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Tropical Pacific Climate Variability under Solar Geoengineering: Impacts on ENSO Extremes

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Many modelling studies suggest that the El Niño Southern Oscillation (ENSO), in interaction with the tropical Pacific background climate, will change under rising atmospheric greenhouse gas concentrations. Solar geoengineering (reducing the solar flux from outer space) has been proposed as a means to counteract anthropogenic greenhouse-induced changes in climate. Effectiveness of solar geoengineering is uncertain. Robust results are particularly difficult to obtain for ENSO because existing geoengineering simulations are too short (typically ∼50 years) to detect statistically significant changes in the highly variable tropical Pacific background climate. We here present results from a 1000-year sunshade geoengineering simulation, G1, carried out with the coupled atmosphereocean general circulation model HadCM3L. In agreement with previous studies, reducing the shortwave solar flux more than compensates the warming in the tropical Pacific that develops in the $4\times CO_2$ scenario: we observe an overcooling of 0.3oC (5 %) and 0.23-mm day-1 (5 %) reduction in mean rainfall relative to preindustrial conditions in the G1 simulation. This is due to the different latitudinal distributions of the shortwave (solar) and longwave (CO_2) forcings.The location of the Intertropical Convergence Zone (ITCZ) located north of equator in the tropical Pacific, which moved 7.5o southwards under $4\times CO_2$, is also restored to its preindustrial location. However, other aspects of the tropical Pacific mean climate are not reset as effectively. Relative to preindustrial conditions, in G1 the zonal wind stress, zonal sea surface temperature (SST) gradient, and meridional SST gradient are reduced by 10 %, 11 %, and 9 %, respectively, and the Pacific Walker Circulation (PWC) is consistently weakened. The overall amplitude of ENSO strengthens by 5-8 %, but there is a 65 % reduction in the asymmetry between cold and warm events: cold events intensify more than warm events. Importantly, the frequency of extreme El Niño and La Niña events increases by 44 % and 32 %, respectively, while the total number of El Niño events increases by 12 %. Paradoxically, while the number of total and extreme events increase, the most extreme El Niño events also become weaker relative to preindustrial state while the La Niña events become stronger. That is, extreme El Niño events in G1 become less extreme than in preindustrial conditions, but extreme El Niño events become more frequent. In contrast, extreme La Niña events become stronger in G1. This is in agreement with the general overcooling of the tropical Pacific in G1 relative to preindustrial conditions, which depict a shift towards generally more La Niña-like conditions.