nature portfolio

Peer Review File

Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon

Corresponding Author: Professor Hong Yan

This file contains all reviewer reports in order by version, followed by all author rebuttals in order by version.

Version 0:

Reviewer comments:

Reviewer #1

(Remarks to the Author)
The manuscript "Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon" (NCOMMS-24-71428-T) presents a new lake record from Bromfield Swamp, tropical northeastern Australia. The authors reconstruct the Australian summer monsoon over the Younger Dryas and the Holocene and compare the results to East Asian monsoon records. The authors suggest that the inter-hemispheric energy imbalance is driving variability in the East Asian and Australian monsoon via the ITCZ position. The manuscript is well written, and the presented lake record is a valuable contribution to the existing paleoclimate records of the Asian-Australian monsoon region. However, the authors omit many recently published records and theories of the winter and summer monsoons in this region and confirm known concepts of the monsoon's phase behavior without an in-depth analysis of potential drivers. In my opinion this work would be better suited in another journal after revision. My main concerns are:

1. The findings on Asian-Australian monsoon drivers presented here have already been discussed in previous publications.
2. There is no newly developed method or framework presented in this work, although the presented data is an important contribution.
3. The authors based their main conclusions on the comparison with two records from East Asia, which is an oversimplification of observations in this region. There are conflicting observations regarding these records and thus no conclusions can be made without an in-depth discussion on why these records were chosen over others.

Please find more detailed comments below:
In the introduction the authors briefly comment on the suitability of speleothem records in reconstructing monsoon variability, suggesting that these records can be biased towards reflecting source dynamics rather than reflecting local rainfall (Lines 42 to 46). Based on this they exclude speleothem records from their synthesis, which is the main basis for their conclusions (Fig. 3). However, in recent years many publications of speleothems across this region (particularly in Southeast Asia) made an effort to distinguish these two signals by using trace elements and carbon isotopes. These records should be discussed in this work as they more directly reflect summer monsoon rainfall. In addition, Eroglu et al., 2016 applied newly developed statistical approaches to the Dongge and KNI-51 cave records, presenting similar conclusions as the authors in this manuscript and should therefore be discussed as well. A deeper discussion of previous work could allow the reader to identify which knowledge gaps in our understanding of the Australian monsoon are being addressed here.
Since the main conclusions of this work are based on the comparison between the Bromfield Swamp record and two records from East Asia, there needs to be an in-depth discussion on the suitability of theses EASM and EAWM records. For example, Kaboth-Bahr et al., 2021 presented a synthesis of non-speleothem archives reconstructing the EASM and EAWM. They found that there was an in-phase relation between EASM and EAWM from 9 to 4 ka and no correlation was observed during the late Holocene. This is in direct contrast to Kang et al, 2020 (presented in figure 3b) who suggested a clear anti-phase relationship between EASM and EAWM from 12 to 0 ka. My concern is that the choice of records directly impacts the conclusions made here and it is not clear to me why the authors chose these records over others.
Overall, it is not clear to me why the authors present the Younger Dryas section of the record in this context. The introduction and title only address Holocene variability and do not mention any knowledge gaps regarding the YD. Therefore, the section "The humid condition during the YD event" and the description in the abstract seem out of place. I would suggest including a short discussion regarding the Australian summer monsoon during the YD in the intro and highlight remaining questions that the data presented here can answer. This should also help to highlight the importance of this new record.
Supplemental figure S2 is a direct copy from Shi, G. et al. Rapid warming has resulted in more wildfires in northeastern

Australia. Science of The Total Environment 771, 144888 (2021) and should be double-checked for potential copy right issues.
Instead of “local summer insolation” please use ”summer insolation at a certain latitude”. “Local” refers to the sample site rather than a certain latitude.

Reviewer #2

(Remarks to the Author)
This new record from Bromfield Swamp is clearly an important one, it is well dated and high resolution from a region where such records are scarce. It provides interesting information on the conditions through the last 13ka at the site and leads to increased understanding of the regional paleoclimate.

I wonder if some of the strength of the record is lost by concentrating the discussion on the PC1 curve rather than looking at some of the differences in response across the multiple proxies. The OC curve seems to show differences from the elemental analyses for example in the earliest part of the record (due to global temperature?) and in the mid Holocene where it shows more of a threshold response to change.

I also found the discussion around the Younger Dryas response a bit oversimplified, as there are similar ‘events’ in the record either side of the YD one i.e. at 10 and 13ka and the wet phase does not occur throughout the YD as delimited in Figure 3.

The discussion of the regional paleoclimate implication of this new record are feasible but may just push the interpretations too far, in terms of what one single record can show when compared with one other. A little caution in the interpretation is probably valid here, despite a fairly convincing story.

Overall a little more consideration of the detail is required throughout, as it’s interesting and potentially adds to, rather than detracts from, any story.

Reviewer #3

(Remarks to the Author)
The manuscript entitled "Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon“ presents a new high resolution summer Australian-Indonesian monsoon (AIM) record, which was derived from lacustrine sediments of Bromfield Swamp in northeastern Australia. The objective of this work was to study the dynamics of the summer AIM as well as the linkage between the East Asian monsoon (EAM) and AIM and western Pacific ITCZ. The studied time interval is represented by the last 13,500 years. The major findings of this study are that the summer AISM was stronger during the Younger Dryas (YD) event, weaker during the early Holocene and stronger again from the middle to late Holocene. The authors conclude that the summer AIM in the Southern Hemisphere tropics was not only controlled by local solar insolation, but also controlled by Northern Hemisphere high latitude climate changes through cross-equatorial airflow from the EAWM, which may have affected the summer AIM during the YD and the early Holocene. The authors further suggest that the Holocene summer AIM show an anti-phase behaviour with the EASM and both were significantly correlated with the Southern-Northern Hemisphere temperature gradients. This most likely suggests that the inter-hemispheric energy imbalance was the direct forcing driving the Holocene AIM system by modulations in the mean position of the western Pacific Intertropical Convergence Zone (ITCZ).

I really appreciate studies like this one trying to better understand the relationship between both monsoon systems because although a link between both monsoon systems is apparent in modern climates (e.g., Trenberth et al., 2000), this relationship has not yet been well defined for past climates. This is an interesting piece of work and an important step forward, as it delivers in my opinion a new, additional viewpoint how to link the EAM and AIM during the past.

I have a few comments and suggestions that the authors might find worth considering. I think the authors could make a stronger point if they would compare their record of changes in summer AIM with previous published summer AIM records, such as those mentioned in their manuscript (lines 14-18) in order to verify that their record is valid (not affected by other local climate perturbations) and are a representative record of summer AIM changes. This could be done for example in Figure 3 or in another figure in the supplements. In addition, the authors could make a stronger argument if the authors would take a look at records from Indonesia since those records are from the same monsoon system. Please see the summer AIM record by Mohtadi et al. (2011). Please also consider the Lynch‘s crater record from tropical northeastern Australia (Müller et al., 2008). Noteworthy, both records do no show a stronger summer AIM during the YD. Please have a look on those records. I am a bit worried to see that the dynamic linkage of both monsoon systems is currently based only on a single summer AIM record. If the proposed driving forces are the dominant control to link both systems, I would expect to see the same summer AIM history also in other records from the AIM region.

Lines 167-172: It appears however from a compilation of tropical Pacific ENSO records from c. 10 ka BP to present that indicates a moderate ENSO activity in the early Holocene, reduced ENSO activity in the middle Holocene and enhanced ENSO during the late Holocene. Please see Mark et al. (2022).

I believe that this manuscript will attract a broad interest from palaeoclimatologists and climate modellers, therefore should be appealing to the palaeo-monsoon community after revisions have been made.

Version 1:

Reviewer comments:

Reviewer #1

(Remarks to the Author)
The authors have carefully responded to all my comments and provided detailed explanations. I really appreciate the effort and find that the manuscript has improved greatly! The impact of this work is now clear, and the addition of further records provides a more in-depth understanding of A-AuMS dynamics.

I recommend publication and suggest the following small edits:
In line 7 and 8: consider changing ‘evolution of Holocene’ to ‘long-term evolution’ or orbital-scale evolution, etc. This way it is not limited to just Holocene and addresses a larger audience.

Figure 3a, the tick marks and labels for insolation are missing.

Figure 4 and the introduction/discussion needs to include recent publications from Vietnam and Thailand as these three records also cover the YD and Holocene. The speleothems have sufficient resolution for the 100 yr/point requirement.
- Speleothems Vietnam: Patterson et al., 2023 (https://www.pnas.org/doi/10.1073/pnas.2219489120) and related manuscripts, which may be helpful to consider (https://www.nature.com/articles/s41467-024-53422-y and https://www.nature.com/articles/s41467-023-41373-9))
- Lakes Vietnam: Đào-Trung et al., 2024 (https://journals.sagepub.com/doi/10.1177/09596836241236342)
- Speleothems Thailand: Jacobson et al., 2024 https://www.sciencedirect.com/science/article/pii/S0277379124000982

Reviewer #2

(Remarks to the Author)
Thank you for the opportunity to look at the revised manuscript, and for some of the changes made based on the reviewers comments. I was reviewer two of the original submission.

I can see that clear effort have been made to address my original comments, but I'm not yet convinced that the spirit of those comments have been taken on board - my overarching feeling from reading the revised paper is that still it tries to do to much with the data produced, in part because it tries to tell an oversimplified story.

For example, the YD may well be 'wet' in the record, but it is not universally 'wet' through the YD, however defined.

I like the new Figure 4, but the time periods chosen for comparison will be important here - I still thing etc YD look like what is going on c. 10k and c.13k in your index - we can agree to disagree on this maybe!

The index (PC1) is strongly driven by the XRF data, at least visibly, so I'm still not sure what part the multi proxies play in the interpretation.

I tend to worry about detail such as this, so please don't take this as detracting from what I think is a nice record that is worthy of publication - I just thing the paper needs to be as polished as it can be, and I'm not fully convinced it is yet.

Reviewer #3

(Remarks to the Author)
I appreciate the effort that the authors made to address my previous comments and suggestions on the manuscript entitled “Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon”. In particular, I really appreciate it that the authors have compared their record with other records in the AIM region – although of lower resolution than their record – these records help to support their interpretation. As I mentioned in my previous review, this is an interesting piece of work and an important step forward, as it delivers in my opinion a new, additional viewpoint how to link the EAM and AIM during the past. Having read their response to the comments and suggestions of the other reviewers, I think that this manuscript can can be accepted for publication now. I believe that this manuscript will attract a broad interest from palaeoclimatologists and climate modellers.

Version 2:

Reviewer comments:

Reviewer #2

(Remarks to the Author)
Thanks to the authors for their responses to points raised in my reviews.

To complete the discussion around definition of the YD, at least in terms of this correspondence, please make sure it is clear which YD is represented by the blue bar in Figure 2 i.e. note in the caption how this is defined (NGRIP?).

I guess we'll have to agree to disagree about some things!

Reviewer #1 (Remarks to the Author):

The manuscript "Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon" (NCOMMS-24-71428-T) presents a new lake record from Bromfield Swamp, tropical northeastern Australia. The authors reconstruct the Australian summer monsoon over the Younger Dryas and the Holocene and compare the results to East Asian monsoon records. The authors suggest that the inter-hemispheric energy imbalance is driving variability in the East Asian and Australian monsoon via the ITCZ position. The manuscript is well written, and the presented lake record is a valuable contribution to the existing paleoclimate records of the Asian-Australian monsoon region. However, the authors omit many recently published records and theories of the winter and summer monsoons in this region and confirm known concepts of the monsoon's phase behavior without an in-depth analysis of potential drivers. In my opinion this work would be better suited in another journal after revision.

