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Supplement of

Using Orbiting Carbon Observatory-2 (OCO-2) column CO_2 retrievals to rapidly detect and estimate biospheric surface carbon flux anomalies

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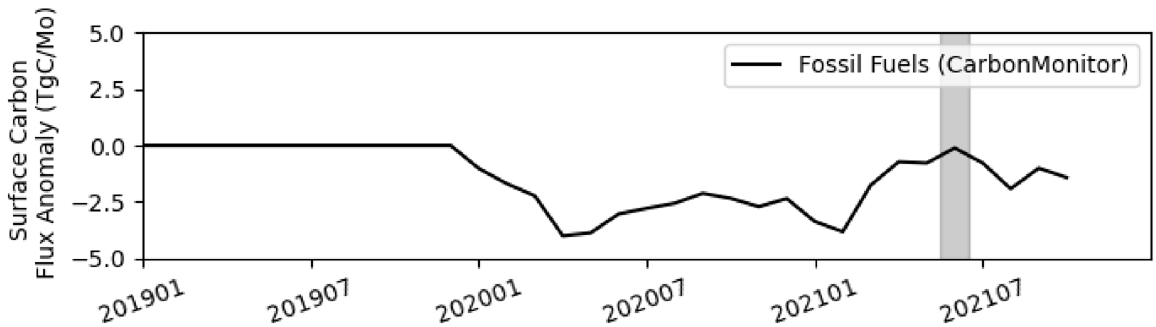

Figure S1. Surface fossil fuel emission anomalies based on CarbonMonitor. Anomalies are computed based on available 2019 months, which was a nominal year compared to COVID-19 related changes to anthropogenic sources through 2020 to 2021. Despite large changes in 2020 and 2021 fossil fuels expected, these only amount to magnitude anomalies of <5 TgC per month, which are much less than anomalies due to biospheric processes.

