Figure S1: Evaluation of the TROPOMI methane data with GOSAT observations. Each panel shows the TROPOMI data (y-axis) plotted against the GOSAT observations (x-axis), each averaged on a 2° × 2° grid over the North America domain (Figure 2). Data density is shown instead of individual points. Columns show data for each season. The top row shows the unfiltered TROPOMI data with only the standard quality assessment filter applied. The bottom row shows the filtered TROPOMI data that removes observations over scenes that are likely snow- and ice-covered following Section 2.4. Inset are the squared Pearson correlation coefficient (R2) and the regional bias defined as the standard deviation of the grid-cell-to-grid-cell bias.



Figure S2: Quantification of (GEOS-Chem - TROPOMI) biases in a simulation run with the prior emissions. The bold line shows the annual mean (GEOS-Chem - TROPOMI) difference by latitude, with error bars given by the one standard deviation range. Light lines show the (GEOS-Chem - TROPOMI) difference averaged seasonally. Grey lines give the mean bias (9.11 ppb) and the latitudinal bias fit (, where is the degrees latitude) used as corrections to the (model - observation) difference in the eight-member inversion ensemble.



Figure S3: Methane emissions from the TROPOMI inversion for the oil and gas sector for individual basins across North America for 2019. Basin boundaries are defined following Shen et al. (2022) and Lu et al. (2023). The posterior emissions are shown as bars, with error bars are given by the eight-member ensemble range. Also shown are basin estimates and error bars from Shen et al. (2022) and Lu et al. (2023) and the 0.5 Tg a-1 threshold for successful emission quantification from Shen et al. (2022).

Table S1 (page 1 of 2): Methane emissions from the 48 states in the contiguous United States for 2019.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Emissions (Gg a-1)**1 | **Livestock** | | **Oil and gas** | | **Coal** | | **Landfills** | | **Wastewater** | | **Other anthropogenic** | | **Total** | | |
| **State** | **GHGI**2 | **x̂**3 | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂**4 | **DOFS**5 |
| 1. Texas | 1023 | 1165 | 2096 | 4299 | 9 | 24 | 509 | 627 | 60 | 48 | 94 | 110 | 3790 | 6274 (6101, 6454) | 0.94 (0.89, 0.97) |
| 2. California | 760 | 1104 | 309 | 231 | 0 | 0 | 348 | 514 | 65 | 58 | 217 | 148 | 1698 | 2055 (1970, 2122) | 0.86 (0.75, 0.93) |
| 3. Oklahoma | 380 | 399 | 643 | 894 | 3 | 20 | 86 | 121 | 10 | 3 | 7 | 6 | 1128 | 1444 (1384, 1511) | 0.86 (0.75, 0.92) |
| 4. Pennsylvania | 199 | 196 | 703 | 238 | 498 | 524 | 109 | 196 | 25 | 20 | 22 | 20 | 1555 | 1194 (1061, 1384) | 0.57 (0.35, 0.77) |
| 5. New Mexico | 170 | 211 | 406 | 925 | 28 | 32 | 34 | -34 | 3 | 2 | 6 | 3 | 647 | 1139 (1100, 1180) | 0.96 (0.93, 0.98) |
| 6. Louisiana | 62 | 79 | 443 | 731 | 1 | 2 | 131 | 126 | 10 | 9 | 119 | 174 | 766 | 1121 (1010, 1258) | 0.55 (0.28, 0.76) |
| 7. Iowa | 555 | 793 | 57 | 59 | 0 | 0 | 63 | 116 | 23 | 13 | 6 | 7 | 705 | 989 (952, 1010) | 0.75 (0.54, 0.88) |
| 8. Illinois | 160 | 191 | 143 | 121 | 126 | 170 | 157 | 368 | 25 | 37 | 17 | 21 | 627 | 907 (862, 944) | 0.55 (0.29, 0.79) |
| 9. Florida | 155 | 250 | 56 | 26 | 0 | 0 | 311 | 540 | 38 | 15 | 22 | 47 | 582 | 878 (699, 1106) | 0.32 (0.04, 0.58) |
| 10. Kansas | 490 | 448 | 373 | 358 | 0 | 0 | 54 | 41 | 18 | 9 | 5 | 3 | 940 | 860 (839, 888) | 0.80 (0.66, 0.89) |
| 11. Colorado | 263 | 232 | 392 | 351 | 65 | 102 | 72 | 110 | 14 | 4 | 10 | 5 | 816 | 804 (740, 861) | 0.59 (0.44, 0.72) |
| 12. Michigan | 182 | 187 | 160 | 121 | 0 | 0 | 196 | 392 | 18 | 19 | 27 | 22 | 582 | 742 (674, 813) | 0.49 (0.16, 0.74) |
| 13. Alabama | 102 | 109 | 122 | 120 | 183 | 154 | 168 | 259 | 21 | 25 | 10 | 11 | 605 | 677 (629, 717) | 0.75 (0.55, 0.89) |
| 14. North Carolina | 266 | 375 | 41 | 23 | 0 | 0 | 185 | 225 | 28 | 17 | 12 | 13 | 531 | 654 (547, 744) | 0.48 (0.24, 0.71) |
| 15. Ohio | 165 | 146 | 348 | 160 | 30 | 32 | 214 | 244 | 19 | 24 | 18 | 16 | 793 | 622 (578, 673) | 0.63 (0.38, 0.82) |
| 16. Indiana | 140 | 170 | 74 | 60 | 132 | 79 | 115 | 274 | 15 | 17 | 13 | 16 | 489 | 616 (561, 676) | 0.54 (0.28, 0.74) |
| 17. Nebraska | 531 | 533 | 45 | 24 | 0 | 0 | 47 | 46 | 22 | 5 | 4 | 3 | 649 | 611 (604, 619) | 0.64 (0.48, 0.73) |
| 18. West Virginia | 28 | 26 | 386 | 182 | 582 | 360 | 30 | 32 | 3 | 2 | 5 | 4 | 1033 | 607 (485, 730) | 0.66 (0.46, 0.83) |
| 19. Arkansas | 124 | 122 | 136 | 134 | 0 | 13 | 61 | 106 | 15 | 10 | 233 | 218 | 568 | 605 (569, 636) | 0.74 (0.48, 0.86) |
| 20. Georgia | 114 | 127 | 51 | 47 | 0 | 0 | 256 | 374 | 28 | 9 | 14 | 18 | 462 | 575 (509, 655) | 0.58 (0.35, 0.73) |
| 21. Wisconsin | 424 | 407 | 46 | 16 | 0 | 0 | 83 | 114 | 15 | 8 | 17 | 14 | 584 | 559 (518, 595) | 0.47 (0.07, 0.70) |
| 22. Idaho | 316 | 317 | 13 | 11 | 0 | 0 | 20 | 219 | 5 | 2 | 8 | 3 | 362 | 551 (498, 596) | 0.63 (0.49, 0.76) |
| 23. Minnesota | 295 | 381 | 48 | 26 | 0 | 0 | 52 | 83 | 16 | 4 | 15 | 10 | 426 | 504 (475, 534) | 0.53 (0.13, 0.69) |
| 24. Mississippi | 77 | 104 | 87 | 132 | 3 | 6 | 73 | 134 | 11 | 24 | 40 | 23 | 291 | 423 (380, 478) | 0.53 (0.22, 0.75) |
| 25. New York | 230 | 139 | 131 | 47 | 0 | 0 | 107 | 154 | 29 | 43 | 27 | 23 | 524 | 405 (352, 445) | 0.30 (0.06, 0.50) |

