Carbon Monitoring system flux estimation and attribution: impact of ACOS-GOSAT XCO2 sampling on the inference of terrestrial biospheric sources and sinks


Objectives:

• In this paper, we describe the variational inversion system developed as part of the CMS-Flux and demonstrate the performance of this system in the context of an Observing System Simulation Experiment (OSSE).
• The study uses an OSSE to investigate the impact of JAXA Greenhouse gases Observing SATellite ‘IBUKI’ (GOSAT) sampling on the estimate of terrestrial Biospheric flux with the NASA Carbon Monitoring System Flux (CMS-Flux) estimation and attribution strategy.
• The study investigated the impact of GOSAT sampling on (1) flux estimation for random error uncertainty reduction and (2) the global and regional bias in posterior flux that results from the spatiotemporally biased GOSAT samples.
• The OSSE uses simulated observations based on the actual column carbon dioxide (X$_{CO2}$)b2.9 retrieval sensitivity and quality control for 2010, processed through the Atmospheric CO$_2$ Observations from Space (ACOS) algorithm.
• Monte Carlo calculations were used to find average flux uncertainty reduction ranges.

New Science:

• The results show that the ACOS-GOSAT observations reduce uncertainty of the monthly global mean flux ranges from 25% in September to 60% in July.
• The annual mean uncertainty reduction ranges from 10% over North American Boreal to 38% over South American temperate, which was driven by the observational coverage and the magnitude of prior flux uncertainty.
• The uncertainty reduction over the South American tropical region is 30%, although the observation coverage is sparse.
• This large uncertainty reduction is mainly from observations over Central America, South American temperate and South Africa, where the CO$_2$ concentrations are sensitive to South American tropical flux.
• The study shows that the reduction results from the large prior flux uncertainty and the impact of non-local observations.
• The impact of GOSAT’s spatiotemporal sampling of the posterior flux was found to have a 0.7 gigatons of carbon bias in the global annual posterior flux resulting from the seasonally and diurnally biased sampling when using a diagonal prior flux error covariance.

Significance:

• CO$_2$ plays a crucial role in climate forcing, and in the uncertainties related to carbon climate feedbacks in global models.
• To better understand this role, it is crucial to accurately monitor CO$_2$ change and to understand and quantify the processes causing changes in CO$_2$. 
• This study demonstrates the significant impact on flux estimation of assimilating simulated ACOS-GOSAT observations with CMS Flux inversion system.
• There is no OSSE study so far that uses the real GOSAT retrieval sampling and sensitivities and few studies have discussed the impact of spatiotemporally biased sampling on CO$_2$ flux estimation.
• This study demonstrates the significant impact on flux estimation of assimilating simulated ACOS-GOSAT observations with CMS Flux inversion system.
• A follow-on paper by these authors will describe the assimilation of real ACOS-GOSAT observation.
• The CMS Flux inversion system has some problems in common with other inversion systems (including) the specification of prior flux error statistics, uncertainty quantification and the impact of transport errors which require further investigation.

Figure 1: (a) Global CO$_2$ flux seasonal cycle (black: the truth; blue: the prior flux; red: the posterior flux assimilating ACOS-GOSAT X$_{CO_2}$; green: the posterior flux assimilating random-sampled X$_{CO_2}$. Unit: GtC/month.
(b) Global total flux uncertainty reduction as a function of month.
Figure 2: Flux seasonal cycle comparison among the truth (black), the prior flux (blue) and the posterior flux (red) at 11 TransCom regions over land; purple line is the total number of simulated ACOS-GOSAT observations at each region as a function of month (unit: 100, right y-axis); (a) North American Boreal; (b) North American Temperate; (c) South American Tropical; (d) South American Temperate; (e) North Africa temperate; (f) Southern Africa; (g) Eurasian boreal; (h) Eurasian temperate; (i) Tropical Asia; (j) Australia; (k) Europe. On the top of each panel lists the RMS error of the prior flux (first number) and the posterior flux (second number). Unit: gC/m²/day; (l) the geographic boundaries of the 11 regions.