EGU 2020, 4-8 May 2020, Session AS3.19: New (Sentinel-5 Precursor) and Evolving (e.g. Sentinel-4) Capabilities to Measure Atmospheric Composition from Space

Sentinel-5 Precursor methane and carbon monoxide column retrievals and assessments related to localized emission sources

Using S5P scientific WFM-DOAS retrievals

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

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Outline

- Essentially overview 3 recent publications covering
  - Retrieval algorithm, products, validation
  - Selected results, e.g.,
    - CO: Californian fires Nov 2018
    - CH_4: Emissions from major natural gas and petroleum production fields

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

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Atmospheric Measurement Techniques
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Schneising et al., AMT, 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]

Atmos. Chem. Phys., 20, 3317–3332, 2020
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2

Atmospheric Chemistry and Physics
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Schneising et al., ACP, 2020

Severe Californian wildfires in November 2018 observed from space: the carbon monoxide perspective

Oliver Schneising, Michael Buchwitz, Maximilian Reuter, Heinrich Bovensmann, and John P. Burrows
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3

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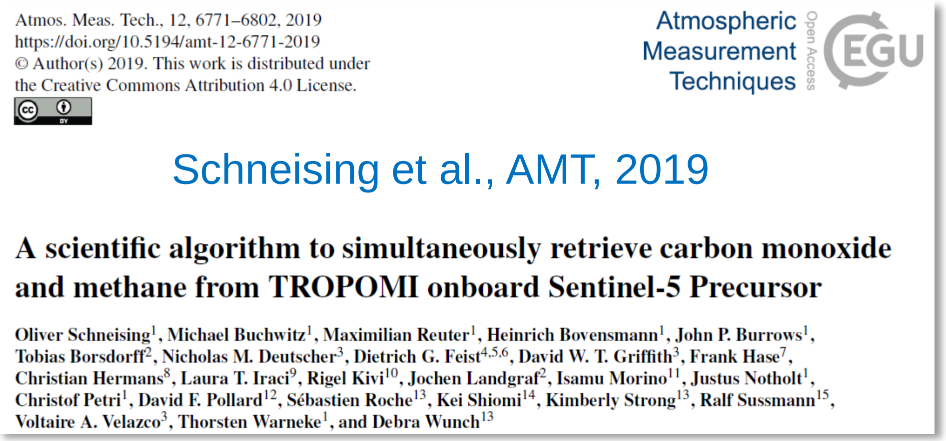
WFM-DOAS (or WFMD) algorithm for S5P



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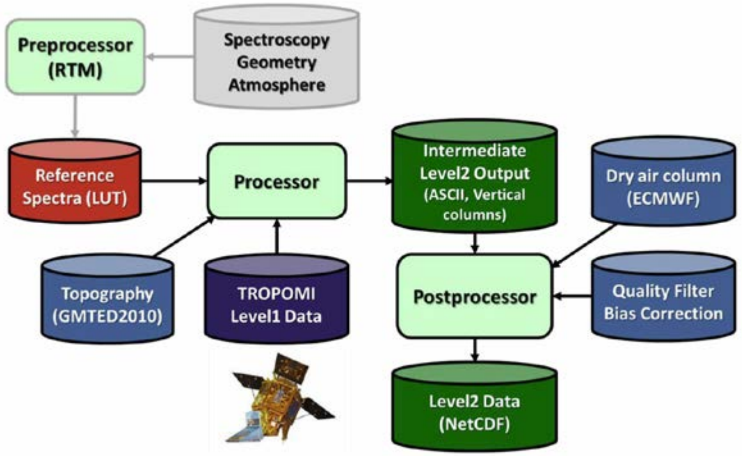
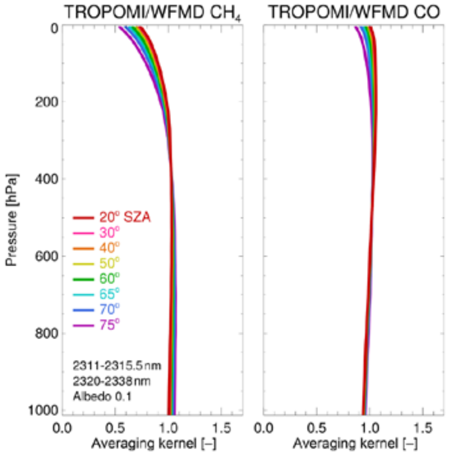
Data flow

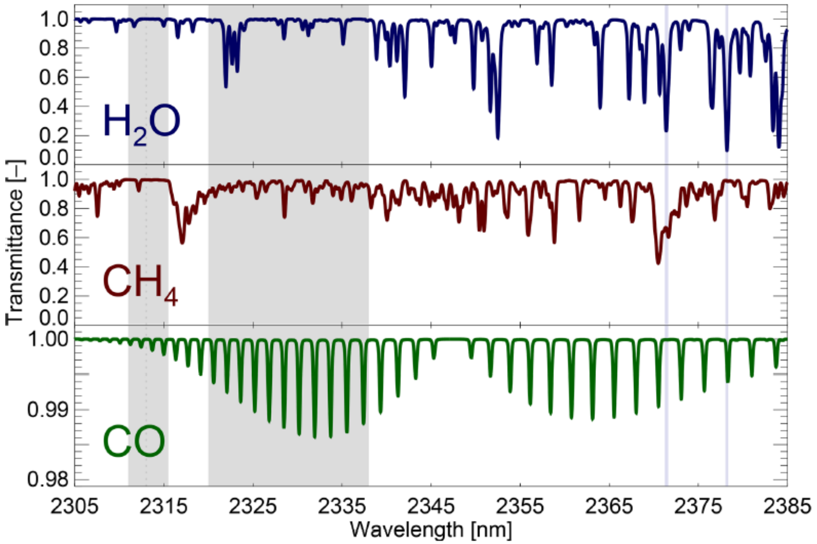


Averaging kernels



Fitting windows

Cloud info



Method:

- Least-squares fit of simulated radiances to S5P radiances
- Very fast Look-Up-Table (LUT) scheme
- Quality flagging (e.g., clouds) and bias correction (only for methane) via Machine Learning (Random Forest; VIIRS for clouds; climatology for methane)

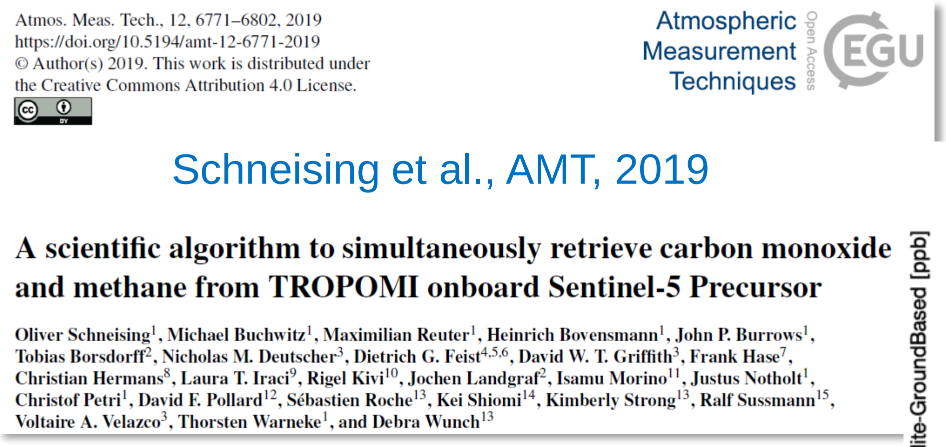
Products:

- CO columns [molec./cm^2] and XCO [ppb]; XCH_4 [ppb]

Differences w.r.t. operational algorithms / products:

- Many as independent algorithms …, e.g., resulting products:
    - WFMD XCH_4: Typically better coverage (incl. some ocean coverage)
    - WFMD CO: Cloud-free only, XCO in addition to CO column, …

S5P/WFMD products: Validation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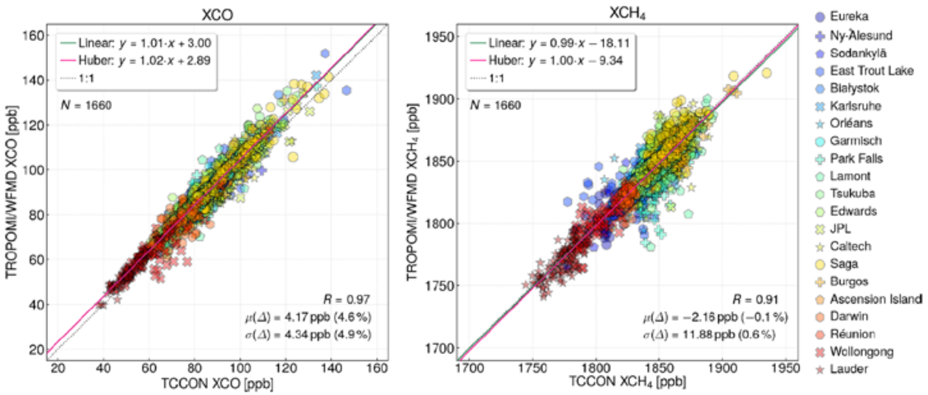
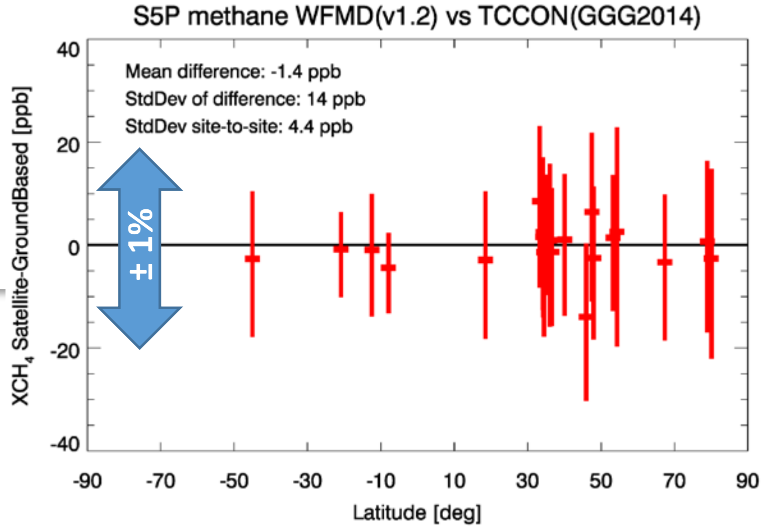
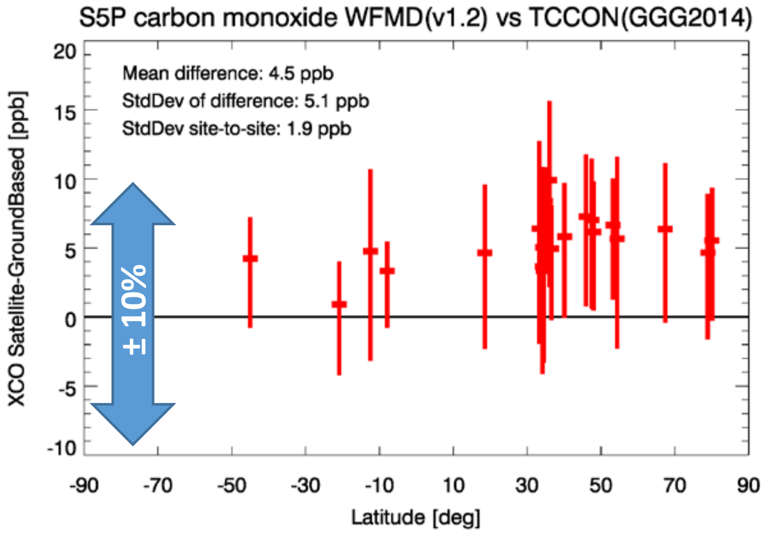


