

EGU21-5414

<https://doi.org/10.5194/egusphere-egu21-5414>

EGU General Assembly 2021

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The effect of differing drought-heat signatures on terrestrial carbon dynamics and vegetation composition

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Droughts and heatwaves have large impacts on the terrestrial carbon cycle. They lead to reductions in gross and net carbon uptake or anomalous carbon emissions by the vegetation to the atmosphere because of responses such as stomatal closure, hydraulic failure and vegetation mortality. The impacts are particularly strong when drought and heat occur at the same time. Climate model simulations diverge in their occurrence frequency of compound hot and dry events, and so far it is unclear how these differences affect carbon dynamics. Furthermore, it is unknown whether a higher frequency of droughts and heatwaves leads to long-term changes in carbon dynamics, and how such an increase might affect vegetation composition.

To study the immediate and long-term effects of varying signatures of droughts and heatwaves on carbon dynamics and vegetation composition, we employ the state-of-the-art dynamic global vegetation model LPX-Bern (v1.4) under different drought-heat scenarios. We constructed six 100-yr long scenarios with different drought-heat signatures: a “control”, “no extremes”, “no compound extremes”, “heat only”, “drought only”, and “compound drought and heat” scenario. This was done by sampling daily climate variables from a 2000-year stationary simulation of a General Circulation Model (EC-Earth) for present-day climate conditions. Such a sampling ensures physically-consistent co-variability between climate variables in the climate forcing.

The scenarios differ little in their mean climate conditions (global mean land temperature differences of around 0.3°C and global mean land precipitation differences smaller than 7%), but vary strongly in the occurrence frequency of extremes such as droughts, heatwaves, and compound drought and heatwaves (up to five times more compound extremes in the “hotdry” scenario than in the “control”), allowing us to study the effects of the extremes on vegetation. Combined hot and dry extremes reduce all tree types and promotes grassland, while only hot extremes favours trees, especially in higher latitudes. No extremes are preferred by all tree types in LPX. Net Ecosystem Production (NEP) is expected to increase in most regions for the “noextremes” scenario, while the “hotdry” scenario is likely to reduce NEP.

Our results provide a better understanding of the links between hot and dry conditions and

vegetation dynamics as well as carbon dynamics. These analyses may help to reduce uncertainties in carbon cycle projections, which is important for constraining carbon cycle-climate feedbacks. The presented scenarios can be used for a variety of purposes such as studying the effects of differing drought-heat signatures on crop yield or the occurrence of fire besides others.