

Dear Christian,

I have gone through the latest version of your manuscript, and while there seems to be no problems with the scientific aspects and the reviewers' comments and questions have been addressed, there is a long list of non-technical modifications which have to be made before proceeding to the final stage.

I have tried to list as many as possible, but first I will give some general remarks.

Despite COSMOS being an acronym for a plural word (Models), I think it may be better to refer to COSMOS as a singular noun, as is usually the case with other models. As it is a name, it would also sound better without the definite article (the) preceding it. In fact, I think both of these were done in Stepanek and Lohmann (2012). In the present manuscript, there are inconsistencies – sometimes there is indeed no definite article, and sometimes the following verb refers to a singular noun. Likewise, it would be better to not use the definite article with ECHAM5 and MPIOM, but I will leave that to you.

Throughout the manuscript, there are words written according to both British and American spelling. Sometimes, the same words appear with both spellings. I have listed British spellings, but you are free to choose American instead. Please do an automatic search for typical words, eg analyse, characterise, initialise, modelled, centre, etc.

The word order of many sentences is slightly awkward, in particular, adverbial phrases which should be moved to another position, or, in some cases, inserted between commas to make reading much easier.

Please check the list of recommended revisions below and make changes as you see fit. The page and line numbers below refer to the file *cp-2020-10-author_response-version1.pdf*.

I am happy to see that you have included the latest proxy data and I look forward to seeing your revised manuscript.

Wing-Le Chan

page 1, line 17: comprises of a pronounced

page 1, line 19: at Northern Hemisphere high latitudes

page 2, line 15: provides us with a

page 3, line 16: Note that our (*remove comma if using the word 'that'*)

page 3, line 17: In order to bridge the gap

page 3, line 26: high carbon dioxide levels

page 4, line 12: applied to

page 4, line 23: is not state-of-the-art anymore.

page 5, line 5: at all other latitude bands.

page 6, line 21: dependency on

page 6, line 34: once a day

page 7, line 23: difference in our

page 8, line 22: the Hudson Bay, Canadian Arctic Archipelago, as well as the Bering Strait

page 9, lines 3, 18: *I don't understand the phrase 'modern, respectively PI' (as on line 15, page 11). 'modern, namely PI'? 'modern, in other words PI'?*

page 9, line 24: described above

page 9, line 32: gateways, the Bering Strait

page 10, line 28: *I am not sure of the phrase 'ramp simulation'. If you want to use the word 'ramp', perhaps you could use*

used in the 'ramp-up' simulation 1pctCO₂

with 'ramp-up' inside inverted commas, as the word 'ramp' does not seem to be commonly used with these CO₂-increasing experiments.

page 10, line 34: an equilibrium PI climate state, conforming to CMIP6 standards, as a

page 11, line 3: This setting has already been

page 11, lines 8, 14: initialisation (*use consistent British spelling, as with the word 'initialise' on line 12*)

page 11, line 16: advantage of shortening spin-up

page 11, line 19: abruptly and steadily increased concentrations

page 11, line 23: states are not affected by drifts in the atmosphere (??)

page 12, line 22: *Where did D come from? Should 'letter D' be 'letters GW'?*

page 12, line 30: the Bering Strait

page 12, line 33: 'enables an identification of synergies' or 'enables us to identify synergies'

page 13, line 3: initialise, analysed (*if using British spelling*)

page 13, line 3: hemispheric

page 13, line 24: Characterisation of the (*if using British spelling*)

page 14, line 1: a comparably mild -48.8%

page 14, line 5: characterised (*if using British spelling*)

page 14, line 8: is, over the analysis period, slightly (*reads better with commas*)

page 14, line 16: focus heavily, is in quasi-equilibrium in Eoi400.

page 14, line 18: cools slightly

page 14, line 21: demonstrate the expediency of simulation Eoi400 and other COSMOS PlioMIP2 simulations for the study of climate anomalies, despite incomplete model equilibration.

page 14, line 32: over (*or across*) Hudson Bay and the Japanese islands (*islands with small 'i' or use 'archipelago'*).

page 15, line 12: Reduced precipitation is also present

page 15, line 29: In our mid-Pliocene simulations, the warmer hemisphere is the northern one, where warmth is more widespread than in the Southern Hemisphere across all seasons.

