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Diagnosing the fraction of inter-annual variability of global carbon cycle driven by atmospheric circulation variability

Na Li[1], Sebastian Sippel[2], Alexander J. Winkler[1], Miguel D. Mahecha[3], Markus Reichstein[1], and Ana Bastos[1]

[1]Max Planck Institute for Biogeochemistry, Department of Biogeochemical Integration, Germany (nali@bgc-jena.mpg.de)
[2]Institute for Atmospheric and Climate Science, and Seminar for Statistics, ETH Zurich, Switzerland (sebastian.sippel@env.ethz.ch)
[3]Remote Sensing Center for Earth System Research, Leipzig University, Germany (miguel.mahecha@uni-leipzig.de)

The inter-annual variability (IAV) of the global carbon cycle (C-cycle) is prone to large uncertainty, which in turn, affects uncertainty in future climate projections. Quantifying the imprint of large-scale atmospheric circulation dynamics and associated carbon cycle responses is a key endeavour to improve our understanding of C-cycle dynamics.

C-cycle IAV mainly results from the balance of carbon uptake by gross primary productivity, carbon release from respiration processes, and other disturbance-induced fluxes. These processes are largely controlled by temperature, water availability, and incoming solar radiation, which are modulated by large-scale modes of atmospheric circulation such as the El Niño/Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO).

Here, we use a data-driven approach [1] to quantify the fraction of IAV in atmospheric CO_2 growth rate and the land CO_2 sink that are driven by atmospheric circulation variability, by using spatio-temporal sea level pressure-a proxy for large-scale atmospheric circulation-as a predictor in ridge regression models of carbon cycle IAV. We use a regularisation approach [1] to curb the problems of overfitting and multicollinearity due to the limited time interval and large number of spatial predictors (spatial gridded time-series of SLP anomalies). We find that the model based on SLP anomalies can achieve high skill in predictions of the IAV in atmospheric growth rate and global land sink, with Pearson correlations between original and predicted test values of 0.7-0.84. The coefficients of the regression indicate two dominant regions contributing to C-cycle IAV: one in the tropical Pacific corresponding to the well-known influence of ENSO, another one located in the western Pacific. We test how the prediction skill depends on the length of the time-series and show that for short time-series (15-20 years) the correlation of predicted vs. observed test values is strongly dependent on the particular period considered, while it is more stable for periods longer than 30 years. These results indicate that the influence of atmospheric circulation variability on IAV of the C-cycle can limit our ability to draw robust conclusions when using short observational records.

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