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Interactive comment on “The influence of land cover change in the Asian monsoon region on present-day and mid-Holocene climate” by A. Dallmeyer and M. Claussen

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We would like to thank the Anonymous Referee 1 for his/her constructive comments that helped to improve our manuscript.

Specific comments

Referee: *‘I miss a method section describing the land surface component JSBACH. Is it a standard component in ECHAM5 or is it a land surface/ecosystem model in its own right?’*

Author: JSBACH has, indeed, the function of both. At the one hand, it is the land-

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surface scheme of ECHAM5 and calculates the land-boundary properties such as albedo or roughness length as well as the fluxes of water, energy and momentum between the land and the atmosphere. On the other hand, it is a land ecosystem model calculating the terrestrial carbon cycle. JSBACH can be used in a coupled and uncoupled (independent) version. In this study, JSBACH acts as a land-surface scheme only. We improved the model description section (p.1698-1699) and wrote:

'JSBACH differentiates eight plant-functional types (PFTs). Forests can contain tropical and/or extratropical trees, which are either evergreen or deciduous. Shrubs are distinguished as raingreen shrubs or cold (deciduous) shrubs. Grass is classified as either C3 or C4 grass. For each PFT, individual physical properties such as albedo or roughness length are defined (Tab. 1, here:Fig.3) The land surface in JSBACH is tiled in mosaics, so that several PFTs can cover one grid cell. Each grid cell also contains non-vegetated area representing the fraction of seasonally bare soil and permanently bare ground (desert). JSBACH calculates dynamically the physical land surface parameters (e.g. albedo or roughness length) in each grid-cell as average of the individual properties of the PFTs and the non-vegetated area, weighted with their respective cover fraction. In the calculation of the albedo, snow-covered soils and snow-covered forest-canopies as well as the masking of snow-covered soils by forests are additionally accounted for. The soil albedo is prescribed from satellite data and does not change during the simulations. The albedo of leaves depends on the leaf area index that is calculated on the basis of temperature, soil moisture and the net primary production of the PFTs. Concerning phenology, JSBACH differentiates the four types evergreen, raingreen, summergreen and grasses. LAI can not exceed a maximum value specified for each PFT (see Tab. 1). The fluxes of energy, water and momentum between the land and the atmosphere are calculated using the averaged land surface parameter of each grid cell.

Referee: *'Since the role of vegetation is the key feature in the article, it would be good to know a bit more about how it is treated in JSBACH. What components are included;*

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phenology, biogeochemistry, vegetation dynamics etc.?’

Author: JSBACH includes a phenology and photosynthesis model and can also be applied as a dynamic vegetation model. In this study, JSBACH acts as a land-surface scheme with prescribed vegetation, carbon cycle dynamics are not considered in this study. For further information, please see also the following manuscripts:

Brovkin et al., *Geophys. Res. Lett.*, 36, L07405, doi:10.1029/2009GL037543, 2009

Raddatz et al., *Clim. Dyn.*, 29, 565-574, DOI 10.1007/s00382-007-0247-8

An extended documentation on the model JSBACH is in preparation.

Referee: *‘Has JSBACH been coupled to other GCMs?’*

Author: Not yet, but this is in progress. So far, JSBACH has been coupled to the regional model REMO and it will be coupled to CLIMBER2 in the near future.

Referee: *‘I wonder whether it would be relevant to include some kind of coupling scheme or perhaps equations that actually describe how the vegetation is coupled to the climate in these two specific models.’*

Author: This would in principle be helpful information, but it goes beyond the scope of this manuscript. A detailed description will be given in the official model documentation which is in preparation.

Referee: *‘I find it a bit difficult to distinguish between the afforestation and deforestation experiments in the results and discussion sections. My suggestion is simply to describe all the (major) vegetation related influences on climate under each experiment. It would improve the readability of the paper. Now, I have to jump back and forth in the text to get the full picture.’*

Author: We first also considered structuring the result and discussion section by experiment and not by parameter. However, we decided in favour of the latter method to facilitate the comparability of the climatic responses to the land cover changes for

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each parameter. In this order, it is easier to compare the effects of deforestation and afforestation on precipitation and temperature. We, therefore, kept the structure of the paper.