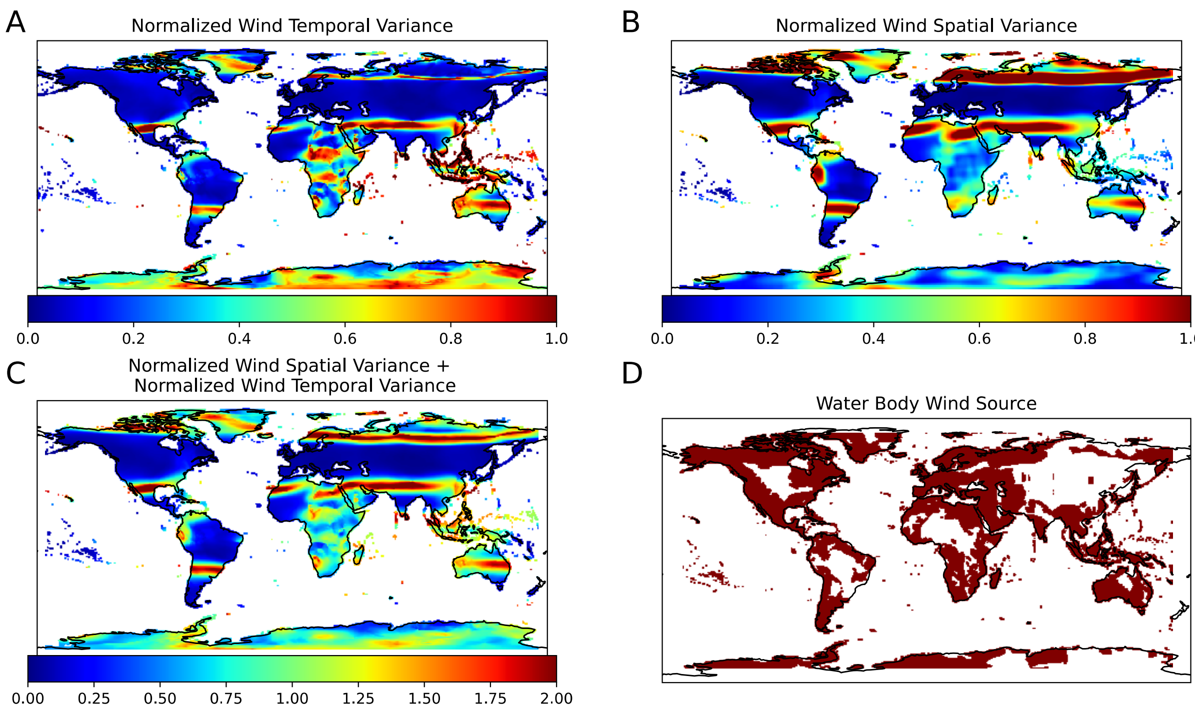

Figure S2. Wind condition favourability for pixel source mass balance methods of surface CO_2 flux estimation using lower troposphere wind directions (surface up to approximately 700 mb) from MERRA2. **(a)** Monthly variance of wind direction within each pixel, normalized by the 95th percentile of global variance values across space. (**b)** Monthly spatial variance of mean annual wind direction within a 20-pixel by 20-pixel boundary centered on each pixel, normalized by the 95th percentile of global variance values across space. **(c)** Spatiotemporal variance by adding **(a)** and **(b)** together. **(d)** Pixels with transport from a water body as a wind source based on mean annual wind direction.

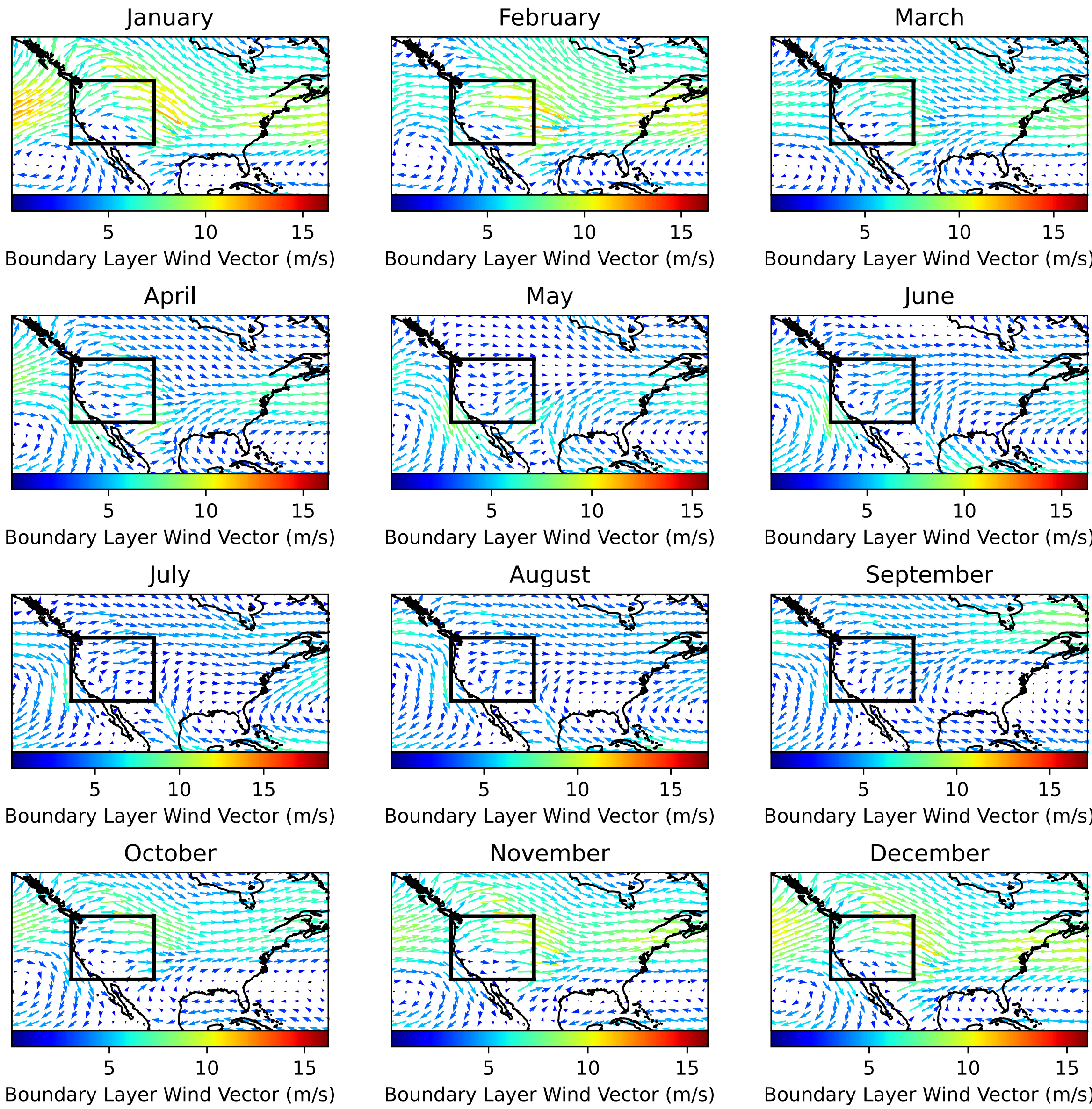

Figure S3. Mean monthly lower troposphere wind (surface up to approximately 700 mb) conditions from MERRA2. The Western US target domain is identified with borders.

