Supplementary material for "Response of the Quasi-Biennial Oscillation to historical volcanic eruptions"'

K. DallaSanta[1,2], C. Orbe[1], D. Rind[1], L. Nazarenko[1,3], J. Jonas[1,3]

[1]NASA Goddard Institute for Space Studies, New York, New York, USA
[2]Universities Space Research Association, Columbia, Maryland, USA
[3]Center for Climate Systems Research, Columbia University, New York, New York, USA

1 Longwave and shortwave contributions of aerosols

To better understand the role of volcanic aerosols in the model's QBO responses, we consider their longwave and shortwave effects through two experiments. First, the historical simulation of Krakatoa is repeated (beginning in 1880) for the member shown in Figure 1 with only the longwave impact of volcanic aerosols turned off. Then, we define the longwave impact as the thermal heating rate in the control run minus this perturbation experiment. The difference includes both direct and indirect effects, such as changes to the QBO phase. Second, the process is repeated with only the shortwave impact turned off, and the result is seen in the solar heating rate.

The results are shown in Figure 1. Prior to the eruption in 1883, the low background aerosol levels provide shortwave heating and a larger longwave heating associated with downward propagation of the warm QBO branch. Thus, the effects of the abruptly increased aerosols in 1883 are commingled with the effects of the background aerosols. Immediately following the eruption, the aerosol heating involves both longwave and shortwave contributions. After the prescribed aerosol decay, the perturbation is still evident, especially in the LW effect, as impacts on composition and the QBO phase persist.

A similar experiment was performed for Pinatubo, but the aerosol contributions were less clear for two reasons. First, the previous restart file available to re-initialize the model was in 1980, such that by the time of the 1991 eruption in the longwave experiment, the QBOs had substantially diverged and the impact was obscured. Second, the shortwave experiment led to a QBO shutdown. Although the contrasting roles of shortwave versus longwave impacts on a QBO shutdown may be of interest in a future study, they are not considered here.

Corresponding author: Kevin DallaSanta, `kevin.dallasanta@nasa.gov`

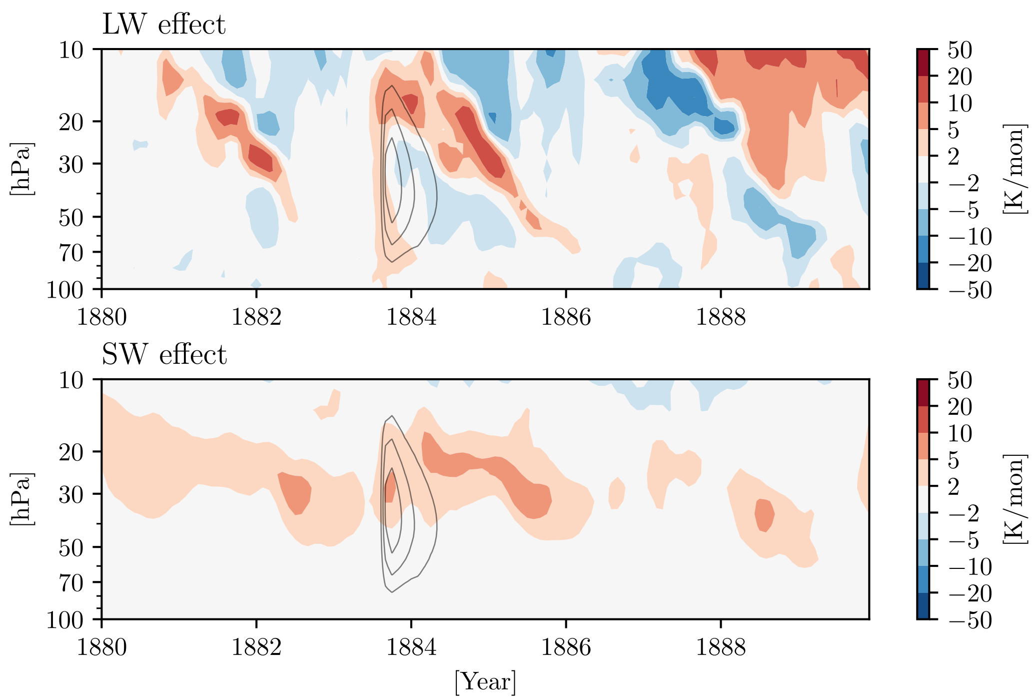

Figure 1. Longwave and shortwave aerosol contributions to Krakatoa, as defined in text, for the member shown in Figure 1. Contours indicate the aerosols prescribed for the eruption, at intervals of 0.02, 0.04 and 0.06 km^{-1}.

