Using TROPOMI observations to derive methane emissions and its driving factors over Lake Chad

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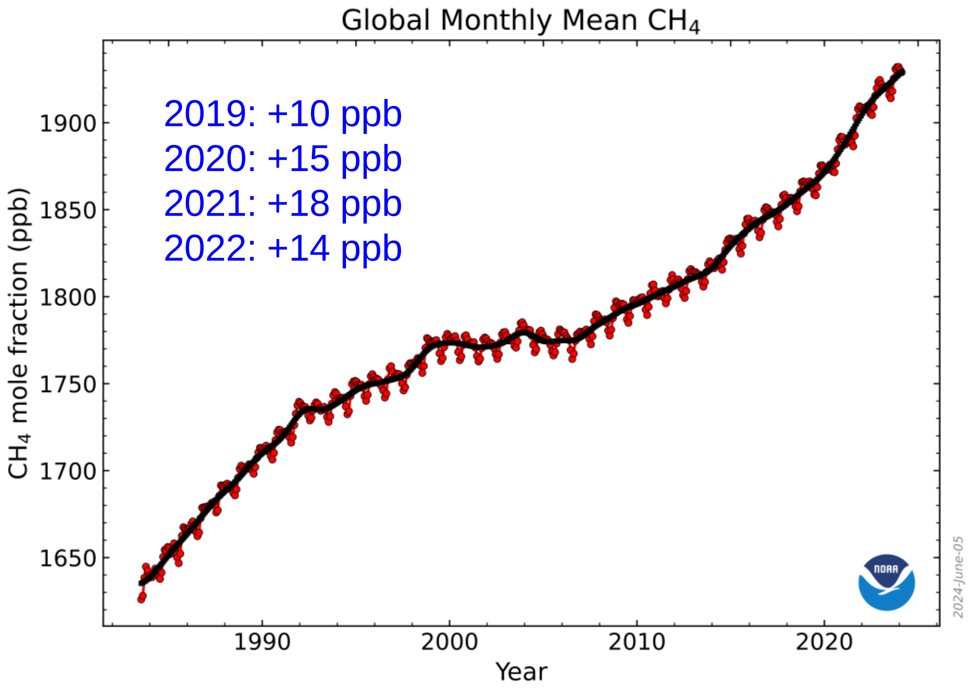
IMPALA

Outline

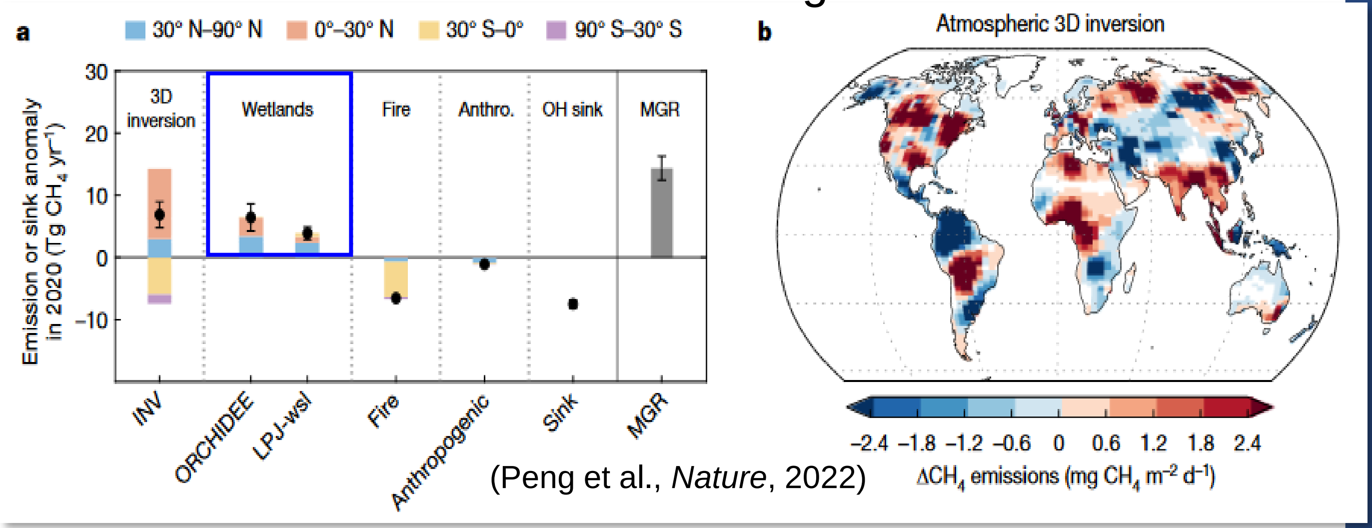
- Background
- Methodology
- Results & Summary

I. Background: What triggers this study?

Methane increase surged in 2020-2022

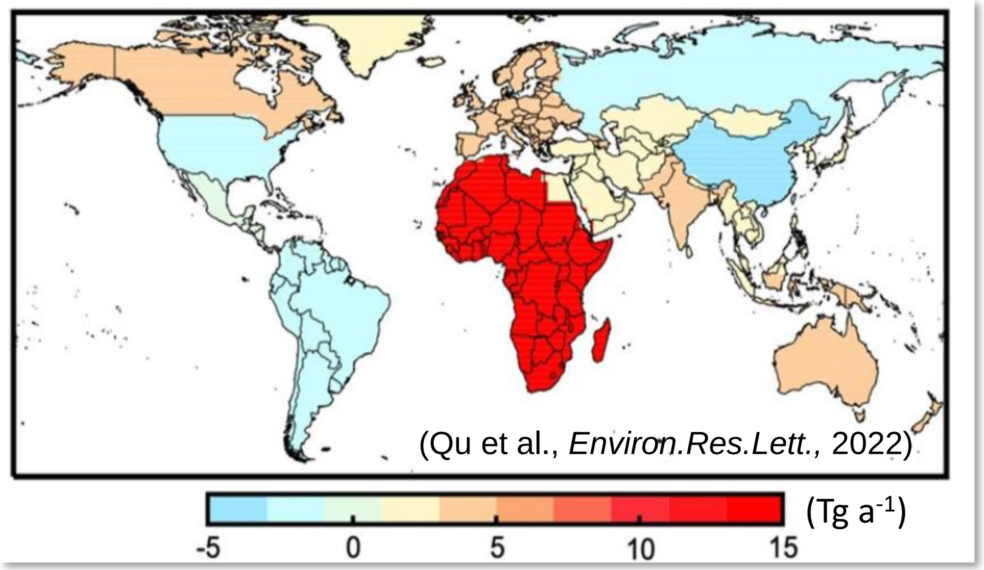


2020-2019 change in emissions



(Peng et al., *Nature*, 2022)

2020-2019 change in emissions (inversion of GOSAT)



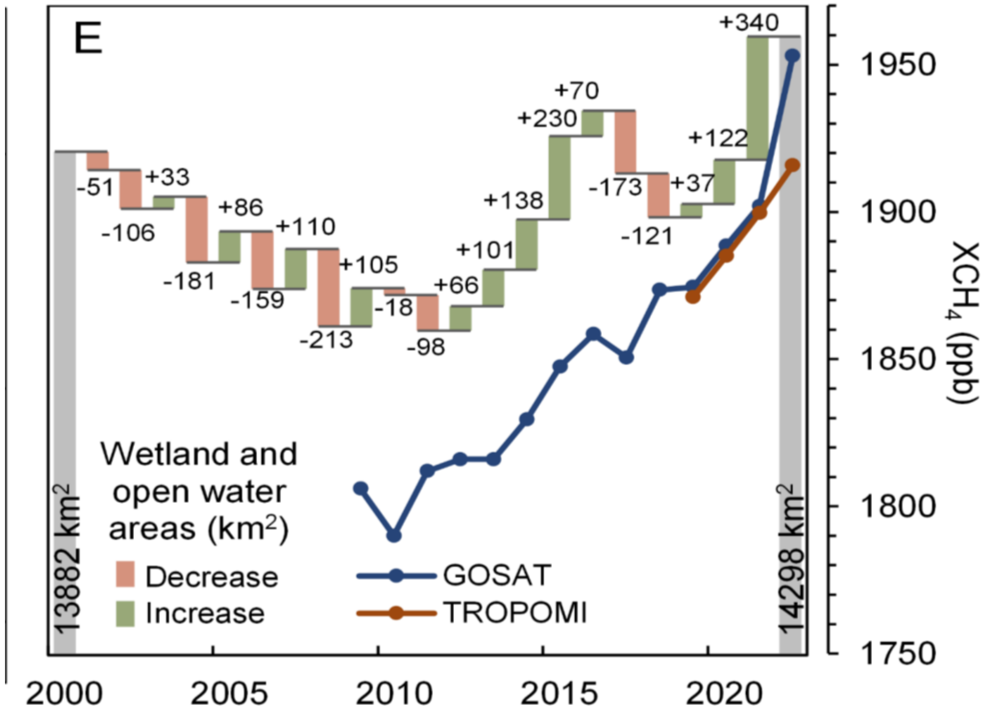
(Qu et al., *Environ.Res.Lett.*, 2022)

- **CH_4 rose rapidly over the last decades**
- **CH_4 annual increase surged in 2020-2022**
- **Emission increases are mainly from boreal regions and the tropics, especially tropical Africa.**

