Response to Anonymous Referee #1

Referee #1: Thank you to the authors for their responses to my comments. This revision is greatly improved relative to the initial submission. The text is much clearer, and the additional figures and text were very helpful, especially the revised section 3 and addition of Figure 2.

This paper is primarily one about methodology. The convective tracking algorithm is complex and sophisticated, and while the description of it was difficult to follow in the original submission, it is much clearer now, and the reader can understand the methodology being described. I appreciate the large amount of technical work that was done here, and think that this tracking system is potentially very useful to studies of tropical convection.

After describing the tracking algorithm, the authors use it to examine some properties of tracked convective segments in the West Pacific. While I agree that it is a good idea to show some results like this, I found this section to be much less compelling than the methodology itself, as the results are presented rather plainly without much context or discussion. In addition, this section still suffers from lack of clarity in some places, which makes it hard sometimes to understand the results. More details provided below.

Response: Thank you for reviewing this paper again. We are sincerely grateful for your insightful comments that help us a lot to revise and improve this paper further. We have revised the manuscript carefully according to the comments. The sect. 4 has been better constructed with more discussion and its motivation has been clarified.

General Comments:

1. ***Clarity of writing.*** *While the writing in the paper is now clear enough to convey most points, it still does not read easily in many places, and the authors may wish to pursue more editing services if that is an option for them.*

   Response: Thanks. More descriptions have been added in the revised manuscript and the language use and grammar are double checked by editing services.

2. ***Unclear definition of the OS life cycle.*** *Section 4 presents statistics about OS properties integrated over the OS life cycle. But since an OS is not the same as a whole convective system, it is not clear when the life cycle begins and ends. The lack of detail here prevented me from understanding and contextualizing the results. When exactly does the life cycle begin and end? How is it calculated when there are mergers and splits? For example, for OS #4 in the third row of Fig 5—when does the life cycle start and end in this case? The current explanation in Table 1 (last row) is not particularly helpful for the reader. A schematic may be helpful here.*

   Response: A schematic has been added as Fig. 6 in the revised manuscript to help understand the OS and CCO tracking (as illustrated below).

Fig. 6 illustrates an idealized tracking for a CCO and its OSs. The real-world CCO tracking can be much longer and more complicated than that in Fig. 6, and here, it is just used to illustrate how to understand the CCO and OS tracking. As illustrated in Fig. 6, the CCO tracking (dashed black line) can capture the variation in precipitation and anvil areas contributed by multiple convections, but it does not link these variations to specific convections. Mergers and splits in the CCO life cycle reflect the connections and disconnections between different convections. With the OS tracking, the CCO life cycle can be decomposed into the life cycles of its structural components (the colored lines in Fig. 6). It can be recognized that the life cycle of the CCO starts with three convective activities, and with time two of them are merged into the OS1 life cycle and the left one splits into two as the OS2 life cycle. In this way, precipitation and anvil clouds are associated with convective activities in CCOs. On the other hand, the CCO is a large envelope of many convective activities and it is not expected that they all have simple perfect life cycles from convective initiation to anvil dissipation. The OS might just be born from the split of the anvil or the secondary convective activity in its parent stronger convective body (e.g., the OS4 life cycle in Fig. 6) and ends by merging into the anvil in the CCO (e.g., the OS3 life cycle in Fig. 6). The OS tracking documents the life cycle of the core structure from initiation to dissipation. It can be expected that the active convective activities have robust and durable core structures in CCOs, while weak secondary convective activities are fragile and short-lived. In Fig. 7 and Fig. 8, the basic features of OS life cycles of different peaking strengths are investigated for their occurrence, duration and contributions to precipitation and anvil clouds.

The OS lifetime-accumulated precipitation and anvil amount are the sum of the observed OS precipitation and anvil in hourly satellite images during its lifetime. For example, for the OS1 life cycle in Fig. 6, the lifetime-accumulated precipitation and anvil amount are the sum of hourly precipitation and anvil in the OS1 life tree.

This clarification has been added to the revised manuscript.

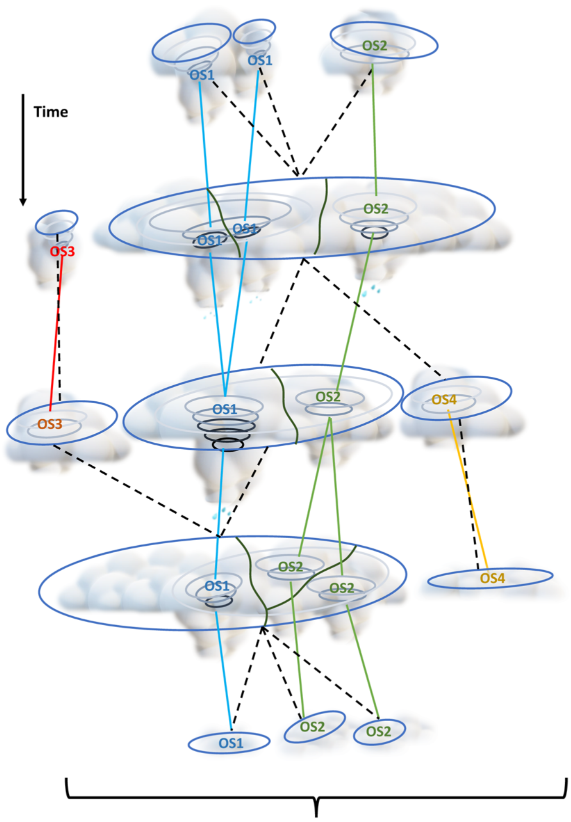


Figure 6. Illustrations of the difference between tracking a CCO and tracking OSs. The CCO life cycle consist of four OSs. The dash black line indicates the tree of the CCO life cycle. The blue, green, red and yellow lines indicate the tree of OS1, OS2, OS3 and OS4 life cycles, respectively.

