*Supplement of*

# Monitoring and quantifying $CO_2$ emissions of isolated power plants from space

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1. The process of cross-sectional flux method and wind direction rotation.

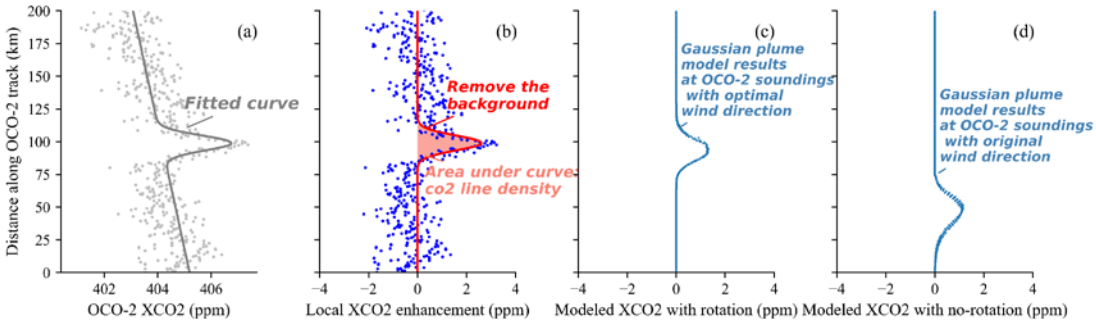



**Figure S1.** (a) Fitting curve (gray line) of good quality XCO2 retrievals (gray point) distributed along OCO-2 orbit using formula (1). (b) The XCO2 retrievals after removing the background concentration (blue dots), the fitted curve (red), and the area under the curve representing the CO2 line density (red shading). (c) Based on the Gaussian plume model, XCO2 local enhancement (blue dot) generated by emission source of power plant matched with CO2 plume is simulated under the condition of wind direction rotation. (d) Based on the Gaussian plume model, XCO2 local enhancement (blue dot) is simulated by the emission source of coal plants matching with CO2 plume under the condition of original wind direction.

2. Different background values lead to different estimation results, and the optimal percentile is obtained by using the minimum error to determine the background. For all 50 cases, the difference between the background calculated by the 99 percentile and the background calculated by the 60 percentile ranges from 0.23 to 0.77 ppm. The standard deviation of the background calculated for the 9 percentile bins for each case ranges from 0.08 to 0.26 ppm.

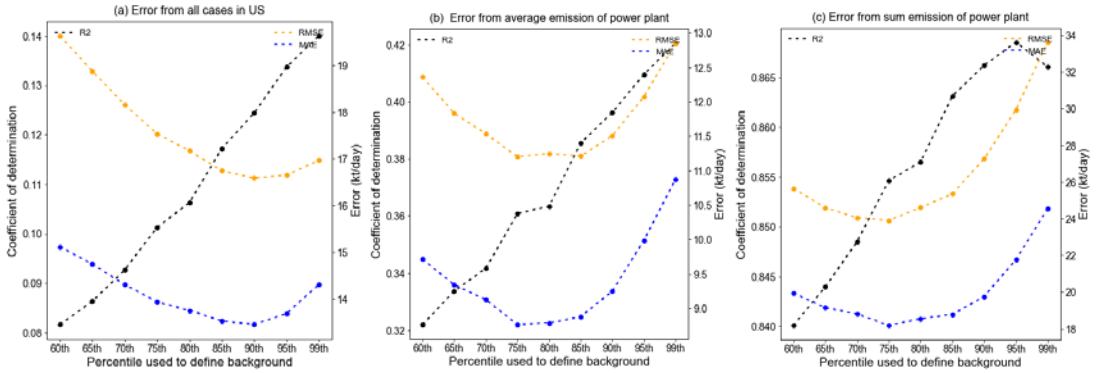



**Figure S2.** Different background results in different errors of estimated emissions and hourly reported emissions for isolated U.S. power plants. The errors of estimated emissions and hourly reported emissions by the GPM of all cases (a), the errors of the average value of emission estimation results of each power plant (b), and the errors of the sum of emission estimation results of each power plant (c).