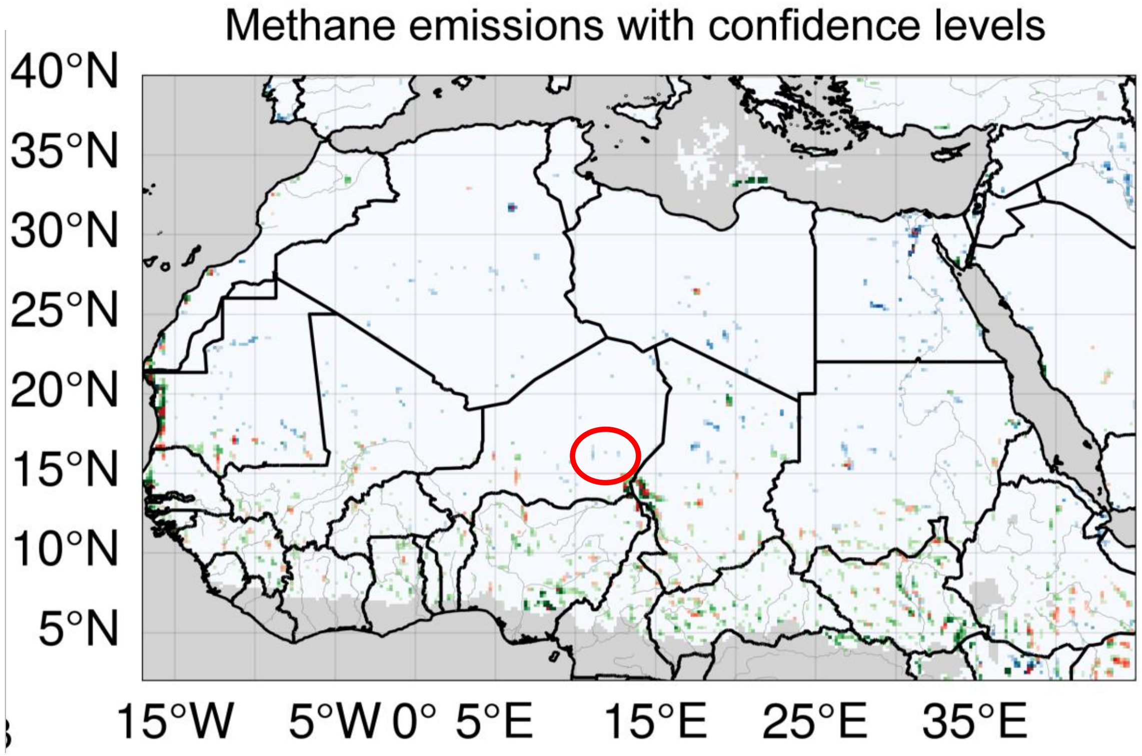
Large methane emissions over Lake Chad have been detected by TROPOMI

IMPALA: IMProved Atmospheric emissions using Low-earth satellites over Africa

(KNMI + BIRA-IASB)



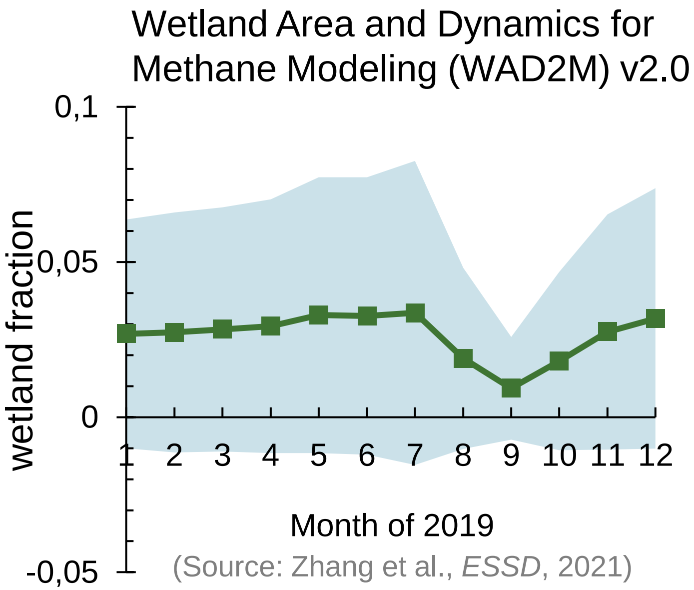
(Liu et al., *in preparation*, 2024)



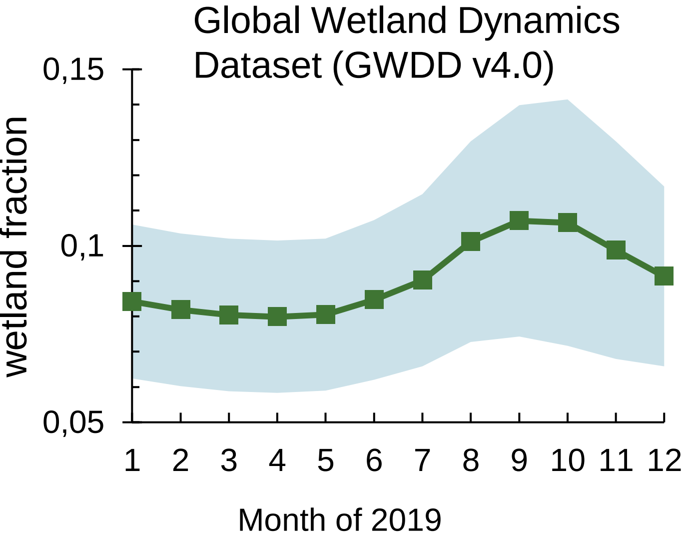
Level-3: identified by WFMD v1.8 and S5P_RPRO_XCH4
Level-4: high confidence, but identified by WFMD v1.8
Level-5: high confidence, identified by WFMD v1.8 and S5P_RPRO_XCH4

https://www.temis.nl/emissions/region_africa/datapage_ch4.php

Wetlands are the main source for seasonal and interannual changes in tropical Africa



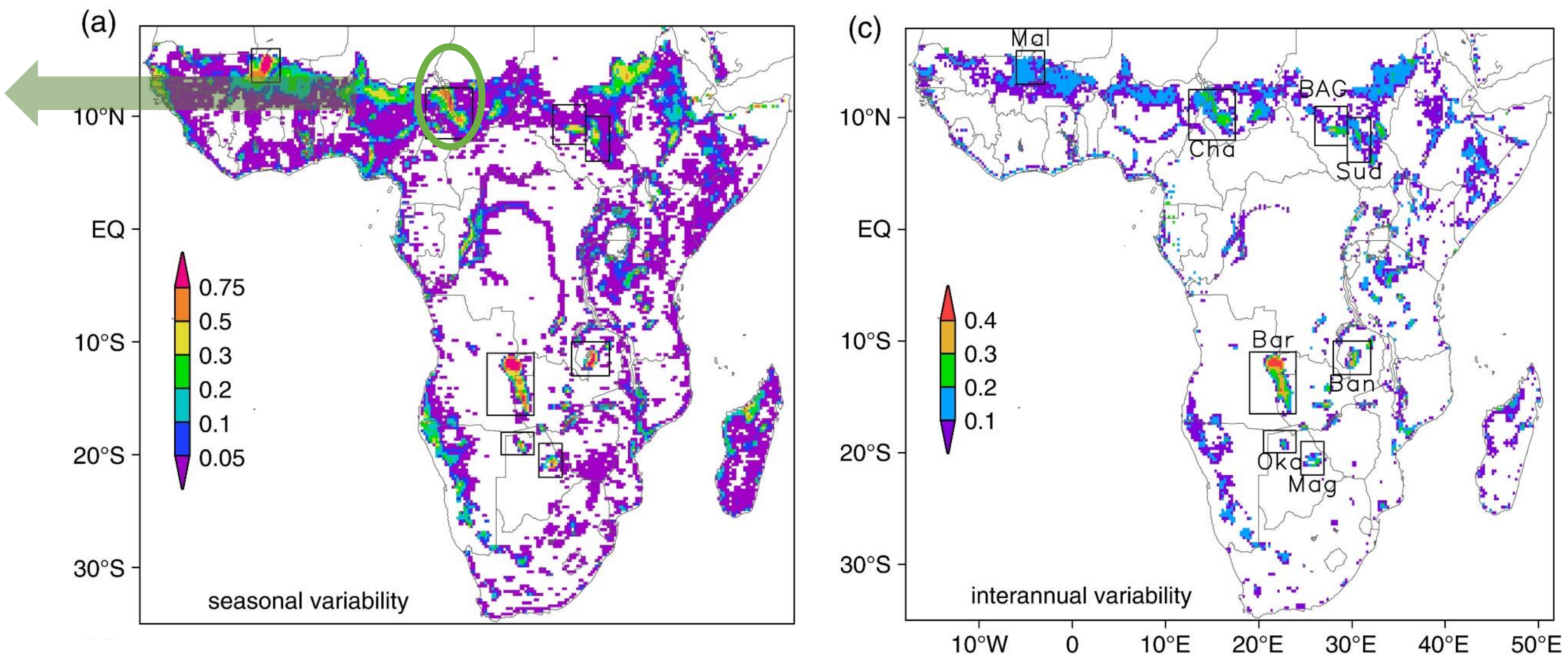
(Source: Zhang et al., *ESSD*, 2021)



(Source: Yi et al., *Sci. Data*, 2022)

Seasonal variability of wetland fraction

Annual variability of wetland fraction



(Taylor, *Quarterly Journal of the Royal Meteorological Society*, 2018)

