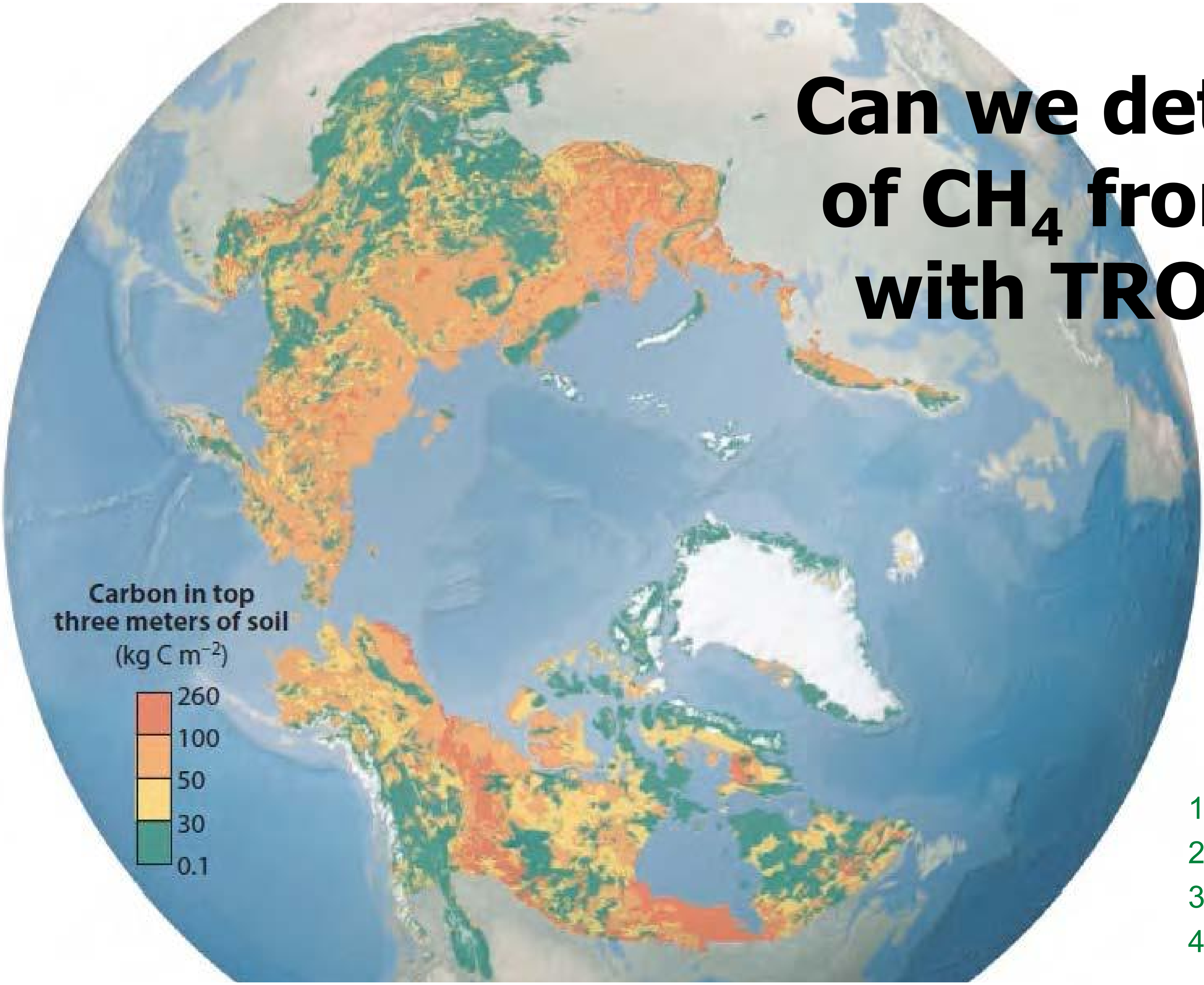
Can we detect emissions of CH_4 from Permafrost with TROPOMI XCH_4?



Ray Nassar[1], Qindii Shafi[2], Joseph Mendonca[1], Sabour Baray[1], Ama Gamage[2], Peter Morse[3] , Oliver Schneising[4], Michael Buchwitz[4]

1) Environment and Climate Change Canada
2) University of Waterloo, Canada
3) Natural Resources Canada
4) University of Bremen, Germany

Figure credit: Schuur et al. (2022), Annual Review of Environment and Resources

PNAS

Submitted Apr 2021
Published Aug 2021

Methane release from carbonate rock formations in the Siberian permafrost area during and after the 2020 heat wave

Nikolaus Froitzheim[a,1], Jaroslaw Majka[b,c], and Dmitry Zastrozhnov[d,e]

[a]Institute of Geosciences, University of Bonn, 53115 Bonn, Germany; [b]Department of Earth Sciences, Uppsala University, 752 36 Uppsala, Sweden; [c]Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, 30-059 Kraków, Poland; [d]A. P. Karpinsky Russian Geological Research Institute, 199106 St. Petersburg, Russian Federation; and [e]Volcanic Basin Petroleum Research, N-0361 Oslo, Norway

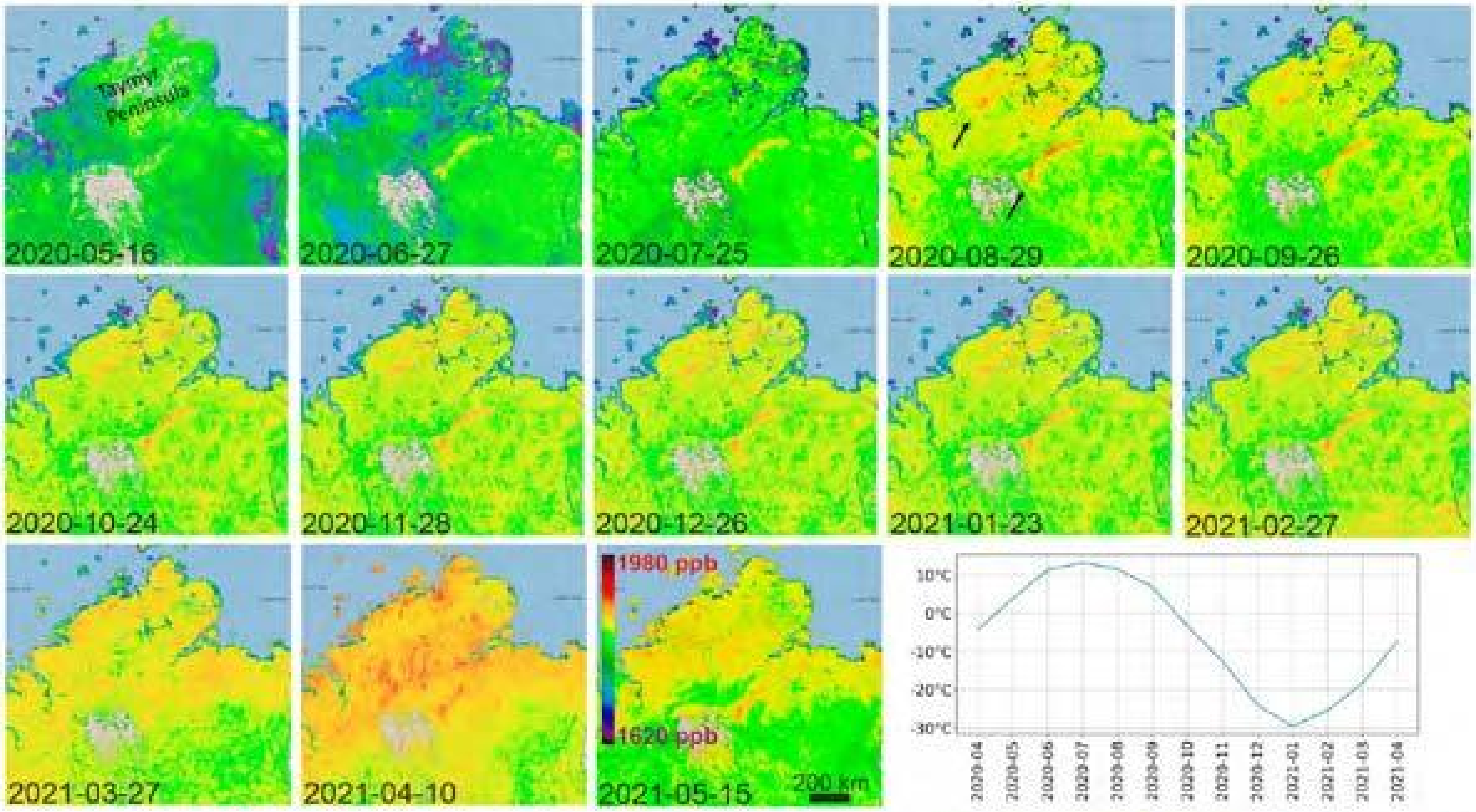


Fig. 1. Atmospheric methane concentrations in North Siberia during 2020–2021, from PULSE map (https://pulse.ghgsat.com/). Note two elongated maxima of methane concentration (arrows) coinciding with carbonate outcrop areas (Fig. 2), and region-wide concentration increase in March to April 2021. See Fig. 2 for location. Curve shows monthly means of 2-m temperature in Siberia (55°N–76°N, 70°E–180°E) during the study period (https://climatereanalyzer.org/).

