

## ***Interactive comment on “The East Asian winter monsoon variability in response to precession and inter-hemispheric heat balance” by M. Yamamoto et al.***

**M. Yamamoto et al.**

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We thank reviewer#1 for his/her review, which has lead us to improve our manuscript. Below we provide our response to queries and comments raised.

Yamamoto et al. have written an interesting manuscript dealing with the reconstruction of the East Asian winter monsoon. In essence, they propose to make use of the difference in sea surface temperature (SST) response to winter monsoon cooling between a site in the South China Sea (SCS; strongly affected by winter monsoon) and a site in the Western Pacific Warm Pool (WPWP; hardly affected by winter monsoon cooling). The author combine several different paleo-SST proxies to make sure that

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the observed changes in SST are true (Uk37, TEX86, Mg/Ca). The idea to contrast the large changes in winter-SST in the SCS against the minimal changes in the WPWP to obtain a measure for the strength of the winter monsoon is clever and the topic is highly suitable for Climate of the Past. Below I will follow the review template provided by CP. Reply: Thank you for the understanding of the significance of this paper.

1. Does the paper address relevant scientific questions within the scope of CP? Yes (see above) Reply: Thank you.

2. Does the paper present novel concepts, ideas, tools, or data? Yes, although the concept of contrasting the climate signal of different regions is not new, the presented study is cleverly designed and I believe this is the first attempt at this kind of reconstruction made in at least this area. A somewhat similar study (for the last 26ky) was published by Huang et al. 2011 (cited in the manuscript), but this study goes back much longer. Reply: Thank you.

3. Are substantial conclusions reached? No, the conclusions are minimal and too general, stating explanations such as "a physical mechanism of inter-hemispheric heat balance". This claim must be substantiated and the mechanism properly explained in the discussion. Reply: The original expression was vague. We removed the words "a physical mechanism" from the title, abstract, discussion and conclusion and discuss the relationship between the East Asian monsoon and inter-hemispheric heat balance more specifically.

4. Are the scientific methods and assumptions valid and clearly outlined? Yes. The methods are properly described. However, there is a need for a more thorough explanation why the measured SST is only affected by the winter monsoon and not by any other factor caused by the extremely large changes in basin geometry and geographical setting that characterize the SCS on glacial-interglacial time scales. Reply: The glacial-interglacial variation in the SST in the SCS was often interpreted by changes in the sea level and the resultant basin geometry (e.g., Zhao et al., 2006). Since the

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SST drop was also seen in the other WPWP region in the glacial periods, the  $\Delta$ SST is used to distinguish the local cooling of the SCS from the regional cooling of the entire WPWP area. The variation of  $\Delta$ SST was not synchronous with the variation of sea level change shown by the oxygen isotopes of benthic foraminifera, and the maximum local cooling of the SCS (maximum  $\Delta$ SST) appeared several thousand years after the minimum sea level (Fig. 6). The local cooling of the SCS was thus independent of sea level change and the resultant basin isolation. We added a new paragraph in section 5.2 (Response of SCS SSTs to orbital forcing).

5. Are the results sufficient to support the interpretations and conclusions? The results support the interpretations, however, it is not clear why only winter monsoon strength would affect SST. The core (MD97-2151) is situated directly at what appears to be the boundary between the weak cyclonic gyre that develops in the northern SCS, and the anti-cyclonic gyre in South (Separated by eastward summer jet) during the summer. How is the circulation pattern influenced by the dramatic change in geography caused by sea level changes? And how are these changes reflected in the proxy records at this site? These questions (and possible complications) are overlooked and need to be addressed. Reply: We added the description on a factor affecting summer SST in the study area in chapter 2 (Oceanographic setting). "Winter monsoon northerly winds cool the surface water in the northern margin of the SCS and advect the cooled water southward (Liu et al., 2004). The SST in the study region is governed by the winter wind strength and the effect of cooling reaches 2°C in the study area (Huang et al., 2011). Summer monsoon southerly winds develop an anticyclonic eddy and cool the surface water by the advection of coastal cool water and upwelling in the study area and the effect of cooling is maximum 1°C (Xie et al, 2003)."

