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Climate of the Past
Discussions
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Interactive comment on "Relative impact of insolation and Warm Pool surface temperature on the East Asia Summer Monsoon during the MIS-13 interglacial" *by* Q. Z. Yin et al.

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We thank reviewer 2 for his/her constructive and interesting comments, and give our answers hereunder.

Reviewer comment 1: P. 1033, L.11: The statement of "This is clearly indicated by the strongest rising motion at 35N in Hadley Cell (Fig. 5a) : : :: : :" is not correct. The rising motion at 35N does not belong to the ascending branch of Hadley Cell. The figure actually shows the difference between the experiment of f10 and the experiment of f00 rather than a real circulation pattern, and thus the figure of difference cannot display Hadley Cell. There are similar problems in other places in the manuscripts.

Author reply 1:

In the revised version, we have modified all the descriptions related to figure 5 when discussing the movement of ITCZ and the Asian jet. To be more clear, we have also added a subplot in figure 5 (attached here) showing the meridional and zonal wind fields of the control experiment.

The related modifications in the text include:

"The ITCZ can be indicated by the strongest rising motion in the Hadley cell (Figure 5a). Under the influence of insolation, there is an anomalous descending motion around 20N and an anomalous rising around 35N, indicating a northward movement of the ITCZ (Figure 5b)."

"As indicated by the zonal wind anomaly at 200 hPa, Figure 5b shows that the southern part of the subtropical East Asian jet is significantly weakened and its northern part is intensified and expanded. This is accompanied with strong anomalous rising motion over northern China providing more rainfall there."

"Such a warmer IPWP reduces the land-sea thermal contrast over the NH land in summer and shifts the ITCZ southward as indicated by the change in the meridional wind circulation anomaly (Figure 5c). Here, the 200 hPa subtropical jet also shifts southward as indicated by the change in the zonal wind circulation anomaly (Figure 5c), leading to more rainfall over East Asia south of 20N."

Reviewer comment 2: P. 1035: As mentioned too in the manuscript, a previous study shows that the Warm Pool temperature increase can lead less rainfall in northern China and more rainfall in southern China (Zhao et al., 2000). Other observational studies with instrumental data or proxy records (e.g., Yang and Lau, 2004, Trend and variability of China precipitation in spring and summer: linkage to seaôĂĂĂsurface temperatures, Inter. J. Climat.; Zhang et al., 2009: Reconstruction of the western Pacific warm pool SST since 1644 AD and its relation to precipitation over East China, Science

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China) have also obtained the same conclusion. However, the modeling result in this manuscript shows that the pure impact of enhanced Warm Pool SST slightly reduces the summer precipitation in both northern and southern China. The authors should give some explanations and discussions for the difference between the observation and their simulation. More important is that the warmer SST may actually increase rather than decrease the rainfall in southern China under a background of higher summer insolation period (see the following).

Author reply 2:

A closer investigation of the literature shows that, actually, different studies based on modern observation data or on proxy reconstructions lead to different relationships between SST and China precipitation, particularly in southern China (see examples given in the next paragraphs). The inconsistency between these studies might be related to different data sets or different analytical techniques used in these different studies. Moreover, some of the conclusions (for example Zhao et al 2000) have been drawn from using only the western Pacific Warm Pool, but in our experiment, the SST has been increased over the whole Indo-Pacific Warm Pool, a region extending from western tropical Pacific to eastern equatorial Indian Ocean. To be more clear, a figure showing such a region is added in the revised version (see figure 1 below). More explanation is also given regarding the comparison between our results and results from other models and observations:

“Our simulated result that increased SST over the IPWP leads to reduced summer precipitation in China is in line with other modeling studies. By using two-level global circulation model, Huang and Sun (1992) showed that when the SST over tropical western Pacific Warm Pool is above normal then East Asia receives below normal rainfall in summer. Tschuck et al (2004) also showed that a warmer western Pacific leads to anomalous north-easterlies wind over China indicating a weakened East Asian monsoon.

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Many studies have used modern observational data or proxy reconstructions to discuss the relationship between SST and the precipitation in China, but interpretations based on data are much more diverse than based on modelling results. Zhao et al (2000) found that increased SST in the western Pacific Warm Pool corresponds to less rainfall in northern China and more rainfall in southern China. Zhang et al (2009) studied the correlation between the western Pacific warm pool SST and the East China precipitation during the past 360 years. They found that this correlation has strong regional diversity, but it is only over the Yellow River and Huaihe River basin in northern China that this correlation (negative) is significant. Yang and Lau (2004) found that the interannual variation of the summer precipitation over central eastern China and over southern coastal China is correlated with a north-south dipole mode of SST anomalies over the western North Pacific, the tropical Indian Ocean and the warm pool: when SSTs are abnormally warm over the warm pool and northern Indian Ocean and are abnormally cold over the western North Pacific, summer precipitation tends to be heavier than usual in central eastern China but to be less in southern coastal China. Lee et al (2008) found that the north EASM precipitation is negatively correlated with the tropical western Pacific SST and is positively correlated to the tropical Indian Ocean SST, and that the south EASM precipitation is positively correlated with the western North Pacific SST but has no obvious correlation with the Indian Ocean SST. However, also based on observational data, Saji and Yamagata (2003) found that the precipitation over India and southern China is enhanced during the positive IOD (Indian Ocean Dipole) event, an event which is characterized by anomalous cooling in the eastern equatorial Indian Ocean and anomalous warming in the western equatorial Indian Ocean.

