Mt. Pinatubo's Impacts on the GEOS Forecasting System

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Motivation

On June 15, 1991, the eruption of Mount Pinatubo in the Philippines abruptly produced a perturbation in the Earth's radiative balance, impacting the climate. Observations showed a cooling of the Earth's surface due to the increase in albedo caused by the volcanic aerosols. However, observations also showed a warming of the Pacific and January 1991 is marked by a strong El Niño events.

Here, we analyze the effects of the Mt.Pinatubo eruption on the El Niño Southern Oscillation (ENSO) in simulations with the GEOS S2S_2 model.

Scientific Context

Due to the increase in stratospheric aerosols load caused by the volcanic eruption, we should expect to see a global surface cooling and a decrease of shortwave radiation at the earth's surface.

However, in the El Niño region, we do not see the same cooling effect occur as we do with the global means. Instead, we see the strengthening of El Niño, associated with a local warming of the ocean surface, and weakened easterly winds, indicating a decrease in upwelling. Similar results were also exhibited in [1].

Model and Experiments

Model:

- **Goddard Earth Observing System Seasonal to Subseasonal System (GEOS S2S_2):** Seasonal atmospheric forecast model that includes the bulk aerosol model GOCART [2] and the interactive ocean model MOM [3].

Experiments:

- Three ensembles of ten 12-month simulations from June 1991 to May 1992.
- Initial conditions from the MERRA2 reanalysis, slightly perturbed among ensemble members.
- 0.5° longitude by 0.5° latitude horizonal resolution and 72 vertical levels up to 1 Pa.
- The eruption is simulated as a 16Tg injection of SO_2 between 17km and 25km altitude

Model Ensembles:

- ***NoVolc****:* no volcanic eruption (unperturbed experiment)
- ***SU1****:* volcanic aerosols effective radius = 0.35 μm (standard GEOS-S2S configuration)
- ***SU2****:* volcanic aerosol effective radius = 0.6 μm (similar to observations of Pinatubo aerosol)

Results: Global

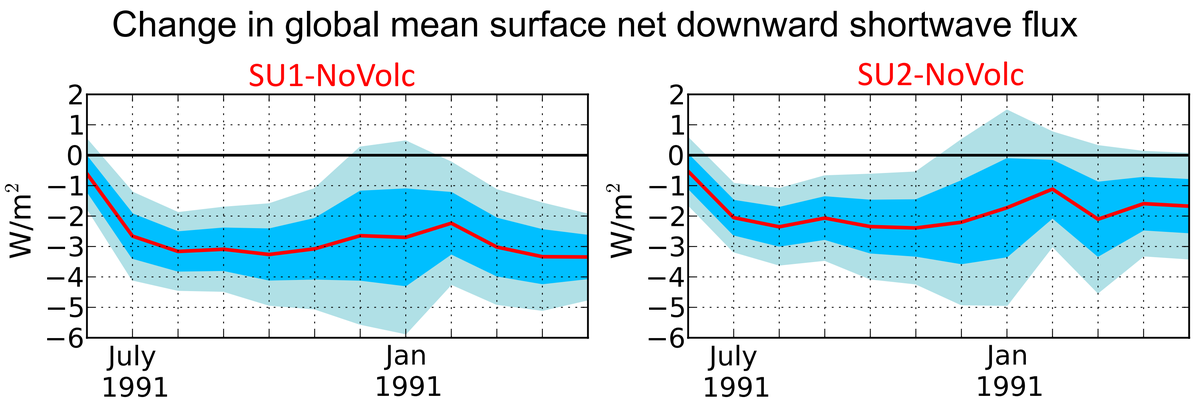

Figure 1: Change in global mean surface net shortwave radiation in the SU1 (left) and SU2 (right) experiments with respect to NoVolc. The red line shows the mean of the difference of 100 randomly chosen pairs of ensemble members. The shaded areas show 1 and 2 standard deviations from the mean. Pinatubo decreased the shortwave flux at the surface. This effect is mildly stronger and longer lasting in the SU1 experiment than in SU2. This is expected, because the scattering efficiency of sufate particles decreases with size.