- **Large uncertainties between different wetland products.**

II. Methodology: emission & water area

Widely used approaches to derive CH_4 emissions from TROPOMI

Plume Fitting / Mass Balance

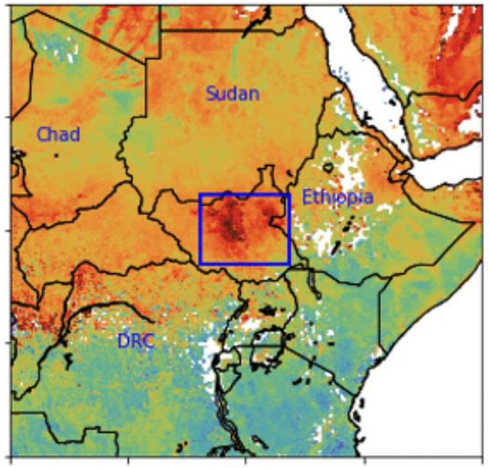
- ✓ Detected big emitters (i.e., Gaussian Plume fitting)
- ✓ Total emission of a certain region, no spatial distribution (i.e., emission from a lake)

Priori emission + model

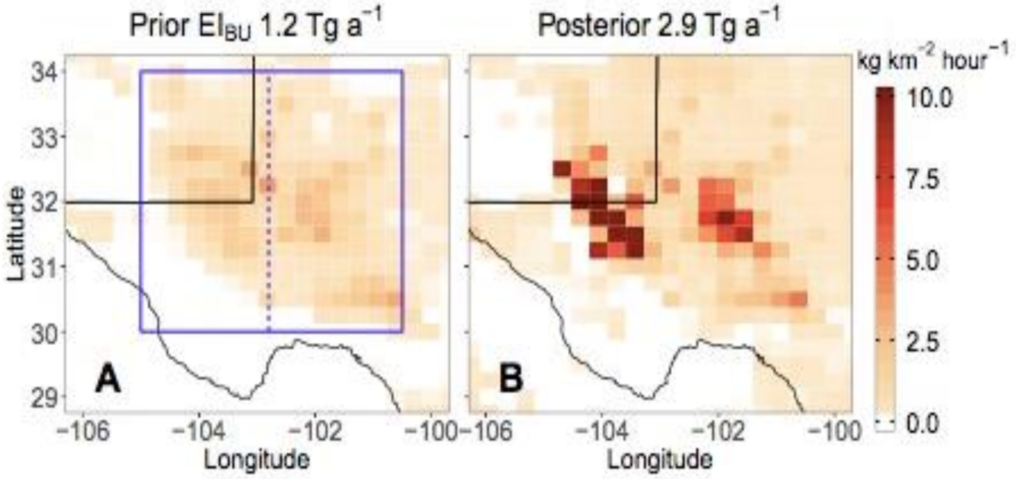
- ✓ Need a priori emission inventory (i.e., anthropogenic and natural bottom-up inventories)
- ✓ Complicated and time-consuming (i.e., long-term spin-up time)

(Lauvaux et al., Science, 2022)

Methane enhancements over the wetlands of South Sudan in TROPOMI observations



(Pandey et al., Biogeosciences, 2021)



(Zhang et al., Science Advance, 2020)

Using the divergence method to derive methane emissions

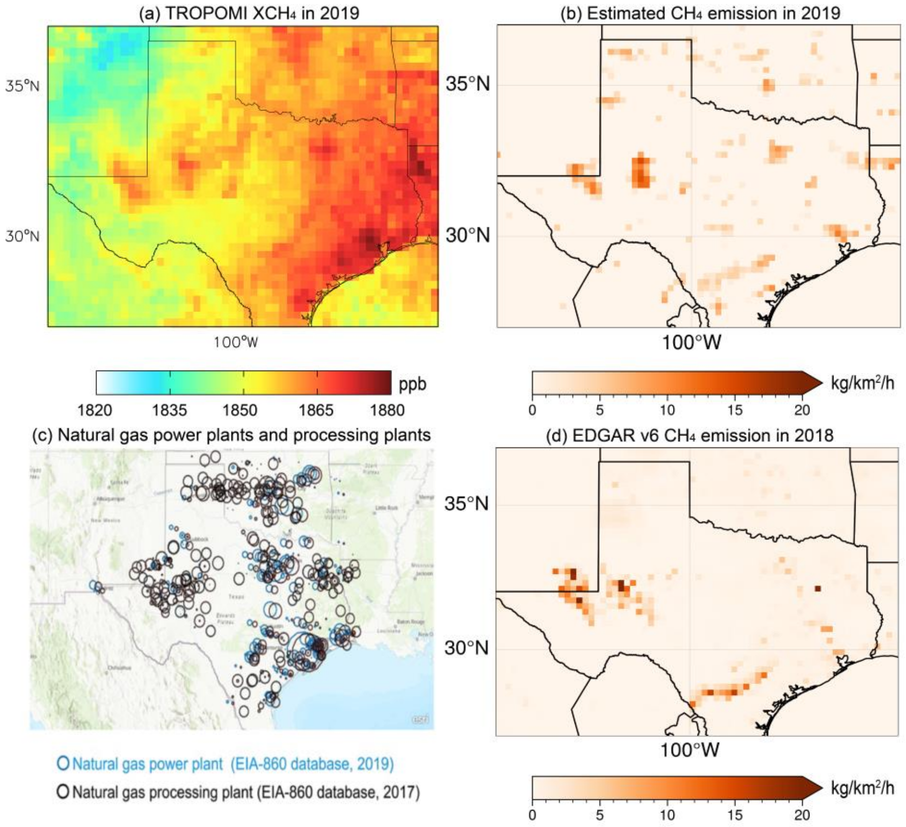
transport

Mass balance incl. transport: $E = \cancel{\boxed{C/\tau}} + \boxed{\nabla F} = \nabla\,(\cancel{C_{back}} + C_{source}) \cdot v$

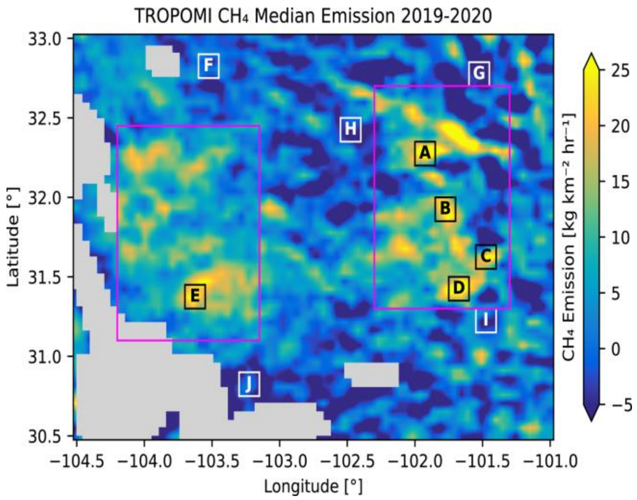
chemical loss

$\nabla F = \nabla\,(C \cdot v)$
$v = wind\ field$

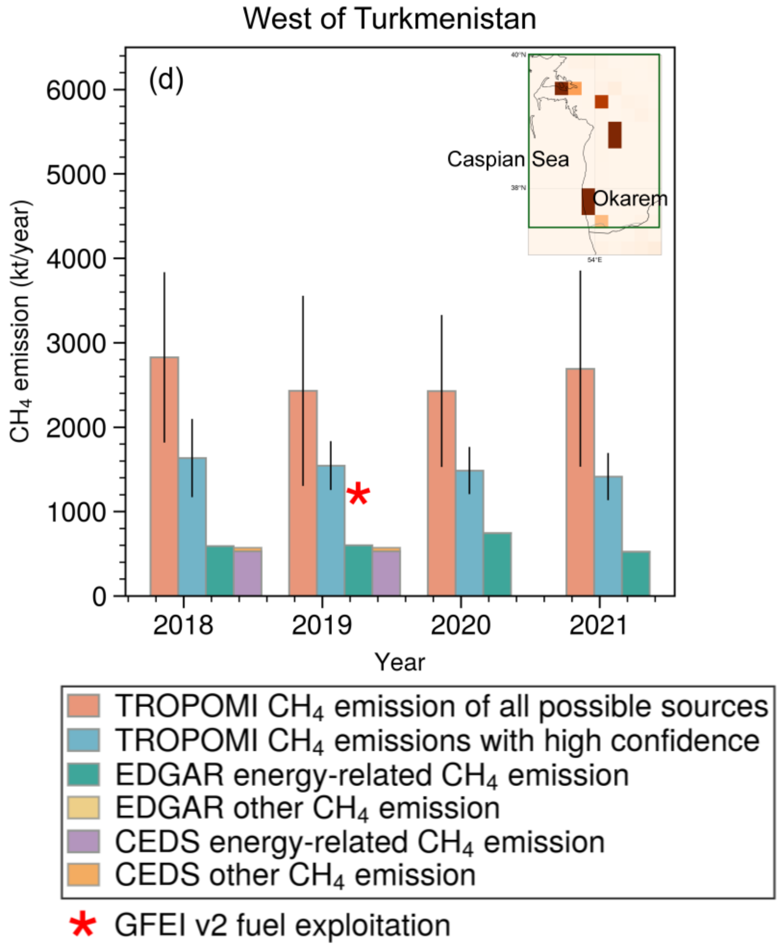
First attempt: Texas oil/gas field



Higher spatial res.



