

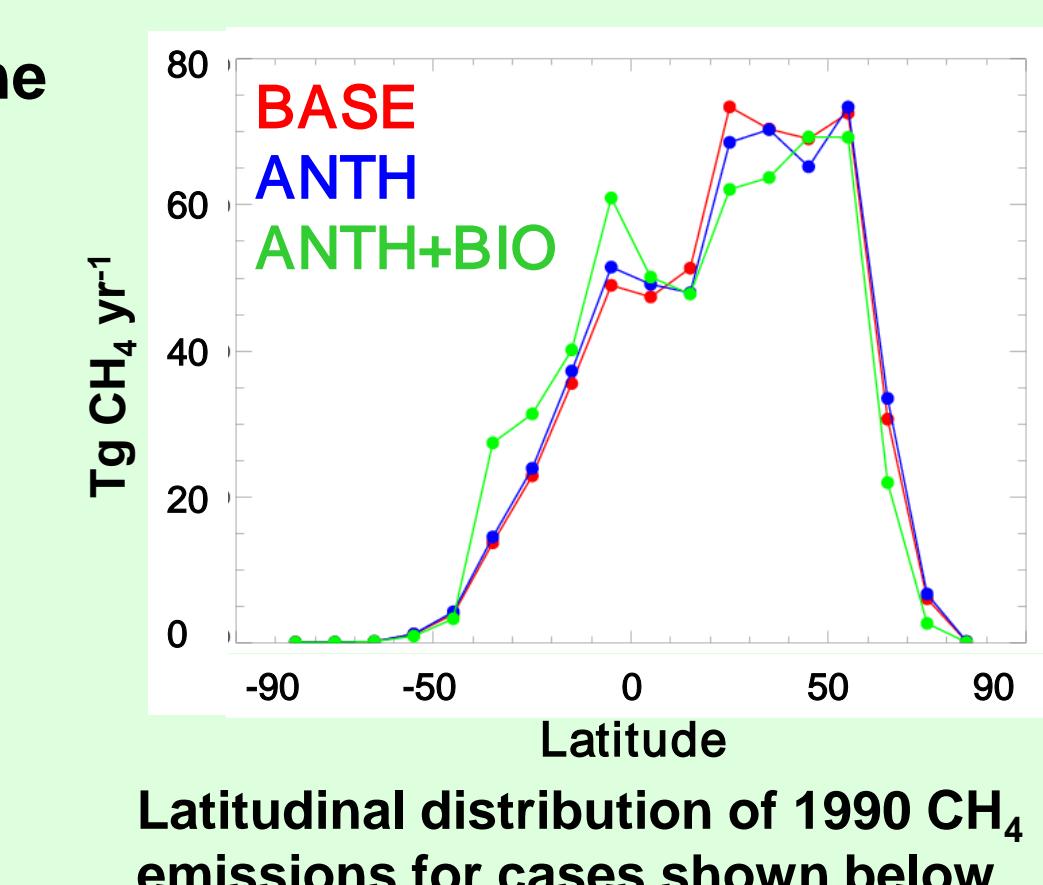
Atmospheric Methane Distribution, Trend, and Linkage with Surface Ozone

Arlene M. Fiore¹ (arlene.fiore@noaa.gov), Larry W. Horowitz¹, Ed Dlugokencky², J. Jason West³

¹NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ ²NOAA Global Monitoring Division, Earth System Research Laboratory, Boulder, CO ³Atmospheric and Oceanic Sciences Program and Woodrow Wilson School, Princeton University, Princeton, NJ

1. Introduction

- Methane (CH_4) emission controls can be a cost-effective strategy for abating both global surface ozone (O_3) and greenhouse warming [West and Fiore, 2005; see also poster by West et al.]
→ previous modeling studies used fixed CH_4 concentrations and globally uniform changes, but CH_4 is observed to vary spatially and temporally
- The major sink of CH_4 is reaction with tropospheric OH; emissions of CH_4 are shown in Section 2
- Surface CH_4 rose by ~5–6 ppb yr^{-1} from 1990–1999, then leveled off (Section 3), possibly reflecting:
 - source changes of CH_4 [e.g. Langenfelds et al., 2002; Wang et al., 2004] or other species that influence OH [e.g. Karlsdóttir and Isaksen, 2000]
 - meteorologically-driven changes in the CH_4 sink [e.g. Warwick et al., 2002; Dentener et al., 2003; Wang et al., 2004]
 - an approach to steady-state with constant lifetime [Dlugokencky et al., 2003]

