National Aeronautics and Space Administration

Postdoc Research

Evaluating global space-based X_{CO2} measurements from OCO-2 against the ground-based TCCON network

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1. OBJECTIVE

Satellite observations of CO_2 are important for understanding the global carbon cycle. Their validation against other CO_2 observations is necessary to evaluate possible biases and scatter in the datasets and provide data users with the essential information to best use these measurements.

Satellite measurements of column-averaged dry-air mole fraction of CO_2 (X_{CO2}) from the **Orbiting Carbon Observatory-2** (OCO-2, Version 11.1) are compared against the ground-based **Total Carbon Column Observing Network** (TCCON (GGG2020), solar-viewing ground-based Fourier Transform Spectrometer) measurements to identify potential biases and errors, and to improve the X_{CO2} data product from OCO-2.

2. DATA

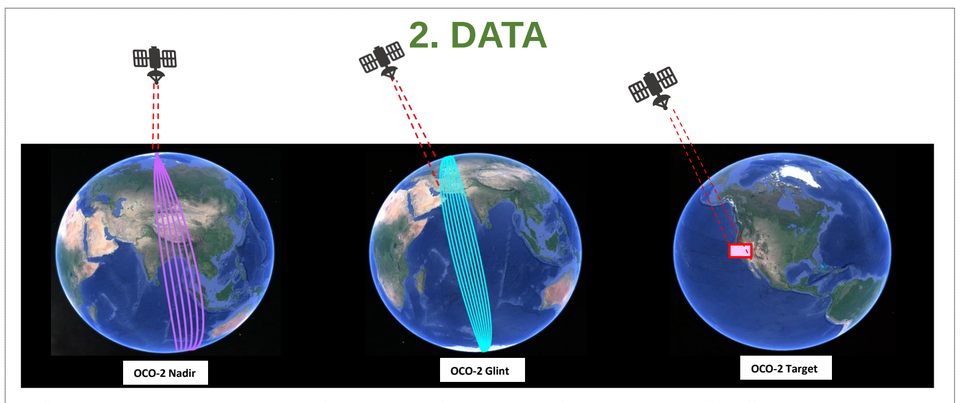


Figure 1. OCO-2 observation modes – Nadir (instrument points downwards), Glint (instrument measures off the glint spot), and Target (instrument locks on a selected target).

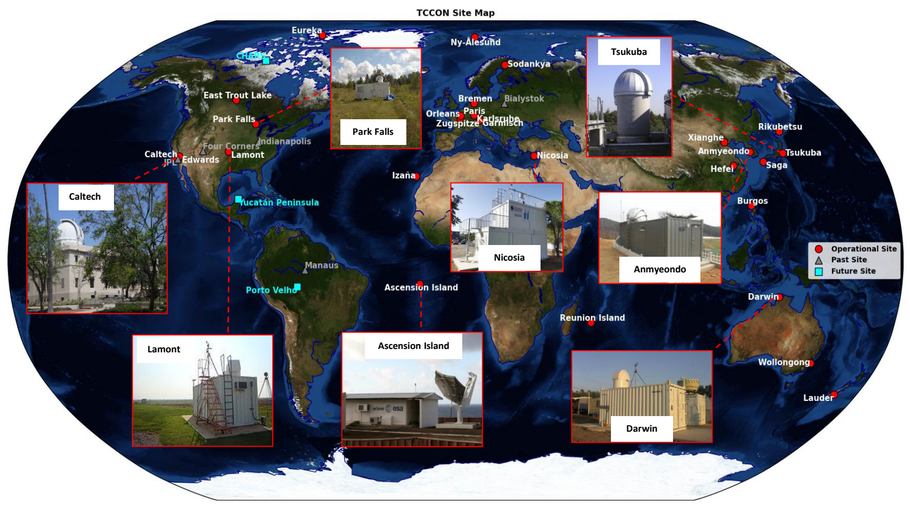


Figure 2. TCCON Sites.

