Growth and persistence of strastopheric sulfate aerosols from the 2022 Hunga eruption until today

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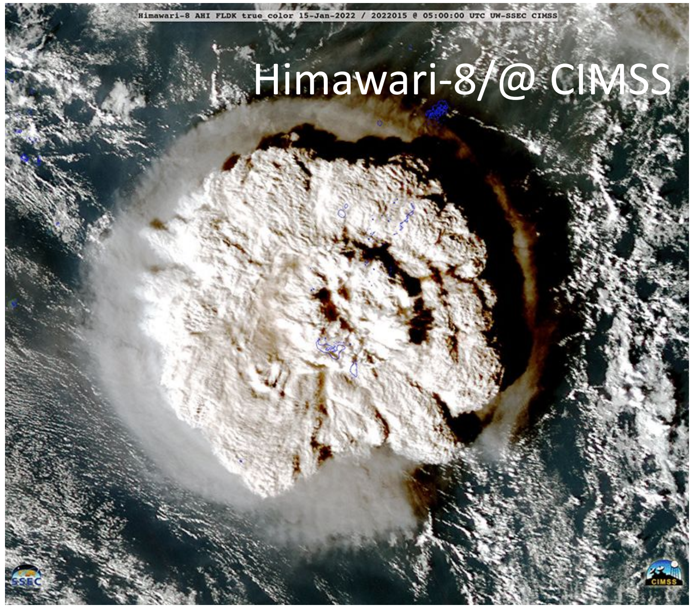


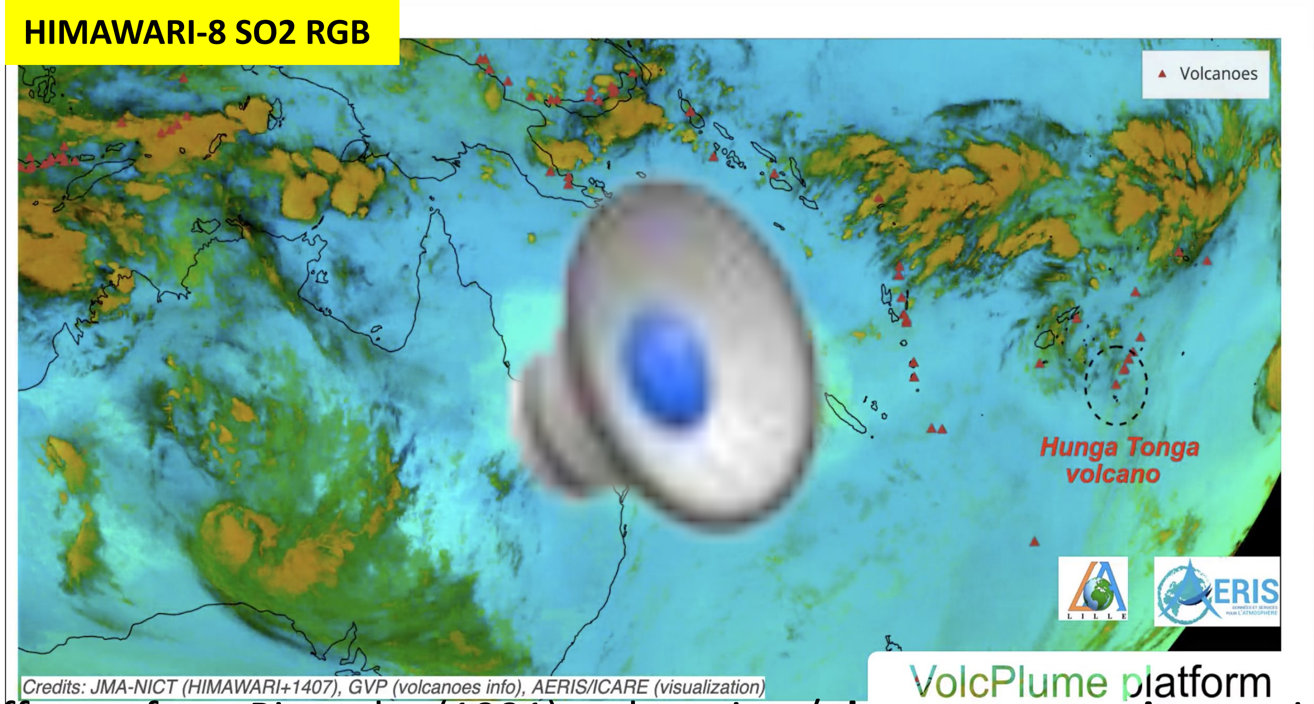
15 Jan 2022

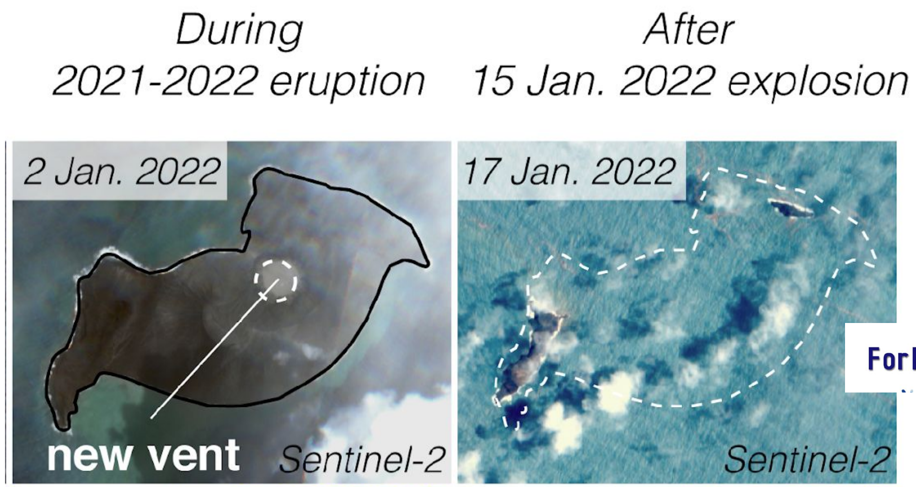
Support from: AERIS, H2020 E-shape, Horizon Europe EOSC FAIR EASE, CaPPA Labex, CNES, HDF region

AERONET
AEROSOL ROBOTIC NETWORK

AERONET Science & Application Exchange, Washington, 17 09 2024

Eruption of Hunga Tonga-Hunga Ha'apai (15 Jan 2022): a record breaking eruption in the satellite era





Courtesy R. Grandin (IPGP)

Different from Pinatubo (1991), submarine /**phreatomagmatic** eruption :

⇒ High **explosivity**: plume up to 57 km of altitude (Carr et al. 2022, Taha et al. 2022)

⇒ Plume very rich in **water** => exceptional hydration of the stratosphere

⇒ Also very high abundance of sulfate aerosols in the stratosphere !


