The changing global methane budget.
NERC's MOYA, ZWAMPS and methane reduction projects, and the need for better tropical information and mitigation.

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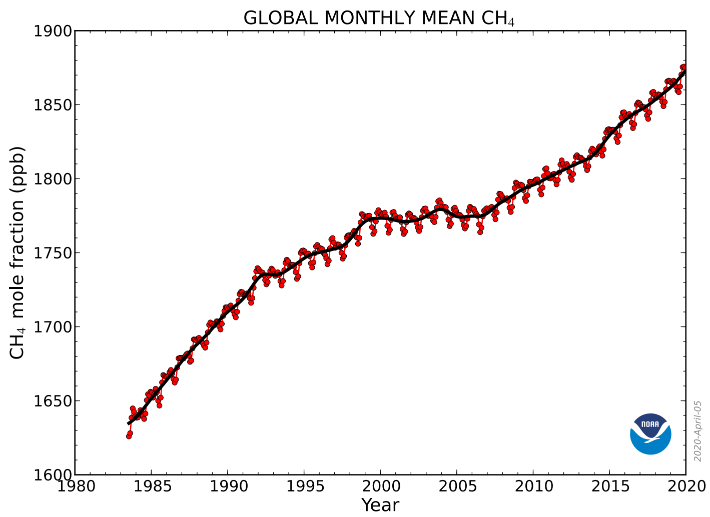
G. Allen, J.D. Lee, the MOYA consortium, ZWAMPS, and the FAAM team
including D. Pasternak, A. Vaughan, P. Barker, T. Bannan, P. Bateson
and all the FAAM core and technical crew.

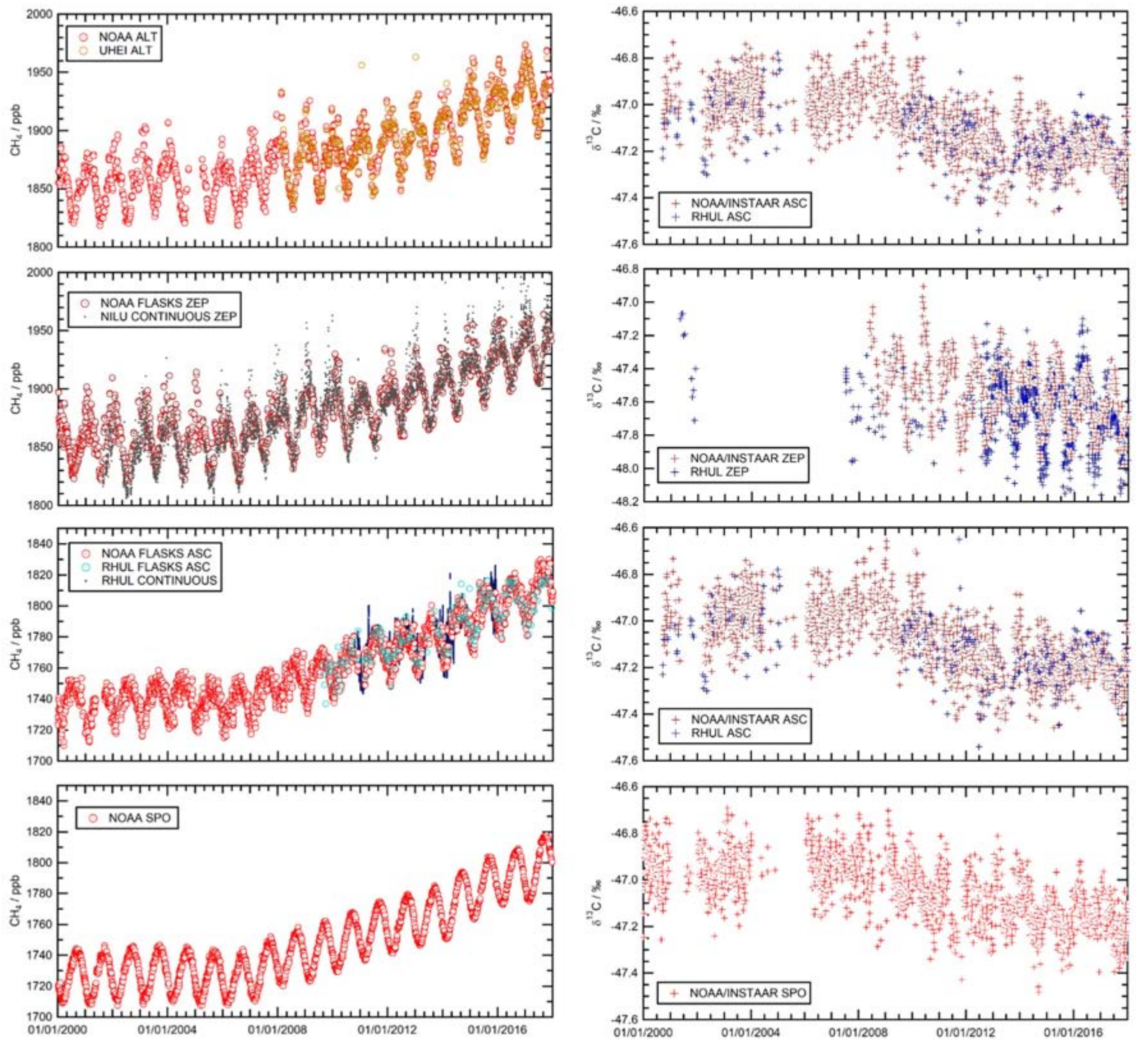
Yi O rice paddies
Hong Kong

Global mean CH_4 from NOAA (Ed Dlugokenkcy)
https://www.esrl.noaa.gov/gmd/ccgg/



The methane rise that began in 2007 and accelerated in 2014 has continued.

