






The Mysterious Global Methane Budget

Lori Bruhwiler, Ed Dlugokencky, Sylvia Michel

Alex Hristov, Mark Leonard, Stefan Schwietzke, Christine Wiedinmyer





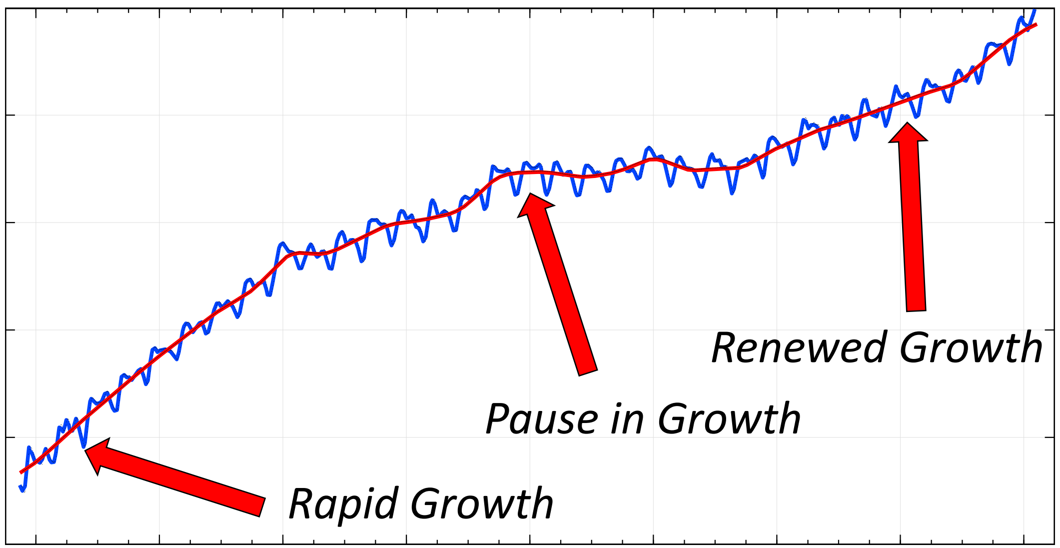

Pause in Growth

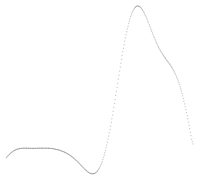
1) Approach to Steady-State (1780 ppb by 2010s) Dlugokencky et al., 1998,2003

2) Decreases in O&G Emissions Since the 1980s (Aydin et al., 2011; Simpson et al., 2012)

3) Reductions in Rice Emissions (Kai et al., 2011)

4) OH Increased (Rigby et al., 2017)





Renewed Growth

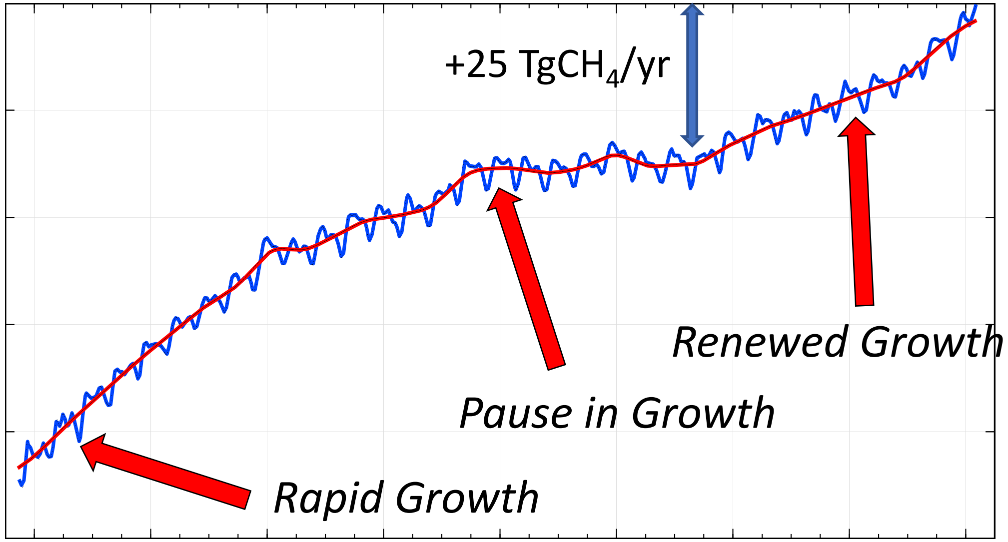
1) Microbial Emissions Going Up (Nisbet et al., 2016, Schaefer et al., 2016, Schwietzke et al. 2016)

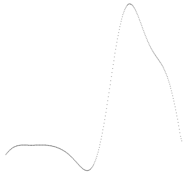
2) Could be Anthropogenic Microbial (Schaefer et al., 2016, Saunois et al., 2016).

3) Significant Contribution from fossil fuel emissions (Turner et al., 2016; Rice et al., 2016, Worden et al., 2017)

4) OH Decreased (Rigby et al., 2017)

5) It could be OH, hard to tell anything from isotopes (Turner et al., 2017)





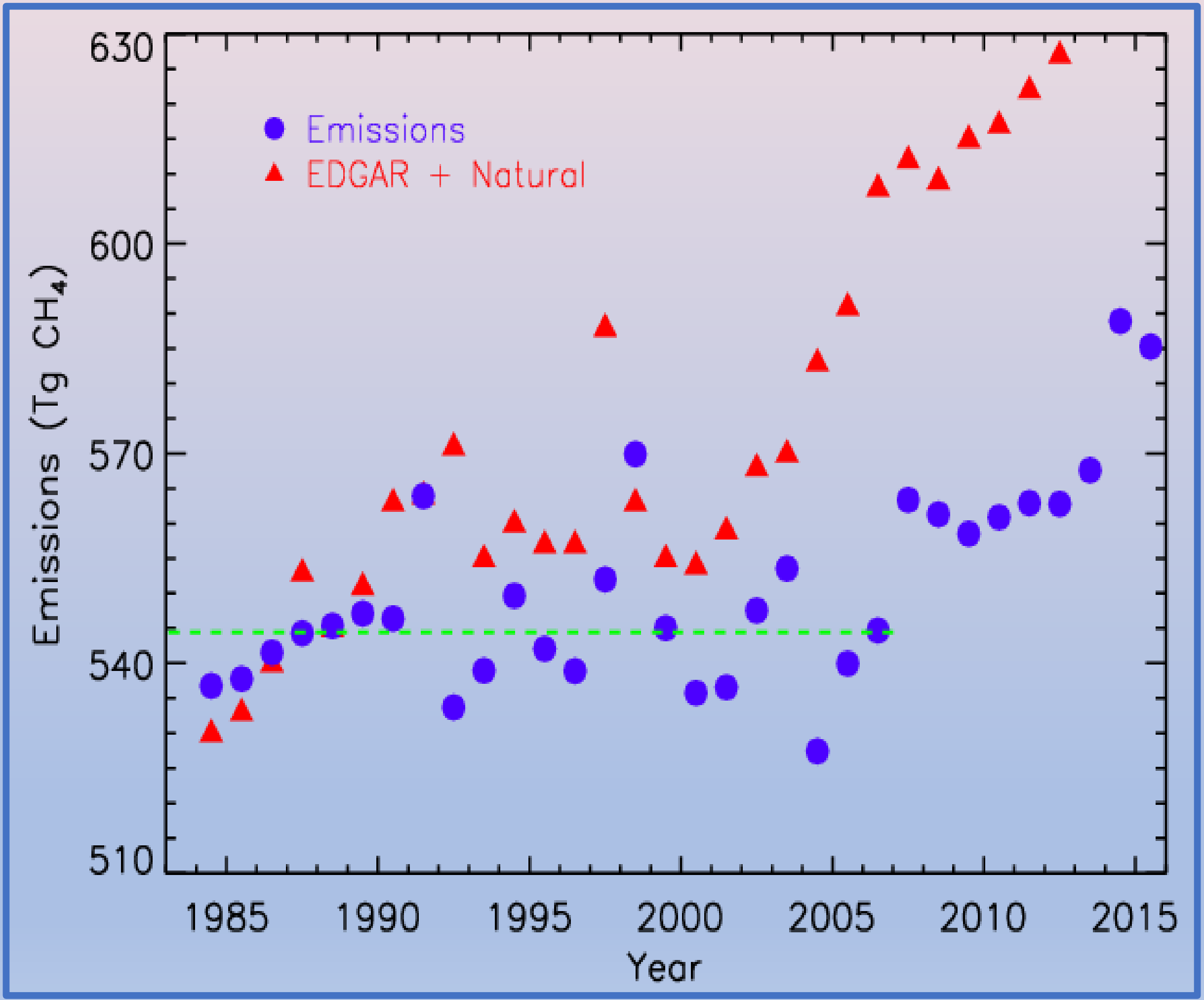
Estimating Global Emissions – A Simple Global Box Model

$$d[CH_4]/dt = \Sigma\, Sources - 1/\tau\, [CH_4]$$

τ = 9-10 years

Inferred from global measurements of CH_3CCl_3

(Note: soil sink is included in Σ Sources)



Estimating Global Emissions – A Simple Global Box Model

We might want to know more than total Sources!

$$d[CH_4]/dt = \Sigma\,Agriculture/Waste + \Sigma\,Natural + \Sigma\,Fossil\ Fuel\ Production + \Sigma\,Biomass\ Burning - 1/\tau\,[CH_4]$$

Agriculture/Waste:	Ruminants, Manure, Rice, Landfills, Wastewater
Fossil Fuel Production:	Coal, Oil, Gas
Natural:	Wetlands, Geologic, Wild Animals
Biomass Burning:	Wildfires, Crop Residue, Traditional Biofuels (Charcoal, Wood)

What Other Observational Constraints Can We Use?

