Investigating the large rise of atmospheric CH_4 in 2020 using TROPOMI observations and TOMCAT chemical transport model

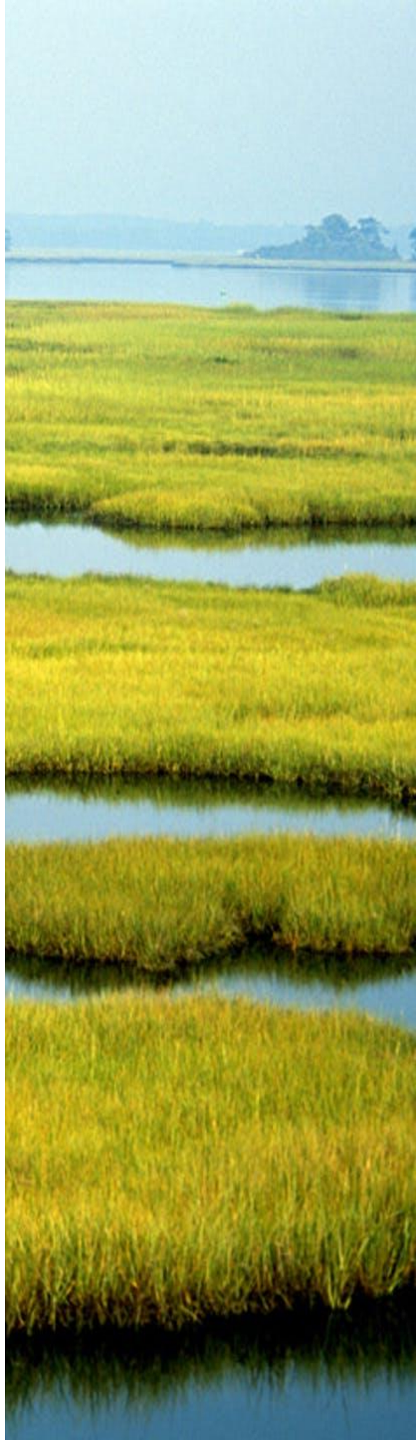
Emily Dowd

School of Earth & Environment, University of Leeds

Email: eeed@leeds.ac.uk

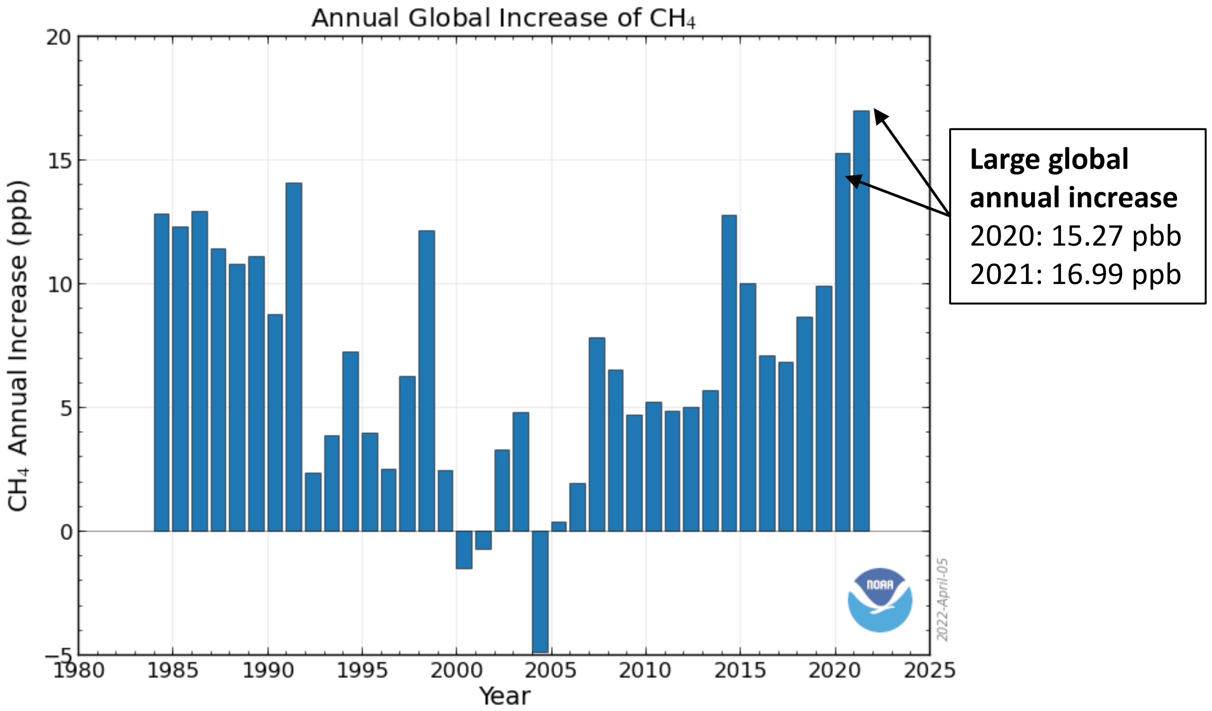
Twitter: @emily_dowd_

Co-Authors:
Christopher Wilson, National Centre for Earth Observation, School of Earth & Environment, University of Leeds
Martyn Chipperfield, National Centre for Earth Observation, School of Earth & Environment, University of Leeds
Emanuel Gloor, School of Geography, University of Leeds
Robert Parker, National Centre for Earth Observation, School of Physics & Astronomy, University of Leicester
Hartmut Boesch, National Centre for Earth Observation, School of Physics & Astronomy, University of Leicester



Why is methane important?

