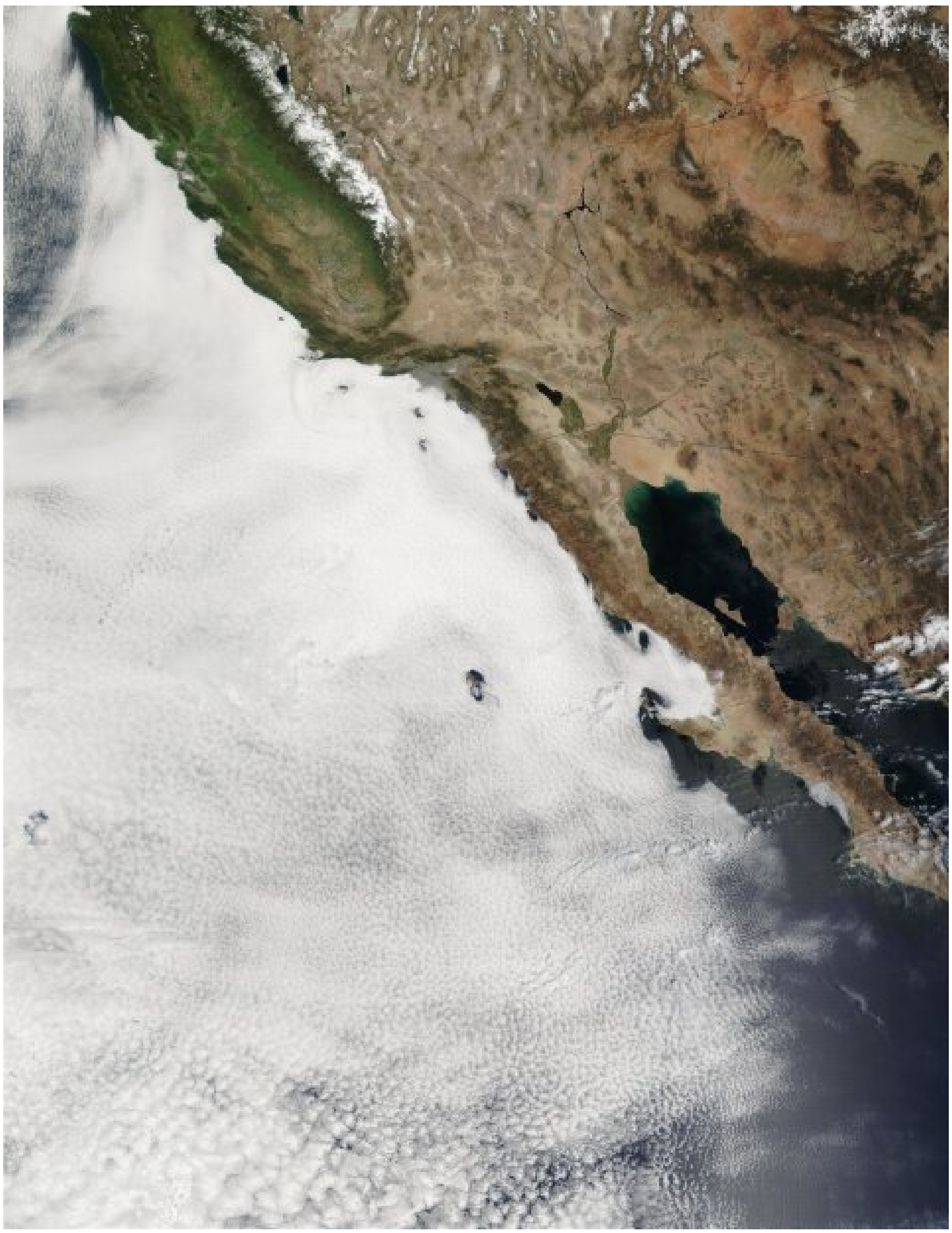
Simulations show radiation changes cause sea-covering clouds to break up

December 8 2020, by Beth Mundy



The research team used data taken from real areas of clouds as a basis for creating their simulated representative cloud patch that served as the general model for stratocumulus clouds. Credit: Jacques Descloitres | NASA

Having clouds in the sky cools off the day, reflecting sunlight and shading the land. Some people have proposed that we use this type of reflective effect to cool the planet—a notion known as solar geoengineering.

Researchers have suggested that this, coupled with current cloud cover, could lower global temperatures. However, reflecting sunlight is not a process that eliminates greenhouse gases and their effects. What happens when clouds interact with high levels of carbon dioxide (CO_2)?

A NASA and NSF-funded study featuring contributions from Pacific Northwest National Laboratory (PNNL) researchers Colleen Kaul and Kyle Pressel investigates these questions. Specifically, they examine how clouds interact with radiation under different conditions, particularly increased levels of greenhouse gases.

The research team, all at the California Institute of Technology at the time, developed a method of modeling clouds that couples high-resolution simulations of the stratocumulus clouds that cover broad stretches of the ocean with a simple climate model. These clouds are key reflectors of solar radiation and persist because of longwave radiation cooling, where the tops of the clouds release energy in the form of low-energy, infrared light waves.

Longwave cooling is critical for connecting the clouds to the moist air at the sea surface that feeds them. However, this natural process can be disrupted by high concentrations of greenhouse gases, such as CO_2, methane, and nitrous oxide that can absorb the infrared light.

Stratocumulus clouds are extremely sensitive to changes in infrared radiation. Credit: Engin_Akyurt | Pixabay

Simulating clouds in the tropics

The researchers used a large-eddy simulation, a way to mathematically model the movement of the atmosphere, to accurately represent the cloud dynamics. They combined it with an established, simple tropical climate model allowing them to use large-eddy simulation to explore climate-related questions.

The research team used data taken from real areas of clouds as a basis for creating their simulated representative cloud patch. This patch then served as the general model for stratocumulus clouds that could be subjected to changing levels of CO_2, with a focus on isolating its effects on infrared radiation.

When CO_2 levels reached 1,700 ppm (more than quadruple today's levels) the simulated clouds became too unstable and dissipated. After that, even if the CO_2 level decreased below the instability threshold, the clouds did not reform, showing a tipping point in the atmosphere where stratocumulus clouds are no longer able to stably exist.

Once the clouds are gone, the modeled climate rapidly and dramatically warms. In an extreme scenario where current warming trends continue for over a century, global CO_2 levels could reach high enough to dissipate stratocumulus clouds and cause tropical sea surface temperature—a proxy for the overall warming—to increase by 5°C.

Keeping temperatures low is complicated

This indicates that stratocumulus clouds are extremely sensitive to changes in longwave infrared radiation. The tendency of clouds to dissipate with high levels of CO_2 indicates solar geoengineering is not a failsafe option to cool the planet. It might work to buy some additional time, but after a certain point the climate could rapidly warm without additional efforts to mitigate emissions.

Researchers exploring the complex interactions that govern the natural world have many considerations to keep in mind. Models that allow exploration of different aspects of the Earth system will be key to understanding the potential ramifications of any plan.

Provided by Pacific Northwest National Laboratory