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

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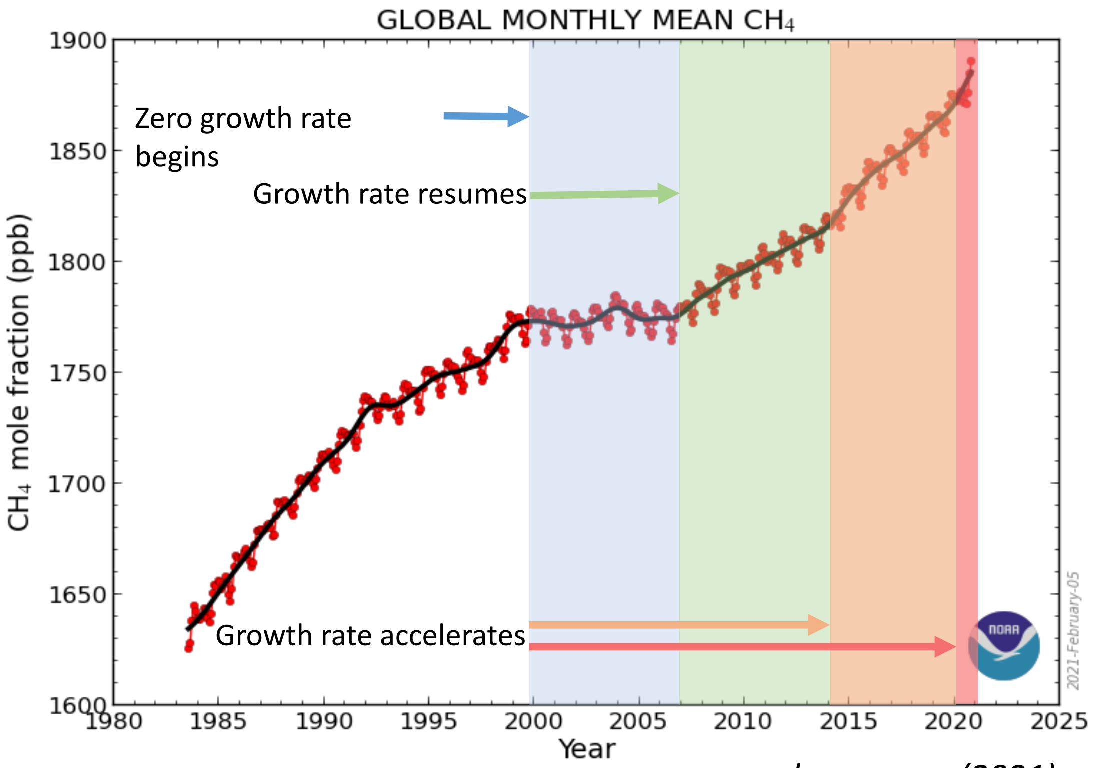
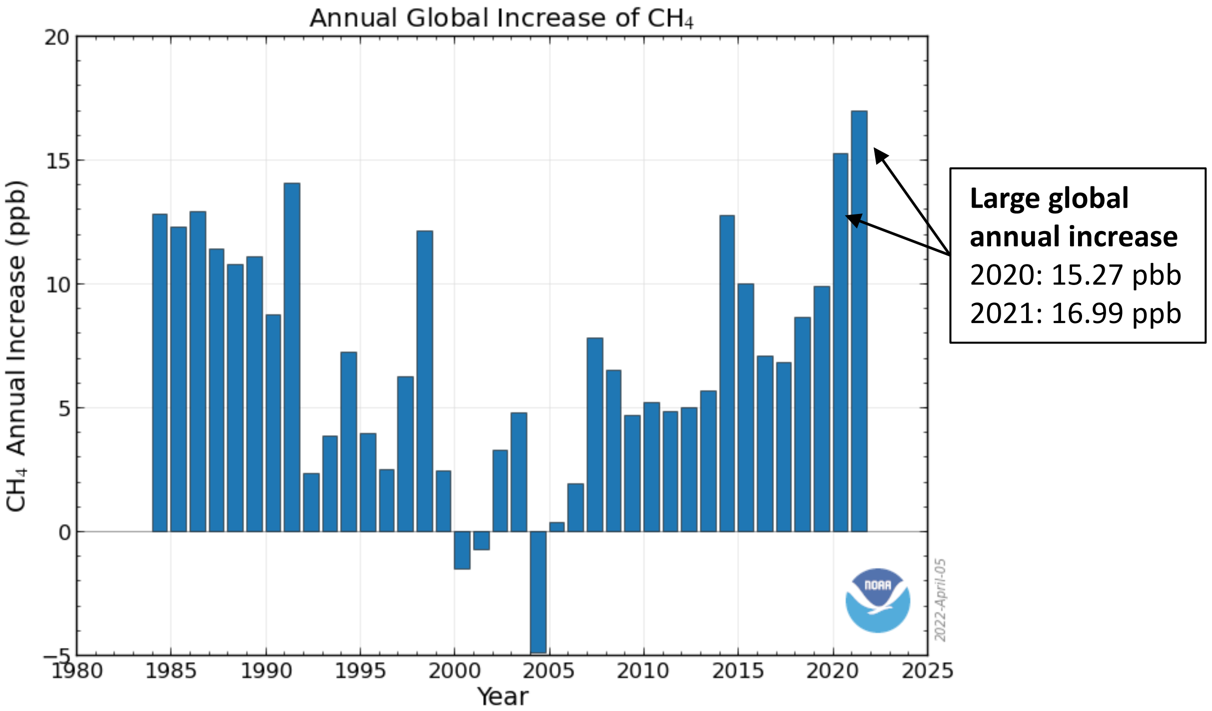
Why is methane important?



esrl.noaa.gov (2021)



esrl.noaa.gov (2022)

- 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

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}

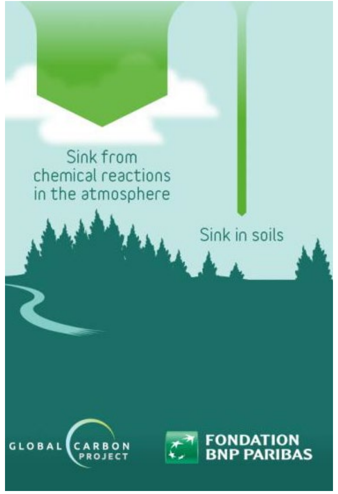
Total Flux = 596[572-614] Tg CH_4 yr^{-1}

Sinks

- Main sink of methane is the hydroxyl radical(OH)

Chemical reactions in atmosphere
531[502-540] Tg CH_4 yr^{-1}

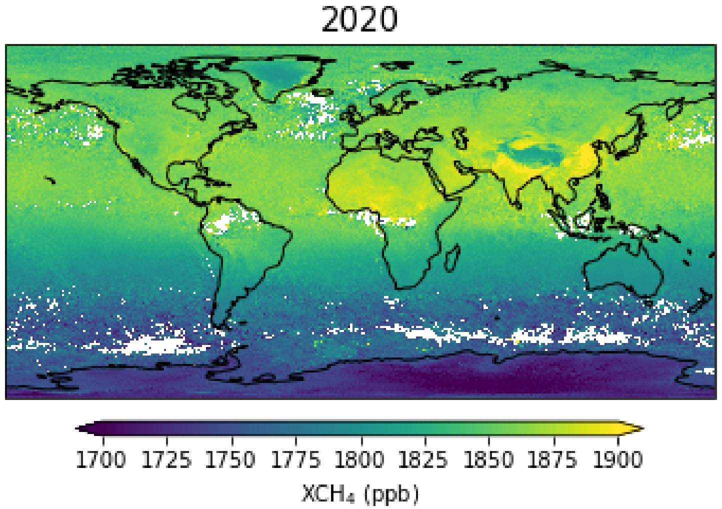
Soil Uptake
40[37-47] Tg CH_4 yr^{-1}



Total Sink = 571[540-585] Tg CH_4 yr^{-1}

(Saunois et al. 2020)