1) **Information about the Spatial Distribution of Emissions, Spatially Distributed Observations, An Atmospheric Transport Model – e.g. An Atmospheric Inversion**

2) **Observations of Other Related Things**

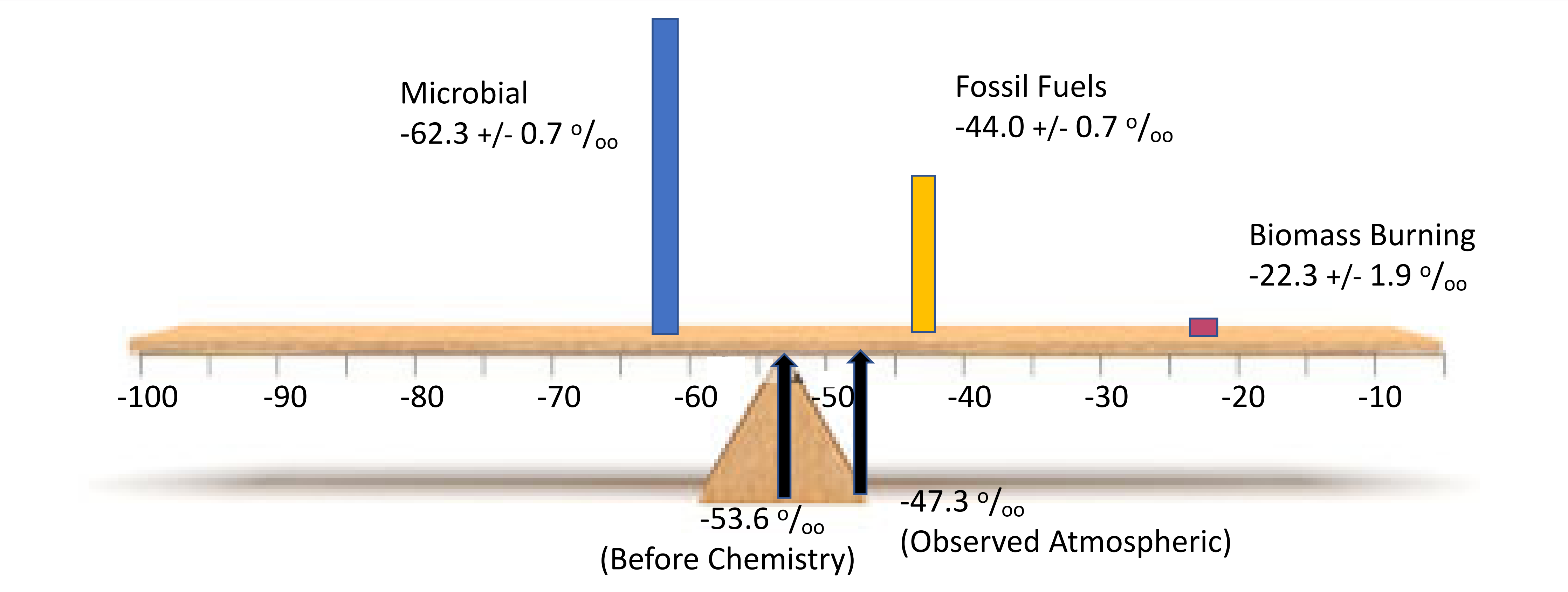
Microbial Emissions: $\delta^{13}C\text{-}CH_4$

$$d[CH_4]/dt = \Sigma\,\textit{Agriculture/Waste} + \Sigma\,\textit{Natural} + \Sigma\,\textit{Fossil Fuel Production} + \Sigma\,\textit{Biomass Burning} - 1/\tau\,[CH_4]$$

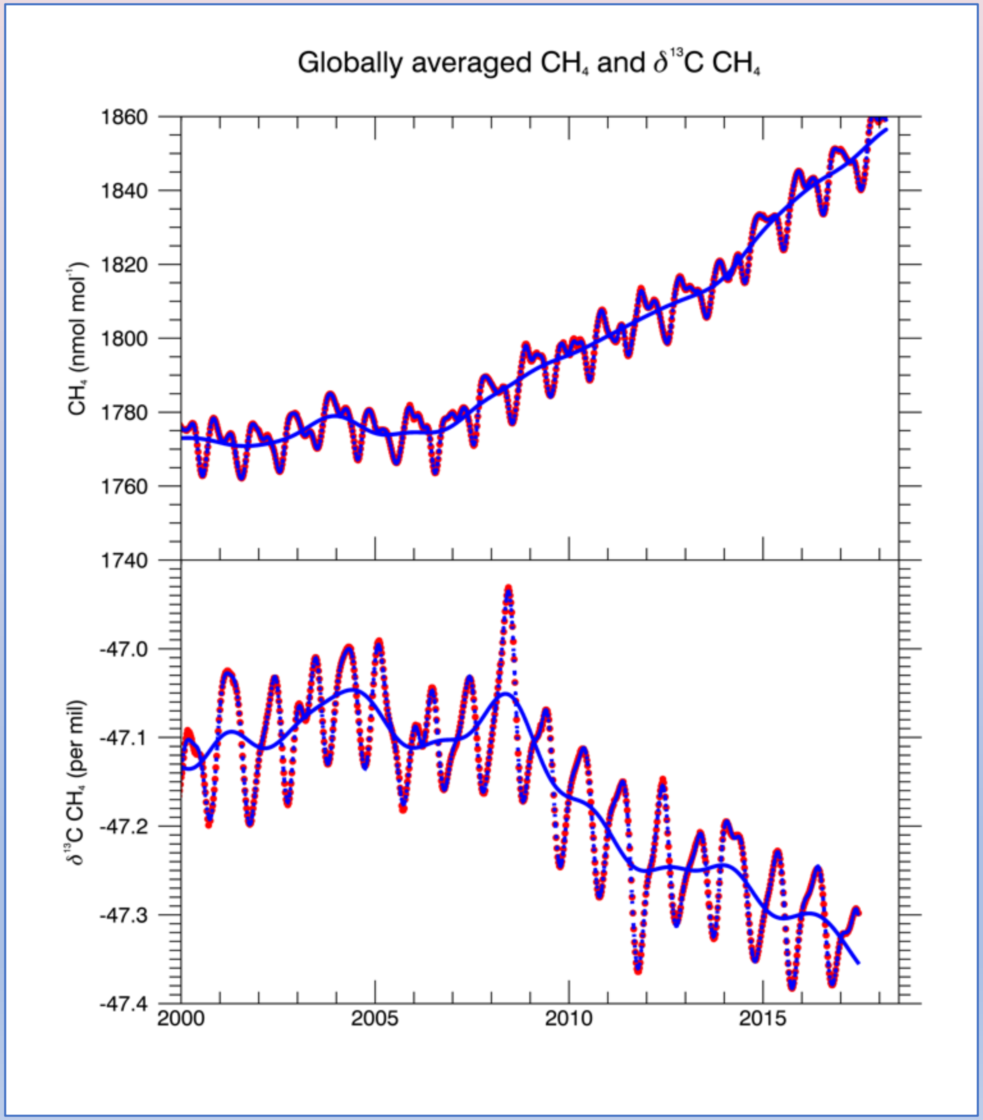
Ethane (C_2H_6)

Area Burned
Carbon Monoxide (CO)

