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Quantification of local methane emissions from the energy sector

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- TROPOMI provides XCH$_4$ with high spatial and temporal resolution

- Sufficiently large emission sources are detected in a **single satellite overpass**

- Emission estimation is based on **daily TROPOMI observations** and a **Gaussian integral method**
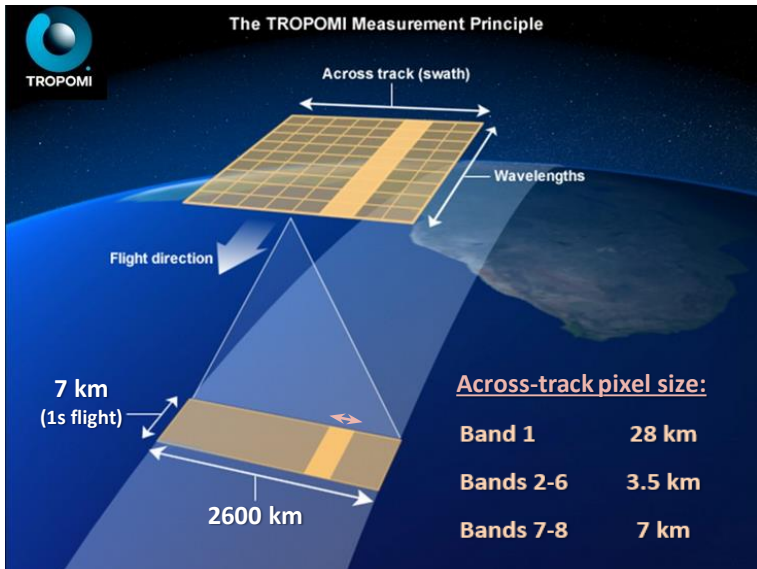(Schneising et al., ACP, 2020)
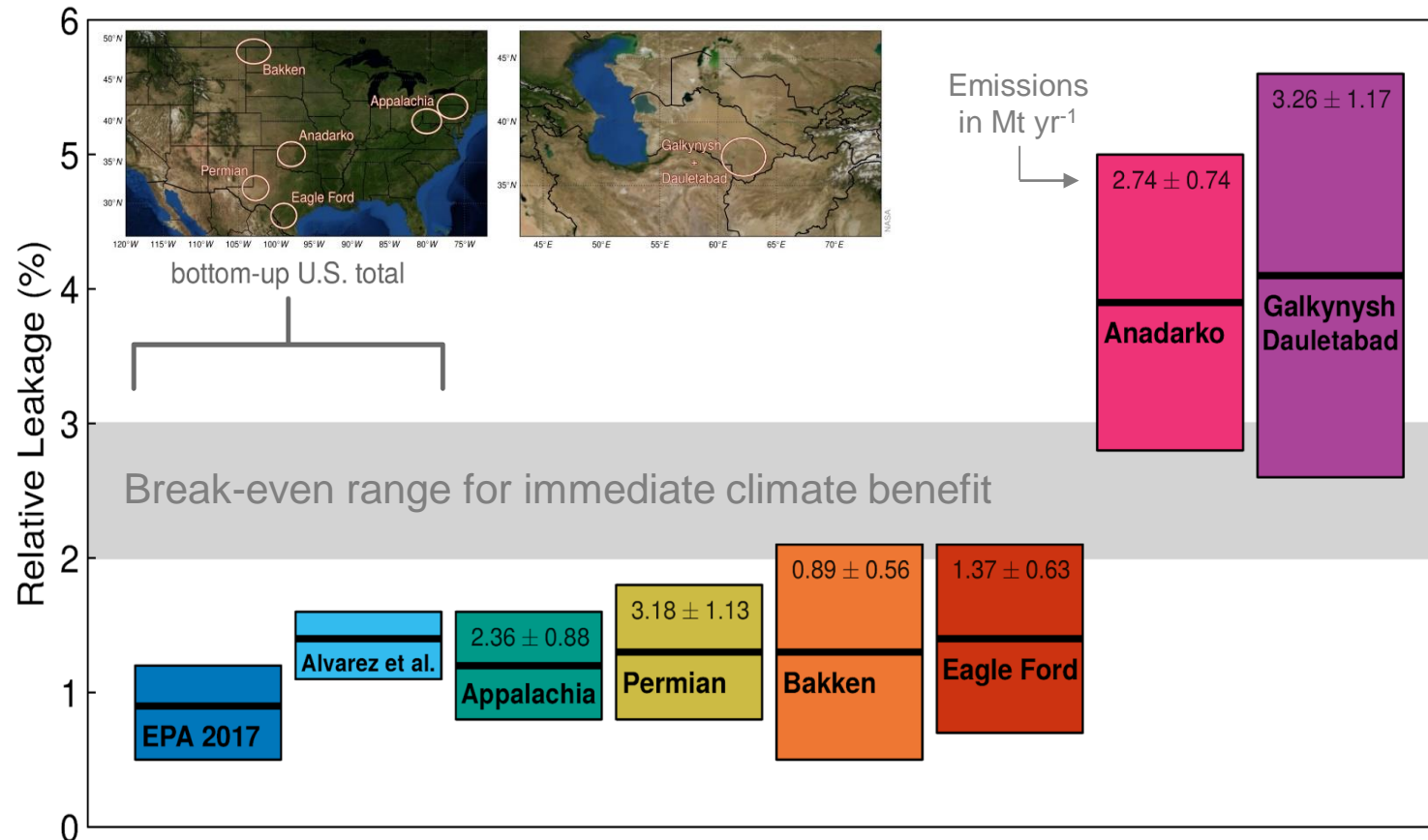
Estimate emissions from the energy sector:

- **Oil and Natural Gas** five most productive basins in the USA and two of the world's largest natural gas fields in Turkmenistan

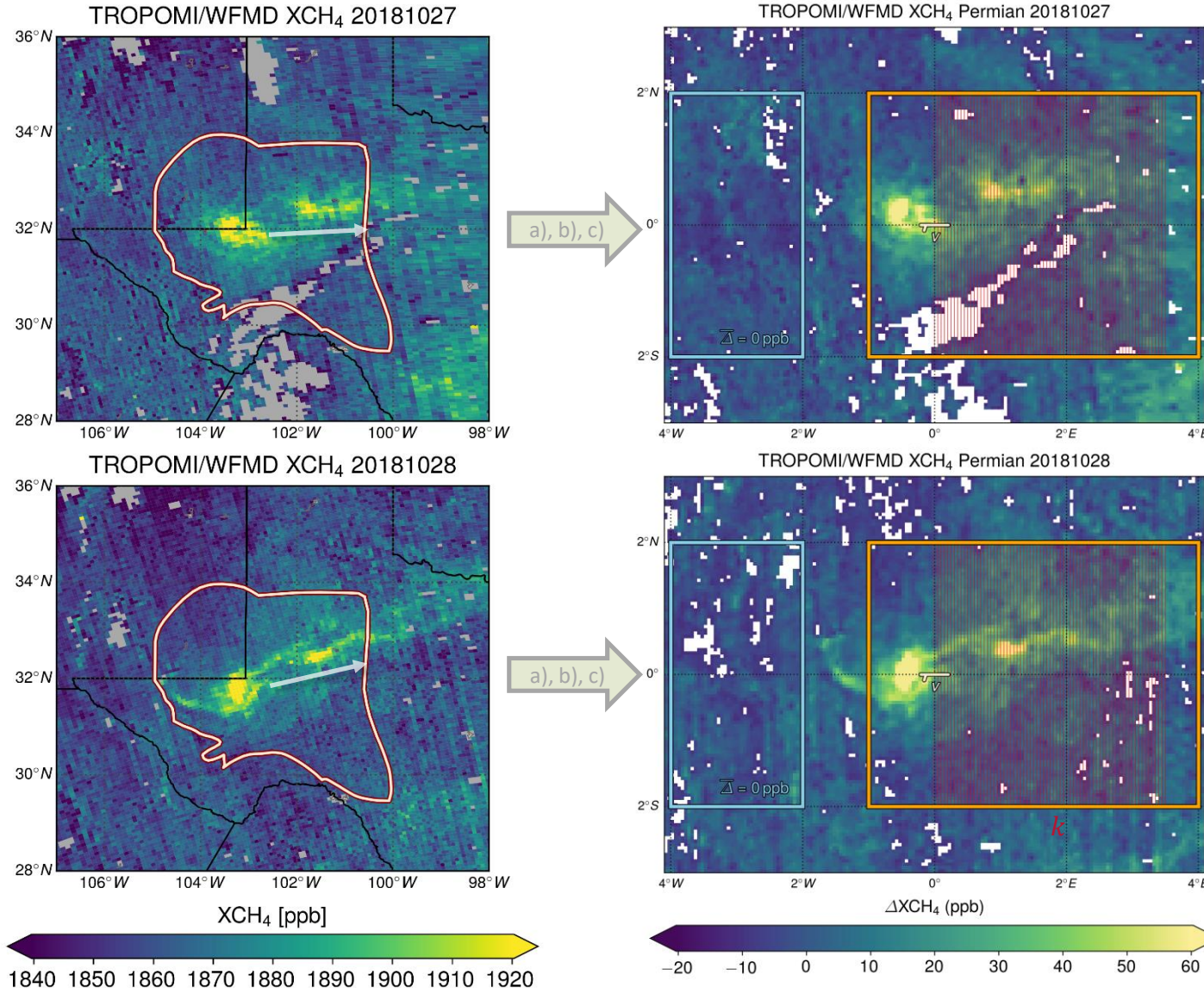- **Coal** Upper Silesian Coal Basin in Europe

