Detection of locally elevated methane concentrations by analyzing Sentinel-5 Precursor satellite data

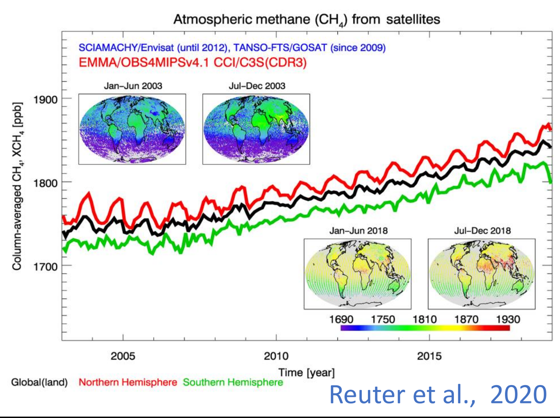
Universität Bremen

S. Vanselow[1], O. Schneising[1], M. Buchwitz[1], H. Bovensmann[1], J. P. Burrows[1]

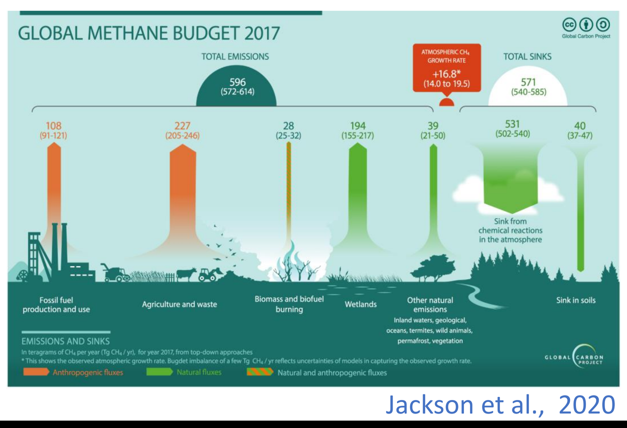
(1) Institute of Environmental Physics (IUP), University of Bremen, Germany
Email: vanselow@physik.iup.uni-bremen.de

1. Introduction

- Methane (CH_4) is an important greenhouse gas which is emitted by many anthropogenic and natural sources
- Many methane sources have large uncertainties or are unknown and therefore need to be detected and quantified
- Sentinel-5 Precursor (S5P) with the TROPOspheric Monitoring Instrument (TROPOMI) onboard provides XCH_4 (=column-averaged methane mole fractions) with high spatial (7 × 7 km²) and temporal (daily) resolution
- We developed an algorithm which uses the S5P data to automatically detect areas with temporally stable strongly elevated methane concentrations