Atmospheric CH_4



- Second most important greenhouse gas after CO_2
- Anthropogenic emissions have contributed an extra 23% to radiative forcing in the troposphere
- Variations of global methane are poorly understood

Sources & Sinks

Wetlands
194[155-217] Tg CH_4 yr^{-1}

Agriculture & Waste
227[205-246] Tg CH_4 yr^{-1}

Fossil Fuels
108[91-121] Tg CH_4 yr^{-1}

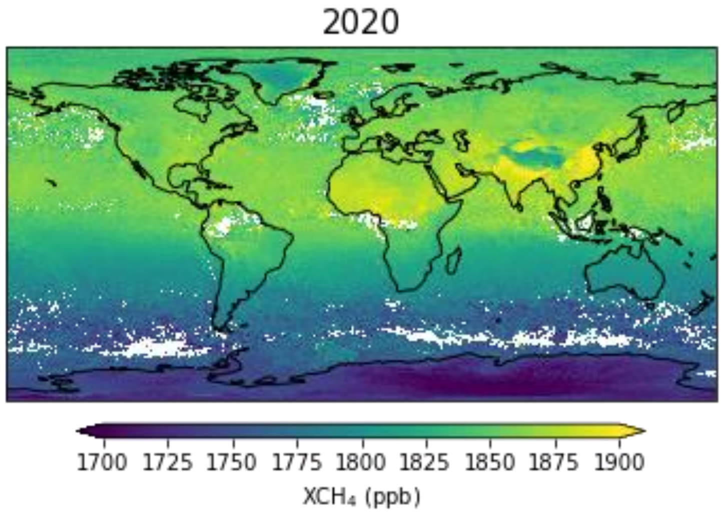
Biomass Burning
28[25-32] Tg CH_4 yr^{-1}

Total Flux = 596[572-614] Tg CH_4 yr^{-1}

Main sink of methane is the hydroxyl radical(OH)

UNIVERSITY OF LEEDS

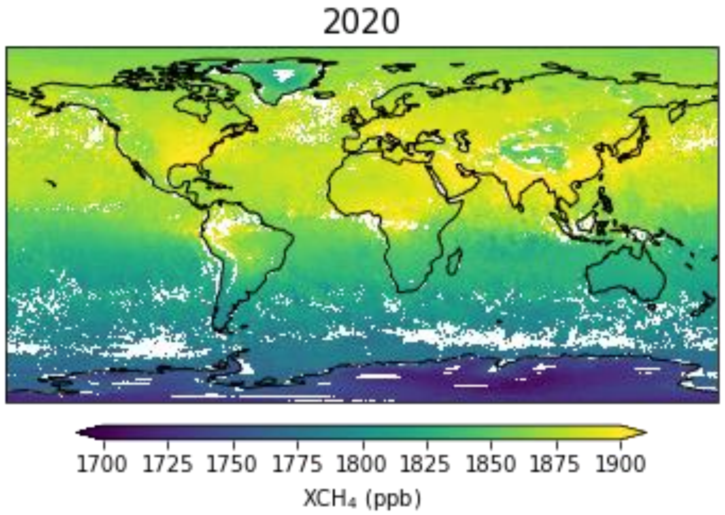
TROPOMI



2020 mean column CH_4 from TROPOMI

- O. Schneising et al. (2019) retrieval algorithm
- 0.5° x 0.5° grid
- Daily data aggregated to monthly mean 2018-2020

TOMCAT

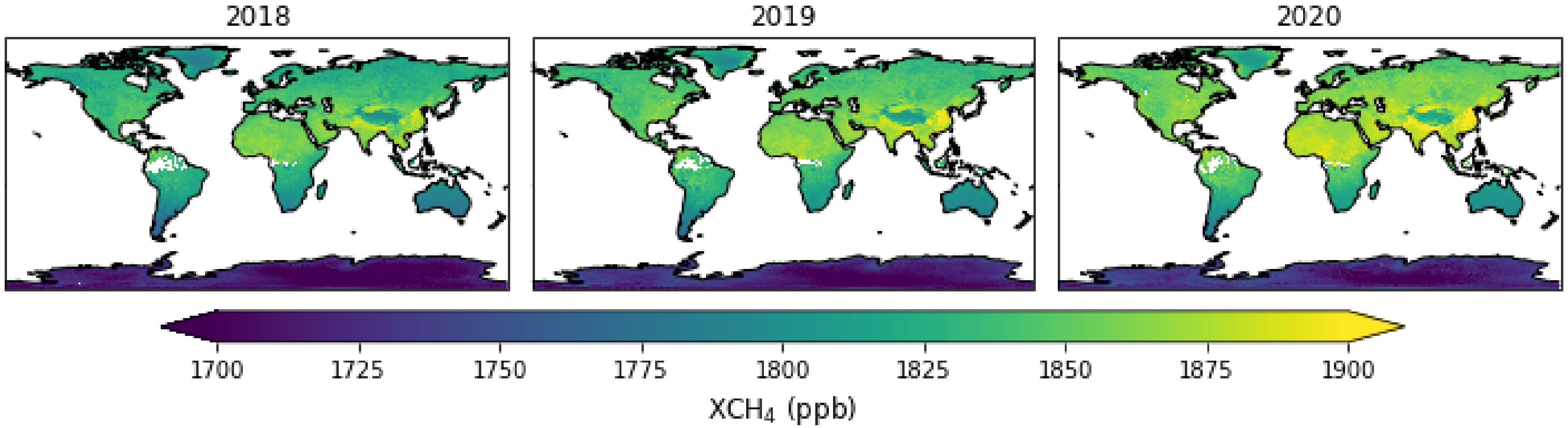


2020 mean column CH_4 from TOMCAT with TROPOMI averaging kernels.

