Arctic wetlands and methane emissions

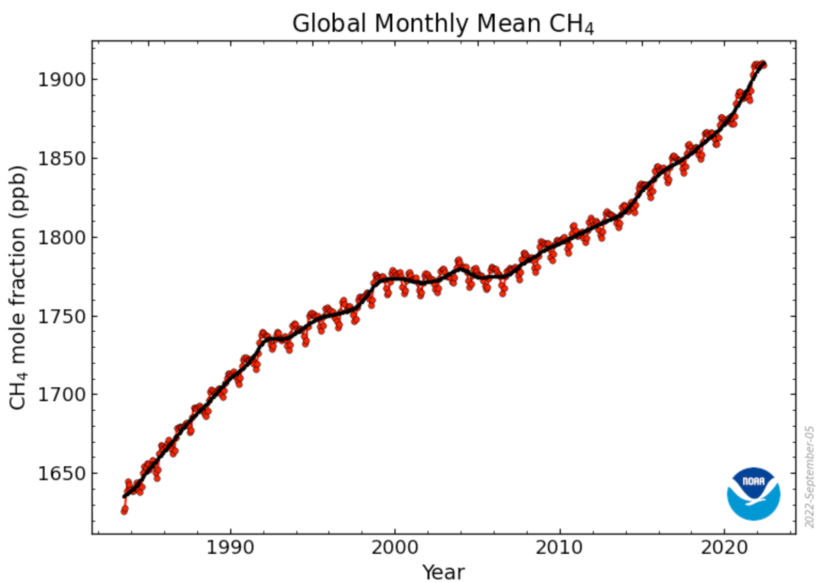
ESA-NASA Arctic Methane Permafrost Challenge (AMPAC)