We truly appreciate the constructive comments the reviewer put forward. In this study, we present a new AuSM record in northeastern Australia, the front edge region of the AuSM, where is of great significance for the study of AuSM dynamics but currently lacks identified high-resolution monsoon records. Combining with the East Asian monsoon records, we find that the AuSM and EASM presented opposite variations during the Holocene, and were highly correlated with the temperature gradient between the Northern and Southern Hemispheres, indicating that the thermal imbalance between the two hemispheres dominated the Holocene Asian-Australian monsoon system (A-AuMS) variations by regulating the mean position of the Intertropical Convergence Zone (ITCZ). Retreat of ice sheets in Northern Hemisphere high latitudes and opposite variations of summer insolation in both hemispheres are proposed as important driving forces for the evolution of A-AuMS during the early to middle Holocene, and middle to late Holocene, respectively. The impact of Northern Hemisphere ice sheets on AuSM evolution during the early to middle Holocene highlighted in this study is quite different from the previous acknowledge that the Holocene tropical monsoon evolution was dominated by low latitude summer insolation. As there have been no AuSM records to detect the influence of Northern Hemisphere high-latitude ice sheets during the Holocene epoch up to now, we believe our work is innovative and suitable for the Nature Communications.

We have carefully revised our manuscript based on the reviewer's comments, including strengthened the comparisons with previous records and supplemented the discussions of existing studies, to enhance the credibility of this work. We have also provided the one-by-one responses to those comments in the following.

My main concerns are:

1. The findings on Asian-Australian monsoon drivers presented here have already been discussed in previous publications. There is no newly developed method or framework presented in this work, although the presented data is an important contribution.

Thank you for the comment. Yes, the "thermal imbalance" hypothesis has been discussed for the Australian monsoon changes, but it is mainly on the millennial timescale (Ayliffe et al., 2013; Gibbons et al., 2014). For changes in the Holocene Australian monsoon, this hypothesis has not been discussed or confirmed yet. Holocene is an essential period on the paleoclimate research that has attracted great attention. Early studies of global monsoon during the Holocene based on stalagmites suggested that the stalagmite records from China and South America were anti-phased (similar phenomena are commonly observed in precessional cycles), which was synchronous with the local summer insolation (Dykoski et al., 2005; Cheng et al., 2016; van Breukelen et al., 2008; Cruz et al., 2005; Mosblech et al., 2012; Novello et al., 2017). An important implication of this viewpoint is that the tropical monsoon evolution over the Holocene is mainly controlled by the low latitude insolation (here we simply call it the "tropical insolation control hypothesis"), but it seems has no relationship with high-latitude processes. However, it is worth noting that the stalagmite records used to support this viewpoint mainly come from Asia and South America. These two monsoons are not included in one coupling monsoon system. It is mainly because that the records coming from Australian monsoon region are largely absent. Later, the Holocene stalagmite record KNI-51 from northwestern Australian continent was reported, but the result doesn't support the above hypothesis, implying that the "tropical insolation control hypothesis" may not be universally applicable. However, the stalagmite record from western Australia is just a single record, lacking cross-validation with other records. Furthermore, many recent studies suggest that stalagmite $\delta^{18}O$ possibly reflects more about oxygen isotopic signal in moisture source region or circulation intensity, rather than monsoon intensity and local precipitation (Liu et al., 2015). In this case, obtaining new monsoon records from other archives in northern Australia becomes very important; the subsequent clarification of the monsoon dynamics may also differ from what we previously understood.

Therefore, just as the reviewer stated, one of the key contributions of this study is that we obtain a high-resolution lake sediment-based Holocene hydrological record from northern Australia. This is important to the paleomonsoon study in monsoonal Australia, where high resolution records are scarce. Meanwhile, we propose that the "thermal control hypothesis" can systematically account for existing paleoclimate records, which is quite different from the previous "tropical insolation control hypothesis". The "tropical insolation control hypothesis" assumes that only low-latitude processes control the Holocene tropical monsoon. Our "thermal control hypothesis" suggests that, in addition to the low-latitude processes, Northern Hemisphere high-latitude ice volume could also influence the early Holocene AuSM through the cross-equatorial air flow. We appreciate the reviewer's comment, which provides us an opportunity to further clarify this issue well in the manuscript. Therefore, in the revised manuscript, we have further emphasized this difference in the Introduction and Discussion.

In addition to the reviewer's suggestion, we have also added the discussion of Asian-Australian monsoon during the YD event in the revised manuscript (in Introduction and Discussion). Although the southward migration of ITCZ and the strengthening of AuSM during the YD event have been suggested by many records and simulations, the detailed spatial pattern of the Asian-Australian monsoon system during the YD event has not yet been displayed. In the revision, we have supplemented relevant content (please see the response to question 5 below).

2. The authors based their main conclusions on the comparison with two records from East Asia, which is an oversimplification of observations in this region. There are conflicting observations regarding these records and thus no conclusions can be made without an in-depth discussion on why these records were chosen over others.

We chose the Gonghai record to represent EASM changes for its precise chronology and high-resolution data. Also, it is located at the margin of EASM region, and hence sensitive to monsoonal changes. The stacked grain size record from 3 loess sections on Chinese Loess Plateau (CLP) was used to reflect EAWM changes. It is because that the CLP was formed by the direct accumulation of sediments brought by the EAWM. Therefore, these two records were considered relatively representative. Reminded by the reviewers and editor, we realize that a single record is insufficient to support our study. In the revision, we have supplemented more records for comparison.

In the revision, we use two integrated records to represent EASM changes during the Holocene (Wang et al., 2010; Wang and Feng, 2013). One is synthesized by pollen records along the EASM margin, the other is an integration of 92 records from the entire monsoon region. As a supplement, we have also collected some new records from the northern to southern EASM region beyond these two composite records, including the records from Lake Gonghai, CLP, Dajiuhu wetland and Huguangyan Maar (see Fig. 3 and Fig. S5) (Chen et al., 2015; Lu et al., 2013; Wang et al., 2014; Xie et al., 2013; Jia et al., 2015). Most of these records consistently show a strong EASM during the middle Holocene, which is the same as the record we cited in our original manuscript.

Meanwhile, we also collected existing Holocene EAWM records comprehensively (Table S2 and Fig. S4). Among 20 collected records, 8 were loess or eolian records from 10 sections on the Chinese Loess Plateau (CLP), and 12 were other records from 11 sites on land or ocean. In the revision, we have synthesized the records from the CLP and other regions respectively (see Method 4). The two composite data sets show similar changes and both indicate decreasing EAWM intensity during the early Holocene. However, it could be observed that the records from the CLP show relatively consistent changes during the Holocene. The records from other regions are not very consistent in comparison. Finally, we choose the composite record from the CLP to represent EAWM changes. The integrated EAWM record from the CLP shows that winter monsoon was weakening from the early to middle Holocene, which is consistent with the commonly accepted viewpoint that the EAWM was influenced by the high-latitude ice volume during the early Holocene. This result is also accordant with our speculation that the early Holocene AuSM was influenced by the Northern Hemisphere ice volume through cross-equatorial airflow.

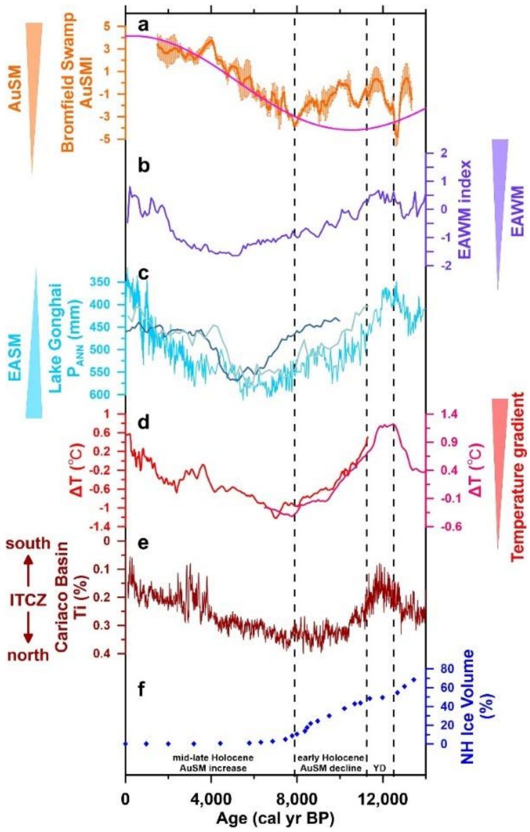

Figure 3 The comparison of AuSM record with other paleoclimate records. (a) AuSM index in this study. The error bar gives SD values among the data of the five proxies. The pink curve is January insolation at the 20° S (Laskar et al., 2004); (b) synthesized EAWM index based on the records on the Chinese Loess Plateau; (c) EASM records, including: pollen-based reconstructed precipitation record from Lake

Gonghai (blue), synthesized moisture index at monsoonal margin (light blue) and integrated EASM index over the whole EASM area (deep blue) (Wang et al., 2010; Wang and Feng, 2013; Chen et al., 2015); (d) Southern-Northern Hemisphere temperature gradients. The red line is the gradient between 90°-30° S and 90°-30° N, the pink line is the gradient between the whole Southern and Northern Hemispheres (Shakun et al., 2012; Marcott et al., 2013); (e) ITCZ record derived from the bulk Ti content in the Cariaco Basin (Haug et al., 2001); (f) Holocene Northern Hemisphere ice sheet content (Dyke et al., 2004). The arrows on both sides of the figure indicate the intensity of AuSM, EWAM, EASM and the magnitude of inter-hemispheric temperature gradient, respectively.

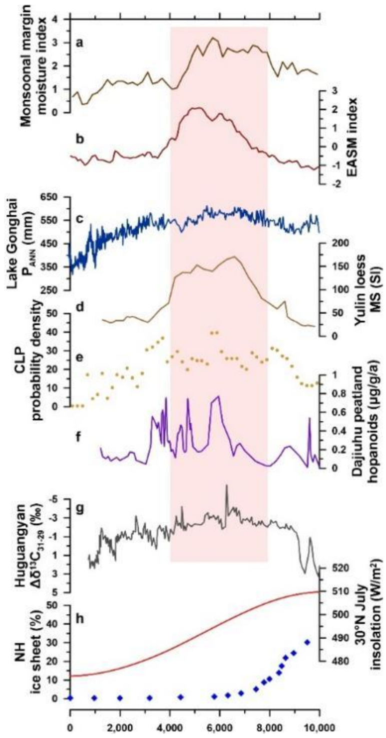

Figure S5 EASM records. (a) integrated moisture index at the EASM marginal region (Wang and Feng, 2013); (b) EASM index reconstructed from 92 records over the whole EASM area (Wang et al., 2010); (c) pollen-based annual precipitation record reconstructed from Lake Gonghai (Chen et al., 2015); (d) magnetic susceptibility at the Yulin Loess section (Lu et al., 2013); (e) probability density of loess and palaeosol dates on the Chinese Loess Plateau (Wang et al., 2014); (f) mass accumulation rate of aerobic hopanoids from the Dajiuhu peatland (Xie et al., 2013); (g) the isotopic difference between C_{31} and C_{29} n-alkanes from Huguangyan Maar (Jia et al., 2015); (h) 30° N July insolation (red line) and Northern Hemisphere ice sheet (blue dots) (Laskar et al., 2004; Dyke et al., 2004).

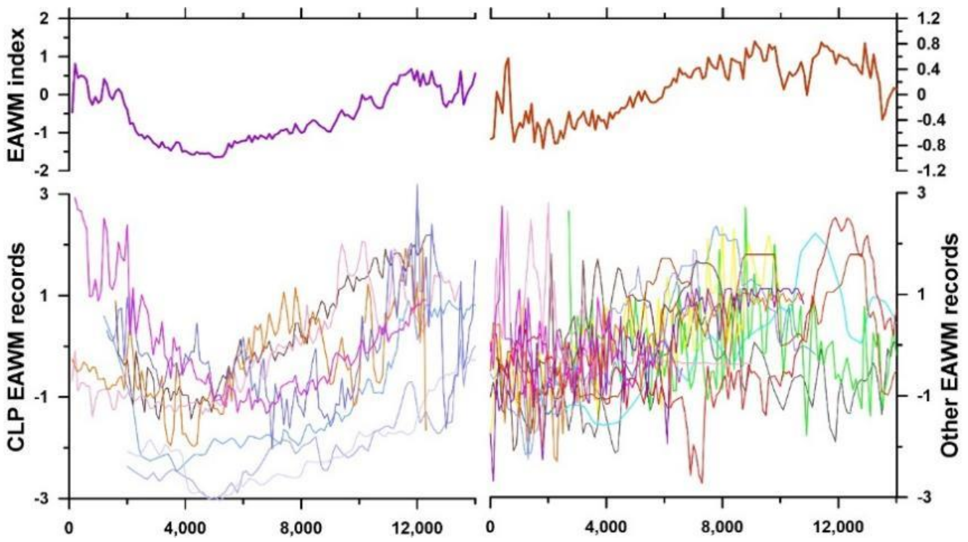

Figure S4 EAWM records. The left shows the EAWM records collected from Chinese Loess Plateau and the integrated EAWM index from them; the right shows the EAWM records from other regions and their integration.