- TOMCAT is a 3D chemical transport model
- Surfaces fluxes were taken from inversions which assimilated GOSAT satellite retrievals and surface observations
- We have done a separate inversion which assimilated NOAA surface observations
- Model was run at 2.8° x 2.8°, 60 vertical levels, annually repeating offline OH fields
- TROPOMI averaging kernels applied to both simulations

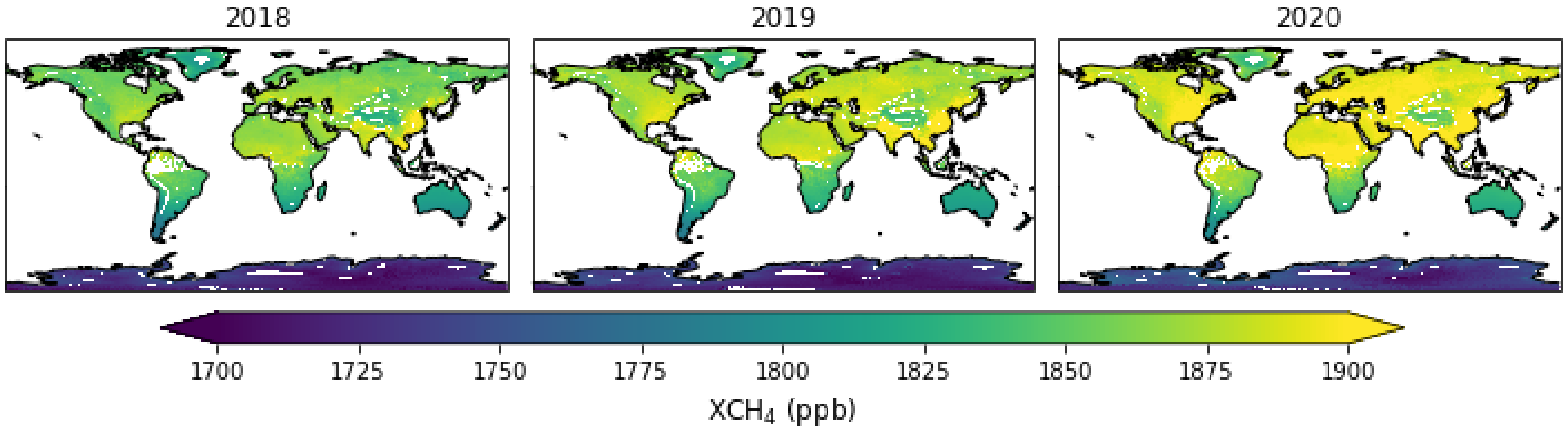
TROPOMI & TOMCAT 2018-2020

TROPOMI Annual Mean XCH_4



- XCH_4 increasing from 2018-2020
- Areas of high CH_4 include northern Africa, India, Bangladesh and China

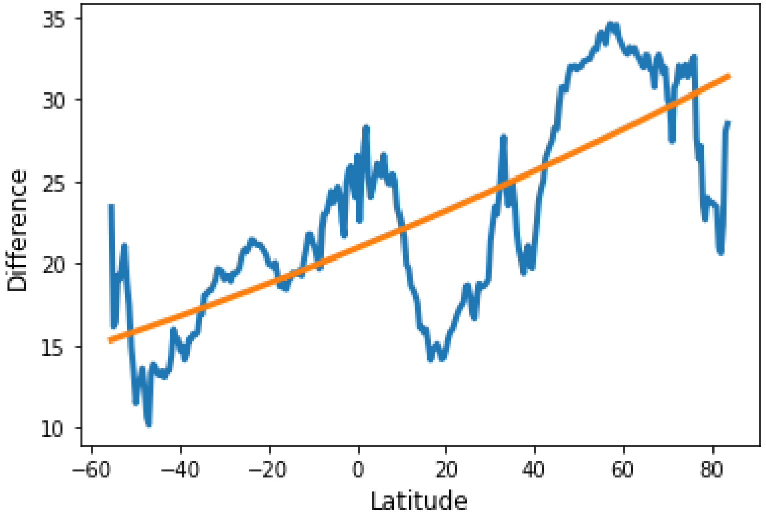
TOMCAT (with GOSAT) Annual Mean XCH_4



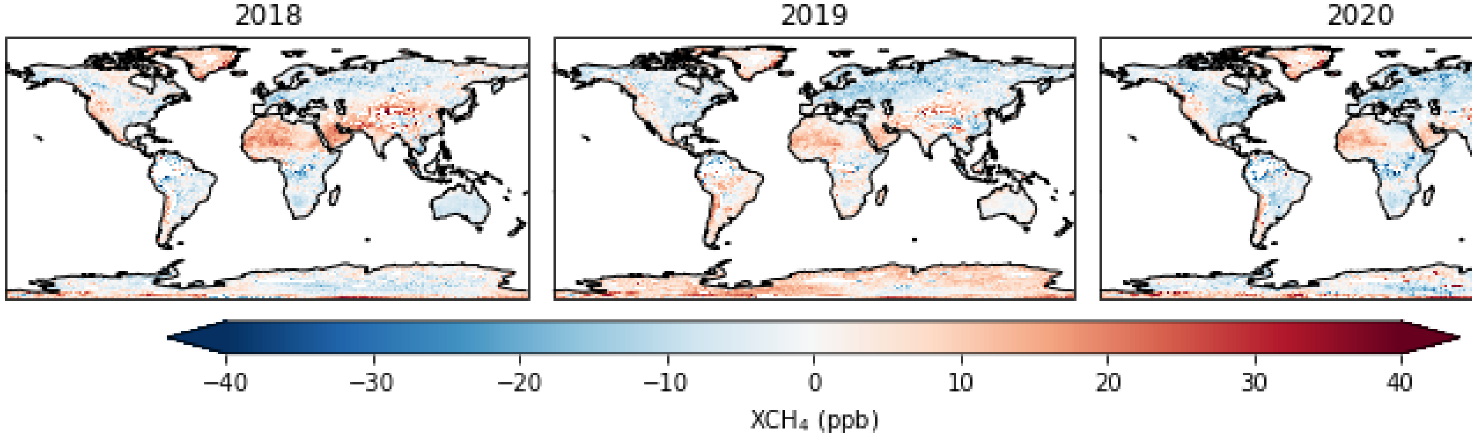
- TOMCAT overestimating total column CH_4
- Areas of high CH_4 include northern Africa, India, China and North America

TOMCAT Latitudinal Bias Correction

Zonal Mean
(TOMCAT-TROPOMI, 2018-2020)
2nd Order Polynomial Fit (orange)



