# Initial Evolution of 15 January 2022 Tonga Volcanic Plume Inferred from COSMIC-2 RO Measurements

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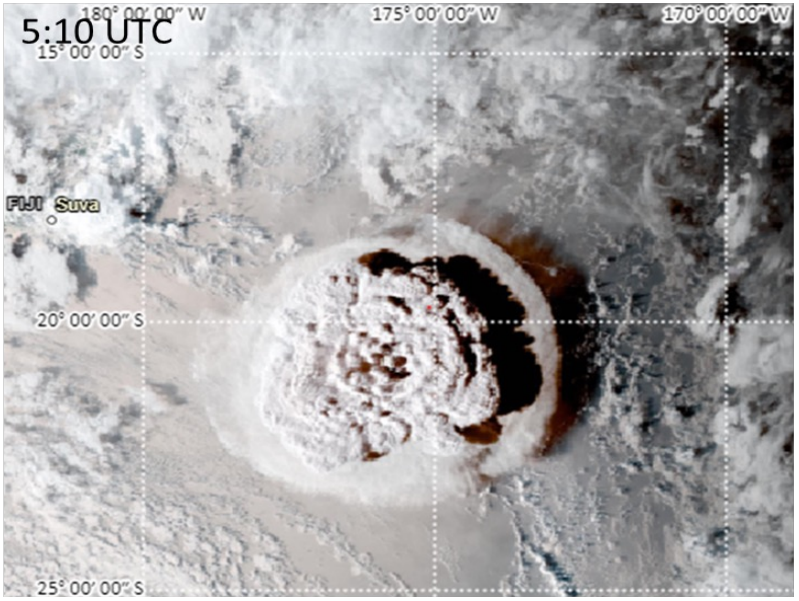


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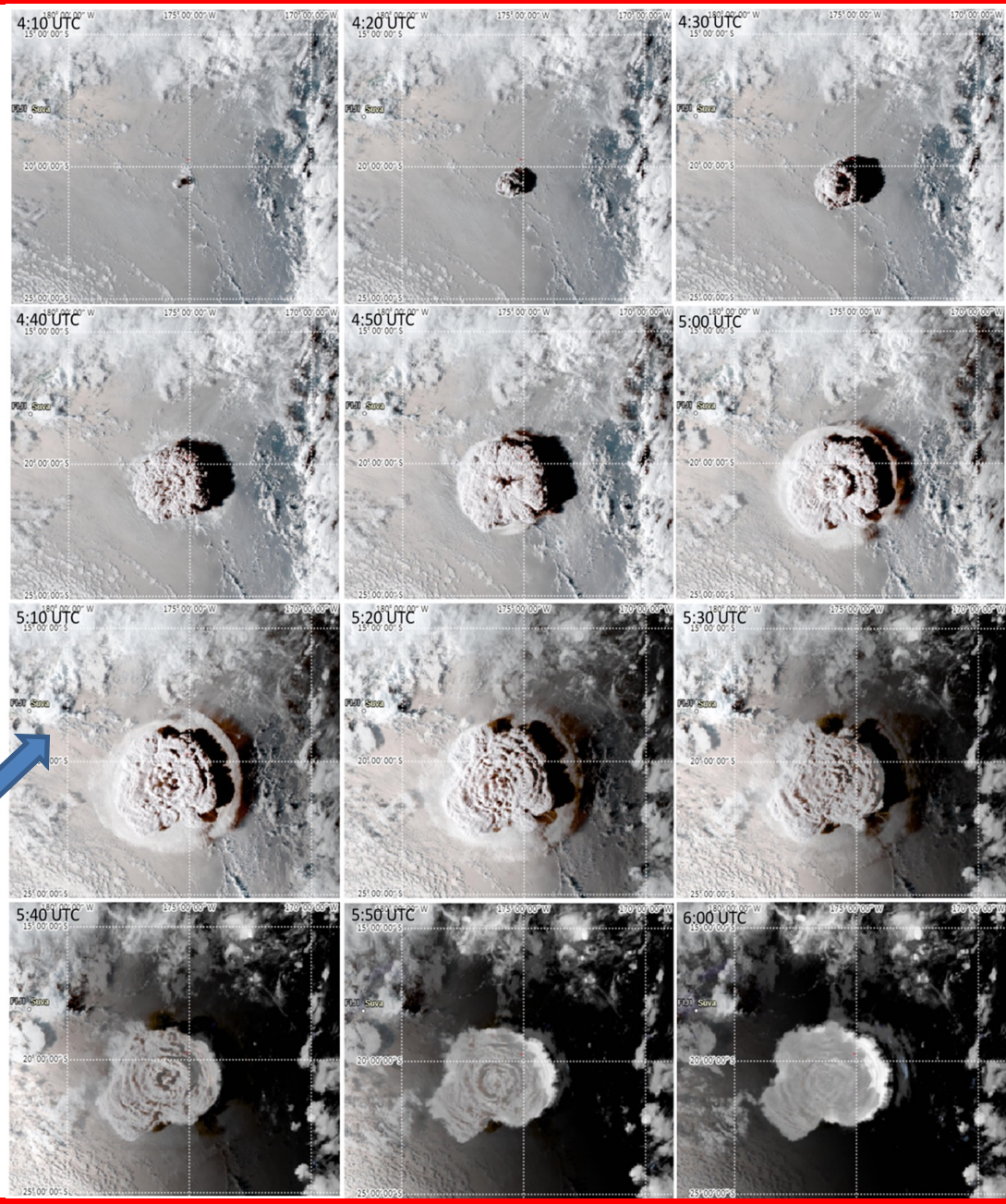
# Introduction

