Improved constraints on global methane emissions and sinks using δ^{13}C-CH_4

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Introduction

The atmospheric burden of CH_4 has renewed its increasing trend since 2007, but the drivers behind are still debated. Hypotheses proposed in recent studies cover a very diverse range of drivers including changes in both CH_4 emissions and sinks. Around the same time that the increase started, the ratio of stable carbon isotopes of CH_4 ($^{13}C/^{12}C$), denoted by δ^{13}C-CH_4, started to decrease after two centuries of increase (Ferretti et al., 2005). In this study, candidate emission and sink scenarios are constructed and simulated in the TM5 chemical transport model to produce 3D fields of atmospheric CH_4 and $\delta^{13}CH_4$, which are compared with observations.

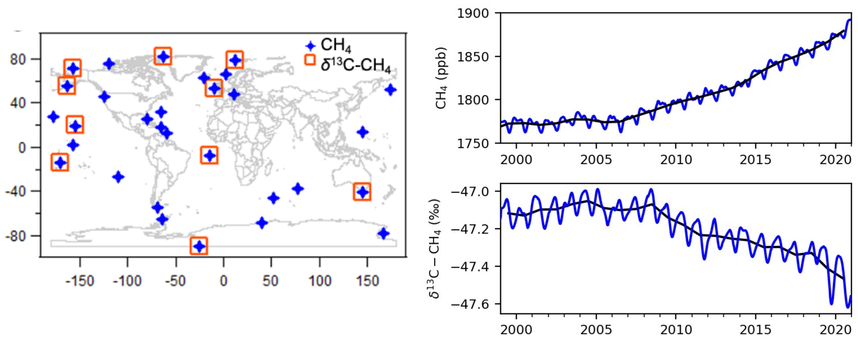
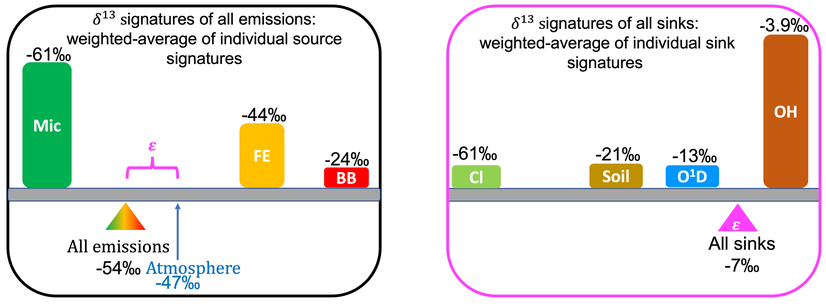


Fig. 1: Marine Boundary Layer sites from NOAA's Global Greenhouse Gas Reference Network (Left). Globally averaged atmospheric CH_4 and δ^{13}C-CH_4 (right); the blue curves are approximately weekly data and the black curves are annual means.

δ^{13}C-CH_4 constraints

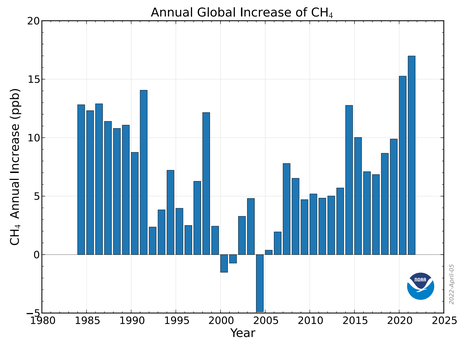
CH_4 and δ^{13}C-CH_4 measurements in the atmosphere see the combined effect of emission and sink processes, including emissions from fossil, wetlands (WL), rice, waste/landfills, ruminants, and biomass/biofuel burning, and sinks from soil consumptions, reactions with hydroxyl radicals (OH), chlorine, etc.

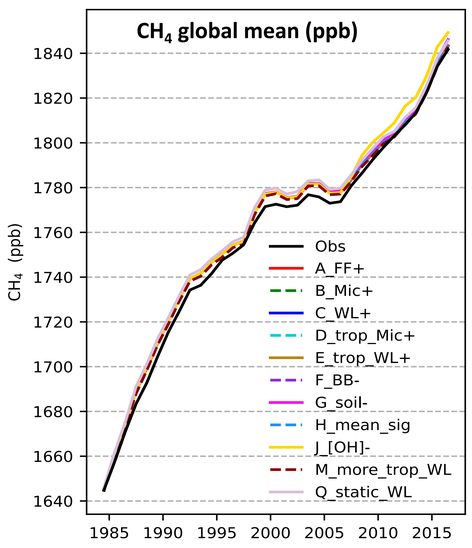


Different CH_4 sources have distinct δ^{13}C-CH_4 signatures and different CH_4 sinks have different preference for oxidation of ^{12}C over ^{13}C. Figure above simplifies the idea of using δ^{13}C-CH_4 to partition microbial (Mic), fossil (FE) and biomass/biofuel (BB) emissions, when assume known sinks from models. δ^{13}C-CH_4 observations also helps to inform recent trends in CH_4 emissions.