page 15, line 35: centre (*if using British spelling*)

page 15, line 35: ice-free

page 16, line 5: characterises (*if using British spelling*)

page 16, line 17: mid-Pliocene in COSMOS is largely

page 16, line 20: less intense clockwise circulation, in other words, negative AMOC anomaly,

page 16, line 34: in the south, and in the north

page 17, line 8: Arctic

page 17, line 11: causing warming

page 17, line 18: 'with modern geography' *or* 'using modern geography'

page 17, line 31: opposes

page 18, line 10: 'Yet, for an interpretation of mid-Pliocene modelling results in terms of near-term future climate,' *or something to that effect*

page 18, line 21: A one percent annual increase in carbon dioxide levels increases global average SST

page 18, line 22: The response of SAT to increased radiative forcing outpaces that of SST, although global mean values of both reach similar values by the end of the simulation.

page 18, line 25: increase of 10°C.

page 18, line 26: 250 years only has a moderate impact on deeper parts

page 18, line 27: also warms

page 18, lines 30,31: 0.8psu, 33.7psu. *psu also needs to be put in Figure 22 or in its caption.*

page 18, lines 31: *Insert commas: ,for both simulations, or rewrite sentence as 'For both simulations, reduction of SSS is related to'*

page 19, line 7: energy imbalance

page 19, line 9: by the increased slope

page 19, line 10: concentration

page 20, line 4: We consider these

page 20, line 17: propose a simulation Eoi560 to consider all nonlinearities

page 20, line 24: this hints at negative feedbacks

page 20, line 28: As in the case of the real world,

page 20, line 31: ice sheets in Greenland and Antarctica

page 21, line 2: both of which are

page 21, line 31: Only for large changes in carbon dioxide does a clear signal of increased AMOC emerge from

page 21, line 32: In comparison to the modern setup, for simulations with the same carbon dioxide forcing, mid-Pliocene geography causes an increase of between 0.48Sv and 1.85Sv in the maximum strength of the AMOC.

page 22, line 1: geographical setup, we find a similar trend towards increased

page 22, line 2: There is a dependency on geography, with a gain of between 0.16 Sv and 1.57 Sv for individual simulations with modern geography

page 22, line 6: no linear relationship between AMOC strength and carbon dioxide.

page 22, line 12: *'overprint' doesn't make sense. Instead, perhaps you can say something like 'although their ranges of values including internal variability overlap one another'?*

page 22, line 14: *insert commas:* we find, for modern geography,

page 22, line 16: in which case the AMOC becomes rather shallow.

page 22, line 17: On the other hand, for both modern and mid-Pliocene geography, carbon dioxide induced strengthening of the AMOC in the upper cell is at the expense of the strength of the lower cell that imports

page 22, line 20: Note also that the mixed layer depth (*no comma*)

page 22, line 21: This implies that characteristics of the North Atlantic Deep Water (NADW) also change with carbon dioxide, although the impact is not evidently represented in the structure (*'albeit' sounds grammatically wrong here*)

page 22, line 33: while the Atlantic

page 22, line 35: *multiple ??*

page 23, line 32: monotonic relationship

page 24, line 3: Our results, however, do not hint that COSMOS might support

page 24, line 9: 200,000 years

page 24, line 9: A need for progression.....has been suggested

page 24, line 22: Note that (*no comma, otherwise remove the word 'that'*)

page 24, line 26: *change 'does have' to 'has'*

page 24, line 29: *The whole sentence sounds awkward, especially with MyClymont et al. (2020) cited twice so closely together, and the word 'respectively' is used in the wrong way again.*

While simulated SST fits similarly well with both UK37'-based and Mg/Ca-based data sets by McClymont et al. (2020), and UK37'-based data sets by Foley and Dowsett (2019), the choice of calibration and time window, respectively, has an impact on the agreement between simulation and reconstruction.

page 24, line 32: SST agree better with...than with

page 25, line 6: Note that (*no comma, otherwise remove the word 'that'*)

page 25, line 6: agreement between model and new data

page 25, line 15: Note that (*no comma, otherwise remove the word 'that'*)

page 25, line 28: The possibility of a cold bias in Mg/Ca records, which requires further attention,

page 26, line 1: Note that (*no comma, otherwise remove the word 'that'*)

page 26, line 1: *I don't understand the use of the word 'where'. These simulations were forced?*

page 26, line 11: *The middle section of the sentence doesn't flow well with the rest of the sentence.*

Where high latitude land surface conditions are appropriate for vegetation growth, vegetation establishes in the model, provided the region is not located on modern or mid-Pliocene ice sheets.

page 26, line 12: *The dashes make the sentence quite difficult to follow, especially the last two.*