Table S1 (page 2 of 2): Methane emissions from the 48 states in the contiguous United States for 2019.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Emissions (Gg a-1)**1 | **Livestock** | | **Oil and gas** | | **Coal** | | **Landfills** | | **Wastewater** | | **Other anthropogenic** | | **Total** | | |
| **State** | **GHGI**2 | **x̂**3 | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂** | **GHGI** | **x̂**4 | **DOFS**5 |
| 26. Kentucky | 154 | 143 | 148 | 68 | 61 | 69 | 152 | 105 | 11 | 4 | 9 | 7 | 536 | 395 (347, 449) | 0.64 (0.40, 0.82) |
| 27. South Dakota | 332 | 347 | 13 | 12 | 0 | 0 | 11 | 18 | 5 | 12 | 2 | 2 | 362 | 392 (376, 401) | 0.38 (0.11, 0.53) |
| 28. Missouri | 331 | 266 | 42 | 14 | 0 | 0 | 64 | 54 | 16 | 9 | 44 | 24 | 497 | 367 (339, 394) | 0.55 (0.29, 0.69) |
| 29. Virginia | 112 | 109 | 88 | 31 | 153 | 20 | 119 | 169 | 20 | 22 | 14 | 11 | 507 | 362 (299, 428) | 0.56 (0.35, 0.75) |
| 30. Tennessee | 132 | 122 | 54 | 40 | 2 | 2 | 114 | 132 | 13 | 20 | 9 | 7 | 324 | 322 (301, 349) | 0.60 (0.33, 0.77) |
| 31. Montana | 215 | 211 | 87 | 63 | 20 | 10 | 13 | 19 | 2 | 1 | 8 | 3 | 344 | 306 (292, 322) | 0.31 (0.22, 0.40) |
| 32. North Dakota | 136 | 124 | 139 | 141 | 5 | 6 | 18 | 26 | 2 | 2 | 3 | 2 | 302 | 300 (286, 317) | 0.59 (0.41, 0.70) |
| 33. Washington | 147 | 149 | 25 | 20 | 0 | 0 | 70 | 98 | 16 | 14 | 21 | 13 | 280 | 293 (269, 337) | 0.10 (0.04, 0.14) |
| 34. Utah | 92 | 105 | 103 | 49 | 28 | 79 | 30 | 49 | 6 | 0 | 5 | 3 | 265 | 285 (248, 336) | 0.74 (0.57, 0.87) |
| 35. Oregon | 115 | 132 | 24 | 23 | 0 | 0 | 55 | 111 | 7 | 3 | 14 | 8 | 215 | 276 (256, 304) | 0.08 (0.05, 0.11) |
| 36. Arizona | 121 | 141 | 50 | 41 | 1 | 2 | 70 | 72 | 11 | 4 | 6 | 3 | 259 | 263 (261, 266) | 0.80 (0.74, 0.84) |
| 37. South Carolina | 37 | 53 | 26 | 11 | 0 | 0 | 68 | 145 | 12 | 21 | 8 | 8 | 151 | 237 (220, 249) | 0.51 (0.20, 0.70) |
| 38. New Jersey | 4 | 4 | 44 | 51 | 0 | 0 | 56 | 116 | 13 | 35 | 11 | 27 | 128 | 233 (186, 294) | 0.28 (0.06, 0.52) |
| 39. Maryland | 23 | 28 | 19 | 20 | 2 | 4 | 44 | 57 | 12 | 4 | 8 | 7 | 109 | 120 (112, 126) | 0.26 (0.04, 0.45) |
| 40. Nevada | 45 | 49 | 20 | 9 | 0 | 0 | 17 | 30 | 4 | 2 | 3 | 2 | 90 | 93 (93, 93) | 0.00 (0.00, 0.00) |
| 41. Massachusetts | 4 | 4 | 29 | 17 | 0 | 0 | 24 | 48 | 10 | 4 | 9 | 7 | 76 | 80 (66, 93) | 0.15 (0.00, 0.35) |
| 42. Wyoming | 109 | 113 | 281 | 142 | 200 | -186 | 6 | 10 | 1 | 0 | 3 | 1 | 601 | 80 (-194, 279) | 0.68 (0.48, 0.86) |
| 43. Vermont | 38 | 29 | 1 | 0 | 0 | 0 | 6 | 13 | 1 | 1 | 6 | 3 | 52 | 46 (45, 49) | 0.02 (0.00, 0.07) |
| 44. Connecticut | 8 | 5 | 12 | 8 | 0 | 0 | 8 | 15 | 5 | 12 | 5 | 4 | 38 | 45 (35, 51) | 0.26 (0.01, 0.50) |
| 45. Maine | 11 | 10 | 4 | 2 | 0 | 0 | 13 | 20 | 3 | 1 | 10 | 6 | 40 | 38 (37, 39) | 0.00 (0.00, 0.00) |
| 46. New Hampshire | 4 | 5 | 3 | 1 | 0 | 0 | 21 | 16 | 3 | 1 | 6 | 3 | 36 | 25 (23, 27) | 0.03 (0.00, 0.08) |
| 47. Delaware | 3 | 4 | 5 | 2 | 0 | 0 | 17 | 8 | 5 | 5 | 1 | 2 | 31 | 20 (19, 22) | 0.12 (0.04, 0.23) |
| 48. Rhode Island | 0 | 1 | 5 | 4 | 0 | 0 | 6 | 11 | 2 | 2 | 2 | 1 | 15 | 18 (14, 21) | 0.19 (0.07, 0.34) |