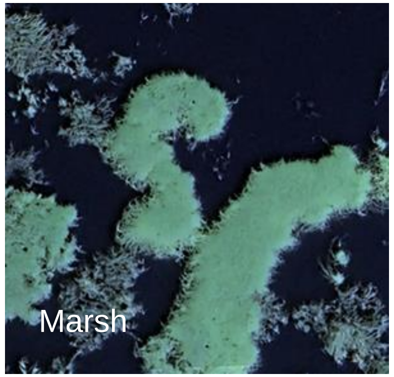
Filter possible false sources



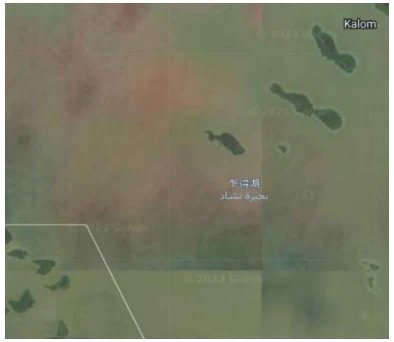
(Beirle et al., *Science Advance*, 2019; Liu et al., *GRL*, 2021, Veefkind et al., *JGR*, 2023, Liu et al., *AMT*, 2024)

Identify vegetated water and permanent open water

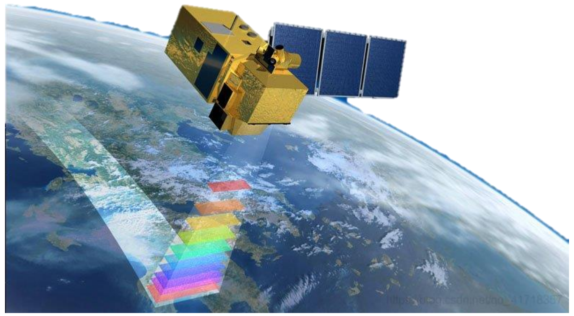
① Vegetated water (Wetland)



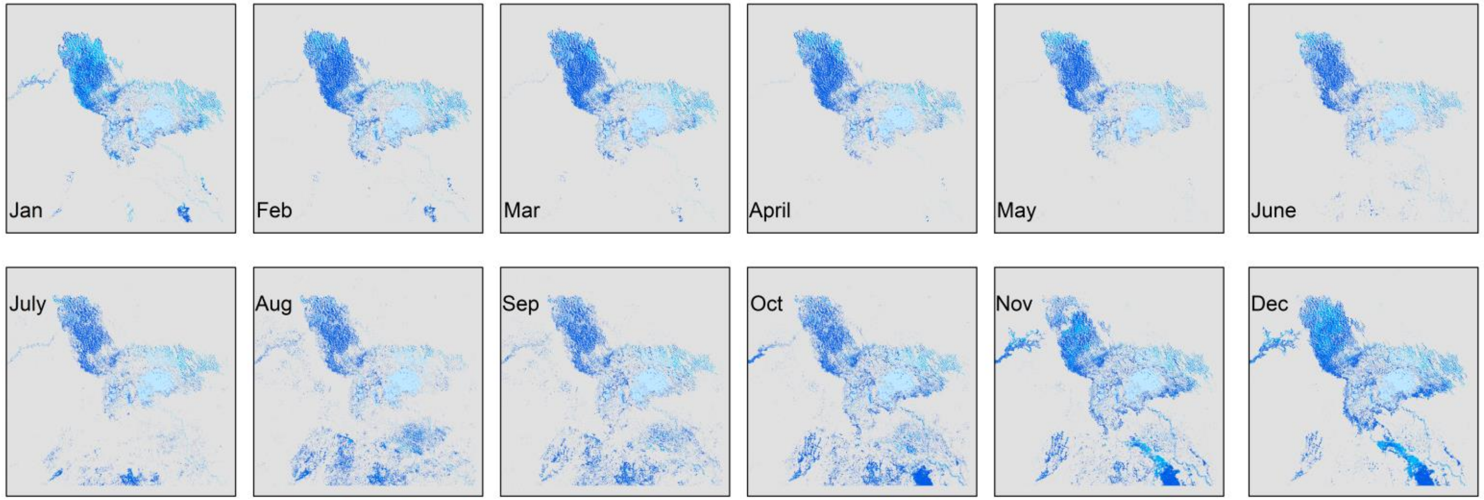
② Permanent water



Time series of Enhanced Vegetation Index (EVI), Land surface water Index (LSWI), and Normalized vegetation Index (NDVI) calculated using Sentinel-2 Images (10m, 5-6d).



