The Effect of using a New Parameterization of Nucleation in the WRF-Chem model on the Cluster Formation Rate and Particle Number Concentration in a Passive Volcanic Plume

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EGU, 19-30 April 2021

Introduction/Objective

- **Volcanic emission** (in both active eruption and passive plumes) is one of the main natural sources of atmospheric **primary or secondary particles**.
- Evidence of **New Particle Formation (NPF) from volcanic emission** is reported in previous studies (Boulon et al., 2011; Sahyoun et al., 2019; Rose at al. 2019), which also suggests an essential role of sulfuric acid in this process.
- It is predicted that the **number and size of the cloud droplets, cloud growing and precipitation processes** might be affected by the frequency of occurrence and characteristics of volcanically induced NPF in both local and regional scales.

Main Steps of the project

Step1: Development of a parametrization based on the aircraft observations

- **The Strong connection** between **the cluster formation rate** and **sulphuric acid** (SA) concentration was evidenced, based on airborne measurements performed in the passive degassing plumes of Etna by **Sahyoun et al. (2019)**, who derived a **new parameterization of nucleation** for these specific conditions: $\mathbf{J = 1.844\times10^{-8}\ [SA]^{1.12}}$

Step2: Preliminary simulation test (Planche et al. (EGU, 2020))

- The new parameterization was implemented in the **WRF-Chem model**. The first simulation provides an adequate model configuration to study the **cluster formation rate** and **particle number concentration** in various size ranges, including CCN (i.e. climate-relevant) sizes.

! **activation mechanism** (Kulmala et al., 2006; Sihto et al., 2006) available in WRF-Chem as default: $\mathbf{J = 2.0\times10^{-6}\ [SA]}$

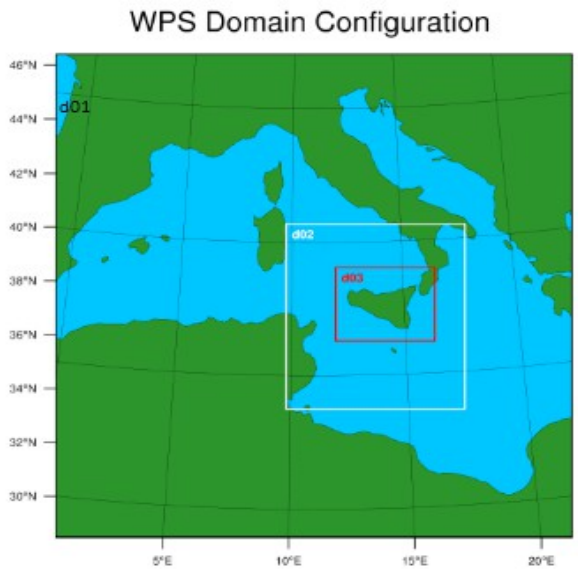
Current Work

- Implement the SO2 source at the Etna location and evaluate the H2SO4 concentration (the main NPF gaseous precursor)
- Compare the results obtained with the NPN to the aircraft observations.
- Assess the NPN effect on the cluster formation rate and particle number concentration including CCN.

Model set up/Simulations

Configuration of the model

- WRF-Chem version 3.9
- 3 nested domains (1km resolution for d03);
- **Developed Aerosol module: MOSAIC with 12 bins (1 nm – 10µm)** ;
- Chemical mechanism: SAPRC99 , no aqueous phase chemistry;
- Meteorological conditions: ERA-Interim (forcing every 6 hours);
- **Continuous SO2 flux released from Etna grid point, representing a total of 0.4 kT/day, consistent with observations** (Carn et al., 2017)**.**
- Simulation time : 3 days (2 days spin-up) from 13 to 15 June 2016



***Implement of SO2 flux*= 4.10*10e+5 mol.km-2.hr-1**

! Other sources for SO2 emission such as biogenic and anthropogenic are ignored

WRF-Chem set-up with new parametrization of Nucleation (NPN)
(Sahyoun et al., 2019., Planche et al. (2020))

