# Exploring how eruption source parameters affect volcanic radiative forcing using statistical emulation

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# What influences volcanic forcing?

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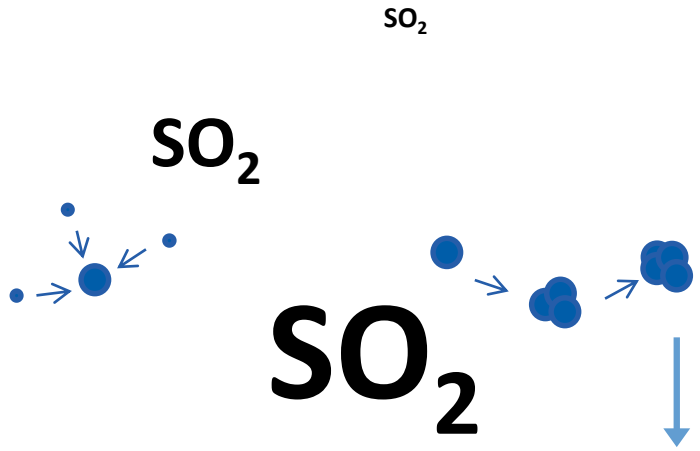
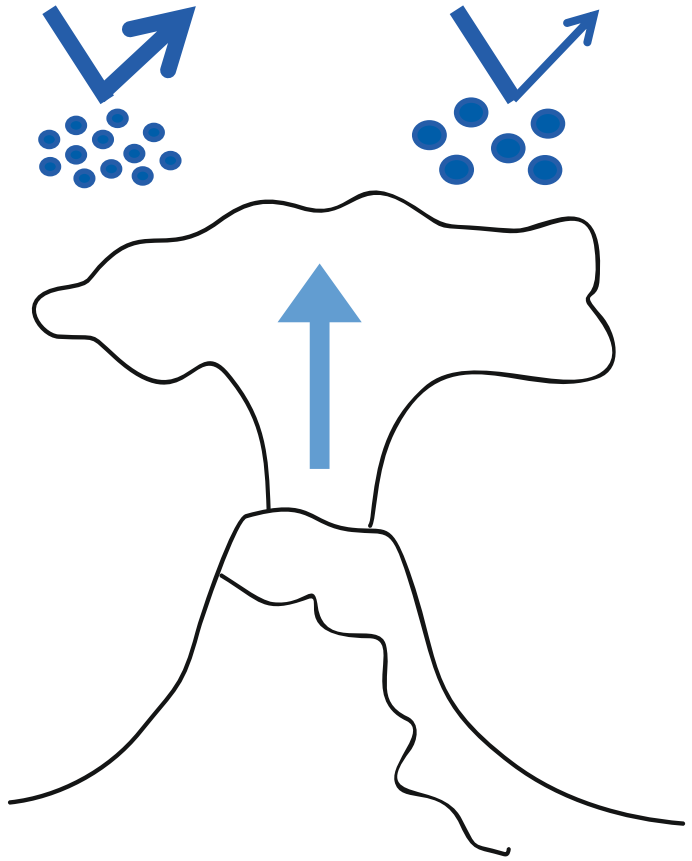
(Pinto et al., 1989; Robock, 2000; Timmreck, 2012)

- Amount of $SO_2$ emitted by the eruption
- The latitude of the volcano
- The injection height of the emissions