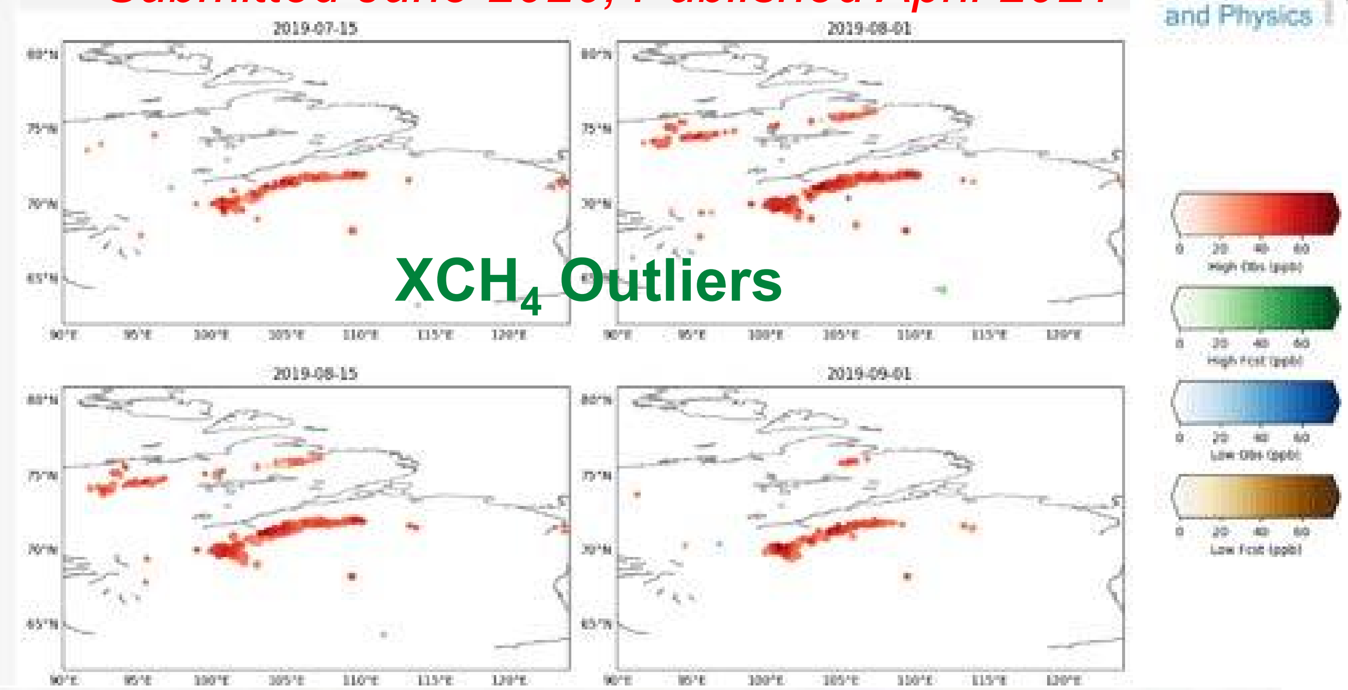
This XCH_4 enhancement is widely understood to be an albedo-related bias, **NOT** permafrost CH_4 emissions.

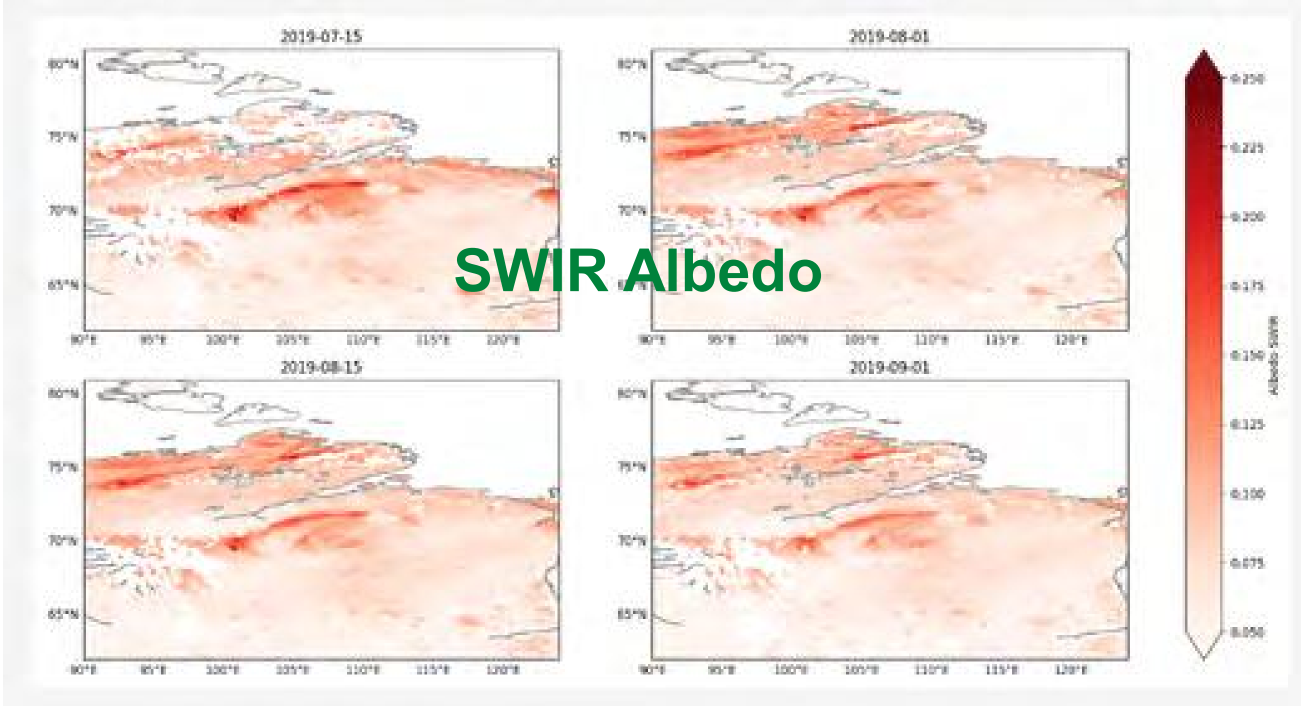
Systematic detection of local CH_4 anomalies by combining satellite measurements with high-resolution forecasts

Jérôme Barré[1], Ilse Aben[2], Anna Agustí-Panareda[1], Gianpaolo Balsamo[1], Nicolas Bousserez[1], Peter Dueben[1], Richard Engelen[1], Antje Inness[1], Alba Lorente[2], Joe McNorton[1], Vincent-Henri Peuch[1], Gabor Radnoti[1], and Roberto Ribas[1]

Atmospheric Chemistry and Physics EGU

Submitted June 2020, Published April 2021





Advances in retrieving XCH_4 and XCO from Sentinel-5 Precursor: improvements in the scientific TROPOMI/WFMD algorithm

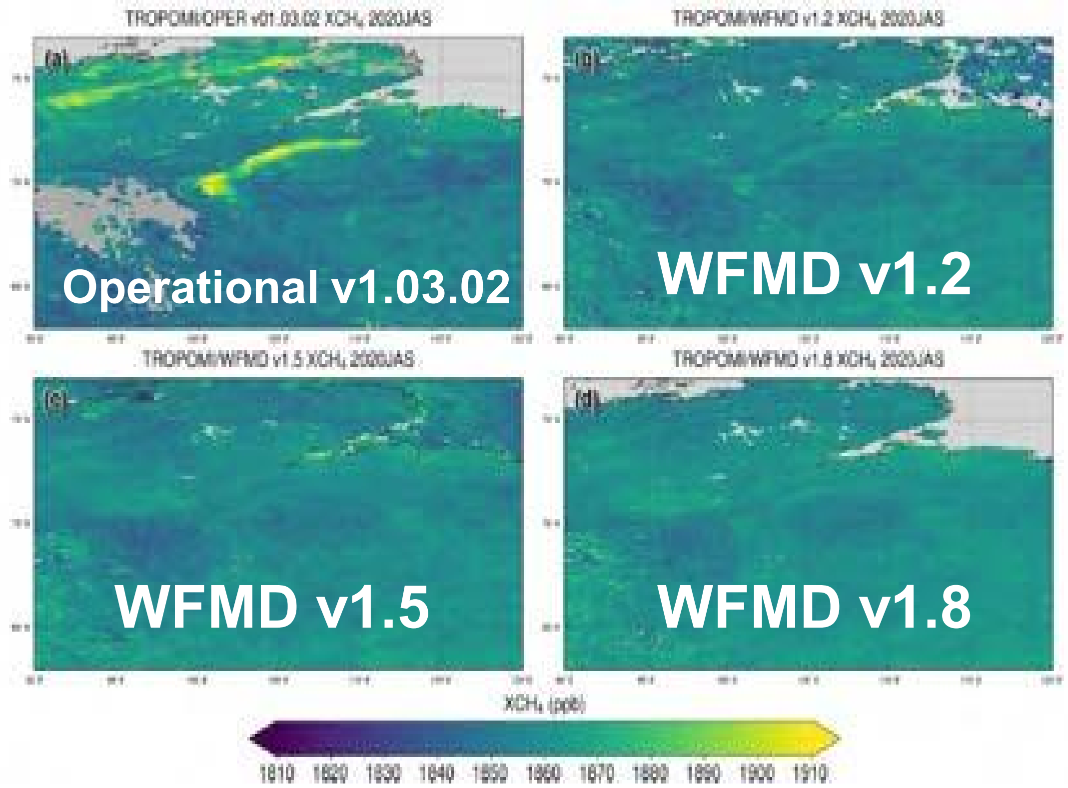
2023

Oliver Schneising, Michael Buchwitz, Jonas Hachmeister, Steffen Vanselow, Maximilian Reuter, Matthias Buschmann, Heinrich Bovensmann, and John P. Burrows