Sectoral emissions in gigagrams per year (Gg a-1) for anthropogenic sources.

2Bottom-up emissions for each state from the 2022 EPA GHGI state estimates for 2019.

3Optimized sectoral anthropogenic emissions from an inversion of TROPOMI data for 2019.

4The total anthropogenic optimized emissions. Values in parentheses give the minimum and maximum of the ensemble of 8 inversions.

5The sensitivity of the total state posterior emissions to the observing system, given by the diagonal elements of the state averaging kernel matrix calculated. Values in parentheses give the ensemble range. Sensitivities range from 0 (unresponsive to the observing system) to 1 (fully responsive).

Table S2 (page 1 of 4): Methane emissions from urban areas in the contiguous U.S. (CONUS) for 2019.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Urban area**1 | **Spatially allocated GHGI emissions (Gg a-1)**2 | | | | | | **Posterior emissions** | |
| **Landfills** | **Wastewater** | **Post-meter gas** | **Gas distribution** | **Other anthropogenic** | **Total** | **Total (Gg a-1)**3 | **Sensitivity**4 |
| 1. New York--Newark, NY--NJ--CT | 68.4 | 42.2 | 27.3 | 37.8 | 37.5 | 213.2 | 309 (241, 417) | 0.28 (0.04, 0.54) |
| 2. Detroit, MI | 56.6 | 6.4 | 5.6 | 8.8 | 16.2 | 93.6 | 210 (170, 259) | 0.33 (0.14, 0.55) |
| 3. Atlanta, GA | 53.8 | 3.1 | 6.7 | 4.6 | 26.8 | 95 | 179 (157, 208) | 0.50 (0.33, 0.65) |
| 4. Dallas--Fort Worth--Arlington, TX | 69.3 | 12.3 | 7.6 | 17.4 | 145.1 | 251.7 | 362 (337, 384) | 0.52 (0.34, 0.70) |
| 5. Houston, TX | 44.9 | 5.7 | 7.4 | 15.3 | 69.6 | 142.9 | 209 (183, 236) | 0.36 (0.21, 0.51) |
| 6. Chicago, IL--IN | 74.3 | 22.7 | 12.8 | 15.9 | 32.7 | 158.4 | 207 (190, 224) | 0.38 (0.18, 0.58) |
| 7. Los Angeles--Long Beach--Anaheim, CA | 112.5 | 12.7 | 18.1 | 14.7 | 30.3 | 188.3 | 121 (116, 127) | 0.76 (0.62, 0.88) |
| 8. Cincinnati, OH--KY--IN | 41.8 | 12.8 | 2.4 | 3.5 | 8.4 | 68.9 | 98 (85, 109) | 0.48 (0.22, 0.74) |
| 9. Miami, FL | 73.3 | 9.0 | 8.2 | 2.8 | 12.4 | 105.7 | 284 (206, 395) | 0.24 (0.06, 0.44) |
| 10. Philadelphia, PA--NJ--DE--MD | 31.8 | 10.9 | 8.1 | 14.8 | 30.2 | 95.8 | 122 (108, 132) | 0.24 (0.07, 0.43) |
| 11. Indianapolis, IN | 22.4 | 1.5 | 2.2 | 3.6 | 16.3 | 46 | 101 (84, 127) | 0.34 (0.13, 0.60) |
| 12. Denver--Aurora, CO | 42.3 | 2.0 | 3.5 | 5.8 | 29.2 | 82.8 | 96 (76, 119) | 0.59 (0.43, 0.73) |
| 13. Reading, PA | 11.4 | 0.3 | 0.4 | 1.0 | 16.3 | 29.4 | 104 (66, 158) | 0.38 (0.15, 0.64) |
| 14. Memphis, TN--MS--AR | 20.1 | 8.1 | 1.6 | 1.4 | 15.9 | 47.1 | 81 (70, 96) | 0.49 (0.26, 0.71) |
| 15. Birmingham, AL | 31.5 | 5.7 | 1.1 | 2.1 | 83.4 | 123.8 | 248 (201, 310) | 0.50 (0.28, 0.74) |
| 16. Austin, TX | 23.1 | 1.1 | 2.0 | 4.3 | 10.0 | 40.5 | 67 (58, 82) | 0.53 (0.32, 0.75) |
| 17. Fort Wayne, IN | 7.9 | 0.5 | 0.5 | 0.8 | 5.3 | 15 | 58 (45, 74) | 0.31 (0.16, 0.50) |
| 18. San Diego, CA | 21.3 | 2.8 | 4.4 | 3.0 | 5.8 | 37.3 | 46 (43, 48) | 0.73 (0.56, 0.88) |
| 19. Davenport, IA--IL | 11.9 | 0.5 | 0.4 | 0.7 | 8.6 | 22.1 | 57 (48, 72) | 0.23 (0.11, 0.37) |
| 20. Rockford, IL | 21.1 | 0.5 | 0.4 | 0.8 | 5.6 | 28.4 | 49 (34, 54) | 0.33 (0.13, 0.58) |
| 21. Corpus Christi, TX | 16.8 | 0.8 | 0.5 | 1.2 | 22.2 | 41.5 | 79 (60, 117) | 0.21 (0.10, 0.34) |
| 22. Peoria, IL | 15.0 | 0.5 | 0.4 | 0.6 | 4.4 | 20.9 | 49 (43, 55) | 0.22 (0.10, 0.33) |
| 23. San Francisco--Oakland, CA | 24.5 | 13.8 | 4.9 | 3.5 | 14.3 | 61 | 69 (59, 87) | 0.30 (0.16, 0.44) |
| 24. San Antonio, TX | 22.2 | 6.2 | 2.6 | 5.4 | 20.2 | 56.6 | 51 (38, 63) | 0.33 (0.22, 0.44) |
| 25. Sacramento, CA | 25.7 | 2.0 | 2.6 | 2.3 | 30.2 | 62.8 | 67 (64, 71) | 0.53 (0.33, 0.71) |
| 26. Charlotte, NC--SC | 14.7 | 1.1 | 1.9 | 0.9 | 13.9 | 32.5 | 50 (42, 59) | 0.39 (0.21, 0.56) |
| 27. Minneapolis--St. Paul, MN--WI | 15.9 | 2.2 | 4.0 | 4.4 | 17.5 | 44 | 53 (42, 70) | 0.23 (0.07, 0.34) |
| 28. Phoenix--Mesa, AZ | 28.9 | 2.4 | 5.4 | 2.1 | 23.8 | 62.6 | 43 (40, 47) | 0.79 (0.67, 0.88) |
| 29. El Paso, TX--NM | 7.1 | 2.1 | 1.2 | 1.5 | 5.2 | 17.1 | 15 (13, 18) | 0.45 (0.33, 0.53) |