In parallel with the rise, the isotopic shift to lighter, more C-12 rich values has also continued.



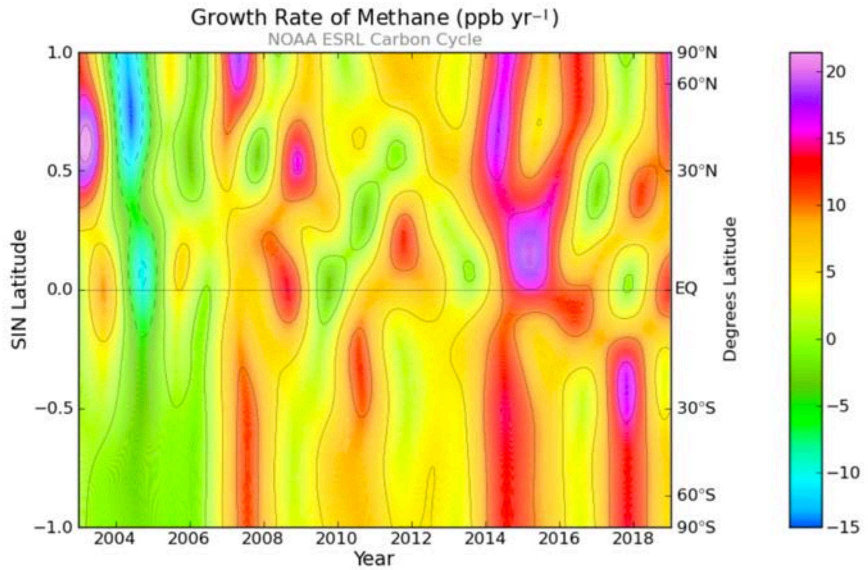
Methane from Arctic, equatorial, and Antarctic sites (from Nisbet et al. 2019)

Left panels: mole fraction.

Right panels: $\delta^{13}C_{CH4}$.

a) Top: Methane at Alert, Canada (ALT; 82°N).
b) Upper Middle: Methane at Zeppelin, Svalbard. (ZEP; 79°N).
c) Lower Middle: Methane at Ascension (ASC; 8°S).
d) Bottom: Methane at the South Pole (SPO).

NOAA Sine-Latitude map of methane growth, 2003-2019
Note importance of the region under the seasonal sweep of the Inter-Tropical Convergence (roughly +0.5 to -0.5 sin lat). Last year plot colouration is provisional (end effects of curve fit)



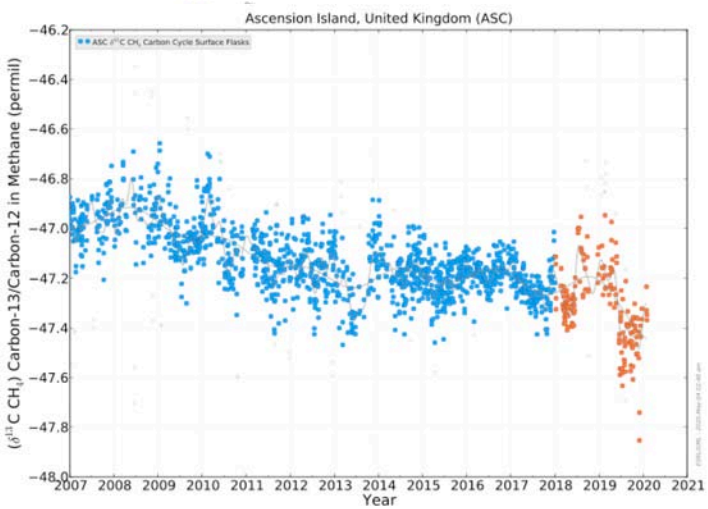
Year	Growth	±
2005	0.28	0.44
2006	1.92	0.54
2007	7.90	0.61
2008	6.51	0.45
2009	4.64	0.51
2010	5.24	0.72
2011	4.89	0.59
2012	4.98	0.51
2013	5.71	0.58
2014	12.72	0.43
2015	10.06	0.74
2016	7.02	0.64
2017	7.02	0.85
2018	8.29	0.56

2019 > 10 ppb

Annual Growth (NOAA)

