Supplement of

Quantifying national, state, and oil/gas field methane emissions and trends in the U.S. (2019-2024) through high resolution inversion of satellite observations

Lucas A. Estrada et al.

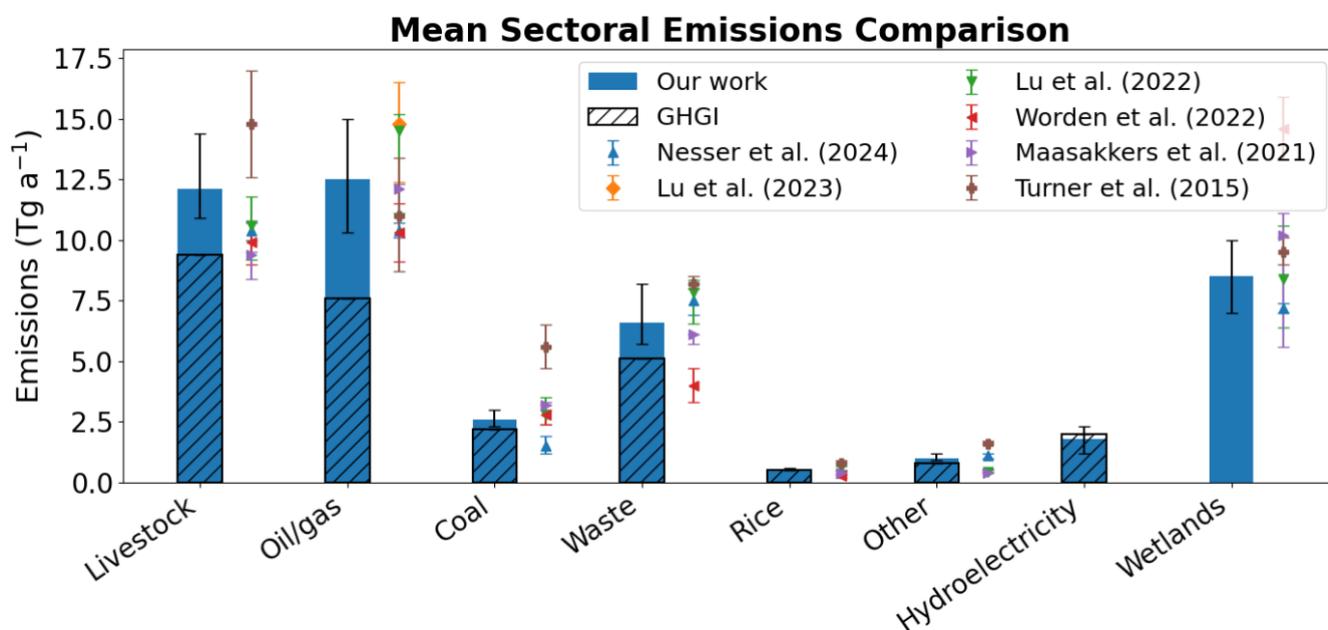*Correspondence to*: Lucas A. Estrada (lestrada@g.harvard.edu)

Figure S1: Comparison of national emissions estimate with other studies. This work is the mean for 2019-2024. Error bars for our work represent the range from the ensemble of estimates.

Table S1: Anthropogenic emissions and trends for 48 states[a]

State	Anthropogenic Mean (Tg a⁻¹)	Annual Trend (% a⁻¹)	Livestock emissions (Tg a⁻¹)	Oil/Gas emissions (Tg a⁻¹)	Coal emissions (Tg a⁻¹)	Landfills emissions (Tg a⁻¹)	Reservoirs emissions (Tg a⁻¹)	Rice emissions (Tg a⁻¹)	Wastewater emissions (Tg a⁻¹)	Other Anthropogenic emissions (Tg a⁻¹)	Sensitivity[b] emissions (Tg a⁻¹)
Alabama	0.9[0.7, 1.0]	3.0 ± 2.4	[0.1, 0.14]	[0.11, 0.16]	[0.16, 0.23]	[0.17, 0.25]	[0.14, 0.19]	[0.0, 0.0]	[0.03, 0.05]	[0.01, 0.01]	0.49
Arizona	0.1[0.0, 0.2]	11.8 ± 8.0	[0.0, 0.09]	[0.01, 0.04]	[0.0, 0.0]	[0.01, 0.05]	[-0.01, 0.01]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.0]	0.35
Arkansas	0.7[0.6, 0.9]	-5.3 ± 1.1	[0.14, 0.19]	[0.15, 0.21]	[0.01, 0.02]	[0.06, 0.1]	[0.06, 0.09]	[0.17, 0.26]	[0.01, 0.02]	[0.01, 0.01]	0.57
California	1.5[1.1, 1.9]	1.6 ± 2.4	[0.75,	[0.12,	[0.0, 0.0]	[0.16,	[0.0, 0.05]	[0.05,	[0.02, 0.05]	[0.01, 0.03]	0.72