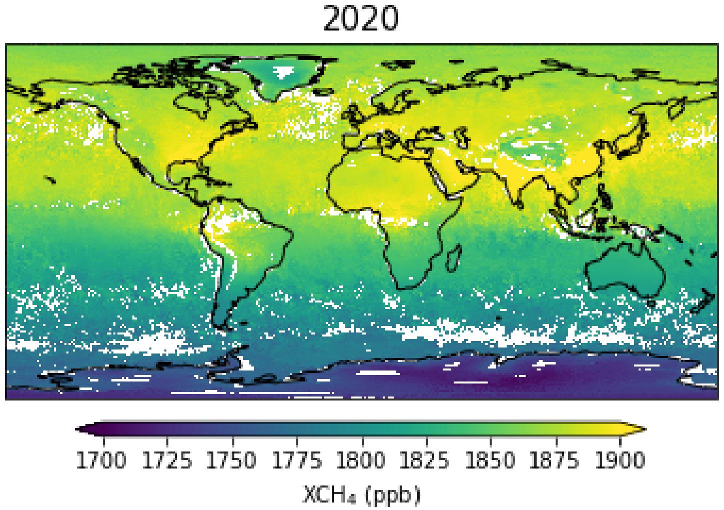
TROPOMI



2020 mean column CH_4 from TROPOMI

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

TOMCAT

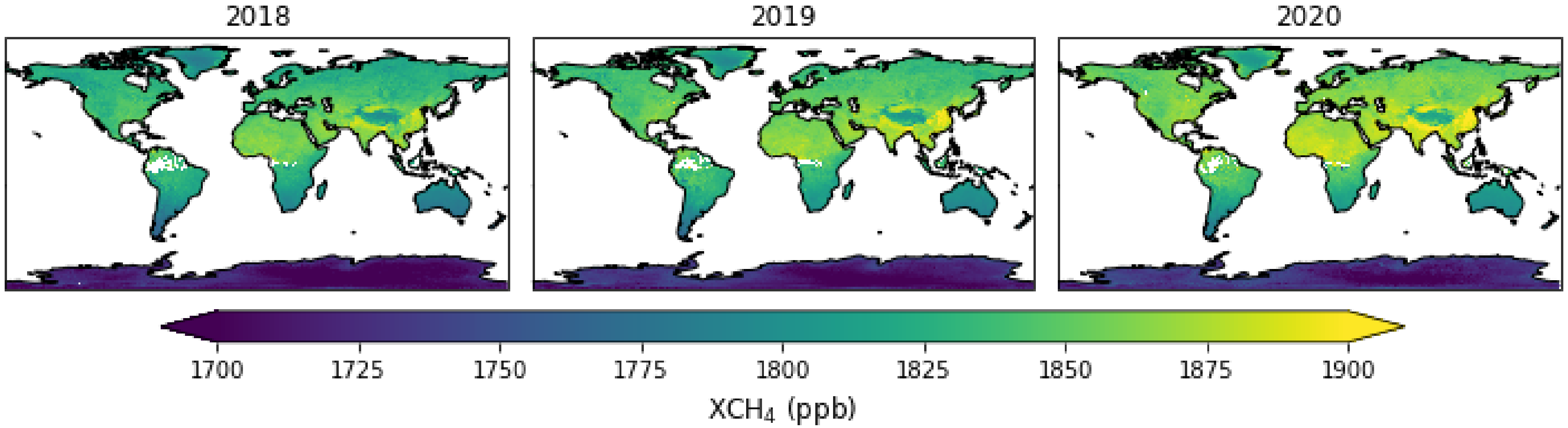


2020 mean column CH_4 from TOMCAT with TROPOMI averaging kernels.

- TOMCAT is a 3D chemical transport model
- Surfaces fluxes were taken from inversions which assimilated NOAA surface observation sites
- Model was run at 2.8° x 2.8°, 60 vertical levels, annually repeating offline OH fields
- TROPOMI averaging kernels applied

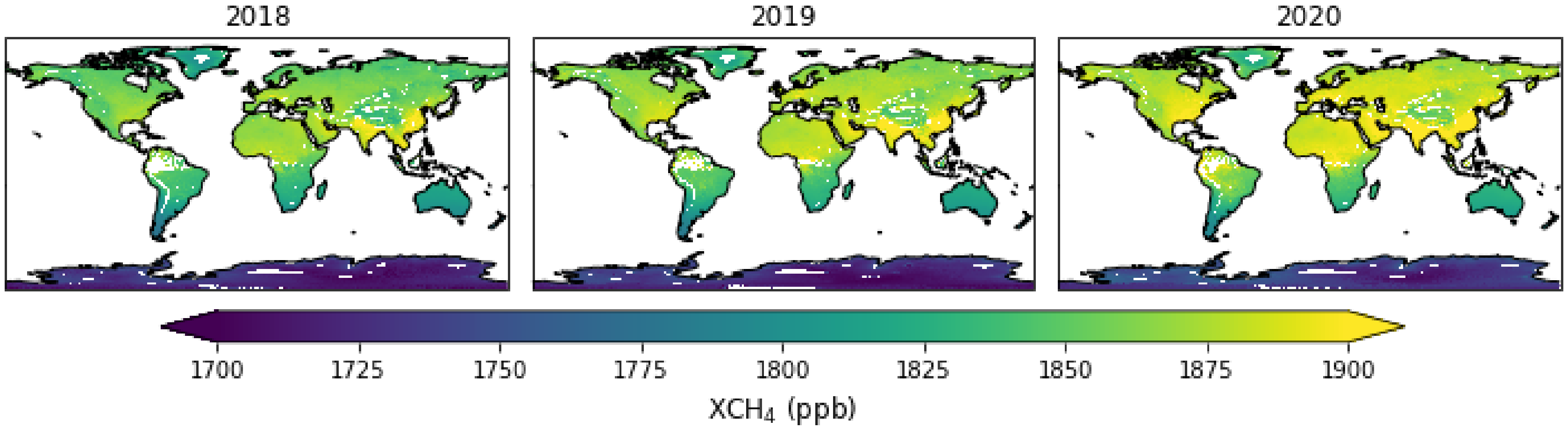
TROPOMI & TOMCAT 2018-2020

TROPOMI Annual Mean XCH_4



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

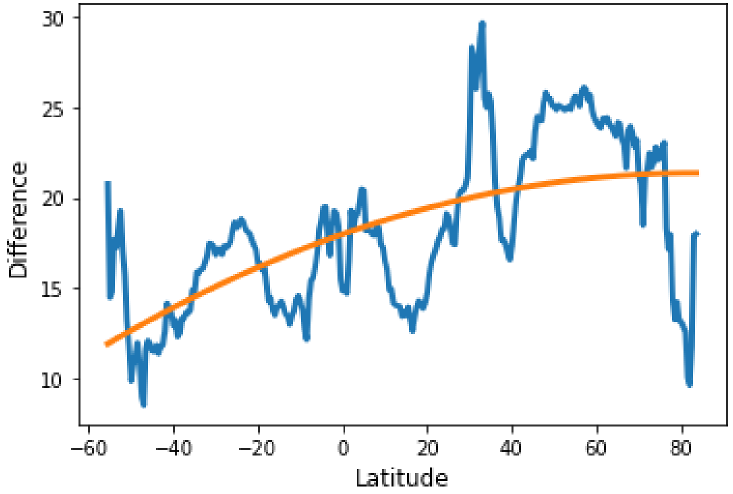
TOMCAT Annual Mean XCH_4



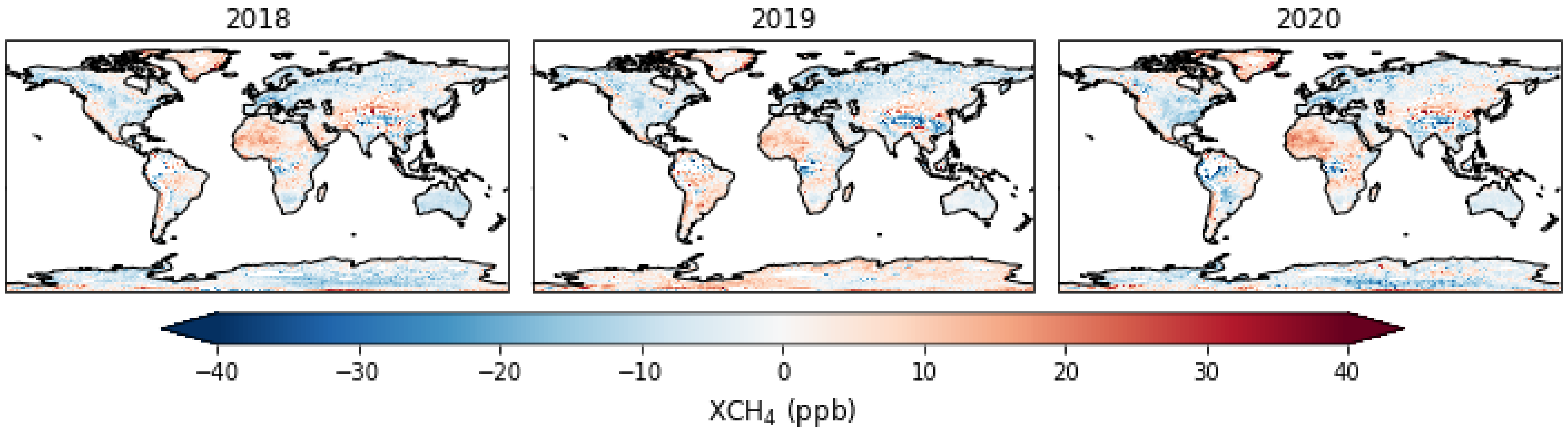
- TOMCAT captures surface CH_4 well due to assimilation of surface observations
- TOMCAT overestimating total column CH_4
- Areas of high CH_4 include northern Africa, India, China and North America

