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Planetary and synoptic-scale dynamic control of extreme cold wave patterns over the United States

Zuowei Xie[1], Robert Black[2], and Yi Deng[2]
[1]Institute of Atmospheric Physics, Chinese Academy Sciences, Beijing 100029, China
[2]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta 30332, GA, USA

The roles of planetary and synoptic-scale waves in extreme cold wave (ECW) events over the southeastern (SE) and northwestern (NW) United States (US) are studied using a spherical harmonic decomposition in conjunction with piecewise tendency diagnosis (PTD). Planetary waves and synoptic waves jointly work together to initiate ECW events. Notably, the planetary waves not only provide a direct contribution to circulation field enacting ECW events but also alter the background circulation field in such a manner that promotes synoptic waves growth via increases in regional barotropic deformation. The SE-ECW events, concurrent with the Northern Hemisphere annular mode (NAM) negative phase, feature high latitude intensification and subsequent southeastward movement of cold surface air temperature (SAT) anomalies. The planetary-scale pattern provides a sizable contribution to the total wave pattern on both sea level pressure (SLP) and upper level. Moreover, the negative NAM planetary anomaly acts to displace the jet equatorward and thereby increases the barotropic deformation of the synoptic-scale anomaly over southeastern US. PTD confirms that the planetary-scale barotropic deformation plays a key role in deepening the negative height anomaly with a secondary contribution from baroclinic growth. In contrast, NW-ECW events feature a regional SAT cold anomaly that intensified in situ in association with a quasi-stationary positive SLP anomaly with a substantial planetary-scale wave component. The upper level circulation is characterized by a pronounced anomalous ridge over the Gulf of Alaska and a northeast-southwest tilted negative height anomaly to its east. The negative height anomaly axis is orthogonal to the planetary-scale dilatation, result in a stronger planetary barotropic deformation of the incipient negative height anomaly.