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10–14 October 2022 | Taormina, Sicily (IT)

Analysis of the 2021 Cumbre Vieja eruption and the long-range transport of SO_2 to Europe using TROPOMI and ground-based measurements

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Taormina,10 October 2022

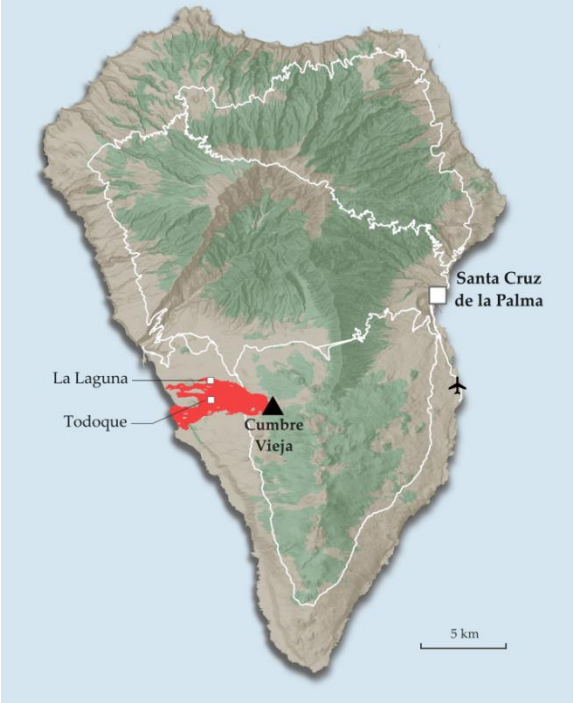
DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

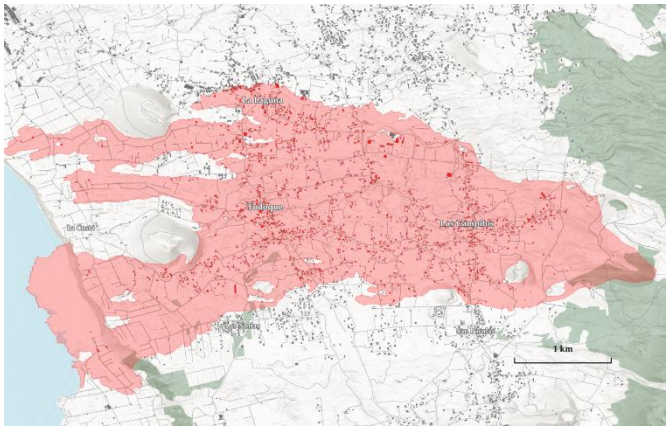
DWD

AEMet Agencia Estatal de Meteorología

La Palma volcanic eruption

- Eruption started on 19 September 2021 at 14:13h UTC in Cumbre Vieja volcanic ridge, and ended on 13 December 2021 (85 days)
- Eruption at several vents, with a variety of eruptive styles, from Strombolian to effusive with partly strong Strombolian and ash-rich explosions, lava effusion, ash and gas jets
- Evacuation of 7.000 people with a strong impact on public health and in the economy of the Island:
  Lava flows covered more than 1.200 ha



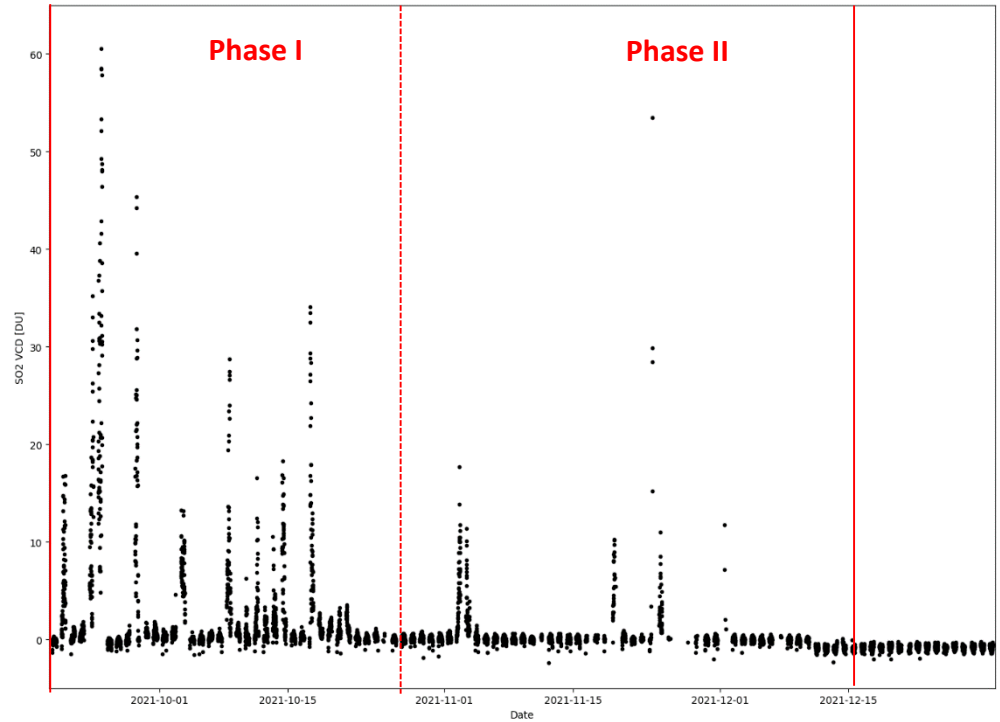


Cumbre Vieja volcanic eruption

Two different phases in terms of SO_2 emission rates:

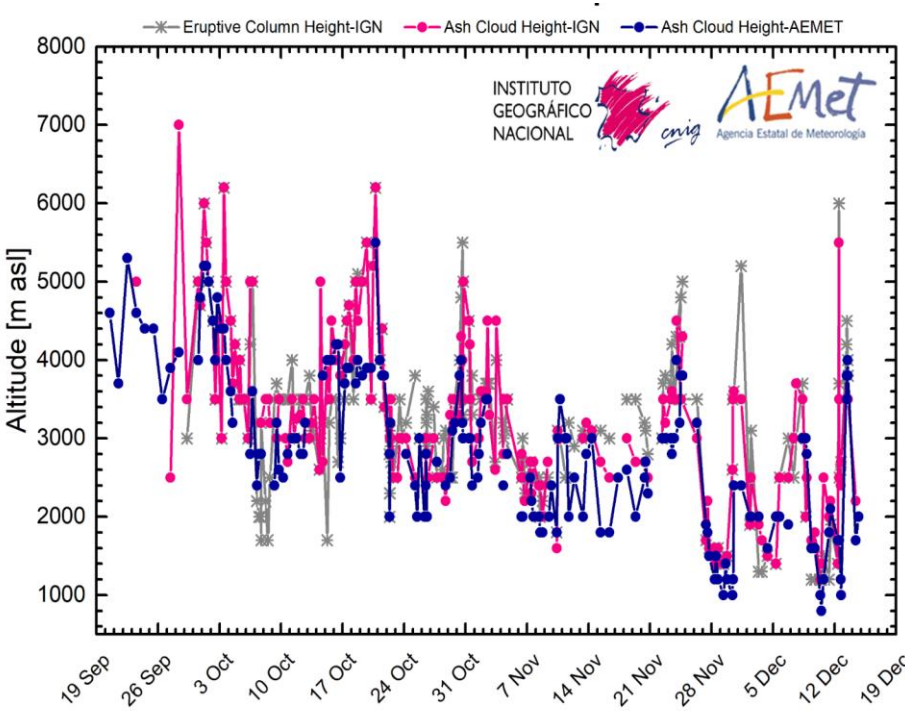
- **Phase I:** alternating **explosive and effusive activity**, emissions at different vents.
- **Phase II:** less energy in the volcanic system, more **effusive** activity (more lava flows, less aerosol and gas emissions)