Comparisons with TCCON





XCH_4:
Global offset: -1.4 ppb
Random (sgl.obs., 1-sigma): 14 ppb
Systematic (site-to-site StdDev): 4.4 ppb

XCO:
Global offset: 4.5 ppb
Random (sgl.obs., 1-sigma): 5.1 ppb
Systematic (site-to-site StdDev): 1.9 ppb

S5P/WFMD products: Comparison with operational products

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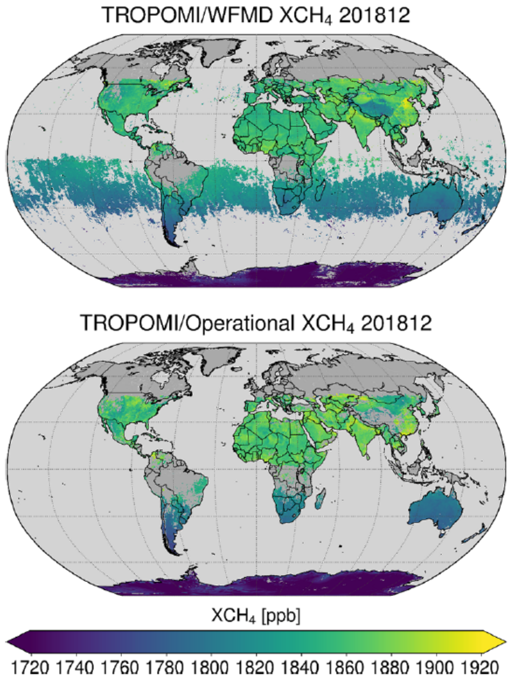

