Inverse modelling of CH_4 emissions in permafrost regions

with

TM5-MP/4DVAR

Santiago Parraguez Cerda - PhD. Candidate

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Supervised by
Maria Kanakidou and Mihalis Vrekoussis

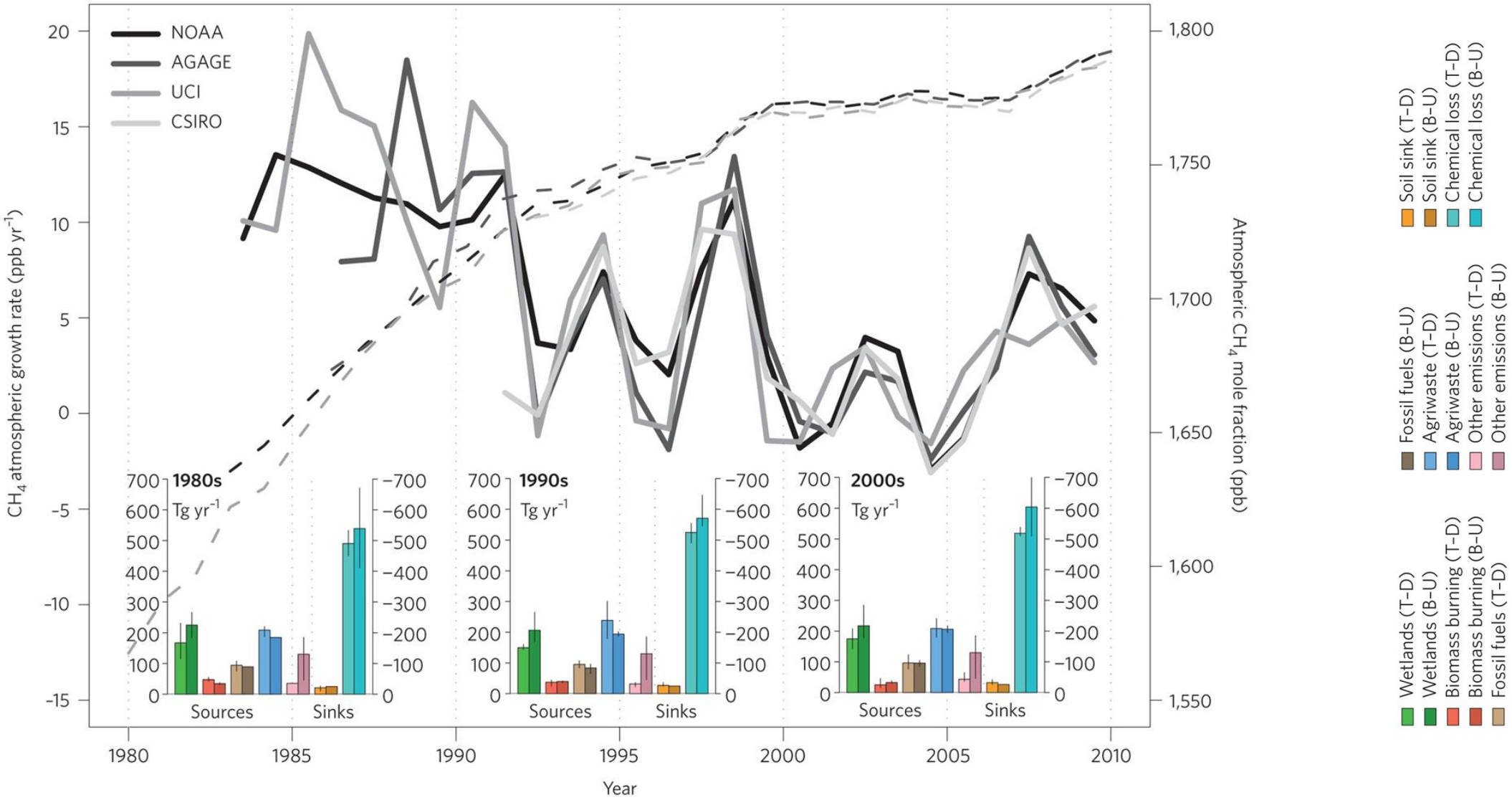
TM Meeting – 16 / 17 October 2023

Methane (CH_4)

Methane is a Greenhouse Gas (GHG) with a long lifetime (over a decade) and a Global Warming Potential (GWG) of 32 in the 100-year horizon [1]

[1] Etminan et al. (2016). Radiative forcing of carbon dioxide, methane and nitrous oxide. In *Geophys. Res. Lett.*

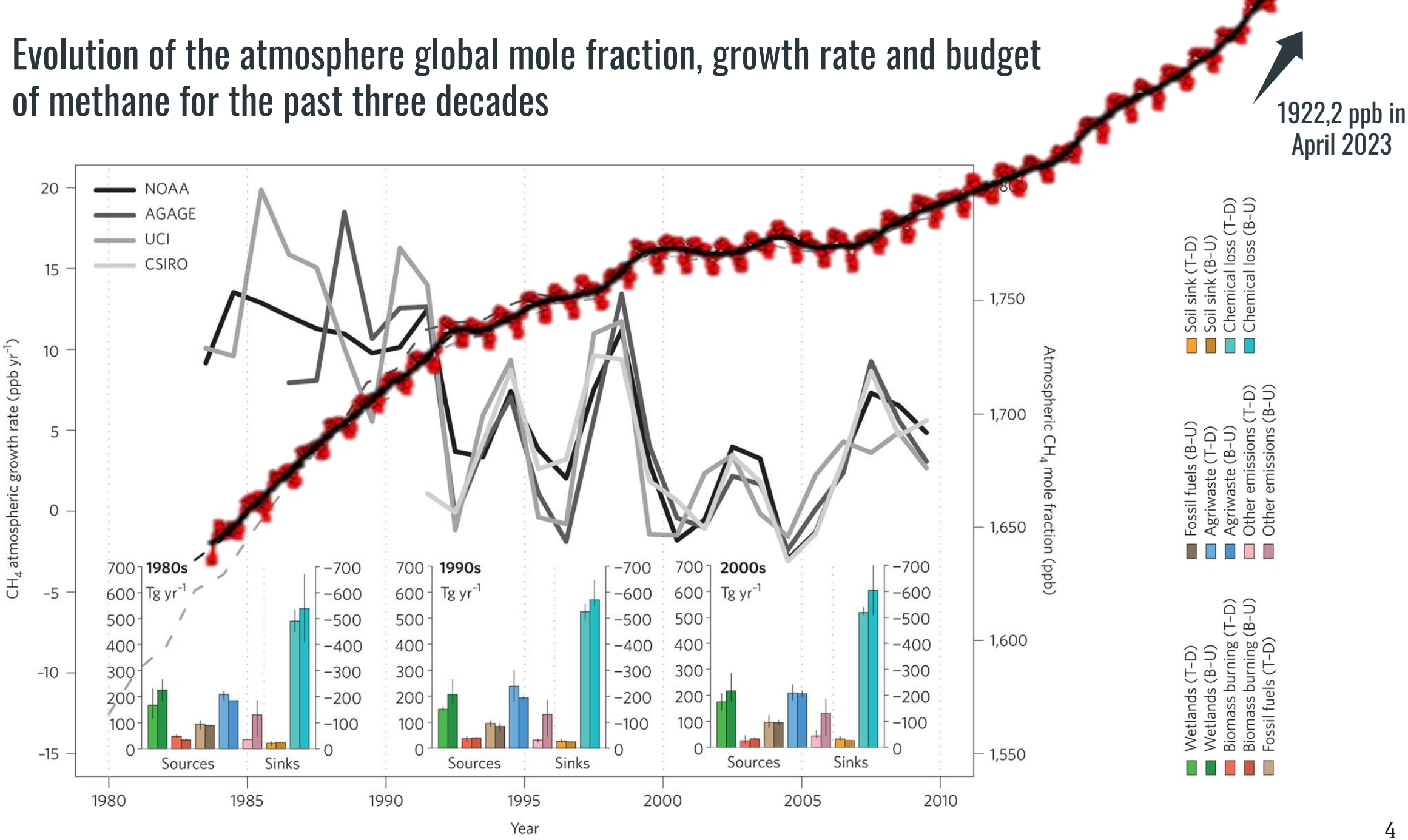
Evolution of the atmosphere global mole fraction, growth rate and budget of methane for the past three decades



