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Global terrestrial moisture recycling in Shared Socioeconomic Pathways

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The global water cycle has undergone considerable changes since pre-industrial times due to global climate change and land-use changes. These drivers will almost certainly continue to change during the course of this century. However, where, how, and to which extent terrestrial moisture recycling will change as a result remains unclear.

Mutually consistent scenarios of climate change and land-use changes for the 21st century are provided by the Shared Socioeconomic Pathways (SSPs). The SSPs provide a framework of five different narratives involving varying degrees of challenges associated with mitigation or adaptation. From each narrative follow different implications for emissions, energy, and land use. The SSPs serve as the conceptual framework behind the sixth generation of the Coupled Model Intercomparison Project, CMIP6.

Terrestrial moisture recycling is often assessed using atmospheric moisture tracking models. An example is UTrack, a Lagrangian model to track moisture through three-dimensional space. Here we present a new forward-tracking version of UTrack that is forced by output of a CMIP6 model to study how terrestrial moisture recycling may change across the globe until the end of the 21st century in a range of SSPs, from mild to severe: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. For this forcing, we chose the Norwegian Earth System Model version 2, or NorESM2. It has a temporal resolution of one day and a spatial resolution of 1.25° × 0.9375° at eight pressure levels.

We find that across the 21st century, the global terrestrial moisture recycling ratio decreases with the severity of the Shared Socioeconomic Pathways (SSPs). We calculate a decrease in global terrestrial precipitation recycling by 2.1% with every degree of global warming. Because the SSPs represent internally consistent scenarios of both global warming and global land cover changes, it is hard to distinguish the relative contributions of these two, but the evidence points at a major influence of global warming on moisture recycling.

We find spatial differences in trends in recycling ratios, but which are broadly consistent among SSPs. If a change in precipitation (either drying or wetting) coincides with an increase in terrestrial precipitation recycling ratio, we call it land-dominated. We call the change in precipitation ocean-dominated if it coincides with a decrease in terrestrial precipitation recycling ratio. Land dominance tends to occur in regions with already large terrestrial precipitation recycling ratios, mainly interior South America (land-dominated drying) and eastern Asia (land-dominated wetting). Land-dominated drying may also happen in eastern Europe, in central America and in subtropical sub-Saharan Africa. Ocean-dominance, mainly in the form of wetting, is found primarily in the high northern latitudes and in central Africa.

We also simulated the changes in basin recycling for the 27 major river basins of the world, confirming the overall tendency of decreasing recycling with severity of the SSP, as well as its spatial variations.