TOMCAT Latitudinal Bias Correction

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



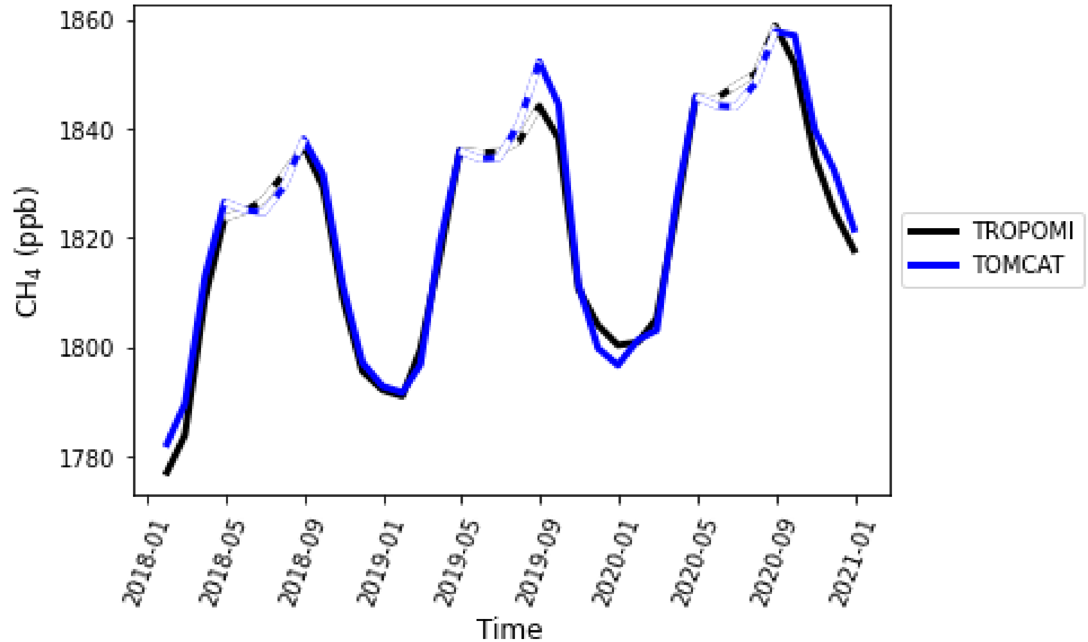
Difference Between TROPOMI & TOMCAT with Latitudinal Bias Removes from TOMCAT
(TROPOMI – TOMCAT)



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

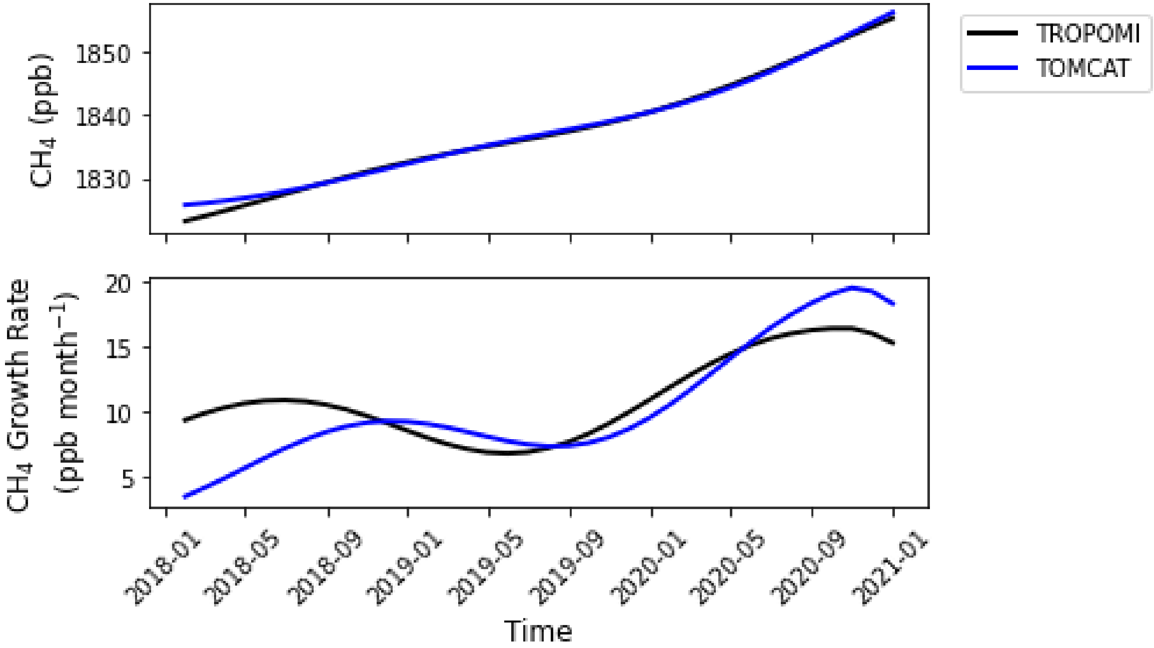
Global CH_4

Global Monthly Mean



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

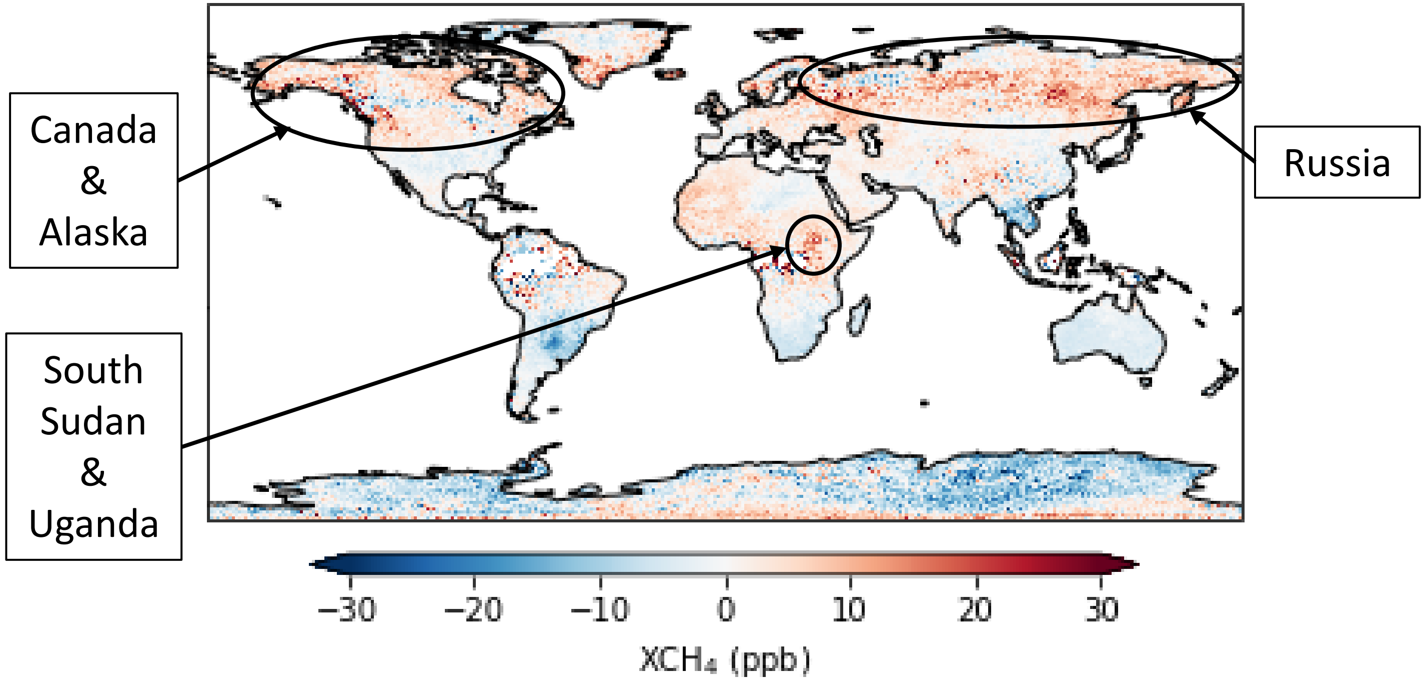
Long Term Trend & Growth Rate



- 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 TOMCAT is 15.8 ppb in 2020
- NOAA observed an annual increase of 15.3 ppb in 2020