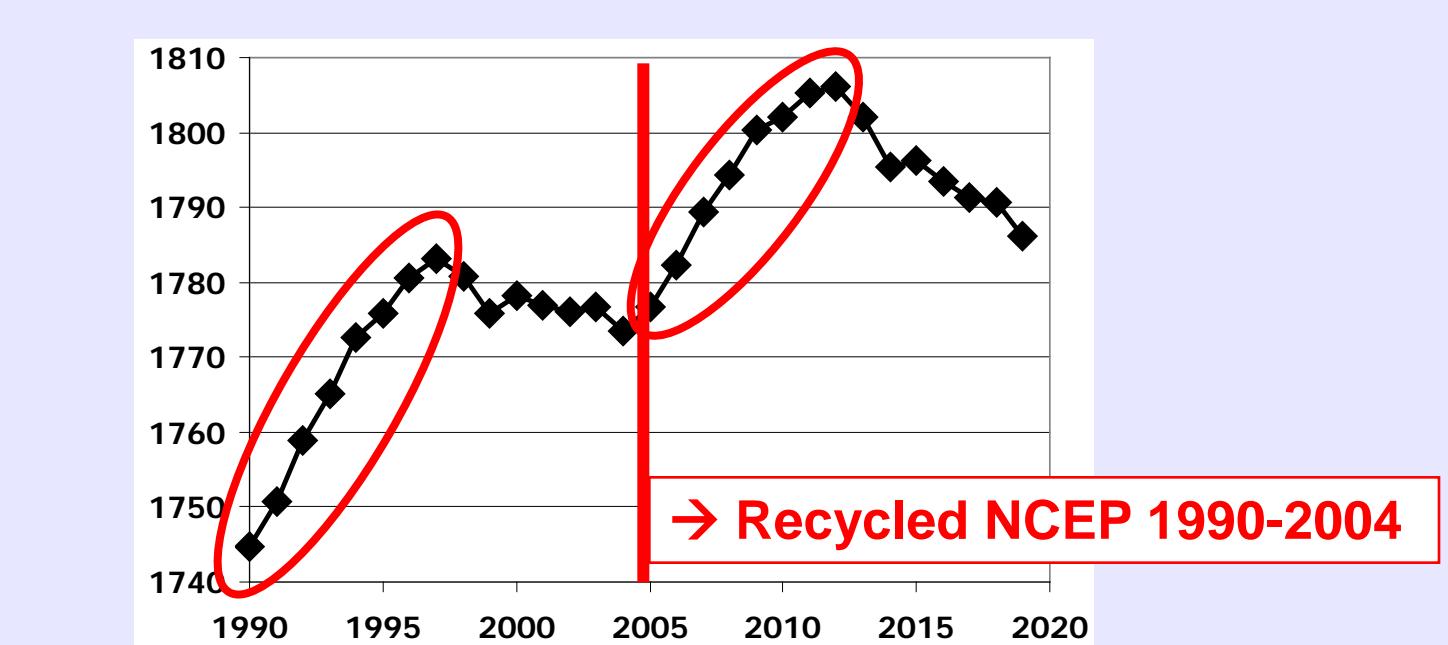


What is driving observed CH_4 trends?

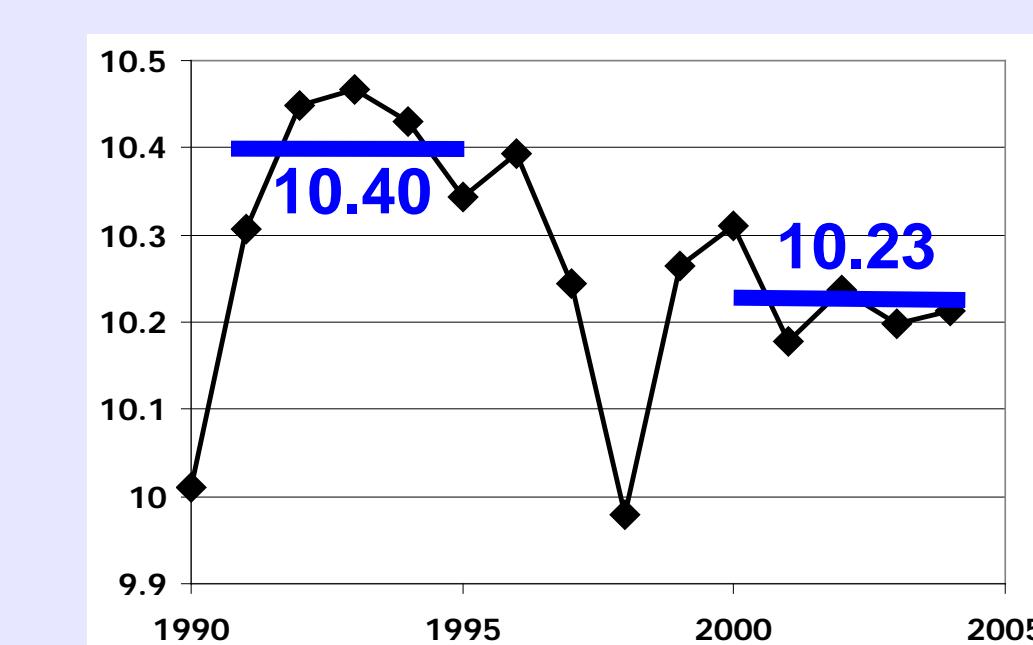
Does CH_4 source location influence the O_3 response?

4. Meteorologically-driven Changes in the CH_4 Lifetime

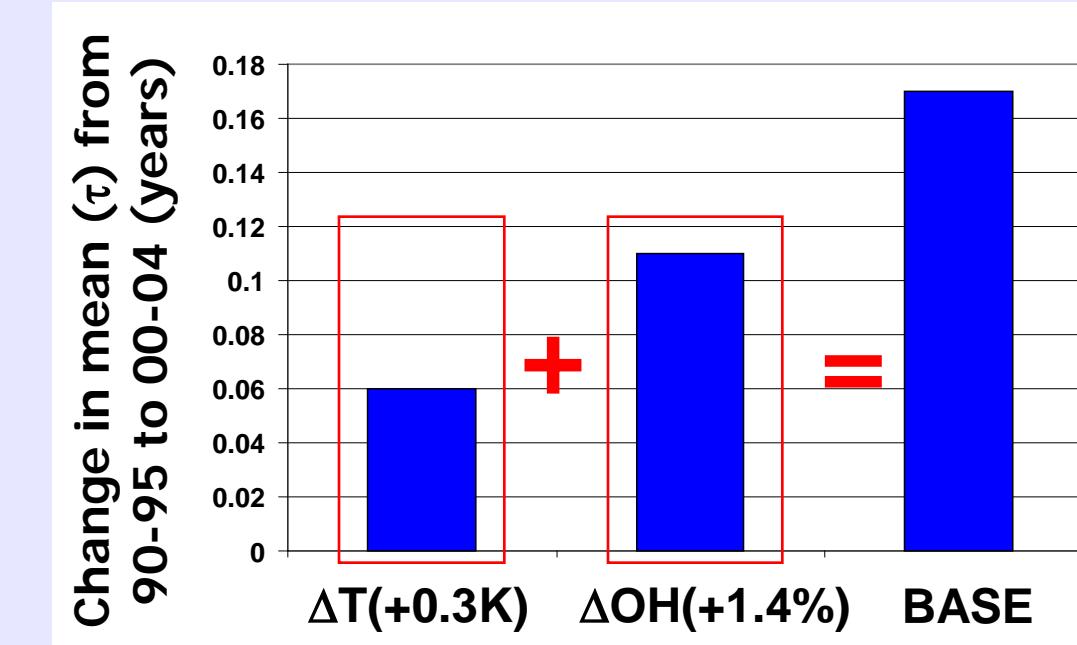
Global mean surface CH_4 in BASE simulation (constant emissions)



CH_4 Lifetime Against Tropospheric OH



Deconstruct $\Delta\tau$ from 91–95 to 00–04 into individual contributions by varying T and OH separately



