



## **On the dominant intra-seasonal modes over the East Asia-western North Pacific summer monsoon region**

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Intra-seasonal monsoon prediction is the most imperative task due to high impact on 2/3 of world populations' daily life, but there remains an enduring challenge in climate science. The present study aims to provide a physical understanding of the sources for prediction of dominant intra-seasonal modes in the East Asian-western North Pacific summer monsoon (EA-WNPSM): preMeiyu&Baiu, Changma&Meiyu, WNPSM, and monsoon gyre modes classified by the self-organizing map analysis. The major modes tend to be dominated by the moisture convergence of the moisture budget equation along the rain-band. The preMeiyu–Baiu mode is strongly linked to both the anomalous low-level convergence and vertical wind shear through baroclinic instability, and the Changma&Meiyu mode has a strengthened tropic–subtropics connection along the western north Pacific subtropical high, which induces vertical destabilization and strong convective instability. The WNPSM and monsoon gyre modes are characterized by anomalous southeasterly flow of warm and moist air from western north Pacific monsoon, and low-level easterly flow, respectively. Prominent difference in response to the ENSO leads to different effects of the Indian Ocean and western Pacific thermal state, and consequently, the distinct moisture supply and instability variations for the EASM intra-seasonal modes. We discuss the major driving forces of sub-seasonal variability over EA-WNPSM regions. Lastly we attempted to determine the predictability sources for the four modes in the EA-WNPSM. The selected predictors are based on the persistent and tendency signals of the SST/2m air temperature and sea level pressure fields, which reflect the asymmetric response to the ENSO and the ocean and land surface anomalous conditions. For the preMeiyu&Baiu mode, the SST cooling tendency over the WNP, which persists into summer, is the distinguishing contributor that results in strong baroclinic instability. A major precursor for the Changma&Meiyu mode is related to the WNP subtropical high, induced by the persistent SST difference between the Indian Ocean and the western Pacific. The WNPSM mode is mostly affected by the Pacific-Japan pattern, and monsoon gyre mode is primarily associated with a persistent SST cooling over the tropical Indian Ocean by the preceding ENSO signal. This study carries important implications for prediction by establishing valuable precursors of the four modes including nonlinear characteristics.