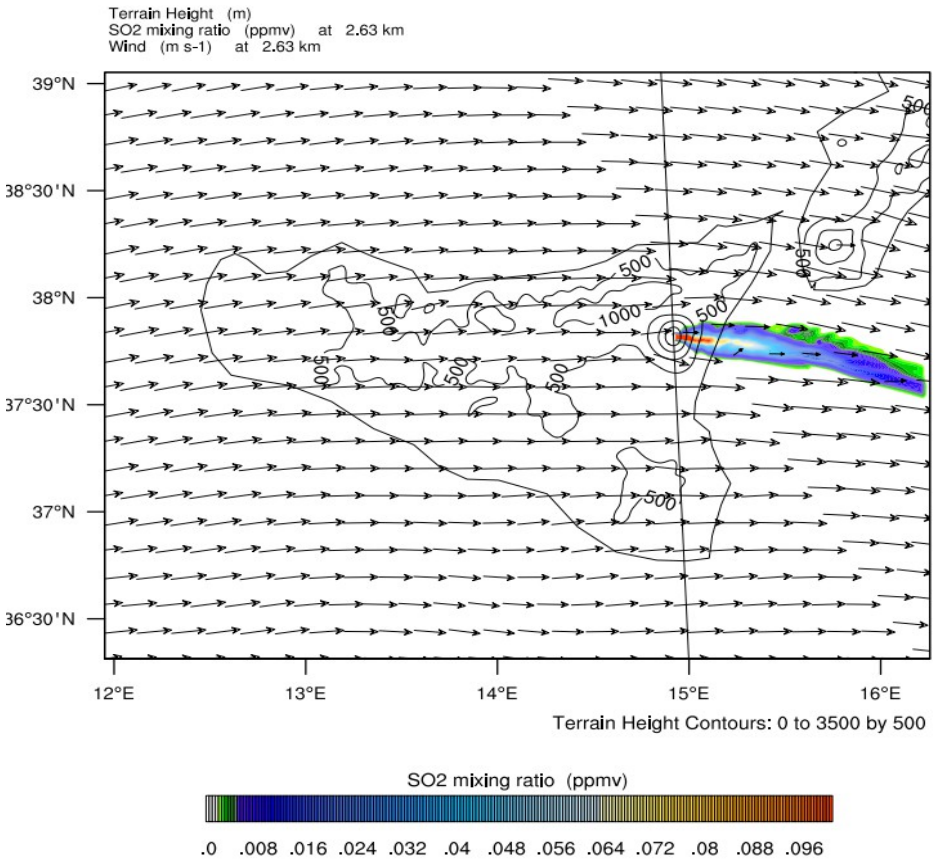
→ **Perform simulations with SO2 volcanic passive emission file**

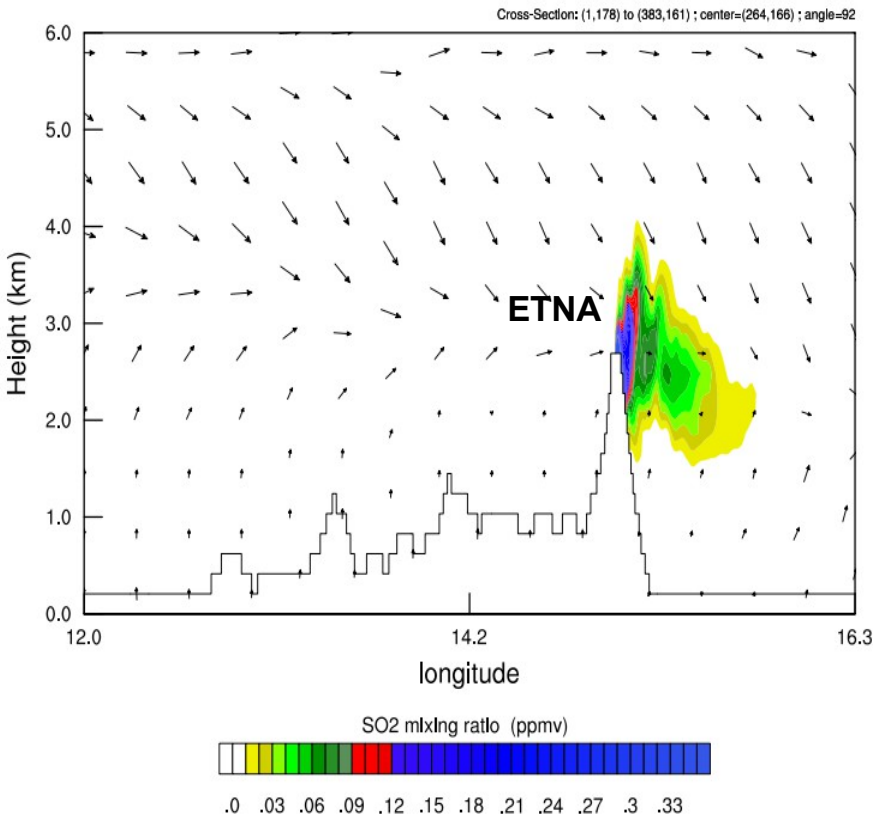
→ **Model Validation for SO2 and H2SO4 using field measurement**

