February 3, 2024

Responses to comments of "Assessment of object-based indices to identify convective organization" egusphere-2023-1985 to GMD

We express our gratitude to the referee for providing constructive criticisms and valuable comments which have been very helpful in improving the quality of this manuscript. We have made the point-by-point response to the comments and revised the manuscript accordingly.

We hope that the revised version can obtain approval and meet the journal's requirements. In this document, the referee's comments are presented alongside our responses (in blue) and the textual modifications (in red). Both authors have thoroughly reviewed the revised manuscript and unanimously agreed to its submission in this improved form.

Request

One significant concern is the absence of a proper review and utilization of other existing trackers for convective system identification. Given the manuscript's focus on comparing nine object-based indices, it is both reasonable and, to some extent, ethical to incorporate at least two (if not more) MCS tracking algorithms. This addition would enhance the robustness of the results. Furthermore, a recent MCS-tracking intercomparison study by Prein et al. 2023 (https://essopenarchive.org/doi/full/10.22541/essoar.169841723.36785590) has documented relevant differences in results related to MCS characteristics and statistics across different tracking algorithms.

Answer

We thank the reviewer for this comment, which highlighted that the data description is very misleading in the manuscript.

In the current analysis, we do not make use of the TOOCAN tracking algorithm. We have only used the brightness temperature measurement calibrated by Fiolleau et al. (2020) which also led to the construction of the TOOCAN systems.

We have modified the manuscript to clarify this point, and we decided not to use the word TOOCAN to refer to the dataset.

Changes in Manuscript (line 37)

2.1 Datsets of convective objects

The statistical comparison between indices needs a dataset of horizontal binary fields that mimic deep convective clouds for which it is possible to compute the convective organization indices.

Since the goal is not to study physical processes but the behavior of the indices, any dataset can be used. However, in order to well represent the typical size, occurrence, and disposition of deep convection in the tropics, we have chosen a real satellite dataset with a good spatial and temporal resolution.

Fiolleau et al. (2020) provide such a dataset with calibrated infra-red (IR) brightness temperatures (T_B) by combining different geostationary satellites to span the entire band from 40N to 40S. The spatial resolution is 0.04°, and the temporal frequency is 30 minutes. For this study, we reconstruct convective objects from cold brightness temperatures with a cold core ($T_B < 190$ K) surrounded by $T_B < 235$ K, by grouping all 8-connected grid boxes. Holes in each object are filled to avoid degenerate dispositions. This procedure is implemented with the Python framework developed by van der Walt et al. (2014). We selected the oceanic tropical Warm Pool region expanding over 0°N-9.6°N and 140.4°E-150°E. The original resolution is downscaled to 0.08°to analyze images with a size of 120x120 grid boxes. Then, images with less than two objects are rejected. Finally, a total of 76462 images in the period 2012-2016 is considered for this study.

Request

In addition to the generated dataset, it is suggested that the authors incorporate at least one more tracker in the analysis to ensure multiple algorithms contribute to convective system identification data. One suitable option is TAMS (Núñez Ocasio et al. 2020a; Núñez Ocasio et al. 2020b; https://tams.readthedocs.io/en/latest/), an objective MCS tracking algorithm. TAMS is open-source, publicly available, and Python-based, making it a viable candidate for comparison with TOOCAN.

Both TOOCAN and TAMS share underlying similarities in identification and tracking, yet they differ sufficiently for a comprehensive comparative analysis. Similar to TOOCAN, TAMS utilizes Tb, allowing authors to download satellite Tb for the warm pool region domain in case TOOCAN systems cannot be separated from the Tb data. Additionally, like TOOCAN, TAMS allows saving the mask for the identified convective objects.

For further reference, authors are encouraged to refer to Prein et al. 2023 for information on other trackers that could be considered, such as MOAAP and PyFLEXTRKR. It is advised to provide a proper review of MCS trackers as convective system identification algorithms, including MOAAP, PyFLEXTRKR, and TAMS (in addition to TOOCAN), which are all current open-source MCS trackers available.

Because of the intrinsic relationship between deep convective organization and how an MCS is defined or identified (the first step of a tracking algorithm), this manuscript would benefit from the inclusion of a discussion regarding how the new index is sensitive to the MCS tracking algorithm being used and vice versa. How does the sensitivity of the new 'well-behaving index' compare to the sensitivity of other indices to multiple MCS trackers?

