Title: The dynamics of spatio-temporal droughts in Northeast Brazil

Authors: Filho et al.

Summary

This study analyzes drought characteristics in Northeast Brazil using the SPI-12 and three new evolution metrics: the growth curve, state curve, and dynamic curve. Using these metrics, drought evolution can be assessed in terms of its expansion, persistence, and contraction phases, and categorized into four drought types. The authors claim that most droughts in Northeast Brazil follow a pattern of rapid expansion, long persistence, and abrupt contraction (Type 2). They also highlight that recognizing this pattern will support drought monitoring and early warning in the region.

Assessment

I find the study and its findings interesting, particularly in developing drought evolution typologies based on three-curve models and in its assessment of drought transformation using a transition matrix. Overall, the manuscript is well written. However, the way the authors formulate the limitations of previous drought studies in analyzing spatio-temporal drought characteristics is somewhat inaccurate. There are many studies that analyze drought characteristics for both spatial and temporal characteristics. Furthermore, this study would benefit from a more thorough discussion of what has already been done in the literature, and how the findings of this study align with or differ from previous studies. Below, I provide five general comments and several line-by-line comments, aimed at improving and clarifying the manuscript. I suggest the authors to consider these comments in their revised manuscript.

General Comments

I have five general comments regarding the manuscript:

1. This study is novel in its analysis of drought evolution typologies using three curve models and drought transformation using a transition matrix. These approaches are complementary to previous studies that have analyzed drought characteristics. However, the way the authors build the storyline in the

introduction is somewhat limited to SAD and NATA. There are many studies that analyze spatio-temporal drought characteristics, such as drought severity, duration, frequency, deficit volume, etc (e.g., Fleigh et al., 2006; Yang et al., 2018; Sutanto and Van Lanen, 2020; Hisdal et al., 2024). I suggest that the authors revise the introduction by incorporating these studies, including SAD and NATA, while clearly emphasizing that existing analyses of drought characteristics generally do not define drought evolution typologies and transformation.

2. I am wondering what the difference is between the so-called 3D drought assessment and conventional spatial-temporal drought assessment based on thresholds. In the 3D framework, the first D is about temporal drought event identification, the second D is about spatial clustering of drought event, and the last D is about spatio-temporal tracking. However, all of these 3D analyses have already been performed in many studies, although they are typically referred to simply as spatio-temporal analysis rather than 3D analyses. The authors also state that traditional drought assessment only provides snapshots of specific areas under drought (Page 14), which is not correct. Spatio-temporal analyses of drought have been introduced decades ago, but again they were not framed using a 3D terminology. I am not against the use of the term 3D assessment but I would appreciate clarification on what is fundamentally new compared to conventional assessment.
3. I am curious about the concept of drought evolution typologies. Could the authors clarify whether this typology is based on existing literature or newly proposed in this study, and please provide the relevant references if applicable. I am also wondering whether flash droughts can be categorized within one of these typologies. If so, which category would flash droughts fall into?
4. The explanation of Figure 7 is unclear, and I find it difficult to follow the description of the findings based on this Figure. For example, the authors state that for severity, the transition probabilities are observed at the expansion and contraction stages shifting toward persistence. However, when I looked at expansion and contraction, I see the probability of 0.13 or 0.04 and when I see persistence, it is 0.73. This raises the question of whether the matrix is meant to

be interpreted from the lowest to the highest value. If so, this interpretation is not clearly explained, and it is also unclear why persistence value is always having the highest probability. I suggest that the authors provide clearer guidance on how to read and interpret this transition matrix and better explain the key findings shown in Figure 7.

5. The method section, especially sections 2.2-2.5 can be enhanced with more references. Moreover, the study findings can be better confronted with previous studies in the discussion section.

Line by line comments

P refers to Page and L refers to Line

P2L44: Please write the citation as: "…. proposed by Andreadis et al. (2025a), subsequent…."

P4L87: This is the first time the authors mention about four drought typologies. However, there is no explanation what they are. Who used this definition in the previous studies?

P4L94: See my previous comment. The authors need to explain what are drought type 1, type 2, type 3, and type 4?

P4L99: Missing dot in the end of sentence.

P7L145: The authors may add "especially in the developing countries"

P7L147: Provide reference from WMO (2012) about SPI guideline.

P9L216-217: Definition of the affected area was already mentioned in the previous paragraph. Redundant.

P13: Section 2.6. Maybe the authors can mention about ENSO that also affected Brazil.

P13L323: Remove word "in the" before "from February to May".

P14L342-343: This statement is not true, please look at my general comment point 2.

P15L350-351: Please check how to mention previous studies in the manuscript.

P15L360: Figure 3. If I am analyzing SPi-12 using gridded precipitation data, then I can also get Figure 3. Why do I need to follow the algorithm proposed by Diaz et al. (2019) and Herrera-Estrada et al. (2017)? Also in Figure 3, could the authors explain what do white and grey colors refer to? Also in Figure 5.

P18L413: The use of word impact is misleading. The growth curve reflects the cumulative drought severity and affected area. Impact if we talk about e.g., economic and damage loses.

P20: Figure 6. Please explain in the Caption what does the shaded yellow color mean?

P21L477: Maybe the authors can discuss the implication using other aggregation periods. For example, if we use SPI-1 or SPI-3, the typology of drought will be different since there may not be long persistent drought due to short rainfall.

P23L508: I am thinking if Brazil drought monitor provides seasonal forecasts, then it can have full drought event for drought < 6 months. However, I am aware that Brazilian Met Office is not in favor having drought forecasting (discussion during the IDMP event).

P24L539-540: Could the authors help the readers to read Figure 7? See my general comment point 4.

P25L547: Could the authors explain why affected area has a more stable and consistent evolution? Is it due to higher diagonal values?

References

Fleig et al. (2006). A global evaluation of streamflow drought characteristics. Hydrol. Earth Syst. Sci., 10, 535–552. www.hydrol-earth-syst-sci.net/10/535/2006/.

Hisdal et al. (2024). Chapter 5: Hydrological drought characteristics. Hydrological Drought (Second Edition), Processes and Estimation Methods for Streamflow and Groundwater, Pages 157-231. https://doi.org/10.1016/B978-0-12-819082-1.00006-0.

Sutanto and Van Lanen (2020). Hydrological drought characteristics based on groundwater and runoff across Europe. Proc. IAHS, 383, 281-290, https://doi.org/10.5194/piahs-383-281-2020.

Yang et al. (2018). Comprehensive drought characteristics analysis based on a nonlinear multivariate drought index. Journal of Hydrology, 557, 651-667. https://doi.org/10.1016/j.jhydrol.2017.12.055.

WMO (2012). Standardized Precipitation Index User Guide. WMO-No. 1090. https://library.wmo.int/idurl/4/39629.