		1.08]	0.23]		0.35]		0.1]			
Colorado	0.7[0.5, 0.8]	2.3 ± 5.1	[0.16, 0.28]	[0.28, 0.39]	[0.01, 0.04]	[0.04, 0.08]	[0.0, 0.01]	[0.0, 0.0]	[0.01, 0.01]	[0.01, 0.01]	0.67
Connecticut	0.0[0.0, 0.0]	1.1 ± 3.2	[0.0, 0.0]	[0.01, 0.01]	[0.0, 0.0]	[0.01, 0.01]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	0.19
Delaware	0.0[0.0, 0.0]	-3.2 ± 7.6	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.01, 0.01]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.0]	0.24
Florida	0.7[0.5, 0.9]	8.3 ± 3.6	[0.15, 0.29]	[0.04, 0.07]	[0.0, 0.0]	[0.27, 0.5]	[0.0, 0.0]	[0.0, 0.0]	[0.02, 0.02]	[0.02, 0.03]	0.39
Georgia	0.8[0.6, 0.9]	-0.4 ± 4.6	[0.14, 0.2]	[0.05, 0.08]	[0.0, 0.0]	[0.27, 0.48]	[0.09, 0.14]	[0.0, 0.0]	[0.02, 0.03]	[0.02, 0.02]	0.44
Idaho	0.2[0.1, 0.3]	1.3 ± 11.2	[0.09, 0.25]	[-0.0, 0.01]	[0.0, 0.0]	[0.01, 0.02]	[-0.02, 0.07]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	0.5
Illinois	1.0[0.8, 1.3]	-0.1 ± 5.9	[0.2, 0.34]	[0.11, 0.2]	[0.15, 0.21]	[0.22, 0.41]	[0.01, 0.02]	[0.0, 0.0]	[0.04, 0.06]	[0.03, 0.05]	0.46
Indiana	0.8[0.6, 1.0]	0.2 ± 4.0	[0.18, 0.28]	[0.07, 0.11]	[0.15, 0.23]	[0.16, 0.3]	[0.0, 0.0]	[0.0, 0.0]	[0.02, 0.04]	[0.03, 0.04]	0.44
Iowa	0.9[0.8, 1.2]	9.1 ± 5.1	[0.62, 0.91]	[0.05, 0.08]	[0.0, 0.0]	[0.08, 0.16]	[0.0, 0.0]	[0.0, 0.0]	[0.01, 0.02]	[0.01, 0.01]	0.49
Kansas	1.3[1.1, 1.5]	6.6 ± 2.2	[0.6, 0.79]	[0.45, 0.58]	[0.0, 0.0]	[0.06, 0.08]	[0.0, 0.0]	[0.0, 0.0]	[0.01, 0.01]	[0.03, 0.03]	0.55
Kentucky	0.8[0.7, 1.0]	-1.0 ± 2.8	[0.19, 0.26]	[0.13, 0.2]	[0.13, 0.21]	[0.15, 0.21]	[0.02, 0.1]	[0.0, 0.0]	[0.01, 0.01]	[0.03, 0.04]	0.5
Louisiana	1.2[1.0, 1.5]	-11.0 ± 2.3	[0.06, 0.08]	[0.51, 0.79]	[0.0, 0.0]	[0.18, 0.3]	[0.01, 0.04]	[0.09, 0.12]	[0.08, 0.11]	[0.03, 0.05]	0.58
Maine	0.1[-0.0, 0.1]	11.7 ± 15.9	[0.0, 0.01]	[0.0, 0.01]	[0.0, 0.0]	[-0.0, 0.02]	[-0.0, 0.09]	[0.0, 0.0]	[-0.0, 0.0]	[-0.0, 0.01]	0.44
Maryland	0.1[0.1, 0.1]	-3.6 ± 10.5	[0.01, 0.02]	[0.01, 0.03]	[0.0, 0.0]	[0.02, 0.05]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.01]	0.26
Massachusetts	0.1[0.0, 0.1]	-4.0 ± 2.6	[0.0, 0.0]	[0.01, 0.02]	[0.0, 0.0]	[0.02, 0.02]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	0.21
Michigan	0.8[0.7, 1.0]	3.2 ± 4.8	[0.23, 0.33]	[0.13, 0.2]	[0.0, 0.0]	[0.23, 0.35]	[0.01, 0.01]	[0.0, 0.0]	[0.03, 0.05]	[0.03, 0.05]	0.58
