Rapid Increases in Methane Concentrations Following August 2020 Suspension of the U.S. Methane Rule

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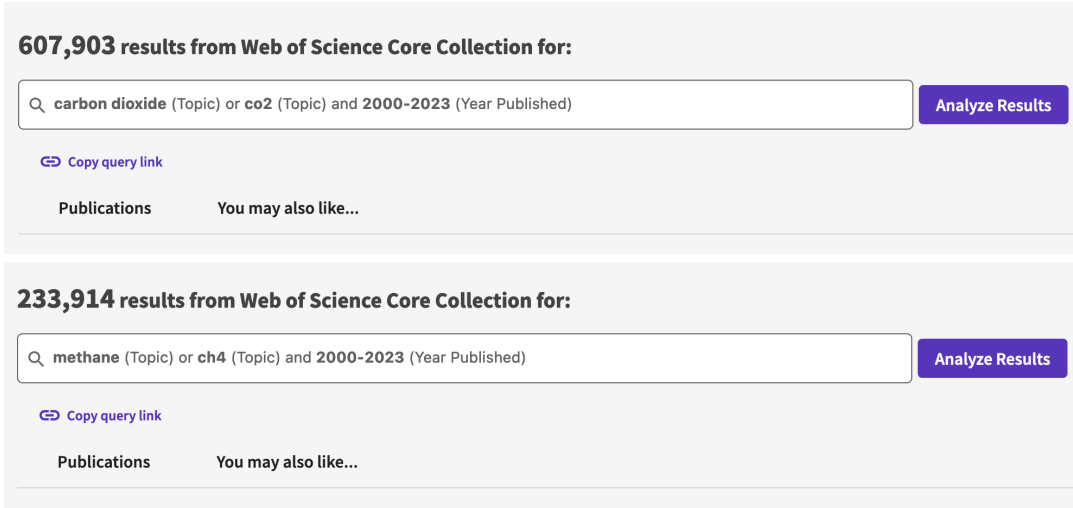
ASSA

Motivation

- Methane is a powerful greenhouse gas:
  - The global warming potential of methane is 24-84 times that of CO_2 (UNECE, 2022).
  - Methane accounts for 30% of the increase in global temperature since pre-industrial times (UNEP, 2021).
- Oil and gas sectors contribute to methane emissions:
  - Globally, fossil fuels and agriculture contribute equally to the increased global methane concentrations.
  - In the U.S., 80% of the methane increase came from fossil fuel emissions since the early 2000s (Jackson et al., 2020).
- Methane emissions are underestimated:
  - Airborne sensors detect over 9% of all methane produced in the Permian Basin is leaked into the atmosphere, five-fold higher than the EPA estimates (Chen et al., 2022).
  - Abnormal operating conditions cause even higher methane emissions, 60% more than the EPA inventory (Alvarez et al., 2018).

Motivation (con't)

- Methane remained far less prominent than carbon in climate policy (Brookings Institution, 2023).