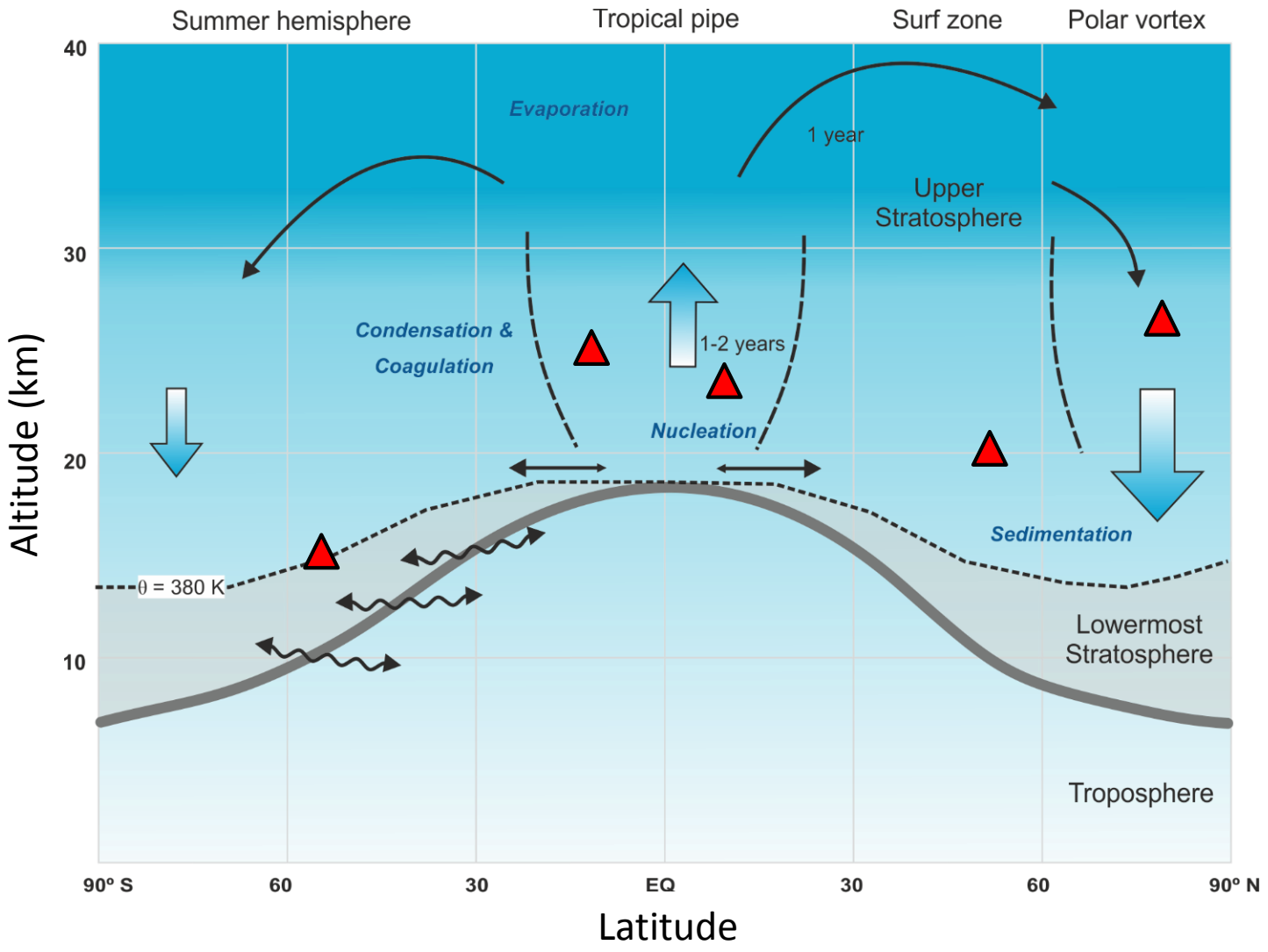


**Which one is most important? Do they have combining effects?**

# Life cycle of stratospheric sulfate aerosol





# Sampling strategies

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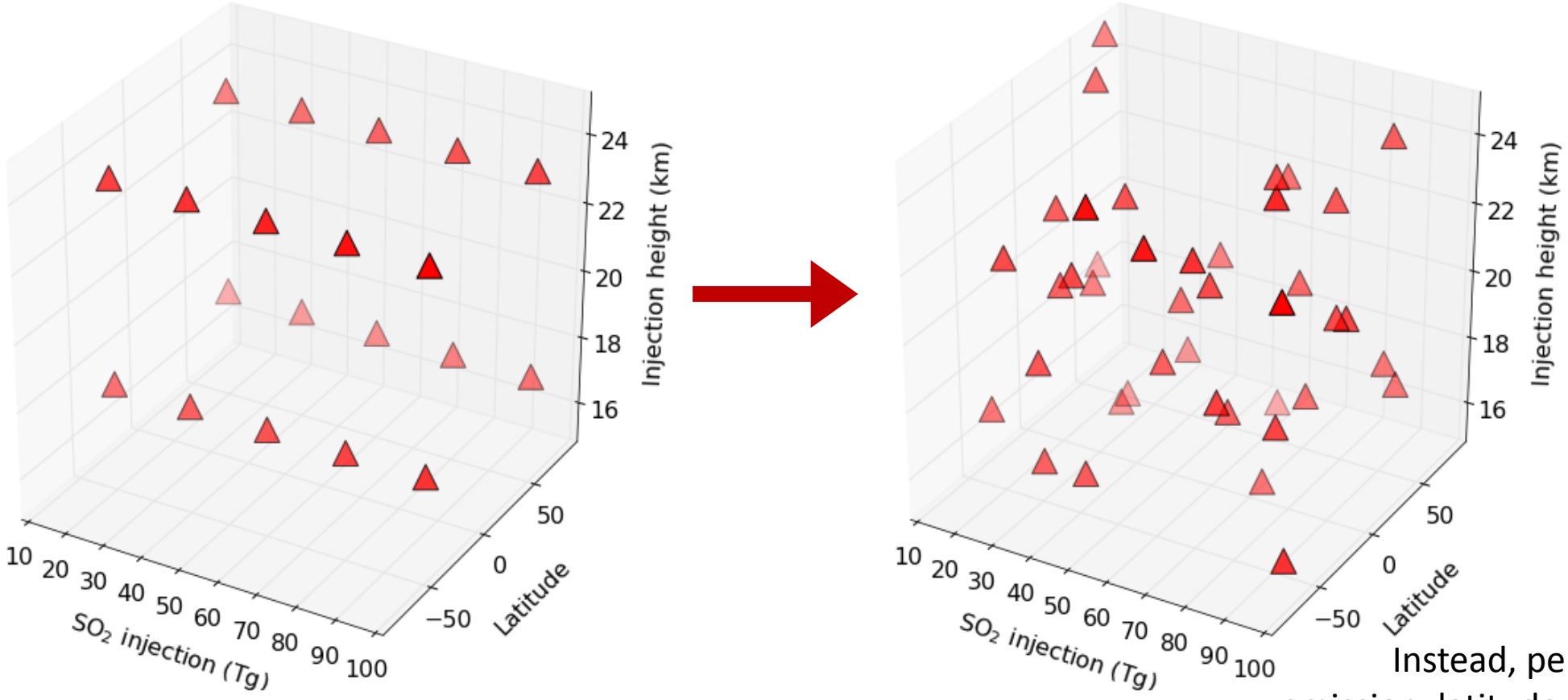
Computationally expensive to cover whole parameter space this way…




