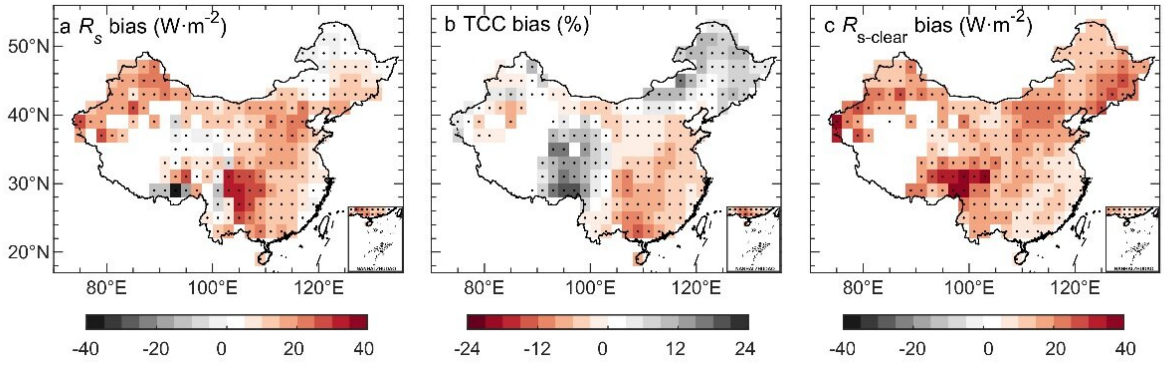
Constrained future brightening of solar radiation in China and its implication for solar power

December 21 2022



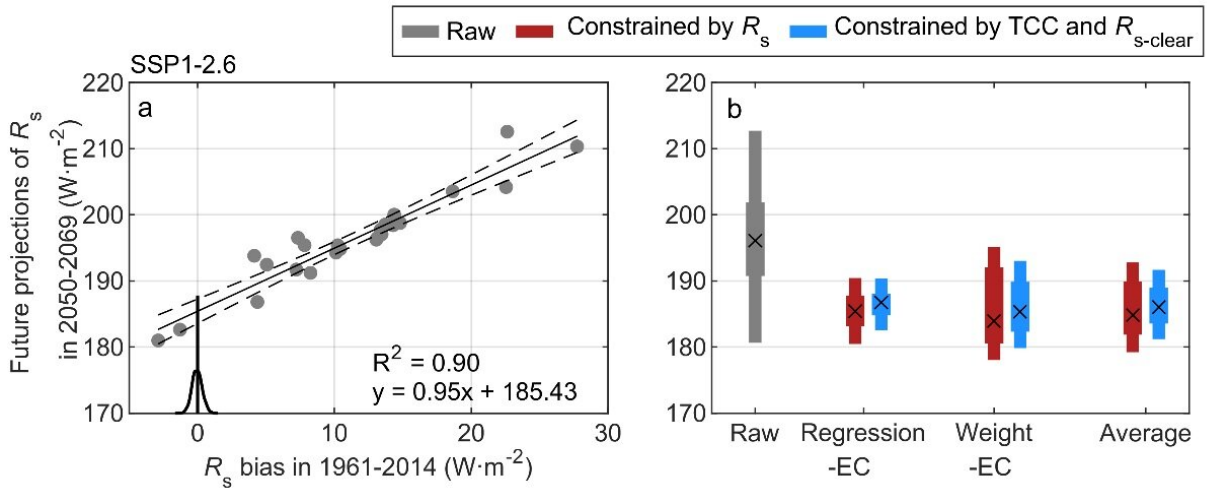
Spatial patterns of multi-year mean biases in (a) surface downward solar radiation (Rs, in W•m^{-2}), (b) total cloud cover fraction (TCC, in %) and (c) clear-sky surface downward solar radiation (Rs-clear, in W•m^{-2}) of the CMIP6 MMM against the ground-based observations averaged from 1961 to 2014. Photo credit: Yanyi He and Kun Yang. Credit: Science China Press

Surface solar radiation (R_s) data is essential information for the development of solar power usage to mitigate the ongoing climate change. To meet China's carbon neutrality goal, China has invested and planned heavily in solar photovoltaic systems.

However, future projections of R_s based on climate models contain large

uncertainties due to internal climate variability, model uncertainty, and scenario uncertainty, which have not been eliminated by previous studies. Moreover, the model biases in R_s and the underlying drivers have yet to be quantified.