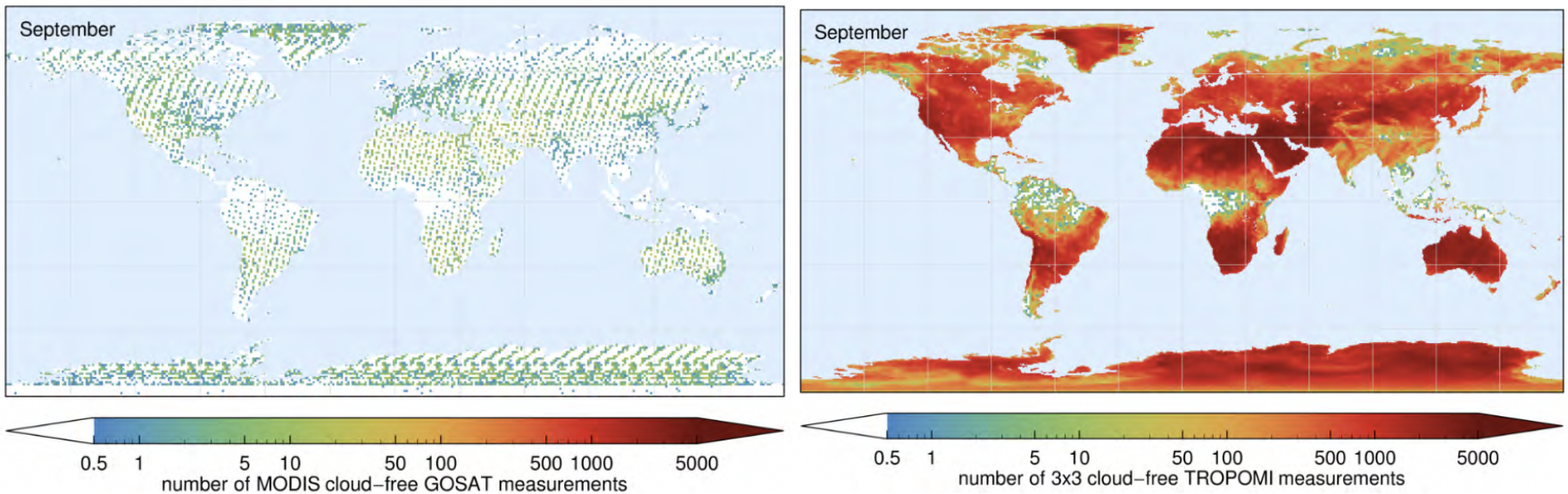


- New data opportunity from TROPOMI:

Satellite instrument	Time	Pixel size	#Measurements per second	Sensitivity per measurements
SCIAMACHY	2002-2012	60×30km	1.35	1.5-4.5%
GOSAT	2009-now	10km	0.22	0.25-0.5%
TROPOMI	2019-now	7km	216	0.1-0.3%

GOSAT vs. TROPOMI

TROPOMI (216) has ∼1000 times more measurements than GOSAT (0.22):



Source: Netherlands Institute for Space Research, 2015

This paper

- Quantify the impact of the August 2020 policy rollback on methane leakages from oil and gas facilities
- Compare results using TROPOMI all pixels, leaky pixels, ultra-emission events, self-reported data

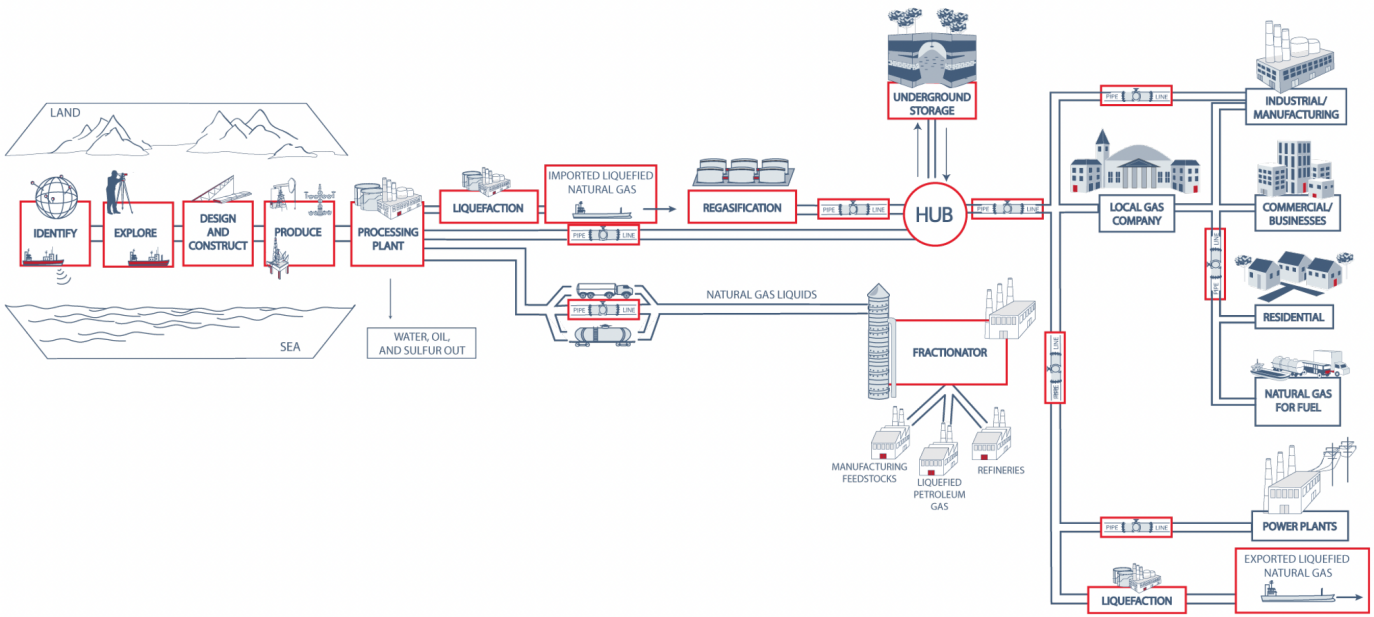
Contribution:

- The first paper economics using TROPOMI satellite and using ambient methane products
- The first empirical evidence on the impact of the 2020 policy rollback

Natural gas production

Natural gas supply chain could be generally divided into four parts:

- production (exploration, pre-production, extraction) at drilling wells,
- processing at processing plants,
- transmission or distribution along pipelines,
- storage in underground facilities.



Source: American Petroleum Institute, Understanding Our Natural Gas Supply Chain

Policy background

On August 13, 2020, the EPA issued two final rules rolling back the New Source Performance Standards (NSPS) for oil and gas facilities.

NSPS has been regulating oil and gas sectors' methane emissions since 1978.

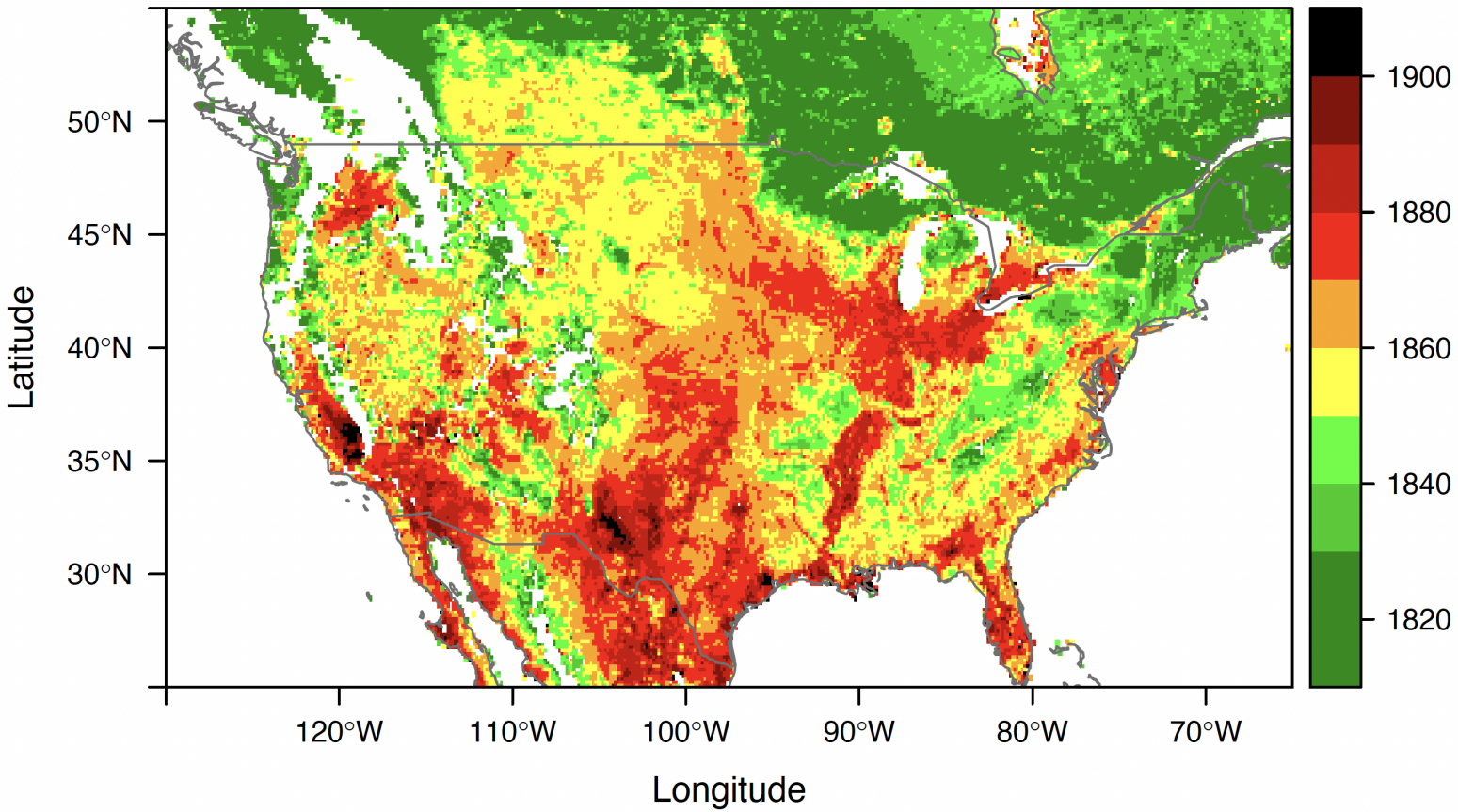
All these four parts are affected by the 2020 Amendment:

- Transmission and storage facilities removed from the NSPS source list.
- Production wells:
  Low-production wells no longer need to have fugitive emission monitoring.
  High-production wells are still required to monitor leaks but have a longer initial monitoring time after startup, from 60 to 90 days.
- Processing plants and compressors have a lower leak monitoring frequency, from quarterly to semiannually.

Data: methane

TROPOMI, column-average dry methane mixing ratios, grid into 0.1° pixel

Average methane 2019-2020, unit: ppb



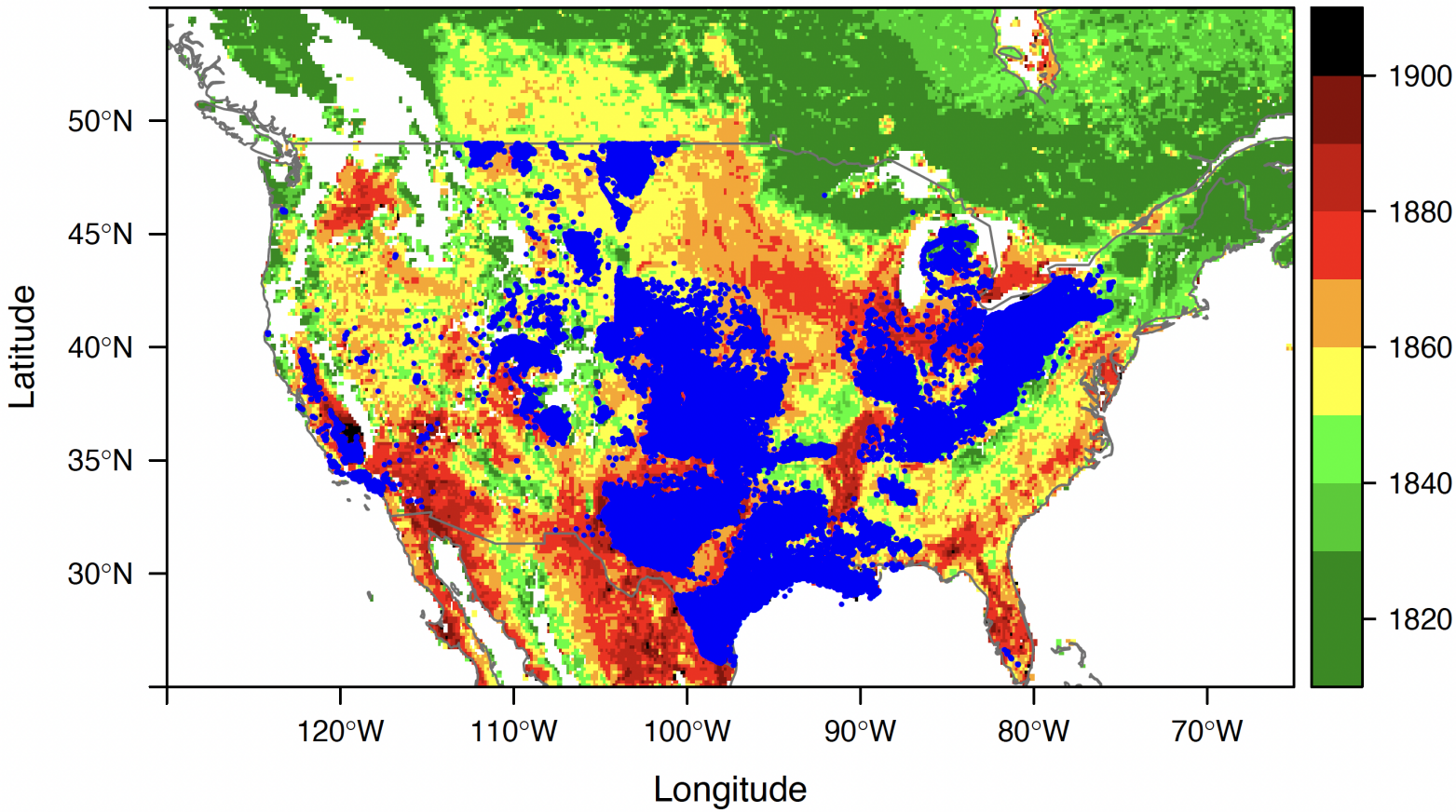
Data: natural gas facilities

EIA provides coordinates for four natural gas facilities:

- Wells:
  1,193,575 wells of any sizes in total. 203,753 are abandoned.
  398,849 are in Texas. 104,143 are in Pennsylvania. California, Kansas and Ohio have more than 90,000 wells.
- Processing plants: 478 plants
- Compressors: 1,367 compressor stations
- Pipelines: 32,961 segments

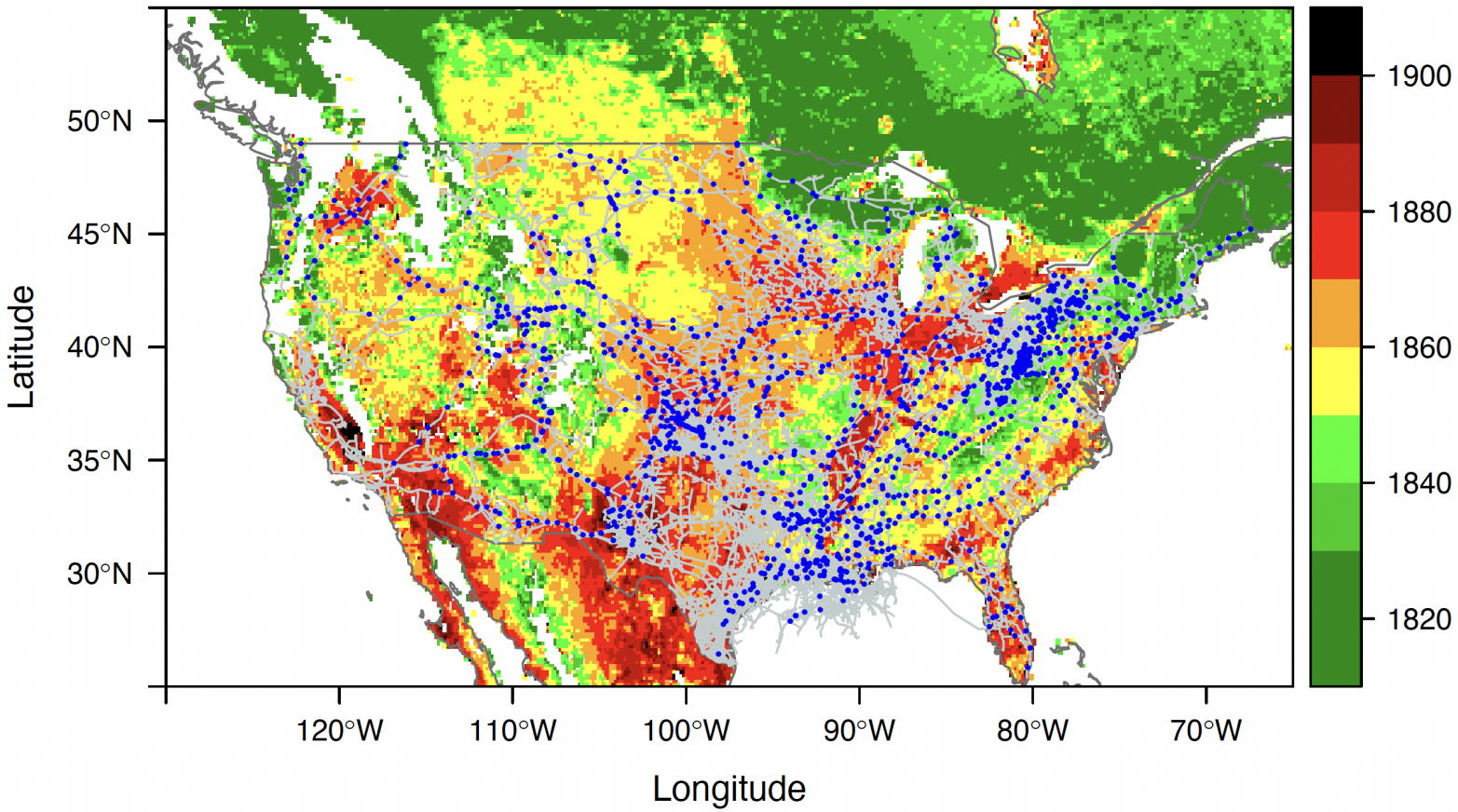
Nature gas facilities and methane distribution