@ Tonga Geological Survey

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Key questions and outline of talk

- **Impact of Hunga Tonga eruption on climate ?**

- **Size and persistence of sulfate aerosols: crucial input parameters for models but poorly-known**

We develop a **synergistic analysis of satellite** (S5P/TROPOMI, MetOp/IASI, HIMAWARI-8/AHI, CALIPSO/CALIOP)

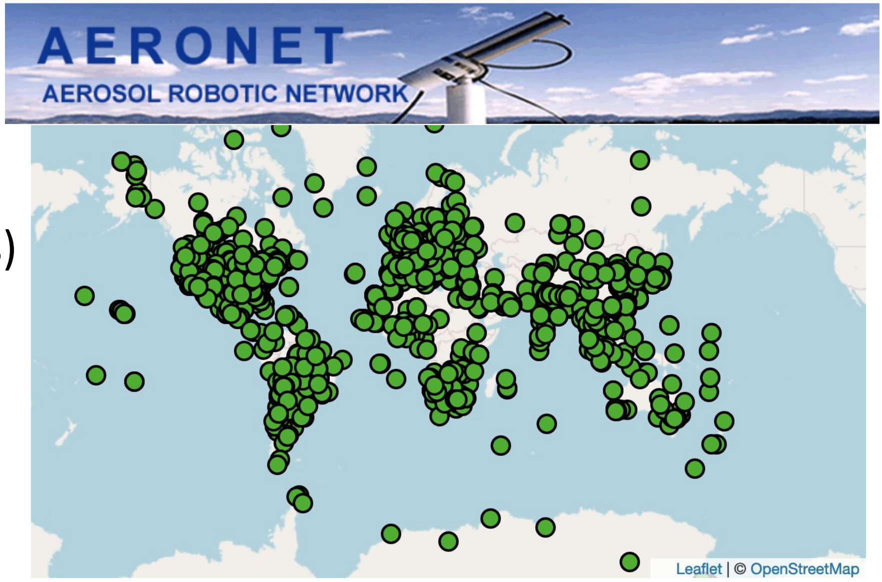
& **ground-based** column-integrated observations of the open-access **AERONET network of sun/sky/lunar photometers**

=> AERONET data allowed us to accurately **track <u>from the ground</u> the detailed size of Hunga <u>stratospheric</u> aerosols** !

1- **Aerosol growth rate** during 1st week after eruption
(eg. 1st plume circumnavigation of the globe)

2- **Aerosol persistence & size** over 2.2 years after eruption (time of analysis)
3- Comparison with **Pinatubo** and other stratospheric eruptions

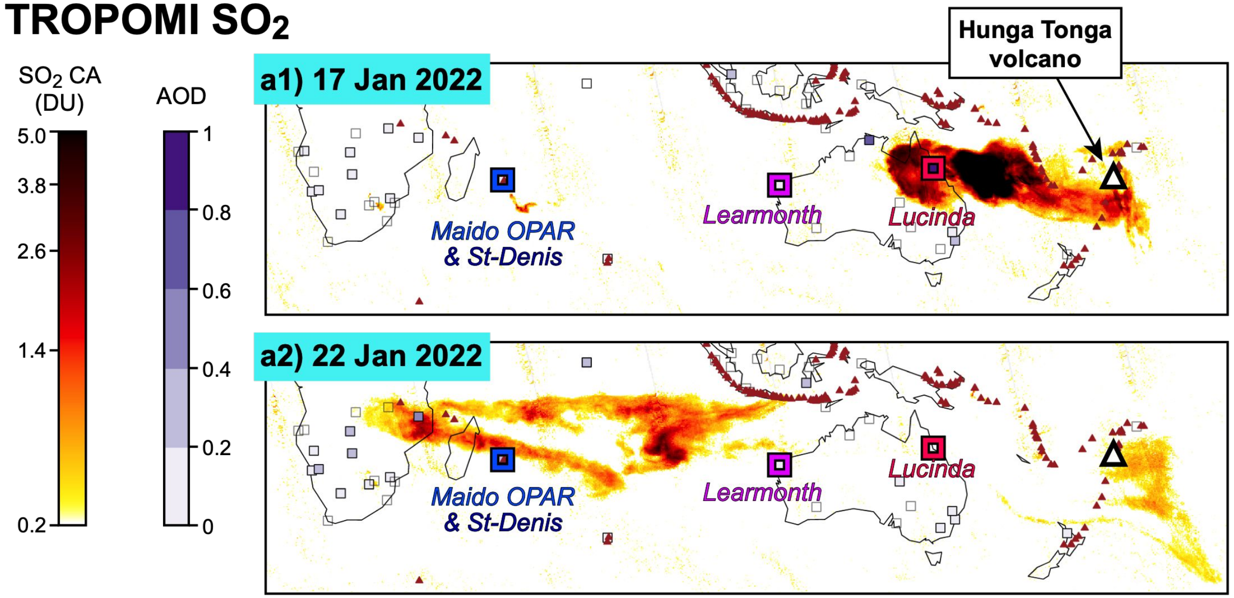
4- Aerosol persistence also in **Northern Hemisphere and Antarctica**



