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Contrasting biosphere response to climate extremes: revisiting the western Russian Heatwave 2010 and other events.

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Combined droughts and heatwaves are among those compound extreme events that are expected to have the most severe impacts on society and the terrestrial biosphere. One prominent, record breaking and well studied compound event of this kind is the western Russian Heatwave 2010 (RHW). The spatiotemporal dynamics of this event cannot be well explained by investigating specific variables like air temperature, water stress, or some vegetation index. In fact, ignoring the multidimensional dynamic of this event obstructs a comprehensive evaluation of the impacts on land surface dynamics.

In this study we use a recently proposed workflow to detect and quantify multivariate extreme event detection by using kernel density estimators in feature space in tandem with a spatiotemporal event delineation. We applied this method to two sets of variables describing the atmosphere (temperature, radiation, precipitation, relative humidity, surface moisture) and biosphere (gross primary productivity, latent heat flux, sensible heat flux, fraction of absorbed photosynthetic active radiation).

We show that the impact of atmospheric extreme events on the terrestrial biosphere strongly depends on the timing, duration, ecosystem type, and affected variables of the atmospheric compound event. In the case of the Russian Heatwave, an increased forest ecosystems primary production at higher latitudes compensates for 54% (36% in spring, 18% in summer) of the carbon losses of agricultural dominated ecosystems in the lower latitudes that are strongly impacted by the RHW. These findings are consistent among different data sets and translate into several other biosphere variables. By extending the case study to a global scale, we show that positive responses of forest dominated ecosystems to heatwaves and droughts are much more frequent than expected, and that forests are very likely partly compensating for carbon losses of other ecosystems through efficient water management and access to deeper water.

Our study suggests that an ecosystem specific and multivariate perspective on extreme events reveals more facets of extreme events, as it is agnostic of the direction of the impacts and allows for considering spatiotemporal compensation effects. For future studies it is important to overcome the focus on negative impacts of the extreme events ('hazards') to fully characterize the effects of extreme events including possible compensatory effects.