Blue dots show natural gas wells, processing plants, and compressors:



Nature gas pipelines and methane distribution

Blue dots show compressors along pipelines, gray lines are pipeline segments:



Data: ultra-emission events

Kayrros ultra-emission event data:

- Derived from TROPOMI. Lauvaux et al. (2022) detect plumes greater than 25 ppb than surrounding pixels. They use atmospheric simulation to track the original emitters' locations and assign emitters' sectors.
- Globally, there are 1763 ultra-emission events from the oil and gas sector, 444 from the coal sector in 2019-2021.
  436 and 114 are in the U.S.
- Event level data: emission rate, date, emitter's coordinates, sector.

Data: self-reported emissions

EPA's Greenhouse Gas Reporting Program (GHGRP) data:

- Facilities with annual emissions over 25,000 metric tons CO2e are required to report GHG emissions.
  8546 facilities in total.
- Unit-year level data: parent company, industry type, coordinate, methane emission (metric ton)
- 41 industry types.
  2032 facilities under type 'Petroleum and Natural Gas Systems'.

Empirical strategy

Methane in treated pixels, before vs. after August 13, in 2019 vs. 2020:

$$Methane_{pwy} = \beta_1 Post_w + \beta_2 Y2020_y + \beta_3 Post_w * Y2020_y$$
$$+\kappa_w + \gamma_p + \epsilon_{pwy}$$

- Sample: 32,601 pixels with natural gas facilities
- $Methane_{pmy}$: TROPOMI methane in pixel p in week w year y
- $Post_w$: week w is after August 13
- γ_p: pixel fixed effects
- β_3: how much more methane level changed after August 13 in 2020 than in 2019

Results: ambient methane levels

Ambient methane increases by 4.6 ppb after August 13, 2020, 0.25% relative the mean.

	CH_4 (ppb)				
Post	14.703***	10.516***	10.037***	2.825***	2.648***
	(0.055)	(0.073)	(0.072)	(0.092)	(0.092)
Y2020	8.786***	0.000	0.000	0.000	0.000
	(0.040)	(.)	(.)	(.)	(.)
Post × Y2020	5.032***	5.234***	5.348***	4.439***	4.618***
	(0.060)	(0.056)	(0.053)	(0.055)	(0.054)
Observations	797790	797790	797790	797790	797790
R-square	0.570	0.612	0.637	0.630	0.663
Y-mean	1862.163	1862.163	1862.163	1862.163	1862.163
Y-sd	20.116	20.116	20.116	20.116	20.116
Year FEs		Y	Y	Y	Y
Quarter FEs		Y			
State*Quarter FEs			Y		
Month FEs				Y	
State*Month FEs					Y
Pixel FEs	Y	Y	Y	Y	Y

Notes: Standard errors are clustered at the pixel level.