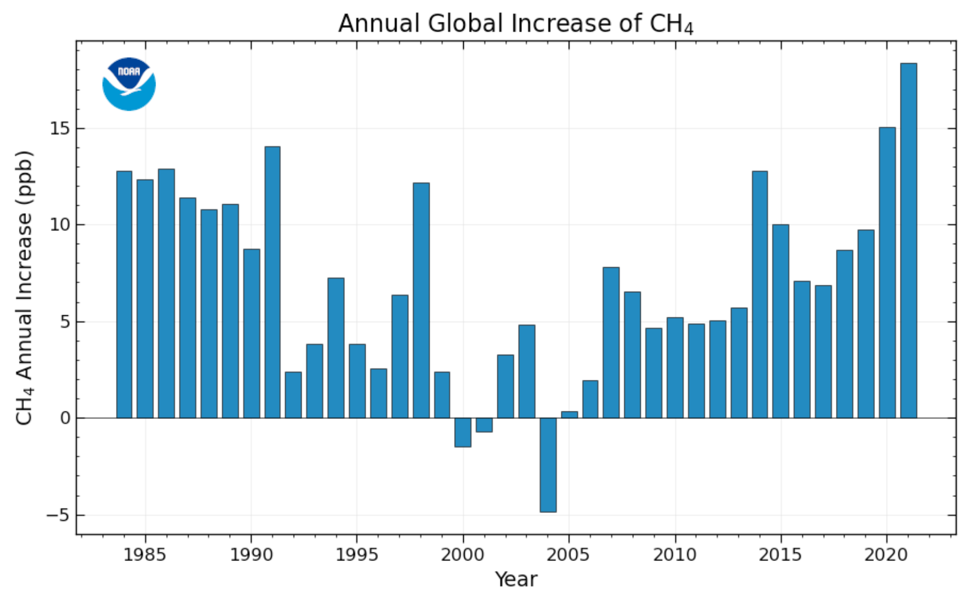
Ben Poulter & GCP Wetland modelers

NASA Goddard Space Flight Center

Longyearbyen, Norway. Credit: John Shaw

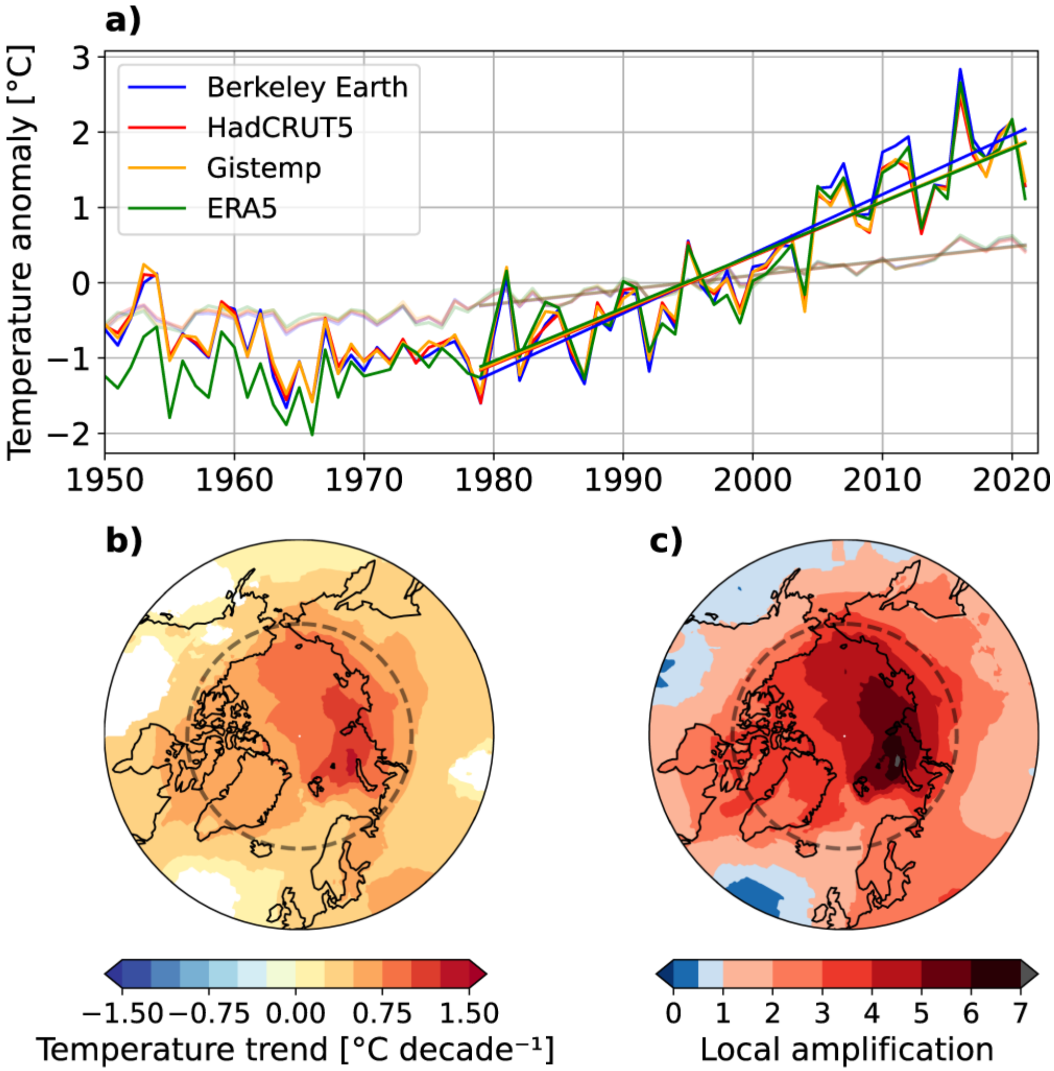
2020 and 2021 record growth of methane





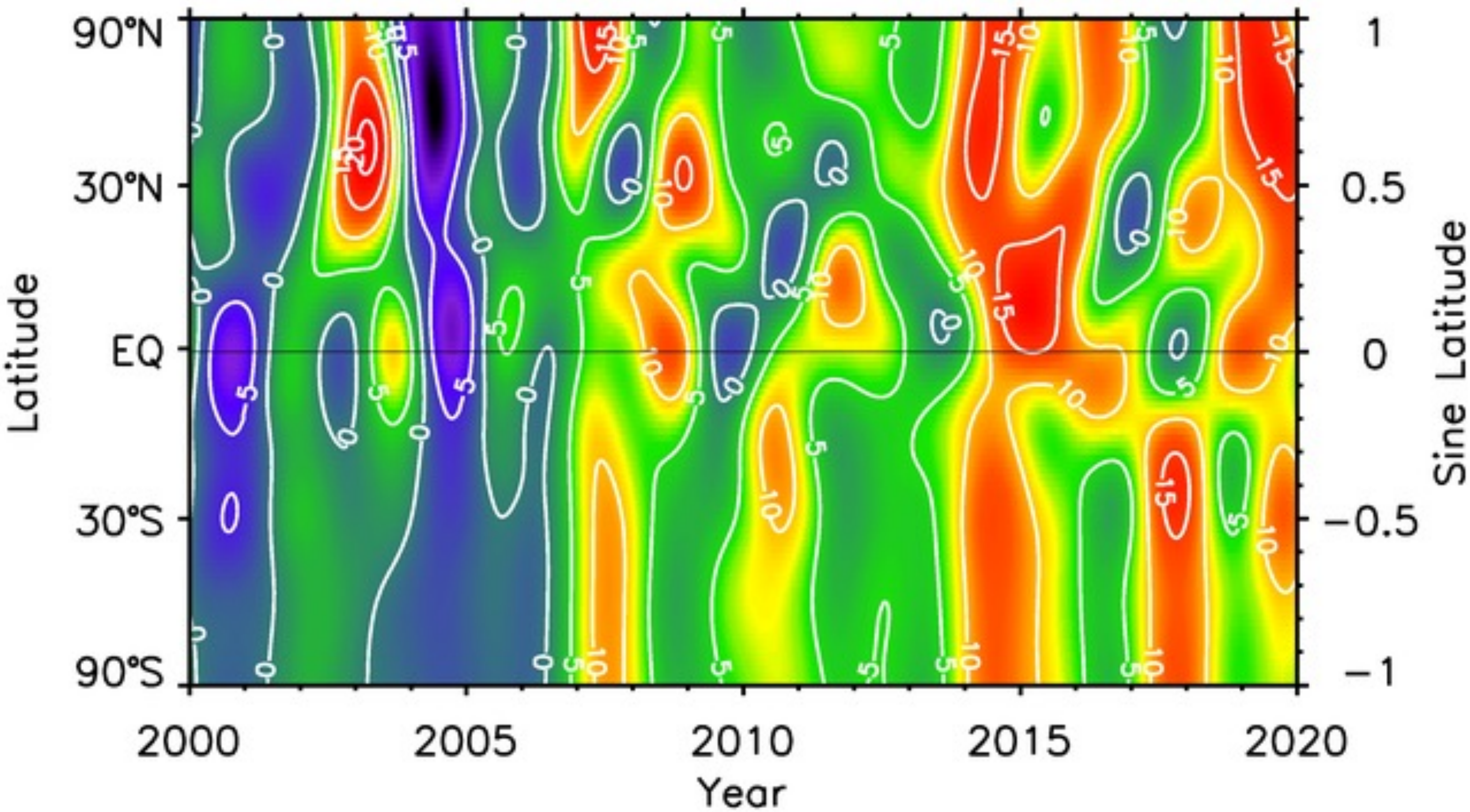
- Is there a wetland methane feedback emerging?