Atmospheric Measurement Techniques EGU

https://doi.org/10.5194/amt-16-669-2023

Universität Bremen

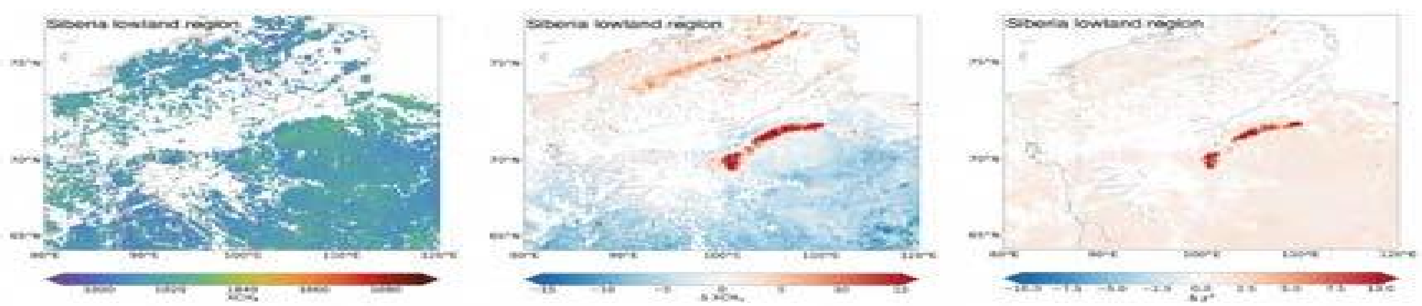


Negligible albedo-related bias and better high latitude coverage than ESA operational product

Accounting for surface reflectance spectral features in TROPOMI methane retrievals

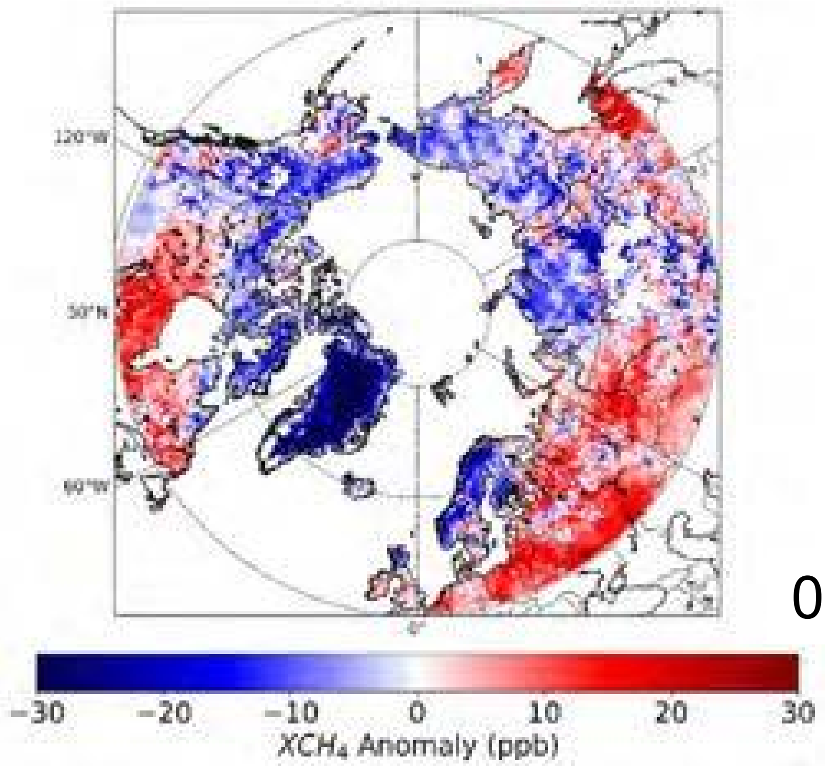
2023

Alba Lorente, Tobias Borsdorff, Mari C. Martinez-Velarte, and Jochen Landgraf



Bimonthly WFMD v1.8 TROPOMI XCH_4 Anomalies

Aug - Sep 2022

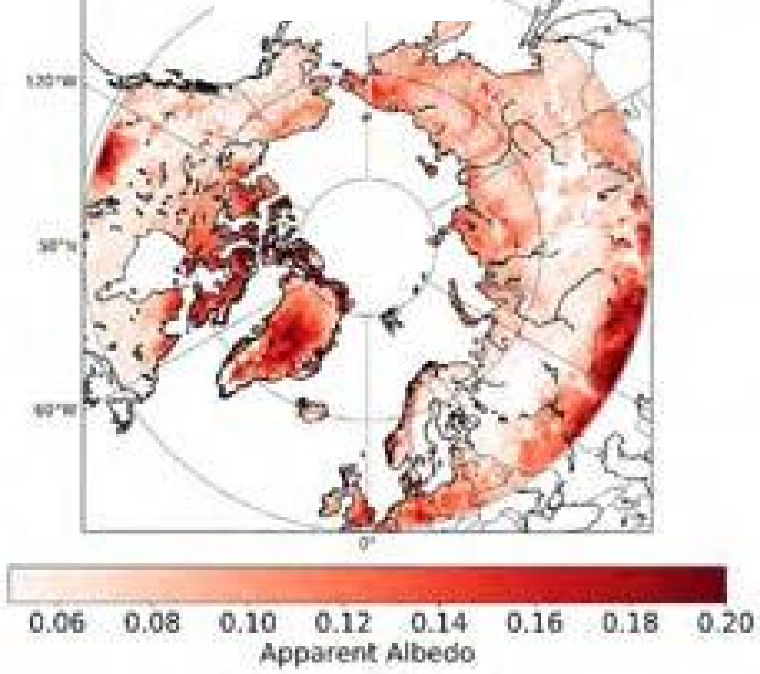


0.5°x0.625°

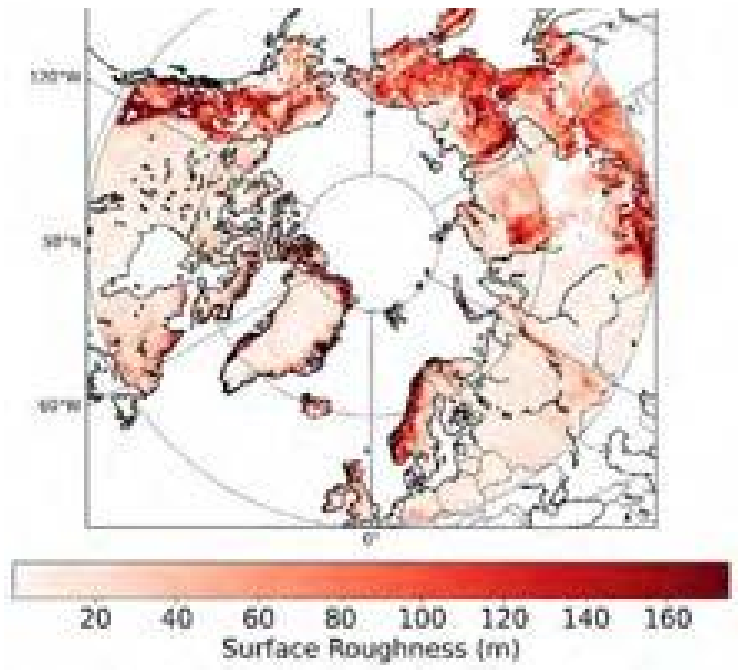
ΔXCH_4 = XCH_4(individual) – XCH_4(daily median at > 50°N)

No significant correlation between ΔXCH_4 and albedo, surface roughness, XCH_4 variability or number of observations.

