Observational Constraints on the Global Methane Budget

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Outline

- Data (NOAA CH₄ observations)
- Long-term trends
- Anomalies in CH₄ growth rate (IAV)
 - Eruption of Mt. Pinatubo
 - Economic collapse of former Soviet Union
- Recent changes in atmospheric CH₄

 Causes of increased CH₄ since 2007
 Potential for climate feedbacks in Arctic

 Summary

GMD Cooperative Global Air Sampling Network



Barrow, AK: www.esrl.noaa.gov/gmd/ccgg/iadv/















Interpolar Difference







Potential Causes

- Increased anthropogenic emissions
 - Expect gradual change
 - Possibly.... relative contribution unclear
- Decrease in OH increased CH₄ lifetime
 Not consistent with CO and other species
- Increased biomass burning – Not consistent with CO nor $\delta^{13}CH_4$
- Increased tropical wetland emissions
- Increased Arctic emissions

ENSO and tropical precipitation anomalies



Potential causes: Tropical wetlands



Increased Amazon CH₄ fluxes in wet years.

Precipitation anomalies in tropics. (Source: GPCP)



Increased tropical emissions consistent with 0.4‰ decrease in δ^{13} C since 2007

Potential causes: Arctic wetlands



GISS: 2007 T anomalies 2007 also very wet

 ΔCH_4 and $\Delta \delta^{13}C$ suggest source with $\delta^{13}C = -66\%$





Potential causes: Arctic wetlands and clathrates? Only 2007



Conclusions

- Observations constrain global CH₄ budget
 Provide budget terms with smallest uncertainties
- IAV tests understanding of processes
 - Wetland emissions drive most IAV
 - Other processes important too
- Increasing CH₄ since 2007
 - Tropical wetland and anthropogenic emissions
 - No measureable change in Arctic emissions



Global CH₄ Budget by Source

Source	Bousquet (Tg/yr)	IPCC Range (Tg/yr)
Anthropogenic		
Energy	110±13	74-106
Enteric fermentation	90±14	76-92
Rice agriculture	31±5	31-112
Biomass burning	50±8	14-88
Waste	55±11	35-69
Natural		
Wetlands	147±15	100-231
Termites	23±4	20-29
Oceans	19±6	4-15
Total	525±8	503-610
Sinks	Bousquet (Tg/yr)	IPCC (Tg/yr)
Troposphere	448±1	428-511
Stratosphere	37±1	30-45
Soil	21±3	26-34
Total	506	492-581
Bousquet et al., 2006, Nat	ure, 443 , 439-443, doi:10.103	38/nature05132.



Quality Control



2007:

Tropical WL – NOAA VPs Arctic WLs - $\delta^{13}CH_4$ at ALT

2008:

Inversions are inconsistent. Data suggest anomalous emissions in tropics and midlatitudes.

High N latitudes recovered.

*NOAA CT-CH₄ 2007 is consistent.

Bousquet et al., ACP, 2010. Dlugokencky et al., GRL, 2009.

1991: Pinatubo and the CH₄ Lifetime

Eruption: 15 June 1991 20 MT SO₂ oxidized to SO₄⁻² 3 to 5 km³ ash

Affects [OH] by affecting photochemistry: Direct absorption of UV by SO₂ Scattering of UV by ash and aerosols

Dlugokencky, E. J., E. G. Dutton, P. C. Novelli, P. P. Tans, K. A. Masarie, K. O. Lantz, and S. Madronich (1996), Geophys. Res. Lett., 23(20), 2761–2764, doi:10.1029/96GL02638.

Potential causes: Arctic processes

- Rate of T increase is 3X global average – Wetland emissions sensitive to soil T $-E_T = E_{T_0}Q_{10}^{(T-T_0/10)}$ where $Q_{10} = E_{T+10}/E_T$
- ~1000 Pg C in top 3 m permafrost soils
 - Melting PF expands wetland area and releases carbon
- 30 to 170 Pg CH₄ in Arctic Ocean hydrates

Chemistry (Largest term in CH₄ budget)

 $OH + CH_4 \rightarrow CH_3 + H_2O$

$$\begin{split} O_3 + hv &(330 \geq \lambda \geq 290 \text{ nm}) \rightarrow O(^1D) + O_2 \\ &O(^1D) + H_2O \rightarrow 2 \text{ OH} \\ &\text{Rate of formation } O(^1D) = j \ [O_3] \\ &j = \int F(\lambda) \ \sigma(\lambda) \ \phi(\lambda) \ d\lambda \end{split}$$

Also affected CO



Potential causes: Sink

- Δ Loss rate (Δ [OH])
 CH₃CCl₃ analysis suggests not (-2 to +1%)
 - PCE suggests not (I. Simpson, UCI)

- CO suggests not

Potential causes: Anthropogenic emissions

Δ Anthropogenic emissions
 – Expect gradual changes



Potential causes: Biomass burning



IPY puts focus on the Arctic

- "Methane Bubbles in the Arctic Ocean Give Climate Scientists the Willies" (Discover, Sept., 2008)
- "Study says methane from ocean floor is 'time bomb'" (CTV.ca, 27 Sept. 2008)
- "Arctic 'methane chimneys' raise fears of runaway climate change" (The Guardian 23 Sept. 2008)
- "Methane 'Fart' from the Earth Poses Enormous Global Warming Risk" (Independent, 24 Sept. 2008)









AI < 0.1 means clear sky; AI > 4 obscures mid-day sun











