

## ***Interactive comment on “Regional climate model experiments to investigate the Asian monsoon in the Late Miocene” by H. Tang et al.***

### **Anonymous Referee #1**

Received and published: 15 April 2011

Tang et al. compare results of global and regional climate model simulations with respect to the representation of the Tortonian climate in the present-day Asian Monsoon region. According to their results, the Asian winter monsoon was stronger and the summer monsoon weaker in the Tortonian compared to present-day. The associated precipitation changes, however, exhibit strong regional contrasts which particularly occur in the regional climate model simulation. The increase (decrease) of precipitation in the Southern (Northern) region of the Asian monsoon domain suggest a southward shift of the Inner Tropical Convergence Zone and a minor penetration of the Asian monsoon onto the continent in the Tortonian simulations. Furthermore, Tang et al. separate the contribution of global forcing and changes in regional boundary conditions to the

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precipitation change. Overall, the study is an important contribution to understand Tortonian climate. The manuscript is well-structured. It is appropriate to be published in *Climate of the Past* after the following aspects have been revised.

General comments:

a) Sometimes it is not clear which region is meant by terms such as N-China, E-Asia, S-China, C-Asia, etc. I would suggest to provide an additional figure (or table) in which you define all regions you want to use.

b) Some readers might be unfamiliar with the Asian monsoon circulation. I suggest adding a map showing the present-day summer and winter circulation (850hPa wind, 500hPa) in the Asian monsoon region, e.g. derived from your CTRL simulation. It would also facilitate the assessment of the circulation anomaly figures you showed.

c) In the discussion chapter, you use a lot of different indices describing the changes in monsoon circulation. Please explain in the text or at least in the caption of Table 3, why you use other regions for averaging than defined for the original indices. It would also be helpful to keep the abbreviations of the indices used in Wang et al. 2008a, so that the reader can easily identify the indices you refer to.

d) In the last part of your manuscript you use the term GTORT as name for a forcing, in the first part as name for the simulation. Please rename one, it is confusing.

e) You sometimes show the land-sea mask of the model in the figures, sometimes not. You also use different projections. It would be much easier to compare the figures if only one standard format is used.

Specific comments and technical corrections:

Abstract:

p.842, l.6: I guess, you have not simulate the entire Tortonian period from 11-7Ma. Be more precise which years you analyse.

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p.842, l.11: write: 'East Asian winter monsoon'

p.842, l.18: What do you mean by the term 'other forcings',? please give examples.

Introduction:

p.843,l.27-p.844, l.2: I don't understand this sentence. Please consider rephrasing.

Model and Model Setup:

p.845, l.5-6: I think, the weather prediction model is called 'Local Model'. In this case you should write: 'CLM ... developed from the weather prediction model Local Model of the German ...'

p.845,l.6: The reference Bohm et al. is not in your reference list.

p.845,l.9: write: 'pattern' instead of 'patterns'

p.845,l.18: write: 'More details ... are described in the original documentation...'

p.845,l.22: write: '...control run and a Tortonian run performed in the AOGCM COS-MOS'

p.846 Say some words on the orbital configuration you used and the spin-up .

p.846, l.12: It is not clear if you reduce orography globally or regionally.

p.846, l.14-18: Say a few more words on how you prescribed vegetation. Is it based on proxies? Is it consistent to the vegetation prescribed in the regional model?

p.846, l.24-26: According to Fig.3, the strongest warming occurs in the Sahara and on the Tibetan Plateau which are located in the low-latitudes. Therefore, the meridional T-gradient is probably not weaker in GTORT.

p.846, l.26-30: You mention the heat transport in the ocean, are these explanations results of other studies? then: please cite them. Perhaps, there are also other explanations for the cooling in Europe, have you analysed e.g. cloud cover? I guess, the

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westerlies also intensify due to the temperature change.

p.847, l.1: The strongest westerly wind anomalies are located south of the strongest precipitation anomalies. Please check the moisture flux and the moisture flux convergence to prove if the increased westerlies are really responsible for the increase in precipitation.

p.847, l.3-5: I think, a large part of the precipitation increase in North Africa is related to a strengthening of the summer monsoon, please check.

p.847, l.9: write: 'anomaly' instead of 'anomalies'

p.847, l.11-13: Figure 2d shows hardly no changes in summer wind field in East China. Thus, a weaker summer monsoon is probably not responsible for the strong reduction in precipitation. Please check if other mechanisms lead to the precipitation anomaly.

p.848, l.6: write: '...in more detail as in the global model to better represent .... the Tortonian.'

p.849, l.3: '... are similar to today' - do you mean present-day potential vegetation?

p.849, l.9: write: 'resemble that in GTORT .... ' ; without a 'to'

p.849 l.11-18: To better understand your experimental setup, you could further describe/repeat what you mean by regional boundary conditions (orography or vegetation,...) and what you mean by global boundary conditions (SST or sea-ice,...)

Results:

p.849, l.25: better use 'most pronounced' instead of 'most significant'

p.850, l.4-7: 'This suggests a reduced thermal contrast between land and oceans' - In my opinion, this sentence seems not to be correct, at least not for the summer season. Large parts of the South and Central Asian continent warm more than the ocean. This increases the temperature gradient, please check.