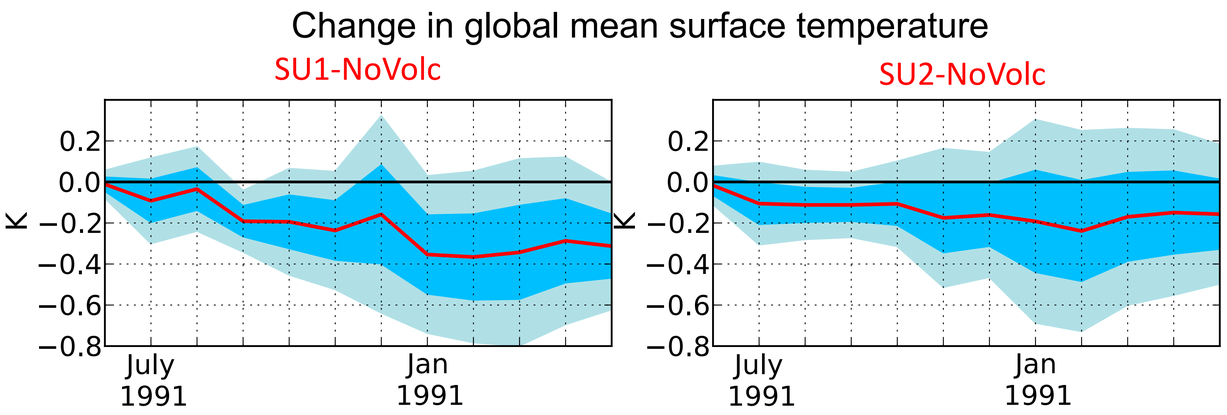

Figure 2: Same as Fig. 1, but for global mean surface temperature. The decrease in SW flux causes a cooling by up to 0.5 K in the ensemble mean. This is significant at 1-σ level in the SU1 experiment, but is not significant in the SU2 experiment.

Results: Tropical Pacific

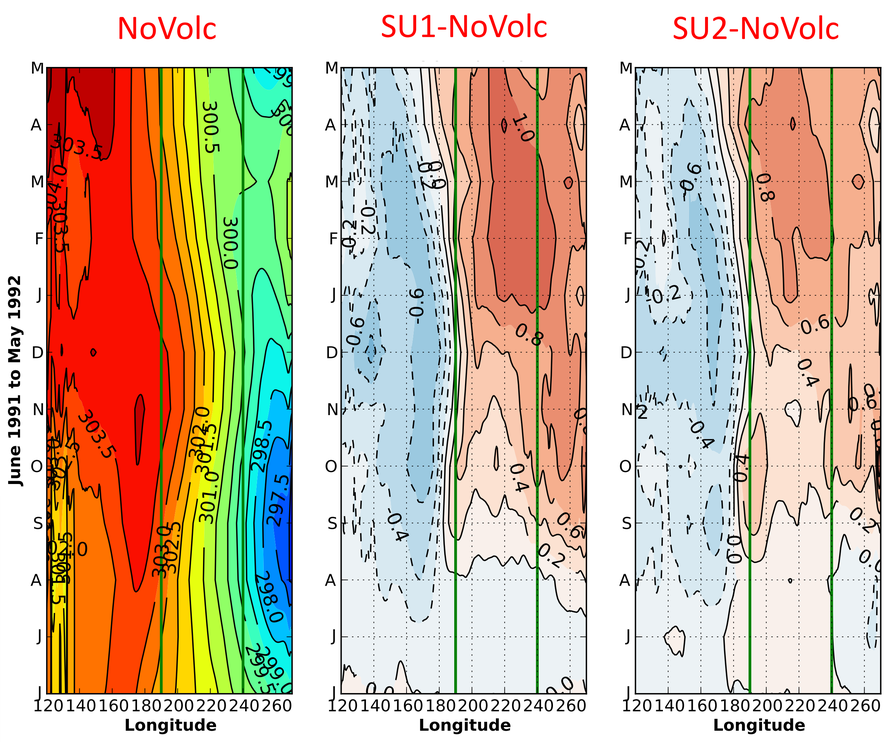

Figure 3: Hovmoller diagram of equatorial skin temperature [5˚S-5˚N] in NoVolc (left), and equatorial temperature changes in SU1 and SU2 with respect to NoVolc (middle and right). The green lines mark the El Niño 3.4 region. Pinatubo induces a warming of the eastern Pacific. The effect is milder in SU2 than SU1.