Top leaky pixels

Focusing on top 5% pixels, methane increases by 6 ppb, 0.32% of the mean.

	CH_4 (ppb)				
Post	17.319***	12.358***	12.344***	5.347***	4.784***
	(0.197)	(0.341)	(0.346)	(0.606)	(0.603)
Y2020	6.865***	0.000	0.000	0.000	0.000
	(0.180)	(.)	(.)	(.)	(.)
Post × Y2020	6.490***	6.944***	7.008***	5.872***	6.058***
	(0.259)	(0.247)	(0.246)	(0.262)	(0.263)
Observations	42438	42438	42438	42438	42438
R-square	0.461	0.487	0.496	0.515	0.535
Y-mean	1887.843	1887.843	1887.843	1887.843	1887.843
Y-sd	19.782	19.782	19.782	19.782	19.782
Year FEs		Y	Y	Y	Y
Quarter FEs		Y			
State*Quarter FEs			Y		
Month FEs				Y	
State*Month FEs					Y
Pixel FEs	Y	Y	Y	Y	Y

Notes: Standard errors are clustered at the pixel level.

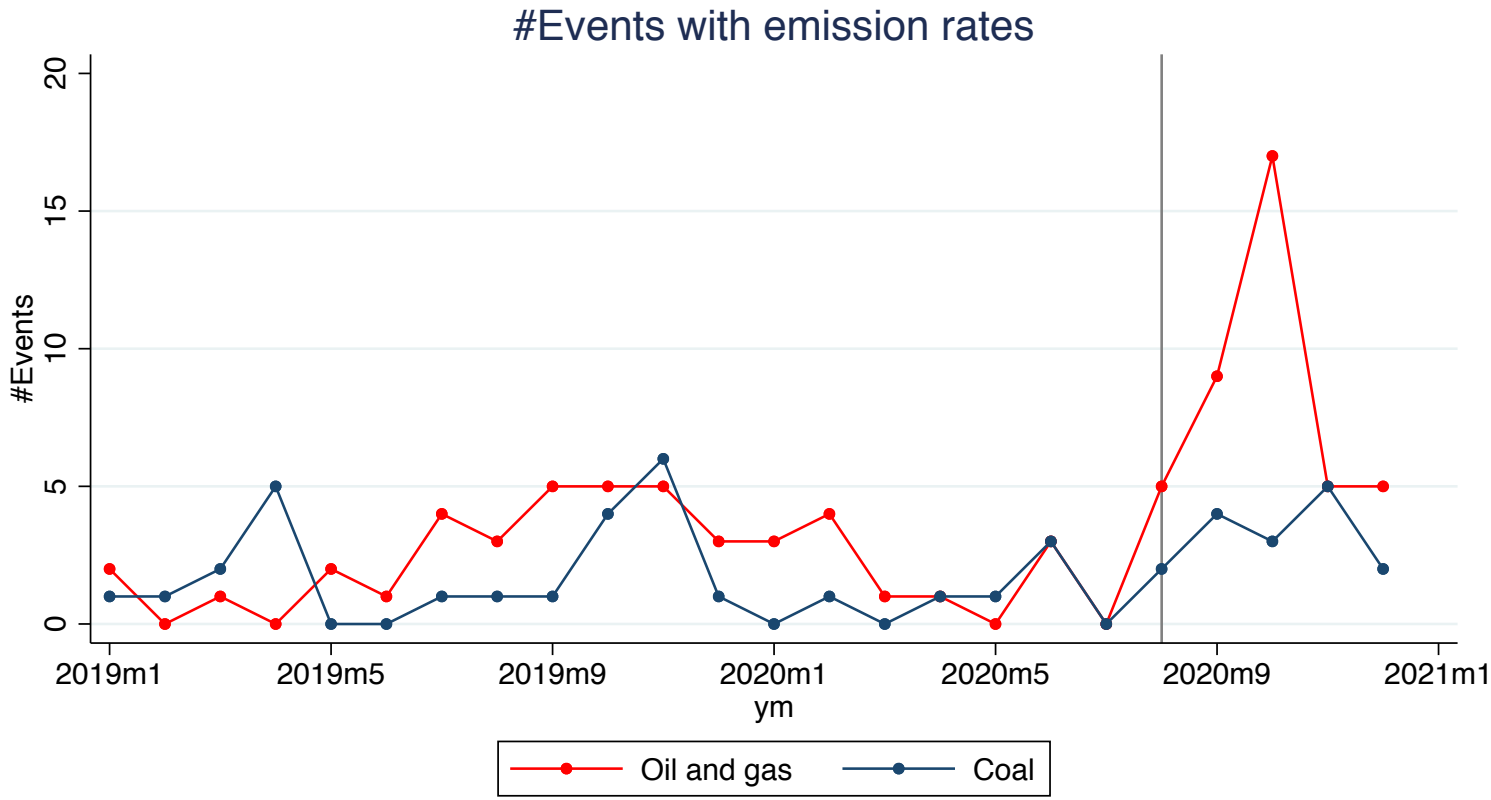
Empirical strategy: ultra-emission events

