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Preconditioned biosphere flux extremes in terrestrial carbon cycle models and reanalyses in the recent past, present, and future

Björn Riebandt, Moritz Adam, Elisa Ziegler, and Kira Rehfeld
University of Tübingen, Geo- and Environmental Research Center, Department of Geoscience, Germany

The increasing frequency and severity of climate extremes pose a multifaceted threat to health, economic stability, and both natural and human-made environments. Potential overlap and accumulation of extremes as compound extremes poses further challenges. Ongoing climate change intensifies these challenges, underscoring the importance of a better understanding of the causes and drivers for compound events. Earth system model projections suggest that more frequent climatic compound extremes affect terrestrial biosphere fluxes, potentially reducing the land's CO_2 storage potential. However, whether models are able to represent such interactions like the priming of the biosphere towards extremes accurately remains to be shown.

Here, we focus on the role of concurrent precipitation and temperature as drivers of biosphere flux extremes and investigate their change in frequency and intensity based on their occurrence in historical simulations, reanalyses, and future projections. We use thresholds to define concurrent extremes and Monte Carlo randomization to constrain uncertainties. Further, we examine the association of climatic compound events with anomalies in biosphere carbon fluxes to ascertain their mutual relation, aiming to establish how these climatic compound events contribute to preconditioning extremes in the biosphere. Given this assessment of the occurrence change of climatic compound events and their connection to extremes in biosphere carbon fluxes, we infer how climatic compound events may precondition the biosphere for extremes. Lagged overlaps show significant seasonality and spatial heterogeneity in preconditioning. Comparing reanalyses and historical simulations in a model of the terrestrial carbon cycle and a comprehensive Earth System Model, we examine how well primed biosphere extremes agree in different data sources. Leveraging these findings, we evaluate if model projections show signs of stronger climatic priming of the biosphere in the next century.