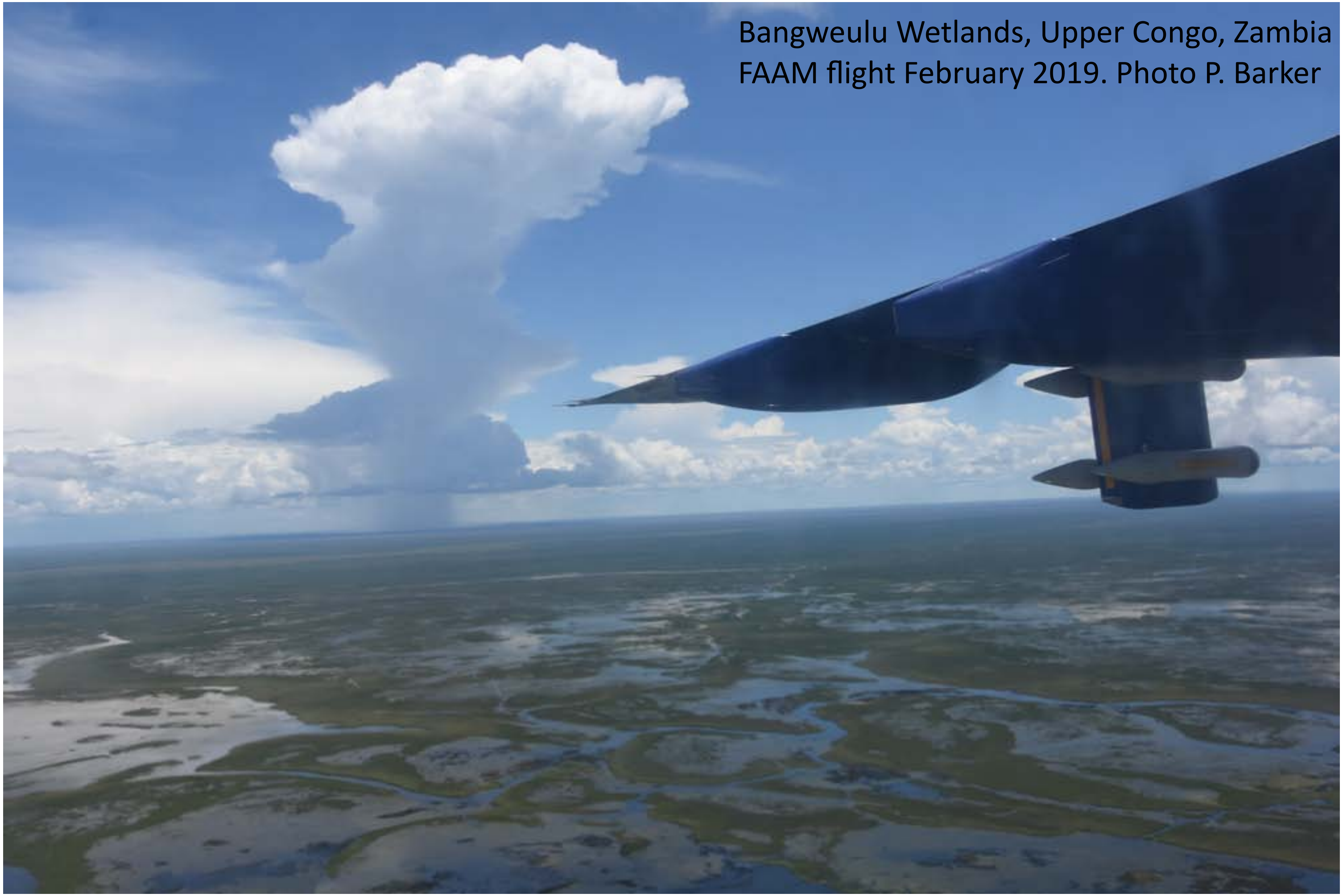
Note: 2019 annual growth in curve fit line not settled until mid-2020 but seems well over 10 ppb.

$\delta^{13}C_{CH4}$ record in NOAA flasks from Ascension Is. (8°S)



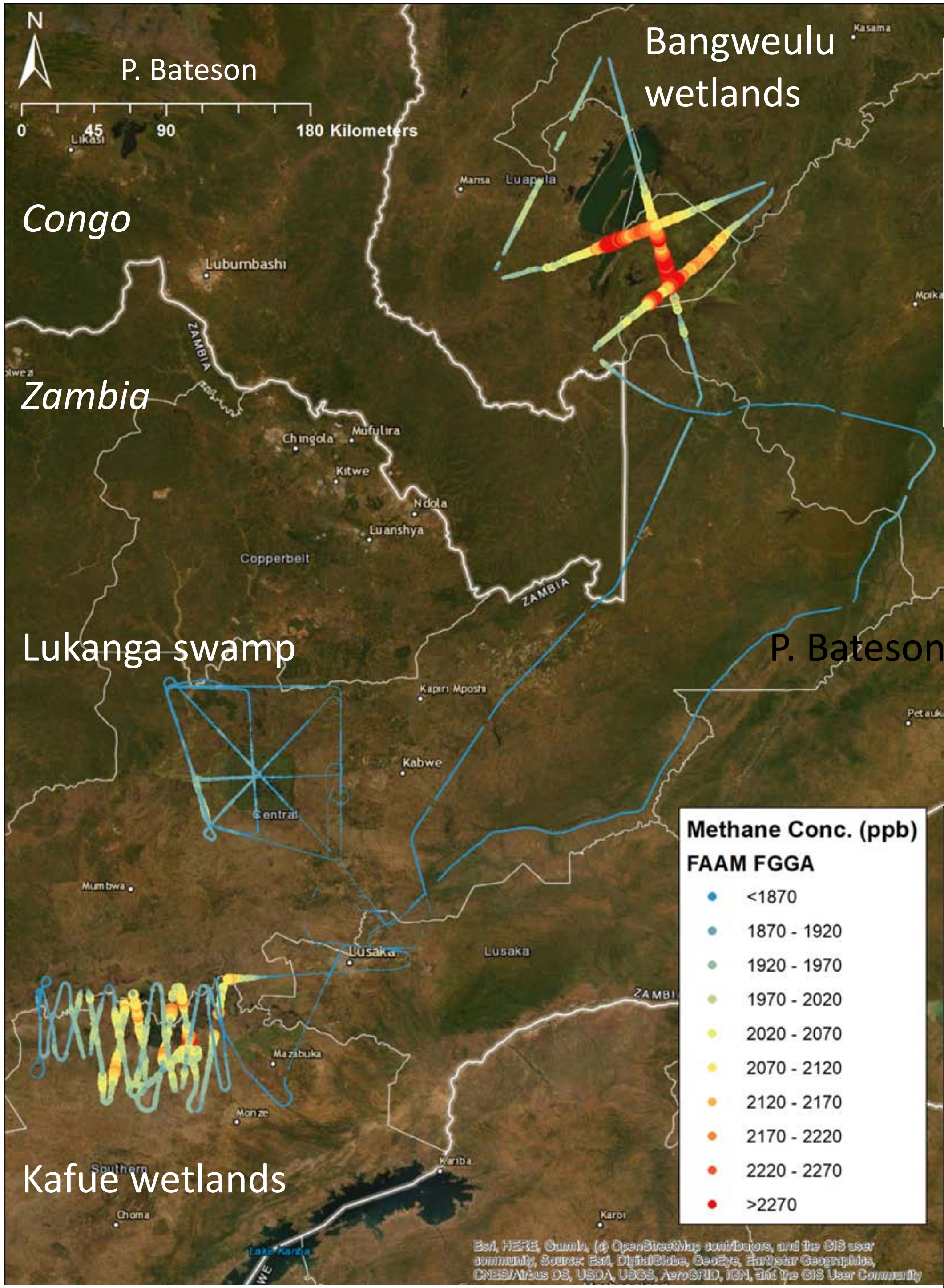
Note: red data points are unvalidated and will include fliers.