3. The estimated emission obtained by the GPM and using WERA and WMERRA are not as good as those of WPBL.

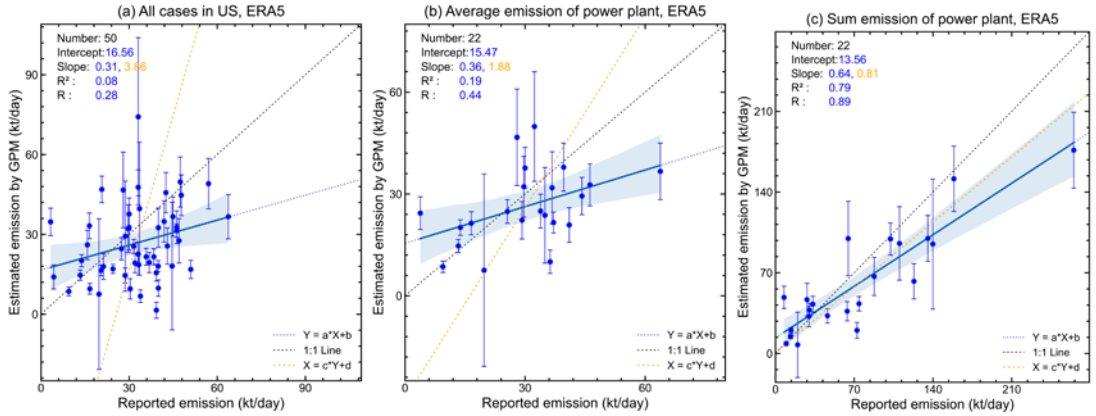



**Figure S3.** The emission estimation results by the GPM of all cases are compared with the hourly reported value (a), the average value of emission estimation results of each power plant is compared with the reported value (b), and the sum of emission estimation results of each power plant is compared with the reported value (c) using WERA. The yellow and blue dashed lines are the fitted lines with the x-axis and y-axis swapped.

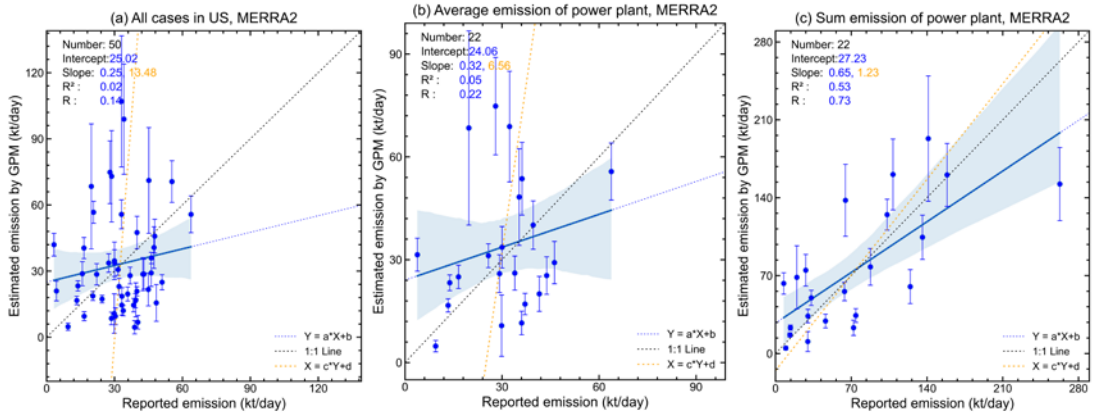



**Figure S4.** The emission estimation results by the GPM of all cases are compared with the hourly reported value (a), the average value of emission estimation results of each power plant is compared with the reported value (b), and the sum of emission estimation results of each power plant is compared with the reported value (c) using WMERRA. The yellow and blue dashed lines are the fitted lines with the x-axis and y-axis swapped.

