

## ***Interactive comment on “Individual and combined effects of ice sheets and precession on MIS-13 climate” by Q. Z. Yin et al.***

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Received and published: 30 May 2009

We thank Dr. Denis-Didier Rousseau for his helpful and constructive comments which answers are given here below in some details.

1. We have added references about the general monsoon system. For example, in the revised version, we have introduced the following lines at the beginning of the sixth paragraph of Section 5.1.

“Although monsoon is emphasized as a global system, for example by considering it as a manifestation of seasonal migration of the ITCZ (Trenberth et al., 2006; Wang, 2009), different monsoon subsystems respond differently to the forcing due to, for example, the different land-ocean configuration and topography (Wang et al., 2003; Ding and

C302

Sikka, 2006).”

And we have introduced the following at the beginning of the second paragraph of Section 5.1.

“The fundamental driving mechanisms of monsoon include: (1) land/ocean thermal contrast and the resulting pressure gradient force between the differentially heated regions and (2) moisture-related processes that determine the strength and location of the monsoon precipitation (Webster et al., 1998).”

2. “Kukla et al, Nature, 1981” and “Kukla and Kukla, Science, 1974” have been cited respectively in the introduction (last paragraph) and in section 4.1 (first paragraph):

“In an attempt to characterize the orbital signature of interglacials (Kukla et al., 1981), climate response to different astronomical forcings will be discussed in Sect.3.”

“The cooling over high-latitudes is mainly due to increasing snow area, sea-ice fraction and albedo, underlining their importance in polar climate change (Kukla and Kukla, 1974).”

3. The references related to the influence of the snow cover on monsoon have been cited in the third paragraph of the introduction:

“Modeling simulations (Barnett et al., 1989; Vernekar et al., 1995) have also shown that an anomalously high Eurasian snow cover leads to a weaker monsoon over India mainly through reducing the land/ocean temperature contrast. From modern observations Goes et al (2005) found that a decline of the Eurasian snow cover is linked to an intensifying Indian summer monsoon.”

4. The model is discussed in the first paragraph of Section 2. And its advantages and limitations have been added as follows:

“LOVECLIM is, within the hierarchy of the Earth system models of intermediate complexity, a low-resolution general circulation model (Claussen et al., 2002). Its main ad-

C303

vantage compared to more sophisticated general circulation models is that it is much faster, allowing to study the behavior of the coupled atmosphere-ocean-sea ice-land surface-ice sheet system over thousands of years (a run of 1000 years takes about 3 days on a workstation AMD Opteron 252/2.6 GHZ with 2 CPU dual core/4 GB RAM). The main simplification within LOVECLIM is the coarse resolution and the low level of complexity of some parameterizations. This leads to some limitations which are related, in particular to the prescribed cloudiness and the difficulty to simulate the atmospheric variability at low latitudes. Accordingly, the model results for the tropics should be treated with caution. In particular, the East Asian summer precipitation is underestimated and the low-level geopotential ridge over the North Pacific is shifted northward 10 degrees in latitude compared to observations (Yin et al., 2008). These weaknesses are most likely caused by insufficient spatial resolution and simplified convective physics. As a consequence, quantitative estimates of the effects of astronomical parameters and ice sheets on East Asian precipitation should not be interpreted too rigidly. Yet, LOVECLIM has proved to be a reasonably appropriate tool to identify teleconnections. Moreover, the synoptic systems for the East Asian monsoon region are of hybrid nature due to the existence of a very significant interaction between the monsoonal aircurrents and impacts from mid and high latitudes (Ding and Sikka, 2006). Along with its computing efficiency, this justifies using this model for a first qualitative assessment of the connections between ice sheets and sub-tropical dynamics by means of a series of sensitivity experiments. Moreover, the reliability of our results is tested on the basis of simulations with more sophisticated ocean-atmosphere general circulation models (such experiments, which confirm our results, will be discussed in companion papers). ”

5. To be clearer with the concentration of the Greenhouse gases we used for MIS-13, the following has been introduced in the second paragraph of section 2:

“The greenhouse gas concentrations (GHG) are quite stable over the whole MIS-13.1 (Siegenthaler et al., 2005; Spahni et al., 2005; Loulergue et al., 2008; Luthi et al.,

C304

2008). The difference between 506 and 495 ka BP being very small, the average over MIS-13.1 is used for both cases with a CO<sub>2</sub> of 240 ppmv, allowing to limit the sensitivity analysis to the astronomical and ice sheets forcings only.”

6. More explanations have been added in the first paragraph of section 3: “The maximum anomaly amounts to about 70 Wm<sup>-2</sup> and is centered at 30°N at the summer solstice reflecting the impact of a smaller obliquity at 506 ka BP”.

7. Response to the comment “. . . Thus could you provide some comment about the impact of greater ice sheets than the range used in the experiment?”

The LGM size of the Eurasian ice sheet used in this paper is about 12 106 km<sup>3</sup> already much larger than the minimum reconstruction by Lambeck et al (2000) (about 5 106 km<sup>3</sup>) and of the order of magnitude of the maximum size of the Eurasian ice sheet estimated by Bintanja et al (2005) over the last 106 years.

8. The abstract has been revised with more explanation:

“An Earth System Model of Intermediate Complexity is used to investigate the role of insolation and of the size of ice sheets on the regional and global climate of marine isotope stage (MIS) 13. The astronomical forcing is selected at two dates with opposite precession, one when northern hemisphere (NH) summer occurs at perihelion (at 506 ka BP) and the other when it occurs at aphelion (at 495 ka BP). Five different volumes of the Eurasian ice sheet (EA) and North American ice sheet (NA), ranging from 0 to the Last Glacial Maximum (LGM) one, are used. The global cooling due to the ice sheets is mainly related to their area, little to their height. The regional cooling and warming anomalies caused by the ice sheets intensify with increasing size. Precipitation over different monsoon regions responds differently to the size of the ice sheets. Over North Africa and India, precipitation decreases with increasing ice sheet size due to the southward shift of the Intertropical Convergence Zone (ITCZ), whatever the astronomical configuration is. However, the situation is more complicated over East Asia. The ice sheets play a role through both reducing the land/ocean thermal contrast

C305

and generating a wave train which is topographically induced by the EA ice sheet. This wave train contributes to amplify the Asian land/ocean pressure gradient in summer and finally reinforces the precipitation. The presence of this wave train depends on the combined effect of the ice sheet size and insolation. When NH summer occurs at perihelion, the EA is able to induce this wave train whatever its size is, and this wave train plays a more important role than the reduction of the land/ocean thermal contrast. Therefore, the ice sheets reinforce the summer precipitation over East China whatever their sizes are. However, when NH summer occurs at aphelion, there is a threshold in the ice volume beyond which the wave train is not induced anymore. Therefore, below this threshold, the wave train effect is dominant and the ice sheets reinforce precipitation over East China. Beyond this threshold, the ice sheets reduce the precipitation mainly through reducing the land/ocean thermal contrast.”

9. Both “Rossignol-Strick, 1983” and “Mélières et al, 1997” are cited for the Africa monsoon.

10. The references have been put in right order, and the figures are re-plotted for an easier read. The letters “a, b, c, d” used to differentiate the figures have been indicated in the captions.

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Interactive comment on *Clim. Past Discuss.*, 5, 557, 2009.