Could CMIP6 climate models reproduce the early-2000s global warming slowdown?

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Introduction

The unexpected global warming slowdown during 1998-2013 despite of the sharp increase in greenhouse gas emissions challenges the existing scientific understanding of global temperature change mechanisms, thus has been one of the most concerning issues in recent climate research and even public. The interannual- to multidecadal- scale climate variabilities are regarded as potential causes for the recent warming slowdown.

However, most of the state-of-the-art climate models in CMIP5 failed to reproduce the warming slowdown.. Therefore, the simulation and prediction ability of sophisticated climate models have been questioned.

The newly developed CMIP6 models include better understanding of the global temperature change mechanisms, especially more reasonable physical processes of climate variabilities. Successful simulations of the global warming slowdown are expected in the CMIP6 models. It will be necessary to examine whether the new-generation models can reproduce the recent warming slowdown.

Data and Method

Based on 28 CMIP6 coupled climate models and six observational combined land/marine surface temperature datasets, we evaluated the ability of the CMIP6 models on simulating the warming slowdown, and further revealed the reasons for the dilemma of slowdown simulation.

To extract the secular trend (ST) and interannual, interdecadal and multidecadal variabilities (IAV, IDV and MDV), the simulated and observed global mean surface temperatures (GMSTs, Fig. 1) were decomposed into different scales by using the ensemble empirical mode decomposition (EEMD).

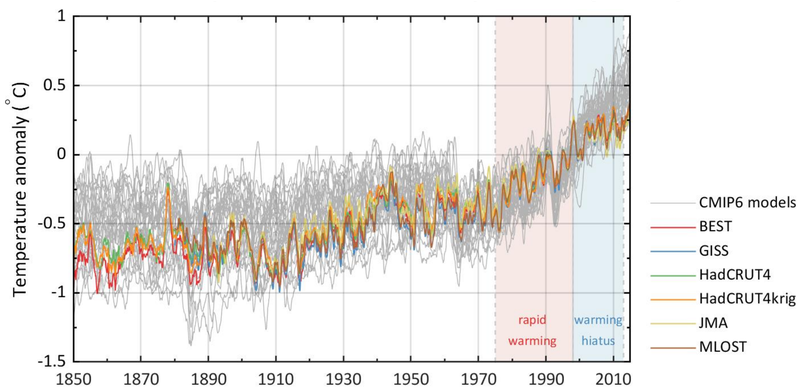

Figure 1 GMST monthly anomaly during 1850-2014

Could CMIP6 models reproduce the slowdown?

Most of the CMIP6 models still have difficulty in reproducing the slowdown during 1998-2013, although they are able to perfectly simulate the previous rapid warming during 1975-1997 and reasonably simulate the long-term warming trend during the whole instrumental period of 1850-2014. The models mostly overestimate the warming rate in 1998-2013 and thus exhibit an obvious warming acceleration rather than the observed deceleration (Fig. 2). Among the 28 models, only four reproduce the recent slowdown.

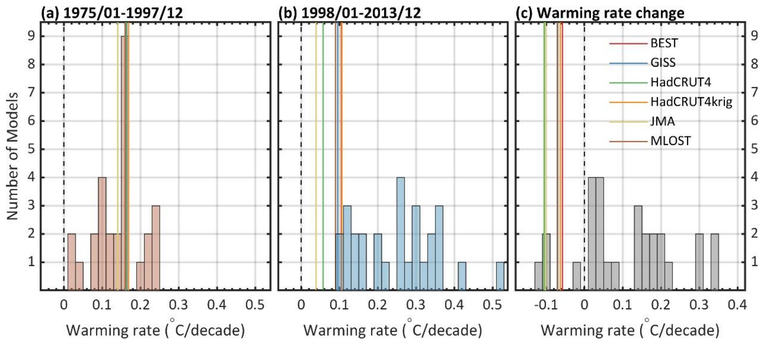

Figure 3 Warming rates during two periods.

Why do models hardly reproduce the slowdown?

The key to simulating the slowdown is to correctly simulate the steady centennial warming trend and crucial natural variabilities, especially IAV, IDV and MDV, which are the major contributors to the observed warming slowdown (Fig.4). Generally, the CMIP6 models perform well in simulating the secular warming trend but have some biases in simulating the three variabilities. During 1998-2013, most models miss the local cooling effect of the IDV and thus introduce a warming bias. The simulated warming rates from the overall ST and the warming phase of MDV are on the high side, further amplifying the warming bias. The four models that successfully reproduce the slowdown show relatively high skills in simulating the ST and three key-scale variabilities. (Fig.5).

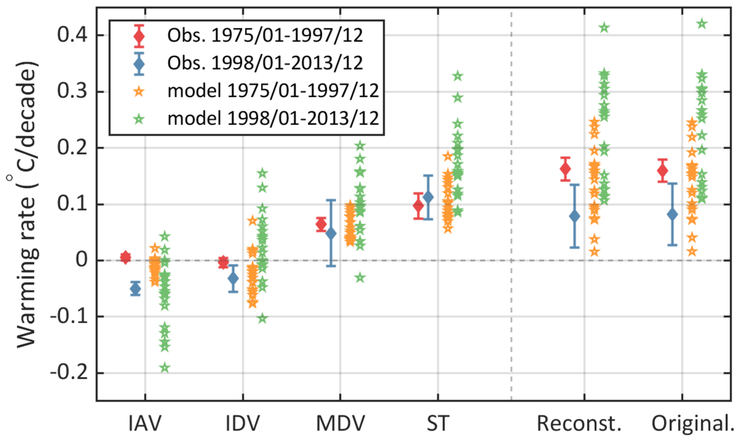

Figure 4 Warming rates of four key terms.

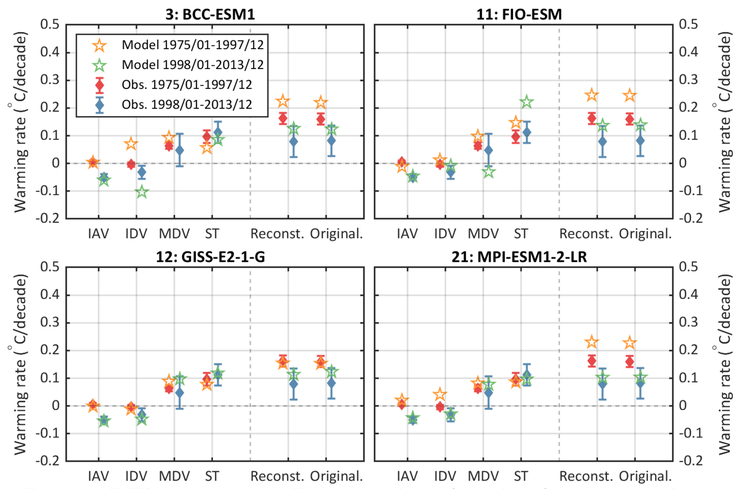

Figure 5 The same as Figure 6 but for the four models succeeding in reproducing the warming slowdown.

Conclusion

This study reveals that the key in simulating and predicting near-term temperate change is to correctly separate and simulate the two distinct signals, i.e., the human-induced long-term warming trend and natural variabilities, especially those at interannual, interdecadal and multidecadal scales.

This suggests that the key-scale variabilities require more attention in the models, considering their vital roles in modulating the warming rate change at decadal to multidecadal scales. This result can provide important insight for the simulation and prediction of near-term climate changes.

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