How does the impact of tropical volcanic eruptions depend on eruption season?

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1. Introduction

Here we examine how the season of eruption affects the distribution of aerosols, and the resulting differences in surface forcing and sulphate deposition.

Volcanic simulations were performed with the MAECHAM5-HAM general circulation model (T42/L39) including detailed aerosol microphysics (Niemeier et al. 2009). Volcanic eruptions are simulated by injecting SO_2 into the lower stratosphere (30 hPa), with parametrized chemistry converting SO_2 to H_2SO_4 aerosols. The model is run in a free running climate mode, with modern day external forcings, including climatological SSTs.

Simulation code	Eruption month	SO2 (Mt)
LC1	January	700
LC7	July	700
LP1	January	17
LP7	July	17

Table 1: Outline of MAECHAM5-HAM simulations used in this work

We focus here on simulations of the eruption of Los Chocoyos (14°N, 91°W, ~84ka), the largest eruption (700 Mt SO_2) in the Central American Volcanic Arc (CAVA) timeseries of the last 200ka (Kutterolf et al. 2008). For comparison, we also simulate a Pinatubo strength (17 Mt SO_2) eruption at the Los Chochoyos location.

2. Dynamics

A direct result of the injection of volcanic aerosols is heating of the lower stratosphere through the absorption of LW radiation emitted by the Earth's surface.

- In our LC simulations, the creation of volcanic aerosols leads to strong temperature anomalies in the tropical lower stratosphere, of magnitudes >20 K (Fig. 1).
- This heating leads to a stronger equator to pole temperature gradient, which in turn leads, through the thermal wind balance, to stronger zonal winds.
- The zonal wind anomalies are strongest in the stratosphere, but significant anomalies (>10 m/s) extend down to the surface, especially in the SH (Fig. 2).

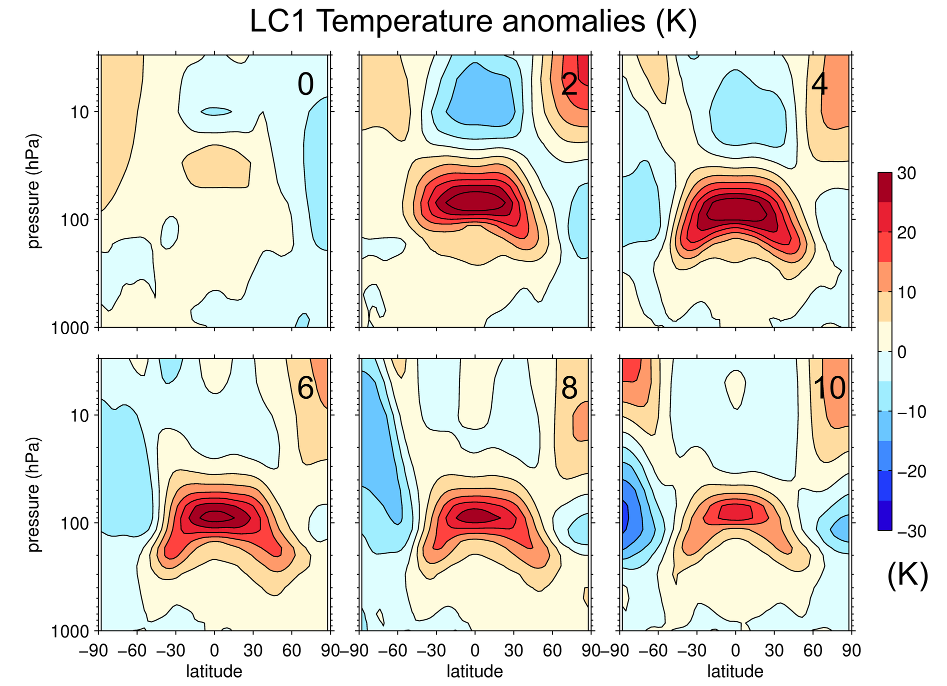

Figure 1: Post-eruption monthly mean, zonal mean temperature anomalies (from a ten year control simulation) in the LC1 simulation. The month after eruption noted in top right corner of each panel (0=Jan).