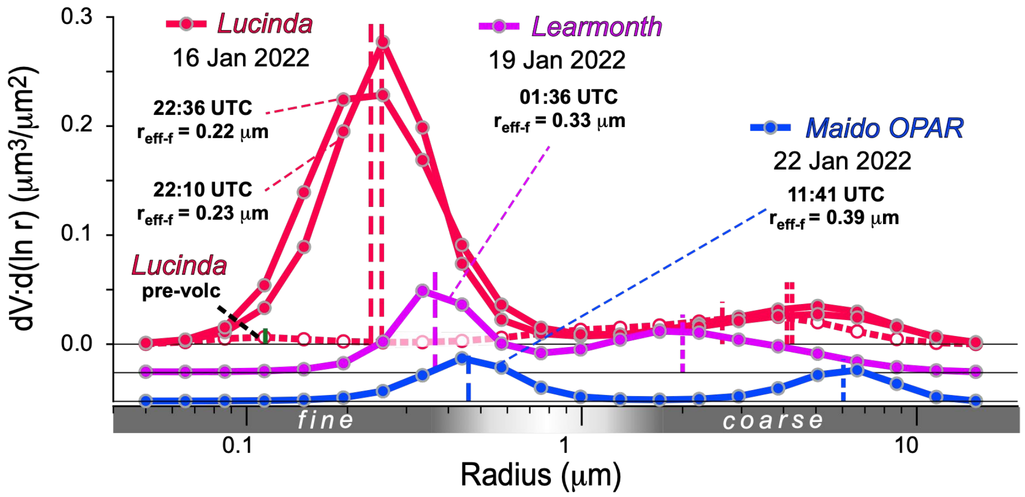
Boichu et al., 2023, https://doi.org/10.1029/2023JD039010
Boichu et al., in prep for GRL (HT aerosol properties in NH and Antarctica)

1- A fast growth of Hunga sulfate aerosols (over 7 days after eruption)

TROPOMI SO_2



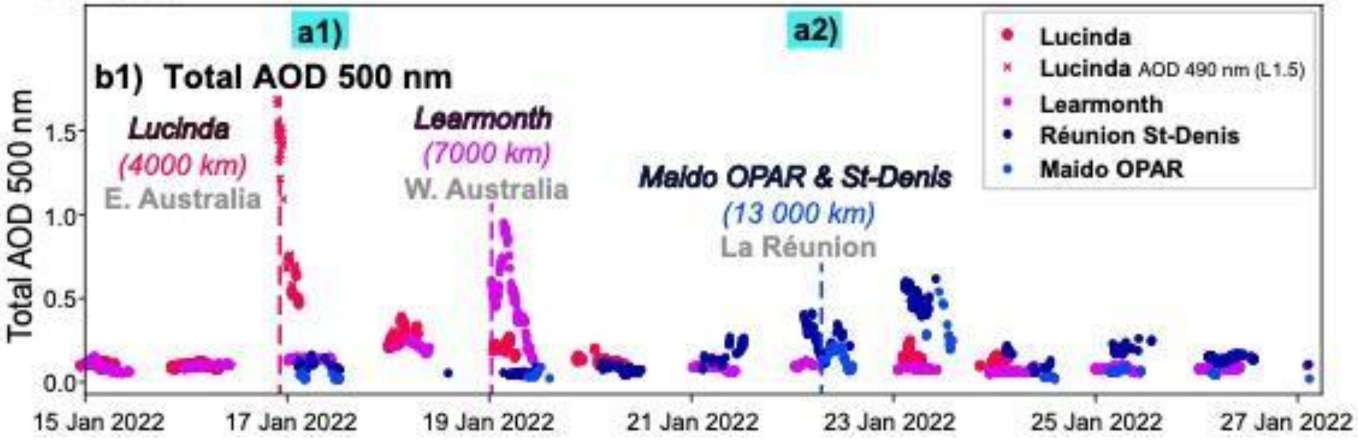
Aerosol volume size distribution



AERONET multi-station analysis using VOLCPLUME portal:

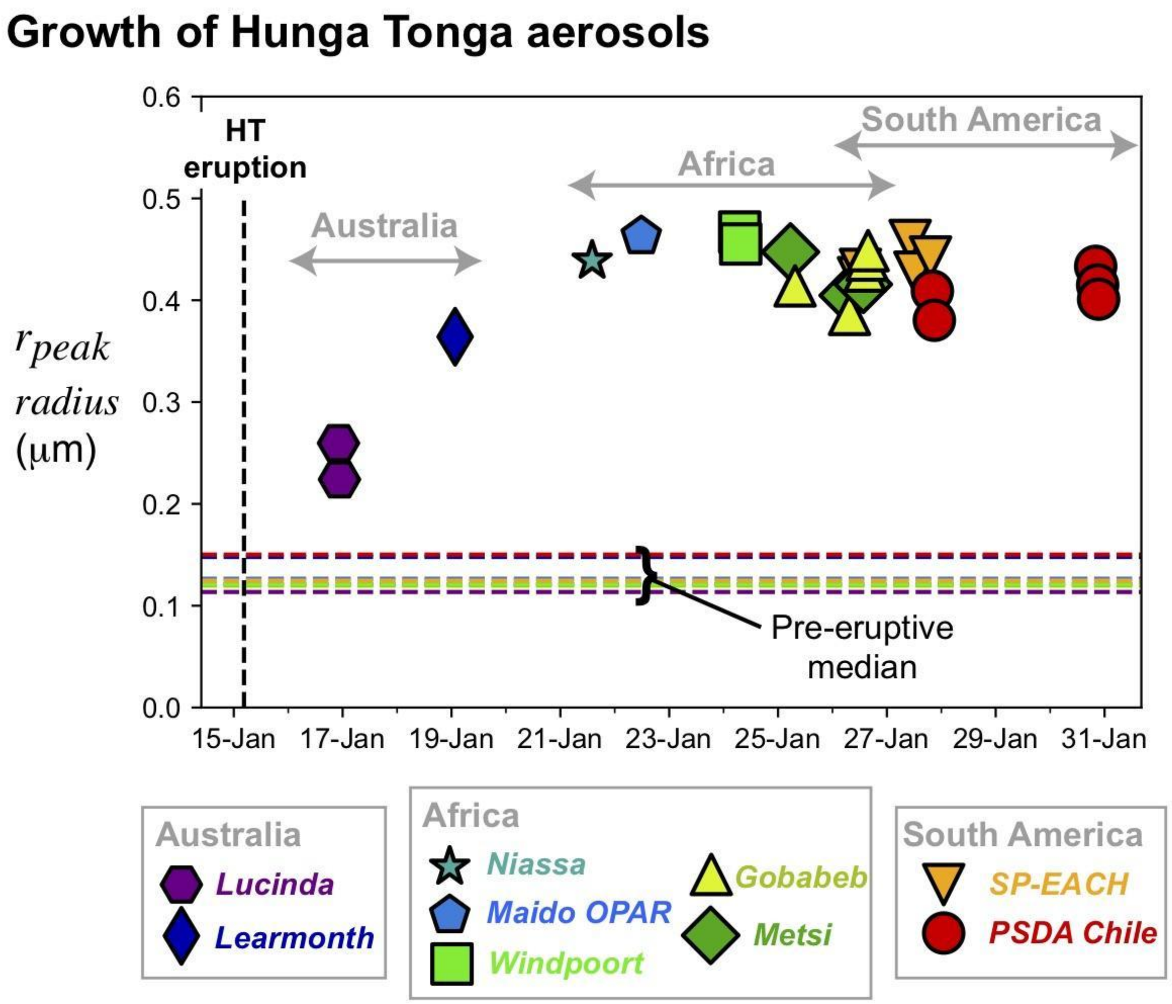
https://volcplume.aeris-data.fr

AOD 500 nm



- Unusual fine mode of volcanic origin (poorly-absorbing, SSA_{440nm}>0.97)
- Hunga aerosol effective radius almost doubles in 6 days from Eastern Australia (+ 1 day after eruption) to La Réunion island (0.22 to 0.39 µm)

1- A faster growth rate of Hunga sulfate aerosols than observed for past stratospheric eruptions

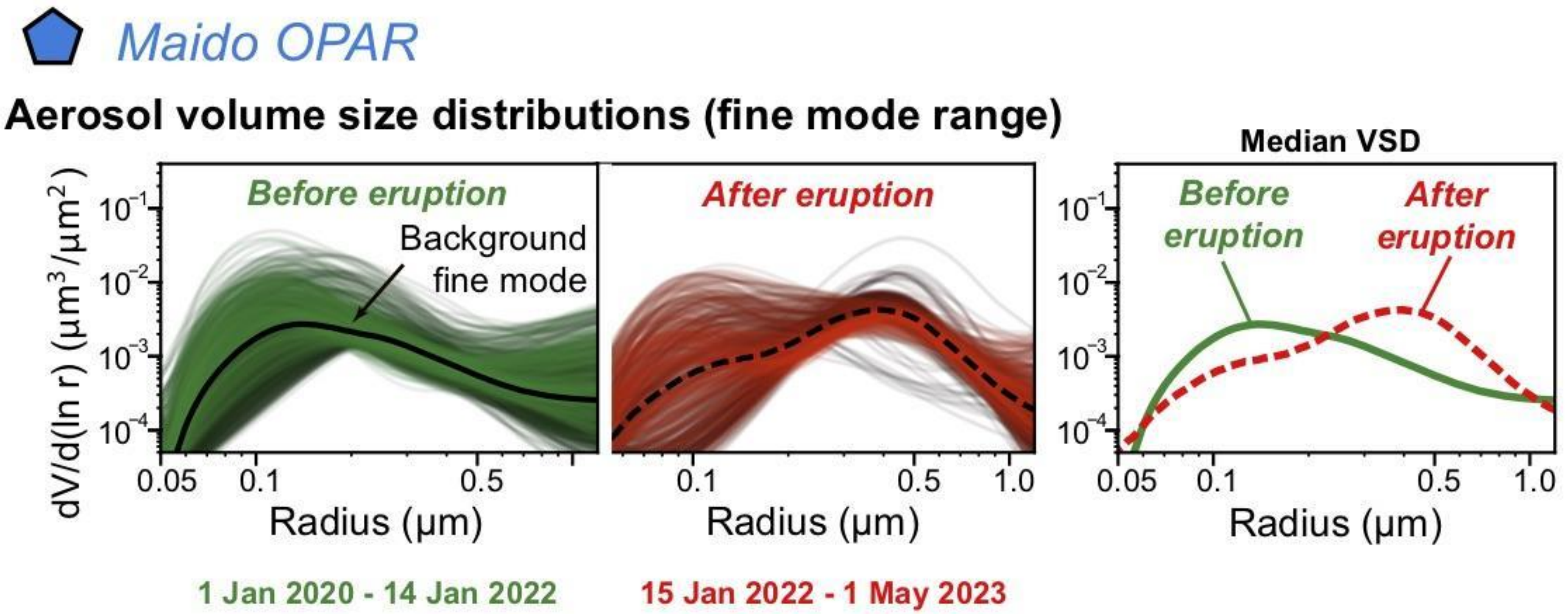


- After rapid growth, stabilisation of Hunga sulfate aerosol size (< 0.50 μm) over 2 weeks
- Faster aerosol growth than observed for other stratospheric eruptions (Pinatubo, Kasatochi, Sarychev, etc…)
- Increased sulfate formation/growth likely due to water-rich plume (submarine eruption)

2- A persistent unusual fine mode of volcanic origin in the years following eruption

