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Effects of climate variability and extreme events on components of the carbon balance in Europe during 1961-2100

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Regional climate models project a change in the annual and seasonal mean of meteorological variables in Europe until the end of the century, e. g. mean air temperature is predicted to dramatically increase until 2100. At the same time, the shape of the probability distribution of meteorological variables will change, leading to an altered variability of meteorological variables and frequency of extreme events. Today, the isolated effects of changing variance versus changing mean of meteorological drivers on ecosystem processes, such as gross primary production, autotrophic and heterotrophic respiration, evapotranspiration, mortality and disturbances have not been quantified at a continental or global scale. We contribute to such quantification from a theoretical, mechanistic modelling point of view by artificial modelling experiments using state-of-the-art generic (LPJmL, ORCHIDEE, JSBACH, CLM) and sectorial (BASFOR, DailyDayCent, PASIM) ecosystem models that has been performed in the EU FP7 project CARBO-Extreme.

Using a control climate data set (CNTL) based on the WATCH forcing data and bias-corrected ECMWF ERA-Interim reanalysis data, factorial model experiments with transient/constant climate and atmospheric [CO_2] concentration have been performed.Then, these factorial experiments were repeated using a climate dataset in which climate variables hold the same long-term seasonal and annual mean but show much reduced short-term variability (“reduced variability”).

Analysis of the resulting carbon and water balance estimations for Europe during 1961-2100 enabled disentangling direct effects of temperature or radiation variability from effects of general climate variability and effects of a trend in mean climate conditions on ecosystem functions.

Generally, reduced variability in short-wave radiation increased the annual gross primary production due to the concave shape of the light response curve of photosynthesis. Therefore, net primary production is also increasing with reduced variability. At the same time, reduced temperature variability reduces respiration components because the mean of two respiration rates at extreme high and low temperature is lower than the respiration rate at the mean temperature due to the convex shape of the respiration response to temperature. However, effects are varying over the continent along different climatic zones and ecosystem types. In addition, combined effects of variability of all meteorological variables, and in particular precipitation variability effects lead to more diverse net effects on the European carbon and water balance. These experiments help to understand the impact of climatic variability on ecosystem responses.