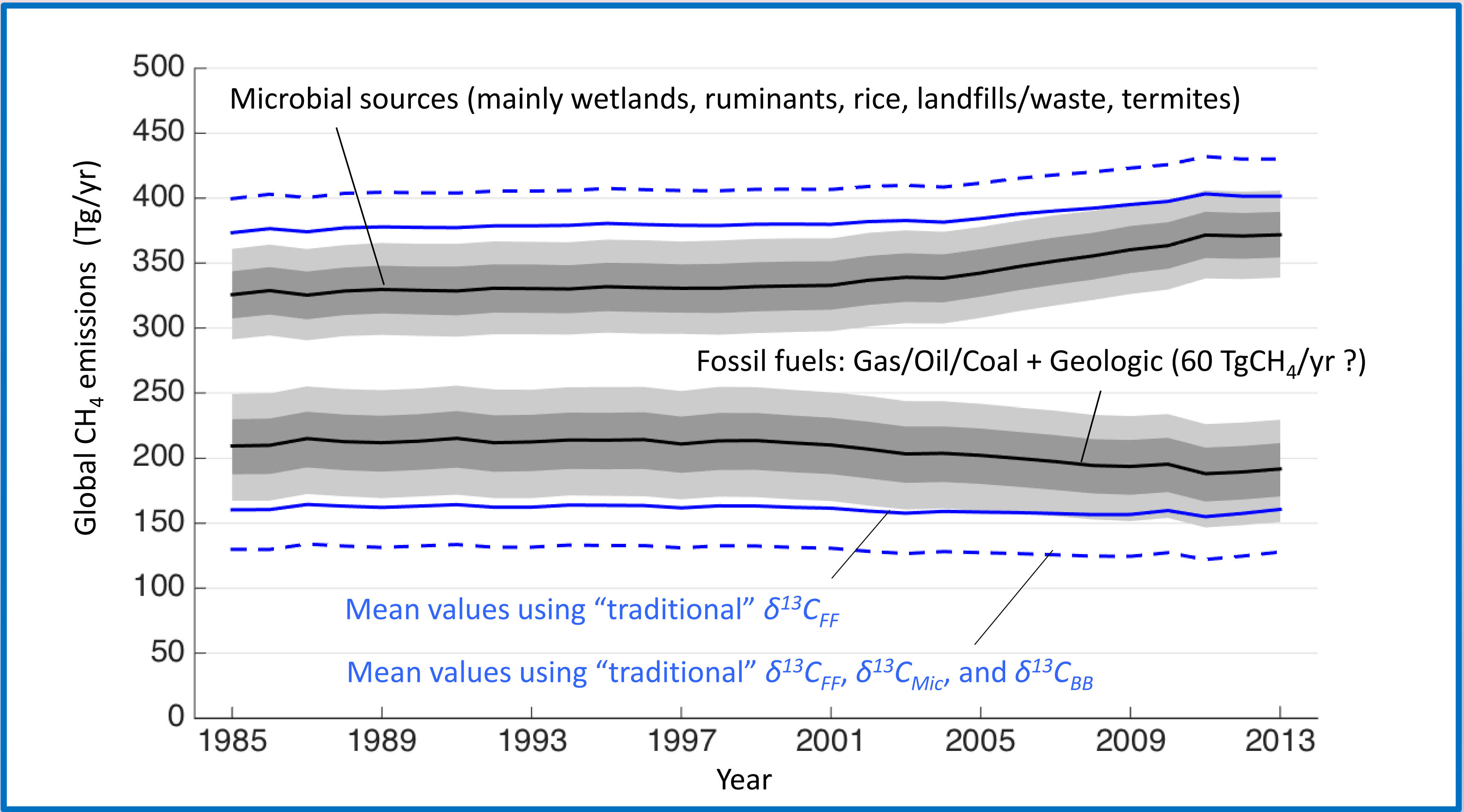
The $\delta^{13}C-CH_4$ Constraint: Part 1



$\delta^{13}C$-CH_4 : A Clear Indication that Microbial Source are Behind the CH_4 Increase

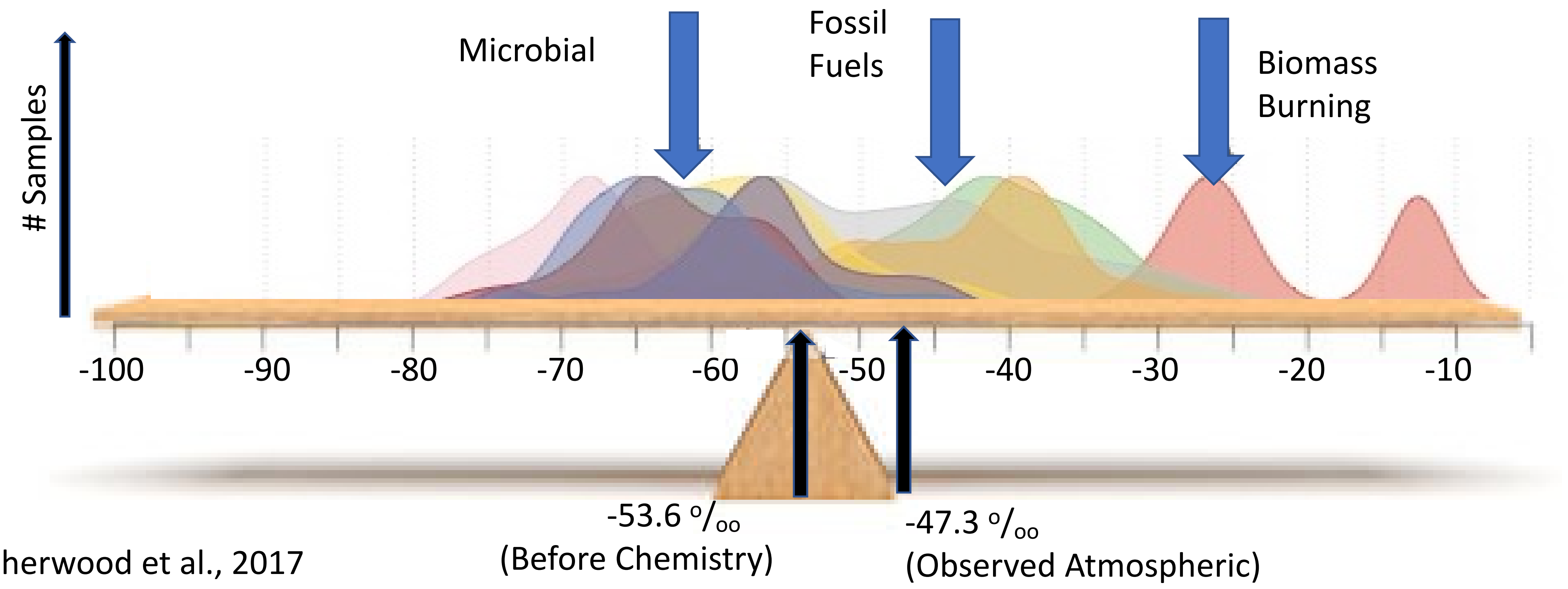


Revision of the Global CH_4 Budget using and extensive source signature database



Schwietzke S., et al., 2017; Sherwood et al., 2017

The δ^{13}C-CH_4 Constraint: Part 2



Sherwood et al., 2017

CH_4 From Animals

Global	Population Change 2006-2016 (+/- 10-20%)	Emission per Animal	Change in Emissions*
Big Ones*	116 M	50-100 kg/yr	7.7 Tg/yr
Little Ones**	238 M	5-8 kg/yr	1.3 Tg/yr

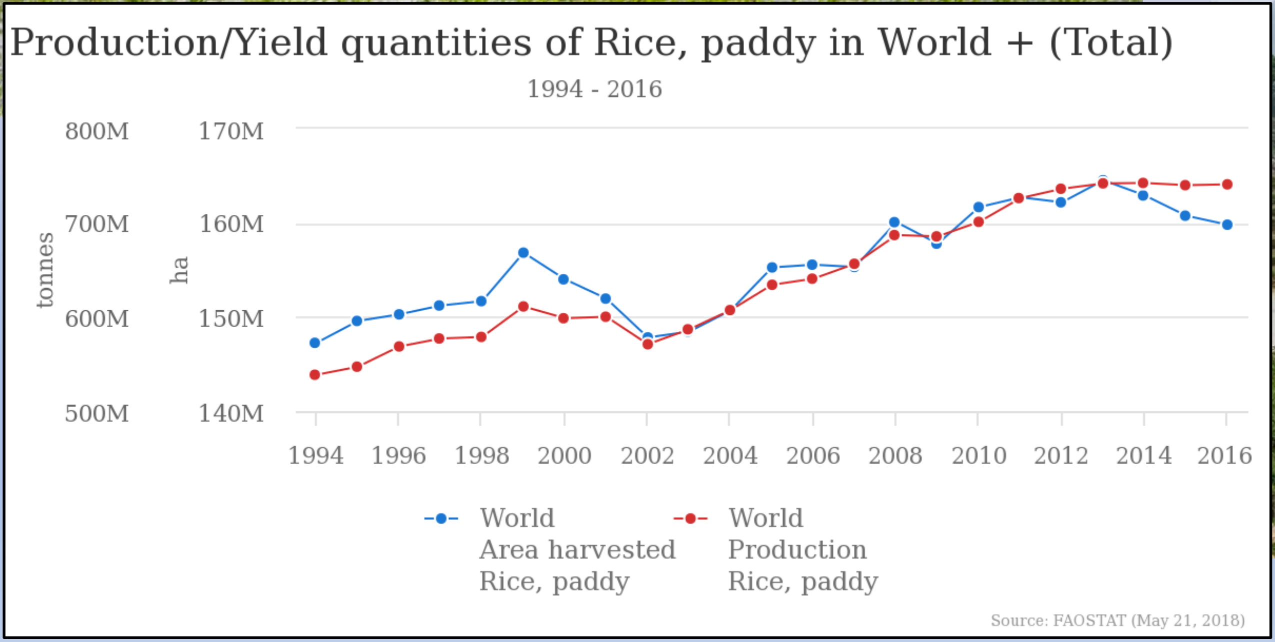
(Another 0.6 Tg/yr for manure)