Source: Kirschke, S. et al. (2013) Three decades of global methane sources and sinks.

Evolution of the atmosphere global mole fraction, growth rate and budget of methane for the past three decades

1922,2 ppb in April 2023



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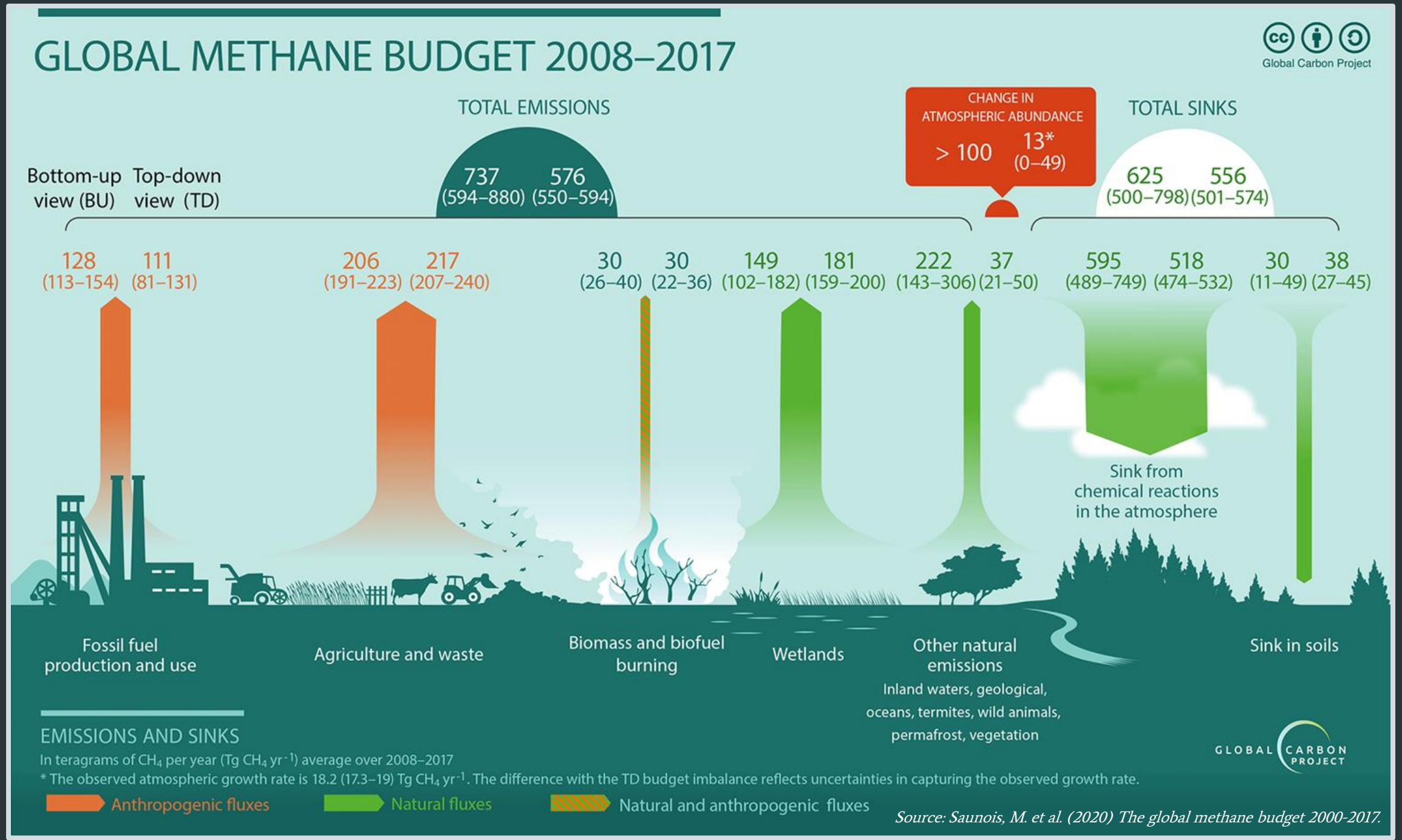


Source: Saunois, M. et al. (2020) The global methane budget 2000-2017.

Permafrost

Permafrost is defined as frozen soil, sediment, or rock
having temperatures at or below 0°C for at least 2 consecutive years [2]