Minnesota	0.6[0.5, 0.8]	0.5 ± 4.2	[0.39, 0.6]	[0.03, 0.05]	[0.0, 0.0]	[0.05, 0.08]	[0.0, 0.01]	[0.0, 0.0]	[0.01, 0.01]	[0.01, 0.02]	0.56
Mississippi	0.3[0.3, 0.5]	-4.3 ± 3.5	[0.09, 0.13]	[0.1, 0.14]	[0.0, 0.0]	[0.06, 0.11]	[0.0, 0.0]	[0.02, 0.04]	[0.01, 0.02]	[0.01, 0.01]	0.44
Missouri	1.0[0.8, 1.2]	3.7 ± 4.2	[0.42, 0.62]	[0.04, 0.07]	[0.0, 0.0]	[0.08, 0.14]	[0.08, 0.11]	[0.04, 0.05]	[0.11, 0.16]	[0.02, 0.02]	0.49
Montana	0.3[0.1, 0.4]	1.9 ± 3.8	[0.1, 0.22]	[0.04, 0.06]	[0.0, 0.02]	[0.0, 0.01]	[-0.01, 0.09]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	0.4
Nebraska	0.9[0.8, 1.2]	1.7 ± 4.1	[0.66, 0.97]	[0.04, 0.07]	[0.0, 0.0]	[0.06, 0.09]	[0.0, 0.01]	[0.0, 0.0]	[0.01, 0.01]	[0.01, 0.01]	0.52
Nevada	0.0[-0.1, 0.1]	2.9 ± 7.8	[-0.0, 0.04]	[-0.01, 0.01]	[0.0, 0.0]	[-0.02, 0.01]	[-0.03, 0.04]	[0.0, 0.0]	[-0.0, 0.0]	[-0.0, 0.0]	0.17
New Hampshire	0.0[0.0, 0.1]	-5.2 ± 11.0	[0.0, 0.01]	[0.0, 0.0]	[0.0, 0.0]	[-0.0, 0.02]	[0.01, 0.02]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	0.31
New Jersey	0.1[0.0, 0.1]	3.2 ± 3.9	[0.0, 0.0]	[0.02, 0.02]	[0.0, 0.0]	[0.02, 0.04]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.0]	0.3
New Mexico	1.3[1.0, 1.5]	0.8 ± 4.2	[0.12, 0.24]	[0.86, 1.09]	[0.01, 0.03]	[0.03, 0.05]	[0.01, 0.03]	[0.0, 0.0]	[0.0, 0.0]	[0.01, 0.01]	0.57
New York	0.6[0.5, 0.7]	4.8 ± 3.6	[0.21, 0.29]	[0.14, 0.19]	[0.0, 0.0]	[0.1, 0.13]	[0.02, 0.03]	[0.0, 0.0]	[0.02, 0.03]	[0.04, 0.05]	0.51
North Carolina	0.5[0.4, 0.6]	0.5 ± 2.9	[0.19, 0.26]	[0.03, 0.04]	[0.0, 0.0]	[0.15, 0.23]	[0.03, 0.04]	[0.0, 0.0]	[0.02, 0.02]	[0.01, 0.01]	0.51
North Dakota	0.4[0.2, 0.5]	4.3 ± 5.8	[0.16, 0.24]	[0.08, 0.15]	[0.0, 0.0]	[0.02, 0.05]	[-0.03, 0.05]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	0.48
Ohio	1.4[1.1, 1.6]	-1.8 ± 4.3	[0.22, 0.38]	[0.34, 0.45]	[0.19, 0.25]	[0.28, 0.43]	[0.0, 0.0]	[0.0, 0.0]	[0.03, 0.04]	[0.07, 0.1]	0.58
Oklahoma	2.2[1.8, 2.7]	-1.4 ± 1.0	[0.53, 0.67]	[0.93, 1.46]	[0.01, 0.03]	[0.14, 0.21]	[0.14, 0.22]	[0.0, 0.0]	[0.01, 0.02]	[0.04, 0.06]	0.62
Oregon	0.1[0.0, 0.2]	-1.0 ± 9.3	[0.01, 0.1]	[-0.0, 0.01]	[0.0, 0.0]	[-0.0, 0.03]	[-0.01, 0.02]	[0.0, 0.0]	[-0.0, 0.0]	[-0.0, 0.01]	0.38
Pennsylvania	1.6[1.3, 2.0]	1.0 ± 2.3	[0.24, 0.41]	[0.54, 0.89]	[0.3, 0.38]	[0.15, 0.23]	[0.0, 0.0]	[0.0, 0.0]	[0.02, 0.03]	[0.08, 0.11]	0.58
Rhode Island	0.0[0.0, 0.0]	-2.2 ± 3.8	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	0.07