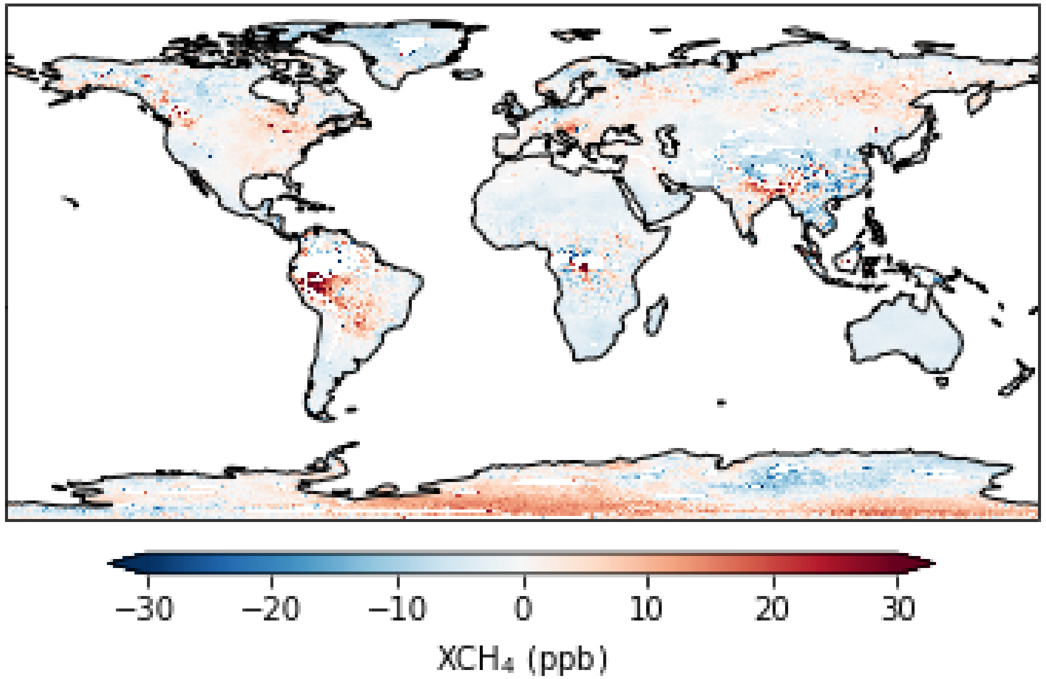
What is driving the large increase in 2020?
2020 Annual Increase Relative to the Global Mean Annual Increase

TROPOMI Relative Annual Increase in 2020



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

TOMCAT Relative Annual Increase in 2020

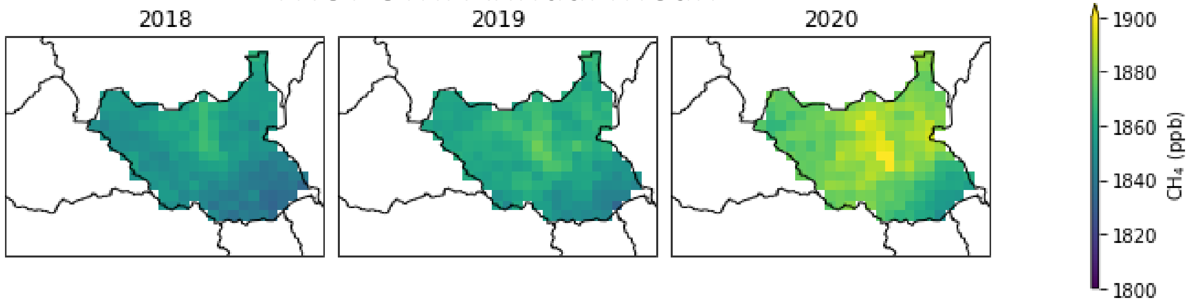


- TOMCAT does not capture large increases in Africa & western Canada
- TOMCAT captures increase over Russia but it is not as large as TROPOMI

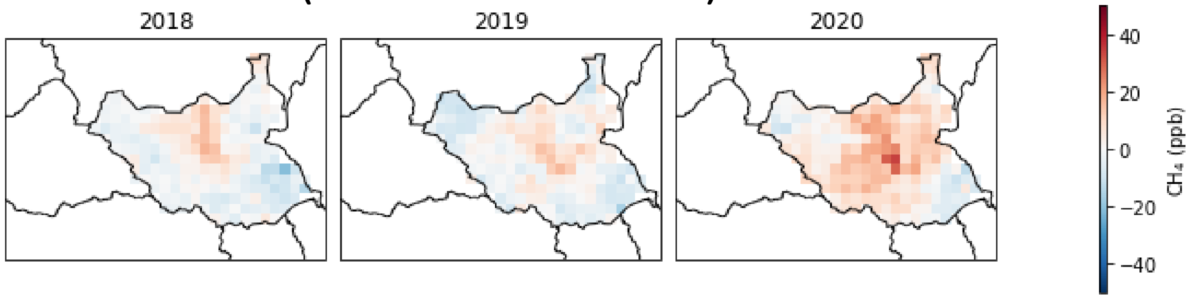
South Sudan

- TROPOMI shows large increases in CH_4 September, October & November (SON) in 2019 and 2020
- Annual peaks in TOMCAT are earlier than TROPOMI
- Pandey et al. (2020) and Parker et al. (2020) find that WetCharts does not capture Sudd seasonal cycle
- 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

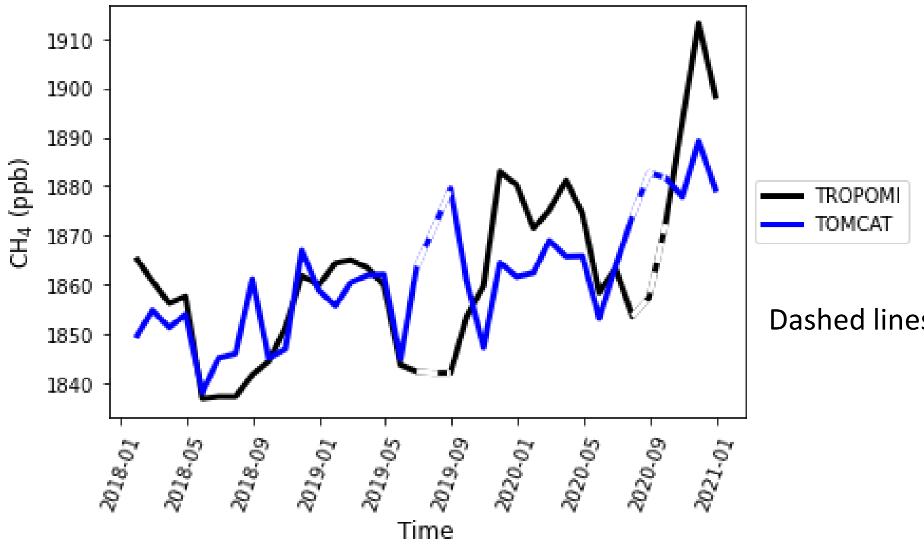
TROPOMI Annual Mean



Difference Between TROPOMI & TOMCAT (TROPOMI – TOMCAT)