Table S2 (page 2 of 4): Methane emissions from urban areas in the contiguous U.S. (CONUS) for 2019.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Urban area**1 | **Spatially allocated GHGI emissions (Gg a-1)**2 | | | | | | **Posterior emissions** | |
| **Landfills** | **Wastewater** | **Post-meter gas** | **Gas distribution** | **Other anthropogenic** | **Total** | **Total (Gg a-1)**3 | **Sensitivity**4 |
| 30. Oklahoma City, OK | 17.4 | 0.7 | 1.3 | 3.7 | 19.0 | 42.1 | 59 (49, 71) | 0.53 (0.30, 0.75) |
| 31. Riverside--San Bernardino, CA | 14.6 | 2.5 | 2.9 | 2.2 | 13.1 | 35.3 | 40 (39, 42) | 0.43 (0.32, 0.54) |
| 32. Montgomery, AL | 8.6 | 4.3 | 0.4 | 0.7 | 5.7 | 19.7 | 32 (27, 37) | 0.20 (0.10, 0.31) |
| 33. Stockton, CA | 7.3 | 2.8 | 0.6 | 0.6 | 17.5 | 28.8 | 57 (47, 68) | 0.25 (0.14, 0.39) |
| 34. San Jose, CA | 12.2 | 4.4 | 2.5 | 1.8 | 2.7 | 23.6 | 26 (24, 32) | 0.31 (0.17, 0.47) |
| 35. Tulsa, OK | 14.3 | 0.6 | 1.0 | 3.0 | 13.4 | 32.3 | 36 (28, 43) | 0.39 (0.24, 0.54) |
| 36. Youngstown, OH--PA | 16.2 | 0.7 | 0.6 | 1.4 | 25.2 | 44.1 | 55 (48, 63) | 0.42 (0.21, 0.63) |
| 37. Grand Rapids, MI | 14.0 | 0.6 | 0.8 | 2.1 | 18.5 | 36 | 45 (41, 52) | 0.22 (0.05, 0.33) |
| 38. Tuscaloosa, AL | 11.8 | 0.2 | 0.2 | 0.4 | 22.2 | 34.8 | 55 (45, 69) | 0.50 (0.27, 0.74) |
| 39. Lancaster, PA | 4.2 | 0.6 | 0.6 | 1.5 | 22.6 | 29.5 | 64 (51, 78) | 0.31 (0.15, 0.47) |
| 40. Pittsburgh, PA | 13.5 | 3.1 | 2.6 | 6.1 | 282.0 | 307.3 | 415 (354, 502) | 0.47 (0.23, 0.71) |
| 41. Lexington-Fayette, KY | 9.3 | 0.3 | 0.4 | 0.4 | 6.8 | 17.2 | 27 (22, 33) | 0.37 (0.21, 0.54) |
| 42. Sioux Falls, SD | 2.2 | 5.5 | 0.2 | 0.3 | 6.8 | 15 | 32 (28, 39) | 0.33 (0.22, 0.48) |
| 43. Fairfield, CA | 10.0 | 0.7 | 0.2 | 0.3 | 3.8 | 15 | 23 (21, 24) | 0.24 (0.11, 0.38) |
| 44. St. Louis, MO--IL | 18.3 | 5.6 | 3.2 | 3.0 | 13.7 | 43.8 | 28 (21, 37) | 0.51 (0.24, 0.73) |
| 45. McKinney, TX | 5.6 | 0.3 | 0.3 | 0.6 | 2.1 | 8.9 | 21 (16, 32) | 0.42 (0.21, 0.65) |
| 46. Chattanooga, TN--GA | 13.8 | 0.7 | 0.6 | 0.6 | 6.1 | 21.8 | 22 (13, 31) | 0.33 (0.21, 0.45) |
| 47. Washington, DC--VA--MD | 12.4 | 6.6 | 6.8 | 7.4 | 16.3 | 49.5 | 29 (15, 39) | 0.24 (0.06, 0.39) |
| 48. Lansing, MI | 11.0 | 0.3 | 0.5 | 0.9 | 6.2 | 18.9 | 22 (12, 28) | 0.33 (0.13, 0.58) |
| 49. Mauldin--Simpsonville, SC | 4.2 | 1.0 | 0.2 | 0.1 | 0.7 | 6.2 | 17 (12, 28) | 0.30 (0.17, 0.45) |
| 50. Greensboro, NC | 12.7 | 0.4 | 0.5 | 0.3 | 5.5 | 19.4 | 19 (15, 23) | 0.44 (0.30, 0.58) |
| 51. Appleton, WI | 9.0 | 0.3 | 0.3 | 0.4 | 11.7 | 21.7 | 33 (25, 44) | 0.22 (0.08, 0.43) |
| 52. York, PA | 5.2 | 1.1 | 0.3 | 0.9 | 6.2 | 13.7 | 25 (20, 31) | 0.21 (0.09, 0.37) |
| 53. Concord, NC | 6.9 | 0.2 | 0.3 | 0.3 | 5.8 | 13.5 | 21 (18, 25) | 0.30 (0.18, 0.42) |
| 54. Kingsport, TN--VA | 17.2 | 0.5 | 0.2 | 0.2 | 11.1 | 29.2 | 22 (19, 28) | 0.52 (0.31, 0.72) |
| 55. Modesto, CA | 3.1 | 0.6 | 0.5 | 0.6 | 47.5 | 52.3 | 103 (89, 127) | 0.38 (0.21, 0.58) |
| 56. Nashville-Davidson, TN | 4.0 | 6.1 | 1.4 | 1.5 | 17.3 | 30.3 | 32 (27, 40) | 0.22 (0.11, 0.32) |
| 57. Fort Collins, CO | 7.6 | 0.2 | 0.4 | 1.0 | 21.3 | 30.5 | 35 (33, 39) | 0.20 (0.11, 0.30) |
| 58. Mission Viejo--Lake Forest--San Clemente, CA | 12.5 | 3.2 | 0.9 | 0.6 | 2.1 | 19.3 | 17 (13, 20) | 0.52 (0.39, 0.65) |

