Seasonal Bias in OCO-2 XCO_2 Satellite Observations

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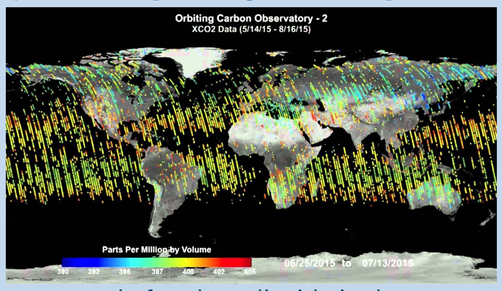
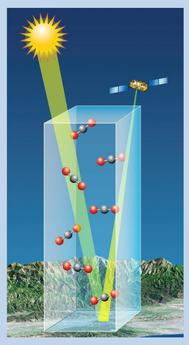
Introduction

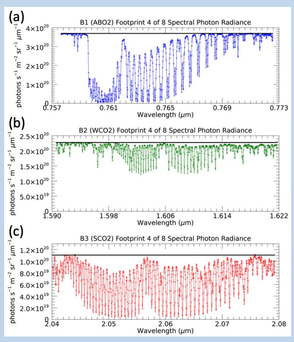
- CO_2 is a significant greenhouse gas and a key driver of climate change. Accurate and continuous monitoring of atmospheric CO_2 levels are crucial for developing climate policies and carbon sequestration strategies.

- NASA's Orbiting Carbon Observatory-2 (OCO-2), launched in 2014, is part of the Afternoon Constellation (A-Train) and completes 233 orbit paths in a 16-day repeat cycle. The satellite collects data across a 0.8° wide swath using eight adjacent footprints, each approximately 3 km^2 in size, at 24 samples per second [Eldering et al. 2017].



- OCO-2 measures column-averaged of carbon dioxide in the atmosphere (XCO_2) by capturing the solar reflectance from the Earth's surface in three spectral bands centered at the 0.76 µm, 1.61 µm, and 2.06 µm wavelengths [Crisp et al. 2004].





- Despite its advanced observational capabilities, OCO-2 measurements are subject to systematic biases that can affect their accuracy and reliability. Previous studies have explored the effects geophysical properties such as latitude and altitude have on OCO-2 bias, compared to ground-based measurements from parallel Total Carbon Column Observing Network (TCCON) sites [Wunch et al. 2017, Jacobs et al. 2024].

- However, the role of seasonal variability in OCO-2 bias remains largely unexplored. This study aims to explore the effects seasonal changes in the atmosphere and surface conditions may have on variation in OCO-2 bias.

Hypotheses and Goals

Considering the footprint's land cover mixture will improve the accuracy of the X_{CO_2} retrieval.

High spatial resolution spectral data and unmixing methods can allow for sub-pixel X_{CO_2} mapping.

→ Studying the relationship between land cover types and X_{CO_2} observations while comparing satellite observations with ground stations.

Contributions

Enhanced Accuracy in XCO_2 Measurements

Applications to Carbon Flux and Removal Models

Broader Climate and Policy Impacts

References

- Eldering *et al.*, "The Orbiting Carbon Observatory-2: first 18 months of science data products," *Atmospheric Meas. Tech.*, vol. 10, no. 2, pp. 549–563, Feb. 2017
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- D. Wunch *et al.*, "Comparisons of the Orbiting Carbon Observatory-2 (OCO-2) XCO2 measurements with TCCON," *Atmospheric Meas. Tech.*, vol. 10, no. 6, pp. 2209–2238, Jun. 2017
- N. Jacobs *et al.*, "The importance of digital elevation model accuracy in X $_{CO2}$ retrievals: improving the Orbiting Carbon Observatory 2 Atmospheric Carbon Observations from Space version 11 retrieval product," *Atmospheric Meas. Tech.*, vol. 17, no. 5, pp. 1375–1401, Mar. 2024

Acknowledgments

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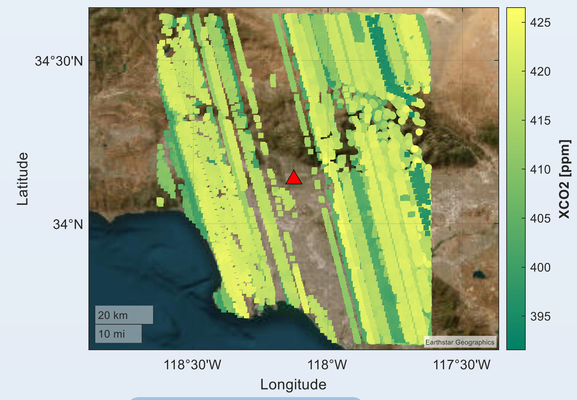
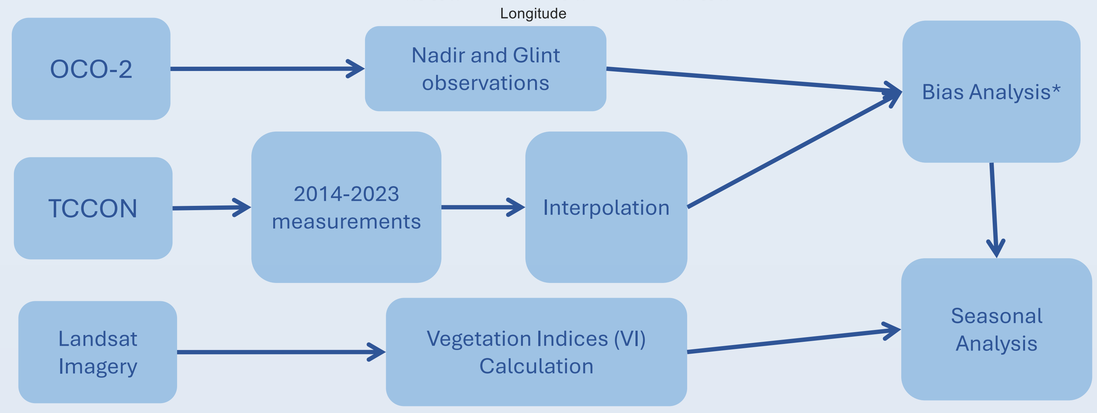
Methodology

