Universität Bremen

Institut für Umweltphysik

Quantification of Local Anthropogenic Methane Emissions using TROPOMI onboard Sentinel-5P

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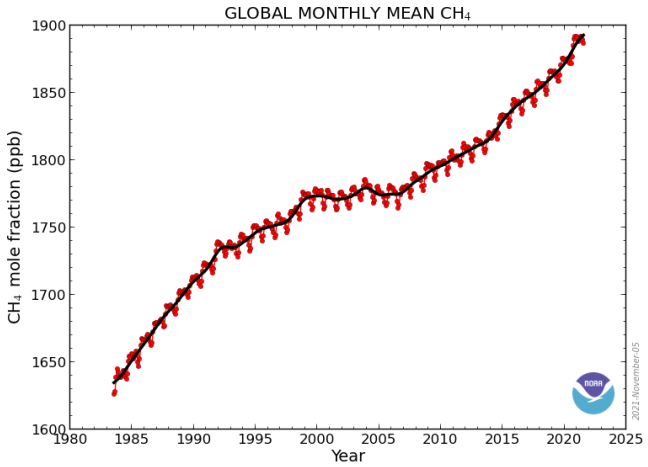
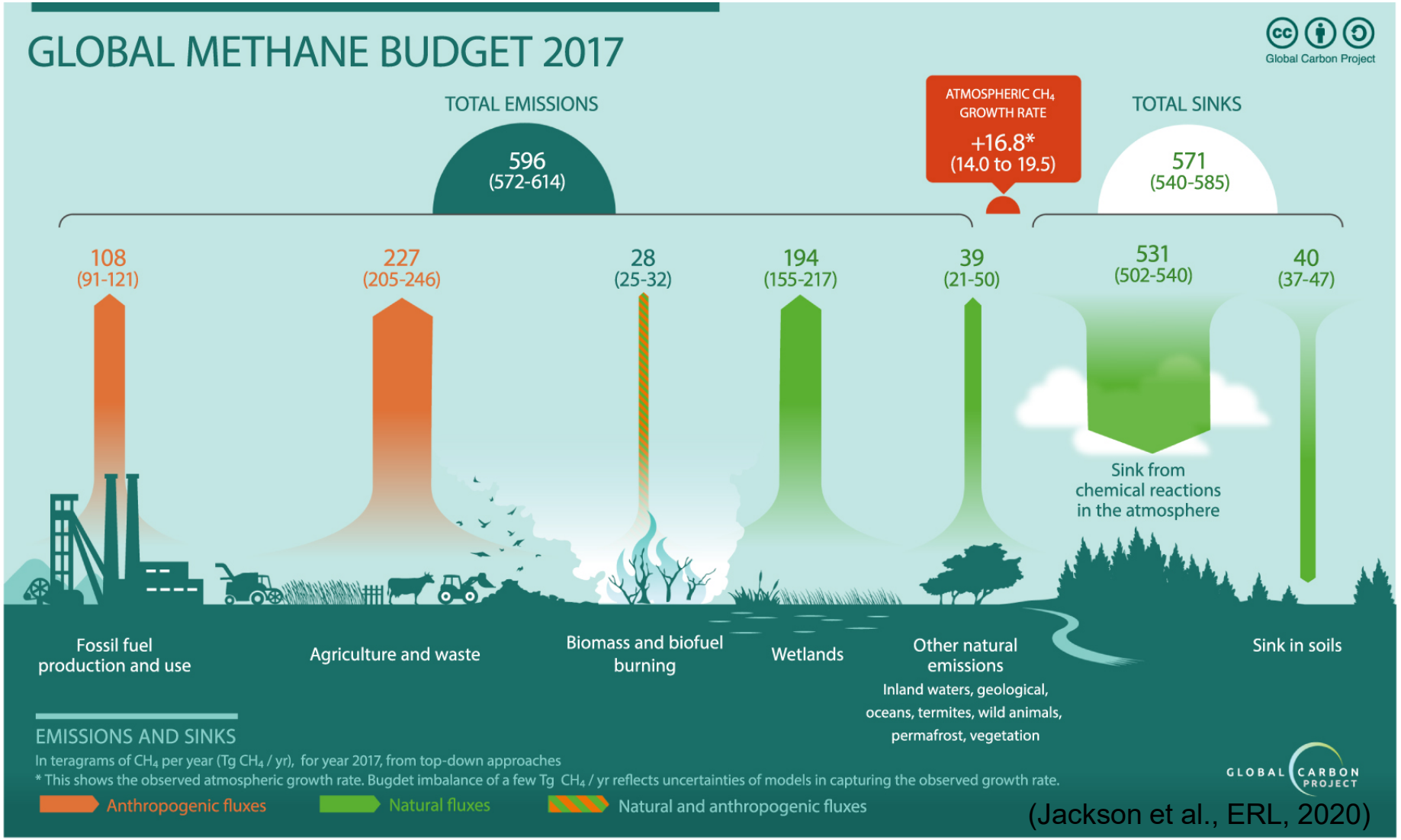
Atmospheric Methane



- CH_4 is the second most important GHG contributing to human-induced climate change
- Satellite measurements can be used in top-down atmospheric inversions to improve estimation of methane sources and sinks



(Jackson et al., ERL, 2020)

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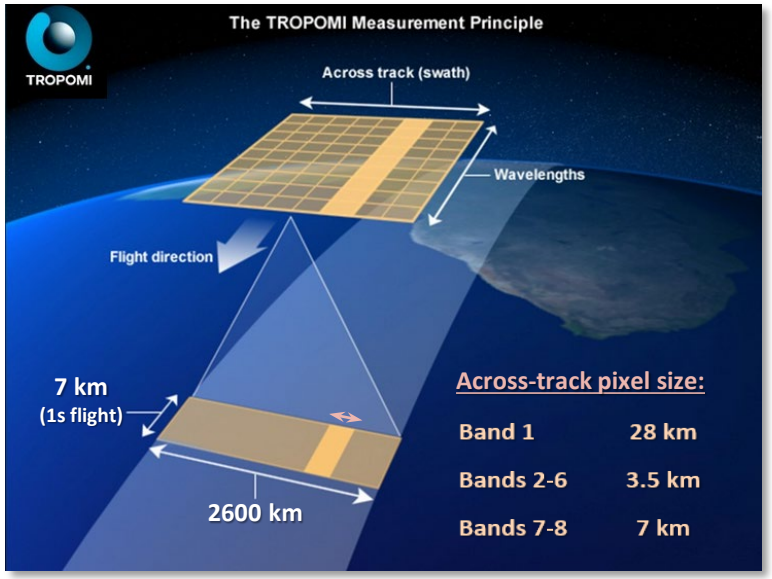
TROPOMI on Sentinel-5 Precursor



- Sentinel-5P was launched in October 2017 with 7 year design lifetime.
- Near-polar, sun-synchronous orbit with ascending node equatorial crossing at 13:30 local solar time
- 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.