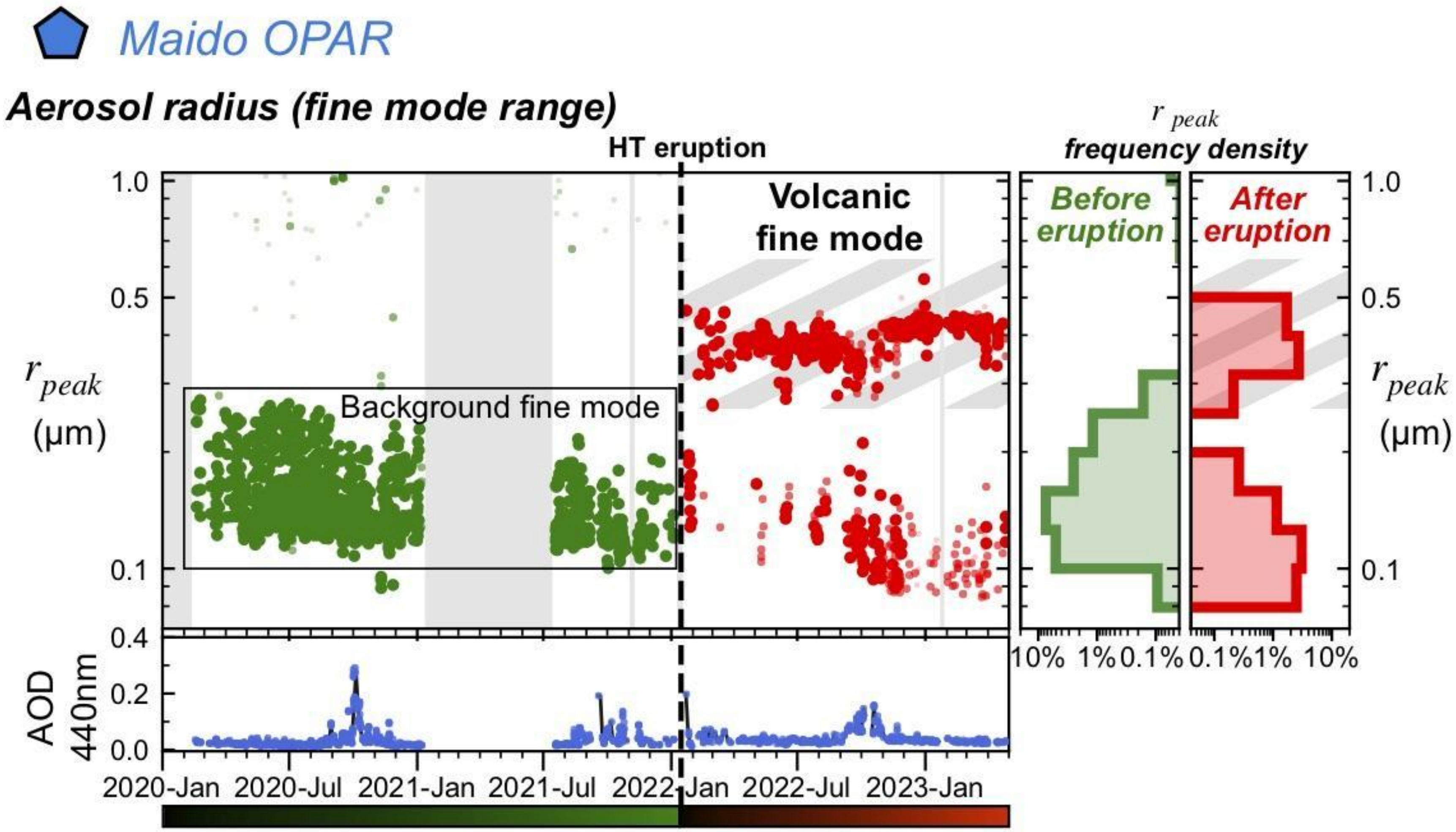
Maido OPAR station (La Réunion island, Indian Ocean): pilot high-altitude station for stratospheric studies

(station PI: V. Duflot)



Stack of 1.3 yrs of data (Jan 2020-May 2023)

2- A persistent unusual fine mode of volcanic origin clearly distinct from background aerosols



 An unusual fine mode of volcanic origin, clearly distinct from background fine and coarse aerosols at Maido OPAR

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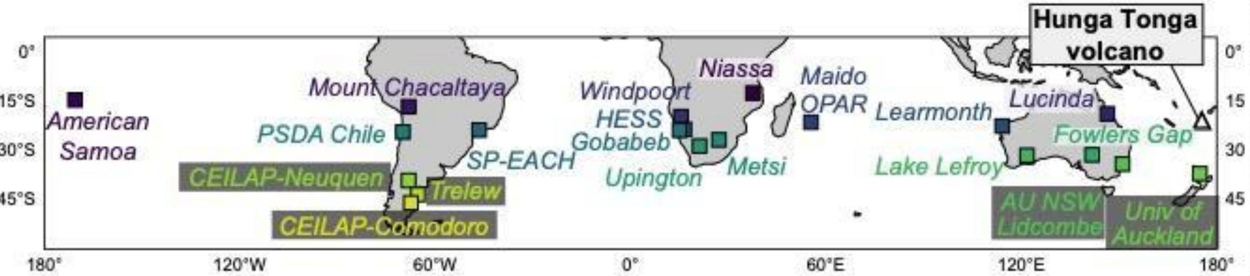
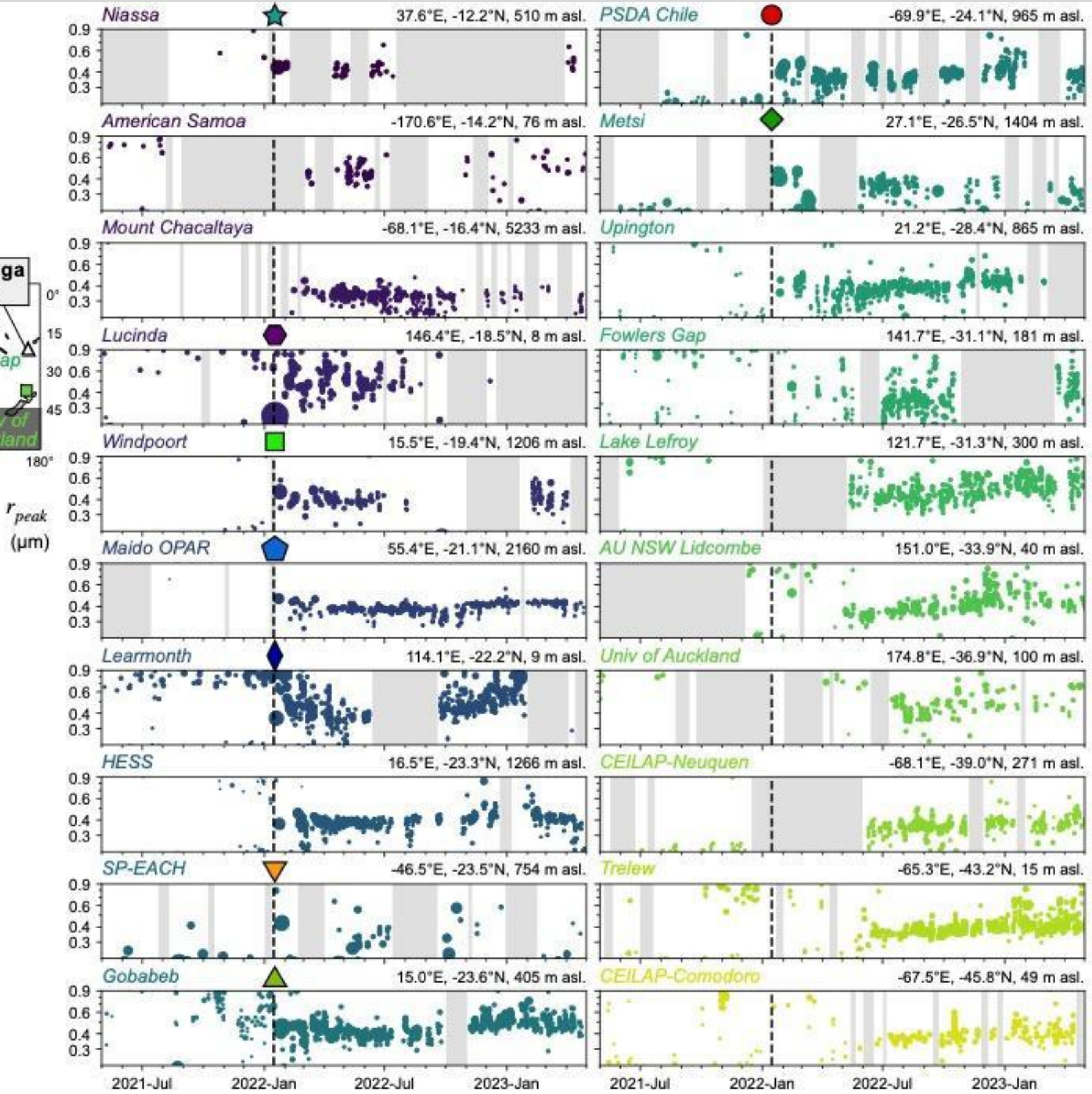
2- Hunga aerosol size determined at many stations of the southern hemisphere