- Sentinel-5P was launched in October 2017 with 7 year design lifetime.
- Near-polar, sun-synchronous orbit with ascending node equatorial crossing at 13:30h
- Loose formation configuration with Suomi-NPP (S5P trails behind by 3.5 min)
- The TROPOspheric Monitoring Instrument (TROPOMI) is a spaceborne nadir viewing imaging spectrometer.
- TROPOMI combines daily global coverage with high spatial resolution.

The TROPOMI Measurement Principle

Across-track pixel size:

Band 1	28 km
Bands 2-6	3.5 km
Bands 7-8	7 km

7 km (1s flight)
2600 km

Spectrometer	UV		UVIS		NIR		SWIR	
Band ID	1	2	3	4	5	6	7	8
Performance range [nm]	270–320		320–490		710–775		2305–2385	
Spectral range [nm]	270–300	300–320	320–405	405–500	675–725	725–775	2305–2345	2345–2385
Spectral resolution [nm]	0.5	0.5	0.5	0.5	0.5	0.5	0.23	0.23
Slit width [μm]	560	560	280	280	280	280	308	308
Spectral dispersion [nm/pixel]	0.065	0.065	0.20	0.20	0.124	0.124	0.084	0.097
Spectral magnification	0.327	0.319	0.231	0.231	0.263	0.263	0.025	0.021

Method to estimate emissions

TROPOMI/WFMD XCH$_4$ 20181027

TROPOMI/WFMD XCH$_4$ Permian 20181027

$\overline{\Delta} = 0\,ppb$

TROPOMI/WFMD XCH$_4$ 20181028

TROPOMI/WFMD XCH$_4$ Permian 20181028

$\overline{\Delta} = 0\,ppb$

k

a), b), c)

XCH$_4$ [ppb]

1840 1850 1860 1870 1880 1890 1900 1910 1920

ΔXCH$_4$ (ppb)

