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Global sensitivity analysis of Indian Monsoon during the Pleistocene

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Abstract

This supplement material focuses on the results given by the emulator when it is applied in another representative region of the Indian Monsoon.

1 Use of the Emulator

In order to have a better understanding of the use and effect of the emulator, a multimedia video was created in order to aid in the understanding of the effects of the scaling lengths on the final results.

As explained in the main text, the construction and use of the emulator, in its simplest form, is a 3 step procedure:

- Design an experiment plan
- Calibrate and validate the emulator
- Quantify and visualize the individual and combined effects of the different factors on the climatic event

The video *videolink* focuses particularly on the calibration of the emulator. The calibration of the emulator is dependent on the experiment design, and each of the scaling lengths (one per initial parameter) has to be calibrated not only according to its corresponding parameter but also with respect to the other four. The nugget allow tolerance between the fitted model and the output of the different experiments.

The quality of the emulator depend on a suitable adjustment of all the parameters involved.

2 Region Selection Effect

When studying specific climatic phenomena, the definition of a particular region of use can have an important effect on the interpretation of the final results, especially if this region encloses geographical patterns that are subject to change within time.

In our particular case, the study of the Indian Monsoon can suffer from this selection bias. The region chosen as the Indian Monsoon by Zhao et al. (2005), which we followed in order to compare our results, covers a vast region of the Tibetan Plateau. This has an effect on land precipitation, which could influence its phase.

In order to test the sensitivity of our results to the definition of the box boundaries, we select another region, proposed by Chen et al. (2011). This region has coordinates 65-105°E, 10-27.5°N. Since it is located more south and to the east of our original region, the Tibetan Plateau is not taken into account.

To do a global sensitivity analysis, we proceed as in the main text, that is, we calculate the season (JJAS) yearly-mean using the last 100 years of all the simulations, we construct a new emulator, we validate it and, finally, we produce the synthetic results.

Since we want to see the effect of land-sea temperature contrast, we remove the cells corresponding to sea from the temperature and precipitation fields. This procedure was not taken into account by Chen et al. (2011), so our results may differ from theirs.

In order to be consistent with the results presented in the main text, we remove from the analysis simulations 11 and 40. A new emulator is calibrated using the remaining 59 experiments, using the procedure described in Sect. 2.3. This calibration is shown in Fig. 1. The scales λ_i and nugget for both emulatores are presented in Table 1. As it was the case in for the previous region, there is a linear response of the fields to CO_2 and ice level.

3 Sensitivity to Precession

Fig. 2 displays the effect of precession on land temperature and land precipitation of the region described in the latter section. For clarity and consistency with the figure presented in the main text, we kept sea surface temperature and mixed-layer depth of the Indian Ocean region described in Sect. 3.

Two immediate effects caused by removing the Tibetan Plateau are clear: mean land temperature has increased by 6°C and the mean total amount of precipitation has slightly decreased. Its maximum and minimum have shifted, i.e., there is an increase of precipitation both at high and low glaciation level, but the mean total amount slightly decreases.

At low glaciation levels, the temperature response is in phase with late May insolation, and in phase with mid-June at mid- and high-glaciation levels. This results slightly differs with the ones presented in the main text, where temperature is in phase with June insolation at high glaciation levels, and with July at mid- and high-glaciation stages.

As for precipitation, its maximum is obtained when perihelion is reached in mid-June at low glaciation levels. The phase response shifts towards July insolation when there is an increase of glaciation levels. This result also varies slightly with the ones of the original region, where maximum precipitation is reached in early July.