Monthly Mean XCH_4 - South Sudan

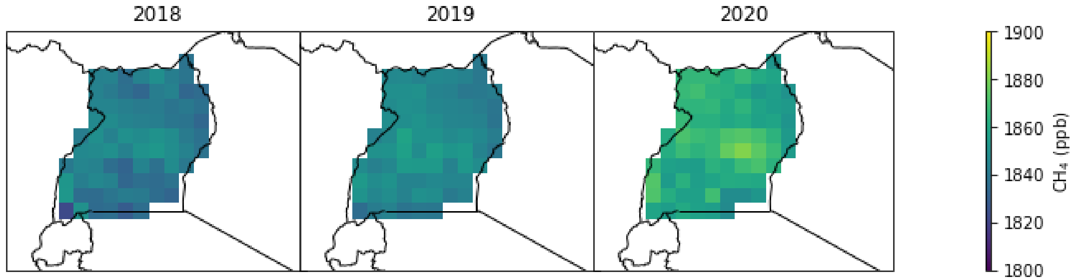


Dashed lines = less coverage

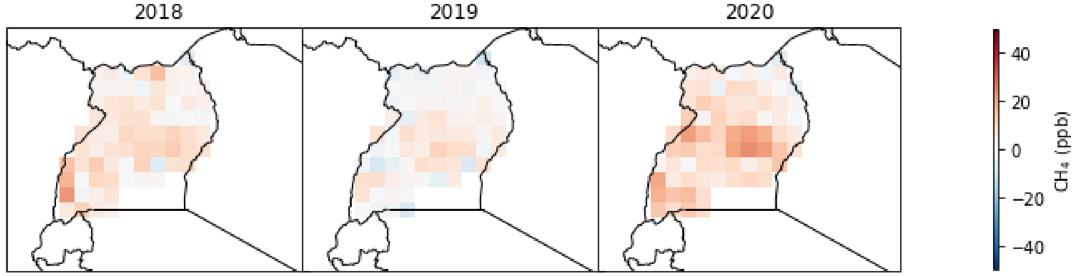
Uganda

- TROPOMI shows large increases in CH_4 between November-January, with largest increase in 2020
- TROPOMI & TOMCAT follow the same seasonal cycle
- TOMCAT annual peaks are too low in 2019 and 2020
- Lunt et al. (2021) found a positive precipitation anomalies OND 2019
- High release rates from dam controlling Lake Victoria outflow in 2020

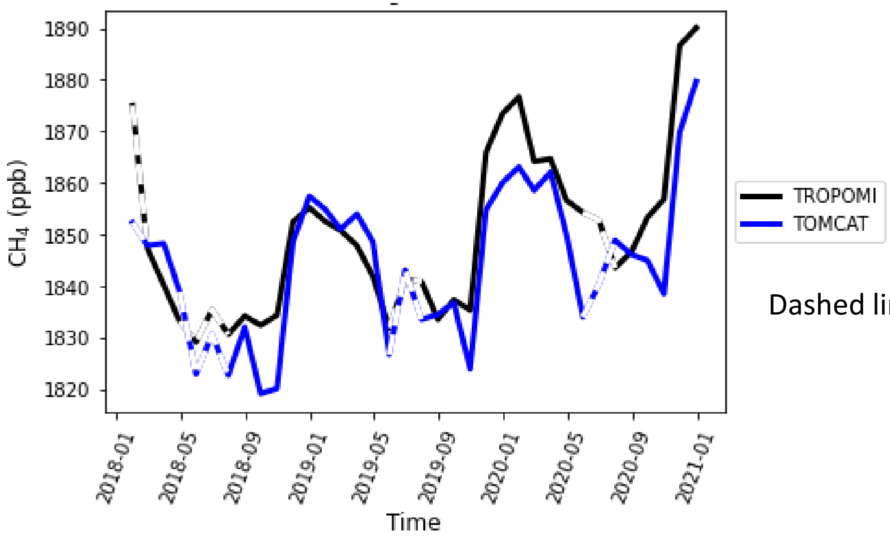
TROPOMI Annual Mean



Difference Between TROPOMI & TOMCAT (TROPOMI – TOMCAT)



Monthly Mean XCH_4 - Uganda



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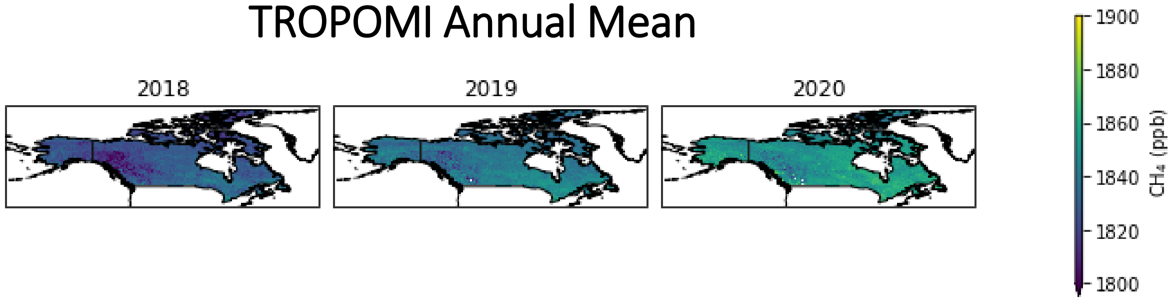
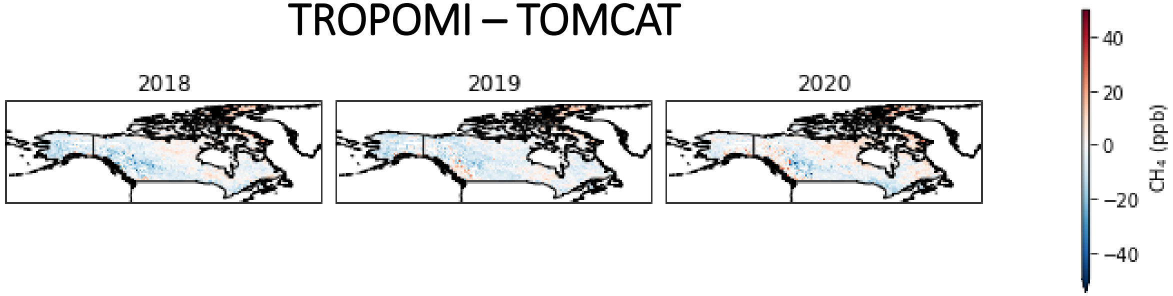
Canada & Alaska

- Higher concentrations in the east where more wetlands are situated
- TOMCAT captures CH_4 well when compares 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

