Dispersion Model Evaluation for the Sulfur Dioxide Plume from the 2019 Raikoke Eruption using Satellite Measurements

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Why Study Volcanic Clouds?

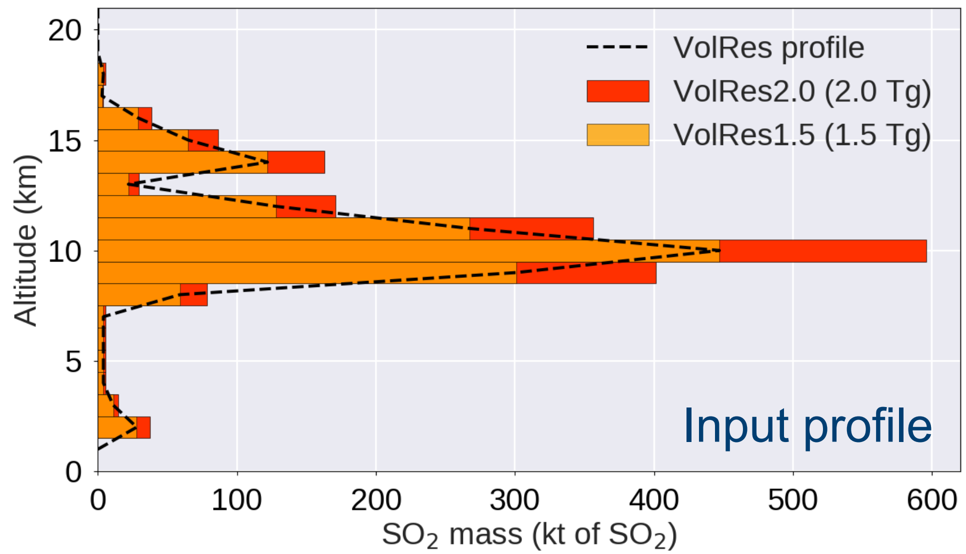
Due to the potential large impact of emitted sulfur dioxide (SO_2) and sulphate (SO_4) from volcanic eruptions, it is **important to have good models to forecast the evolution of volcanic clouds.** Our aim is to increase our understanding of volcanic cloud dispersion to improve these forecasts.

In this study**, the focus is on validation of the sulfur dioxide cloud dispersion**. We compare the Met Office NAME dispersion model with the TROPOMI satellite product **for the 2019 Raikoke eruption** between 21st June and 16th July 2019

Eruption Source Parameters for Raikoke 2019

Input parameters for NAME:

- A total of 1.5 Tg of SO_2 is released between 21st June 1800 UTC and 22nd June 0300 UTC. We used a constant rate for 9 hours at the location of the volcano [48.3ºN, 153.2ºE].
- Vertical profile split in 20 layers; each layer 1000 m thick.
- Also investigate a simulation with same profile shape but with an increased total emission of 2 Tg of SO_2 (VolRes2.0).



Estimated total emitted SO_2 mass for the Raikoke 2019 eruption. The emission profile was provided by the VolRes (Volcano Response) team. The bars represent the implementation of the profile in NAME for the two simulations.

Numerical Weather Prediction (NWP) input:

Global Met UM (~10 km resolution)