→ **Evaluate the influence of newly formed and grown particles on cloud formation and properties based on numerical simulations**

Simulation results

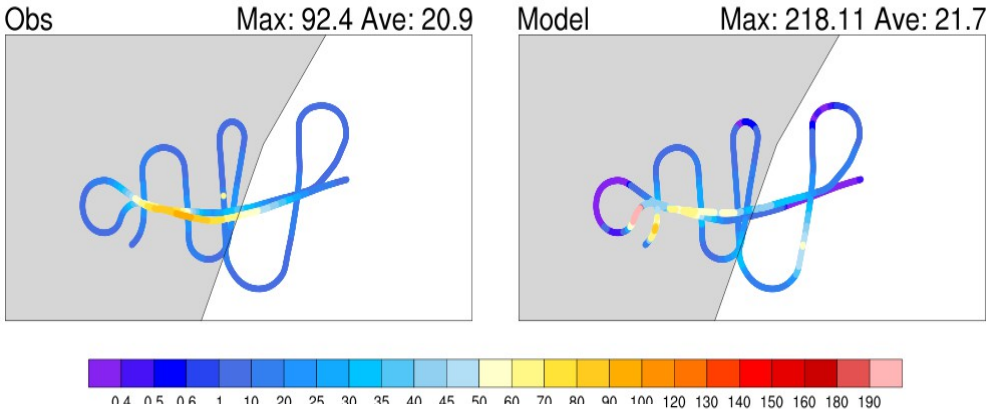
Horizontal and Vertical Cross sections of SO2





The plume is visible in the simulations with a high concentration close to the vent.

Comparison of observation vs. simulation along the flight path



SO2 (ppbv)