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

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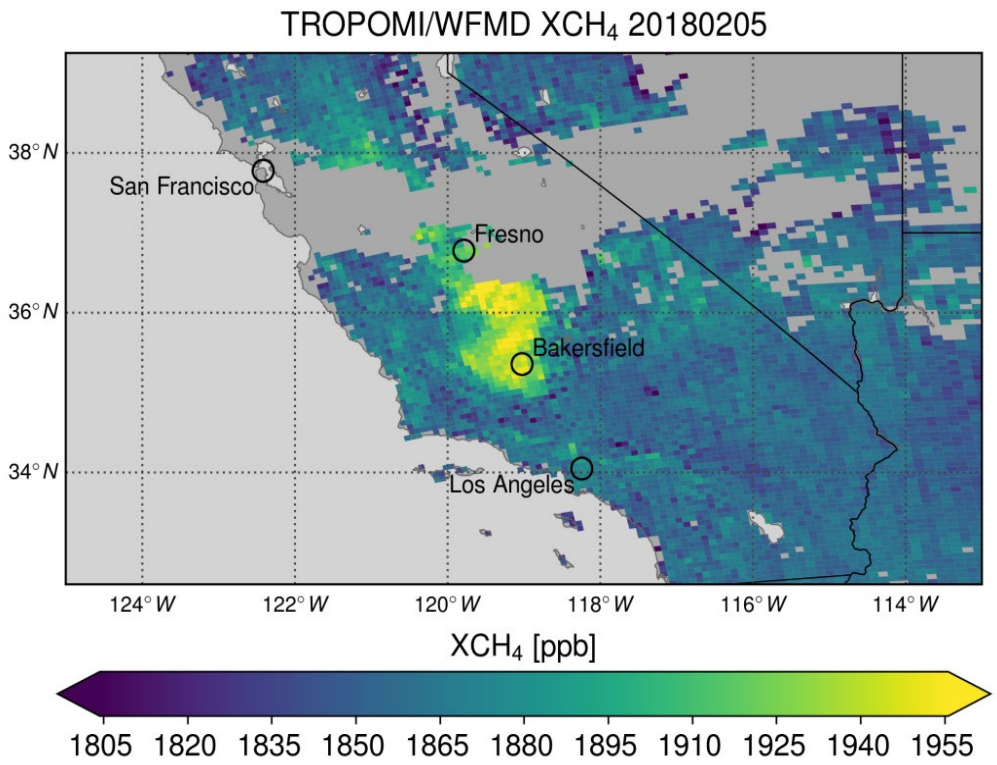
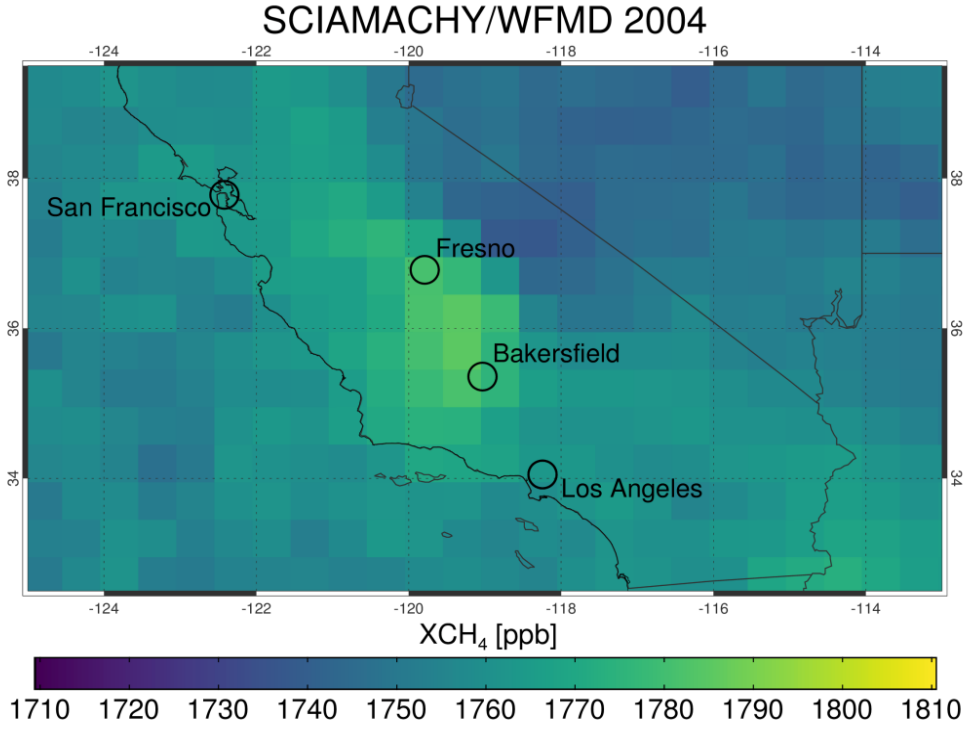
Source detection: California

TROPOMI	SCIAMACHY
Single overpass	Yearly average





Main sources: Oil fields and agriculture (dairy, cattle)