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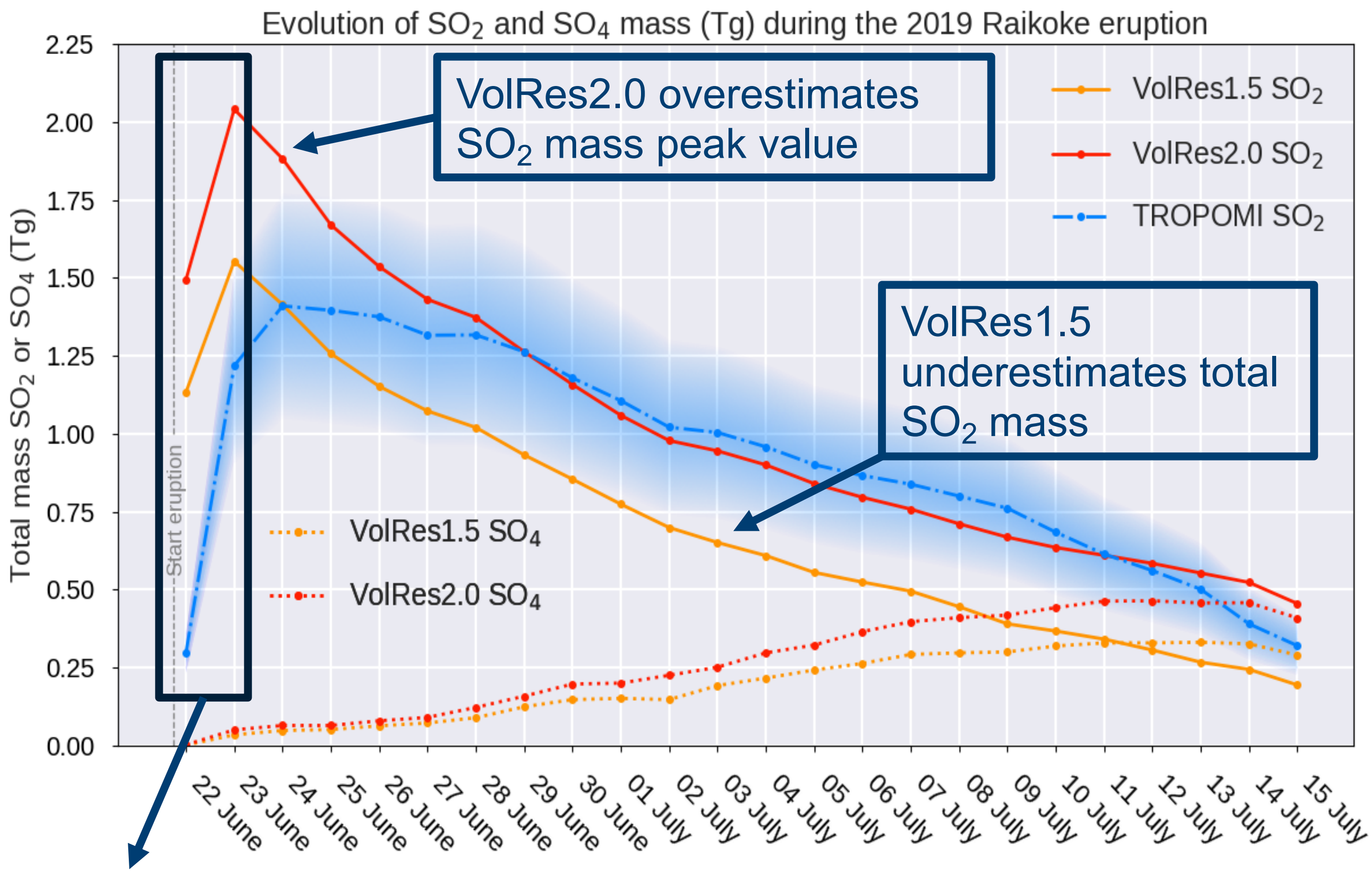
Raikoke sulfur mass burden evolution



The daily evolution of the SO_2 mass (Tg of SO_2) and the SO_4 mass (Tg of SO_4) for the Raikoke eruption. We have included the TROPOMI estimate and the evolution of two NAME runs with 1.5 Tg (VolRes1.5) and 2.0 Tg (VolRes2.0) of SO_2 emission estimates. For TROPOMI we use a 0.3 DU cut-off to remove data below the detection limit. The blue shading represents the standard error estimate.