(Line 404 / Fig 7a) It is surprising, almost hard to believe, that so many OSs with cold- core-peak BT < 220 K would have a life cycle of just 1 hour. Convection with this BT is near the cold point, and I would expect the life cycle to far exceed 1 hour in almost all cases.

Response: It is not expected that the OS would have a perfect life cycle from convective initiation to anvil dissipation. Some of OSs, even for those very cold structures, are just very short-lived overshooting with only 1-hour duration for the secondary convection in its parent stronger convective body and then disappear or could be annexed by its neighborhood stronger vertical-developing convection in CCOs.

Since the authors are using hourly BT images, a 1-hr lifecycle would mean that the OS appears in only a single image, which seems very strange for a convective plume with a BT as cold as 190 K. Is this real, or is this caused by something else (e.g., storms moving out of the study region, or a brief split in the OS before it merges back together). And for a 1-hr lifecycle consisting of just one BT image, how are the development and decay stages defined?

Response: The life cycles touching the missing images and edges are excluded from the analyses for quality control. The peaking time is counted as the development stage. Thus, for those short-lived OSs with only 1-hour duration, their development time is just 1 hour and the decay time is zeros. This has been clarified in the revised manuscript.

(Line 453 / Fig 9f) Because the life cycle is not clearly defined, the N parameter used in section 4 was confusing. Until N was introduced, I thought the results in section 4 were for individual OSs. I was then confused as to how a single OS could contain more than one OS. This must be because two OSs that merge together at a later time are actual considered as the same OS (as in Fig 5). Even so, I am not sure how N would be defined in many cases. E.g., if two cores merge together and later split back up, is N equal to 1, 2, 3, or 5?

Response: The N has been replaced with the lifetime (L) for understanding the impacts of mergers and splits on the precipitation and anvil production. The life cycle with mergers and splits has been illustrated in Fig. 6 in the revised manuscript. Yes, if two cores merge together and later split back up, N is equal to 5. We have revised this part to understand the mergers and splits from the lifetime instead of N. In the OS life cycle, the variation in the accumulated precipitation and anvil cloud amounts can be attributed to two possible factors: (1) the hourly precipitation and anvil production in the life cycle are enhanced by mergers and splits, and (2) the lifetime is prolonged by mergers and splits.

3. ***Motivation for section 4.*** *The results in section 4, if I am understanding correctly, are for individual OSs. It would be helpful to motivate this analysis more clearly. Why do we care about properties of individual OSs, as opposed to properties of entire convective systems?*
Response: The motivation for section 4 has been clarified at its beginning as follows: "The total precipitation and anvil cloud amounts of convection are important for tropical water and radiative budgets. They can be attributed to two factors: (1) the occurrence frequency of convection and (2) the precipitation and anvil production for the duration of convection. However, over the warm pool of tropical oceans, convective activities are clustered in CCOs and their precipitation and produced anvil clouds are merged (as discussed in Sect. 3). As a result, identifying their contributions to precipitation and anvil clouds is difficult. On the other hand, the CCO is a large cluster for a series of alternating successive convective activities, which are initiated at different times and evolve in different ways. Thus, there is a dilemma in tracking convection: convection is not isolated naturally for tracking, whereas the CCO is the envelope of many convections whose precipitating and anvil areas are mixed, and it is difficult to identify single convective processes from the CCO life cycle.
It has long been well observed by various active and passive sensors that tropical convections have core structures, e.g., convective pillars observed by active sensors (Igel et al., 2014; Takahashi and Luo, 2012; Deng et al., 2016), heavy raining cores observed by radar or passive microwave radiometer (Yuan and Houze, 2010; Feng et al., 2011), and cold cores of BT11 observed by GEO or MODIS radiometers (Yuan and Houze, 2010; Yang

et al., 2023; La and Messager, 2021). Although convective structures can be better identified by active sensors than by passive sensors, active sensors are only available at a limited number of ground-based sites or on polar-orbit satellites, and their samplings are too sparse for tracking. Yuan and Houze (2010) and Yang et al. (2023) both used active and passive sensors in combination and demonstrated that the BT11 structures are strongly associated with the convective structures. Yuan and Houze (2010) reported that cold and warm BT11 correspond to two distinct types of clouds detected by active sensors: very deep convective clouds and elevated anvil clouds. They partitioned the CCO into single-core high cloud systems (i.e., the OS defined in this work) and identified those OSs with heavy precipitation and the cold-core BT11 colder than 220 K as mesoscale convective systems (MCSs). For these MCSs, Yuan et al. (2011) observed that the cloud vertical structures are well organized, in which high-topped clouds extend outward from raining cores and the thickness of the anvil and the sizes of ice particles are closely related to the distance to the raining cores. Similarly, Yang et al. (2023) identified the cold cores of BT11 as convective centers and also found that the cold-core structures of BT11 are highly consistent with the convective structures detected by active sensors. These findings suggest that cold cores of BT11 can be used to identify the most convective-developing centers and distinguish convective activities in CCOs. In Sect. 3, a novel algorithm was developed to accomplish tracking for convective cold-core structures on the basis of previous studies (Yuan and Houze, 2010; Yuan et al., 2011) and GEO observations.