Sentienl-2 surface reflectance dataset

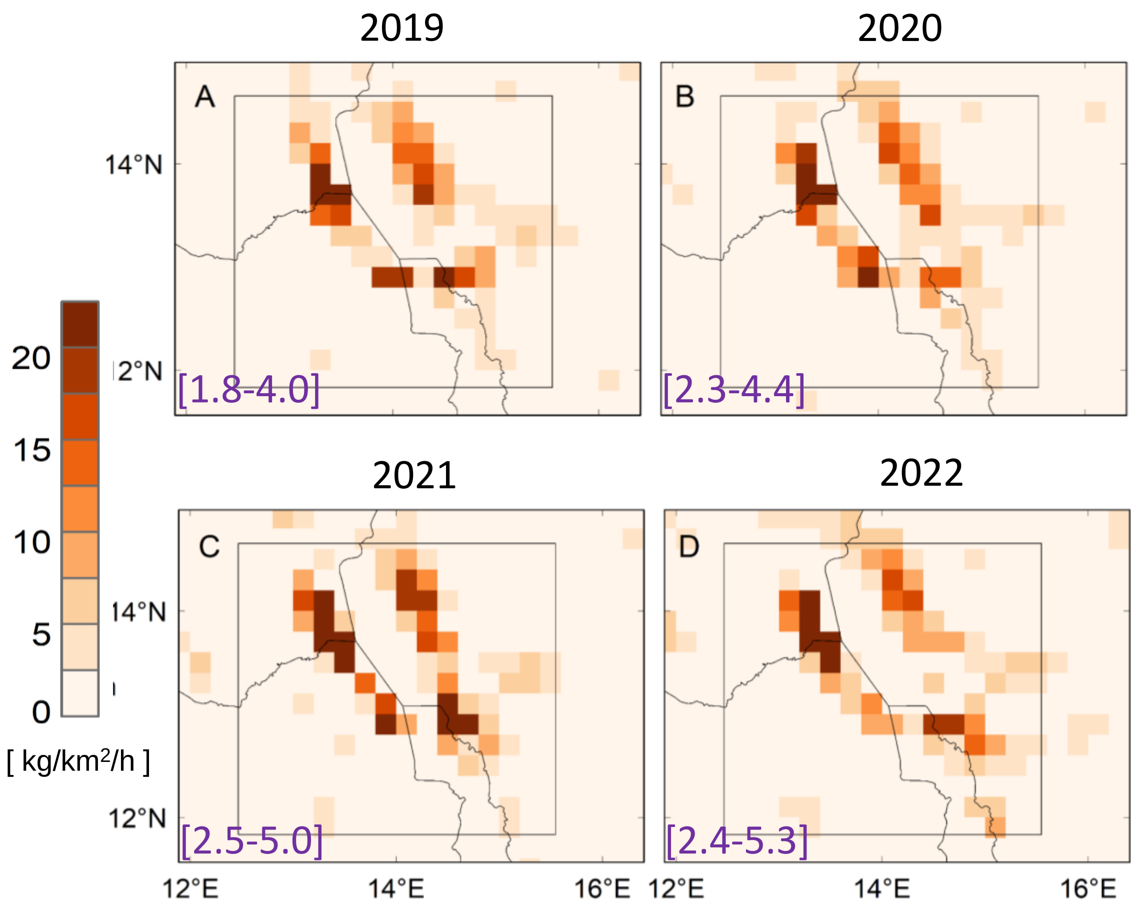


Vegetated water | Open water | Monthly open water of permanent water

III. Results & Discussion

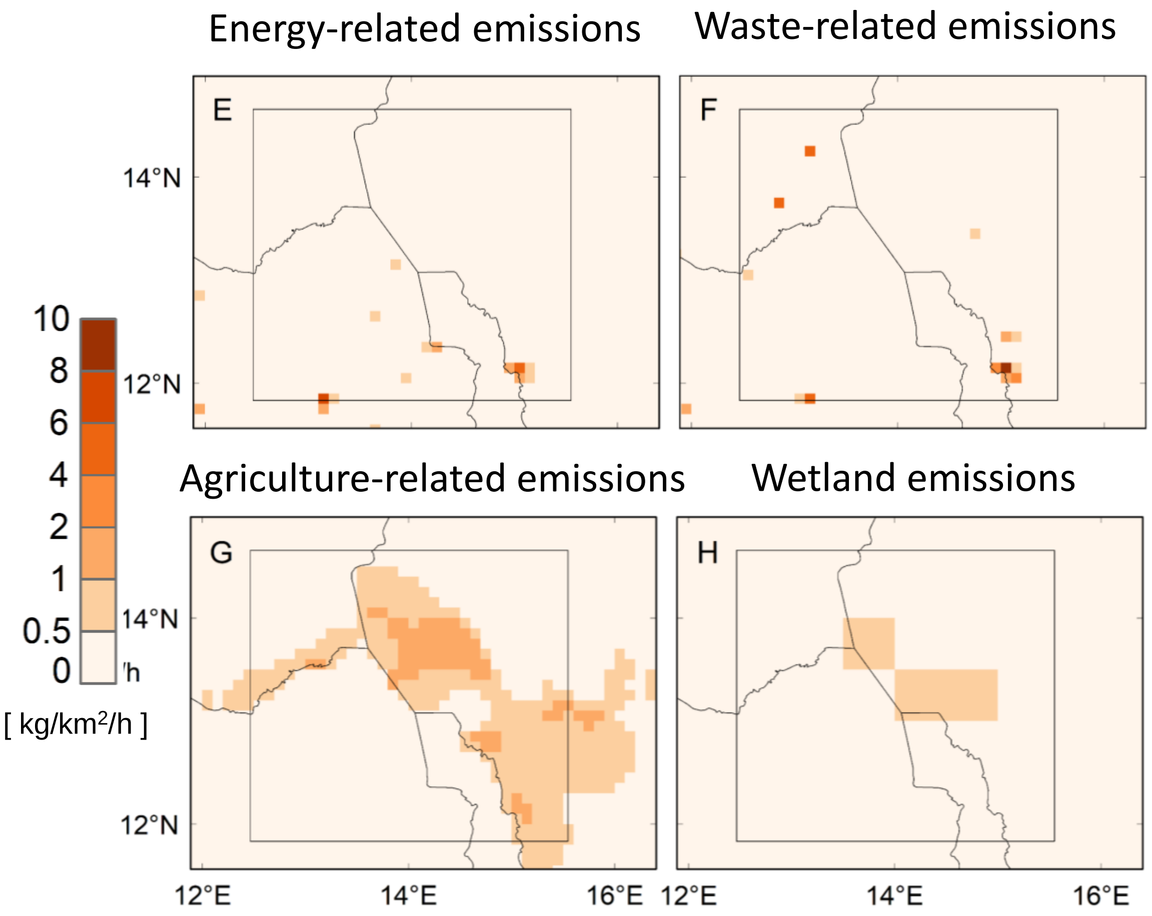
Annual methane emissions derived from TROPOMI

Annual methane emissions (0.2° × 0.2°)
(sources > 1kg/km²/h, obs. num. >= 10 days, unit: Tg/yr)



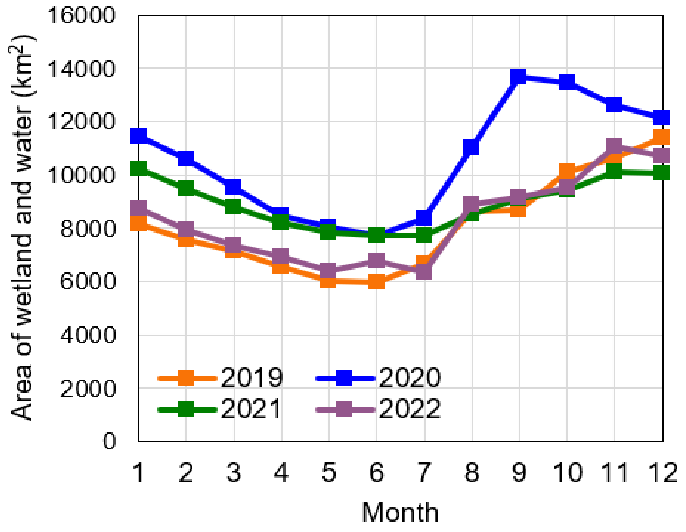
(Liu et al., in preparation, 2024)

Anthropogenic methane emissions from EDGAR v8.0 (0.1°) and wetland emissions from WetCHARTs v1.3.1.1 (0.5°) in 2019

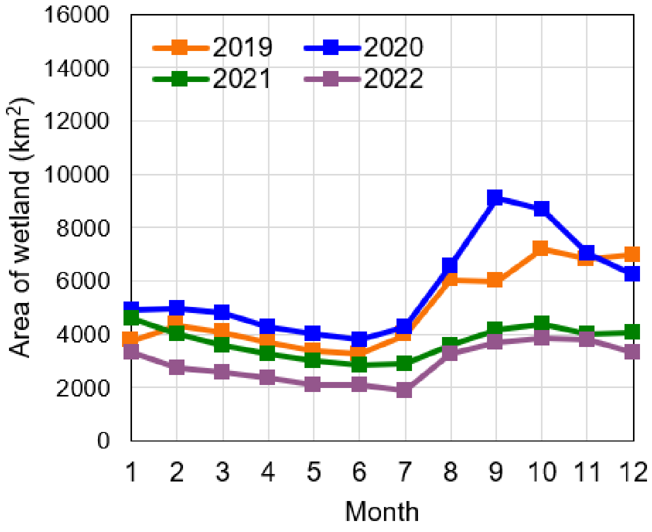


Relationship between methane emissions and water changes

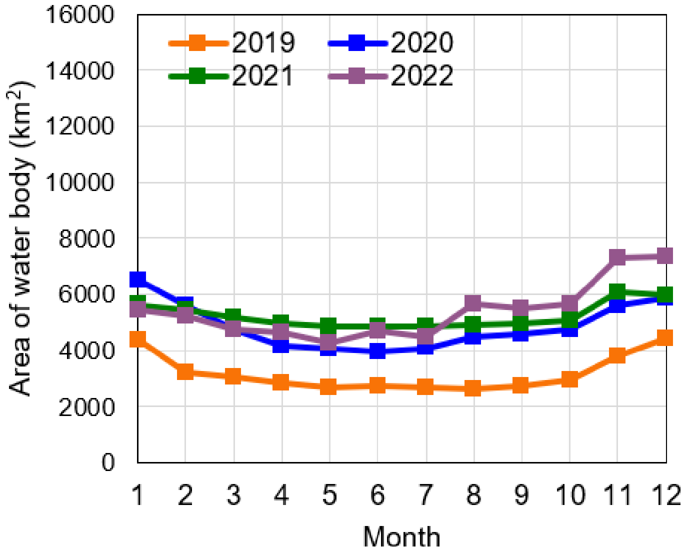
Total waters



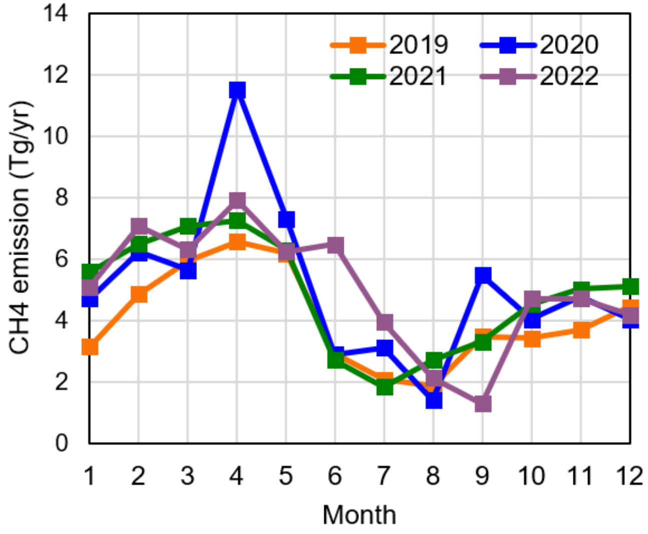
Wetlands (vegetated water)



Open water



Methane emissions

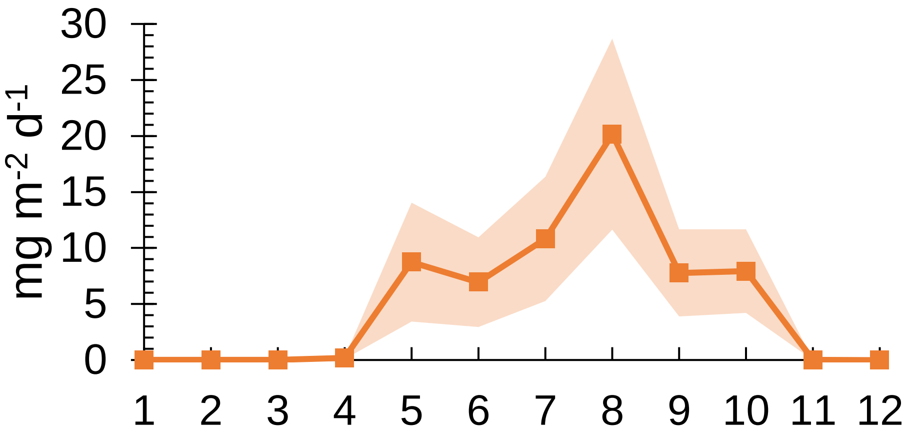


delayed months	r
0	-0.12
1	0.15
2	0.40
3	0.52
4	0.58
5	0.48

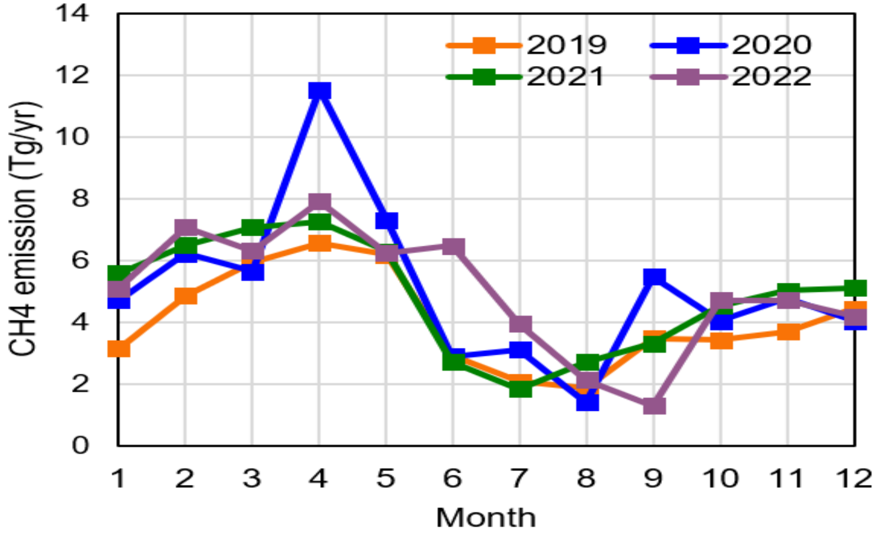
- **Changes in the water extents show a delayed impact on the methane emission.**

