Super Drought: An Innovative Framework for Understanding Compound Drought Risk with Online Monitoring Platform

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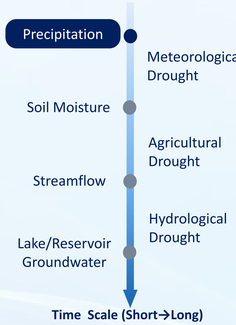
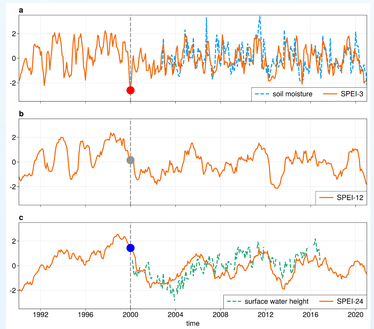
1. Motivation

The Multiscalar Challenge of Drought

- Drought is fundamentally a multiscalar phenomenon affecting water resources differently
- At the same location and time, meteorological, agricultural, and hydrological systems can experience divergent conditions
- Traditional indices focus on single time scales, failing to capture the complex nature of drought events
- This fundamental challenge obscures the identification of truly extreme drought events





◂ Illustration of the multiscalar nature of drought at a single location. (a) SPEI-3 (orange line) with soil moisture (blue dashed line) at Steel Creek Park station. (b) SPEI-12 (orange line) at the same grid point. (c) SPEI-24 (orange line) with surface water height (green dashed line) at nearby Flaming Gorge Reservoir.
The December 1999 case (highlighted) demonstrates the challenge of drought definition at the same location - extreme meteorological drought at 3-month scale, normal conditions at 12-month scale, and wet conditions at 24-month scale.

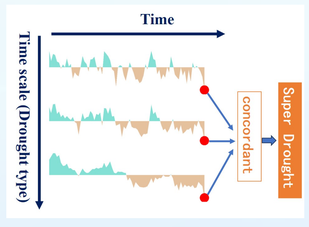
2. Super drought concept

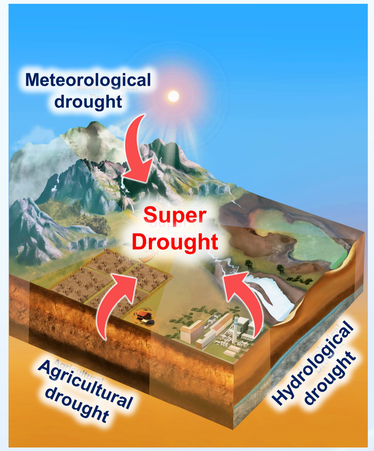
Definition:

Simultaneous occurrence of extreme droughts at multiple time scales

Why is important:

- Compound water deficits in all parts of water resources
- Super drought = Grand loss in total water storage
- Essential for integrated drought assessment approach





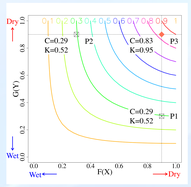
3. Monitoring Index CMI

Comprehensive Multiscalar Index (CMI)

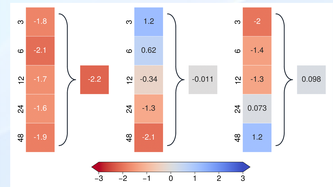
- Probabilistically integrates drought conditions across time scales
- Based on advanced vine copula framework
- Captures joint behavior of multidimensional drought

Performance against GRACE TWS

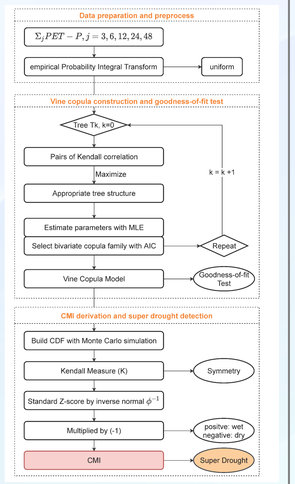
- CMI exhibits superior correlation with total water storage compared to traditional drought indices
- More accurate detection of real water scarcity



▲ Bivariate normal copula with correlation ρ=0.5. The joint probability of drought extremes (P3) is much higher than individual components (P1, P2), demonstrating the probabilistic basis of CMI.



▲ Example of joining multiscalar drought states with CMI. Three cases at the same location showing how CMI effectively integrates drought conditions across multiple time scales.

