HYDROLOGICAL DROUGHT-TO-FLOOD TRANSITIONS ACROSS BRAZILIAN CATCHMENTS

Abderraman R. Amorim Brandão[1] & Paulo Tarso Sanches de Oliveira[1,2]

Keywords – hydrological extremes, water management, hydrological signatures.

INTRODUCTION

Droughts and floods are often examined as separate hydrological extremes, yet recent events and emerging research have shown that their temporal sequencing can generate additional risks when catchments shift from water scarcity to water excess over short periods or within seasonal time windows (Brunner, 2023; Barendrecht et al., 2024). These drought-to-flood transitions pose important challenges for water resources management, as flood impacts may be amplified when they occur after drought conditions, and their identification depends strongly on how droughts, floods, and transition windows are defined (Anderson et al., 2025). Recent large-sample studies have started to quantify the occurrence, timing, and drivers of hydrological drought-to-flood transitions across contrasting hydroclimates, showing that transition times vary substantially among catchments and are shaped by climate, water storage, and catchment response characteristics (e.g., Götte and Brunner, 2024; Matanó et al., 2024; Simeone and Hammond, 2026).

In Brazil, previous studies have advanced the understanding of hydrological droughts, drought-rich and flood-rich periods, and spatially compounding drought events (Gesualdo et al., 2024; Chagas et al., 2024). Because drought-to-flood transitions are modulated not only by climate but also by catchment response characteristics, hydrological behavior groups provide a useful framework for examining whether the frequency and timing of these transitions vary across distinct modes of catchment functioning, reflecting differences in how Brazilian catchments store, release, and transform water into streamflow (Almagro et al., 2024). However, observed drought-to-flood transitions remain poorly assessed at the national scale in Brazil, particularly when considered in relation to hydrological behavior groups. Here, we address this gap using daily streamflow records from 476 Brazilian catchments to identify rapid and seasonal drought-to-flood transitions and to evaluate how their frequency and seasonality vary among groups of similar hydrological behavior.

METHODOLOGY

We selected Brazilian catchments with daily streamflow records available between 1981 and 2024 and low flow regulation, defined by a regulation degree lower than 5%, from the Catchment Attributes and Meteorology for Large-sample Studies for Brazil, CAMELS-BR (Chagas et al., 2020). Drought and flood events were identified using a percentile-based threshold approach, following methods commonly applied in hydrological drought studies (Van Loon and Laaha, 2015; Gesualdo et al., 2024). Streamflow drought events were identified from the 30-day moving average of daily streamflow using a variable daily threshold based on the 20th percentile, with a minimum drought duration of 30 days. Flood events were defined using a threshold based on the 50th percentile of annual maximum streamflow, considering independent flood events separated by at least 10 days.

Drought-to-flood transitions were identified when a flood event occurred after the end of a streamflow drought event. We classified transitions as rapid when the interval between drought termination and flood onset was ≤14 days, and as seasonal when this interval was between 15 and 90 days. Catchments

1) University of São Paulo, *abderraman.brandao@usp.br
2) University of North Carolina at Charlotte

were grouped into six classes of similar hydrological behavior based on hydrological signatures proposed for Brazilian catchments (Almagro et al., 2024). For catchments without an original hydrological class, missing classes were filled using a nearest-centroid approach based on available hydrological signatures.

RESULTS AND DISCUSSIONS

A distinct pattern emerged between hydrological behavior groups, distributed along a gradient from wetter to drier catchments, and the occurrence of drought-to-flood transitions (Figure 1). Transition times varied widely, from 6 to 1781 days, approximately 4.87 years, with a median of 121 days and a mean of 207 days. This indicates that the shift from drought to flood conditions may occur across time scales ranging from rapid reversals to interannual transitions. This broad range is consistent with recent studies showing high spatial and temporal variability in drought-to-flood transitions across different hydroclimates (Götte and Brunner, 2024; Simeone and Hammond, 2026). Considering only transitions occurring within 90 days, seasonal transitions, defined as 15 < transition time ≤ 90 days, were approximately 25 times more frequent than rapid transitions, defined as transition time ≤14 days, representing 96.1% of this subset of events. Most rapid transitions occurred close to the upper limit of the rapid window, with a strong concentration between 10 and 14 days (Figure 1c). In contrast, seasonal transitions were widespread across Brazil and occurred across all hydrological groups, with the highest concentration within the first 15 to 30 days after drought termination, followed by a gradual decrease throughout the 30 to 90-day window (Figure 1d).