Izana Brewer SO_2 measurements



Source: EUBREWNET

LIDAR ash measurements



Source: IGN, AEMET

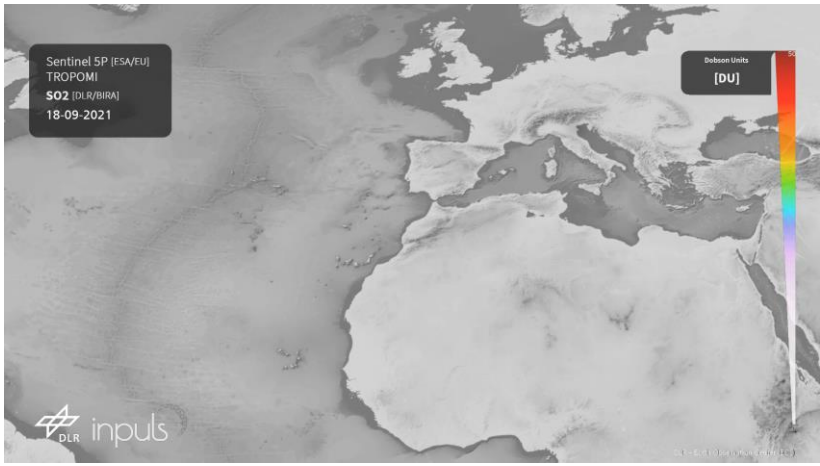
S5P/TROPOMI SO_2 column & LH retrieval

Operational SO_2 VCD retrieval (Theys et al. 2017)

- SO_2 SCD via DOAS fit
- SO_2 VCD via AMF for different scenarios
  - VCD for 15km LH (Explosive)
  - VCD for 7km LH (Moderate)
  - VCD for 1km LH (Weak & Degassing)
  - VCD for SO_2 in PBL (Anthropogenic)

Semi-operational SO_2 LH retrieval (Hedelt et al. 2019)

- Combined PCA & Neural Network retrieval
- Extremely fast & accurate
  - 3min / TROPOMI orbit
  - σ_{LH}<2km
  - SO_2 VCD > 20 DU
- DLR INPULS: Generation of NRTI L2 products
- Assimilation by ECMWF/CAMS (Inness et al. 2022)



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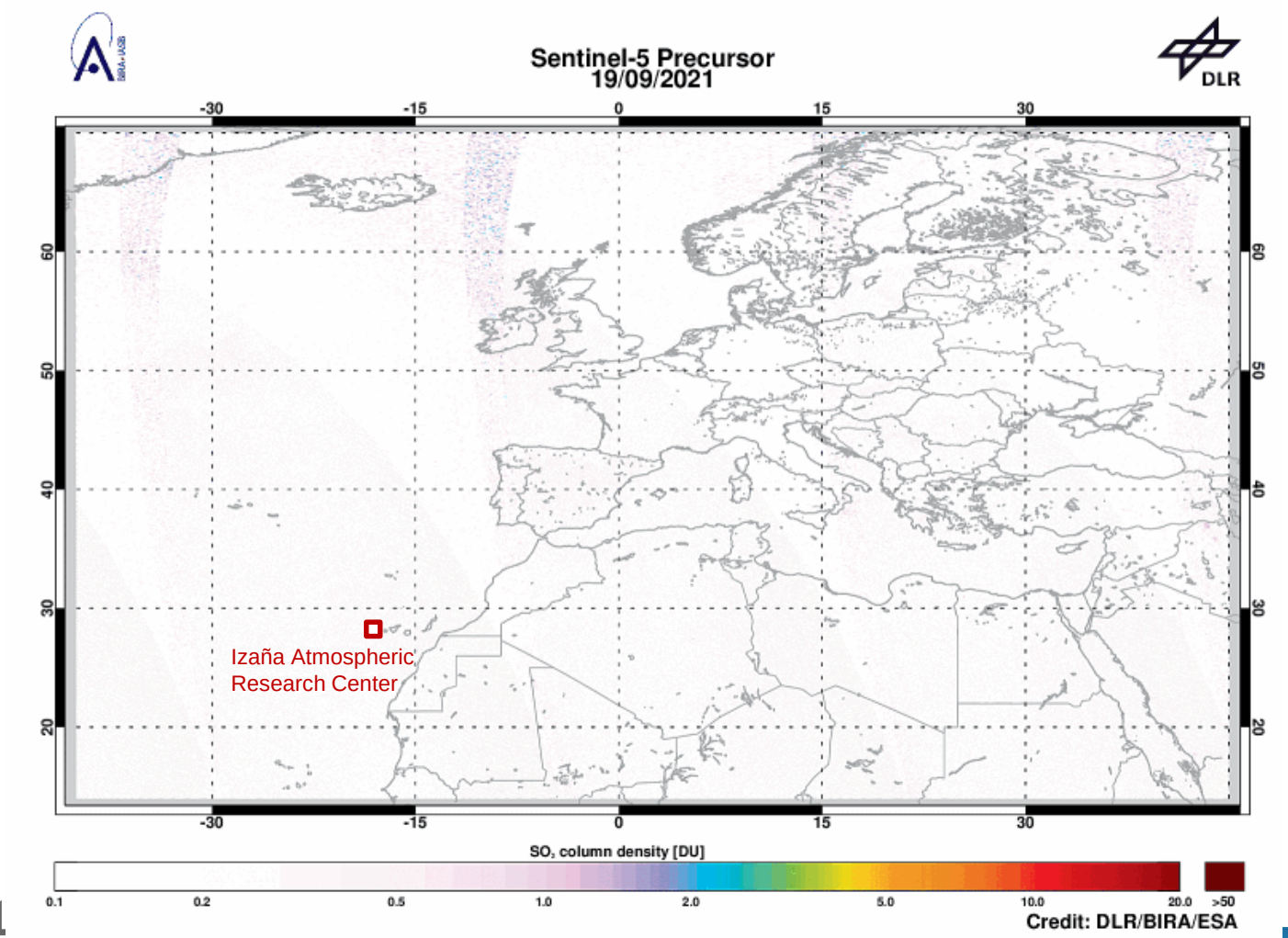
Cumbre Vieja: TROPOMI SO_2 VCD measurements



