

Investigating CO<sub>2</sub> space-time variability in satellite - chemistry transport model differences using aircraft measurements

Chiranjit

Das

Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, India

Naveen Chandra[1], Ravi Kumar Kunchala [2], Prabir K. Patra [1,3,\*]

1. Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama 236-0001, Japan
2. Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, India
3. Research Institute for Humanity and Nature (RIHN), Kyoto 6038047, Japan

\* Presenting author (prabir@jamstec.go.jp)

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Orbiting Carbon Observatory-2 (OCO-2) is providing global spatiotemporal distribution of column average dry-air mole fraction of CO<sub>2</sub> (XCO<sub>2</sub>) at finer spatial resolution and covering the globe compared to the high precision surface network and aircraft measurements. This information offers a unique opportunity to the carbon cycle community to utilize satellite retrievals for policy-relevant source and sink estimations through top-down inversion. This study extensively examines CO<sub>2</sub> variability from OCO-2 retrieval, aircraft measurements (Atmospheric Tomography Mission; ATom and Amazon aircraft program), and their representation in the MIROC4-ACTM chemistry transport model, aiming to understand CO<sub>2</sub> difference (model-observation) across measurement platforms, tropospheric layers and regions.

Our results demonstrate the largest mismatch variability of aircraft ( $\sim -0.01 \pm 0.4$  ppm) and OCO-2 ( $\sim -0.34 \pm 1$  ppm) against ACTM over land in North America and Amazon sites (SAN, ALF, RBA, TEF) likely due to uncertainty in prior land CO<sub>2</sub> flux constrained at lower troposphere (lowest level- 2 km). Additionally, best match of aircraft and OCO-2 against ACTM (mismatch less than  $-0.04 \pm 0.3$  ppm; ATom and  $-0.27 \pm 0.4$  ppm; OCO-2) is observed over background remote troposphere in Pacific and Atlantic regions. However, in southern ocean ATom measurements showed better concurrency with ACTM (mismatch  $\sim 0.06 \pm 0.15$  ppm) as compared to OCO-2 XCO<sub>2</sub> (mismatch  $\sim -0.06 \pm 0.7$  ppm). In all the regions, we observe that the aircraft tropospheric column (lowest level-8 km) and OCO-2 XCO<sub>2</sub> pattern matches well with ACTM, but there is more systematic bias in OCO-2 as compared to aircraft in ACTM.

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