Variation Characteristics of Drought in Southwest China and Its Relationship with Atmospheric Circulation (Postprint)

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Abstract

Using observational data of daily precipitation and daily mean temperature from 90 surface meteorological stations in Southwest China (Sichuan, Guizhou, Yunnan, and Chongqing) for the period 1962–2017 (October to May of the following year), the cumulative drought days and frequency in Southwest China were calculated using the Composite Meteorological Drought Index WTBX[WTBZ], and their spatiotemporal variation characteristics over the past 56 years were analyzed, followed by selecting high- and low-value years to discuss atmospheric circulation patterns; finally, difference maps (all high-value years minus low-value years) were produced and compared with correlation field constructed maps. The results indicate that: both cumulative drought days and frequency show a gradually decreasing trend; the decadal anomalies of both were positive during the 1960s–1980s, negative during the 1990s, and opposite to each other in the early 21st century; cumulative drought days exhibit interannual periodicities of 5 and 9 years, and an interdecadal periodicity of 12 years; drought frequency has an interannual periodicity of approximately 8 years and an interdecadal periodicity of 20 years; both have high-value centers in western Sichuan and north-central Yunnan, and low-value centers in western Yunnan, Chongqing, and east-central Guizhou; the upper-, middle-, and lower-level circulation patterns also lack the necessary configurations such as water vapor and systematic lifting.

Full Text

Drought Variation Characteristics and Its Relationship with Atmospheric Circulation in Southwest China

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Abstract: Based on daily precipitation and daily average temperature data from 90 meteorological stations in Southwest China (Sichuan, Yunnan, Guizhou provinces and Chongqing municipality) during 1962–2017, this study calculates cumulative drought days and drought frequency using the meteorological drought composite index (CI). Wavelet analysis and linear trend methods are employed to analyze the temporal and spatial variation characteristics of drought over the 56-year period. Furthermore, correlation and composite analysis are used to investigate the atmospheric circulation patterns in years with anomalously high and low drought values. The results indicate: (1) The overall trend of cumulative drought days and frequency shows a gradual decrease, with positive correlation between the two anomalies from the 1960s to 1980s, negative correlation in the 1990s, and positive correlation again at the beginning of the 21st century. (2) The drought duration (cumulative dry days) exhibits inter-annual variation periods of 5 years and 9 years, and decadal variation of 12 years. Drought frequency shows an inter-annual period of 8 years and decadal variation of 20 years. (3) Both duration and frequency share common high-value centers in western Sichuan and central-northern Yunnan, and common low-value centers in western Yunnan, central-eastern Guizhou, and Chongqing. (4) Circulation analysis reveals that precipitation deficits in the region are associated with disadvantageous water vapor conditions and weak upward dynamics across high, middle, and low-level atmospheric circulation.

Keywords: meteorological drought composite index (CI); temporal and spatial distribution; atmospheric circulation

2 Data and Methods

2.1 Data Sources and Processing

The study utilizes daily precipitation and temperature data from 90 meteorological stations in Southwest China spanning 1962–2017. The NCEP/NCAR reanalysis dataset with 2.5°×2.5° horizontal resolution is employed for atmospheric circulation analysis. The meteorological drought composite index (CI) is calculated as:

$$CI = 0.4Z_{30} + 0.4Z_{90} + 0.8M_{30}$$

where Z_{30} and Z_{90} represent the standardized precipitation index (SPI) for 30-day and 90-day periods, respectively, and M_{30} denotes the 30-day relative moisture index. Drought events are identified following the national standard GB/T 20481−2006, with CI values -0.6 indicating drought conditions.

3 Results

3.1 Temporal Variation Characteristics

The cumulative drought days show significant inter-decadal variability [Figure 2: see original paper]. The linear trend slope is -0.26 days per year, indicating a gradual decreasing trend. Notable drought years include 1963, 1969, and 1979, with the most severe drought occurring in 2010 (134.39 days). The wavelet analysis reveals prominent periodicities of 5-9 years inter-annual variation and 12-year decadal oscillation [Figure 3: see original paper].

3.2 Spatial Distribution

Spatial analysis demonstrates that high-value centers of both cumulative drought days and frequency are concentrated in western Sichuan and central-northern Yunnan, while low-value centers appear in western Yunnan, central-eastern Guizhou, and Chongqing [Figure 4: see original paper]. The spatial pattern exhibits strong consistency between drought duration and frequency.

3.3 Atmospheric Circulation Analysis

Correlation and composite analysis of atmospheric circulation fields reveal distinct patterns associated with drought conditions:

At 1000 hPa: High drought years are characterized by anomalous high pressure over the Tibetan Plateau region, with significant positive correlation coefficients exceeding 0.4 over Southwest China [Figure 5: see original paper]. This anomalous anticyclone suppresses moisture transport from the Bay of Bengal.

At 850 hPa: The wind field shows anomalous easterly flow over the region, weakening the climatological southwesterly moisture transport [Figure 6: see original paper]. The correlation pattern indicates that enhanced easterlies are associated with increased drought severity.

At 500 hPa: The mid-troposphere exhibits a pronounced ridge pattern with positive height anomalies over the plateau region [Figure 7: see original paper]. This configuration results in subsidence and inhibits convective development, with correlation coefficients of 0.3-0.5.

At 100 hPa: The upper-level circulation shows weakened South Asian High intensity and eastward displacement of its center [Figure 8: see original paper], affecting the regional Hadley circulation and reducing upward motion over Southwest China.

4 Conclusions

(1) The overall trend of cumulative drought days and frequency in Southwest China shows a gradual decrease from 1962 to 2017, with decadal anoma-

lies shifting from positive correlation (1960s-1980s) to negative correlation (1990s) and back to positive correlation in the early 21st century.

(2) Drought duration exhibits inter-annual variation periods of 5 and 9 years, with a decadal period of 12 years. Drought frequency shows an 8-year inter-annual period and 20-year decadal variation.

(3) Spatially, drought duration and frequency share consistent patterns: high-value centers in western Sichuan and central-northern Yunnan, and low-value centers in western Yunnan, central-eastern Guizhou, and Chongqing.

(4) Atmospheric circulation analysis indicates that severe drought conditions are associated with: (a) anomalous high pressure at 1000 hPa over the Tibetan Plateau, (b) weakened southwesterly moisture transport at 850 hPa, (c) mid-tropospheric ridging at 500 hPa causing subsidence, and (d) weakened South Asian High at 100 hPa. These combined circulation anomalies create unfavorable conditions for precipitation through reduced moisture supply and suppressed vertical motion across all atmospheric levels.

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Note: Figure translations are in progress. See original paper for figures.