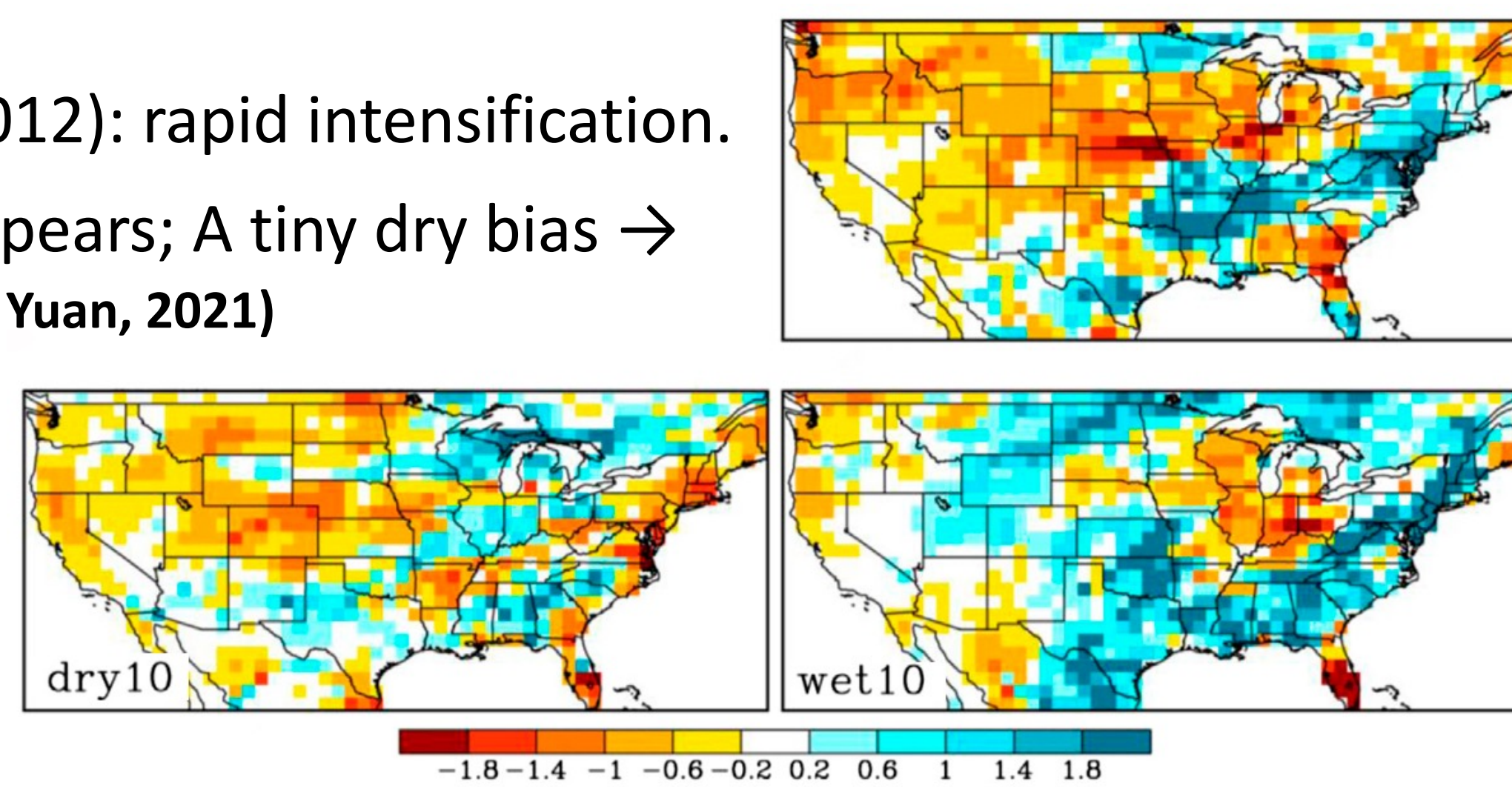


Introduction and Motivation

- Determining memory is of fundamental importance for modelling characteristics of any real world processes.
- In many physical systems, memory arises from correlations between observable and hidden degrees of freedom, e.g., soil moisture (SM) memory emerges as an interaction between antecedent SM, Drainage Losses and atmospheric forcing.
- We treat soil moisture memory as an emergent property of stochastic, threshold-driven (asymmetric) dynamics, moving from one ACF e-folding time to an information- and recurrence-based description that resolves dry and wet memories.

Why it matters:

- Flash draught (central US, 2012): rapid intensification.
- 10% wet bias: drought disappears; A tiny dry bias → drought intensifies (Liang and Yuan, 2021)
- Drought prediction is *highly sensitive* to soil moisture memory.

