Model simulations of atmospheric methane
and their evaluation using AGAGE/NOAA
surface- and IAGOS-CARIBIC airborne
observations, 1997-2014

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Mai 2017, Paul Crutzen becomes honorary member of the Royal Dutch Association of Chemists
The Anthropocene, Homo Sapiens ("wise man") at work

[Graph showing data trends and two vertical lines labeled Pieter and Ed]
Methane and Nitrous Oxide: Their Effects on the Terrestrial Climate

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ABSTRACT

Simplified band models are developed for methane (CH₄) and nitrous oxide (N₂O) bands in the longwave radiation spectrum. The band models are then employed in a radiation model to calculate the seasonally and latitudinally varying contributions of CH₄ and N₂O to the radiative energy balance of the earth-troposphere system. From the energy balance calculations, it is concluded that the longwave opacity (i.e., the so-called "greenhouse effect") due to present-day observed concentrations of CH₄ and N₂O contribute nearly 2 K to hemispherical mean surface temperature with possible larger contributions to polar surface temperatures. The paper also discusses stratospheric effects of CH₄ and N₂O and examines the sensitivity of tropospheric radiation energy balance to large increases in CH₄ and N₂O.

1. Introduction

Methane and N₂O possess several strong absorption bands in the longwave radiation spectrum. The strength of these bands, when considered in conjunction with the observed present-day concentrations of CH₄ and N₂O, suggest that these species may exert a non-negligible influence on the present-day climate. The purpose of the present paper is to modified slightly by Ramanathan (1976). The model describes the total band absorbance $A$ as

$$A(U, \beta) = 2A_0 \ln \left[ 1 + \frac{U}{[4 + U(1 + 1/\beta)]^{1/2}} \right],$$

(1)

where

$$U = SW/A_0,$$

(2)

$$A = A_0 \left( P/P_0 \right).$$

(3)
The Lowlands, OR
..a „beach house“ with 16 million people
Atmospheric Methane

- It is the second most important greenhouse gas (Daniel Kahneman)

- It is a greenhouse gas with the lifetime of a dog
- It determines a significant fraction of the OH reactivity of the troposphere
- It is a precursor of stratospheric water
- It is Occam’s worst nightmare (ask Martin Manning)
- If its growth has been ameliorated by increasing OH, future growth may be strong, endangering the 2 degree target
• It is a greenhouse gas with the lifetime of a dog (can we control methane?)

**Figure 1.** Tropospheric CH$_4$ lifetime by month calculated for each POLMIP CTM included in this analysis. CAM indicates CAM-Chem ver-
• It determines a significant fraction of the OH reactivity of the troposphere

Note: OH reactivity at cruise altitude

Courtesy: Hella Riede, MPIC
• It is a Trojan Horse precursor of stratospheric water (don’t mess with the stratosphere)
Friendly Termites Turn your home into a natural gas source, it beats fracking!

Don’t wreck the planet, wreck your home!
Gas Raid from Mars in 1938, a wave of Mass Hysteria in New York, fake gas news

On the other hand....“Methane is a sign of LIFE“

H.G. Wells
CARIBIC

10 feet wide, 1.6 ton (0.4378260 % tow)
Number of CARIBIC-2 samples to geographical regions
*(color coded)*
EMAC model support for the interpretation of CARIBIC CH₄ measurements
The procedure used

- Period 1997-2014 (GHG measurements, Tanja Schuck)
- Apply a well documented model and use adequate resolution
- Keep the OH distribution fixed
- Take existing sources
- Use tagging
- Get a steady state and tune sources to get best possible burden and NS gradient
- Add an extra source (a constant one) starting in 2007 for simulating the „renewed increase“
- Split this source between NH and SH to optimize the NS gradient and stations’ fits.
The numerical model setup

**EMAC**: Numerical chemistry and climate simulation system of sub-models describing
- tropospheric and middle atmospheric processes (up to 1 Pa)
- interaction with oceans
- land and human influences

**using:**
- **ECHAM5** - European Centre Hamburg general circulation model \[^{[2]}\]
- **MESSy2.50.4** – with a novel CH$_4$ submodule (*introduced Feb. 2014*)
- Modular Earth Sub-model System to link multi-institutional computer codes\[^{[1]}\]

**Grid Resolution** :
- Horizontal: T106  \(\sim 1.\text{°} \times 1.\text{°}\)
- Vertical:  90 hybrid pressure levels - \(\sim 500\) m vertical layers near CARIBIC cruise altitude.

**Time step**: 2 min

**Meteorology**: Troposphere nudged towards ECMWF analyses wrt temperature, divergence, vorticity and surface pressure.
## Methane emissions:

Input for MESSy2.50.4 submodel “offemis”

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<th>Source type</th>
<th>Tg / CH4 y⁻¹</th>
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</tbody>
</table>

**Grand Total** 551.7

Sander Houweling
CH4 composition along CARIBIC flights 218 / 219, Dec 2007

**EUR** → Denver, CO → EUR

- ani
- lan
- ric
- gas
- coa
- bog
- oil
- bib
- ter
- bfc
- EMAC
- CARIBIC

°E longitude

(swamps left out - no variability)
A jump in global source strength

Global Mass development kg/CH4 - 2007 Trend

y = -1.12E+06x + 4.89E+12
Emission distribution optimization

% of observed station mix. rat. 2001-2005

ΔNS (obs - model)

RMS (obs-model)
Methane trend period 2007 - 2014

\[ y = 1.02\times 10^0 \times x - 4.39\times 10^1 \]

\[ R^2 = 9.47\times 10^{-1} \]
CH4 contribution (%) by category at stations

- Mace Head, Ireland
- Trinidad Head, California
- Mauna Loa, Hawaii
- Ragged Point, Barbados
- Cape Matatula, Am. Samoa
- Cape Grim, Tasmania

Categories:
- swamps
- animals
- landfills
- rice
- gas
- coal
- oil/oceans
- biom. brn.
- termites
- biofuel
- Linear (swamps)
- Linear (landfills)
- Linear (bogs)
Conclusions

The model results closely follow all stations’ monthly means over the years 1997-2014.

The model results match the CARIBIC aircraft data around the tropopause. This involves the variations in time and those due to geographical position. The modeled dynamic range is still too small (a typical UTLS issue). A higher resolution can fix this.

The required additional emissions are for 2/3 to be placed in South America.