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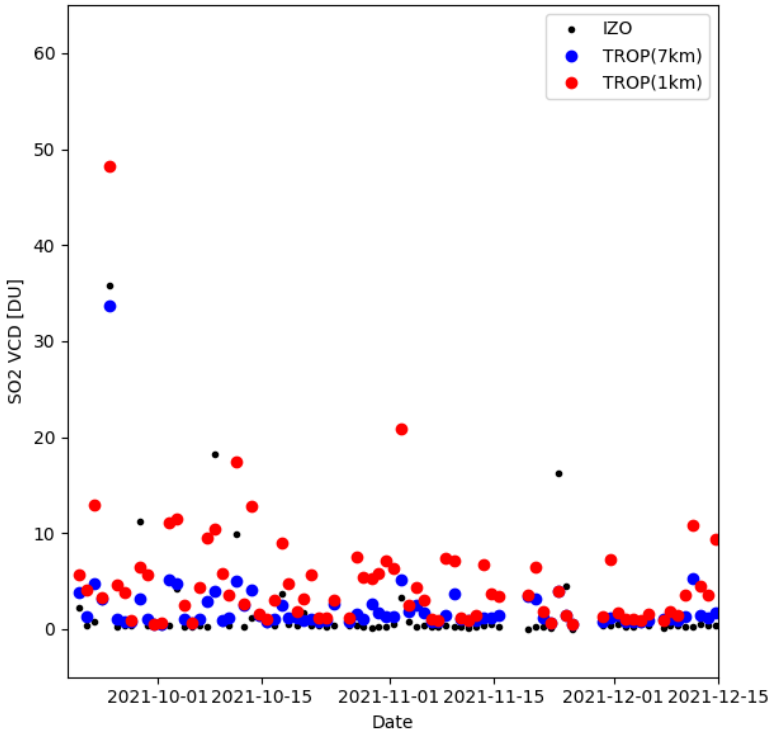
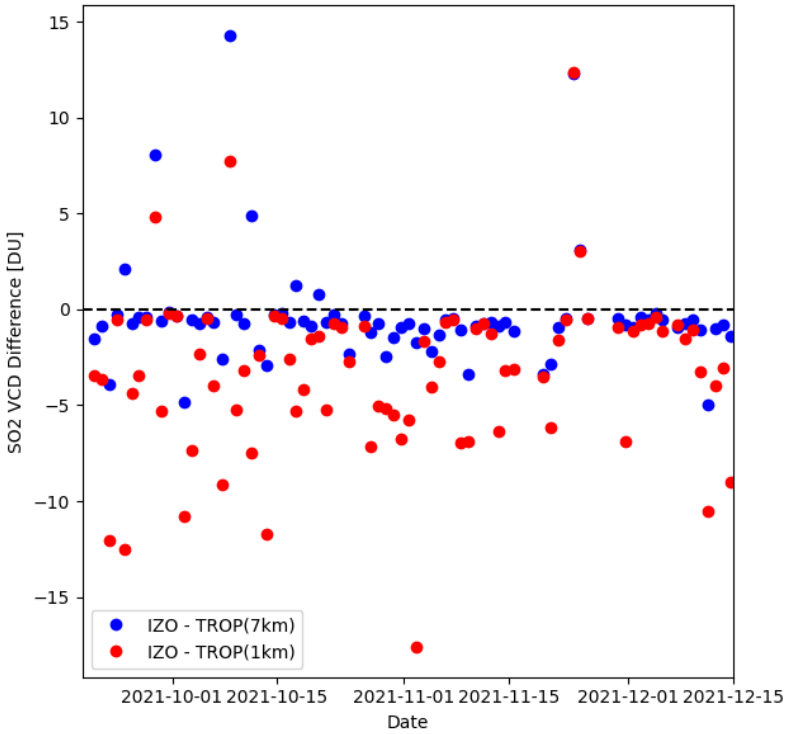
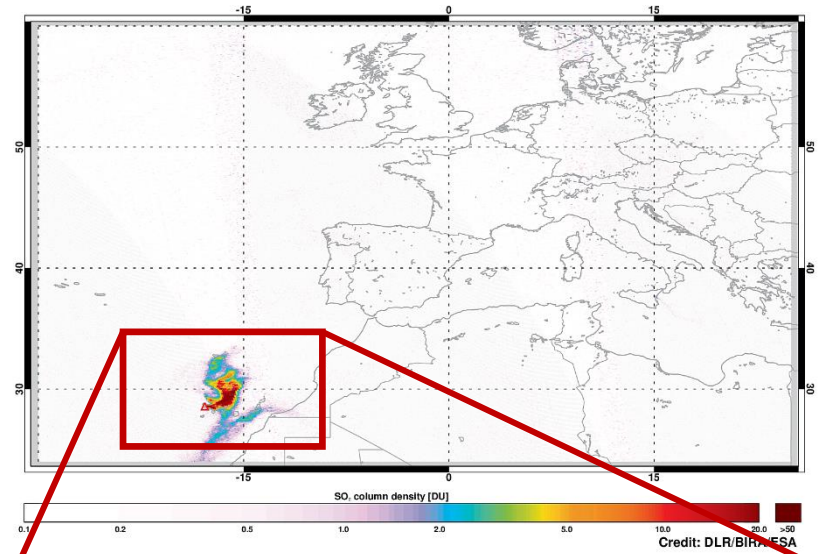
Collocation of Izana Brewer & TROPOMI SO_2 measurements