4. Time series results of single power plant from multiple observations.

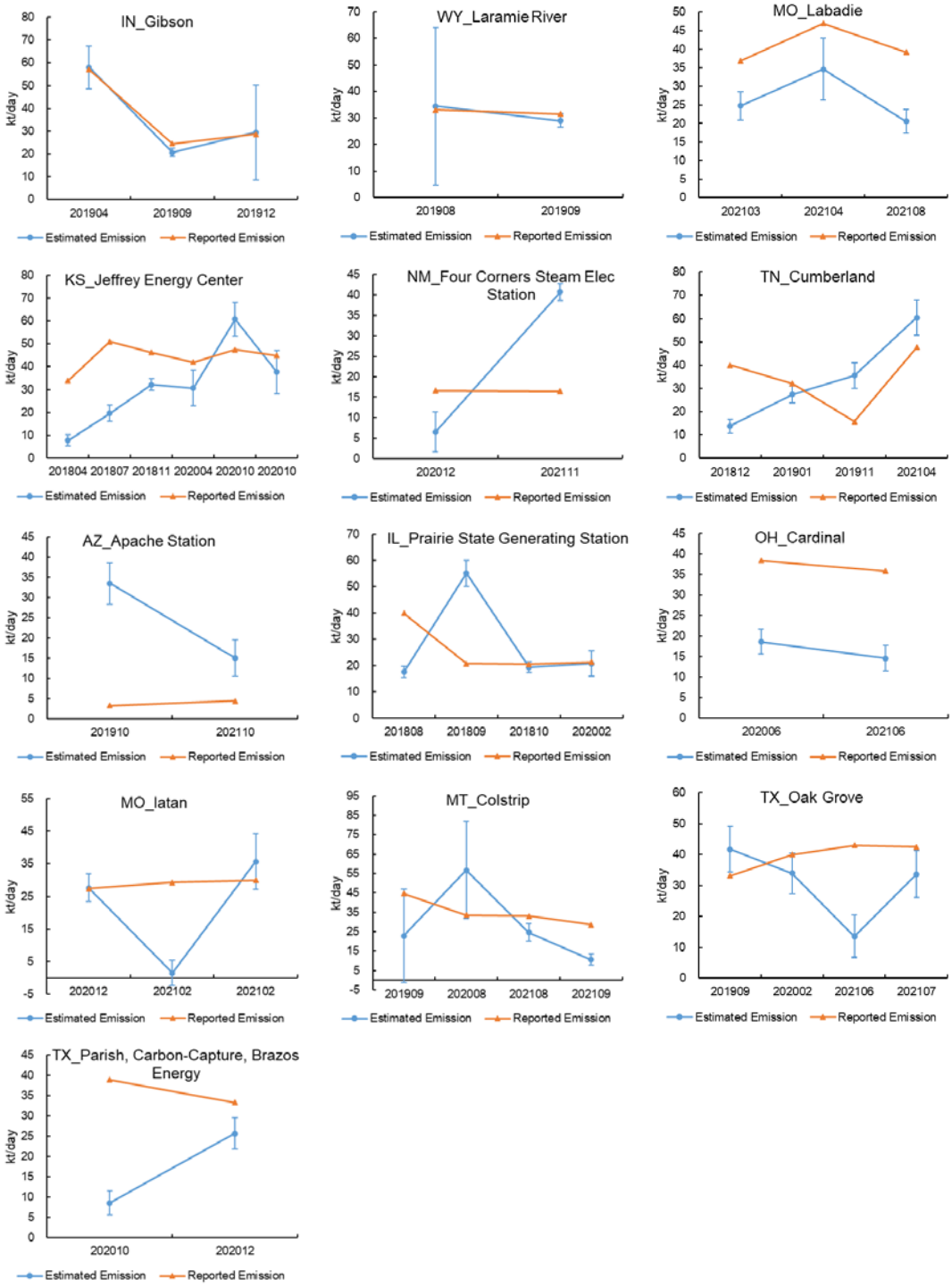



**Figure S5.** Estimated emission results by the GPM for each power plant that has multiple observation cases.

5. Compare reported emission of EIA with EPA.

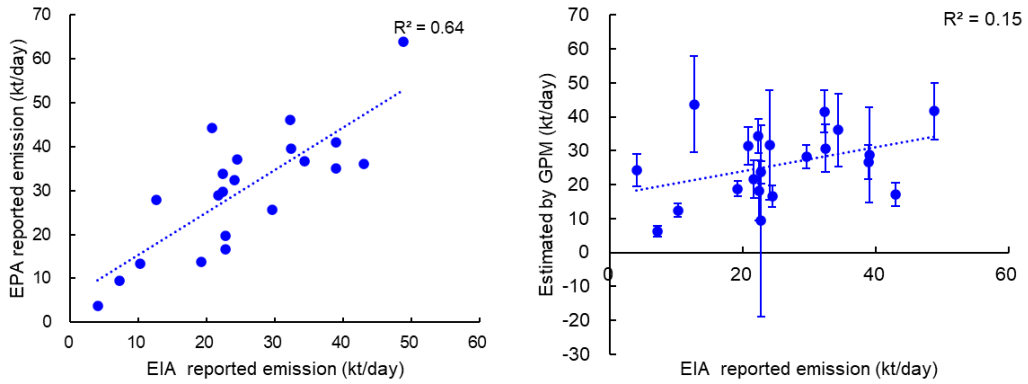



**Figure S6.** Comparison of reported values of plant level emissions from EIA and EPA, and comparison of average