Report on the outcomes of a Virtual Mobility[1]

Action number: CA21119

Grantee name: Juan Luis Guerrero Rascado

Virtual Mobility Details

Title: Analyzing the horizontal extent and persistence of volcanic emissions from the Hunga Tonga eruption through synergy of ground-based Sun-photometry and satellite data

Start and end date: 31/08/2023 to 29/09/2023

Description of the work carried out during the VM

Description of the virtual collaboration and activities carried out during the VM, with focus on the work carried out by the grantee. Any deviations from the initial working plan shall also be described in this section.

(max. 500 words)

The Hunga-Tonga volcano (South Pacific Ocean) began its recent activity on 20/12/2021 with multiple explosions and a high ash plume. The main objective of this VM was to assess the horizontal extent and persistence of the volcanic emissions from this eruptive event. More specifically, we performed a synergic analysis of the ash/SO2 plume horizontal extent from satellite imagery and the changes observed in aerosol background levels and precipitable water content from ground-based Sun-photometers. The VM allowed to strengthen the collaboration between different research groups (Spain, Portugal and Brazil) and to perform the virtual activities according with the proposed working plan. Thus, the following activities were carried out (all virtual meetings by Google Meet). This topic is relevant for other international initiatives (in addition to HARMONIA) dealing with the aerosols vertical profiling, such as ACTRIS/EARLINET, E-PROFILE and LALINET.

Firstly, a kick-off meeting with a length of 1 day was organized in order to identify the available datasets, gaps and discussion on relevant days and atmospheric products to be analysed.

As result of this meeting, the following sensors/products were selected: (i) MODIS sensor onboard Aqua satellite providing1-km resolution calibrated radiances (collection 6.1) for the ash plume characterization, including the horizontal dispersion and vertical extent; (ii) TROPOMI sensor operating on board the Sentinel-5p platform and measuring the backscattered solar radiation of the Earth-atmosphere system in eight spectral bands ranging from the ultraviolet to the near infrared for SO2 plume detection; (iii) CALIOP active remote sensing lidar system operating aboard the CALIPSO satellite and measuring the

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

detailed vertical distribution of aerosol particles and clouds along with their optical properties, with signal depolarization measurements allowing discrimination of the sphericity and non-sphericity of clouds and aerosol particles; (iv) sun photometer products, focusing on the detection of aerosol particles by using aerosol optical depth (AOD), Angström exponent (α440-870) and fine mode fraction (FMF500), together with precipitable water vapor content (w); and (v) radiosondes allowing measurements of meteorological parameters at different heights in the atmosphere.

The core phase of this VM was split into four blocks of tasks concerning the horizontal dispersion of ashes and SO2 (block#I), vertical distribution of ashes and sulphates (block#II), persistence of the volcanic emissions by Sun-photometry (block#III) and vertical distribution of water vapour by radiosondes (block#IV). Each block contained several sessions for discussions.

In the block#I, download and preprocessing of satellite data for ash plume characterization using the aforementioned MODIS data were performed together with the implementation ash masks and daily horizontal extent characterization. However, this technique (widely used in the past) did not offer satisfactory results. Then, we focused on the download and preprocessing of TROPOMI data for SO2 plume characterization, estimating the SO2 total vertical column density data, and implementing SO2 masks for the daily horizontal extent characterization (Figure 1).