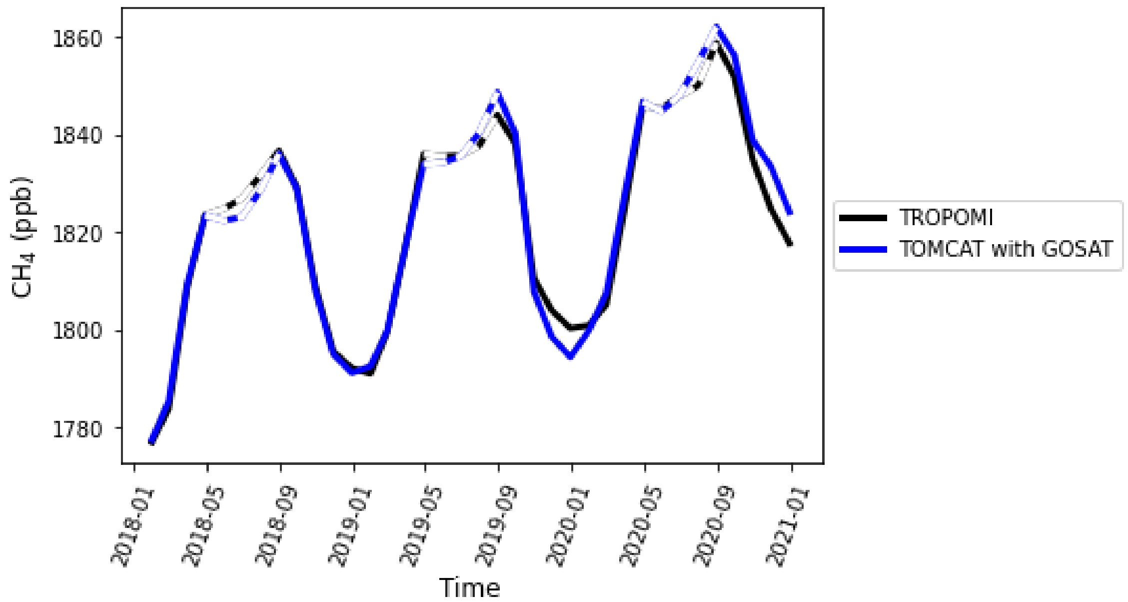
Difference Between TROPOMI & TOMCAT with Latitudinal Bias Removed from TOMCAT
(TROPOMI – TOMCAT with GOSAT)



- Global mean bias correction shows latitudinal bias
- Calculated 2nd order polynomial fit for latitudinal bias correction
- TOMCAT still overestimates but biases are now always within ±15 ppb instead of ±30 ppb – largest biases remain in high albedo areas
- The latitudinal bias correction has been applied TOMCAT in the following analysis

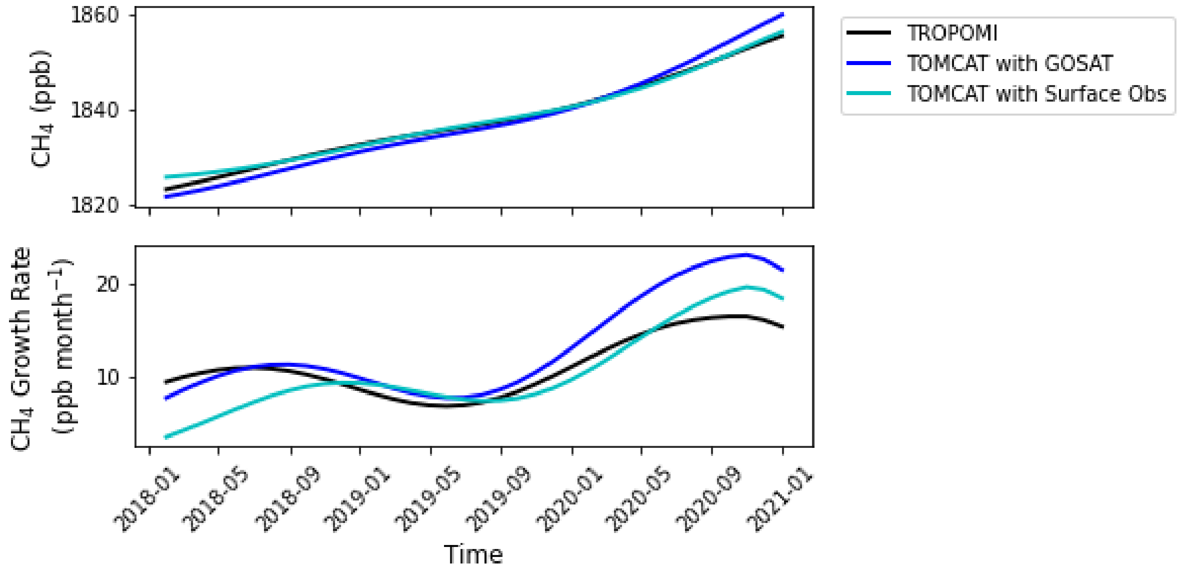
Global CH_4

Global Monthly Mean



The dashed lines represent time period where there are less than 80% of the maximum number of grid boxes.