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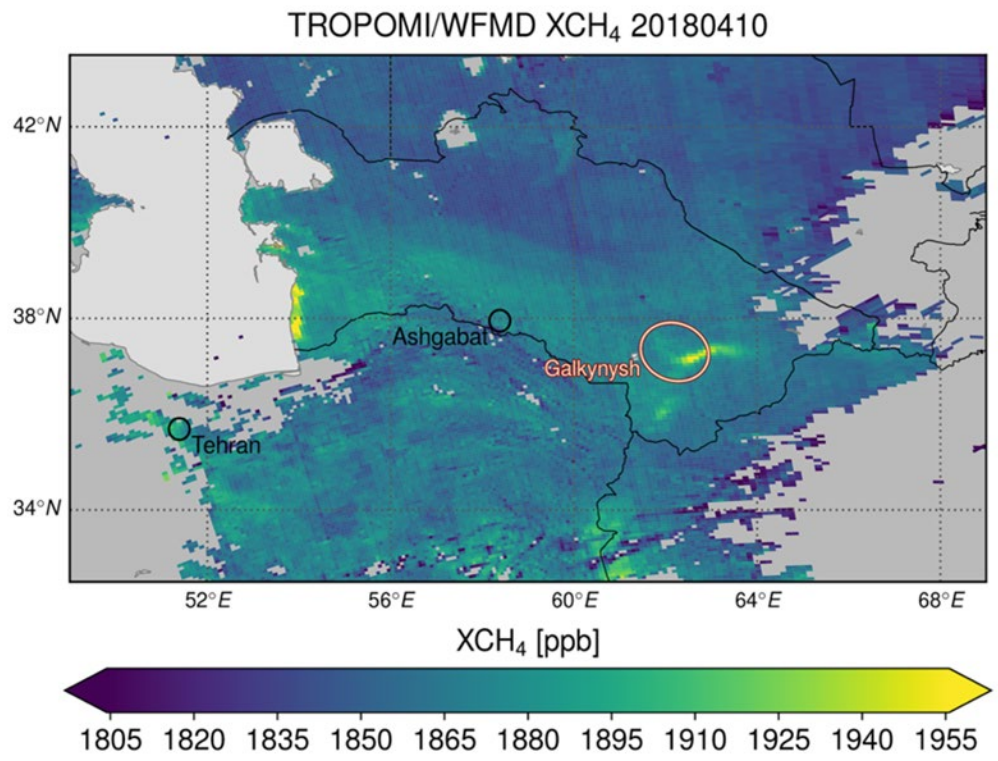
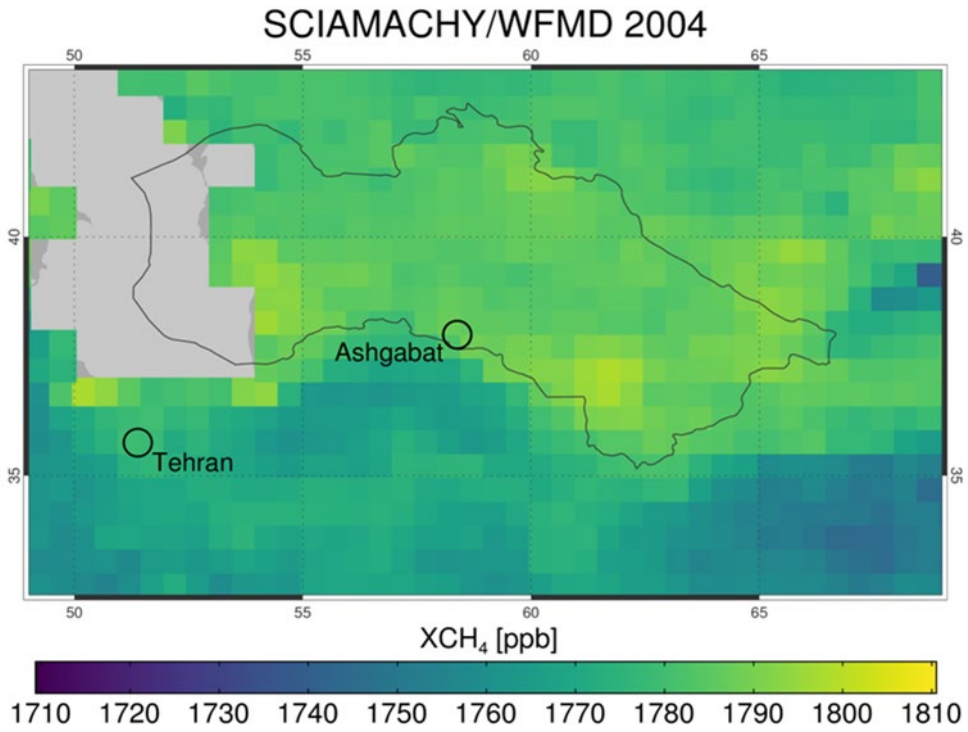
Source detection: Turkmenistan

TROPOMI	SCIAMACHY
Single overpass	Yearly average





Main sources: Natural gas and oil fields

Methane emissions from oil & gas industry

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EGU

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

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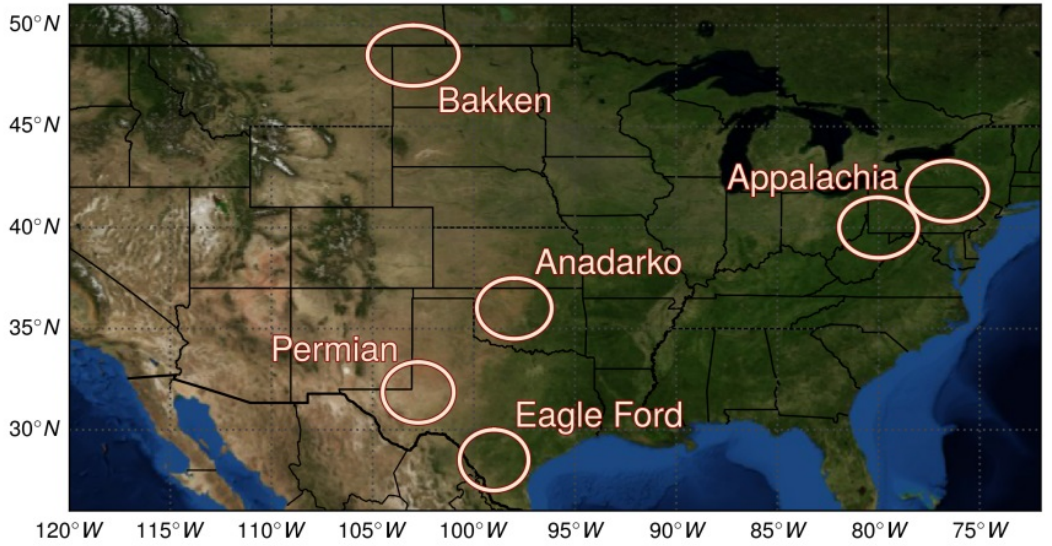
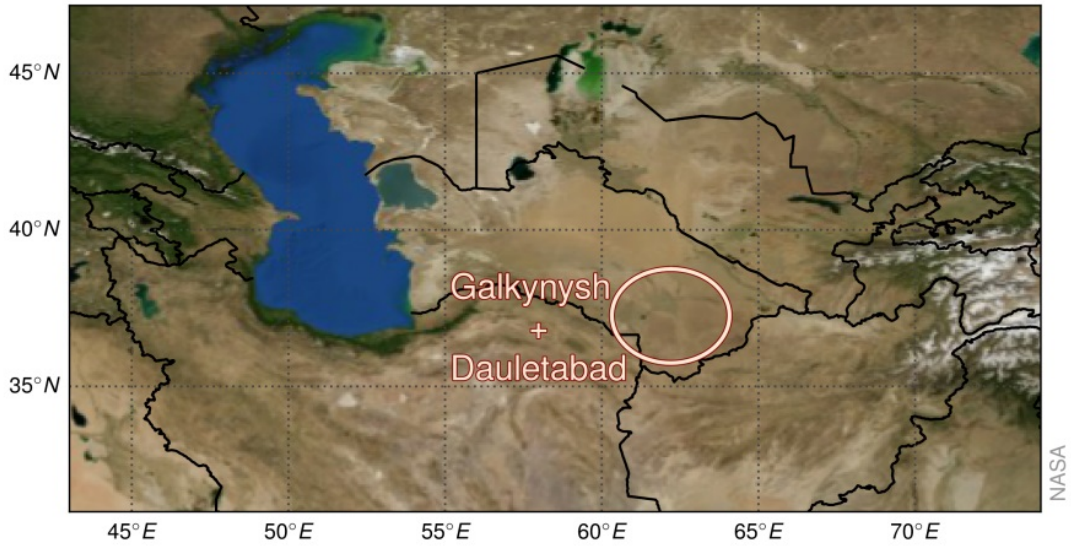
(Schneising et al., ACP, 2020)

- **Estimate emissions** from the five most productive basins in the United States and for two of the world's largest natural gas fields in Turkmenistan
- Emission estimation is based on **daily TROPOMI observations** and a **Gaussian integral method**