Arctic warming at 4x global rate

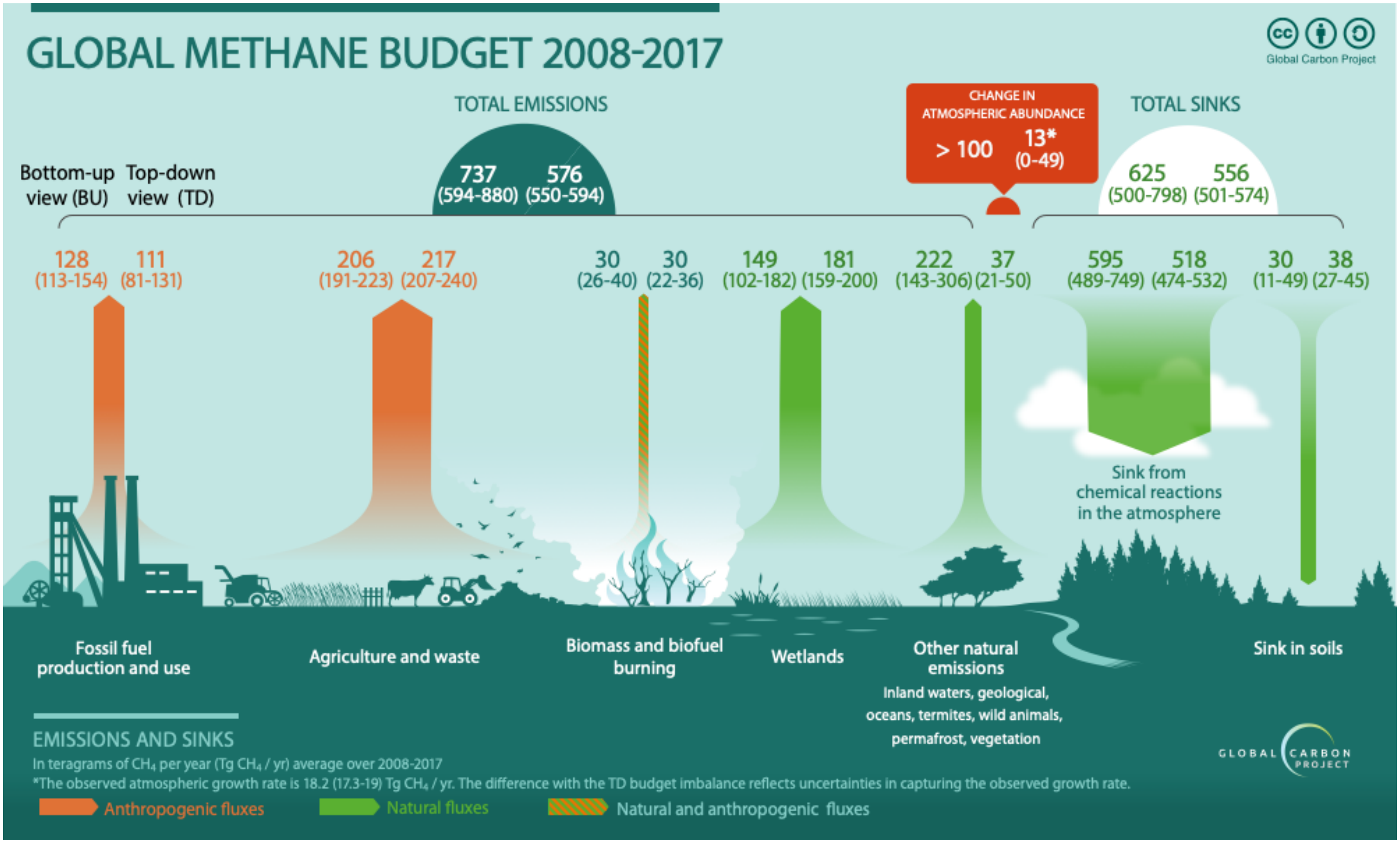


Rantanen et al. 2022

No sustained signal in Arctic methane growth

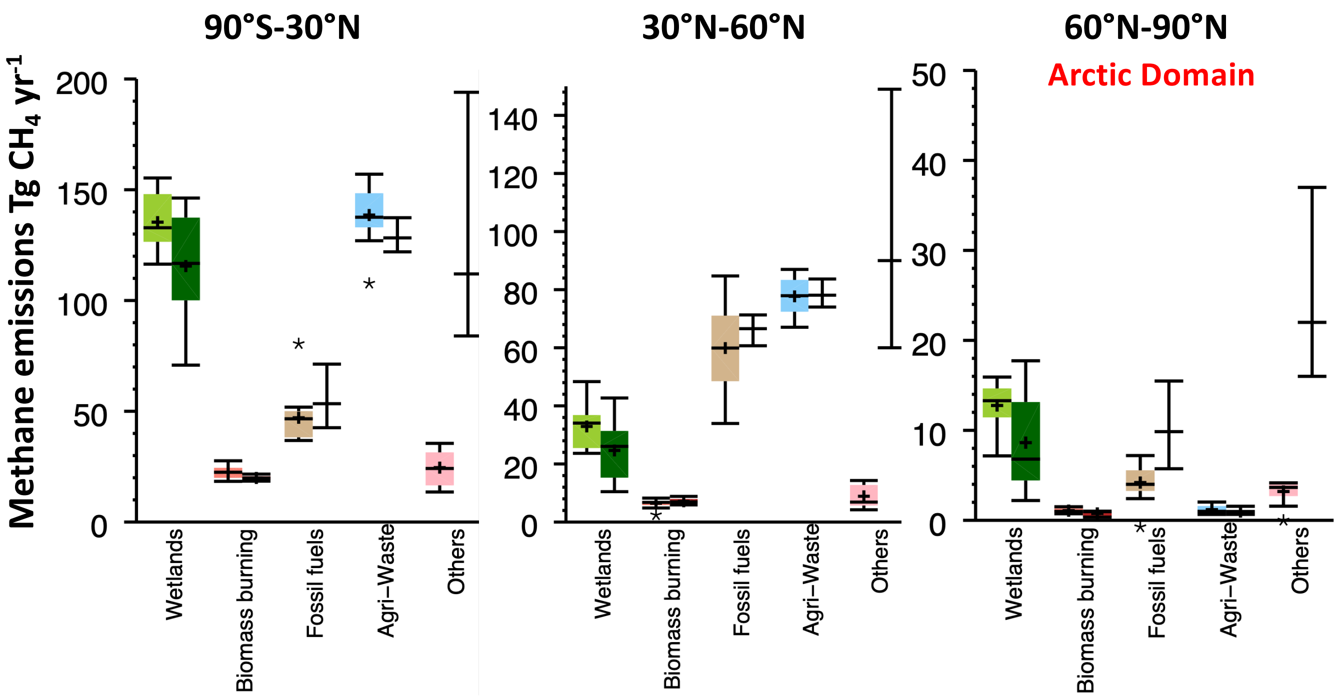


(E. Dlugokencky & L. Bruhwiler)



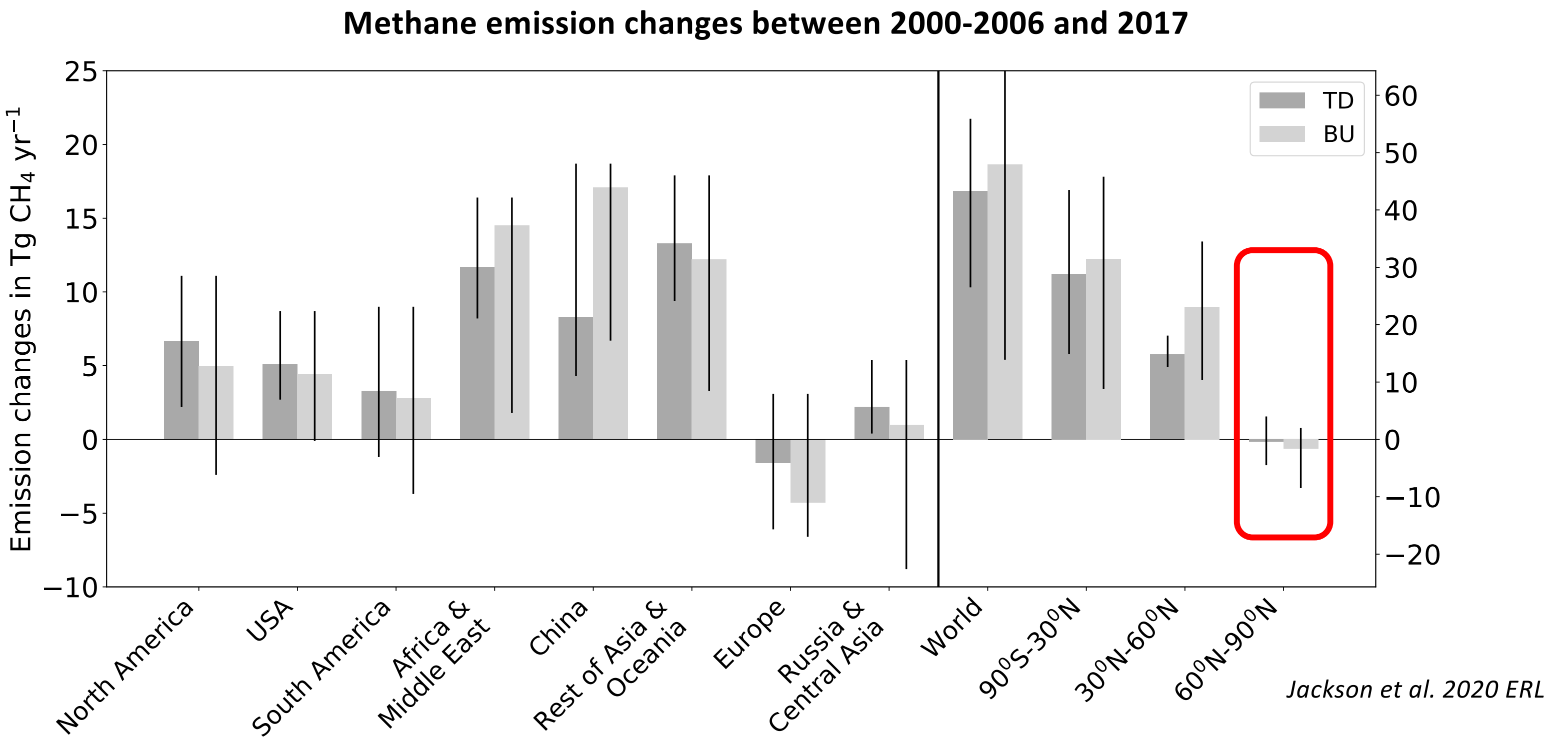
GLOBAL METHANE BUDGET 2008-2017
Global Carbon Project
TOTAL EMISSIONS
737 (594-880) 576 (550-594)
CHANGE IN ATMOSPHERIC ABUNDANCE
> 100 13* (0-49)
TOTAL SINKS
625 (500-798) 556 (501-574)
Bottom-up view (BU) Top-down view (TD)
128 (113-154) 111 (81-131)
206 (191-223) 217 (207-240)
30 (26-40) 30 (22-36)
149 (102-182) 181 (159-200)
222 (143-306) 37 (21-50)
595 (489-749) 518 (474-532)
30 (11-49) 38 (27-45)
Sink from chemical reactions in the atmosphere
Fossil fuel production and use
Agriculture and waste
Biomass and biofuel burning
Wetlands
Other natural emissions
Inland waters, geological, oceans, termites, wild animals, permafrost, vegetation
Sink in soils
EMISSIONS AND SINKS
In teragrams of CH4 per year (Tg CH4 / yr) average over 2008-2017
*The observed atmospheric growth rate is 18.2 (17.3-19) Tg CH4 / yr. The difference with the TD budget imbalance reflects uncertainties in capturing the observed growth rate.
Anthropogenic fluxes
Natural fluxes
Natural and anthropogenic fluxes
GLOBAL CARBON PROJECT

