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Interactive comment on "The onset of Asian Monsoons: a modelling perspective" *by* Delphine Tardif et al.

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Dear referee,

Thank you for allowing us to go forward in the publication process. We hereby answer to comments and propose a corrected version of the manuscript. You'll find below the answers to the suggested corrections and comments point by point.

Delphine Tardif, on behalf of the co-authors

RC2: The authors conclude there were no modern-like Asian monsoons based on atmospheric circulation (Fig. 4) rather than precipitation seasonality (Fig. 8) in the Eocene simulation. I think it is necessary to have criteria of what atmospheric patterns can be viewed as modern-like monsoons or not. Otherwise, one may argue that Fig. 4c

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also shows a modern-like monsoon pattern since there is still cross-equator circulation over the Indian ocean though it locates at much lower latitudes.

Authors response: The cross equatorial circulation is indeed simulated at very low latitudes in our late Eocene experiment, over India and SE Asian Peninsula. However, we stress in the paper that this cross-equatorial circulation is deviated to the East at a lower latitude in the Eocene than in the modern climate (Fig. 4c-d). This pattern already dismisses the existence of EAM and suggest a weaker SAM. We also did apply the Webster-Yang Index over the region where the cross-equatorial flow is observed and we showed in the original submitted ms. that values obtained for the late Eocene were significantly lower than modern ones (Lines 355-364 and Figure 9). In order to make our point stronger, we have added the water column integrated moisture flux crossing the equator (Figure 5 in revised ms, see Figure below) where the opposite pattern between the control and the Eocene simulation is clearly visible. In particular, one can see that most moisture transport goes from the Indian ocean to the African continent during the Eocene in the 30°E – 60°E sector. To the contrary, the South East Asian monsoon remains well represented in the Eocene (60-90°E). For full analysis of this new Figure 5, the reviewer is referred to the supplementary document attached to the present response, which shows the modifications made in Section 3.2 (in italic).

RC2: When explaining the Eocene atmospheric circulation (section 3.2), I suggest considering some existing monsoon theories (Boos and Kuang 2010), in which low-level enthalpy or equivalent potential temperature is more physically fundamental to cause circulation and convection anomaly than “blocked by the Tethysian high in Line 267” and “mid-level atmospheric layers very dry and prevents air masses to reach...” in Line 280. Generally, we can say that without the blocking of the TP and Iranian Plateau, cold air is easy to intrude the Indian subcontinent and does not allow building up strong positive low-level enthalpy anomaly, thus not triggering much convection as today.

Authors response: We have added a similar diagnostic as the one proposed by Boos

and Kuang 2010, i.e. the temperature (in °K) at 300 hPa (Figure 8 in the revised version, see Figure below). We show that continental Asia is not the main source of heat for the upper troposphere in the Eocene (a), but rather the western Pacific, which contrasts strongly with the modern case (b, Control Simulation). This also confirms our first interpretations that the High Pressure – Low Pressure zonation and location in the Eocene induces a cascade of events leading to the absence of deep convection over the Himalaya – Tibetan Plateau system. For full analysis of this new Figure 8, the reviewer is referred to the supplementary document attached to this response, which shows the modifications made in Section 3.2 (in italic).

RC2: I feel like the word "onset" (of Asian monsoons) is confusing. I know that it refers to the beginning of the modern-like monsoons over the geological time scales, but it is also usually used to represent the starting time (day or month) of the summer monsoon season and actually authors use this meaning in Line 144. I suggest replacing "onset" with "origin" or other synonyms.

Authors response: We thank the reviewer for this suggestion and have replaced the word "onset" by synonyms

RC2: The authors discuss the model-data comparison problem and point out the importance of correct interpretations of paleo-records. One way to better fill in the gaps between model and proxy records is by using isotope-enabled models (e.g., comparing simulated precipitation isotope ratios to proxies based on precipitation isotopes) and proxy forward modeling (e.g., translating climate variables of simulations directly to pseudoproxies). It would be great if authors can add discussion about this.

