Review of: ***A Cellular Automaton Model of Tropical Oceanic Rain Clusters with Criticality*** **by Cheung et al.**

I found the methodology, scaling analysis, and discussion to be thoughtful and transparent. In particular, I appreciated the authors' careful distinction between the CA analyzed in the manuscript and more classical SOC formulations discussed later in Section 4. The scaling analyses are carefully conducted, and the demonstration that the non-interacting case maps closely to two-dimensional site percolation is convincing. Overall, I found the manuscript interesting and well written and would propose only minor revisions.

1. Historical context of cellular automata in atmospheric modeling

The introduction provides a useful overview of CA approaches for cloud and rain organization. However, I think the discussion of CA applications in convection parameterization could be expanded and historically reframed somewhat.

The manuscript may benefit from distinguishing between CA used primarily as idealized/statistical models of criticality and CA used as stochastic organization operators embedded within physical parameterization frameworks.

The manuscript currently cites Palmer (1997, 2001) and Bengtsson et al. (2022), but this compresses a substantial body of work on CA-based representation of convective organization and memory in numerical weather prediction models. Following the original conceptual proposals of Palmer (1997, 2001), a series of studies developed and implemented CA-based convective organization frameworks within mass-flux convection parameterizations (e.g., Bengtsson et al., 2011, 2013, 2019, 2021, 2022). These studies demonstrated applications to sub-grid convective organization, convective memory, and cross-grid communication in atmospheric models, including implementation in operational forecast systems (e.g., GFSv17; Bengtsson and Han, 2024).

2. Framing of criticality and self-organized criticality

Some of the discussion surrounding criticality could perhaps be framed somewhat more cautiously.

I very much liked Sections 2 and 3, which I found clear, transparent, and thoughtfully presented. However, after reading these sections, it appears that the discussion of criticality and SOC could perhaps be framed more carefully already in the Introduction.

In particular, the emergence of scaling behavior near a parameter-dependent critical value appears conceptually closer to tuned critical phenomena or absorbing-state transitions than to classical self-organized criticality in the strict sense, where the system dynamically evolves toward criticality without external parameter tuning. Since the manuscript already acknowledges some of these distinctions in Sections 2-4, it may be beneficial to introduce this nuance earlier in the paper as well.

More generally, power-law cluster statistics are certainly suggestive of critical behavior, but they do not uniquely imply SOC. Similar scale-invariant behavior can emerge from a variety of multiscale dynamical processes. I therefore encourage slightly more cautious wording in the Introduction and Abstract regarding the interpretation of tropical rainfall as a critical phenomenon.

3. Physical interpretation of the percolating regime

The discussion of percolating clusters and the critical transition is mathematically clear, and I learned a lot from this section. However, I would welcome additional discussion of the physical interpretation of the percolating regime in the context of tropical convection.

In percolation theory, a percolating cluster corresponds to a connected structure spanning the computational domain. Since one does not typically observe a continuous precipitating cluster spanning an entire tropical basin (or the tropical belt) in nature, some discussion of the atmospheric analogue of the percolating state would be useful.

Relatedly, the discussion section linking basin-wide RCM rain clusters to incipient infinite percolation clusters is intriguing. However, it may be useful to distinguish more clearly between a mathematical analogy and a demonstrated physical correspondence. Additional discussion of what atmospheric structures would physically correspond to the percolating regime would help place this interpretation in context.

4. Interpretation of the scaling exponents

I found one of the most interesting results of the manuscript is that the interacting CA departs from standard site percolation in several respects (e.g., D_s, η_s, and d_c vary with γ), while the cluster-size exponent ζ_A remains approximately invariant and close to the percolation value.

This raises interesting questions regarding universality and the physical interpretation of the critical transition. Additional discussion of why ζ_A appears robust to the introduction of local convective interactions, despite substantial changes in the other critical exponents, would further strengthen the manuscript.

Similarly, because the inferred scaling exponents vary with the coupling parameter γ, some discussion of the physical interpretation of γ and the implications of the resulting changes in scaling behavior would be valuable.

Finally, it would be useful to distinguish more clearly which scaling relationships are emergent properties of the CA dynamics and which are externally constrained. For example, the cluster geometry and associated scaling exponents appear to emerge naturally from the model, whereas the area-conditioned rain-rate scaling is imposed through Eq. (6). Explicitly separating these aspects would help readers understand which observed characteristics are explained by the model and which are prescribed.

References:

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