These OSs can be used to infer different convective activities clustered in CCOs. They are organized differently with various depths of development, precipitation and anvil production and have distinct evolution processes. In this section, on the basis of variable-BT11 tracking, the relationships of convective contributions to precipitation and anvil clouds with their BT11 structural evolution are explored. This would provide an opportunity to compare convections of different development strengths and evolutions for their contributions to precipitation and anvil clouds.”.

Specific Comments:

- There is no comment or justification about the choice of the 50% threshold for the Dynamic Overlap Ratios (lines 237-245). Is this an arbitrary choice or based on previous work? Do the authors expect the results to be sensitive to this choice? Have there been any sensitivity tests conducted, or at least a tally of how often an OS match fails due to DOR below 50%?

Response: The 50% threshold for the dynamic overlap ratios is based on the previous work (Williams and Houze, 1987). There is no doubt that the lower the area threshold is, the more easily the OS associations are.

In Fig. 1c-d (as shown below), the occurrence frequency of those overlapping conditions is listed at the top of each subpanel (the blue numbers), in which the red numbers in the parentheses refer to the frequency for conventional stationary overlaps without consideration of the OS movement. Here, every pair of OSs with overlaps is counted as one sample. For instance, if one OS has overlaps with five OSs of the next moment, there would be five pairs of overlapped OSs and the sample number is five. The frequency is defined as the occurrence of each overlapping condition in Fig. 1c-d divided by the total sample number. It is not surprising that the condition of (iii) in Fig. 1d accounts for the largest portion of samples, since the OSs in CCOs are close to each other and their margins are easily overlapped. As compared with the stationary overlaps, the dynamic overlaps increase the frequency of the overlapping condition of (ii) of Fig. 1c twofold and decrease the frequency of all other conditions. Overall, the dynamic overlaps increase the frequency of associations (the sum of frequency of (i), (ii) and (iv) in Fig. 1c and (ii) in Fig. 1d) by 2.5% from 21.2% (the frequency of associations for stationary overlaps) to 23.7%.

This has been clarified in the revised manuscript.

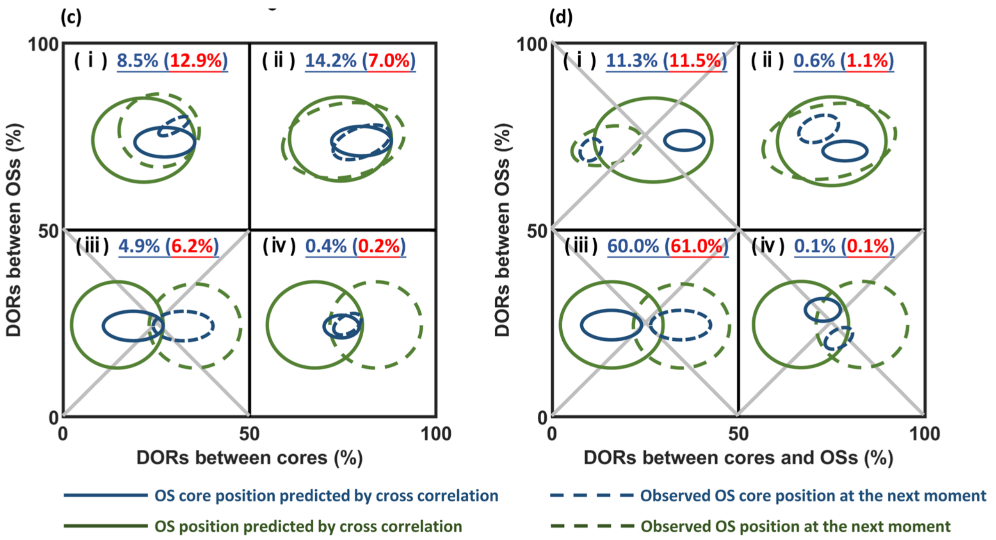


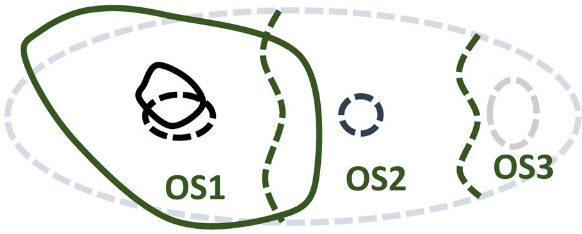
Fig. 1c-d. The dynamic overlapping situations of two OSs of different moments when their cores have overlaps and no overlaps, respectively. The solid blue and green lines indicate the core and OS of the current moment at the position predicted by cross correlation. The dashed blue and green lines indicate the core and OS positions of the next moment. The gray cross indicates the non-association between OSs. The occurrence frequency of each condition is listed at the top of each subpanel by blue numbers. The frequency for overlaps without consideration of the OS movement is listed in parentheses by red numbers.

