Model bias corrections for reliable projection of extreme El Niño frequency change

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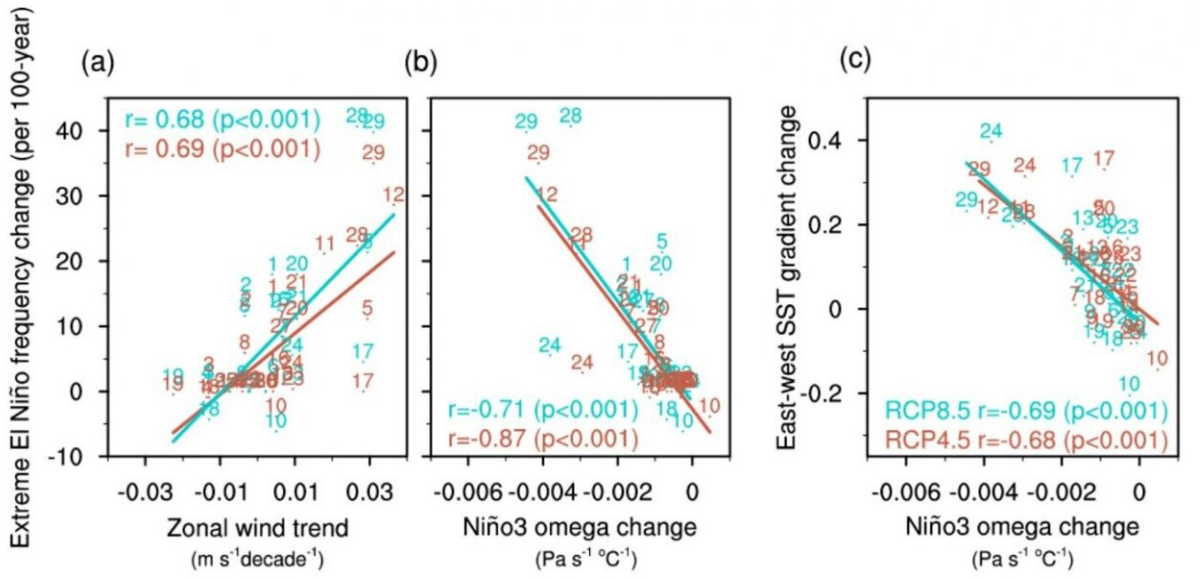

Inter-model correlation between the projected change in the extreme El Niño frequency during 2011-2098 and the simulated zonal wind trend during 1901-2010 (a), and the change in mean-state convection (represented by omega) over Niño3 region (b). Inter-model correlation between the Niño3 mean-state convection change and the Pacific east-minus-west SST gradient change (c). Credit: Science China Press

A reliable projection of extreme El Niño frequency change in a future warmer climate is critical to managing socio-economic activities and human health, strategic policy decisions, environmental and ecosystem

managements, and disaster mitigations in many parts of the world. Unfortunately, long-standing common biases in CMIP5 models, despite enormous efforts on the numerical model development over the past decades, make it hard to achieve a reliable projection of the extreme El Niño frequency change in the future. While increasing attentions have been paid to estimate possible impacts of models' biases, it is not yet fully understood whether and how much models' common biases would impact the projection of the extreme El Niño frequency change in coming decades. This is an urgent question to be solved.

According to the original projection of CMIP5 models, the extreme El Niño, defined by Niño3 convection, would increase twice in the future. However, Prof. Luo and his research team find that models which produce a centennial easterly trend in the tropical Pacific during the 20th century would project a weak increase or even a decrease of the extreme El Niño frequency in the 21st century. Since the centennial easterly trend is systematically underestimated in all CMIP5 models compared to the historical record, a reasonable question is whether this common bias might lead to an over-estimated frequency of the extreme El Niño frequency change in the models' original projections (Figure 1a).

Based on their results, the change in the frequency of extreme El Niño, which was defined by the total convection in the eastern equatorial Pacific (i.e. the sum of the mean-state and anomaly value of the vertical velocity in Nino3 region), is mostly determined by the mean-state change of the Nino3 convection (Figure 1b). In addition, change in the mean-state convection in Nino3 region is highly controlled by the change in the east-minus-west sea surface temperature (SST) gradient that determines the tropical Pacific Walker circulation (Figure 1c). Therefore, the change in the extreme El Niño frequency defined by the total convection in Nino3 region boils down to the change in the tropical Pacific east-minus-west SST gradient (i.e., 'El Niño-like' or 'La Niña-like' change).

By identifying systematic impacts of 13 common biases of CMIP5 models in simulating the tropical climate over the past century, they find that change in the tropical Pacific east-minus-west SST gradient in the future was significantly over-estimated in the original projection. In stark contrast to the original El Niño-like SST warming in the future projected by the CMIP5 models, the Pacific SST change, after removing the systematic impacts of the models' 13 common biases, shows that the strongest SST warming would occur in the tropical western Pacific rather than in the east (i.e., a La Niña-like SST warming change), coupled with stronger trade winds across the Pacific and suppressed convection in the eastern Pacific.

As mentioned above, change in the frequency of the so-defined extreme El Niño would be determined by the change in the Pacific mean-states. Therefore, by carefully removing the impacts of the models' common biases on the mean-state changes, Luo and colleagues find that the extreme El Niño frequency would remain almost unchanged in the future.

In summary, this finding highlights that the impacts of models' common biases could be great enough to reverse the original projection of the change in the tropical Pacific climate mean-states, which would largely affect the projection of the extreme El Niño frequency change in the future. Thus, it sheds a new light on the importance of model bias -correction in order to gain a reliable projection of future climate change. More importantly, this finding suggests that much more efforts should be put to improve climate models and reduce major systematic biases in coming years/decades.

More information: Tao Tang et al, Over-projected pacific warming and extreme El niño frequency due to CMIP5 common biases, *National Science Review* (2021). DOI: 10.1093/nsr/nwab056

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