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# Sea spray geoengineering can reduce ocean net primary productivity and carbon uptake

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Sea spray geoengineering or marine cloud brightening is one of the proposed methods to deliberately increase planetary albedo and thus counteract climate change. Previous studies have shown that it has potential to significantly alter the global energy balance and reduce impacts on temperature and precipitation. However, its effects on ecosystems have received considerably less attention. Our goal is to assess the effects of sea spray geoengineering on marine biological productivity and global carbon cycle. We use the University of Victoria Earth System Climate Model (UVic ESCM) to simulate the effects of prescribed aerosol forcing from previous simulations with the aerosol-climate model ECHAM-HAMMOZ.

In our baseline simulation (GEO), forcing from geoengineering was applied over three persistent stratocumulus regions off the coasts of North America, South America, and South Africa. The global mean forcing was -1 W $m^{-2}$. Other forcings and emissions were set according to the RCP4.5 scenario. The control run (CTRL) was identical to GEO except that no geoengineering was present. As a more extreme case, we simulated a scenario where forcing from geoengineering was applied over all ocean area (GEO-ALL) giving a global mean forcing of -4.9 W $m^{-2}$.

Geoengineering decreased the global total ocean net primary productivity (NPP) during the first decades, but the effect was insignificant by the end of the 21st century. The decrease was caused by decreased temperature of the ocean and climate system in general, not by the decrease in available sunlight as might have been expected. This was demonstrated by two sensitivity simulations where geoengineering was affecting only either temperature or the light available to marine ecosystems.

The simulation GEO-ALL behaves in a different way than GEO: ocean NPP was lower than that in CTRL for the first three decades of geoengineering as in GEO, but then NPP increased over the level in CTRL for the remaining of the simulation.

In contrast to previous studies on geoengineering and carbon cycle, geoengineering decreased the ocean carbon uptake during the whole 21st century. Even though carbon export into deep ocean was increased due to geoengineering, the upper ocean was gaining carbon at a lower rate than in CTRL. The exact reasons why cooling climate (compared to CTRL) did not increase ocean carbon uptake also in the upper ocean in any part of the simulation require more investigation.

Our results imply that dynamics between radiation, carbon cycle, and ocean need to be considered to understand the effects of sea spray geoengineering on the marine ecosystems and carbon uptake. Considering only the reduced sunlight for marine ecosystems would lead to a strong underestimation of the impacts.