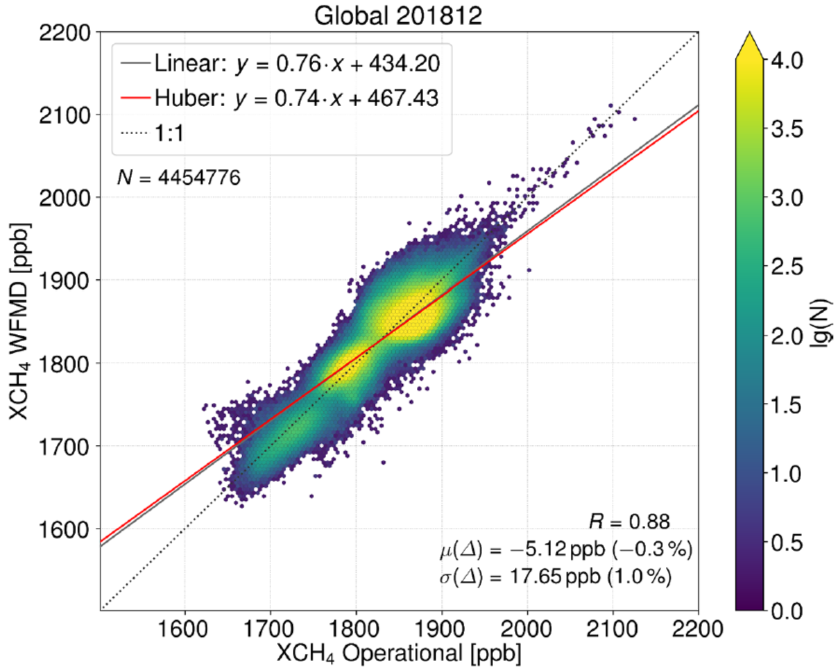

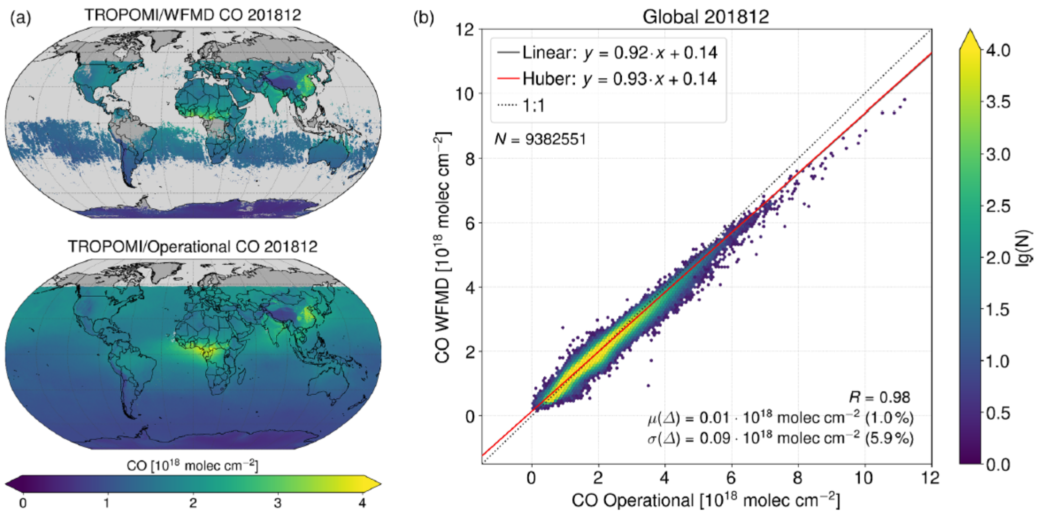

- **Overall** reasonable to good agreement
- **CH_4:** WFMD typically better coverage (e.g., also some ocean coverage but also over land)
- **CO:** WFMD much sparser (cloud-free only)

S5P/WFMD CO: Some details …

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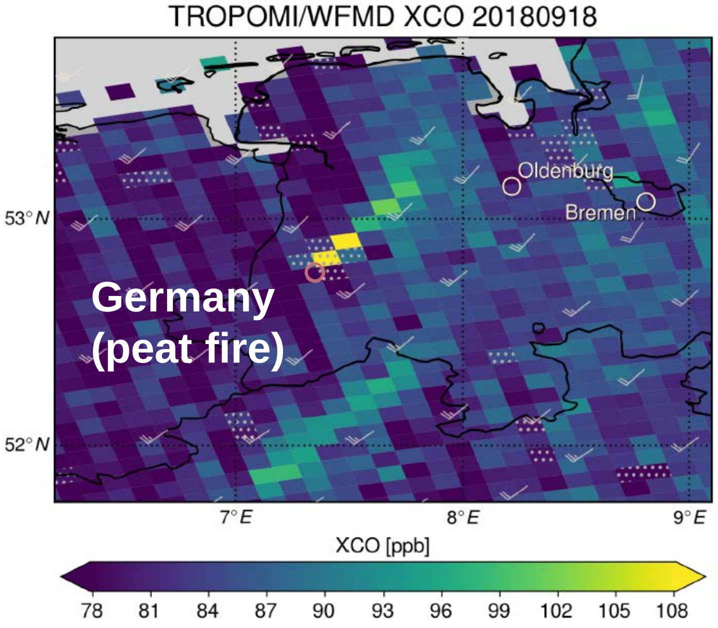
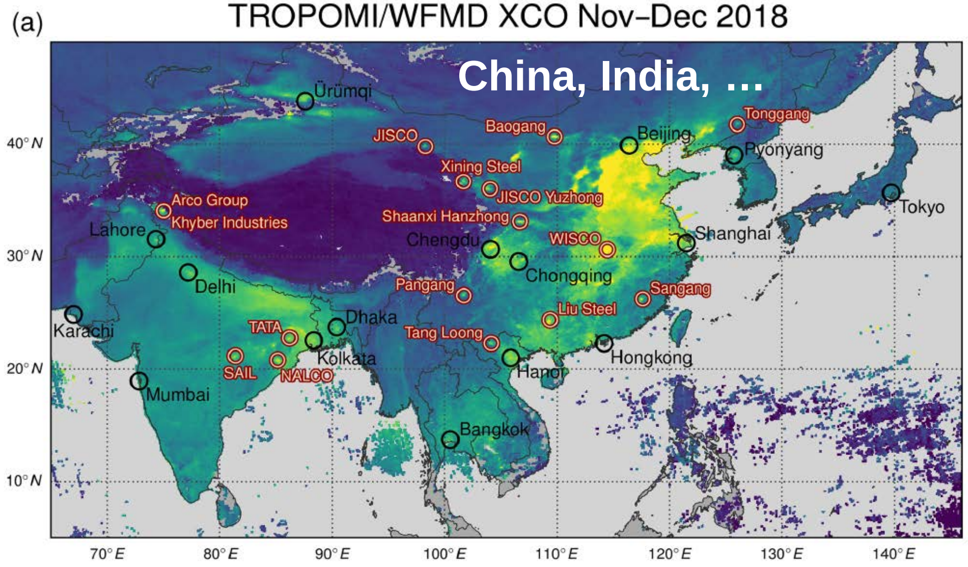
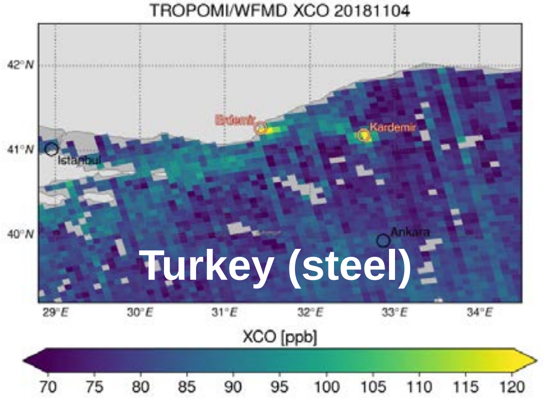
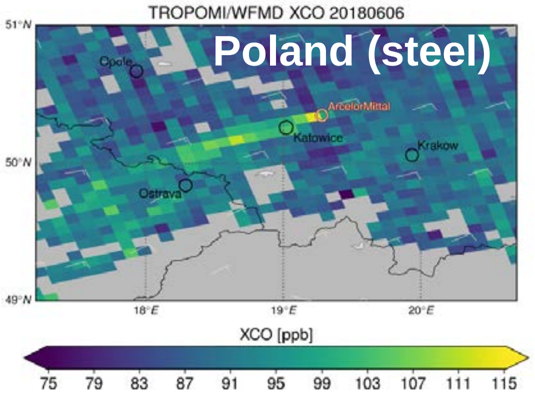