Instead, perturb the $SO_2$ emission, latitude and injection height in every simulation

# Simulation design: UM-UKCA composition-climate model

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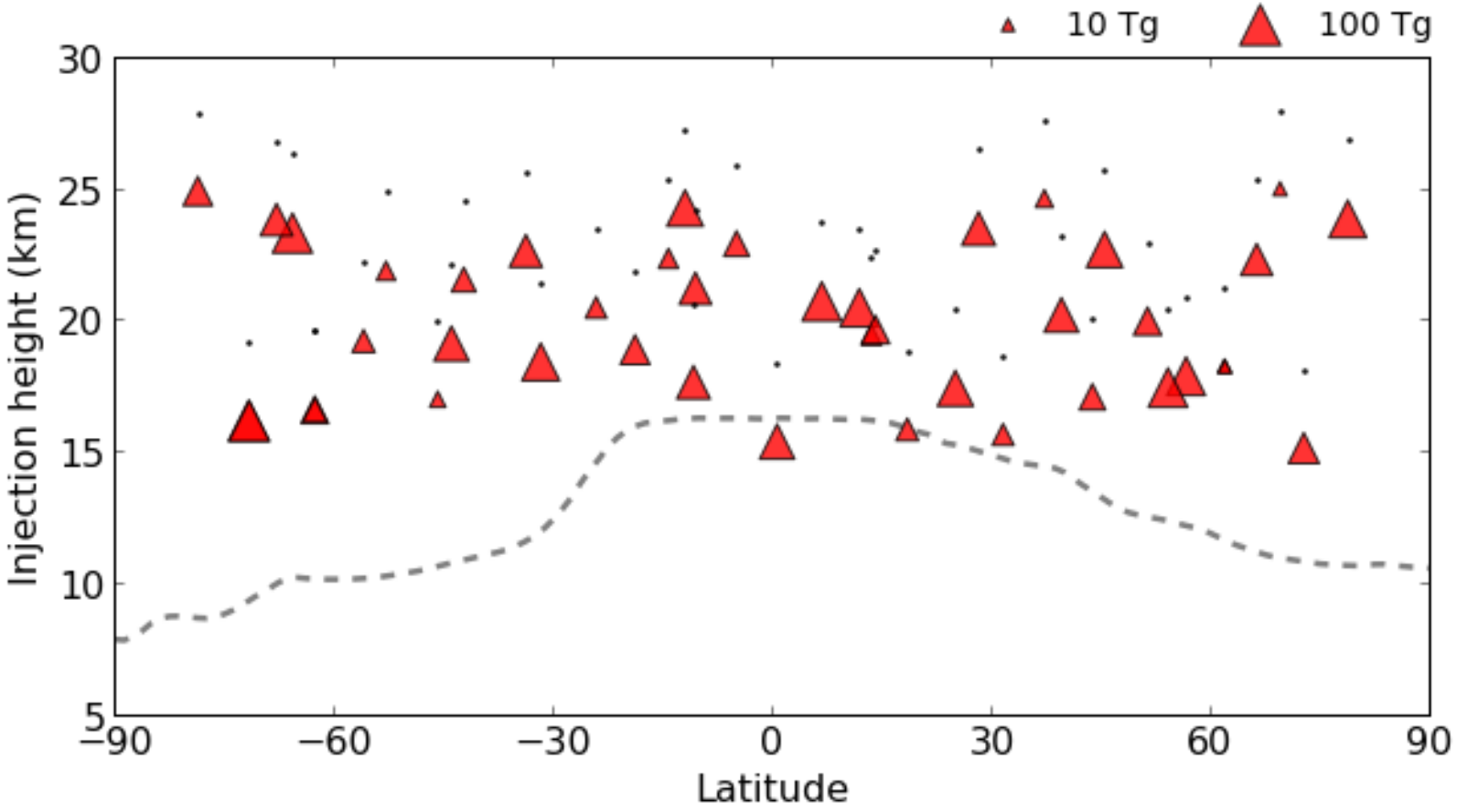
## Large-magnitude hypothetical stratospheric eruptions