- 20 stations in very different atmospheric conditions
- Time lag (> 3 months) for stations in the far South > 30°S (eg. AU NSW Lidcombe, Trelew)

A detailed spatial (and temporal) resolution on aerosol size

Aerosol radius with time



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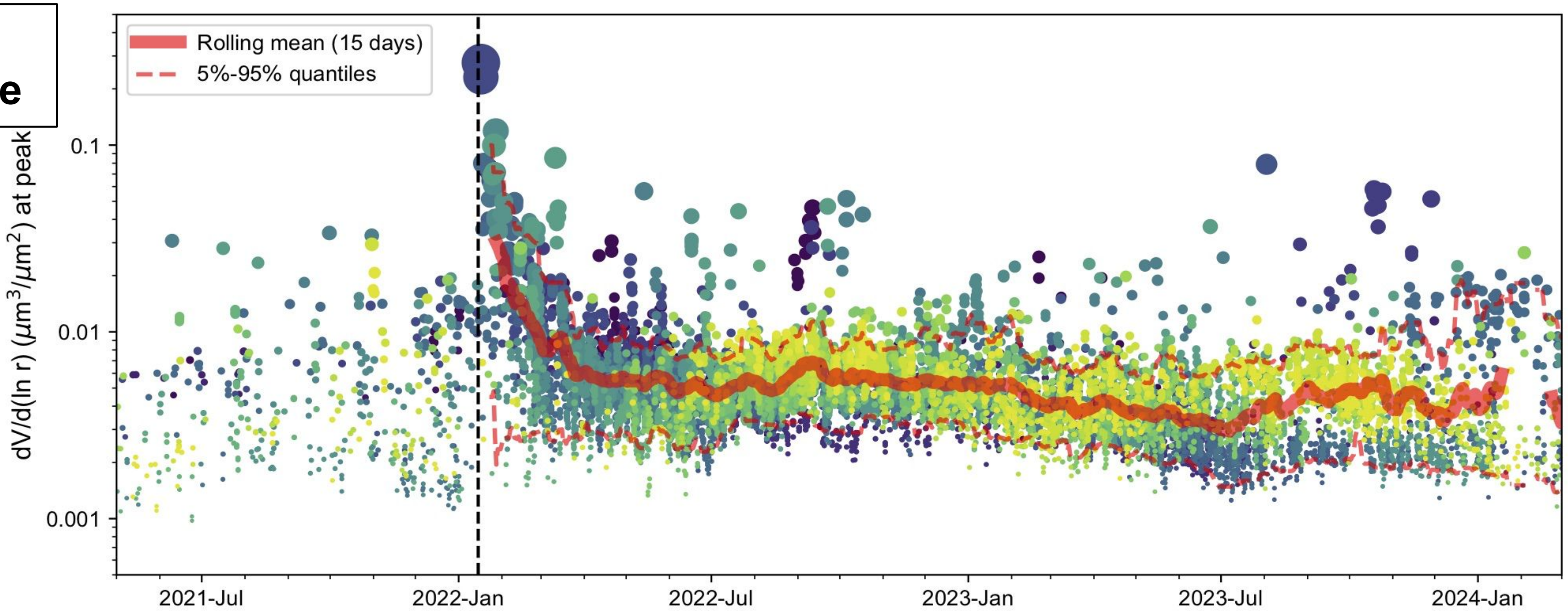
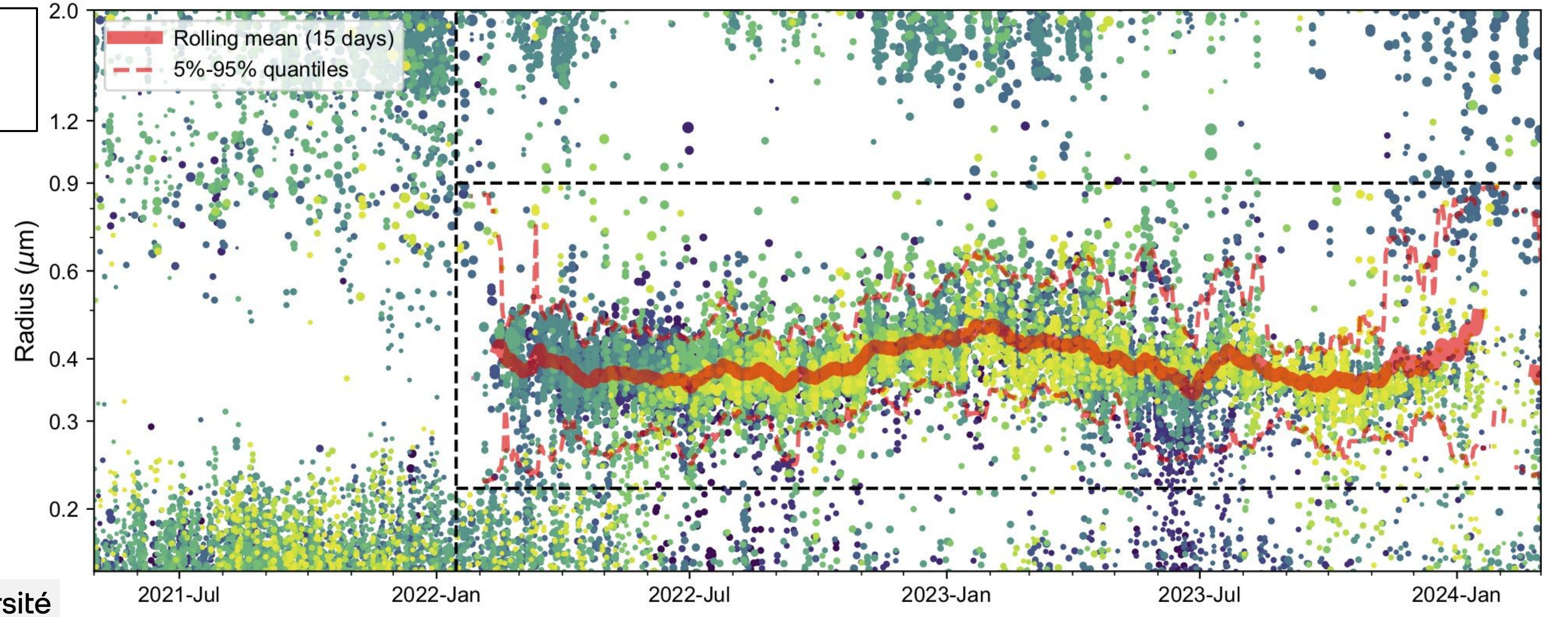
2- Year-long persistence of Hunga aerosols in the Southern Hemisphere until today (March 2024)