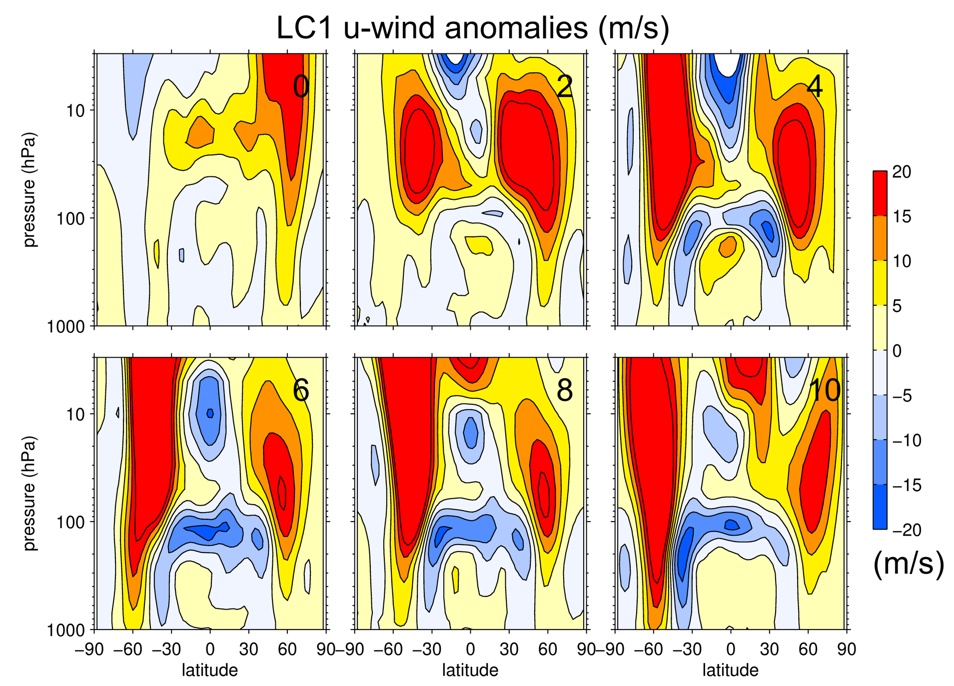

Figure 2: Post-volcanic monthly mean zonal wind anomalies (from a ten year control simulation) in the LC1 simulation. The month after eruption is noted in top right corner of each panel (0=Jul).

3. Sulphate Burden

Total atmospheric sulphate (SO_4) aerosol burden, as a function of latitude and month after eruption, is shown below (Fig. 3) for the four simulations (see Table 1).

- The morphology of the sulphate burden distribution is quite different for the simulations of different magnitudes. In comparison to the LP simulations, in the LC simulations we see that:
  1. sulphate is relatively restricted from the polar latitudes, most likely due to the enhanced zonal winds (see Box 2) acting as mixing barriers.
  2. there is a much stronger and faster initial movement of sulphate from the tropics to the extratropics, likely a byproduct of the strong tropical heating (see Box 2).
  3. together, these two factors lead to high sulphate burdens in the midlatitudes of each hemisphere.
- There is a high degree of hemispheric asymmetry in the LC simulations compared to the LP simulations. While the LC1 simulation shows a NH:SH burden asymmetry comparable to that of both LP simulations (with most sulphate in the NH), the LC7 simulation shows more sulphate in the SH.