TROPOMI derived emissions show a different seasonality

CH_4 emission of Lake Chad in 2019 from WetCHARTs v1.3.1

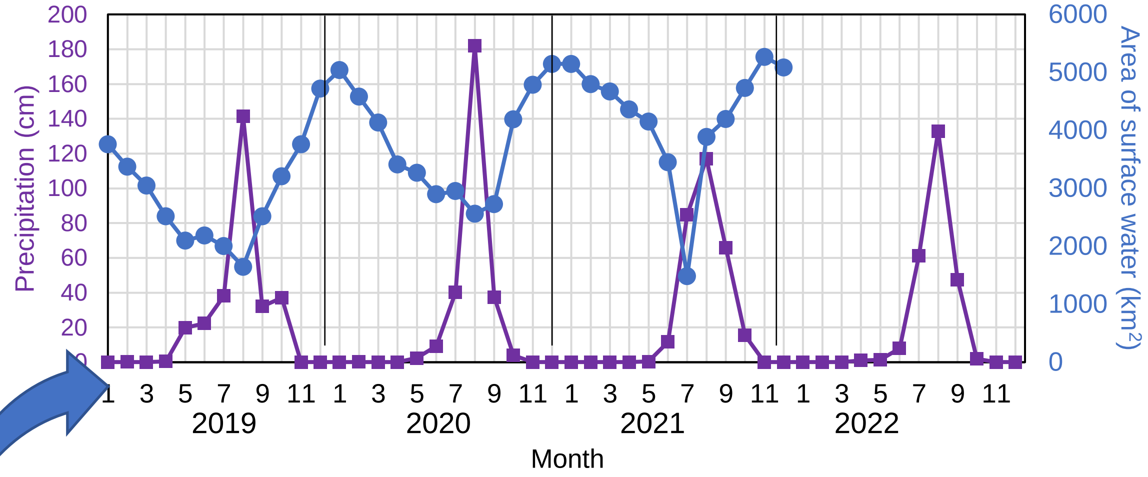


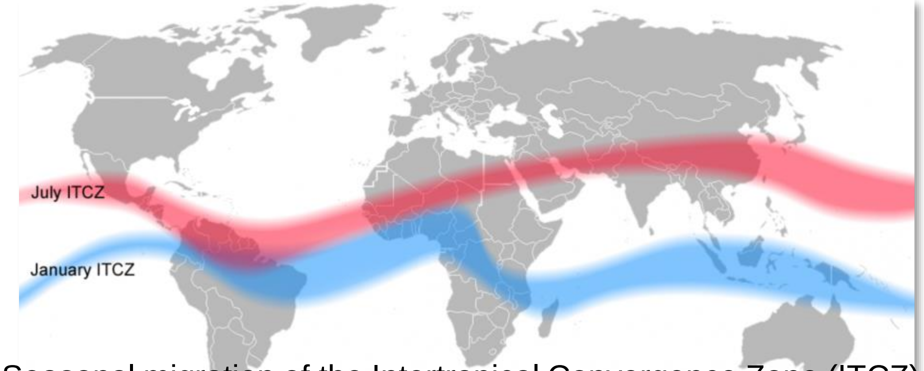
CH_4 emission of Lake Chad derived from TROPOMI



(Liu et al., in preparation, 2024)

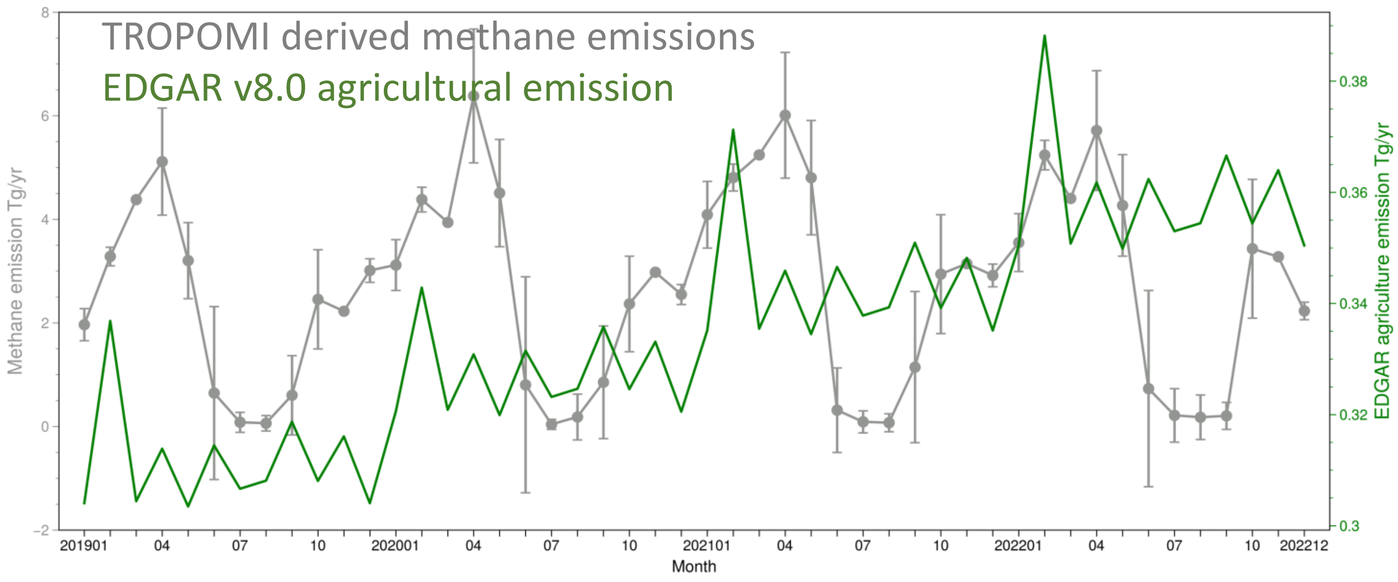
Seasonal changes in precipitation and surface water extent

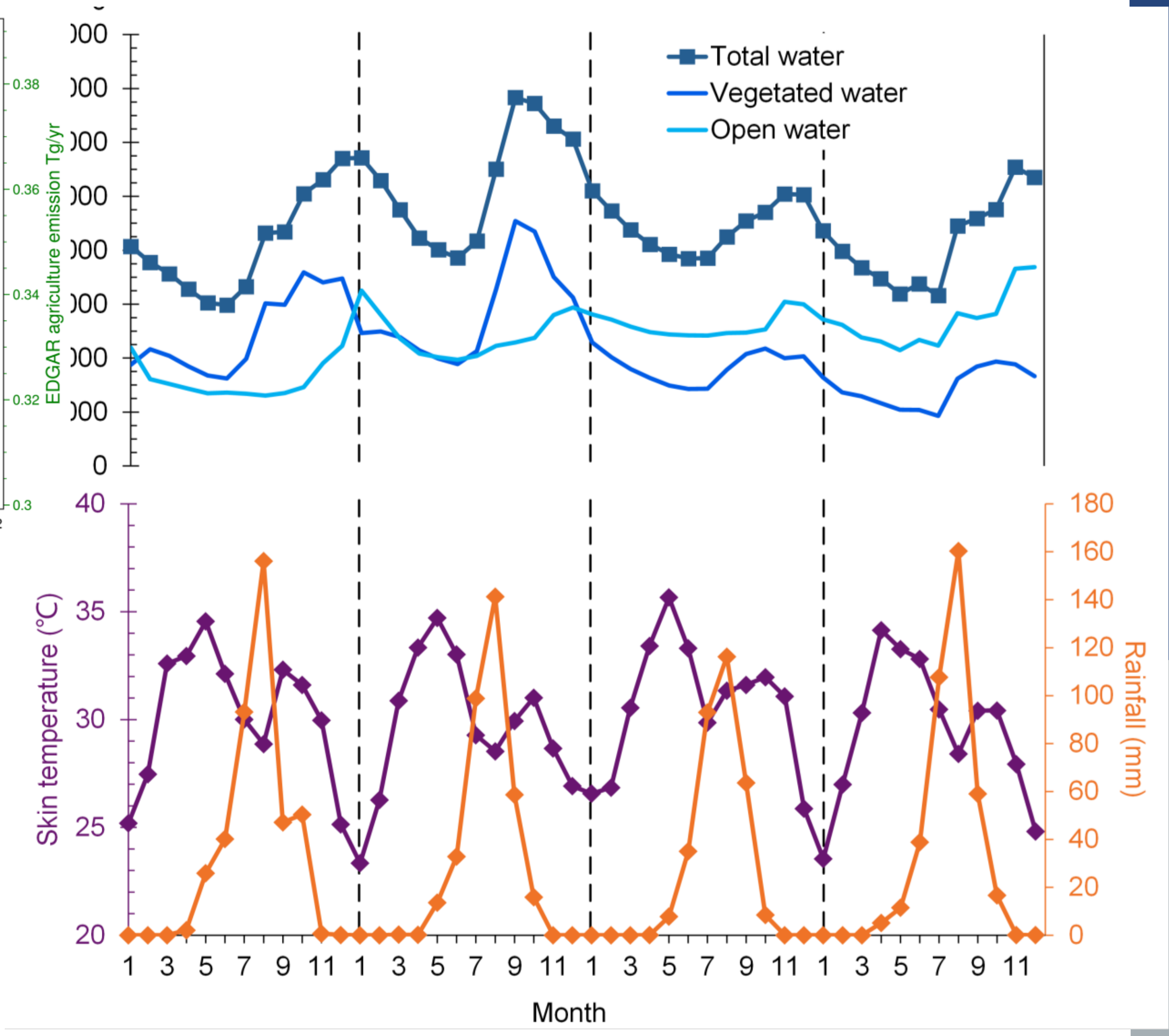




Seasonal migration of the Intertropical Convergence Zone (ITCZ)
(Wikicommons. Author Mats Halldin, 13 Dec 2006)