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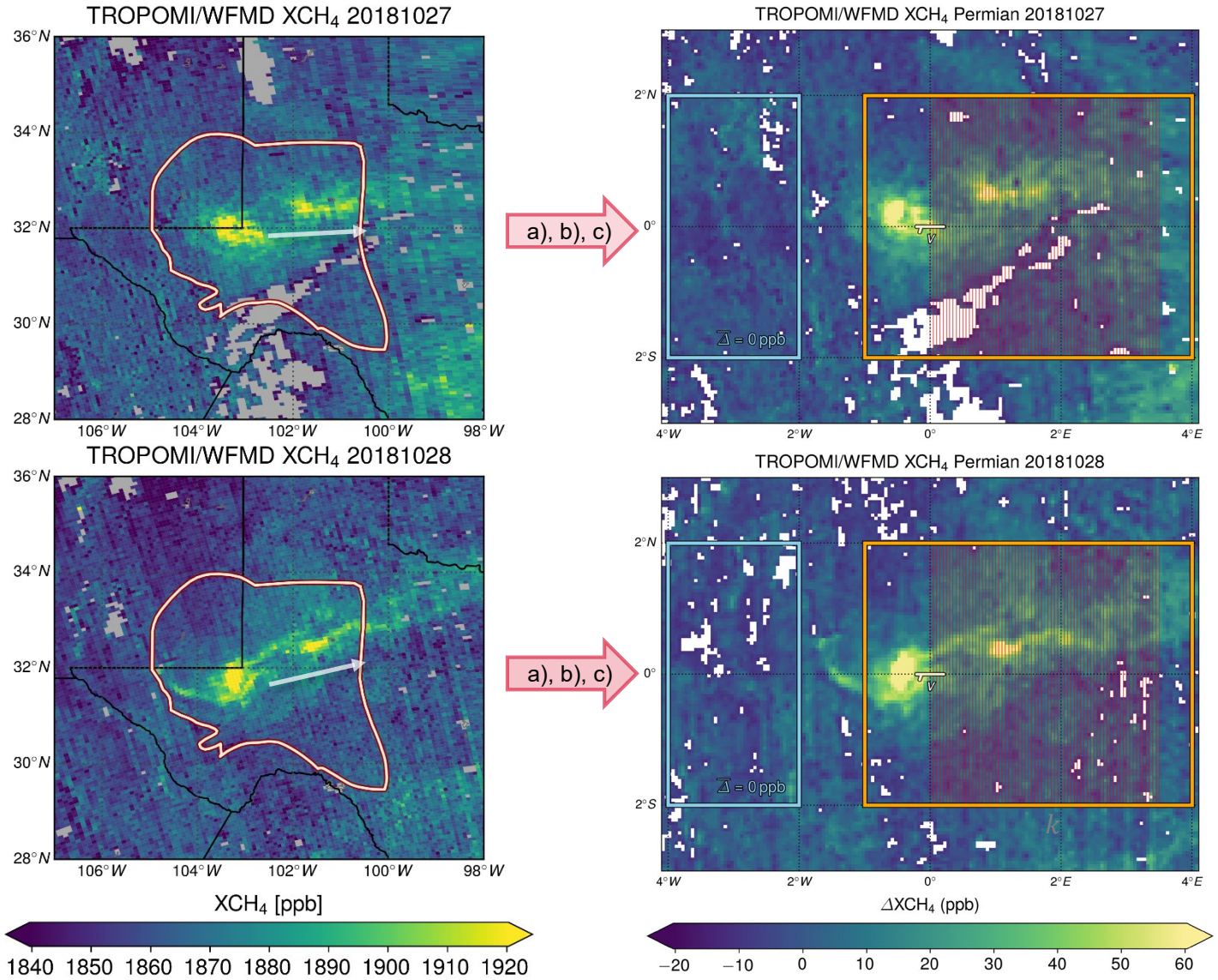
Methane emissions from oil & gas industry



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:

$$\Phi_k = \int_V (\nabla \cdot E\boldsymbol{v})\, dV = \oint_{\partial V = S} E\boldsymbol{v} \cdot d\boldsymbol{S} = \sum_i E_i\, v\, \Delta l_i$$