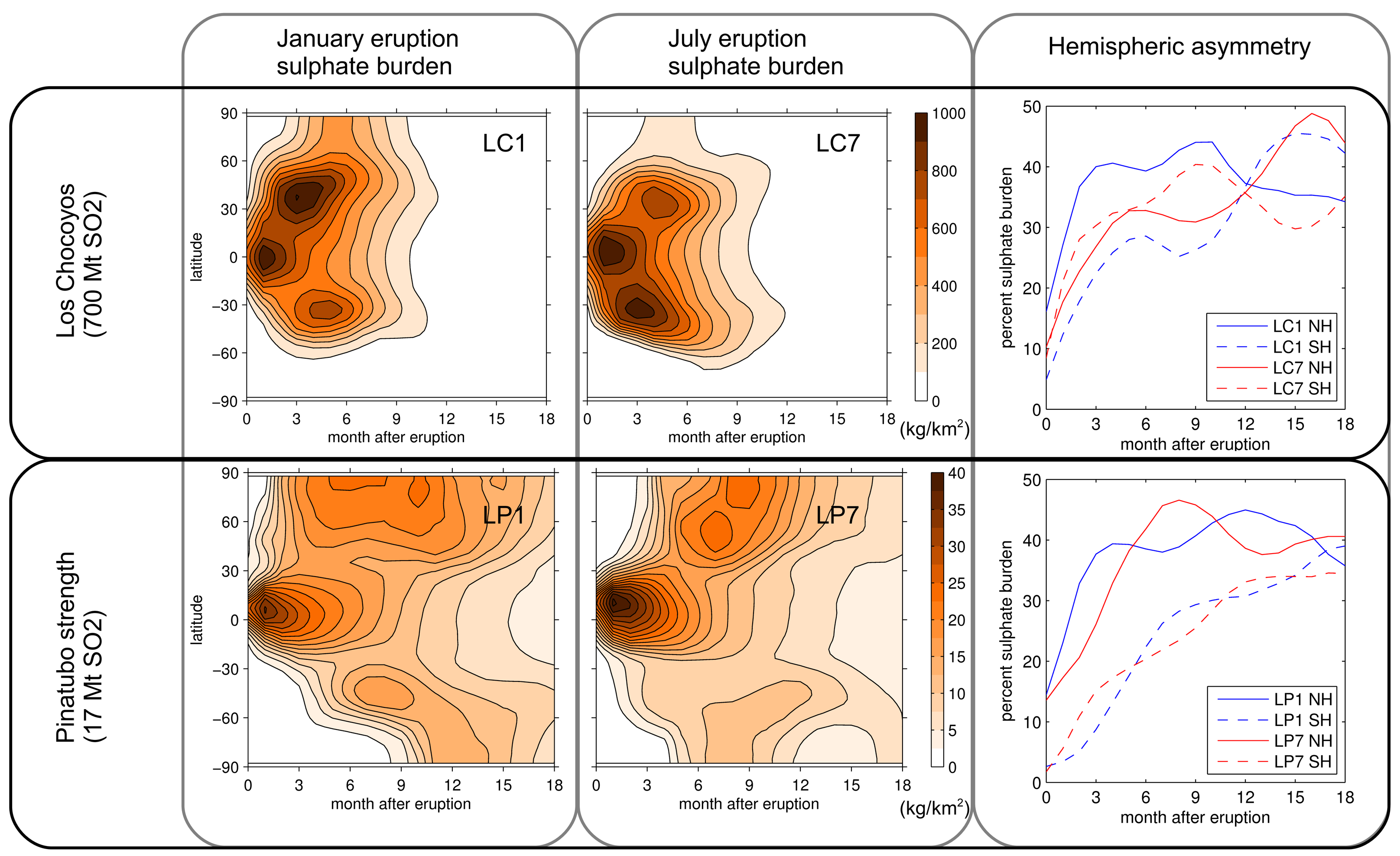

Figure 3: (Left and middle columns); Monthly mean, zonal mean sulphate burden (kg/km²) for four eruption simulations, (Right column); Percent of total global sulphate burden in NH and SH extratropics (20° – 90° latitude).

4. Radiative Forcing

In addition to the LC1 and LC7 simulations, we have also performed simulations of eruptions in April and October. Figure 4 shows the aerosol optical depth (AOD) distributions resulting from LC strength eruptions in four different seasons.