results of power plant estimated emissions with EIA. We scale the 2019 plant level emission value reported by EIA to days as the EIA reported emission in this figure.

6. Integration of simulation enhancement and observation enhancement in latitude direction.

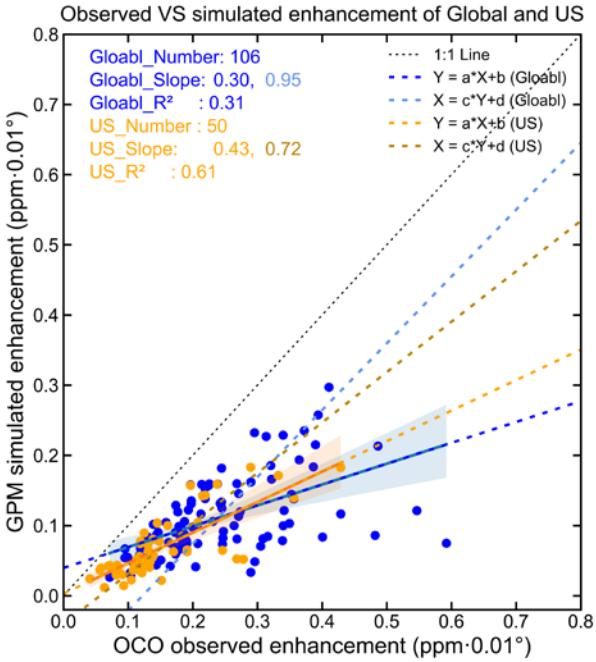



**Figure S7.** Comparison of the observed and simulated XCO2 enhancement, that is, the integration of XCO2 in the latitude direction.

