Session: *Regional-to-Global Fluxes*

Investigating CO_2 space-time variability in satellite - chemistry transport model differences using aircraft measurements

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1. Overview

☞ Accurate accounting of surface CO_2 flux is crucial for policymaking toward mitigation of greenhouse gases emissions for limiting global warming below 1.5 or 2.0 ^oC by 2100. This ambition requires accurate and spatiotemporally dense coverage of satellite CO_2 monitoring and application of top-down inversion system. Our study reports (probable) systematic biases in OCO-2 satellite retrievals (version 10r) through comparison with highly accurate aircraft CO_2 measurement in an inversion system.

2. Data

CO_2 dataset	Data source
1.Aircraft vertical profile (VP) of CO_2	1. Atmospheric Tomography Mission (ATom) and JAL/NIES CONTRAIL from obspack_co2_1_ GLOBALVIEWplus_v6.1 (Schuldt et al., 2021) 2. Brazilian Amazon VP of CO_2 from four aircraft sites (SAN, ALF, RBA, TEF) (Gatti et al., 2021)
2. Surface CO_2	1. Global in-situ sites from obspack_co2_1_GLOBALVIEWplus_v6.1 2. WMO WDCGG (World Data Centre for Greenhouse Gases)
3. Column CO_2 (XCO_2)	1. NASA/JPL OCO-2 Level–2, version 10r (O'Dell et al.)

3. Transport model

Transport Model	MIROC4-ACTM
Prior	$FG = CO_{2,ff\ (GridFED)} + CO_{2,lnd\ (CASA–3hr)} + CO_{2,ocn\ (Taka–Ocn)}$
ACTM XCO_2	$XCO_2^{ACTM} = \sum_i CO_2^{priori} . dp_i + \sum_i A_i . dp_i \left(\sum_i CO_2^{ACTM} i - \sum_i CO_2^{Priori} \right)$

☞ Details on forward and inversion can be found in Chandra et al. (2022); Das et al. (2022), whereas XCO_2^{ACTM} calculation is in Patra et al. (2017)

4. Data analysis

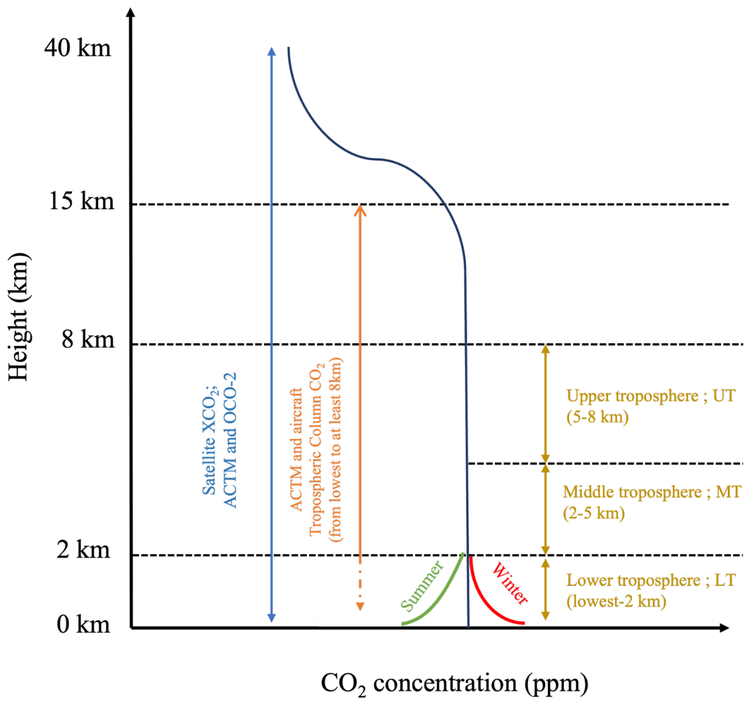

Fig. 1: Vertical profile of CO_2 from aircraft and ACTM for total column calculation, and the definitions of tropospheric layers LT (lowest-2 km), MT (2-5 km) and UT (5-8 km) are denoted with different colors.

☞ Aircraft vertical profiles of CO_2 is subdivided into three tropospheric layers LT, MT, UT, and tropospheric Column or Aircraft XCO_2

☞ Mismatch of ACTM against OCO-2 XCO_2 and aircraft CO_2 at vertical layers are evaluated considering airmass/pressure layers of partial columns (Fig. 1)

