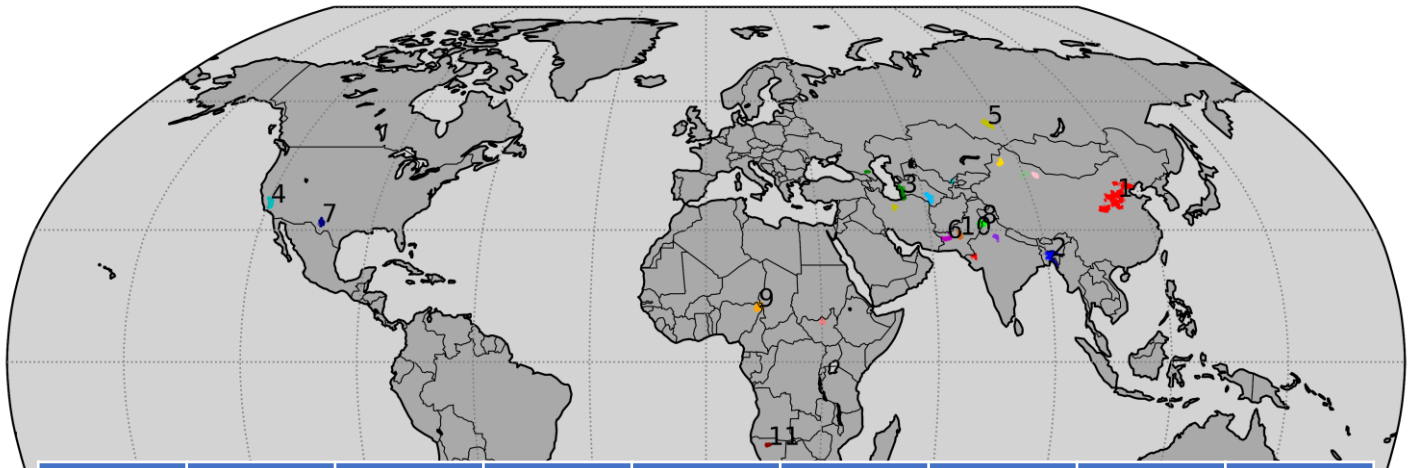
Detection of locally elevated methane concentrations by analyzing Sentinel-5 Precursor satellite data

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, 28334 Bremen, Germany

- 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

S5P/WFMDv1.5 hotspot cluster



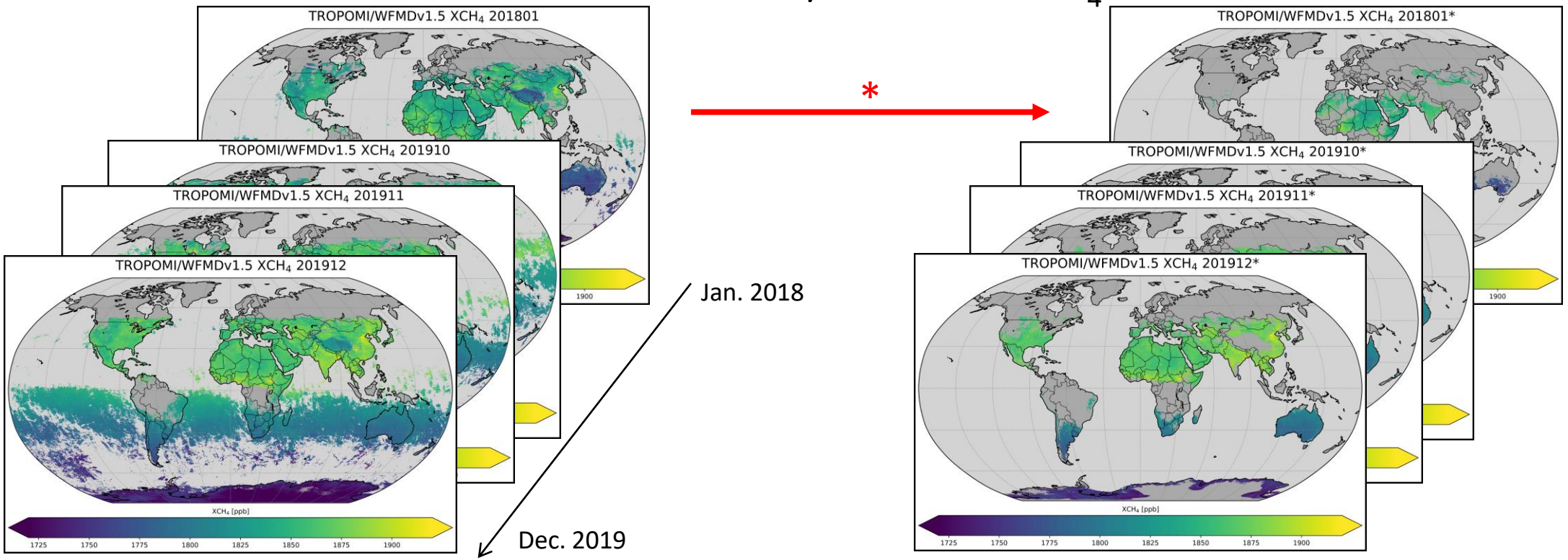
S5P Cluster	Strength= Area*ΔXCH_4	Area[km^2]	ΔXCH_4 [%]	ΔXCH_4 [ppb]	Months over limit	Months measured	Scarpelli [kt/yr]	EDGAR [kt/yr]
1	630	103803	0.60	11.18	10.02	22.83	14394	16028
2	242	33918	0.81	15.17	6.33	11.58	45	386
3	160	23594	0.66	12.26	15.60	22.59	673	613
…	…	…	…	…	…	…	…	…