Table S2 (page 3 of 4): Methane emissions from urban areas in the contiguous U.S. (CONUS) for 2019.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Urban area**1 | **Spatially allocated GHGI emissions (Gg a-1)**2 | | | | | | **Posterior emissions** | |
| **Landfills** | **Wastewater** | **Post-meter gas** | **Gas distribution** | **Other anthropogenic** | **Total** | **Total (Gg a-1)**3 | **Sensitivity**4 |
| 59. Tallahassee, FL | 3.5 | 0.0 | 0.4 | 0.2 | 2.1 | 6.2 | 16 (13, 18) | 0.23 (0.05, 0.44) |
| 60. Laredo, TX | 7.9 | 1.1 | 0.4 | 0.6 | 12.6 | 22.6 | 25 (17, 30) | 0.36 (0.18, 0.58) |
| 61. Wichita, KS | 6.2 | 2.4 | 0.7 | 1.4 | 5.2 | 15.9 | 16 (14, 18) | 0.29 (0.17, 0.42) |
| 62. Canton, OH | 8.8 | 0.4 | 0.4 | 0.8 | 15.3 | 25.7 | 25 (15, 33) | 0.36 (0.15, 0.61) |
| 63. Fort Smith, AR--OK | 4.0 | 0.4 | 0.2 | 0.5 | 14.9 | 20 | 38 (32, 41) | 0.50 (0.27, 0.75) |
| 64. Jacksonville, NC | 4.6 | 0.0 | 0.2 | 0.1 | 5.2 | 10.1 | 15 (13, 17) | 0.24 (0.06, 0.53) |
| 65. Lincoln, NE | 7.3 | 0.2 | 0.4 | 0.7 | 6.5 | 15.1 | 15 (12, 17) | 0.20 (0.10, 0.33) |
| 66. Bakersfield, CA | 3.6 | 0.9 | 0.8 | 0.7 | 30.9 | 36.9 | 78 (71, 90) | 0.61 (0.37, 0.80) |
| 67. Tucson, AZ | 6.6 | 0.3 | 1.3 | 0.6 | 6.7 | 15.5 | 17 (14, 22) | 0.24 (0.16, 0.34) |
| 68. Amarillo, TX | 3.7 | 1.1 | 0.3 | 0.7 | 16.4 | 22.2 | 40 (31, 51) | 0.57 (0.39, 0.74) |
| 69. Antioch, CA | 4.9 | 0.4 | 0.4 | 0.5 | 9.1 | 15.3 | 13 (-1, 22) | 0.24 (0.13, 0.37) |
| 70. Santa Clarita, CA | 7.5 | 0.8 | 0.4 | 0.6 | 3.9 | 13.2 | 10 (7, 12) | 0.27 (0.19, 0.36) |
| 71. El Centro--Calexico, CA | 3.2 | 0.6 | 0.2 | 0.2 | 8.9 | 13.1 | 22 (19, 27) | 0.29 (0.17, 0.44) |
| 72. College Station--Bryan, TX | 3.3 | 0.1 | 0.3 | 0.5 | 15.8 | 20 | 29 (26, 31) | 0.22 (0.12, 0.34) |
| 73. Waco, TX | 4.4 | 0.1 | 0.3 | 0.6 | 3.9 | 9.3 | 11 (8, 14) | 0.20 (0.10, 0.32) |
| 74. McAllen, TX | 7.3 | 1.0 | 1.1 | 2.2 | 21.0 | 32.6 | 38 (32, 46) | 0.33 (0.19, 0.49) |
| 75. Yuba City, CA | 3.4 | 0.1 | 0.2 | 0.2 | 19.1 | 23 | 24 (20, 26) | 0.41 (0.25, 0.58) |
| 76. Denton--Lewisville, TX | 2.2 | 0.2 | 0.5 | 1.2 | 17.1 | 21.2 | 34 (32, 37) | 0.36 (0.21, 0.51) |
| 77. Greeley, CO | 2.4 | 0.0 | 0.2 | 0.5 | 31.4 | 34.5 | 57 (44, 76) | 0.58 (0.36, 0.79) |
| 78. Redding, CA | 3.4 | 0.6 | 0.2 | 0.2 | 1.3 | 5.7 | 7 (6, 8) | 0.53 (0.36, 0.66) |
| 79. Norman, OK | 2.1 | 0.1 | 0.2 | 0.4 | 1.9 | 4.7 | 8 (8, 9) | 0.23 (0.12, 0.37) |
| 80. Victorville--Hesperia, CA | 3.4 | 0.4 | 0.5 | 0.4 | 5.9 | 10.6 | 10 (8, 13) | 0.22 (0.13, 0.31) |
| 81. Visalia, CA | 2.6 | 0.5 | 0.3 | 0.4 | 76.5 | 80.3 | 72 (63, 82) | 0.22 (0.13, 0.33) |
| 82. Gainesville, GA | 3.7 | 0.0 | 0.2 | 0.2 | 4.4 | 8.5 | 8 (3, 11) | 0.21 (0.10, 0.33) |
| 83. Murrieta--Temecula--Menifee, CA | 1.5 | 1.0 | 0.7 | 0.6 | 4.4 | 8.2 | 11 (10, 12) | 0.21 (0.14, 0.29) |
| 84. Monroe, LA | 3.8 | 0.2 | 0.2 | 0.3 | 10.3 | 14.8 | 8 (-4, 14) | 0.22 (0.10, 0.35) |
| 85. Merced, CA | 1.0 | 0.3 | 0.2 | 0.2 | 71.4 | 73.1 | 146 (130, 171) | 0.44 (0.27, 0.63) |
| 86. Abilene, TX | 2.4 | 0.7 | 0.2 | 0.3 | 4.6 | 8.2 | 9 (8, 10) | 0.20 (0.10, 0.34) |
| 87. Charleston, WV | 5.2 | 0.4 | 0.2 | 1.8 | 116.8 | 124.4 | 24 (-3, 52) | 0.52 (0.29, 0.76) |

