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Interactive Comment

Interactive comment on “The origin of the European “Medieval Warm Period"” *by* H. Goosse et al.

H. Goosse et al.

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We have indeed addressed different issues regarding the European climate in previous papers. Nevertheless, the goal of those previous papers was not to study the European climate specifically but Europe was used as an example to illustrate some mechanisms (the respective role of internal and forced variability in Goosse et al 2005, QSR or a new technique in Goosse et al. 2006, Clim. Dyn). Our goal in this paper is different here as we intended to describe the causes of the seasonal temperature changes during the last millennium in Europe. In particular we aimed at estimating whether the so-called Medieval Warm Period was warmer in Europe than the last decades of the 20th century and to analyse the causes of the difference (or similarity) in winter and summer temperature between those two periods. This is the reason why we use now a relatively large compilation of long term seasonally resolved temperature reconstructions of temperature from Europe. We also performed 70 new simulations covering the last millennium (i.e., 70 000 years of simulation with a three-dimensional climate model). Those simulations allow determining the role of the various forcings in the temperature changes. As underlined by the referee, Fig.6 is very important in our analysis. We compared there two 25-year periods: one warm period during the early millennium (1026-1050) and the last 25 years of the 20th century (1976-2000). Such 25-year periods were selected in order to have a reasonable signal to noise ratio. Strictly speaking, when discussing the role of the various forcings, we should talk only of those two periods. Nevertheless, the results are not qualitatively different if a 20-year period is selected at the end of the 20th century (period 1981-2000) or if different periods of the 11th and 12th century are selected. This is the reason why in the manuscript we did not specify systematically the years involved when using the terms "late twentieth century". Nevertheless, the late 20th century always include in our mind a period finishing in 2000 AD, not in 1980 AD. We selected 1500-1980 as the reference period because some proxy records ended in 1980 (see the caption of Fig 3), however, all our figures ended in 2000 AD. In the next version of the manuscript, we will mention that clearly in the figure caption. We will also replace the words "late 20th century" and "end of the 20th century" by the precise years except in the first paragraph of the introduction that provides a brief overview of past work. Our results clearly indicate that, in our model, the MWP and the last 25 years of the 20th century have similar temperature during summer. That is due to the combined effect of different forcings. Internal variability could play a role, by masking the forced signal or by contributing to a larger warming signal during some years (it is well known that MWP was not a homogenous periods with only warm years) but internal variability in our model is not the cause of the warm conditions during MWP in Europe. The next version of the manuscript will addresses this issue and make this point even more clear (introduction and section 5).

1/ The observed evolution of the various greenhouse gases is derived from a combination of values obtained in different ice cores (J. Flueckinger, personal communication). In the next version of the manuscript, a figure will be added showing this time evolution.

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2/ A reference for the land use scenario was given on page 289, line 23. The scenario is similar to Bauer et al. (2003) but different than Brovkin et al. (1999). In the next version of the manuscript, a figure showing the time evolution of forest cover in Europe will be added.

3/ As mentioned in the submitted manuscript to CPD, the response of the model to changes in the external forcing at global scale is indeed relatively weak compared to AOGCMs, with a 1.8 C increase of global surface temperature for a CO2 doubling. This is largely due to the weak response in tropical regions, which of course contribute to a large extent to the weak global mean response. On the other hand, model response is similar to that of GCMs in mid and high latitudes. Furthermore, the model response is in very good agreement with the empirical independent reconstructions over Europe for the last half millennium. The consequences of the weak model sensitivity are discussed in Goosse et al. 2005b. The value was mentioned here just for reader's information and to provide references to the reader who would like to obtain more details about model behaviour in different regions. As our interest is focused on Europe, we do not consider very useful to discuss again the behaviour of the model at hemispheric or global scale. Nevertheless, in the next version of the manuscript we will provide two additional references describing the model response to a CO2 increase (Petoukov et al. 2005, Selten 2002) and we will modify slightly this section to make this point more clear. In this framework, we will also add in the next version of the manuscript a general discussion about the limitation of the study, including the fact that we are using only one model and that the exact response of European temperature to forcing is not known.

4/ We agree with the reviewer that this sentence is not clear in the submitted version and will be modified in the next version. We fully agree with the referee that the evaluation of internal variability is complicated and that forced simulations contain variability caused by external and by internal factors. This issue was the subject of Goosse et al. (2005a). We also fully agree that a reconstructed temperature in the range of model simulations does not prove the validity of the simulated temperature anomalies as the

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agreement could be related by chance to a compensation of errors or the simulated anomaly could be associated with a wrong mechanism (linked with internal variability of the system or the forced response). This will be modified in the next version of the manuscript. We will also cite the study of Hunt (2006) in the next version of the manuscript.

5/ As explained above, we will be more specific in the next version of the manuscript and specify clearly the years considered in the discussion.

6/ The reconstruction of Luterbacher et al. (2004) only used Low Countries (i.e. Belgium and Netherlands) (Van Engelen et al., 2001; Shabalova and Van Engelen, 2003) for a couple of winters in the 16th century and for one winter (1739/1740), the anomaly provided by Brazdil (1996), so the regional/local proxy-based reconstructions we used are almost independent of Luterbacher et al. (2004).

7/ See the general comment and point 4.

8/ We agree with the reviewer that this sentence about the role of volcanic forcing was not clear. We simply want to express that, when we compare the periods 1976-2000 and 1801-1825, the former is warmer mainly because of a strong positive forcing associated with the increase in greenhouse gas concentration during the last decades of the 20th century. Nevertheless, the cooling due to the volcanic and solar forcings during the period 1801-1825 also contribute to the difference between those two periods.

9/ Indeed, we agree to name the forcings. This will be done in the next version of the manuscript.

10/ We only include the low-frequency variations in the Earth's orbital parameters and the value of 0.15C mentioned in the manuscript is for Europe. That will be specified in the next version of the manuscript. In our simulation, the decrease in seasonal contrast occurs during the whole Holocene for Europe, including the last millennium. Indeed, the perihelion 'moved' from December to January during the last millennium. However,

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when taking into account all the orbital parameters, the insolation at 45N decreased by 0.4 W/m2 at the top of the atmosphere in June and increased by 0.8 W/m2 in December between 1000 AD and 2000 AD (M.F. Loutre, personal communication 2006). This forcing change is very weak but is consistent with the (very small) decrease in seasonal contrast in Europe in our simulation caused by this forcing during the last millennium, which is following the strong decrease that occurs during the Holocene in our model.

11/ As suggested by the reviewer, figure 6 will be modified in the next version of the manuscript. The panels a and b will have the same y-scale, the error bar will be in colour and the changes from the fully forced simulation will be added as well. The contribution of the greenhouse gas forcing is different in the panels a and b because the greenhouse gas concentration is generally higher for the period 1801-1825 than for 1025-1050. Furthermore, as displayed on the figure, our estimate of the forced response in the model is not exact (error bar on the figure) as we are using a finite ensemble to estimate this response. Differences between different periods with the same forcing could thus also occur because of this uncertainty, but in that case the difference should be in the range of the error bar on the figure.

The technical corrections will be taken into account in the next version of the manuscript.

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Interactive comment on Clim. Past Discuss., 2, 285, 2006.