Referee: *'The results and discussion section are also very detailed. My suggestion is to focus on the main results and leave out weaker signals to improve the clarity of the paper.'*

Author: We agree, these sections are very detailed, but they are nevertheless short and we only focus on significant signals. We think the details are useful for the understanding of the involved processes leading to the climate change, since the response of the climate to the land cover disturbance is not in all cases intuitive (e.g. the chessboard-like precipitation signal in the monsoon season related with the afforestation). We therefore did not revise the result and discussion section.

Referee: *'Given that you have focused on drastic shifts in vegetation cover (complete afforestation/deforestation), what is the generality in your results? I mean, why is it important to study these two extremes?'*

Author: In a previous study, we have analysed the contribution of the vegetation-atmosphere interaction to the Holocene climate change in the Asian monsoon region by using a comprehensive Earth system model with dynamic vegetation included (Dallmeyer et al., *Clim. Past*, 6, 195-218, 2010). This study showed a rather small contribution of the simulated vegetation change on Asian monsoon climate. Perhaps, the model underestimated the amplitude of Holocene forest cover changes which could explain the weak vegetation impact. Therefore, we decided to force the model with a very strong (the maximum) forest cover change to get a stronger signal and to assess the maximum effect of forest cover change on climate.

In our revised version we added the following information in the introduction (p.1697): 'In a previous study, we analysed the contributions of the vegetation-atmosphere interaction, the ocean-atmosphere interaction as well as their synergy to the Holocene

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climate change in the Asian monsoon region by using a comprehensive Earth system model with dynamic vegetation included (Dallmeyer et al., 2010). This study showed a rather small contribution of the simulated vegetation change on Asian monsoon climate. The mid-Holocene to pre-industrial climate change was predominantly caused by the response of the atmospheric circulation to the insolation forcing as well as oceanic feedbacks. The synergy effect was mostly negligible. Presumably, the model underestimated the amplitude of Holocene forest cover changes which could explain the weak vegetation impact. At least compared to the former pollen-based vegetation reconstructions (see above) the simulated vegetation change seemed to be too small. Since the simulated vegetation change has only revealed a weak effect on climate, we decide to confront the model with a strong forest cover change to assess the maximum effect of large-scale land-cover changes on the climate in the Asian monsoon domain. For this purpose, we perform idealised sensitivity experiments with either a complete forest cover or a complete grass cover prescribed in the monsoon region. The domain of land cover change is ...'

Referee: *'On P1696 L5-15 and also in the discussion section you mention a number of previous studies on land cover – climate interactions in the Asian monsoon region. What is the added value of your study compared to these?'*

Author: The experimental design and research question of the previous studies and our study strongly differ. While previous studies focus on the impact of recent anthropogenic land use change on the regional climate in China our study assesses the maximum effect of large-scale forest cover change on the climate in the entire Asian monsoon domain. The study does not aim to represent the reality, i.e. the land cover change of the past decades. Our study is rather a sensitivity study on the general effect of large-scale deforestation and afforestation in the Asian monsoon region on climate. Therefore, we have already emphasised in the introduction that we performed 'idealised numerical experiments' (p. 1697, l.27). Furthermore, in most of the previous studies, regional climate models were used. The Asian monsoon system is very com-

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plex and involves large-scale circulation systems. Regional models can not capture the impact of vegetation changes on the large-scale circulation, but these changes are important for the regional climate change. In addition our study also aims to investigate the remote effect of Asian land cover change.

Referee: *'P1698, L13: What does 1.875 correspond to in km?'*

Author: We added the information: '... spectral resolution of T63, which corresponds to a grid-box width of 1.875° (i.e., ca. 210 km on a great circle).

Referee: *'P1698, L19: "The models have been tested against observations and reanalysis data". . . – in this constellation, i.e. ECHAM5-JSBACH?'*

Author: This statement is indeed misleading. Cui et al. have only tested the atmospheric model ECHAM5 with an older land-surface scheme and not ECHAM5/JSBACH. We compared our simulations with reanalysis data and observations and our results looks similar to the results of Cui et al.. We, therefore, took their paper as reference. Published literature on the representation of the Asian monsoon in ECHAM5/JSBACH does not exist. To avoid misunderstanding we deleted the reference in our revised manuscript and wrote:

'The models have been tested against observations and reanalysis data proving that they capture the major structure of global and regional climate (not shown).'