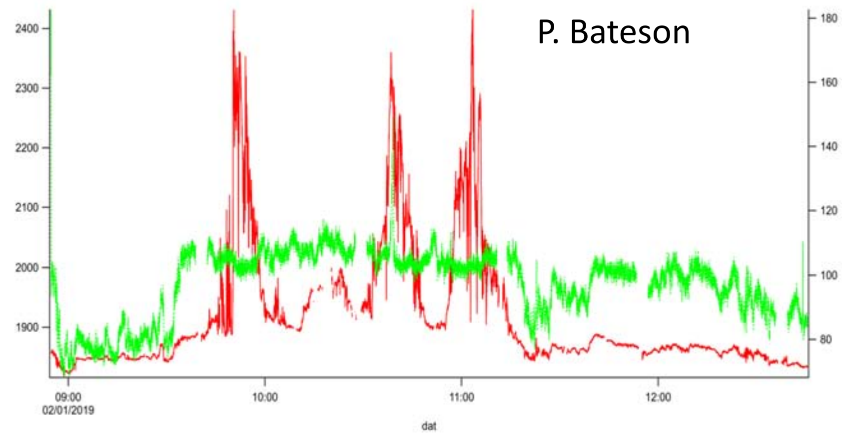
Figures and Table from NOAA (Ed Dlugokenkcy) https://www.esrl.noaa.gov/gmd/ccgg/



Bangweulu Wetlands, Upper Congo, Zambia
FAAM flight February 2019. Photo P. Barker

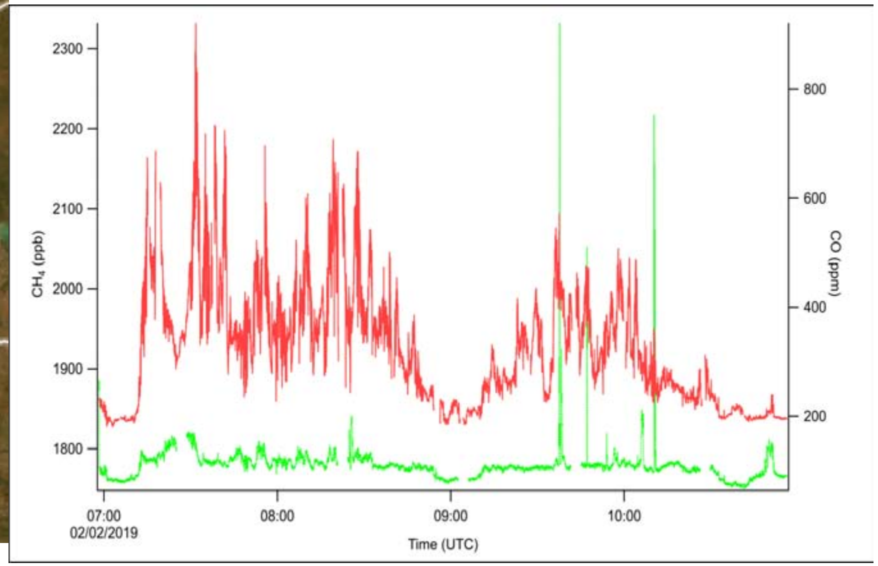
NERC Project MOYA flights in S. America (Bolivian Amazonia) and Africa (Ugandan Nile and Upper Congo wetlands around Bangweulu, Zambia), have found significant tropical emissions