Aerosol abundance



Aerosol radius



Stack of data at 23 stations in SH, AOD<0.1 for radius

- Identification of volcanic fine mode at 23 AERONET stations of the southern hemisphere (different regions: Africa, South America, Australia, etc; very contrasted atmospheric environments)
- Hunga aerosols persist for >2.2 yrs (date of talk)
- Despite a decreasing particle load (x 1/25), a relatively stable radius of Hunga aerosols is observed, ranging in 0.35-0.50 μm.

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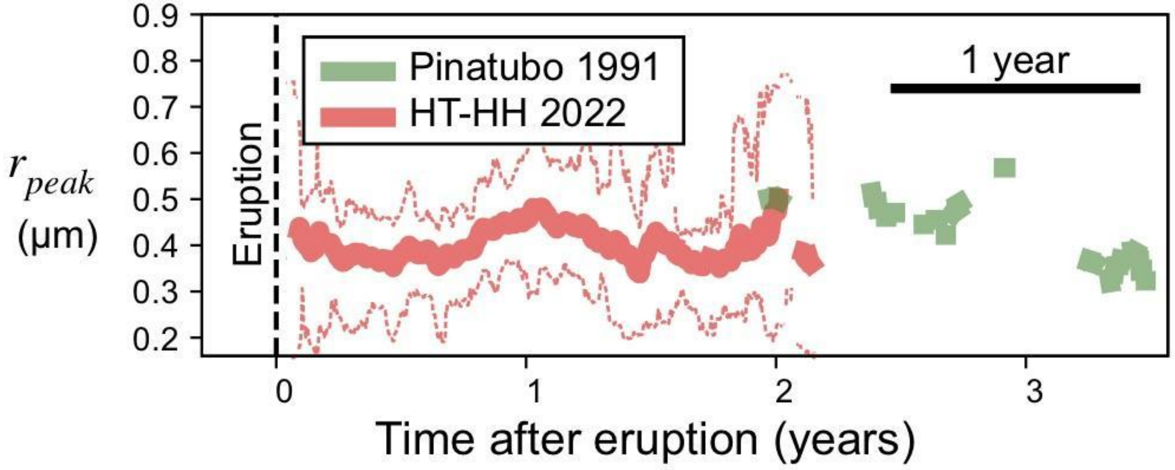
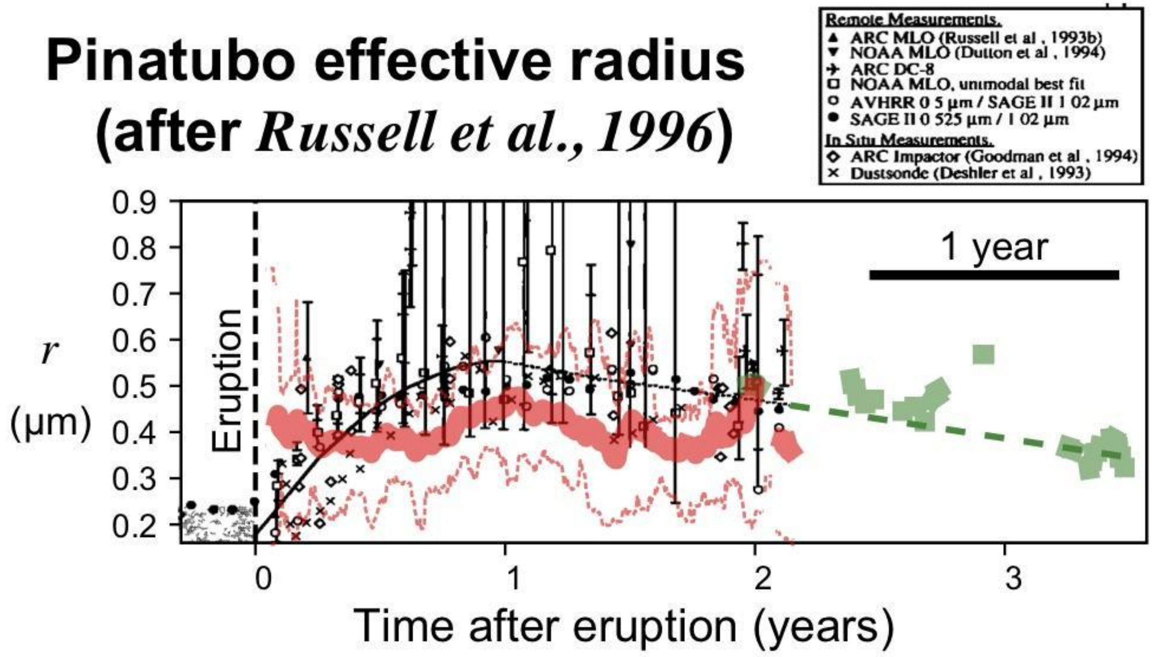
3- Retrospective analysis of the size of aerosols from the 1991 Pinatubo eruption (using AERONET data)

