Dear Editor and Referee #1

We would like to thank the reviewer for the valuable comments to improve the quality of our manuscript. These comments effectively clarified the analyses and embedded the results in a small window for misinterpretation. Please find enclosed a point-by-point reply to the reviewer' comments and suggestions.

Answer to reviewer comments in BLUE

Reviewer primary comments –

-*"The introduction is missing some introductory texts regarding the main message given in the title and abstract."*

The revised version of the Manuscript (MS) exhibits a modified **Introduction** in order to address in more details the issues investigated. It begins covering the importance of ENSO and equatorial Pacific for the global climate in distinct eras. The new **Introduction** also includes discussion of previous studies on the relationship between the ENSO and the monsoonal system. We finalize the **Introduction** exploring the importance of understanding the ENSO, the equatorial Pacific and the monsoon system during interglacial stages to shed light on the potential effect of future human-induced climate change.

- *"I think the authors should add few lines that why they use a certain method for their analysis, in particular harmonic analyses)"*

We have provided in the revised MS a better explanation of harmonic analyses as well as put forward advantages of using this approach to explore the magnitude of the annual cycle, as shown below:

We have included the following paragraph to describe in more details the choice for using harmonic analyses.

The use of harmonic analysis allows the identification of dominant climate signals in the space–time domain, separating small and high frequency processes (e.g diurnal cycle) from large-scale features (e.g. seasonal). Analyses conducted on the frequency domain can capture and differentiate the contribution of all time-scales. Thus, different climate regimes and transition regions can be characterized. The 1st harmonic shows the dominance of the annual cycle when most of the variance is represented by this harmonic. It has to be stressed that investigations based upon area averaged time series are embedded with small and large-scale processes dictated by distinct periodicity, this in turn hampers the identification of periodic climatic signals in the space–time domain \citep{justino-ijoc,cli4010003}.

-*"Results in the manuscript and their implications are interesting but the main story is sometimes hidden behind"*

The revised MS provides much deeper discussion on the results exploring the question and comments of both reviewers. Moreover, we have provided additional figures as Supplemetary Material. Those figures are shown in the document which includes responses to the reviewer #2.

SECTION 2

Line 122: which year did you use for the present-day run?

The paragraph below has been included in the revise MS:

Two simulations are evaluated: a modern climate driven by present-day boundary conditions (CTR) and a second experiment for the MIS31 forcing. The CTR simulation was run to equilibrium for 2000 years, and our modern climate is the time average of the last 500 years of the CTR simulation. The CTR is run under present day orbital forcing and CO$_2$ concentration of 325 ppm as it characterizes emission by the year 1950. The MIS31 run starts from equilibrated CTR conditions, including modifications of the WAIS topography based on \citet{pollardnature}, and the planetary astronomical configuration of 1.072 Ma according to \citet{coletti}. It has been carried out for 1000 years and the analyses take into account the last 500 years of the simulation.

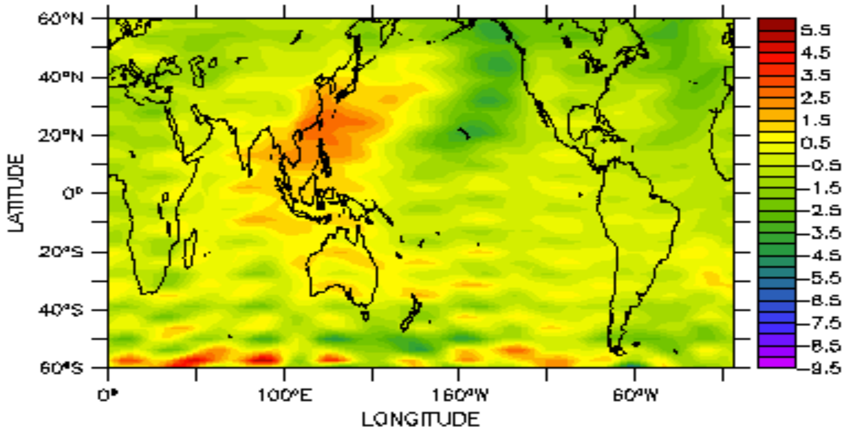
The implementation of MIS31 Antarctic topography differs from the CTR counterpart primary by the absence of the WAIS, which according to \citet{pollardnature}, was induced by changes in ocean melt via the effect on ice-shelf buttressing that coincides with strong boreal summer insolation anomalies. In all experiments, the CO$_2$ concentration was set to 325 ppm which is based on boron isotopes in planktonic foraminifera shells for the MIS31 interval \citep{Honisch}.

