A Wall-like Sharp Downward Branch of the Walker Circulation above the Western Indian Ocean

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Abstract

In the zonal direction, the downward branch of the Walker circulation above the Indian Ocean is only 20 degrees wide, whereas the Pacific counterpart is 90 degrees wide. This zonal sharpness is notable because atmospheric disturbances smaller than the planetary scale, such as the Asian Summer Monsoon, can interact with the planetary-scale Walker circulation through this branch. As a moist circulation, this zonal sharpness is imprinted on a unique zonal discontinuity of the tropical rain belt above Northeast Africa. Therefore, in this study, we refer to this narrow downward branch as the "Wall", investigate its climatology and interannual variability, and aim at determining its reason for existence. The strongest season of the lower tropospheric Wall in boreal summer is sustained by horizontal cold advection associated with the Asian Summer Monsoon. Two weak phases of the Wall correspond to two rainy seasons at the Eastern Horn of Africa, which are not reproduced well by state-of-the-art global climate models. As for interannual variability, one standard deviation change of a strength of the downward motion at the Wall is associated with about one degree of sea surface temperature variation in the tropical Pacific, and the regression and correlation coefficients are highest in boreal autumn. Nevertheless, total variance is explained more by local sea surface temperature. Experiments using a convection-permitting atmospheric model show that vertical mixing forced by mountain waves in East Africa are necessary for sustaining the Wall. After flattening the East African topography, zonal discontinuity of the tropical rain belt disappears.