**UM-UKCA:**

- General circulation model HadGEM3
- GLOMAP-mode aerosol microphysics
- Whole-atmosphere chemistry

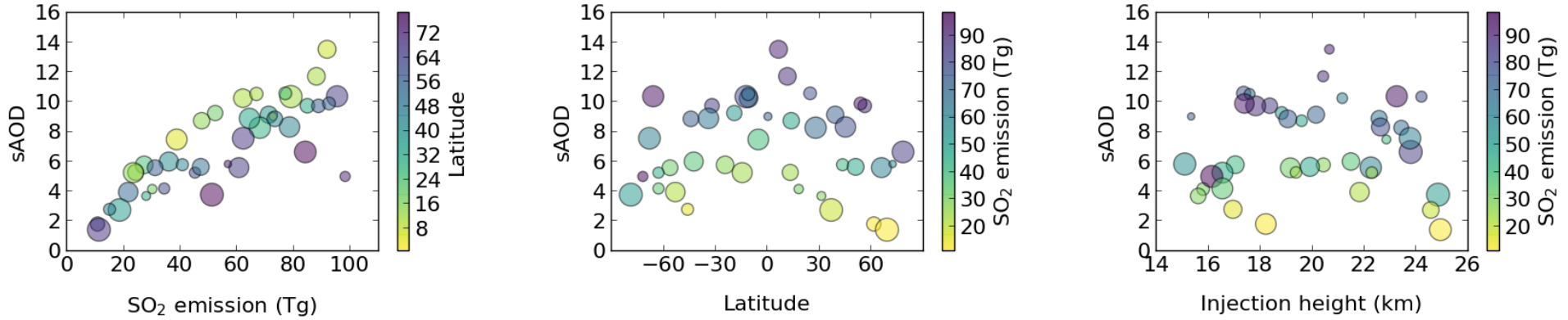
= 3 km

(Mann et al., 2010; Dhomse et al., 2014; Marshall et al., 2018)