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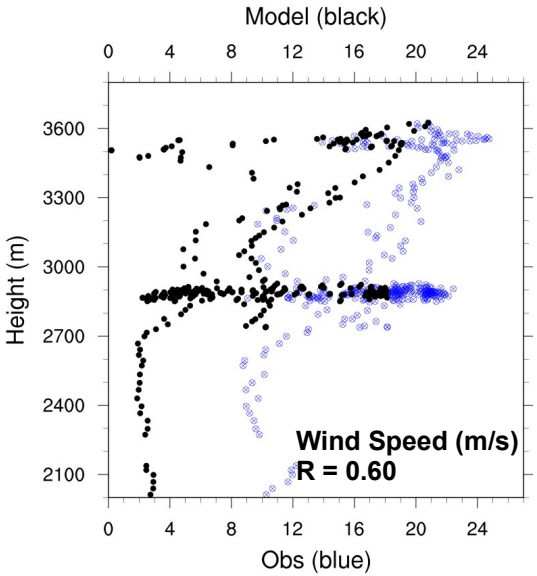
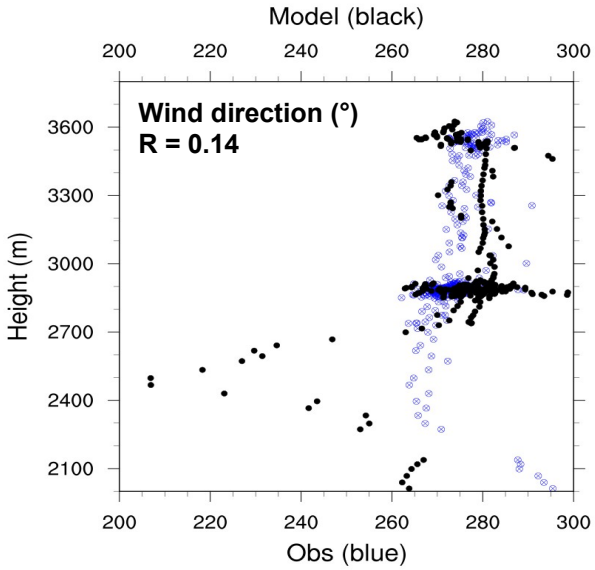
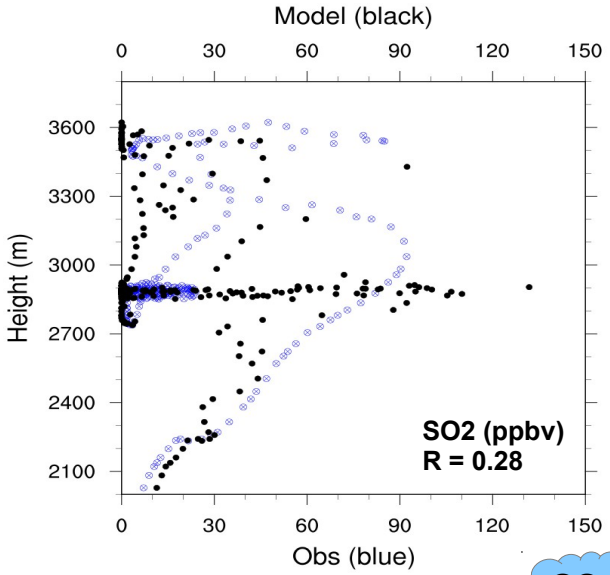
- **Spatial variations** are **well simulated**.
- **Overestimation** of **SO2 concentration** close to the vent.







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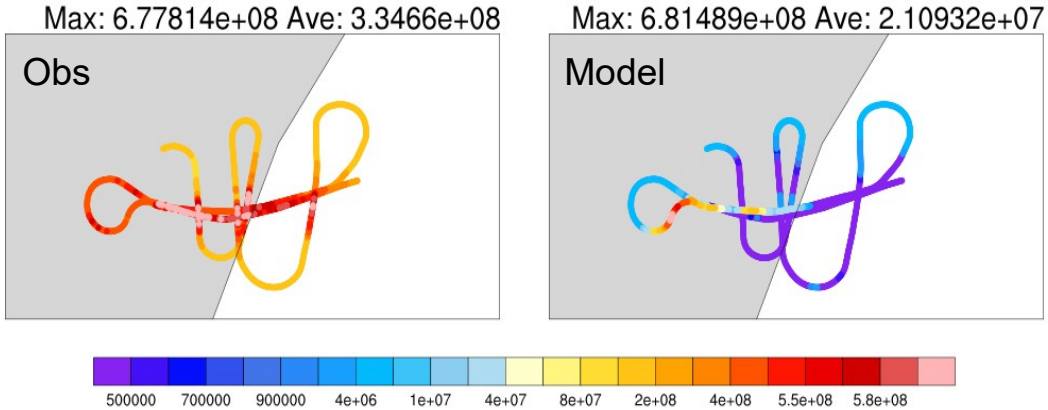
Underestimation of wind speed >>>> lower dispertion rate >>>> SO2 overestimation close to the vent

Southward shift of simulated wind >>>> mistmatch between flight path (observed plume) and simulated volcanic passive plume

! Mistmach between the real height of the vent and model set-up (3300 m vs. 2620 m)

! Find the best approach for model validation

Comparison of observation vs. simulation along the flight path



H2SO4 (molec/cm3)

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- **Variations** are **not well reproduced** by the model.
- **Absolute concentrations** predicted by the **model** are **lower** compared to observations.

Future work

The oxidation rate of SO2 is underestimated in different chemical options in WRF-Chem

→

Underestimation of new particle number in the passive plume due to the underestimation in SA

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! increase the gas-phase oxidation rate of SO2 in the model configuration In order to study new particle numbers