Goats:	5 kg/yr
Sheep:	8 kg/yr
Dairy Cattle:	110 Kg/yr
Non-Dairy Cattle:	50 kg/yr

* Population growth of animal types in each category taken into account

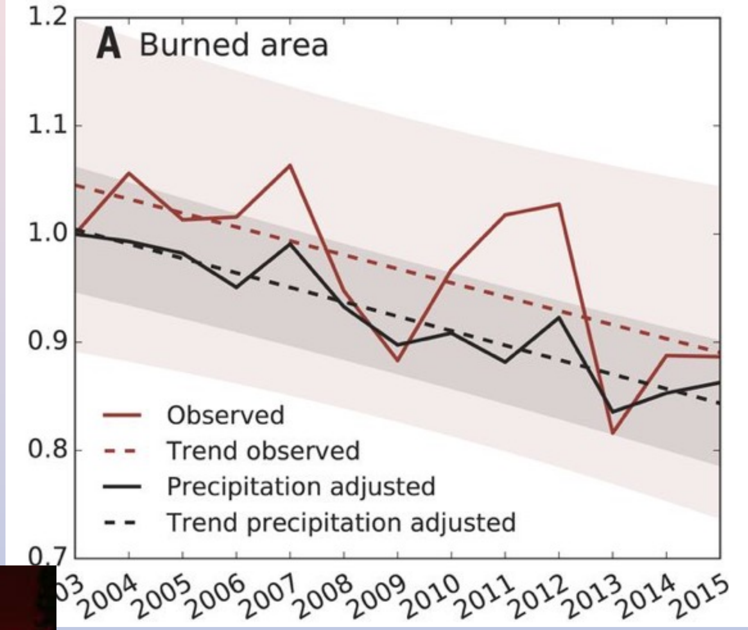
Rice Agriculture

From 2006-2016, growth in CH_4 Emissions from rice agriculture are likely to have been small: < 0.8-1.4 $TgCH_4$/yr



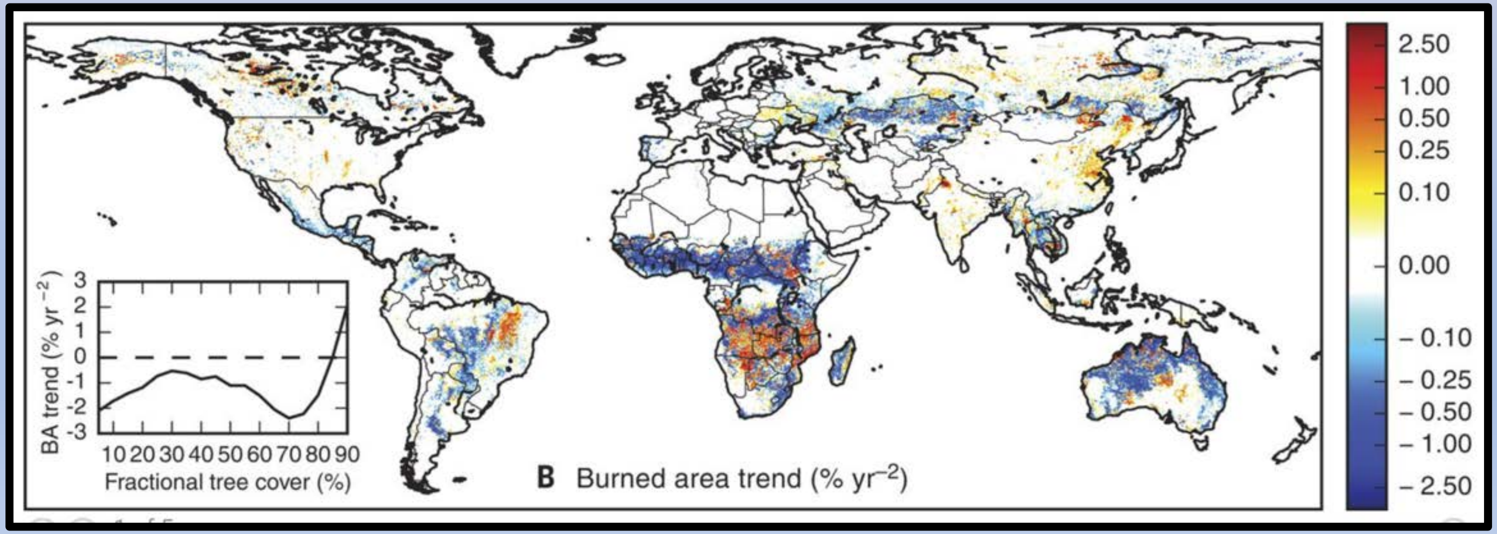
Biomass Burning- Trends could change the interpretation of Methane Isotope Observations

~ 25% decline in global burned area since 2003, due to reduced savannah burning (tropics) Andela et al., 2017



Worden et al., 2017 -6 to -10 $TgCH_4$/yr
(Fossil Fuels account for majority of global growth)

Schwietzke et al., 2017 Model -2.5 to -3.0 $TgCH_4$/yr



Biomass Burning- Part 2
Traditional Biofuels

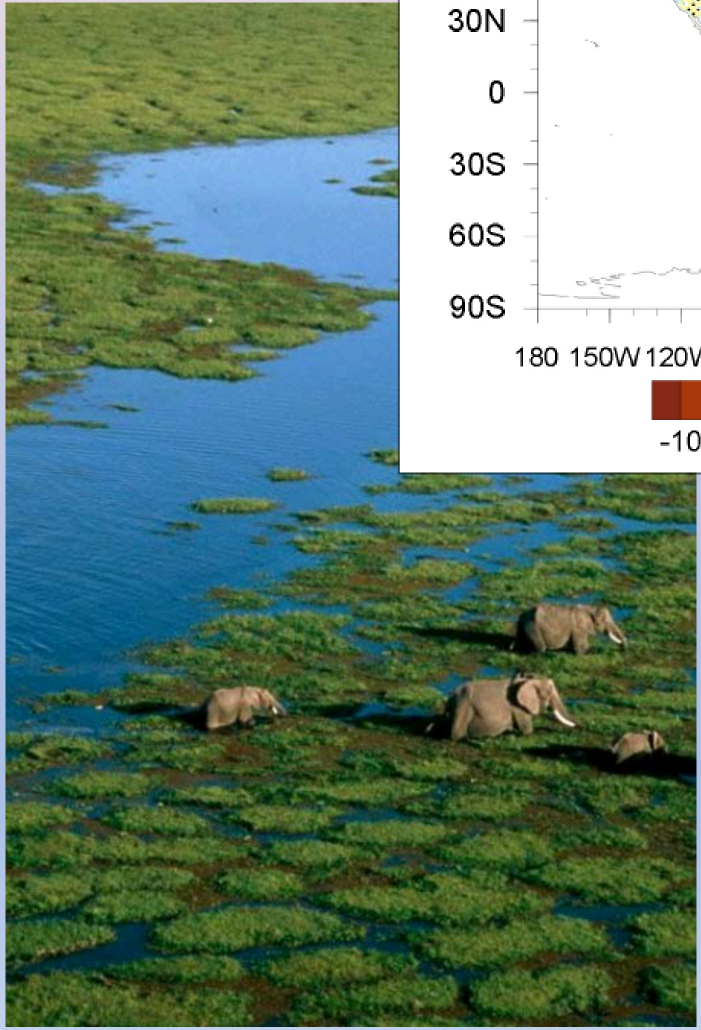
Traditional Biofuels ~12 TgCH_4/yr
(Yevich and Logan, 2003)