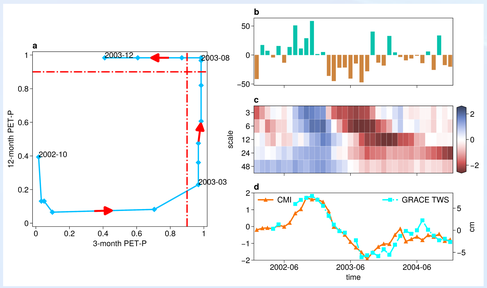


▲ Flowchart of CMI construction based on vine copula.

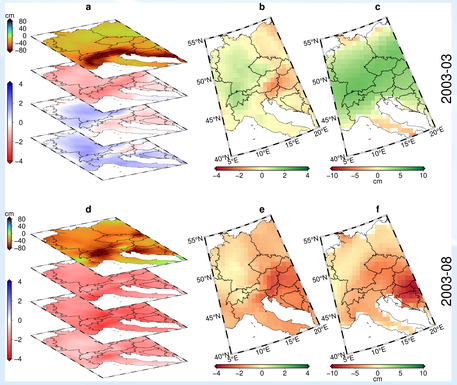
4. Case illustration: European drought in 2003

True drought extremes occur when water deficits coincide across all time scales

- March 2003: Short-term extreme drought (SPEI-3 = –1.68) with normal long-term conditions
- August-September 2003: Synchronous extreme drought across all time scales
- Post-2003: Hydrological drought lingered while meteorological drought recovered
- Strong agreement between CMI and GRACE TWS confirms validity of the super drought framework



▲ Temporal evolution of drought in Central Europe (2002-2004): (a) Drought trajectory in percentile space of 3-month and 12-month water balance (PET–P), (b) Precipitation anomalies, (c) SPEI at multiple time scales, and (d) CMI and GRACE



Spatial comparison between March 2003 (a-c) and August 2003 (d-f) drought conditions: (a,d) Precipitation anomalies and SPEI at multiple time scales, (b,e) CMI spatial distribution, and (c,f) GRACE TWS measurements in Central Europe ▸

5. superdrought.com platform

Features

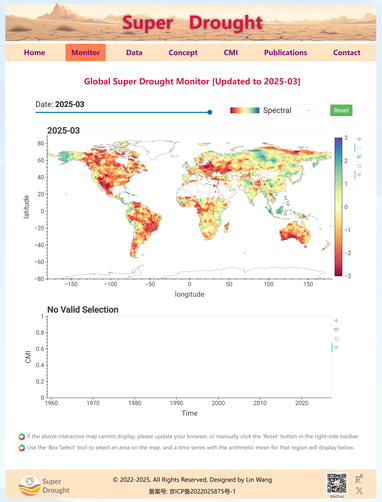
Monitor

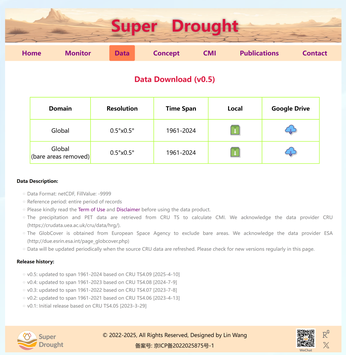
- global monitoring with monthly updates
- Interactive visualization tools

Time Selector | Theme Switching | Regional Analysis | Spatial Navigation

Data

- Historical CMI dataset from 1961 to present
- Global coverage at 0.5°×0.5° resolution





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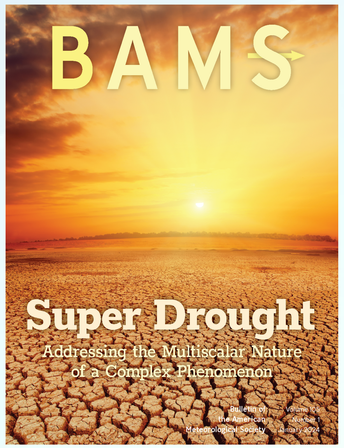

Abstract: EGU25-2379

Sharing is encouraged

Publications:

① Wang Lin, Huang Gang, Chen Wen, Wang Ting (2023) Super Drought under Global Warming: Concept, Monitoring Index, and Validation. Bulletin of the American Meteorological Society 104:E943-E969

② Wang Lin, Chen Wen, Huang Gang, Wang Ting, et al (2024) Characteristics of super drought in Southwest China and the associated compounding effect of multiscalar anomalies. Science China Earth Sciences, 67 (7): 2084–2102