Regional breakdown of methane emissions



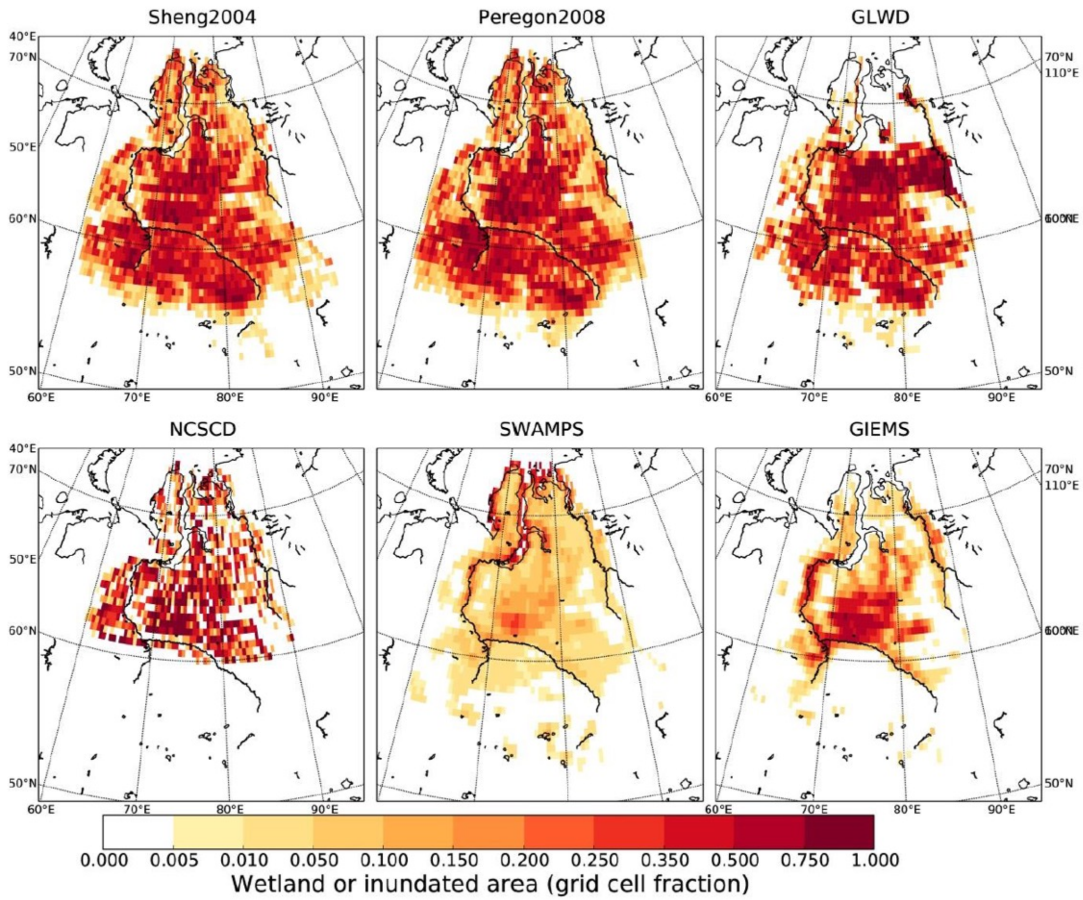
- Arctic: 24 Tg CH_4 yr^{-1} (4%)
- Temperate: 188 Tg CH_4 yr^{-1} (32%)
- Tropics: 383 Tg CH_4 yr^{-1} (64%)

Regional changes in methane growth



- About 50 $TgCH_4$/yr emissions increase between 2000-2006 and 2017
- Increase mainly from the Tropics (about 30 $TgCH_4$/yr), followed by mid-latitudes (15-20 $TgCH_4$/yr)
- Increase in North America driven by the increase from USA
- Decrease in Europe