7. NO2 concentration CO2 concentration on the same day.

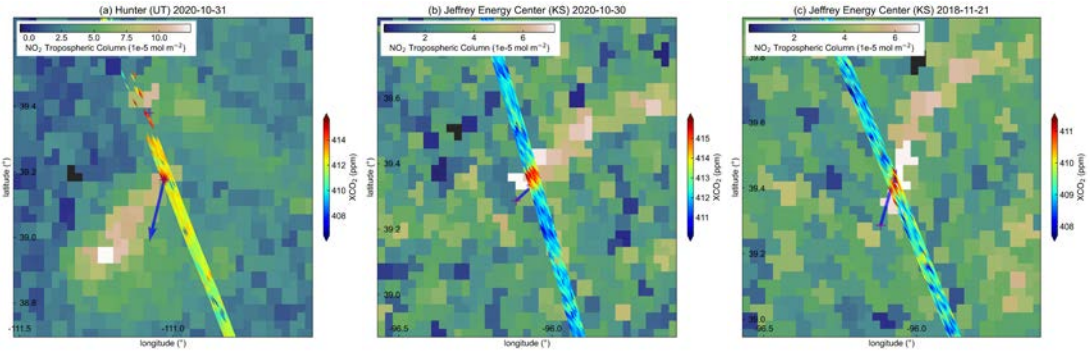



**Figure S8.** XCO2 and same-day NO2 concentration (0.025° × 0.025°) for three OCO2 cases. (a) 2020-10-31 Hunter (UT), (b) 2020-10-30 Jeffrey Energy Center (KS), (c) 2018-11-21 Jeffrey Energy Center (KS). The arrow is the wind field halfway the height of the PBL.

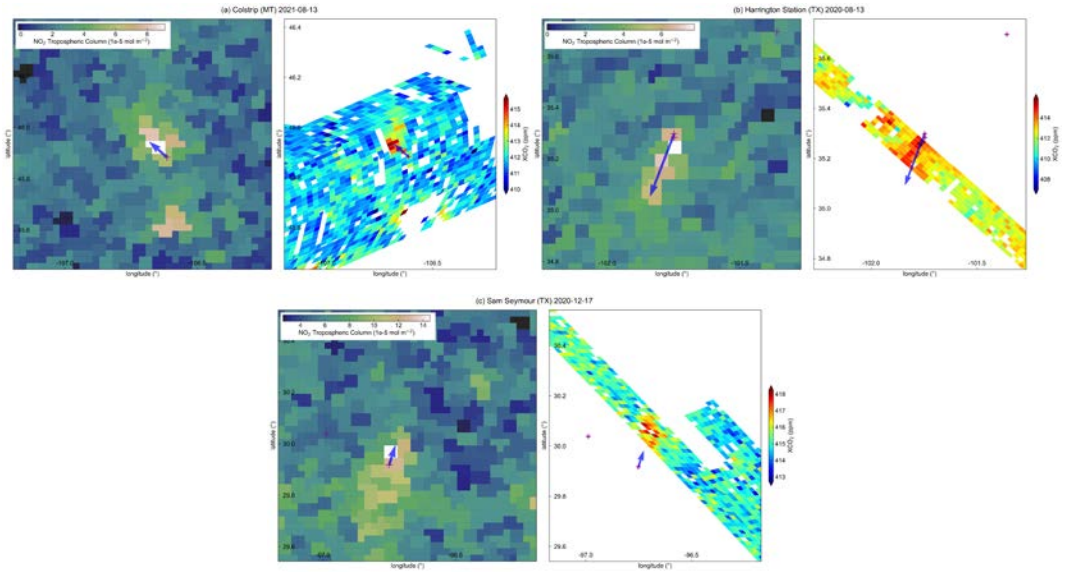


**Figure S9.** XCO2 and same-day NO2 concentration (0.025° × 0.025°) for three OCO3 cases. (a) 2021-08-13 Colstrip (MT), (b) 2020-08-13 Harrington Station (TX), (c) 2020-12-17 Sam Seymour (TX). The arrow is the wind field halfway the height of the PBL.