Long Term Trend & Growth Rate

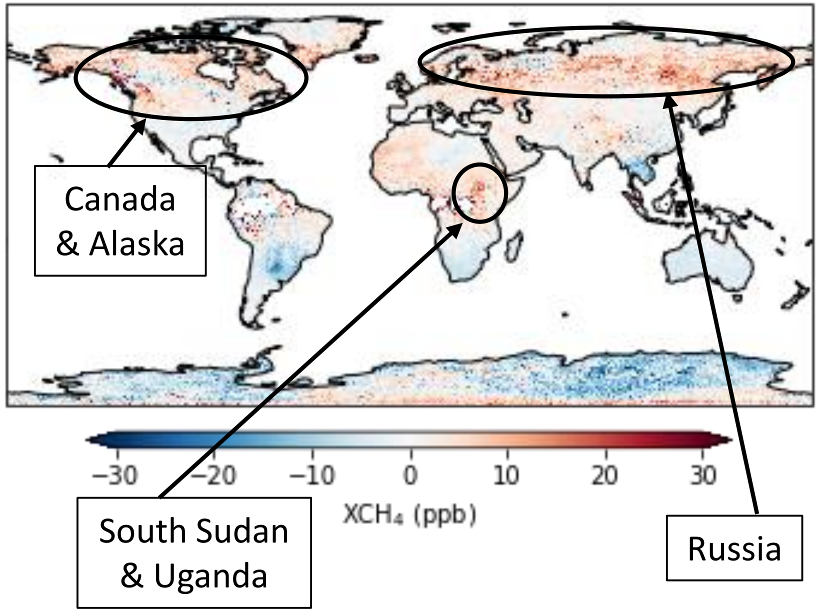


- The model captures the seasonal cycle and long term trend of CH_4 well when compared with TROPOMI
- The global annual increase for TROPOMI is 14.9 ppb and for GOSAT is 17. 1 ppb in 2020
- NOAA observed an annual increase of 15.3 ppb in 2020
- The global annual increase for TOMCAT with Surface Observations is 15.8 ppb and TOMCAT with GOSAT is 19.7 ppb in 2020

UNIVERSITY OF LEEDS

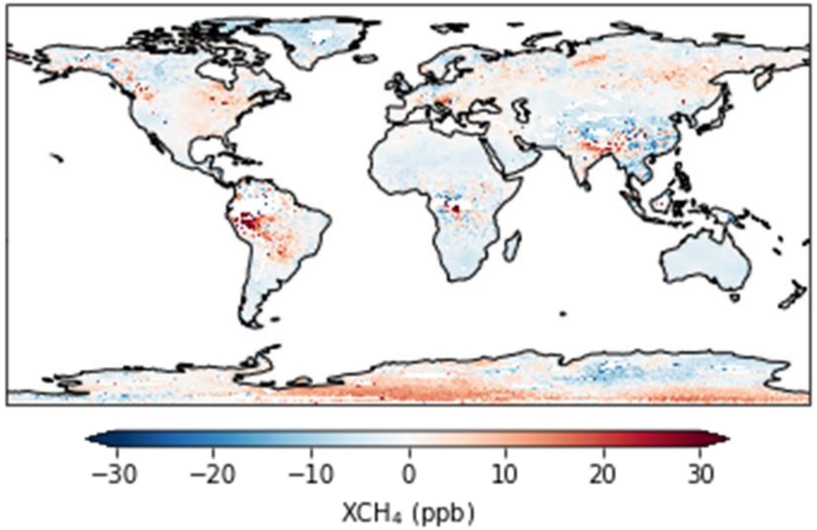
What is driving the large increase in 2020?
2020 Annual Increase Relative to the Global Mean Annual Increase

TROPOMI Relative Annual Increase in 2020

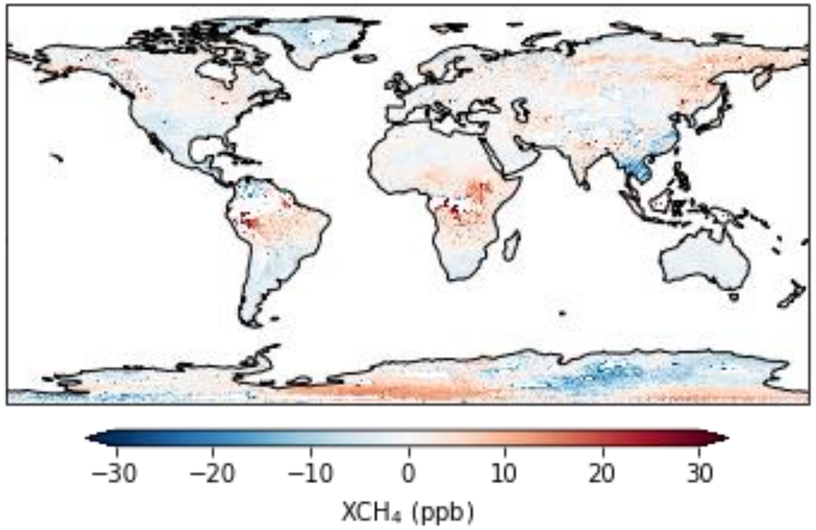


- Latitudinal variation in annual increase
- Most variations in the Northern Hemisphere driving the increase in 2020

TOMCAT (with Surface Observations)
Relative Annual Increase in 2020



TOMCAT (with GOSAT)
Relative Annual Increase in 2020

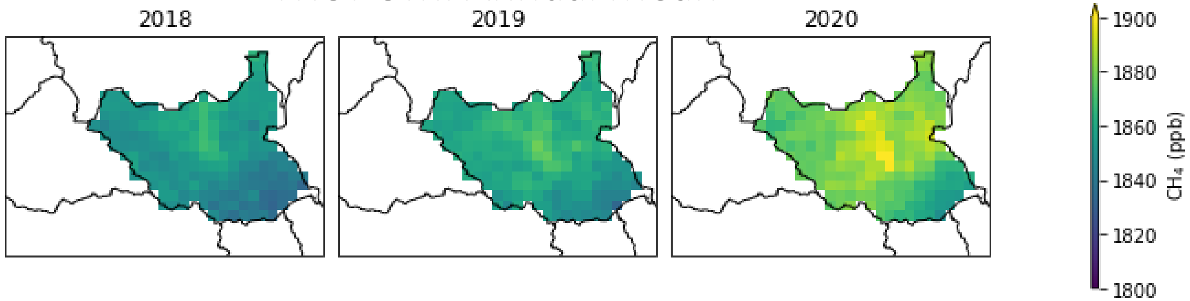


- TOMCAT with Surface Observations does not display relative increases shown by TROPOMI well
- TOMCAT with GOSAT:
  - Displays the large increase over Africa and Russia
  - Displays increase in Russia but not as large as TROPOMI
  - Does not display large rise over Canada