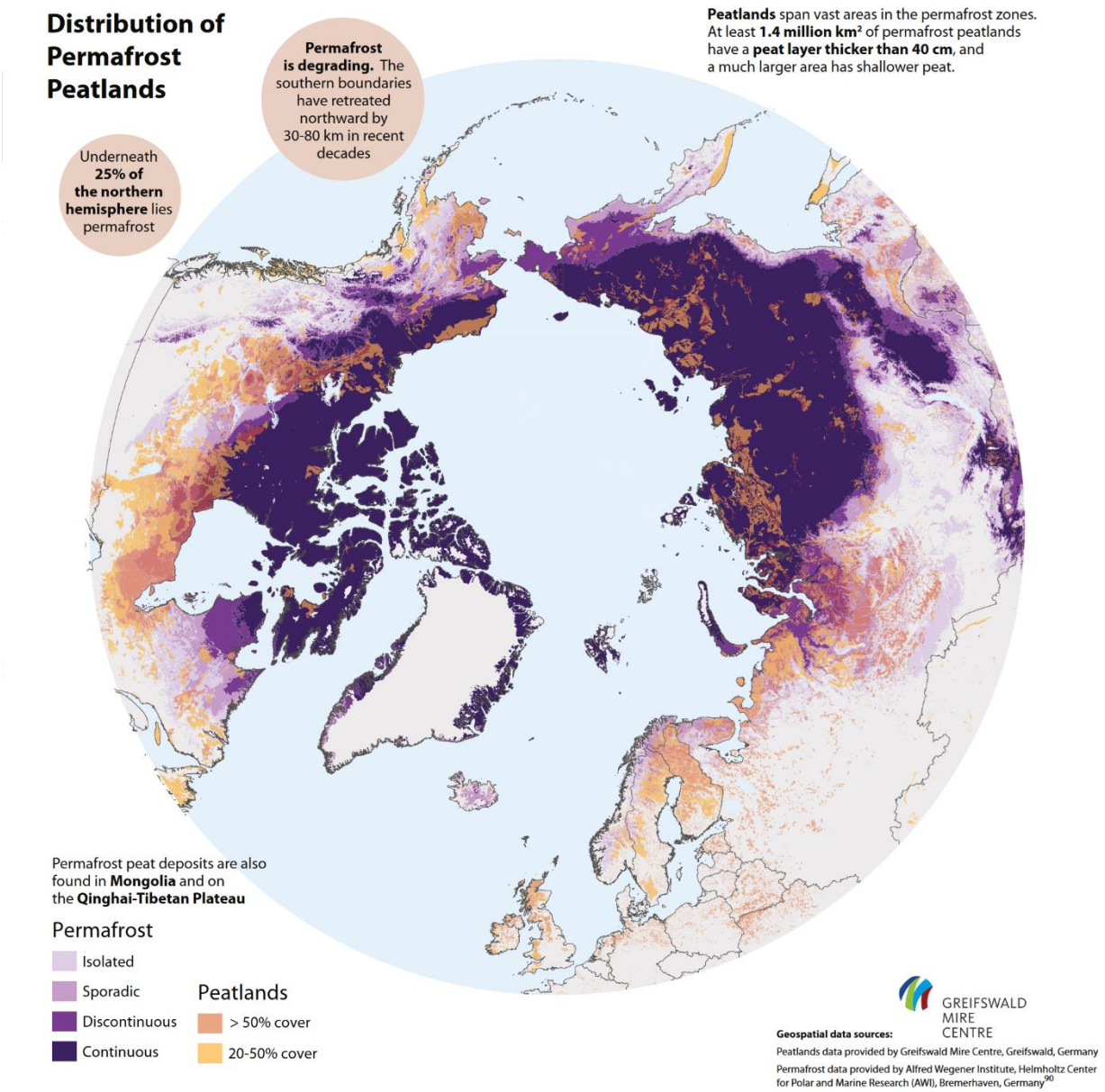
[2] Harris and Pedersen (1998). Thermal regimes beneath coarse blocky materials. In *Permafrost and Periglacial Processes.*

Relevance of permafrost

Contains **~1,300 Pg of organic carbon**. [3]

Thawing of permafrost releases carbon as CO_2 and CH_4

Drives a **positive feedback** on **climate change**



Source: UNEP (2019). Frontiers 2018/19 Emerging Issues of Environmental Concerns

[3] Hugelius et al. (2014) Estimated Stocks of Circumpolar Permafrost Carbon with Quantified Uncertainty Ranges and Identified Data Gaps.

Inverse modeling of emissions

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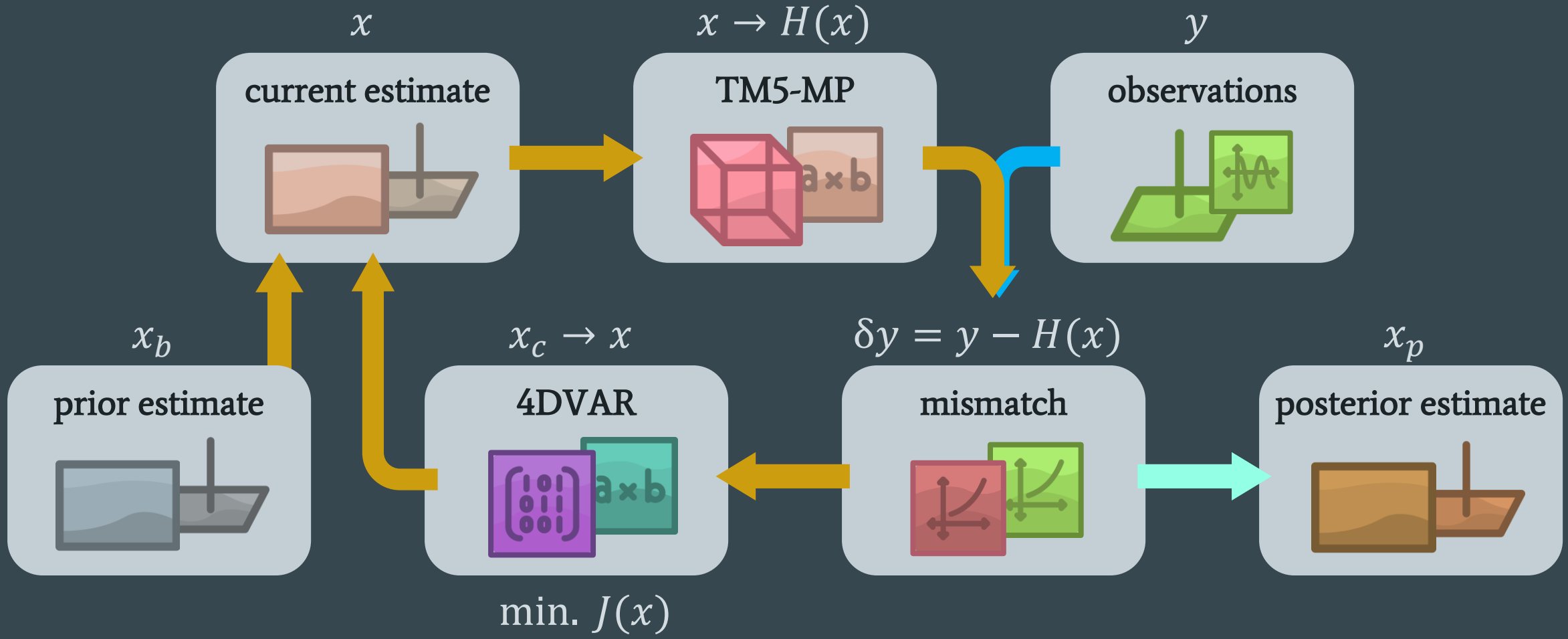
Inverse modeling of emissions