8. Cases rejected through visual check.

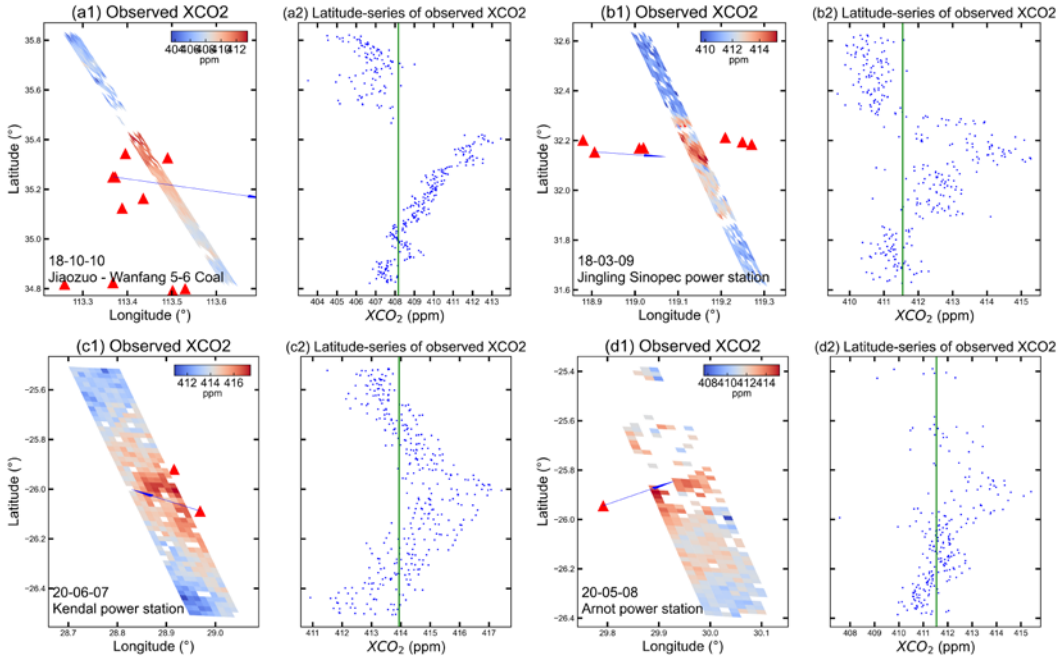



**Figure S10.** Four Cases rejected through visual check due to insignificant XCO2 enhancement, missing data and emission source cluster interference (a-d). The background value determined from the average of the observations below the 90th percentile (green line), XCO2 data (blue pints), and power plants from GPPD (red triangle).