Elevated CO due to various CO emission hotspots (urban areas, steel plants, …)







S5P/WFMD CO: Californian fires Nov 2018

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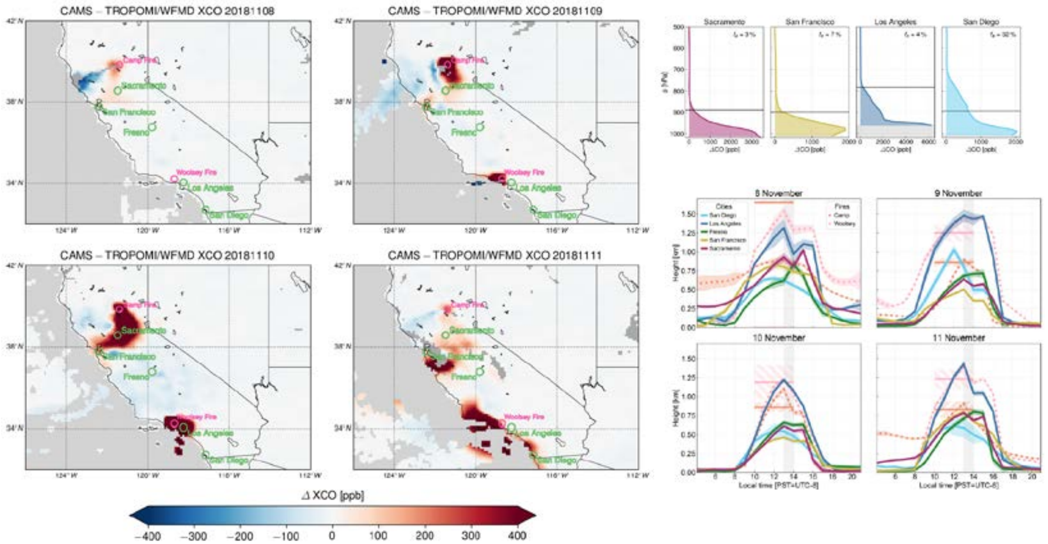
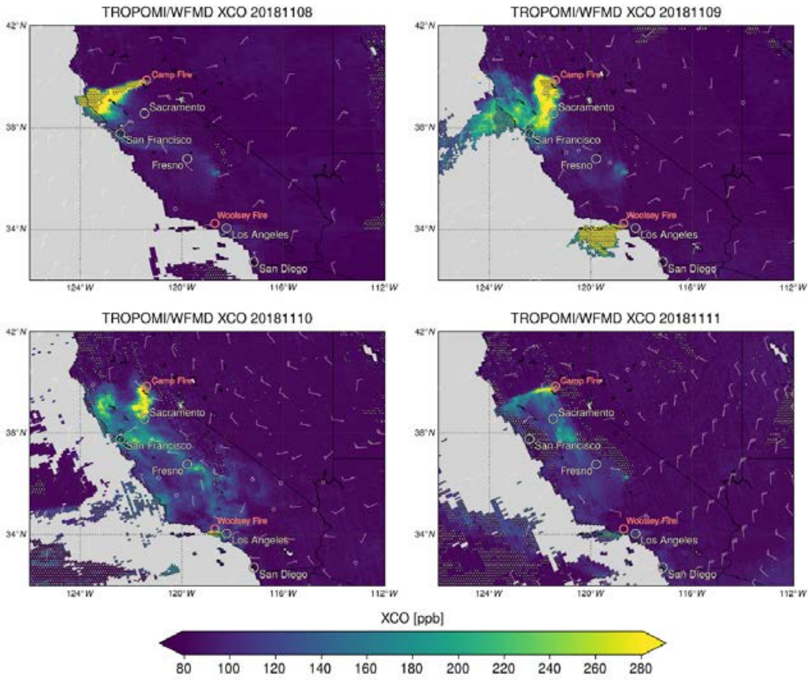
Comparisons with CAMS, use of ERA5, …



