Webinar

Volcanic eruptions and aerosols – what did we learn from the Hunga-Tonga?

Questions & Answers

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1	Have you compared LiDAR data to your balloon-borne measurements at Maïdo?	**CNES:** The in-situ balloon-borne payloads are complementary with lidar remote sensing measurements. Thus, direct comparison is not straightforward. Still, we did observe strong correlations of different variables measured: water vapour, ozone, aerosol concentration, aerosol extinction.
2	Which parameters do you measure at OPAR?	**CNES:** A wide range of climate and meteorological parameters are monitored at OPAR. Among them: ozone (total column and lidar profiles), water vapour, aerosols, temperature, greenhouse gases, … I suggest to visit the website to have detailed information https://opar.univ-reunion.fr/
3	Why could we observe the plume especially well at Maïdo observatory?	**CNES:** Especially because the plume overflew La Réunion Island which is located at the same latitude that the Hunga-Tonga Volcano (~20°S). The atmospheric flow in the stratosphere being almost strictly westward at that time the plume headed directly toward the Indian Ocean. Also, the Maïdo observatory is well equipped with suited lidars for these kind of events. Finally, we were quick enough to begin an intensive measurement campaign just before the first parts of the plume arrived.

4	Won't the volcanic ash reach the stratosphere?	**CNES:** Ash can reach the stratosphere but only the tiny part of the ash size distribution (submicronic part). Still, it is not the preponderant aerosol type in the stratosphere following a volcanic eruption, sulfates aerosols are.
5	Did other observatories do similar observations?	**CNES:** Yes, several stations equipped with lidars have made observations. For instance, the plume was detected in Lauder, NZ and even in DDU Antarctica. However, these detections occurred after the plume circled the Earth one or several times, being spread both in latitude in longitude. Hence, to my knowledge, the first ground-based lidar measurements of the plume are derived from OPAR observations.
6	How unusual is it to have detected such a high AOD (ca. 0.32) in these volcanic plume layers? You have been speaking about a "tremendous AOD". And how much larger is this than the strat-AOD seen from other stratospheric-injecting volcanic plumes?	**CNES:** Values observed in Reunion Island are on the same order of magnitude that the three most impacting volcanic eruption of the century (mentioned in the intro by Mr. Peuch). The zonal mean of the sAOD will have to be carefully assessed, probably using satellites retrievals to see how this eruption fit in the recorded sAOD historical perturbation.
7	How do you quantitatively estimate aerosol concentration?	**CNES:** From lidar derived aerosol extinction coefficient you can derive aerosol concentration with some hypothesis on the extinction cross-section of these aerosol, linked to their chemical composition and nature (complex refractive index). Otherwise, you can use in-situ instruments lifted by a stratospheric balloon to sample directly the plume with an aerosol counter.
8	Did you observe tropospheric ash layers?	**CNES:** We are not sure about that yet. The stratospheric layer headed westward and was really unambiguous whereas with the tropospheric flow going eastward we have to wait for an Earth full circle to have

		Tonga's tropospheric air masses above us. Hence, given the quite high sedimentation rate of ashes we are not sure to have captured ashes yet. It's a work in progress. Feel free to reach out if you are interested in the results.
9	What do you mean by "most powerful blast" since Krakatoa? Regarding to plume height? Or water? Or another factor?	**CNES:** First estimates are talking about values in terms of TNT equivalent. To this extent it is probably the most powerful blast since the Krakatoa (Krakatoa was far more powerful).
10	How could you tell the volcanic composition (ash/sulfate or other particles) from your observation?	**CNES:** Optical properties of ashes, sulfates aerosols or sea-salts can be quite different, especially in terms of their depolarization capability of the laser light. Measuring what we call a depolarization ratio can allow us to determine whether we can have ash presence or not or even a mix of different aerosols. (Ashes depolarize, and sulfates aerosols do not).
11	How do you quantitatively estimate aerosol concentration? What do you mean by climate impact is possible only if 5 Tg of SO_2 is released?	**CNES:** For aerosol concentration estimate, I replied higher in the Q&A feed. For the estimation of the mass injected, I am not really well confident to answer that. I guess the value is deduced from satellites measurements of SO_2. The 5 Tg value is a commonly accepted threshold saying that if you reach this value of injected SO_2 in the stratosphere, the event will have a climate impact. Mr. Peuch has talked about such events in the past (Mount Pinatubo 1991, El Chichon 1982 for instance). You can find details in this article: https://eos.org/science-updates/anticipating-climate-impacts-of-major-volcanic-eruptions
12	What about the spectacular sunsets that we still enjoy at Reunion Island - are they still due to aerosols in the atmosphere today?	**CNES:** Yes, they are! The plume is still going around and overflying La Réunion periodically. Enjoy them while they last!