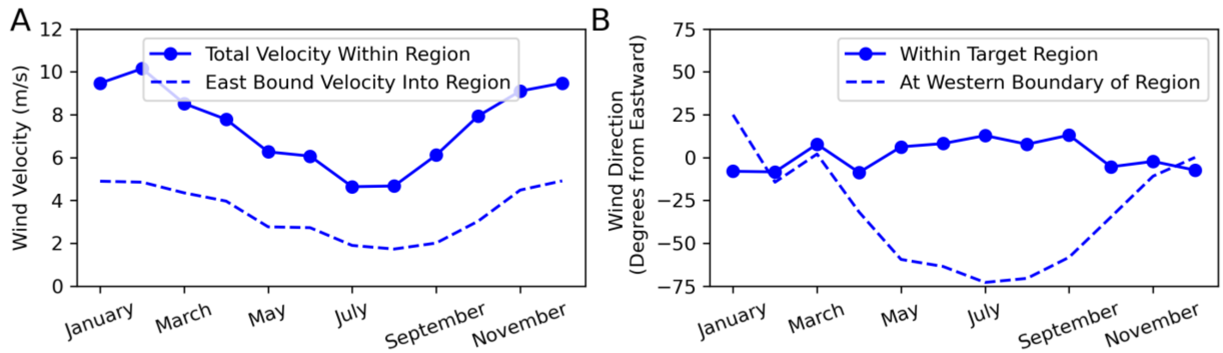

Figure S4. Mean monthly lower troposphere wind (surface up to approximately 700 mb) conditions from MERRA2. **(a)** Mean wind velocity and **(b)** mean wind direction within the target region and eastward into the target domain from the Pacific Ocean on its western border.

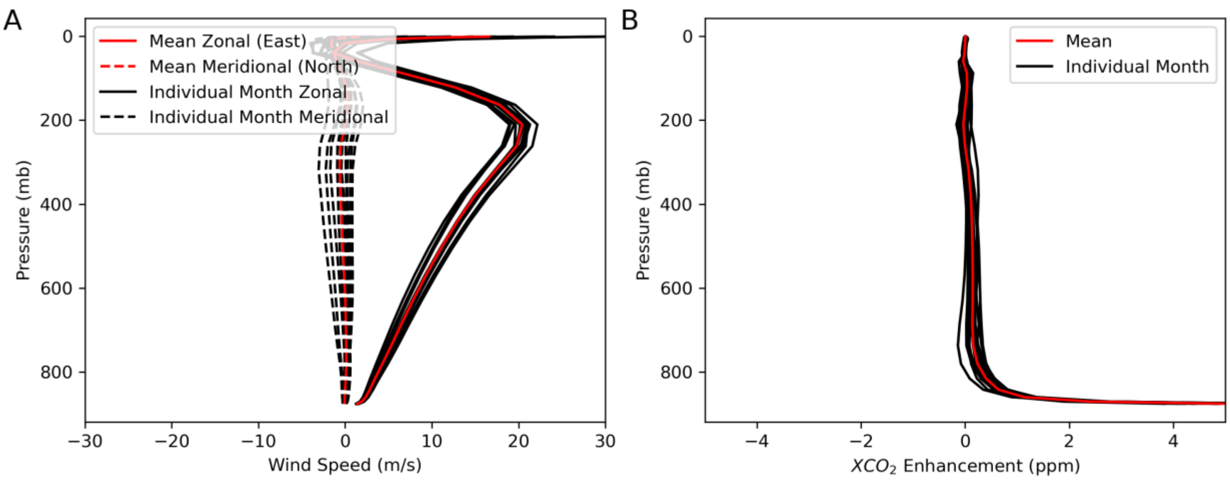

Figure S5. Vertical profile of monthly wind velocity and XCO_2 from CarbonTracker spatially averaged within the Western US target region. **(a)** Profile of wind velocity in the zonal (positive is wind from west to east) and meridional (positive is wind from South to North) directions. **(b)** Profile of XCO_2 enhancement between spatially averaged values within the Western US target region and background Pacific Ocean region. In (a) and (b), mean of all months (red lines) and mean of individual months throughout the year (black lines) are shown.