→ Meteorological drivers for trend

→ Not just an approach to steady-state

→ Mean annual CH_4 lifetime shortens

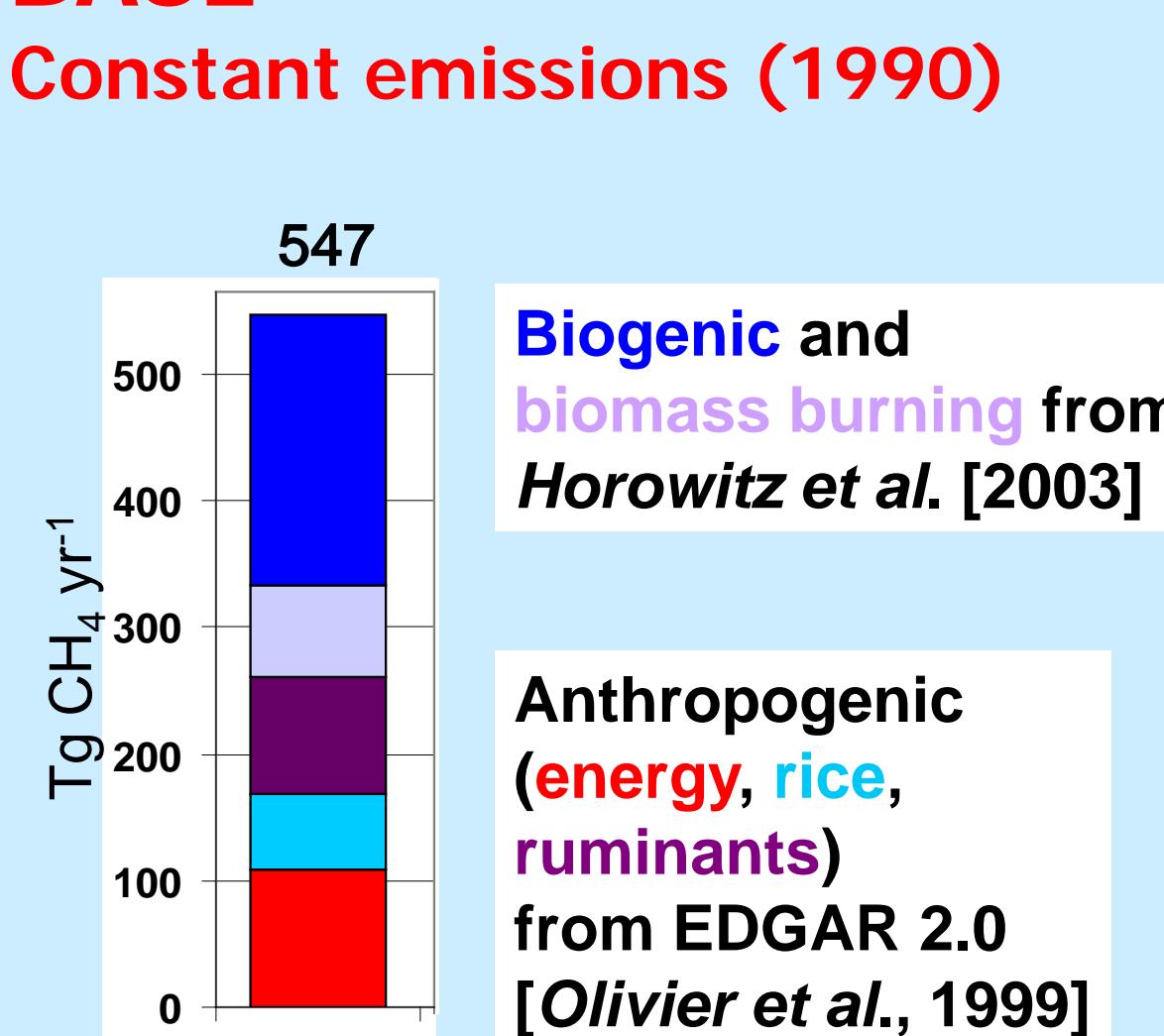
→ OH increases in the model by +1.4% due to a 0.3 Tg N yr^{-1} increase in lightning NO_x