Table S2 (page 4 of 4): Methane emissions from urban areas in the contiguous U.S. (CONUS) for 2019.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Urban area**1 | **Spatially allocated GHGI emissions (Gg a-1)**2 | | | | | | **Posterior emissions** | |
| **Landfills** | **Wastewater** | **Post-meter gas** | **Gas distribution** | **Other anthropogenic** | **Total** | **Total (Gg a-1)**3 | **Sensitivity**4 |
| 88. Odessa, TX | 3.7 | 0.3 | 0.2 | 0.4 | 81.9 | 86.5 | 175 (139, 217) | 0.46 (0.36, 0.58) |
| 89. Avondale--Goodyear, AZ | 1.6 | 0.3 | 0.3 | 0.1 | 3.2 | 5.5 | 5 (5, 6) | 0.42 (0.27, 0.57) |
| 90. Midland, TX | 2.4 | 0.2 | 0.2 | 0.5 | 83.5 | 86.8 | 41 (-22, 90) | 0.71 (0.52, 0.86) |
| 91. Las Cruces, NM | 0.7 | 0.3 | 0.2 | 0.2 | 6.3 | 7.7 | 6 (4, 8) | 0.21 (0.13, 0.30) |
| 92. Pueblo, CO | 4.1 | 0.1 | 0.2 | 0.3 | 1.1 | 5.8 | 1 (-3, 3) | 0.26 (0.16, 0.39) |
| 93. Simi Valley, CA | 2.1 | 0.1 | 0.2 | 0.1 | 0.3 | 2.8 | -1 (-4, 0) | 0.27 (0.19, 0.37) |
| 94. Clarksville, TN--KY | 7.0 | 0.6 | 0.2 | 0.2 | 3.7 | 11.7 | 0 (-5, 5) | 0.28 (0.16, 0.43) |
| 95. Kansas City, MO--KS | 34.6 | 3.2 | 2.3 | 3.3 | 17.3 | 60.7 | 3 (-19, 21) | 0.45 (0.22, 0.71) |

Urban areas with populations greater than 1 million that are optimized by the inversion (mean urban averaging kernel sensitivity greater than 0.2), ordered by posterior emissions from landfills, wastewater, and gas distribution. Urban area extents are given by the U.S. Census Topographically Integrated Geographic Encoding and Referencing system (TIGER)/Line Urban Areas.

2The anthropogenic emissions for urban source sectors for each city in gigagrams per year (Gg a-1) from the 2023 EPA GHGI for 2019 allocated using the Gridded EPA inventory (Maasakkers et al., 2016) with post-meter emissions distributed by population. Other emissions include contributions from upstream oil and gas, coal, livestock, and other sources.

3Optimized emissions from inversion of TROPOMI observations in gigagrams per year. Values in parentheses represent the range from an eight-member inversion ensemble.

4The sensitivity of an urban area to the satellite-model observing system as given by the diagonal elements of the urban averaging kernel matrix calculated as described in Section 2.8. Values close to 1 indicate that the posterior emissions are fully sensitive to the observing system, while values close to 0 rely almost entirely on the prior estimate. Values in parentheses give the ensemble range.