Zambian flights.
Flight missions over Bangweulu wetlands, Lukanga Swamp and Kafue flats wetlands

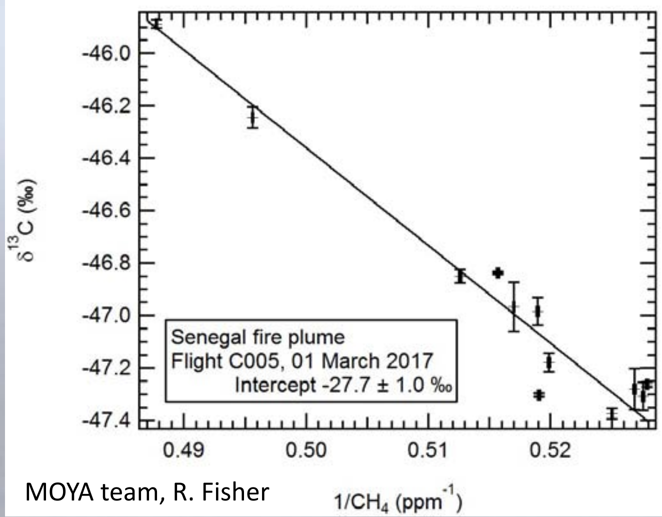
Above: Bangweulu transect.
methane (red) and CO (green).
Below: Lukanga transect. P. Bateson.



Fire is a major methane source in the tropics, including biomass burning of C3 leaf litter in wooded savanna.

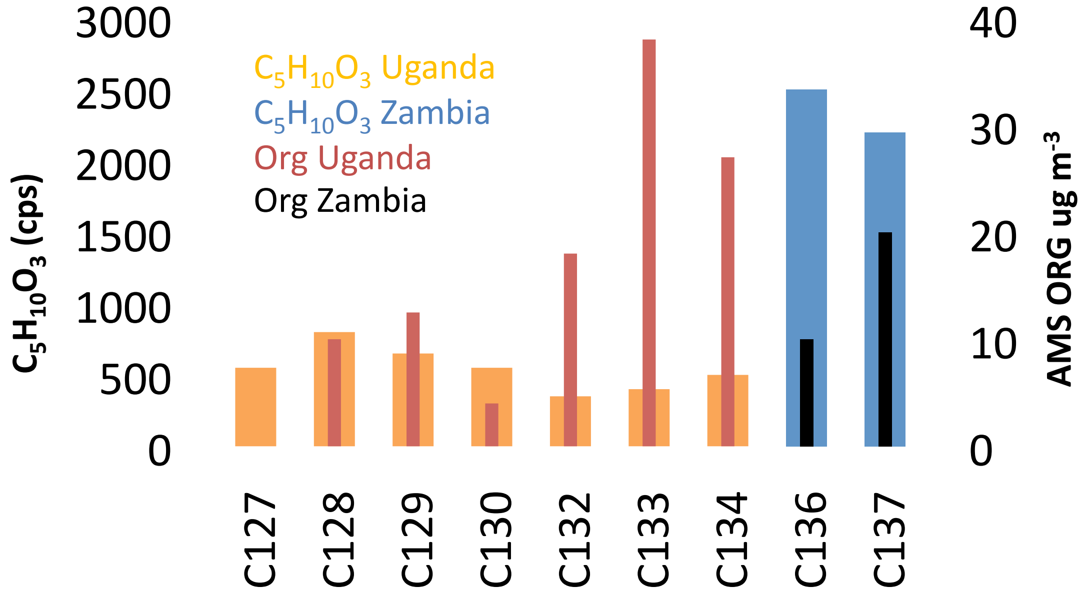
Senegal fires have $\delta^{13}C_{CH4}$ -28‰

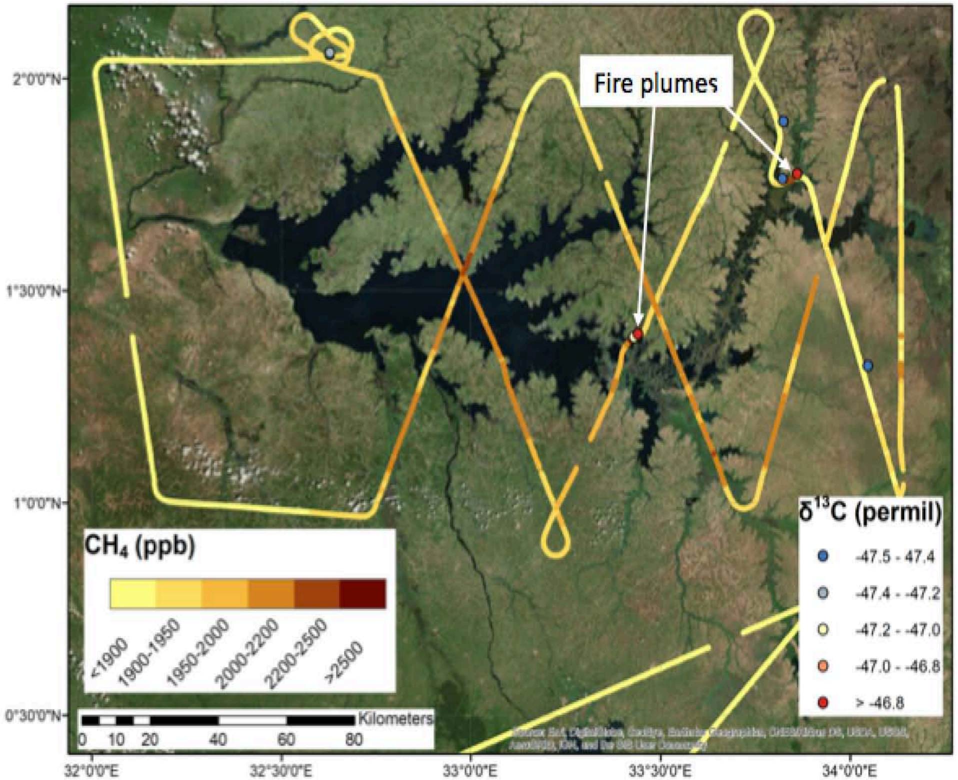
Ugandan fires (grass) have $\delta^{13}C_{CH4}$ around -12 to -16‰,