9. Comparison of two methods of computing background.

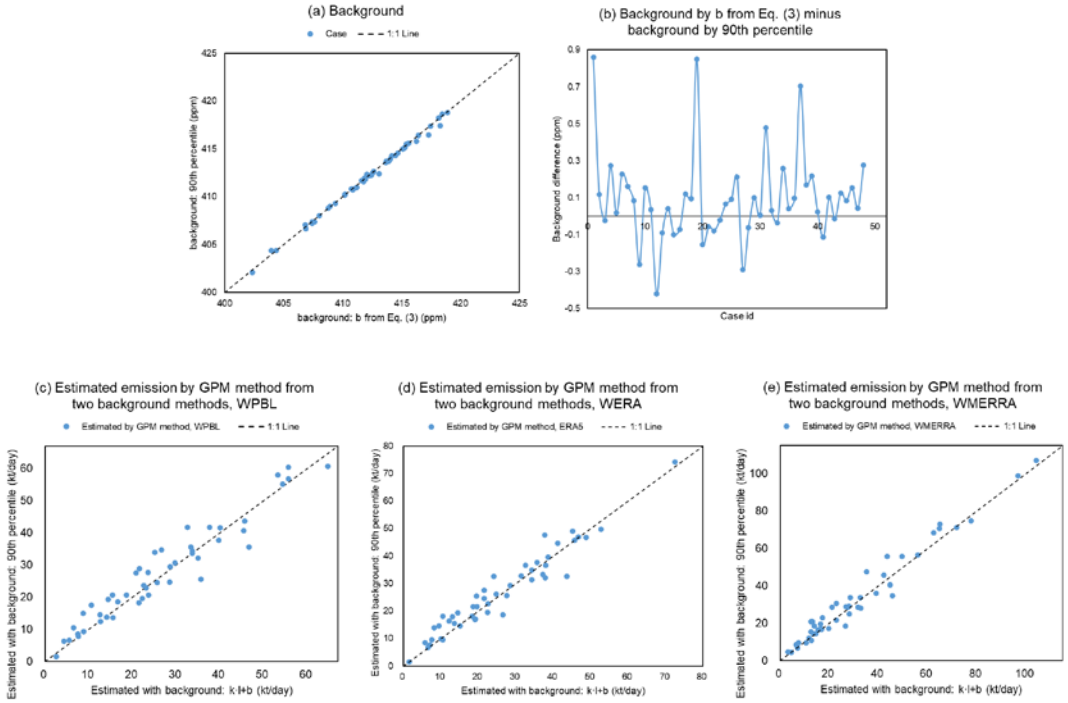
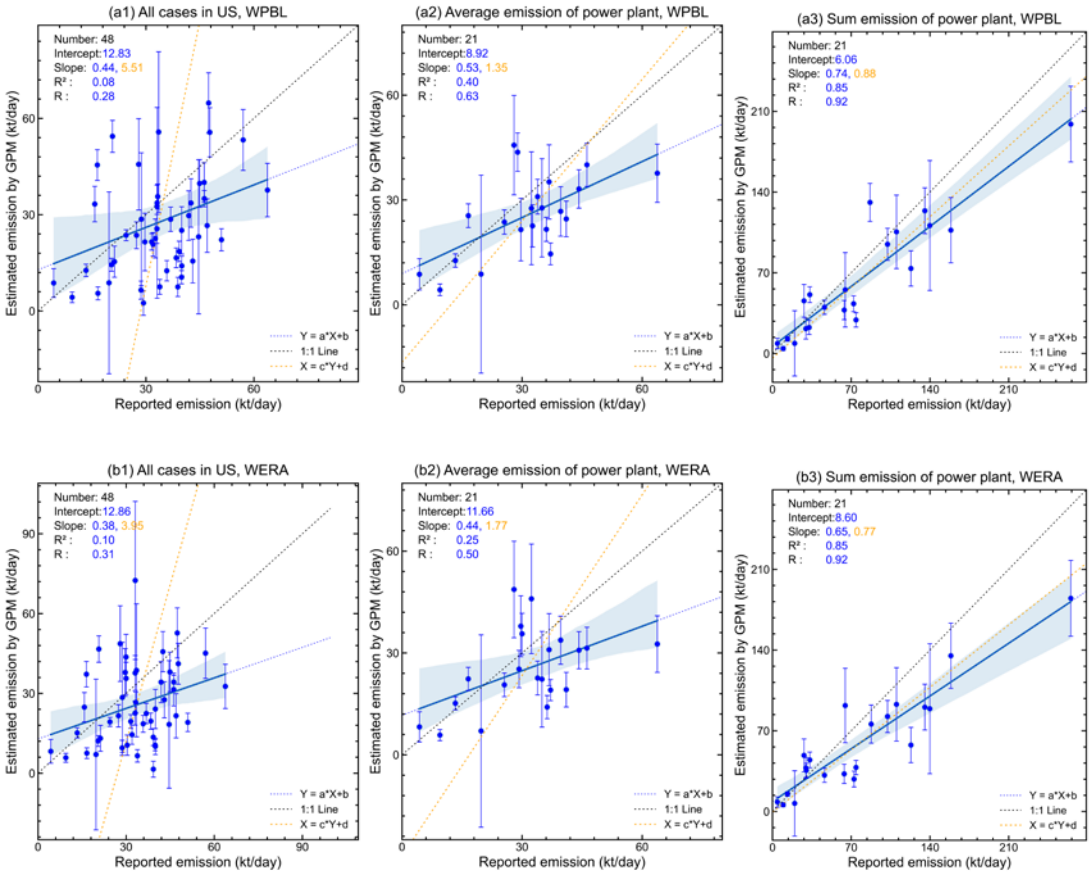



**Figure S11.** Comparison of two methods of computing the background. The background constant b from Eq. (3) is in good agreement with the background calculated by using the 90$^{th}$ percentile (a), and their difference is small (b). Under the two background calculation methods, the GPM method has good consistency in the estimation results driven by WPBL (c), WERA (d), and WMERRS (e) wind fields, respectively.