−20   −10   0   10   20   30   40   50   60

a) **Rotation** of single days so that ERA5 wind direction matches zonal direction

b) The transformed daily data are **gridded** on a 0.05°×0.05° grid

c) Mean **background** upwind of the source is subtracted

d) Calculate **fluxes** of the vector field $E\boldsymbol{v}$ through cross sections k perpendicular to wind direction (meridional red lines) according to the divergence theorem:
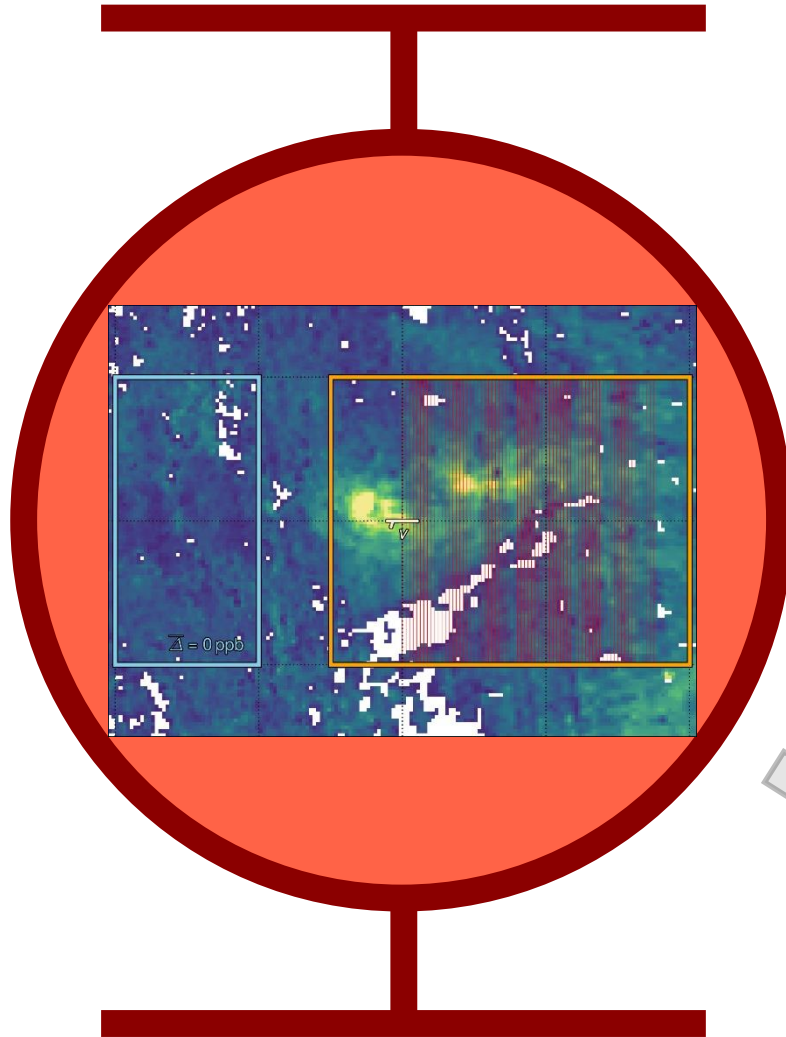
$$\Phi_k = \int_V (\boldsymbol{\nabla} \cdot E\boldsymbol{v})\,dV = \oint_{\partial V = S} E\boldsymbol{v} \cdot d\boldsymbol{S} = \sum_i E_i\, v\, \Delta l_i$$