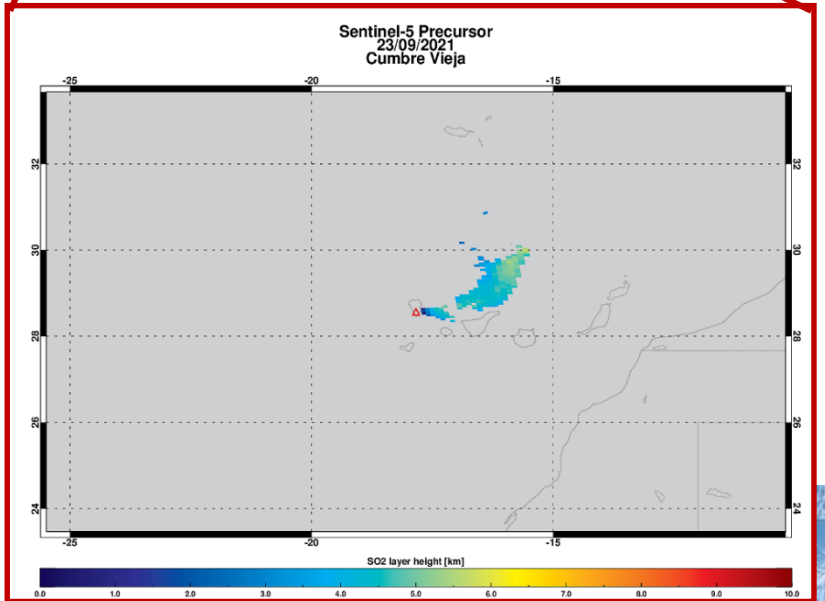


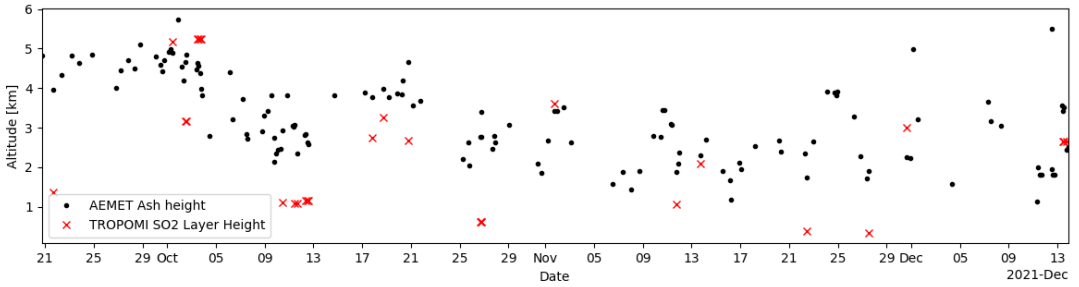


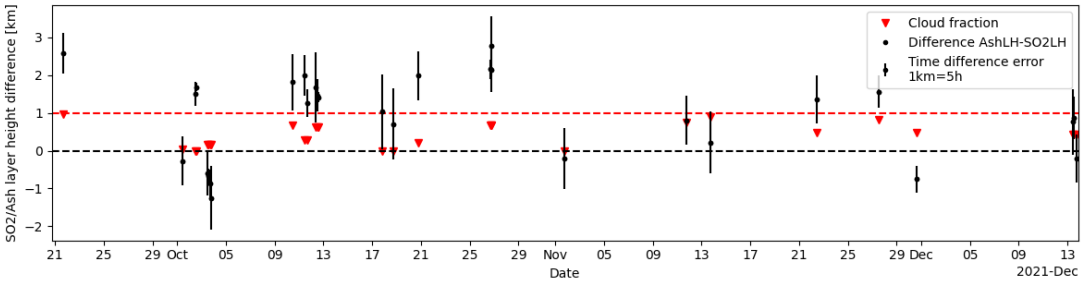
- TROPOMI 7km SO_2 VCD very close to Izana ground-based measurements

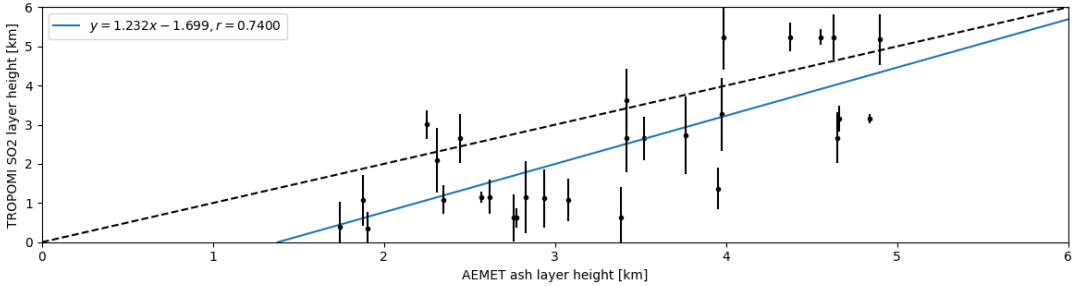
AEMET LIDAR ash height vs TROPOMI SO_2 LH