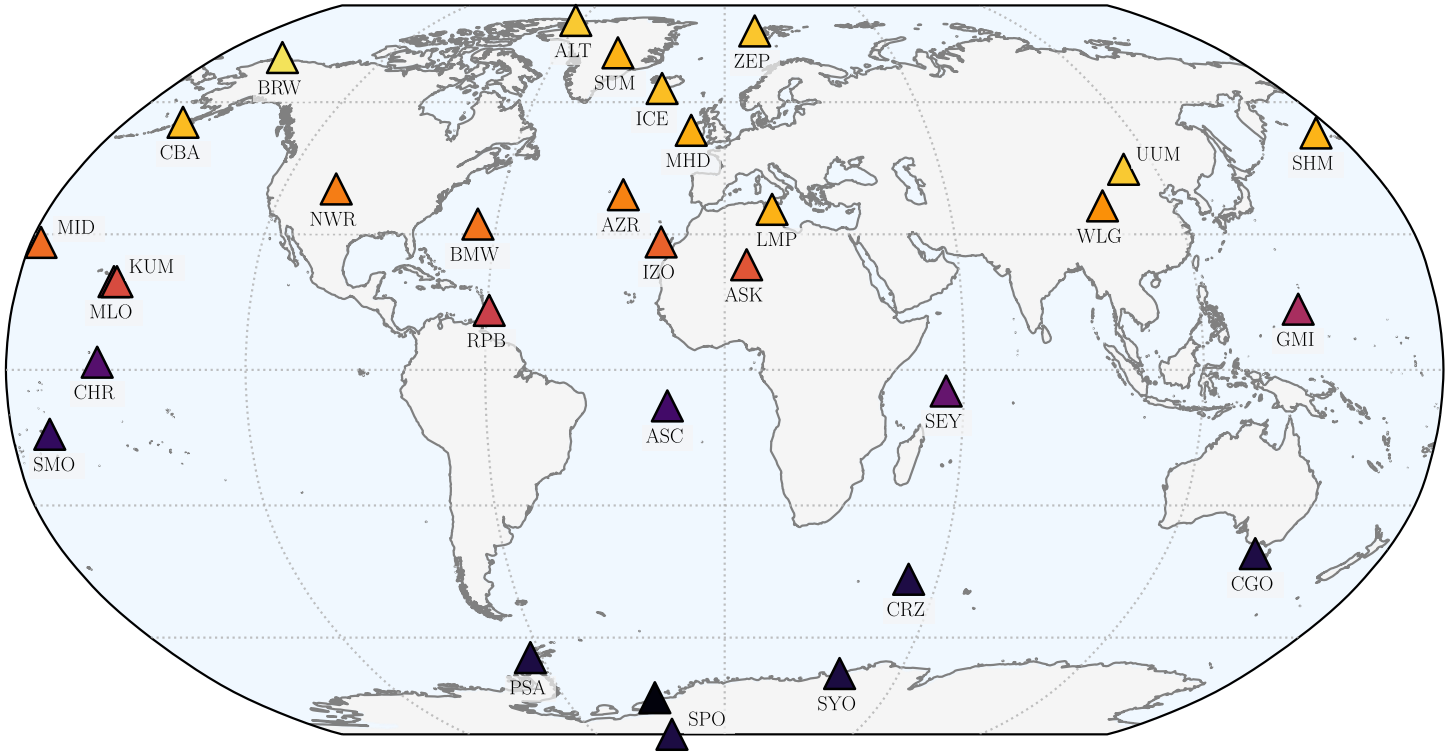


Measurements and remote observations

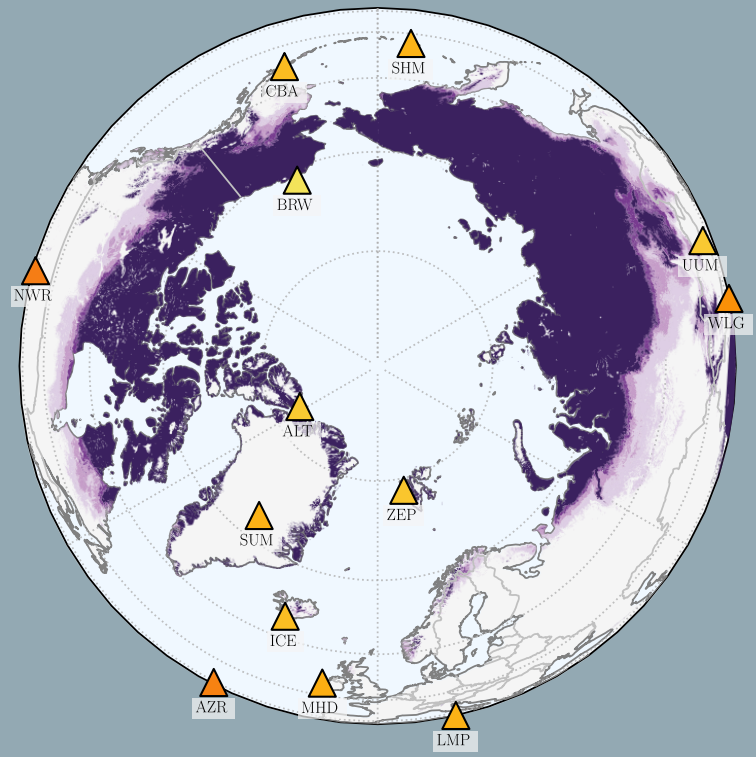
- Stations flask measurements
- Satellite instrument observations

Stations flask measurements

Station locations from NOAA network

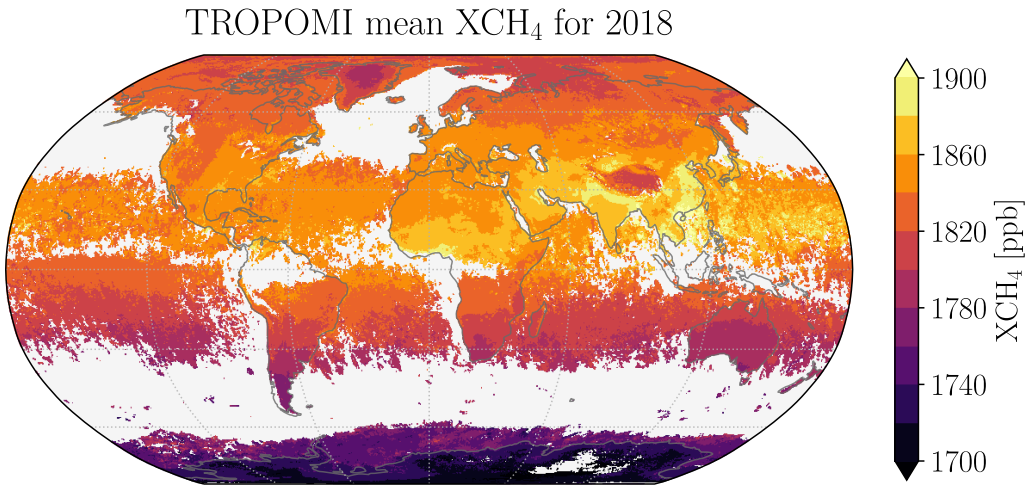


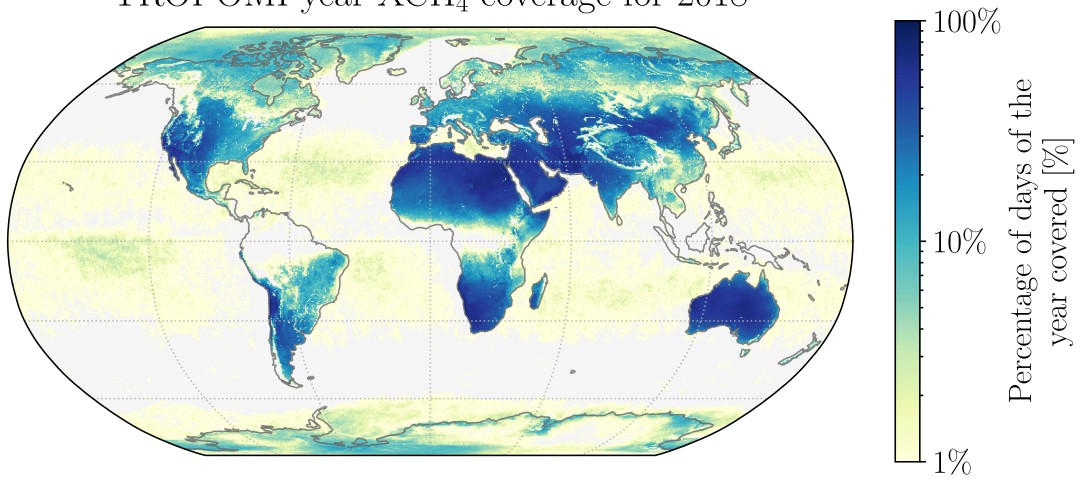
Permafrost region



Remote observations: TROPOMI

- High resolution (7.0×3.6 km^2)
- Global daily coverage
- Continuous data since November 2017
- Improved retrieval (WFMD CH_4 product) covers high latitudes [4]