- The Apr. and Oct. eruption AOD distributions are comparable to the Jul. and Jan. distributions, respectively.
- Like the SO_4 burden distributions, the AODs are hemispherically asymmetric, with largest AODs in the NH (SH) for Oct. and Jan. (Apr. and Jul.) eruptions.

Volcanic aerosols decrease the amount of solar radiation reaching the surface of the Earth. While the global mean reduction in net surface radiative forcing does not depend on eruption month (Fig 5, left), the radiative effects in a particular hemisphere or region do.

- Fig. 5 (right) shows that in the NH midlatitudes, the radiative effect of a January eruption is almost twice as large as one in July.
- The seasonal dependence of regional surface radiation on eruption month is not only due to the hemispherically asymmetric AOD patterns, but also on the timing of the peak AOD: the effect on solar forcing in the NH midlatitudes is weaker for an eruption in October than in January since the peak AOD for an October eruption occurs during mid winter.

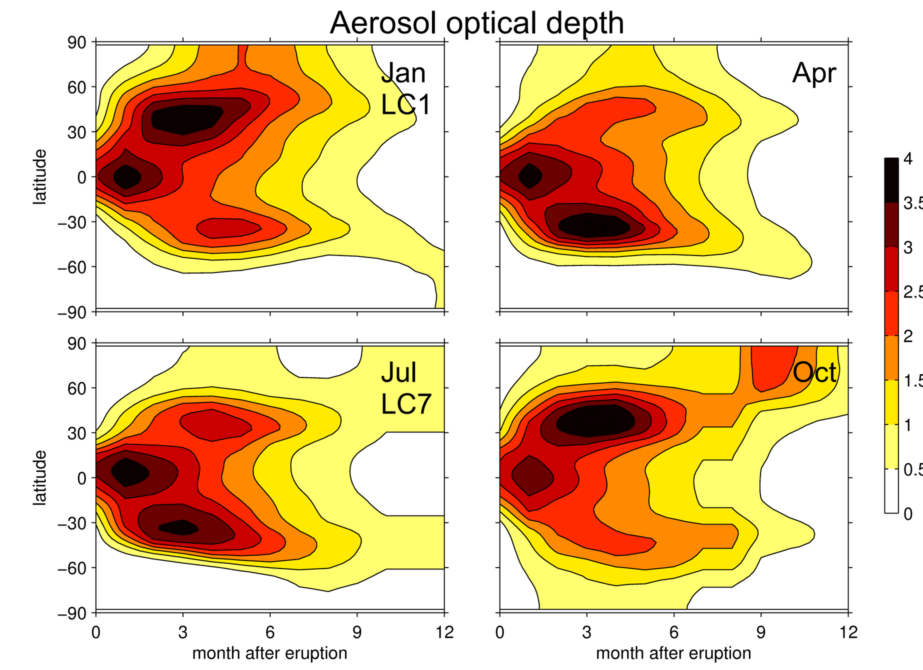

Figure 4: Zonal mean, monthly mean aerosol optical depth (AOD) for LC eruptions in four seasons.

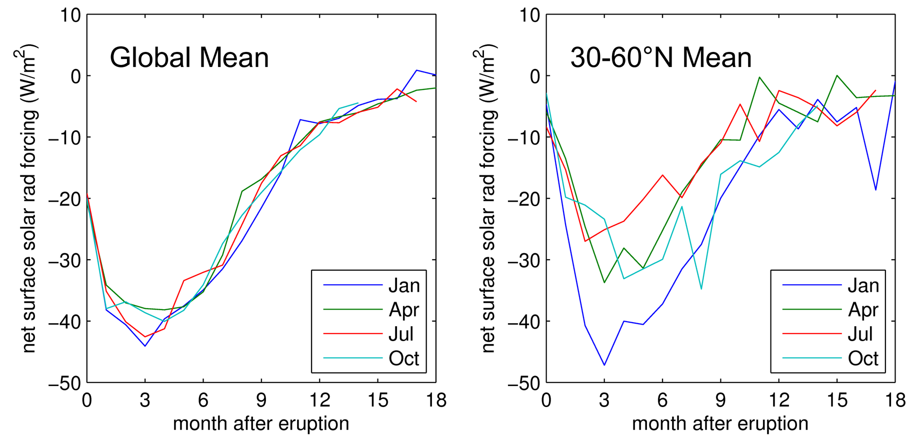

Figure 5: Net surface solar flux anomalies after LC eruptions in four seasons.