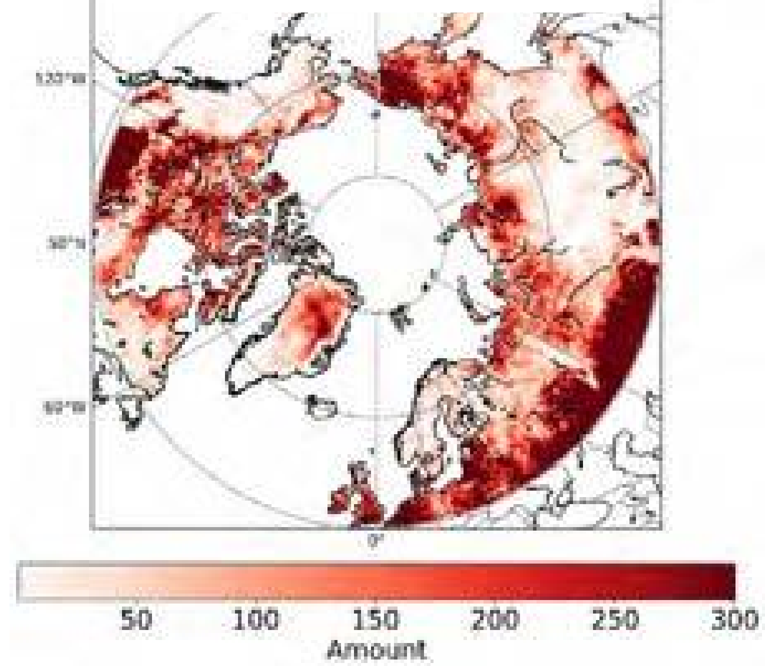
Albedo



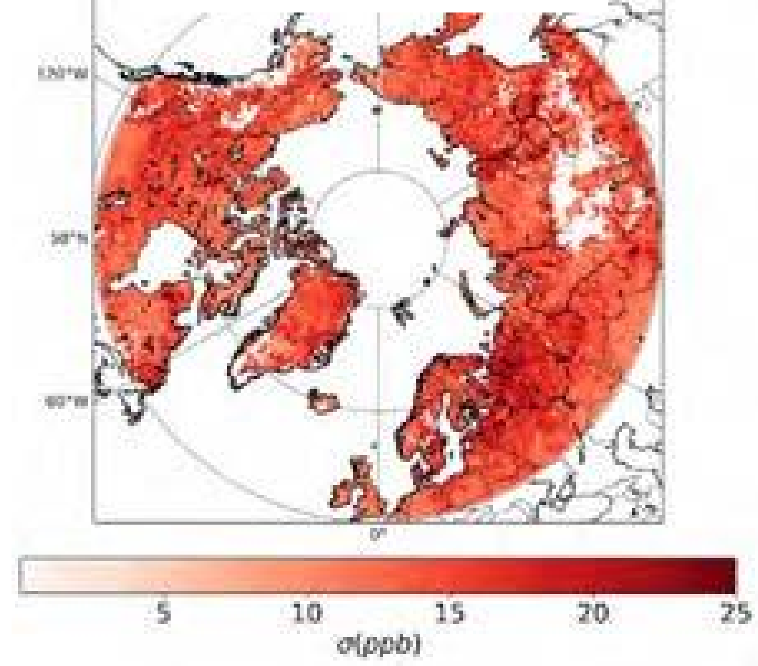
Surface Roughness



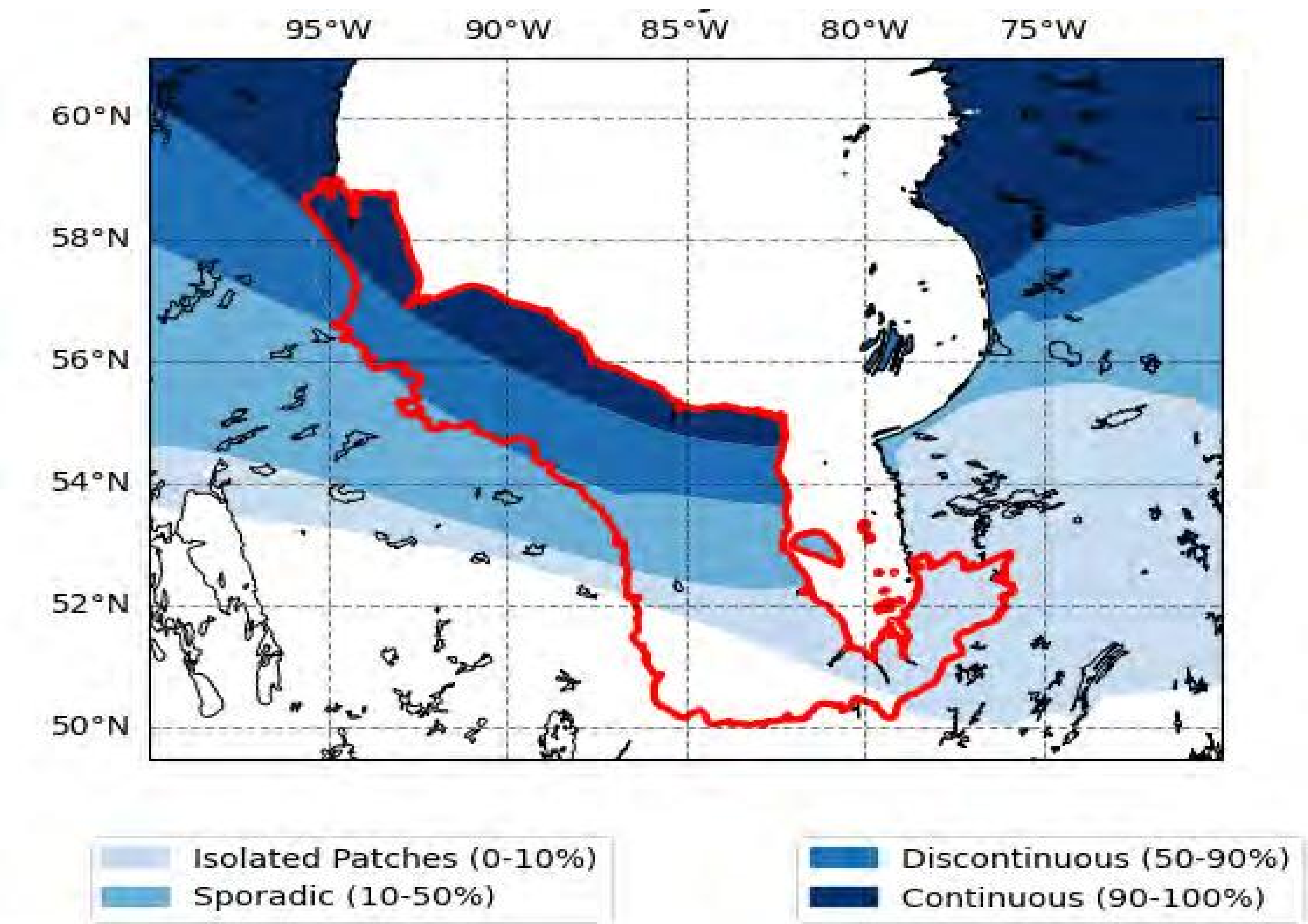
***N* observations**

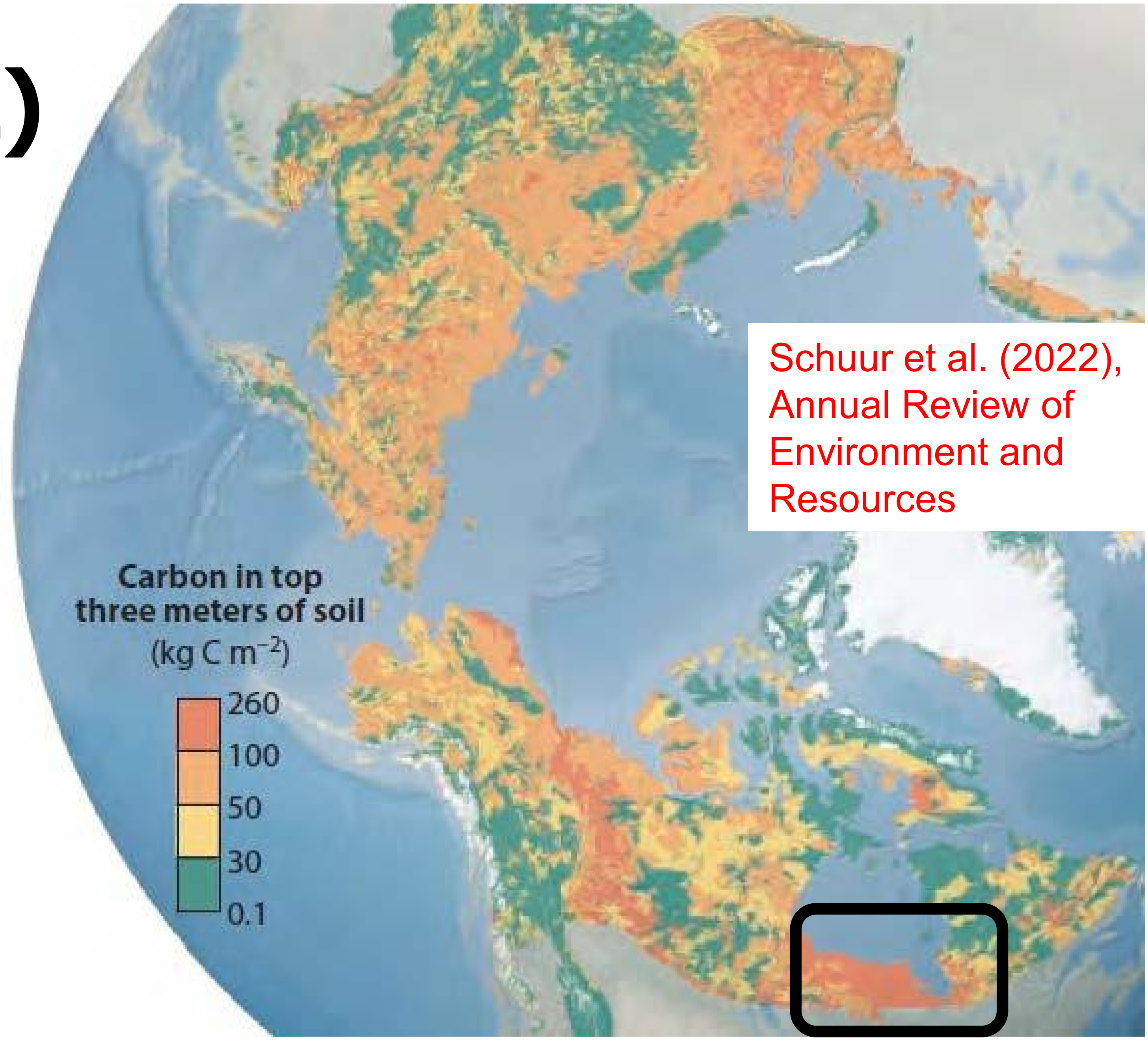


Standard Dev



Hudson Bay Lowlands (HBL)





Schuur et al. (2022), Annual Review of Environment and Resources

- Sub-Arctic area of 320,000 km^2
- Wetlands and peatlands underlain by continuous through to isolated permafrost
- Some of the highest soil carbon content in northern circumpolar permafrost zone
- Estimated to store ~30 PgC (Packalen et al. 2013, Nature Communications)
- Global anthropogenic CO_2 emissions ≈10 PgC/yr