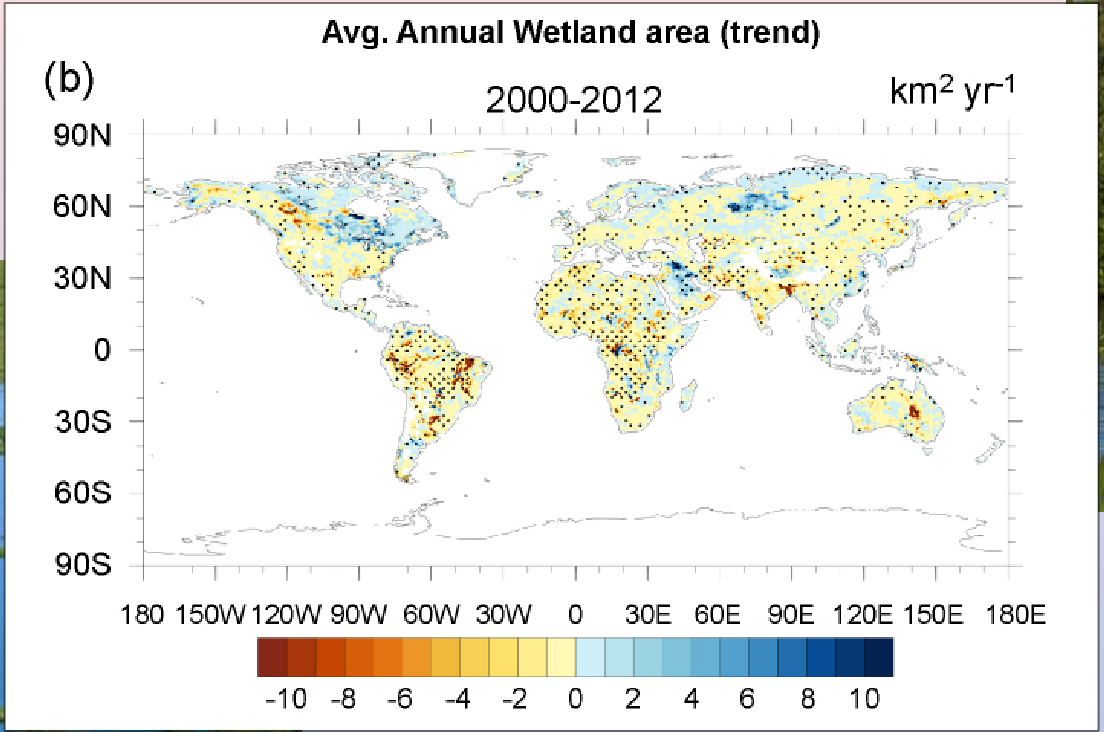
Biofuel use is increasing in Africa
(Marais and Wiedinmyer, 2016)

<u>Change: 2006-2013</u>

Crop Residue	+6%
Household Wood Fuel	+7%
Commercial Wood Fuel	+35%
Charcoal Production	+26%
Household Charcoal Use	+25%

Wetlands





Poulter et al., 2017: Global wetland emissions constant over 2002-2012, with small decreases in the Tropics (~1 Tg/yr).

Increasing emissions from tropical (and global) wetlands likely cannot explain trend in atmospheric CH_4: it must be …. *everything else*!

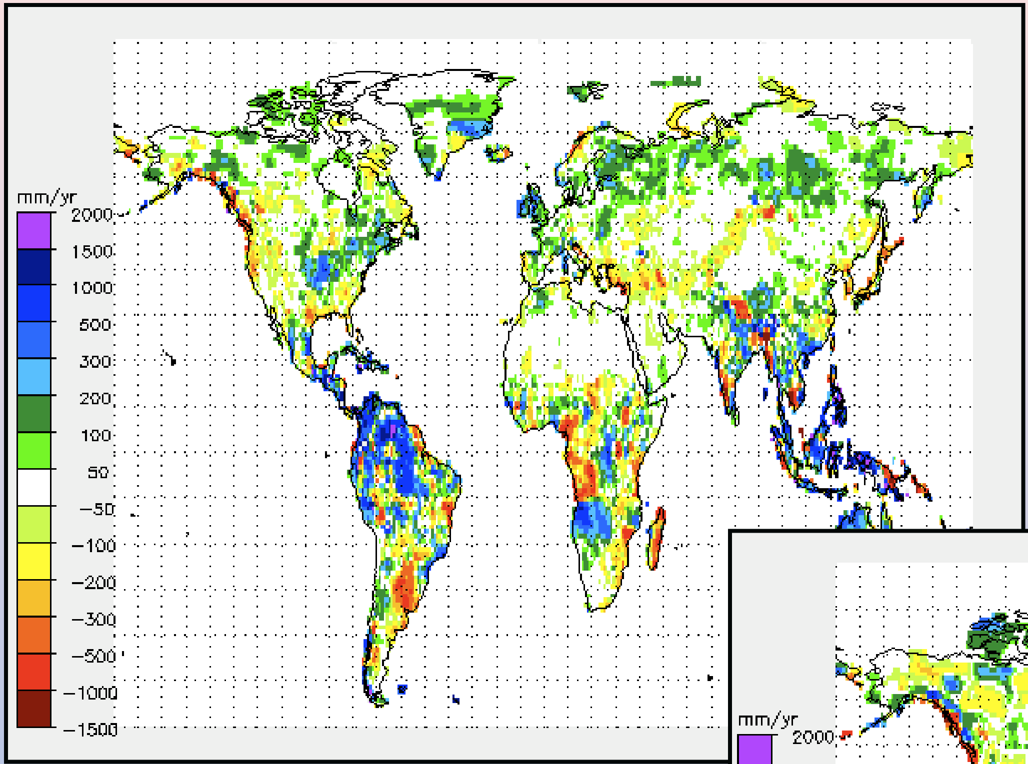
But the SWAMPS-GLWD dataset used for wetland areas may underestimate actual wetland variability.

Conclusions

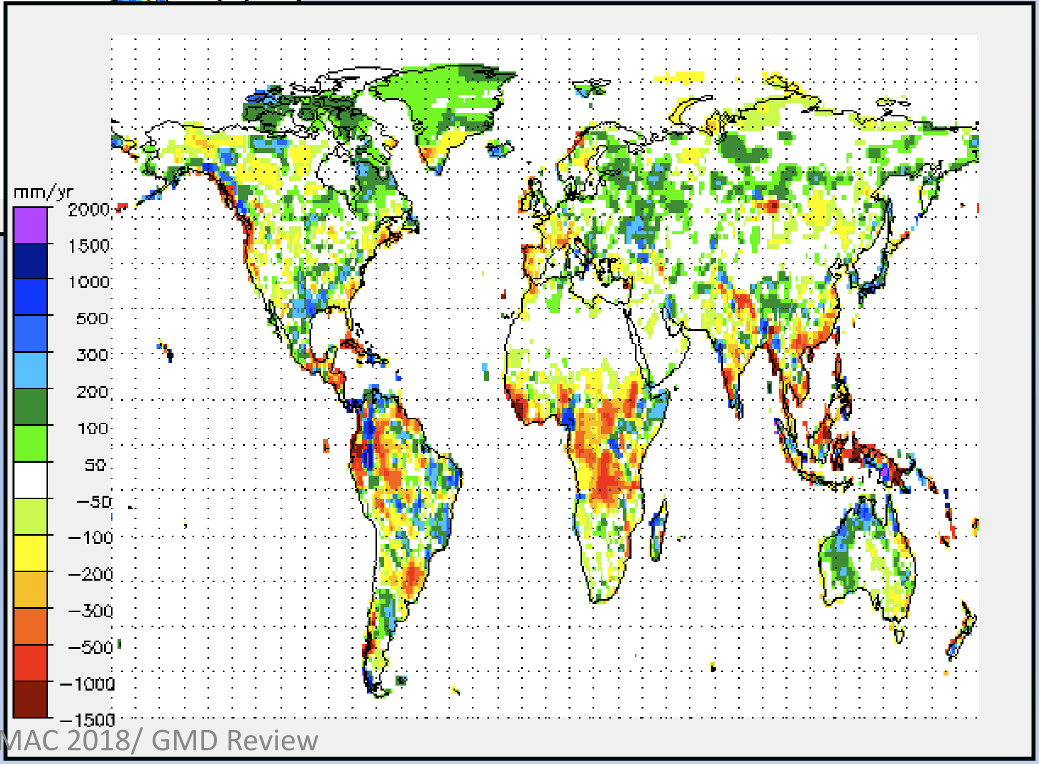
- NOAA GMD observations are essential for understanding the global CH_4 budget. We need more observations, and more samples of source signatures.
- Recent global CH_4 growth is likely to be dominated by microbial sources, rather than fossil fuels, and biomass burning trends are unlikely to change this interpretation of the isotope data.
- Anthropogenic microbial emissions may account for ~10 $TgCH_4$/yr out of 25 $TgCH_4$/yr increase in emissions since 2006 (but waste was not addressed).
- *So where is the other 15 $TgCH_4$/yr coming from?*