- I understand why the situations in Fig 1c (iii) and Fid 1d (i, iii, and iv) are excluded based on DOR below 50%. These examples are obviously idealized cartoons used to explain the methodology, and I find them quite effective in doing so, but I am curious if situations like these would even be possible in the first place. Consider 1d (iii) as an example, which is the simplest because the structure of the OS is identical between the two time steps. In the first part of the tracking algorithm, cross-correlation is used to predict the location of the OS one hour into the future. This should predict a position that has maximum correlation with the actual BT11 observations from the next time step. So, why would the cross-correlation ever place the OS prediction in the spot that is shown in the figure? Shouldn't the maximum

correlation occur when the two solid and dashed lines exactly overlap?

Nothing has to be changes here, since these are just cartoon examples and the real observations are more complex. But I'm curious if these is just an idealized example that would not actually occur, or if I am misunderstanding something about the tracking procedure.

Response:



An OS might have overlaps with many OSs of the next moment simultaneously and the overlapping situations are various. For instance, as shown above, one OS can have large overlaps with the major core structure of an OS of the next moment (such as the overlap with OS1). And meanwhile it also can have some overlaps with the margins of another OS of the next moment (such as the overlap with OS2). The overlap in margins is the condition of (iii) in Fig. 1d. It can happen very frequently since the OSs in CCOs are close to each other and their margins are easily overlapped. The occurrence frequency of each overlapping condition in Fig. 1c-d has been listed in each subpanel (please see our response to the last comment).

More descriptions have been added to clarify the tracking procedures of Fig. 1c-d as follows: "Two OSs of different moments are associated in time and considered the same one OS at different times when these two OSs overlap sufficiently. With the dynamic overlap, an OS is moved to the new predicted location via cross correlation to overlap with the OSs at the next moment. In this case, a necessary condition to consider the associations of the OSs at the next moment to the OS is their DORs at least greater than zeros. After moving it to the new predicted location, an OS might have overlaps with many OSs of the next moment simultaneously and the overlapping situations are various. For instance, one OS can have large overlaps with the major core structure of an OS of the next moment and meanwhile it also can have some overlaps with the margins of another OS of the next moment. Those three DOR indices can be used to identify these distinct overlapping conditions from the overlapping degrees of their cores and OSs, as illustrated in Fig. 1c-d.

The overlapping situations of two OSs are distinguished by whether they have core overlaps (Fig. 1c) or not (Fig. 1d). A sufficient overlapping degree is discriminated by more than 50% of DORs, which is consistent with that in Williams and Houze (1987). If their cores have overlaps, with the DOR between either cores or OSs greater than 50%, the major parts of those pairs of OSs in situations (i), (ii) and (iv) in Fig. 1b are all sufficiently overlapped, and thus are associated as the same one OS of different times. The situation (ⅲ) in Fig. 1c with DORs of both cores and OSs less than 50% indicates that these two OSs are only overlapped in margins, without associations in time. In Fig. 1d, when the cores of two OSs are not overlapped, the determinant of the OS association relies on the DOR between OSs and the DOR of OSs to cores. In those cases, the OSs are associated in time only in situation (ⅱ) in Fig. 1d, with large overlaps of their major parts and those two DOR indices both larger than 50%. Those pairs of OSs in the other situations in Fig. 1d are obviously not associated. Overall, if the DORs of two OSs satisfy the overlapping conditions of (ⅰ), (ⅱ) and (ⅳ) in Fig. 1c and (ⅱ) in Fig. 1d, they are associated in time and regarded as the same OS evolving with time.

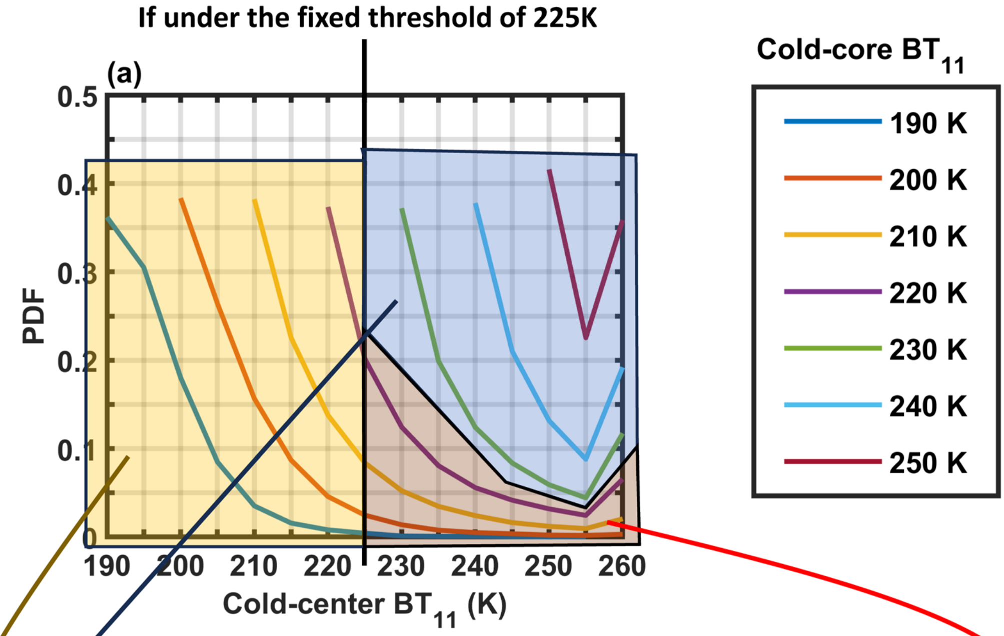
In Fig. 1c-d, the occurrence frequency of those overlapping conditions is listed at the top of each subpanel (the blue numbers), in which the red numbers in the parentheses refer to the frequency for conventional stationary overlaps without consideration of the OS movement. Here, every pair of OSs with overlaps is counted as one sample. For instance, if one OS has overlaps with five OSs of the next moment, there would be five pairs of overlapped OSs and the sample number is five. The frequency is defined as the occurrence of each overlapping condition in Fig. 1c-d divided by the total sample number. It is not surprising that the condition of (ⅲ) in Fig. 1d accounts for the largest portion of samples, since the OSs in CCOs are close to each other and their margins are easily overlapped. As compared with the stationary overlaps, the dynamic overlaps increase the frequency of the overlapping condition of (ⅱ) of Fig. 1c twofold and decrease the frequency of all other conditions. Overall, the dynamic overlaps increase the frequency of associations (the sum of frequency of (ⅰ), (ⅱ) and (ⅳ) in Fig. 1c and (ⅱ) in Fig. 1d) by 2.5% from 21.2% (the frequency of associations for stationary overlaps) to 23.7%.".