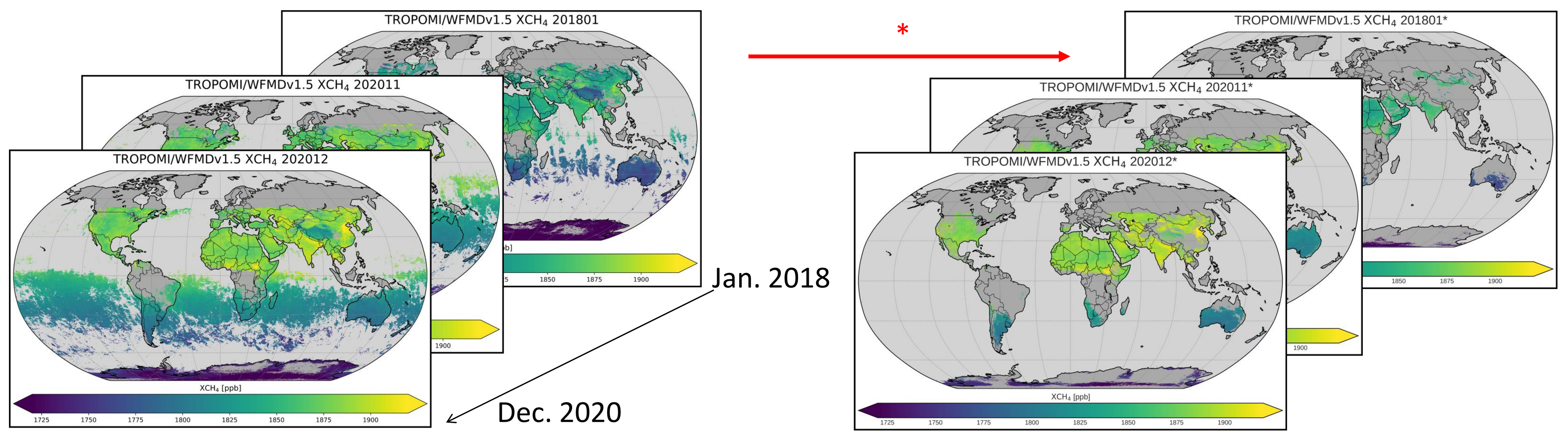
Reuter et al., 2020



Jackson et al., 2020

2. Dataset

- Latest version (1.5) of the XCH_4^* Data product of the WFM-DOAS retrieval algorithm (Schneising et al., 2019)
- Monthly XCH_4 data (2018 - 2020) on latitude longitude grid with 0.1° x 0.1° resolution
- Preparation of the Dataset (filtered data denoted with *):
  - Only consider grid boxes with monthly XCH_4 values calculated from 6 or more days
  - Elevation correction to account for XCH_4 variations due to variations of surface elevation (Buchwitz et al., 2017)
  - Ignore grid boxes with surface roughness over 80m



3. Hotspot detection

Step 1: Calculation of local methane anomalies ΔXCH_4^*

- Large-scale methane fluctuations (such as the hemispherical gradient) must be eliminated to analyze local methane enhancements
- Apply spatial high-pass filter to calculate methane anomalies ΔXCH_4^* from absolute XCH_4^* values

High-pass filter applied to every grid box:

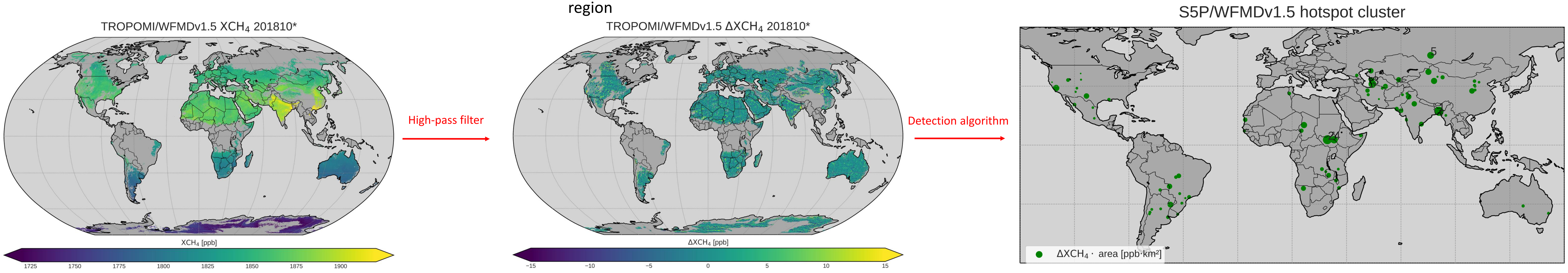
- Define area around gridpoint (e.g. 3° × 3°)
- Area must have at least 33% grid boxes with measurements
- Define background of the area by applying a threshold model
- ΔXCH_4^* of grid box $= XCH_4^*$ of grid box – median of background

Step 2: Identifying areas with temporally stable elevated ΔXCH_4^*

- Analysis of the monthly maps of methane anomalies to identify areas with temporally stable methane enhancements by defining "possible hotspot areas" around every grid box (e.g. . 0.5° × 0.5°)
- If these areas contain grid boxes with methane anomalies above a defined threshold value (e.g. 20ppb) in a certain number of months, they will be marked as hotspot regions
- To determine the whole extent of a hotspot region, a segmentation algorithm is applied which merges overlapping hotspot regions and considers grid boxes with methane anomalies below the threshold that also belong to the hotspot region

Step 3: Quantification of detected areas

- Quantification of detected areas by calculation of their properties such as area size, methane enhancement $\Delta XCH_4^*$and strength, which is defined as product of the area and ΔXCH_4^*. To calculate the monthly ΔXCH_4^* of a hotspot region, a surrounding area is defined as background: ΔXCH_4^*= mean(XCH_4^* of hotspot region) – mean(XCH_4^* of background)
- In detected areas: check supporting data like albedo and polynomial parameter to identify potential false positives
- Assignment of detected areas to possible anthropogenic emission sources due to comparison with databases for methane emissions related to fossil fuels, enteric fermentation and rice cultivation (EDGAR v5.0, Crippa et al., 2021 and Scarpelli et al., 2020)