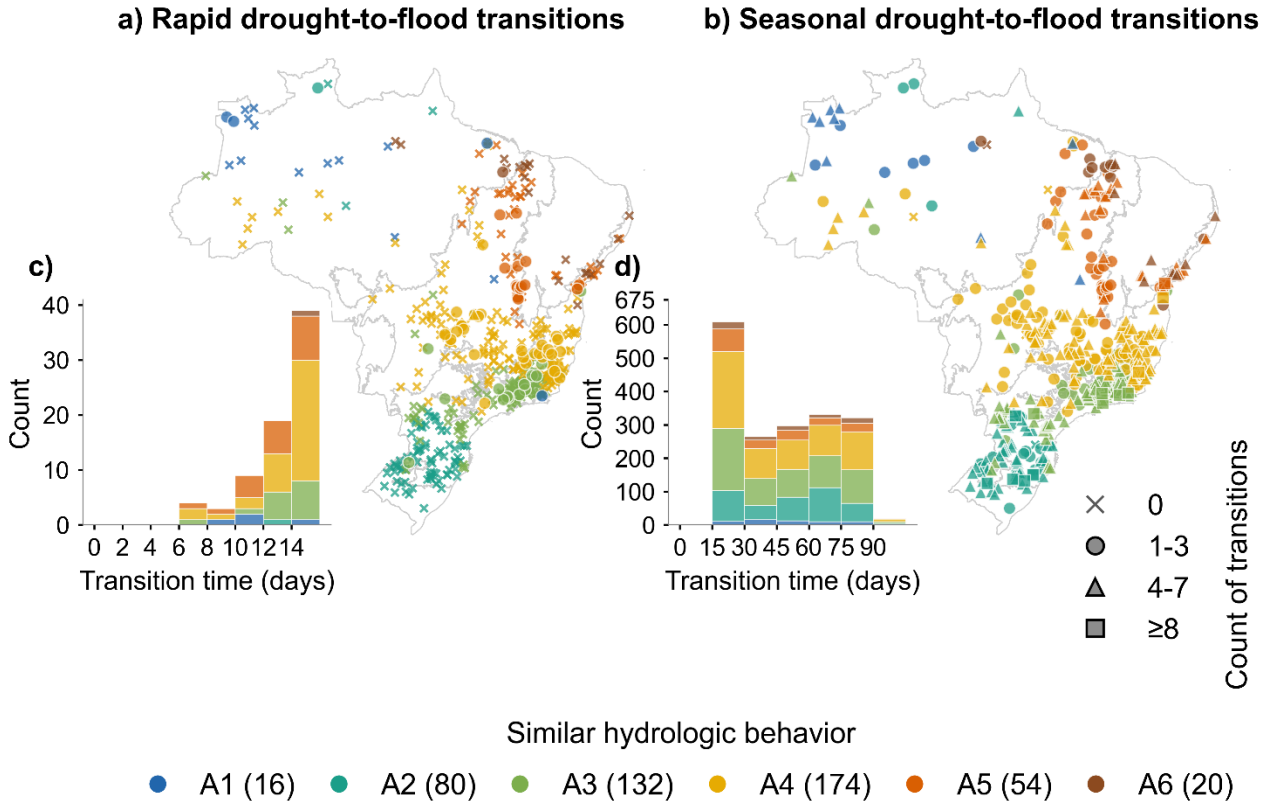


Figure 1. Spatial and temporal distribution of drought-to-flood transitions across Brazilian catchments. Panels (a) and (b) show the spatial distribution of rapid and seasonal transitions, respectively. Panels (c) and (d) show the distribution of transition times by hydrological behavior group. Colors indicate hydrological behavior groups: A1, Wet Catchments; A2, Transitional Wet Catchments; A3, Seasonal Wet Catchments; A4, Seasonal Dry Catchments; A5, Transitional Dry

Catchments; and A6, Dry Catchments. Symbols indicate classes of the number of transitions per catchment.