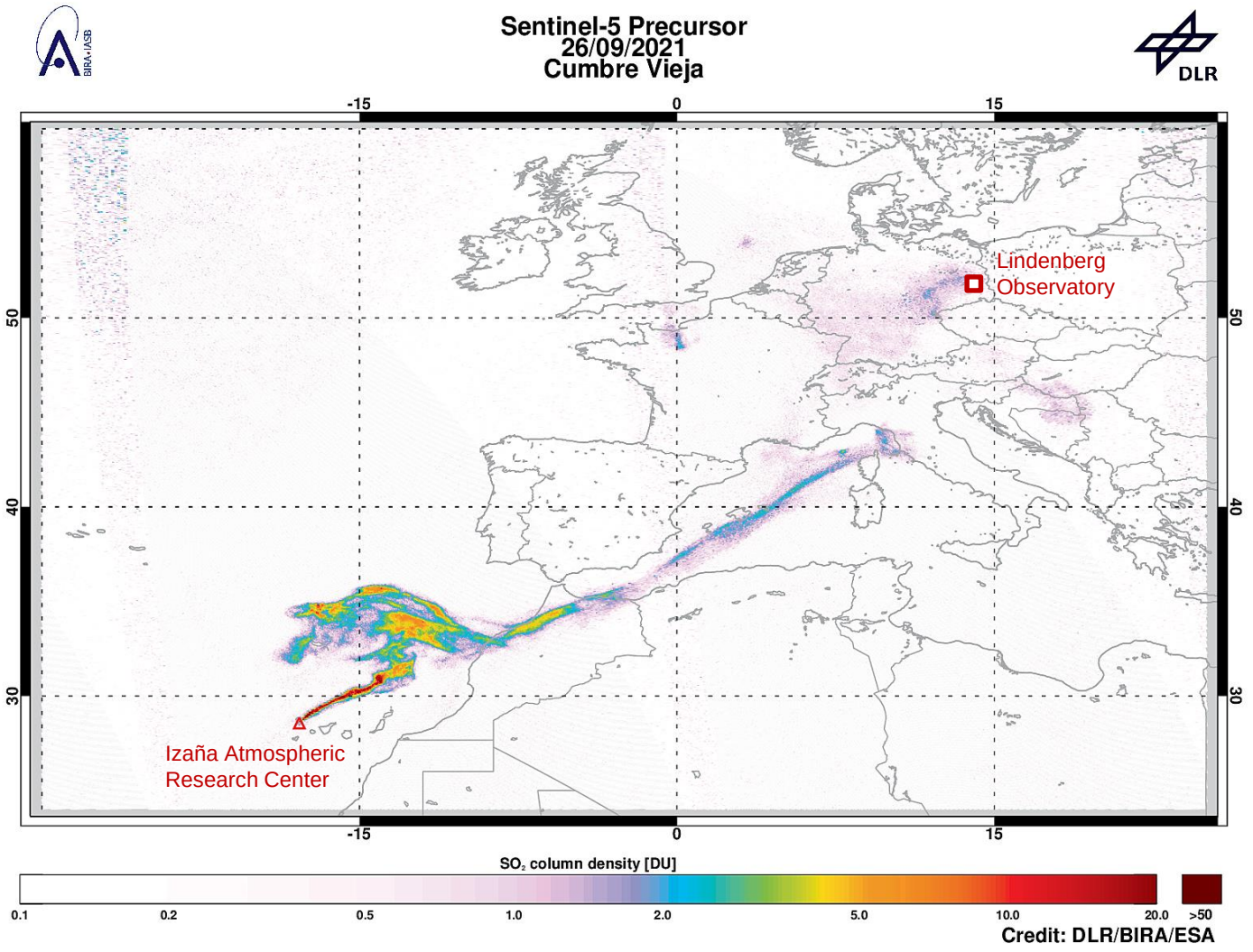




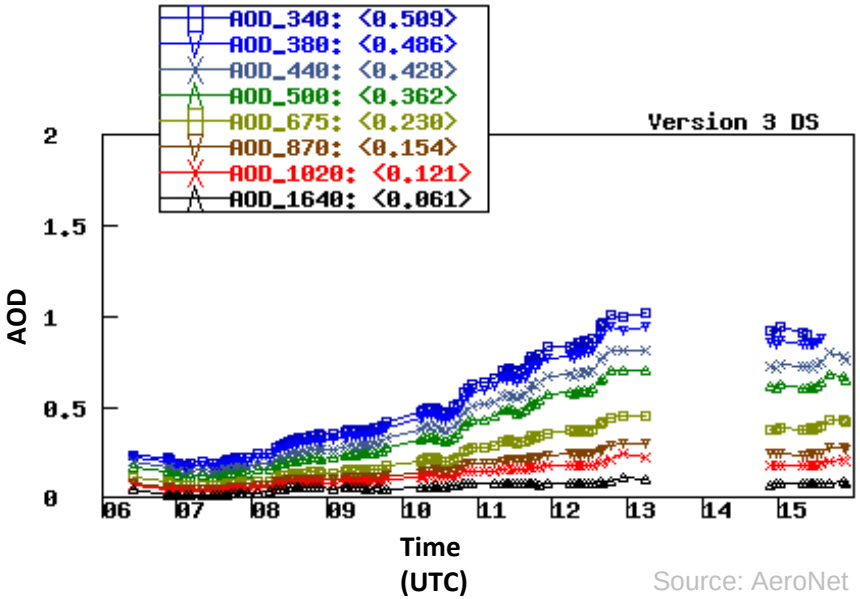


- Collocated SO_2 LH in good agreement with LIDAR ash height, slightly lower by 1-2km

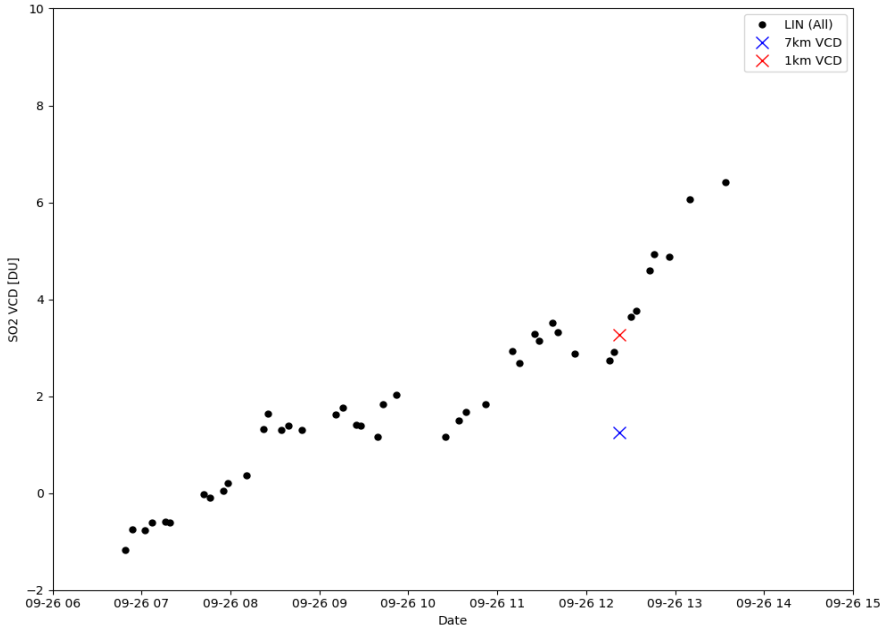
Cumbre Vieja: TROPOMI SO_2 VCD measurements