High concentrations of ash present

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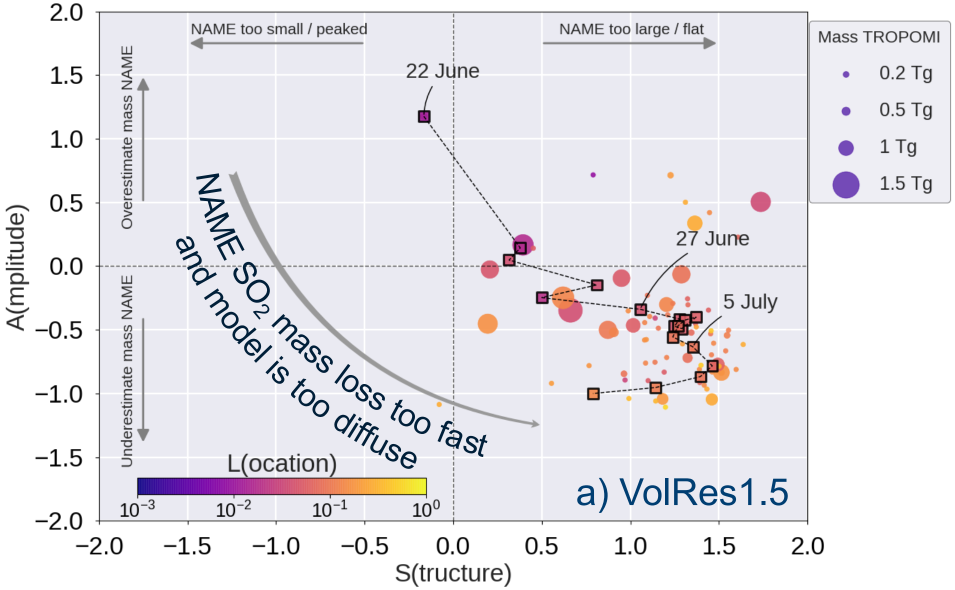
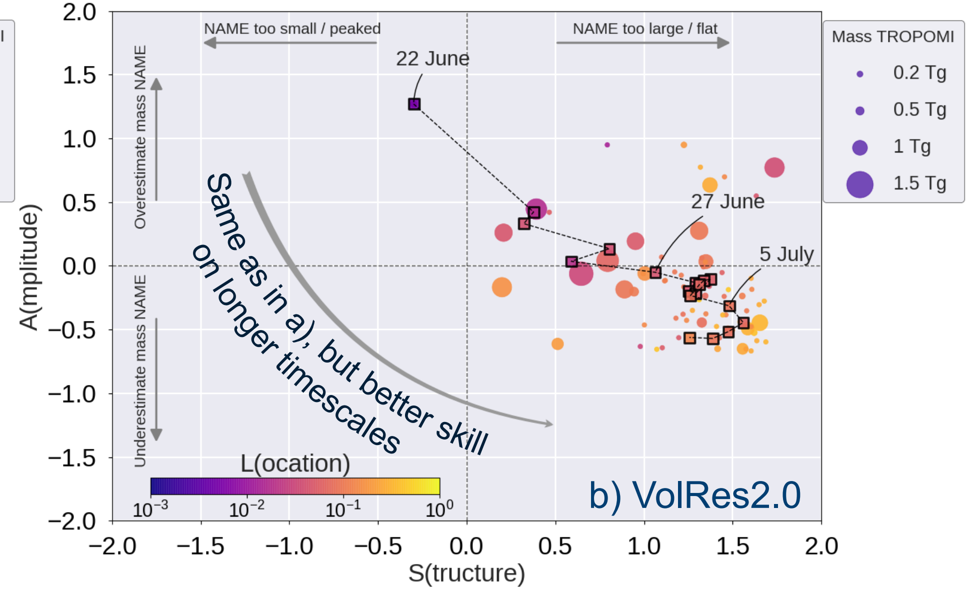
TROPOMI and NAME compare well

SAL-score[1] shows the skill of NAME for representing the **S**tructure, **A**mplitude and **L**ocation of the retrieved TROPOMI cloud. Values close to (0,0,0) represent the best comparison.





Time evolution of the SAL-values for the NAME simulations with a) 1.5 Tg emission and b) 2 Tg emission. The squares show the daily average evolution of the S and A and L parameters, while the dots represent the SAL-values for each individual TROPOMI overpass.

The NAME simulations: 1) capture the location of the cloud well (low L value)
2) overestimate the cloud diffusion (increasing S value)
3) lose mass faster than observed by TROPOMI (decreasing A value)

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[1] Wernli et al., *SAL - A Novel Quality Measure for the Verification of Quantitative Precipitation*, 2008, Mon. Weather Rev.