The obvious result is that some regions cannot produce vegetation – for a modern geography this refers to Greenland, and for mid-Pliocene geography, this refers to parts of Greenland and, in the Southern Hemisphere, to East Antarctica, due to ice sheets prescribed in the model.

page 26, line 19: with modern geography

page 26, line 21: and the dependency

page 26, line 28: monotonic

page 26, line 29: tree cover does not reach

page 27, line 2: forests in some regions

page 27, line 4: whereby the extent of tree cover returns from the northeast towards

page 27, lines 6, 11, 14: Factorisation (*if using British spelling*)

page 27, line 14: information necessary for

page 27, line 21: albeit a small one.

page 27, line 26: characterised (*if using British spelling*)

page 28, line 3: 'As these gateways' mid-Pliocene configuration' *or, better still*, 'As the mid-Pliocene configuration of these gateways'

page 28, line 4: model-data mismatch

page 28, line 11: on a global scale

page 28, line 21: towards the Canadian Arctic Archipelago

page 28, line 22: the North Atlantic Ocean realm is, for both summer and winter, cooler

page 28, line 24: a cooling by modern gateways extends across all longitudes

page 28, line 25: is weaker for precipitation than for temperature.

page 28, line 31: extent of the EqWP vanishes

page 28, line 32: the Bering Strait

page 29, line 2: the Bering Strait

page 29, line 3: is indeed

page 29, line 17: Hence, COSMOS allows us to examine the extent to which changes in modelling methodology

page 30, lines 2, 4: in order from highest to lowest

page 30, line 9: its ECS in PlioMIP2 is larger than the CS reported for PlioMIP1.

page 30, line 15: among which

page 30, line 24: leading towards consistency

page 30, line 27: *Because of the length, structure and word order, this sentence is very difficult to follow.*

The relationship between simulated mid-Pliocene SAT anomaly and ECS in COSMOS may change from PlioMIP1 to PlioMIP2 due to changes in modelling methodology, including the addition of dynamic vegetation. Below, using reasonable assumptions, we investigate how much the change in this relationship impacts on the PlioMIP2 ensemble relationship between model sensitivity to carbon dioxide and modelled temperature anomaly.

page 31, line 1: First, we exclude two and three models with high ECS from the analysis (Fig. S2c and Fig. S3c, respectively).

page 31, lines 1-5: *Correct the usage of the word, 'respectively', as above.*

page 31, line 2: we change COSMOS' ECS to its PlioMIP1 value

page 31, line 3: Third, we carried out a test to investigate the impact that COSMOS would have on the model ensemble if the simulated mid-Pliocene PlioMIP2 SAT were as high as in PlioMIP1

page 31, line 4: we assume COSMOS provides

page 31, line 11: We find that the linear relationship

page 31, line 12: the regression for PlioMIP1 and for the 15 member PlioMIP2 ensemble is so large

page 31, line 16: Note that (*no comma*)

page 31, line 21: Adopting the lower CS of PlioMIP1 for COSMOS

page 31, line 27: Only when we remove models (excluding COSMOS) which do not show a significant relationship between ECS and SAT, do we find a significant relation between model ECS and simulated SAT anomaly with increased slope in the 15-member ensemble.

But isn't this sentence obvious? You are removing the 'undesirable' models', so you will obviously be left with the 'desirable' models

page 31, line 30: causes COSMOS to exhibit opposing differences in ECS and SAT anomaly

page 31, line 34: In PlioMIP2, model characteristics other than ECS, and the potential impact of PRISM4

boundary conditions, may be more important for the simulated amplitude

I don't think 'relevant' is the right word

page 32, line 4: larger than it is in the case for PRISM3

page 32, line 6: have been shown

page 32, line 7: is rather small in COSMOS. Whether these inferences are also robust for

page 32, line 11: of particular relevance to the question of the extent to which the mid-Pliocene may serve as an analogue of future climate. *or*

of particular relevance to the question: "To what extent may the mid-Pliocene serve as an analogue of future climate?"

page 32, line 17: Based on the PlioMIP2 simulation ensemble, which is greatly extended in comparison to PlioMIP1,

'that' suggests that there are other PlioMIP2 simulations.

