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Interactive comment on "Technical Note: Characterising and comparing different palaeoclimates with dynamical systems theory" *by* Gabriele Messori and Davide Faranda

Anonymous Referee #2

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In this technical note, the authors introduce their method of recurrence-based "dynamical systems analysis" to the field of Paleoclimate simulations. By estimating the statistics of extremely close recurrences in one or two variables, their method summarizes the instantaneous state of a dynamical system by the effective degrees of freedom, the persistence, and the coupling between different variables. As an example application, the authors show how their metrics can detect differences in the dynamics of Mid-Holocene North African Monsoon circulation under various vegetation and aerosol forcings.

Overall, I would agree that the approach presented here can be especially helpful for

the analysis of Paleo-simulations: Uncertain forcing and boundary conditions can potentially lead the simulated system into unknown dynamical regimes, which might differ from our present-day intuitions in unexpected ways. Objective, generally applicable measures of the overall dynamical behavior may be rather helpful in detecting differences and similarities of various simulated climates.

The manuscript is very well-written and overall fits the scope of the journal. The description of the method and the presented case study do, however, raise several concerns which should be addressed before publication.

Main points: The assumption of stationarity is not sufficiently discussed. If a substantial regime shift occurs at some point during the simulation, I would expect that recurrences will only be observed within each regime but not between the two. Doesn't the estimated dimension then depend massively on the length of the time-series before and after the shift? Say we have simulated 1000 years before and 9000 years after a de-glaciation phase. Won't the dimension in the first 1000 years be artificially increased just because there are fewer recurrence candidates? Wouldn't this result change completely if we had stopped the simulation 1000 years after the shift?

The use of binary precipitation fields seems worrying: If I understand correctly, the distance measure is then effectively no longer a continuous but a discrete random variable. Do we know that the theoretical limit results apply in the discrete case?

Depending on the domain, we might have many time-steps with identical zero precipitation. What happens to theta and d in such cases? Shouldn't the persistence be effectively infinite and the dimension zero if two subsequent time steps are exactly identical?

Please include significance tests for your composites (Fig.3, 5, 6). As it is, we don't know which of these patterns might just be random chance.

Minor points: Neither the abstract not the Motivation chapter gives the reader any idea what the dynamical indicators actually do. “Different dynamical properties“ (l.9) is too vague. Please add at least an intuitive explanation of what kinds of properties you mean.

L.20 “new challenges“ I‘m no expert on this but you cite Paleo-simualtions going back at least to 1996, this is hardly a “new“ issue.

L.30-33 this paragraph is copied nearly verbatim from the abstract, maybe instead you could give some more explanation of what the dynamical indicators actually do.

You mention that theta and alpha are bounded, what about d?

Section 2.2: Maybe mention that x(t) corresponds to the sea level pressure or precipitation field from the example before.

Eq.3 looks like alpha was asymmetric with respect to x and y because the denominator contains only x, but nu(g(x) > sx) = nu(g(y) > sy) = 1 - q, correct ? Maybe make that more clear.

L. 155 how do you arrive at these definitions of Monsoon and Pre-Monsoon? Are those the present day conditions?

Fig.1 there is almost no visible difference between b and c, maybe plot the difference between GS-PD / GS-RD and CNTL instead?

Fig. 2 Please explain more specifically what a) and b) are telling us besides the shift in monsoon onset and ending, both of which we already see in c). In particular, how do you interpret the fact that the maxima in d shift from blue to red, but the decrease in theta (b) happens nearly at the same time in all three curves.

Also in Fig.2 there is no appreciable difference between the red and yellow curve. Do these systems have different dynamics or not?

In Fig.5 a) and b) (also Fig. 6) it is impossible to tell what the actual values of the contours are because there are only negative anomalies. Maybe add labels? In any

case this figure in particular needs a significance test in order to decide which patterns are actually worth interpreting.

Section 4: You say that your method can complement “other“, “conventional“ approaches but never name any of these other techniques. Can you give an example of a standard method with similar goals as yours? Perhaps PCA? That might help readers grasp what (approximately) your method does. You could also discuss some similarities or differences, highlighting what sets your approach apart.

L. 285 can you please be a little more specific than “several good recurrences”? Very roughly how much data do I need for this method? How can I check if I have sufficiently “good” recurrences?

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