To give an overview we added two figures to this response. Fig.1 shows the near-surface temperature averaged over the monsoon season and dry/cold season. We compared the model results with observation (CRU TS 2.1) and ERA40 reanalysis data. Fig.2 shows the annual mean precipitation, derived from GPCP and CMAP and calculated by the model.

References:

CRU: www.cru.uea.ac.uk/cru/data/hrg/cru_t_s2.10/

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ERA40: Simmons, A. J. and Gibson, J. K.: *The ERA-40 Project Plan*, ERA 40 Project Report Series No. 1 ECMWF. Shinfield Park, Reading, UK, 63 pp., 2000.

GPCP: Adler, R.F., Huffman, G.J., Chang, A., Ferraro, R., Xie, P., Janowiak, J., Rudolf, B., et.al.: *The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present)*. *J. Hydrometeor.*, 4,1147-1167, 2003.

CMAP: Xie, P., and P.A. Arkin, 1997: *Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs*. *Bull. Amer. Meteor. Soc.*, 78, 2539 - 2558.

Referee: 'P1699, L3: *How is the natural land cover of CTRL determined?*'

Author: The potential vegetation distribution in the CTRL simulation is based on the potential vegetation map provided by Ramankutty and Foley (*Glob. Biogeochem. Cyc.*, 13 (4), 997-1027, 1999). Their vegetation types had been translated into the plant functional types used in JSBACH. The global distribution of deserts follows the distribution described in the Global Land Cover Characteristics data base of the U.S Geological Survey (Loveland et al, *Int. J. Remote Sens.*, 21, 1303-1330, 2000) In our study, the anomalies of the land cover between the different experiments are more important than the present-day distribution. Therefore we did not show a present-day land cover map in our manuscript.

Referee: 'P1700, L1: *Is there a reason to why the simulations span 100 years? Could it be less or more?*'

Author: Performing complex climate model simulations in relatively high resolutions needs lots of computing power. However, the natural variability of precipitation in the Asian monsoon region is high. Thus, one needs a long simulation period to get significant results. The usual taken 30-year climate period is not long enough. We choose a simulation period of 100 years (ca. 3x30years) as a compromise to assure significant differences between the deforestation/afforestation simulation and control simulation, but keep computing costs relatively low. A longer simulation period would probably fur-

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ther increase the significance of our results. In the revised version of the text we wrote: 'Each experiment spans 102 years to get significant results despite of the high natural climate variability in the Asian monsoon system. The first two years are considered as spin-up time and excluded from our analysis.'

Technical corrections:

'P1702, L24-L25: . . . "though vegetation change can also indirectly influences the other parameters". . . - also indirectly can influence' . . .done

'P1707, L3: . . . "precipitation change than model studies". . . - it should read "as" and not "than" or do I misunderstand?' . . .Yes, it is 'as' not 'than'. We corrected it.

'P1709, L19: . . . "afforestation and control experiment with same boundary conditions". . . - with "the" same ' . . .done

'P1709, L22: . . . "then defined as difference". . . - as "the" difference' . . .done

'P1710, L23: . . . "to the decrease of summer monsoon". . . - decrease "in" . . .done