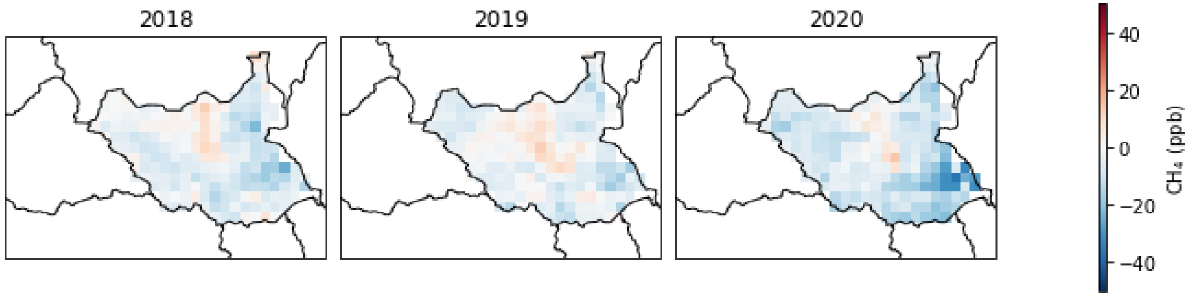
South Sudan

- TROPOMI shows large increases in CH_4 September, October & November (SON) in 2019 and 2020
- Pandey et al. (2020) and Parker et al. (2020) find that WetCharts does not capture Sudd seasonal cycle
- TOMCAT with GOSAT assimilated, TROPOMI and GOSAT all show a large rise in SON 2020.
- Lunt et al. (2021) large enhancements of CH_4 during large positive anomalies in the 2019 short rains season (October-December) and these continued into 2020

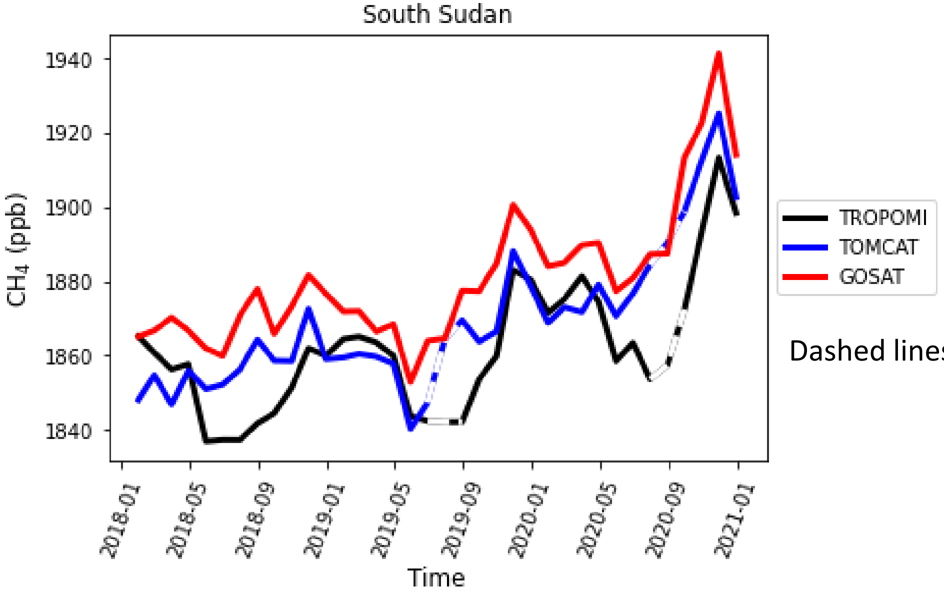
TROPOMI Annual Mean



Difference Between TROPOMI & TOMCAT (TROPOMI – TOMCAT)



Monthly Mean XCH_4 - South Sudan

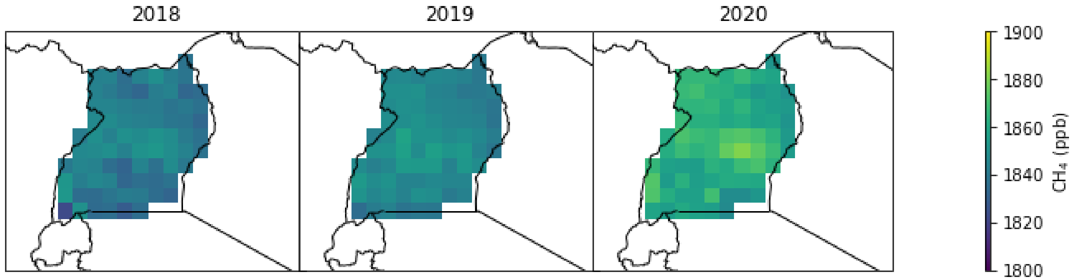


Dashed lines = less coverage

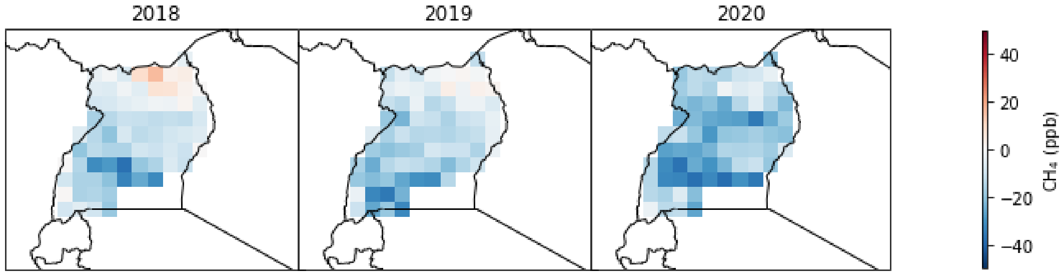
Uganda

- TROPOMI shows large increases in CH_4 between November-January, with largest increase in 2020
- Lunt et al. (2021) found a positive precipitation anomalies OND 2019
- High release rates from dam controlling Lake Victoria outflow in 2020