Before vs. after August 13 2020, oil & gas sector vs. coal sector:

$$\#Emissions\ events_{st} = \theta_1 Post_t + \theta_2 OG_s + \theta_3 Post_t * OG_s + \gamma_t + \epsilon_{st}$$

- $\#Emissions\ events_{st}$: #ultra-emission events in sector s on day t
- $Post_t$: day t is after August 13, 2020
- OG_s: one for oil & gas sector, zero for coal sector
- θ_3: how many more daily emission events there were in the oil and gas sector after the policy rollback

Figure: ultra-emission events



Notes: Emission events without emission rates are mostly clustered in the Permian Basin and are hard to estimate flows.

Table: ultra-emission events

The number of ultra-emission events increases by 0.1 per day in the oil & gas sector, 124% of the mean.

	#Emission events				
Post	0.063**	0.025	0.038	-0.002	0.016
	(0.031)	(0.037)	(0.039)	(0.039)	(0.042)
Post × OG	0.148***	0.148***	0.121**	0.148***	0.112**
	(0.043)	(0.043)	(0.050)	(0.043)	(0.053)
OG	0.027	0.027	0.000	0.027	0.000
	(0.018)	(0.018)	(.)	(0.018)	(.)
Observations	1438	1438	1438	1438	1438
R-square	0.042	0.058	0.060	0.067	0.078
Y-mean	0.090	0.090	0.090	0.090	0.090
Y-sd	0.322	0.322	0.322	0.322	0.322
Year FEs		Y	Y	Y	Y
DOW FEs		Y	Y	Y	Y
Quarter FEs		Y			
Sector*Quarter FEs			Y		
Month FEs				Y	
Sector*Month FEs					Y

Results: self-reported emissions

Oil & gas companies have a lower decrease by 3.8 metric tons per unit-year, 14.9% relative to the average.

	CH_4 (metric tons)		
Post	-4.150***	-4.150***	-4.150***
	(0.601)	(0.602)	(0.602)
Post × OG	3.753***	3.753***	3.753***
	(0.613)	(0.614)	(0.614)
OG	-24.340***	-28.852***	0.000
	(2.169)	(3.004)	(.)
Observations	11418	11418	11418
R-square	0.008	0.023	0.976
Y-mean	22.874	22.874	22.874
Y-sd	110.716	110.716	110.716
State FEs		Y	Y
Company FEs			Y

How severe is the extra methane emissions?

- Assuming the maximum duration, i.e. 24-hour operation, the policy relaxation leads to the oil and gas sector's more methane emissions by 221.8 tons per day, 80,957 tons per year.
- This is equivalent to 0.87% of the total methane emissions from the oil & gas sector. 92 million more trees should be planted to offset the additional warming effect.

Implications:

- Private benefit of reducing leakage: natural gas is a commercial product.
- Social benefit is ignored by private companies.

Appendix

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