Authors response: We thank the reviewer; teh following paragraph has been added in the Conclusion: "Also, rather recent specific modelling techniques could be very promisingly applied as a complement to complex climatic modelling reconstructions. For example, isotopic-enabled models, by simulating paleoprecipitations δ18O, allow a direct comparison of the model output to δ18O values that can be measured in a

wide variety of proxies (shells, carbonates, etc.) and therefore provide robust physical mechanisms to explain the measured patterns (Botsyun et al., 2019; Poulsen et al., 2010). Additionally, the application of proxy forward modelling methods (Dee et al., 2016; Evans et al., 2013), by mimicking the mechanisms through which a particular proxy will record a climatic perturbation (e.g. the translation of a precipitation decrease in an ice core) taking into account the proxy's specificity (e.g. ice compaction and diffusion) and the time uncertainty could contribute greatly to help fill the gap between proxy records and model results."

RC2: Line 71: These findings "postpone"... Is it "postpone" or "bring forward"?

Authors response: They postpone from 22Ma to 40Ma the inception of monsoons

RC2: Line 75: ÂńdoubthouseÂż -> "doubthouse"

Authors response: Done

RC2: Line 98: "A third mechanism": It is not a mechanism but a conjecture (or other synonyms)

Authors response: Done, replaced by "theory"

RC2: Line 128: expend -> expand

Authors response: Done

RC2: Line 136: improved -> improves

Authors response: Done

RC2: Line 218-221: Cloud feedbacks can also contribute to the model bias: Zhu, J.,Poulsen, C. J., & Tierney, J. E. (2019). Simulation of Eocene extreme warmth and high climate sensitivity through cloud feedbacks. Science Advances, 5(9), eaax1874.https://doi.org/10.1126/sciadv.aax1874

Authors response: Indeed. We have added this reference and propose the following

correction: "Underlying causes remain unclear and could be attributed to proxy uncertainties, missing processes in the models, (Huber and Caballero, 2011) or biases in the way models handle small-scale processes, such as cloud feedbacks (Zhu et al., 2019)."

RC2: Line 270: I don't see easterly winds from the Pacific Ocean

Authors response: In Fig 4c, the Asian east coast receives westerlies (>30°N) and weak easterlies (<30°C, northern part of Southeast Asian Peninsula). We have clarified the sentence.

RC2: Line 272: Theses-> These

Authors response: Done

RC2: Line 275: How to determine the condensation height? The condensation can occur at multiple layers at a single time in the model.

Authors response: It is the minimal altitude of condensation, corresponding to an approximation of clouds base level

RC2: Line 282: Figure 5->6?

Authors response: Done

RC2: Line 283: "multiple deep convection": how do you identify convection here? By upward motion?

Authors response: Yes

Line 283: add "center" between humidity and around

Authors response: Done

RC2: Line 320-325: Do these records all represent precipitation seasonality/seasonal contrast or annual mean precipitation?

Authors response: They all suggest highly seasonal precipitations. Some also provide Mean Annual Precipitations estimates, but we choose to focus on seasonality because it appears to be a more robust criteria, as explained at Line 393.

RC2: Line 392-393: “When oriented in a NW-SE orientation”: change one of the “orient” words

Authors response: Done

RC2: All figures: please enlarge the font size of labels of latitude/longitude/color bar. It is especially important for Figure 7.

Authors response: Done

RC2: Figure 2: How do you calculate sea level pressure anomaly? Is it seasonal mean minus annual mean? Are winds climatological mean or anomalies?

Authors response: Yes and yes, we’ve modified the Figure legend to be more specific.

RC2: Line 462: Please add “5” before “Pondaung”

Authors response: Done

RC2: It would be great to add a figure like Figure 5 (a)(b) but in the summer monsoon season in the supplements

Authors response: Done, is is now in Figure 5c-d, (see Figure 5 below)

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2019-144/cp-2019-144-AC2-supplement.pdf

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2019-144, 2019.