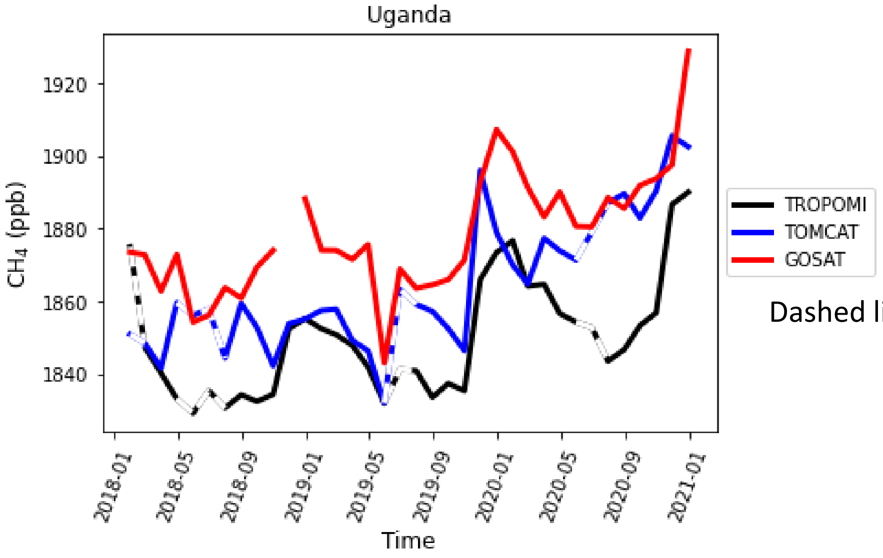
TROPOMI Annual Mean



Difference Between TROPOMI & TOMCAT (TROPOMI – TOMCAT)



Monthly Mean XCH_4 - Uganda

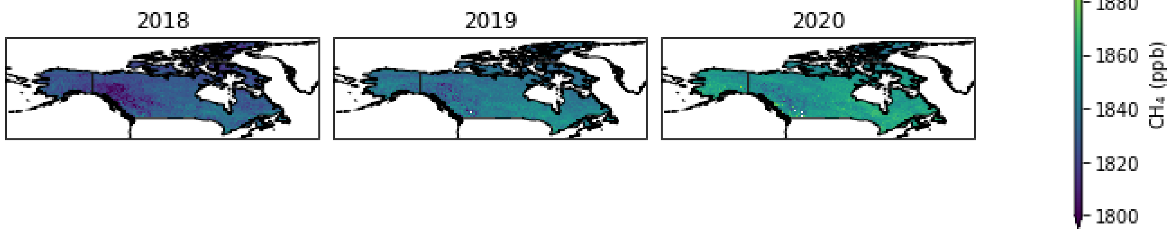


Dashed lines = less coverage

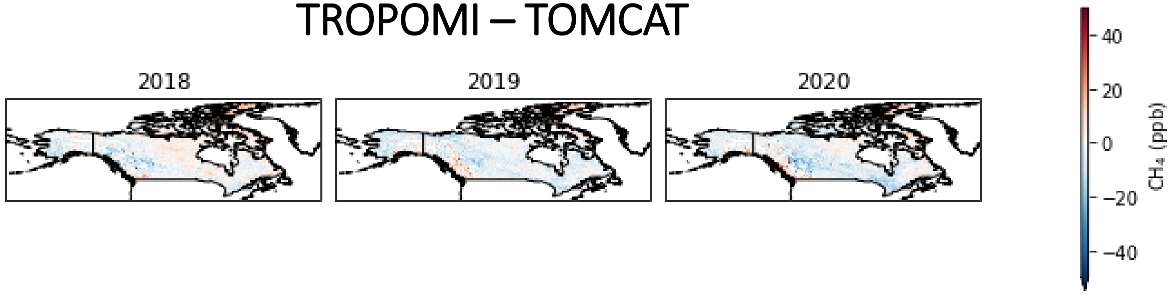
Canada & Alaska

- Higher concentrations in the east where more wetlands are situated
- TOMCAT captures CH_4 well when compared with TROPOMI
- Islam et al. (2021) found, using GOSAT, that wetlands and oil and gas emissions are controlling the growth rate during 2009-2019 in western Canada
- Scarpelli et al. (2021) produced a gridded inventory of anthropogenic emissions and eastern Canada emissions are mostly from livestock along the US/Canadian border