Lindenberg Observatory (Germany)
Brewer measurements on 26 Sept. 2021



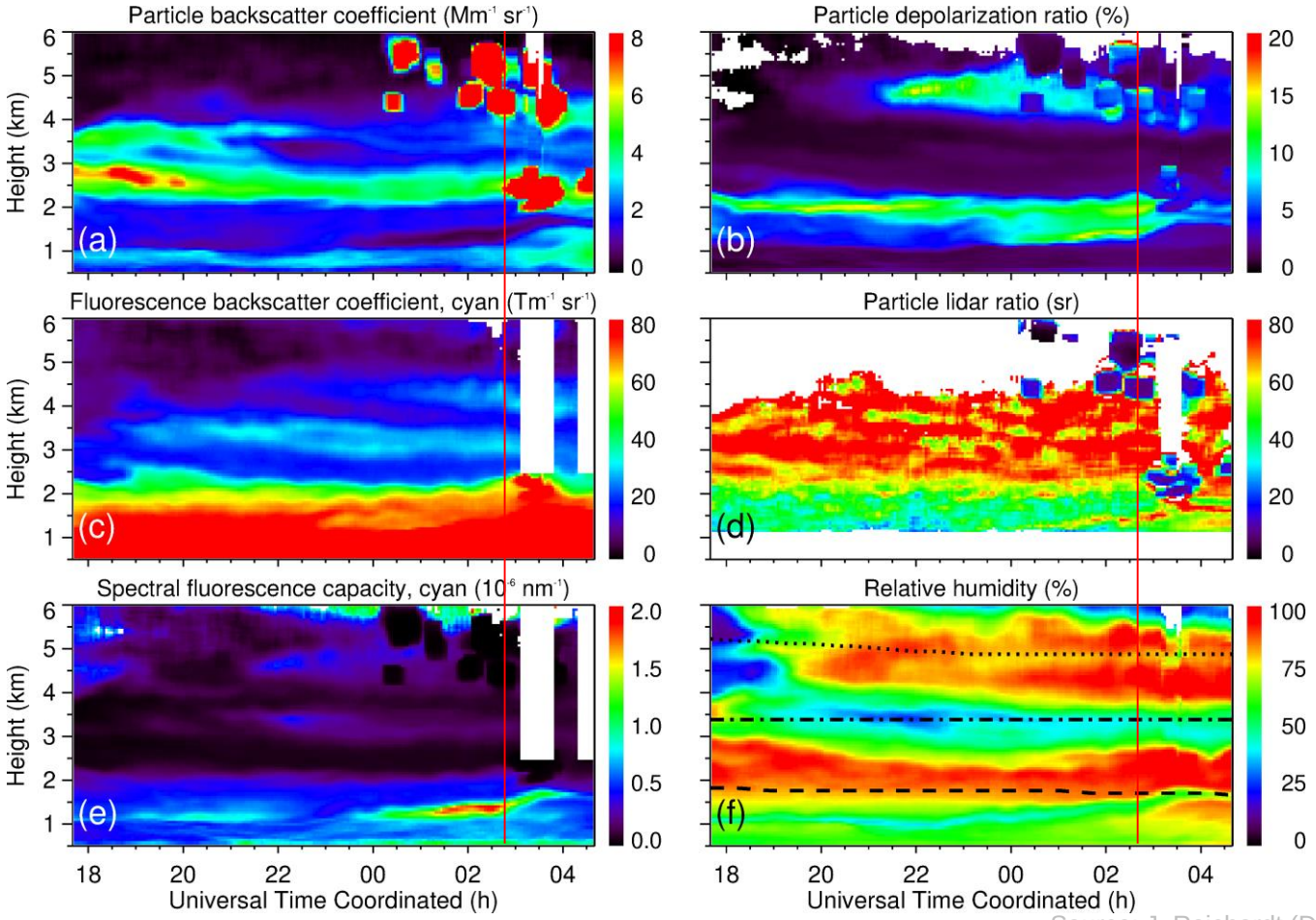
Source: AeroNet



Source: L. Doppler (DWD)

- Detection of increased AOD and SO_2 on 26 Sept. 2021
- Maximum at about 14:00 UTC

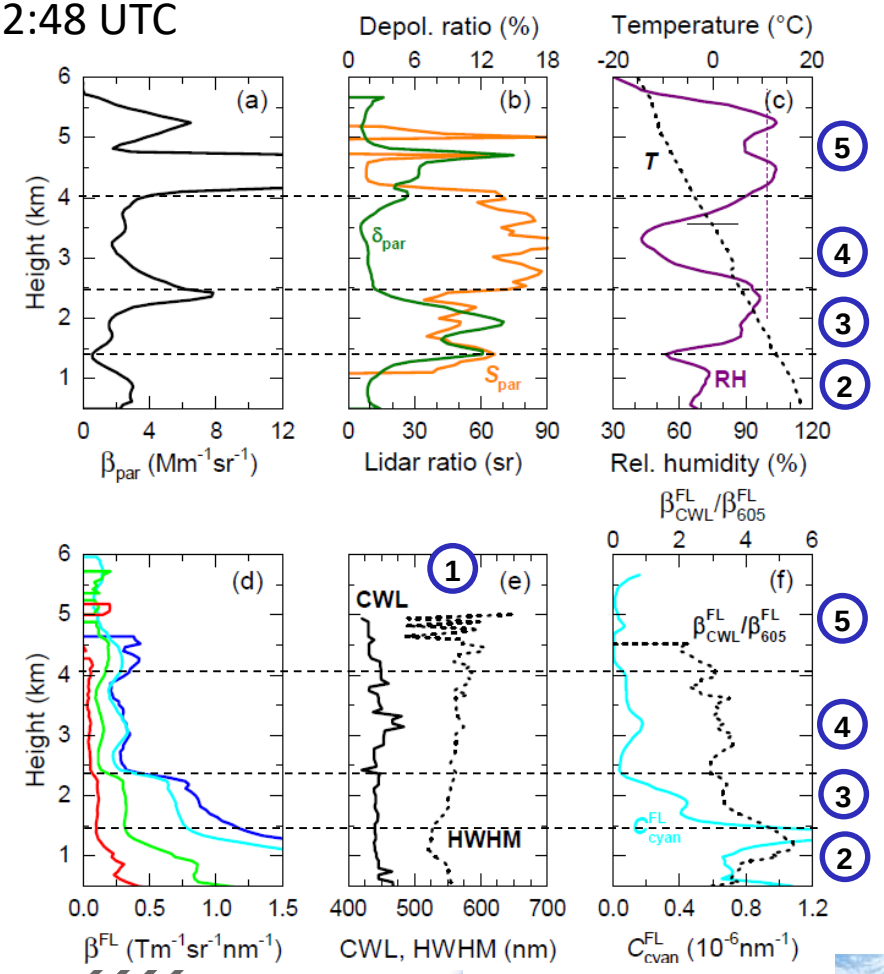
Lindenberg Observatory (Germany)
Raman-LIDAR measurements 26/27 Sept. 2021



Source: J. Reichardt (DWD)

Lindenberg Observatory (Germany)
Raman-LIDAR measurements 27 Sept. 2021

02:48 UTC



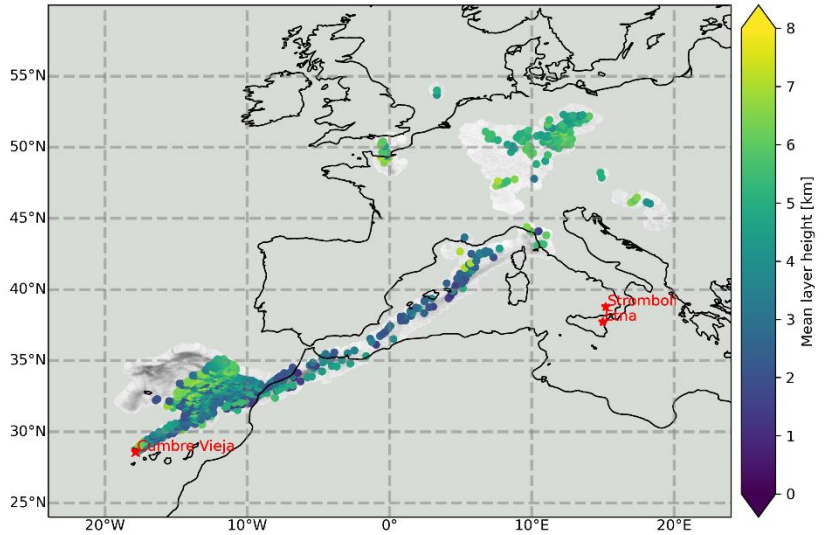
1. CWL, HWHM constant over height
   - **<u>Aerosols detectable in all layers</u>**
   - CWL ~440nm, HWHMr ~ 120nm
   → <u>no organic aerosols</u>
2. < 1.2km: dry,
   - medium Depol. & Lidar ratios
   - increased fluorescence
3. 1.2-2.5km: increasing humidity,
   - elevated Depol. & medium Lidar ratios
   - low Flcap
   → <u>mixture of Sahara dust/volcanic ash</u>
4. 2.5-4km: Dry center, humid boundaries,
   - elevated BSC,
   - very low Depol. & high Lidar ratio,
   - extremly low Flcap (Forest fires: 50x higher)
5. 4.5km: High humidity → Water cloud
   - low Flcap → <u>Aerosol layer</u>