Sources of uncertainty: wetland area

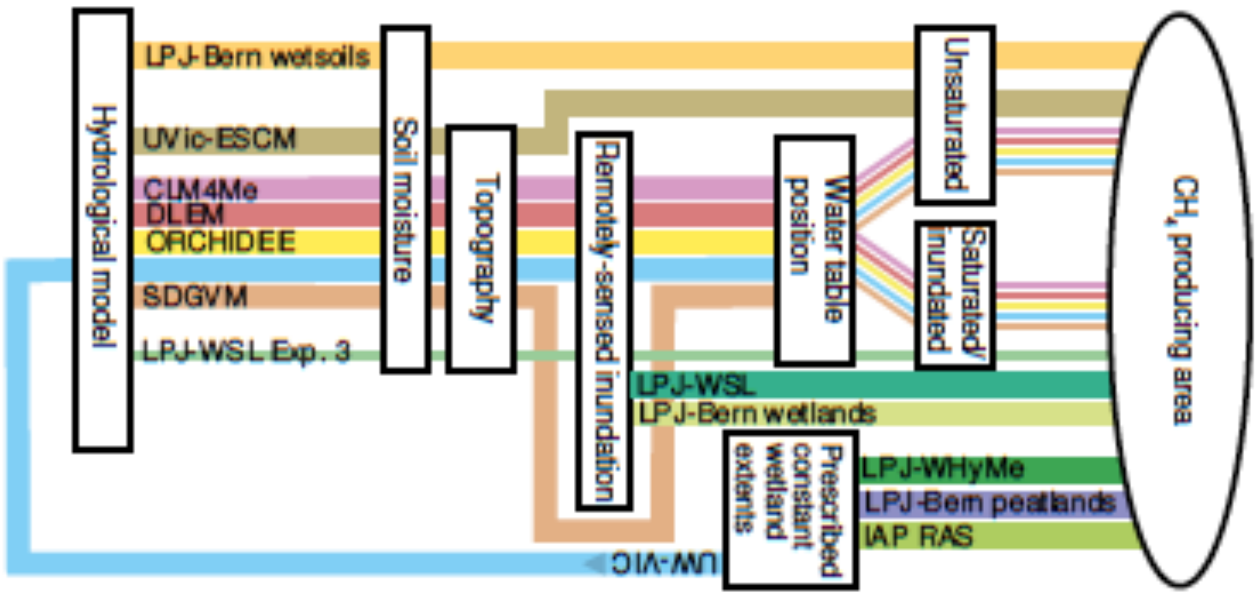


Bohn 2015

Sources of uncertainty: wetland area

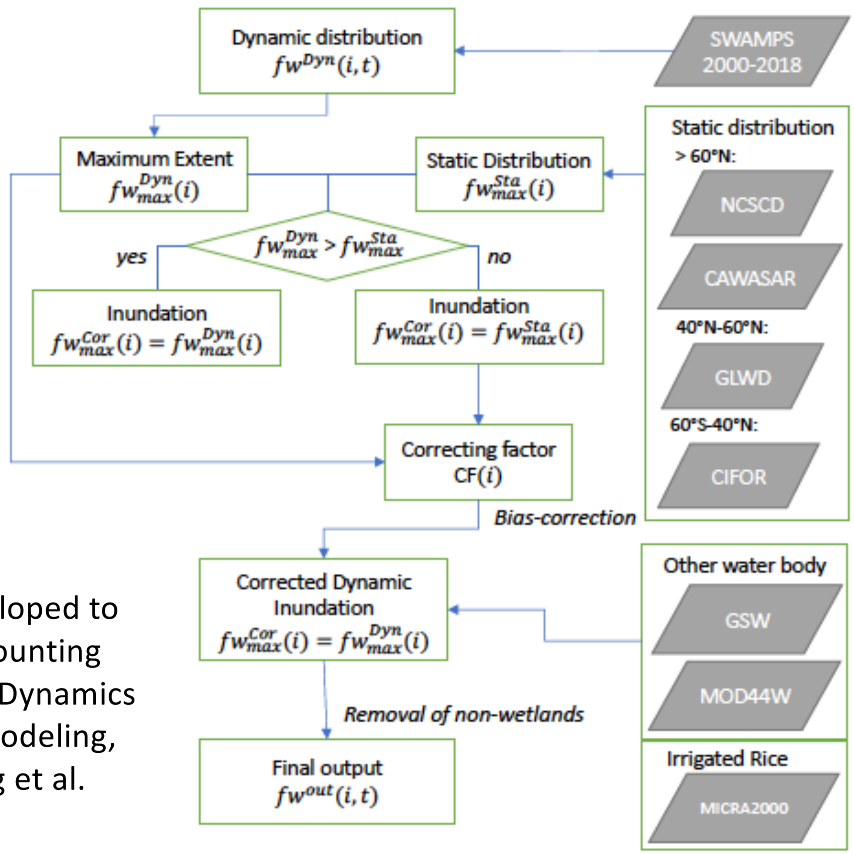
Process Understanding (production and consumption)

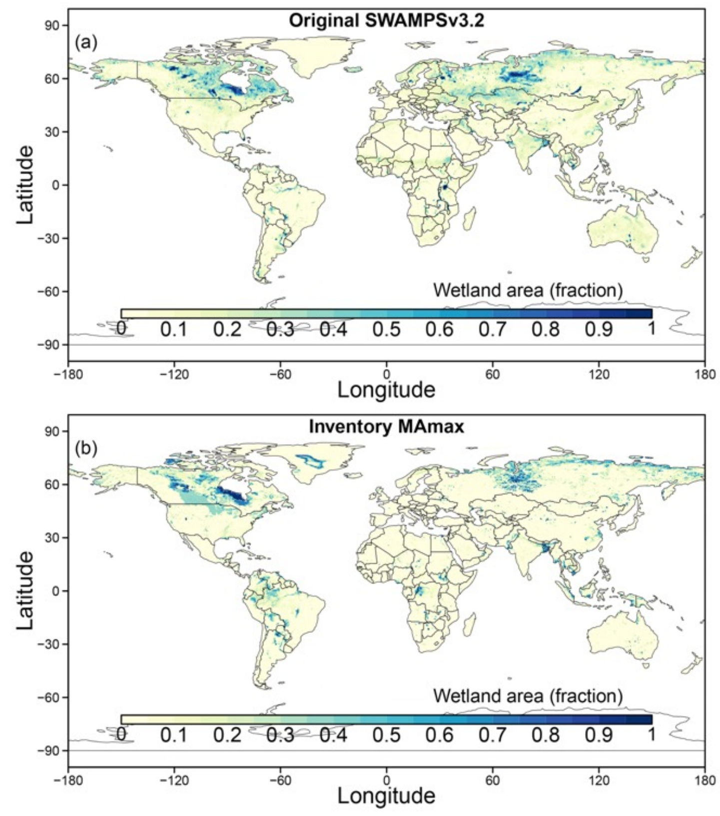
- Ratio of carbon substrate to CH_4 emissions (Christensen et al. 1996)
- Ignores lateral fluxes, e.g., methane emitted in inland waters and produced by veg. wetlands



(Wania et al. 2013)