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? The phase relationships between the different monsoon proxies are difficult to follow, and on several occasions the authors refer to the Ice Volume Maxima in a way that gives the impres-

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sion that ice volume is controlled by precession. I believe obliquity and eccentricity play a considerably larger role in controlling ice volume. Reply: The benthic oxygen isotope records always show a precession cycle, though the intensity of the signal is weaker than those of eccentricity and obliquity. Thanks to this comment, we realize the significance of the  $\Delta$ SST record that has strong precession signal rather than obliquity and eccentricity signals. We thus added a new paragraph to explain the characteristics of the periodicity in section 5.2. (Response of SCS SST to orbital forcing). "The strong precession signal seen in  $\Delta$ SST supports the hypothesis that monsoon is regulated by insolation changes at low-latitudes (Kutzbach, 1981). The obliquity and eccentricity signals in  $\Delta$ SST are much weaker than the precession signal (Fig. 7). This is contrast with the previous marine records of the East Asian winter monsoon that has a similar variation to that of continental ice volume (e.g., de Garidel-Thoron et al., 2001). The glacial-interglacial pattern in proxy records presumably reflected the variation of the entire WPWP region rather than local variation sensitive to the East Asian monsoon activity. The approach of  $\Delta$ SST successfully extracted the signal of the East Asian winter monsoon from the climate variation in this region."

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes Reply: Thank you for your recognition.

8. Does the title clearly reflect the contents of the paper? No. The expression "Inter-hemispheric heat balance" occurs in the title, the abstract, twice in the discussion, and once in the conclusion without any explanation of what this would mean in the physical world. If this is central to the study, as indicated by the title, then this concept must be explained properly, and its relevance to the winter monsoon must be explained in detail. Reply: The conclusion on interhemispheric heat balance was overstated in the original manuscript. We removed the words " interhemispheric heat balance" from the title and abstract. Discussion parts were revised to explain the possible relationship between the East Asian winter monsoon variability and interhemispheric heat imbalance more specifically in section 5.4 (Response of the East Asian winter monsoon to

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interhemispheric heat imbalance).

9. Does the abstract provide a concise and complete summary? Yes Reply: Thank you.

10. Is the overall presentation well structured and clear? Yes, until 5.2 when it becomes difficult to follow the arguments regarding the phasing of different components of the climate system. Reply: The section 5.2 of the original manuscript was separated to three sections, i.e, section 5.2. (Response of SCS SST to orbital forcing), section 5.3. (Phase relationship with Indian and East Asian summer monsoon), and section 5.4. (Response of the East Asian winter monsoon to interhemispheric heat imbalance). The issue of the phase is discussed in the sections 5.2 and 5.3. The original discussion was thoroughly reorganized.

11. Is the language fluent and precise? Generally yes. Reply: Thank you.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes, as far as I can judge. Reply: Reviewer #2 pointed that there are grammatical mistakes. We will check and correct them.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? Under section 5.2, the part dealing with the phase relationships needs to be expanded and better explained. Reply: Section 5.2 was separated to three sections. The interpretation was thoroughly revised and reorganized.

14. Are the number and quality of references appropriate? The general oceanographic description appears to largely be based on Wyrski (1961). There is a large literature summarizing the recent understanding of the SCS that need to be considered: Hu, J., Kawamura, H., Hong, H. and Qi, Y., 2000. A review on the currents in the South China Sea: Seasonal circulation, South China Sea Warm Current. *Journal of Oceanography*, 56: 607-624. Wang, P. and Yu, Q. (Editors), 2009. *The South China Sea. Developments in Paleoenvironmental Research*, 13. Springer. And especially the effect of

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local upwelling near the studied site: Xie, S.-P., Ilmberger, J., Xie, Q., Wang, D. and Liu, W.T., 2003. Summer upwelling in the South China Sea and its role in regional climate variations. *Journal of Geophysical Research*, 108(C8). Reply: These papers are cited. We added the description of SCS oceanography based on these papers in section 2 (Oceanographic settings).