The different findings from these studies based on data or proxy reconstructions might be related to different data sets or different analytical techniques which have been used. Nevertheless, these studies tend to show that the summer precipitation in northern China is negatively correlated with the SST in the western Pacific Warm Pool, which is in agreement with our model results. However, the conclusions are more controversial for southern China. Among them, Zhao et al (2000) found a positive cor-

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relation between southern China precipitation and the SST of western Pacific Warm Pool. This, at a first glance, seems to be contrary to our results, but actually it is not because it is not appropriate to compare the finding of Zhao et al (2000) with our results. In our experiment the SST is indeed enhanced not only over the western Pacific Warm Pool but also over the Indian Ocean Warm Pool, a region extending from the tropical western Pacific to the eastern equatorial Indian Ocean (Figure 1). It means that in our simulation the precipitation in southern China responds to changes in SST not only in the western Pacific Warm Pool but also in the Indian Ocean Warm Pool. In our experiment, due to the SST increase in the eastern equatorial Indian Ocean, a negative "IOD-like" event is created. Presumably opposite to the positive IOD situation as in Saji and Yamagata (2003), a negative IOD might be associated with reduced precipitation over India and southern China, which is indeed the case in our simulation (Figure 4b)."

Reviewer comment 3: P. 1036: We may have a different understanding for the synergism effect. According to the authors, f11+f00-f10-f01 = (f11-f00)-(f10-f00)-(f01-f00). There is another explanation: f11+f00-f10-f01 = (f11-f01)-(f10-f00), or f11+f00-f10-f01 = (f11-f10)-(f01-f00). Here, (f11-f01) reflects the response of monsoon to insolation under the warmer SST background, while (f10-f00) reflects the response of monsoon to insolation under the control (present-day) SST background. Either (f11-f01) or (f10-f00) can be seen as a pure effect of insolation. Therefore, (f11-f01)-(f10-f00) may be explained as the modulation of the SST change over the Pacific warm pool on the insolation effect. In this way, pure effect of insolation can lead less rainfall (f10-f00) or more rainfall (f11-f01) in southern China. In other words, the response of monsoon rainfall over East Asia to insolation strongly depends on the background state of SST. As a matter of fact, all experiments were conducted with an atmosphere-only model in this study, an atmosphere-ocean coupled model can modify the conclusion (Duan et al., 2008: Simulation of local air-sea interaction in the great warm pool and its influence on Asian monsoon, JGR). So the authors should be careful in explaining their results of numerical experiments.

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Author reply 3:

The reviewer is mathematically correct in his/her explanation, and it is certainly true that, in general, developing an interpretation of second-order effects, which is in essence what synergism is, it is not straightforward. Here, we observe that synergism is much larger than the first order effects established from the reference state f00. From our experience, it may be in this case misleading to develop an "asymmetric" interpretation, "insolation effect modulated by SST". We could as well have said: "SST effect modulated by insolation". We are generally rather facing here a kind of threshold effect, that is being crossed by the collaborative action of SST and insolation.

Moreover, we have to stress that, different from some traditional studies where sensitivity experiments were made to investigate the impact of only one factor (insolation or SST), our study would like to test the relative importance of insolation and warm pool SST on the EASM. In the traditional study where only the impact of one factor is evaluated, the common method is to analyze the difference between a control run and a simulation where this factor is switched off. (f11-f01) is actually following this common procedure with which the impact of insolation is analyzed. When we only care about the impact of insolation for a given background SST, this method seems to be appropriate. However, the difference between two experiments (eg. f11-f01) does not have a simple meaning when more than one factor are involved, and in fact may be quite misleading. In our case, two factors, insolation and SST, are involved. In this case, (f11-f01) shows the pure effect of insolation (f10-f00), plus the joint effect (synergism) between insolation and SST and therefore can not be considered as the pure effect of insolation.

In order to isolate the individual effects of insolation and of SST, we have indeed used the Alpert-Stein factor separation methodology. The advantage of this methodology is to allow isolating the interactions between different factors. In the book "Factor Separation in the Atmosphere: Applications and Future Prospects" edited by Alpert and Sholokhman, it is said in page 2 that "No sensitivity studies had been proposed to isolate these interactions before our Factor Separation methodology was introduced in 1993.”.

We note that, due to the difference in methodology between our study where both insolation and SST are evaluated at the same time with the factor separation analysis and the traditional study where only one factor is evaluated at a given specific value of the other factor, we must be cautious when comparing our results with those from the traditional studies.

In order to be clearer, we have made major modifications in section 2 with more explanations on the Alpert-Stein factor separation method as well as reminding the difference between our study and the traditional ones.