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p.850, l.18-19: Most of the Tibetan Plateau receives more precipitation. There is no distinctive north-south difference.

p.851, l.5-7: At least according to reanalyses data, N-India is affected by westerly winds (850hpa), S-India by easterlies. Thus, the Indian winter monsoon is not intensified in TORT.

p.851, l.10-11: 'The Asian trough is a little shallower resulting...' - I'm not sure, do you mean 'ridge' and not 'trough' ? Please add the atmospheric level: the ridge/trough in 500hPa ... .

p.851, l.23 and Fig. 5: The term 'geopotential height' does not fit to your numbers and the unit  $m^2/s^2$ . You just show the geopotential.  $geopotential\ height = geopotential / (9.81m/s^2)$ ; unit: m or gpm.

p.852, l.11: jumbled letters in 'Tortonian'

p.852, l.16: write: '... as at present-day, but ...'

p.852, l.19: write: 'This results from ... ', instead of: 'This is resulted from'

p.852, l.25-26: One of your key results is the confirmation of the existence of monsoonal influenced climate in large parts of South and Central Asia during the Tortonian. It would be interesting to further examine the extent of the monsoon region. You could use modern definitions like described in Wang and Linho, J. Climate, 2001.

## Discussion:

p.853, l.15-19: According to Fig.7, you average over longitudes between  $80^\circ$  and  $95^\circ E$ . This region does not represent the Indian subcontinent. It covers rather the Bay of Bengal region. Better use longitudes between  $70^\circ$  or  $75^\circ$  and  $85^\circ E$ .

p.853, l.20-21: In my opinion, one can see an ITCZ shift in Fig.7a,b. In TORT, there is still a strong upward motion at  $20^\circ N$ , south of it (between  $15$  and  $18^\circ N$ ) downward motion appears. Maybe the upward motion at ca.  $12^\circ N$  is induced by a change in

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upper-tropospheric wind divergence. The upward motion at ca.12°N does not start at the surface as it should do in the ITCZ.

p.853, l.23: The sinking motion in TORT is enhanced only south of TP. North of TP, the descending motion is extended to the upper troposphere. Descending motion also occur in the upper troposphere above the northern TP. Be more precise.

p.854, l.3: write: 'Asian monsoon region' instead of: 'monsoon regions'. The complex orography is a particular feature of the Asian monsoon domain not of other monsoon regions.

p.854, l.10: Just using two points for representing the pressure gradient in TORT and GTORT is probably insufficient. You should average over a few grid-boxes or, at least, use the centre of the pressure systems in each simulation. I guess, the lowest pressure in TORT is not located at the same coordinates as in GTORT.

p.855, l.2-3: better write: '40°N-50°N' instead of '50°N to 40°N'

p.855, l.9: write: '...2009) and, hence, may result ...'

p.855, l.3-12: ODP site 885/886 is located far in the north. It is possible that the westerly wind belt is shifted southward in the Tortonian, and that this site is not located downstream of the Loess Plateau any more.

p.855, l.17: write: '...in China in most of ... than at present-day...'

p.855, l.28: As the studies are written by two different authors, I would write: '...studies by L. Liu et al.(2009) and Y.-S. Liu et al. (2010) ...'

p.856,l.13-18: I suggest rewriting this section. It would be useful to add a sentence on the problem of different definition of the monsoon strength in literature (instead of referring to other papers), and that nowadays the term 'weak East Asian Monsoon' is commonly used for describing an anomaly with little precipitation in N-China and more precipitation in South China. Afterwards you could go on with the following issues: -

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your results show this anomaly pattern - conclusion: the East Asian summer monsoon was weaker in the Tortonian.

p.856, l.19: it is: 'a marked decline' not 'an marked decline'; I suggest using 'distinct' instead of 'marked'

p.857, l.1-3: I don't understand this sentence, please consider rephrasing.

p.857, l.4: better write: 'This agrees with the studies...'

p.858, l.1: better write: '...Tortonian simulation'

p.859, l.16: Have you prescribed an open Indonesian seaway? In this case I suggest mentioning this fact in your model setup section.

Figure captions:

Tab.1, l.3: You write: '...model domain are in bold.' There is no bold text in my pdf version, correct?

Tab.3: It is not clear, which indices are used (see above) and I wonder if it is appropriate to use these indices at all. Have you adjusted the indices to your model output? The regions of averaging are derived from EOFs or climatological data, one can not simply modify them.

Fig.2: better write: '...shaded areas show...' ; also in the other captions

Fig.2: If I interpret this plot correctly, almost all anomalies are significant. To make the plot clearer and less confusing you could plot only significant values in shaded, without the contour lines.

Fig.3: Please add a reference for the GLC2000 data set.

Fig.5: You plot sea level pressure anomalies to the domain average, did you use the entire domain for calculating the reference value? In general, the centre of the winter high-pressure system is located further to the west.

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Fig.5: geopotential vs. geopotential height (see above)

Fig.7: please add a colourbar

Fig.7: You use grey colour for orography but also for small values of the vertical wind, the colours are not easily distinguishable.

Fig.8: Is the annotation of the colourbar correct? Large parts are white or grey, but not as high as 8000-9000m. The labels of the small plots (a,b,c,...) as well as the annotation of the axes are not readable. In addition, it would be better to plot the model output (purple and red bars) to the according time in the reconstruction curves. That means: a red and a purple bar in Miocene and a red and a purple bar in present-day, but not the Tortonian purple bar right next to the present-day bar.

Fig. 9: What are the stars in your plot? I wonder, how good the hypsodonty is as proxy for the climate. Lower hypsodonty values are related to more precipitation. That means: in present-day, Eastern China receives much more precipitation than India. There are also other examples.

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Interactive comment on Clim. Past Discuss., 7, 841, 2011.

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