Answer

We appreciate the referee for bringing up this important topic, which holds particular significance for those delving into the study of convective organization applied to MCS.

Indeed, different tracking algorithms can identify different convective systems, thus they can produce different values of convective organization indices. A deep study of such a sensitivity is crucial and it should be a focal point for future investigations.

A first international workshop on Cloud Tracking was already held in April 2023 (hosted in Oxford by Philip Stier), and a Joint NASA (AOS) – INCUS – GEWEX Convection Tracking workshop is planned for April 2024 in New York.

Our current work is independent and complementary to the assessment of the tracking algorithms. The primary objective of this study is to analyze the consistency of the convective organization indices. The identification of well-behaving indices equates to discerning which indices consistently reflect convective organization. It is important to stress that only well-behaving indices offer a reliable measurement of organization, thus they are the only ones that can be used in climate analyses, regardless of the MCS tracker employed. However, we have added a small paragraph in the introduction to make this clearer.

The sensitivity of the indices to different tracking algorithms is instead something very different because it does not assess the consistency of the indices. This type of test depends also on the algorithms, and it should be performed only after having a complete well-behaving index (one that fulfills all seven conditions).

Changes in Manuscript (line 31)

The convective objects have been identified by images of continuous areas of cold infrared brightness temperature measurements. This assessment is complimentary and independent of the assessment of convection tracking methods (e.g. Prein et al., 2023), which have been developed to identify the convective objects.

Request

The introduction would benefit from a review of what is convection and convective organization. Although it does not have a rigorous definition, certainly, past papers must have addressed convective organization that is relevant to include here to introduce such indices.

Answer

The reviewer is certainly right. We have expanded the introduction of the manuscript by adding a small review of convection and convective organization.

Changes in Manuscript (line 16-23)

Atmospheric convection is a fundamental process characterized by the vertical movement of air masses within the Earth's atmosphere. As the sun heats the Earth's surface, warm air rises, transporting heat and moisture through the atmosphere. This upward motion triggers the formation of clouds and weather phenomena, playing a crucial role in shaping our planet's weather and climate. In Radiative-convective equilibrium simulation, convection shows a tendency to cluster horizontally as time passes. This behavior was firstly pointed out by Held et al. (1993), and then it was confirmed in several other studies (Tompkins, 2001; Bretherton et al., 2005; Wing and Emanuel, 2014). Because of this feature, clustered convection is referred to as aggregated or organized convection, or convective organization. In recent years, because of the great importance of convection on climate, many studies have been focusing their attention on convective organization. Either looking for an explanation of such a phenomenon with simulation (Wing and Emanuel, 2014; Tompkins and Semie, 2017; Cronin and Wing, 2017; Muller and Romps, 2018; Muller et al., 2022) or trying to measure convective organization in observations and relate it to known quantities (Wing et al., 2017, 2020; Bony et al., 2020; Bläckberg and Singh, 2022; Stubenrauch et al., 2023). Both types of analysis need a method to quantify convective organization. However, quantifying the degree of convective organization is challenging. There is still no consensus on the best method to use and various methods have been proposed in recent years, reviewed by Biagioli and Tompkins (2023).

Question

Lines 59-65: This methodology is not clear. Why tune the generated dataset to TOOCAN? Doesn't seem to be a fair comparison then. Please address.

Answer

The reviewer has highlighted a crucial point that has been neglected in the manuscript.

The behavior of certain indices can be dependent on the number of objects (N), for example as shown in Fig. 5. Consequently, they can depend on the distribution of N.

When comparing different datasets, several differences may emerge. Some can be caused by the inherent nature of the datasets, including the shape and spatial distribution of objects, while others arise just from different distributions of N.

In this manuscript, our primary focus was on addressing the former, as they bear a more direct relevance to the intrinsic concept of convective organization. Differences attributed to N were not considered within the scope of this article. Therefore, in order to get rid of any difference due to N we have simulated a dataset in such a way that it reproduces the same distribution of the convective object dataset constructed from cold T_B.

Similarly, the object size can affect the indices behavior as well, therefore we simulated the dataset to reproduce also the distribution of object size.

