Geophysical Research Abstracts
Vol. 17, EGU2015-5362, 2015
EGU General Assembly 2015

Modelling the climatic drivers determining secondary growth in Mediterranean forests using a process-based model and multiproxy data

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Different physiological processes determine gross primary productivity (GPP) and carbon allocation in relation to environmental forcing. Climatic variability limits these two processes differently and this needs to be properly addressed in process-based forest models. Generally, empirical models have been preferentially used in dendrochronological studies. However, it is necessary to better address the interaction between climate and other factors such as CO_2 to properly assess the instability in the climate-growth response expressed by trees and increase the accuracy of the modelled relationships both in forward and inverse models. In this study we evolved an existing mechanistic model originally developed with dendrochronological data. The model was calibrated to fit a combination of eddy covariance CO_2 flux data, dendrochronological time series of secondary growth and forest inventory data at two Mediterranean evergreen forests. Among other differences with the original formulation, the model was modified to be climate explicit in the key processes addressing acclimation of photosynthesis and allocation. It succeeded to fit both the high- and the low-frequency response of stand GPP and carbon allocation to the stem as calculated from tree-rings. Simulations suggest a decrease in mean stomatal conductance in response to environmental changes and an increase in mean annual intrinsic water use efficiency in both species during the last 50 years. However, this was not translated on a parallel simulated increase in ecosystem water use efficiency. A long-term decrease in annual GPP matched the local trend in precipitation since the 1970s observed in one site. In contrast, GPP did not show a negative trend and the trees buffered the climatic variability observed at the site where long-term precipitation remained stable. Long-term trends in GPP did not match those in growth, in agreement with the C-sink hypothesis. There is a great potential to use the model with abundant dendrochronological data to analyse forest performance under climate change and in dendroclimatic reconstructions. This would help to understand how different interfering environmental factors produce divergence in the climatic signal expressed in tree-rings.