Composite Precipitation - La Ninã

Inter-annual Variability

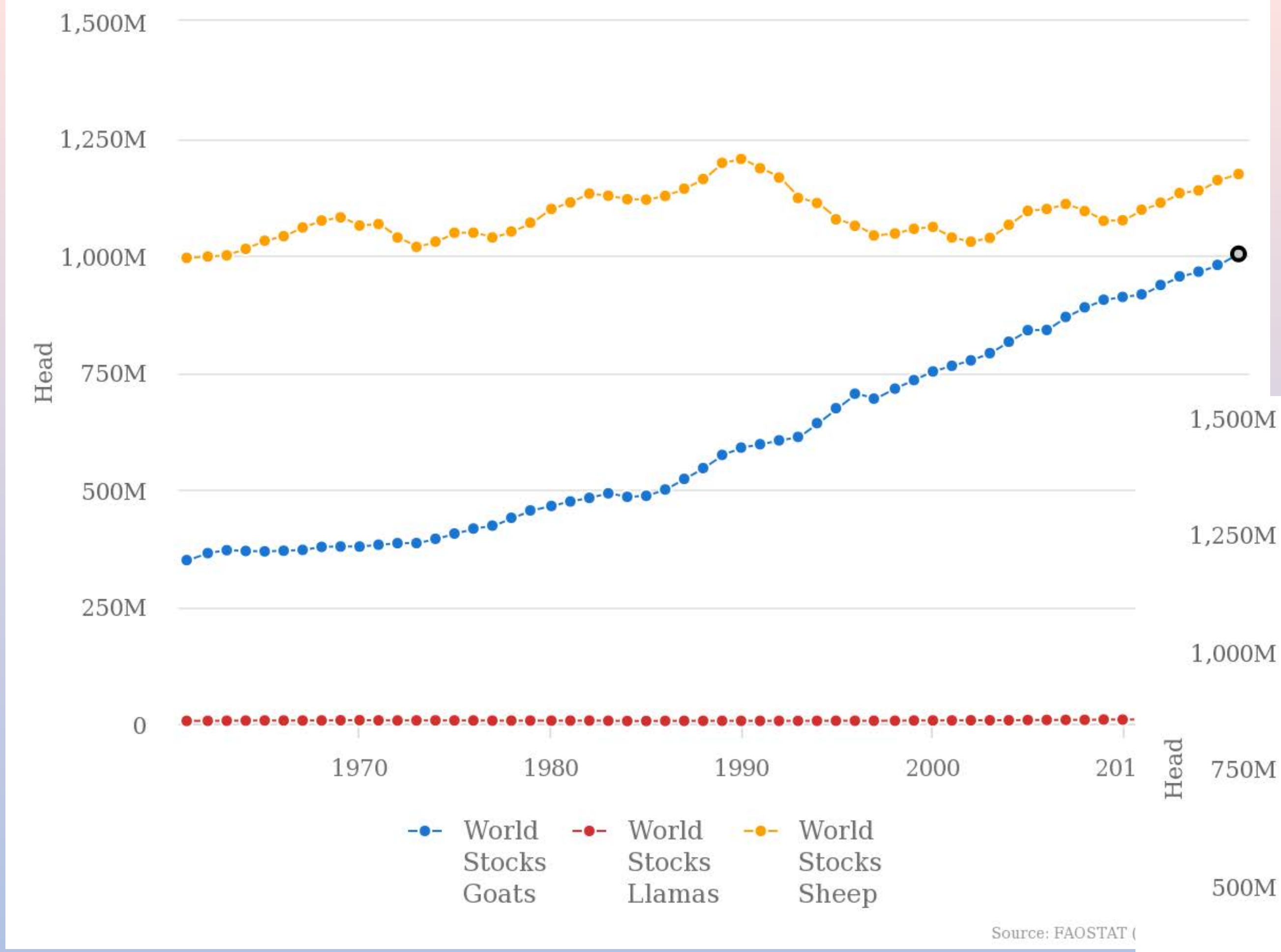


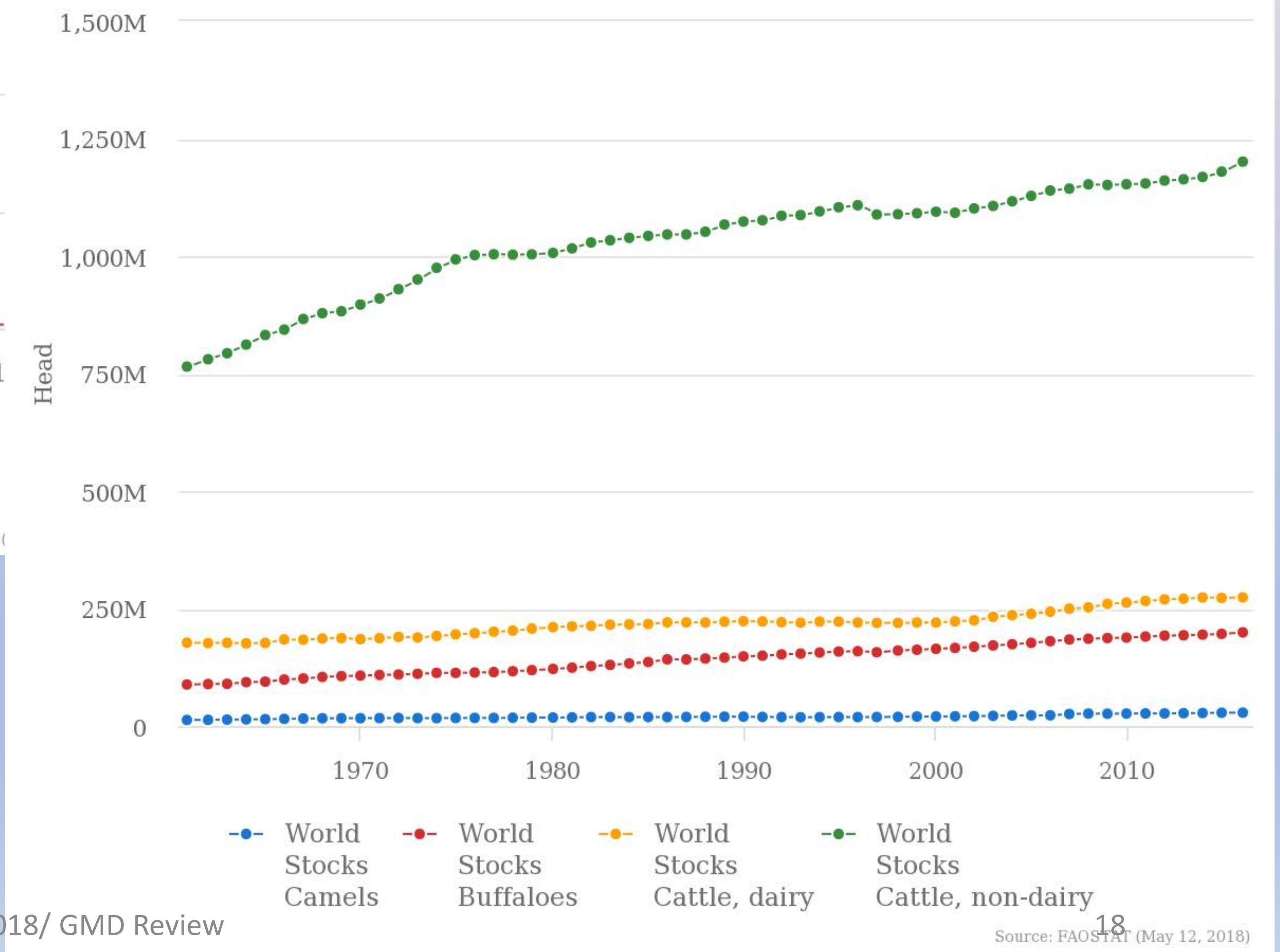
El Niño

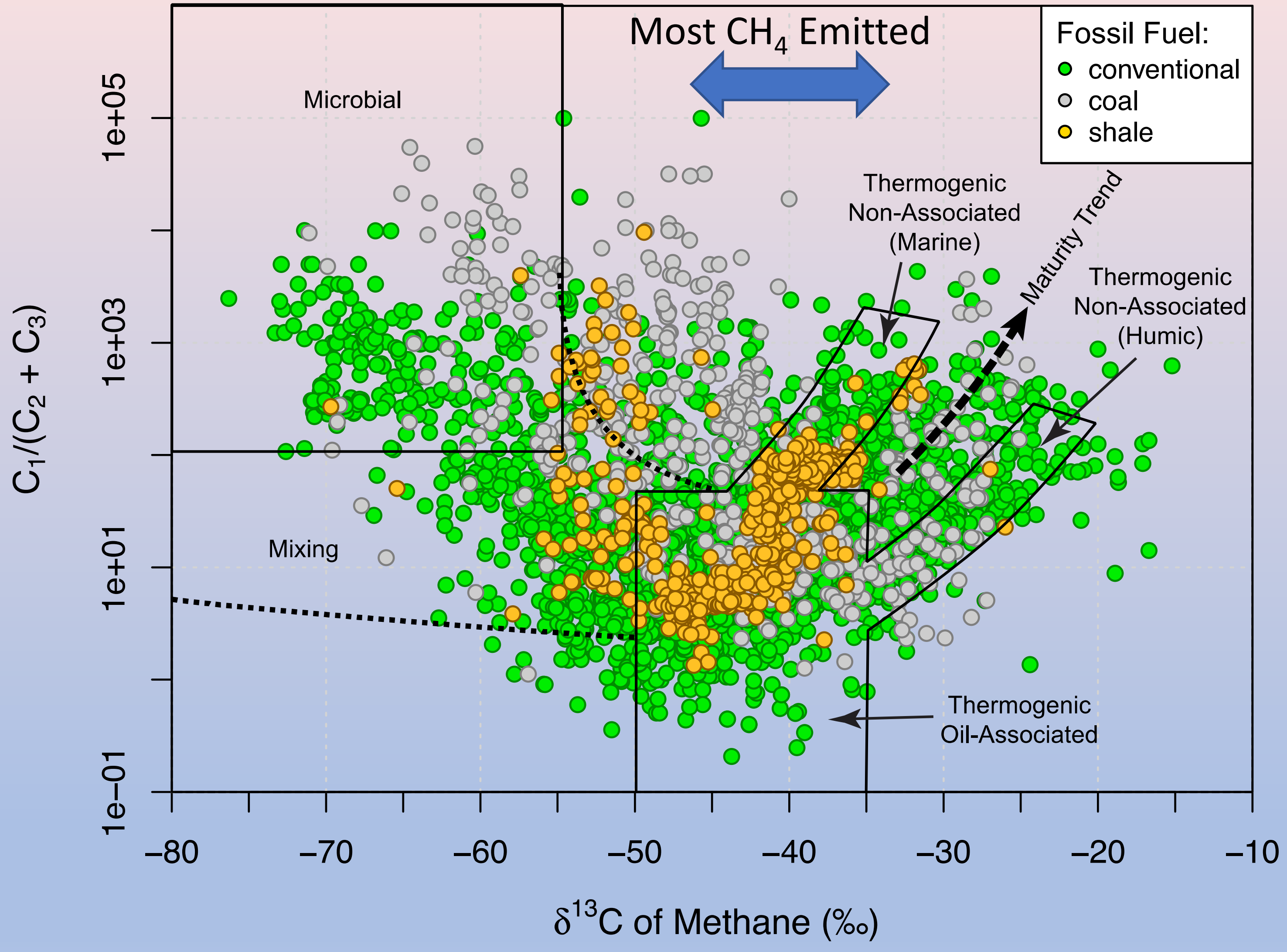


Source: GPCP

FAO Statistics





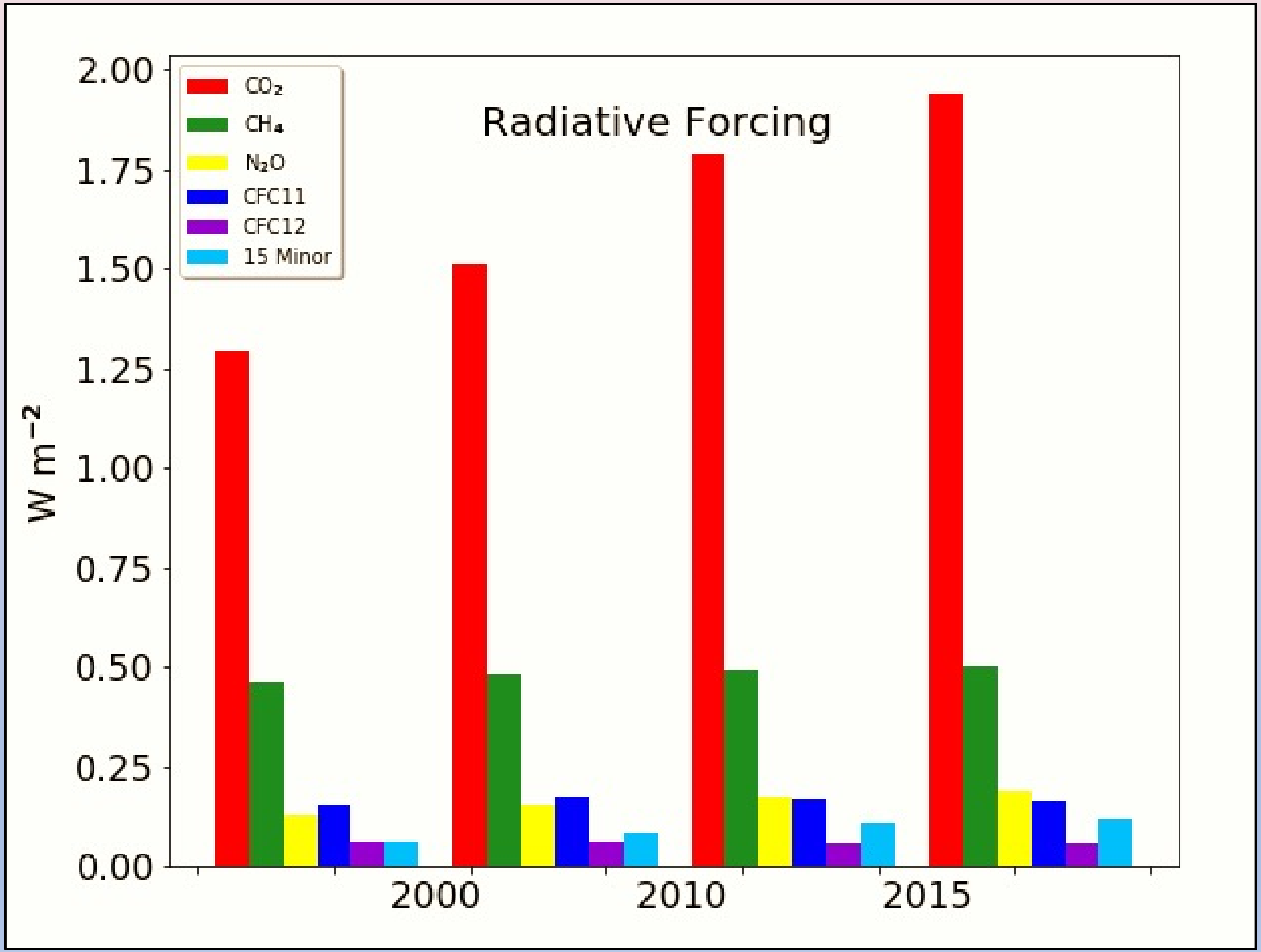