❖ On 15 January 2022, the underwater volcano in Hunga Tonga-Hunga Ha'apai island (20.57°S, 175.38°W) erupted violently at 17:30 local time (4:30 UTC) and released enormous amounts of energy, ash, gases, and steam into the atmosphere.

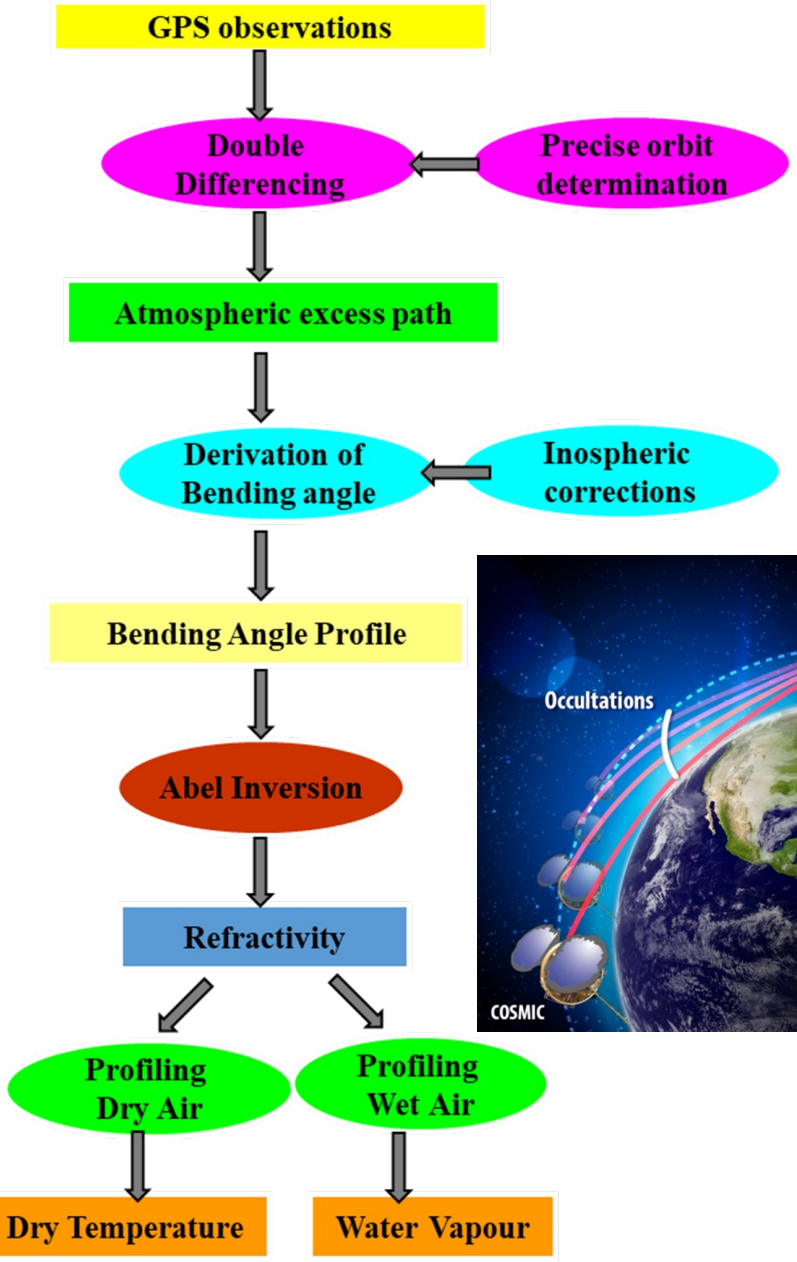
❖The geostationary GOES-17 and Himawari-8 satellites captured this explosive eruption and showed volcanic plume dispersion.

