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The potential of space-based carbon dioxide retrievals to evaluate land surface models

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Space-based retrievals of column-averaged carbon dioxide (XCO_2) help constrain the regional sources and sinks of atmospheric CO_2 through data assimilation. However, this approach is sensitive to multiple factors, including residual regional-scale biases in the observations that may induce errors in the fluxes, and also potential error sources within the model inversion system (e.g., in the transport model, inversion setup, or prior flux components). We are investigating the benefits of a parallel research effort: we compare satellite-retrieved XCO_2 directly to simulated XCO_2 fields from models that assimilate in-situ measurements of CO_2. We concentrate especially on quantitative comparisons of the regional XCO_2 seasonal cycles from the Greenhouse Gases Observing Satellite (GOSAT) and the Orbiting Carbon Observatory -2 (OCO-2) to those from a variety of models.

Our results show that the XCO_2 seasonal cycle amplitude from GOSAT and OCO-2 observations generally agrees with models in regions where the models are well constrained by in-situ measurements. However, we identify several regions where the seasonal cycle amplitudes differ by up to about 3 ppm or are out of phase. We explore the underlying reasons for these discrepancies by comparing model fluxes in these regions, and discover a systematic connection between a too shallow XCO_2 seasonal cycle amplitude and a low variability in the net ecosystem exchange at the biome types of subtropical savannas, grasslands and seasonally dry forests. In these particular regions, the in-situ measurements of CO_2 are scarce, so the models are less constrained by measurements and, thus, may give more weight to their prior flux constraints, which for the biospheric fluxes are provided by their land surface models. Our tests with different land surface models imply that models driven by NDVI of fPAR (e.g., CASA, CASA-GFED, SiB-3) consistently underestimate the seasonality of the biospheric CO_2 fluxes in these biomes, whereas models with prognostic plant growth (e.g., ORCHIDEE, SiB-4) lead to a better agreement with the GOSAT and OCO-2 satellites. The results of this study provide example guidance to what extent satellite-retrieved XCO_2 can directly be used to learn about land surface models.