Please find more detailed comments below:

3. In the introduction the authors briefly comment on the suitability of speleothem records in reconstructing monsoon variability, suggesting that these records can be biased towards reflecting source dynamics rather than reflecting local rainfall (Lines 42 to 46). Based on this they exclude speleothem records from their synthesis, which is the main basis for their conclusions (Fig. 3). However, in recent years many publications of speleothems across this region (particularly in Southeast Asia) made an effort to distinguish these two signals by using trace elements and carbon isotopes. These records should be discussed in this work as they more directly reflect summer monsoon rainfall. In addition, Eroglu et al., 2016 applied newly developed statistical approaches to the Dongge and KNI-51 cave records, presenting similar conclusions as the authors in this manuscript and should therefore be discussed as well. A deeper discussion of previous work could allow the reader to identify which knowledge gaps in our understanding of the Australian monsoon are being addressed here.

We appreciate these constructive comments.

According to the reviewer's suggestion, we have summarized existing hydrological records in the Indonesian-Australian monsoon region, including the trace element and carbon isotope proxies of stalagmites from western Pacific region, from three aspects: millennial scale, orbital scale, and Holocene sub-orbital scale, which are showed in the Introduction and Discussion sections of the revised manuscript. The work of Eroglu et al., 2016 is also involved. In fact, the millennial-centennial "seesaw" pattern between EASM and AuSM has been extensively documented, including the records of YD and H events from the Australian monsoon region (triggered by fresh water input into the North Atlantic Ocean) (Denniston et al., 2013a; Denniston et al., 2017; Ayliffe et al., 2013; Gibbons et al., 2014), as well as the Holocene millennial-centennial scale variations discovered by Eroglu et al., 2016 (probably related to the solar activities). In our study, we find that the changes of the Northern Hemisphere high-latitude ice volume had significant impacts on AuSM evolution from the early to middle Holocene (sub-orbital scale), which has not been reported in any previous Holocene records and quite different from the above studies on millennial-centennial scale monsoon changes.

The main summarize in the revised manuscript includes:

(1) On millennial timescale, variations of AuSM during the YD and H events have been relatively well studied. Some hydrological records derived from stalagmites and lacustrine sediments indicate that the monsoon precipitation increased in northern Australia during the YD and H events (Denniston et al., 2013a; Muller et al., 2008; Denniston et al., 2017; Li et al., 2022). This interpretation is also supported by many hydrological records from Maritime Continent area, indicating that the Southern Hemisphere Indonesian-Australian summer monsoon may have experienced systematic strengthening during the YD and H events (Griffiths et al., 2009; Shiau et al., 2011; Ayliffe et al., 2013). The strengthening of the monsoon in the Southern Hemisphere during these millennial-scale abrupt events is consistent with the hypothesis of ITCZ southward movement caused by the heat imbalance between the Northern and Southern Hemispheres triggered by freshwater input into the North Atlantic Ocean. However, the drought conditions or a lack of significant hydrological changes during the YD period are also observed in the western Pacific region, indicating that the scope, magnitude, and spatial pattern of hydrological changes in the Asian-Australian monsoon region during the YD period still need further clarification (Krause et al., 2019; Russell et al., 2014; Gibbons et al., 2014). Meanwhile, the millennial-centennial scale see-saw pattern between EASM and AuSM has also been detected in stalagmite records during the Holocene and the solar activity is proposed as the potential driving force (Eroglu et al., 2016).

(2) Compared to millennial scale variations, the change of AuSM on orbital scale remains more uncertain, both in terms of records and driving mechanisms. Only few records describing the orbital-scale hydroclimate changes in the monsoon domain of northern Australia. The major one is a 45 ka humification record from lake sediment in Lynch's Crater, which suggests that the precipitation changes in northeastern Australia followed a semi-precessional cycle associated with long-term changes in ENSO variability, rather than with direct monsoon evolution (Turney et al., 2004). Although there are few records from the northern Australian continent, marine and lake records from nearby oceans and islands also have important contribution for

understanding the AuSM. Riverine runoff flux over the past 25 ka reconstructed from four marine sediment cores off northwestern Australia suggest that the Australian monsoon changes were closely related to southern hemisphere warming and deglacial sea level changes (Kuhnt et al., 2015). A marine sediment record in Papua New Guinea shows that the obliquity changes played a more significant role than precession in influencing the regional precipitation and western Pacific ITCZ migration (Liu et al., 2015). Precipitation over the past 60 ka reconstructed from Lake Towuti, Indonesia suggests that hydroclimate changes had glacial-interglacial variability, which was probably resulted from the migration of the ITCZ caused by nonlinear threshold response to Northern Hemisphere ice sheet boundary conditions (Russell et al., 2014). Hydrological reconstruction over the past 26 ka derived from marine sediment of Mandar Bay off west Sulawesi suggests that multiple factors, such as the Northern Hemisphere ice volume, the Southern Hemisphere summer insolation and the sea level change may jointly modulate the variations of summer monsoon (Wicaksono et al., 2017). However, there is also a study from the marine sediment core in northwest Sumatra suggests that changes in ITCZ and sea level have no significant impact on hydrological changes in the western IPWP region, and the hydrological evolution of the IPWP region exhibits heterogeneous patterns at different locations (Niedermeyer et al., 2014). Cave sediments in Maritime Continent area are also important for understanding the orbital scale Indonesian-Australian monsoon evolution. The northern Borneo stalagmite $\delta^{18}O$ record over the past 100 ka suggests that the hydroclimate changes were mainly controlled by the precessional cycles, with little influence of sea level rise (Carolin et al., 2013). However, another northern Borneo stalagmite record over the last 27 ka and some other stalagmite records in the Maritime Continent area emphasize the impacts of rising sea level during the deglaciation on the hydroclimate changes (Partin et al., 2007; Ayliffe et al., 2013; Krause et al., 2019). The current research findings reflect that considerable controversy still exists regarding the orbital scale Indonesian-Australian monsoon evolution. Moreover, the studies most concentrated on the western Pacific region, only few records are derived from the Australian monsoon front area. (These contents have been condensed into the Introduction.)

(3) The sub-orbital scale monsoon variations during the Holocene are also very important for understanding the monsoon dynamics, as it represents a recent interglacial period with relatively unambiguous climate boundary conditions (Chen et al., 2015; Cheng et al., 2016). However, the changes of the Holocene AuSM remain unclear. A Holocene stalagmite $\delta^{18}O$ record from northwestern Australia seems to be decoupled with the Southern Hemisphere summer insolation, which couldn't be reconciled with the classical hypothesis of tropical insolation control deduced by comparison of Asian and South American stalagmite $\delta^{18}O$ records (Denniston et al., 2013b; Dykoski et al., 2005; Cheng et al., 2016; van Breukelen et al., 2008; Cruz et

al., 2005; Mosblech et al., 2012; Novello et al., 2017). However, the stalagmite $\delta^{18}O$ record from western Australia is just a single record, lacking cross-validation with other records in northern Australia. There also exist some Holocene stalagmite $\delta^{18}O$ records in the Maritime Continent area, but most of them were influenced by sea level rise during the early Holocene. In addition, stalagmite $\delta^{18}O$ records at different locations also have obvious diversities (Partin et al., 2007; Griffiths et al., 2009; Ayliffe et al., 2013; Krause et al., 2019; Wurtzel et al., 2018). Stalagmite $\delta^{18}O$ are suggested to be influenced by circulation or source effects in recent years, and thus some studies have attempted to develop new hydrological proxies from stalagmites, such as carbon isotopes ($\delta^{13}C$) and trace elements (Liu et al., 2015; Griffiths et al., 2010; Griffiths et al., 2020; Yuan et al., 2018; Partin et al., 2013). These new proxies are related to prior calcite precipitation and have been proposed to be associated with local hydrological conditions. However, these records from different study sites in the Maritime Continent also show inconsistency with each other. Some studies suggest that these proxies have thresholds when responding to hydrological changes in this region (Griffiths et al., 2010; Yuan et al., 2018; Partin et al., 2013). Moreover, most of these records exist in Southeast Asia or the western Pacific region, similar records in northern Australia are still absent until now. In addition to stalagmite records, some marine sediment records in the western Pacific are also used to infer the Holocene Indonesian-Australian monsoon variations. However, these studies also fail to reach consistency (Stott et al., 2004; Tierney et al., 2012; Ardi et al., 2020; Mohtadi et al., 2011; Hendrizan et al., 2016). Overall, the dynamics of Holocene Australian summer monsoon currently remain unclear, probably due to the scarcity of high-resolution records from the monsoon front region of northern Australia, with current records mainly coming from the Maritime Continent area. However, due to the distance from the front edge of the AuSM, complex terrain, and the influence of multiple meridional and latitudinal climate systems, hydroclimatic records from Maritime Continent area may be difficult to accurately capture the evolution of Holocene AuSM. In this case, it can be of great interest to obtain new Holocene hydrological records from northern Australia beyond stalagmites to understand Holocene Australian monsoon dynamics.

4. Since the main conclusions of this work are based on the comparison between the Bromfield Swamp record and two records from East Asia, there needs to be an in-depth discussion on the suitability of theses EASM and EAWM records. For example, Kaboth-Bahr et al., 2021 presented a synthesis of non-speleothem archives reconstructing the EASM and EAWM. They found that there was an in-phase relation between EASM and EAWM from 9 to 4 ka and no correlation was observed during the late Holocene. This is in direct contrast to Kang et al, 2020 (presented in figure 3b) who suggested a clear anti-phase relationship between EASM and EAWM from 12 to

0 ka. My concern is that the choice of records directly impacts the conclusions made here and it is not clear to me why the authors chose these records over others.

Thank you for your comment. Yes, there is indeed inconsistency between the two EAWM records integrated by Kaboth-Bahr et al., 2021 and Kang et al, 2020, respectively. We have carefully examined the two papers and found that there are significant differences in their integration methods. Kang et al, 2020 mainly uses loess records from the Chinese Loess Plateau, ignoring records from other regions. This is mainly because they believe that loess on the CLP mainly comes from the dust deposition of the winter monsoon and is a direct indicator of the EAWM. In contrast, Kaboth-Bahr et al., 2021 integrates only a few lake records to infer the EAWM, ignoring loess and many other records. To address this issue, in the revised manuscript, we collect EAWM records as many as possible and integrate them into two categories: loess and non-loess. The two composite records show similar changes and indicate that the EAWM intensity was decreasing during the early Holocene. However, it could be observed that the records from the CLP show relatively consistent changes with each other during the Holocene, while the records from other regions are more diverse in comparison. Therefore, in the revision, we choose the composite record from the CLP to represent EAWM changes (Method 4, Fig. 3, Table S2 and Fig. S4).

For EASM, we use two composite records in revision (Wang et al., 2010; Wang and Feng, 2013). One is synthesized from pollen records along the EASM margin, the other is an integration of 92 records from the entire Asian monsoon region. As a supplement, we also collect some other EASM records from the northern to southern EASM region beyond these two composite records. Most of these records consistently show stronger EASM during the middle Holocene, which is the same as the record we cited in our previous manuscript (Fig. 3 and Fig S5).

5. Overall, it is not clear to me why the authors present the Younger Dryas section of the record in this context. The introduction and title only address Holocene variability and do not mention any knowledge gaps regarding the YD. Therefore, the section "The humid condition during the YD event" and the description in the abstract seem out of place. I would suggest including a short discussion regarding the Australian summer monsoon during the YD in the intro and highlight remaining questions that the data presented here can answer. This should also help to highlight the importance of this new record.

