Observations of Atmospheric Methane and Implications for Emissions

Dave Hofmann for Ed Dlugokencky
NOAA Climate Monitoring & Diagnostics Laboratory
Boulder, CO

Contact: Ed.Dlugokencky@noaa.gov
Internet: www.cmdl.noaa.gov/ccgg
CMDL Global Cooperative Air Sampling Network

November 2004

Surface Observatory Aircraft Tower Open symbol represents inactive site
Global Methane Observations

Some Interesting Features:

- Long period of little growth
- 1991-1992 Growth rate increase and decrease
- 1998 Growth rate increase
Global Burden

\([\text{CH}_4]\) (2003) = 1755 ppb \rightarrow \sim 4900 \text{ Tg burden}

Global Emission Rate

Growth Rate = Emission Rate – Removal Rate

Emission Rate = \( \frac{d[\text{CH}_4]}{dt} + \frac{[\text{CH}_4]}{\tau} \)

\( d[\text{CH}_4] / dt \) and \([\text{CH}_4]\) are measured

\( \tau \) = \( \text{CH}_4 \) lifetime \( \approx 8.9 \) years, due mainly to chemical removal by OH, is assumed constant
Average Emissions = 550.6 ± 9.4 Tg CH$_4$ yr$^{-1}$
Trend (1984-2004) = 0.4 ± 0.4 Tg yr$^{-1}$
1991 - 1992

• The volcano Pinatubo erupted

Stratospheric SO$_2$ and sulfate aerosol reduced solar UV which decreased the production of OH, decreasing chemical methane loss (increased growth rate) in 2nd half of 1991. This was followed by tropospheric cooling (decreased growth rate) in 1992.

• The former Soviet Union collapsed
Methane Growth Rate Contours (ppb/yr)
(red is high, blue is low)
\[ f(t) = a_1 + a_2 t + a_3 t^2 + \sum_{i=1}^{4} [a_{2i+2} \sin(2\pi it) + a_{2i+3} \cos(2\pi it)] \]

More accurate event timing using residuals
Changes in CH$_4$ Spatial Pattern

CH$_4$ Growth Rate anomaly in 1992 coincident with collapse of economy in the former Soviet Union. Emission Data Base suggests decreased fSU emissions from 1990 to 1995 in sectors:

- Fossil fuels
- Animals

Total decrease: 10.6 Tg CH$_4$

1992 also cool (post-Pinatubo) and dry – wetland emissions down.
Interpolar Difference (IPD) = (53-90N) – (53-90S)

Lasting Impact of decreased emissions from fSU
Methane Growth Rate Contours (ppb/yr)
(red is high, blue is low)
Large positive growth rates observed in High NH and Low SH latitudes - ~24 Tg.

Process-based wetlands model indicated ~12 Tg each from High NH and Low SH source. In addition, boreal forest and peat fires estimated to have added ~6 Tg in 1998.

$^{13}$CH$_4$ measurements support both biomass burning and wetland sources (Morimoto et al.) as contributors to the 1998 increase in High NH.
Using Carbon Monoxide as a Tracer of Biomass Burning

Biomass burning in southern tropics was not the source of the 1998 methane increase in Low Lat. SH
Using Carbon Monoxide as a Tracer of Biomass Burning

Biomass burning in Siberia and northern Canada were at least partially responsible for the 1998 methane increase.
Verification

How can emissions reported to UNFCCC or under Kyoto agreement be verified?

Measurement Programs:
• NACP – North American Carbon Program.
• Meth-MonitEUr – European program.

Measurements and Inverse Models:
• Bergamaschi et al., Inverse modeling of national and European CH$_4$ emissions using the atmospheric zoom model TM5, Atmos. Chem. Phys. Discuss., 5, 1007-1066, 2005.
Major disagreements between reported and measured emissions

**Verification of 2001 EU emissions**

Bergamaschi et al., 2005
North America Carbon Program

Expansion of profile measurements in US, using aircraft and tall (~500 m) towers, is underway. Goal: 24 aircraft, 12 towers by 2008.

Nested grid inverse transport models will provide the needed spatial scales to utilize the new measurements in order to extract sources and sinks at higher resolution.
Summary and Conclusions

Observations provide key constraints:
Methane burden, trend, global emissions, spatial gradients, seasonal cycles.

Growth rate variations and CO obs. → Processes
Wetland emissions, biomass burning.

Verification
Europe ahead of US but we’re working on it.
Need higher density of observations and continued inverse model improvements.
Annual Variation in Global Direct Radiative Forcing by Major Greenhouse Gases in ppm EQCO2