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Linear response theory applied to geoengineering

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We investigate in an intermediate-complexity climate model the applicability of linear response theory to a geo-engineering problem. Global climate change with respect to an appropriate ensemble average of the surface air temperature $\langle[T]\rangle$ due to a given rise in carbon dioxide concentration [CO_2] is attempted to be canceled out or modulated by an appropriately chosen modulation of the solar forcing. The latter is predicted by linear response theory in frequency-domain as: $\Delta f_s(\omega) = (\Delta\langle[T]\rangle(\omega) - \chi_{CO_2}(\omega)\Delta f_{CO_2}(\omega))/\chi_s(\omega)$, where the χ's are linear susceptibilities.

With a doubling of [CO_2] the response is nonlinear to a certain degree, but a significant cancellation with respect to (wrt.) $[T]$ is achieved, the asymptotic total response to combined forcing being only 10% of that with [CO_2]-doubling alone.

We investigate in this geoengineering scenario the response wrt. zonal or regional averages of T too. The nonlinearities have a more severe effect with respect to the predictability of the spatial total response pattern, but in actual fact a significant cancellation is achieved even locally.

Similar conclusions can be drawn wrt. the model variable of large scale precipitation.

The regional and global response can be characterized by a single dominant multi-year time scale. The spatial pattern of the response time is rather nontrivial.