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Solar geoengineering, atmospheric water vapor transport, and land plants

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This work, using the GeoMIP database supplemented by additional simulations, discusses how solar geoengineering, as projected by the climate models, affects temperature and the hydrological cycle, and how this in turn is related to projected changes in net primary productivity (NPP).

Solar geoengineering simulations typically exhibit reduced precipitation. Solar geoengineering reduces precipitation because solar geoengineering reduces evaporation. Evaporation precedes precipitation, and, globally, evaporation equals precipitation.

CO_2 tends to reduce evaporation through two main mechanisms:

(1) CO_2 tends to stabilize the atmosphere especially over the ocean, leading to a moister atmospheric boundary layer over the ocean. This moistening of the boundary layer suppresses evaporation.

(2) CO_2 tends to diminish evapotranspiration, at least in most land-surface models, because higher atmospheric CO_2 concentrations allow leaves to close their stomata and avoid water loss.

In most high-CO_2 simulations, these effects of CO_2 which tend to suppress evaporation are masked by the tendency of CO_2-warming effect to increase evaporation. In a geoengineering simulation, with the warming effect of CO_2 largely offset by the solar geoengineering, the evaporation suppressing characteristics of CO_2 are no longer masked and are clearly exhibited. Decreased precipitation in solar geoengineering simulations is a bit like ocean acidification – an effect of high CO_2 concentrations that is not offset by solar geoengineering.

Locally, precipitation ultimately either evaporates (much of that through the leaves of plants) or runs off through groundwater to streams and rivers. On long time scales, runoff equals precipitation minus evaporation, and thus, water runoff generated at a location is equal to the net atmospheric transport of water to that location. Runoff typically occurs where there is substantial soil moisture, at least seasonally. Locations where there is enough water to maintain runoff are typically locations where there is sufficient water to maintain plant growth.

This work aims at:

(i) Identifying the geographical distribution of sensitivity of modeled-NPP to changes in CO_2, temperature, and various parameters related to the hydrological cycle;

(ii) Geographically partitioning changes in modeled-NPP to changes in CO_2, temperature, and hydrological variables (and a non-linear interaction term).