Simulation of Laki eruption and associated issues with aerosol coagulation

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IMPORTANCE OF HIGH-LATITUDE VOLCANO ERUPTIONS

LAKI-TYPE ERUPTION USING NorESM

High-Latitude Volcanic Eruptions

Lakagigar (LAKI) eruption in 1783
Lasted about 8 months from 8 June 1783 to 7 February 1784
Largest basaltic lava flow in historic time

Emitted 122 Tg of SO₂ of which 95 Tg into the LS/UT 9-13 km
Pinatubo emitted “only” 20 Tg of SO₂ (up to 24 km though)!

Thordarson and Self, 2003

Meteorological Institute and Bolin Centre for Climate Research

24/10/14
**LAKI-TYPE ERUPTION USING NorESM**

### 4-month eruption:
- 100 Tg SO₂
- 100 Tg Dust

### Time distribution:
Not evenly distributed (i.e. 0.83 Tg/day)
Impulses of 5 days every 2 weeks
Stronger the first 2 months (80 %)

### Height distribution:
Not evenly distributed
- <5km(500mb): 20 Tg
- 9-13km(300-150mb): 70 Tg
- 13-15km (150-100 mb): 10 Tg

<table>
<thead>
<tr>
<th>Eruption date</th>
<th>Jun 1st</th>
<th>Jun 15th</th>
<th>Jul 1st</th>
<th>Jul 15th</th>
<th>Aug 1st</th>
<th>Aug 15th</th>
<th>Sep 1st</th>
<th>Sep 15th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total SO₂ (Tg)</td>
<td>42</td>
<td>11</td>
<td>11</td>
<td>15</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>100 &lt; p &lt; 150 hPa</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>150 &lt; p &lt; 300 hPa</td>
<td>29</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>p &gt; 300 hPa</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
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</tr>
</tbody>
</table>
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SO$_4$ burden and concentrations

Ensemble mean change in SO$_4$ (Tg) mass loading (left) and 30°W to 45°E mean SO$_4$ concentrations (ppbv) for the summer following the eruption (JJA year 01) over the Northern Hemisphere (NH) from the surface to 100 mbar (right)
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SO$_4$ burden and concentrations

Oman et al. 2006

SO$_2$ and SO$_4$ (Mt) for Laki Eruption

Ensemble mean change in SO$_4$ (Tg) mass loading for the summer following the eruption (JJA year 01) over the Northern Hemisphere (NH) from the surface to 100 mbar
LAKI-TYPE ERUPTION USING NorESM

Oman et al. 2006

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AOD CHANGES

ΔAOD: 1.53 vs. 0.51

Oman et al. 2006
LAKI-TYPE ERUPTION USING NorESM

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$\Delta$RF: –11 vs. –4 W/m²
LAKI-TYPE ERUPTION USING NorESM

\[ \Delta \text{AOD: } 1.53 \text{ vs. } 0.51 \]

\[ \Delta \text{RF: } -11 \text{ vs. } -4 \text{ W/m}^2 \]

The differences in the AOD are most likely due to the differences in effective radii: smaller particles scatter light more efficiently.

The specific surface area, i.e. surface area seen by radiation goes as the inverse of twice the effective radius (\(\sim 1/2 \text{reff}\)).
LAKI-TYPE ERUPTION USING NorESM

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Average effective radius:

\[ 0.54-0.61 \mu m \text{ vs. } 0.2 \mu m \]
Average effective radius:

0.54-0.61 μm vs. 0.2 μm

2.5—3 times fewer large particles than in Oman et al. (2006)

greater optical depth by a factor of 2-3
The reason of such small particles?
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**CAM4–Oslo does not simulate growth by self coagulation** (coagulation of Aitken-mode particles combining to form larger particles).

CAM4–Oslo simulates nucleation and growth to Aitken mode size, and also growth of background aerosols (there prior to the eruption).
The reason of such small particles?

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Self-coagulation is an important mechanism after an eruption when a massive amount of sulfate is injected.

In CAM4-Oslo the only growth mechanism is condensation, and intra-modal coagulation is not taken into account.
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To test whether in our model the presence of larger particles would lead to a reduced AOD

we run three additional sensitivity simulations in which:

a) We impose that 2.5% of SO$_4$ mass is already in the accumulation mode (PCT2.5);
EXPERIMENT SET-UP

**LAKI-TYPE ERUPTION USING NorESM**

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a) We impose that 2.5% of $\text{SO}_4$ mass is already in the accumulation mode (PCT2.5);

b) We impose that 10% of $\text{SO}_4\ 263$ mass is already in the accumulation mode (PCT10);
LAKI-TYPE ERUPTION USING NorESM

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we run three additional sensitivity simulations in which:

a) We impose that 2.5% of SO$_4$ mass is already in the accumulation mode (PCT2.5);

b) We impose that 10% of SO$_4$ 263 mass is already in the accumulation mode (PCT10);

c) We impose that 25% of SO$_4$ 264 mass is already in the coarse mode (PCT25ss).

However, the model does not allow sulfate in the coarse mode. Hence, we emit the primary sulfate as "sea salt" (SS) since coarse sea salt already exists and they are optically similar to sulfate.
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LAKI-TYPE ERUPTION USING NorEJM

CONCLUSIONS

NorEJM is able to reproduce the correct SO$_4$ concentrations, whereas it cannot capture the right particle size and consequently the radiative forcing induced by the volcanic SO$_2$ emission.

The sensitivity tests shows that if our model had included intra-modal coagulation leading to coarse SO$_4$ particles, the simulated radiative properties would have been more accurate.