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Understanding long-term carbon dioxide (CO_2) variability and its link with ENSO and climate parameters over India using satellite retrievals

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India is primarily concerned with comprehending regional carbon source-sink response in tandem with changes in atmospheric carbon dioxide (CO_2) concentrations or human-caused anthropogenic emissions. Atmosphere CO_2 is the most significant greenhouse gas contributing to climate change and global warming. To develop a countrywide mitigation policy, it is therefore critical to identify underlying source-sink locations and their mechanisms at various temporal scales and regional levels. To better understand the variability of CO_2 and its relationship with the climate variables requires long-term observations. Recent advancements in high-resolution satellite measurements provide a viable opportunity to examine CO_2 variability at a regional level. In this work, we presented the long-term variations and growth rates of the Greenhouse Gas Observing Satellite (GOSAT) and Orbiting Carbon Observatory-2 (OCO-2) satellite retrieved column-averaged dry-air mole fraction of CO_2 (XCO_2) and the relationship of XCO_2 growth rate with ENSO and climate parameters (temperature, precipitation, soil moisture, and NDVI) over India for the period 2010 to 2021. Results revealed an increase of 2.54 (2.43) ppm/yr of XCO_2 in GOSAT (OCO-2) retrievals during overlapping measurement period (2015-2021). In addition, a wavelet analysis shows an increase in XCO_2 every year for GOSAT; however, OCO-2 decreases and increases in XCO_2 every 5-6 months. This is attributable to high resolutions measurements of OCO-2 favouring better capture of source (high XCO_2)-sink (low XCO_2) signal than GOSAT. The Principal Component Analysis (PCA) analysis on XCO_2 anomalies showed EOF-1 contributed mainly by the south and southeast of India. Further analysis demonstrated that the trend and seasonal cycle of XCO_2 regulates the variability. The XCO_2 growth rates strongly correlate with ENSO and NDVI (clear during major ENSO events), whereas precipitation and temperature show a weak correlation. Further, lag correlation analysis reveals that ENSO and climate parameters precede the GOSAT XCO_2 growth rates, with soil moisture, NDVI, and ENSO having a good correlation with 8,4 and 3 months of leads, respectively.