No returning to climate of the past even with carbon dioxide reduction

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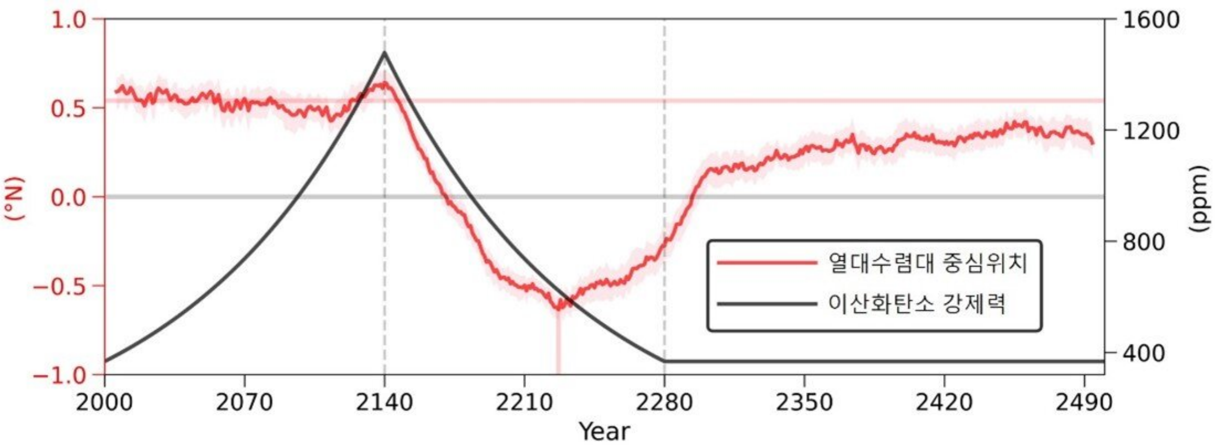
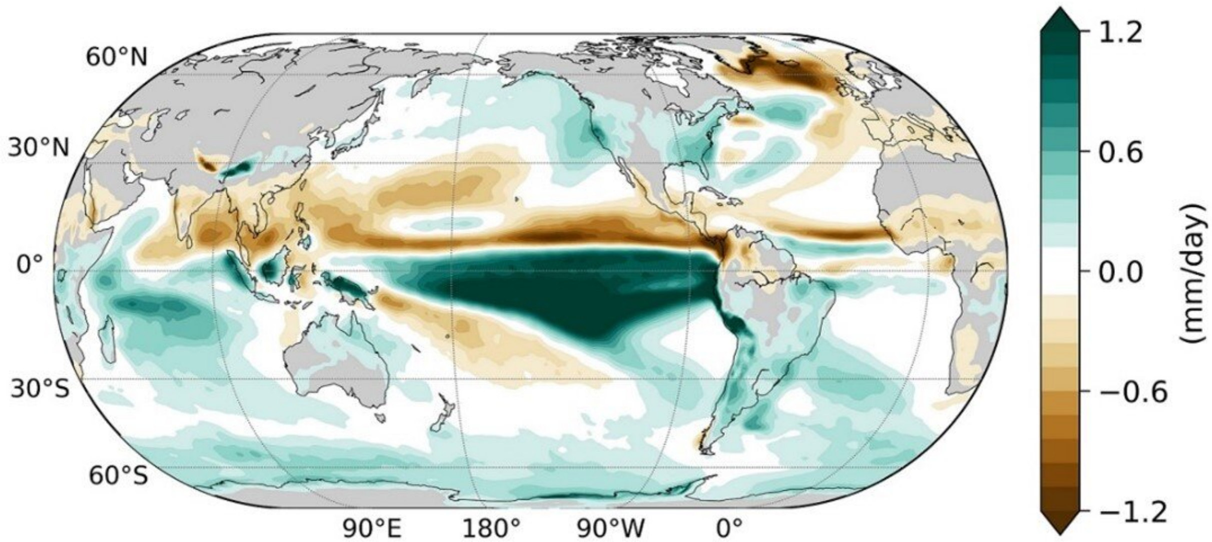