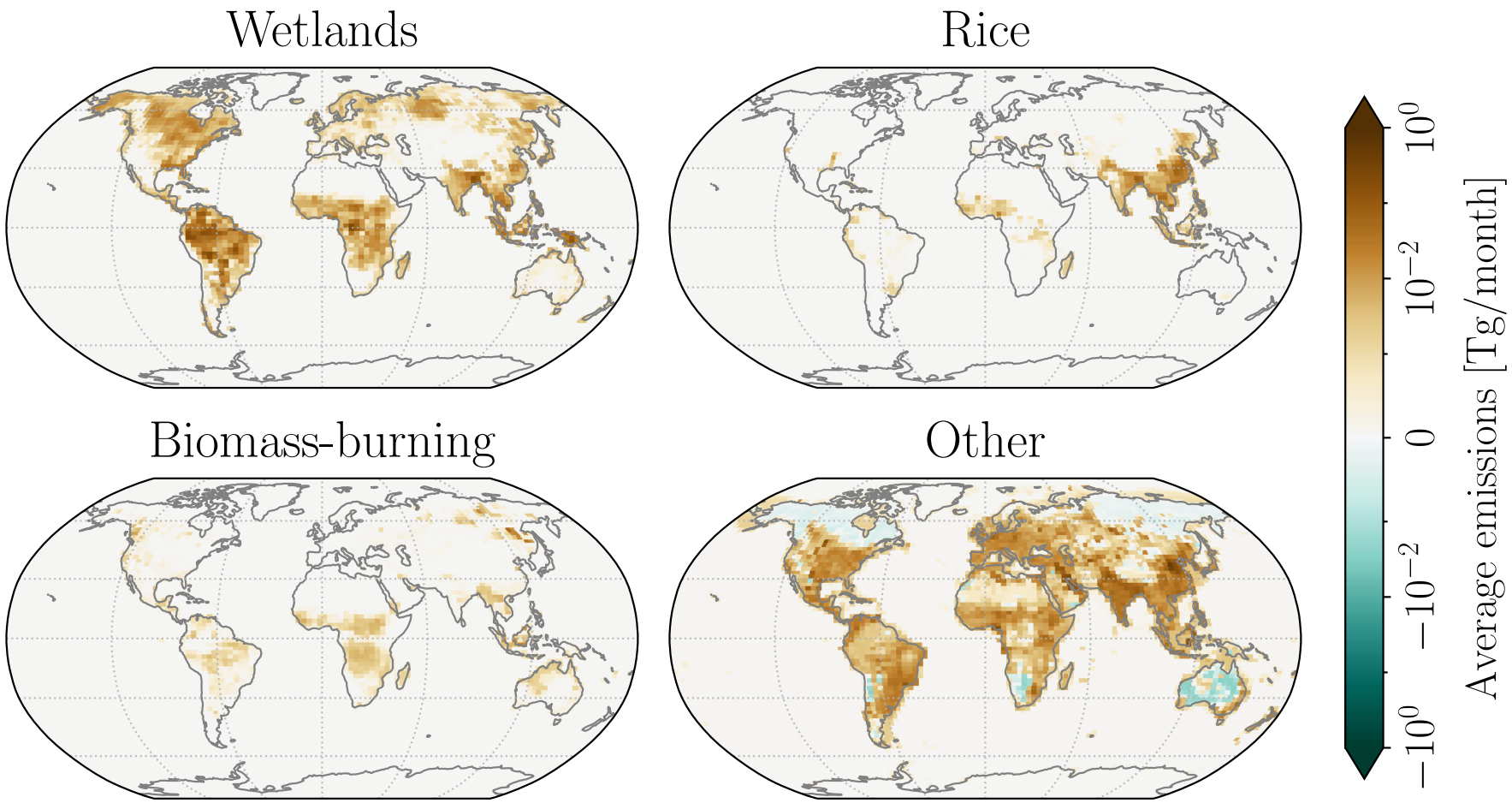




[4] Schneising et al. (2023). Advances in retrieving XCH4 and XCO from Sentinel-5 Precursor: improvements in the scientific TROPOMI/WFMD algorithm. In *Atmos. Meas. Tech.*

Emission categories for inversion, yearly mean

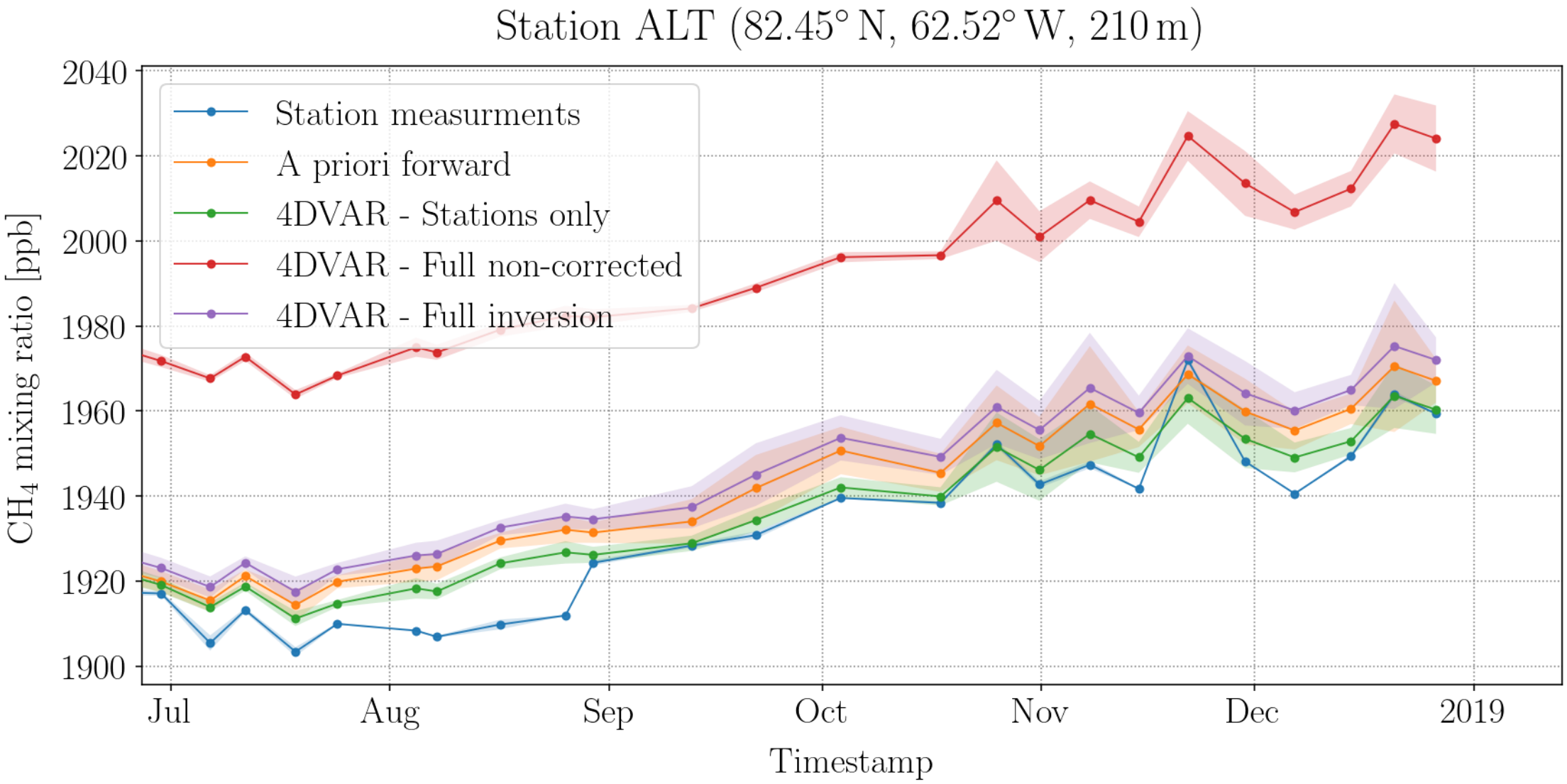
Category	[Tg/year]
Wetlands	188,3
Rice	36,3
B. burning	14,4
Other	338,0
Total	577,3



