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Future land use influences on the global monsoon: An energetic perspective

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Understanding the impact of future land use changes on the global monsoon system is crucial for the economy, water supply and food security. Here, we use future deforestation and afforestation simulations under different SSP scenarios from 10 CMIP6 models participating in the Land Use Model Intercomparison Project (LUMIP). We apply an energy flux potential (EFP) framework to connect shifts in the Intertropical Convergence Zone and regional monsoons to changes in the atmospheric energy transport, and examine the contribution from individual flux components (latent heat flux, sensible heat flux, shortwave and longwave radiation). The linearity of this method allows us to attribute atmospheric EFP changes to different land and ocean regions without the need for additional simulations.

We find consistent zonal-mean precipitation shifts over oceanic regions across models in the deforestation and afforestation scenarios. However, changes in the global monsoon (as represented by zonal-mean precipitation changes over land) show large model dependence. The energy flux analysis reveals a consistent mechanism across models: The surface latent heat flux is the dominant driver of land use-induced changes in EFP in the tropics. In most regions and models, an increase in the latent heat flux component of EFP corresponds to tropical precipitation decrease and vice versa.

Our regional analysis reveals that remote oceanic energy-budget anomalies are the main contributor to the global EFP patterns and monsoon precipitation anomalies for all models, while land energy-budget anomalies modulate both patterns over land. Decomposing the EFP pattern into the contribution from different land regions indicates model consensus regarding the strong contribution from North and South America to the land-only anomaly, while inter-model differences primarily stem from different model responses to African land use change. These findings highlight the complexity of rainfall shifts to future land use change scenarios and also emphasize the value of the energy flux potential method to quantitatively link remote forcing to regional rainfall changes.