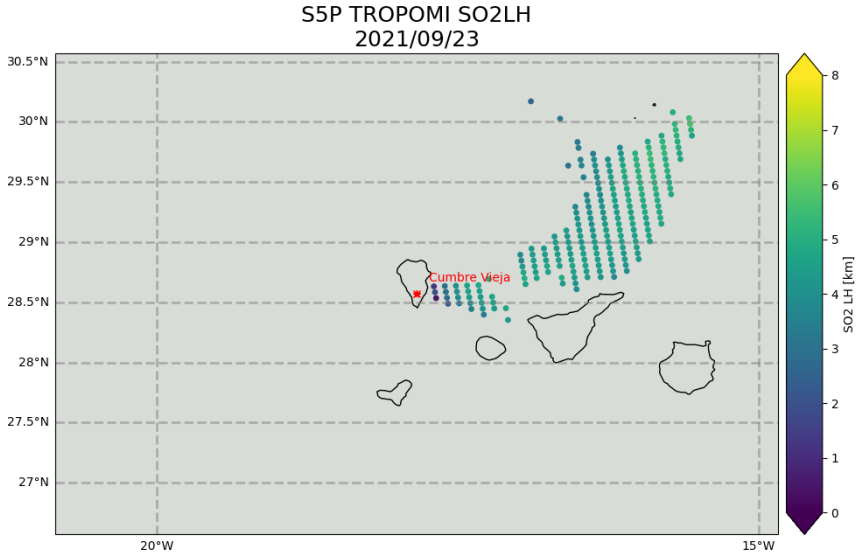
➢ **Layers with different properties/sources**

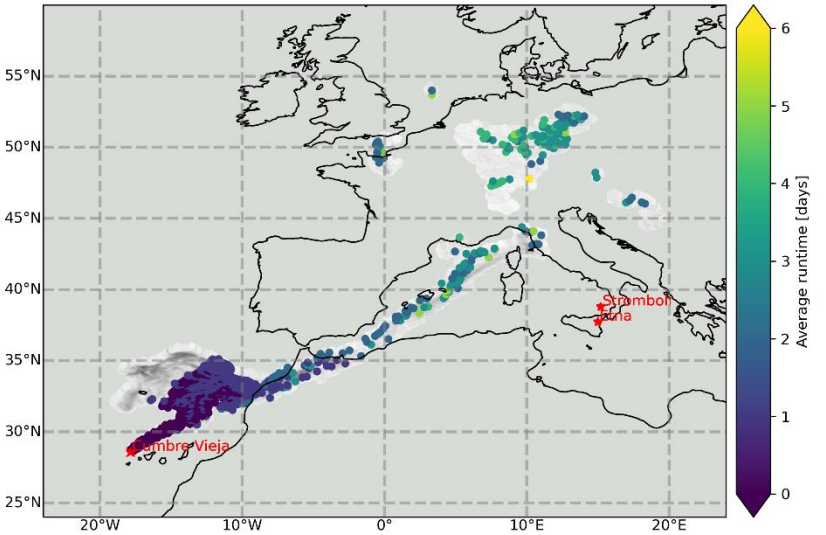
Source: J. Reichardt (DWD)

HySplit backtrajectory analysis 26 Sept 2021

- Starting from TROPOMI pixels h=[0.5 – 7km]
  - Random selection of pixels > 0.6DU
- Filter trajectories reaching Cumbre Vieja
- Signal measured over Germany
  - Average layer height: 4-6km
  - Injected on 22/23 September at 4-6km
  - Perfect agreement with TROPOMI SO_2 LH