*Geostationary Operational Environmental Satellites (GOES)-West satellite (currently, GOES-17) images observed on 15 January 2022*.

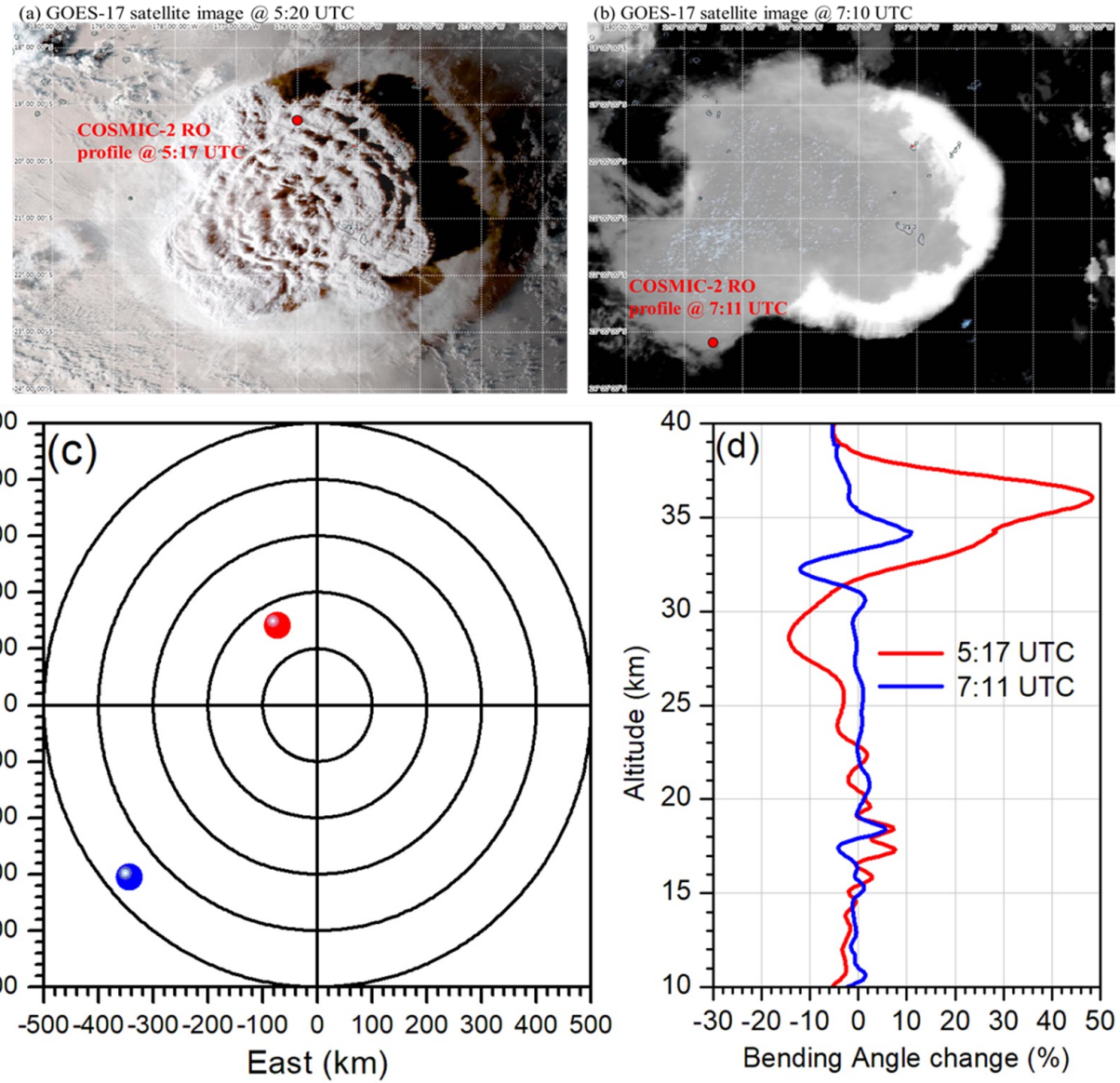


# Database and Methodology

- We utilized Global Navigation Satellite System (GNSS) radio occultation (RO) measurements acquired onboard COSMIC-2 satellites.
- To see the deviations in the bending angle (BA) for the eruptive profiles, we first derive a reference profile by using all the available RO profiles within the 5-degree latitude and longitude around each RO profile.