Summary

- The observed Raikoke 2019 volcanic cloud by TROPOMI is captured well by the NAME dispersion model simulations in terms of the main structure and location.
- NAME underestimates the SO_2 mass burden of the eruption after 3 days when emitting 1.5Tg of SO_2 (VolRes1.5). A better comparison on longer timescales is obtained when using an emission of 2.0Tg of SO_2 (VolRes2.0).
- The NAME simulations overestimate the cloud diffusion (large S value in the SAL-score), resulting in too low vertical column densities on longer timescales.
- Reducing the parameterised mesoscale diffusion improves model skill, indicating that the constant free atmosphere mesoscale diffusion parametrisation in NAME is potentially too strong for eruptions emitting sulfur into the upper troposphere/ lower stratosphere.

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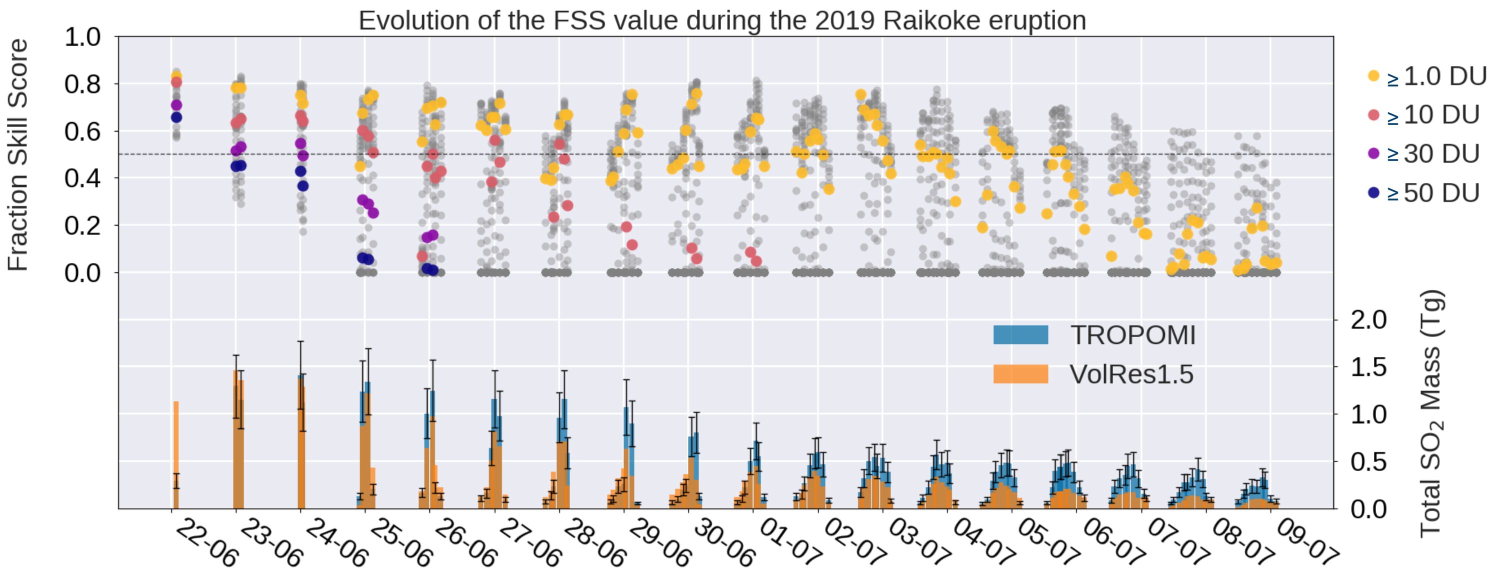
Additional slide: Fractional Skill Score

- Fractional skill score[2] shows the comparison between two fields (VolRes1.5 and TROPOMI) based on spatial (horizontal) pattern of the plume.

- A value for FFS > 0.5 shows significant skill of the model.



Time evolution of the FSS and the SO_2 mass for each individual overpass of TROPOMI. Each annotated date represent 00UTC. Grey dots represent all concentrations between 0.3 and 100 DU.

- The VolRes1.5 simulation and TROPOMI compare well during the first ~10 days for low vertical column densities (VCD < 5 DU).

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[2] Roberts and Lean, *Scale-Selective Verification of Rainfall Accumulations from High-Resolution Forecasts of Convective Events*, 2008, *Mon. Weather. Rev.*