Climate Sensitivity to Volcanic Aerosol Forcing

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Abstract

Volcanic aerosol forcing has been reported in the literature to be less effective in changing the earth's surface temperature than CO2 forcing. This implies a different feedback strength, and therefore different contributions from individual feedback mechanisms. We employ the CMIP6 version of MPI-ESM to understand the reasons for these apparent differences in the ability to change the surface air temperature. Using a highly idealized eruption scenario and comparing it to a doubling and a halving of CO2 concentration, we identify key reasons for changes in the magnitude of the feedback parameter. We show that the "efficacy" [Hansen et al. 2005] of volcanic aerosol forcing depends strongly on the method and the time scale used to calculate it. We argue that the seemingly established result of a lower-than-unity efficacy of volcanic aerosol forcing might only hold under the specific methodological choices other authors have made, but not in general. Furthermore, we find qualitative differences between the cooling and warming simulations, but strong similarities between the 0.5xCO2 and the idealized eruption cases. This hints towards processes, which are not forcing agent-specific, but specific to the sign of the forcing. A pronounced curvature in the N(T) plot ("Gregory plot") for the cooling scenarios makes the computation of feedback through regression even more sensitive to subjective choices than in the 2xCO2 case. We disentangle the role of ocean heat uptake efficacy and atmospheric feedback processes in the framework of the pattern effect.

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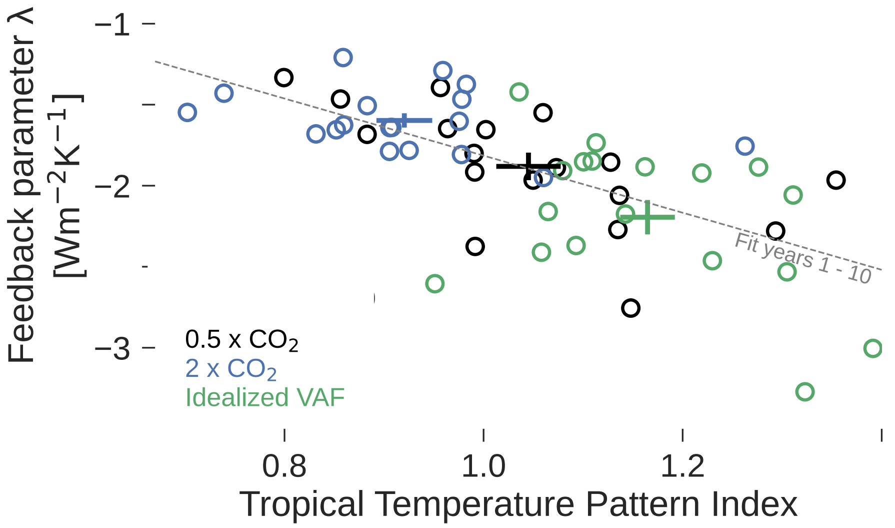
- Volcanic aerosol forcing produces stronger feedback than 2xCO2 forcing
    - Hansen et al. 2005
    - Gregory et al. 2016
    - Gregory et al. 2020
    - Marvel et al. 2016
    - Ceppi et al. 2019
    - Boer et al. 2006
    - Modak et al. 2016
    - Merlis et al. 2014

- Meridional temperature pattern determines feedback



More extratropical → Weak feedback

More tropical → Strong feedback

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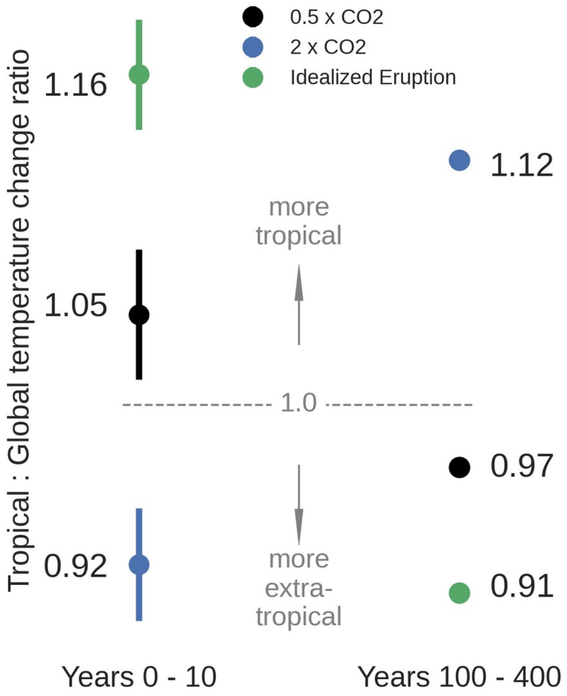
The temperature pattern