13	Can we delineate the volcanic aerosol signal in the stratospheric aerosol extinction?	**CNES:** There are hardly any aerosols in the usual unperturbed stratospheric background (this is not the case in the troposphere on the contrary). Therefore, we can be quite sure when we say that these aerosols in the stratosphere are originating from the Hunga-Tonga eruption.
14	Regarding SO_2 Rayleigh scattering: It is not clear to me why it would scatter red rather than shorter wavelengths like other gas molecules?	**CNES:** SO_2 as a molecule will interact with light following the Rayleigh scattering framework. The redder sunset visible at La Réunion (and I suppose everywhere the plume is passing) and the fact that evening lights are visible clearly later than usual is a dual effect involving both Rayleigh scattering by molecules and Mie-Scattering by the high altitude aerosol plume. The plume acts a bit like a mirror placed high in the stratosphere and the usual red sun-light beam associated with sunset is scattered back to the surface even if the Sun has passed the horizon for an observer located at the ground (after sunset, at 25 km of altitude you can look directly to the Sun compared to being at the ground). So the sky is not dark so early but streaked with red and purple colors.
15	Which reanalysis data is used for clear sky GHI shown in your figure?	**Reuniwatt:** As written next to the figure, it shows the Copernicus Atmosphere Monitoring Service (CAMS) McClear Clear-Sky GHI
16	As several clear sky models exist, which clear sky model is being referred to?	**Reuniwatt:** See answer above.
17	How important is the impact of aerosol composition on solar production when compared to the impact of clouds and cloud forecasting?	**Reuniwatt:** The impact of clouds on the solar production is generally well above the impact of aerosols. GHI can fluctuate by several hundred W/m^2 within a few seconds due to clouds. Nonetheless, in some desert regions with frequent clear sky conditions and a lot of aerosols (such as

		sand or even human pollution) we can observe big fluctuations of solar production on a day-to-day basis only related to aerosols. Clear-sky GHI at noon can vary by 100-200 W/m² from one day to another just because of aerosols.
18	Do the marine aerosols projected by the volcano into the atmosphere have an impact in the troposphere and stratosphere?	**CNES:** In general, marine aerosols have an impact on the marine boundary layer (the atmospheric layer just above the ocean), in particular they act as cloud condensation nuclei to allow cloud formation. In our volcanic case, even if a large amount of oceanic water has been lifted in the atmosphere, for now it is difficult to estimate the amount of sea-salt injected and then the part they can represent in the aerosol mix issued from this event. Still, they can participate to the atmospheric perturbation and impact the radiative balance (to be quantified) and the atmospheric chemistry.
19	Isn't there water vapour and ozone remote sensing at Maïdo, and if yes did you see an impact of the eruption?	**CNES:** Yes, there are both. For the water vapor, the technique used can allow us to reach stratospheric altitudes. For ozone measurements we can observe in the stratosphere but the presence of aerosols biases the signal and further work has to be done to obtain an ozone lidar profile of quality in the volcanic plume. However, we did see the impact of the eruption in the ozone and water vapor profiles recorded using balloon-borne in-situ observations launched during the measurement campaign.
20	What are the main aerosols detected at Réunion Island?	**CNES:** At reunion Island, the main aerosols are sea salt originating for the ocean. Then we also could find some traffic and industrial activities induced aerosols (soots). Furthermore, the vegetation can act has a biogenic source of gas (COVs) precursors for the formation of secondary organic aerosols. During eruptions of the local volcano (Piton

	de La Fournaise), we also can have SO_2 emissions and thus sulfates aerosols. These aerosols concern the lowermost atmospheric layer. Higher, in the free troposphere we can be impacted by biomass burning plume transport, mainly originating from forest fires activities during the dry season of the Southern Hemisphere. Then, up to the stratosphere, OPAR lidars can document the passage of volcanic plumes (ashes and sulfates particles).