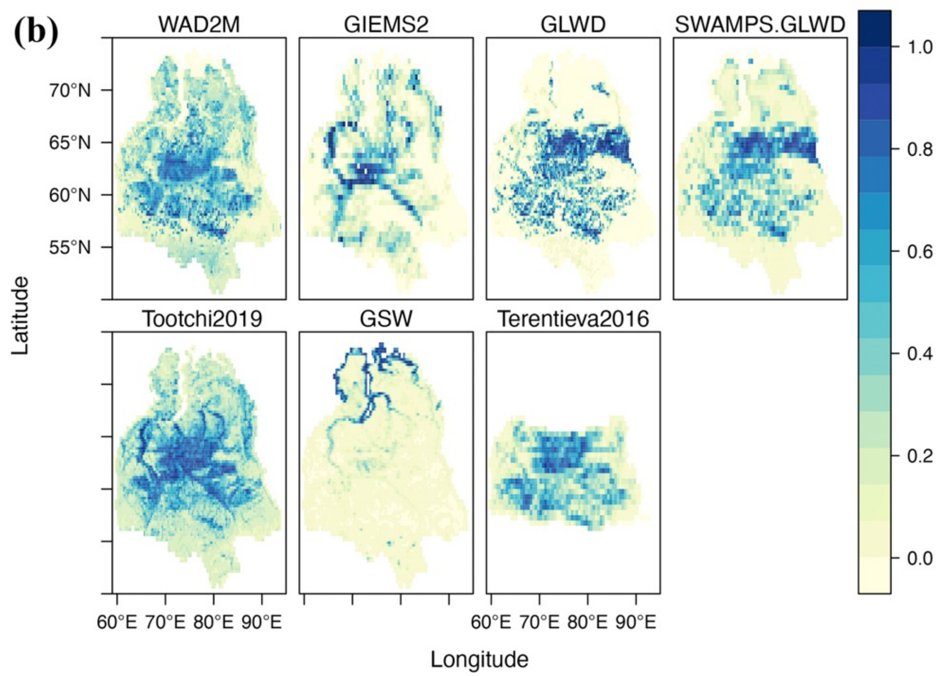
Sources of uncertainty: wetland area

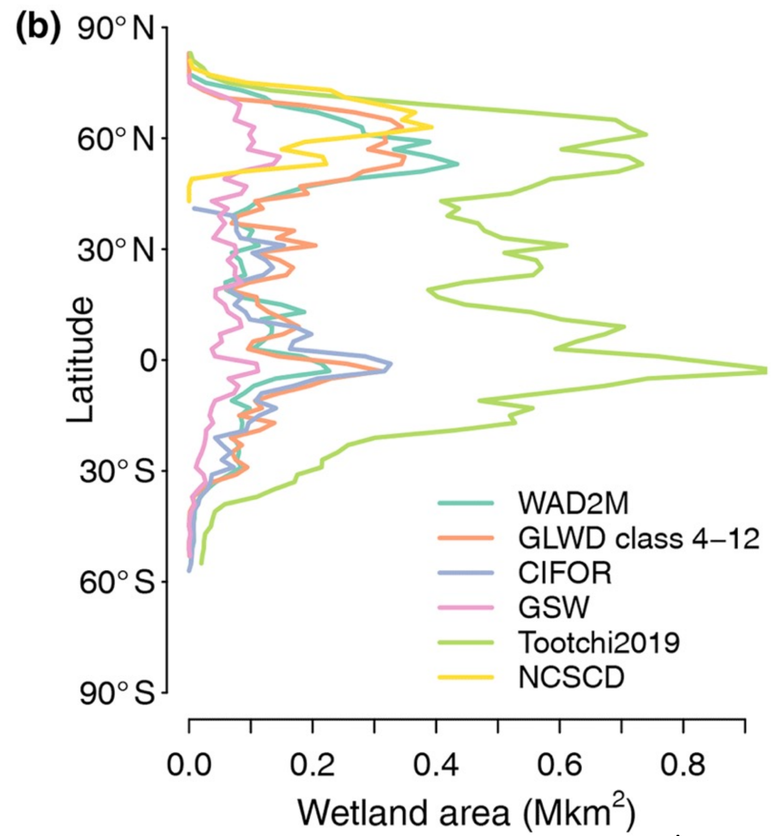




Workflow developed to avoid double counting (Wetland Area Dynamics for Methane Modeling, WAD2M, Zhang et al. 2022)

Sources of uncertainty: wetland area





Zhang et al 2021

Sources of uncertainty: methane emissions

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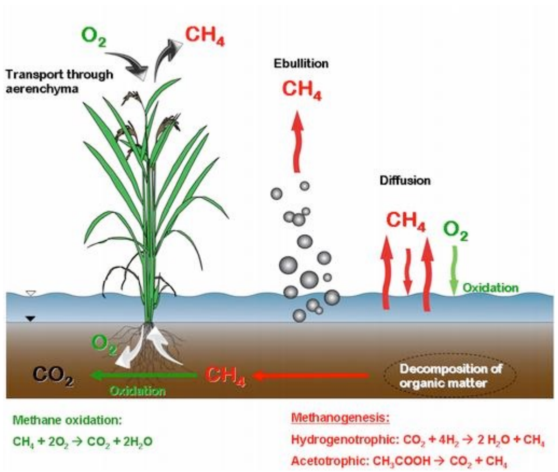
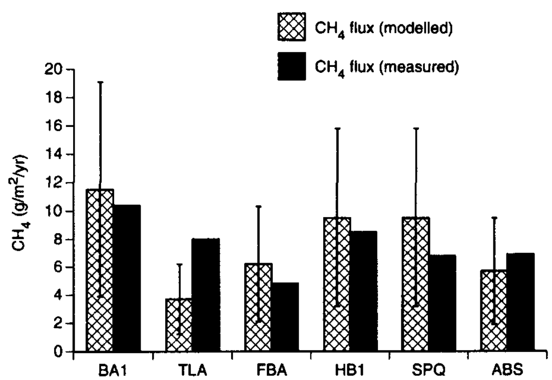


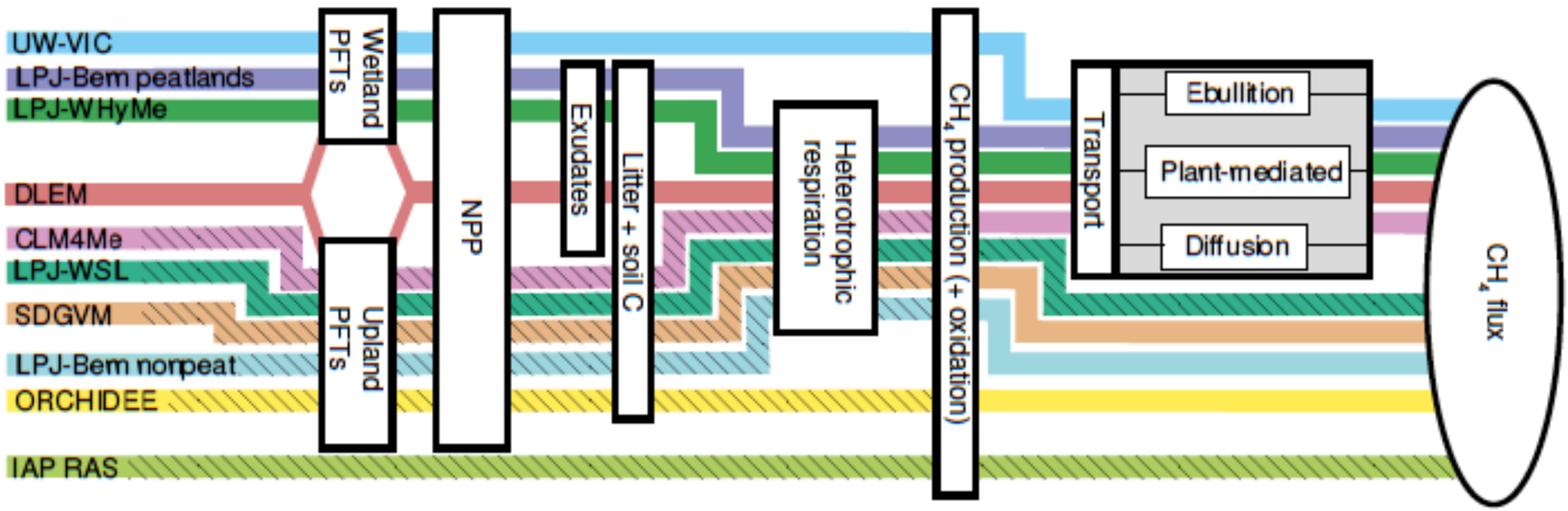
Table 1. *Ratios of C_{CH_4} flux to total carbon flux as found in different studies.*

Relationship	%	Source	Ref
C_{CH_4}/C_{resp}	1–4.5	field study in Britain	Clymo and Reddaway (1971)
C_{CH_4}/C_{resp}	1.8	field study in Sweden	Svensson (1980)
C_{CH_4}/C_{NPP}	2–7	literature study	Aselmann and Crutzen (1989)
C_{CH_4}/C_{NPP}	<2	field study in HBL, Canada	Klinger et al. (1994)
C_{CH_4}/C_{NPP}	3.4	modelling study	Cao et al. (1996)
C_{CH_4}/C_{resp}	2.7–4.7	field study in Siberia	Christensen et al. (1995 and unpub.).



