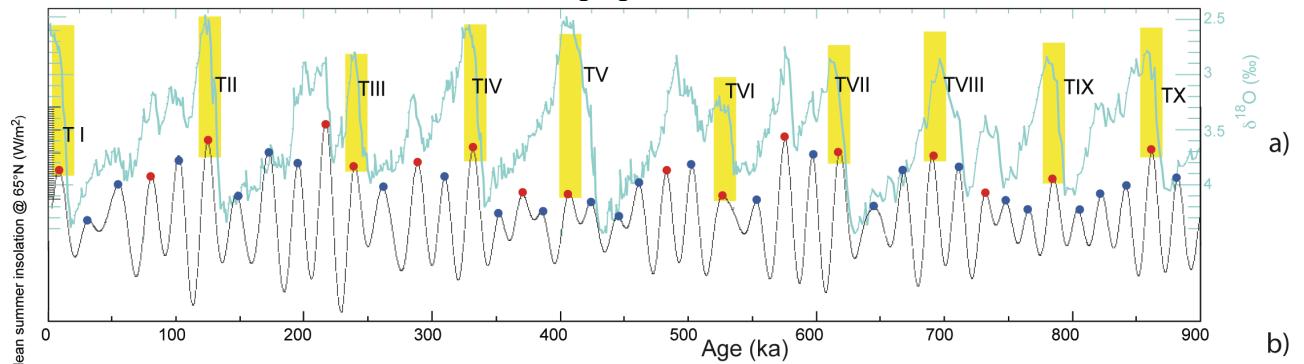


Objections raised by Reviewer #1 can be summarized in two major points:

- 1) He/She laments the lack of any hypothesis about the mechanism after which the proposed triggering cause (i.e. the cumulated amount of solar radiation hitting latitude 65°N during the summer months through each minimum and maximum of insolation) works.
- 2) He/She doesn't see the actual match between the occurrence of maxima at which the cumulated insolation reaches 742 Kw/m^2 and the occurrence of the glacial terminations or other, equivalent significant climatic (warming) events.

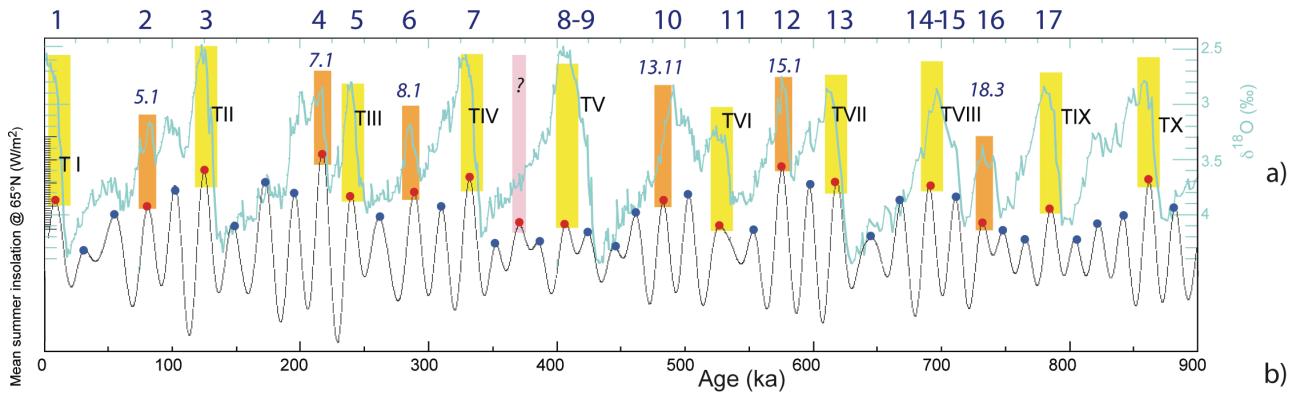
Regarding the first point, it was not the scope, nor it is a field in which I have the necessary competence, to explain how the solar forcing works. As the reviewer says, it is simply the starting point of a complex series of processes leading to a relatively sudden and fast melting of the ice sheets. The aim of this work was to evidence that this starting point coincides with the occurrence of each maximum of insolation at which the sum of the solar radiation released on the earth surface since the preceding minimum of insolation is larger than a cumulated value of 742 Kw/m^2 . In other words: in order to estimate the potentiality of one maximum of insolation to trigger a glacial termination it is necessary to consider not only the actual intensity of insolation at the maximum, but also the conditions from which the deglaciation process starts. These conditions are expressed by how much low was the intensity of insolation during the glacial maximum (i.e. the insolation value at the preceding minimum of insolation). I believe that it is physically correct to assume that two maxima of insolation characterized by the same intensity may produce or not produce a glacial termination depending on the total amount of ice covering the earth surface at the moment in which earth's temperature inverts its trend (i.e. at the starting point of the process)