- Sentinel-5 Precusor (S5P) provides XCH_4 (=column-averaged methane mole fractions) with high spatial (7 × 7 km^2) and temporal (daily) resolution
- We developed an algorithm which uses the S5P data to automatically detect areas with temporally stable strongly elevated methane concentrations

Universität Bremen

Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany

Dataset: TROPOMI/WFMDv1.5 XCH_4



- Latest version (1.5) of the XCH_4 Data product of the WFM-DOAS retrieval algorithm (Schneising et al., 2019)
- Monthly XCH_4 data (2018/2019) on latitude longitude grid with 0.1° x 0.1° resolution

Atmos. Meas. Tech., 12, 6771–6802, 2019
https://doi.org/10.5194/amt-12-6771-2019

Atmospheric Measurement Techniques
EGU

Schneising et al., 2019

A scientific algorithm to simultaneously retrieve carbon monoxide and methane from TROPOMI onboard Sentinel-5 Precursor

Oliver Schneising[1], Michael Buchwitz[1], Maximilian Reuter[1], Heinrich Bovensmann[1], John P. Burrows[1], Tobias Borsdorff[2], Nicholas M. Deutscher[3], Dietrich G. Feist[4,5,6], David W. T. Griffith[3], Frank Hase[7], Christian Hermans[8], Laura T. Iraci[9], Rigel Kivi[10], Jochen Landgraf[2], Isamu Morino[11], Justus Notholt[1], Christof Petri[1], David F. Pollard[12], Sébastien Roche[13], Kei Shiomi[14], Kimberly Strong[13], Ralf Sussmann[15], Voltaire A. Velazco[3], Thorsten Warneke[1], and Debra Wunch[13]