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

⇒ Daily emission and uncertainty estimate

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

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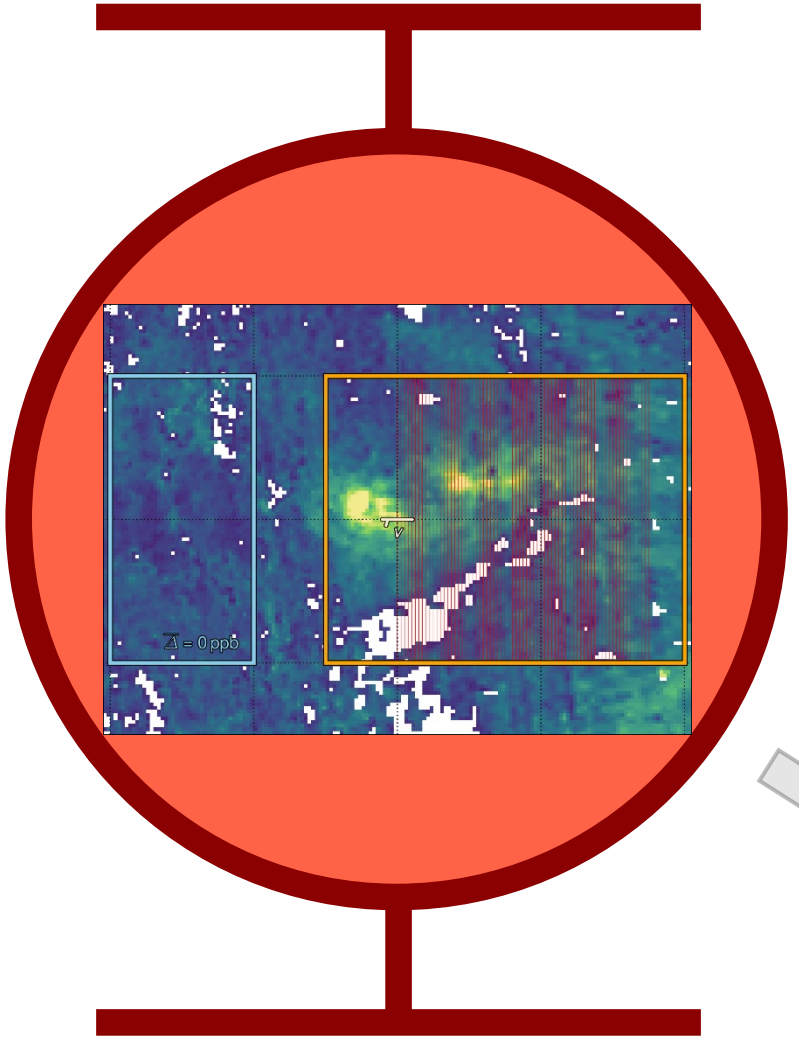
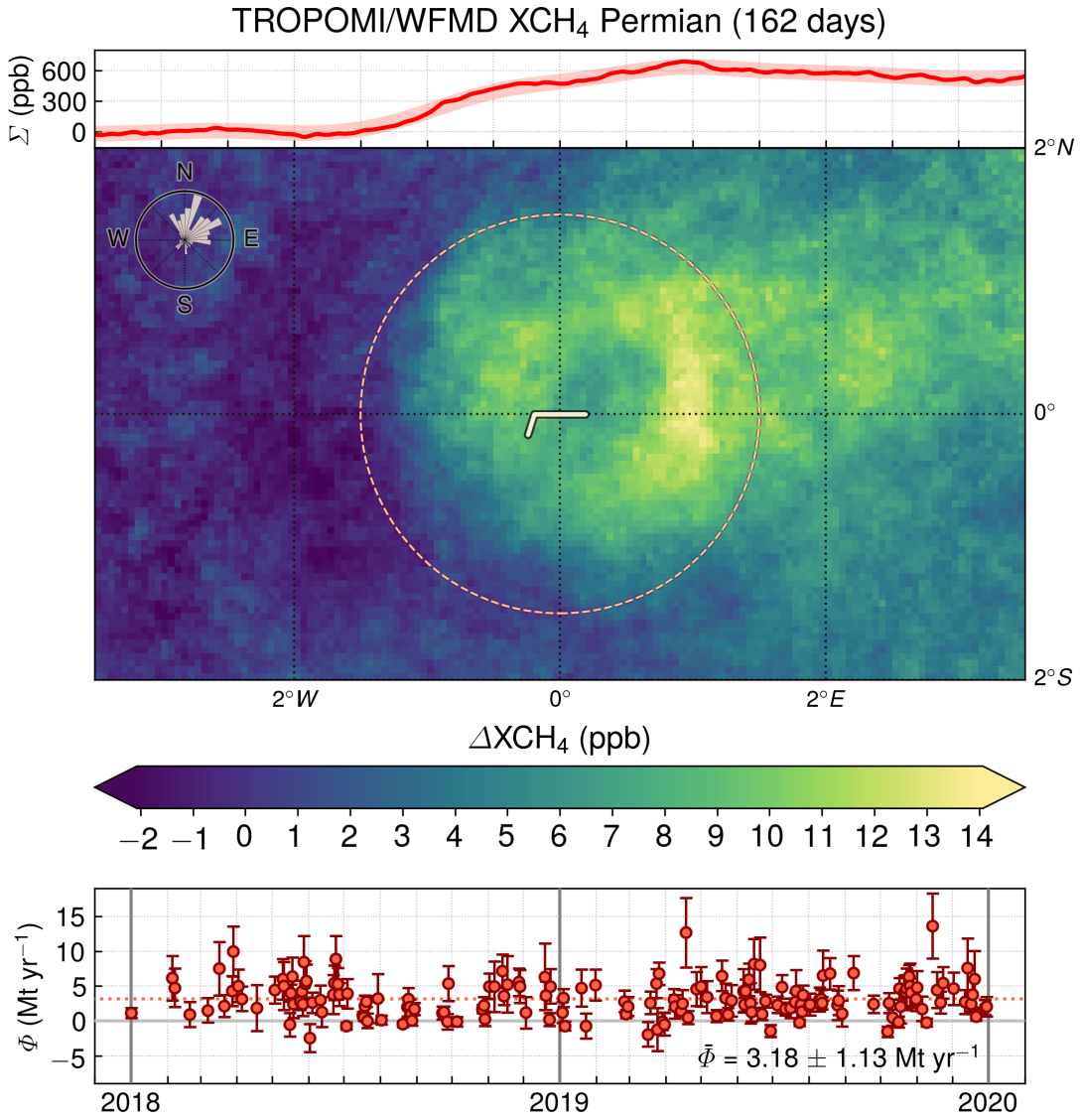
Methane emissions from oil & gas industry



Daily emission and uncertainty estimates



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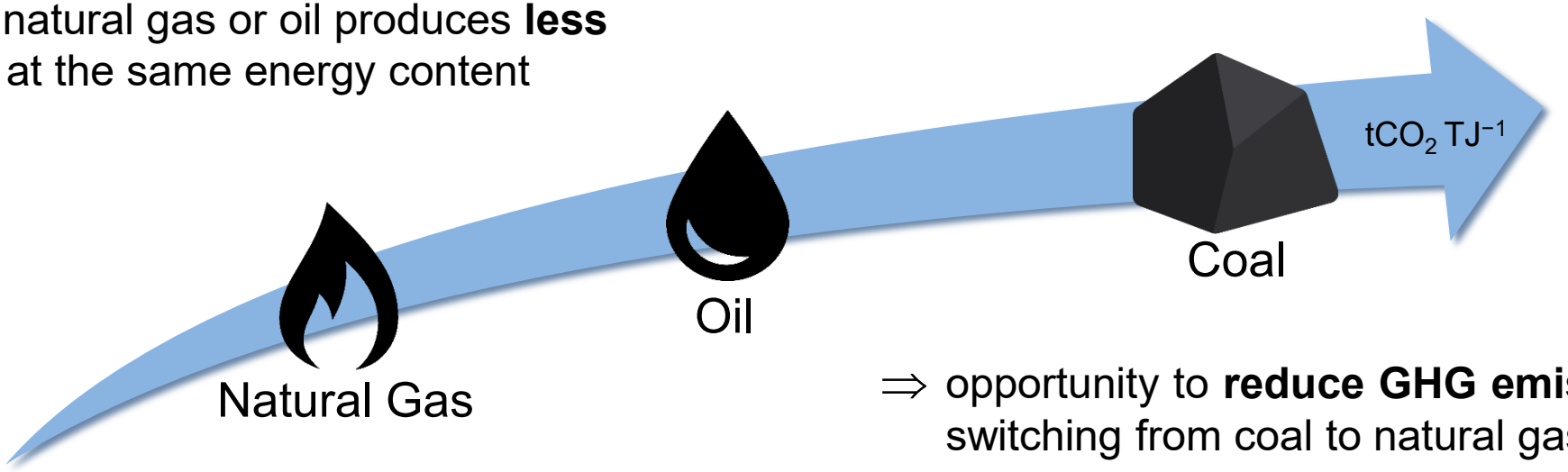
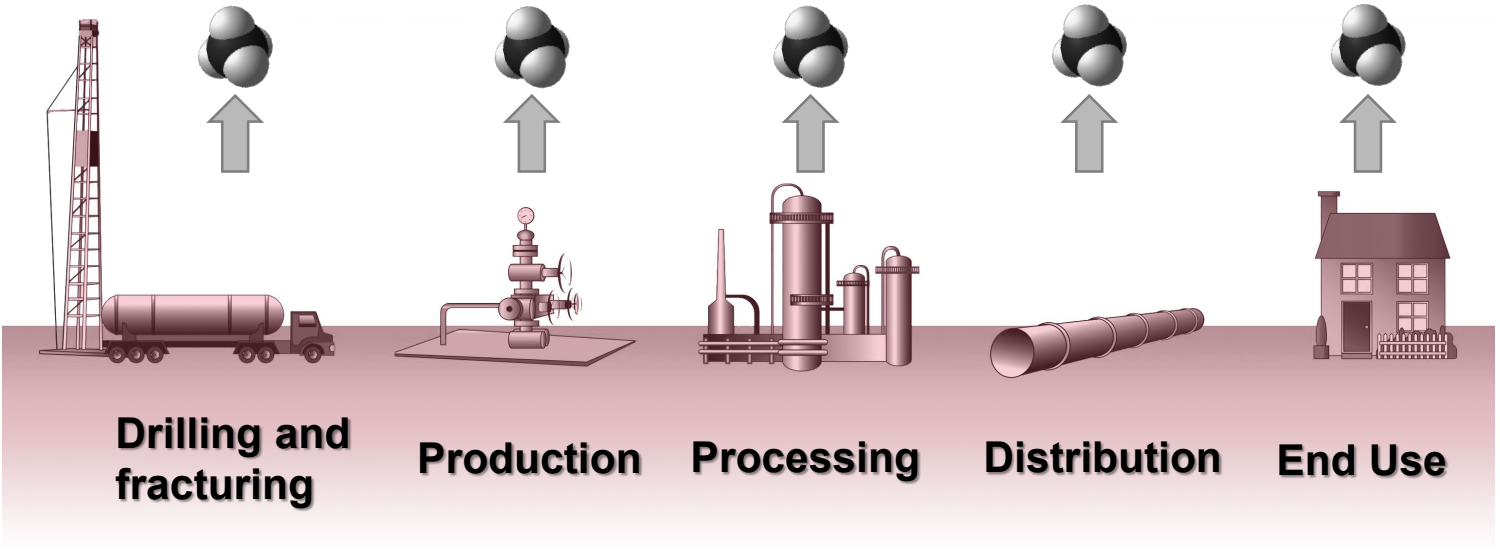
Assessment of climate impact of oil & gas industry

