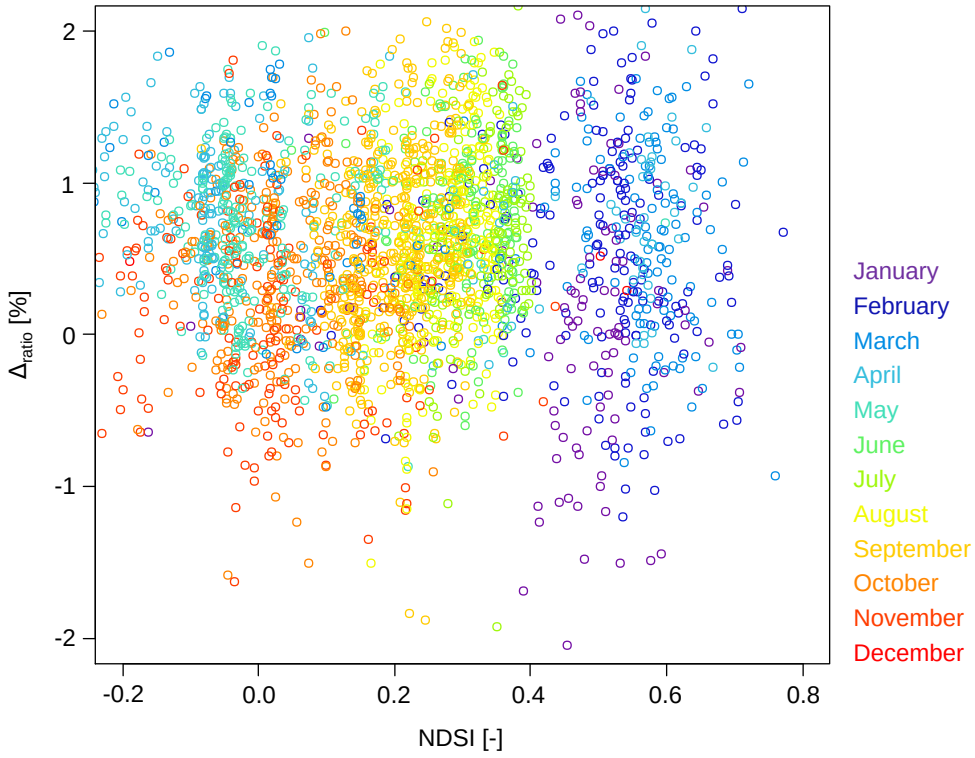

Figure S1. Relationship among the Normalized Difference Snow Index (NDSI), relative difference in the ratio component between GOSAT and TCCON (Δ_{ratio}), and month of observation.

Each circle indicates the result for a matched GOSAT and TCCON data point for the Lamont site. Data with cloud fraction (f_c) = 0 and that with normalized 2 μm band radiance ($I_{2\mu m}$) ≤ 1 were used. The plot can be split in two clusters at NDSI of 0.4. The data with large NDSI values were obtained in winter. We confirmed that the probability of snow cover was high for the data with NDSI ≥ 0.4 by checking the TANSO-CAI images visually. No remarkable bias was seen for the data with large NDSI because problematic scenes due to snow were screened out by the screening using degree of freedom for signals (see Section 2.2 in the main text about the data screening). Although visible band (around 0.55 μm) and near infrared band (around 1.6 μm) are used to calculate NDSI usually (an O_2 A band was used instead of a visible band in the present study), the threshold of 0.4 is consistent with studies detecting snow using satellite NDSI (e.g., the MODIS Snow Cover product: https://modis-snow-ice.gsfc.nasa.gov/?c=atbd#al). This is probably because the difference in snow reflectance between visible and O_2 A bands is smaller than the difference in snow reflectance between the visible and near infrared bands.