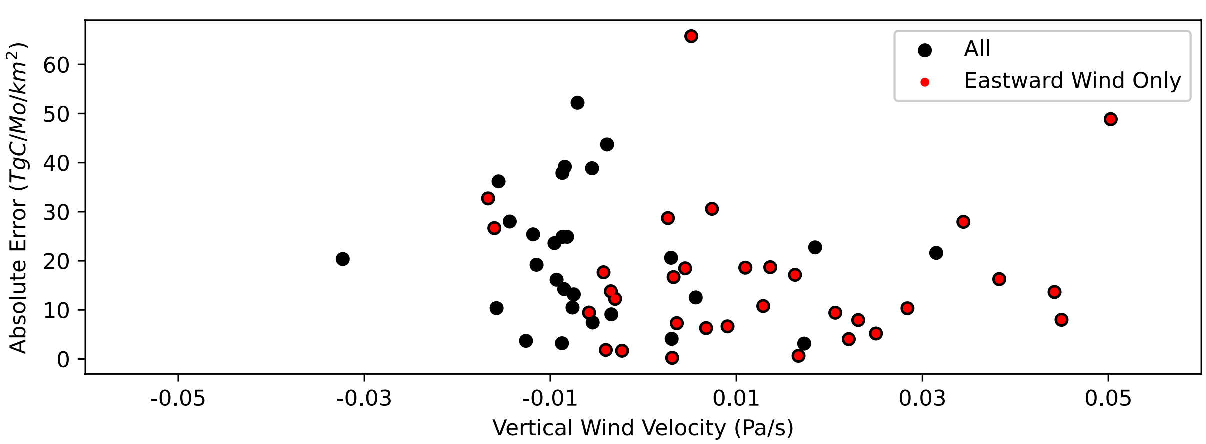

Figure S6. Carbon flux anomaly estimation error using CarbonTracker outputs with respect to MERRA2 vertical wind speeds at 700 mb. An increase in estimation errors occurs in some cases of months with downward vertical winds, but this increase cannot be separated from horizontal wind angle issues shown in Fig. 4, given that these are also months when winds shift toward the south in the Pacific Ocean. Negative vertical wind velocity is toward the surface. Absolute error is the absolute value of the difference between each pair of CarbonTracker XCO_2 flux anomaly estimates using Eq. 1 and CarbonTracker surface CO_2 flux anomaly outputs.

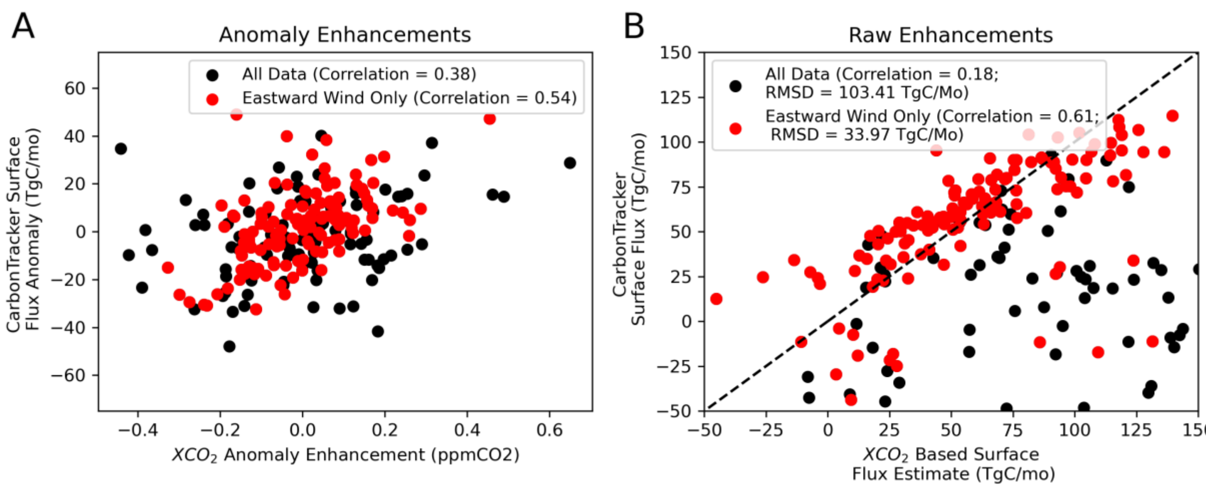

Figure S7. (a) Relationship between CarbonTracker-output surface CO_2 flux anomalies and CarbonTracker XCO_2 anomaly enhancements between the Western US and background Pacific Ocean. **(b)** Same format as Fig. 5 but estimating non-anomaly total surface CO_2 fluxes with total XCO_2 enhancements.