4. First results

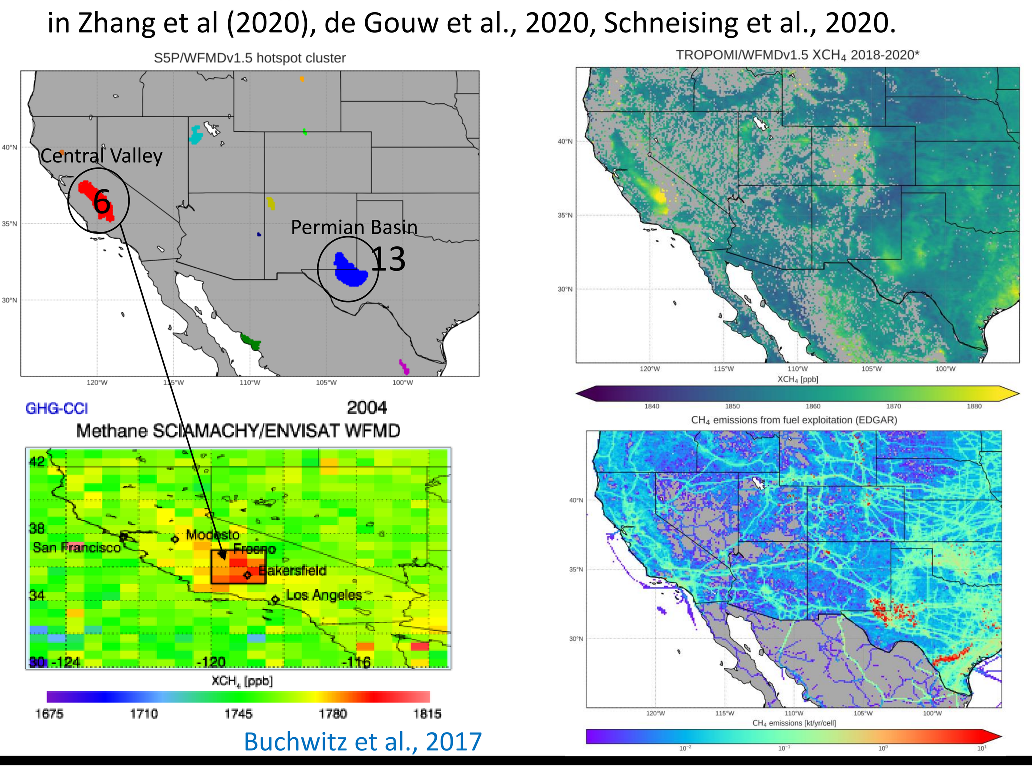
Strongest detected S5P hotspot cluster for one parameter setup:

S5P Cluster	Area [10³ km²]	ΔXCH_4^m [ppb][1]	Months measured[2]	Scarpelli [kt/yr]	EDGAR [kt/yr]
1 Bangladesh	63.7	16.3	14	34	306
2 South Sudan	156.9	10.1	17	38	0
3 Turkmenistan (Balkan)	30.5	16.2	33	658	521
4 South Sudan	81.7	9.2	14	0	0
5 Russia (Kuzbass)	31.7	12.2	11	1161	1637
6 USA (Central Valley)	25.4	11.5	23	74	10
…	…	…	…	…	…
13 USA (Permian)	28.1	7.7	35	159	1120
…	…	…	…	…	…
18 Turkmenistan (Galkynysh/Dauletabad)	41.7	5.4	35	135	160
…	…	…	…	…	…

[1] XCH_4^m is the mean value of all monthly methane enhancements ΔXCH_4^* in the specific hotspot region
[2] Months measured are months in which 33% of all grid boxes in the hotspot and background region contain XCH_4^* values

6 USA

- Central Valley: gas and oil production and livestock, e.g., discussed in Buchwitz et al., 2017
- Permian Basin: large area of oil and natural gas production, e.g., discussed in Zhang et al (2020), de Gouw et al., 2020, Schneising et al., 2020.

