Geophysical Research Abstracts
Vol. 21, EGU2019-10004-1, 2019
EGU General Assembly 2019

Ecosystem responses to rainfall manipulation experiments: A novel model-data intercomparison

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Terrestrial carbon dynamics are very sensitive to variations in precipitation. Water limitation to vegetation productivity has been attributed as the main source of variability of the global carbon sink. Plant water stress is highly dependent on precipitation amount and frequency, both of which are expected to change according to the latest climate change projections. For this reason, being able to robustly simulate the sensitivity of plant productivity to changes in precipitation, is crucial.

In this study we present the results of a new model-data intercomparison project. In this project eleven terrestrial biosphere models were evaluated in reproducing water and carbon dynamics at 10 sites worldwide where either rainfall exclusion, irrigation, or both treatments were applied. The sites included the LTER tallgrass Konza Prairie (KS, USA) and shortgrass steppe (CO, USA), two semi-arid sites in Israel (Lahav, Matta) primarily vegetated by annuals and shrubs, a mesic grassland (Stubai Valley, Austria), a mesic heathland (Brandbjerg, Denmark), a broadleaf deciduous temperate forest (Walker Branch, MO, USA), two Mediterranean forests (Puechabon, France; Prades, Spain), and a Mediterranean shrubland (Garraf, Spain).

Overall the models were able to robustly reproduce the relation between precipitation amount and productivity between sites (i.e. spatial dependence) but diverged on their estimates within sites (i.e. temporal dependence). Most models were able to correctly simulate the overall size effect of productivity reduction/enhancement due to rainfall exclusion/irrigation but had low skill in reproducing the observed interannual variability of net primary productivity. The largest fraction of the model divergence was attributed to the functional form of the water stress factor which exceeded model disagreement related to changes in phenology and carbon allocation. Finally, uncertainties related to the short duration of most experiments, measurement limitations, and the conversion of harvested biomass (i.e carbon stock) to net primary productivity (i.e. carbon flux) could mask key signals related to long term carbon dynamics, highlighting the need of more long term high quality data and the importance of comparing models across each other.