- Line 315-327 / Fig 4a: I've read this paragraph several times and think I mostly understand the point the authors are making here, but I think some of it is still not getting though. I think the authors are just saying that fixed BT thresholds do not capture the structural complexity that still exists in the region where BT is colder than the threshold. But I am not sure how this related to Fig 4a, which I am struggling to understand. Why would most of OSs have cold-center BTs equal to their cold-core BT? Shouldn't the cold-center BTs always be warmer? And if they are indeed equal, wouldn't that mean that most cores are only ~1K colder than the rest of the convective complex? I am pretty sure I am misunderstanding something here, so it would be helpful to clarify this section.

Response: The cold core and cold center are identified by a set of adaptive thresholds of 180-260 K per 5-K interval. Thus, the cold-core and cold-center BT11 is 180, 185, 190, … 260K. If the cold-core BT11 is 190K, the cold-center BT11 could be 190, 195, … 260K. If the cold-center BT11 is 200K, it means that this OS can be isolated within the 200-K isotherm and there is no need of segmentation (the fixed-threshold identification under 200 K can be used), but in the 205-K or warmer isotherm it would be connected with other OSs (the variable-BT11 identification is needed for segmentation).

There is no doubt that the warmer the selected BT11 threshold is, the more complex the identified target is in the fixed-threshold identification. But, can we just use one cold

BT11 threshold to avoid the complicated connected convective organizations? If it works, the fixed-BT11 tracking under the cold threshold would perform well. The aim of Fig. 4a is to answer this question. For instance, Feng et al. (2018) tried to use two thresholds to identify convective systems with a cold threshold of 225K to capture the cold core and a warm threshold of 241K to find the cloud pixels associated with the cold cores. In this case, is the 225-K cutoff the simple or complicated structure? Fig. 4a gives the answer as shown below.



(1) For the OSs of the cold-core BT11 from 230-260K, they would be ignored since these OSs develop warmer than 225K;

(2) For the OSs of the cold-core BT11 from 190-220K and the cold-center BT11 190-220K, these OSs would be in complicated convective organizations, which cannot be simply identified by the fixed threshold of 225K;

(3) For the OSs of the cold-core BT11 from 190-220K and the cold-center BT11 225-260K, they can be directly isolated by the fixed threshold of 225K, but it only accounts for a small portion of the OSs with cold-core BT11 from 190-220K.

This paragraph has been modified as: "In Fig. 4, the OS structural characteristics (i.e., the connecting conditions with other surrounding OSs in CCOs and their contributions to precipitation and anvil cloud areas) of different development depths with the cold-core BT11 from 190-250 K are investigated. In Fig. 4a, for the OSs of the cold core from 190-250 K, the probability distribution functions (PDFs) of the cold-center BT11 are shown. The cold-core and cold-center BT11 are both identified by 5-K-interval adaptive thresholds (see details in Section 3.1). The PDFs in Fig. 4a have a maximum peak of approximately 36-41% when the cold-center BT11 is equal to the cold-core BT11. This implies that for most of them only the cold core can be isolated by the fixed threshold. For the deep convection of the cold-core

BT11 at 190-220 K, the isolated structure with a cold-center BT11 of 260 K is rare, but it is relatively more frequent and seems to be another mode for the shallow warm systems of the cold-core BT11 at 230-260 K. However, fixed-threshold tracking is not capable of discriminating between isolated and complicated structures.

There is no doubt that the warmer the selected BT11 threshold is, the more complex the identified target is in the fixed-threshold identification. However, can one cold BT11 threshold be used to avoid complicated connected convective organizations? If feasible, the fixed-BT11 tracking under the cold threshold performs well. For instance, Feng et al. (2018) tried to use two thresholds to identify convective systems with a cold threshold of 225 K to capture the cold core and a warm threshold of 241 K to find the cloud pixels associated with the cold cores. In this case, is the 225-K cutoff a simple or complicated structure? If under the fixed threshold of 225 K, Fig. 4a shows that:

1) For the OSs of the cold-core BT11 from 230-260 K, they would be ignored since these OSs develop warmer than 225 K;
2) For the OSs of the cold-core BT11 from 190-220 K and the cold-center BT11 from 190-220 K, they would be in complicated convective organizations, and cannot be simply identified by the fixed threshold of 225 K;
3) For the OSs of the cold-core BT11 from 190-220 K and the cold-center BT11 from 225-260 K, they can be directly isolated by the fixed threshold of 225 K, but it accounts for only a small portion of the OSs of the cold-core BT11 from 190-220 K.