- We considered all the available RO profiles from 07-13 January 2022 (one week before the eruption) within the 5-degree latitude and longitude region around each RO profile. Then, we take the difference between the eruptive profile from the reference profile to find deviations.
- The obtained BA anomaly was expressed in percentage change and a prominent peak in the BA is defined as the altitude of the volcanic cloud top (VCT).



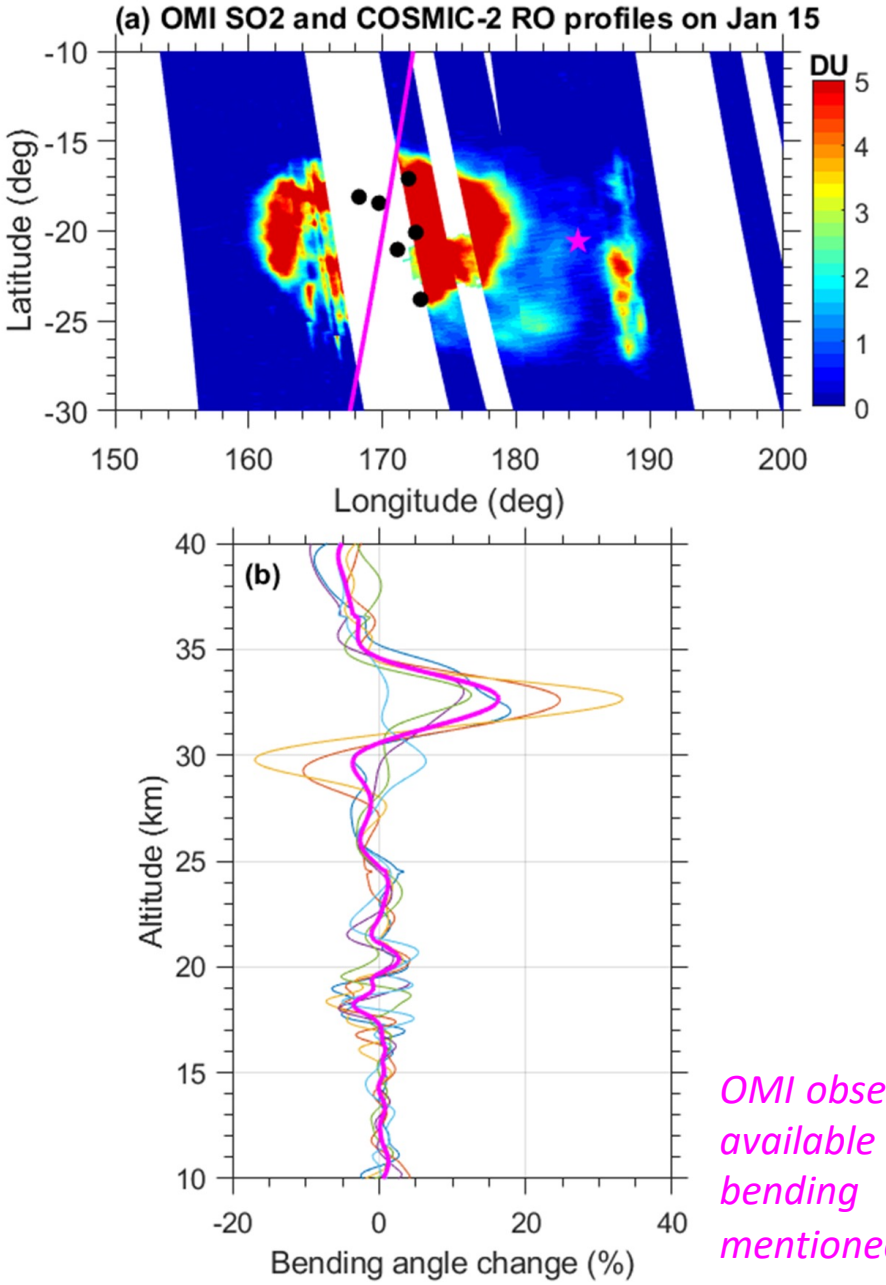
# Tonga volcanic cloud top from COSMIC-2 RO




