

# Geo-INQUIRE Transnational Access Project Report: 4D modelling volcanic plume on Venus from Maxence Lefevre (LATMOS, France)

**Project report ID:** C3-TA2-531-2-1 (1<sup>st</sup> Call)

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**Project title:** 4D modelling volcanic plume on Venus

**Project acronym:** 4D-MOVPOV

**Hosting installation:** [\(TA2-531-2\) OpenFOAM Applications in Volcanology](#)

**Hosting team:** Matteo Cerminara (Istituto Nazionale di Geofisica e Vulcanologia, Pisa)

**Period of access:** 12-25 Oct. 2025; 22-28 Feb. 2026

## **Report of activities:**

The ASHEE volcanic plume column model<sup>[1]</sup> was successfully used in the hot and dense Venusian environment. This is the first time that a transient 3D plume model was applied to Venus.

As input, vertical profiles of the temperature, pressure, zonal winds and density have been extracted from the Venus Climate Database<sup>[2]</sup>. Based on a 1D column eruption study<sup>[3]</sup>, conditions at the vent were selected to study a stable plume, a collapsing plume and a partially collapsing plume. The dynamics of such explosive volcanic eruption scenarios was studied by varying wind shear, plume volatile mass fractions and composition, pyroclasts grain size distribution, vent height, and magma temperature. The specific heat of Venusian atmosphere has been modeled both as a constant and a function of temperature, as already done in 1D<sup>[3]</sup>. In total 20 simulations were performed in the local and national HPC.

With the 3D ASHEE Large Eddy Simulations model, one can free oneself of parametrization of entrainment and resolve the vertical propagation of a volcanic plume, resolving transient dynamics and partial collapses. Under extreme vent conditions (mass flow rate, exit temperature and velocity), the 3D plume can reach the clouds (48-70 km), as seen in Fig. 1, both with and without wind shear. There are significant discrepancies between the height reached by the plume in 1D versus 3D. This could mean that the parametrization of entrainment valid for the Earth

atmosphere is not valid for the Venus environment. New entrainment coefficients will be established. For different conditions at the vent, there is either a total collapse of the plume, a partial collapse, or the generation of a secondary plume from the collapsing ash cloud. The impact of the ash solid particle on the radar reflectivity will be quantified. This study will lead to a peer-reviewed publication.

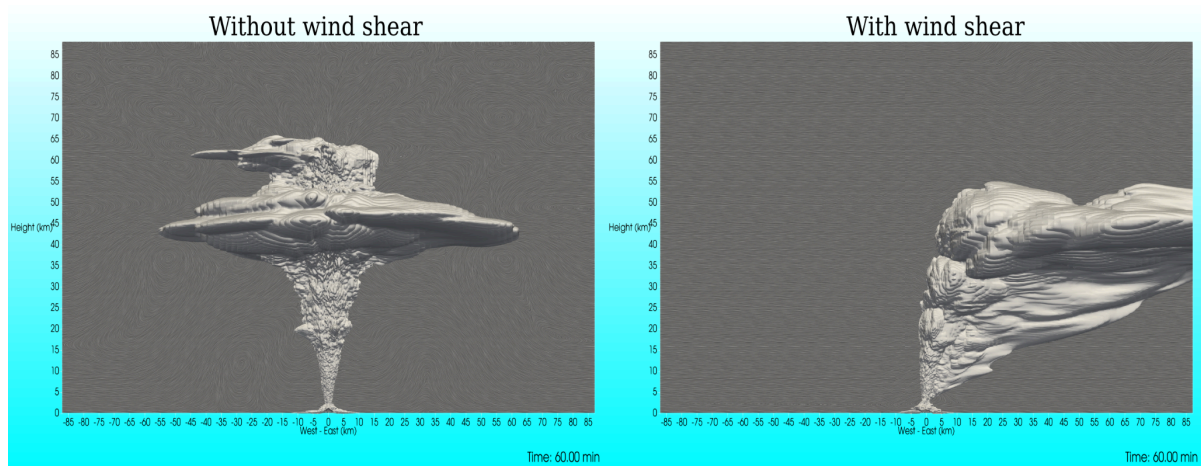


Figure 1 - Instantaneous fine ash bulk density equal to  $2 \text{ mg/m}^3$  iso-surface of a plume without (left) and with wind shear (right)

A parametrisation for volcanic plumes will be extracted from ASHEE simulations, to be used in the 1D Venus Planetary Climate Model<sup>[4]</sup> to establish the impact of such an eruption on the observable cloud chemistry. The impact of water and sulfur dioxide injection on the clouds will be studied with a comprehensive photochemical model. The results will be compared to the decadal variation of sulfur dioxide measurements at 70 km<sup>[5]</sup>. This study will lead to a peer-reviewed publication.

