EGU21-4609
https://doi.org/10.5194/egusphere-egu21-4609
EGU General Assembly 2021


# Anomalies in vegetation activity in the early growing season determine the climate-vegetation coupling in Europe

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Recent accelerating global warming with increasing climate variability exerts a strong impact on terrestrial carbon budgets, but the ecosystem response to the changing climate and the overall climate-vegetation coupling remain largely unclear during different stages of the growing season. The timing of growing seasons can be modulated by different environmental conditions (e.g., thermal and hydrological changes) and affect the overall interpretation of regional climate-vegetation coupling. Here, we analyse the climate-vegetation coupling for Europe during 1982–2014 using a grid-wise definition of the growing season period based on remote sensing data. We quantify sub-seasonal anomalies of vegetation greenness from long-term vegetation indices (Normalized Difference Vegetation Index and two-band Enhanced Vegetation Index), and their relationships with corresponding local growing conditions (2m temperature, downwards surface solar radiation and root-zone soil moisture); and with multiple climate variability indices that reflect the large-scale climatic conditions over Europe. We find that early growing season anomalies in vegetation greenness tend to be large during the first two months of the growing season and that the coupling of these anomalies with large-scale climate largely determines the full-year climate-vegetation coupling. The North Atlantic Oscillation (NAO) and Scandinavian Pattern (SCA) phases evaluated one to two months before the start of growing season are the dominant drivers of the early growing season climate-vegetation coupling over large parts of boreal and temperate Europe. However, the sign of the effect of these indices on vegetation greenness is opposite. The East Atlantic Pattern (EA) evaluated several months in advance of the growing season is instead a main controlling factor on the temperate belt and the Mediterranean region. These findings highlight the importance of accounting for the spatial heterogeneity of growing season periods using location-specific definitions when studying large-scale land-atmosphere interactions.