Regarding the second point, it seems to me that this coincidence is evidenced beyond any possible questioning for the time span Present - 900 ka. Indeed, if we rely only on the "canonical" ten glacial terminations univocally recognized by the scientific literature, it is not questionable the fact that each one of them occurs during a maximum of insolation characterized by a cumulated insolation value $\geq 742 \text{ Kw/m}^2$, as the following figure shows:



All the red dots represent cumulated insolation values $\geq 742 \text{ Kw/m}^2$ (hereafter: hot maxima), whereas the blue dots represent all the other maxima of insolation of the last 900 ky for which the cumulated insolation is lower than 742 Kw/m^2 ("cold maxima"). There are 17 hot maxima and 25 cold maxima, for a total of 42. ALL the "canonical" glacial terminations (T I through T X) are associated to one hot maximum (yellow bars).

But the figure below evidences one more significant thing: 16 hot maxima out of 17 are associated to a significant warm event, represented by a glacial termination or by what can be considered an equivalent event ("extra red dots"):



I have to amend the fact that I have given too much importance to glacial terminations, rather than referring to the 17 events that characterized the global climatic history during the last 900 ky. Indeed, there are 17 climatic "events" that have been identified and described in the literature since publication of the SPECMAP $\delta^{18}\text{O}$ stack (Imbrie et al., 1984). Unfortunately, I didn't refer to Huybers and Wunsch (2004) in the paper, which is a seminal work at the base of the concept I used to compare the insolation history to the climate history. I excuse for this omission, which is probably at the base of the mislead interpretation by Reviewer 1 about the actual match of the proposed model.

Huybers and Wunsch (2004) have developed an age model for these 17 events that I have now reported on the Lisiecki and Raymo (2005) $\delta^{18}\text{O}$ curve in the figure above (arabic blue numbers). ALL the six "extra" events by Huybers and Wunsch that are not a canonical glacial termination, but are associated with sub-stages 5.1, 7.1, 8.1, 13.11, 15.1, 18.3 (italics blue numbers), match one "extra red dot" (orange bars). Considering the double events 8-9 and 14-15 (which in reality evidence two anomalously long terminations) as single climatic events, and including termination X to Huybers and Wunsch dataset of climatic events, we have 16 (out of 17) climatic events that are associated to 16 (out of 17) hot maxima in the last 900 ky. This can also be said in the following way: 41 maxima of insolation out of 42 obey at the principle that a global warm climatic event is triggered whenever a critical threshold of cumulated insolation (742 Kw/m^2) is reached. From a statistically point of view this mechanism has a 97.6 % confidence.

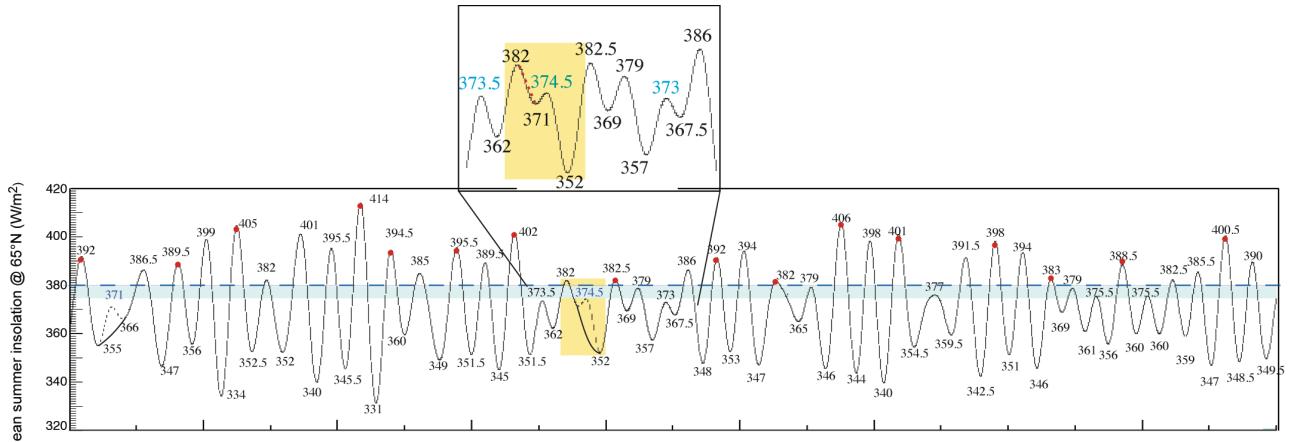
Therefore the statement by Reviewer 1:

"Unfortunately, amongst all the potential terminations identified from the index, and even after excluding a few of them, there are still almost as many correct and wrong guesses for the terminations."

is proved to be totally unsupported, and, to my feeling, somewhat unfair.

In the light of the abovementioned statistics, the only extra red dot indicating the occurrence of a hot maximum (red bar in the figure above) that does not match any glacial termination (or equivalent warm event) is to be considered an exception. Moreover, I think that the explanation given in the paper shows that this is the "exception confirming the rule".

Indeed, this explanation, as it is detailed discussed in the paper, relies on the same principle after which the triggering mechanism works: a threshold value of insolation. In the same way as a glacial termination-like event requires the surpassing of a threshold of cumulated insolation to be triggered, one maximum of insolation has a potentiality to affect the global climatic processes only if it is warm enough. That's to say, only if a threshold value of insolation (i.e. $> 374.5 \text{ Kw/m}^2$, see graphic below) is surpassed. Otherwise, the occurrence of a maximum has no influence and it should be neglected, as shown in the figure below, where the dashed blue line and shaded bar represent the threshold value for a maximum to be effective.



I understand that one who is skeptical about the leading role of insolation (and especially the summer insolation at 65°N) may find this explanation, as well as the proposed triggering mechanism, as a "not convincing" one. However, I remark that, when this full principle of threshold mechanism based on mean summer insolation at 65°N is applied, a 100% match is obtained between the occurrence of the glacial termination-like events and the surpassing of the empirically established threshold values, during the last 900 ky. A 100% match is also obtained considering that no global warm climatic event is associated to the remaining maxima not overpassing these threshold values.

This is not trivial, in my opinion, and I think that it represents an important contribution to assess the role played by insolation, and to investigate better the effective complex process after which it works.

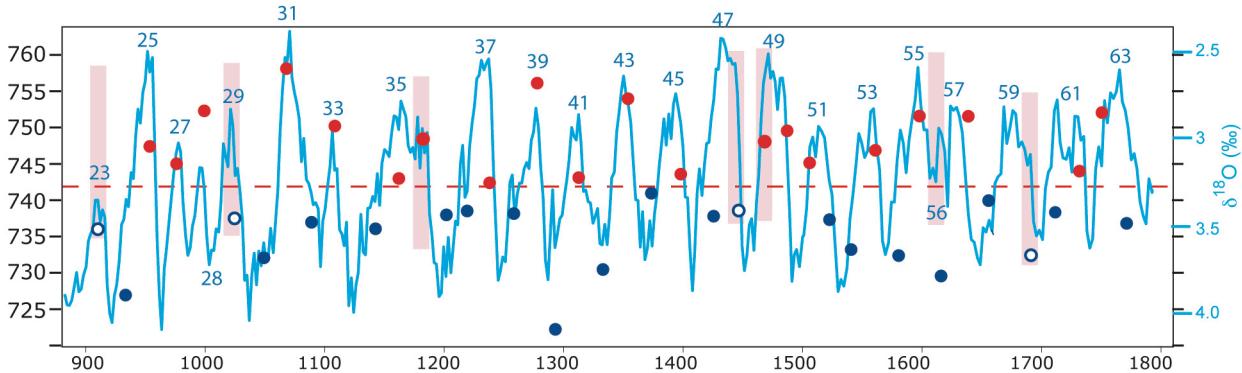
I have left the discussion of the time span 900-1800 ky apart, because it needs to be discussed in a different perspective.

The climatic signal represented by the $\delta^{18}\text{O}$ has no direct age constraint and its timescale is assessed by sedimentation rate and sediment compaction estimation, coupled to the tuning by means of automated correlation algorithms to provide the best fit between maxima of insolation and negative peaks (warm stages) of the $^{18}\text{O}/^{16}\text{O}$ ratio. However, "understanding and removing the age depth (or age model) errors is one of the most important of all problems facing the paleoclimate community" (Huybers and Wunsch, 2004). This is particularly true for the signal older than 900 ka.