When normalized by the number of catchments in each group, rapid and seasonal transitions showed contrasting hydrological patterns. Overall, the gradient from energy-limited to water-limited catchments relatively favored rapid transitions, whereas seasonal transitions showed a unimodal pattern, peaking in Transitional Wet Catchments (A2). Transitional Dry Catchments (A5) had the highest mean frequency of rapid transitions, with approximately 0.4 events per catchment. This suggests that drier systems, characterized by higher evaporative demand and lower subsurface buffering capacity, may respond more abruptly when precipitation occurs after drought periods. In contrast, Transitional Wet Catchments (A2) had the highest mean frequency of seasonal transitions, with approximately 4.5 events per catchment, indicating that wetter and more hydrologically connected systems are more prone to shift from drought to flood conditions over subseasonal time scales. This contrast reinforces the need to analyze droughts and floods as hydrologically connected events, since storage, connectivity, and runoff-generation processes may modulate both the speed and frequency of these transitions.

CONCLUSIONS

This study shows that drought-to-flood transitions are a recurrent and spatially structured feature of Brazilian catchments. Seasonal transitions were the dominant mode of drought-to-flood sequencing, accounting for 96.1% of transitions occurring within 90 days and being approximately 25 times more frequent than rapid transitions. This indicates that, in Brazil, the shift from drought to flood conditions is more commonly expressed over subseasonal time scales than as an immediate hydrological reversal. However, rapid transitions were not randomly distributed: their higher relative frequency in Transitional Dry Catchments (A5) suggests that drier systems may be more susceptible to abrupt responses when rainfall follows drought conditions. In contrast, the peak of seasonal transitions in Transitional Wet Catchments (A2) indicates that wetter and more hydrologically connected systems are more prone to cumulative wetting processes that lead to flood-generating conditions over weeks to months. These findings demonstrate that drought-to-flood transitions are shaped not only by climate variability, but also by catchment functioning, including storage, connectivity, and runoff-generation processes. Therefore, assessing droughts and floods as connected hydrological extremes can improve the understanding of compound hydrological risk and support more integrated water-resources and disaster-risk management in Brazil.

REFERENCES

ALMAGRO, A.; MEIRA NETO, A. A.; VERGOPOLAN, N.; ROY, T.; TROCH, P. A.; OLIVEIRA, P. T. S. (2024). "T*he drivers of hydrologic behavior in Brazil: insights from a catchment classification*". Water Resources Research, v.60, e2024WR037212.
ANDERSON, B. J.; MUÑOZ-CASTRO, E.; TALLAKSEN, L. M.; et al. (2025). "*What is a drought-to-flood transition? Pitfalls and recommendations for defining consecutive hydrological extreme events*". Hydrology and Earth System Sciences, v.29, p.6069–6092.
BARENDRECHT, M. H.; et al. (2024). "*Exploring drought-to-flood interactions and dynamics: a global case review*". WIREs Water, v.11, e1726.
BRUNNER, M. I. (2023). "*Floods and droughts: a multivariate perspective*". Hydrology and Earth System Sciences, v.27, p.2479–2502.
CHAGAS, V. B. P.; CHAFFE, P. L. B.; BLÖSCHL, G. (2024). "*Drought-rich periods are more likely than flood-rich periods in Brazil*". Water Resources Research, v.60, e2023WR035851.

CHAGAS, V. B. P.; CHAFFE, P. L. B.; ADDOR, N.; et al. (2020). "*CAMELS-BR: hydrometeorological time series and landscape attributes for 897 catchments in Brazil*". Earth System Science Data, v.12, p.2075–2096.
GESUALDO, G. C.; et al. (2024). "*Spatially compounding drought events in Brazil*". Water Resources Research, v.60, e2023WR036629.
GÖTTE, J.; BRUNNER, M. I. (2024). "*Hydrological drought-to-flood transitions across different hydroclimates in the United States*". Water Resources Research, v.60, e2023WR036504.
SIMEONE, C. E.; HAMMOND, J. C. (2026). "*Assessing the prevalence, timing, and rapidity of transitions between hydrological extremes and their relation to meteorological extremes in the conterminous United States*". EGUsphere [preprint], egusphere-2026-2731.
VAN LOON, A. F.; LAAHA, G. (2015). "*Hydrological drought severity explained by climate and catchment characteristics*". Journal of Hydrology, v.526, p.3–14.

AGRADECIMENTOS

This study was supported by the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) through the first author's grant no. 88887.184632/2025-00.