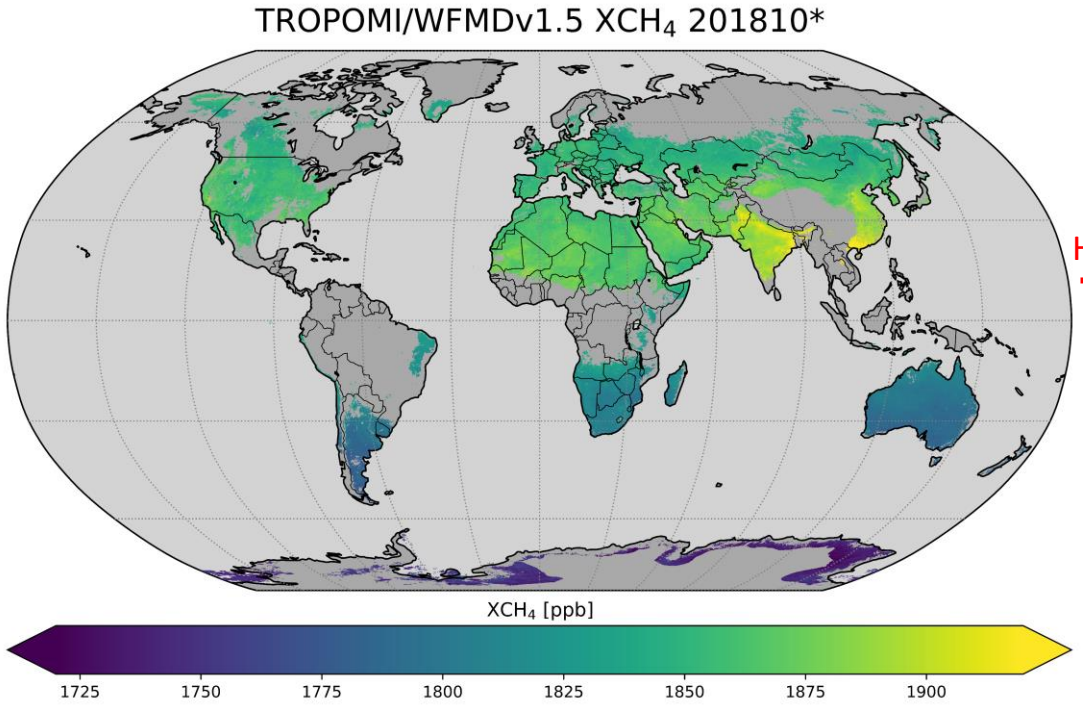
Preparation of the Dataset (*):

- Only consider gridpoints 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)