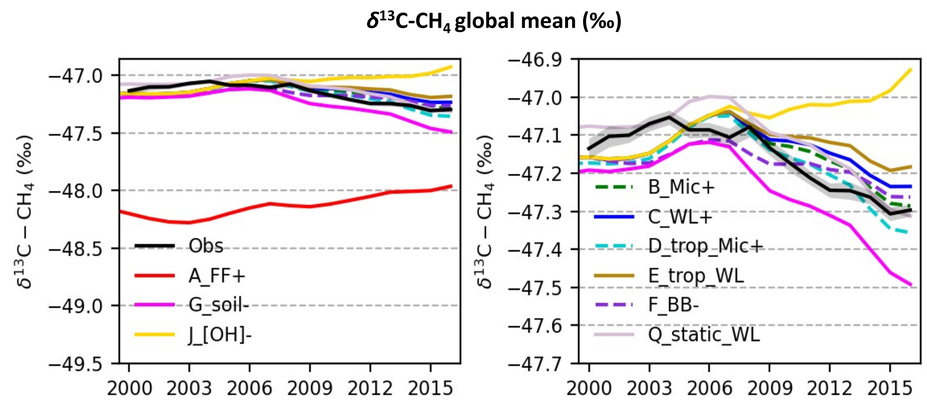
Key findings

- Increased FF emissions are unlikely the dominant driver for the post-2006 global CH_4 increase. The dominant driver must be microbial emission increases to be consistent with δ^{13}C-CH_4 observations.
- A large decreasing trend in [OH] cannot explain the post-2006 global CH_4 increase.
- Large uncertainties remain in wetland areas and emissions, which are not well-constrained by current measurements, but significantly influence our interpretation of emissions from wetland and other sources.





The observed atmospheric CH_4 growths suggest large increases in global total emissions of >40 Tg/yr in 2016 and > 80 Tg/yr in 2021 from the 1999-2006 stabilization period.

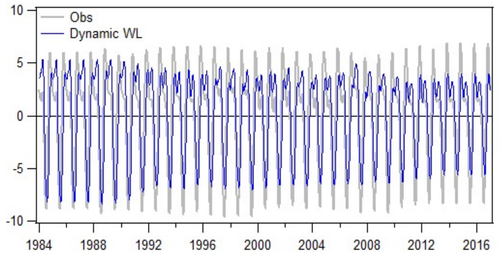


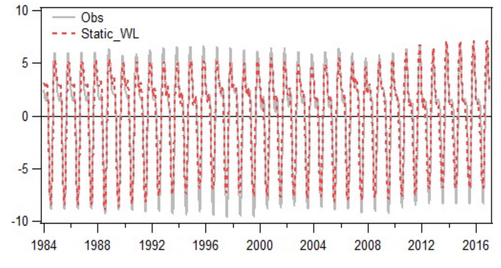
A	EDGAR 4.3.2	2017	Positive trends in ONG and coal emissions from EDGAR 4.3.2 inventory
B, C	Schwietzke et al.	2016	Larger fossil emissions magnitude (167 Tg/yr) than inventory; Mic emission increases contribute to global CH_4 increases
D, E	Nisbet et al.	2016 2019	Large increases in tropical microbial emissions or WL emissions
F	Worden et al.	2017	Decreases in biomass burning emissions with moderate increases in FF emissions
G	Ni & Groffman	2017	Significant decreases in soil sink with moderate increase in FF emissions
J	Rigby et al. Turner et al.	2017	Renewed growth of atmospheric CH_4 after 2006 is due to a decreasing trend in atmospheric [OH]
Q	This study		Mic emission increases contribute to global CH_4 increases; static wetland map is used in modeling (see below)

Large uncertainties in wetland CH_4 emissions

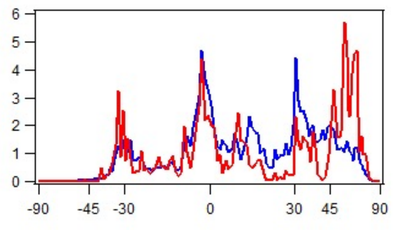
Wetland (WL) emissions are the biggest natural source of atmospheric CH_4 and their uncertainties are also the largest. We compare model results based on a static WL area map (Mathew and Fung, 1987), and a dynamic inundation map combined with the Global Lake and Water Dataset (Poulter et al., 2017).

Seasonal cycles





Latitude distribution of WL emission



Global total annual WL emissions from both the **static** WL map and the **dynamic** WL map are similar, but discrepancies exist in the spatial distribution of emissions.