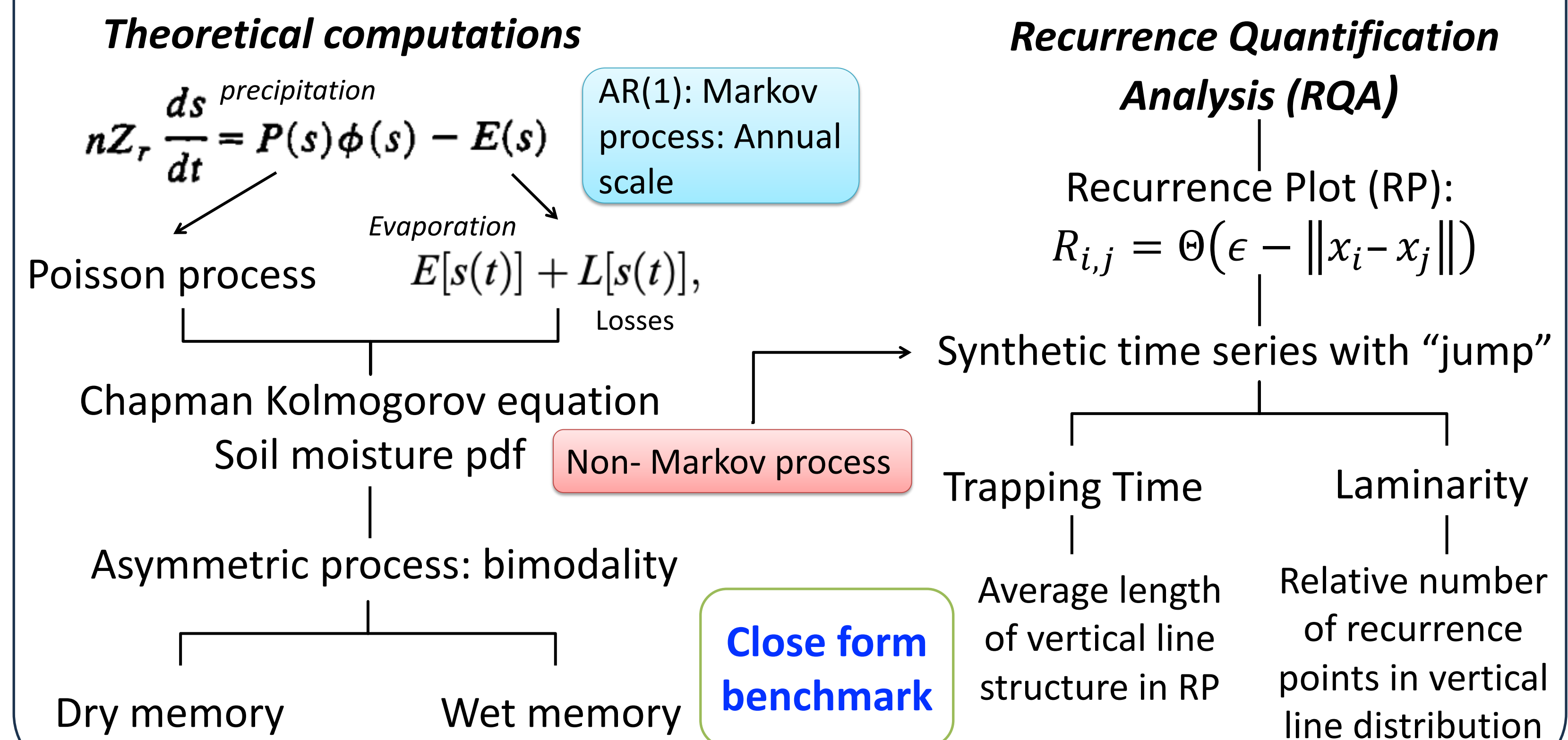


Methodology

Refined framework

- Time series – Binary Markov process of order m : defined as memory
- Quantified as a convergence time scale of the Block Shannon Entropy (BSE).

