

## ***Interactive comment on “Contribution of oceanic and vegetation feedbacks to Holocene climate change in Central and Eastern Asia” by A. Dallmeyer et al.***

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Received and published: 9 February 2010

We would like to thank Oliver Elison Timm for his constructive comments, which helped to improve our manuscript.

General comments:

1.) Number of regions and results, significance:

RC: “My major criticism is that the authors try to discuss too many aspects of the very complex Monsoon processes. A more concise and more compelling discussion of one monsoon season (e.g. the extended summer from spring to autumn) and focus on the

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key regions with significantly different contributions from the ocean/vegetation feedback would have been sufficient.”

RC: “As outlined above, the biggest concern is the huge number of sub-results: Presenting and discussing 11 regions, 4 seasons, 4 response types for 2 variables is not manageable in one paper of this length. The result is that the subparagraphs are sometimes confusing (see examples below) and important physical feedback processes are not discussed in more comprehensive terms”

RC: “The model results are sufficient, but a statistical significance test of the feedback influence (especially from synergistic effects and vegetation) are required.”

RC: “The result section needs to become more concise.”

AC: We agree that we should focus on fewer regions and on robust results. Therefore, we considerably changed our paper. In the revised version of our manuscript, we restrict our analyses to the Asian monsoon region. We now consider only 6 (instead of 11) regions, two in the Indian Monsoon (IND, PAK), two in the East Asian monsoon region (YANG, NECH) and two, which are affected by both monsoon systems (TP and INCPIN). We kept the number of seasons, because of the interesting differences between processes and factors emerging in different seasons. Furthermore, we applied a student’s t-test to test significance, or robustness, of our results. In the main text, we highlight only robust results, which makes the text more concise. Thereby we are able to include more explanation of the robust processes. These are underlined by new, additional figures.

Individual comments:

1.) Abstract ll.13-15:

a) RC: “You mentioned the lagged ocean SST response to the seasonal forcing here and in the text. It is an important part of the feedback mechanism and deserves an extra figure in the result section.”

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AC: We fully agree and provide an extra figure in section 4.) showing the sea-surface temperature difference between mid-Holocene and present-day for each season.

b) RC: "The abstract is a good summary of the major results. These would be worth to concentrate on throughout the result and discussion (e.g. the summer monsoon (Spring to Autumn) for Indian and East Asian Monsoon."

AC: We agree and we focus our attention on the Asian monsoon region in the revised version.

2.) Page 2353, l. 26: We corrected this sentence, and we write: However, modeling studies just focusing on the direct response to orbital forcing tend to underestimate the monsoon expansion and associated increase of rainfall, at least over North Africa (Joussaume et al., 1999).

3.) Page 2355, ll. 11-16: comparison with present-day observations: The biases between the simulated Asian climate and observations are indeed represented by the study of Cui et al. (2006). The additional deviation attributed to the coarse resolution (cf. Roeckner et al., 2006) is small compared to the bias between model and observation.

4.) Page 2357, ll. 10-20: We agree, and we included a more detailed description of the regions under consideration in the revised version. Additional information on the choice of regions is given. We write: Ad hoc, we define the following regions of interest: In the region of the large plain in East China, (referred to as YANG in the following) and in North-East China (NECH) we expect a clear signal of the East Asian monsoon, whereas in the regions PAK and IND of the Indian subcontinent, the Indian monsoon is likely to dominate climate dynamics. The areas roughly identified with the Tibetan Plateau and the Indochina Peninsula (INCPIN) are presumably affect by both monsoon systems.

5.) Page 2357 l.15: We changed the sentence to: Our analyses show that even in re-

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gions influenced by only one of the above mentioned circulation systems the response of the different climate components locally varies. Therefore, we divided the Asian monsoon region into sub-areas, which differ with respect to orography and vegetation changes.

6.) Page 2357 l. 25: This sentence is deleted in the revised version of our paper. We now write: Although these sub-regions cover only nine grid boxes in some cases, the differences between the areas, we used for the allocation, consistently stay the same regarding orography and vegetation change.

7.) Page 2357: RC: "I suggest to end this section with a note that the main focus is on the regions of the Indian and East Asian Monsoon, for example."

AC: We agree. In fact the entire study now focuses on Indian and East Asian Monsoon only.

Section 3:

8.) Result section 3:

RC: "Please make use of your defined 11 regions (if you decide to keep them) from Tab. 1 in the text. Otherwise it's very difficult to understand to what regions the results apply to. I'd like to see two or three key regions being followed throughout the result sections (East Asian Monsoon vs Indian and Tibet Plateau for example). Interesting outlier regions may then be mentioned in addition."

AC: We agree with the referee's suggestion to focus on interesting regions rather than to stick with all 11 regions. Accordingly we arranged our Sections in the following way: The aim of section 3 is a presentation of the overall climate change in the Asian monsoon domain and surrounding regions. The sub-regions are considered in the following section.