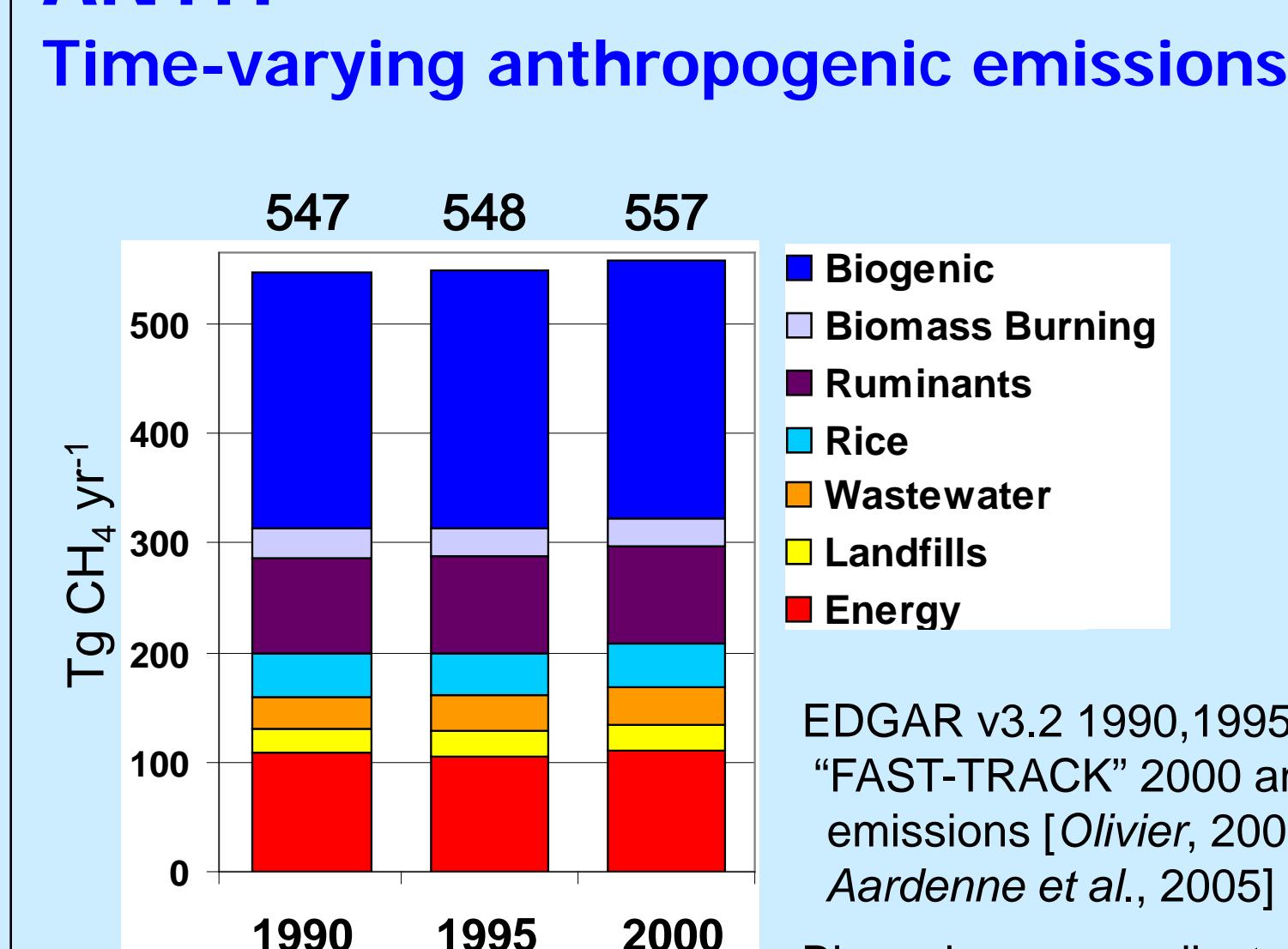
2. Methane in the MOZART-2 CTM

Sensitivity simulations applying different CH_4 emission inventories:

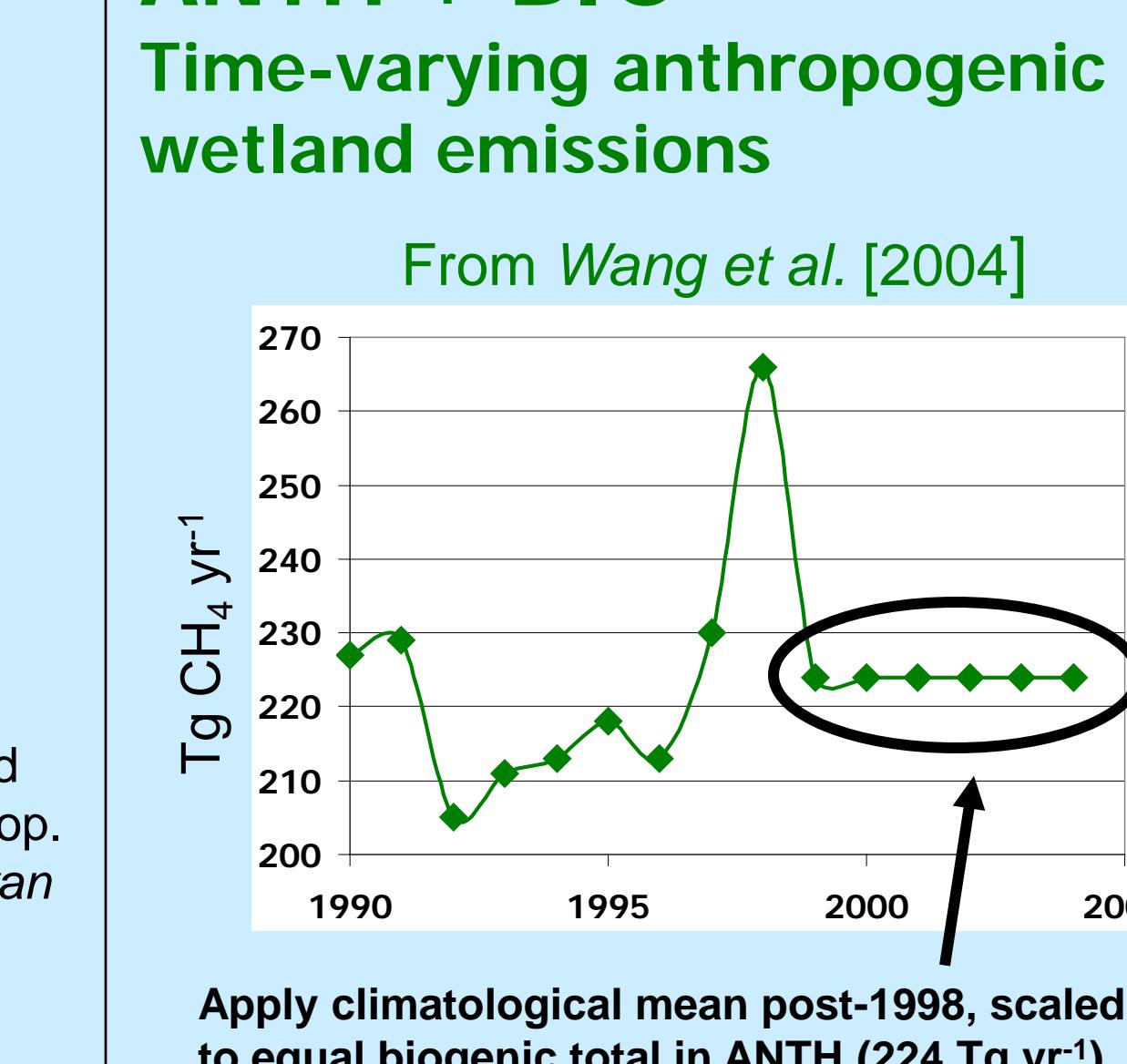
BASE Constant emissions (1990)