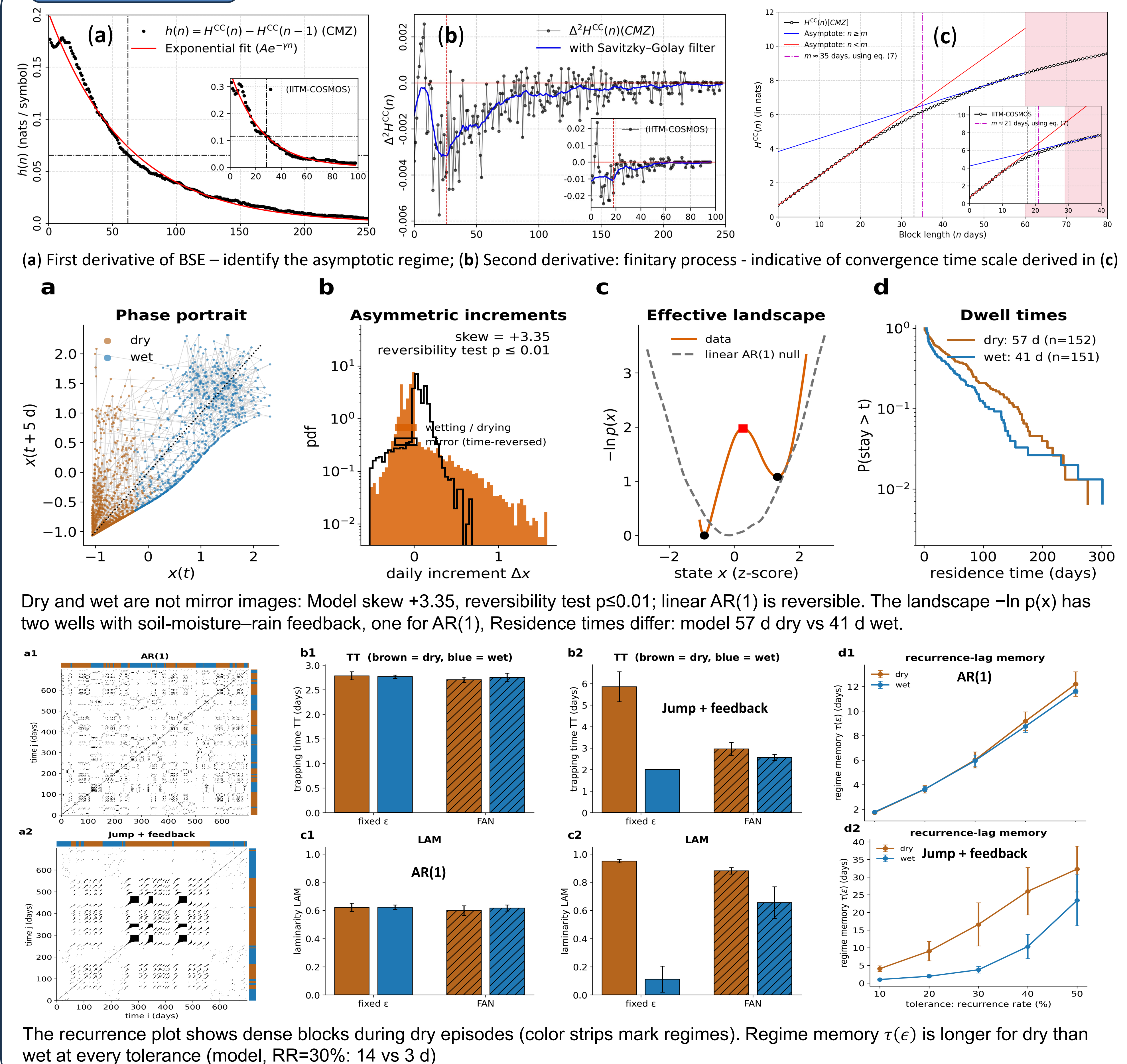
Improved Methodology



Discussion

- Information theory based refined framework: Symbolic time series: meteorological time series with observational threshold, exhibit signature of persistence
- Though it improves over conventional methods,
 - It demands “sufficiently” long time series
 - Yields scalar: single ensemble / time average
 - Lacks regime (dry / wet) resolution
- We improve it by formulating entropy and thus the SM probability distribution via RQA, where the persistence time scale for two attractor states can be quantified using Trapping Time (TT) and Laminarity (LAM) of the recurrence structure.
- Physical reading: at daily scale, soil moisture is rain-pulse driven (abrupt wetting, threshold-dependent loss), unlike annual-scale diffusion picture (Delworth & Manabe 1988).
- A theoretical framework due to --- based on Chapman Kolmogorov equation provides benchmark as well as inputs for constructing synthetic time series (that mimics the behaviour of SM).
- Daily bimodality needs feedback (state-dependent rain frequency; D’Odorico & Porporato 2004).
- Model simulation suggests: Longer dry memory is expected if loss shuts down near the wilting point while wet states drain fast.
- A critical comparison of AR(1) – which is a typical Markov process (memory less) against non-Markov process gives an important insights into the mechanism of memory

Results



Conclusions

- **Information theoretic framework:** (Panel 1) soil moisture is a finitary, non-Markov process; memory $\approx 35d$ (CMZ, GLDAS) and $\approx 21d$ (COSMOS).
- **Simulation with synthetic time series:** (panel 2 and 3) Recurrence extension: dynamics are asymmetric, with abrupt wetting and slow drying, and metastable dry and wet states with different residence times
- The behavior is consistent with McColl et al. (2017, 2019): coarse, ET-dominated estimates overstate memory.

Acknowledgement and References

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