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Global two-way interactions between climate and vegetation over multiple time scales

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Climate affects the global distribution and growth of vegetation, while vegetation dynamics in turn also affect the climatic environment. Apart from being bi-directional, these interactions are often complex and lagged in time. Unravelling these complex interactions is crucial to understand the progress of climate and the state terrestrial ecosystems as we move into the future. A better representation of these interactions can help improve the reliability of the next generation of climate models. However, a first and necessary step involves benchmarking climate model performance against observations. In this presentation, remotely-sensed observations of multiple climatic variables (near surface air temperature, net radiation, and precipitation) and vegetation leaf area index (LAI) will be analysed using Conditional Spectral Granger Causality (CSGC) to reveal the sensitivity of global ecosystem dynamics to different climatic factors, and vice versa. This observational study will allow for the creation of a benchmark that facilitates evaluating the skill of current CMIP5 climate models. Compared to more traditional causal inference techniques (such as e.g. regression analyses or standard Granger Causality), CSGC allows for an evaluation of the scale-by-scale interaction between climate and vegetation, from e.g., monthly to decadal time scales. Moreover, it provides a means to disentangle the impact of climate on ecosystems from the overall feedback of ecosystems on climate.

Results confirm the expectations that monthly variations in LAI are driven by radiation dynamics in high northern latitudes, while water availability is the main limiting factor in the subtropics. Dynamics of tropical forests are driven by a combination of temperature and radiation. At seasonal scales, air temperature is more relevant for global ecosystems, becoming crucial at explaining subtropical seasonal phenology. At inter-annual scales, the role of water availability becomes overall more dominant. Climate models are capable of reproducing the radiation control in high latitudes, but tend to overestimate the influence of air temperature in subtropical regions. Regarding the local feedback of global ecosystems on climate, the strongest monthly feedbacks of LAI are observed for net radiation, which can be explained by changes in albedo. However, feedbacks on air temperature are important over seasonal scales, and reflect the expected warming effect of increasing vegetation density in boreal regions and the cooling effect in tropical forests. Inconsistencies among the different CMIP5 models suggest a wide range of model skills at reproducing vegetation-climate interactions.