9.) Page 2359 l.20-24: We revised our text by following the referee's suggestion. We now write: On average, the region, affected by the Asian monsoon in spring, and

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adjacent oceans receive less spring precipitation (up to 1mm/day) under 6k orbital conditions, likely indicating a later onset of the summer monsoons.

10.) Page 2360-2361 l.27 l.3: We agree, and we have modified the text: The Tibetan Plateau is a large orographic barrier, preventing a further inland penetration of the Indian (northward) and East Asia summer monsoon (westward), whereas the African monsoon is able to expand northward. Since most of the total precipitation in those regions can be attributed to the summer monsoons, changes in the amount of rain at the lee side of the Tibetan Plateau and thereby the reduction of the desert fraction must be small. Thereby, the Tibetan Plateau limits the expansion of vegetation north of the Plateau.

11.) Page 2361 ll.13-14: We agree, and we change the sentence to: The model indicates a significant shift of forest to the west. However, in the low resolution of the model this shift is expressed by one single grid-box. A northward displacement cannot be detected.

12.) Page 2361 l. 25:

RC: "what about the proxy ambiguity in their vegetation reconstruction? Is it only the coarse resolution that limits the agreement? A sketch of a map with the proxy-based reconstructions (maybe only in form of "+" and "-" regions would be helpful to illustrate this).

AC: Since vegetation reconstructions are sparse and Asia exhibits a very heterogeneous landscape, a comparison of land cover change with reconstructions is expected to be more appropriate in numerical experiments with higher spatial resolution. Probably, the coarse resolution is not the only factor limiting the agreement. Unfortunately, we are not able to provide a map like this.

Section 4:

We took up the referee's suggestion to restrict our analysis to fewer regions. Hence,

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we have rewritten this part of our result section (section 4)

13.) Page 2362: RC: "Please make sure you reference the regions by using your 11 region acronyms from Tab. 1. For example line 15-16: "[...] in a large area between the Tibetan Plateau and the east coast of China [...]" ... " l. 20: "[...] in the other regions [...]"

AC: In our revised manuscript, we relate all statements to our defined regions, using the respective acronyms.

14.) Page. 2363 l. 11: RC: "write: "[...] atmosphere-only runs: Despite the fact [...]" "

AC: Done.

15.) p. 2365 l. 11:

a) RC: "write: "land masses" " AC: Done.

b) RC: "what regions are meant by "northern Asia" "

AC: "Northern Asia" is not related to a specific region. The anticyclone develops above the whole northern (extratropical) continent. To specify the region, we now write: ...weakens the anticyclone, which develops in autumn over the cold land masses of the extratropical Asian continent ...

16.) Page. 2365, l.17-19: Significance of the differences:

This was, indeed, a very fruitful suggestion. Therefore, we have tested the robustness of our results by using a student's t-test, and we present only robust factors and contributions in the revised version of our manuscript.

17.) p. 2366, l6-29: RC: "please indicate after each region which of the regions in Tab. are included in terms like Indochina, India, Yangtze-Huanghe-Plain, Central Asian continent"

AC: We now use acronyms throughout the paper.

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18.) p. 2367, l. 7: RC: "Are the changes small compared with the summer changes or are they considered small relative to the winter mean precipitation?"

AC: We agree, and we write: The change of wintertime precipitation is small compared to the other seasons and not robust in all regions.

19.) p. 2368, l. 1-10: RC: "Here is one of the most interesting results of the paper, in my opinion: The ocean feedback can counteract the direct atmospheric response. Without ocean feedback IND would appear drier in the 6,000BP period. very interesting result. Also, later in the summary figure 9 and the discussion it seems to me that the regionality matters: whether regionally or averaged over the entire region, the feedback can be interpreted as either positive or negative feedback."

AC: It is an important result. In our revised version, we emphasize this point in the summary.

20.) p. 2368-2369 l. 24-1.6:

RC: "Here it would be important to make a statistical test of the significance: First it is said the differences are small. Then, the feedback is described as "mostly positive in except for winter." And in spring there is a north-south gradient with a highlighted center around the Tibetan Plateau. But all this is under the overall assumption that everything is statistically significant and robust regarding the model and its resolution?"

AC: We performed a T-test to estimate the robustness of our results. In our revised manuscript, we only mention the robust factors (see above, comment 16).

21.) p. 2369, l. 13-17:

RC: "Statistical significance test? And is the contribution measured against the overall changes. In figure 6. the green bars look as 'important' as in the other seasons compared with the total length of the bars. I suggest to add for each season and each region an extra bar (maybe at the top of the plots) that indicates the minimum difference that is still significant (using a t-test for example or ANOVA). Or at least an indicator for

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the variance in the model runs (divided by the square root of the sample size)."

