Biogenic Contributions to Methane Trends from 1990 to 2004

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1. Introduction

Methane (CH_4) emission controls are a cost-effective strategy for abating global surface ozone, while simultaneously slowing greenhouse warming [*West and Fiore*, 2005]. Sources of CH_4 are shown to the right; the major CH_4 sink is reaction with the hydroxyl radical (OH) in the troposphere. Surface CH_4 concentrations rose by 5-6 ppb yr^{-1} on average until 1999 when they leveled off (see Figure below). There is no clear consensus on the driving mechanism.

Possible explanations suggested by previous studies:

(1) Source changes of CH_4 [*e.g. Langenfelds et al.*, 2002; *Wang et al.*, 2004] or other species [*e.g. Karlsdóttir and Isaksen*, 2000]

(2) Meteorologically-driven changes in the CH_4 sink [*e.g. Warwick et al.*, 2002; *Dentener et al.*, 2003; *Wang et al.*, 2004]

(3) Approach to steady-state with constant lifetime [*Dlugokencky et al.*, 2003]

What is the contribution from each process?

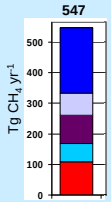
Are existing bottom-up CH_4 emission inventories for the 1990s consistent with observations?

2. Methane in the MOZART-2 CTM

- ~100 gas and aerosol species, ~200 reactions
- NCEP meteorology 1990-2004
- 1.9° latitude x 1.9° longitude x 64 vertical levels
- detailed description in *Horowitz et al.* [2003]

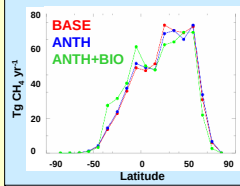
Sensitivity simulations applying different CH_4 emission inventories:

BASE
Constant emissions (1990)



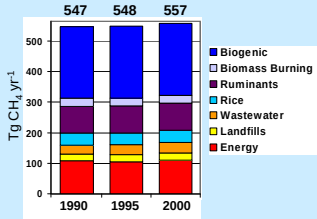
Biogenic and biomass burning from *Horowitz et al.* [2003]

Anthropogenic (energy, rice, ruminants) from EDGAR 2.0 [*Olivier et al.*, 1999]



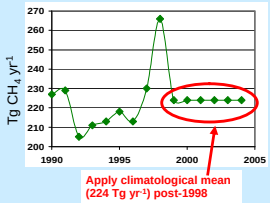
Latitudinal distribution of 1990 CH_4 emissions for each case

ANTH
Time-varying anthrop. emissions



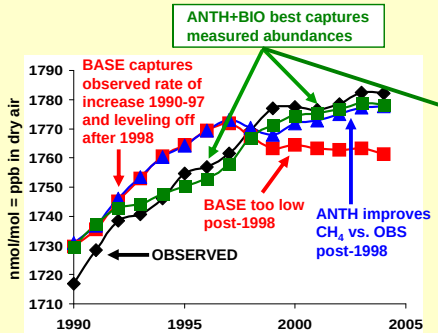
- EDGAR v3.2 1990 and 1995 anth. emissions [*Olivier*, 2002]
- EDGAR "FAST-TRACK" for 2000 [*van Aardenne et al.*, 2005]
- Linear interpolation applied for intermediate years
- Biogenic source adjusted to maintain same global total emissions in 1990 as in BASE

ANTH + BIO
Time-varying anthrop. and wetland emissions



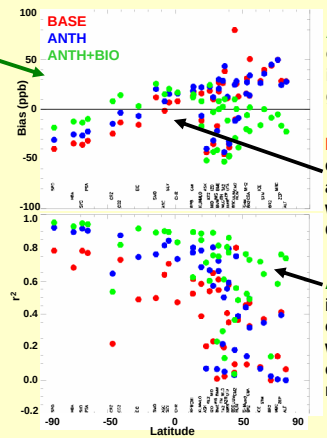
Combine wetland emissions from *Wang et al.* [2004] (above) and anthropogenic emissions from ANTH, constraining global mean 1990-1998 wetland emissions to equal those in ANTH

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

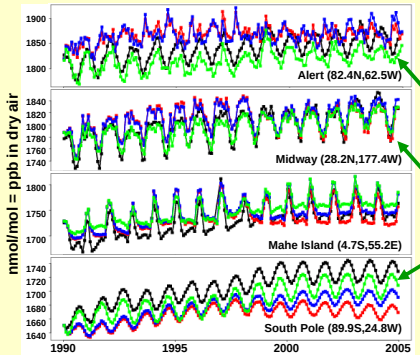


ANTH+BIO best captures the CH_4 interhemispheric gradient

BASE wetland emissions yield a closer match with observed CH_4 in tropics

ANTH+BIO improves the correlation with with observations, especially at high northern latitudes

Surface CH_4 concentrations at selected GMD stations



ANTH+BIO improves:

1) high N latitude seasonal cycle

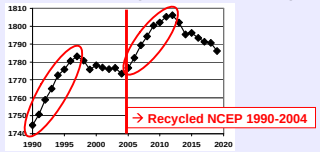
2) Trend

3) Low bias at S Pole, especially post-1998

→ Model captures the observed seasonal cycles

4. Meteorologically-driven Changes in the CH_4 Lifetime

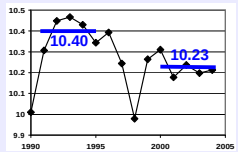
Area-weighted global mean surface CH_4 in BASE simulation (constant emissions)



→ Meteorological drivers for observed trend

→ Not just simple approach to steady-state

CH_4 Lifetime Against Tropospheric OH (τ)



→ Mean annual CH_4 lifetime shortens

How might meteorology affect τ?

$$\tau = \frac{[CH_4]}{k[OH][CH_4]}$$

Transport to sink regions

Temperature

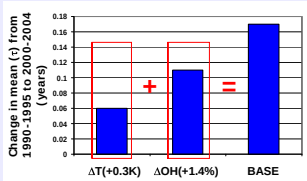
Humidity

Lightning NO_x

Photolysis (changes in stratospheric O_3 columns neglected)

Changes in emissions of other species (neglected)

Deconstruct $\Delta\tau$ (-0.17 years) from 1991-1995 to 2000-2004 into individual contributions by varying temperature and OH separately



→ OH increases in the model by +1.4% from 1991-1995 to 2000-2004 due to a 0.3 Tg N yr^{-1} (~10%) increase in lightning NO_x

→ Large uncertainties in magnitude (and trend) of lightning NO_x emissions in the real atmosphere

5. Conclusions

- **BASE simulation (constant emissions) captures observed rate of CH_4 increase from 1990-1997, and leveling off post-1998**
- **ANTH emissions (EDGAR 3.2 + FT-2000 inventories) improve modeled CH_4 post-1998**
- **ANTH+BIO spatial and temporal distribution of wetland CH_4 emissions is critical for reproducing the observed seasonality, interhemispheric gradient, and global mean trend**
- **τ_{CH4} 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 biogenic emissions and fires (CH_4, CO, NO_x, NMVOC) on τ_{CH4}
- develop more physically-based parameterizations of lightning NO_x emissions to determine whether higher emissions are a robust feature of a warmer climate

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