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South Carolina	0.3[0.2, 0.4]	-3.0 ± 7.2	[0.04, 0.07]	[0.02, 0.04]	[0.0, 0.0]	[0.07, 0.14]	[0.04, 0.11]	[0.0, 0.0]	[0.01, 0.01]	[0.01, 0.01]	0.5
South Dakota	0.7[0.5, 0.8]	1.1 ± 6.2	[0.42, 0.64]	[0.01, 0.01]	[0.0, 0.0]	[0.02, 0.03]	[0.05, 0.15]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.01]	0.47
Tennessee	0.8[0.6, 1.0]	-3.4 ± 3.8	[0.17, 0.3]	[0.08, 0.12]	[0.0, 0.0]	[0.16, 0.25]	[0.2, 0.27]	[0.01, 0.02]	[0.02, 0.03]	[0.02, 0.03]	0.49
Texas	7.2[5.8, 8.6]	-2.6 ± 1.3	[1.34, 1.78]	[3.38, 5.32]	[0.01, 0.02]	[0.61, 0.85]	[0.15, 0.2]	[0.04, 0.07]	[0.07, 0.12]	[0.18, 0.23]	0.69
Utah	0.4[0.2, 0.5]	-4.8 ± 8.1	[0.05, 0.1]	[0.15, 0.27]	[0.03, 0.04]	[0.01, 0.03]	[-0.02, 0.03]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	0.38
Vermont	0.0[0.0, 0.1]	2.4 ± 8.9	[0.02, 0.04]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	[0.0, 0.01]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.0]	0.41
Virginia	0.5[0.4, 0.6]	4.3 ± 4.9	[0.11, 0.18]	[0.04, 0.06]	[0.08, 0.12]	[0.1, 0.16]	[0.03, 0.05]	[0.0, 0.0]	[0.01, 0.02]	[0.01, 0.01]	0.45
Washington	0.1[0.0, 0.3]	-0.3 ± 9.1	[0.02, 0.12]	[0.0, 0.02]	[0.0, 0.0]	[-0.01, 0.06]	[0.01, 0.03]	[0.0, 0.0]	[0.0, 0.01]	[-0.0, 0.01]	0.51
West Virginia	1.8[1.5, 2.1]	-0.7 ± 2.9	[0.07, 0.1]	[0.48, 0.79]	[0.88, 1.08]	[0.05, 0.07]	[0.0, 0.0]	[0.0, 0.0]	[0.0, 0.01]	[0.02, 0.04]	0.65
Wisconsin	0.7[0.6, 0.8]	1.0 ± 5.1	[0.42, 0.57]	[0.03, 0.04]	[0.0, 0.0]	[0.09, 0.14]	[0.02, 0.04]	[0.0, 0.0]	[0.01, 0.01]	[0.02, 0.02]	0.55
Wyoming	0.5[0.4, 0.7]	-2.9 ± 5.9	[0.07, 0.11]	[0.21, 0.34]	[0.03, 0.14]	[0.0, 0.01]	[0.04, 0.06]	[0.0, 0.0]	[-0.0, 0.0]	[0.0, 0.0]	0.57