As is mentioned in our manuscript, our purpose is to test the relative impact of insolation and warm pool SST which had to be prescribed according to some proxy reconstructions. This is why we must use an atmosphere-only model. Many thanks for having recommended the interesting paper of Duan et al 2008 to us. More explanations have been accordingly added in section 3.2:

“We note that an atmosphere-only model is used in our study. It means that there is no feedback from atmosphere to ocean. Duan et al (2008) found that the atmospheric feedbacks cool SST through enhanced evaporation and reduced solar heating caused by deep convection during the active phase of monsoon. They found that absence of such kind of feedbacks in the atmosphere-only model generates more precipitation over the Warm Pool by maintaining the high SST for too long time. According to their study, the large precipitation increase over the Warm Pool in our study might therefore be exaggerated.”

Interactive comment on Clim. Past Discuss., 10, 1025, 2014.

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Interactive Comment

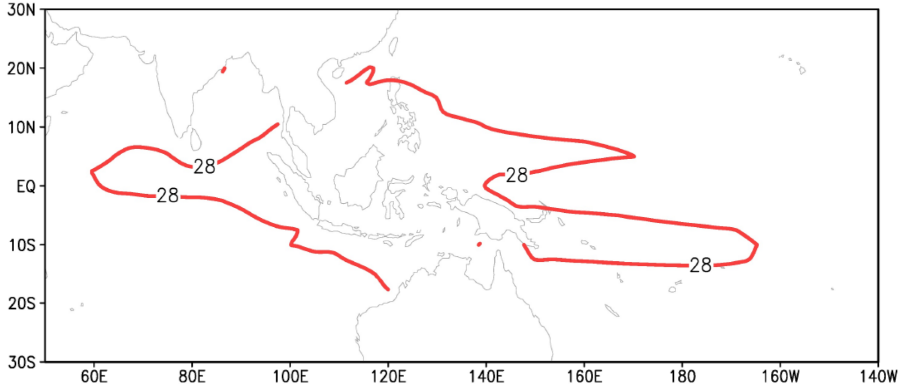

Figure 1. Area of the Indo-Pacific Warm Pool surrounded by 28˚C isotherm line.
Annual mean SST values are provided by the HadCM3 simulation for MIS-13 (Muri et al., 2013).

Fig. 1.

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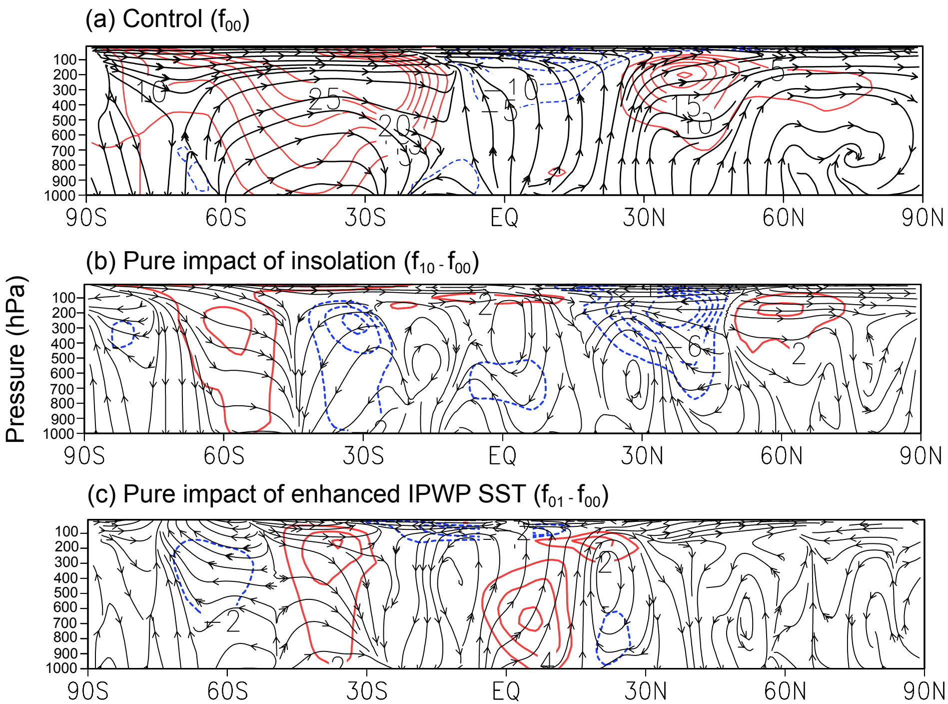

Figure 5. JJA mean meridional wind circulations averaged over 105°E to 120°E. (a) The control experiment (f00), (b) the pure impact of insolation (f10-f00), and (c) the pure impact of enhanced IPWP SST (f01-f00). Stream lines indicate meridional wind circulation for (a) and anomalies for (b) and (c). Contour lines indicate zonal wind circulation or anomalies (with an interval of 5 m/s for (a) and 2 m/s for (b) and (c)).

Fig. 2.