EXTREMELY LOW FREQUENCY DETECTION OF ELECTRICAL DISCHARGES AT MINAMIDAKE CRATER (SAKURAJIMA VOLCANO, JAPAN)

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How is volcanic lightning generated?

- Plume electrification is caused by charge separation as a result of:
  - Fracto-electrification (emission of charged species from freshly fractured surfaces)
  - Tribo-electrification (electron transfer through the collision of ash particles)
  - Ice nucleation/riming
  - Natural radioactivity

- If the breakdown voltage is exceeded, this will result in an electrical discharge.
Biral Thunderstorm Detector (BTD)

- Two prototypes of the BTD were installed at 3-4 km distance from Minamidake crater at Sakurajima volcano, Japan.

- Detects the change in electrostatic field, which is caused by charge neutralisation.

- Extremely low frequency range: 1-45 Hz

- Sample rate: 100 Hz
Data processing and analysis

• BTDs recorded between July 2018 – January 2020.

• Eruption database based on observations from the Japan Meteorological Agency (JMA) and Tokyo VAAC. The JMA gives an estimated time of the eruption onset (to the minute precise).

• Flash detection algorithm suitable for volcanic lightning.

• Compare to data from the World Wide Lightning Location Network (WWLLN): Global Volcanic Lightning Monitor and Earth Networks Total Lightning Network (ENTLN).
• One vertical line equals one discharge.
• Primary antenna is the most important, because it is the most sensitive.
• Electrical discharges detected in relatively small explosive eruption.
• Ash plume did not reach the 0°C isotherm, so no ice nucleation.
• Eruption was not detected by ENTLN and WWLLN.
• Electrical discharges started 20s before the estimated eruption onset given by the JMA.
• Several pulses were detected by the BTD, but were not reported by the JMA.
• Ash plume reached just above the 0°C isotherm. Ice nucleation is possible as a charge separation mechanism, but unlikely on these relatively short time scales.
• Eruption was not detected by ENTLN and WWLLN.
• Biggest eruption at Sakurajima in 2019.
• Ash plume reached the -20°C isotherm. Ice nucleation likely played an important role as a charge separation mechanism.
• >800 discharges detected by BTD.
• Only 1-2 discharges detected by ENTLN and WWLLN.
Conclusions

• Electrical discharges mark the inception of the explosion more precisely.
• Electrical discharges can indicate a new pulse.
• Most eruptions did not reach freezing levels, indicating that ice nucleation did not play a (important) role as charge separation mechanism during those eruptions.
• The eruptions at Sakurajima volcano between July 2018 and January 2020 had plume heights ranging between 100 and 5500 meter above the crater rim.
• The BTDs detected electrical activity in 50% of the eruptions, regardless of plume height.
• ENTLN and WWLLN detected less than 1% of the eruptions.
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