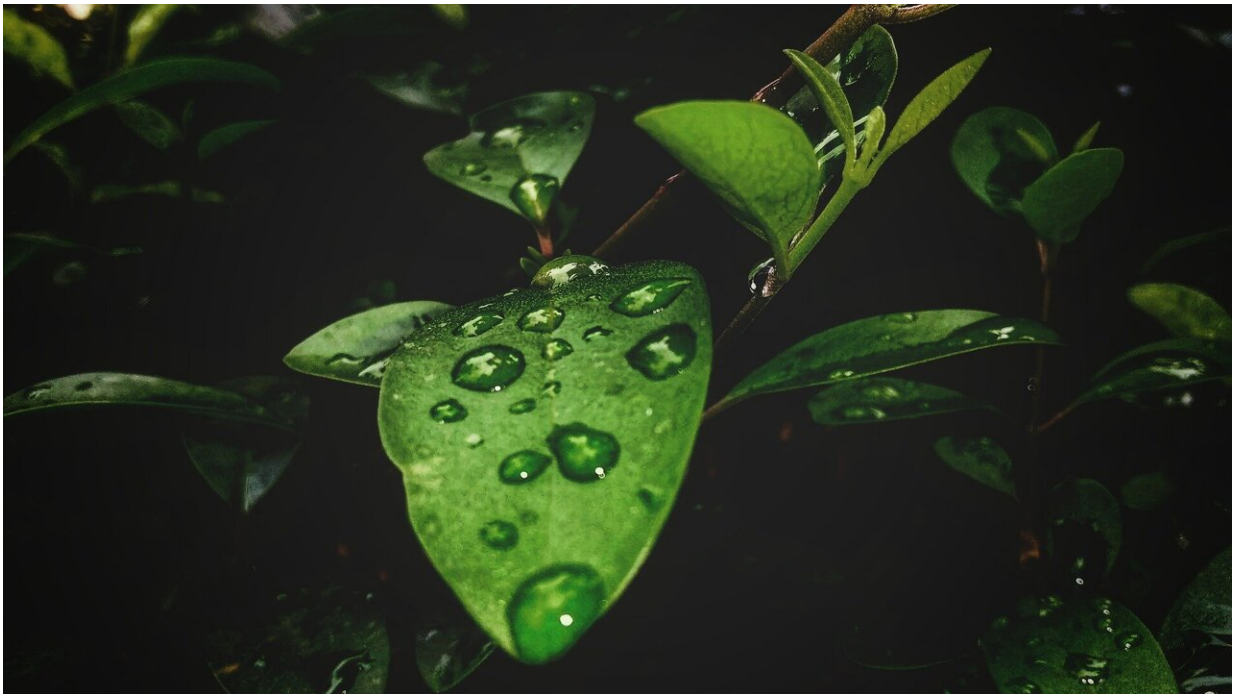


Delayed slow ocean response to CO₂ removal causes asymmetric tropical rainfall change

July 6 2022, by Li Yuan



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Carbon dioxide (CO₂) is one of the major greenhouse gases responsible for global warming. Climate changes under increasing CO₂ radiative forcing (called "CO₂ ramp-up") have been widely projected using numerical experiments.

For a carbon-neutral world, more studies have begun to focus on the

regional climate responses under decreasing CO₂ forcing from a high CO₂ concentration to the pre-industrial level (called "CO₂ ramp-down").

A new study, published on July 4 in *Science Bulletin*, shows that the changes in tropical [rainfall](#)—one of the most important indicators for [global climate change](#)—are asymmetric at the same warming level (such as 2°C) during CO₂ ramp-up and ramp-down. The spatial variation of tropical rainfall change is stronger during CO₂ ramp-down than ramp-up, increasing over the equatorial Pacific with a southward extension but decreasing over the Pacific [intertropical convergence zone](#) and the South Pacific convergence zone.

This study is based on an idealized CO₂ ramp-up/ramp-down scenario, in which the CO₂ continuously increases at 1% year⁻¹ from the pre-industrial level to a quadrupled level during ramp-up, followed by ramp-down at the same rate of 1% year⁻¹ to reach the pre-industrial level.

Using a moisture budget decomposition method, the researchers demonstrated that this asymmetric tropical rainfall change was mainly due to the tropical circulation change, which was further closely related to the local sea surface temperature (SST) change.

"The multi-timescale processes could be tangled up during the CO₂ ramp-up/ramp-down scenario, forming a complex time-evolving pattern of tropical rainfall changes," said the corresponding author, Dr. Huang Ping, a professor at the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences. "These time-dependent SST responses during the two periods are a hybrid of responses at different timescales."

The researchers applied a timescale decomposition method to the climate response to separate the impacts of SST responses at different timescales on the tropical rainfall change. A fast SST response and a slow one based on processes at different timescales were defined to be

evaluated in terms of their time-varying contributions and impacts under the CO₂ ramp-up/ramp-down scenario.

Results showed that the impact of the fast SST response on the tropical rainfall change was much weaker than that of the slow SST response during CO₂ ramp-down, and its contribution was also much smaller. The slow SST response could induce a stronger [tropical rainfall](#) change due to an El Nino-like warming pattern over the equatorial eastern Pacific. A stronger subsurface warming during the CO₂ ramp-down period suppressed the ocean dynamical thermostat effect, leading to the El Nino-like warming pattern.

"Our results indicate that returning the global mean temperature increase to below a certain goal, such as 2°C, by removing CO₂, may fail to restore tropical convection distribution, with potentially devastating effects on climate worldwide," said the first author Dr. Zhou Shijie, a postdoctoral researcher at IAP.

More information: Shijie Zhou et al, Varying contributions of fast and slow responses cause asymmetric tropical rainfall change between CO₂ ramp-up and ramp-down, *Science Bulletin* (2022). [DOI: 10.1016/j.scib.2022.07.010](#)

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