Anonymous Referee #2

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The authors examined response of Australian monsoon to LGM forcing among CMIP5/PMIP3 multiple models. Simulated annual range of Australian monsoon rainfall during LGM is larger than present day, distinct from other regional monsoon systems. However, in a previous paper published in 2016, it has been already explored that this unique monsoon behavior was found among CMIP5/PMIP3 models and changes in land-sea contrast (due to change in land sea configuration arising from sea level drop) and east-west SST gradient are important for that. In that paper, the authors emphasized dynamic contribution to the spring-to-summer monsoon enhancement (rooted from changes in land-sea contrast and SST gradient) because thermodynamic contribution (reduced surface water vapor rooted from surface cooling) cannot explain this enhancement. Most of the contents described in the current paper are just reconfirmations of previous paper (Yan et al. 2016).

In the current paper, the authors also tried to quantify relative contributions of dynamic and thermodynamic components related to the LGM Australian monsoon response. However, their quantitative decomposition is not reasonable. They did not follow widely-accepted methodology decomposing dynamic and thermodynamic components of rainfall response under climate change based on concepts of atmospheric water vapor budget. They also simply compared model-ensemble-mean anomaly between LGM and present day and dismissed inter-model differences in regional gradients in temperature, pressure and circulation response although they are essential for their main discussion. As an overall evaluation, novelty of this study seems very limited. I would like to recommend the authors to conduct any additional tests (e.g. Chiang et al. 2003: Toracinta et al. 2004; Ueda et al. 2011) to quantify effect of the land configuration (for example) to the Australian monsoon circulation and rainfall. Such sensitivity tests in addition to the quantitative evaluation of the hydrological response in multiple models are necessary for improving quality of this study.

Reply: Thank you for your valuable and constructive comments for improving our study.

In the revised version, we have added the decomposing method to assess the hydrological response and have added two additional simulations to test the effect of land-sea configuration on Australian monsoon.

Please find the detailed method of quantitative assessment of the hydrological response in the Reply to Comment 1.

The additional simulations have been added in the Discussion Section in the revised text. To isolate the impacts of land-sea configuration change, two experiments are conducted using a fully coupled earth system model (NESM v1, Cao et al., 2015). One is the PI control run designed the same as PMIP3 protocol, the other is the same as PI control run but with LGM land-sea configuration. The sensitive simulation illustrates that the local dynamical process induced by the land-sea configuration change is essential to the Australian monsoon precipitation change. The additional simulated results are shown in Figure 12 in the revised version. The additional simulations and results are included in the Discussion Section, Lines 367-382.

Other comments

1. *Please follow commonly-used dynamic-thermodynamic decomposition method. In line 165-173, 183-191 and other parts, ratio of specific humidity change should not be simply converted to that of precipitation change. Please read carefully Held and Soden 2006, O'Gorman et al. 2012 to catch current understanding of response of hydrological cycle under climate change, and Chou et al. 2009, Seager et al. 2010, and Chadwick et al. 2013 to understand widely-accepted methods for decomposition of dynamic and thermodynamic contributions to rainfall response under different climate states.*

Reply: Thank you for your suggestion. In the revised work, we have made a rigorous quantitative analysis of the precipitation response to dynamic and thermodynamic factors.

For attribution of precipitation changes, we use a simplified relation based on the linearized equation of moisture budget used in the previous works (Chou et al., 2003; Seager et al., 2010; Huang et al., 2013; Endo and Kitoh, 2014; Liu et al., 2016). Considering a quasi-equilibrium state, the vertical integrated moisture conservation can be approximately written as:

$$-\int_{1000}^{0} \nabla \cdot (q\vec{v})dp = P - E \qquad (1)$$

where q is specific humidity, $\vec{v}$ is horizontal velocity, p is pressure, P is precipitation, and E the surface evaporation. Since water vapor is concentrated in the lower troposphere, the vertical integrated total column moisture divergence can be approximately replaced by the integration from the surface to 500 hPa. Define the Δ (.) as the change from PI to the LGM, i.e.,

$$\Delta(.) = (.)\mathrm{LGM} - (.)\mathrm{PI} \qquad (2)$$

Then the precipitation change $\Delta \mathrm{P}$ can be approximately calculated as follows:

$$\Delta \mathrm{P} = -\int_{p1000}^{p500} \Delta(\mathrm{q} \cdot \nabla\vec{v})dp - \int_{p1000}^{p500} \Delta(\vec{v} \cdot \nabla q)\, dp + \Delta E \qquad (3)$$