Sherwood OA, Schwietzke S, Arling VA, Etiope G (2017) Global Inventory of Gas Geochemistry Data from Fossil Fuel, Microbial and Biomass Burning Sources, Version 2017. Earth Syst Sci Data Discuss:1–35.

Methane is important in the Climate System

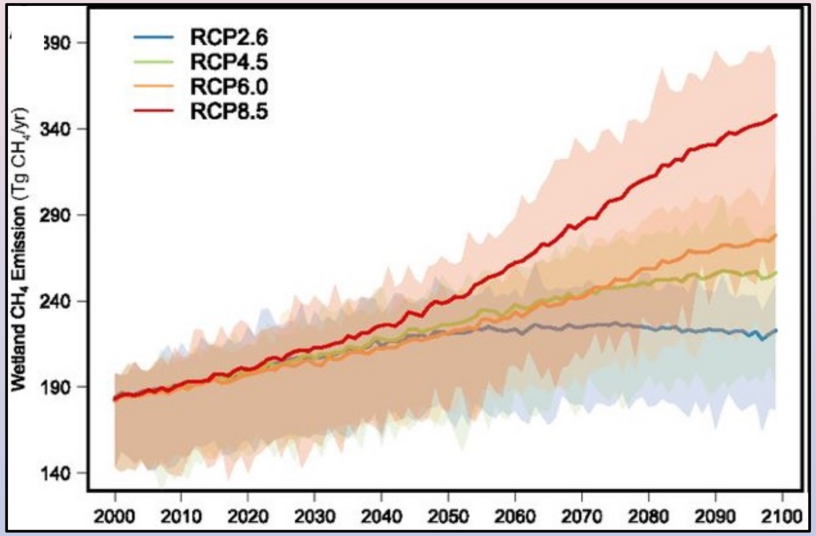
Methane is the 2nd largest contributor to radiative forcing after CO_2.