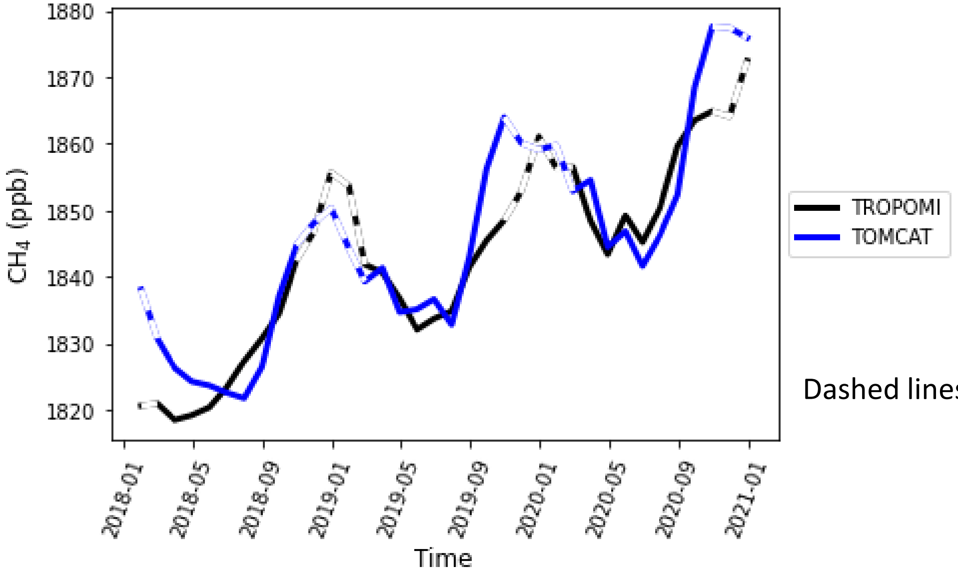
TROPOMI Annual Mean



TROPOMI – TOMCAT



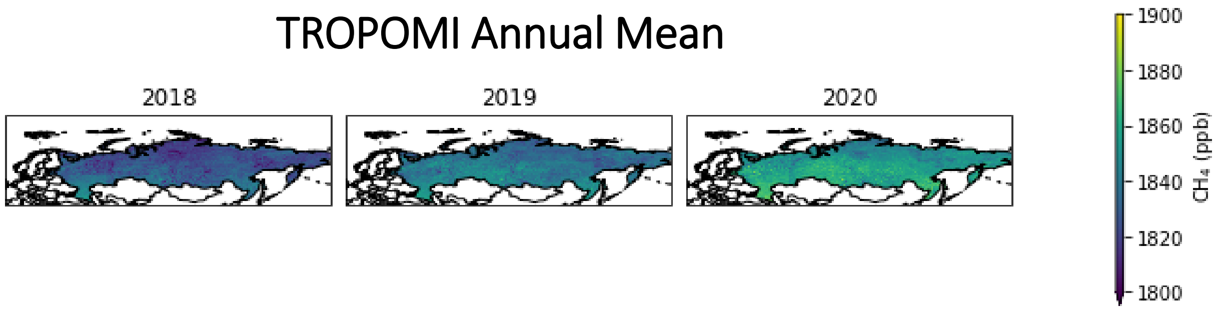
Monthly Mean XCH_4 – Canada & Alaska

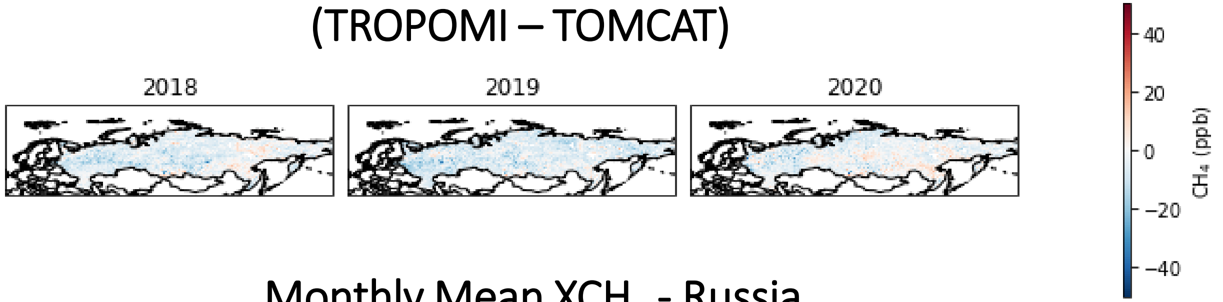


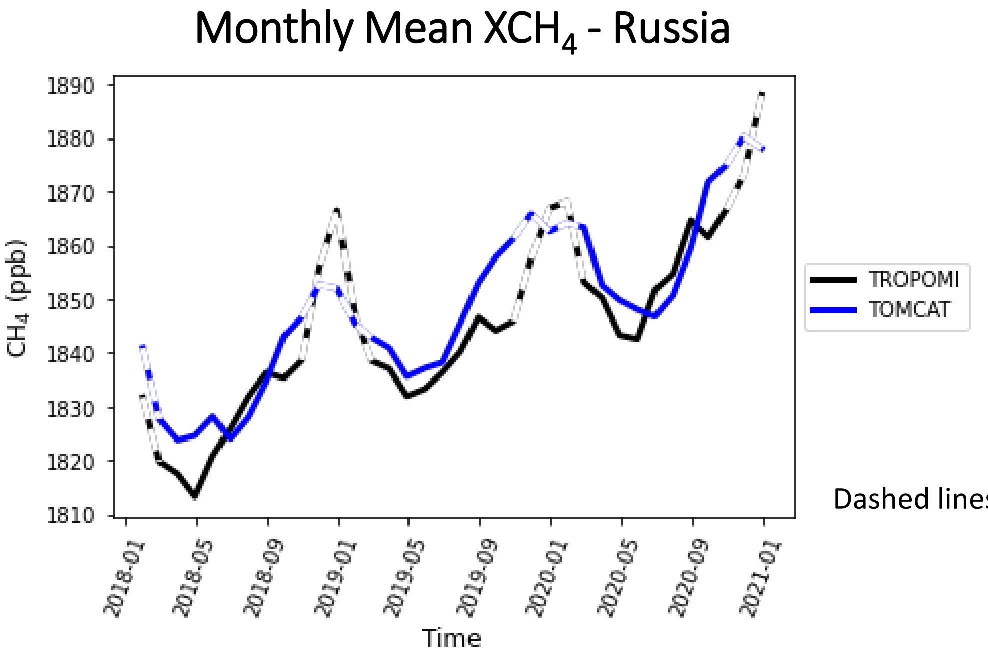
Dashed lines = less coverage

Russia

- TOMCAT captures CH_4 variation but overestimates
- 2019 and 2020 had large wildfire seasons
- Cherepanova et al. (2020) found using TROPOMI and MODIS burnt area that wildfires in previous years could be contributing to increased methane in subsequent years







Dashed lines = less coverage

Summary

- Large global annual increased in 2020 shown by NOAA surface observations (15.27 pbb), TROPOMI (14.87 ppb) and TOMCAT (15.79 ppb)
- 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 does not capture large concentrations in 2020 over South Sudan and has mismatched seasonal cycle
- From the selected areas it seems wetlands are a large contributor to the increase in CH_4 during 2020

Next Steps

- Compare TROPOMI with TOMCAT using GOSAT inversions – better top down emissions
- Develop a nested grid model for TOMCAT in order to do high resolution comparisons with TROPOMI

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Back Up Slides -What is driving the large increase in 2020?

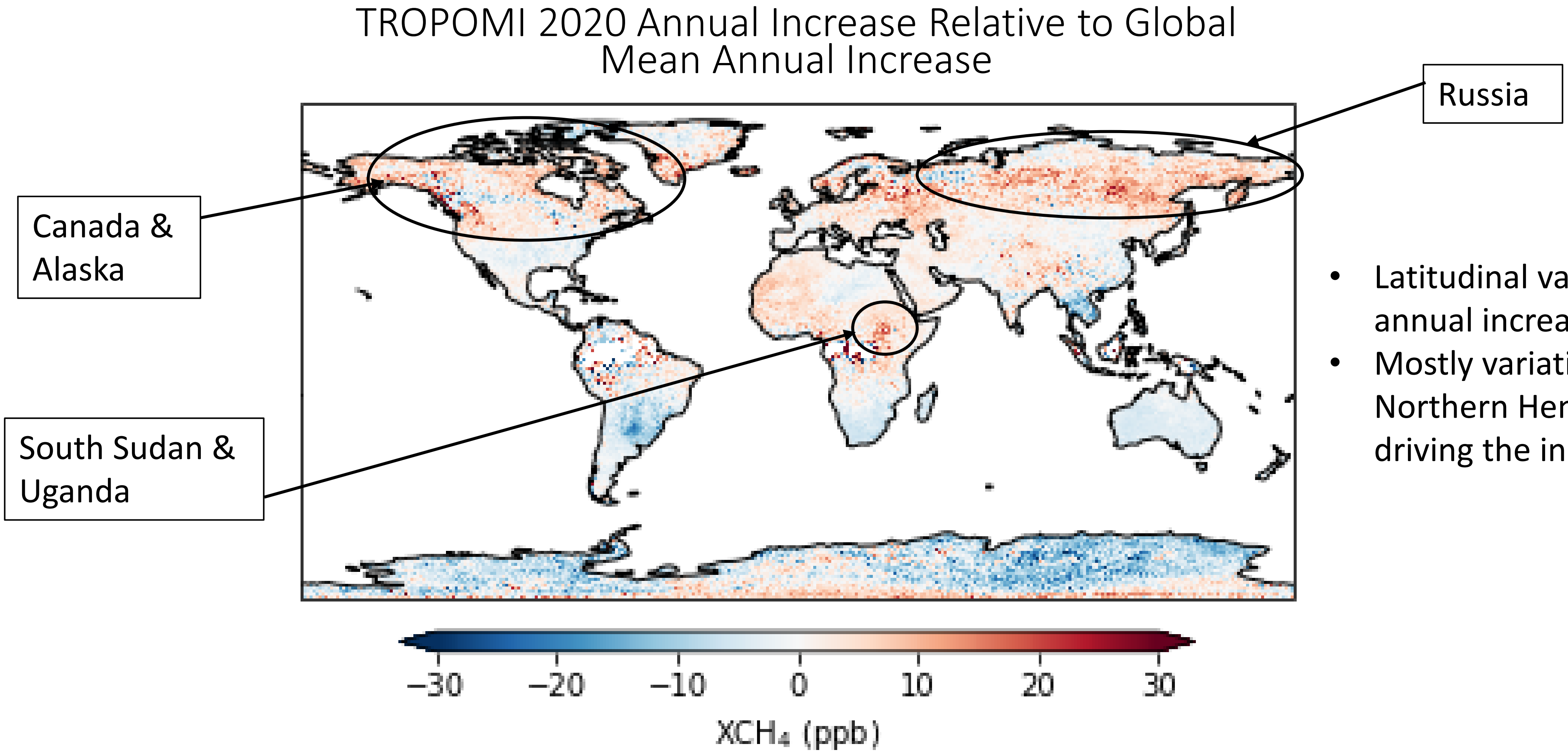


Figure: Annual increase in CH_4 in 2020 relative to the global mean annual increase in 2020

