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A statistical model of the global carbon budget

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We propose a statistical model of the global carbon budget as represented in the annual data set made available by the Global Carbon Project (Friedlingsstein et al., 2019, Earth System Science Data 11, 1783-1838). The model connects four main objects of interest: atmospheric CO2 concentrations, anthropogenic CO2 emissions, the absorption of CO2 by the terrestrial biosphere (land sink) and by the ocean (ocean sink). The model captures the global carbon budget equation, which states that emissions not absorbed by either land or ocean sinks must remain in the atmosphere and constitute a flow to the stock of atmospheric concentrations. Emissions depend on global economic activity as measured by World gross domestic product (GDP), and sink activity depends on the level of atmospheric concentrations (fertilization). The model is cast in a state-space system, which facilitates estimation of the parameters of the model using the Kalman filter and the method of maximum likelihood. We illustrate the usefulness of the model in two applications: (i) short-horizon forecasts of all variables in the model, which is an output of the Kalman filter; and (ii) long-horizon projections of climate variables, implied by certain assumptions on future World GDP, are constructed from the model and compared with those coming from the Representative Concentration Pathway scenarios. The statistical nature of the model allows or an assessment of parameter estimation uncertainty in the forecast and projection exercises.