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Evaluating effects of climate stratospheric geoengineering on the hydrological cycle, ocean heat content, sea level, and sea ice extent

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In this study we take advantage of the analogy between stratospheric geoengineering and volcanic impacts to better quantify the effects of geoengineering on hydrological cycle, the ocean, and sea ice extent that are crucial for assessing biospheric and economic consequences of geoengineering. We employ the coupled climate model CM2.1, developed at NOAA's Geophysical Fluid Dynamics Laboratory, and simulate responses to quasi-permanent geoengineering forcing, as well as transient impacts of the 1991 Pinatubo and 1815 Tambora eruptions. Testing volcanic model simulations against observations allows us to more reliably estimate the range of climate system responses to stratospheric aerosols, their dependence on the magnitude of forcing, and associated characteristic times. We found that stratospheric aerosol cooling intensifies ocean vertical mixing and tends to strengthen the meridional overturning circulation. Sea ice appears to be sensitive to volcanic forcing, especially during the warm season. Volcanic ocean temperature signals scale roughly linearly with respect to radiative forcing, but ocean overturning circulation response is less than linear. In two-three years after injection of aerosols, while ocean temperatures decrease and global hydrological cycle remains suppressed, precipitation over land tends to recover. The quasi-permanent cooling from geoengineering aerosols penetrate into the deep ocean more slowly than from sporadic volcanic cooling, which more vigorously intensifies ocean vertical mixing. The sea ice extent responds in about a decade after eruption. This suggests that it is more sensitive to changes of the global ocean circulation and ocean temperature than to the direct effect of aerosol radiative cooling. Therefore regional dimming of solar radiation in the high northern latitudes, proposed as a means to preserve sea ice in the Northern Hemisphere, might not be effective. Ocean subsurface temperature, sea level, and overturning circulation have an extremely long relaxation time of about a century. Therefore geoengineering consequences in the ocean, despite a quicker atmospheric temperature recovery, will be felt for at least a century after geoengineering forcing is turned off.