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Towards implementing an atmospheric observation-based modelling system for estimating the source-sink distribution of CO_2 over India: an assessment of fine-scale CO_2 spatiotemporal variability

Vishnu Thilakan[1], Dhanyalekshmi Pillai[1], Christoph Gerbig[2], Julia Marshall[2,3], Aparnna Ravi[1], Michal Galkowski[2], and Thara Anna Mathew[1]
[1]Indian Institute of Science Education and Research Bhopal (IISERB), Bhopal, India
[2]Max Planck Institute for Biogeochemistry, Jena, Germany
[3]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Climate change mitigation strategies require regional-scale estimations of CO_2 fluxes, but estimates are often tampered with a significant amount of uncertainties due to multiple factors. In the case of the top-down approach, the error associated with the forward transport model is one of the major causes of uncertainty. Current generation global atmospheric transport models are more often simulated at a horizontal resolution of one degree or less, which omits a large number of small-scale processes and creates a significant amount of uncertainty in estimations. Attempts for the estimation of CO_2 fluxes at fine scales over India using the top-down approach is essentially new compared to some other parts of the globe like North America or Europe. The study focuses on implementing an inverse modelling system, by considering high-resolution atmospheric transport and flux distribution, to retrieve the fluxes at spatial scales relevant for ecosystem and policy-making. Using WRF-Chem (GHG) model, we estimate the transport error in CO_2 simulations over India during July and November 2017 which is associated with different processes whose scale is smaller than the resolution of current-generation global transport models. We show that the overall sub-grid variability (or representation error) at the surface can go up to ~10 ppm for the surface CO_2, which is markedly higher than the sampling errors. Total column-averaged CO_2 also shows similar variability in the spatial pattern though the magnitude is less compared to the surface, which indicates the prominence of heterogeneity at surface flux in modulating the entire column variability. Our results show that there exist regional differences in sub-grid scale variability for both surface and column CO_2 with very high magnitude observed at coastal and mountain regions and at emission hot spots. In addition to spatial variability, the sub-grid variability of CO_2 over India exhibits seasonal variations as well. The vertical distribution of sub-grid variability during July shows its association with the monsoon circulations, which is much different than those during November. Our estimates suggest that the terrain heterogeneity alone can explain about 53-63% of the surface representation errors over the domain, which shows the importance of using accurate Digital Elevation Models in the atmospheric transport model simulations. With underlying assumptions, the total flux uncertainty solely due to the unresolved

sub-grid scale variations is estimated to be 8.1 to 14.4% of the total NEE. These results will be discussed and presented in the context of our attempts towards estimating the source-sink distribution of CO_2 over India.