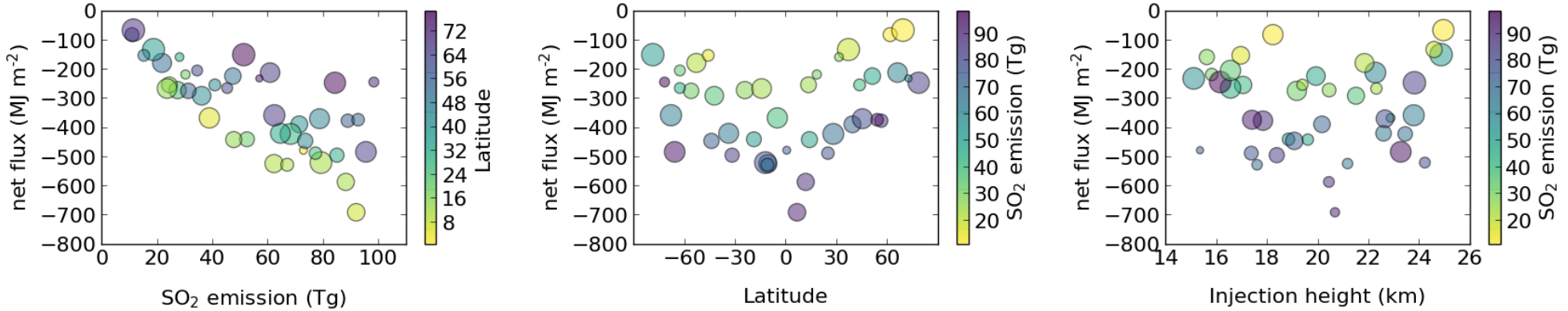
# Stratospheric aerosol optical depth and net radiative forcing

## **Time-integrated global** model output

### 3-year integrated global mean sAOD




### 3-year integrated global mean net radiative forcing



# Build emulator to represent the model output

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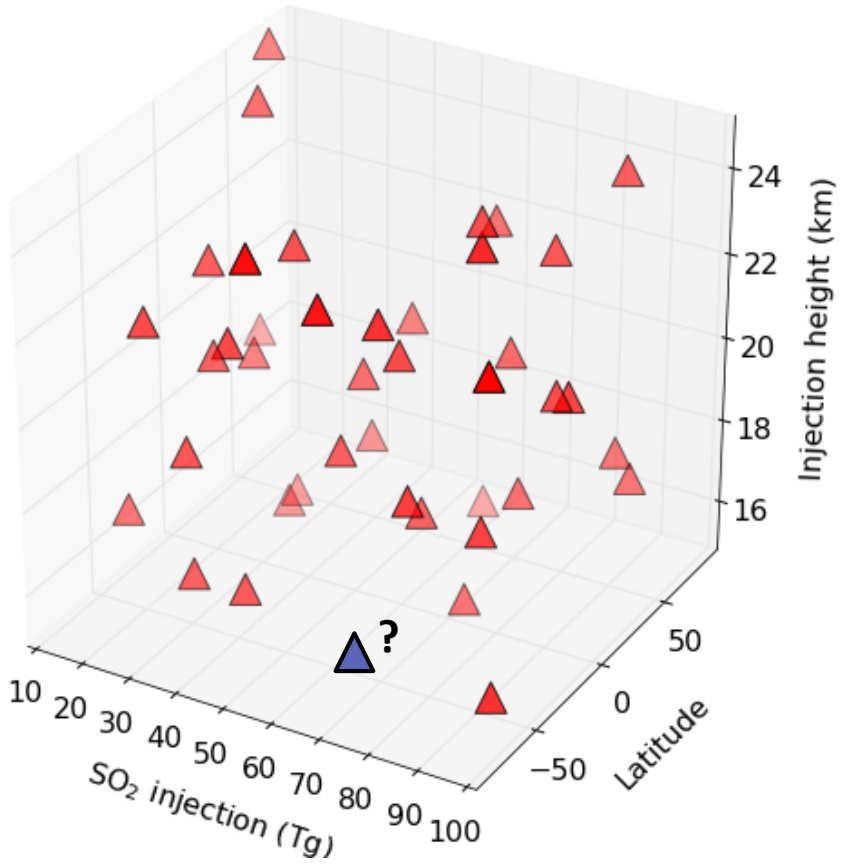
Emulators provide a **statistical representation** of model output for all points within the multi-dimensional parameter space

