Reviewer Comment on: Weather persistence on sub-seasonal to seasonal timescales: a methodological review

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Summary

The authors present a manuscript for a review article on persistence as the occurrence of approximately constant or recurrent atmospheric states in the subseasonal to seasonal (S2S) time range. Persistence determines damages, challenges understanding and promises predictability. The review considers various aspects of persistence: definitions, methodologies, and examples encompassed by this rather general notion.

In their review, the authors undertake a challenge when they combine meteorological observations and a mathematical definition in terms of advanced statistical and dynamical approaches. While a general definition of persistence is already hard, the related notion recurrence is even more difficult to grasp and to distinguish. Not surprisingly, the review is weak when the authors attempt the almost impossible task to provide a comprehensive theoretical framework, but it gets stronger when it resorts to methodologies and meteorological examples. In particular the variety of examples and their properties show the width of the seemingly simple notion persistence.

The authors are well aware of the difficulties involved and do not hide that. The review is worth to read for two reasons: the collection of methodologies that have been suggested to analyze persistence, and the huge amount of examples. In summary, the authors provide a broad and useful overview with a lot of insight. Below I mention some aspects that I noticed.

Specific comments

Line 55: Since persistence needs a timescale for the definition this question is somehow circular: ‘At which timescale(s) does the persistence occur? There could be reference to Section 3.4.

Line 124, Eq $(\mathbf{x}(t))_t \in R^m$ what is the meaning of the subscript t together with the argument t? This should be explained.

Line 126, I recommend to use ‘state space’ instead of phase space (the often used notion phase space is reserved for Hamiltonian systems).

Line 136: To characterize the difference between precipitation and temperature an autocorrelation time would be appropriate here. This is better than ‘inertia’ since it is difficult to associate precipitation with an inertia, while temperature, on the other hand, has something like an inertia due to the heat capacity.

Lines 143, 155 in Section 3.1 *Global, state and episodic persistence.* It seems that global and state persistence are different concepts. Global persistence appears nothing else than stationarity which includes recurrence. Why is global persistence ‘strongly related to intrinsic system predictability’? Maybe these definitions could be useful: Does persistence of a state x(t) mean dx(t)/dt=0. And could global persistence be defined in terms of integrals or averages like d<x(t)>/dt=0? And are conservation laws useful?

Line 184: What is a ‘symmetrically, persistent state’?

Line 188: How can this sentence be understood: ‘However, state persistence only characterizes the average behavior of system states.’

Line 201: Section 3.2 *Lagrangian and Eulerian perspectives.*

Here is a good opportunity to define Lagrangian stationarity of a quantity $\psi(\mathbf{x},t)$ along a flow **u**, by $\partial\psi/\partial t + \mathbf{u}\cdot\nabla\psi = 0$, in comparison to the Eulerian stationarity with $\partial\psi/\partial t = 0$.

Line 216: The authors write 'self-similarity of system values $\mathbf{x}(t)$ with a metric' but this notion can be confused with geometric self-similarity used in the definition of fractal objects for example. Or is that what the authors intend?

Line 300: write what the symbol E(…) denotes.

Line 348: On Long-range memory: mention the absence of a timescale.

Line 360: Write that the Hurst exponent H and d are related by H=2d+1, see the Table 1 in Franzke et al. (2020).

Line 382: Written is: 'If temporal dependence is present'. This is unclear. Eq. (10) is the result a power-law in of ρ (Eq.(6)), line 350.

Line 490: Section 4.2.4 *Extreme values and dynamical systems theory*. The role of the extremal index θ is difficult here. In extreme value statistics the extremal index is the inverse time scale with co-occurring extreme events, used to eliminate short term variability and to combine events. Why is this index a measure of stationarity? Is it correct that short term excursions are allowed with θ in Eq (13)?

Line 569: Please write that $R_{\mathbf{x}0}$ is the residence time for state $\mathbf{x}_0$.