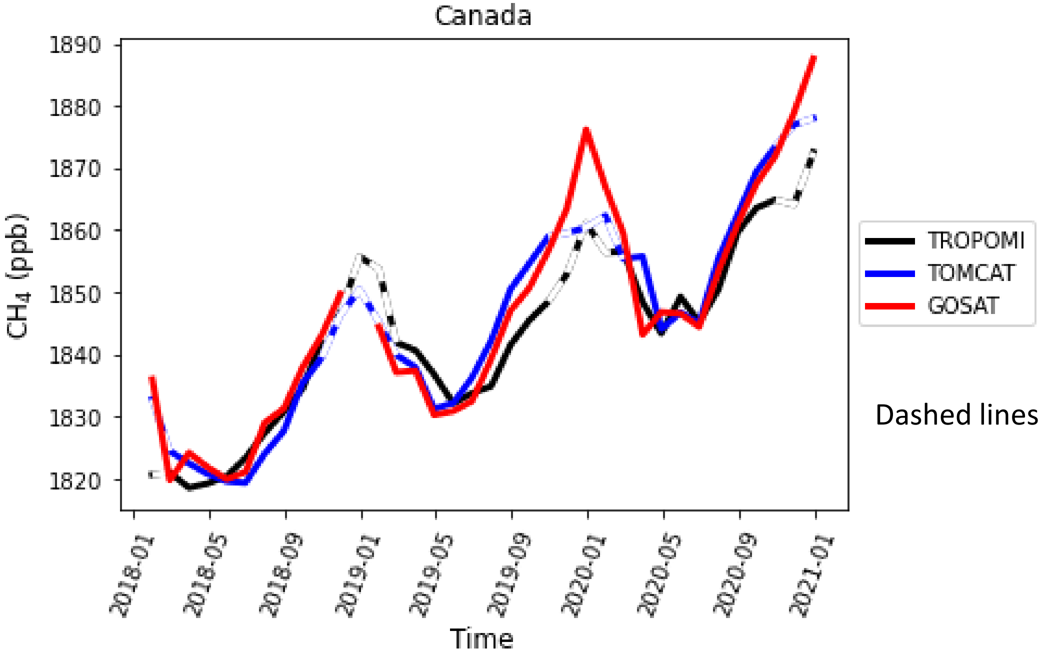
TROPOMI Annual Mean



TROPOMI – TOMCAT



Monthly Mean XCH_4 – Canada & Alaska

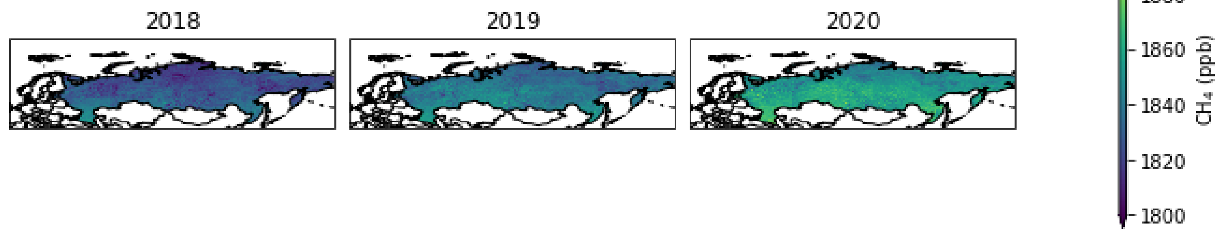


Dashed lines = less coverage

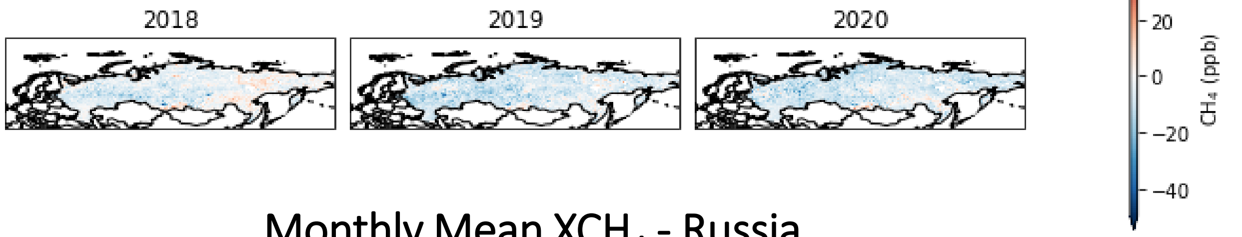
Russia

- TOMCAT captures CH_4 variation but generally overestimates when compared with TROPOMI
- 2019 and 2020 had large wildfire seasons

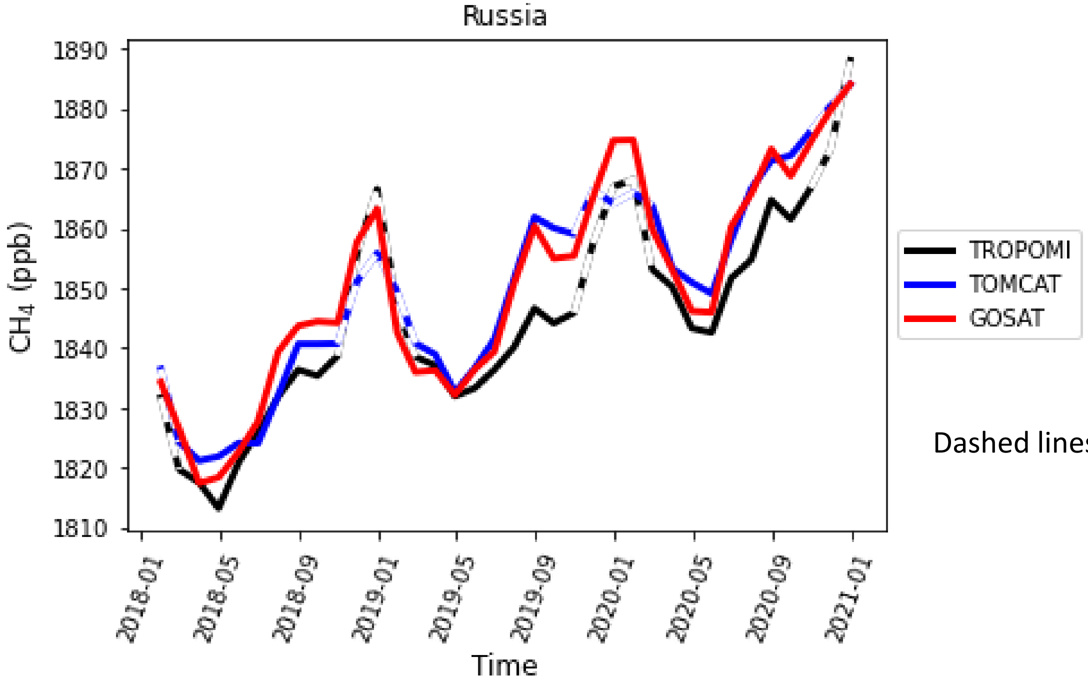
TROPOMI Annual Mean



Difference Between TROPOMI & TOMCAT (TROPOMI – TOMCAT)



Monthly Mean XCH_4 - Russia



Dashed lines = less coverage

UNIVERSITY OF LEEDS

Summary

- Large global annual increased in 2020 shown by NOAA surface observations (15.27 pbb) and TROPOMI (14.87 ppb)
- GOSAT has a larger annual increase of 17.1 ppb and TOMCAT with GOSAT (with TROPOMI averaging kernels) is 19.7 ppb
- TOMCAT with GOSAT captures spatial distribution of relative annual increase shown by TROPOMI
- TOMCAT shows a latitudinal bias when compared with TROPOMI
- Areas with large annual increase in 2020 include: South Sudan, Uganda, Canada & Alaska and Russia
- TOMCAT captures the large concentrations in 2020 over South Sudan but has a weaker seasonal cycle
- From the selected areas it seems wetlands are a large contributor to the increase in CH_4 during 2020

Next Steps

- Develop a nested grid model for TOMCAT in order to do high resolution comparisons with TROPOMI

Get in Contact: Emily Dowd

Email: eeed@leeds.ac.uk Twitter: @emily_dowd_

UNIVERSITY OF LEEDS