e) **Average** over all cross sections k

$\Rightarrow$ Daily emission and uncertainty estimate

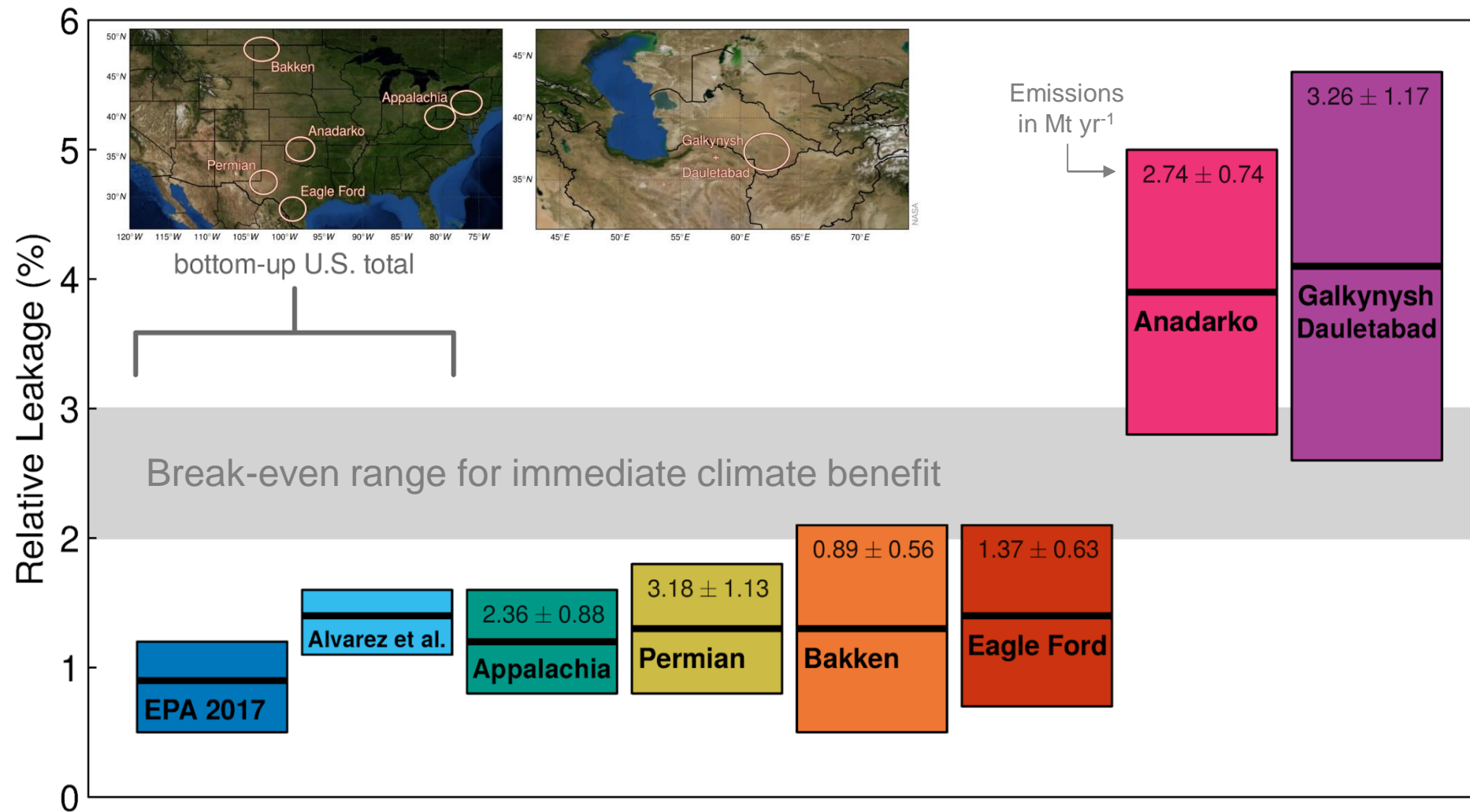E: total column enhancement (in units of mass per area)

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Methane emissions from oil & gas industry

Daily emission and uncertainty estimates

TROPOMI/WFMD XCH$_4$ Permian (162 days)

Σ (ppb)

ΔXCH$_4$ (ppb)

Φ (Mt yr^{-1})