To further simplify the equation, we use $-\omega_{500}$ to represent vertical integrated $\nabla\vec{v}$, and q at the surface to represent vertical integrated specific humidity (Huang et al., 2013). Thus, the precipitation change (ΔP) can be represented as

$$\Delta \mathrm{P} \propto \overline{\omega}_{500} \cdot \Delta \mathrm{q} + \bar{\mathrm{q}} \cdot \Delta\omega_{500} + \Delta E - \Delta T_{adv} \qquad (4)$$

where $\overline{\omega}_{500}$ is 500 hPa vertical velocity in PI, $\bar{\mathrm{q}}$ is surface specific humidity in PI, ΔT_{adv} is the changes due to the moisture advection ($\int_{p0}^{p500} \Delta(\vec{v} \cdot \nabla q)\, dp$).

The first term in the right-hand side of (4) ($\overline{\omega}_{500} \cdot \Delta \mathrm{q}$) represents thermodynamic effect

(due to the change of q), and the second term ($\overline{q} \cdot \Delta\omega_{500}$) represents dynamic effect (due to the change of circulation).
The above method has been added in the revised Sec. 2.2, Lines 151-172.
The spatial distributions of each term in JJA and ND have been provided in the revised version as supplementary figures (Figure S3 and Figure S6). The descriptions are added in the revised text, Lines 226-229 and Lines 301-305.
It is clear that the dynamic effect plays more important role than the thermodynamic effect in the precipitation change over Australia and Maritime Continent. But this is not always true for other regions, such as South Africa and South America, where the thermodynamic and dynamic effects have comparable contributions.
Based on the new decomposition method, we modified the statements about the contributions of thermodynamic and dynamic effects.

2. *Please show inter-model consistency in (1) regional gradient in surface temperature, sea level pressure and rainfall, and (2) east-west SST gradient. In this paper, the authors checked inter-model consistency in LGM anomaly compared to PI. However, inter-model consistencies in the regional gradients in LGM anomaly (for example, are east-west dSST gradients really consistent among 7 models?) are not accessed although they are essential for the conclusion.*

Reply: The inter-model consistencies of regional gradient in temperature, SLP and SST have been provided in the revised version as supplementary (Figure S5).
The east-west SST gradient (warm western tropic Pacific Ocean and cold eastern tropic Indian Ocean) is consistent among the models, please refer to the Figure S5e.

3. *Please check inter-model consistency in LGM land configuration. Although the LGM land configuration was specified in PMIP3 protocol, land configuration implemented in each model could be different because model resolutions are much different between different model. Land-sea mask data in native grid of each model should be checked because any inter-model difference possibly affect inter-model difference in results.*

Reply: Although the resolutions of atmospheric component in each model are much different, four of the seven models have higher resolutions than 2-degree. For the oceanic component, most models (except IPSL-CM5A-LR) have higher resolutions than 1-degree. We have added the resolutions used in the oceanic component of the models in Table 1.
It's hard to obtain the land-sea mask data from each model, here we use the climatology of SST in the LGM to illustrate the land-sea configuration in each model (Figure A). We are focusing on the tropical Indian Ocean and tropical west Pacific Ocean. Note that the resolution of 7MME is 2.5°*2.5°, lower than the individual models.

The resolution of land configuration might not be the key question that will affect the results.

