GOSAT and OCO-2: New tools for studying interactions between the carbon cycle and climate

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Space based remote sensing is now providing new tools for studying atmospheric carbon dioxide (CO_2) and the interactions between the global carbon cycle and climate. The Japanese Greenhouse gases Observing SATellite, GOSAT, has been operating since 2009, collecting up to a thousand high-spectral-resolution measurements of reflected sunlight in cloud-free skies each day. These spectra are analyzed with remote sensing retrieval algorithms to estimate the column-averaged dry air mole fractions of CO_2 (X_{CO2}) and CH_4 (X_{CH4}) with single-sounding precisions and regional scale biases < 0.5% (~2 ppm X_{CO2}, ~10 ppb X_{CH4}). In July of 2014, the NASA Orbiting Carbon Observatory-2 (OCO-2) joined GOSAT and is now returning around 100,000 X_{CO2} estimates over the sunlit hemisphere each day. OCO-2 X_{CO2} estimates have single sounding random errors near 0.5 ppm (0.125%), and biases typically < 1 ppm.

The OCO-2 team retrieved X_{CO2} and solar induced chlorophyll fluorescence (SIF) from the first 7 years of the GOSAT V201 product using the same retrieval algorithm used to generate the OCO-2 Version 7 (v7) product. The carbon cycle science community is now using this combined GOSAT/OCO-2 science data record to study the response of the carbon cycle to the strong 2015-2016 El Niño. By comparing OCO-2 observations to a climatology compiled using earlier GOSAT data, Chatterjee et al. (2017) find an X_{CO2} reduction of 0.5 ppm in the central equatorial Pacific Ocean (Nino 3.4 region) between March and July of 2015, consistent with a reduction in ocean outgassing associated with El Niño. However, in August 2015, while D*p*CO_2 measurements from a TAO/TRITON buoy in the Nino 3.4 region still showed suppressed CO_2 outgassing at that location, OCO-2 observations over the equatorial Pacific showed enhanced X_{CO2}. Chatterjee et al. attribute this change to a combination of biomass burning and general reduction in vegetation uptake over tropical continents.

To test this further and assess the relative roles of drought, temperature stress, and fires on the Net Biospheric Exchange (NBE) during the 2015-2016 El Niño, Liu et al. (2017) used the Carbon Monitoring System (CMS-Flux) flux analysis system to analyze GOSAT and OCO-2 observations. They compared the El Niño results to a baseline NBE derived from GOSAT X_{CO2} estimates collected during the 2011 La Niña. Relative to 2011, they found enhanced CO_2 emissions throughout the tropics during the 2015-2016 El Niño, with an additional 0.91 ±0.24, 0.85 ±0.21, and 0.60 ±0.31 gigatons of carbon (GtC) from tropical South America, tropical Africa, and tropical Asia, respectively.

While these CO_2 anomalies had similar amplitudes, different processes dominated in each region. MOPITT CO data indicate that fires aided by high temperatures and drought dominated the CO_2 emissions over tropical Asia. GOSAT SIF estimates indicate increased respiration over central Africa, which had high temperatures but nearly normal rainfall, while tropical South America had reduced gross primary production (GPP) and drought. These observed changes may reflect differences in forcing or differences in prior conditions (prior natural disturbance, drought, etc.). They support the hypothesis that the high CO_2 growth rate during the 2015-2016 El Niño was primarily due to tropical land carbon fluxes, but show that the mechanisms may vary from continent to continent. This has important implications for both the predictability of carbon-climate feedbacks and future efforts to manage ecosystem carbon emissions.

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