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

Back Up Slides – TOMCAT Global Mean Bias Correction

TROPOMI – TOMCAT (Global Mean Bias Removed)

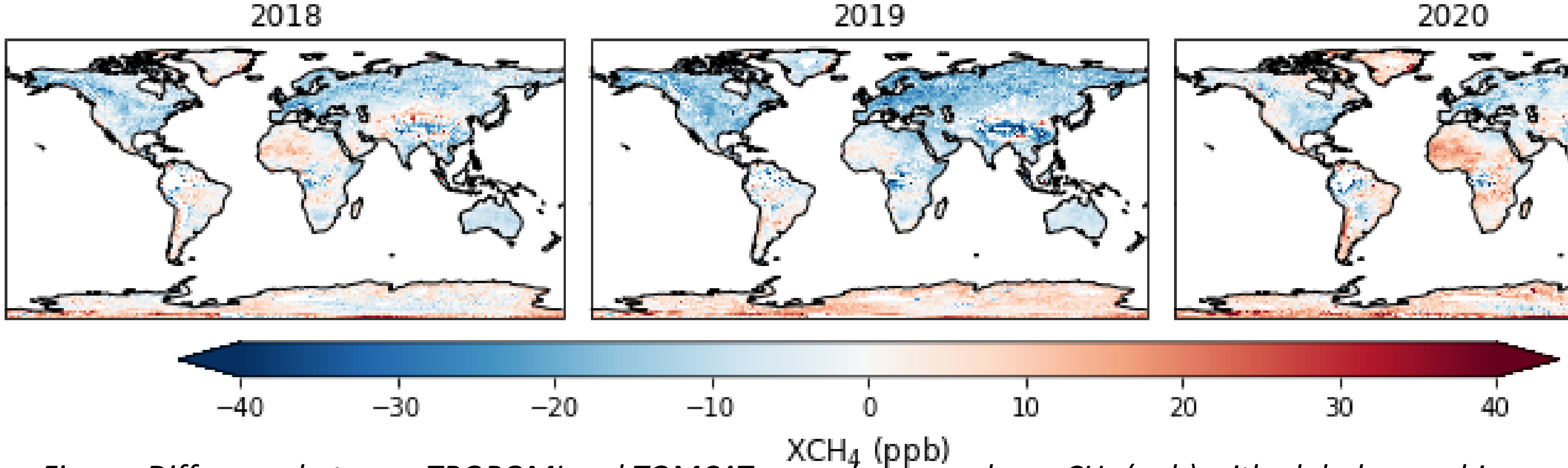
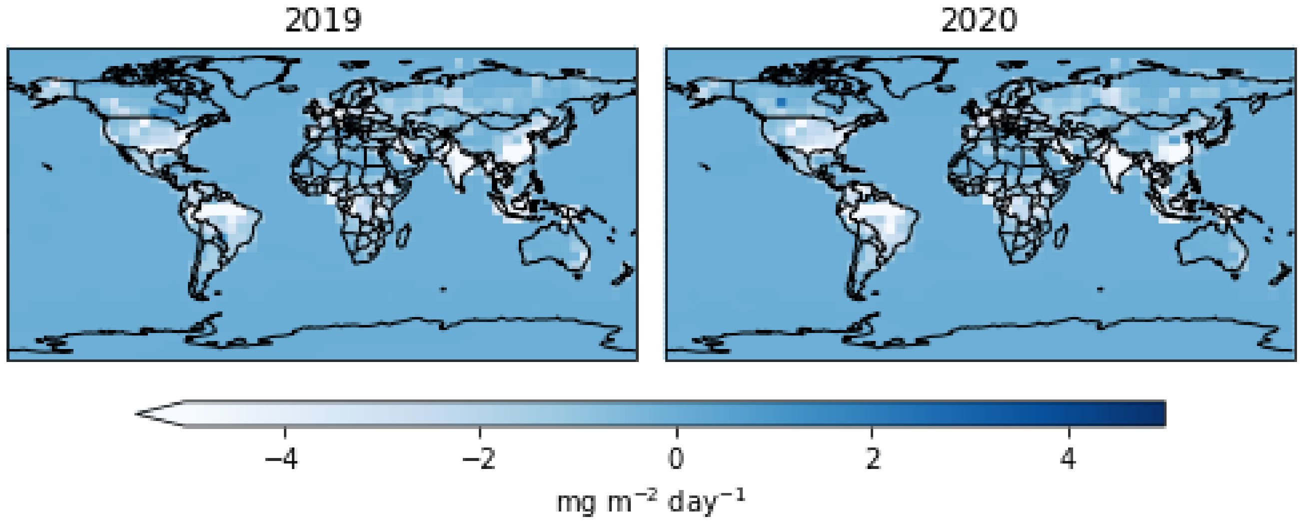


Figure: Difference between TROPOMI and TOMCAT annual mean column CH_4 (ppb) with global mean bias removed from TOMCAT.

- Global mean bias subtracted from TOMCAT
- TOMCAT overestimates in large parts of the Northern Hemisphere (NH)
- TOMCAT underestimates more in in NH, particularly over Africa and China in 2020
- Shows a latitudinal bias

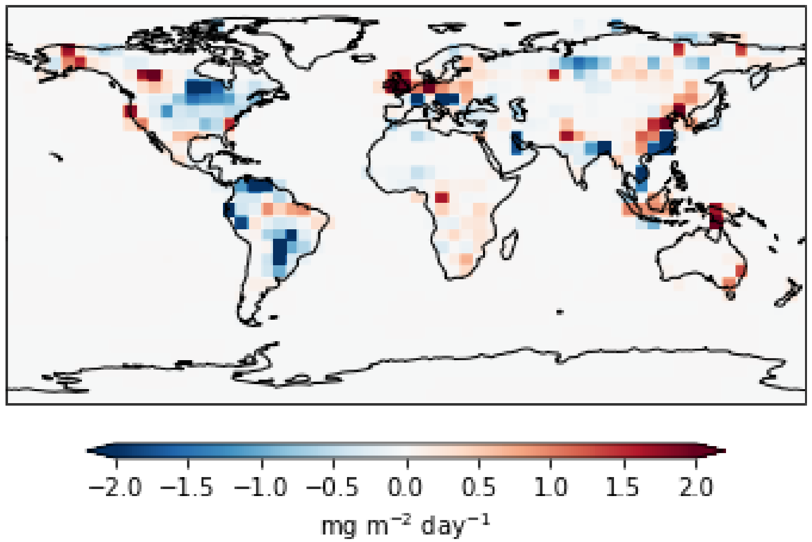
Back Up Slides - Emissions

Emission Used in TOMCAT



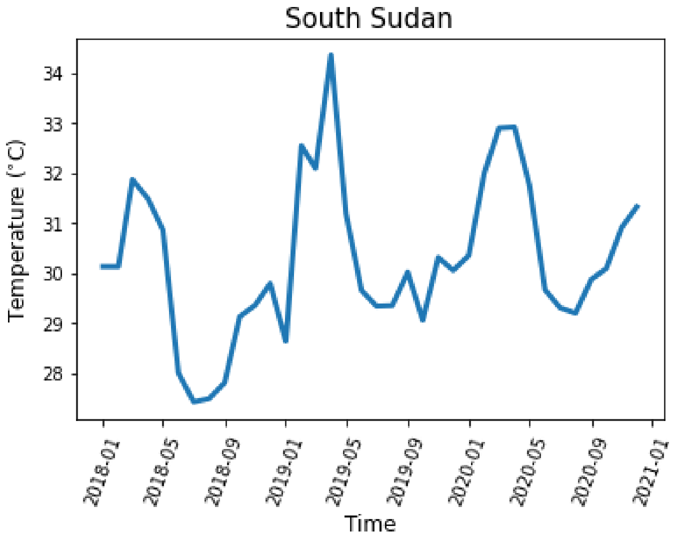
- Inversion of surface observation sites does not capture high emissions of South Sudan and Uganda.