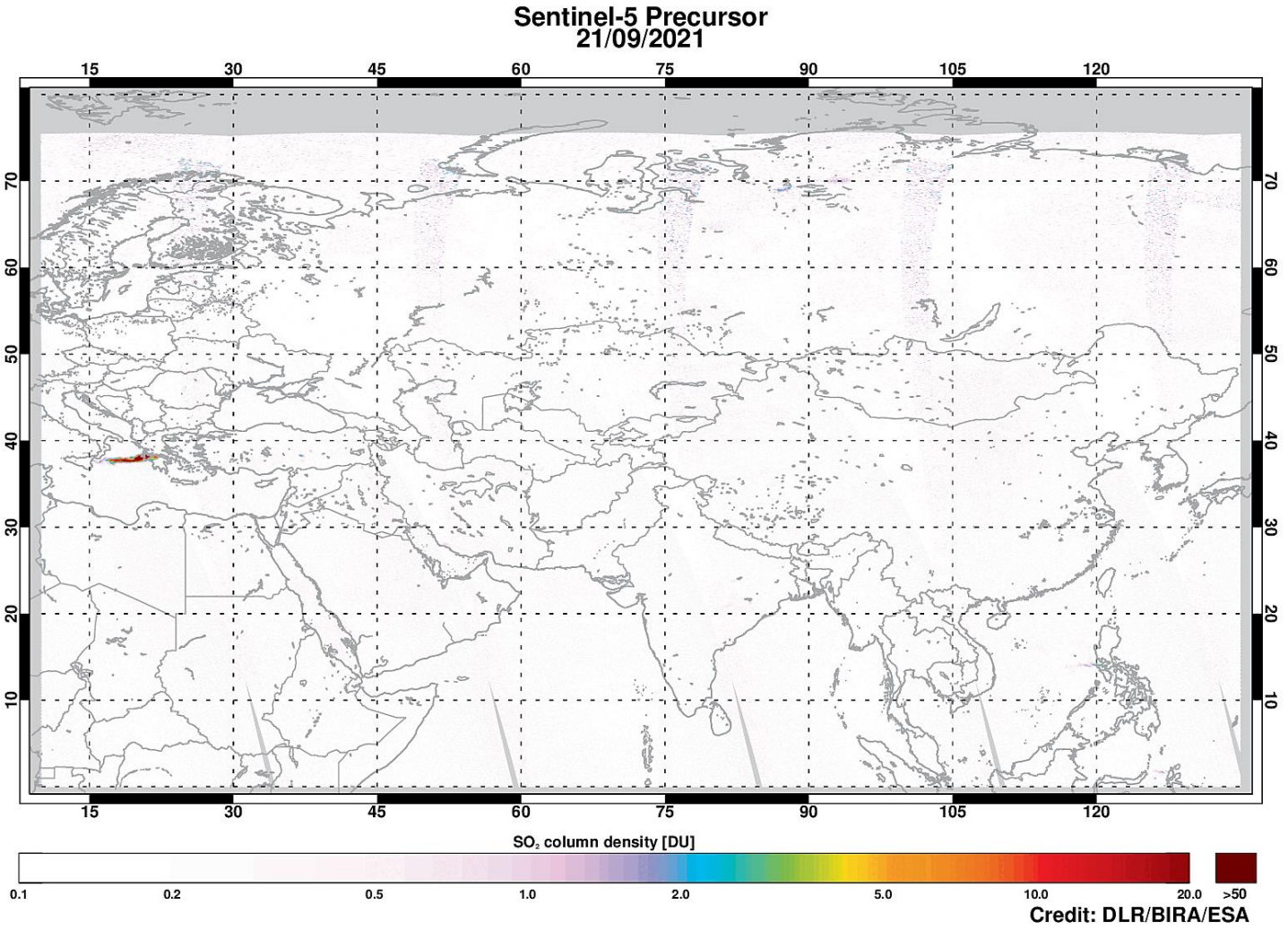


Summary & Conclusions

- Comparison of ground-based Brewer & LIDAR measurements of the volanic cloud over Canary Islands and Europe with TROPOMI SO_2 data
  - Very good agreement wrt SO_2 VCD and LH

- Detection of volcanic cloud after long-range transport to Europe
  - First detection of volcanic aerosol at Lindenberg Observatory!
  - Detailed analysis of LIDAR data shows several layers of mineral aerosol
  - HYSPLIT calculations proof volcanic source: Cumbre Vieja

But what about… Etna???

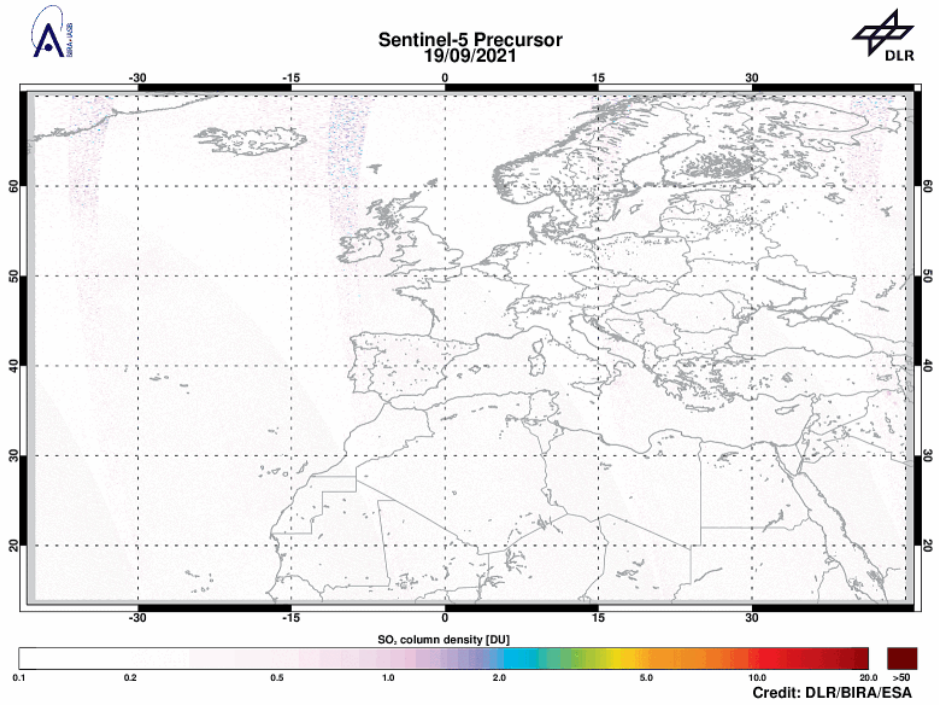


TROPOMI SO_2 VCD & LH Outreach

- **Twitter** account @DlrSO2: https://twitter.com/DlrSo2
- Automatic detection of volcanic eruptions & immediate twitter notification
  - Name of volcano erupted, SO_2 VCD, SO_2 LH, SO_2 mass

TROPOMI SO2 @DlrSo2 · 23. Nov.

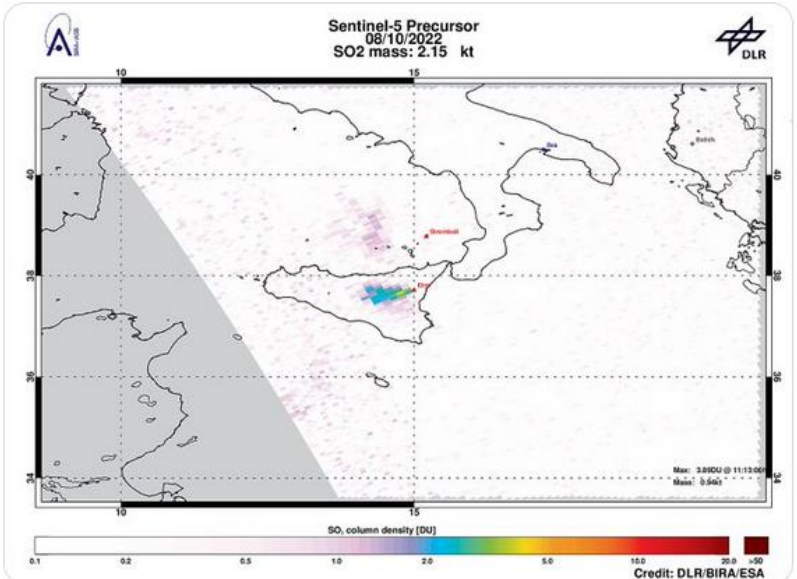
Updated animation of #S5p #tropomi SO2 measurements of the #CumbreVieja volcanic eruption from 19 Sept - 22 Nov. Note the extended plume from #Etna on 24 Oct!



TROPOMI SO2
@DlrSo2

On 2022-10-08 #TROPOMI has detected an enhanced SO2 signal of 3.89DU at a distance of 22.2km to #Etna. Other nearby sources: #Stromboli. @tropomi #S5p #Sentinel5p @DLR_en @BIRA_IASB @ESA_EO #SO2LH

Tweet übersetzen



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