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Climatology and Structures of Southwest Vortices in NCEP Climate Forecast System Reanalysis

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A southwest vortex (SWV) refers to the meso-α-scale cyclonic low-pressure system originating in southwest China, as a result of interactions of large-scale circulations and the specific multi-scale topography, such as the Tibetan Plateau, Hengduan Mountain and Sichuan Basin. It is a high-impact precipitation-generating weather system in southwestern China, in the Yangtze River valley and even in north China. This paper reports on a systematic investigation of its climatological and structural characteristics over the 32-yr period of 1979-2010 using the high-resolution NCEP Climate Forecast System Reanalysis data. The present study has the several unique features. First, the new generation reanalysis product possesses high spatial and temporal resolution, arguably being more suitable for mesoscale vortex studies as compared to the preceding reanalysis datasets and moreover enabling an examination of the diurnal behavior. Second, our 32-yr statistics are capable of producing a robust representation of the SWV climatology. Third, the application of an objective identification methodology avoids some subjective ambiguities in the manual approach that has exclusively been adopted before. Lastly, a systematic exploration of thermodynamic and kinematic structures is conducted, unlike the previous exclusive heavy-rain-generating case studies. Our major findings are summarized as follows.

The SWV is a common regional weather system with an annual count of $\sim$73. Two primary source regions are identified, located in the Sichuan Basin and southeast flank of the Tibetan Plateau, respectively. The genesis displays striking seasonality, characteristic of a spring-summer (March-August) preference with a peak in May. Remarkable diurnal variations are present, with two active periods around 07 and 19 Local Time. There exist prominent regional disparities in both the seasonal and diurnal variability though. A large portion of the vortices travel a rather limited distance due partially to their short persistence. The average duration time, horizontal dimension (effective diameter), and translation speed are 15.1 h, 435 km, and 8.6 m s-1, respectively.

The SWV structures show regional and seasonal contrasts. The winter-spring elevated dry vortex in the basin is vertically confined to a shallow layer between 850-600 hPa and tilts northeastward. The low level has a cold center, and the mid-upper levels feature apparent baroclinicity. The nighttime warm-season precipitating vortex system in the basin has a deep structure with the cyclonic vorticity extending from the surface into the upper-troposphere. The non-severe precipitating vortex is weakly baroclinic and tilts northward with height, whereas the severe precipitating vortex is vertically aligned. In the southern mountainous region, the shallow surface-based vortex develops in a well-mixed planetary boundary layer during the evening-early-night time and exhibits vertical tilting toward the elevated upslope and a warm and low-humidity core. When attendant with precipitation, the mountainous system is large, deep and nearly upright at most levels with a fairly barotropic environment.