5. Results

5.1 MIROC4-ACTM comparison with OCO-2 and surface CO_2

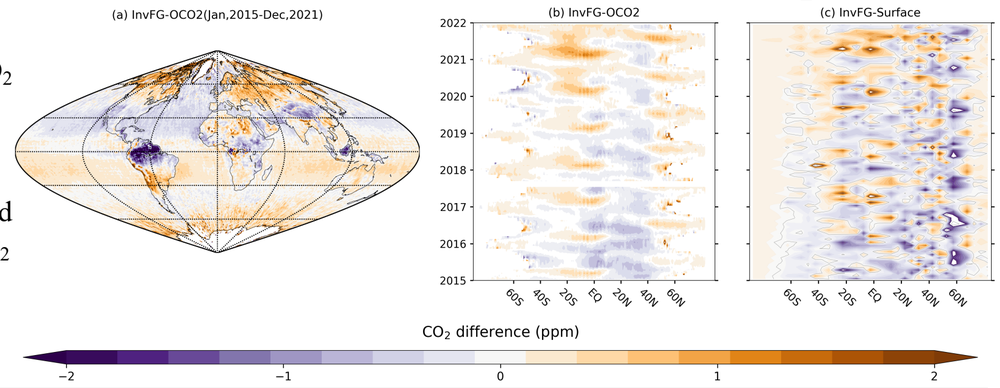

Fig. 2: CO_2 space-time variability w.r.t. OCO-2 and surface CO_2

☞ Mismatch between XCO_2^{ACTM} and OCO-2 are observed over land than ocean likely due to uncertainty in prior flux in land biosphere than the oceanic CO_2 exchange [Fig. 2a]

☞ XCO_2^{ACTM} shows seasonally repeating difference with respect to OCO-2 observed XCO_2 [Fig. 2b], as opposed to surface CO_2 [Fig. 2c]

5.2 CO_2^{ACTM} difference against XCO_2 from Aircraft and OCO-2

5.2.1 North America, Southern Ocean, Pacific, and Atlantic

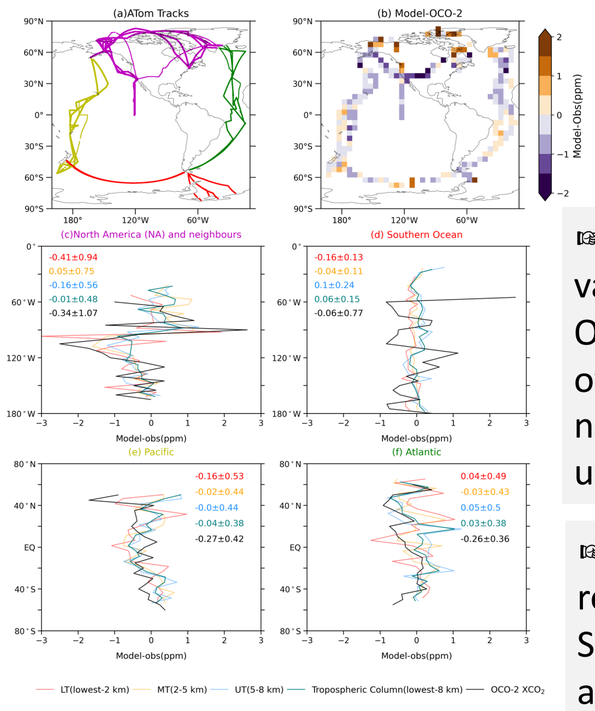

Fig. 3: XCO_2^{ACTM} difference with OCO-2 and aircraft CO_2 along several ATom aircraft campaign tracks.

☞ Largest mismatch (mean and variability) of XCO_2^{ACTM} against OCO-2/Aircraft XCO_2 observed over North America and neighbours in LT are due to uncertainty in prior land flux.

☞ Best match is observed over remote tropospheric air in Southern Ocean, also in Pacific and Atlantic Ocean sectors due to less impact of land airmass.

5.2.2 Amazon

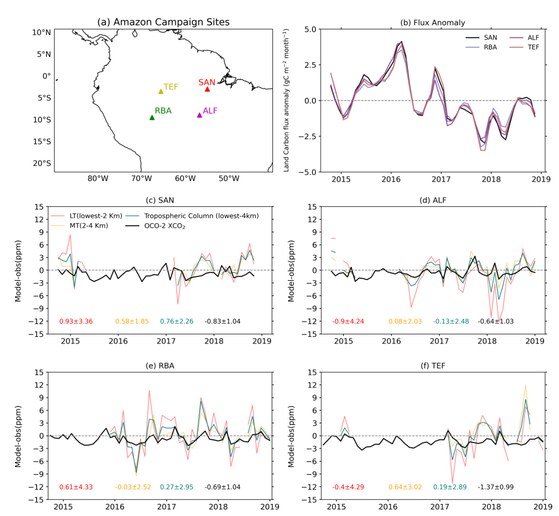

Fig. 4: CO_2 differences at the Amazon aircraft sites

☞ Largest mismatch of ±12 ppm is found in LT at ALF, RBA and TEF specific aircraft measurement site. Also, a systematic difference against OCO-2 XCO_2 is evident, but mostly less than 1 ppm.

☞ Differences also arise due to illrepresentation of sub-grid scale process in MIROC4-ACTM due to coarse resolution 2.8°×2.8°, which are further evident at the CONTRAIL airport sites

5.3 Conclusion

☞ Systematic retrieval bias is evident in OCO-2 across time period with pronounced effect in southern hemisphere ocean region.

☞ Most model-CO_2 differences exist in LT because of uncertainty in prior flux, and coarse model resolution. MIROC4-ACTM simulated CO_2 at MT, UT well by capturing the large scale dynamical transport.