ANTH Time-varying anthropogenic emissions

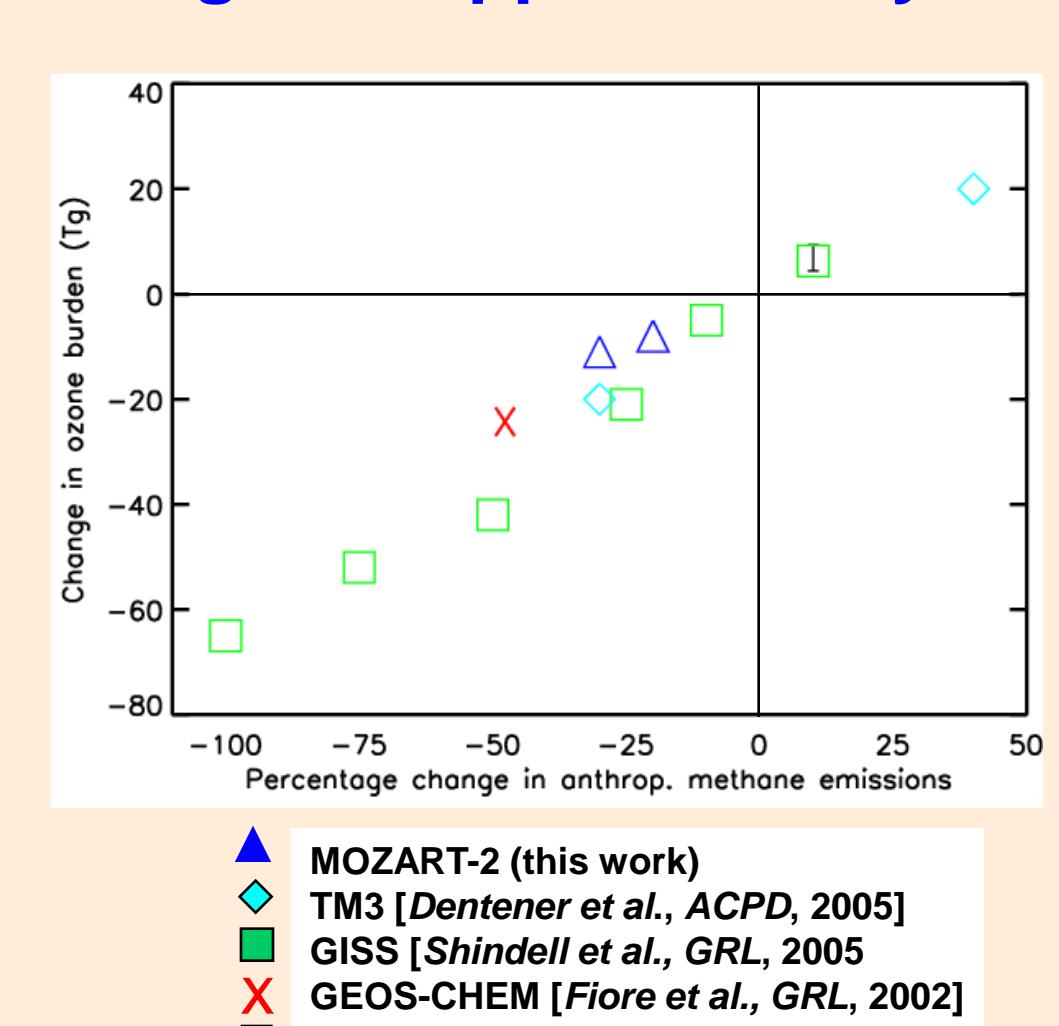


ANTH + BIO Time-varying anthropogenic and wetland emissions



5. Ozone Response to CH_4 Emission Controls

Tropospheric O_3 response to anthropogenic CH_4 emission changes is approximately linear



ZERO ASIAN ANTHROPOGENIC CH_4

GLOBAL 30% DECREASE IN ANTHRO. CH_4

MOZART-2 (this work)