page 32, line 23: Thanks to this effort

page 32, line 32: most likely

page 33, line 3: and, according to our results, certainly

page 33, line 7: analyse (*if using British spelling*)

page 33, line 8: *I don't understand this phrase 'agreement, respectively discord,'. Probably better to just say 'agreement'*

page 33, line 14: Consequently, and also with respect to the updated reconstructions, discord between model and reconstructions

page 33, line 15: the discord that results from low model resolution

page 33, line 18: newly emerging

page 33, line 26: was unlikely

page 33, line 32: state that, based on proxy-data, mid-Pliocene ESS

page 34, line 1: The ratio of ESS to ECS in the mid-Pliocene for our model is 1.2, which is less than the values in the PlioMIP1 simulation - 1.5 for the model ensemble and 1.7 for COSMOS.

page 34, line 4: in COSMOS, carbon dioxide is less effective in reducing the mid-Pliocene meridional temperature gradient, and in increasing global average SAT, when raising the concentration

page 34, line 6: in comparison to the initial change in carbon dioxide, from 280 ppmv to 400 ppmv.

page 34, line 22: *the phrases before and after the dash do not flow together.*

quite different from conditions observed and felt today, when levels of greenhouse gas concentrations in the atmosphere are likely to be higher than those during the mid-Pliocene.

page 34, line 25: characterised (*if using British spelling*)

page 34, line 31: climate patterns and mechanisms which may be representative of, or at least similar to,

page 35, line 2: *I don't understand the use of the word 'respectively' here. 'Imperfect' is a strange choice of word here.*

On the other hand, there are marked differences between the paleogeography of the mid-Pliocene and of modern day, or rather the near-future, in particular.....the latter will be different

page 35, line 10: with a potential change of about 50 ppmv

page 35, line 17: It is relevant to test

page 35, line 18: *no need to state Pliocene twice*

to the overall mid-Pliocene climate state to yield a climate estimate which may be of relevance to the near or more distant future.

page 35, line 23: have already

page 35, line 30: albedo effects (*no hyphen needed*)

page 35, line 32: in the Northern

page 35, line 32: These results are, in general, also reproduced by COSMOS within PlioMIP2.

page 35, line 34: over the last few decades

page 35, line 35: hinting at increasing similarity between

page 36, line 2: realised (*if using British spelling*)

page 36, line 5: *commas in the wrong position*

the warming components, carbon dioxide, ice sheets and topography,

page 36, line 11: this leads

page 36, line 13: useful for correcting the modelled mid-Pliocene climate state for gateway effects in order to obtain a simpler interpretation

page 36, line 15: For future phases of the PlioMIP, an additional

page 36, line 21: we stress that

page 37, line 4: corrected for an interpretation in terms of the near to distant future climate.

page 37, line 7: *no need for the word 'strongly'*

page 37, line 8: *need commas*

if we consider that, for modern geography, vegetation

page 37, line 11: Similar findings in COSMOS hold for

page 37, line 17: Based on proxy data, it

page 38, line 5: model representations

page 38, line 7: not all dynamical aspects of the mid-Pliocene climate geared towards understanding the future

page 38, line 14: due to a large additional spin-up time

page 38, line 15: Instead, we implemented

page 38, line 20: is, in principal, possible

page 38, line 23: parameterised (*if using British spelling*)

page 38, line 24: Dolan et al. (2018) highlight the uncertainty

page 39, line 9: carbon dioxide (*no hyphen*)

page 39, line 14: may, in the future, also become a test bed

page 39, line 15: currently projected

page 39, line 16: food chain

page 39, line 19: to simulate

page 39, line 20: at a smaller scale

page 39, line 24: the effect of further increased carbon dioxide

page 39, line 25: characterised (*if using British spelling*)

page 39, line 29: the question of how far

page 39, line 34: There is an increase in the AMOC of the equilibrium state, a characteristic observed in only some models of PlioMIP1.

page 40, line 4: two-thirds

page 40, line 18: We have also

page 40, line 20: *Use commas*

we have considered, in our simulations,

page 40, line 21: in the North Atlantic

Figs. 3, 8, 9, 10, 26, 28: two metres (*if using British spelling*)

Fig. 11: Surface air temperature (SAT) here refers to the surface skin temperature

Fig. 13: for all simulations considered

Fig. 14: by also showing results.....depending on the volume mixing ratio

Fig. 15: depending on the volume mixing ratio

Fig. 17, 18: clockwise circulation from the viewpoint

Fig. 19: The ZMLD is defined by an increase of 0.125 kgm⁻³ in seawater density

Table 3: which are given for reference

Table 8: depending on carbon dioxide concentration

that is arbitrarily defined here as the isoline

We specify the northward shift for WC, EC, and ES, and the eastward shift for G.

kilometres (*if using British spelling*)

Note that the (*no comma*)

In simulations with high concentrations of carbon dioxide, the tree line defined here is absent