2 Ozone responses to eruptions

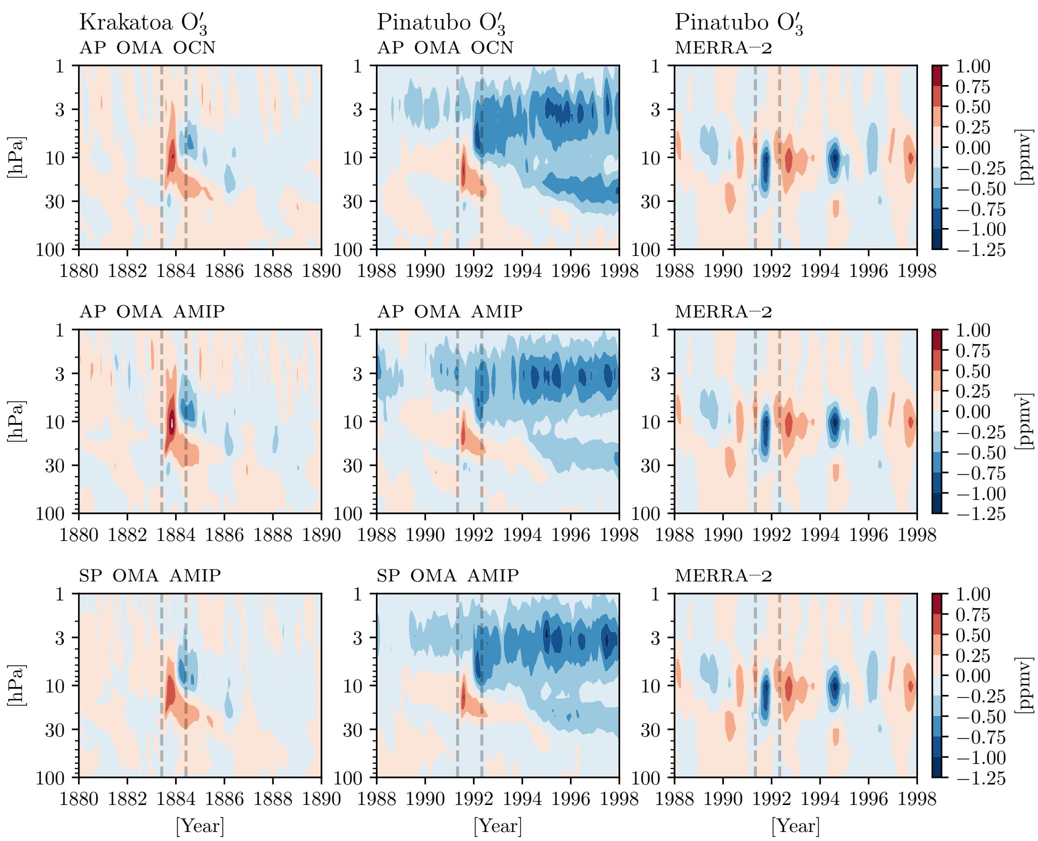

Figure 2. Ensemble-averaged tropical ozone anomalies for the model configurations (columns 1 and 2) and for MERRA-2 reanalysis (column 3). A tropical average is taken from $[-10, 10]$ degrees latitude. Anomalies are defined as departures from the climatological average over the decade preceding the eruption. The dashed lines indicate the one-year interval following the eruption. Values are gently smoothed for plotting, using a 3-month filter.

3 Temperature responses to eruptions

Table 1. Globally and tropically averaged responses to Krakatoa and Pinatubo of sea surface temperature (SST) and associated momentum flux due to convection (MF). The ensemble average and standard deviation are shown; AMIP is forced with observed SSTs. Here, responses are the 2-year average after the eruption minus the previous 2 years. Tropical averages are taken from $[-5, 5]$ degrees latitude.

Configuration	Global SST [K]	Tropical SST [K]	Global MF [mPa]	Tropical MF [mPa]
Krakatoa				
AP OMA OCN	-0.12 ± 0.06	-0.16 ± 0.30	-0.02 ± 0.06	-0.04 ± 0.13
AP NINT OCN	-0.08 ± 0.03	0.17 ± 0.27	-0.04 ± 0.03	-0.05 ± 0.12
SP NINT OCN	-0.10 ± 0.03	0.05 ± 0.26	-0.04 ± 0.03	-0.12 ± 0.12
AP OMA AMIP	-0.01	0.10	-0.003 ± 0.000	0.09 ± 0.07
SP OMA AMIP	-0.01	0.10	-0.01 ± 0.000	-0.04 ± 0.09
Pinatubo				
AP OMA OCN	-0.06 ± 0.12	0.24 ± 0.78	-0.02 ± 0.12	0.08 ± 0.26
AP OMA AMIP	-0.08 ± 0.07	0.16 ± 0.42	-0.04 ± 0.07	-0.09 ± 0.08
SP NINT OCN	-0.12 ± 0.11	-0.17 ± 0.65	-0.005 ± 0.11	-0.02 ± 0.09
AP NINT OCN	-0.07	0.06	-0.005 ± 0.000	0.12 ± 0.13
SP OMA AMIP	-0.07	0.06	-0.02 ± 0.000	0.02 ± 0.02