1. Replace the UM-UKCA model output with an emulator and validate

2. Sample from the emulator thousands of times to predict output for **any eruption**

Emulator is **very fast** to use



# Emulator response surfaces

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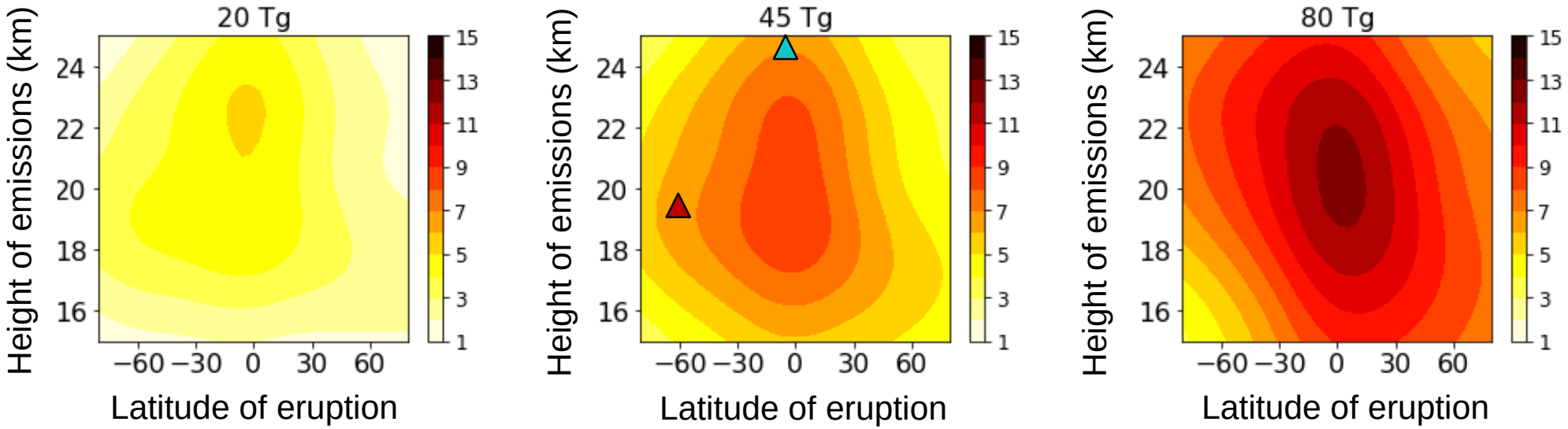
How does sAOD depend on the latitude and injection height of the $SO_2$ emissions?

**3-year integrated global mean sAOD**




△ + △ have same sAOD but very different eruption source parameters

Marshall et al. (submitted to JGR)

# How do eruption source parameters affect sAOD?

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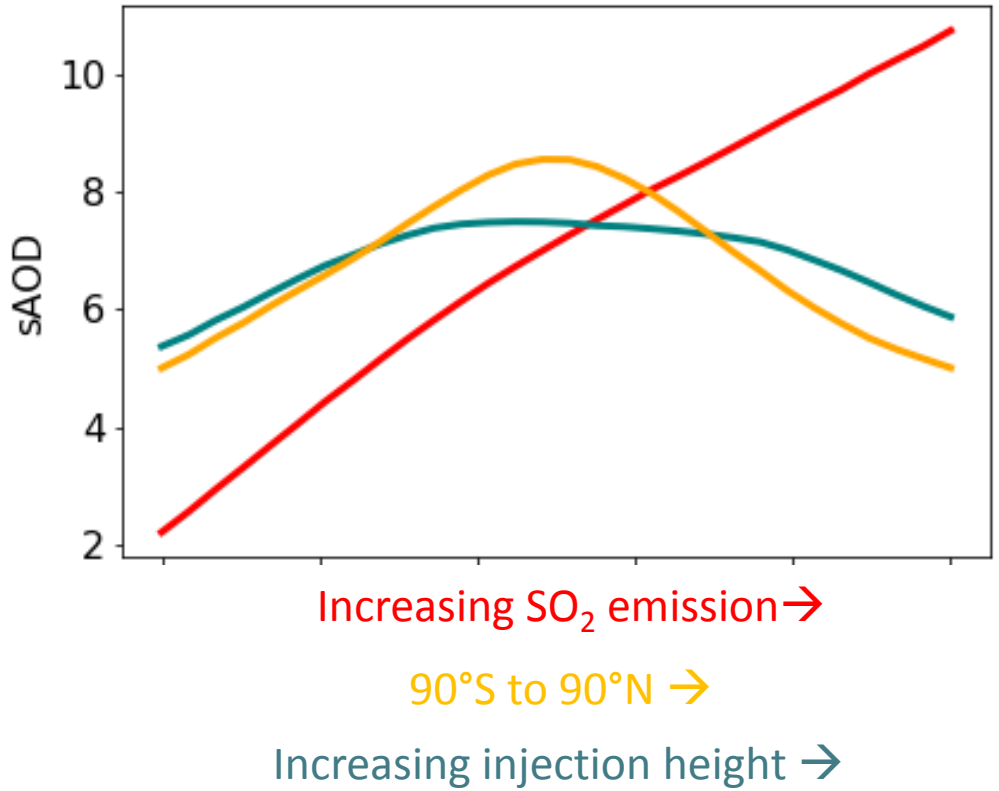
What is the **average effect** of the eruption source parameters?