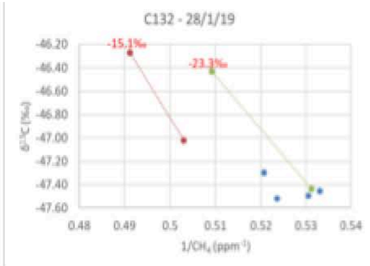


MOYA team, R. Fisher

Casamance, Senegal, Feb/March 2018







C132 – 28 January 2019

Isotopic analysis in progress

$\delta^{13}C$ enriched samples in narrow fire plumes at edge of lake

200 ppb elevations in CH_4 across the lake, 400 ppb spikes in fire plumes.

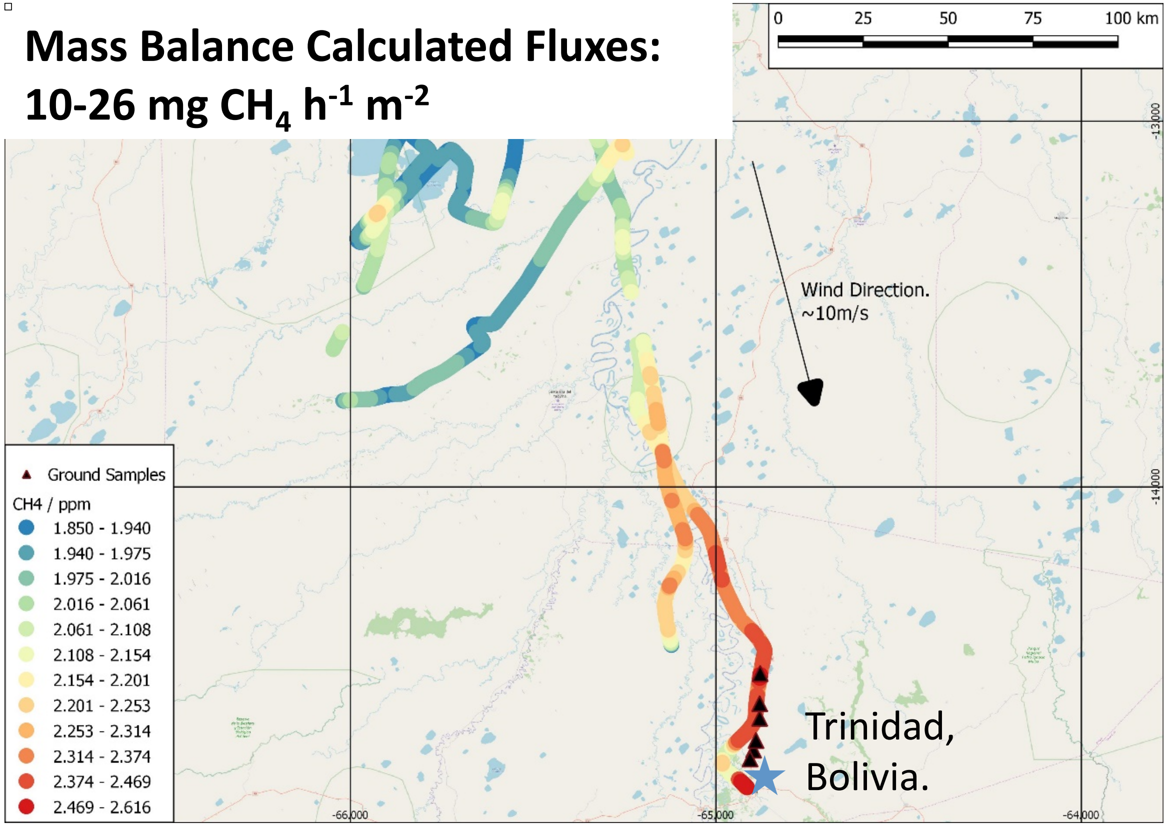
Lake Kyoga

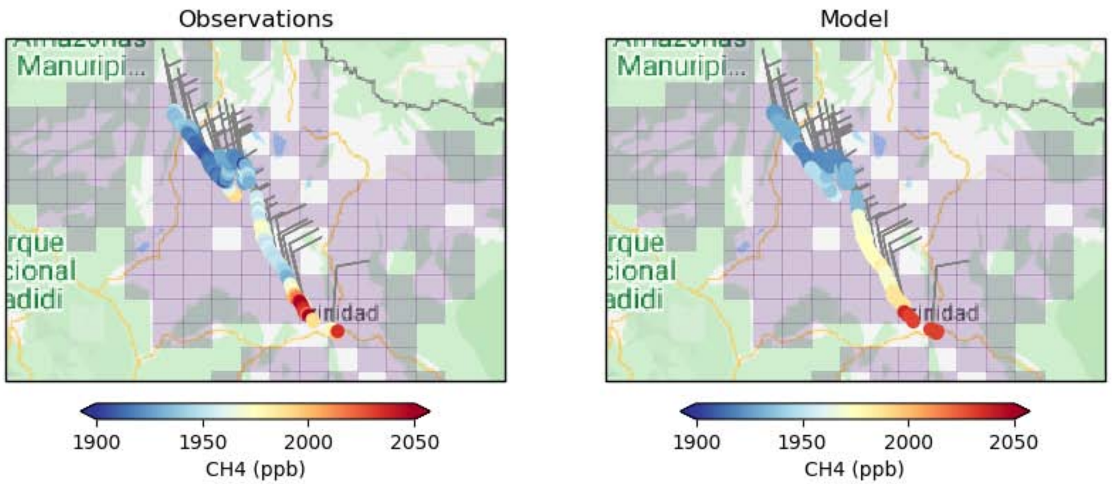
MOYA Uganda, Jan 2019

Fires from crop waste and grass burning, as well as plastic waste.

T. Bannan, P. Barker, R. Fisher, P. Bateson, MOYA team

Mass Balance Calculated Fluxes: 10-26 mg CH_4 h^{-1} m^{-2}





MOYA Bolivian Amazonia Wetlands:
Field campaign with British Antarctic Survey Twin Otter, in collaboration with M. Andrade & I. Moreno, UMSA La Paz.

The Llanos de Moxos in Northern Bolivia consists of tropical savannahs with seasonally flooded wetlands ~120,000 km^2.

Two MOYA flights were undertaken on consecutive days, each ~700 km round trip.

Fluxes determined using two methods show very high methane emission rates for peak wetland period.