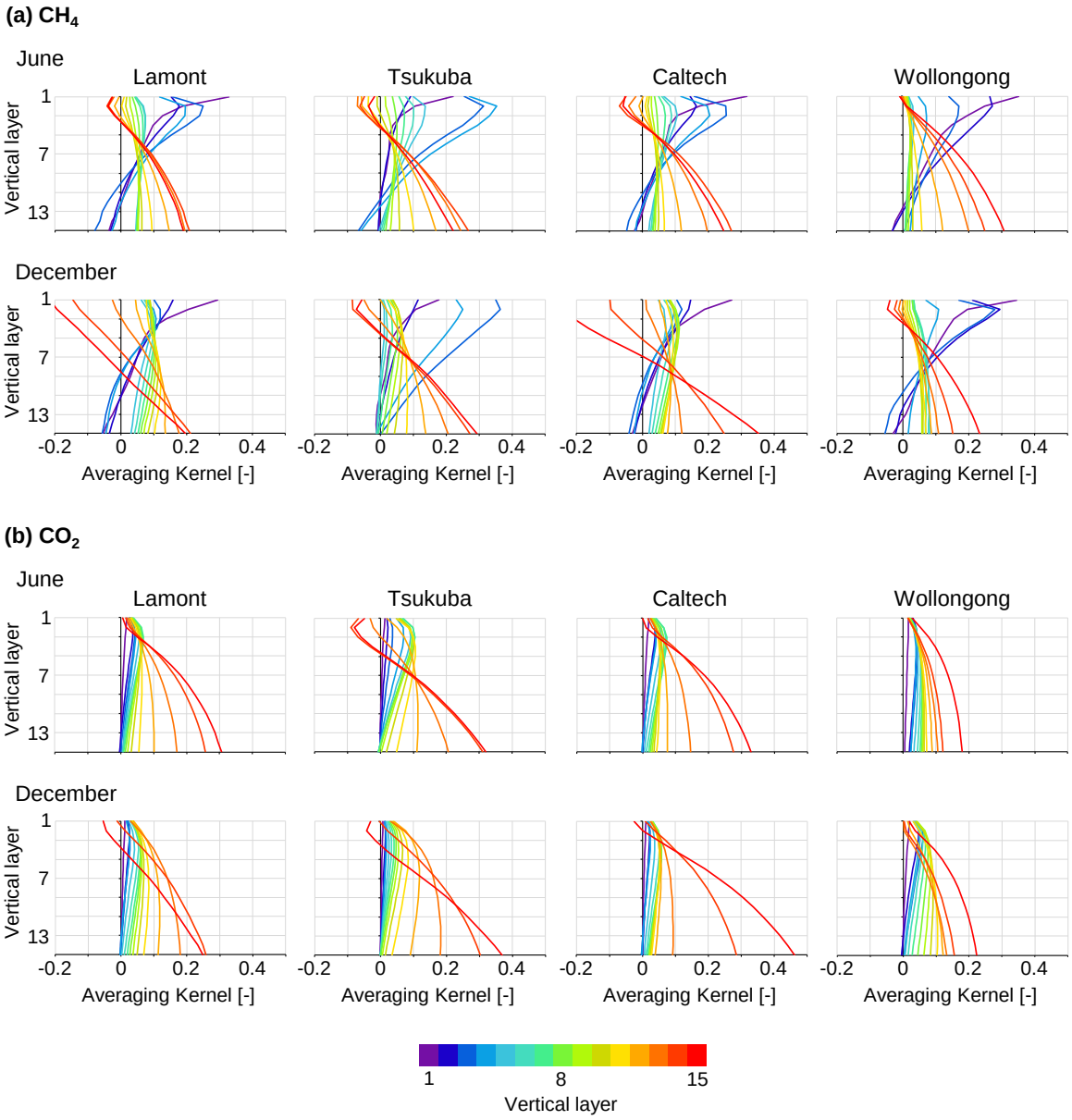

Figure S2. Averaging kernel of the GOSAT clear-sky retrieval for (a) XCH_4 and (b) XCO_2 (monthly mean values of GOSAT data matched the TCCON data).