Christensen 1996

Sources of uncertainty: methane emissions

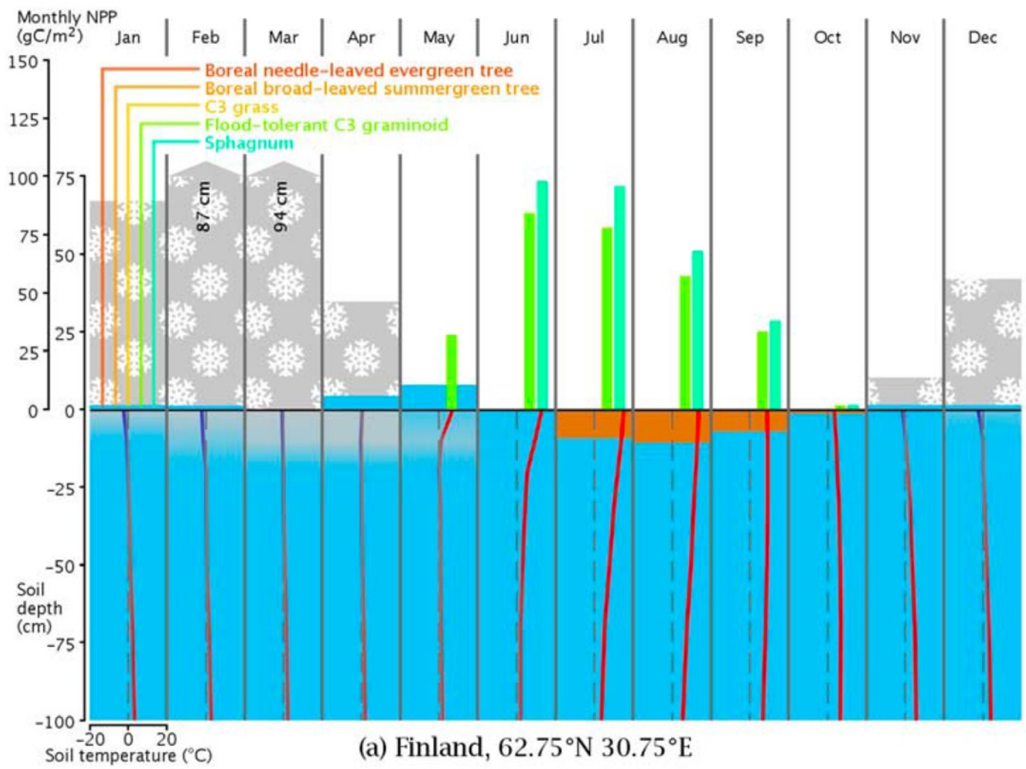


(Wania et al. 2013)

Sources of uncertainty: methane emissions

Permafrost, peatland hydrology and vegetation

1. *Temperature by depth to determine active layer depth*
2. *Non-peat and organic soil sub-routines*
3. *Snow ageing and snow density*
4. *Sphagnum and flood tolerant C3 graminoids*
5. *Inundation stress mechanism to represent anoxic effects on plant growth*
6. *Root exudation and soil priming*
7. *Timing of litter turnover*
8. *Leaf dark respiration related to carboxylation capacity*



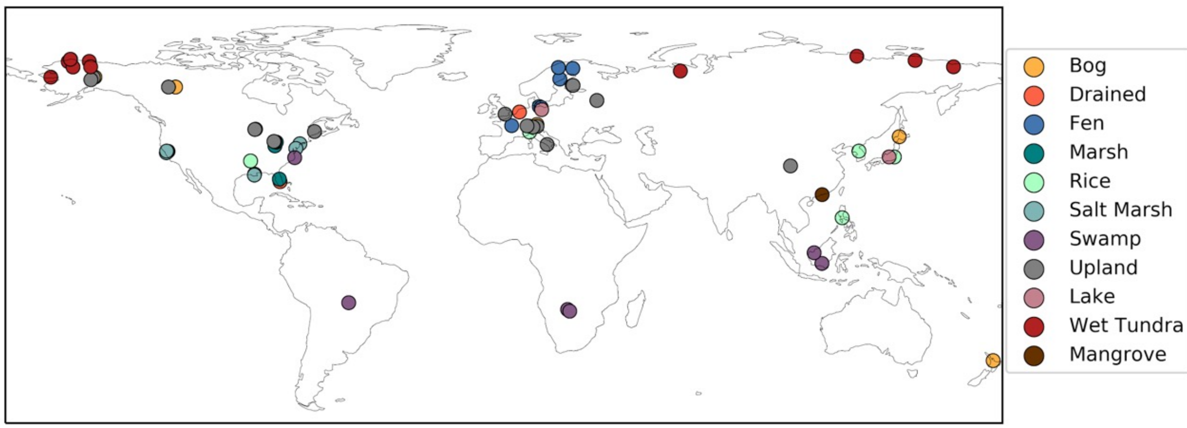
(a) Finland, 62.75°N 30.75°E

Wania 2009

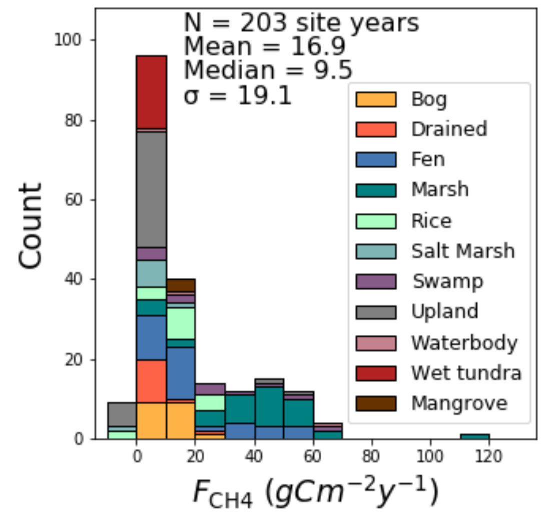
Sources of uncertainty: methane emissions

Fluxnet-CH4

- Established new flux tower database (Fluxnet-CH_4), Knox et al. 2020, Delwiche et al. in rev.
- Basis for model parameterization, data assimilation, benchmarking
- Seasonal diagnostic, lags/peaks/shoulder-season fluxes, being used to evaluate models