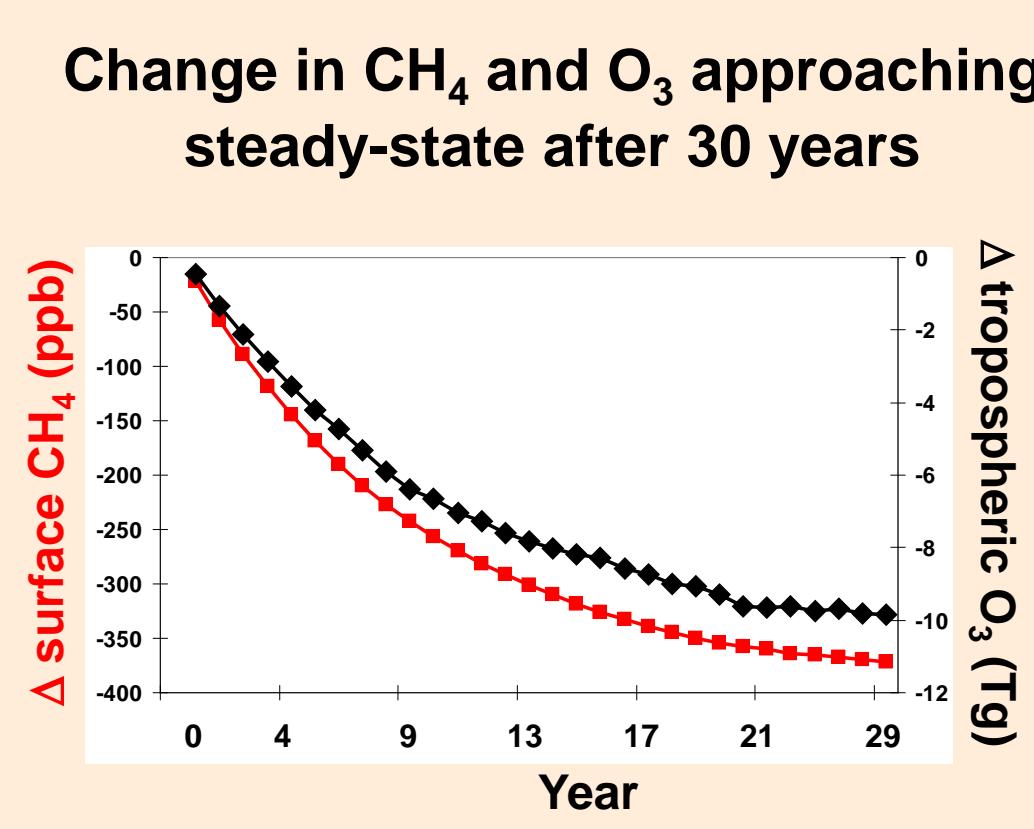
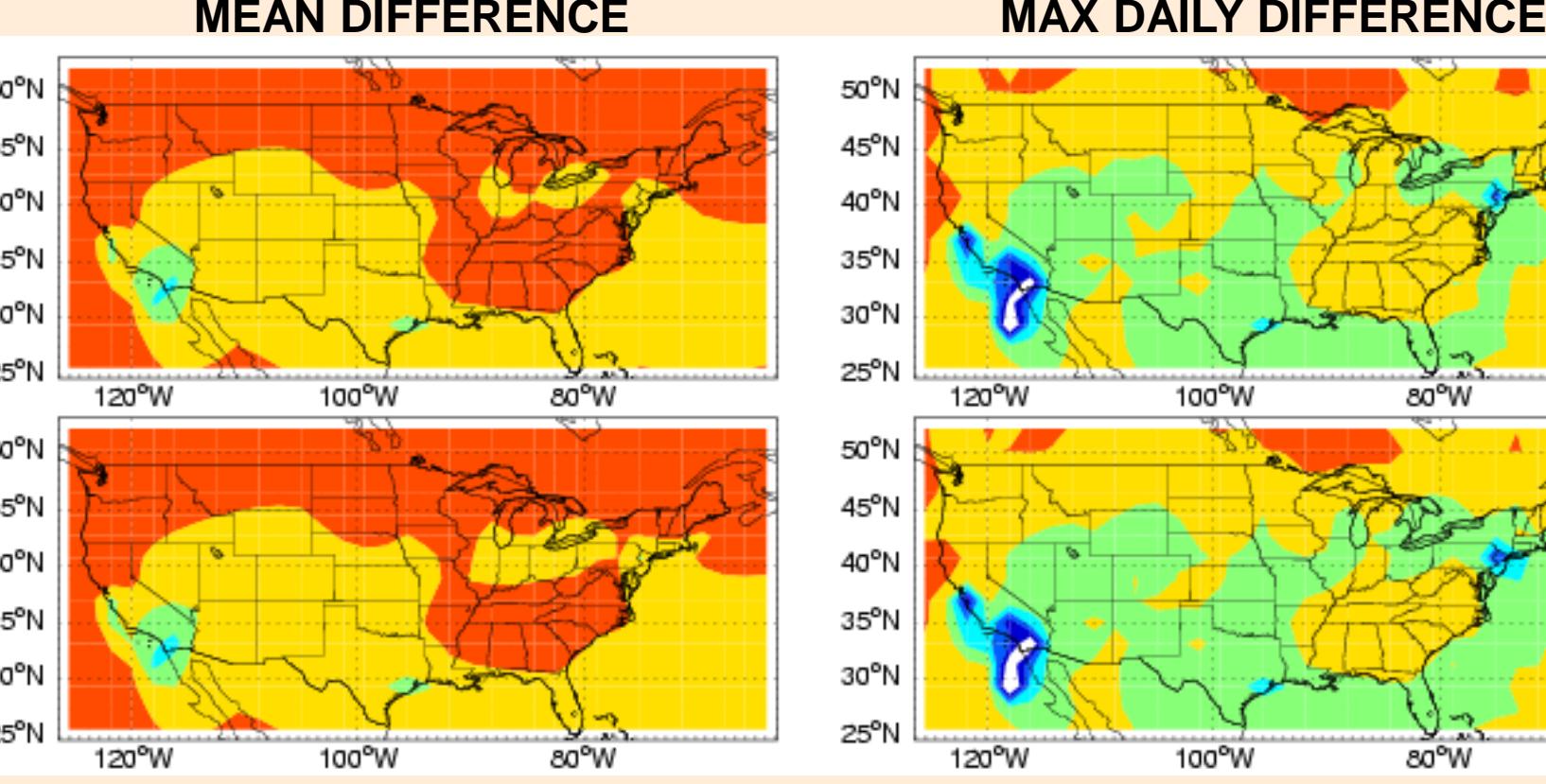
TM3 [Dentener et al., ACPD, 2005]

GISS [Shindell et al., GRL, 2005]

X GEOS-CHEM [Fiore et al., GRL, 2002]

I IPCC TAR [Prather et al., 2001]

Change in summertime U.S. afternoon surface O_3
MEAN DIFFERENCE MAX DAILY DIFFERENCE