This implies that even under the cold BT11 threshold, most of the identified targets still have complex organizations.”.

- Line 343-344: “The results in Figs. 4c-e might imply that the OSs of colder cores have increased precipitation efficiency, which contributes to both more precipitation and anvil clouds.” I do not see how the authors can claim that greater precip efficiency leads to greater anvil cloud area. What would be the proposed mechanism for this? Lindzen et al (2001) suggested the exact opposite, although I am not presently aware of any evidence for their claim that does not rely on model microphysics parameterizations. The authors find that storms with lower BT have greater precip efficiency, greater precip area, and greater anvil area. But this might simply mean that storms with lower BT are larger storms. To assess the relationship between precip efficiency and anvil area, one would have to control for BT. I suggest revision of this sentence. Another conclusion could be that the observed relationship between BT and precip efficiency might be expected – storms with higher precip efficiency generally have less dry air entrainment, which may allow updrafts to reach higher altitudes and lower BTs.

Response: Thanks. The previous statement has been removed. A new conclusion according to the reviewer’s comment has been added: “the observed relationship between BT11 structures and precipitation efficiency might be expected. Storms with higher precipitation efficiency generally have less dry air entrainment, which may allow updrafts to reach higher altitudes and lower BT11.”.

- How exactly is the lifetime-accumulated anvil fraction defined? Are you simply adding up the anvil areas from each BT image? The units are km^2, but if you are measuring area over

*a period of time, shouldn't the units be hours*km^2?*

Response: Yes, the lifetime-accumulated anvil areas are computed by adding up the anvil areas from each hourly BT image during the lifetime. The unit of the anvil area in each hourly BT images is km^2 and thus the sum of it over a period of time is km^2*hour. The units have been corrected in the revised manuscript.

- Fig 9 / line 446-450. I imagine that much of the differences in anvil area and precip between four these subgroups can be explained simply by the differences in life cycle duration shown in Fig 9c. The fractional changes in anvil/precip seem to roughly line up with the fractional changes in duration. I would not expect this to be exact of course, but maybe this could explain most of the difference.

Response: Yes, the changes in the duration are very important for explaining the differences in anvil area and precipitation.

This paragraph has been modified as: "How do mergers and splits influence the lifecycle-accumulated precipitation and anvil cloud amounts? This question is simply explored from the OS tracking. In the OS life cycle, the variation in the accumulated precipitation and anvil cloud amounts can be attributed to two possible factors: (1) the hourly precipitation and anvil production in the life cycle are enhanced by mergers and splits, and (2) the lifetime is prolonged by mergers and splits.

In Figs. 11a-b, the hourly mean precipitation and anvil amount in the OS life cycles are shown for different types of life cycles. For the same cold-core-peak BT11, the hourly mean precipitation of different lifecycle types is nearly invariant (Fig. 11a). However, in the life cycles with the occurrence of mergers and splits, the hourly mean anvil production is enhanced (Fig. 11b), and the lifetime (L) is significantly prolonged (Fig. 10c). To quantify their impacts, in Figs. 11c-d, the anomalies of the lifetime-accumulated precipitation and anvil cloud amounts can be decomposed as follows:

$$PL - \bar{P}\bar{L} = \bar{L}P' + \bar{P}L' + P'L', \quad (7)$$

$$AL - \bar{A}\bar{L} = \bar{L}A' + \bar{A}L' + A'L'. \quad (8)$$

P and A are the hourly precipitation and anvil cloud amount, respectively. L is the lifetime. Thus, PL and AL represent the lifetime-accumulated precipitation and anvil cloud amount, respectively. The bar over the letter represents the mean of different lifecycle types. The prime over the letter represents the anomaly of different lifecycle types relative to their mean value. In this way, $\bar{L}P'$ and $\bar{P}L'$ indicate the contributions of the hourly precipitation anomaly and the lifetime anomaly, respectively, to the variation in lifetime-accumulated precipitation. Similarly, $\bar{L}A'$ and $\bar{A}L'$ indicate the contributions of the hourly anvil production and lifetime anomalies, respectively, to the variation in the lifetime-accumulated anvil amount. $P'L'$ and $A'L'$ are high-order small quantities and are neglected. The fraction of the contribution can be computed by dividing the left-hand-side quantities of Eq. 7 and Eq. 8. Fig. 11c (Fig. 11d) shows the fractions of the contributions of $\bar{L}P'$ and $\bar{P}L'$ ($\bar{L}A'$ and $\bar{A}L'$) to the increase in lifetime-accumulated precipitation (anvil) from simple to complicated life cycles. For the life cycles of the cold-core-peak BT11 colder than 220 K, $\bar{L}P'$ has a relatively small contribution of approximately 10-25%, whereas $\bar{P}L'$ has a large contribution of approximately 60-80%. In addition, $\bar{L}A'$ and $\bar{A}L'$ both have positive comparable contribution fractions, approximately 20-40% and 40-60%, respectively. For the warmer life cycles, the contributions from $\bar{L}P'$ and $\bar{L}A'$ increase and are more important than the lifetime anomaly for the variation in the lifetime-accumulated precipitation and anvil cloud amounts.