Thanks for this suggestion. In this revision, we add the discussion of Asian-Australian monsoon evolution during the YD period in the Introduction and Discussion. Although the southward migration of the ITCZ and strengthening of the Indonesian-Australian summer monsoon during the YD and H events have been verified by many paleoclimate records and modeling simulations (Denniston et al., 2013a; Muller et al., 2008; Denniston et al., 2017; Li et al., 2022; Griffiths et al., 2009; Shiau et al., 2011; Ayliffe et al., 2013; Broccoli et al., 2006; Meissner et al., 2007), the spatial pattern of the Asian-Australian monsoon system has not yet been assembled in detail. In this revision, we collect hydrological records of the YD event in the western Pacific and surrounding Asian and Australian landmasses and calculated hydrological indexes to reveal the spatial pattern of hydrological conditions in this region. The result shows that the Asian monsoon region generally exhibits a dry condition during the YD period, while the northern part of Australia shows a humid state. In the western Pacific region, the transition zone between the Asian and Australian monsoon, the hydroclimate is mostly characterized by no obvious changes. This spatial mode further confirms the significant southward migration of the ITCZ during the YD period (Fig 4, Fig. S7, Table S3).

The Asian-Australian monsoon changes during the YD also conform to the “thermal control hypothesis”, but its drivers differ from that of the Holocene long-term changes. During the YD event, thermal imbalance was mainly caused by freshwater injection in the North Atlantic Ocean. During the Holocene, the thermal imbalance was probably caused by the Northern Hemisphere ice volume (early Holocene) and the insolation imbalance between two hemispheres (mid to late Holocene).

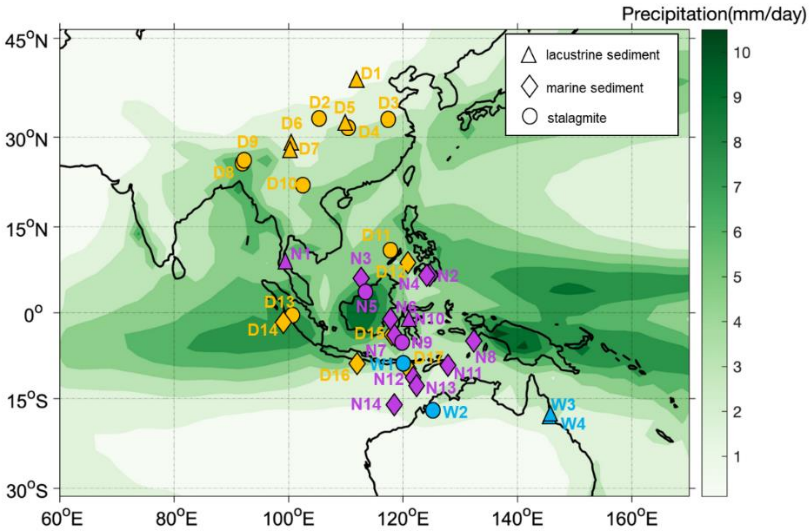

Figure 4 Distribution of hydrological records in A-AuMS region during the YD event. Yellow symbols indicate drier condition, purple indicate no obvious change, and blue indicate wetter condition. The base map shows annual mean precipitation from 1979-2020, with the data from the Global Precipitation Climatology Project (GPCP).

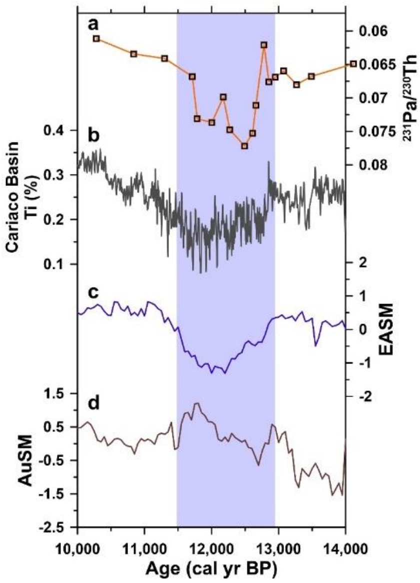

Figure S7 Comparison of EASM and AuSM changes during the YD event. (a) AMOC changes reconstructed by $^{231}Pa/^{230}Th$ from marine sediment core OCE326-GGC5 in the Atlantic Ocean (McManus et al., 2004); (b) ITCZ shift reflected by Ti concentration from the Cariaco Basin (Haug et al., 2001); (c) composite EASM record, including D1-D10 in Table S3 and Figure 4; (d) composite AuSM record, including W2-W4 in Table S3 and Figure 4.

6. Supplemental figure S2 is a direct copy from Shi, G. et al. Rapid warming has resulted in more wildfires in northeastern Australia. Science of The Total Environment 771, 144888 (2021) and should be double-checked for potential copy right issues.

We have deleted this figure.

7. Instead of "local summer insolation", please use summer insolation at a certain latitude". "Local" refers to the sample site rather than a certain latitude.
We have changed the description.

Reviewer #2 (Remarks to the Author):

This new record from Bromfield Swamp is clearly an important one, it is well dated and high resolution from a region where such records are scarce. It provides interesting information on the conditions through the last 13ka at the site and leads to increased understanding of the regional paleoclimate.

1. I wonder if some of the strength of the record is lost by concentrating the discussion on the PC1 curve rather than looking at some of the differences in response across the multiple proxies. The OC curve seems to show differences from the elemental analyses for example in the earliest part of the record (due to global temperature?) and in the mid Holocene where it shows more of a threshold response to change.

Thanks for your helpful suggestion and we added some detailed description about the proxies in revised Supplementary Information.

In lacustrine sediments, many proxies have been developed to reflect hydrological changes, but the sensitivity of proxies to hydrological responses often varies, and some proxies may also be affected by other factors such as temperature. Therefore, some mathematical methods, such as the PCA, are often used to extract their common signal to reflect regional hydrological changes (Wold et al., 1987; Wang et al., 2010; James et al., 2025).

In our study, the differences in details among proxies might also arise due to above reasons. For example, the organic matter in peatlands usually comes from in-situ vegetation, which may be highly correlated with precipitation in tropics (Zinck, 2011; Page et al., 2006). The organic content in Bromfield Swamp rapidly increased after 7.8 cal kyr BP, probably indicating an increase of precipitation from the middle to late Holocene. However, temperature will also have potential influence on the organic content. Global temperature integration suggests that the climate experienced a gradual warming trend from the last deglaciation to middle Holocene in tropical area (30° N-30° S) (Marcott et al., 2013; Shakun et al., 2012). The relative lower temperature, together with the relative less precipitation during the early Holocene than during the late Holocene, may suppress the growth of vegetation, thus reducing the organic matter accumulation in sediments before 7.8 cal kyr BP (Zinck, 2011). These may be the potential reasons why the organic content was not very high in the early part of the core. However, compared to high latitudes, temperature usually plays a less important role in the formation of the peat and the development of vegetation in tropics (Zinck, 2011; Page et al., 2006).

Grain size of lake sediments is typically influenced by hydrodynamic conditions associated with precipitation (Peng et al., 2005; Liu et al., 2016). Except for the bottom 10 cm (approximately before 12.8 cal kyr BP), the sediment core is mainly composed by peat deposits, which means it was mostly a swamp environment under the deposition processes. Before 5.6 cal kyr BP, the grain size stayed stable and relatively lower, which may because that the coarser particles couldn’t reach the sampling site under the lower precipitation and weaker hydrodynamic condition in the swamp environment. The element ratios and OC proxies indicate that the precipitation increased significantly during the late Holocene, which may be sufficient to bring the coarser particles to the center of the swamp, leading to rapid increase of the MGS after 5.6 cal kyr BP.

The diversity in sensitivity of these proxies to hydrological changes indeed lead to differences in their details, but it is worth noting that a common characteristic of these proxies is their sensitivity to precipitation. At the same time, the proxies obtained from the Bromfield Swamp in this study show strong consistency, which further proves that they may be simultaneously affected by precipitation. In this study, we mainly discuss precipitation changes in northern Australia at the sub-orbital scale. Therefore, we believe that the common signal extracted by the PCA technique can better indicate changes in regional hydroclimate on this timescale. We have added the discussion about the proxy significance in supplementary text 4.

We agree with the reviewer that this method may lose some short-term signals, such as events on millennial to centennial scale. We wish to discuss these events in our next work, in conjunction with a higher-resolution core from another nearby lake (Please see the response to Comment #4 below).

2. I also found the discussion around the Younger Dryas response a bit oversimplified, as there are similar ‘events’ in the record either side of the YD one i.e. at 10 and 13ka and the wet phase does not occur throughout the YD as delimited in Figure 3.

Actually, the similar event at 13 ka is not really an “event”. It’s because there’s a dry event before YD, approximately at 12.5 ka, which is called the B/A warm period in Northern Hemisphere, and the Antarctic Cold Reversal (ACR) in the Southern Hemisphere. During the B/A period, AMOC was strong, more energy and heat were transported to the middle and high latitudes of the Northern Hemisphere. The ITCZ shifted northward, so the EASM became stronger but the AuSM became weaker. Our record almost ended at the B/A event, so it’s hard to discuss what happened before that. When entering the Holocene, there are also many millennial-centennial scale rapid climate events. These events are initially detected in the North Atlantic and high latitudes in the Northern Hemisphere, but later were also found in the low latitudes and even the Southern Hemisphere. The early Holocene is a period with many of those climate fluctuations, such as the 10.3 ka, 9.2 ka, 8.2 ka and 7.2 ka events (Bond et al., 1997). These events are characterized by cold and dry climates in the Northern Hemisphere, but in the Southern Hemisphere, they might be opposite. Therefore, the 10 ka wet phase might be related to these events. The millennial-centennial scale monsoon dynamic is another question that deserves further study. Given that the main focus of this article is on monsoon changes on sub-orbital scale and limited by the article length, we did not focus on these events in this study. We will discuss them in conjunction with a new record in our next work (please see the details in response to Comment #4).

The reviewer states that "the wet phase does not occur throughout the YD as delimited in Figure 3". We consider if it should depend on the YD time we marked in the figure? Due to dating errors or regional differences, etc., the time and duration of the YD present by different records are generally not entirely consistent. In order to facilitate the inclusion of the YD event in all records in the Fig. 3, we delineated the dotted line as shown in the figure. Therefore, for our AuSM record, the delineated time includes the entire process of the YD event from the beginning to the end.

We agree with the reviewer that the discussion about the YD event in this study is a bit oversimplified. Therefore, we have added the discussion of Asian-Australian monsoon evolution during the YD period in the revised Introduction and Discussion. Although the southward migration of the ITCZ and strengthening of the Indonesian-Australian summer monsoon during the YD and H events have been suggested by many paleoclimate records and modeling simulations (Denniston et al., 2013a; Muller et al., 2008; Denniston et al., 2017; Li et al., 2022; Griffiths et al., 2009; Shiau et al., 2011; Ayliffe et al., 2013; Broccoli et al., 2006; Meissner et al., 2007), the spatial pattern of the Asian-Australian monsoon system has not yet been provided in detail. In this revision, we collected hydrological records of the YD event in the western Pacific and surrounding Asian and Australian landmasses and calculate hydrological indexes to reveal the spatial pattern of hydrological conditions in this region (Method 5, Fig. 4, Fig. S7, Table S3). The result shows that the Asian monsoon region generally exhibited a dry condition during the YD period, while the northern part of Australia showed a humid state. Meanwhile, in the western Pacific region, the transition zone between the Asian and Australian monsoon, the hydrological conditions were mostly characterized by no obvious changes. This spatial mode further confirms the southward migration of the ITCZ during the YD period. The Asian-Australian monsoon changes during the YD also conform to the “thermal control hypothesis”. During the YD event, the shutdown of AMOC cooled the Northern Hemisphere, resulting in a higher south-north temperature contrast.