5. Sulphate Deposition

The deposition of sulphate to the surface is shown in Fig. 6 as a function of latitude and month after eruption for the LC1 and LC7 simulations.

- Most sulphate is deposited to the surface between 3 and 12 months after the eruption.
- The strong zonal winds at ~60° latitude in winter impede the transport of sulphate to the high latitudes.
- As a result, there is a sizeable difference between sulphate deposited to the Antarctic and Greenland land masses as function of eruption month (Fig. 7).

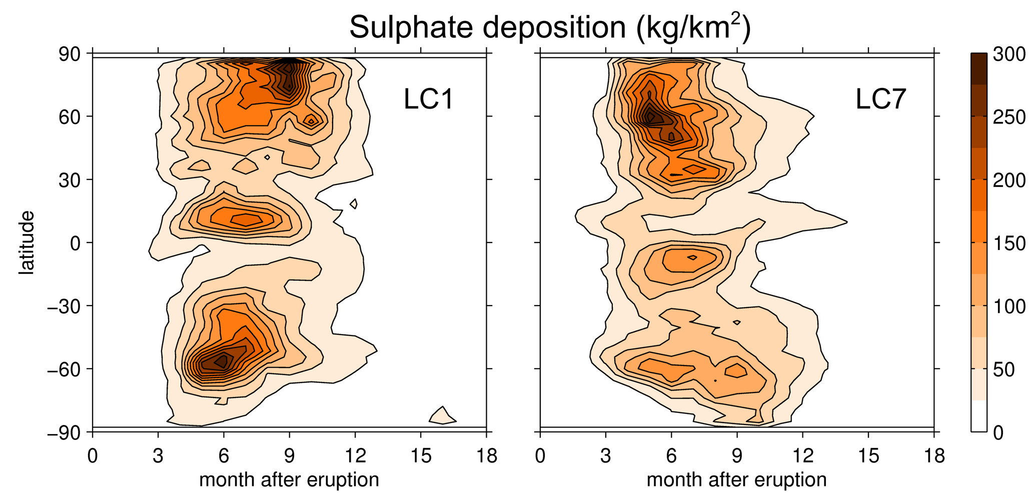

Figure 6: Zonal mean, monthly total sulphate deposition (kg/km²) for the LC1 and LC7 simulations.

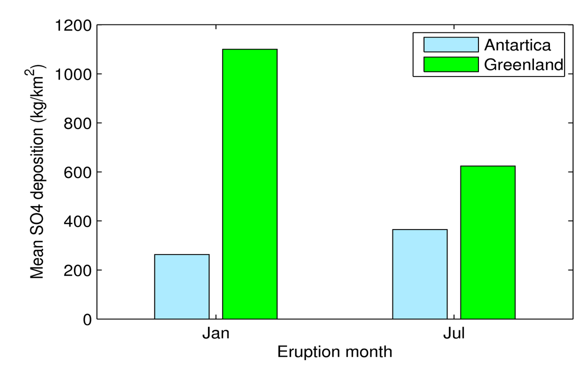

Figure 7: Area mean total sulphate deposition (kg/km²) in Antarctica and Greenland after 2 years for the LC1 and LC7 simulations.

6. Conclusions

For eruptions of LC magnitude, the season of eruption has significant effect on hemispheric asymmetry of SO_4 loading, AOD, surface radiation, and SO_4 deposition

- All are related to anomalous dynamics: zonal winds and probably Brewer-Dobson circulation changes.

Ongoing work is focusing on:

- Better understanding of the direct effect of LC strength eruptions on atmospheric dynamics.
- The influence of the dynamically induced AOD hemispheric asymmetry on surface climate effects.