GEOS-Chem model with WETCHARTS for wetlands compared to observations. Excellent agreement to in-flight measurements.

Best fit flux for wetlands to measured observations:
13 mg CH_4 h^{-1} m^{-2}.

Zimbabwe cattle

L. Broderick

Lukanga Swamp, Zambia

T. Broderick

To a methanogen, there’s little difference between a tropical cow and a tropical wetland.

Both are warm, wet habitats, with lots of incoming organic substrate creating steady anoygenic conditions.

On sunny afternoons, wetlands may even become nearly as warm as cows’ stomachs.

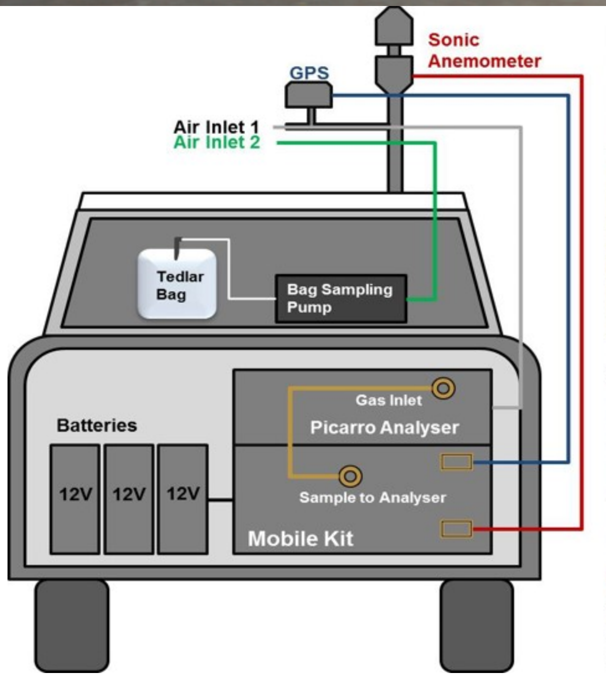
Unlike boreal bogs, Tropical wetlands are rich in C4 plants, with isotopically heavy Carbon. So is cow diet (maize waste, sugar, etc, C4 grasses).

Many methane sources are very easy to mitigate. Tropical landfills are an obvious candidate. They are often very large, very poorly managed and often on fire. In addition to methane, they emit a wide spectrum of pollutants. It would be inexpensive to regulate their methane emissions, even with simple soil coverings, and would have strong public health benefits also.