3. METHODOLOGY

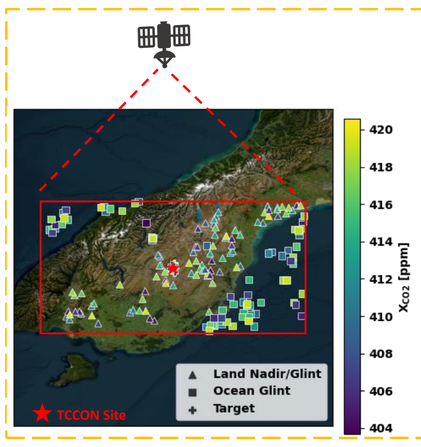


Figure 3. OCO-2 data within the coincidence box are used.

Coincidence Criteria

- ± 2.5° x ± 5° latitude-longitude boxes around TCCON sites.
- Minimum of 100 good quality OCO-2 soundings required.
- TCCON X_{CO2} (median) ±1h of overpass time.

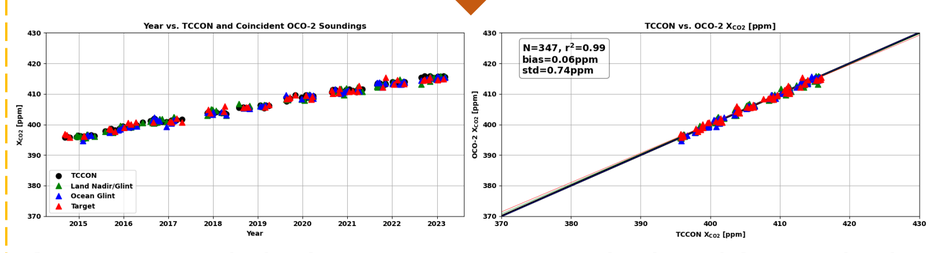


Figure 4. Statistical parameters are calculated for each site.

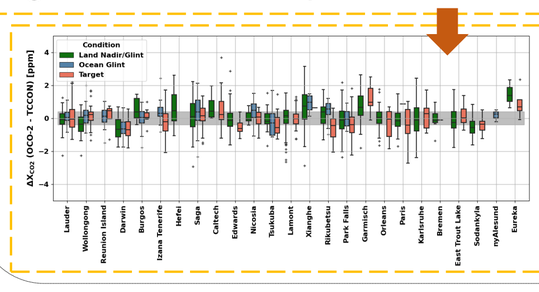
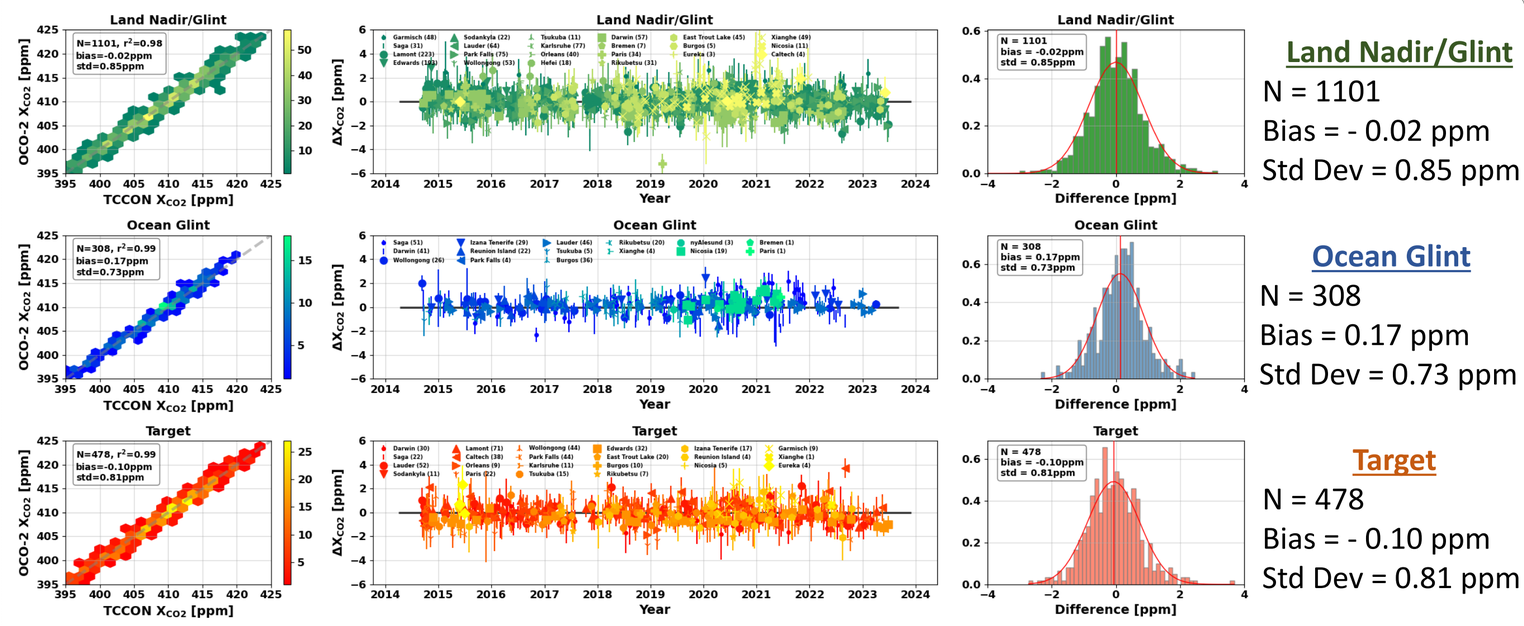