S5P/WFMD CO: Elevated CO due to fires

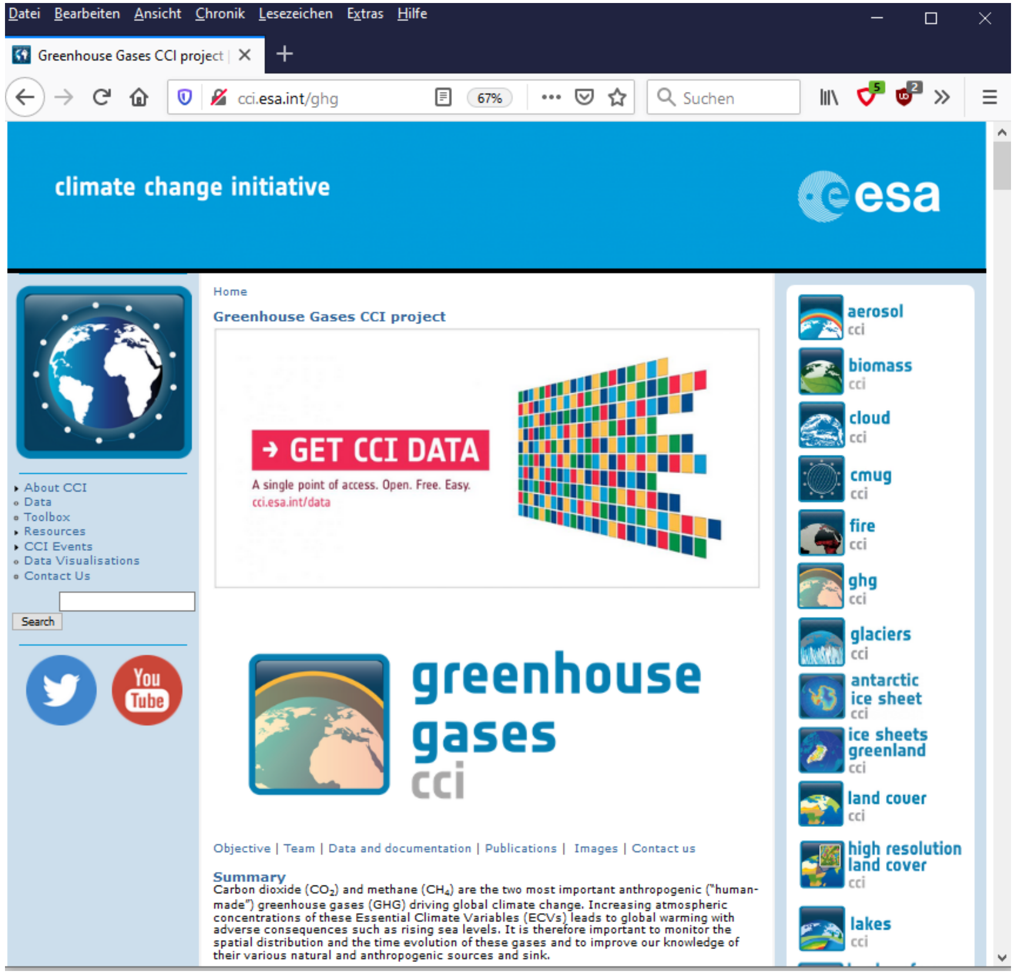


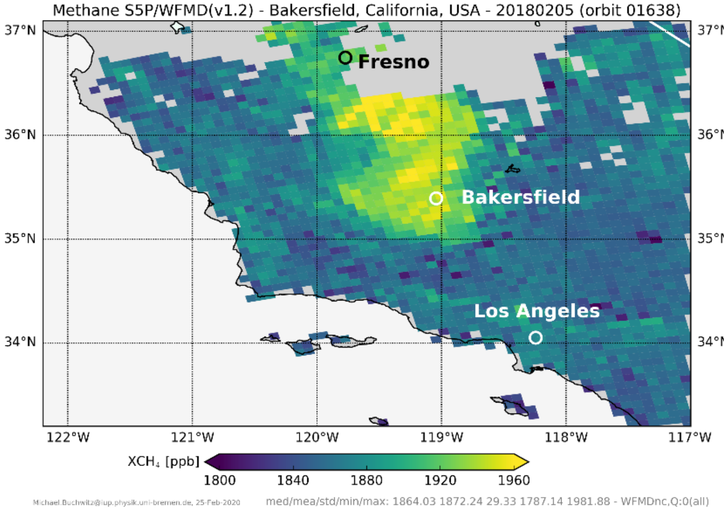
Main air quality / health-related conclusion:

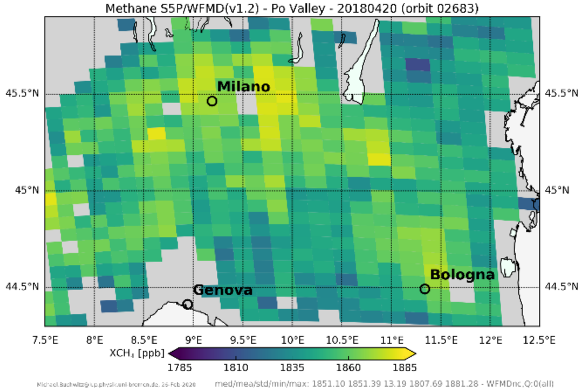
Even the most polluted city scenes likely comply with the national ambient air quality standards (10 mgCO/m^3 with 8 h averaging time). This finding based on dense daily recurrent satellite monitoring is consistent with isolated ground-based air quality measurements.