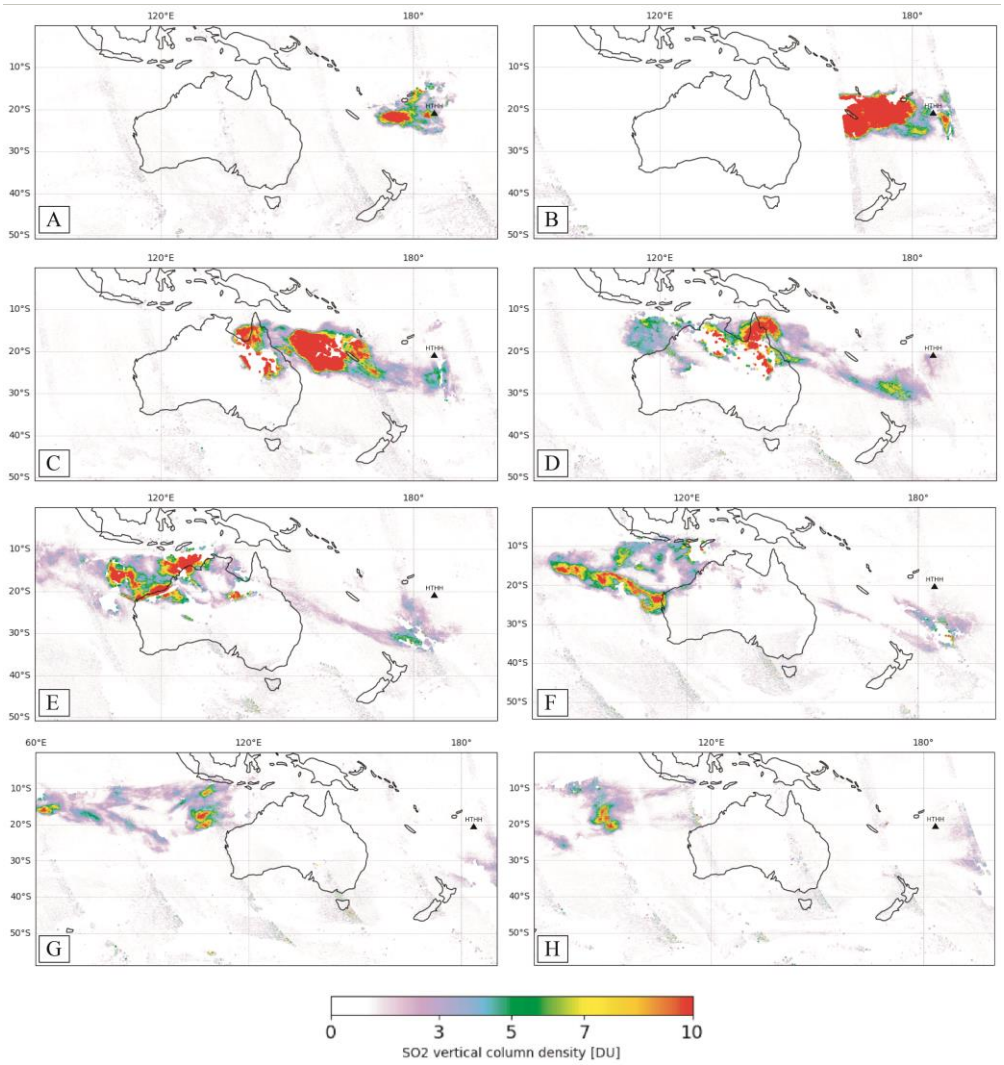

Figure 1.

In the block#II, the vertical distribution of ashes and sulphate particles were identified by using CALIPSO data. The summarized results were the following. The ash-enriched plume was initially located at a height of approximately 20 km on January 15. Later, it increased its thickness and rised above 30 km in altitude.

By then, the presence of sulphate aerosol particles, which have resulted from the rapid conversion of SO2, were detected. This was due to the large availability of water vapor in the atmosphere injected by this explosive surtseyan-type eruption. Although this instrument has a maximum range of 30 km, it was estimated by other authors that this eruption exceeded 50 km in height.

In the block#III, identification of relevant Sun-photometer sites for the proposed anomaly study was carried out, including only site with long-term datasets (at least 10 years) in order to compute the historical time series. Anomalies were computed for all the sun-photometric products aforementioned, revealing that the persistence of particle in the atmosphere was shorter than expected for a huge volcanic event like this. Also, the water vapour anomalies detected by Sun-photometers were less marked as expected, taking into account the observations reported recently by other studies (Figure 2).