Figure 5. Global Analysis - All sites are evaluated against TCCON based on the mode of observation.

4. RESULTS



Land Nadir/Glint
N = 1101
Bias = - 0.02 ppm
Std Dev = 0.85 ppm

Ocean Glint
N = 308
Bias = 0.17 ppm
Std Dev = 0.73 ppm

Target
N = 478
Bias = - 0.10 ppm
Std Dev = 0.81 ppm

Figure 5. Left columns indicate the OCO-2 one-to-one plot against TCCON, middle columns indicate the time series of the differences, and the right columns show the statistical parameters. 'N' and 'r^2' indicate the number of points on the graph and the coefficient of determination, respectively. The colors in the left column represent the number of points per bin, but in the middle column differentiate sites.

Location - Dependent Biases: Significant spurious variability in the OCO-2 X_{CO2} can occur due to spatial dependence of the target-mode measurements on surface properties (e.g., albedo, altitude, surface roughness). '★' or '★' indicates the TCCON site.

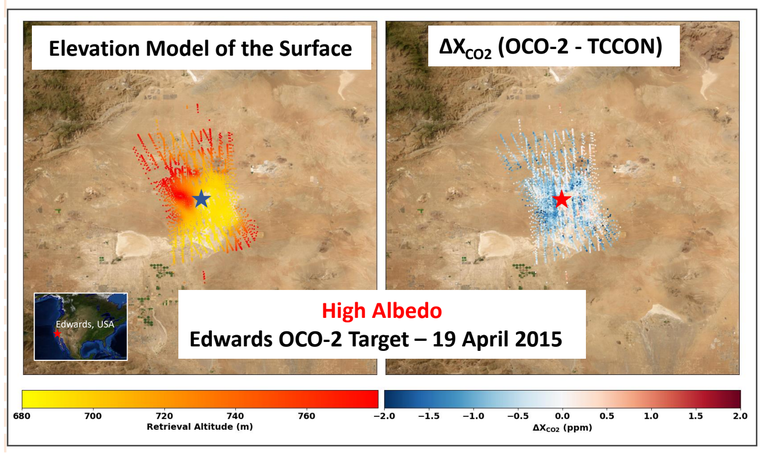


Figure 7. The Edwards TCCON station is situated in the California high desert on the edge of a very bright playa. Higher X_{CO2} are retrieved over brighter surfaces. OCO-2 X_{CO2} retrievals are biased lower than TCCON.

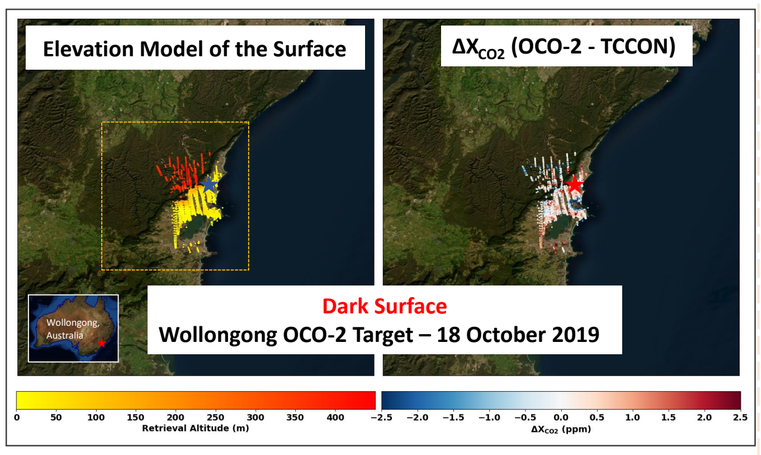


Figure 8. The Wollongong TCCON station is situated between the Tasman Sea to the east and the Illawarra escarpment to the west (region within the box). OCO-2 X_{CO2} retrievals are biased higher than TCCON.