This is also one of the reasons why comparing different tracking algorithms is complex and beyond the scope. Different tracking algorithms may strongly affect the indices behavior via their N, thus, extracting the differences coming from the algorithms itself is challenging.

Changes in Manuscript (line 58-63)

The following analysis aims to study the behavior of the organization indices, and the results shall not be dependent on the dataset used. The robustness of this analysis against the dataset can be proved by comparing the results obtained using different datasets. When comparing datasets, several differences may emerge. Some can be caused by the inherent nature of the datasets, including the shape and spatial distribution of objects, while others arise just from different distributions of objects number and sizes. The primary focus of this work is addressing the former, as they bear a more direct relevance to the intrinsic concept of convective organization. To prove the reliability of the results here presented, we have simulated a dataset to compare with the convective object dataset obtained from cold brightness temperatures. Therefore, we have built images of randomly placed circular objects of different sizes. We used a Monte Carlo simulation technique which follows distributions of object sizes and number of objects with the same shape as the ones of the convective object dataset from cold T_B. Examples of images generated with this method are given in the supplement material. Despite the large differences in shape and spatial distribution of the objects in the two datasets, the final results are similar, meaning that they don't depend on the nature of the objects. The results obtained with the brightness temperature database are shown in the following, while the ones obtained with the newly simulated dataset are shown in the supplement material.

Question

Lines 110-115: This is confusing, are the authors referring to the numbers in Table 1? They are all way above or way below 0.5. As the author pointed out, it is incoherent. Is there a clearer way to represent these numbers?

Answer

Lines 110-115 refer to Table 1.

We agree with the referee that such a big table looks unclear. To facilitate the reading, we have modified the Table as follows:
- Numbers exceeding 0.5 correlation are presented in bold for emphasis,
- Correlations located below the diagonal have been omitted,
- A demarcating line has been added to distinguish the indices from the other variables.

Furthermore, we have updated the table caption to align with these improvements.

Changes in Manuscript:

Table 1: Correlation coefficients, multiplied by 100, of the indices with each other and with number, total area, and mean size of convective objects. Bold numbers highlight correlations with coefficients larger than 0.5.

	I_{org}	L_{org}	COP	ABCOP	ROME	SCAI	MCAI	MICA	OIDRA	number	total area	mean size
I_{org}	**100**	**74**	38	-15	-25	35	31	43	10	-23	-33	-26
L_{org}		**100**	47	-16	-16	41	40	**56**	22	-26	-27	-16
COP			**100**	-1	39	47	50	**72**	48	-43	1	39
ABCOP				**100**	47	-34	-31	-13	39	33	**81**	46
ROME					**100**	5	10	14	**52**	-10	**68**	**100**
SCAI						**100**	**99**	49	31	**-96**	-48	5
MCAI							**100**	**51**	34	**-96**	-43	10
MICA								**100**	49	-43	-19	13
OIDRA									**100**	-29	39	**51**

Question

For Condition 7: What happens if a study has a continuous domain? Like uninterrupted global datasets? Will the results change?

Answer

Condition 7 applies to open domains (i.e. with defined borders), which are what most of the studies of convective organization are targeting. Some studies instead consider uninterrupted domains, like CRM with double periodic conditions or global datasets. For such domains, perturbation 7 is ineffective and the indices should not change when the domain is shifted. Therefore, condition 7 is satisfied automatically. As a consequence, indices that do not satisfy condition 7 cannot be used on open domains but they still can be used on continuous domains.

Request

Can the authors provide some additional discussion on which of the indices compared the most with OIDRA?

Answer

We have added a discussion of OIDRA in comparison with the other indices in the appendix, just after explaining of the properties of OIDRA's definition.

Changes in Manuscript:

Because of its specific formulation, OIDRA is different from all the other indices. The main reason can be attributed to its dependence on the object sizes, which are squared. This feature makes OIDRA very sensible to object sizes, which makes it similar to ROME. ROME and OIDRA exhibit similar behaviors for conditions 1, 2, and 5, where the object size plays a crucial role. Moreover, ROME and OIDRA correlate higher than 0.5. Nevertheless, OIDRA's response to object proximity aligns more closely with L_{org} than with other indices.

Sincerely,

Giulio Mandorli,
Claudia Stubenrauch