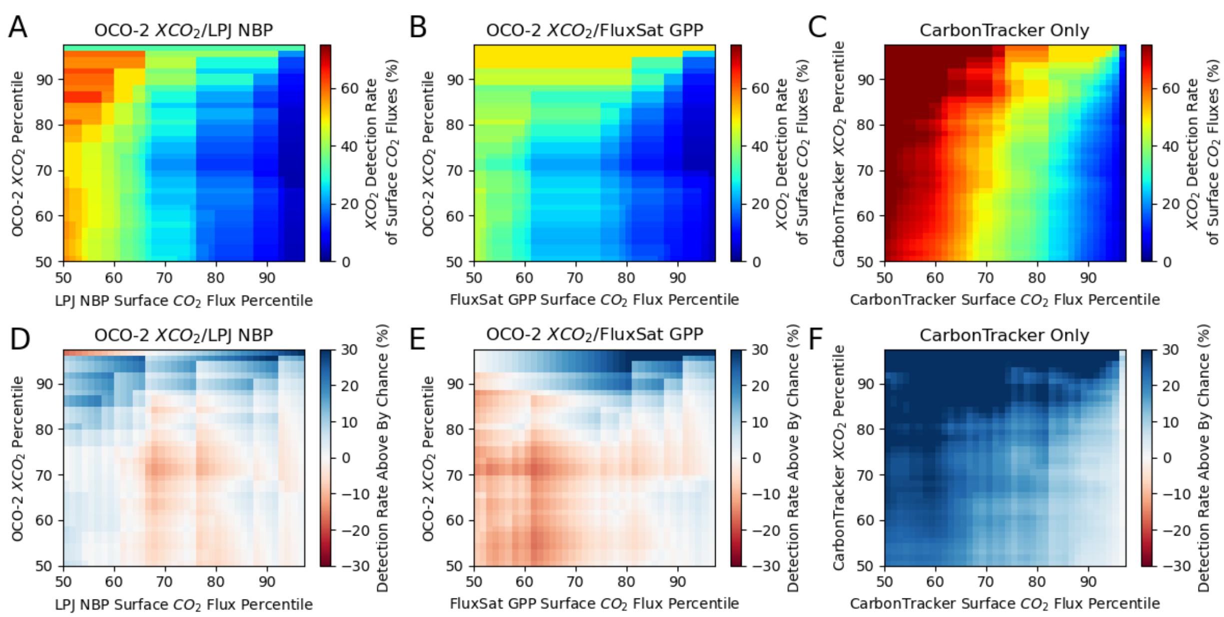

Figure S8. OCO-2-retrieved XCO_2 anomaly enhancements that are more extreme (>90^{th} percentile) can detect surface CO_2 anomalies. By contrast, more nominal OCO-2 retrieved XCO_2 anomaly enhancements (50^{th}-80^{th} percentile) have little ability to detect surface CO_2 anomalies. **(a, b, c)** Western US observed XCO_2 anomaly enhancements detection rate of surface CO_2 flux anomalies for **(a)** OCO-2 XCO_2 detection of LPJ NBP surface fluxes and **(b)** OCO-2 XCO_2 detection of FluxSat GPP surface flux anomalies. These metrics are compared to **(c)** detection rates from the reanalysis testbed in the absence of satellite retrieval error for CarbonTracker XCO_2 detection of CarbonTracker CO_2 surface flux anomalies. Each detection rate value is estimated by binning all XCO_2 anomaly enhancements above the given percentile (y-axis) and determining the number of coincident monthly surface CO_2 flux anomalies that are above the given CO_2 flux percentile (x-axis). Detection rates are computed based on Eq. 2. **(d, e, f)** Same as **(a, b, c)** but subtracting the rate of detection by chance. Values that are positive (blue) indicate that XCO_2 anomaly enhancements are better able to detect surface CO_2 fluxes than by chance.