[a] Numbers in brackets represent the range from the ensemble.

[b] Averaging kernel sensitivities from the reduced averaging kernel matrix (Nesser et al., 2024) for the 2019-2024 mean of ensemble members using normal error pdfs. They describe the relative contributions of the TROPOMI observations and the prior estimates to the posterior estimates. Value of 1 indicates 100% contribution from the observations; value of 0 indicates no contribution from the observations.
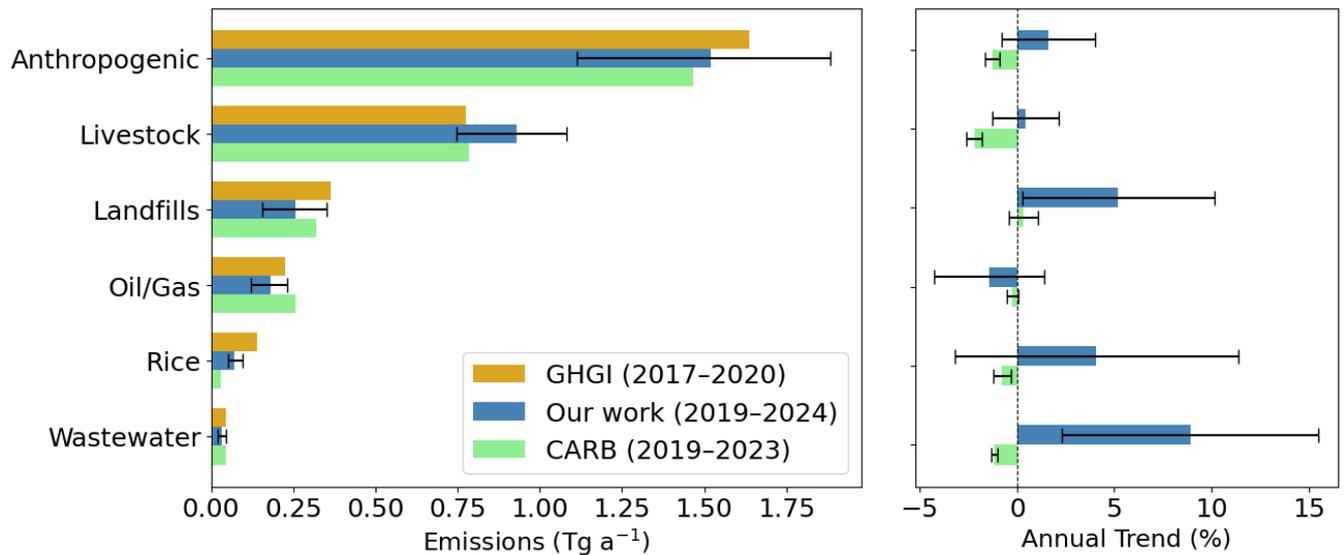
Figure S2: Comparison of trends and estimates of inventory values for major sectors in California. Upper panel shows the mean emissions for each inventory (period in legend). Error bars on mean are the range from the inversion ensemble. Lower panel shows the trend of the state inventory and our work calculated with OLS regression. Error bars are the standard error from the regression line.
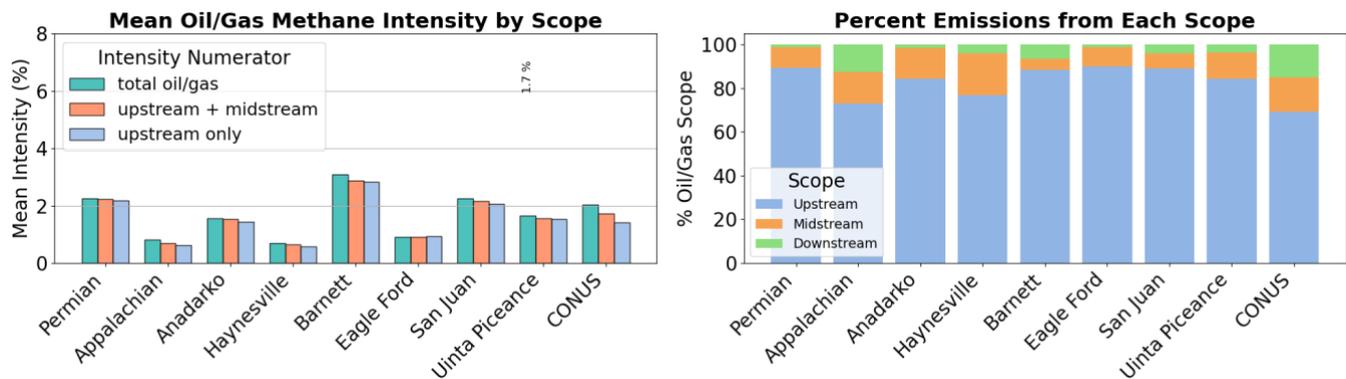
Figure S3: Mean oil/gas production methane intensities with different scope definitions and breakdown of scope contributions to emissions. Left panel calculates methane intensity including: all oil/gas emissions, upstream and midstream emissions, and only upstream emissions. Percent of emissions from each scope (upstream, midstream, downstream) for individual production fields and CONUS. Scope emissions calculated using GHGI emission distributions for each grid cell applied to posterior emissions.