Combustion of natural gas or oil produces **less CO_2 than coal** at the same energy content



⇒ opportunity to **reduce GHG emissions** when switching from coal to natural gas or oil



⚠ Climate benefit from substituting coal is offset by fugitive methane release

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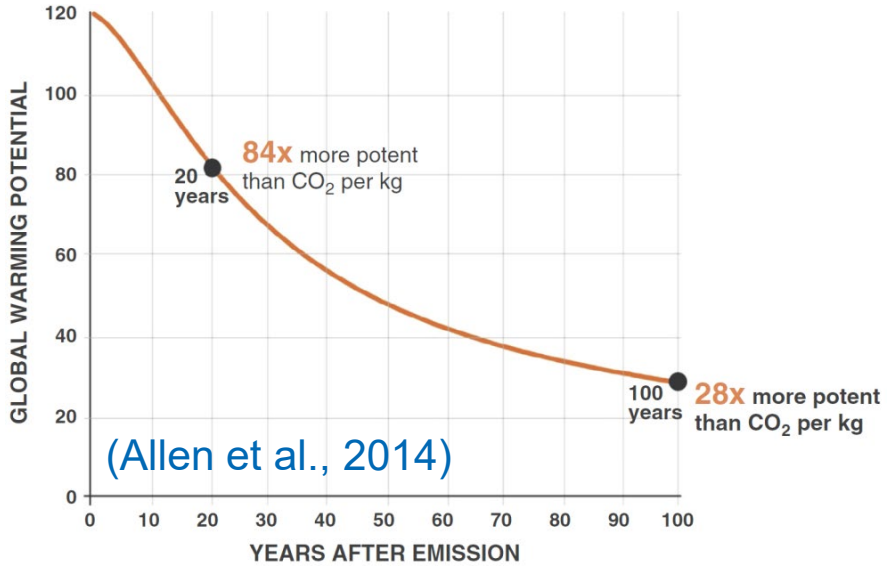
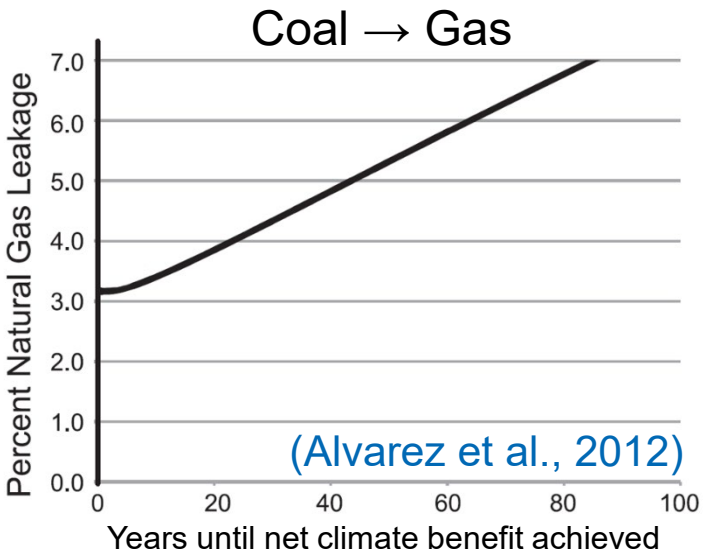
Assessment of climate impact of oil & gas industry





To assess the **climate impact** of the production of natural gas or oil in comparison to coal, the **fugitive emission rate** relative to total production is a key parameter.

$$\frac{\text{Emission}\ [\text{BOE/d}]}{\text{Production}\ [\text{BOE/d}]}$$

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

⚠ The break-even range for immediate climate benefit is about 2-3% for the analysed basins.