3-year integrated global mean sAOD




$SO_2$ emission is **most important** parameter, injection height is **least important**.

# What parameter values result in a very large climatic response?

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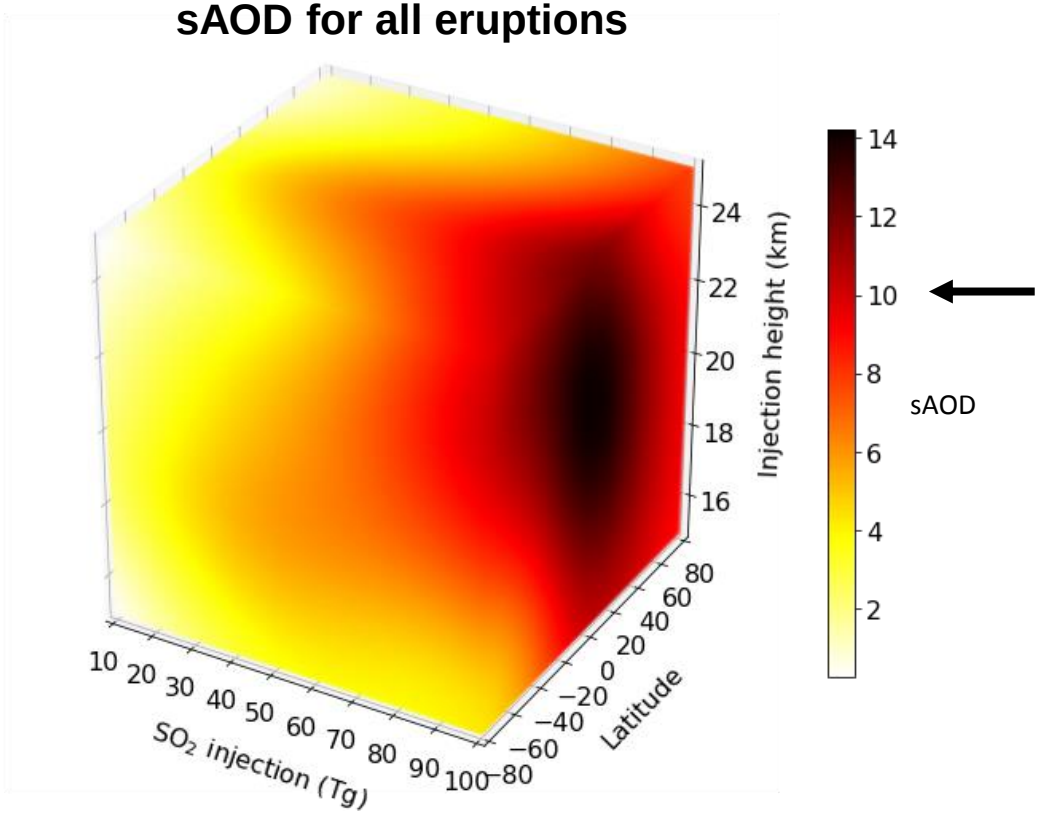
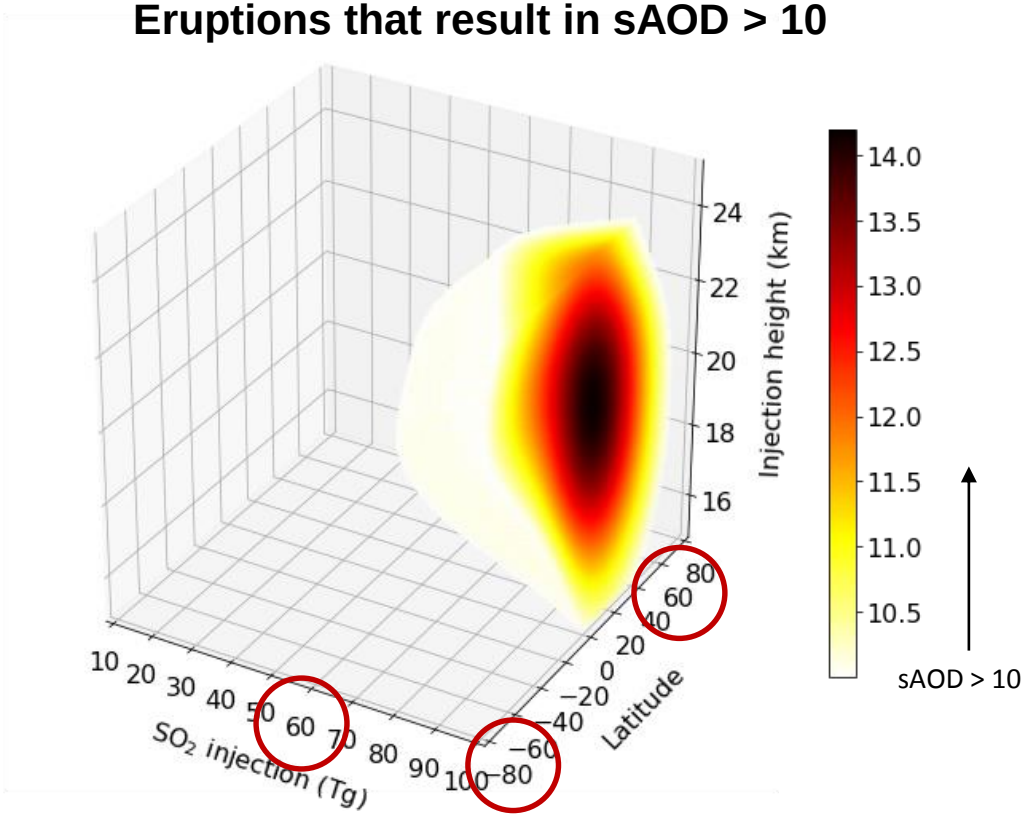
What parameter values are required for an **sAOD > 10?** (= 3 x impact from 1991 Mt. Pinatubo)