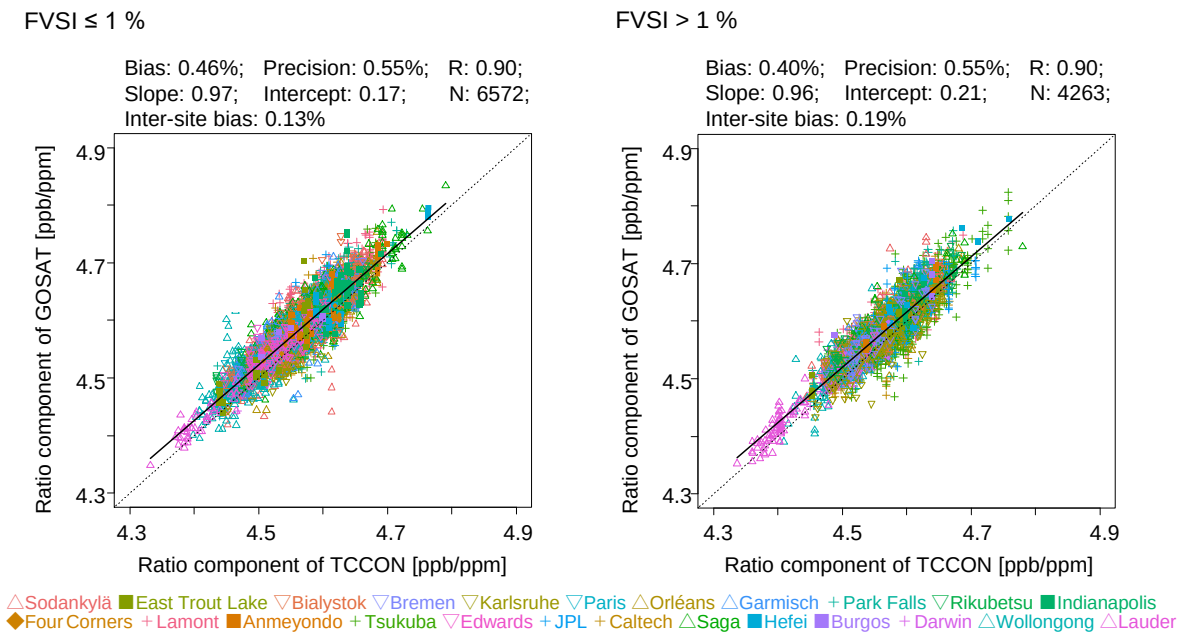

Figure S3. Similar to Figure 1, but for the data with TCCON Fractional Variation in Solar Intensity (FVSI) ≤ 1% and the data with FVSI > 1%.

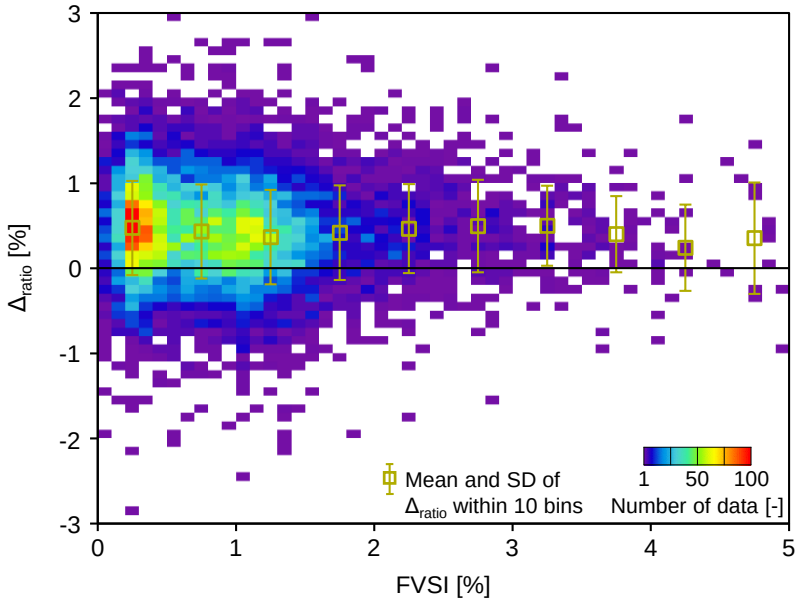

Figure S4. Relationship between the relative difference in the ratio component between GOSAT and TCCON (Δ_{ratio}) and the TCCON Fractional Variation in Solar Intensity (FVSI).

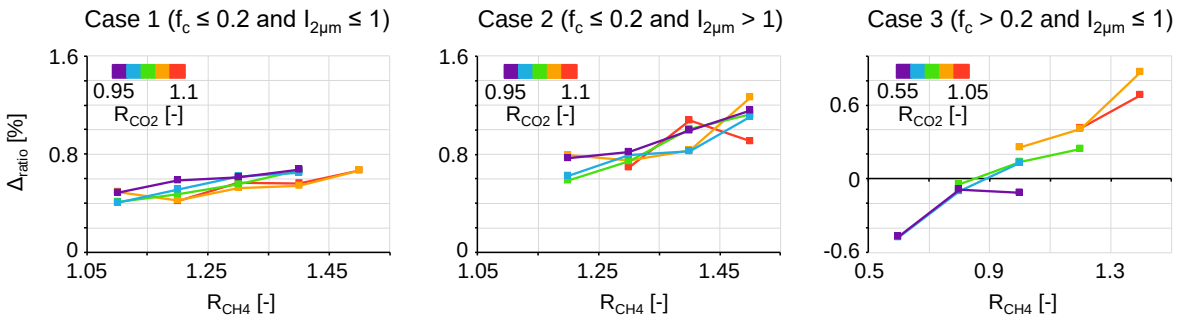

Figure S5. Similar to Figure 5, but using GOSAT data with DFS for $XCO_2 \geq 1.3$.