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Moisture and heat advection as drivers of global ecosystem productivity

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Terrestrial ecosystems play a key role in climate by dampening the increasing atmospheric CO_2 concentrations primarily caused by anthropogenic fossil fuel emissions. The capability of the land biosphere to act as a carbon sink largely depends on climate conditions, which determine the energy and water availability required by plants to grow. Even though only a small part of the global land area is covered by vegetation, the impact of extreme dry and wet seasons has been shown to largely drive the global interannual variability of gross primary production. The climate in a certain area can be seen as the balance of different heat and moisture fluxes: local surface–atmosphere fluxes from below, entrainment of heat and moisture from aloft, and 'horizontal' advection of heat and moisture from upwind regions. The latter provides a mechanism for remote regions to impact gross primary production downwind, and has received less scientific attention. Here, advection is inferred from a bird's eye perspective, focussing on the five ecoregions with the largest interannual variability in peak productivity around the globe. Employing the atmospheric Lagrangian trajectory model FLEXPART, driven by ERA-Interim reanalysis data, we track the air residing over ecoregions back in time to deduce the origins of heat and moisture that affect ecosystem gross primary production. Utilizing the evaporative source regions supplying water for precipitation to these ecosystems, as well as the analogous source regions of advected heat, we estimate the contribution of advection to gross primary production. Our findings show that source regions of heat and moisture are not congruent: upwind land surfaces typically supply most of the advected heat, whereas upwind oceans tend to provide more moisture. Moreover, low gross primary production in heat-stressed and water-limited ecosystems is often accompanied by enhanced heat and reduced moisture advection from land regions, exacerbated by upwind land–atmosphere feedbacks. These results demonstrate that anomalies in atmospheric advection can cause ecosystem productivity extremes. Particularly in light of ongoing climate change, we emphasize the potentially detrimental effects of upwind areas that may cause long-lasting impacts on the terrestrial carbon budget, thereby further affecting the climate.