Line 126: When you talk about the difference between MIS31 and CTR, so you mean the difference between their mean over 500 years?

Yes, it is. This has been clarified in the revised MS.

Line 175: eddy SLP is confusing here. I would show SLP itself as it is easier to compare it to SST and wind field. Instead, you might show eddy Z200.

We have shown the SLP$_e$ because differences between high and low pressure dominant features in the MIS31 and CTR are enhanced, such as at the subtropical N. Pacific and Azores high, the Aleutian low. This facilitates the interpretation of wind anomalies at the subtropics and equatorial region (e.g the trade wind anomalies). It is shown below, for your consideration, the SLP differences between the two runs, where is noted very similar pattern as delivered by the SLP$_e$ presented in Figure 1a. We have included the text above in the revised MS.



SLPMIS31 − SLP

Line 201: Add the latitude to the thermocline figure. You need to highlight this paragraph better as it is part of your main story.

The new thermocline figure includes the latitude labels.

We have added to the revised MS a discussion on the role of the thermocline to characterize the ENSO phase and amplitude, as below:

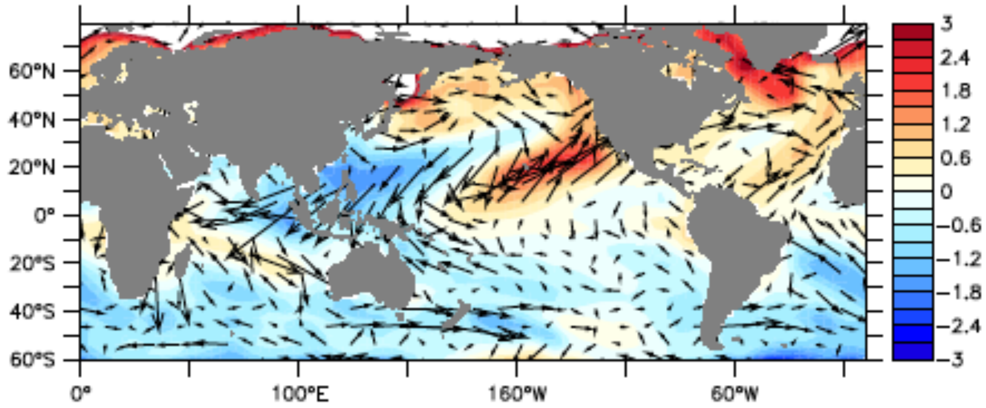
Modification in the near surface atmospheric circulation can also modify the oceanic vertical characteristics affecting the thermocline depth and ENSO \citep{wen2014,bush01}. As discussed by \citet{yang2009} for the equatorial Pacific, changes in the depth of the thermocline determines the SST magnitude and the behavior of the air-sea interaction, influencing the phase, amplitude, and time scale of the tropical climate.

The ICTP-CGCM properly reproduces the equatorial thermocline depth (using the depth of maximum vertical temperature gradient) compared to the Levitus dataset \citep{Levitus} and to GLORYS reanalysis. The MIS31 forcing leads to a shallower thermocline and reduction of its zonal gradient (Fig. \ref{fig1}d), which is primarily related to the anomalous wind flow \citep[e.g.,][]{zebiak86,an1999}.

A deeper thermocline however, is observed in part of the NI\~NO3 region (Fig. \ref{fig1}d, contour). In the eastern Pacific, thermocline dynamics have been associated with changes in SST, the air-sea coupling, and ENSO \citep{leduc,yang2009}. This implies a weaker Walker circulation during the MIS31 interval that is supported by SST reconstructions (from Ocean Drilling Program sites 849, 847, 846, and 871) in the western and eastern equatorial Pacific \citep{clymont}.

Line 224: cold SST anomalies could be because of the displacement of Kuroshio current. Try to make this paragraph more related to the main story.

The negative SST anomalies are primary located in the warming pool region (10S-20N) and reach only the south-most part of the Kuroshio current (Figure below). Therefore, we argue that the intensification of the trade winds, local upwelling and the evaporative feedback should play the main role in leading the anomalous SST pattern.



Section 3: suggested headline: Enhance seasonality in MIS31

The section title has been modified.