Where are wind conditions favorable for detecting emissions without conducting an inversion?

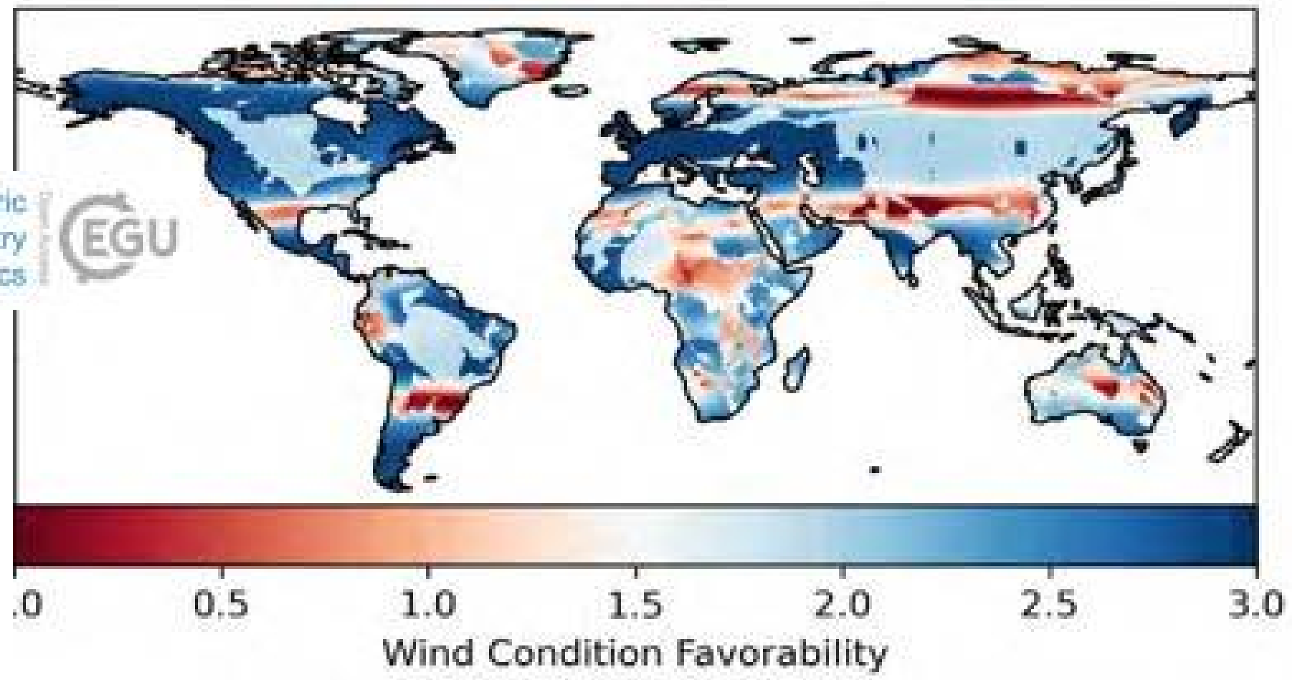
Using Orbiting Carbon Observatory-2 (OCO-2) column CO_2 retrievals to rapidly detect and estimate biospheric surface carbon flux anomalies

Andrew F. Feldman, Zhen Zhang, Yasuko Yoshida, Abhishek Chatterjee, and Benjamin Poulter

Atmospheric Chemistry and Physics

Articles / Volume 23, issue 2 / ACP, 23, 1545–1563, 2023

https://doi.org/10.5194/acp-23-1545-2023



Areas with lower wind speeds and more constant wind speed and direction are more favorable for flux detection.

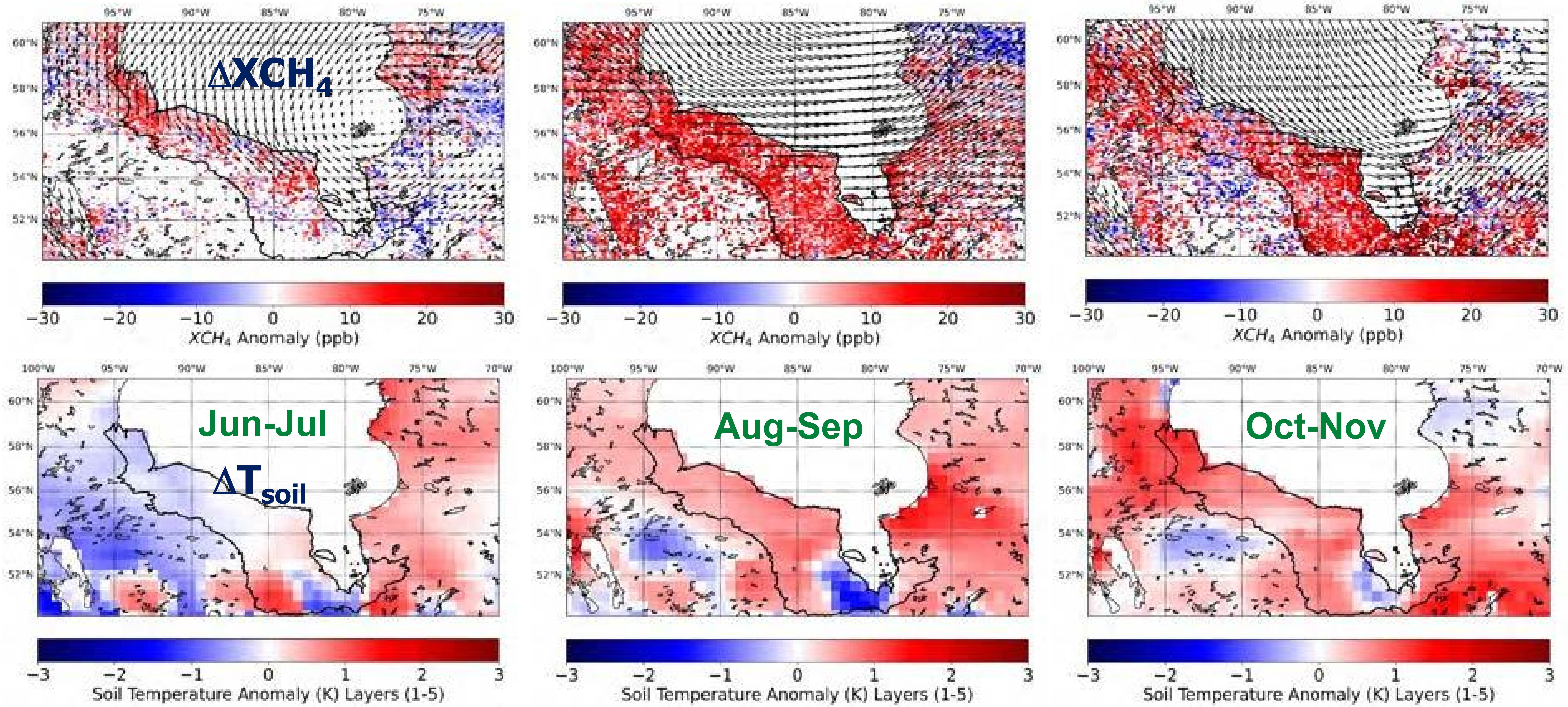
We use 2-m winds and soil temperature from NASA MERRA-2