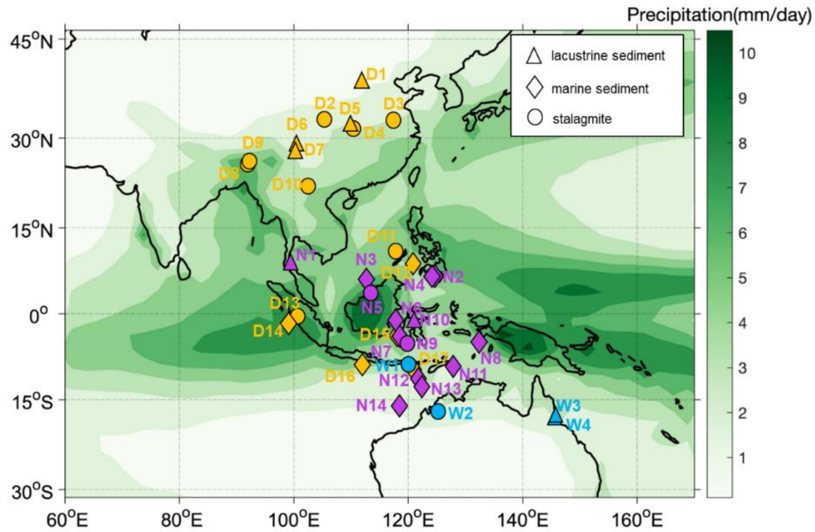

Figure 4 Distribution of hydrological records in A-AuMS region during the YD event. Yellow symbols indicate drier condition, purple indicate no obvious change, and blue indicate wetter condition. The base map shows annual mean precipitation from 1979-2020, with the data from the Global Precipitation Climatology Project (GPCP).

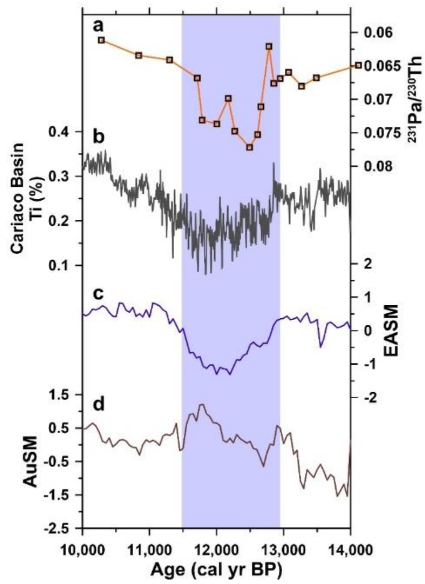

Figure S7 Comparison of EASM and AuSM changes during the YD event. (a) AMOC changes reconstructed by $^{231}Pa/^{230}Th$ from marine sediment core OCE326-GGC5 in the Atlantic Ocean (McManus et al., 2004); (b) ITCZ shift reflected by Ti concentration from the Cariaco Basin (Haug et al., 2001); (c) composite EASM record, including D1-D10 in Table S3 and Figure 4; (d) composite AuSM record, including W2-W4 in Table S3 and Figure 4.

3. The discussion of the regional paleoclimate implication of this new record are feasible but may just push the interpretations too far, in terms of what one single record can show when compared with one other. A little caution in the interpretation is probably valid here, despite a fairly convincing story.

Thanks for the reminder. In the revised manuscript, we have used more representative integrated records of EASM and EAWM instead of one single record. (please refer to Method 4, Fig. 3, Fig. S4, S5, Table S2 and the response to the first reviewer's Comment #2). Meanwhile, in the introduction, we also provide a more detailed summary and discussion of paleoclimate records from northern Australia and the western Pacific region. In addition, we also compare our AuSM record with some hydrological records from the Indonesian-Australian monsoon region to increase reliability of our interpretation (For details, please see Fig. S3 below).

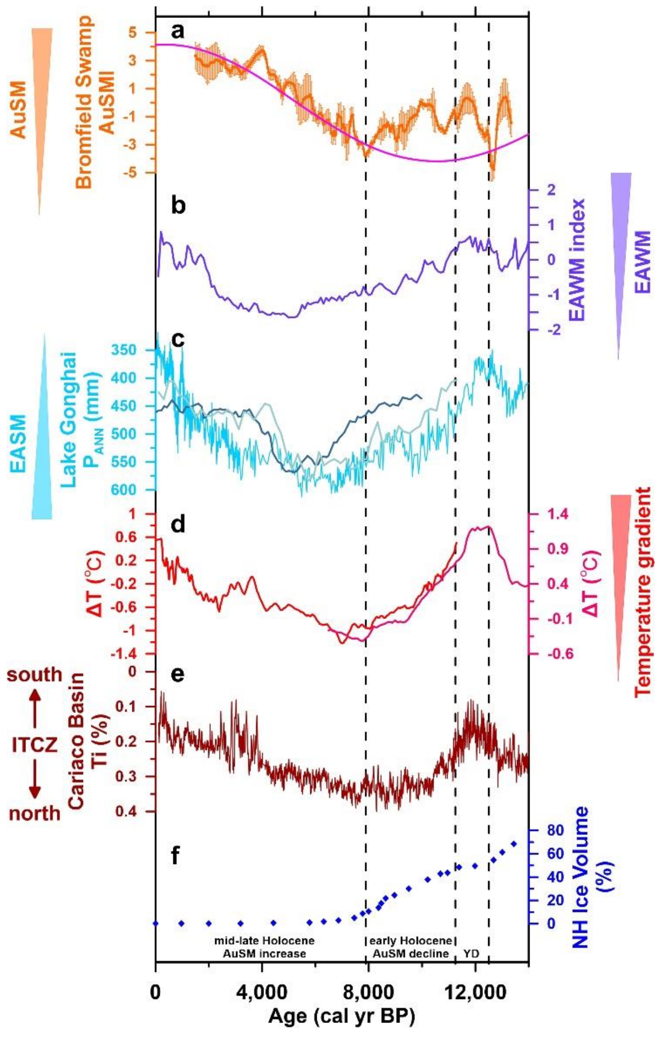

Figure 3 The comparison of AuSM record with other paleoclimate records. (a) AuSM index in this study. The error bar gives SD values among the data of the five proxies. The pink curve is January insolation at the 20° S (Laskar et al., 2004); (b) synthesized EAWM index based on the records on the Chinese Loess Plateau; (c)

EASM records, including: pollen-based reconstructed precipitation record from Lake Gonghai (blue), synthesized moisture index at monsoonal margin (light blue) and integrated EASM index over the whole EASM area (deep blue) (Wang et al., 2010; Wang and Feng, 2013; Chen et al., 2015); (d) Southern-Northern Hemisphere temperature gradients. The red line is the gradient between 90° -30° S and 90° -30° N, the pink line is the gradient between the whole Southern and Northern Hemispheres (Shakun et al., 2012; Marcott et al., 2013); (e) ITCZ record derived from the bulk Ti content in the Cariaco Basin (Haug et al., 2001); (f) Holocene Northern Hemisphere ice sheet content (Dyke et al., 2004). The arrows on both sides of the figure indicate the intensity of AuSM, EWAM, EASM and the magnitude of inter-hemispheric temperature gradient, respectively.

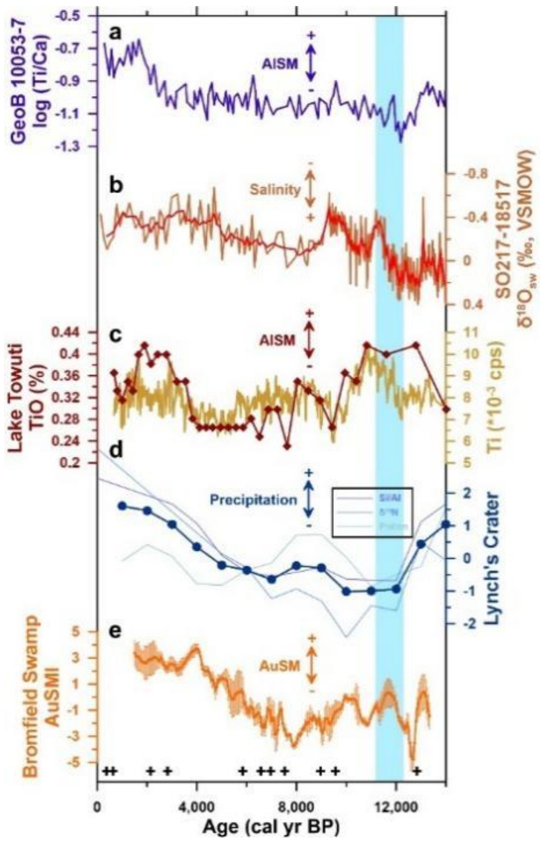

Figure S3 Comparison of AuSM index in this study with other monsoon records from northern Australia and Maritime Continent area. (a) GeoB 10053-7 Ti/Ca ratios off South Java (Mohtadi et al., 2011); (b) (b) SO217-18517 $\delta^{18}O_{sw}$ off the Mahakam Delta (Hendrizan et al., 2016); (c) Ti concentrations at Lake Towuti in Sulawesi, Indonesia (Russell et al., 2014); (d) Si/Al (purple), $\delta^{15}N$ (light blue) and Cyperaceae/Poaceae (green) at Lynch's Crater in northeastern Australia. The blue line with dots is the composite of above three proxies (Muller et al., 2008); (e) AuSM index reconstructed from muti-proxies in the Bromfield Swamp, northeastern

Australia (this study). The blue bar indicates the YD event.

4. Overall a little more consideration of the detail is required throughout, as it's interesting and potentially adds to, rather than detracts from, any story.

We sincerely thank the reviewer for your valuable suggestions and comments. We have discussed more about details of the YD event in our revision. We have also been paying attention to the details and shorter-scale climate changes in our record all along, just as the reviewer put forward. However, we do not delve too deeply into these questions in this study, mainly due to two reasons:

(1) The millennial-centennial scale monsoon fluctuation during the Holocene is another question that deserves systematic study. Given that the main focus of this article is on monsoon changes on sub-orbital scale and limited by the article length, we do not focus on these events in this study. We have another core from a maar lake close to the Bromfield Swamp. The dating result shows it covers the past 6 ka and it has a higher resolution. The long-term changes of proxies in this core are consistent with the records in Bromfield Swamp, but this core could record the millennial-centennial scale fluctuations more detailed. We will combine this core to specifically learn the Holocene shorter scale climate fluctuations in the next study.

(2) YD is one of the most obvious and generally studied millennial-scale climate events. Its dynamic mechanism is also relatively clear. However, compared to the YD, the dynamic mechanisms of the millennial-centennial scale climate events over the Holocene are possibly more complex. Bond initially proposed that the North Atlantic ice raft debris modulated the Holocene millennial scale climate fluctuations (Bond et al., 1997, 2001). However, subsequent studies suggest that the solar activities and low-latitude hydrological processes also played important roles (Yan et al., 2015; Eroglu et al., 2016; Zhang et al., 2018). Records from the Southern Hemisphere are essential for clarifying these questions. We will conduct more in-depth research on this problem in the future. In this study, limited by the record, the topic of the paper and the length of the manuscript, we are not able to discuss more about it.

Reviewer #3 (Remarks to the Author):

The manuscript entitled "Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon “presents a new high resolution summer Australian-Indonesian monsoon (AIM) record, which was derived from lacustrine sediments of Bromfield Swamp in northeastern Australia. The objective of

this work was to study the dynamics of the summer AIM as well as the linkage between the East Asian monsoon (EAM) and AIM and western Pacific ITCZ. The studied time interval is represented by the last 13,500 years. The major findings of this study are that the summer AISM was stronger during the Younger Dryas (YD) event, weaker during the early Holocene and stronger again from the middle to late Holocene. The authors conclude that the summer AIM in the Southern Hemisphere tropics was not only controlled by local solar insolation, but also controlled by Northern Hemisphere high latitude climate changes through cross-equatorial airflow from the EAWM, which may have affected the summer AIM during the YD and the early Holocene. The authors further suggest that the Holocene summer AIM show an anti-phase behaviour with the EASM and both were significantly correlated with the Southern-Northern Hemisphere temperature gradients. This most likely suggests that the inter-hemispheric energy imbalance was the direct forcing driving the Holocene AIM system by modulations in the mean position of the western Pacific Intertropical Convergence Zone (ITCZ).
I really appreciate studies like this one trying to better understand the relationship between both monsoon systems because although a link between both monsoon systems is apparent in modern climates (e.g., Trenberth et al., 2000), this relationship has not yet been well defined for past climates. This is an interesting piece of work and an important step forward, as it delivers in my opinion a new, additional viewpoint how to link the EAM and AIM during the past.

