Temporal and Spatial Variations of Atmospheric CO2 Growth reproduced by Ground-Based Remote Sensing and CO2 Inverse Modelling

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Atmospheric CO2 growth rate is the primary driver of the global warming and a valuable indicator of the interannual changes in carbon cycle. We broaden the knowledge about temporal and spatial variations of annual CO2 growth (AGR) by using CO2 observations from the Total Column Observing Network (TCCON), CO2 simulations from Carbon Tracker (CT) and Copernicus Atmospheric Monitoring System (CAMS) models together with the global-scale AGR references from Global Carbon Budget (GCB) and satellite data (SAT) for 2004-2019 years. TCCON and the CO2 models reveal temporal AGR variations (AGR_TCCON = 1.71 – 3.35 ppm, AGR_CT = 1.59 – 3.30 ppm, AGR_CAMS = 1.66 – 3.13 ppm) of the similar magnitude to the global-scale CO2 growth references (AGR_GCB = 1.59 – 3.23 ppm, AGR_SAT = 1.55 – 2.92 ppm). However, TCCON estimates of global AGR agree well with the referenced AGR growth only during the 2010s since the network has considerably improved its spatial coverage after 2009. Moreover, TCCON-based AGRs reasonably agree (r = 0.67) with strength of El Nino Southern Oscillations (ENSO) in the 2010s. The highest atmospheric CO2 growth (2015-2016) driven by the very strong El-Nino event is accurately reproduced by TCCON that provided AGR of 2015-2016 years (3.29 ± 0.98 ppm) in very close agreement to the SAT reference (3.23 ± 0.50 ppm). We validate CAMS and CT simulations of AGR versus the newly-acquired TCCON-based AGR (as the point-location reference) for an every single TCCON site and low agreement (r < 0.50) is evidenced only at 3 out of 20 stations. This minor caveat has not affected the accuracy of simulated global AGR since it exhibits high agreement with SAT, GCB (r = 0.74 – 0.78) and TCCON (r > 0.65) references at global scales. Moreover, the correlation of AGR simulations across all grid cells (3 x 2 degree) between CAMS and CT is nearly perfect (r = 0.95) for the modeling period (2004-2016). Similarly, land-wise AGR intercomparison between CAMS and CT yields in perfect correlation (r ≥ 0.90) for 15 out of 20 MODIS land classes where the least vegetated areas exhibit the highest agreement. From spatial perspective, the highest AGR estimates (> 20% from the median value) are observed in the regions with intense combustion (East Asia) or with frequent biomass burning (Amazon, Central Africa). The slight disagreement of AGR spatial variability simulated by CT and CAMS is likely driven by the latter two regions of SH where drier conditions during El-Nino events allegedly increase the probability for
divergence between the models. In overall, the current estimates of global AGR are consistent across a wide range of the data sources and strengthening of CO₂ observational infrastructure should further improve the accuracy of AGR estimates on global and fine spatial scales.