Driving factor of seasonality of methane emissions over Lake Chad





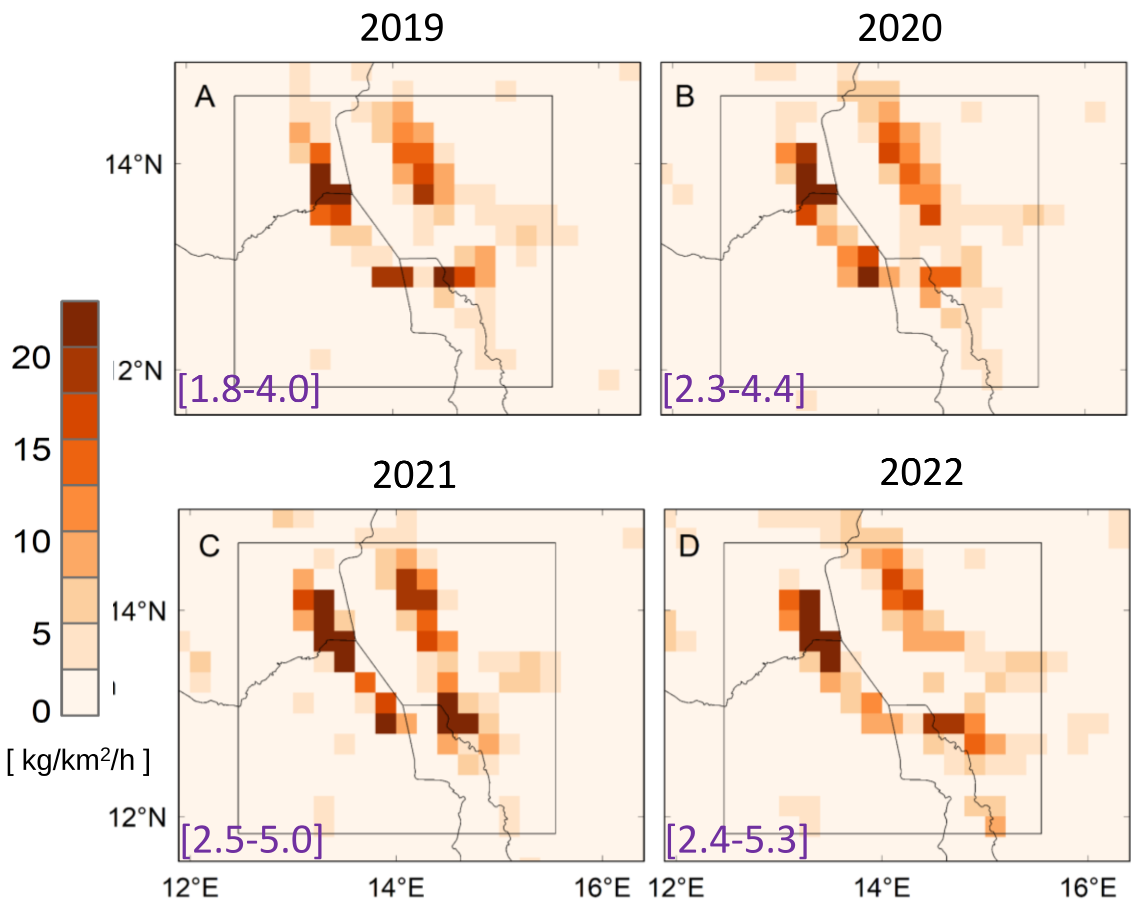
- **The seasonality of methane emissions is not driven by agricultural activities.**
- **Methane emissions are mostly consistent with water expansion in autumn and mainly driven by surface temperature in spring.**

Summary

- Both official XCH_4 reprocessing dataset and WFMD v1.8 product identify the enhanced methane emissions over Lake Chad Basin.
- The monthly methane emission changes over Lake Chad are not driven by precipitation.
- The area of water bodies increase since 2019 while the area of wetlands shows a significant annual variability.
- Changes in methane emissions are delayed by 3–4 months relative to total water area.
- Methane emissions are mostly consistent with water expansion in autumn and mainly driven by temperature in spring.

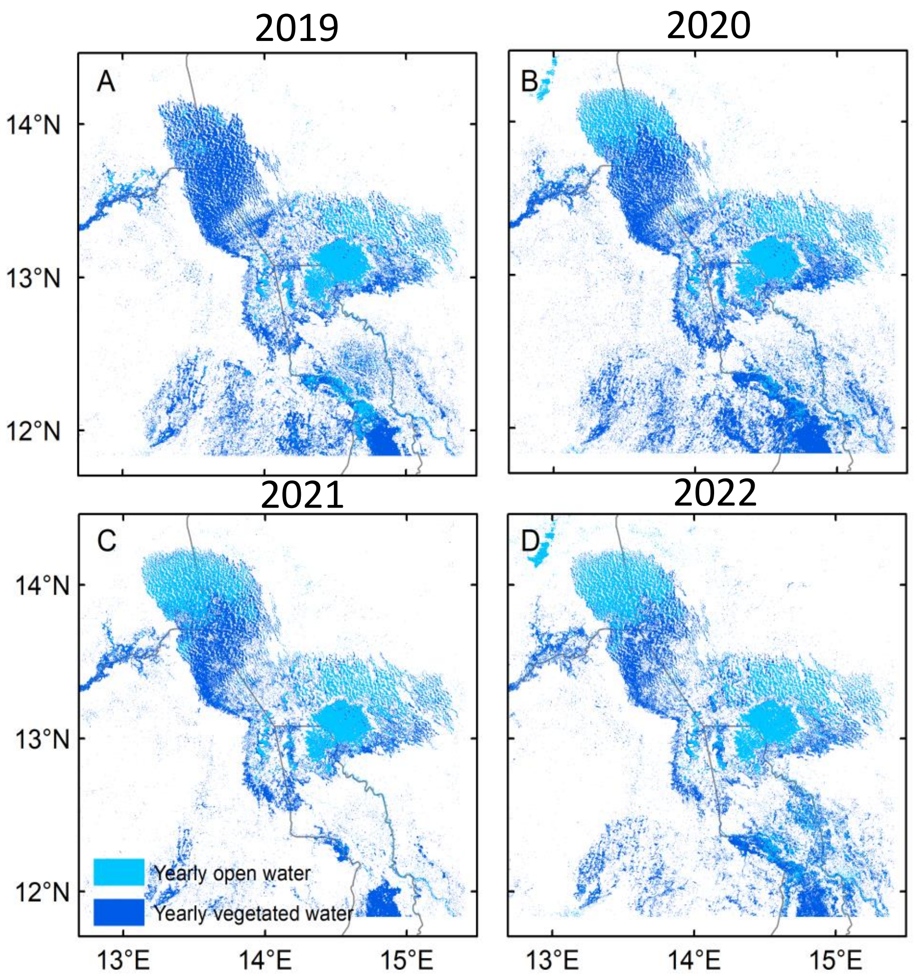
Annual methane emissions derived from TROPOMI

Annual methane emissions
(sources > 1kg/km²/h, obs. num. >= 10 days, unit: Tg/yr)



(Liu et al., in preparation, 2024)

Yearly open water
Yearly vegetated water

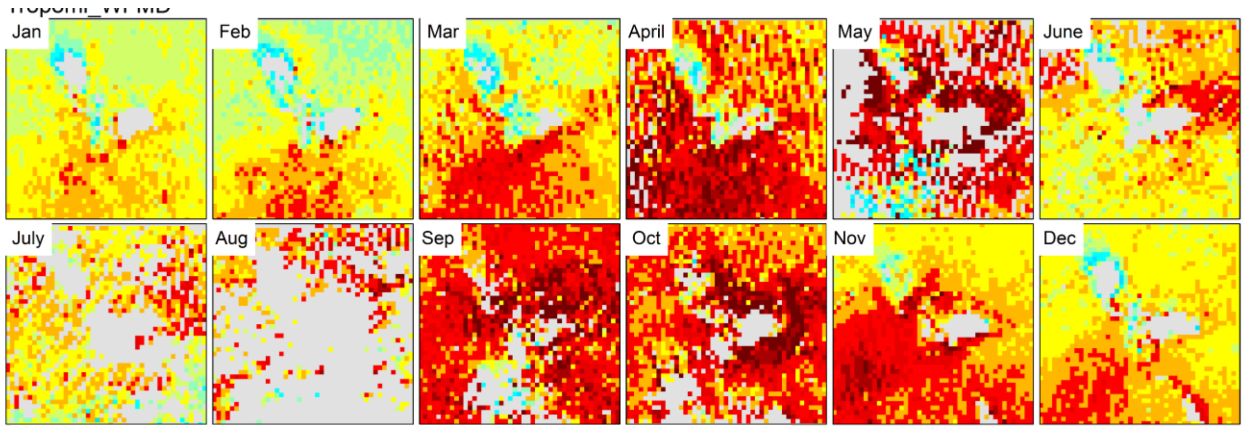


(Sources: GLC_FC30, *ESSD*, 2023)

