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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Motivation

Atmospheric CO_2 is the most important greenhouse gas produced anthropogenically and the main driver behind climate change. Still, there is limited understanding of their global or regional (this study focuses on) variability because of large uncertainty in quantifying their source-sink fluxes at different temporal/spatial scales. This attempt was designed *to understand the long-term variability (LTV) and fine scale variability (FSV) of XCO_2 seen from space and its controlling large/local scale drivers over India* since there are,

- No detailed study investigated the LTV of column-averaged CO_2 or XCO_2 over India utilising the latest high-resolution satellite measurements.
- No study documented the inter-annual variability of the XCO_2 growth rate and its control drivers.

Preliminary Results

(A) LTV of retrieved XCO_2

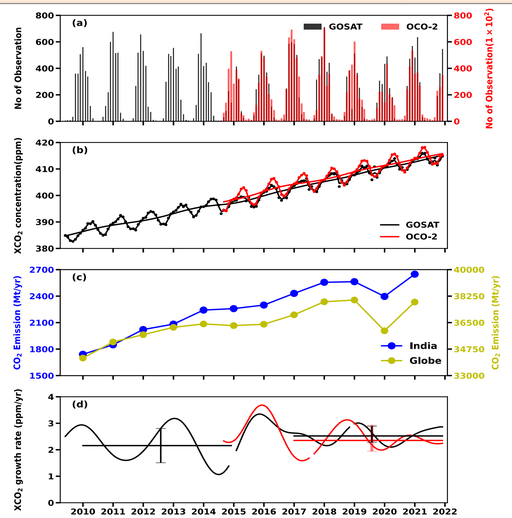
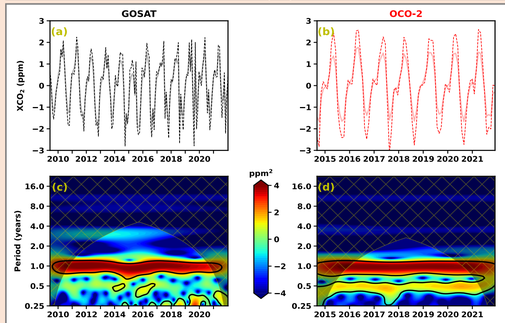


Figure 1: (a)Time series of soundings, (b)concentrations, (c) CO_2 emission and (d) growth rate at a monthly scale over Indian landmass.

- The time series of the total number of soundings for OCO-2 is 100 folds w.r.t to GOSAT on a monthly scale. Therefore, OCO-2 is more capable of capturing more source-sink signals.
- Seasonal cycle amplitude (SCA) is seen more in OCO-2 than in GOSAT.
- Increasing CO_2 emission is also observed in India mainly because of fossil fuel burnings consistent with concentration trend.
- The inter-annual variability of the XCO_2 growth rate was seen in both satellites with similar patterns during merging periods.

(B) FSV of retrieved XCO_2



- OCO-2 with high resolution, cloud-free soundings capable of capturing finer resolution variability, as seen in the power spectrum with clearly defined signals.

Figure 2: Morlet wavelet (ω_0=6) inverse wavelet transform (a,b) and normalised wavelet power spectrum in $(ppm)^2$ (c,d) for time series XCO_2 concentration over Indian landmass.

(C) ENSO-CO_2 relation in homogeneous regions

- *A heterogeneous relationship between ENSO-CO_2 is observed over precipitation-derived homogenous regions of India, having a strong (weak) correlation in South Peninsular (Hilly regions) with lag ranges between 3 to 9 months between ENSO and CO_2.*

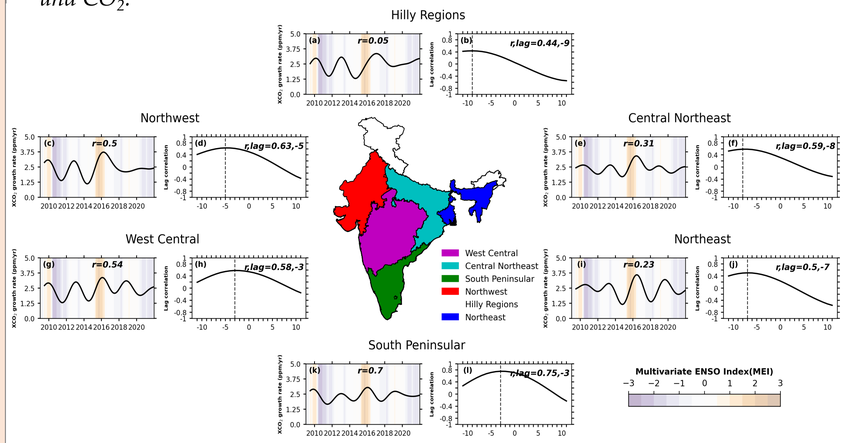


Figure 3: Time series of GOSAT XCO_2 growth rate with ENSO shown in the shaded background (small panels) for each homogeneous region in India (centre plot).

Methodology

The preliminary methodology flow steps can be vizualised below

Data

1. GOSAT (2009-2021)
2. OCO-2 (2014-2021)

Retrieve and resampling of swath datasets

- Retrieve and resampling of column average atmospheric CO_2 (XCO_2) from GOSAT and OCO-2 to 2.5×2.5 degree grid resolution using k-nearest neighbour approach

Analyzing variability of resampled data

- Analyzing the LTV of soundings, concentrations and growth rate of resampled XCO_2.
- Fine scale variability (FSV) captured using Morlet wavelet transform.

Analyzing ENSO-CO_2 covariance

- Examining the influence of climate mode ENSO on growth rate variability over different homogeneous regions in India

Conclusions

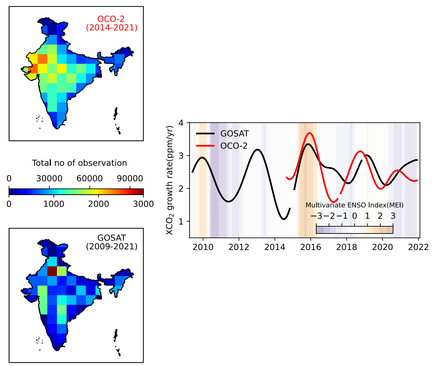


Figure 4: Total no of observations for OCO-2 and GOSAT observations (left panel), (right panel)growth rate of CO_2 with ENSO in shaded colours.

- The total no of observations is 100 folds in OCO-2 than GOSAT, capable of more regional integrated flux signals than GOSAT.
- The local scale variability is clearly defined for OCO-2 than GOSAT. The fine (long) scale variability is captured will OCO-2 (GOSAT) retrieval.
- The ENSO-CO_2 heterogeneous relationship is evident in homogeneous regions, with SP having the strongest correlation.

Future work

- Investigating the role of transport and underlying flux changes through running the state-of-art MIROC4-ACTM model simulation.
- Assessing the role of tropical climates in influencing the variability of fluxes and their imprint in recorded XCO_2.