Comparison with Pinatubo eruption



Pinatubo effective radius (after *Russell et al., 1996*)



- Much faster growth of Hunga aerosols compared to Pinatubo
- 2.2 yrs after eruption: size of Hunga aerosols is smaller/similar to those of Pinatubo particles

Key results & perspectives

Boichu et al., 2023, https://doi.org/10.1029/2023JD039010
Boichu et al., in prep for GRL (HT aerosol properties in NH and Antarctica)

- ✔ Together with satellite observations, a multi-station analysis of ground AERONET photometric observations provides a detailed size distribution of Hunga aerosols over years, not accessible with such temporal/spatial resolutions from satellite occultation or limb-scattering observations (eg. SAGE III)
- ✔ Aerosol size in agreement with in situ balloon-borne POPS measurements (APARC report on Hunga eruption for IPCC, chapter 2, *under review*)
- ✔ In crisis time, the AERIS **VolcPlume Web Portal** was fundamental to support a near-real time response (Lac et al. 2022)
- ✔ Faster growth of Honga sulfate aerosols (almost doubling in 6 days) than Pinatubo particles
- ✔ Honga sulfate aerosols persist for >2.2 yrs, as identified at many AERONET stations of the Southern hemisphere, and of the Northern hemisphere, also in Antarctica!
- ✔ Relatively stable radius of Honga sulfate aerosols, ranging in 0.35-0.50 μm (over >2.2 yrs)
- ✔ 2.2 yrs after eruption: Hunga aerosols appear smaller than Pinatubo particles
  - backscatter more efficiently visible light
  - sediment more slowly than larger particles
    - ⇒ Longer-lasting negative radiative forcing/surface cooling due to sulfate aerosols ?
  - sAOD 6 times less than Pinatubo, but higher altitude (in 22-26 km?)

    ⇒ Strength & duration of climate impact ?

VolcPlume Portal: multi-scale NRT 4D monitoring & analysis of volcanic plumes

ANR & AERIS projects - PI: M. Boichu (LOA), main software engineer: T. Mathurin (AERIS/ICARE)

https://volcplume.aeris-data.fr (portal access) - https://www.icare.univ-lille.fr/volcplume/ (portal website)

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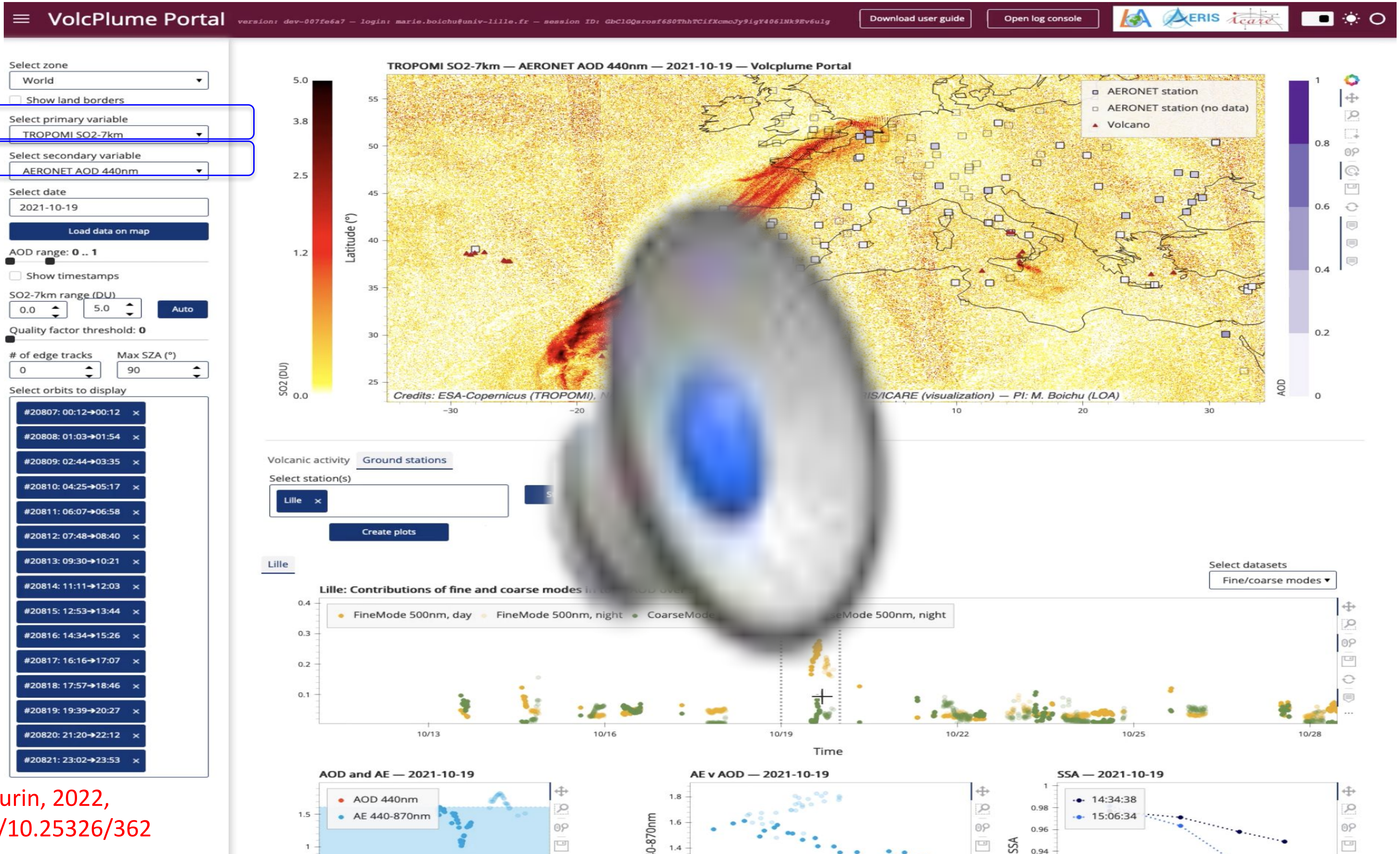
Satellite

Ground

remote sensing
+ in situ

- **Gas (SO_2)**
- **Particles**
- **Clouds**



Boichu & Mathurin, 2022,
https://doi.org/10.25326/362