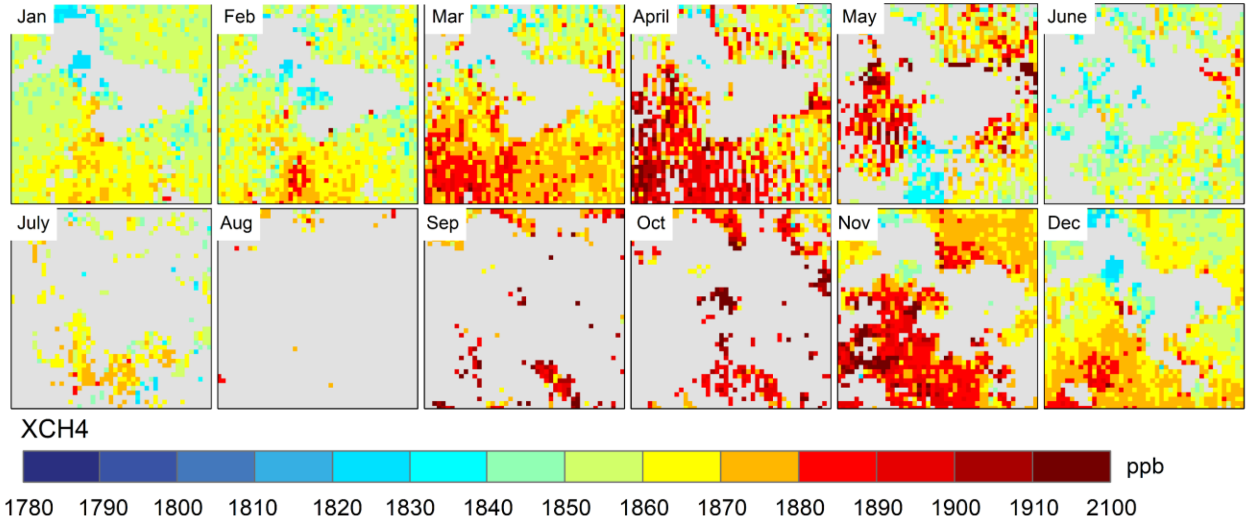
Results

Performance of two TROPOMI XCH_4 products

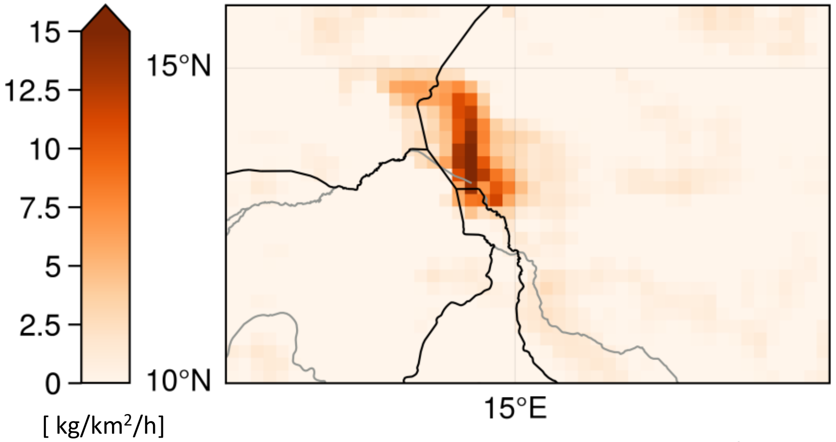
XCH_4 WFMD v18 (2019)



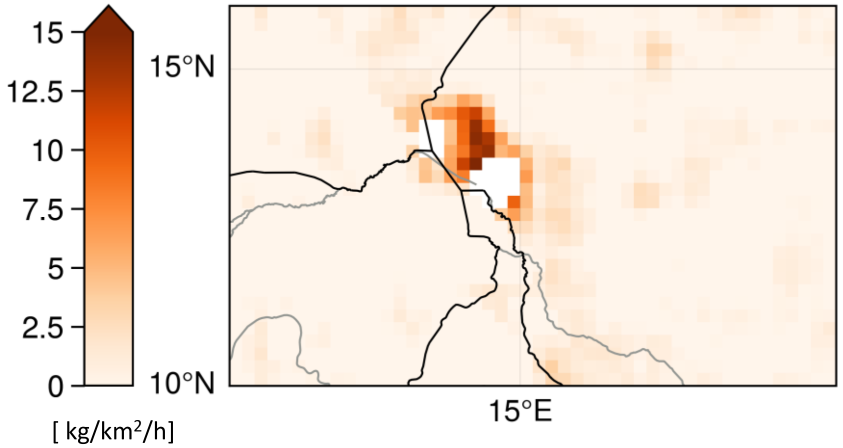
XCH_4 official reprocessing (2019)



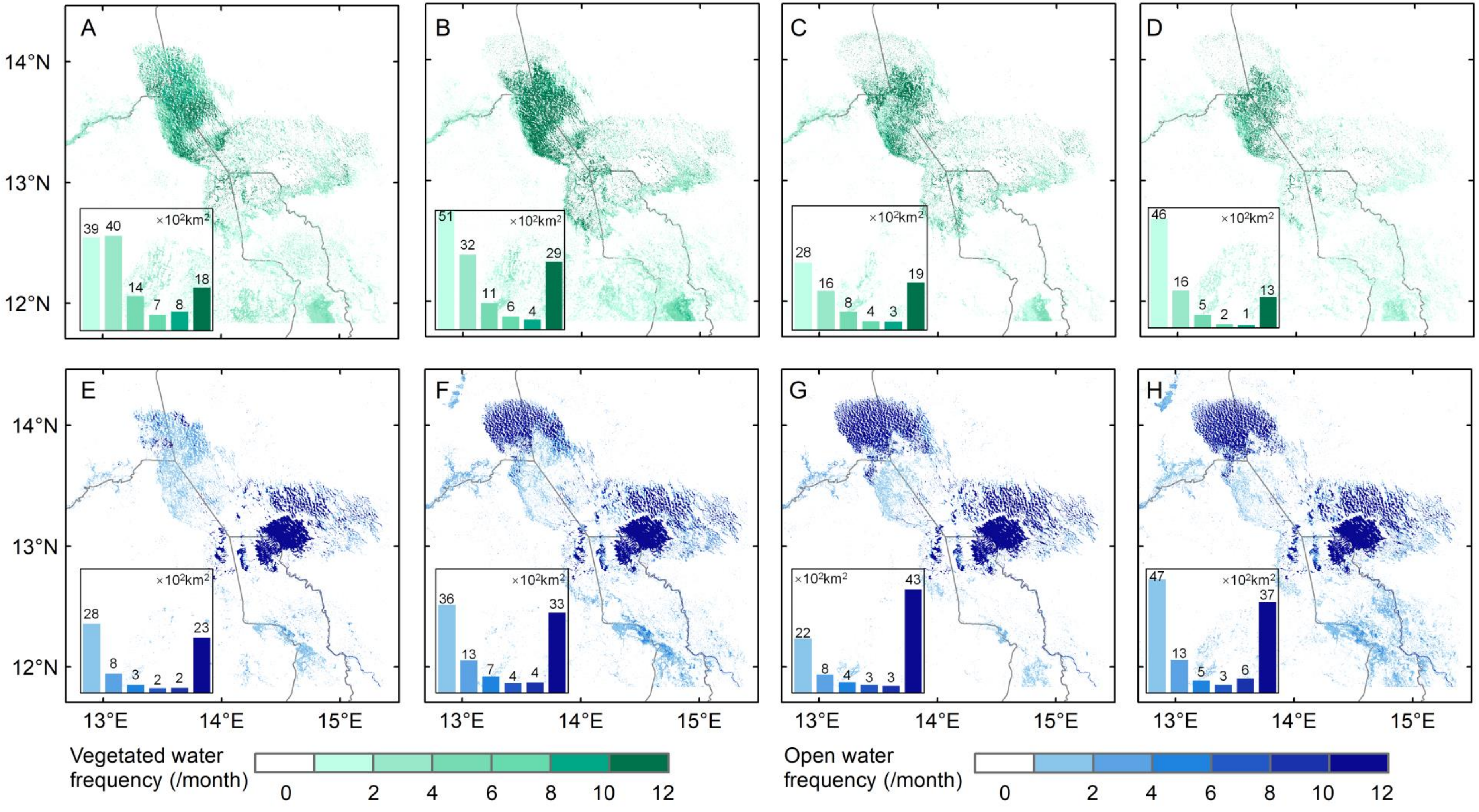
Methane emissions in 2019 (WFMD v18)



Methane emissions in 2019 (official)



vegetated
water
frequecy



Annual methane emissions over Lake Chad derived from TROPOMI