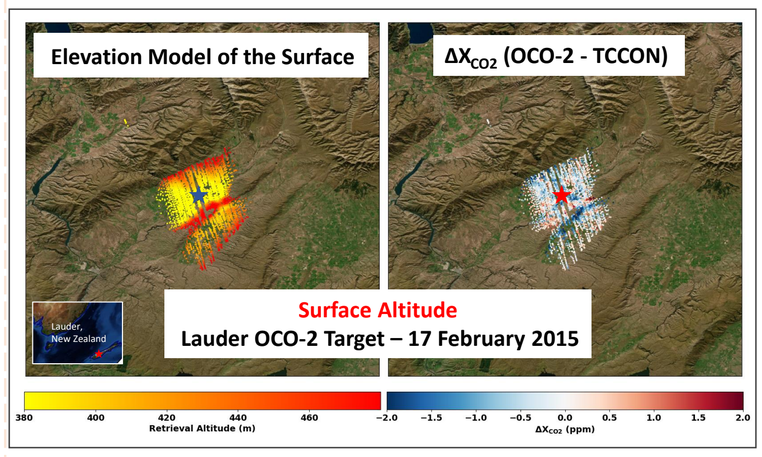


Figure 9. The Lauder TCCON station is located in a valley between rolling hills. The surface altitude is spatially correlated with the changes in X_{CO2} measured during each target-mode maneuver.

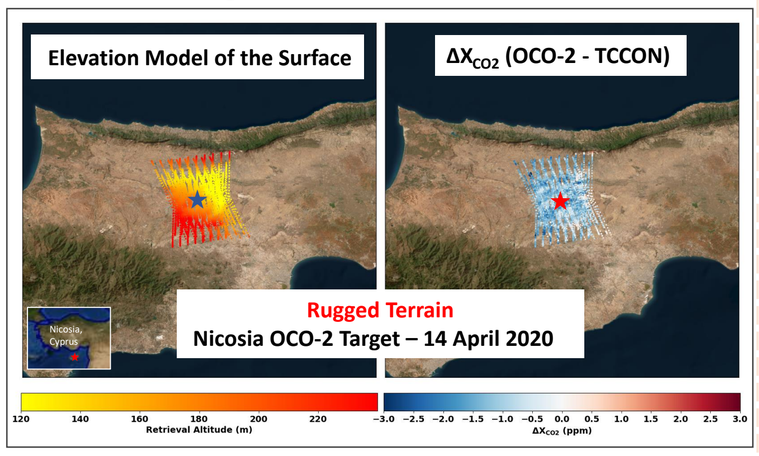


Figure 10. Nicosia has a rugged terrain and is dominated by two mountain ranges. OCO-2 data coincident to the TCCON site indicate a low bias in the X_{CO2} measurements. Further investigation is needed.

5. SUMMARY, IMPORTANCE and FUTURE WORK

- Aggregated OCO-2 X_{CO2} estimates filtered with xco2_quality_flag = 0 indicate absolute average bias values close to 0 ppm for TCCON in the Land Nadir/Glint and Target modes of observation.
- This study bridges the gap between satellite and ground-based X_{CO2} measurements, and aids the improvement of the OCO-2 X_{CO2} data product. Further, it provides the latest validation analysis for OCO-2 against TCCON, using the most recent data sets for both and providing the most up to date information on biases and uncertainty in the OCO-2 data.
- Future work will include the COllaborative Carbon Column Observing Network (ground-based) and aircraft measurements for the continued validation of the OCO-2 and the Orbiting Carbon Observatory (OCO-3) X_{CO2} products.

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Das et al., (in prep), *Comparisons of the V11.1 Orbiting Carbon Observatory-2 (OCO-2) X_{CO2} measurements with GGG2020 (X2019) TCCON*

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