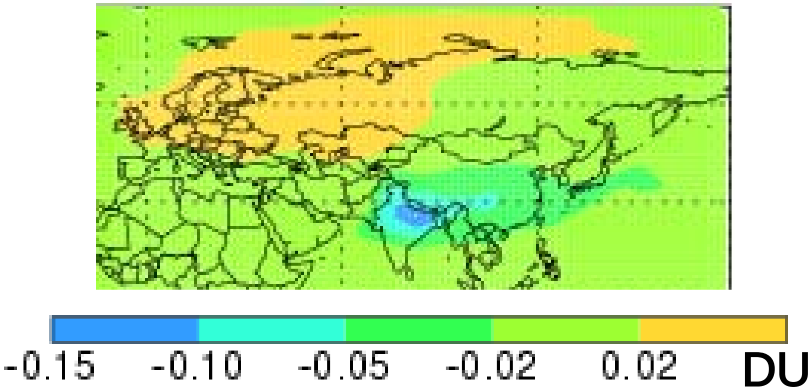
CLIMATE IMPACTS: Change in July 2000 Trop. O_3 Columns (to 200 hPa)

40% decrease in global anthrop. CH_4 emissions

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



No Asia – (40% global decrease)



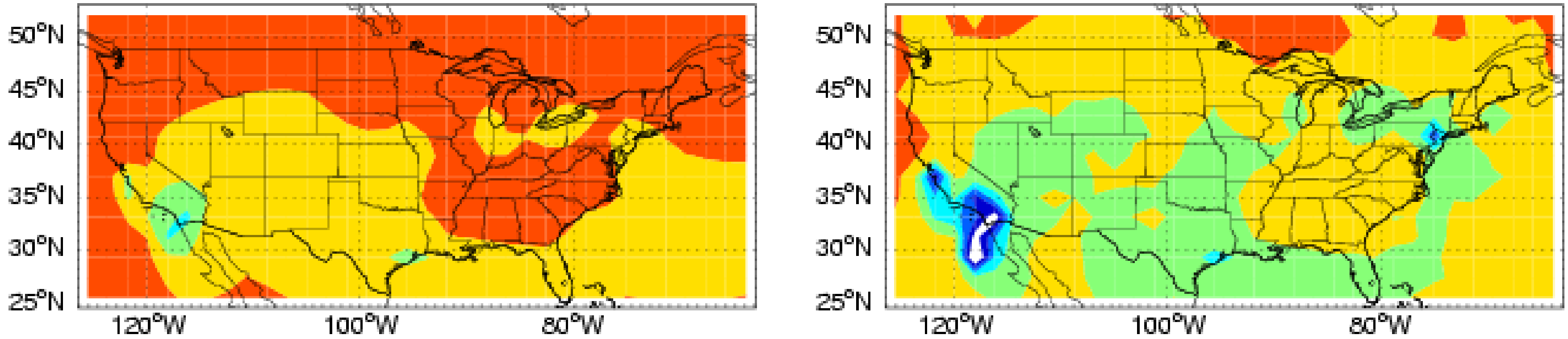
Tropospheric O_3 column response is independent of CH_4 emission location except for small (~10%) local changes

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

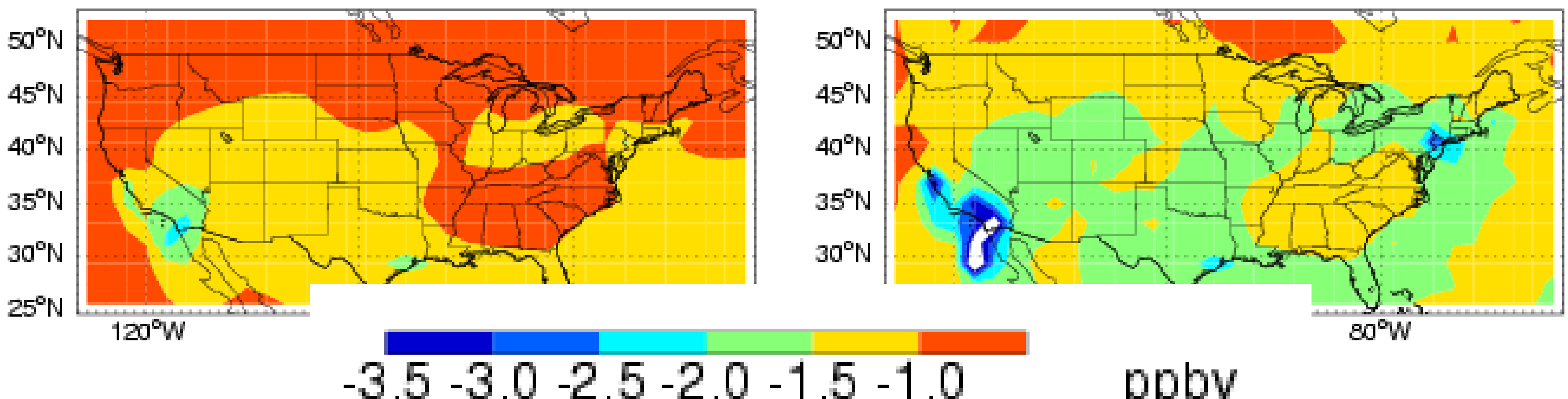
MEAN DIFFERENCE

MAX DIFFERENCE (Composite max daily afternoon mean JJA)

NO ASIAN CH_4



GLOBAL 40% DECREASE IN ANTHROP. CH_4



→Stronger sensitivity in NO_x-saturated regions (Los Angeles), partially due to local ozone production from methane

Summary: MOZART Development, Evaluation, and Applications at GFDL

- **Surface Ozone Bias over the United States**
  - Typically 15-20 ppbv; sensitive to local chemistry
- **Evaluation with 2004 ICARTT observations**
  - Generally good; many species too high in boundary layer
- **Vertically distributed biomass burning**
  - Small mean effect, up to ~10% episodically
- **Trends (historical, future) in ozone and aerosols**
  - Past increases, future increases under some scenarios
  - First step towards studying chemistry-climate interactions
  - MOZART-2 near ensemble mean in IPCC 2030 comparisons
- **Methane control for climate and air quality**
  - Good agreement btw transient runs and remote surface obs.
  - Nearing steady-state after 30 years (~3 e-folding lifetimes)
  - 40% anthrop. CH_4 decrease → -9 Tg O_3; -(1-3) ppbv U.S. JJA
  - Ozone response largely independent of CH_4 source location