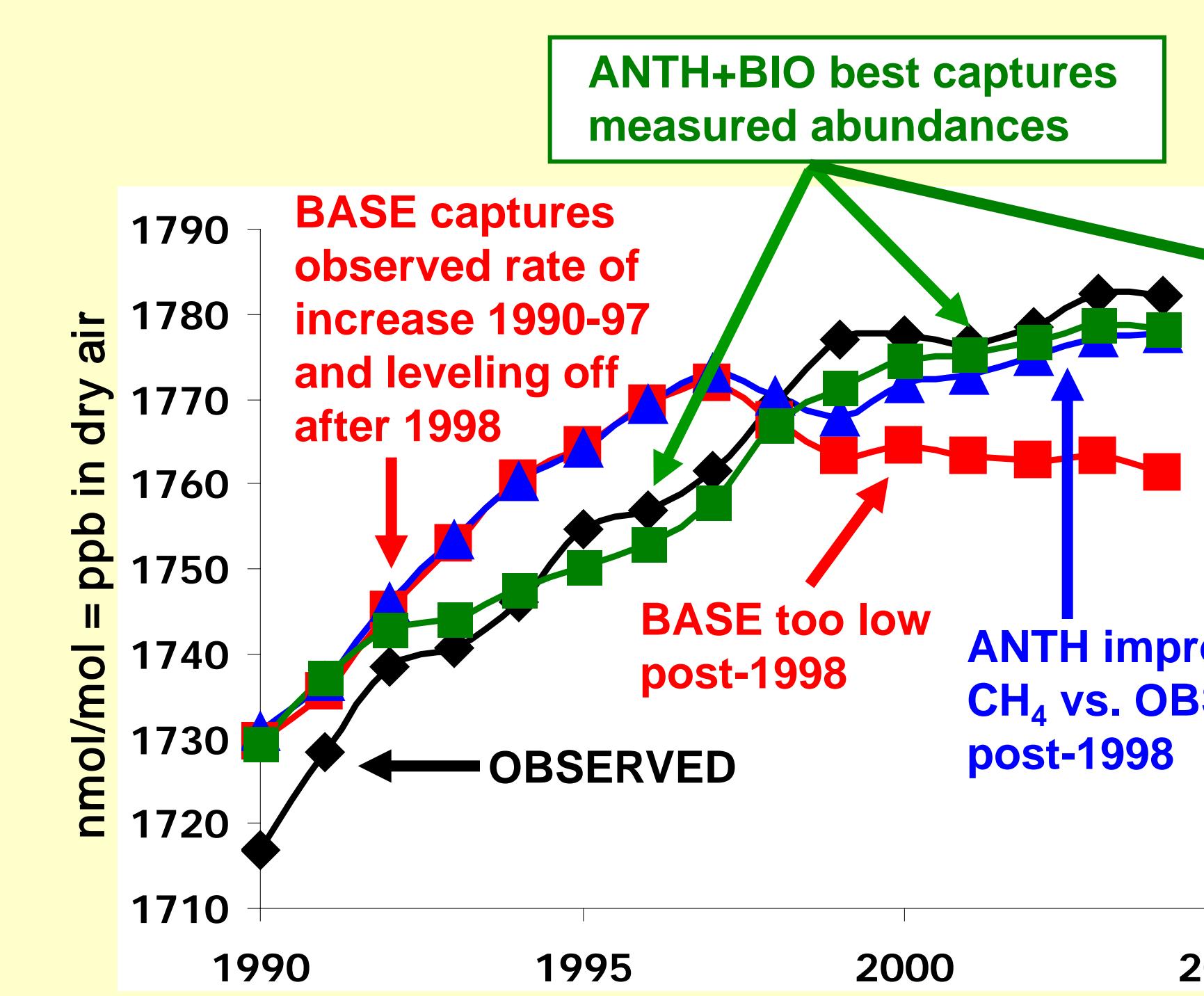


Change in CH_4 and O_3 approaching steady-state after 30 years

→ Stronger sensitivity in NO_x -saturated regions (Los Angeles), partially due to local O_3 production from CH_4

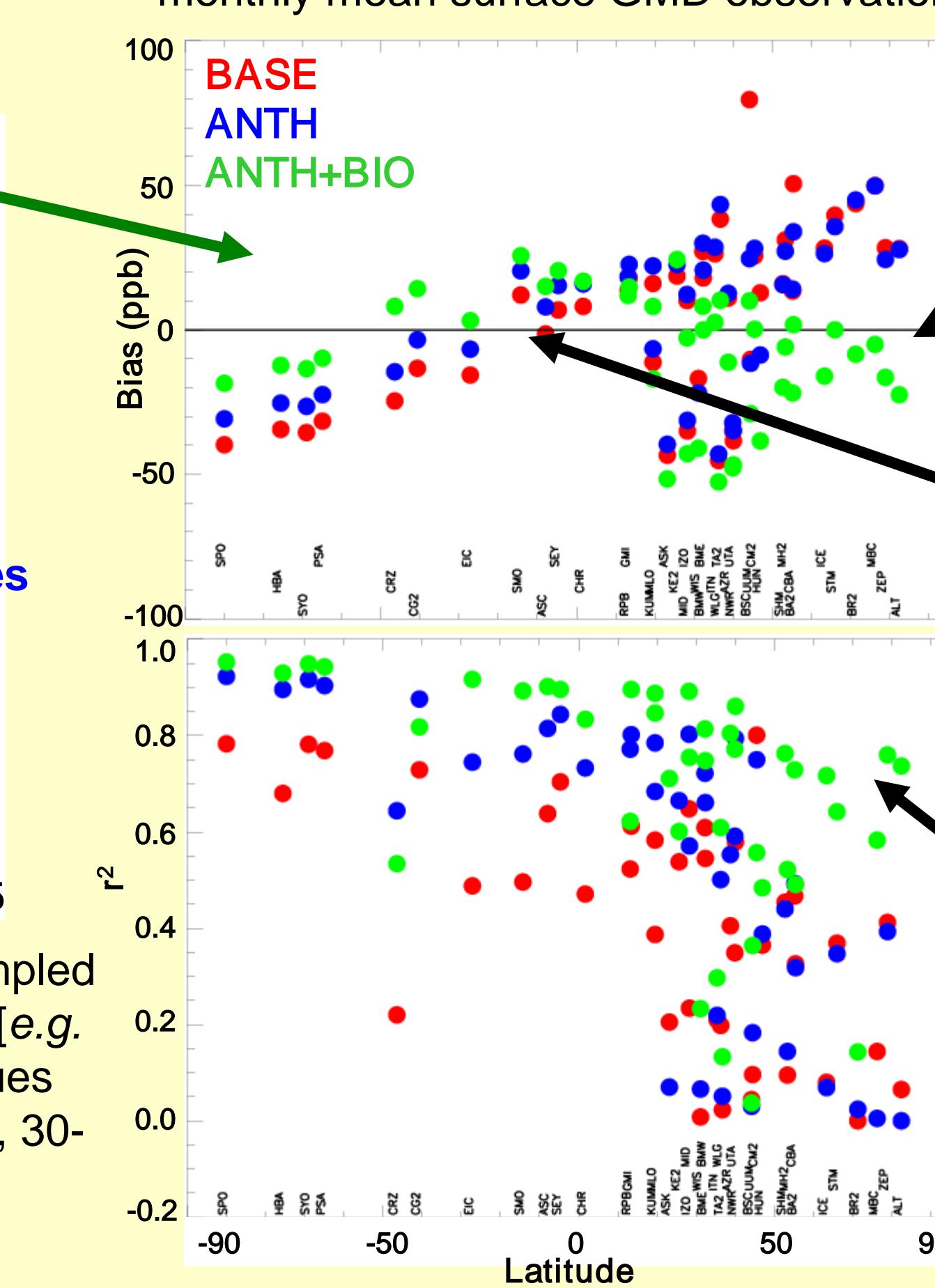
→ O_3 change independent of CH_4 source location except for <10% effects in the Asian source region

3. Influence of Sources on Surface CH_4 Distribution and Trend



Global mean surface CH_4 concentrations as measured (or sampled in the model) at 42 Global Monitoring Division (GMD) stations [e.g. Dlugokencky et al., 2005] with an 8-year minimum record. Values are area-weighted after averaging in latitudinal bands (60–90N, 30–60N, 0–30N, 0–30S, 30–90S).

