



## **Long-term variation of the principal mode of boreal spring Hadley circulation linked to SST over the Indo-Pacific warm pool**

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The variability of the boreal spring (March to May, MAM) Hadley circulation (HC) is investigated, focusing on the long term variation of the first principal mode for 1951–2008, which is an equatorially asymmetric mode (AM) with the rising branch located around 10S. This mode explains  $\sim 70\%$  variance of the MAM HC and shows an obvious upward trend, and thus contributes to the strengthening of the MAM HC. The robust warming trends of sea surface temperature (SST) over the Indo–Pacific warm pool (IPWP) play an essential role in the variations of the MAM HC. When SST over the IPWP is warm, anomalous meridional circulation is induced with descending branches located in regions 30–20S and 5–15N in each hemisphere and rising located near 10S. The anomalous rising south of the equator is due to the inhomogeneous warming of SST over the IPWP. SST within the IPWP in the Southern Hemisphere shows a larger warming trend than that in the Northern Hemisphere. The position of the anomalous convergence associated with SST variations over the IPWP is aligned with the maximum meridional gradient of zonal mean SST, resulting in an equatorially asymmetric meridional circulation. This point is further established in theoretical analyses. However, the meridional SST gradient within IPWP shows a decreasing trend, suggesting the associated anomalous meridional circulation intensifies, which in turn explains the strengthening of the MAM HC. Under this scenario, the accompanied descent in the regions of 30–20S and 5–15N is enhanced, implying a frequent drought in these regions during MAM.