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Reconciling bilateral connections of atmospheric moisture within the hydrological cycle

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To improve our understanding of how we are connected globally through water flows, at scales relevant to policy and management, is imperative for global water stewardship. It is therefore crucial to describe the fate of moisture in the atmosphere by evaluating the global moisture inter-dependencies at the country level. However, few studies have addressed global moisture inter-dependencies at the country level.

In this study, we present a novel dataset of country-to-country atmospheric moisture flows, including both terrestrial and oceanic sources, and propose an approach to assure the closure of the global and country-scale atmospheric water balance. By adopting an analogy with international trade analysis, we employ an iterative proportional fitting method to adjust the bilateral exchanges of water vapor from sources to sinks, ensuring that the total imported (exported) atmospheric moisture equals the total precipitation (evaporation) derived from ERA5 on an annual basis.

Relevant analysis to understand water inter-dependencies between countries and regions can be performed from the bilateral matrix we present. We assess the terrestrial moisture recycling ratio (TMR) as the portion of countries' or regions' precipitation originating from terrestrial evaporation. Furthermore, we estimate a global TMR of 36%, while we find the highest TMRs are those of Eastern Asia (64%), Eastern Europe (68%), and Central Africa (79%). The bilateral structure of the dataset allows also to shed light on key links (and relative weights) dominating the exchange of atmospheric moisture between two countries or regions, thus supporting inter-countries water governance. For example, Central Africa receives 80% of its terrestrially sourced precipitation from Eastern Africa, while Eastern Europe evenly gets moisture from four distinct links, Eastern Asia, Central Asia, Southern Europe and Northern Europe, covering 70% of its import from terrestrial sources.

Future studies can leverage the dataset to explore nations' links in the global atmospheric moisture flow network and assess their role in the global hydrological cycle.