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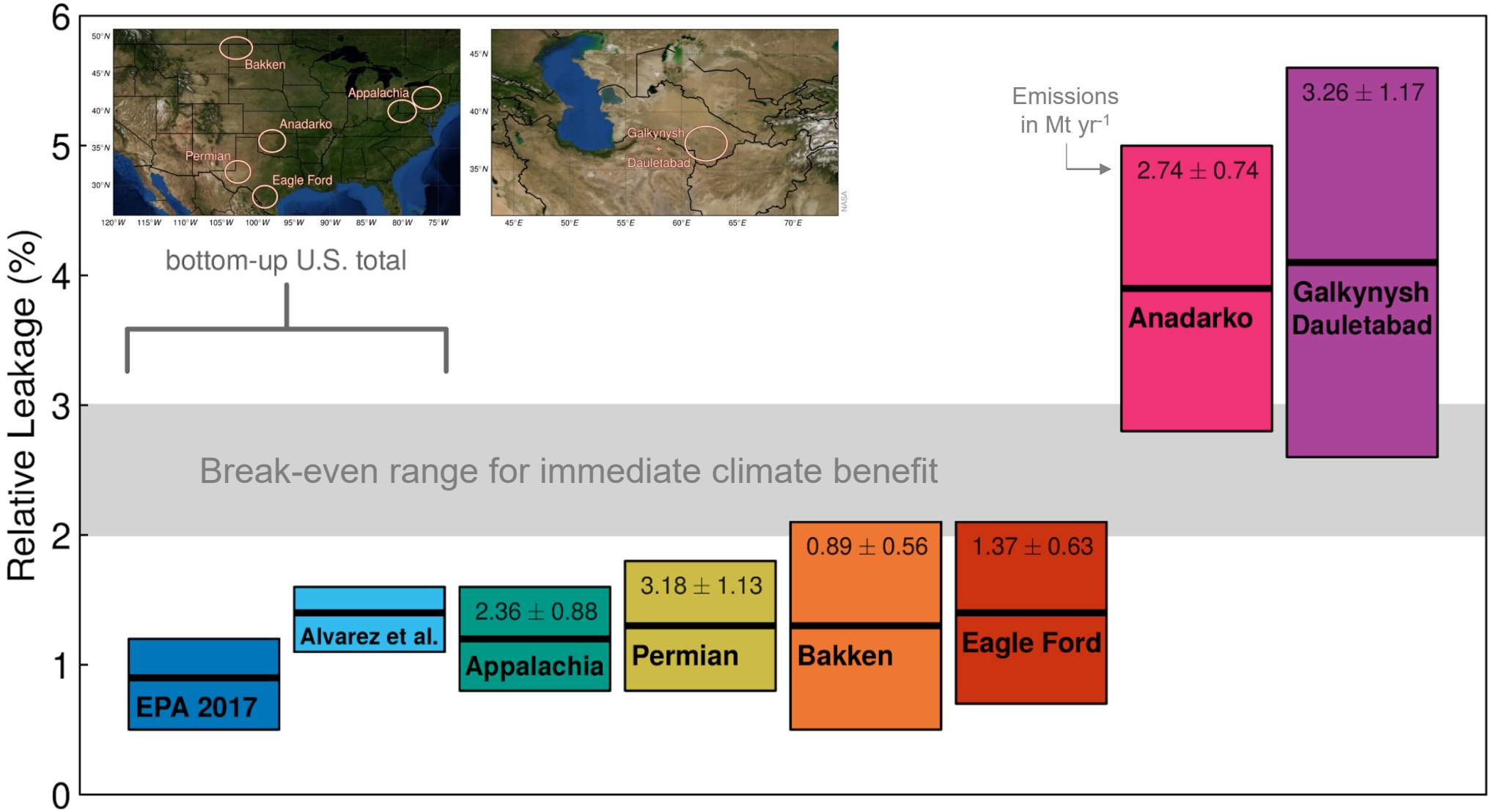
Assessment of climate impact of oil & gas industry



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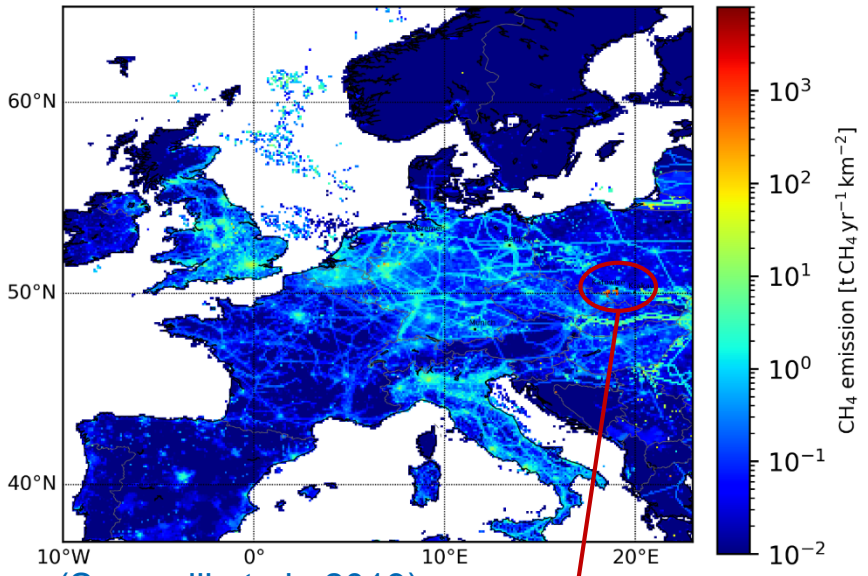
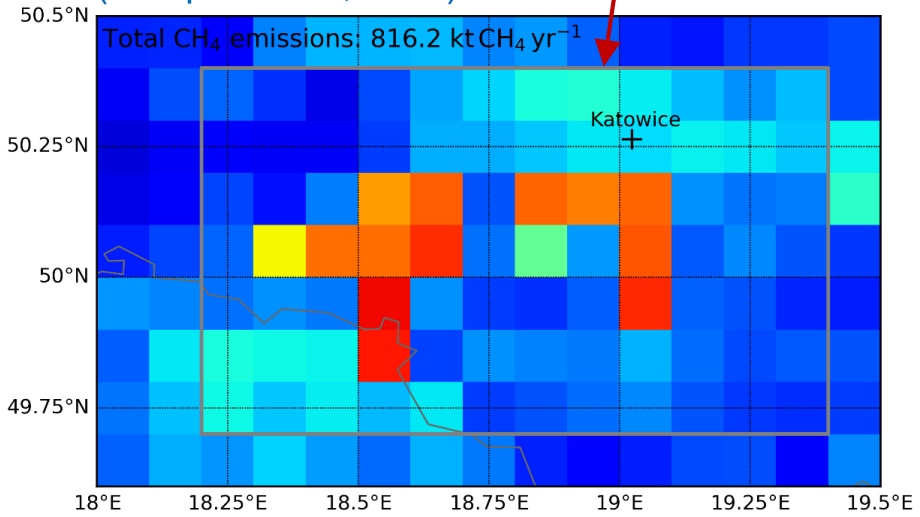
Methane emissions from coal mining



(Scarpelli et al., 2019)



Large CH_4 emission hot spot in Europe is located in the Upper Silesian Coal Basin (USCB)

(Osička et al., 2020)