The change in the location of the center of the intertropical convergence zone (ITCZ) according to the concentration of CO_2 . When the CO_2 level increases, the center does not change much but as it increases, the ITCZ descends southwards, eventually ending up in the Southern Hemisphere. Credit: POSTECH

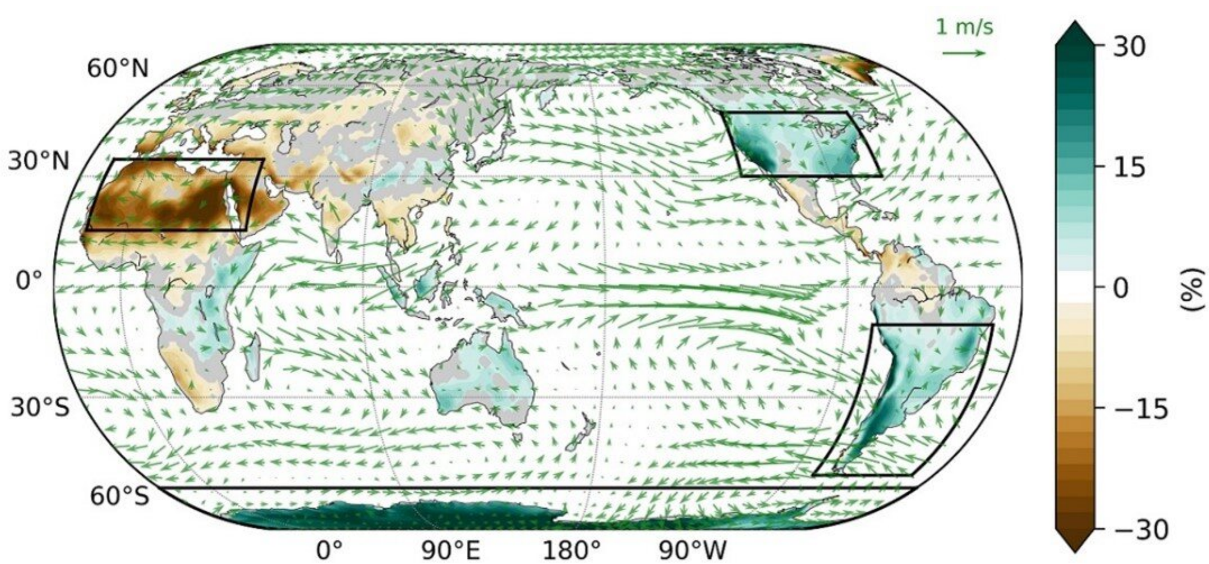
While the entire world focuses on achieving carbon neutrality—zero carbon dioxide (CO_2) emissions—new research shows climate change in some regions is inevitable even if the already increased CO_2 level is reduced. As CO_2 decreases, the intertropical convergence zone (ITCZ) shifts southwards, which can trigger persistent El Niño conditions. El Niño refers to a phenomenon in which the sea surface temperature near the equator rises by 1 to 3°C above its surroundings, causing droughts, storms, and floods around the world.

A POSTECH research team led by Professor Jong-Seong Kug and Ji-Hoon Oh (Division of Environmental Science and Engineering) conducted a simulation on the Earth system model that can ramp-up and ramp-down the concentration of atmospheric CO_2. The researchers observed that the ITCZ, which hardly moved when the CO_2 concentration increased, sharply shifted southwards when the CO_2 level decreased. Even when the CO_2 concentration was returned to its original level, its center still remained in the Southern Hemisphere.

The shift of the ITCZ, where 32% of the global precipitation occurs, is an extremely important factor in determining the amount of precipitation in the tropics and subtropics. The shift can change the Hadley circulation—the starting point of the global atmospheric circulation—to cause abnormalities in the global climate. Through this study, Professor Kug's team has confirmed that as CO_2 begins to decrease, the ITCZ moves to the Southern Hemisphere which remains warm, unlike the Northern Hemisphere that cools down with CO_2 reduction.