The top panel shows (a) GOES-17 image observed at 5:20 UTC, and (b) at 7:10 UTC on 15 January 2022. The red-colored (blue) dot represents the available COSMIC-2 RO profile at 5:17 (7:11) UTC. (c) The location of above mentioned RO profile concerning Tonga volcano center. (d) perturbations of Bending Angle for above mentioned RO profiles concerning the reference profile.

The top of the BA perturbation, where the negative to positive change occurred (~38 km), indicates the first height where the RO line-of-sight encountered the volcanic plume

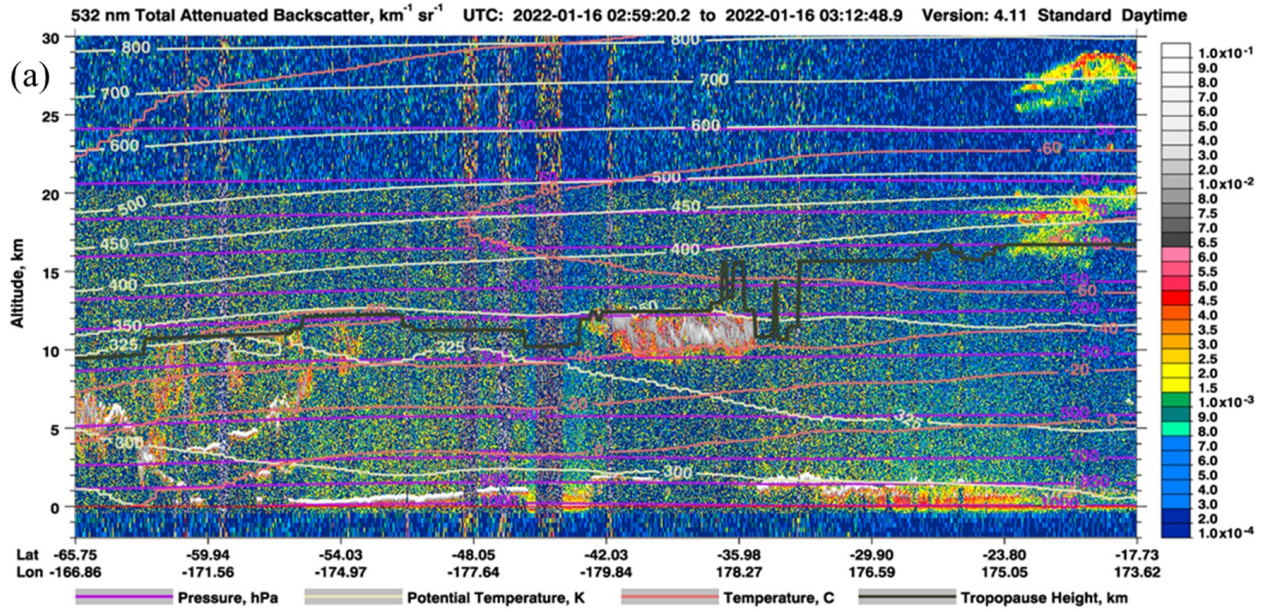
# Tonga volcanic cloud top from COSMIC-2 RO

