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Southern Annular Mode response to volcanic eruptions in the MPI-ESM

S. Gleixner (1), M. Toohey (2), K. Krüger (2), and H. Schmidt (3)

(1) Geophysical Institute and Bjerknes Centre, University of Bergen, Norway, (2) GEOMAR, Kiel, Germany, (3) MPI-M, Hamburg, Germany

Large explosive volcanic eruptions represent a natural external forcing on climate with the strongest direct radiative impact in the stratosphere. The indirect circulation response to such eruptions in the Southern Hemisphere (SH) is analyzed by examining the post-volcanic Southern Annular Mode (SAM) at the surface as well as in the stratosphere. ERA-40 reanalysis data is compared to ensemble simulations of the CMIP5 historical experiment of the Max-Planck Institute Earth System Model (MPI-ESM), a high-top earth system model with a well resolved stratosphere.

The SAM response to 10 volcanic eruptions within the time period of 1850 to 2000 is investigated in the ensemble mean of the MPI-ESM simulations, while only the latest 5 eruptions are covered by the ERA-40 data. In the reanalysis data a shift to a negative stratospheric SAM can be found after 4 out of 5 eruptions, but only after the eruptions of Fuego and Mount Pinatubo are these changes statistically significant. In the first winter after all eruptions the surface SAM is negative, leading to a significantly negative SAM in the composite mean. These "observed" SAM changes are in sharp contrast to the simulated SAM changes. A significant positive stratospheric SAM is found in the SH spring seasons after the eruptions of El Chichon in 1982 and Mount Pinatubo in 1991, the two eruptions that showed the strongest AOD forcing in the 20th century. Composites of post-volcanic SAM changes with regard to the strength of the eruptions' AOD signals highlight the fact that only the strongest eruptions considered in this study evoke a significant SAM response. There is no significant surface SAM response after any of the eruptions in the MPI-ESM simulations.

Overall, the findings about the simulated SAM response to large volcanic eruptions of this study are very similar to previous modeling studies, suggesting that the inability of models to simulate observed annular mode changes after volcanic eruptions is not only due to an insufficiently resolved model stratosphere.