We really appreciate your affirmation and suggestions.

I have a few comments and suggestions that the authors might find worth considering.

1. I think the authors could make a stronger point if they would compare their record of changes in summer AIM with previous published summer AIM records, such as those mentioned in their manuscript (lines 14-18) in order to verify that their record is valid (not affected by other local climate perturbations) and are a representative record of summer AIM changes. This could be done for example in Figure 3 or in another figure in the supplements.

In addition, the authors could make a stronger argument if the authors would take a look at records from Indonesia since those records are from the same monsoon system. Please see the summer AIM record by Mohtadi et al. (2011). Please also consider the Lynch‘s crater record from tropical northeastern Australia (Müller et al., 2008). Noteworthy, both records do no show a stronger summer AIM during the YD. Please have a look on those records. I am a bit worried to see that the dynamic linkage of both monsoon systems is currently based only on a single summer AIM record. If the proposed driving forces are the dominant control to link both systems, I would expect to see the same summer AIM history also in other records from the AIM region.

Thanks for your suggestion. In the revised manuscript, we have compared our record with other records in the AIM region, including the Lynch's Crater record in northeastern Australia, the marine and lake sediment records in the Maritime Continent area (marine sediment core GeoB 10053-7, SO217-18517 and record from Lake Towuti) (Figure S3). These records show similar changes with our record, supporting our interpretation/hypothesis. However, compared with the record we derived from the Bromfield Swamp, these records are either of relatively low resolution (for example the Lynch's Crater), or not located in the monsoon front (such as the records in the Maritime Continent region), which may cause them difficult to catch all details of the monsoon changes during the early Holocene or the YD event.

We speculate whether a wetter YD not shown in Lynch's Crater record is due to the record's resolution? The record reflected a wet H1. Actually, we checked this record, and found the wet condition in some of the proxies is likely extended to the time of YD. The record by Mohtadi et al. 2011 indicates a weaker AISM during the YD, but it seems that the dry condition didn't exist throughout the event. Given that a single record may be affected by dating errors, local conditions or other interferences, we have collected the paleo-hydrological records from EASM and AISM regions in the revision to see the detailed spatial pattern of the hydrological condition during the YD event. The result shows that a generally dry condition was presented in the EASM region, while the AuSM region was generally wet. It could be seen that in the warm pool, the transition zone between the Asian and Australian monsoon, some records indicate dry condition and most of them present no obvious changes. We think this is reasonable. Because given the continents distribution of the Northern and Southern Hemispheres, the spatial pattern of the hydroclimate may not be strictly symmetrically distributed along the equator. Meanwhile, most of the records in the IPWP are derived from marine sediment and the larger thermal capacity of the IPWP may also result in less significant influence of the millennial scale abrupt events (Sutton et al., 2007). At least at the marginal region of the AuSM, the northern Australia, the records show consistently wetting condition, suggesting a "weaker EASM but stronger AuSM" pattern during the YD event.

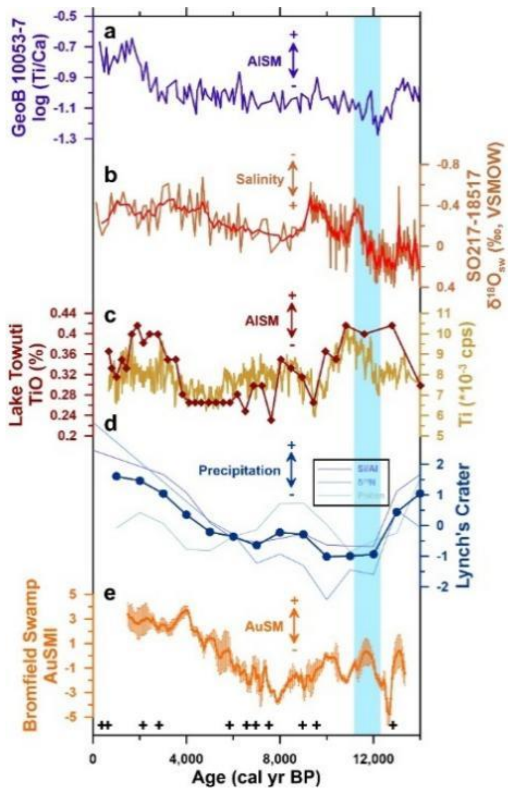

Figure S3 Comparison of AuSM index in this study with other monsoon records from northern Australia and Maritime Continent area. (a) GeoB 10053-7 Ti/Ca ratios off South Java (Mohtadi et al., 2011); (b) (b) SO217-18517 $\delta^{18}O_{sw}$ off the Mahakam Delta (Hendrizan et al., 2016); (c) Ti concentrations at Lake Towuti in Sulawesi, Indonesia (Russell et al., 2014); (d) Si/Al (purple), $\delta^{15}N$ (light blue) and Cyperaceae/Poaceae (green) at Lynch's Crater in northeastern Australia. The blue line with dots is the composite of above three proxies (Muller et al., 2008); (e) AuSM index reconstructed from muti-proxies in the Bromfield Swamp, northeastern Australia (this study). The blue bar indicates the YD event.

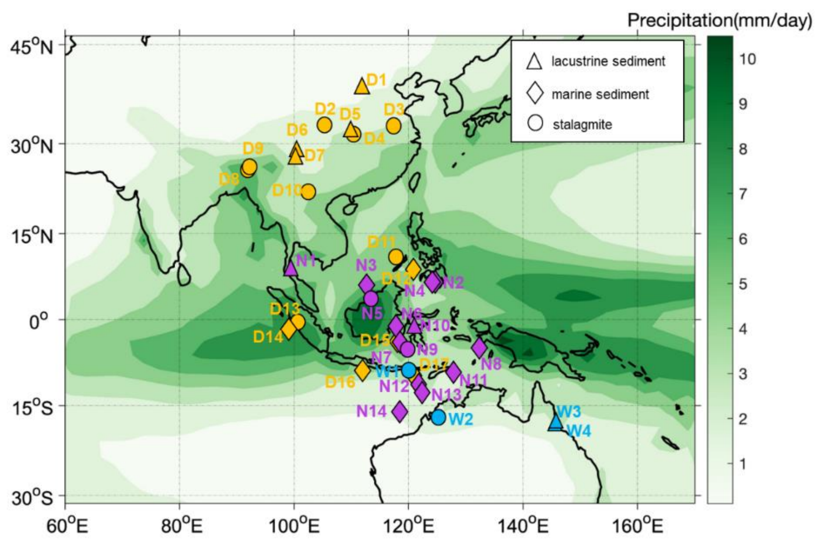

Figure 4 Distribution of hydrological records in A-AuMS region during the YD event. Yellow symbols indicate drier condition, purple indicate no obvious change, and blue indicate wetter condition. The base map shows annual mean precipitation from 1979-2020, with the data from the Global Precipitation Climatology Project (GPCP).

2. Lines 167-172: It appears however from a compilation of tropical Pacific ENSO records from c. 10 ka BP to present that indicates a moderate ENSO activity in the early Holocene, reduced ENSO activity in the middle Holocene and enhanced ENSO during the late Holocene. Please see Mark et al. (2022).

We have added a discussion about this paper in the revised manuscript. In modern observational data, strong El Niño activity usually corresponds to weak Australian monsoon (Heidemann et al., 2023), so weak ENSO activity during the middle Holocene cannot explain the drought in northern Australia during the middle Holocene. Therefore, we believe that rather than ENSO activity, the ITCZ movement caused by the heat imbalance between the two hemispheres may have largely controlled the evolution of the Holocene Australian summer monsoon.

I believe that this manuscript will attract a broad interest from palaeoclimatologists and climate modellers, therefore should be appealing to the palaeo-monsoon community after revisions have been made.

Thanks so much for your positive evaluation of our research. We have carefully considered the comments and suggestions of all the reviewers, and made systematic revisions of the manuscript. We sincerely hope our work can be of value of the palaeo-monsoon study.

References:

Ardi, R. D. W. *et al.* Last Deglaciation—Holocene Australian-Indonesian Monsoon Rainfall Changes Off Southwest Sumba, Indonesia. *Atmosphere* **11**, 932 (2020).

Ayliffe, L. K. *et al.* Rapid interhemispheric climate links via the Australasian monsoon during the last deglaciation. *Nature Communications* **4**, 2908 (2013).

Broccoli, A. J., Dahl, K. A. & Stouffer, R. J. Response of the ITCZ to Northern Hemisphere cooling. *Geophysical Research Letters* **33**, L01702 (2006).

Bond, G. *et al.* A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates. *Science* **278**, 1257-1266 (1997).

Bond, G. *et al.* Persistent Solar Influence on North Atlantic Climate During the Holocene. *Science* **294**, 2130-2136 (2001).

Carolin, S. A. *et al.* Varied Response of Western Pacific Hydrology to Climate Forcings over the Last Glacial Period. *Science* **340**, 1564-1566 (2013).

Chen, F. *et al.* East Asian summer monsoon precipitation variability since the last deglaciation. *Scientific Reports* **5**, 11186 (2015).

Cheng, H. *et al.* The Asian monsoon over the past 640,000 years and ice age terminations. *Nature* **534**, 640-646 (2016).

Cruz Jr, F. W. *et al.* Insolation-driven changes in atmospheric circulation over the past 116,000 years in subtropical Brazil. *Nature* **434**, 63-66 (2005).

Denniston, R. F. *et al.* North Atlantic forcing of millennial-scale Indo-Australian monsoon dynamics during the Last Glacial period. *Quaternary Science Reviews* **72**, 159-168 (2013a).

Denniston, R. F. *et al.* A Stalagmite record of Holocene Indonesian–Australian summer monsoon variability from the Australian tropics. *Quaternary Science Reviews* **78**, 155-168 (2013b).

Denniston, R. F. *et al.* Decoupling of monsoon activity across the northern and southern Indo-Pacific during the Late Glacial. *Quaternary Science Reviews* **176**, 101-105 (2017).

Dyke, A. S. An outline of North American deglaciation with emphasis on central and northern Canada. *Developments in Quaternary Sciences* **2**, 373-424 (2004).

Dykoski, C. A. *et al.* A high-resolution, absolute-dated Holocene and deglacial Asian monsoon record from Dongge Cave, China. *Earth and Planetary Science Letters* **233**, 71-86 (2005).

Eroglu, D. *et al.* See–saw relationship of the Holocene East Asian–Australian summer monsoon. *Nature Communications* **7**, 12929 (2016).

Gibbons, F. T. *et al.* Deglacial $\delta^{18}O$ and hydrologic variability in the tropical Pacific and Indian Oceans. *Earth and Planetary Science Letters* **387**, 240-251 (2014).

Griffiths, M. L. *et al.* Increasing Australian–Indonesian monsoon rainfall linked to early Holocene sea-level rise. *Nature Geoscience* **2**, 636-639 (2009).

Griffiths, M. L. *et al.* Evidence for Holocene changes in Australian–Indonesian monsoon rainfall from stalagmite trace element and stable isotope ratios. *Earth and Planetary Science Letters* **292**, 27-38 (2010).