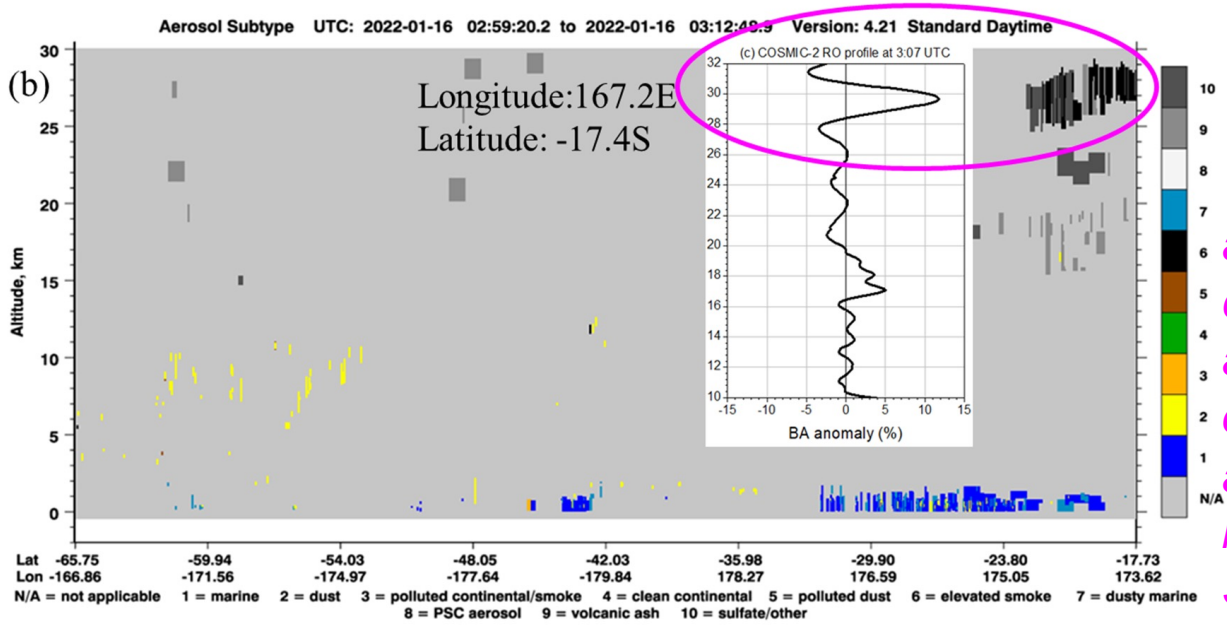



- six collocated RO profiles with the volcanic cloud after the initial eruption on 15 January.
- The magenta-colored line shows the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard the CALIPSO overpass at 15:20 UTC on January 15.
- significant enhancement of the BA anomaly was noticed between the 30 to 35 km region, with a maximum peak at ~32 km

*OMI observed UTLS SO2 on 15-16 January 2022 along with the available COSMIC-2 RO profiles (black dots) on 15 January, (b) bending angle (BA) percentage change for the above-mentioned RO profiles.*