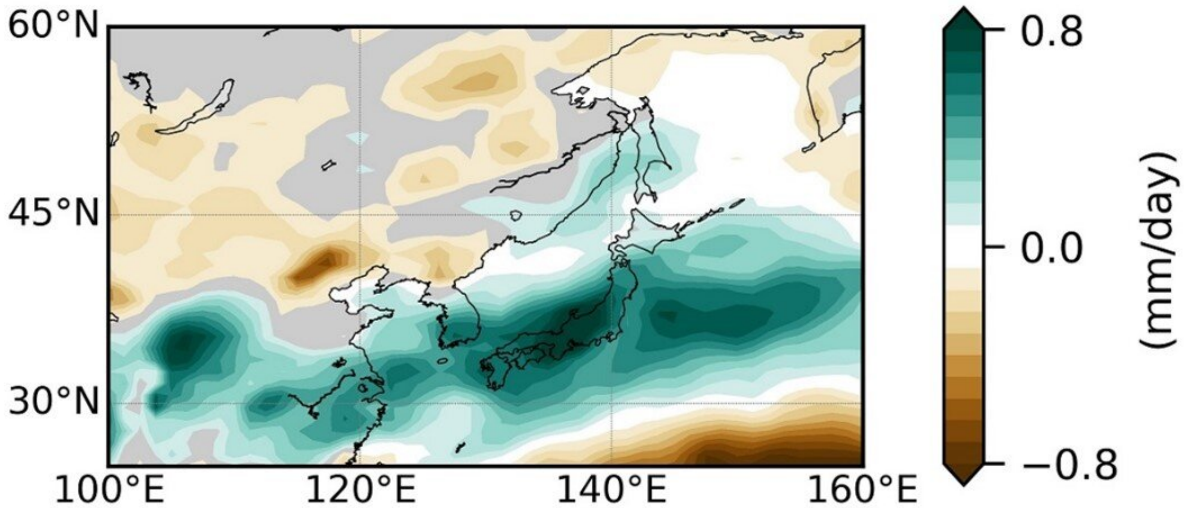
The change in the annual average precipitation relative to the current climate when CO_2 is reduced. Average precipitation decreases in the tropical and subtropical regions of the Northern Hemisphere, and increases in the tropical and subtropical regions of the Southern Hemisphere, resulting in a southwards pattern of the intertropical convergence zone (ITCZ). Credit: POSTECH



The percentage change in annual average land precipitation relative to the current climate when CO_2 is reduced. Precipitation decreases in the Sahel zone and around the Mediterranean, while precipitation and snowfall increase in North and South America and Antarctica. Credit: POSTECH

Atmospheric CO_2 reduction could slowly return the average global temperature and precipitation to normal. However, the researchers claim that the climate may appear completely different in some regions. The change in precipitation due to the southwards shift of the ITCZ is very similar to the pattern during an extreme El Niño. In other words, it is expected that some regions will experience an abnormal climate condition where an extreme El Niño persists.

The model simulations confirmed that even if the increased CO_2 concentration is reduced and returned to its original value, the Sahel zone including the Sahara Desert and southern Europe around the Mediterranean Sea experienced a 20% decrease in average annual precipitation compared to the current levels, leading to further desertification. In contrast, North and South America had an increase in precipitation by about 15%. In fact, a risk of more frequent flooding was found in the western regions of North and South America where the increase in precipitation was noticeable. In East Asia, including the Korean Peninsula, a possibility of more rain during the monsoon season was found due to the increased precipitation in summer.



The change in summer precipitation in East Asia compared to current climate when CO_2 is reduced. It increases in Korea, China and Japan. During the monsoon season, more precipitation is likely in Korea, China, and Japan. Credit: POSTECH

"It is impossible to properly reflect the complex climate system if only the average global temperature and precipitation levels are considered when creating mitigation policies to prevent climate change, such as carbon neutrality or carbon reduction," explained Professor Jong-Seong Kug. Emphasizing that regional changes such as the southwards shift of the ITCZ should be fully taken into account, Professor Kug added, "The already emitted greenhouse gasses have lasting effects on the planet so we need to recognize their long-term impacts as well as their immediate effect on climate change."

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More information: Jong-Seong Kug et al, Hysteresis of the intertropical convergence zone to CO2 forcing, *Nature Climate Change* (2021). DOI: 10.1038/s41558-021-01211-6

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