Griffiths, M. L. *et al.* End of Green Sahara amplified mid- to late Holocene

megadroughts in mainland Southeast Asia. *Nature Communications* **11**, 4204 (2020).
Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C. & Röhl, U. Southward Migration of the Intertropical Convergence Zone Through the Holocene. *Science* **293**, 1304-1308 (2001).
Hendrizan, M., Kuhnt, W. & Holbourn, A. Variability of Indonesian Throughflow and Borneo runoff during the last 14 kyr. *Paleoceanography* **32**, 1054-1069 (2017).
Heidemann, H. *et al.* Variability and long-term change in Australian monsoon rainfall: A review. *WIREs Climate Change* 14, e823 (2023).
James, A. *et al.* Regime Shifts in Holocene Paleohydrology as Recorded by Asian Speleothems. *Paleoceanography and Paleoclimatology* **40**, e2024PA004974 (2025).
Jia, G. *et al.* Biogeochemical evidence of Holocene East Asian summer and winter monsoon variability from a tropical maar lake in southern China. *Quaternary Science Reviews* **111**, 51-61 (2015).
Kaboth-Bahr, S. *et al.* A tale of shifting relations: East Asian summer and winter monsoon variability during the Holocene. *Scientific Reports* **11**, 6938 (2021).
Kang, S. *et al.* Early Holocene weakening and mid- to late Holocene strengthening of the East Asian winter monsoon. *Geology* **48**, 1043-1047 (2020).
Kuhnt, W. *et al.* Southern Hemisphere control on Australian monsoon variability during the late deglaciation and Holocene. *Nature Communications* **6**, 5916 (2015).
Krause, C. E. *et al.* Spatio-temporal evolution of Australasian monsoon hydroclimate over the last 40,000 years. *Earth and Planetary Science Letters* **513**, 103-112 (2019).
Laskar, J. *et al.* A long-term numerical solution for the insolation quantities of the Earth. *Astronomy & Astrophysics* **428**, 261-285 (2004).
Li, T. *et al.* Environmental change inferred from multiple proxies from an 18 cal ka BP sediment record, Lake Barrine, NE Australia. *Quaternary Science Reviews* **294**, 107751 (2022).
Liu, J. *et al.* Holocene East Asian summer monsoon records in northern China and their inconsistency with Chinese stalagmite $\delta^{18}O$ records. *Earth-Science Reviews* **148**, 194-208 (2015).
Liu, X. *et al.* Grain size of Lake Qinghai sediments: Implications for riverine input and Holocene monsoon variability. *Palaeogeography, Palaeoclimatology, Palaeoecology* **449**, 41-51 (2016).
Liu, Y. *et al.* Obliquity pacing of the western Pacific Intertropical Convergence Zone over the past 282,000 years. *Nature Communications* **6**, 10018 (2015).
Lu, H. *et al.* Variation of East Asian monsoon precipitation during the past 21 k.y. and potential CO_2 forcing. *Geology* **41**, 1023-1026 (2013).
Marcott, S. A., Shakun, J. D., Clark, P. U. & Mix, A. C. A Reconstruction of Regional and Global Temperature for the Past 11,300 Years. *Science* **339**, 1198-1201 (2013).

Mark, S. Z., Abbott, M. B., Rodbell, D. T. & Moy, C. M. XRF analysis of Laguna Pallcacocha sediments yields new insights into Holocene El Niño development. *Earth and Planetary Science Letters* **593**, 117657 (2022).

McManus, J. F., Francois, R., Gherardi, J.-M., Keigwin, L. D. & Brown-Leger, S. Collapse and rapid resumption of Atlantic meridional circulation linked to deglacial climate changes. *Nature* **428**, 834-837 (2004).

Meissner, K. J. Younger Dryas: A data to model comparison to constrain the strength of the overturning circulation. *Geophysical Research Letters* **34**, L21705 (2007).

Mosblech, N. A. S. *et al.* North Atlantic forcing of Amazonian precipitation during the last ice age. *Nature Geoscience* **5**, 817-820 (2012).

Mohtadi, M. *et al.* Glacial to Holocene swings of the Australian–Indonesian monsoon. *Nature Geoscience* **4**, 540-544 (2011).

Muller, J. *et al.* Possible evidence for wet Heinrich phases in tropical NE Australia: the Lynch's Crater deposit. *Quaternary Science Reviews* **27**, 468-475 (2008).

Niedermeyer, E. M., Sessions, A. L., Feakins, S. J. & Mohtadi, M. Hydroclimate of the western Indo-Pacific Warm Pool during the past 24,000 years. *Proceedings of the National Academy of Sciences of the United States of America* **111**, 9402-9406 (2014).

Novello, V. F. *et al.* A high-resolution history of the South American Monsoon from Last Glacial Maximum to the Holocene. *Scientific Reports* **7**, 44267 (2017).

Partin, J. W., Cobb, K. M., Adkins, J. F., Clark, B. & Fernandez, D. P. Millennial-scale trends in west Pacific warm pool hydrology since the Last Glacial Maximum. *Nature* **449**, 452-455 (2007).

Partin, J. W., Cobb, K. M., Adkins, J. F., Tuen, A. A. & Clark, B. Trace metal and carbon isotopic variations in cave dripwater and stalagmite geochemistry from northern Borneo. *Geochemistry, Geophysics, Geosystems* **14**, 3567-3585 (2013).

Page, S. E., Rieley, J. O. & Wüst, R. *Lowland tropical peatlands of Southeast Asia*. Vol. 9 (Developments in Earth Surface Processes, 2006).

Peng, Y., Xiao, J., Nakamura, T., Liu, B. & Inouchi, Y. Holocene East Asian monsoonal precipitation pattern revealed by grain-size distribution of core sediments of Daihai Lake in Inner Mongolia of north-central China. *Earth and Planetary Science Letters* **233**, 467-479 (2005).

Russell, J. M. *et al.* Glacial forcing of central Indonesian hydroclimate since 60,000 y B.P. *Proceedings of the National Academy of Sciences of the United States of America* **111**, 5100-5105 (2014).

Shiau, L.-J. *et al.* Warm pool hydrological and terrestrial variability near southern Papua New Guinea over the past 50k. *Geophysical Research Letters* **38**, L00F01 (2011).

Shakun, J. D. *et al.* Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. *Nature* **484**, 49-54 (2012).

Stott, L. *et al.* Decline of surface temperature and salinity in the western tropical Pacific Ocean in the Holocene epoch. *Nature* **431**, 56-59 (2004).

Sutton, R. T., Dong, B. & Gregory, J. M. Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations. *Geophysical Research Letters* **34**, L02701 (2007).

Tierney, J. E. *et al.* The influence of Indian Ocean atmospheric circulation on Warm Pool hydroclimate during the Holocene epoch. *Journal of Geophysical Research: Atmospheres* **117**, D19108 (2012).

Turney, C. S. M. *et al.* Millennial and orbital variations of El Niño/Southern Oscillation and high-latitude climate in the last glacial period. *Nature* **428**, 306-310 (2004).

van Breukelen, M. R., Vonhof, H. B., Hellstrom, J. C., Wester, W. C. G. & Kroon, D. Fossil dripwater in stalagmites reveals Holocene temperature and rainfall variation in Amazonia. *Earth and Planetary Science Letters* **275**, 54-60 (2008).

Wang, Y., Liu, X. & Herzschuh, U. Asynchronous evolution of the Indian and East Asian Summer Monsoon indicated by Holocene moisture patterns in monsoonal central Asia. *Earth-Science Reviews* **103**, 135-153 (2010).

Wang, W. & Feng, Z. Holocene moisture evolution across the Mongolian Plateau and its surrounding areas: A synthesis of climatic records. *Earth-Science Reviews* **122**, 38-57 (2013).

Wang, H., Chen, J., Zhang, X. & Chen, F. Palaeosol development in the Chinese Loess Plateau as an indicator of the strength of the East Asian summer monsoon: Evidence for a mid-Holocene maximum. *Quaternary International* **334-335**, 155-164 (2014).

Wicaksono, S. A., Russell, J. M., Holbourn, A. & Kuhnt, W. Hydrological and vegetation shifts in the Wallacean region of central Indonesia since the Last Glacial Maximum. *Quaternary Science Reviews* **157**, 152-163 (2017).

Wold, S., Esbensen, K. & Geladi, P. Principal component analysis. *Chemometrics and Intelligent Laboratory Systems* **2**, 37-52 (1987).

Wurtzel, J. B. *et al.* Tropical Indo-Pacific hydroclimate response to North Atlantic forcing during the last deglaciation as recorded by a speleothem from Sumatra, Indonesia. *Earth and Planetary Science Letters* **492**, 264-278 (2018).

Xie, S. *et al.* Concordant monsoon-driven postglacial hydrological changes in peat and stalagmite records and their impacts on prehistoric cultures in central China. *Geology* **41**, 827-830 (2013).

Yuan, S. Hydroclimate changes in the Maritime Continent over the past 30,000 years recorded by speleothems from Sulawesi, Indonesia Doctor of Philosophy thesis, *Nanyang Technological University*, (2018).

Yan, H. *et al.* Dynamics of the intertropical convergence zone over the western Pacific during the Little Ice Age. *Nature Geoscience* **8**, 315-320 (2015).

Zhang, W. *et al.* The 9.2 ka event in Asian summer monsoon area: the strongest millennial scale collapse of the monsoon during the Holocene. *Climate Dynamics* **50**, 2767-2782 (2017).

Zinck, J. A. in *Peatlands of the Western Guayana Highlands, Venezuela: Properties and Paleogeographic Significance of Peats* Vol. 217 (eds Joseph Alfred

Zinck & Otto Huber) Ch. 2, 5-25 (Springer-Verlag Berlin Heidelberg, 2011).

Reviewer #1 (Remarks to the Author):

The authors have carefully responded to all my comments and provided detailed explanations. I really appreciate the effort and find that the manuscript has improved greatly! The impact of this work is now clear, and the addition of further records provides a more in-depth understanding of A-AuMS dynamics.

We truly appreciate the reviewer's recognition of our work. We'd like to express our gratitude to the reviewer again for your valuable comments on our manuscript. We have adjusted and revised the small defects and supplemented records and discussions in the manuscript according to your suggestions. Please see the following for details.

I recommend publication and suggest the following small edits:

In line 7 and 8: consider changing 'evolution of Holocene' to 'long-term evolution' or orbital-scale evolution, etc. This way it is not limited to just Holocene and addresses a larger audience.

We have changed the description. Please see Line 7 and 8.

Figure 3a, the tick marks and labels for insolation are missing.

Thank you for pointing out this omission. We have made the corrections accordingly.

Figure 4 and the introduction/discussion needs to include recent publications from Vietnam and Thailand as these three records also cover the YD and Holocene. The speleothems have sufficient resolution for the 100 yr/point requirement.

- Speleothems Vietnam: Patterson et al., 2023 (https://www.pnas.org/doi/10.1073/pnas.2219489120) and related manuscripts, which may be helpful to consider (https://www.nature.com/articles/s41467-024-53422-y and https://www.nature.com/articles/s41467-023-41373-9))
- Lakes Vietnam: Đào-Trung et al., 2024 (https://journals.sagepub.com/doi/10.1177/09596836241236342)
- Speleothems Thailand: Jacobson et al., 2024 https://www.sciencedirect.com/science/article/pii/S0277379124000982

Thanks for providing us these references. We have added them in our revised manuscript (Line 75, 88, 146-148). We also added the stalagmite record from Vietnam into Fig.4 and Table S3. The stalagmite record from Thailand (discontinuous during the YD period) and the lake sediment record from Vietnam (with lower resolution) are not included in the new Fig.4.

Reviewer #2 (Remarks to the Author):

Thank you for the opportunity to look at the revised manuscript, and for some of the changes made based on the reviewers comments. I was reviewer two of the original submission.

I can see that clear effort have been made to address my original comments, but I'm not yet convinced that the spirit of those comments have been taken on board - my overarching feeling from reading the revised paper is that still it tries to do to much with the data produced, in part because it tries to tell an oversimplified story.

We would like to express our gratitude to the reviewer again for your effort during the review. We have carefully gone through the manuscript to make clarifications, in particular addressing the following two points raised by the reviewer. We have added the related content in the manuscript (Line 282-287, 345-351). In this response, we have tried additional analyses and provided additional explanations to address the reviewer's comments. Please see the following for details.

For example, the YD may well be 'wet' in the record, but it is not universally 'wet' through the YD, however defined.

I like the new Figure 4, but the time periods chosen for comparison will be important here - I still thing etc YD look like what is going on c. 10k and c.13k in your index - we can agree to disagree on this maybe!