OCO-2 data were extracted from a 1° × 1° region centered over Caltech, California (34.136° N, -118.126° W). TCCON data were taken from the Caltech site.



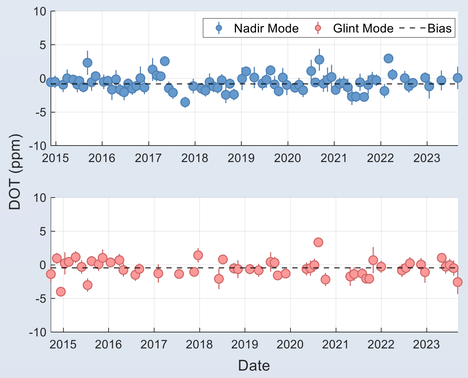


* Bias Analysis for observation mode i:

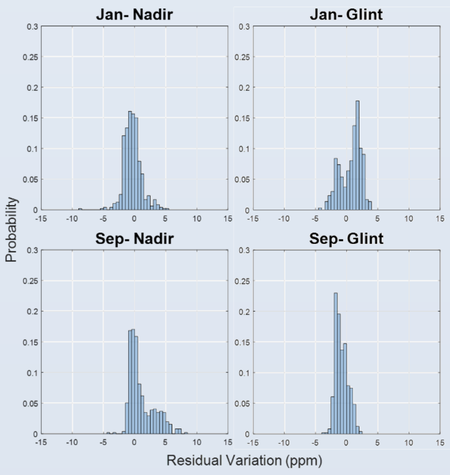
$$DOT_i = OCO2_i - TCCON$$

$$Bias_i = 1/n \sum_{j=1}^{n} DOT_{i,j}$$

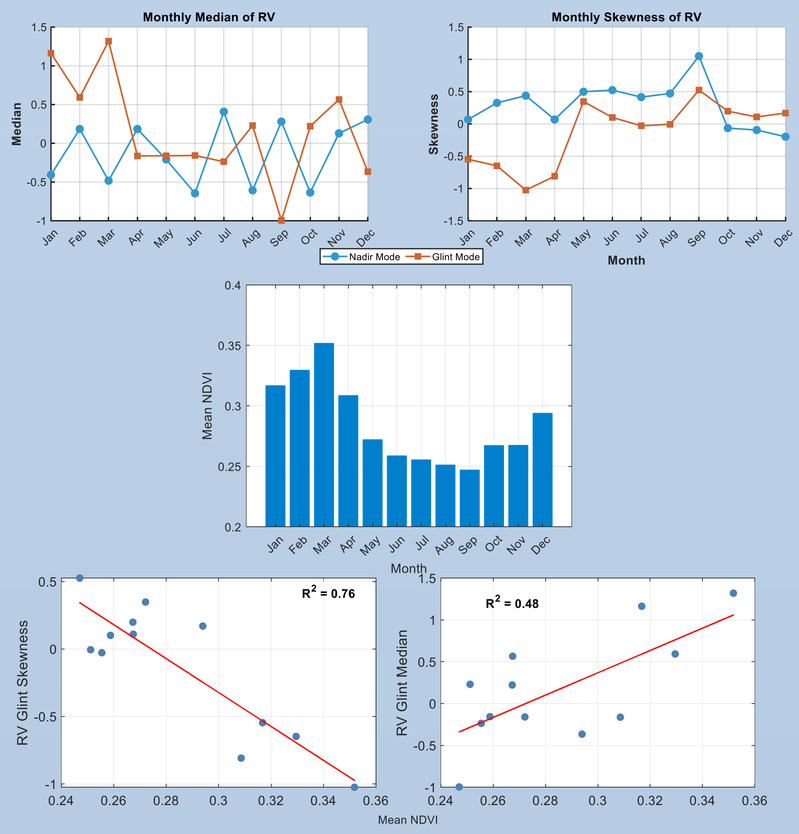
$$Residual\ Variation_i = DOT_i - Bias_i$$



Seasonal Analysis



Results and Conclusions



- RV in nadir exhibited relatively stable results with minimal variation from the bias.
- RV in glint showed higher variability, particularly during the winter and early spring.
- Correlation analysis shows high correlation between RV glint skewness NDVI ($R^2 = 0.76$) which imply a connection between vegetation cover and OCO-2 measurement outlies in glint mode.
- Correlation between RV nadir skewness and median with NDVI were very low – suggesting stable seasonal observations in nadir.