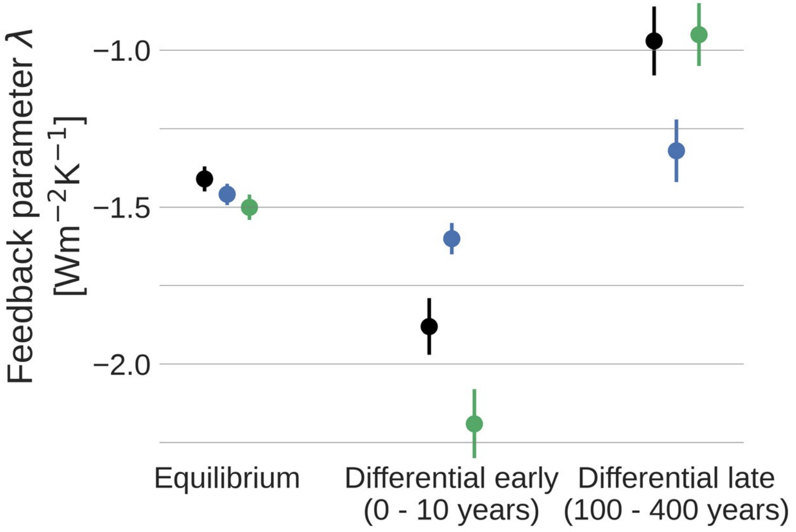
Main reason:
tropical vs. extratropical
lapse rate feedback

$$\lambda = \left\langle \lambda(\vec{x}) \frac{\Delta T(\vec{x})}{\langle \Delta T(\vec{x}) \rangle} \right\rangle$$

Temperature pattern

Local feedback

The feedback



Implications

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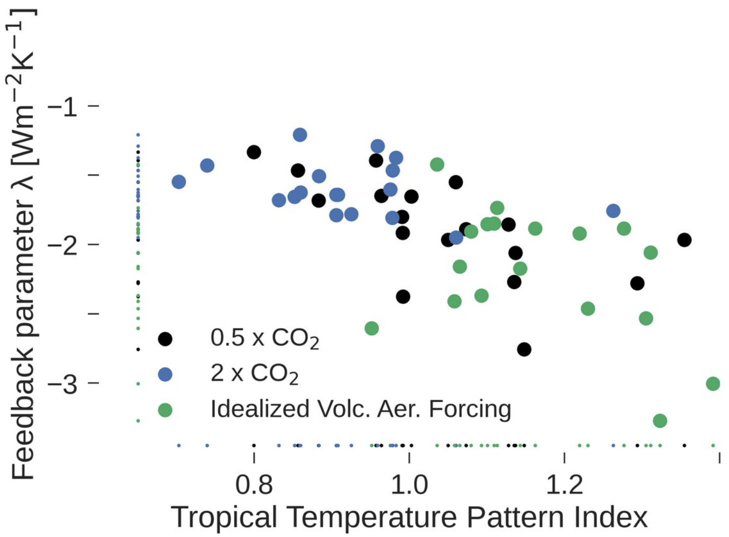
1. Meridional temperature pattern causes the low efficacy of Volcanic Aerosol Forcing

2. No efficacy differences in equilibrium

3. Constraining ECS from volcanic eruptions is not straightforward

4. The important distinction is cooling vs. warming, not aerosol vs. CO2 forcing

possibly only in MPI-ESM



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