Kutzbach is sometimes misspelled Kutsbach or Kutsbach. Reply: All right. These are corrected.

15. Is the amount and quality of supplementary material appropriate? I couldn't find any supplementary material, but that might be my own fault. Reply: We did not attach the supplementary materials.

Additional, specific comments: Page 4230, line 24: inter-hemispheric phenomena is very wide and sweeping, specify or remove. Reply: The last part of the sentence "and is characterized by inter-hemispheric phenomena" was removed.

Page 4233, line 12-13: The sentence is a bit awkward and I think it actually means that the site has been located offshore from Vietnam for 150,000 years. Obviously what is meant is that the records goes back 150,000 y. Reply: All right. We corrected the sentence. "Here, we present 150 kyr records of TEX86H-derived temperatures from southern SCS core MD97-2151 at the offshore of Vietnam. We obtained a record of SST differences between the SCS and the central WPWP to understand the Asian winter monsoon variability and mechanisms during the last 150,000 yr."

Page 4235, line 14: Awkward English: He was the carrier gas at 30 cm/s. Reply: This sentence was corrected. "Helium was used as the carrier gas at 30 cm/s."

Page 4236, line 1: SSC? Should be SCS? Reply: Yes, it is SCS. Corrected.

Section 5.2: For the sites in the WPWP only coordinates are give. It may help to plot them on the map in figure 1, or to describe their position in the text. Simply giving coordinates forces the reader to look up those positions by them selves. Reply: Thanks

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to this comment, we added the locations of reference cores in Fig. 1.

The SST record of MD97-2140 was re-tuned to the age model of Martinson et al. (1987). Is this really the best age model available for the WPWP? Reply: We revised the age-depth models for all of the cores. The age models were created by correlating with the LR04 stack record (Lisiecki and Raymo, 2005). Changes in the age-depth models did not modify the records of SST and delta-SST and unaffected the discussion and conclusions.

Page 4242, line 10-14: Other possible factors influencing the SST of the SCS site must be addressed, such as geographic/bathymetric changes due to sea level, upwelling changes due to changed deep circulation (there are a couple of recent studies addressing deep water changes in the SCS on glacial time scales). Reply: The discussion on the factors affecting the SCS SST was expanded in section 5.2.

Page 42-42, line 19: Huguang is a maar, which is a kind of lake, thus no need to call is Huguang Maar Lake (although Wang et al does it...) Reply: Because Huguang Maar Lake record is one of few records of Asian winter monsoon, we cited this paper.

Page 4243, line 6: Here ice volume is stated to be at a maximum at the March perihelion, but ice volume doesn't change on the 23k precession cycle, does it? Reply: The benthic oxygen isotope records always show precession cycles, though the intensity of the signal is weaker than those of eccentricity and obliquity.

On page 42-44, the authors list a number of records from East Asia that show other phase relationships. If the winter monsoon is offset at these locations, how can the authors then be certain that their record is generally valid? Reply: A paragraph was added to explain why the records are different in section 5.2. "The strong precession signal seen in  $\Delta$ SST supports the hypothesis that monsoon is regulated by insolation changes at low-latitudes (Kutzbach, 1981). The obliquity and eccentricity signals in  $\Delta$ SST are much weaker than the precession signal. This is contrast with the previous marine records of the East Asian winter monsoon that has a similar variation to that of

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continental ice volume (e.g., de Garidel-Thoron et al., 2001). The glacial-interglacial patten in proxy records presumably reflected the variation of the entire WPWP region. The approach of  $\Delta$ SST successfully extracted the signal of the East Asian winter monsoon from the climate variation in this region."

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Interactive comment on Clim. Past Discuss., 9, 4229, 2013.

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