On average, in comparison with simple life cycles, mergers and splits can significantly prolong the duration of OSs while enhancing the hourly precipitation slightly and increasing the hourly anvil production strongly. From simple to complicated life cycles, a prolonged lifetime accounts for the largest contribution to the increase in accumulated precipitation and anvil clouds for cold structures.”.

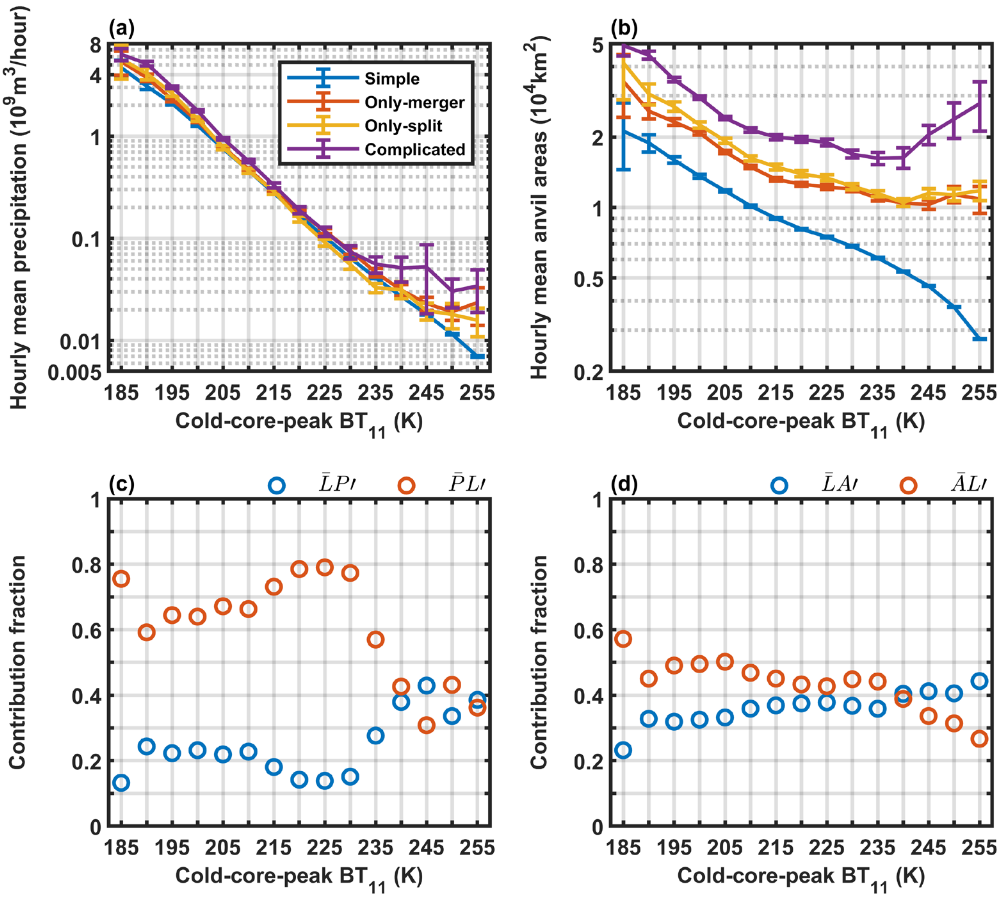


Figure 11. Composites of the hourly mean precipitation (a) and anvil cloud amounts (b) of different lifecycle types in each bin of the cold-core-peak BT11, respectively. The blue, red, yellow and purple lines indicate the simple, only-merger, only-split and complicated life cycles, respectively. (c) The fractions of contributions of the hourly precipitation anomalies ($\bar{L}P'$) and the lifetime anomalies ($\bar{P}L'$) to the variation in lifetime-accumulated precipitation. (d) The fractions of contributions of the hourly anvil production anomalies ($\bar{L}A'$) and the lifetime anomalies ($\bar{A}L'$) to the variation in the lifetime-accumulated anvil amount. The error bars indicate the 95% confidence intervals of the means based on the t test.

- Line 452: Is the difference in life cycle duration not another mechanism that could explain these differences?

Response: Yes, the changes in the duration are very important and account for the largest contribution to the variation of the accumulated precipitation and anvil clouds. This paragraph has been revised and please see our responses to the last comment.

- Line 467: if A and P are hourly anvil and precip, and N is the total accumulated number of OSs, I do not understand how AN and PN are the lifecycle accumulated A and P. Doesn't there need to be a life cycle duration term in here to achieve that result? E.g., PND, where P is mean hourly precip for a single OS, N is the number of OS, and D is the life cycle duration of each OS?

I do not doubt that the author's analysis and units are correct, but I think there is a miscommunication or mislabeling here.

Response: Thanks. We have decomposed the lifetime-accumulated precipitation and anvil areas into the hourly mean precipitation and anvil and lifetime, respectively, to explain the variation in the precipitation and anvil clouds in the OS life cycles. Please see our responses to the comments on Fig. 9.

- It would help contextualize the results in section 4 if the frequency of the four life cycle categories are provided somewhere. The authors state that simple life cycle events are rare, but I don't believe the numbers are not actually provided.