Thanks for your comments. First, we would like to clarify that although the period of the Younger Dryas (YD) event is well defined, 11.7-12.9 ka, based on the NGRIP ice core records (Rasmussen et al., 2006, JGR), it is difficult to assign this precise timing to lacustrine (and marine) records, whose chronology is largely inferred from ^{14}C dates and bears relatively large uncertainty as compared to the speleothem chronology. In most lacustrine/marine studies, the YD event is assigned based on both its absolute chronology and the relative changes in the records, yielding slightly variable intervals for the YD event. We have applied the same practice here by defining the YD event with positive values (~12.5 and 11.5 ka) in our AuSMI record. With this chronological uncertainty, it is difficult for us to address the reviewer's comment whether the YD interval is universally wet solely based on our AuSMI record. However, we examined a speleothem record from Australia (Ball Gown Cave, Denniston et al., 2013a, QSR), which indeed indicates wet conditions during essentially the whole YD period. Moreover, when we do the analysis for Figure 4, we take the dating error and the regional differences of all the records into consideration. We initially choose a time duration of 600 yrs (12.3-11.7 ka) as the time window, so that it could capture the strongest period of YD in as many records as possible and would not weaken the characteristics of the YD due to choice of an overly broad time period. In order to test if the selection of time period would have significant influence on the analysis result, we recalculated the hydrological indexes by selecting a different and longer-time period (YD: 12.5-11.5 ka, before YD: 13.7-12.7 ka, after YD: 11.3-10.3 ka). The result and comparison with the previous result is shown in the Table below. No substantial differences are observed with the previous result, suggesting that choice of time period doesn't strongly influence the spatial pattern of the YD event over the Asian-Australian monsoon region.

Second, we assume that the reviewer meant the data fluctuations occurring at ~10 ka and 13 ka in our AuSMI record. If correct, we agree with the reviewer as millennial-scale climate fluctuations also occurred before and after the YD event (Bond et al., 1997, Science; North Greenland Ice Core Project members, 2004, Nature. Also appeared at the Australian stalagmite records: Denniston et al., 2013a, b, QSR). However, in our record, the YD event stands out as the most clearly defined millennial scale event. Before the YD, our record is a bit short to capture the full event. At ~10 ka, the ending time for the event is difficult to define. In fact, for the early Holocene period, we largely address its long-term trend. We added some words about these events in the revised manuscript to address the reviewer's concern, please see Line 282-284.

The index (PC1) is strongly driven by the XRF data, at least visibly, so I'm still not sure what part the multi proxies play in the interpretation.

Firstly, we would like to clarify that all of our elemental data were obtained through ICP-AES testing after acid dissolution. The data obtained by this method is usually more reliable and accurate than XRF scanning.

We agree with the reviewer that the PC1 is strongly driven by the elemental data. However, our OC and grain size records share an overall structure of changes similar to the elemental records, although they differ slightly in detail. For instance, the detailed structure of grain size changes during the YD event differs from others. The PCA analysis is indeed intended to obtain the most significant and primary information shared by those proxies, which is also a commonly used method for multi-proxy analysis of lake sediments (e.g. Muller et al., 2008, GCA; Ribeiro et al., 2021, NC; Baxter et al., 2023, Nature). To address the reviewer's concern, we repeated the PCA analysis by (1) removing OC, (2) removing grain size, and (3) using only one composited elemental record. The results are shown below. PC1 in these experiments is essentially the same as before, indicating the robustness of the PC1 signal. We have also added the testing processes in the revised manuscript, please see Method 2 (Line 342-348) and Fig. S3.

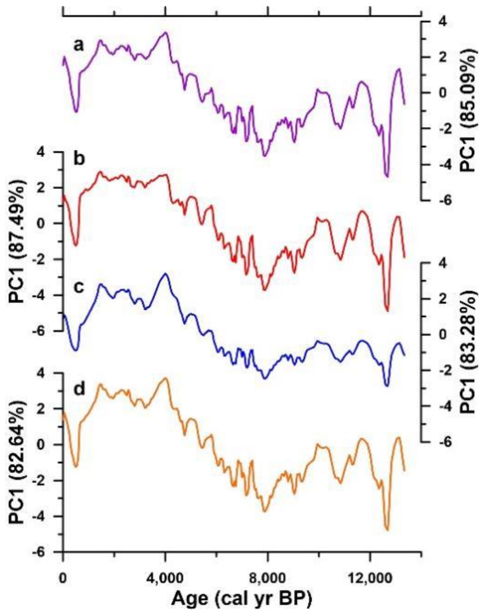

Figure S3 Comparison of PC1 results. (a) (b) and (c) are the PC1 results by: (a) removing OC; (b) removing MGS; (c) using a composited elemental record; (d) is the AuSMI used in this study.

I tend to worry about detail such as this, so please don't take this as detracting from what I think is a nice record that is worthy of publication - I just thing the paper needs to be as polished as it can be, and I'm not fully convinced it is yet.

Comparison of Hydrological Indexes and climatic conditions of the YD event.

Site no.	Site name	Proxy	Hydrological Index (before)		Hydrological Index (after)	
			HI1 (%)	HI2 (%)	HI1 (%)	HI2 (%)
D1	Gonghai Lake	pollen	-175.5	-67.0	-178.0	-73.4
D2	Xianglong Cave	stalagmite $\delta^{18}O$	-198.7	-195.1	-178.6	-168.0
D3	Hulu Cave	stalagmite $\delta^{18}O$	-177.5	-179.8	-179.1	-183.6
D4	Qingtian Cave	stalagmite $\delta^{18}O$	-197.2	-185.3	-190.9	-174.5
D5	Dajiuhu	$\delta^{13}C$	-100.6	-142.1	-85.7	-42.3
D6	Lake Lugu	δD_{wax}	-182.4	-164.4	-179.5	-141.9
D7	Lake Chenghai	authigenic carbonates $\delta^{18}O$	-173.7	-139.5	-146.6	-58.0
D8	Umsynrang cave	stalagmite $\delta^{18}O$	-19.3	-179.6	-74.0	-180.5
D9	Mawmluh Cave	stalagmite $\delta^{18}O$	-169.7	-53.1	-151.6	-39.7
D10	Tham Mai Cave	stalagmite $\delta^{18}O$	-189.3	-124.3	-187.9	-142.2
D11	Hoa Huong Cave	stalagmite $\delta^{18}O_{corr}$	-176.9	-181.9	-177.7	-182.2
D12	Palawan stalagmite	stalagmite $\delta^{18}O$	-189.2	-130.7	-187.1	-97.5
N1	Lake Nong Thale Prong	δD_{wax}	63.6	-72.1	49.9	-82.5
N2	MD81	$\delta^{18}O_{sw}$	-91.6	142.0	90.7	-128.7
D13	MD97-2141	planktonic $\delta^{18}O_{ruber}$	-144.8	-133.5	-159.8	-122.9
N3	MD01-2390	planktonic $\delta^{18}O_{ruber}$	-187.3	79.8	-169.7	9.5
N4	MD06-3075	planktonic $\delta^{18}O_{ruber}$	-165.4	7.6	-154.5	23.4
N5	Malaysian Borneo	stalagmite $\delta^{18}O$	-0.8	175.2	-76.7	108.8
D14	Tangga Cave	stalagmite $\delta^{18}O$	-191.3	-155.8	-186.4	-91.4

D15	SO189-39KL	planktonic $\delta^{18}O_{ruber}$	-142.5	-119.0	-132.6	-120.1
N6	SO217-18517	$\delta^{18}O_{sw}$	-139.0	16.9	-106.3	50.3
N7	BJ8-03-70GGC	δD_{wax}	-144.7	163.8	-127.6	161.5
D16	SO217-18515	$\delta^{18}O_{sw}$	-155.4	-46.2	-161.7	-78.0
N8	MD76	$\delta^{18}O_{sw}$	-53.3	121.8	108.7	-79.0
N9	Gempa Bumi Cave	stalagmite $\delta^{18}O$	-178.8	75.3	-181.0	100.0
W1	Liang Luar Cave	stalagmite $\delta^{18}O$	177.7	54.4	89.1	75.3
N10	Lake Towuti	Ti	159.1	-17.4	129.8	-31.5
D17	GeoB 10053-7	marine sediment log(Ti/Ca)	-71.2	-117.2	-109.9	-142.8
N11	SO185-18460	marine sediment Ln(K/Ca)	-166.0	125.8	-167.8	146.6
D18	GeoB10069-3	planktonic $\delta^{18}O_{ruber}$	-173.4	-101.8	-152.9	-72.3
N12	SO185-18479	marine sediment Ln(K/Ca)	-180.3	131.1	-181.5	125.7
N13	MD01-2378	marine sediment Ln(K/Ca)	-178.7	104.6	-184.0	84.6
N14	SO185-18506	marine sediment Ln(K/Ca)	-168.3	178.2	-162.2	179.7
W2	Ball Gown Cave	stalagmite $\delta^{18}O$	86.4	99.0	31.6	110.7
W3	Lake Barrine	Ti	138.7	117.0	136.5	133.1
W4	Bromfield Swamp	PC1	77.9	10.9	37.0	5.1

Note: In the “Site no.” column, D means “dry”, N means “no obvious change”, W means “wet” during the YD event.

Reviewer #3 (Remarks to the Author):

I appreciate the effort that the authors made to address my previous comments and suggestions on the manuscript entitled "Modulation of inter-hemispheric temperature gradients on the Holocene Asian-Australian summer monsoon". In particular, I really appreciate it that the authors have compared their record with other records in the AIM region – although of lower resolution than their record – these records help to support their interpretation. As I mentioned in my previous review, this is an interesting piece of work and an important step forward, as it delivers in my opinion a new, additional viewpoint how to link the EAM and AIM during the past. Having read their response to the comments and suggestions of the other reviewers, I think that this manuscript can can be accepted for publication now. I believe that this manuscript will attract a broad interest from palaeoclimatologists and climate modellers.

Thanks again for your positive evaluation of our work. We truly appreciate your effort in reviewing our manuscript.

References:

Rasmussen, S. O. *et al.* A new Greenland ice core chronology for the last glacial termination. *Journal of Geophysical Research: Atmospheres* **111**, D06102 (2006).

Denniston, R. F. *et al.* North Atlantic forcing of millennial-scale Indo-Australian monsoon dynamics during the Last Glacial period. *Quaternary Science Reviews* **72**, 159-168 (2013a).

Denniston, R. F. *et al.* A Stalagmite record of Holocene Indonesian–Australian summer monsoon variability from the Australian tropics. *Quaternary Science Reviews* **78**, 155-168 (2013b).

Bond, G. *et al.* A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates. *Science* **278**, 1257-1266 (1997).

North Greenland Ice Core Project members. High-resolution record of Northern Hemisphere climate extending into the last interglacial period. *Nature* **431**, 147-151 (2004).

Muller J. *et al.* The use of principle component analyses in characterising trace and major elemental distribution in a 55kyr peat deposit in tropical Australia: Implications to paleoclimate. *Geochimica et Cosmochimica Acta* **72**, 449-463 (2008).

Ribeiro S. *et al.* Vulnerability of the North Water ecosystem to climate change. *Nature Communications* **12**, 4475 (2021).

Baxter A. J. et al. Reversed Holocene temperature–moisture relationship in the Horn of Africa. *Nature* **620**, 336-343 (2023).

Reviewer #2 (Remarks to the Author):

Thanks to the authors for their responses to points raised in my reviews.
To complete the discussion around definition of the YD, at least in terms of this correspondence, please make sure it is clear which YD is represented by the blue bar in Figure 2 i.e. note in the caption how this is defined (NGRIP?).
I guess we'll have to agree to disagree about some things!

Thanks for the suggestions. We defined the YD event in the caption of Figure 2 according to the nearby Liang Luar Cave stalagmite $\delta^{18}O$ record (Griffiths et al., 2009). This record is the nearest stalagmite record in the Indonesian-Australian summer monsoon region to our record that has been well dated.

Reference:

Griffiths, M. L. et al. Increasing Australian–Indonesian monsoon rainfall linked to early Holocene sea-level rise. Nature Geoscience 2, 636-639 (2009).