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New Study Shows Climate Change Largely Irreversible

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A new scientific study led by the National Oceanic and Atmospheric Administration reaches a powerful conclusion about the climate change caused by future increases of carbon dioxide: to a large extent, there's no going back.

The pioneering study, led by NOAA senior scientist Susan Solomon, shows how changes in surface temperature, rainfall, and sea level are largely irreversible for more than 1,000 years after carbon dioxide (CO_2) emissions are completely stopped. The findings appear during the week of January 26 in the Proceedings of the National Academy of Sciences.

"Our study convinced us that current choices regarding carbon dioxide emissions will have legacies that will irreversibly change the planet," said Solomon, who is based at **NOAA's Earth System Research Laboratory** in Boulder, Colo.

"It has long been known that some of the carbon dioxide emitted by human activities stays in the atmosphere for thousands of years," Solomon said. "But the new study advances the understanding of how this affects the climate system."

The study examines the consequences of allowing CO_2 to build up to several different peak levels beyond present-day concentrations of 385 parts per million and then completely halting the emissions after the peak. The authors found that the scientific evidence is strong enough to quantify some irreversible climate impacts, including rainfall changes in certain key regions, and global sea level rise.

If CO_2 is allowed to peak at 450-600 parts per million, the results would include persistent decreases in dry-season rainfall that are comparable to the 1930s North American Dust Bowl in zones including southern Europe, northern Africa, southwestern North America, southern Africa and western Australia.

The study notes that decreases in rainfall that last not just for a few decades but over centuries are expected to have a range of impacts that differ by region. Such regional impacts include decreasing human water supplies, increased fire frequency, ecosystem change and expanded deserts. Dry-season wheat and maize agriculture in regions of rain-fed farming, such as Africa, would also be affected.

Climate impacts were less severe at lower peak levels. But at all levels added carbon dioxide and its climate effects linger because of the ocean.

"In the long run, both carbon dioxide loss and heat transfer depend on the same physics of deep-ocean mixing. The two work against each other to keep temperatures almost constant for more than a thousand years, and that makes carbon dioxide unique among the major climate gases," said Solomon.

The scientists emphasize that increases in CO_2 that occur in this century "lock in" sea level rise that would slowly follow in the next 1,000 years. Considering just the expansion of warming ocean waters—without melting glaciers and polar ice sheets—the authors find that the irreversible global average sea level rise by the year 3000 would be at least 1.3–3.2 feet (0.4–1.0 meter) if CO_2 peaks at 600 parts per million, and double that amount if CO_2 peaks at 1,000 parts per million.

"Additional contributions to sea level rise from the melting of glaciers and polar ice sheets are too uncertain to quantify in the same way," said Solomon. "They could be even larger but we just don't have the same level of knowledge about those terms. We presented the minimum sea level rise that we can expect from well-understood physics, and we were surprised that it was so large."

Rising sea levels would cause "...irreversible commitments to future changes in the geography of the Earth, since many coastal and island features would ultimately become submerged," the authors write.

Geoengineering to remove carbon dioxide from the atmosphere was not considered in the study. "Ideas about taking the carbon dioxide away after the world puts it in have been proposed, but right now those are very speculative," said Solomon.

The authors relied on measurements as well as many different models to support the understanding of their results. They focused on drying of particular regions and on thermal expansion of the ocean because observations suggest that humans are contributing to changes that have already been measured.

Besides Solomon, the study's authors are Gian-Kasper Plattner and Reto Knutti of ETH Zurich, Switzerland, and Pierre Friedlingstein of Institut Pierre Simon Laplace, Gif-Sur-Yvette, France.