Response: The simple life cycle without mergers and splits is the most frequent and accounts for 93.9% of samples. The only-merger, only-split and complicated life cycle have the frequency of only 3.0%, 1.4% and 1.7%, respectively. This has been provided in the Section 4.3 in the revised manuscript.

- In section 4, it would be appropriate to remind the readers that "anvil" as defined here still requires BT<260. In reality, much the area of detrained cirrus has BT warmer than 260. Berry & Mace 2014 and Sokol & Hartmann 2020 show that anvils with optical depth of 1-2 are extremely common, and Gasparini et al 2022 (DOI: 10.1175/JCLI-D-21-0211.1) showed that these anvils can have BTs warmer than 260.

Response: This has been added at the beginning of Section 4 to remind the readers about the anvil definition in this work, as follows: "Notably, the anvil identification requires that the BT11 is colder than 260 K and the precipitation is less than 1 mm/hour. It can be used to reflect the anvil productivity in the convective systems (Yuan and Houze, 2010; Yuan et al., 2011; Yuan and Houze, 2013), but much the area of detained cirrus has the BT11 warmer than 260 K in reality (Gasparini et al., 2022; Sokol and Hartmann, 2020; Berry and Mace, 2014). Normally, those thin cirrus clouds are not well identified by GEO radiometers and thus in this work, the anvil just refers to the thick anvil portion identified by the 260-K BT11 threshold but not all detrained anvil cirrus clouds.".

- An interesting validation experiment for the tracking algorithm could be done using a cloud-resolving model with high-frequency output and a BT11 simulator. "Observations" could be taken from the simulation at every hour, and the tracking could be applied to those

"observations". The tracking results could then be compared to the higher-frequency model output to see if the segments are correctly tracked. This is a big undertaking and is not a suggestion for the current paper, simply an idea if the authors ever wished to further validate the algorithm while avoiding the uncertainties associated with the wind observations.

Response: Thanks. We believe it is a very constructive and interesting idea for our future work to further evaluate this tracking algorithm from cloud-resolving models and to apply this algorithm to compare the difference between observed and simulated life cycles. Thanks to the reviewer again for your precious insightful comments.

Minor/Line Comments:
- Line 311-314: I suggest revising this section, as I am not sure what it is saying after reading it a few times: "The complexity of convective organizations can be inferred from the cold-center BT11 of OSs. Only when the cold-center BT11 is 260 K is the OS of the isolated convective body. Under the fixed BT11 threshold, the OS of the cold-core BT11 that is warmer than the selected threshold cannot be identified. The OS of the cold-center BT11 that is colder than the selected threshold cannot be isolated from CCOs.".

Response: This sentence has been deleted and more specific descriptions have been added:

"There is no doubt that the warmer the selected BT11 threshold is, the more complex the identified target is in the fixed-threshold identification. However, can one cold BT11 threshold be used to avoid complicated connected convective organizations? If feasible, the fixed-BT11 tracking under the cold threshold performs well. For instance, Feng et al. (2018) tried to use two thresholds to identify convective systems with a cold threshold of 225 K to capture the cold core and a warm threshold of 241 K to find the cloud pixels associated with the cold cores. In this case, is the 225-K cutoff a simple or complicated structure? If under the fixed threshold of 225 K, Fig. 4a shows that:

1) For the OSs of the cold-core BT11 from 230-260 K, they would be ignored since these OSs develop warmer than 225 K;
2) For the OSs of the cold-core BT11 from 190-220 K and the cold-center BT11 from 190-220 K, they would be in complicated convective organizations, and cannot be simply identified by the fixed threshold of 225 K;
3) For the OSs of the cold-core BT11 from 190-220 K and the cold-center BT11 from 225-260 K, they can be directly isolated by the fixed threshold of 225 K, but it accounts for only a small portion of the OSs of the cold-core BT11 from 190-220 K.

This implies that even under the cold BT11 threshold, most of the identified targets still have complex organizations.".

- Fig 1c,d: the terminology in the labels is a bit confusing here, and it took me a while to figure out what was being shown. One possible revision is to label the solid lines as "OS position predicted by cross correlation" and the dashed lines as "observed OS position".

Response: Thanks. The labels in Fig. 1c and 1d have been modified as "OS position predicted by cross correlation" and "Observed OS position at the next moment", as shown below.

- Line 247-248: "The variation in the cold-core BT11 is prior to the variation…and decay." The use of the word "prior" here was a bit confusing – perhaps "considered first" instead?

Response: It has been corrected.

- Line 329: "the colder OS" -> "a colder OS"

Response: It has been corrected.

- Line 330: "the warmer OS" -> "a warmer OS"

Response: It has been corrected.

- Line 434-435: "is more distributed". Is there a word missing here between "more" and "distributed"?

Response: It has been revised as: "the cold-core BT11 of mergers is distributed at colder BT11 values than that of splits"

- Line 480: "anvil production is enhanced" – is the evidence for this just that the $\overline{N}A^{'}$ term is positive? I am just trying to understand.

Response: Yes, the term of $\overline{N}A'$ has a positive contribution. And according to the Fig. 11 in the revised manuscript (or the Fig. 9 in the previous manuscript), for the life cycles from simple to complicated, the hourly anvil production is gradually enhanced with the occurrence of mergers and splits.

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