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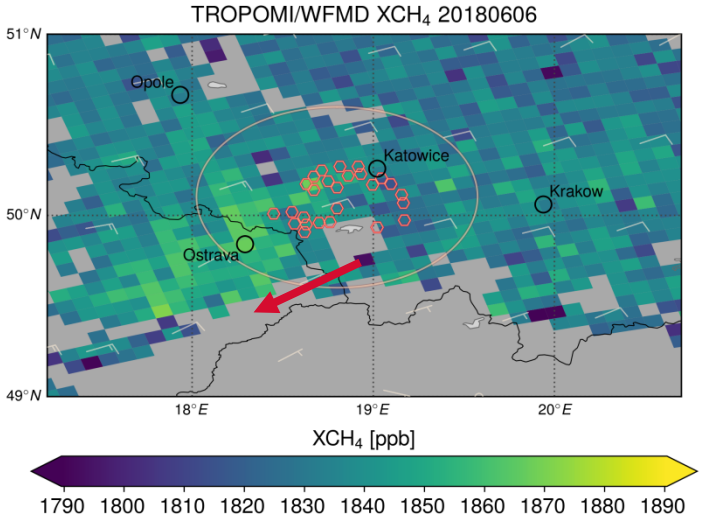
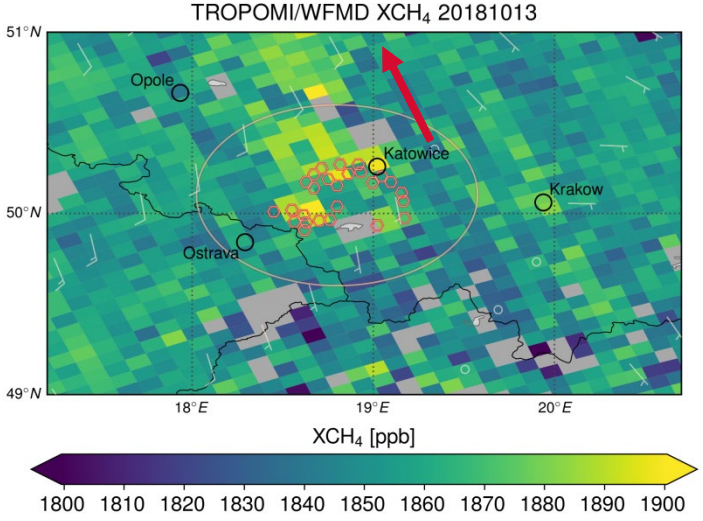
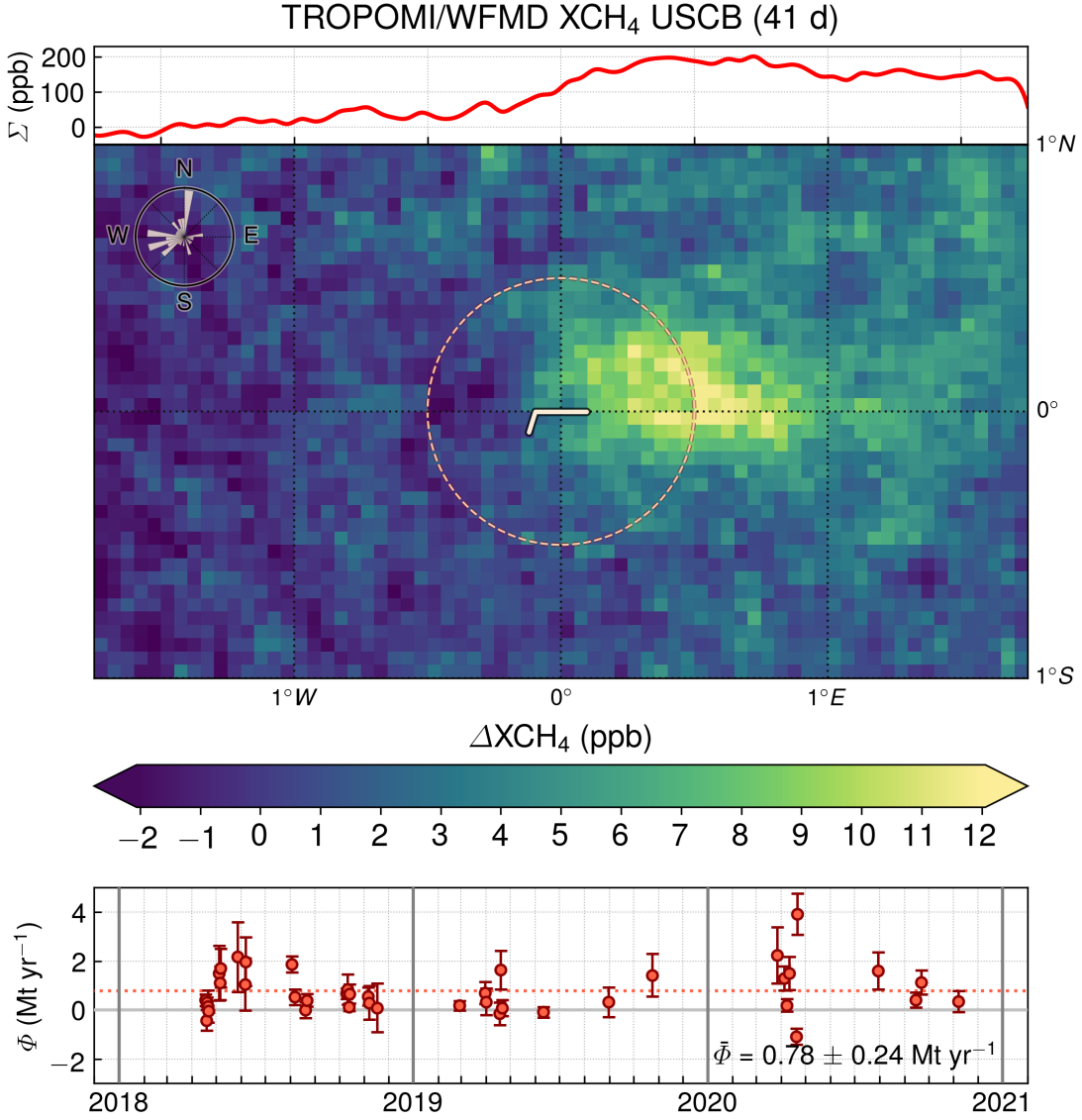
Methane emissions from coal mining







- 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

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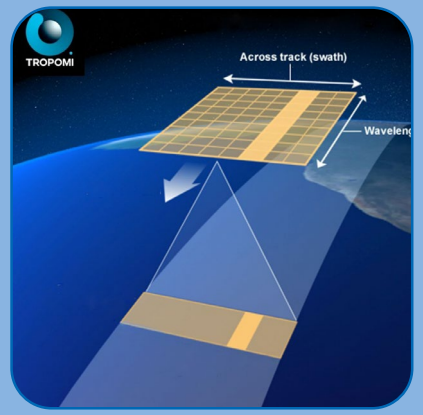
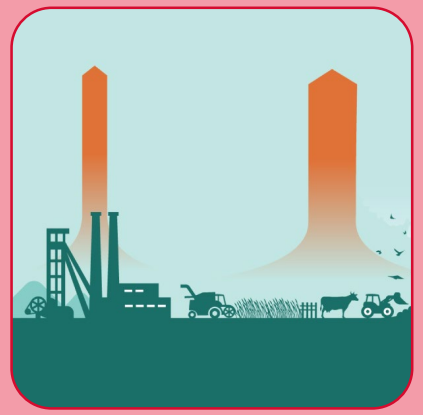
Summary & Conclusions



General

- TROPOMI offers a unique combination of high precision, accuracy, and coverage
- New fields of application are enabled
- Detection of sufficiently large emission sources in a single satellite overpass



Anthropogenic Emissions

- Emission estimation from productive oil, gas, and coal basins based on daily observations
- The results suggest that it is possible to reduce methane emissions from the oil and gas industry below the break-even leakage rate for immediate climate benefit
- However, this does not seem to have been achieved everywhere yet