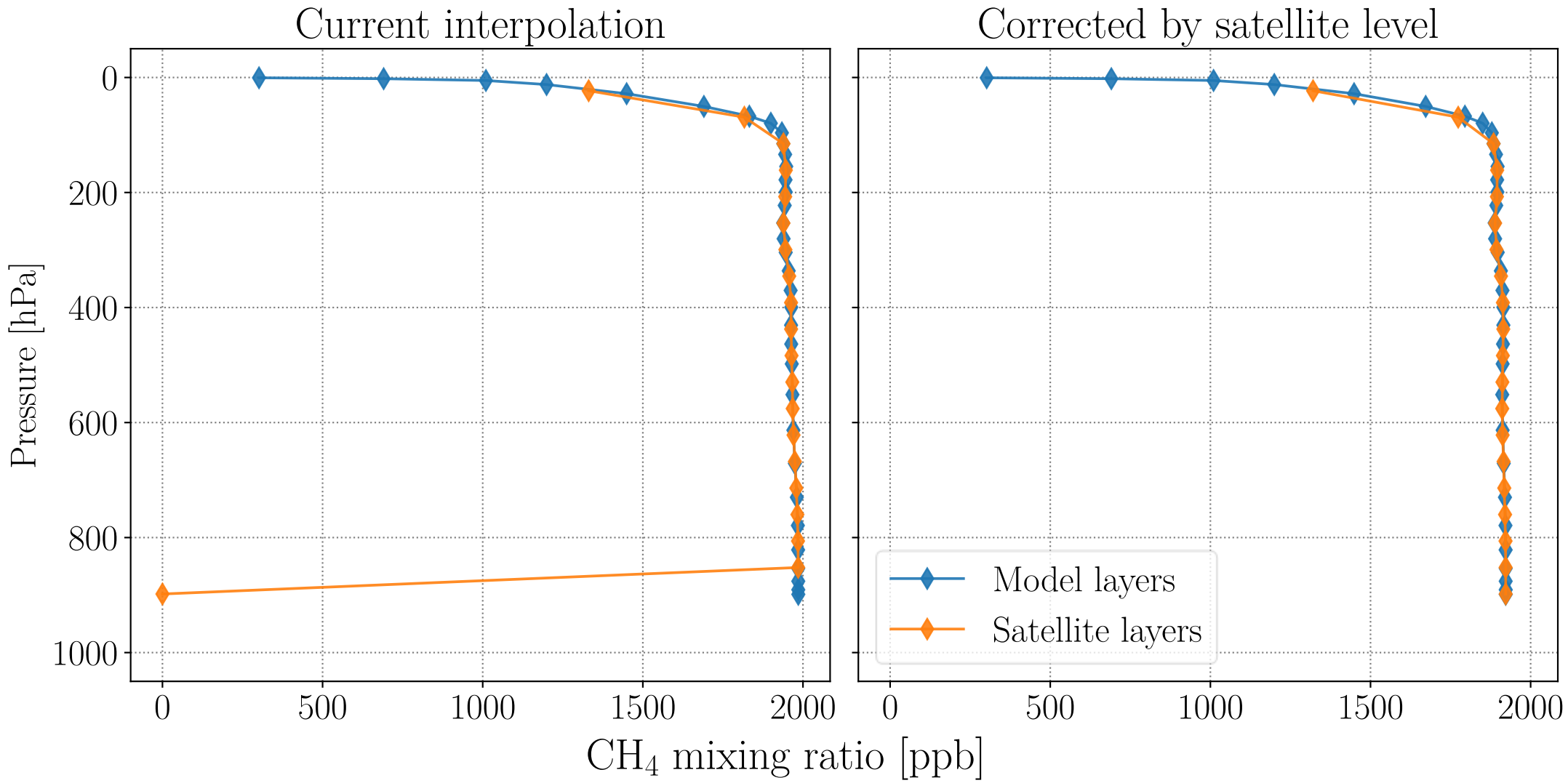
Inversion preliminary results

- Single year simulation (6 months of spin-up) for 2018
- Inversion with only stations and with both stations and satellite

