State of the Science FACT SHEET

Methane and Climate Change

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

Methane and its role in the climate system

Methane (CH_4) is produced by human activities and natural sources, is an economically important hydrocarbon, and is the second most important driver of human-induced climate change after carbon dioxide (CO_2). Human activities related to fossil fuel production, waste and agriculture contribute more than half of global methane emissions. The globally averaged surface mixing ratio of methane in 2020 was 1879 ± 0.6 ppb (https://gml.noaa.gov/ccgg/), 157% higher than pre-industrial levels and about 200 times lower than current levels of carbon dioxide. As of 2020, methane directly contributes 16% of the total radiative forcing, the largest contribution after carbon dioxide, which contributes 66% of total radiative forcing (https://gml.noaa.gov/aggi/aggi.html). It is estimated to be about 30 times more efficient than carbon dioxide at trapping energy in the climate system (per-mass emitted over 100 years). The strong influence of methane on surface temperature is a result of its direct influence on radiation as well as its indirect influence on carbon dioxide, ozone, stratospheric water vapor, and aerosols. Methane also contributes to air pollution via its role in the formation of ground-level ozone, which damages human health and crops.

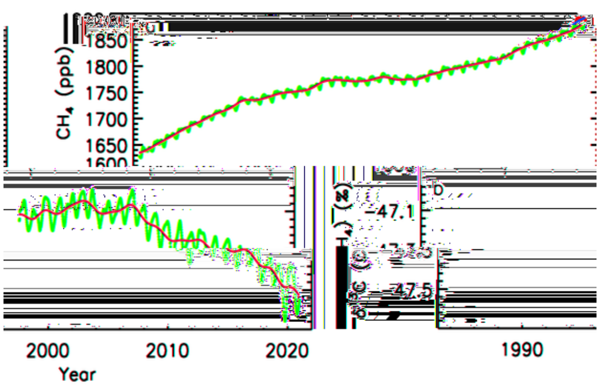

Figure 1. (a) Global average methane mole fraction and (b) methane isotope measurements from the NOAA Global Greenhouse Gas Reference Network marine boundary layer sites. The blue line shows annual average mole fractions, while the red symbols are monthly averages showing the seasonal cycle. CH_4 isotopes are measured by the Institute of Arctic and Alpine Research at the University of Colorado Boulder.

Methane has a significant chemical sink that approximately balances emissions and results in a 9-year atmospheric lifetime. Small imbalances between emissions and sinks have led to the observed variable growth of atmospheric methane, such as the period of low atmospheric growth during 1999–2006 and the recent accelerating growth rate since 2006, (Figure 1a). The low-growth period is believed to be due to a temporary balance between global emissions and sinks, and measurements of isotopic composition of atmospheric methane (Figure 1b) point to microbial sources as the predominant cause of the recent increase in global growth.

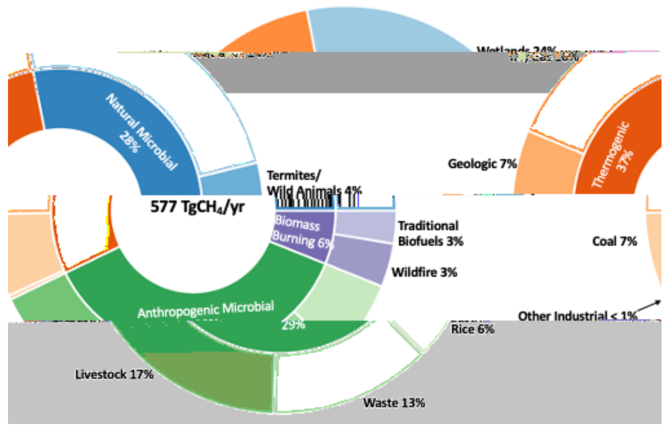

Figure 2. A plausible CH_4 emissions budget ca. 2015 based on Lan et al., 2021 that is in agreement with both observed atmospheric CH_4 and $^{13}CH_4$. Atmospheric methane grew by 10 ppb in 2015 implying a global atmospheric chemical sink of 548 TgCH that year (https://gml.noaa.gov/ccgg/trends_ch4)

The largest share of methane's emissions is due to microbial sources (Figure 2). Microbial sources resulting from human activities include livestock (especially cows and sheep), rice agriculture, and waste (landfills and sewage). Natural microbial sources include wetlands and freshwater systems. Leaking oil and gas infrastructure, coal mining, and natural emissions from geologic features, such as gas seeps (including shallow marine seeps) and mud volcanoes, also emit methane to the atmosphere. The relative share of these sources to total emissions is highly uncertain, however, measurements of isotopic composition of atmospheric methane can be used to estimate the contribution of microbial sources.

Natural microbial sources of methane have the potential to change significantly in response to climate change, a possible climate feedback. For example, wildfires and permafrost thawing in a warming Arctic can lead to significant increases in carbon dioxide and methane emissions. Climate change can also affect uptake of methane by microbes in soil and chemical losses in the atmosphere. Such climate feedbacks have the potential to alter the effectiveness of climate change mitigation strategies. It is therefore critical to detect such feedbacks as early as possible.