**sAOD for all eruptions**




**Eruptions that result in sAOD > 10**




Marshall et al. (submitted to JGR)

# Conclusions

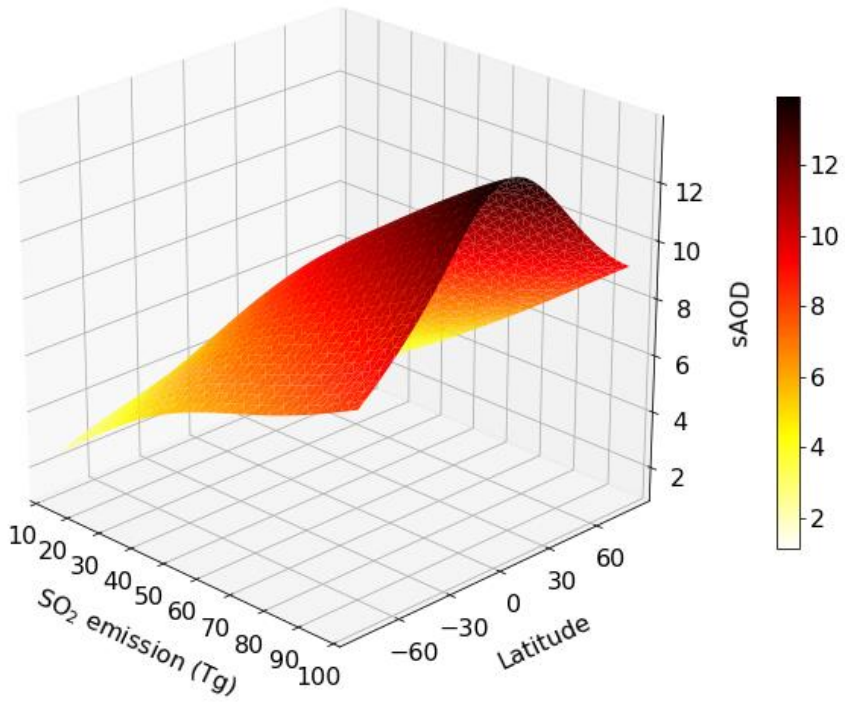
- Based on only 30 simulations we can **predict** the atmospheric impact **of any eruption** that has:
  - $SO_2$ emission 10 -100 Tg
  - latitude 80°S - 80°N
  - height of emissions 15 - 25 km

- Emulated response surfaces show how model output depends on the eruption source parameters revealing **more dependencies** than model simulations alone

- Emulators can be used to **constrain the eruption source parameters** for a given volcanic response often resulting in multiple solutions

- Future work to constrain eruption source parameters for sulfate deposition from ice core records

**3-year integrated global mean sAOD**




*sAOD vs. $SO_2$ emission and latitude for a fixed injection height of 20 km*

Marshall et al. (submitted to JGR)