References

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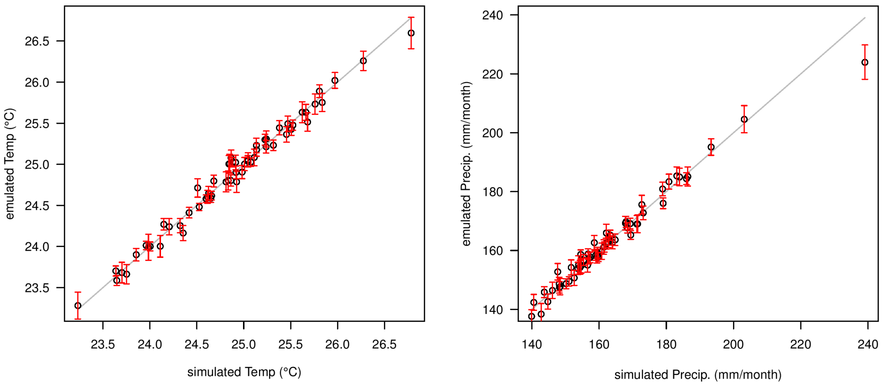

Figure 1. Diagnostic of emulator performance for land temperature (left panel) and land precipitation (right panel) for the region described in the text. Shown are the mean and standard deviation of the simulated and emulated data points for all simulations, except simulations 11 and 40.

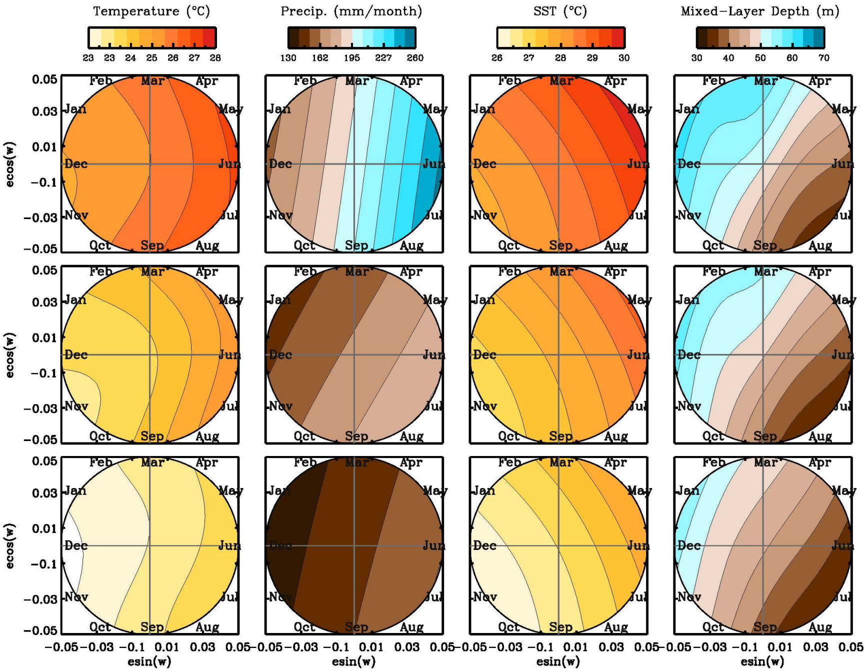

Figure 2. Sensitivity to $e\cos(\varpi)$ and $e\sin(\varpi)$ for land temperature and precipitation of the new region. Included also are sea surface temperature and mixed-layer depth of the Indian Ocean region. From top to bottom, each panel shows the four fields with a different configuration of glaciation level – CO_2. Top panels: glaciation level $= 1$ and $CO_2 = 280$ ppmv. Middle panels: glaciation level $= 5$ and $CO_2 = 230$. Bottom panels: glaciation level $= 11$ and $CO_2 = 180$. All fields were integrated over obliquity.

Table 1. Emulator scales for land temperature and land precipitation for the region mentioned in the text. As with the quantities of the original region, scales are commesurate with the range cover by the input factors. There is also a linear response of the fields to CO_2 and obliquity.

	Lambda					Nugget
	$\lambda_{e \cos \varpi}$ –	$\lambda_{e \sin \varpi}$ –	λ_{ε} ($^\circ$)	λ_{CO_2} (ppm)	λ_{ice} –	
Land temperature	0.0582	0.0652	6.655	13810.78	2.870	0.0140
Land precipitation	0.378	0.129	10.276	10427.69	1.637	0.0117