Landfill fire, Harare, Zimbabwe

Mitigating Emissions

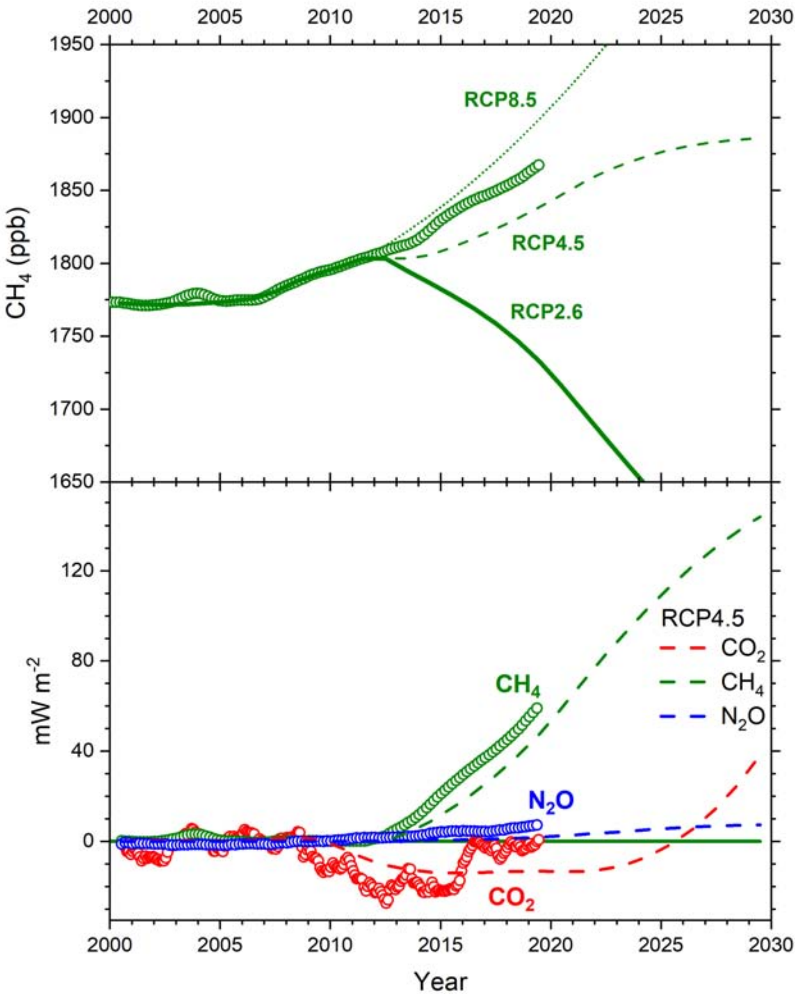
Fossil fuel industry sources are widespread and include both leaks and deliberate venting. Detection is very easy with mobile vehicle-mounted systems and emisison-prevention can in some cases be profitable as leaks are plugged.



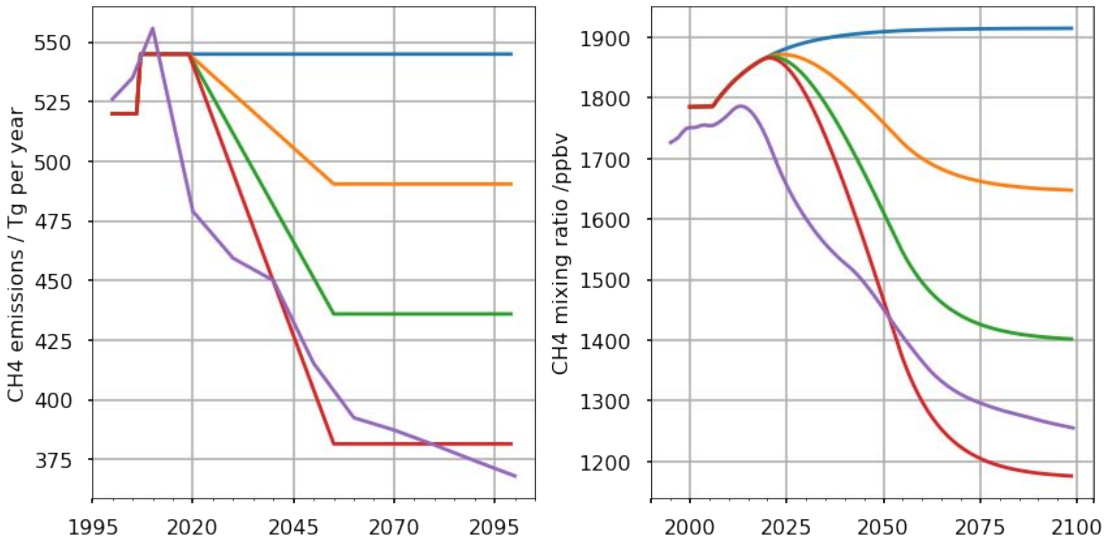
Zazzeri, G. et al. (2017) *Scientific* Reports 7: 4854

Calculation by M. Manning.

Modelling by P. Griffiths.



Top: Global methane (green) compared to RCP2.6 consistent with the Paris Agreement and other scenarios. Lower: actual differences in radiative forcing from RCP2.6 methane (green), CO_2 (red), and nitrous oxide (blue).



Potential impact of mitigation. Purple - RCP2.6 compliant with Paris Agreement. Red assumes recent observational record. Blue —no change in after 2020. Orange —10% cut spread over 2020–2055, then stable. Green —20% cut to 2055, then stable. Red —30% cut to 2055, then stable.

Methane and the Paris Agreement.

Figures from Nisbet et al. 2020, Methane Mitigation, Reviews of Geophysics


L. Broderick
Thanks to FAAM team, Zambian Geological Survey, the Ugandan Met Office, all on ZWAMPS, Tim Broderick (Zimbabwe), NOAA (Ed Dlugokencky) and many others.
Nisbet E.G. et al. (2020) Methane mitigation: methods to reduce emissions, on the path to the Paris Agreement. *Reviews of Geophysics* https://doi.org/10.1029/2019RG000675
Nisbet et al. (2019) Very strong atmospheric methane growth in the four years 2014-2017 Implications for the Paris Agreement. *Glob. Biogeochem Cycles* doi10.1029/2018GB006009