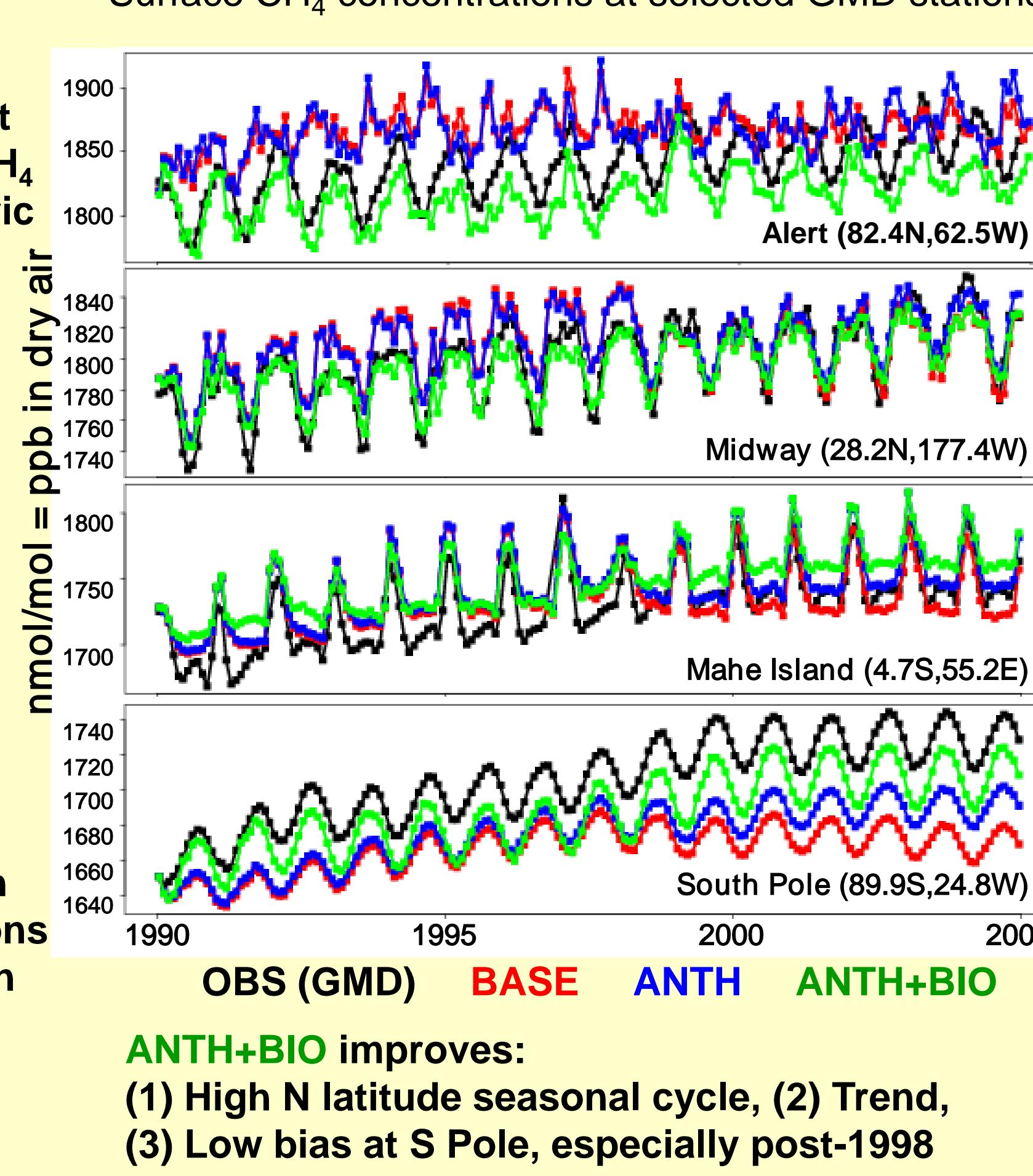
Mean model bias and correlation with 1990–2004 monthly mean surface GMD observations



r^2

Latitude

Surface CH_4 concentrations at selected GMD stations



ANTH+BIO improves:
(1) High N latitude seasonal cycle, (2) Trend,
(3) Low bias at S Pole, especially post-1998

6. Conclusions

- Ozone response is largely independent of CH_4 source location
- 30% decrease in global anthropogenic CH_4 emissions reduces JJA U.S. surface afternoon O_3 by 1–4 ppbv
- BASE simulation (constant emissions) captures observed rate of CH_4 increase from 1990–1997, and leveling off post-1998
- ANTH emissions improve modeled CH_4 post-1998
- Wetland emissions in ANTH+BIO best match the observed CH_4 seasonality, interhemispheric gradient, and global mean trend
- τ_{CH_4} decreases by ~2% from 91–95 to 00–04 due to warmer temperatures (35%) and higher OH (65%, resulting from a ~10% increase in lightning NO_x emissions)

Future research should:

- consider climate-driven feedbacks from fire and biogenic emissions on τ_{CH_4}
- develop more physically-based parameterizations of lightning NO_x emissions to determine whether higher emissions are a robust feature of a warmer climate

REFERENCES

- Dentener, F., et al. (2003), *J. Geophys. Res.*, 108, 4442, doi:10.1029/2002JD002916.
 Dlugokencky, E.J., et al. (2003), *Geophys. Res. Lett.*, 30, 1992, doi:10.1029/2003GL018126.
 Dlugokencky, E.J., et al. (2005), *J. Geophys. Res.*, 110, D18306, doi:10.1029/2005JD006035.
 Horowitz, L.W., et al. (2003), *J. Geophys. Res.*, 108, 4784, doi:10.1029/2002JD002853.
 Karlsson, S., and I.S.A. Isaksen (2000), *Geophys. Res. Lett.*, 27 (1), 93–96.
 Langenfelds, R.L., et al. (2002), *Global Biogeochem. Cycles*, 16, 1048, doi:10.1029/2001GB001466.
 Olivier, J.G.J., et al. (1999), *Environmental Science & Policy*, 2, 241–264.
 Olivier, J.G.J. (2002) In: "CO2 emissions from fuel combustion 1971–2000", 2002 Edition, pp. III.1–III.31. International Energy Agency (IEA), Paris. ISBN 92-64-09794-5.
 Van Aardenne, J.A., F. Dentener, J.G.J. Olivier and J.A.H.W. Peters (2005), The EDGAR 3.2 Fast Track 2000 dataset (32FT2000).
 Wang, J.S., et al. (2004), *Global Biogeochem. Cycles*, 18, GB3011, doi:10.1029/2003GB002180.
 Warwick, N.J., et al. (2002), *Geophys. Res. Lett.*, 29 (20), 1947, doi:10.1029/2002GL015282.
 West, J.J. and A.M. Fiore (2005), *Environ. Sci. & Technol.*, 39, 4685–4691.