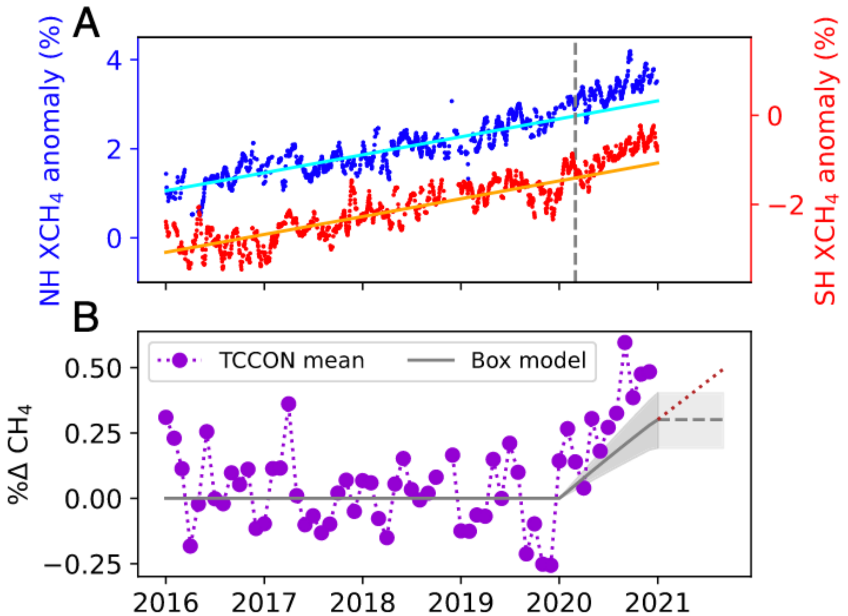


81 sites globally
44 freshwater, 6 brackish/saline, 7 drained, 7 rice paddy, 2 lakes, 15 upland sites

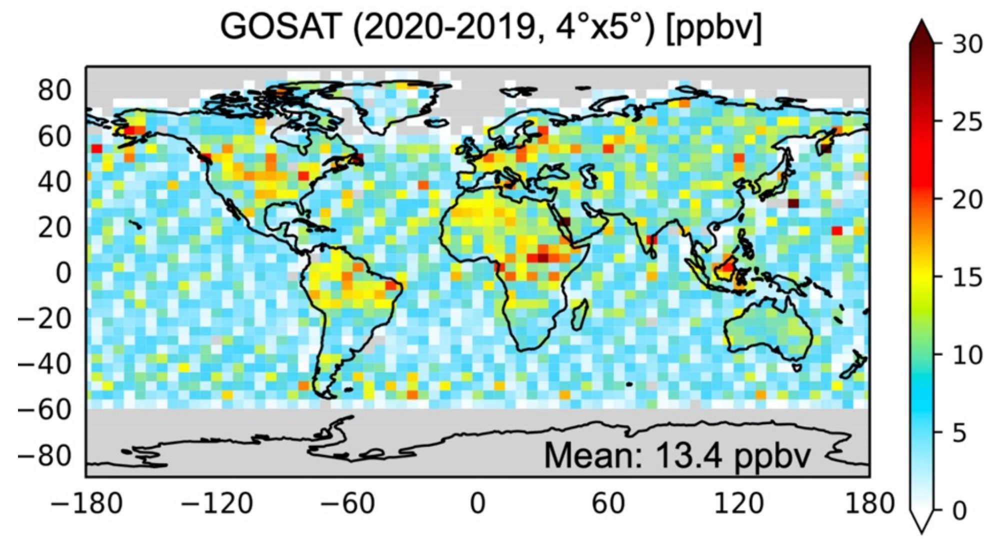


Knox et al 2021

Ways forward: 2020 as test case



Laughner et al., 2021



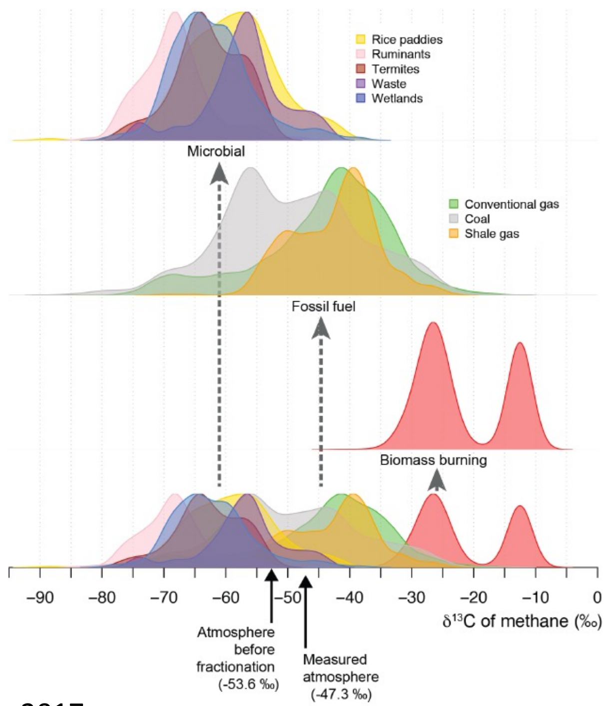
Qu et al., 2022

- Decrease in NOx reduce ozone and led to 2-4% decrease in OH
- 2021 recovery of NOx growth associated with even higher CH4 growth

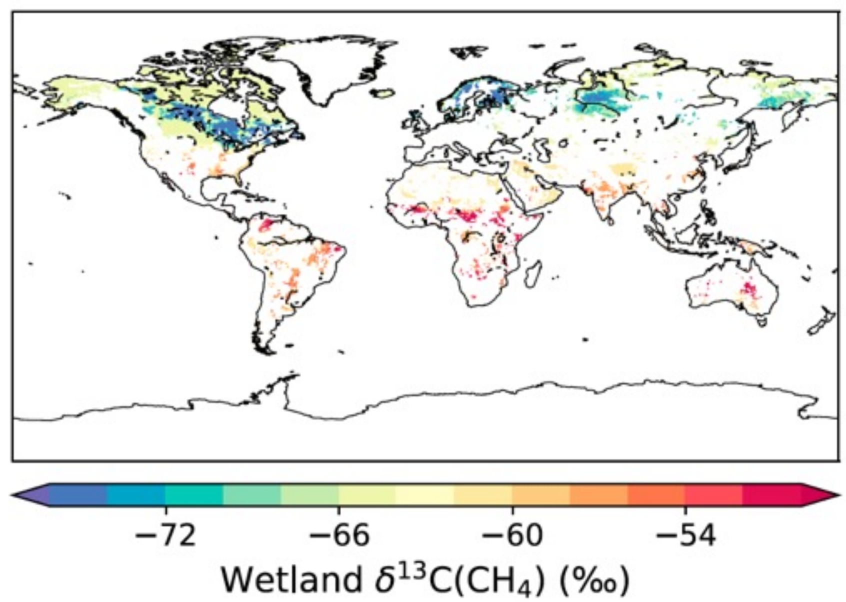
- GOSAT inversion attributed 50% of growth to Africa, 14% to OH sink, and 24% to N America
- Forthcoming paper by Sushi Peng attributes 40% of growth mainly to N wetlands and remainder to OH decline

Ways forward: isotopic modeling

- Sources of methane has difference stable isotope signatures
- Provide constraint on attributing the cause of atmospheric methane concentrations



Sherwood et al., 2017



Ganesan et al., 2018

Ways forward: point source imagers?

Recommendations

- Coordination with remote sensing wetland mapping community
  - Optical remote sensing for vegetation types
  - Radar remote sensing for surface inundation
  - Radar remote sensing for active layer depth
- Explore use of commercial and hyperspectral GHG remote sensing for partitioning natural from anthropogenic signals
- Communication with field campaigns, i.e., ABoVE, CoMET2, for targeted opportunities for calibration, validation, near-real time applications
- Expansion of ground networks, eddy covariance (towers, airborne), air sampling (isotopes)
- Continue to implement high-latitude processes within models, e.g., shoulder-season fluxes, freeze-thaw dynamics, lateral fluxes