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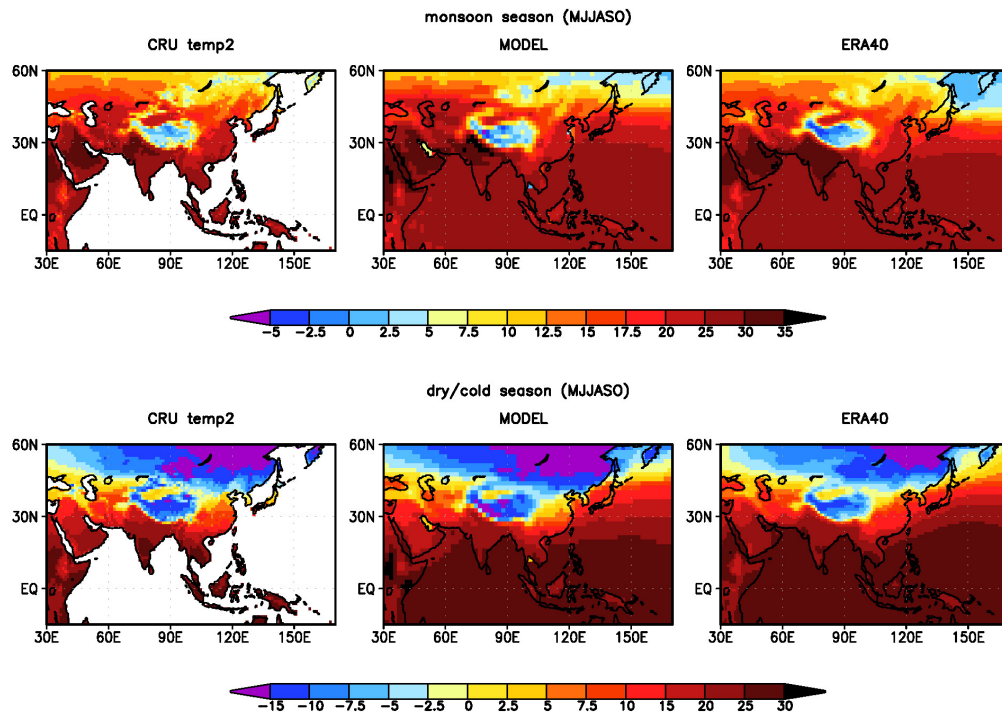


Fig. 1. Simulated near-surface temperature [$^{\circ}\text{C}$] compared to observations (CRU TS 2.1) and reanalysis data (ERA40), averaged over the monsoon season (May–October) and the dry/cold season (November–April).

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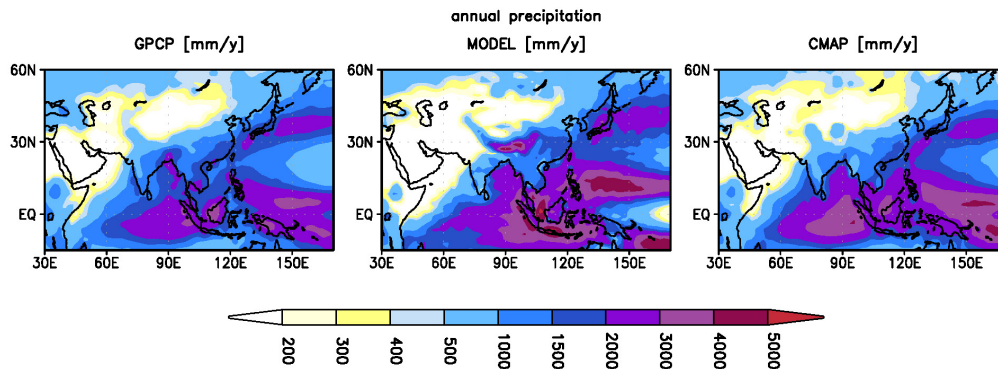


Fig. 2. Simulated annual precipitation [mm/year] compared to GPCP and CMAP data.

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PFT	phenology	LAI _{max} [m ² /m ²]	α_{VIS}	α_{NIR}	z_0 [m]
tropical evergreen forest	raingreen	7	0.03	0.22	2.0
tropical deciduous forest	raingreen	7	0.04	0.23	1.0
extratropical evergreen forest	evergreen	5	0.04	0.22	1.0
extratropical deciduous forest	summergreen	5	0.05	0.25	1.0
raingreen shrubs	raingreen	3	0.05	0.25	0.5
deciduous shrubs	summergreen	2	0.05	0.28	0.5
C3 grass	grass	3	0.08	0.34	0.05
C4 grass	grass	3	0.08	0.34	0.05

Tab.1: Physical properties and phenology type of each plant functional type (PFT), i.e. LAI_{max}: maximum value of the leaf area index; α_{VIS} : albedo in the visible solar spectrum; α_{NIR} : albedo in the near infrared solar spectrum; z_0 : roughness length of vegetation.

Fig. 3.

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