By integrating the high-quality observations and the latest Coupled Model Intercomparison Project Phase 6 (CMIP6) model data of R_s, a research team led by Prof. Kun Yang (Department of Earth System Science, Tsinghua University) has explored the model bias of CMIP6 models in R_s and quantified the physical causes of the model bias in China. The systematic bias in R_s in CMIP6 models is revealed to be caused by clouds and aerosols, resulting in largely uncertain projections for future changes in R_s.



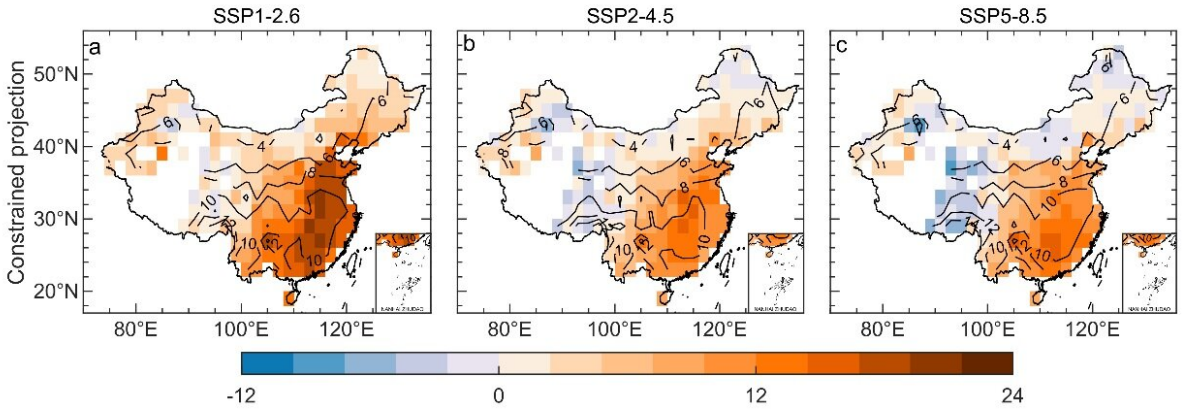
(a) The relationship between the future Rs during 2050-2069 in SSP1-2.6 (a low-emission scenario) and the historical bias in Rs during 1961-2014 for the 24 models. (b) Comparisons of raw and constrained projections of Rs in SSP1-2.6. Rs projections are constrained by the historical bias in Rs (red bars) and the historical bias in TCC and Rs-clear, respectively (blue bars). Photo credit: Yanyi He and Kun Yang. Credit: Science China Press

To correct this effect, the team used historical biases of models to constrain the future projections of R_s under three possible future scenarios based on emergent constraints, an approach with a solid physical basis for narrowing the uncertainties of future climate projections through the combination of an ensemble of climate simulations with contemporary measurements.

The research is published in the journal *National Science Review*.

The constrained results substantially reduce the projection uncertainties by about 56% in the mid-21st century. Moreover, the team found that the constraints using the combined effect of the TCC and $R_{s\text{-}clear}$ biases can account for about 81% of the projection uncertainties using R.

The constrained projections of R_s show a spatial pattern significantly favorable for the future solar energy layout. The researchers found that the mean R_s change during 2050-2069 relative to 1995-2014 is brightening. Particularly in North China and Southeast China with higher power demand, the constrained projections present more significant brightening.



Future changes (shading; in W•m^{-2}) in the 20-year mean of Rs during 2050-2069

relative to the 1995-2014 mean from constrained values in three possible future scenarios, i.e., SSP1-2.6 (a), SSP2-4.5 (b) and SSP5-8.5 (c), with the 66% confidence interval shown as contour. Photo credit: Yanyi He and Kun Yang. Credit: Science China Press

With increased anthropogenic forcing, the constrained future changes show weaker brightening in eastern China and more dimming in western China. "Low anthropogenic emissions under the carbon neutrality actions would not only help to mitigate global warming but also increase solar energy potential, consequently creating positive feedback for building a climate-resilient society," Yang says.

Better estimates and uncertainties of future R_s changes improve the reliability of climate projections to facilitate effective investment of solar power in China. These results highlight the need to consider the change in spatial pattern of future R_s when making policies or decisions associated with future solar energy deployment.

More information: Yanyi He et al, Constrained future brightening of solar radiation and its implication for China's solar power, *National Science Review* (2022). DOI: 10.1093/nsr/nwac242

Provided by Science China Press