It has a GWP of ~25 over 100 years

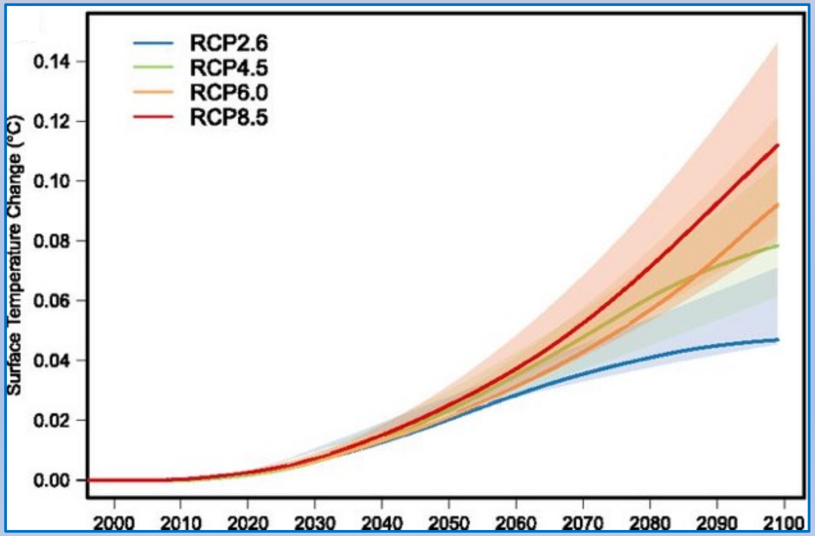


Source: NOAA GMD Annual Greenhouse Gas Index

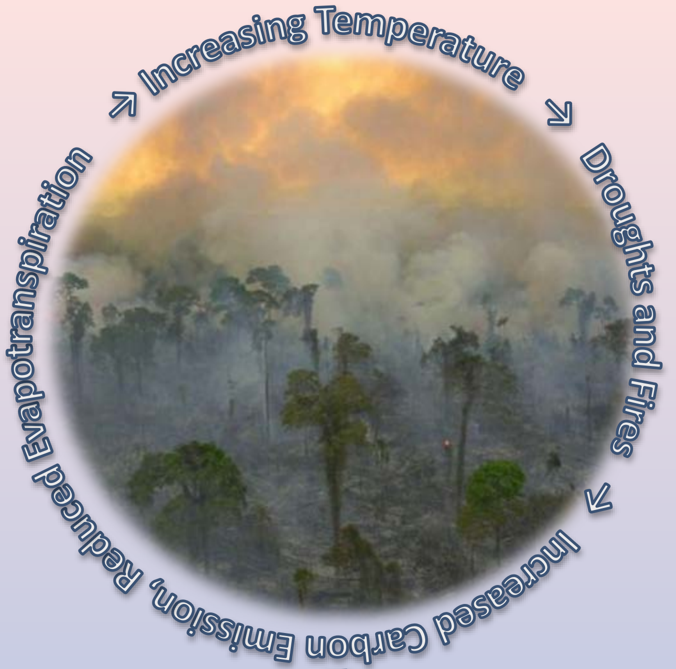
Possible Methane-Climate Feedbacks



Predicted CH_4 Wetland Emission Increase by 2100

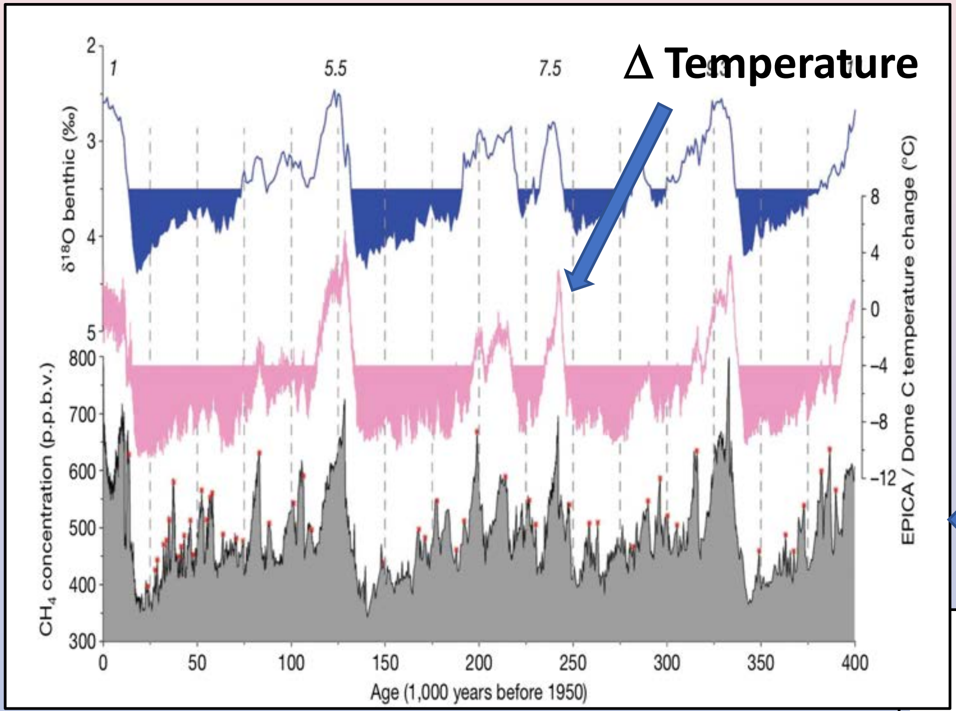


Extra Surface Temperature Increase by 2100



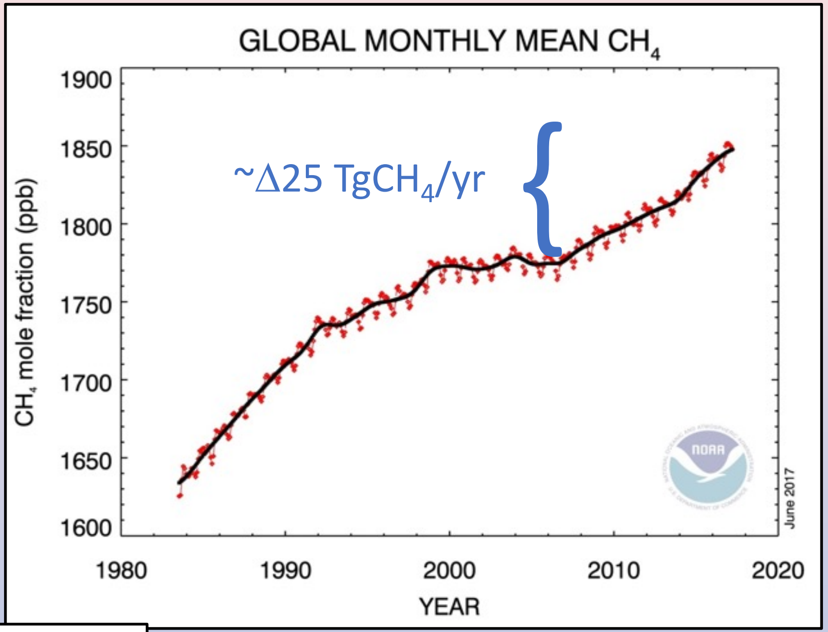
Zhang et al., PNAS, 2017

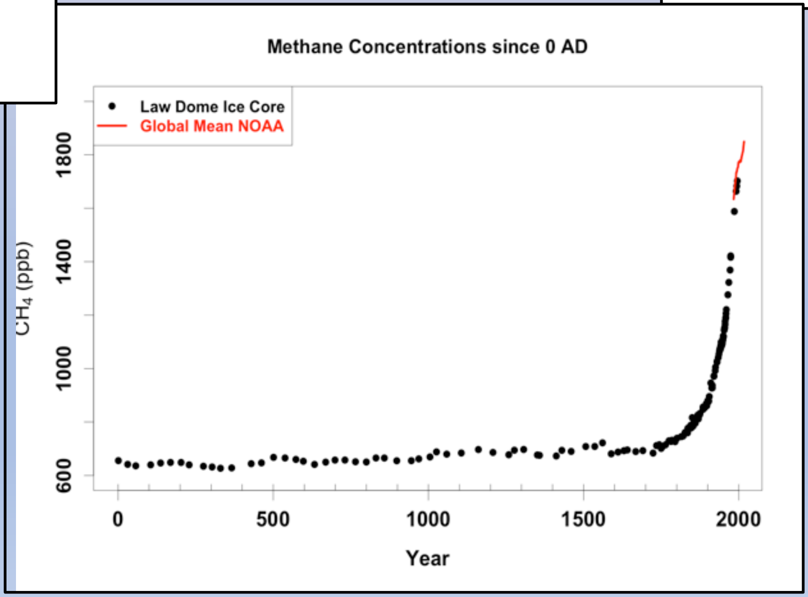
Methane Through the Ages



CH_4

EPICA/Dome C Ice Core Data
Loulergue et al., 2008





NAS Methane Report, 2018