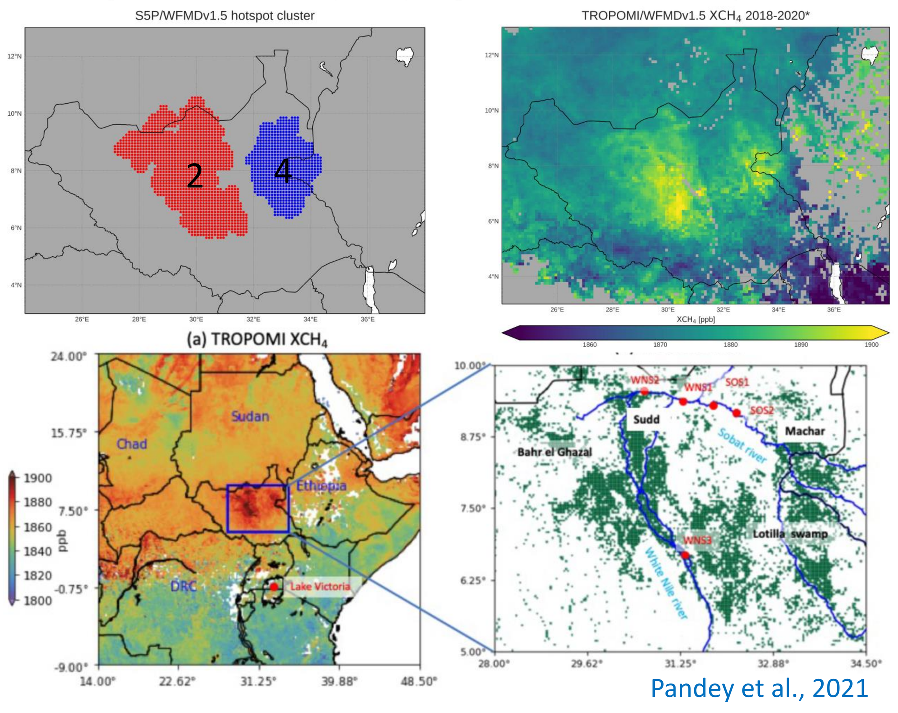


Buchwitz et al., 2017

Some detected areas are subject in several studies:

2 & 4 South Sudan

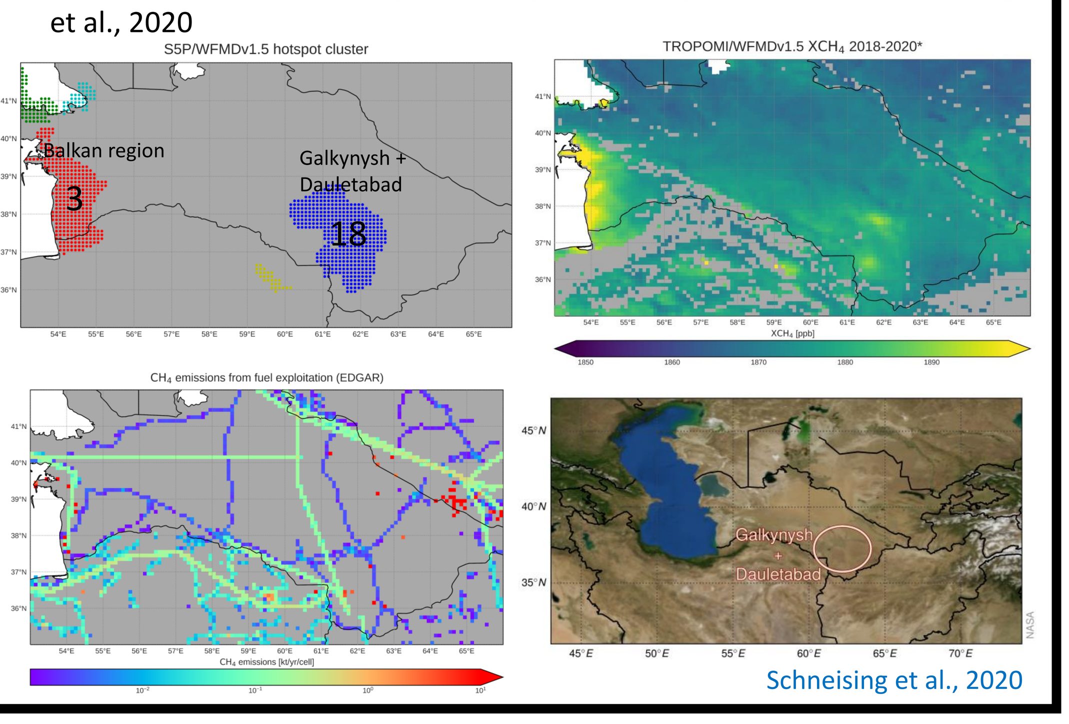
- Large wetland areas (Sudd), e.g., discussed in Pandey et al., 2021



Pandey et al., 2021

3 Turkmenistan

- Westcoast: many gas and oil fields, e.g., discussed in Varon et al., 2019
- Galkynysh/Dauletabad: large natural gas fields, e.g., discussed in Schneising et al., 2020



Schneising et al., 2020

5. First conclusions

- We were able to identify areas with temporally stable methane enhancements in a global monthly data set based on the S5P satellite data by applying an automatic detection algorithm
- A Comparison of the detected S5P hotspot cluster with emission databases shows that several detected areas are regions with high anthropogenic methane emissions related to fossil fuel
- The detection algorithm has also the potential to identify unreported emission sources
- In addition, the algorithm may be helpful to identify local retrieval errors by correlation analyses of detected methane enhancements with other parameters such as albedo.
- In order to be able to assign the detected areas more precisely to the specific emission sources, further comparisons with other databases are planned (e.g. for wetland emissions)

6. References

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