# Tonga volcanic cloud top from COSMIC-2 RO

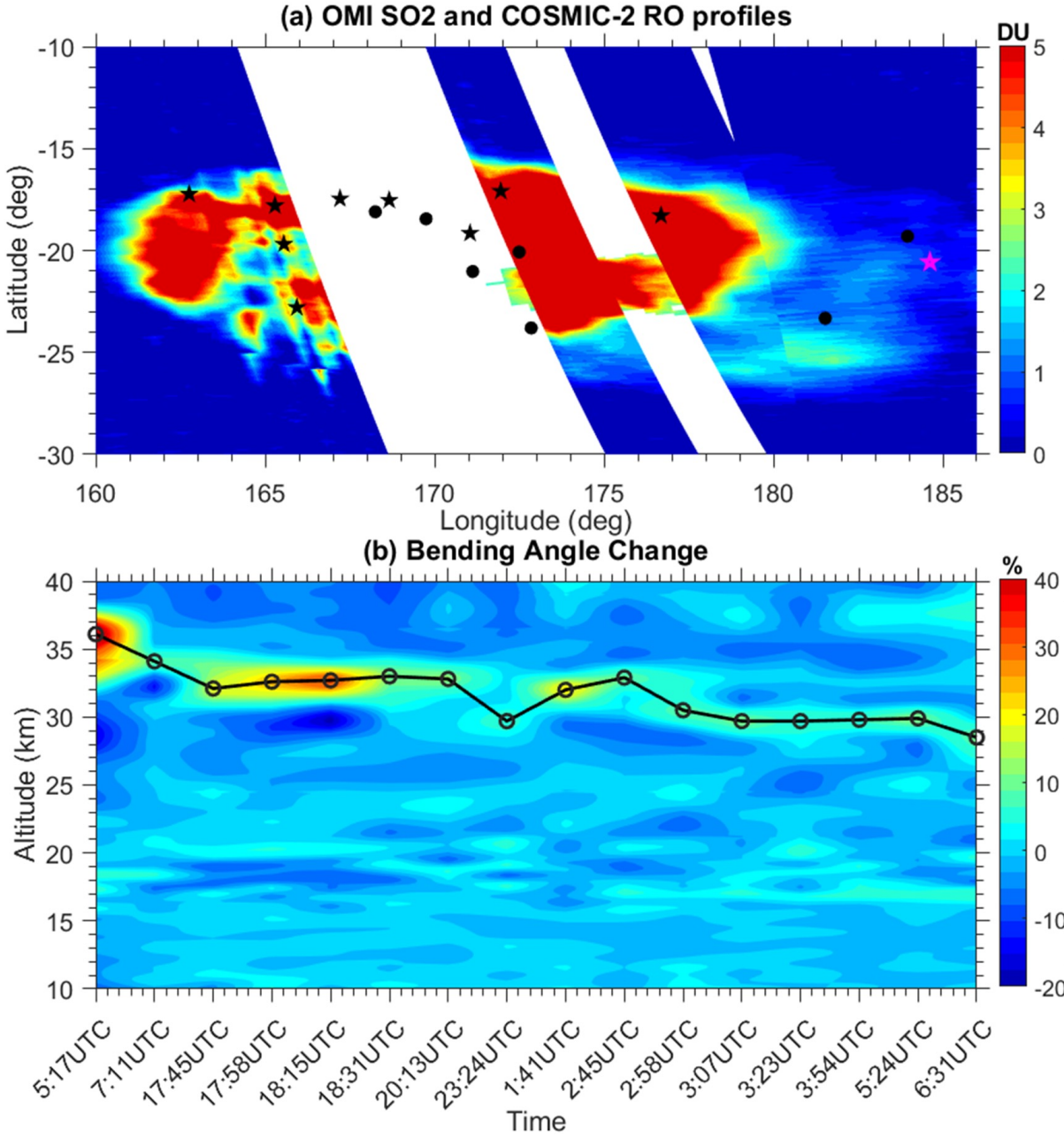



- COSMIC-2 RO estimated the BA anomaly peak change height at 3:07 UTC to be ~29 km, which matches the presence of a stratospheric aerosol layer at ~29 km.
- Close agreement between the RO-estimated peak change in the BA anomaly height and the CALIPSO aerosol plume height.