Soil temperature anomalies from MERRA-2 (Modern Era Retrospective analysis for Research and Applications 2) soil temperature at levels 1-5*:

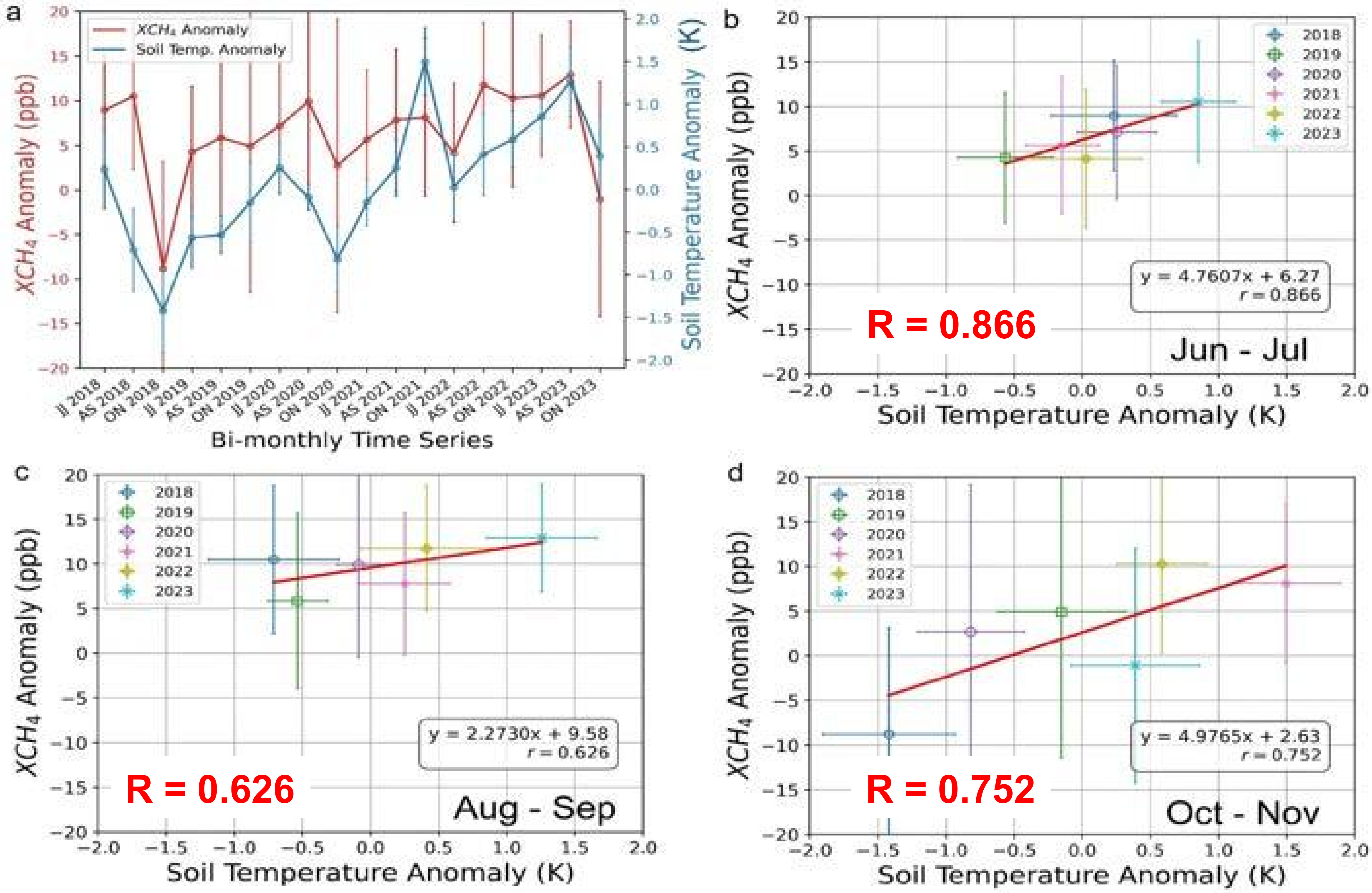
$$Anomaly = Average_{target\ period} - Average_{5-year\ period}$$

*Levels 1-5 span 0-1.5 m depth

ΔXCH_4 and ΔT_{soil} in 2022



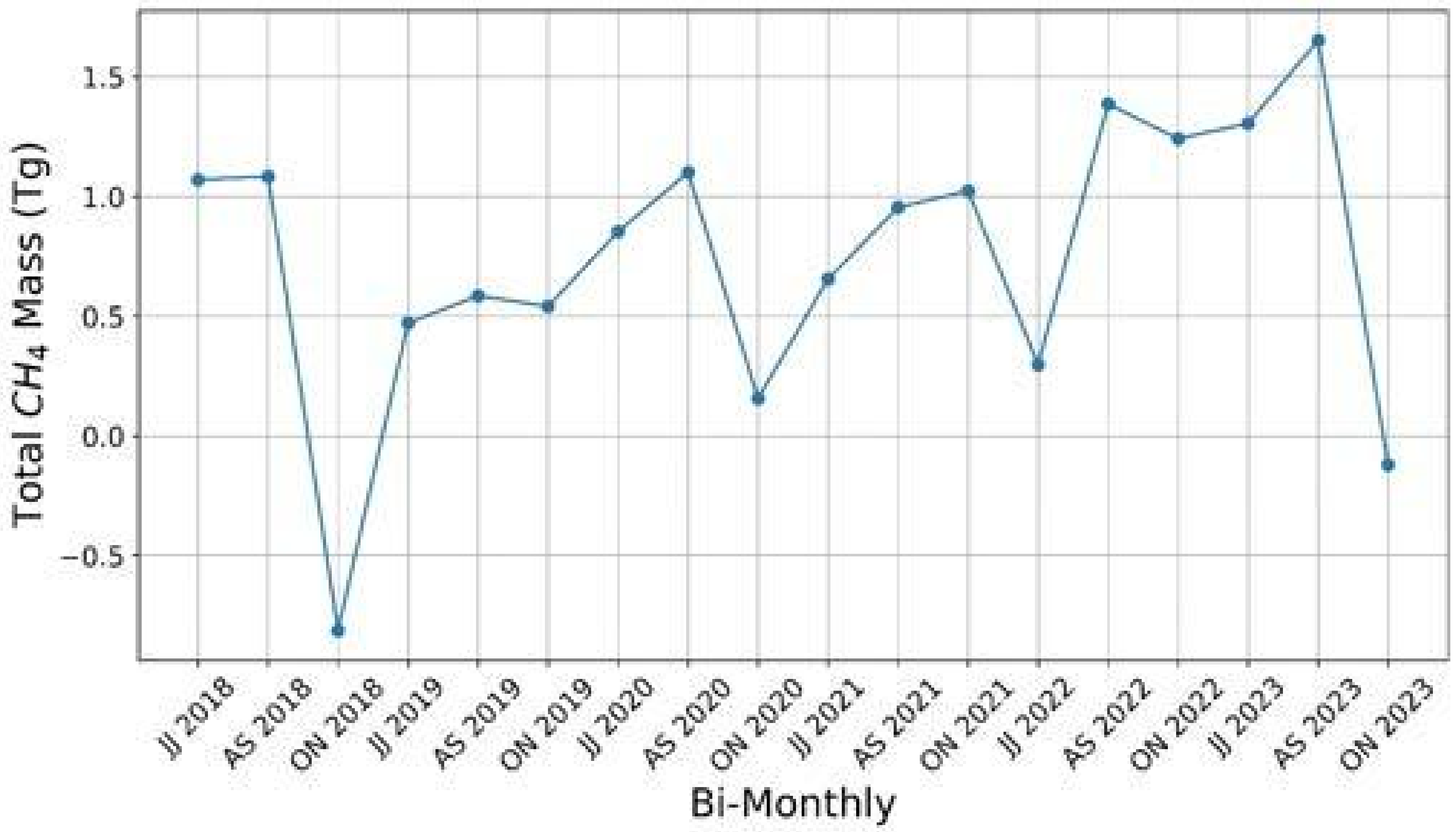
HBL CH_4 emissions are clearly linked to ΔT_{soil}



