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The role of water vapor and cloud radiative effects in monsoons: Perspectives from retrograde Earth simulation

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In a retrograde Earth simulation using the fully coupled MPI-ESM, we find that the climate in the Sahara goes from arid to monsoonal. By understanding this transition of the Sahara, we can gain insights into some of the key processes necessary for the existence of monsoons. We find that theories of monsoons based on land-sea thermal contrast and meridional shifts in the interhemispheric convergence zone (ITCZ) are not adequate to explain this change in the climate of the Sahara. Hence, we use the energetics of monsoons, which is based on local moist static energy and moisture budgets. In the regular forward-rotating Earth, the net energy input into the atmospheric column (NEI) is negative over the Sahara, implying a net energy import over the region. The reversed winds in the retrograde simulation advect moisture from the Arabian Sea and the equatorial Atlantic into the Sahara during the boreal summer. The greenhouse effect of water vapor instantaneously reduces the outgoing longwave radiation, thereby increasing the NEI. As NEI becomes positive, the Sahara exports energy, increasing convection (and, hence, monsoon precipitation). The increased cloud cover further enhances NEI through cloud radiative feedback, strengthening the monsoon. Therefore, we conclude that the radiative effects of water vapor and clouds are an essential ingredient for monsoons.