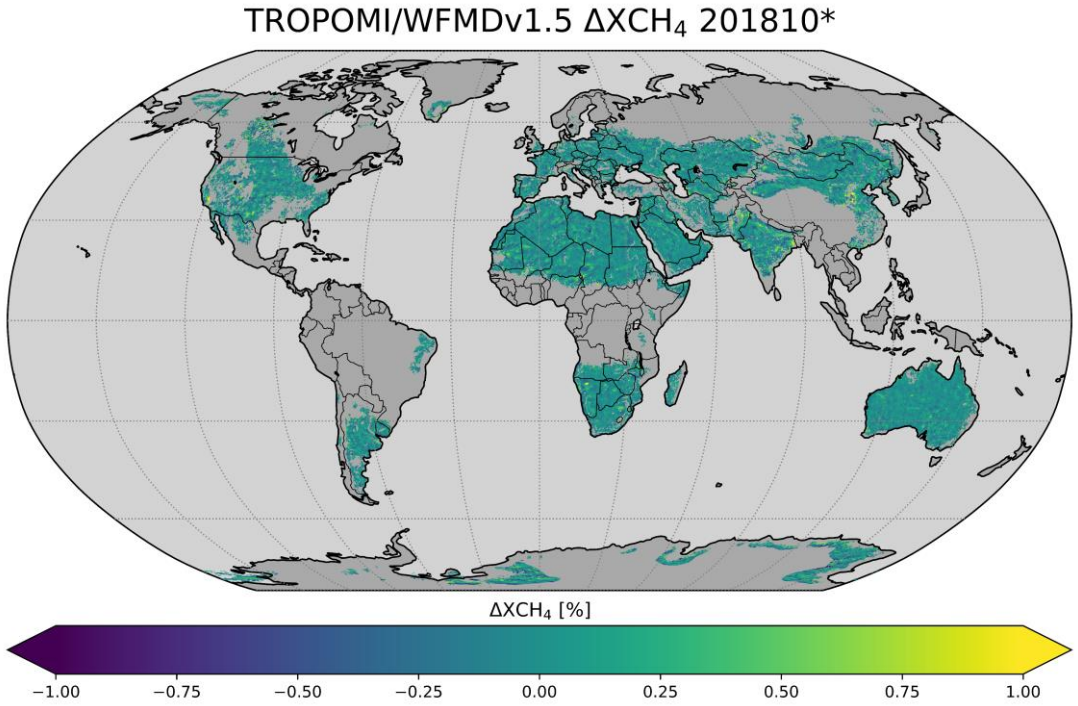
Universität Bremen
iup

Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany

Hotspot detection step 1: Calculation of local methane anomalies ΔXCH_4



High-pass filter



- 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

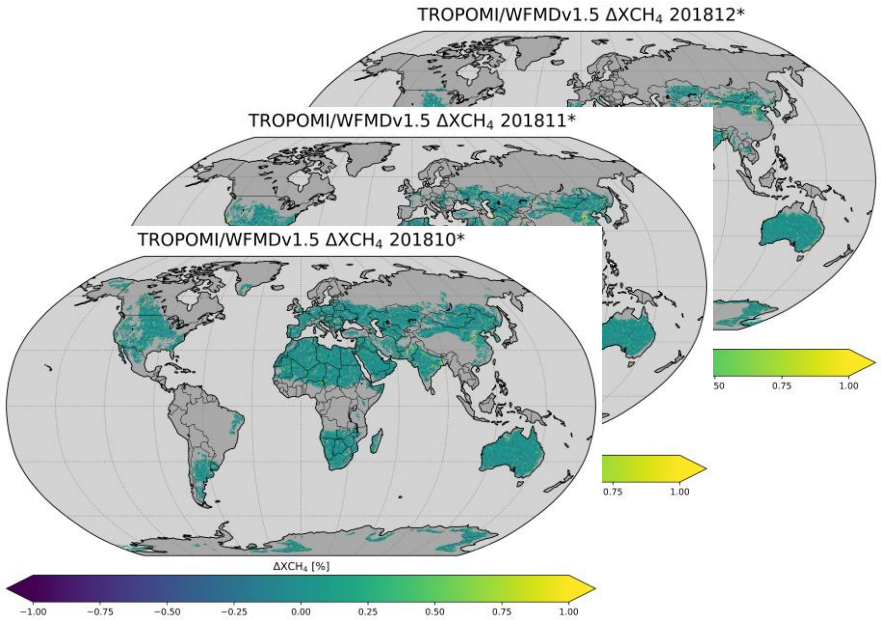
High-pass filter applied to every gridpoint:

- Define area around gridpoint (e.g. 2° × 2°)
- Area must have at least 33% gridpoints with measurements
- Define background of the area as the gridpoints with XCH_4 less than the 95th percentile of the XCH_4 values
- Calculate median of background
- Calculate anomaly ΔXCH_4 of gridpoint:
  ΔXCH_4 = XCH_4 of gridpoint – median of XCH_4 of background

Universität Bremen

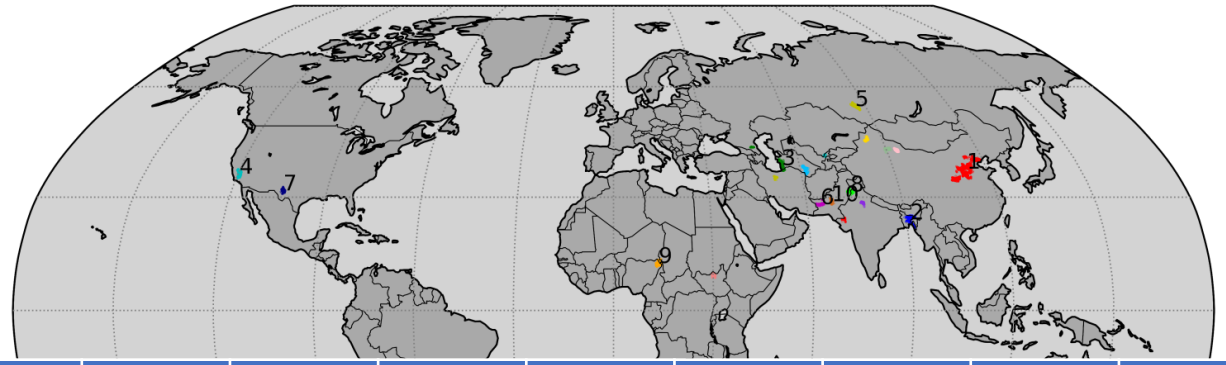
Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany

Hotspot detection step 2: Identifying areas with temporally stable elevated ΔXCH_4



Detection algorithm

S5P/WFMDv1.5 hotspot cluster



S5P Cluster	Strength= Area*ΔXCH_4	Area[km²]	ΔXCH_4 [%]	ΔXCH_4 [ppb]	Months over limit	Months measured	Scarpelli [kt/yr]	EDGAR [kt/yr]
1	630	103803	0.60	11.18	10.02	22.83	14394	16028
2	242	33918	0.81	15.17	6.33	11.58	45	386
3	160	23594	0.66	12.26	15.60	22.59	673	613
…	…	…	…	…	…	…	…	…