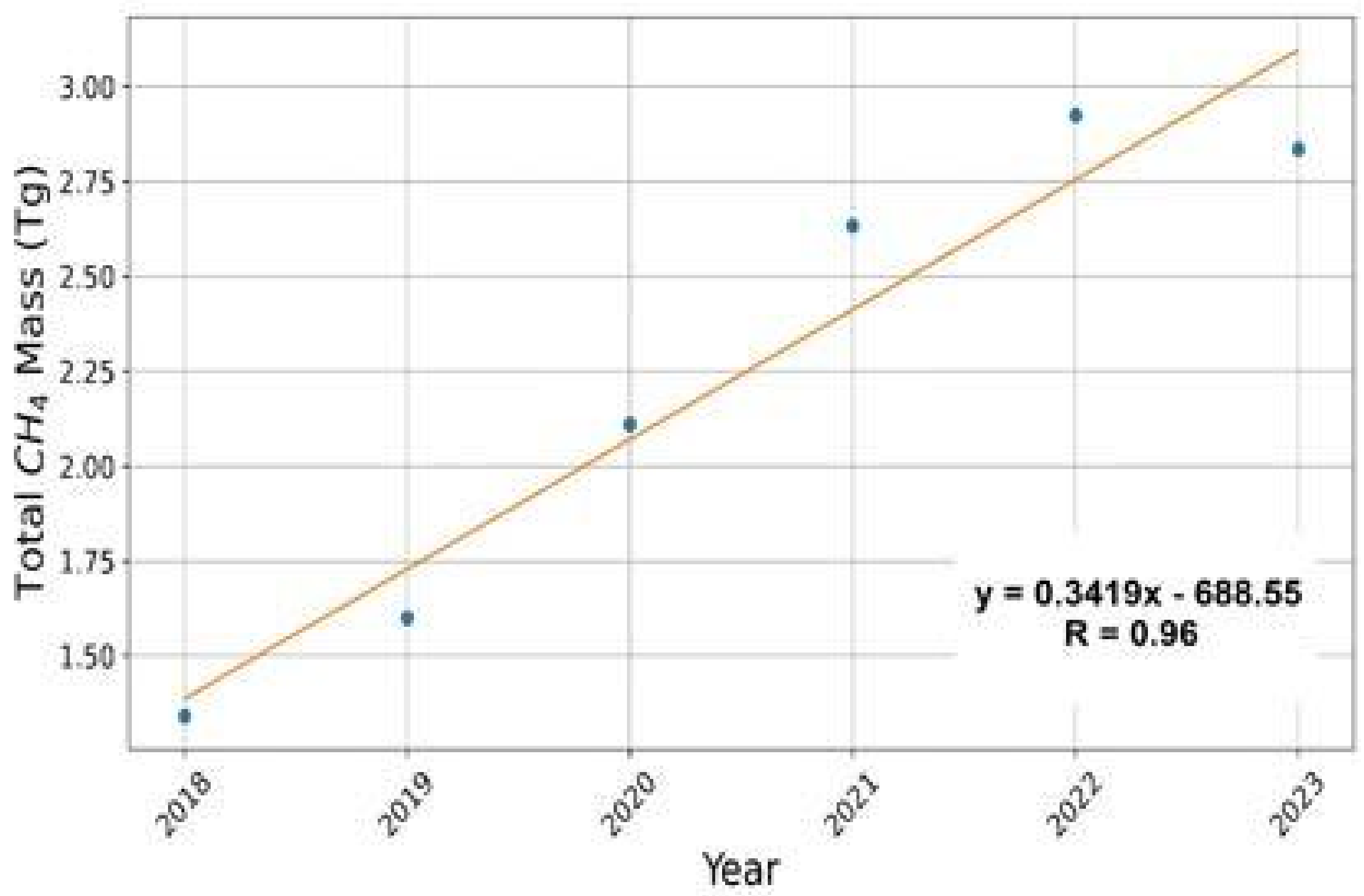
Strong correlations for each bi-monthly period over 6 years, indicate a clear temperature dependence for CH_4 emission.

CH_4 Emission Mass and Trend

Converted bi-monthly ΔXCH_4 to mass as a proxy for emissions



Warm season emissions determined from sum over six warm months (Jun to Nov)



Since 2021, CH_4 emissions exceed high end of past HBL estimates of 2.3 Tg/year (Pickett-Heaps et al. 2011 ACP).

Can we attribute these increasing HBL CH_4 emissions to permafrost thaw?

Large stocks of peatland carbon and nitrogen are vulnerable to permafrost thaw

PNAS

Gustaf Hugelius, Julie Loisel, Sarah Chadburn, Robert B. Jackson, Miriam Jones, Glen MacDonald, Maija Marushchak, David Olefeldt, Maara Packalen, Matthias B. Siewert, Claire Treat, Merritt Turetsky, Carolina Voigt, and Zicheng Yu +10 Authors Info & Affiliations

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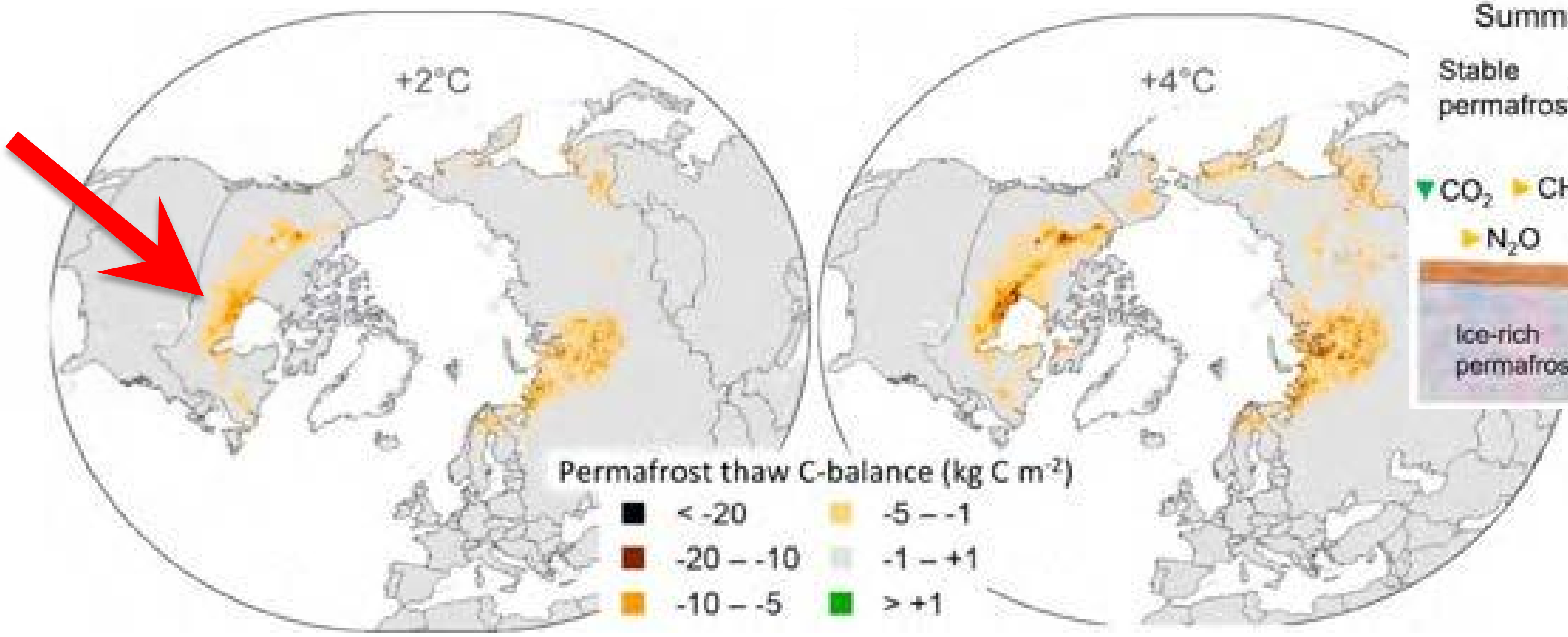
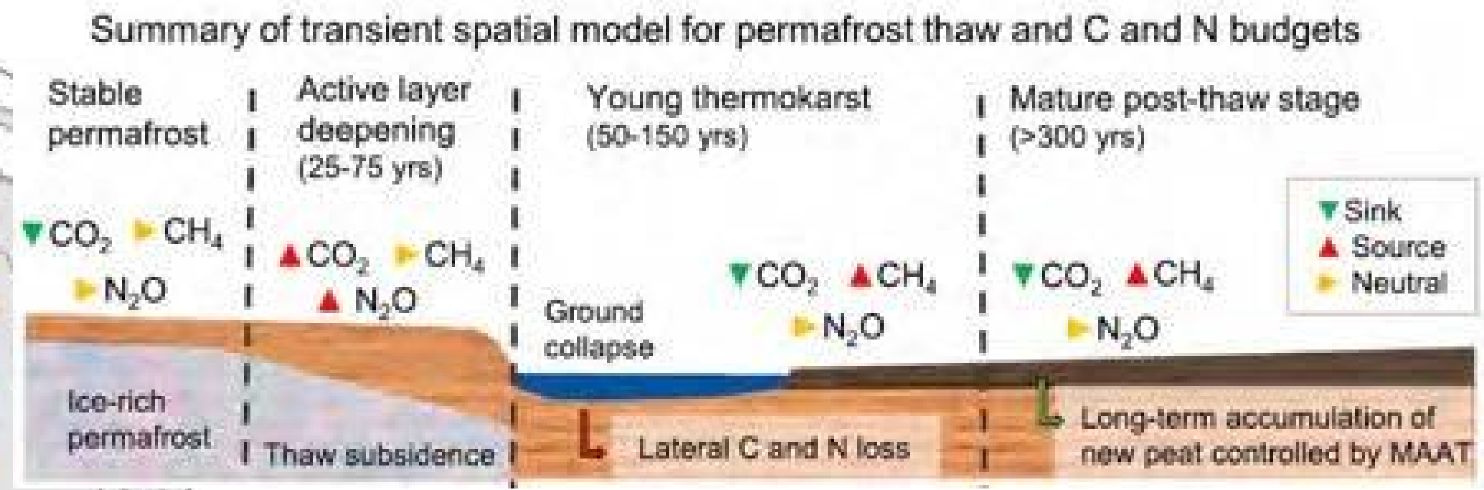
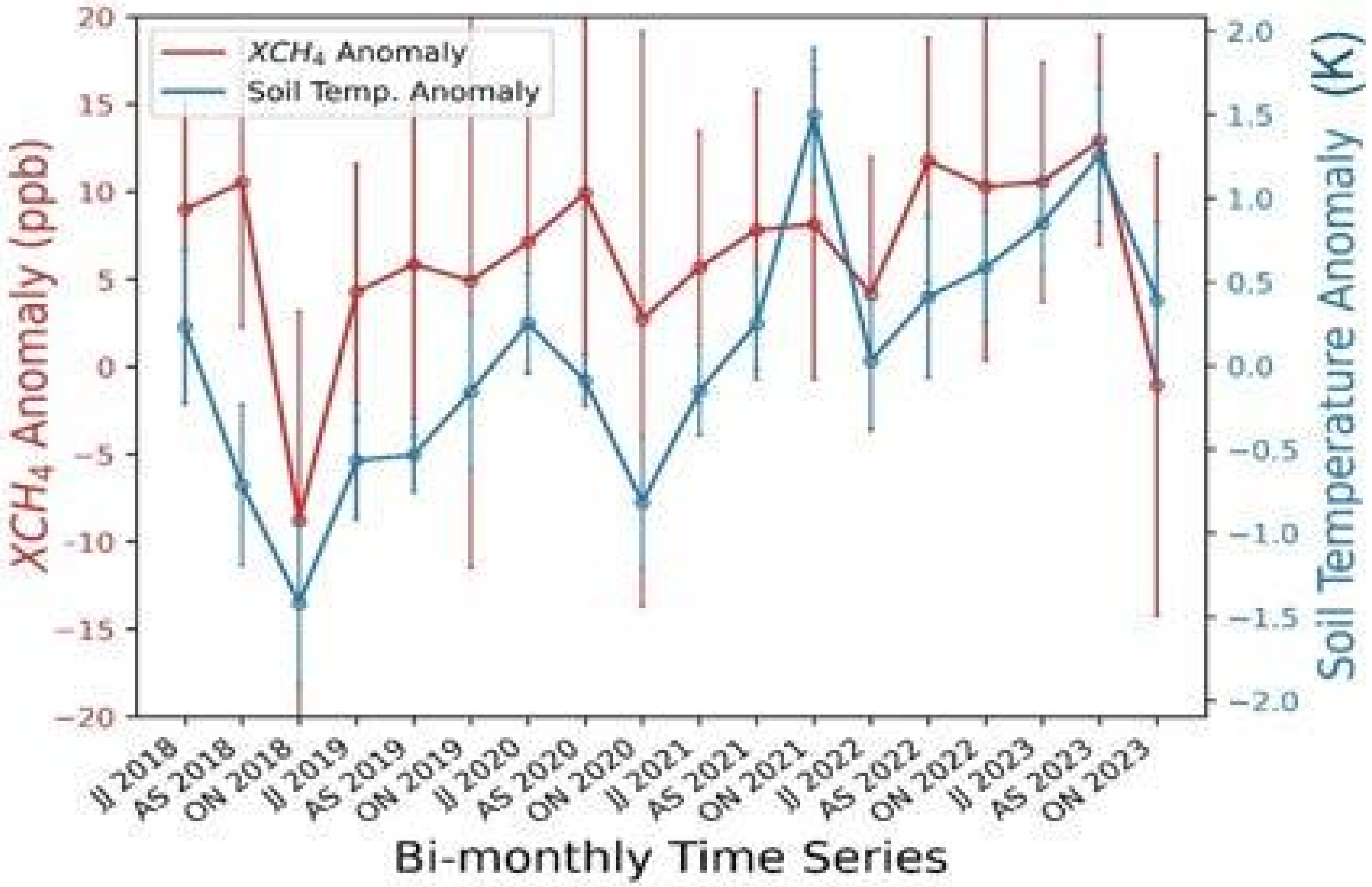