Table S3 (page 1 of 2): Methane emissions from landfills in the contiguous United States (CONUS) for 2019.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Facility**1 | **Location** | **Emissions (Gg a-1)** | | **Gas capture efficiency** | |
| **GHGRP**2 | **Posterior**3 | **GHGRP**4 | **Posterior**5 |
| 1. National Serv-All Landfill | Fort Wayne, Indiana | 3.4 | 44 (34 - 59) | 0.86 | 0.32 (0.26 - 0.37) |
| 2. South Shelby Landfill | Memphis, Tennessee | 4.1 | 41 (30 - 56) | 0.86 | 0.39 (0.31 - 0.46) |
| 3. South Side Landfill Inc. | Indianapolis, Indiana | 4.7 | 39 (32 - 52) | 0.8 | 0.33 (0.27 - 0.38) |
| 4. Rumpke Sanitary Landfill | Cincinnati, Ohio | 10.1 | 39 (33 - 43) | 0.84 | 0.58 (0.55 - 0.61) |
| 5. Quad Cities Landfill Phase IV | Milan, Illinois | 3.7 | 35 (28 - 47) | N/A | N/A |
| 6. City of Dothan Sanitary Landfill | Dothan, Alabama | 5.8 | 35 (28 - 43) | N/A | N/A |
| 7. Rochelle Municipal Landfill | Rochelle, Illinois | 2.7 | 32 (25 - 39) | 0.76 | 0.22 (0.18 - 0.26) |
| 8. Seminole Road MSW Landfill | Ellenwood, Georgia | 12.3 | 30 (25 - 36) | 0.18 | 0.08 (0.07 - 0.1) |
| 9. Caterpillar Inc.-Mapleton | Mapleton, Illinois | 6.4 | 25 (23 - 29) | N/A | N/A |
| 10. Sampson County Disposal, LLC | Roseboro, North Carolina | 29.2 | 25 (23 - 29) | 0.37 | 0.41 (0.38 - 0.44) |
| 11. West Miramar Sanitary Landfill | San Diego, California | 6.2 | 24 (22 - 25) | 0.78 | 0.47 (0.46 - 0.49) |
| 12. Seneca Meadows SWMF | Waterloo, New York | 8.3 | 24 (14 - 36) | 0.88 | 0.73 (0.63 - 0.81) |
| 13. Kiefer Landfill | Sloughhouse, California | 6.5 | 24 (19 - 31) | 0.81 | 0.54 (0.46 - 0.58) |
| 14. Charlotte Motor Speedway Landfill V | Concord, North Carolina | 6.9 | 23 (18 - 30) | 0.75 | 0.48 (0.41 - 0.54) |
| 15. Puente Hills Landfill and Energy Recovery | Whittier, California | 2.7 | 22 (19 - 27) | 0.94 | 0.67 (0.61 - 0.69) |
| 16. Atascocita Recycling and Disposal Facility | Humble, Texas | 11.9 | 21 (16 - 26) | 0.59 | 0.45 (0.4 - 0.52) |
| 17. Frank R. Bowerman Landfill | Irvine, California | 11.8 | 21 (16 - 32) | 0.77 | 0.66 (0.56 - 0.71) |
| 18. Kimble Sanitary Landfill | Dover, Ohio | 2.8 | 19 (17 - 24) | N/A | N/A |
| 19. 121 Regional Disposal Facility | Melissa, Texas | 20.7 | 19 (14 - 29) | 0.49 | 0.52 (0.4 - 0.58) |
| 20. New Georgia Landfill | Birmingham, Alabama | 5.5 | 19 (17 - 21) | N/A | N/A |
| 21. Sussex County Landfill | Waverly, Virginia | 7.3 | 17 (12 - 25) | N/A | N/A |
| 22. Altamont Landfill & Resource Recovery Facility | Livermore, California | 7.3 | 17 (13 - 23) | 0.74 | 0.56 (0.48 - 0.63) |
| 23. Enoree Landfill | Greer, South Carolina | 3.4 | 17 (11 - 28) | 0.52 | 0.19 (0.11 - 0.24) |
| 24. Brent Run Landfill | Montrose, Michigan | 18.2 | 17 (14 - 21) | 0.35 | 0.37 (0.32 - 0.42) |
| 25. Livingston Landfill | Pontiac, Illinois | 4.9 | 17 (14 - 20) | 0.85 | 0.62 (0.58 - 0.66) |
| 26. Big River Landfill | Leland, Missouri | 6 | 16 (13 - 21) | N/A | N/A |
| 27. Modern Landfill | York, Pennsylvania | 3.4 | 15 (11 - 22) | N/A | N/A |
| 28. Newby Island Landfill | Milpitas, California | 5.5 | 15 (13 - 21) | N/A | N/A |
| 29. Landfill of North Iowa | Clear Lake, Iowa | 2.8 | 14 (11 - 18) | N/A | N/A |
| 30. Beech Hollow Sanitary Landfill | Wellston, Ohio | 14.5 | 13 (9 - 20) | N/A | N/A |
| 31. Eastman Chemical Company | Kingsport, Tennessee | 9.3 | 12 (10 - 16) | N/A | N/A |
| 32. Rumpke of Kentucky Inc. | Jeffersonville, Kentucky | 9.2 | 12 (9 - 15) | N/A | N/A |
| 33. Jefferson County Landfill No. 1 | Gardendale, Alabama | 8.8 | 11 (10 - 14) | N/A | N/A |
| 34. Keller Canyon Landfill | Pittsburg, California | 5.6 | 10 (8 - 13) | 0.55 | 0.4 (0.35 - 0.47) |
| 35. Big Run Landfill | Ashland, Kentucky | 20.9 | 10 (9 - 12) | N/A | N/A |
| 36. Rockingham County Landfill | Madison, North Carolina | 3.4 | 10 (6 - 13) | 0.3 | 0.13 (0.1 - 0.19) |
| 37. Granger Grand River Avenue Landfill | Grand Ledge, Michigan | 4.3 | 10 (2 - 14) | 0.57 | 0.4 (0.3 - 0.71) |
| 38. Leon County Landfill | Tallahassee, Florida | 3.2 | 9 (8 - 11) | N/A | N/A |
| 39. City of Laredo Landfill | Laredo, Texas | 6.6 | 9 (4 - 12) | N/A | N/A |