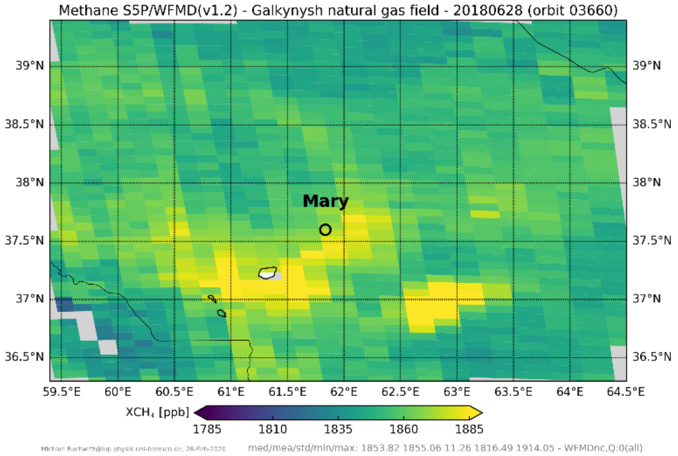
S5P/WFMD XCH_4: A GHG-CCI product

http://cci.esa.int/ghg









https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/Satellites_providing_clear_picture_of_greenhouse_gases

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S5P/WFMD XCH_4: Methane emissions from gas & oil fields


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Preprint. Discussion started: 14 April 2020

Atmospheric Chemistry and Physics Discussions

Schneising et al., ACP (in review), 2020

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

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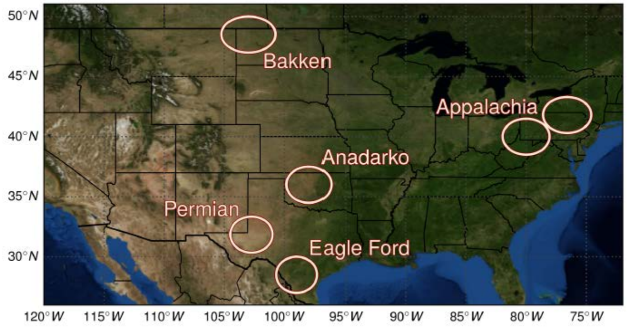
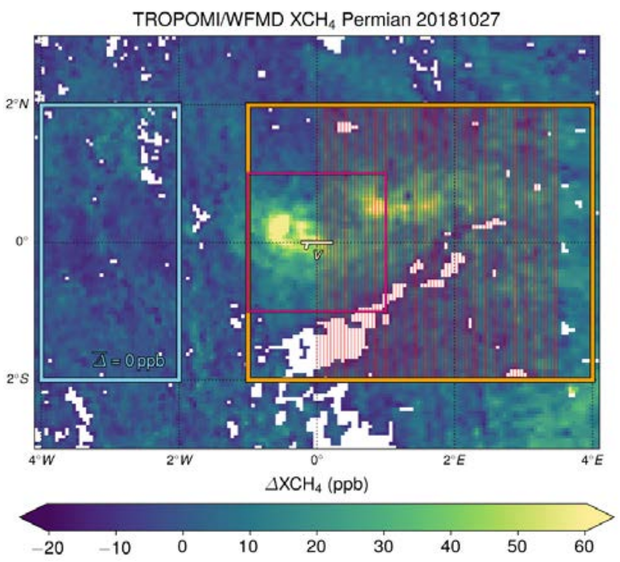
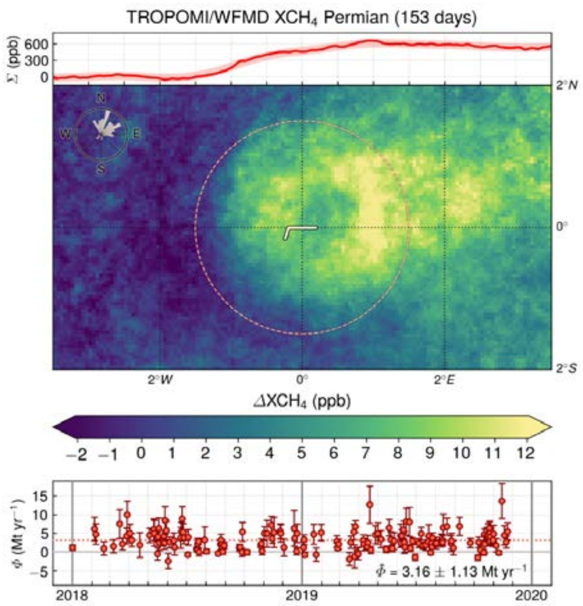
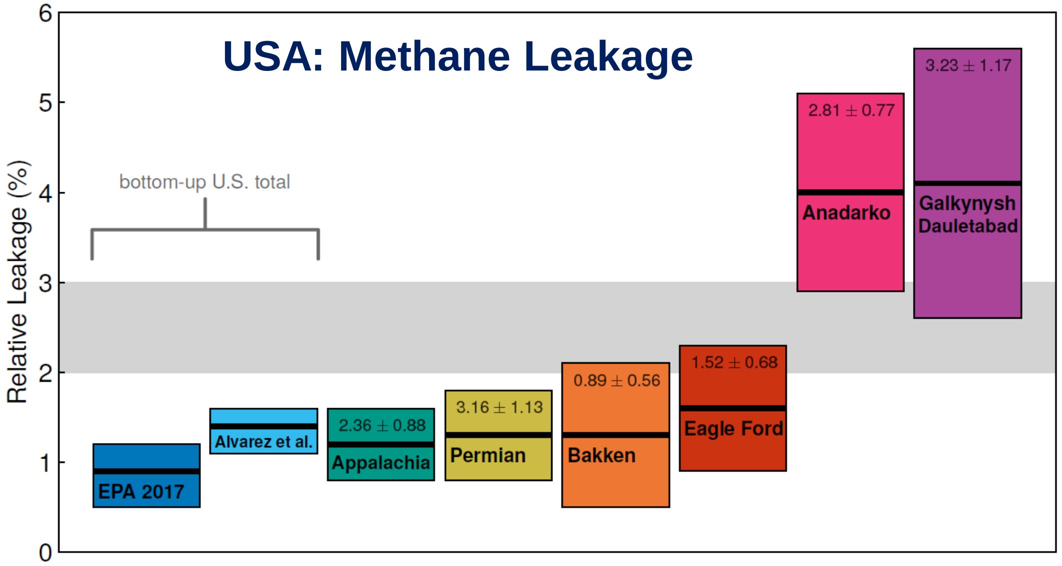
Major gas & oil production regions