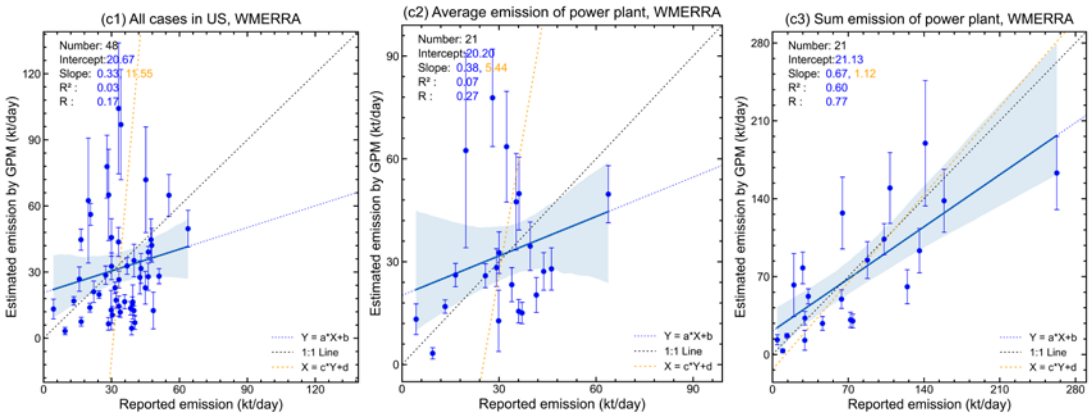



**Figure S12.** The conclusion that estimated emissions have better accuracy under the WPBL is still valid when using the background calculated by the method of Eq. (3). These three panels are based on WPBL (a1-a3), WERA(b1-b3), and WMERRA(c1-c3).

**Table S1.** The uncertainties of wind speed in m $s^{-1}$ and background in ppm for each plant

| Name | Uncertainty of background (ppm) | Uncertainty of wind (m/s) |
|---|---|---|
| James H Miller Jr (AL) | 0.098 | 0.087 |
| Apache Station (AZ) | 0.039 | 0.235 |
| Arlington, Mesquite, Redhawk Facility (AZ) | 0.043 | 0.246 |
| Prairie State Generating Station (IL) | 0.063 | 0.238 |
| Gibson (IN) | 0.067 | 0.307 |
| Jeffrey Energy Center (KS) | 0.062 | 0.220 |
| Iatan (MO) | 0.076 | 0.355 |
| Labadie (MO) | 0.069 | 0.315 |
| Colstrip (MT) | 0.067 | 0.421 |
| Gerald Gentleman Station (NE) | 0.110 | 0.548 |
| Four Corners Steam Elec Station (NM) | 0.052 | 0.727 |
| Cardinal (OH) | 0.066 | 0.230 |
| Conemaugh, Seward (PA) | 0.054 | 1.491 |
| Cumberland (TN) | 0.066 | 0.940 |
| Harrington, Nichols station (TX) | 0.078 | 0.172 |
| Oak Grove (TX) | 0.077 | 0.366 |
| Parish, Carbon-Capture, Brazos Energy (TX) | 0.069 | 0.528 |
| Sam Seymour (TX) | 0.070 | 0.583 |
| Hunter (UT) | 0.070 | 0.219 |
| Intermountain (UT) | 0.051 | 0.209 |
| Dry Fork Station (WY) | 0.042 | 0.960 |
| Laramie River (WY) | 0.062 | 1.052 |