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Dynamic study of extreme climate events based on the three-pattern decomposition of global atmospheric circulation

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In recent years, the eastern China and even the whole northern hemisphere have suffered from frequent extreme climate events in summer. For example, the extremely hot summer of 2018 over East Asia, the abnormal precipitation in eastern China in the midsummer of 2021, and the high summer temperature in the Northern hemisphere in 2022 August. These extreme climate events have brought severe challenges to human life, economic development and ecological environment. Revealing the physical mechanism of such events is of great significance for disaster prevention and mitigation and policy making.

In fact, atmospheric circulation anomalies play an important role in regulating extreme climate events on a regional scale. However, the existing research mainly focus on the influence of the horizontal vortex circulations processes such as blocking and wave train, but the effects of local vertical circulations, especially the interaction between the local vertical and horizontal circulations, are still lacking. To explore a dynamic approach that considers the actual atmospheric circulation as a whole, Hu et al. (2017,2018a, 2018b, 2020) proposed a novel method called the three-pattern decomposition of global atmospheric circulation (3P-DGAC). Unlike the traditional two-dimensional decomposition method, which ignores the effects of the horizontal motion of low-latitudes and the vertical motion of mid-high latitudes, this method considers the effects of mid-high latitude divergent circulation and low latitude vortex circulation on the actual atmospheric circulation, which is conducive to the study of the dynamics of the actual atmospheric circulation from the global perspective. Specifically, the 3P-DGAC extends Rossby wave at mid-latitudes, Hadley circulation and Walker circulation at low latitudes to the global scale, and argues that the actual atmospheric circulation can be understood as the sum of the superposition of the horizontal vortex circulation, the meridional and zonal circulation. Thus, the 3P-DGAC provides a suitable tool for studying the dynamics of three-dimensional structure of local atmospheric circulation.

Using the 3P-DGAC method, we have studied the dynamics of the extreme climate events that have occurred in recent years and revealed the corresponding physical mechanisms, the findings suggest that local vertical circulations play a non-negligible role in extreme climate events. This study is expected to provide a reliable theoretical reference for the prediction of extreme climate events.