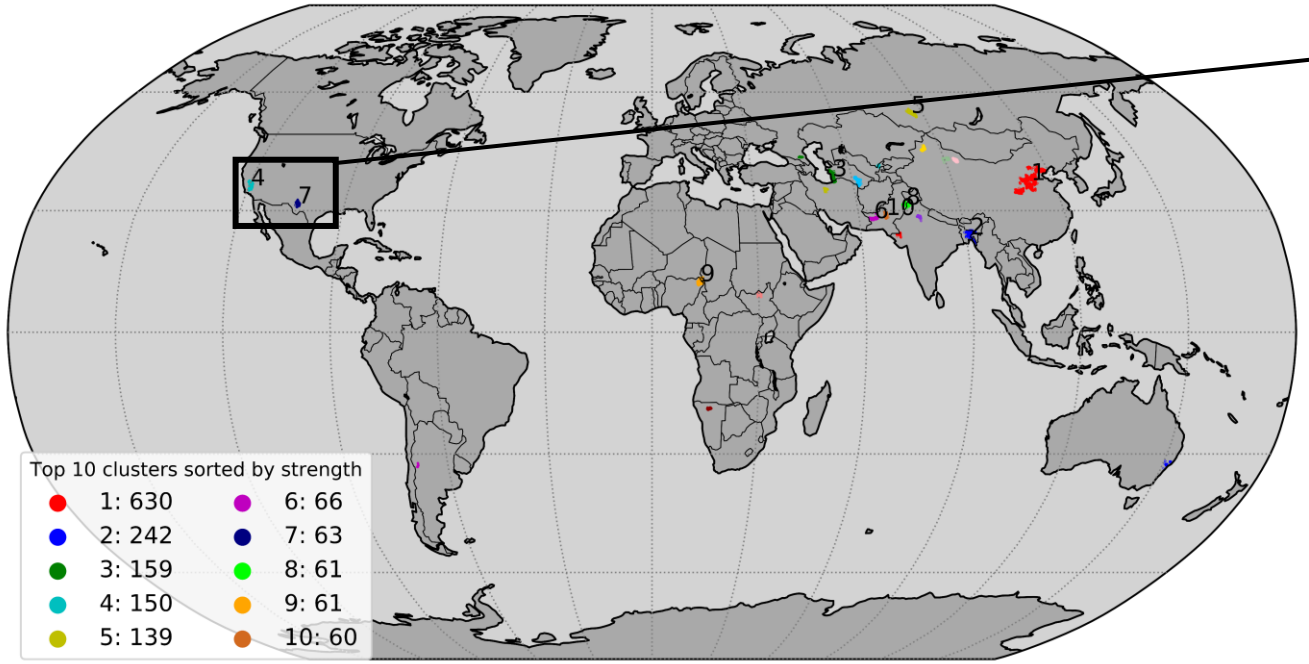
- Analysis of the monthly maps of methane anomalies to identify areas with temporally stable methane enhancements
- The associated algorithm depends on many (threshold) parameters, which affect, e.g.
  - How strong the ΔXCH_4 of the area should be at least
  - In how many months the methane enhancement should be present
  - How large the detected area should be

- Quantification of detected areas by calculation of their properties such as area size, averaged methane enhancement and strength
- Assignment of detected areas to possible anthropogenic emission sources due to comparison with databases for methane emissions related to fossil fuels (EDGAR v5.0, Crippa et al., 2021 and Scarpelli et al, 2020)

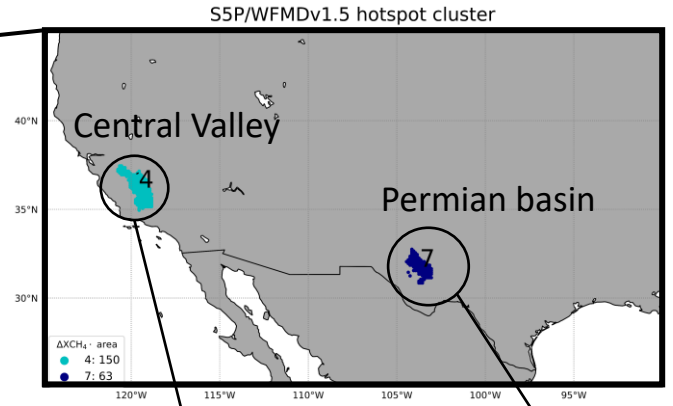
Universität Bremen
iup
Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany

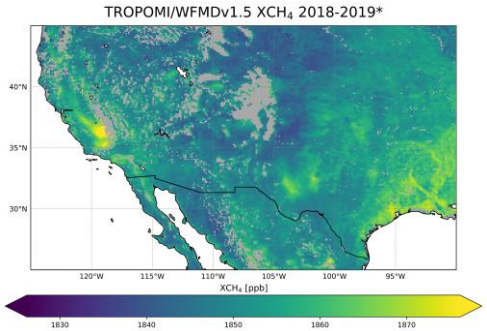
First results: Some detected areas are subject of several studies

S5P/WFMDv1.5 hotspot cluster

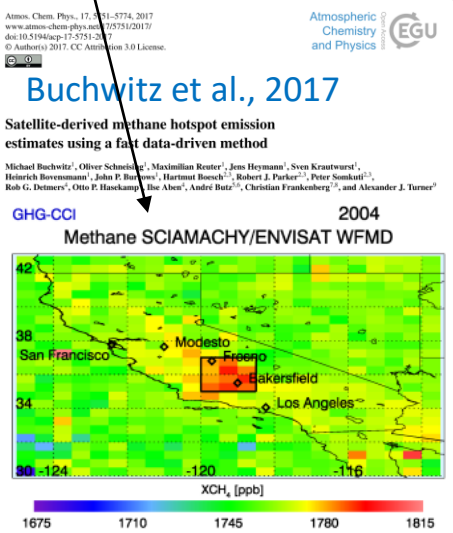


Southwestern USA

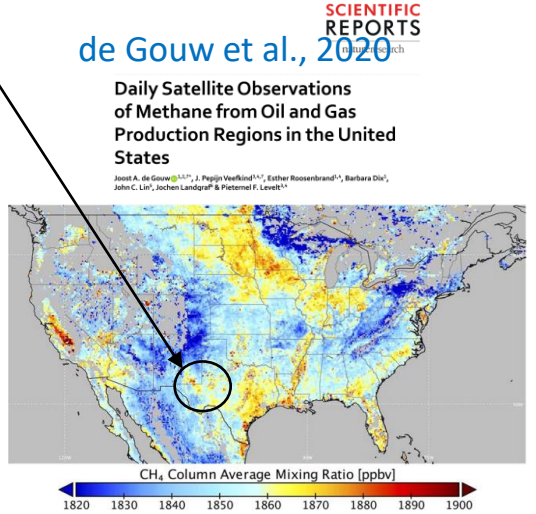




Buchwitz et al., 2017



de Gouw et al., 2020

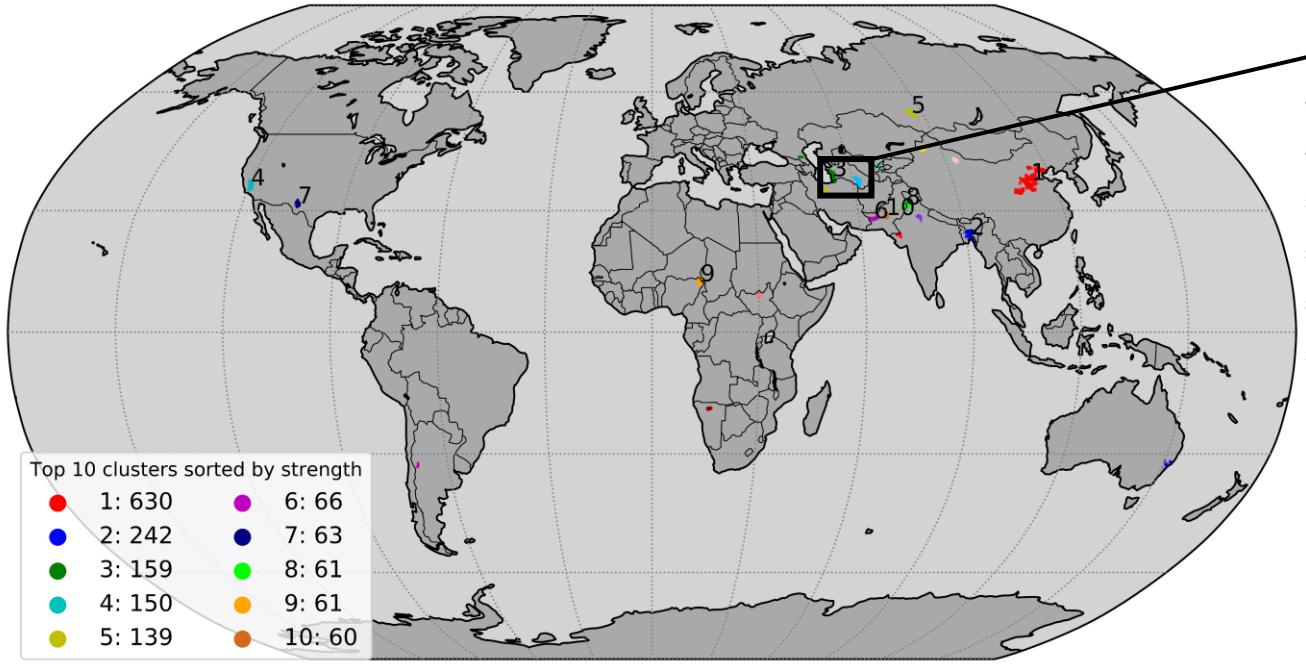


S5P Cluster	Strength= Area*ΔXCH	Area[km²]	ΔXCH_4 [%]	ΔXCH_4 [ppb]	Months over limit	Months measured	Scarpelli [kt/yr]	EDGAR [kt/yr]
4	150	22035	0.68	12.66	16.00	23.00	156	20
7	63	13446	0.49	9.17	9.57	23.23	293	1254

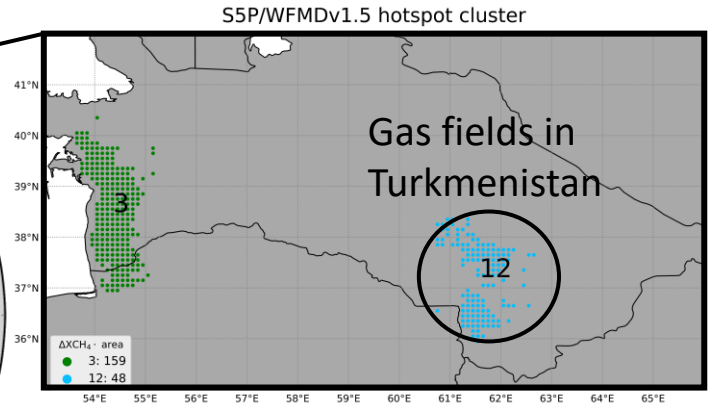
Universität Bremen
iup
Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany

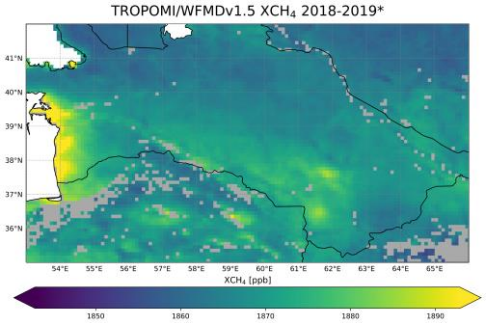
First results: Some detected areas are subject of several studies

S5P/WFMDv1.5 hotspot cluster



Turkmenistan





https://doi.org/10.5194/acp-2020-274
Preprint. Discussion started: 14 April 2020

Atmospheric Chemistry and Physics Discussions

Schneising et al., 2020

Remote sensing of methane leakage from natural gas and petroleum systems revisited

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

S5P Cluster	Strength= Area*ΔXC_4	Area[km²]	ΔXCH_4 [%]	ΔXCH_4 [ppb]	Months over limit	Months measured	Scarpelli [kt/yr]	EDGAR [kt/yr]
3	160	23594	0.66	12.26	15.60	22.59	673	613
12	48	13675	0.35	6.47	6.78	23.00	251	219

Universität Bremen
iup

Steffen Vanselow
Institute of Environmental Physics (IUP)
University of Bremen, Germany