Figure 5: Comparison of EOC4X (a, c) and Control (b, d) water column integrated moisture fluxes. (a, b) Meridional component of JJA moisture fluxes averaged between 2°S and 2°N (black lines and left axis); dotted lines represent the elevation of land masses within the same latitudinal band (right axis); arrows and legends indicate the direction of the zonal component of moisture fluxes. (c, d) JJA moisture fluxes (vectors) and cumulated precipitations for the same period (mm/day). Black boxes highlight the area used to compute meridional moisture fluxes in (a, b).

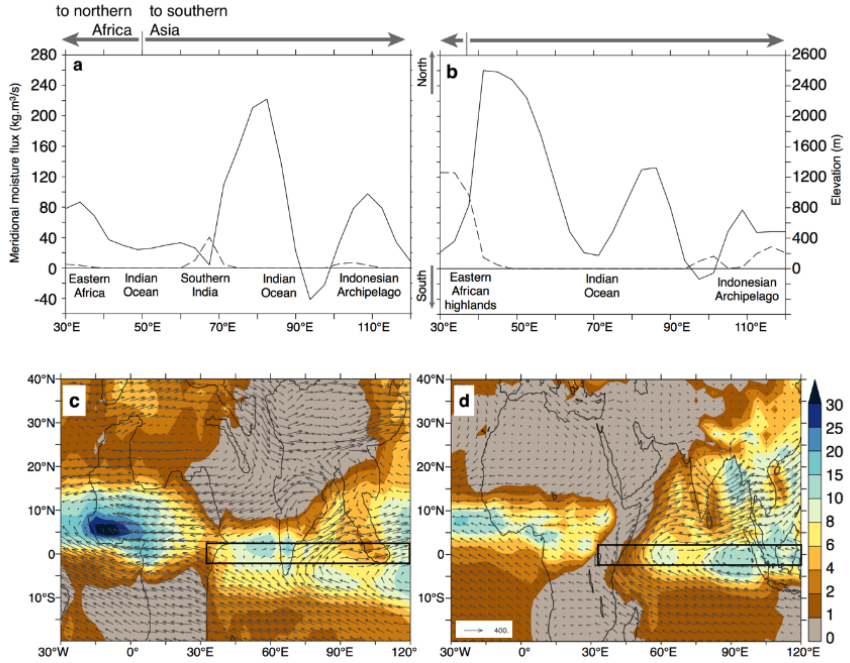

Fig. 1. Figure 5: integrated moisture flux crossing the equator

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Figure 8: Air Temperature (in Kelvin) at 300 mb for EOC4X (a) and Control (b) with contours overlaid each degree.

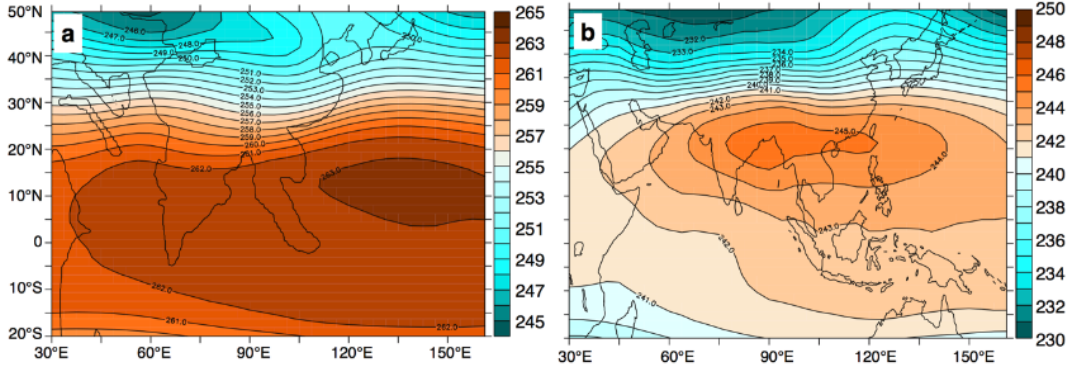

Fig. 2. Figure 8: Air Temperature at 300hPa

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