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The relationship between atmospheric heat transport and monsoonal precipitation variability

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During the boreal summer monsoon, the temperature gradient between land and ocean in the Northern Hemisphere (NH) facilitates large transports of moist air masses towards the land regions, where their convergence causes precipitation. This is associated with an export of net energy (internal, potential, and latent energy) away from the land. On a global scale, there is a tight relationship between the location of the intertropical convergence zone (ITCZ) and the cross-equatorial atmospheric heat transport (AHT) on seasonal, interannual and climate time scales: a more northward cross-equatorial AHT is associated with a displacement of the ITCZ (as defined by precipitation) toward the equator. We further analyse the relationships between cross-equatorial AHT and common streamfunction-based measures of the ITCZ position and width found in the literature. However, it remains unclear whether links between energy transport and the monsoonal precipitation exist at the scale of monsoon regions.

To address this question, we combine data from the European Centre for Medium-Range Weather Forecast (ECMWF) reanalysis ERA5 and Global Precipitation Climatology Project (GPCP-version 2.3) rainfall data. In the annual cycle, the cross-equatorial northward AHT transport peaks in July and the annual net northward cross-equatorial AHT is -0.34 PW (negative sign denotes southward). A regression analysis confirms that the global ITCZ shifts southward when the cross-equatorial AHT is anomalously large, although we demonstrate this mainly happens over the Pacific Ocean. Outside of the Pacific sector, the relationship between cross-equatorial AHT and JJA precipitation is complex. For the West African monsoon region, greater northward cross-equatorial AHT is related to weaker rainfall along the Gulf of Guinea coast, while there is stronger rainfall in the Atlantic Ocean ITCZ. In the Indian sector, anomalous northward AHT is associated with a weak monsoon, marked by strong decreases in precipitation on the Western coast of India and the southern flank of the Himalayas.

In future work, the CMIP6 multi-model dataset will be analysed to examine future projection of AHT and its impact on monsoonal precipitation. The characteristics of the ITCZ will be explored using the same datasets.