Compound Drought-Heatwave Events in Brazil's Energy System

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Project aim:
Assess the impacts of temperature extremes and drought on energy demand and hydropower generation and characterise energy-relevant compound drought-heat events.

Compound (weather and climate) definition: the co-occurrence of weather and climate hazards which amplifies societal or environmental risks through interconnected physical processes across multiple scales[1]. In Brazil, high temperatures can increase electricity demand for cooling, while droughts reduce hydropower availability. When these conditions coincide, they place additional stress on the energy system.

Conclusions:
- Energy-relevant compound days increased in Brazil from 2004-2023.
- Drought was the dominant driver of compound days, particularly during 2020-2022.
- Heatwave-driven compound days are most common in austral summer, whereas drought-driven compound days are more prevalent in austral autumn, showing seasonality.
- Copula analysis captures dependence-driven risk between heatwave and drought events that are not identified by simple threshold-based compound approaches.

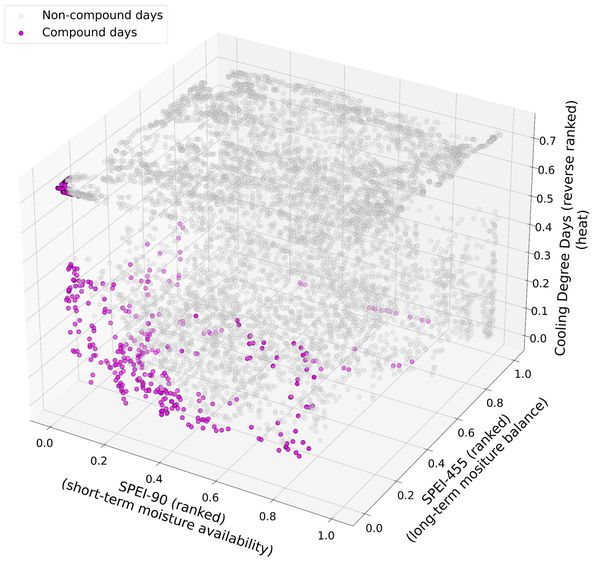

Figure 1 - Empirical copula of constructed from pseudo-observations of SPEI-90, SPEI-455 and reverse-ranked CDD-23. Grey points represent the days without compound conditions, whilst pink dots indicate compound days, defined as the lower 5th percentile of the copula.

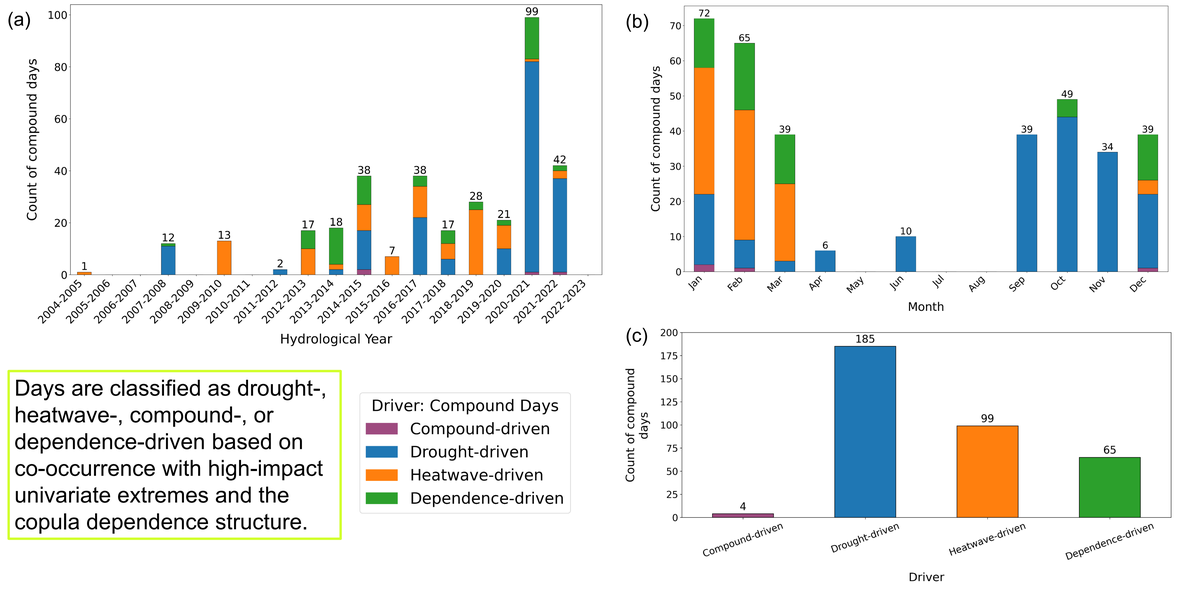

Figure 2 - Frequency of compound days at yearly **(a)**, monthly **(b)** and full-period **(c)** timescales, disaggregated by the dominant driver. Annual totals are reported by hydrological year (October-September).

Data (daily timescale):
- Reanalysis and satellite climate data (ERA5, CHIRPS) → Climate Indices (Simplified Wet Bulb Globe Temperature (WBGT), Cooling Degree Days (CDD), Standardised Precipitation Evapotranspiration Index (SPEI)).
- National Energy Demand and Hydropower records (Operador Nacional do Sistema Elétrico).

Methods:
- Derived Cooling Degree Days by identifying a base temperature (22.80°C) using piecewise linear regression of detrended energy demand and population weighted WBGT.
- Assessed links between hydroclimatic conditions (SPEI at multiple accumulation periods) and hydropower indicators, identifying SPEI-90 as most relevant for run-of-the-river plants, and SPEI-455 for reservoir storage.
- Defined high impact extremes using percentile thresholds (low SPEI, high CDD).
- Characterised compound days using the empirical copula of SPEI-90, SPEI-455 and CDD, defining compound days in the lower 5th percentile of the joint distribution.
- Classified compound days by dominant driver (drought-, heatwave, compound-, or dependence-driven).

References:
[1]Zscheischler J, Martius O, Westra S, Bevacqua E, Raymond C, Horton RM, et al. A typology of compound weather and climate events. Nature Reviews Earth & Environment. Jul 2020; 1(7):333-47

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