*CALIPSO 532 nm total attenuated backscatter coefficient; (**b**) the CALIPSO aerosol subtypes at @3 UTC on 16 January; (**c**) the available COSMIC–2 RO bending angle anomaly at 3:07 UTC on 16 January.*

# Initial Evolution of Bending Angle Pertubations




- There are a total of 16 RO profiles collocated with the volcanic cloud between 5 UTC on 15 January and 7 UTC on 16 January (approximately 24 h).
- We considered all the available RO profiles during the period of 7–13 January 2022 (one week before the eruption) within the 5° latitude and longitude region around each RO profile.
- Then, we removed the reference profile from each RO profile and estimated the change in the BA.
- The obtained perturbations of each profile were arranged according to the time needed to show the evolution.
- A clear descent of the peak altitude of the BA anomaly change, from ~36 km to ~29 km within 24 h after the initial eruption was noticed.

*Thank you for your kind attention!!!*

*Ravindra Babu S, Lin N-H. Extreme Heights of 15 January 2022 Tonga Volcanic Plume and Its Initial Evolution Inferred from COSMIC-2 RO Measurements. Atmosphere. 2023; 14(1):121. https://doi.org/10.3390/atmos14010121*

Details of collocated COSMIC-2 radio occultation profiles with the volcanic cloud on 15 and 16 January. The highlighted file names are related to the RO profiles that were available during the eruptive stage, as shown in Figure 2.

| File Name | Longitude | Latitude | Starting Time for RO | |
|---|---|---|---|---|
| | | | Hour | Minutes |
| atmPrf_C2E3.2022.015.05.20.G05_0001.0001_nc | 183.9595 | −19.299 | 5 | 17 |
| atmPrf_C2E3.2022.015.07.11.G08_0001.0001_nc | 181.5302 | −23.3197 | 7 | 11 |
| atmPrf_C2E6.2022.015.17.47.G22_0001.0001_nc | 171.1261 | −21.0282 | 17 | 45 |
| atmPrf_C2E6.2022.015.17.58.G15_0001.0001_nc | 172.4965 | −20.0758 | 17 | 58 |
| atmPrf_C2E1.2022.015.18.15.R05_0001.0001_nc | 172.8534 | −23.7979 | 18 | 15 |
| atmPrf_C2E4.2022.015.18.31.R05_0001.0001_nc | 169.7485 | −18.4442 | 18 | 31 |
| atmPrf_C2E4.2022.015.20.13.G15_0001.0001_nc | 168.2508 | −18.0995 | 20 | 13 |
| atmPrf_C2E4.2022.015.23.27.G17_0001.0001_nc | 171.9524 | −17.0892 | 23 | 24 |
| atmPrf_C2E3.2022.016.01.45.R04_0001.0001_nc | 165.9369 | −22.7931 | 1 | 41 |
| atmPrf_C2E4.2022.016.02.47.G02_0001.0001_nc | 162.7582 | −17.231 | 2 | 45 |
| atmPrf_C2E4.2022.016.02.58.G16_0001.0001_nc | 165.553 | −19.6844 | 2 | 58 |
| atmPrf_C2E2.2022.016.03.10.G02_0001.0001_nc | 167.2092 | −17.463 | 3 | 7 |
| atmPrf_C2E2.2022.016.03.23.G26_0001.0001_nc | 176.6833 | −18.2854 | 3 | 23 |
| atmPrf_C2E5.2022.016.03.54.G16_0001.0001_nc | 168.662 | −17.5328 | 3 | 54 |
| atmPrf_C2E5.2022.016.05.27.G15_0001.0001_nc | 165.2896 | −17.7996 | 5 | 24 |
| atmPrf_C2E2.2022.016.06.34.G12_0001.0001_nc | 171.0468 | −19.1492 | 6 | 31 |