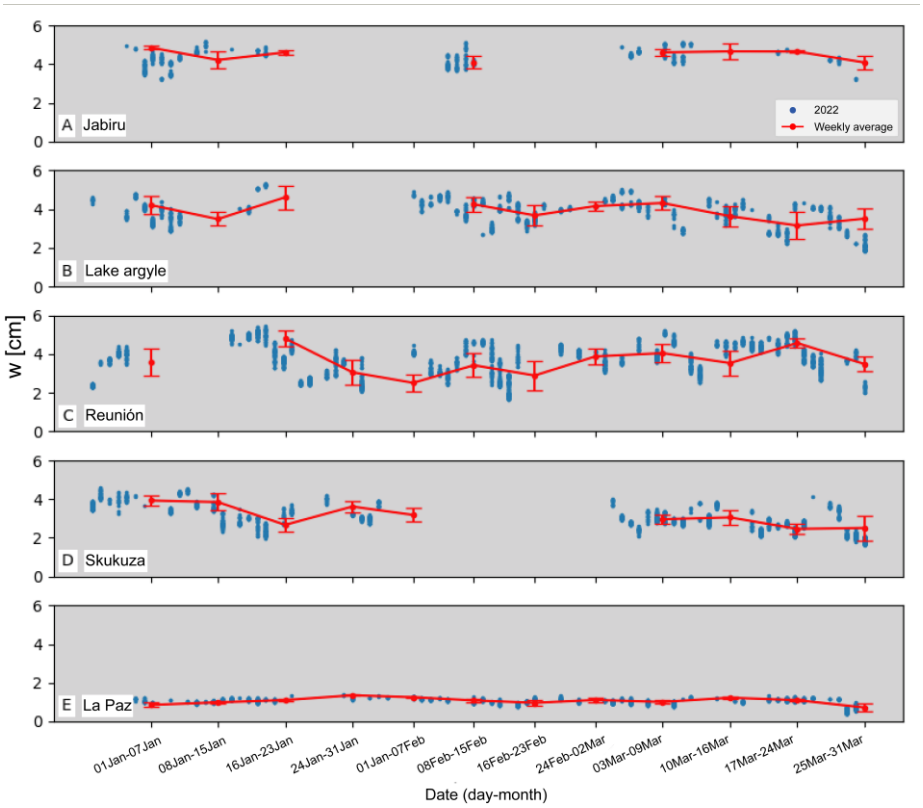

Figure 2.

Due to the unexpected results related to water vapour, we decided to analyse radiosounding data to check the presence of water vapour in the atmosphere (Block#IV not initially planned in the proposal). Using radiosoundings we certified the presence of water vapour enriched layers as a consequence of the volcanic event. This highlights the need to improve the solar photometry technique to measure the amount of water vapor in the atmosphere, especially in extreme events such as the eruption analyzed, since the data provided by sun photometers were not sufficiently conclusive.

Finally, a general meeting with a length of 1 day took place with the aim of presenting and discussing the final results to be published, including the selection of the congress.

Description of the VM main achievements and planned follow-up activities

Description and assessment of whether the VM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the VM. Agreed plans for future follow-up collaborations shall also be described in this section.

(max. 500 words)

The planned main goals of the VM were achieved. This VM has contributed to demonstrate how the synergic use of remote sensing systems can support the precise assessment of the horizontal extent and persistence of volcanic emissions. Furthermore, this virtual mobility had a clear social (health), economic (prevention of potential damages in aviation) and climate (atmospheric composition) impact, because the atmospheric information can be applied to improve medium- and long-term warning systems.

In addition, it is important to highlight that although the results of this virtual mobility were not as satisfactory as expected, the study can be easily replicated in other eruptions occurring in our planet. Improving such kind of aerosol information will be beneficial for various atmospheric aspects including trend analysis and reporting local phenomena.

During the final meeting, the researchers involved in this VM agreed to present the results in an international conference (WLMLA, EAC or EGU). This is a contribution for the HARMONIA's objectives mainly for the MoU general objectives O1 ('Homogenization and harmonization of global aerosol measurements and retrievals') and O3 ('Increase the applicability for aerosol optical properties for different scientific fields'), in particular (i) demonstrating the relevance of aerosol optical properties to various communities (satellite atmospheric composition, solar energy, aerosol forecasting and aviation), and (ii) identifying new value-added products resulting from synergistic approaches. Regarding capacity-building objectives, this VM contributes to an action related with O1 ('Assess the current geographical distribution of ground-based measurements and report on the needs of spatial and temporal optimization based on relevant high impact applications (e.g. satellite validation, high impact areas as deserts, urban environments, etc.)'), and to an action related with O3 ('Create the links of the aerosol measurement (ground based and satellite based) and the modelling community in order to promote new synergistic techniques for targeted applications'). Besides, this work promoted the collaboration between different academic and research institutions, in the framework of WG2 (Improvement of aerosol products) and it contributes for the MoU deliverable D2.1. 'Report on synergistic approaches towards better quality products'.

This VM also contributed to the COST excellence and inclusiveness policy, due to this action involve researchers from an Inclusiveness Target Country (ITC) and an International Partner Country (IPC), i.e. Portugal and Brazil, respectively. This virtual mobility contributed to gender balance (2 female and 2 male researchers) and simultaneously some of the researchers involved are young researchers (Vanda Salgueiro and Fabio Juliano da Silva Lopes) aiming at developing their scientific career and fostering international collaborations, being this virtual mobility great opportunity for this purpose.