Volcanic eruptions generate a spectrum of waves in the atmosphere, from infrasound to gravity waves. The characteristics of those waves were never established for Venus. With the ASHEE model, these waves are resolved, as the gravity waves seen in Fig. 2. This study will lead to a peer-reviewed publication.

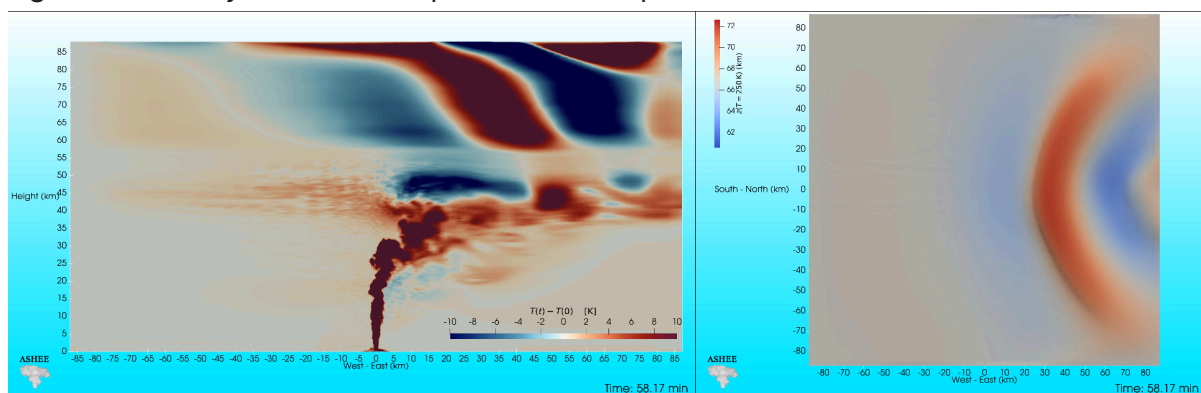


Figure 2 - Instantaneous vertical cross-section of the temperature perturbation (left). Instantaneous height of the 250 K temperature level (right)

The study of the exotic, hot, sulphur cycle of Venus is a priority of the European, U.S. and international scientific community, with the observations of active volcanism the primary target. The ESA's EnVision, and two NASA missions, DAVINCI and VERITAS, were all three selected to launch around 2031. The result of this project will be crucial for the community, and orders of magnitude of several key parameters (plume height and concentration, ash dispersion, gravity waves amplitude, ...) will be estimated.

#### References:

- [1] Cerminara, M., Esposti Ongaro, T., and Berselli, L. C., 2016: ASHEE-1.0: a compressible, equilibrium–Eulerian model for volcanic ash plumes, *Geosci. Model Dev.*, 9, 697–730, <https://doi.org/10.5194/gmd-9-697-2016>
- [2] Lebonnois, S., Millour, E et al.,. Venus Climate Database 2.3 [http://www-venus.lmd.jussieu.fr/vcd\\_python/](http://www-venus.lmd.jussieu.fr/vcd_python/)
- [3] Lefèvre, M., M. Cerminara, and A. Costa, 2025. Eruption Column Modeling of Explosive Volcanism on Venus. *Journal of Geophysical Research (Planets)*, 130, e2025JE009320. <https://doi.org/10.1029/2025JE009320>
- [4] Stolzenbach, A., F. Lefèvre, S. Lebonnois, and A. Määttänen, 2023. Three-dimensional modeling of Venus photochemistry and clouds. *Icarus*, 395, 115447. <https://doi.org/10.1016/j.icarus.2023.115447>
- [5] Marcq, E., J.-L. Bertaux, F. Montmessin, and D. Belyaev, 2013. Variations of sulphur dioxide at the cloud top of Venus's dynamic atmosphere. *Nature Geoscience*, 6, 25. <https://doi.org/10.1038/ngeo1650>

#### **Project outcomes:**

The data generated by the ASHEE model are stored in the online database doi: [10.82554/sdl-441.493](https://doi.org/10.82554/sdl-441.493)

Four papers are in the writing phase to be submitted to open-access peer-reviewed journals.

The results of the project will be presented at several international workshops/conferences: VenSpec meeting in Mars 2026 and EPSC 2026.