Methane & Climate Science

by Joe Melton, MSc

Methane (CH_4) is the most abundant organic molecule in the Earth's atmosphere and plays important roles in both the planet's radiative energy budget and global atmospheric chemistry (Brasseur et al., 1999). It's presence in the atmosphere was first noted in 1948 from features in the infrared absorption spectrum [Migeotte, 1948] and it is now routinely measured. CH_4 is the third most important greenhouse gas after H_2O vapor and carbon dioxide (CO_2) and has a Global Warming Potential (GWP) 25 times that of CO_2 on a 100 –year timescale (Forster et al., 2007).

The direct radiative forcing (warming) due to the CH_4 concentration increase in the industrial era (i.e. after 1750 AD) is 0.48 W/m^2 (Forster et al., 2007). Increasing methane concentration also contributes a radiative forcing indirectly, through tropospheric interactions that influence ozone concentrations, increasing stratospheric water vapor (of which it is the main source), as well as providing a small additional source of CO_2 (methane, in its destruction, is oxidized to CO_2). If these indirect effects are taken into account, the radiative forcing due to anthropogenic (from human origin) methane increase is estimated at ~ 0.85 W/m^2 , as compared to 1.66 W/m^2 for CO_2 (Forster et al., 2007).

Methane production processes include methanogenesis by microorganisms under anoxic (without oxygen) conditions, thermogenic (heat) and abiogenic (non-living) methane production occurring below the Earth's surface, and recently discovered, and controversial, aerobic methane production by plant matter (Keppler et al. 2006). Methane destruction, in turn proceeds by the actions of oxidative methantrophic bacteria, both aerobically and anaerobically, and abiotic processes. It is the second most important sink (after carbon monoxide (CO)) of tropospheric hydroxyl radicals (·OH) (Brasseur et al., 1999). Tropospheric ·OH is the "cleaning agent" of the atmosphere and is responsible for the oxidation and removal of most organic compounds. Substantial fluctuations in CH_4 concentration have the power to influence ·OH concentrations and thereby change the lifetimes of many other atmospheric trace species (Forster et al., 2007). The oxidation of CH_4 by ·OH is also one of the main sources of CO and formaldehyde in the troposphere (Hobbs, 2000). Changes in CH_4 concentration also influence tropospheric ozone production (Brasseur et al., 1999).

Methane records, along with paleo-temperature proxies, from both Antarctica (Petit, et al., 1999) and Greenland (Chappellaz, et al., 1993) reveal the close correlation between methane and millennial-scale warming and cooling. Indeed, CH_4 more closely parallels the rapid variations of polar temperature records than any other measured gas (Chappellaz, et al., 1993). Humans have perturbed the atmospheric methane budget to a remarkable extent. Ice core records have shown that the CH_4 concentration had remained between 350 and 800 parts per billion (ppb) for the past 650 thousand years (kyr) (Brook et al., 2000; Spahni et al., 2005); whereas presently global mean CH_4 concentration is 1775 ppb (Forster et al., 2007).

The CH_4 concentration rise due to anthropogenic activities (which includes rice agriculture, ruminants (for eg. cattle), biomass burning (forest and grass fires), coal mining, and landfills) is usually considered to have begun around 1750 AD, although it is also argued that humans significantly affected the global methane budget starting around 5 kyr before present (Ruddiman, 2003).

From the methane record, the CH_4 concentration is seen to start to rise from ~700 ppb around 1750 AD and increased in an approximately exponential fashion until about the 1980s. In the 1990s, the rise slowed and CH_4 concentration leveled off around the year 2000, which has been attributed to the stabilization of the cumulative CH_4 emissions (Forster et al., 2007).

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International Panel on Climate Change
"The global atmospheric concentration of CH4 has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s and was 1774 ppb in 2005. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period."
International Panel on Climate Change, Climate Change 2007: Synthesis Report, p. 37

Methane Links
Information

- NOCS | Warming ocean triggers methane release, acidification, etc | Aug 2009 (Media: 1|2)
- Science Daily | Methane flux from Arctic tundras | Apr 2009
- NOAA | Greenhouse gases to continue to climb despite economic slump | Apr 2009
- CSIRO | Global methane levels on the rise again | 2008

- NASA | Atmospheric Methane
- NOAA | The Second Greenhouse Gas
- NOAA | CO2, Methane Rise Sharply in 2007 | 2008
- Science Daily | Bubbling methane on seafloor creates undersea hills | 2007
- Science Daily | Alaska lakes with boiling methane | 2007 (more: 1)
- Science Daily | Siberian lakes burp time-bomb GHGs | 2006 (more: 1)
- RealClimate.org | Rasslin' Swamp Gas (RealClimate.org / 2006)
- Scientific American | Mysterious Stabilization of Methane | 2006
- NASA News | Seven-year Stabilization of Methane | 2006
- NY Times | Stabilization of Methane After 200 Years | 2006
- RealClimate.org | Methane Hydrates and Global Warming | 2005
- NASA Goddard | Alternate Scenario for Climate Change | 2002

Data

- Methane Instrument Data: Mauna Loa Observatory since 1987 (Wed Sep 26 14:07:09 2007 / NOAA)
- Ice Core Data Sets (NOAA / NCDC)