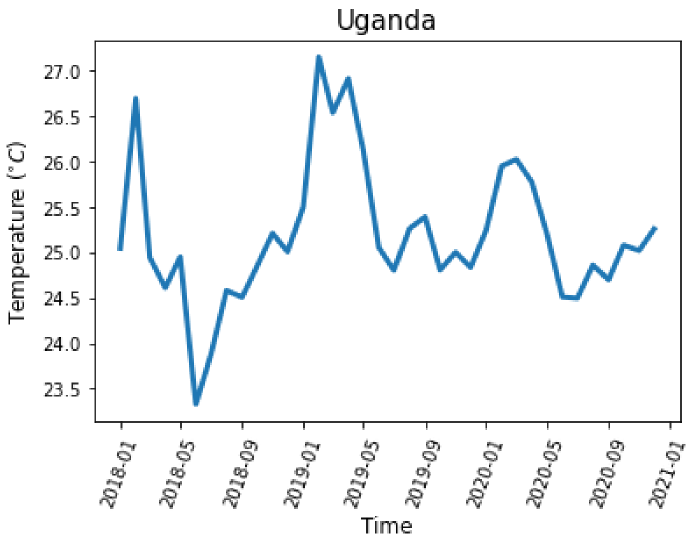
2020 annual increase relative to global annual increase

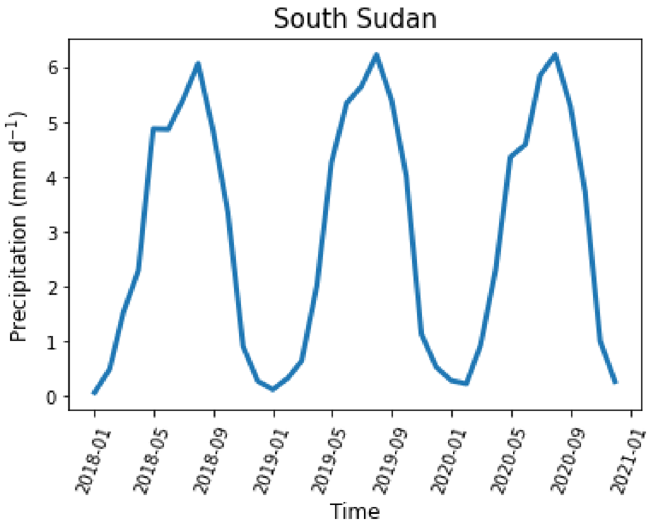


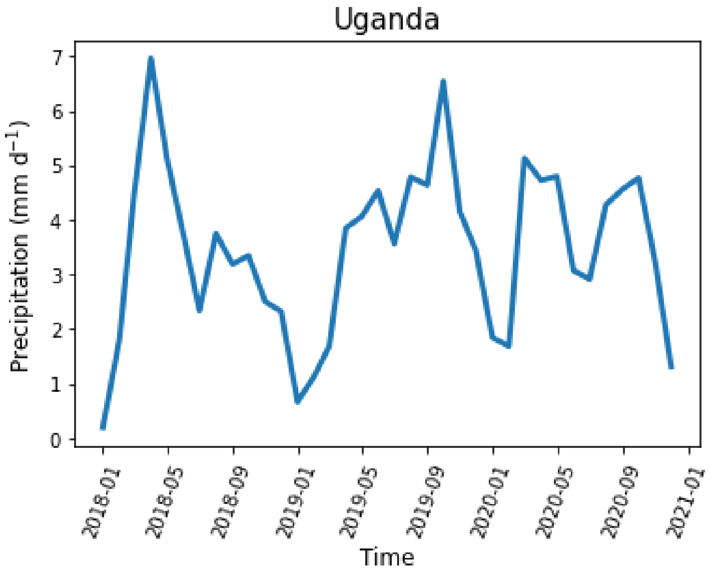
- Emissions don’t capture large methane emissions over Africa

Back Up Slides – Temperature & Precipitation

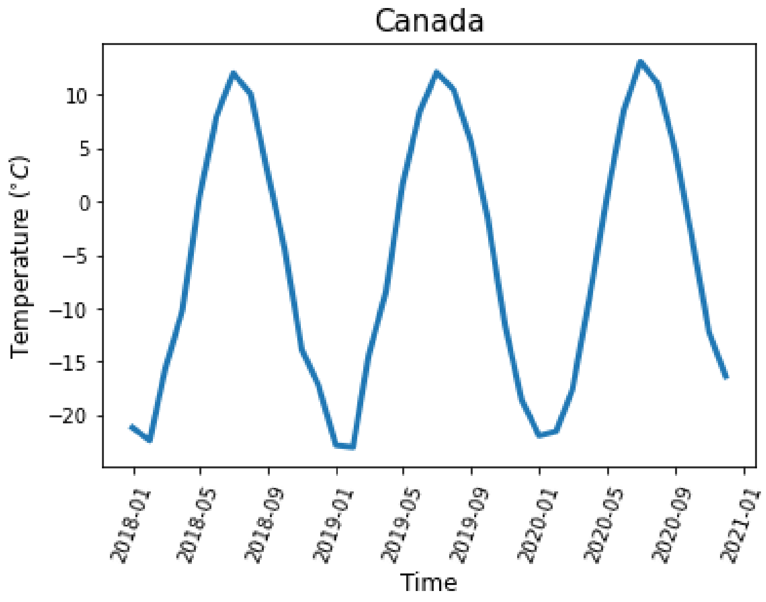


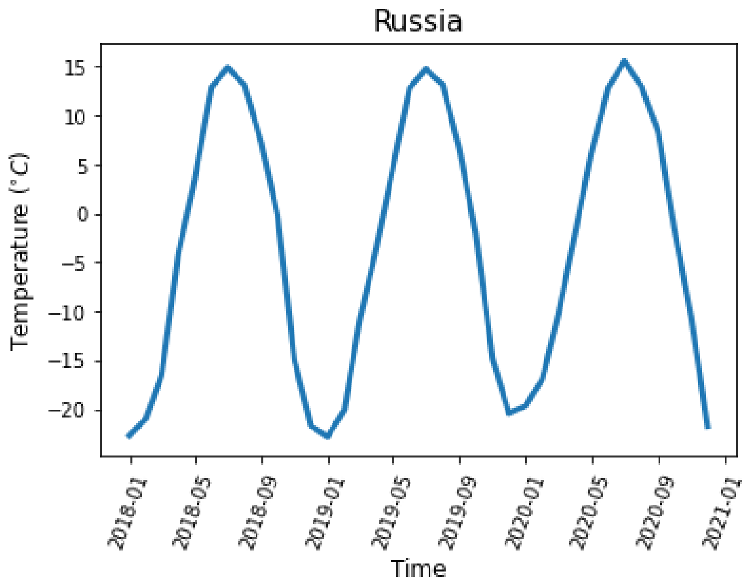


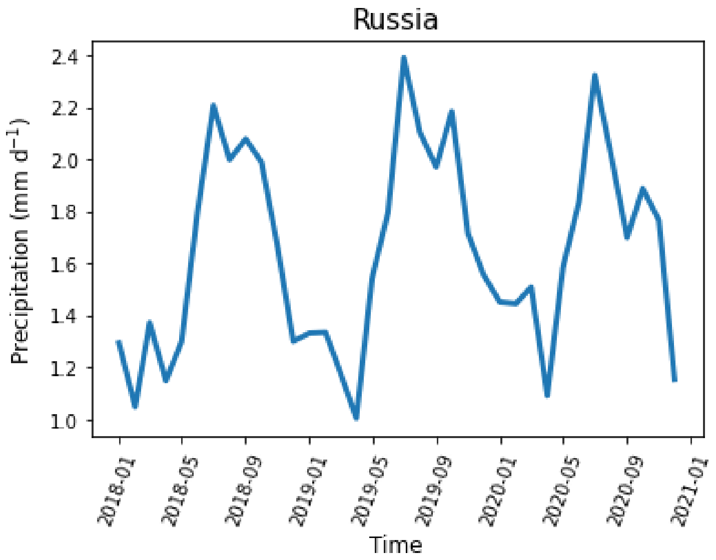




Back Up Slides – Temperature & Precipitation







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