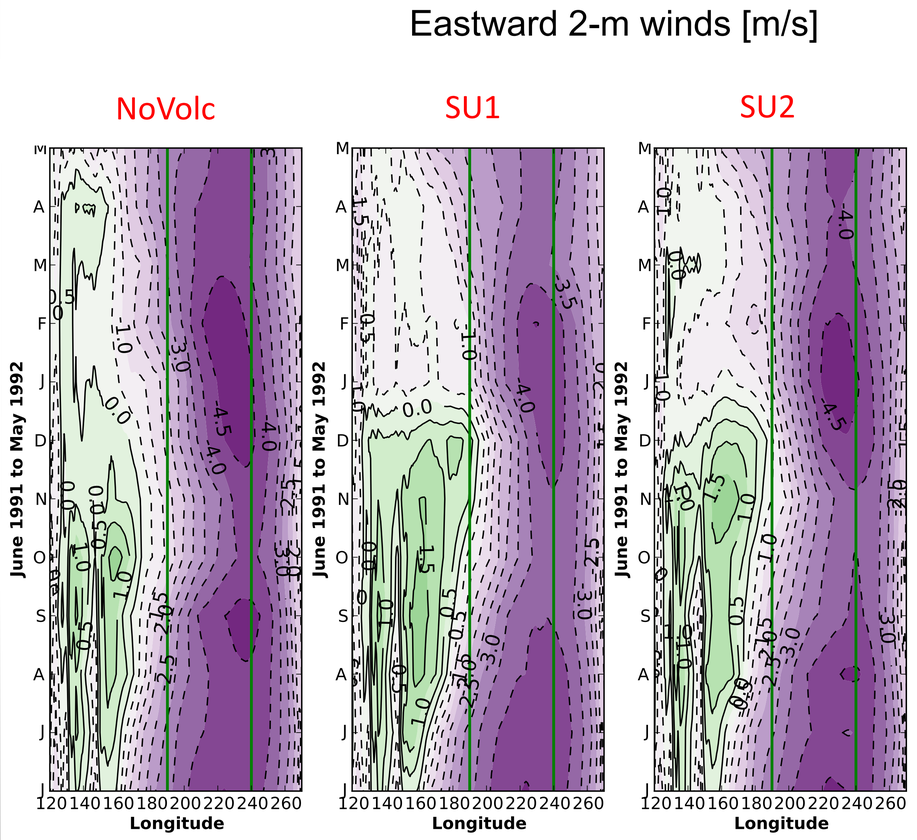

Figure 4: Hovmoller diagram of equatorial winds [5˚S-5˚N]. Green colors indicate eastward winds. Pinatubo strengthen the eastward winds in the western Pacific.

Summary

1. After the Mt.Pinatubo eruption, global mean temperatures were reduced as expected from volcanic aerosol.
2. The eruption also caused a strengthening of eastward winds in the western Pacific, which leads to a suppression of the upwelling of cold water and a strengthening of El Niño.
3. When a more realistic volcanic aerosol radius than in the standard GEOS S2S_2 is used, the effects on the global temperature and El Niño are weakened.

References: [1] Predybaylo et al. (2017), Impacts of a Pinatubo-Size Volcanic Eruption on ENSO, *J. Geophys. Res.*, doi:10.1002/2016JD025796. [2] Colarco et al. (2010), Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth, *J. Geophys. Res.*, doi:10.1029/2009JD012820. [3] Griffies et al. (2007), Ocean modelling with MOM. *Clivar Exchanges*, 12(3).

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