Inversion for Jul-Dec 2018 NOAA sample and TROPOMI

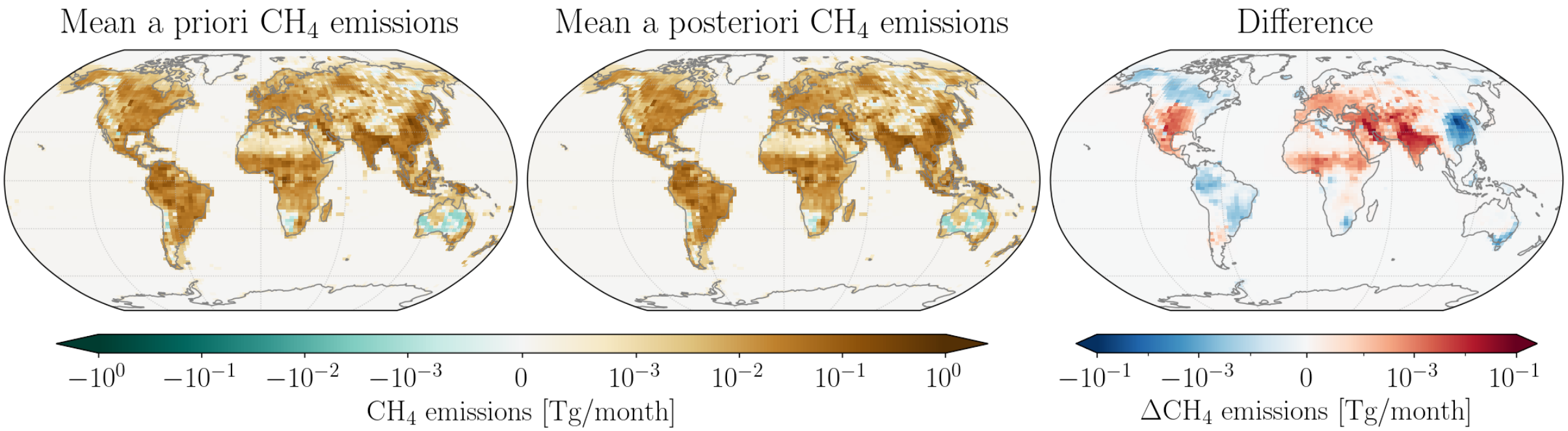


Model concentration interpolation to satellite layers



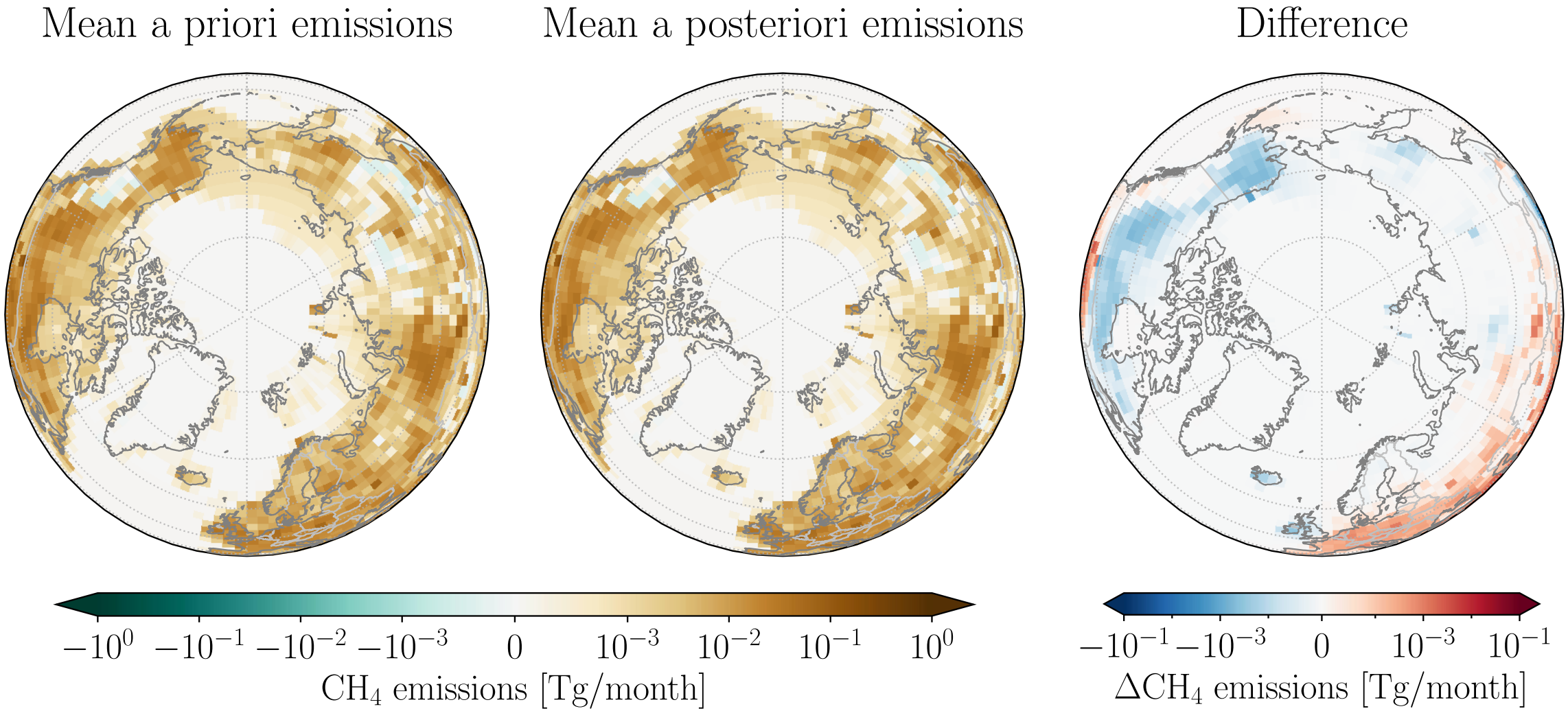
Inversion for Jul-Dec 2018, global view

NOAA sample and TROPOMI



Inversion for Jul-Dec 2018, northern region view

NOAA sample and TROPOMI



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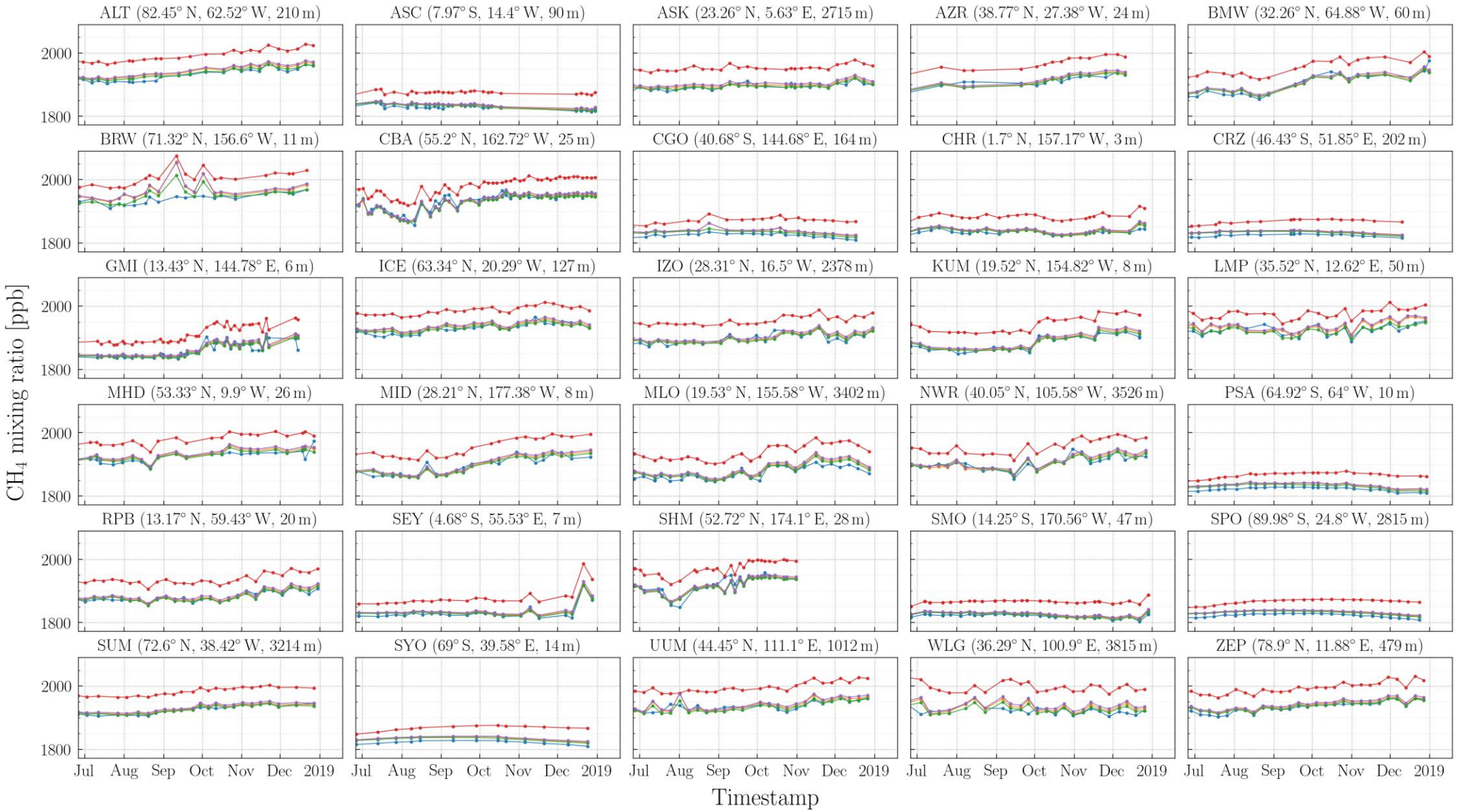
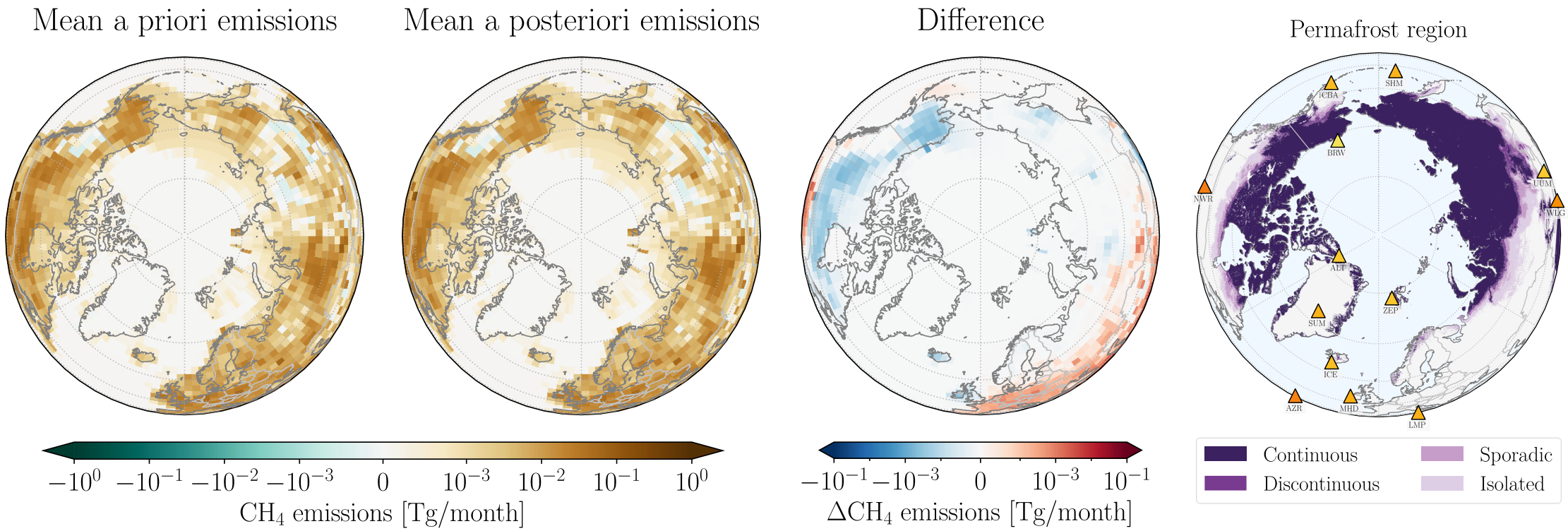
Inversion for Jul-Dec 2018 NOAA sample and TROPOMI