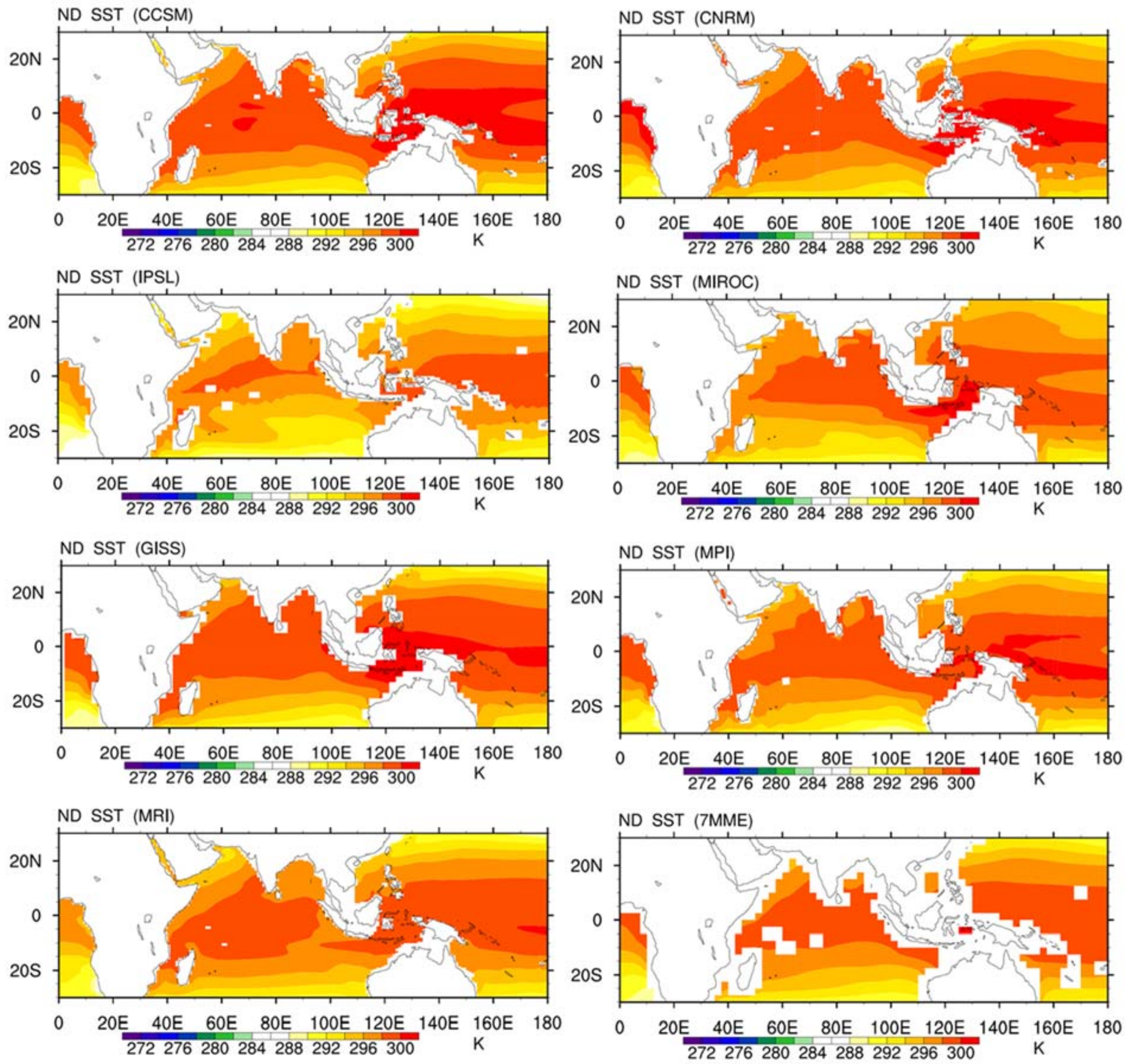

Figure A ND mean SST in LGME derived from each model and 7MME.

4. *Figures S1 and S2 seem identical to Figures 2 and 1 of Yan et al. (2016). You may need any copyright permission from Springer-Nature.*

Reply: The paper of Yan et al. (2016) has been purchased "Open Access" in Climate Dynamics. So, we don't need to obtain the copyright.

5. *Line 26: relative -> related?*

Reply: Yes, it should "be related", changed in the revised version. Please refer to Line 26 in the revised text.

6. *Line 41-44: I couldn't catch what do you mean here. Are "the local processes" you mention here land-sea configurations?*

Reply: Some synthesis suggests that the change of Australian monsoon during the

LGM might be related to the large-scale circulation change such as the shifted position of ITCZ. However, in this work we find that it is not closely related to this large-scale circulation change, but to the local dynamics.

In this study, "the local dynamics" not only represents the dynamics due to the "land-sea contrast", but also due to the "asymmetric SST changes between the east tropical Indian Ocean and tropical western Pacific Ocean".

The statement has been modified in the revised version as follows:

“The enhanced Australian monsoonality in the LGM is not associated with global scale circulation change such as the shift of the ITCZ, rather, it is mainly due to the change of regional circulations around Australia arising from the changes in land-sea contrast and the east-west SST gradients over the Indo-western Pacific oceans. This finding should be taken into account …” Please refer to Lines 42-45.

7. *Line 110: thermal dynamics -> thermodynamic*

Reply: Thank you for pointing out this. All the terms of "thermal dynamics" have been changed into "thermodynamics" in the revised version.