Table S3 (page 2 of 2): Methane emissions from landfills in the contiguous United States (CONUS) for 2019.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Facility**1 | **Location** | **Emissions (Gg a-1)** | | **Gas capture efficiency** | |
| **GHGRP**2 | **Posterior**3 | **GHGRP**4 | **Posterior**5 |
| 40. Onslow County Landfill | Jacksonville, North Carolina | 3.1 | 9 (8 - 10) | 0.53 | 0.28 (0.25 - 0.3) |
| 41. Waste Management Skyline Landfill | Ferris, Texas | 13.8 | 9 (6 - 12) | 0.4 | 0.5 (0.43 - 0.6) |
| 42. Matlock Bend Landfill | Loudon, Tennessee | 6.2 | 8 (6 - 14) | N/A | N/A |
| 43. Waste Management of OK | Tulsa, Oklahoma | 6.2 | 8 (6 - 13) | 0.29 | 0.24 (0.17 - 0.29) |
| 44. City of Chattanooga Summit Landfill | Ooltewah, Tennessee | 3.1 | 8 (2 - 14) | N/A | N/A |
| 45. Resolute Forest Products Calhoun Operation | Calhoun, Tennessee | 5.6 | 8 (5 - 12) | N/A | N/A |
| 46. La Salle/Grant Parish Sanitary Landfill | Jena, Louisiana | 5.3 | 7 (5 - 8) | N/A | N/A |
| 47. Badlands Sanitary Landfill | Moreno Valley, California | 3.2 | 7 (5 - 8) | N/A | N/A |
| 48. Bluff Road Landfill | Lincoln, Nebraska | 2.9 | 7 (5 - 10) | 0.69 | 0.5 (0.4 - 0.57) |
| 49. Bradley County Landfill | Mcdonald, Tennessee | 10.2 | 7 (4 - 9) | N/A | N/A |
| 50. Mccombs Landfill | El Paso, Texas | 11.5 | 6 (5 - 8) | N/A | N/A |
| 51. Toro Energy of Ohio - America's Landfill Gas | Waynesburg, Ohio | 2.7 | 6 (1 - 10) | 0.78 | 0.63 (0.47 - 0.9) |
| 52. Carbon Limestone Landfill | Lowellville, Ohio | 3.6 | 6 (3 - 8) | 0.89 | 0.83 (0.79 - 0.89) |
| 53. City Of Glendale - Landfill | Glendale, Arizona | 5 | 5 (5 - 6) | 0.5 | 0.49 (0.44 - 0.52) |
| 54. Lone Cactus Landfill | Phoenix, Arizona | 2.7 | 5 (4 - 7) | N/A | N/A |
| 55. Tangerine Landfill | Marana, Arizona | 2.6 | 5 (3 - 7) | N/A | N/A |
| 56. Outagamie County Landfill | Appleton, Wisconsin | 2.8 | 5 (3 - 7) | 0.75 | 0.65 (0.55 - 0.72) |
| 57. Champ Landfill | Maryland Heights, Missouri | 9.8 | 4 (1 - 8) | 0.73 | 0.86 (0.77 - 0.97) |
| 58. Rhea County Landfill | Dayton, Tennessee | 8.3 | 4 (4 - 5) | N/A | N/A |
| 59. Noble Road Landfill | Shiloh, Ohio | 16.2 | 4 (1 - 7) | N/A | N/A |
| 60. Copper Mountain Landfill | Wellton, Arizona | 4.7 | 4 (4 - 4) | N/A | N/A |
| 61. Black Oak Landfill | Hartville, Missouri | 3.8 | 4 (2 - 6) | 0.48 | 0.49 (0.36 - 0.64) |
| 62. Brooks Landfill | Wichita, Kansas | 8.3 | 3 (2 - 4) | N/A | N/A |
| 63. American Environmental Landfill | Sand Springs, Oklahoma | 7 | 3 (2 - 4) | 0.45 | 0.66 (0.59 - 0.78) |
| 64. Prima Deshecha Landfill | San Juan Capistrano, California | 5.1 | 3 (2 - 4) | 0.66 | 0.78 (0.73 - 0.85) |
| 65. Meadow Branch Landfill | Athens, Tennessee | 11.2 | 3 (2 - 3) | 0.44 | 0.77 (0.72 - 0.81) |
| 66. West Central Landfill | Redding, California | 2.8 | 3 (2 - 4) | N/A | N/A |
| 67. Northwestern Landfill | Parkersburg, West Virginia | 3.7 | 2 (0 - 4) | N/A | N/A |
| 68. Northwest Regional Landfill | Surprise, Arizona | 4.5 | 2 (2 - 3) | 0.51 | 0.7 (0.61 - 0.74) |
| 69. Apex Environmental, LLC - Sanitary Landfill | Amsterdam, Ohio | 19.5 | 2 (-9 - 8) | 0.27 | 0.17 (-4.29 - 1.53) |
| 70. Apache Junction Landfill | Apache Junction, Arizona | 2.8 | 2 (1 - 2) | N/A | N/A |
| 71. Hall County Candler Road MSWLF | Gainesville, Georgia | 2.9 | 2 (-2 - 4) | N/A | N/A |
| 72. Laurel Ridge Landfill | Lily, Kentucky | 10.1 | 1 (0 - 4) | 0.3 | 0.77 (0.52 - 0.96) |
| 73. Cactus Landfill | Eloy, Arizona | 3.2 | 1 (-1 - 1) | N/A | N/A |

1The 73 landfills that report methane emissions of 2.5 Gg a-1 to the EPA GHGRP and that are located in a grid cell where TROPOMI provides a constraint (averaging kernel sensitivity > 0.2) and where a single landfill explains more than 50% of the prior emissions estimate. Facilities are ranked by the posterior emissions estimate from largest to smallest.

2Emissions reported by individual landfills to the EPA GHGRP for 2019 in gigagrams per year.

3Posterior emissions from inversion of TROPOMI observations in gigagrams per year. Posterior emissions are allocated to individual facilities as described in Sections 2.8 and 3.2. Values in parentheses represent the range from the eight-member inversion ensemble.

4For facilities that capture landfill gas, the recovery efficiency as calculated from emissions and avoided emissions reported by individual landfills to the EPA LMOP. Facilities that do not capture landfill gas are listed as N/A.

5The posterior recovery efficiency as calculated from posterior emissions and the avoided emissions reported by individual landfills to the EPA LMOP.