Permian





- Use of S5P WFMD XCH_4 to get emission estimates
- Conversion to relative leakage by division with total production
- Comparison with published values

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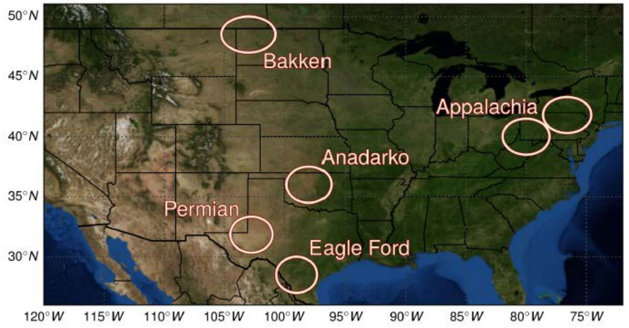

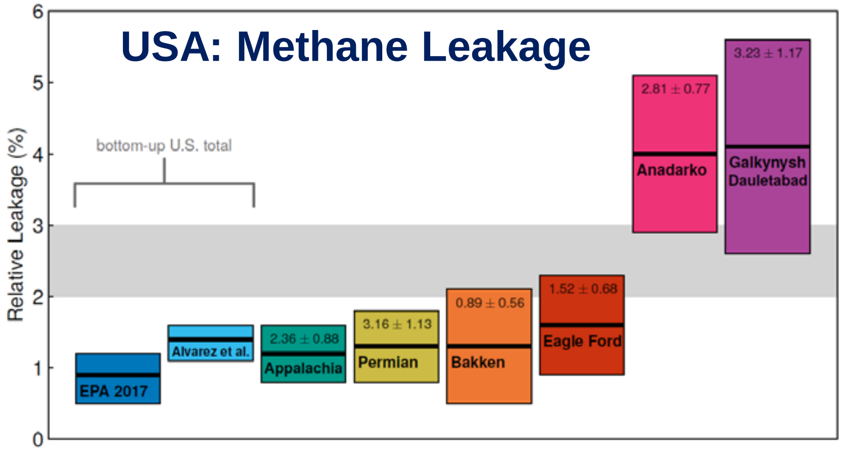

Table 1. Summary of the emission and production values used to determine the leakage rates (emissions divided by combined oil and gas production). All values have been converted to $kBOE\,d^{-1}$ as described in Section 2. Also shown are the mean percentage variance contributions to the emission estimates for the relative uncertainty components of Equation 2.

Region	Emissions ($kBOE\,d^{-1}$)	Production: Oil ($kBOE\,d^{-1}$)	Production: Gas ($kBOE\,d^{-1}$)	Production: Oil (%)	Production: Gas (%)	Production: Oil+Gas ($kBOE\,d^{-1}$)	Leakage (%)	Variance contributions (%): E	v,abs	v,dir	ρ_{dry}
Permian	81	3897	2197	64	36	6094	1.3	60.2	38.6	0.6	0.6
Appalachia	60	127	5052	2	98	5179	1.2	73.2	26.4	0.2	0.2
Eagle Ford	39	1344	1112	55	45	2456	1.6	64.3	34.7	0.5	0.5
Bakken	23	1361	444	75	25	1805	1.3	64.9	34.5	0.4	0.2
Anadarko	72	548	1237	31	69	1785	4.0	70.8	28.4	0.4	0.4
Galkynysh/ Dauletabad	83	0	1533	0	100	2017	4.1	74.9	21.8	0.5	2.8

Summary & conclusions

- Scientific WFM-DOAS (or WFMD) algorithm to retrieve XCH_4 and XCO from TROPOMI/S5P
- Access to data products (free of charge):
  - S5P WFMD XCO: https://www.iup.uni-bremen.de/carbon_ghg/products/tropomi_wfmd/
  - S5P WFMD XCH_4: http://cci.esa.int/data
- Estimated quality of WFMD products (relative to TCCON): Single observation uncertainty (= root-sum-square of sgl.obs. random and site-to-site systematic differences):
  - XCH_4: ~15 ppb (~1%); excluding 1.4 ppb global low bias
  - XCO: ~5 ppb (~5%); excluding 4.5 ppb global high bias
- Comparison of WFMD & OPERational products:
  - Overall good agreement
  - Coverage may be significantly different
- As shown in this presentation, we started to use these information rich products to obtain information on various (localized) methane and CO emission sources
- See also: https://www.iup.uni-bremen.de/carbon_ghg/

Acknowledgements

- Funding:
  - ESA (projects GHG-CCI/GHG-CCI+, S5L2PP, Methane+)
  - German BMBF (project AIRSPACE)
  - State & University of Bremen

- Data:
  - Copernicus (EU / ESA) TROPOMI/S5P products:
    - L1b
    - L2 CH_4 & CO
    - VIIRS-based L2 cloud product for TROPOMI
  - Ground-based validation data: TCCON
  - Meteorological data: ECMWF
  - Other: see publications