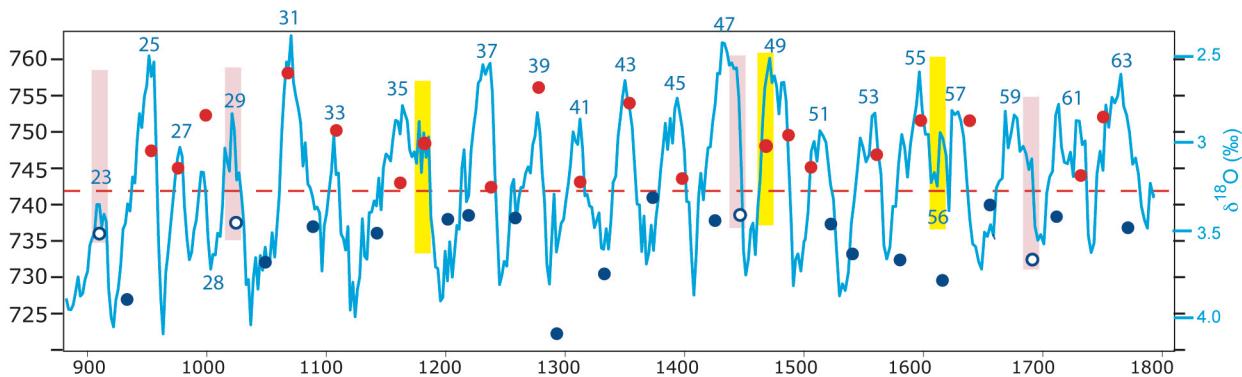
Whereas the hot and cold maxima are univocally defined and exactly dated through the earth's orbital parameters, the definition of the significant climatic events in the time span 900 -1800 ka is highly subjective, also standing to the fact that the $\delta^{18}\text{O}$ signal "run at irregular rates, stop completely, or even rewind and erase previous sections", Huybers and Wunsch (2004).

Based on this evident limitation, all the inferences based on this part of the work should be considered as less "definitive" with respect to those, in my opinion quite objective ones, discussed for the time span younger than 900 ka. Therefore, even the least favorable assessment of the match of the prevision to 83% (as discussed ahead), considering that the $\delta^{18}\text{O}$ record could be adjusted to fit the remaining 17% of cases without incurring in any conceptual or physical objection, should be considered an evidence supporting the model rather than proving its failure.

I recognize that I have used a subjective approach to identify the significant climatic events in the time span 900-1800 ka, justifying in this case the objection be the reviewer. However, also using a completely neutral approach (based on the comparison to the isotopic stages defined in this time span in Lisiecki and Raymo, 2005: blue arabic numbers in the following figure), there are 7 mismatches out of a total of 42 maxima of insolation. In my opinion, this cannot be defined almost as many correct and wrong guesses, rather it represents 83% of positive matches.



However, even at a preliminary analysis of the isotopic record, some of the mismatches seem to be reasonably adjustable (those highlighted in yellow in the graphic below).



Indeed, stages 35 and 49 display evident double peaks that match the "extra" red dots associated to this portion of the curve (similarly to what observed previously for stage 13).

Moreover, I have conservatively marked as mismatch the occurrence of one minor peak during MIS 57. Indeed, based on the introduction of the even number 56, it is clear that Lisiecki and Raymo have interpreted the small peak between MIS 57 and 55 as a sub-stage, in the same way as they did for MIS 28, which I have consequently interpreted as a match for the test. Consistently, I'm obliged to consider the equivalent peak between MIS 57 and 55 as an unforeseen occurrence by the model. However, I think that no one will blame me if I state that this minor peak may be interpreted as a bias on the record, similar to other small peaks that are not labeled by Lisiecki and Raymo, and can be neglected.

If you allow me to do so, the mismatch reduces at 4 out of 42, meaning a positive match of 95% (38 out of 42). Not so bad.

Finally, regarding these 4 mismatches (that I have previously underestimated as three) I have made the following consideration in the paper: the misfit may be a consequence of an incorrect tuning, and it may be eliminated by a different calibration of the curve.

This consideration, in the light of the previously literally reported statement by Huybers and Wunsch, seems a quite reasonable hypothesis to me.

In conclusion, I feel that the comparison of the proposed causative mechanism with the $\delta^{18}\text{O}$ record older than 900 ka reinforces its credibility, which for the previous time span, in my opinion, is not questionable from a statistical point of view.