AC: We agree, and we have done the test (see above, comments 16, 20)

Summary and discussion:

22.) p. 2370 l. 8: RC: " write "[...] change over land for each [...]"

AC: Since we restrict our analyses to 6 regions, Figure 9 (now Figure 14) depicts averages over all 6 regions. The new regions cover only land areas.

23.) P. 2370, l. 20-25:

RC: "is everything explained by the thermal inertia of the ocean SST. Could ocean dynamics, feedbacks for example in the upwelling region off the Arabian coast, or suppressed variability when ocean SST are held fixed lead to monsoon changes?"

AC: Presumably, it could. However, in the current model set up, we are not able to easily distinguish between effects of ocean current, upwelling etc. on SSTs.

24.) p. 2371, l. 2-4: RC: "Maybe add: " The detailed mechanism behind the feedback between ocean and the Tibet Plateau is still not fully understood, though."

AC: In the revised version we changed the text: Due to the oceanic-induced cooling in summer and warming in winter, the ocean modifies the thermal processes in the monsoon system. TP is an area, where this mechanism might be particularly interesting. The Tibetan Plateau is a large elevated heat source in summer (March to October) and a weak heat sink in winter, exerting a strong impact on the Asian climate and the regional energy balance (Wu et al., 2007, Liu et al., 2007). By cooling the Plateau in summer and warming it in autumn, the ocean attenuates the magnitude of the heat source at the beginning of the monsoon season, which might affect the climate in the whole region. However, the detailed mechanism behind the feedback between ocean and the Tibetan Plateau is still not fully understood.

25.) p 2371, l. 13-14: RC: "write: "Despite the very different [...]" "

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AC: Done.

26.) p. 2371, l. 15: RC: " remove "respectively" ; AC: Done.

27.) p. 2371, l. 17: RC: "which regions according to Tab. 1"

AC: Here, "regions" refer to the Asian monsoon region and the northern latitudes, the study region of Otto et al., 2009, but not to specific sub-regions of our study.

28.) Page 2372, l.5: RC: " Check: "If applicable [...]" or "Where applicable [...]"

AC: We now write: If comparable, our results are in line with . . .

29.) p. 2372 l.10:

RC: "This is important to emphasize: If averaged over the larger region (Fig 9b.) the ocean feedback appears as an positive feedback (enhances the atmosphere only response). But in regional analysis of Fig. 6, we find that several regions have opposing signs in atmosphere-only and ocean feedback response . . ."

AC: We fully agree, and we highlight this point in our text: Although the ocean-atmosphere feedback appears positive averaged over all domains, our regional analyses reveal a negative feedback in some regions and seasons. The most remarkable example is IND, showing a strongly negative ocean-atmosphere feedback in summer. In that region, the atmosphere-only run suggests less precipitation in 6k compared to present-day. The ocean is able to overcompensate the direct effect, yielding to the wetter climate in 6k. Whether the ocean-atmosphere feedback can be interpreted as either positive or negative, thus, depends on the spatial averaging (regionally versus entire monsoon region).

30.) Page 2373, l.17: We omitted this sentence in the revised version of our paper.

31.) p. 2373, l. 20-22: RC: "Could you discuss further, how proxies could help to validate model results. "

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AC: This is a good idea. In fact, we plan to do this in cooperation with palaeontologists. The work is in progress, and it will be subject of a separate full paper.

32.) RC: "Do you think that the proxy data allow already to validate the regional aspects of your simulation and even higher resolution (regional paleomodeling) are really necessary to (a) understand the proxy records in their spatial complexity or (b) to represent the Indian and East Asian Monsoon interplay and the oceanic-vegetative feedbacks in a proper way [to understand the paleo-evidence from proxies].

AC: We agree that much higher spatial resolution is needed for an in-depth intercomparison of data and model. Hence in this study, we could only pursue qualitative and fairly general arguments. Asia has a very heterogeneous topography. The proxy sites are sparsely distributed and often present local rather than regional vegetation. Furthermore, an enhancement of the Asian monsoon does not yield large shifts in the vegetation zone (desert to vegetated area) like in the African Monsoon. In the Asian Monsoon region, shifts from one vegetation type to another are more important. In most Central, East and South Asian regions our model is not able to simulate these vegetation changes well. This might result from an inadequate presentation of the Tibetan Plateau. In our coarse-scale model, the averaged height of the Plateau is ca. 2000m (just an estimate). Orography reaches values of 4000m heights only in few grid-boxes. In reality, the averaged height exceeds 4000m, and some mountain ranges are higher than 8000m. Therefore, detailed comparison of data from various sites with a climate system model is sensible only when using much higher horizontal resolution. Such a study is under way, as mentioned above. But it requires a new model and at least an order-of-magnitude more computer power. This is available with the inauguration of the new computer at the German Climate Computing Centre at the end of last year. The new model is expected to run in a few months.

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Interactive comment on Clim. Past Discuss., 5, 2351, 2009.

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