Benefits of Reducing Methane Emissions

Long-term climate stabilization requires controlling cumulative carbon dioxide emissions in tandem with strong reductions of other greenhouse gas emissions. Because of its relatively short lifetime, reducing methane emissions, particularly from human activities, is recognized to be a cost-effective strategy for rapidly reducing the rate of global warming. Methane emission reductions provide an additional benefit of reducing ground-level ozone, which causes harmful effects on human health, crops, and ecosystems, offering a "win-win" strategy for tackling climate change and air pollution simultaneously. An assessment conducted for the United Nations reports that measures to limit human-caused emissions are readily available, and if implemented, can reduce global methane emissions by about 30%. In 2021, the US joined over 100 countries in pledging a 30% reduction in methane emissions by 2030 relative to 2020, which is expected to reduce global warming by at least 0.2℃ by 2050. The US has already made steps towards reducing methane emissions: states have enacted legislation aimed at limiting emissions from oil and gas production and are requiring more stringent leak detection; power plants that use landfill gas as a fuel have been constructed; and adjustments to cattle diet have been shown to reduce CH_4 emissions.

How NOAA Advances Understanding of Methane's Role in the Climate System

Monitoring
NOAA measures the global atmospheric distribution and trends of greenhouse gasses, including methane and other gasses co-emitted with methane during oil and gas production (for e.g., ethane). Together with the Institute of Arctic and Alpine Research at the University of Colorado, Boulder, NOAA collects observations of stable isotopes of methane that provide important insights into the source of observed methane trends. All measurements are traceable to international calibration scales and are subject to stringent quality controls. NOAA also develops atmospheric methane monitoring products using satellite platforms.

Field Campaigns
NOAA engages in intensive field campaigns to enhance understanding of the distribution of methane and its sources. These atmospheric measurements help quantify emissions from oil and gas production regions in the U.S., as well as from landfills, coal mining, and livestock. These studies have verified and improved state and federal greenhouse gas inventories and helped shed light on inventory shortfalls.

Marine Methane
NOAA uses ship-mounted multibeam sonar to map the distribution of methane gas seeps and subsurface gas accumulations on continental margins in the Atlantic and Pacific. With nearly 2000 active gas seep sites identified through 2020, additional surveys are investigating the distribution of methane hydrates and the potential for their destabilization due to warming oceans.

Modelng/Data Assimilation

NOAA develops modeling tools to estimate and track methane emissions over multiple decades and to improve understanding of the source contributions. Such modeling systems are essential for verifying the success of emission mitigation policies (such as the Paris Agreement) and for detecting potential feedbacks between climate and methane emissions. (https://gml.noaa.gov/ccgg/carbontracker-ch4/, HYSPLIT)

Earth System Modeling
NOAA develops earth system models (ESMs) with realistic representation of the physical, chemical, and biogeochemical processes to simulate the global methane cycle. These models are used to improve understanding of the drivers of atmospheric methane, examine air quality and climate impacts from future changes in emissions, and assess carbon cycle feedbacks from climate-induced changes in methane.

Participating NOAA Organizations

Office of Oceanic and Atmospheric Research (OAR)/Air Resources Laboratory – Conducts research to gain new insights into atmospheric dispersion, atmospheric chemistry, climate change, the complex behavior of the atmosphere near the Earth's surface, and the natural surface-atmosphere exchange of energy and greenhouse gases. arl.noaa.gov

OAR/Global Systems Laboratory - Conducts research to advance regional and global predictive models for weather, air quality, pollutant transport, and the coupling between Earth system components (such as that between air quality and weather). gsl.noaa.gov.

OAR/Chemical Sciences Laboratory - Investigates the chemical and physical processes that affect Earth's atmospheric composition and climate. csl.noaa.gov

OAR/Global Monitoring Laboratory – Operates the Global Greenhouse Gas Reference Network which collects observations of key long-lived greenhouse gases, including methane. Develops the CarbonTracker global and regional data assimilation and flux inversion modeling systems. gml.noaa.gov

OAR/Geophysical Fluid Dynamics Laboratory – Develops global Earth system models to improve understanding of the global methane cycle and feedbacks, and provides predictions of climate and air quality implications of changes in methane. gfdl.noaa.gov

OAR/Pacific Marine Environmental Laboratory – Explores and characterizes the seafloor to reveal connections between biogeochemical processes, benthic ecosystems, and marine chemistry. pmel.noaa.gov

OAR/Ocean Exploration and Research - Explores the deep ocean and delivers valued mapping and characterization information through expedition operations, including the detection and mapping of methane seeps along the US continental margin. oceanexplorer.noaa.gov

OAR/Climate Program Office - Supports research on process-level understanding of the climate system through observation, modeling, analysis, and field studies to improve models and predictions. cpo.noaa.gov/AC4

OAR/Weather Program Office – Supports air quality research and forecasting for $PM_{2.5}$ and ozone predictions. wpo.noaa.gov

National Environmental Satellite, Data, and Information Service (NESDIS)/Center for Satellite Applications and Research (STAR) – Transitions satellite observations of air quality, including fire emissions of methane, from scientific research and development into routine operations, and provides state-of-the-art data, products and services to decision makers. star.nesdis.noaa.gov