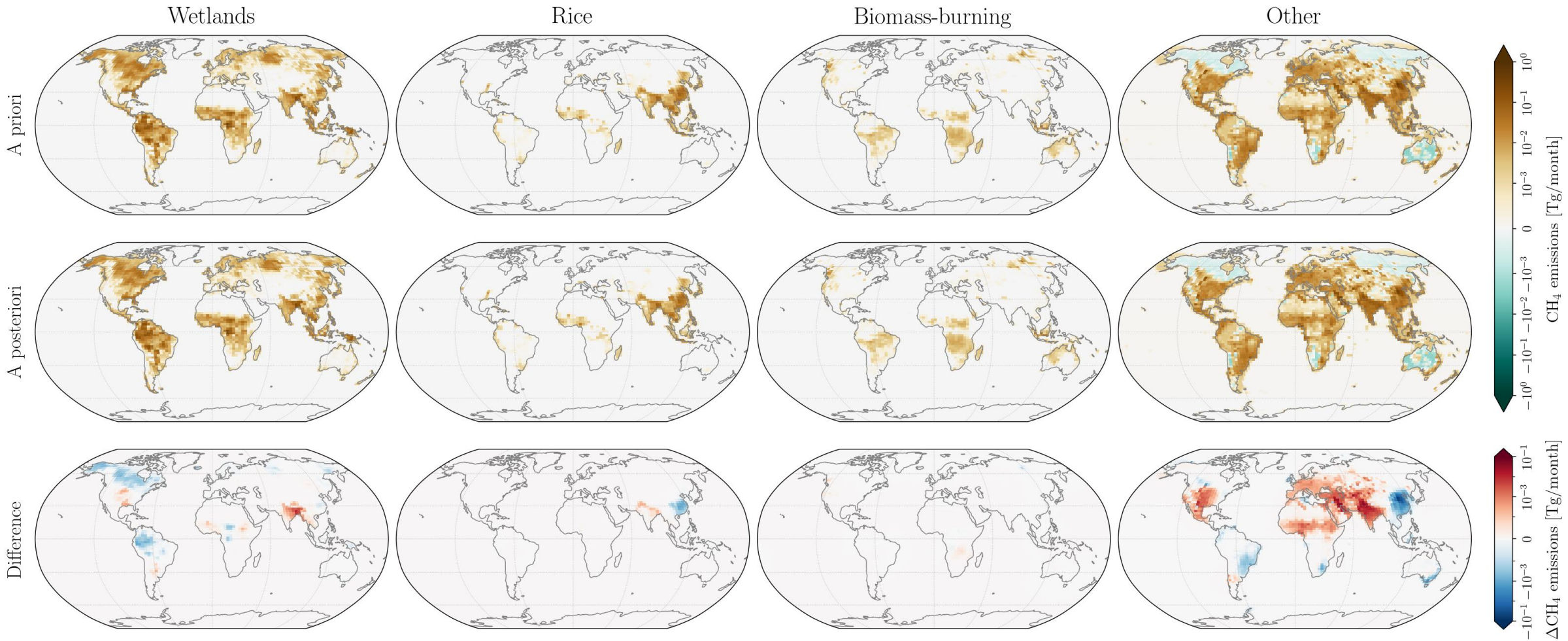
Inversion for Jul-Dec 2018, northern region view

NOAA sample and TROPOMI



Inversion for Jul-Dec 2018, mean emissions by category

NOAA sample and TROPOMI



Year emissions comparison by category

Category	A priori [Tg/year]	A posteriori [Tg/year]	Difference [Tg/year]	Relative difference [%]
Wetlands	188,3	188.,0	-0,23	-0,12
Rice	36,3	36,6	-0,05	-0,14
B. burning	14,4	14,3	-0,13	-0,94
Other	338,0	345,8	7,84	2,32
Total	577,3	584,7	7,42	1,29

Inversion for Jul-Dec 2018, monthly total emissions

NOAA sample and TROPOMI