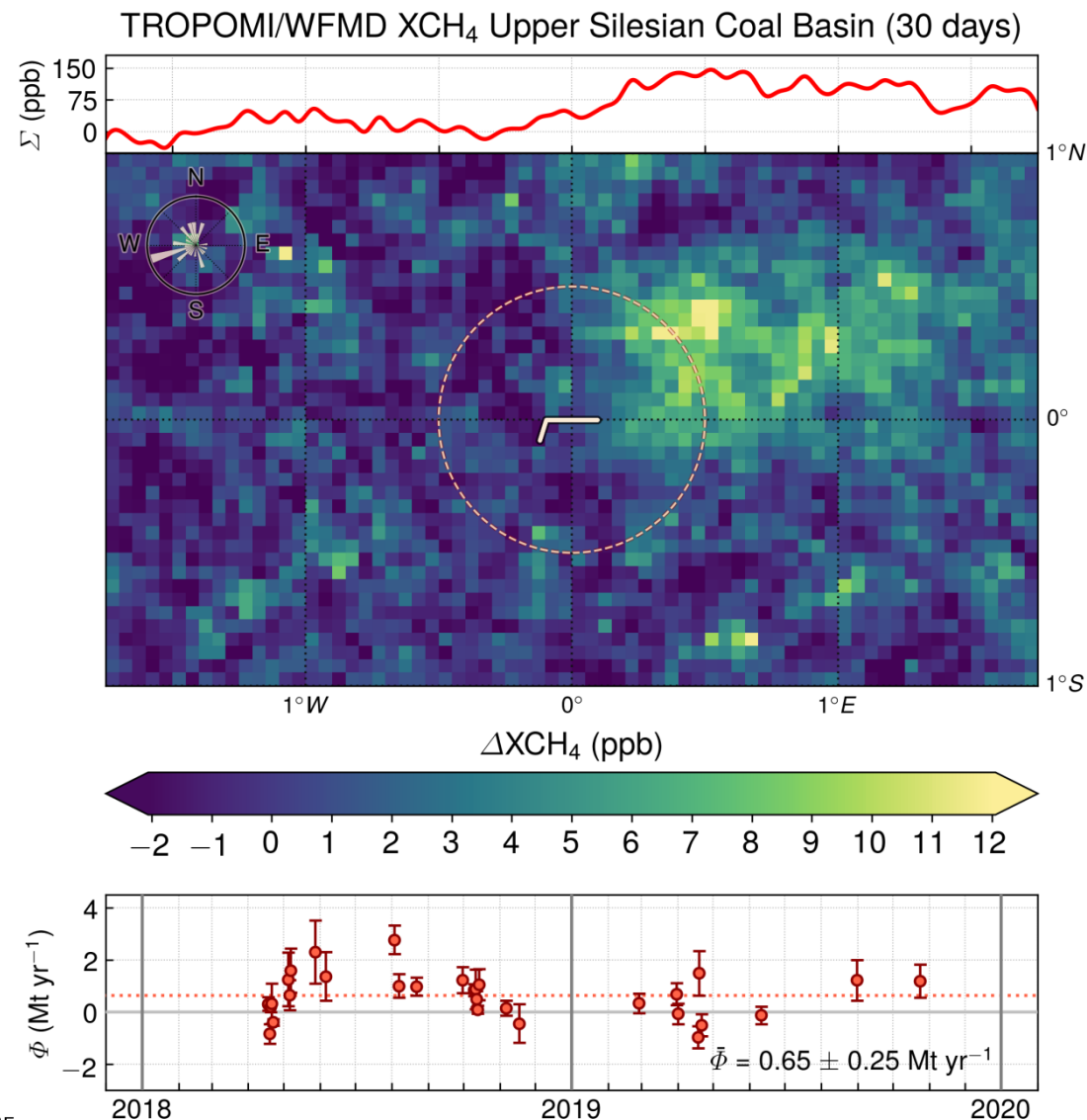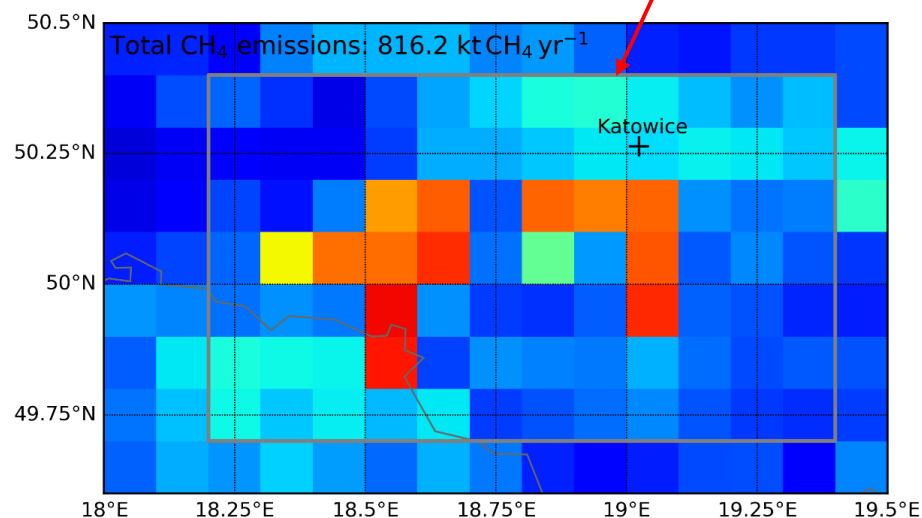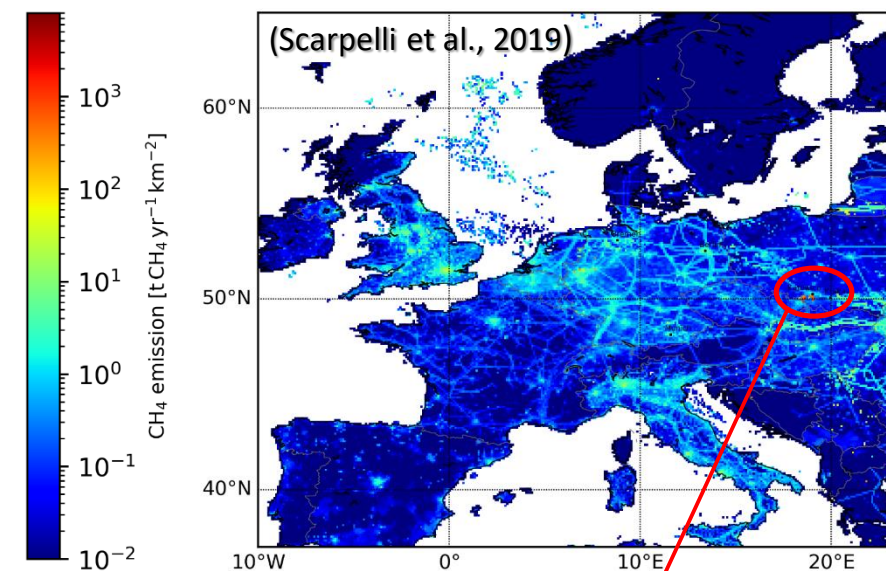$\bar{\Phi} = 3.18 \pm 1.13$ Mt yr^{-1}

- Conversion to **relative leakage** by division of emission with total production

$$\frac{\text{Emission} \quad \boxed{\text{BOE/d}}}{\text{Production} \quad \boxed{\text{BOE/d}}}$$

- Climate benefit from substituting coal with oil or gas is offset by **fugitive methane release** during production and distribution.

- There is a **break-even rate** (depending on time horizon) at which the climate impacts of the gas-oil mix and coal coincide.

TROPOMI/WFMD XCH$_4$ Upper Silesian Coal Basin (30 days)

(Scarpelli et al., 2019)

Total CH$_4$ emissions: 816.2 kt CH$_4$ yr^{-1}

Katowice

ΔXCH$_4$ (ppb)

$\bar{\Phi} = 0.65 \pm 0.25$ Mt yr^{-1}

- Large CH$_4$ emission hot spot in Europe is located in the Upper Silesian Coal Basin (USCB)

- Only few observation days due to overpass time (13:30) and development of clouds in the early afternoon

- Averaged estimated emission for entire basin is consistent with inventory based estimates