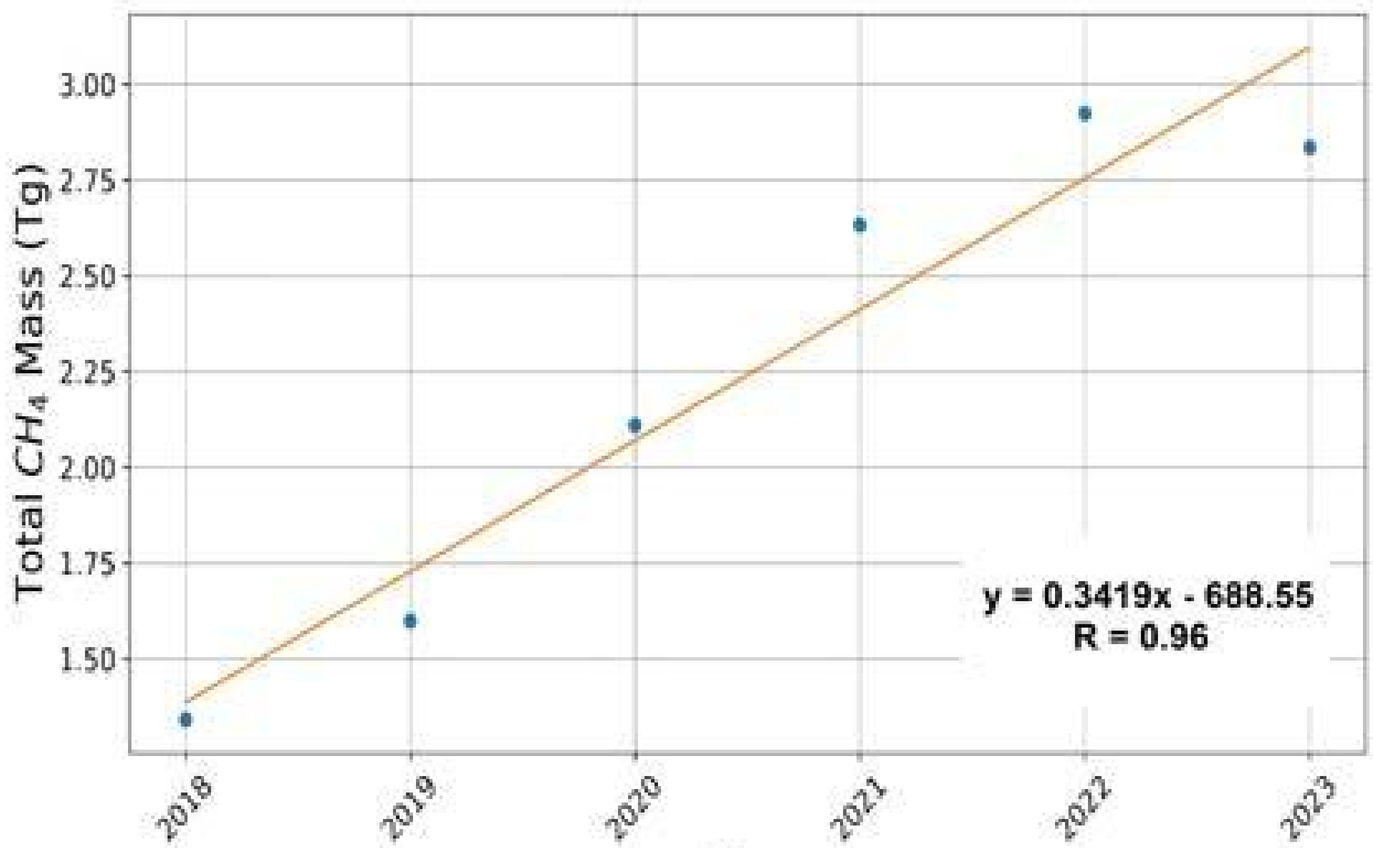
Time period of this study (2018-2023) has global warming of ~1.2 - 1.5°C above pre-industrial temperatures.

Time scale for CH_4 emission following thaw in this model is on the scale of decades. Other studies on abrupt thaw suggest only slightly reduced time scales of emissions.

Short-term and Long-term CH_4 Emission Changes



The bi-monthly XCH_4 variations we observe are dominated by the temperature sensitivity of wetland emissions. CH_4 emission from permafrost happens on longer multi-year (or decadal) time scales.



The long-term increase in seasonally-integrated CH_4 emission is likely 'co-driven' by current wetland processes and past permafrost thaw generating emissions on multi-year timescales. In future work, we will attempt to disentangle these contributions via an inversion using the Integrated methane inversion (IMI) with WFMD v2.0 XCH_4.