Design of ash dispersion and deposition products for volcanic emergencies in Argentina

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1. Introduction

Argentina is exposed to ash fall and ash dispersion from frequent explosive eruptions originating mostly from Chilean volcanoes and less frequently from Bolivian and Peruvian volcanoes. In this context, volcanic activity on the border of Argentina poses a unique challenge in relation to volcano monitoring and volcanic emergency management (Garcia and Badi, 2021).

The Servicio Geológico Minero Argentino (SEGEMAR) through the Observatorio Argentino de Vigilancia Volcánica (OAVV) monitors the volcanic activity and manage volcanic emergency in the country in collaboration with the Servicio Meteorológico Nacional (SMN), where VAAC Buenos Aires operates. SMN monitors the presence of volcanic ash in the atmosphere in the VAAC area of responsibility and produce numerical forecast of ash dispersion and deposition to advise the aeronautical community as VAAC and to contribute to the National management of volcanic emergency as SMN.

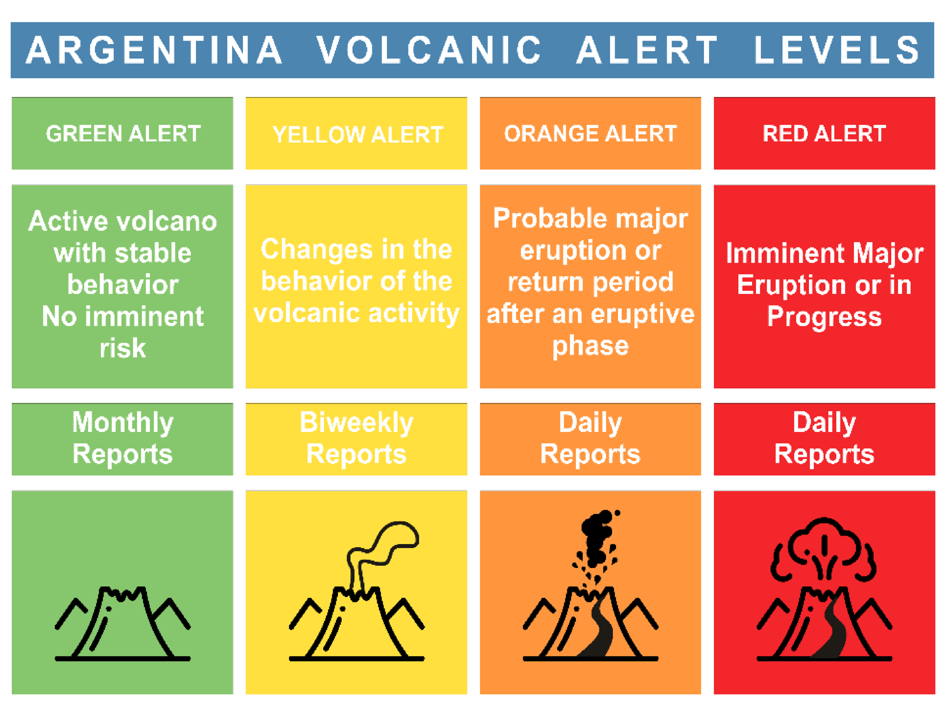
By the end of 2026, all the VAACs will produce as a Recommended Practice the Quantitative Volcanic Ash (QVA) Concentration Information, which is a Deterministic and Probabilistic ash concentration forecast based on impact-based thresholds for aviation (ICAO, 2024). This product in Argentina will coexist with ash dispersion and deposition numerical forecast produced for civil protection purposes. Here we show the design of the ash dispersion and deposition products for civil protection in this new context to guarantee the harmony between both products.

2. Metodology

When SEGEMAR-OAVV indicates a Volcanic Alert Orange level, the SMN starts running the model daily with different plume heights to produce ash dispersion and deposition forecasts. Eruptive plume heights are agreed upon by both organizations based on historical data. This was done in 2023 when the alert level for Lascar volcano was raised to Orange.

From November 2026, when an eruption occurs, the SMN will run the model as an ensemble and another deterministic run in a smaller domain, with higher resolution and a grain size distribution with coarser particles to produce dispersion a deposition for civil protection.the dispersion a deposition for civil protection.

The QVA Information will only consider the dispersion of fine ash (grain size > 64μm) while the Civil Protection product will consider the dispersion and deposition of coarser particles (grain size > 2mm).



SMN uses the FALL3D model (Folch et al., 2020) to predict volcanic ash dispersion and deposition. The model is coupled with the Global Forecasting System (GFS, NOAA) meteorological model. Volcanic ash particle characteristics are assigned using volcano analogs considering Mastin et al., (2009), Aubry et al., (2023) and Scasso et al., (1994) and the emission profile is defined by column height estimates based on remotely sensed data and a Suzuki parameterization (Pfeiffer et al., 2005).

The QVA information will have a horizontal resolution of 0.25°. It will take into account the uncertainty in the column height and the shape of the emission profile. While the Civil Protection product will be a deterministic run with a horizontal resolution of 0.1° as a first step. Figure 1 shows the process flow diagram.

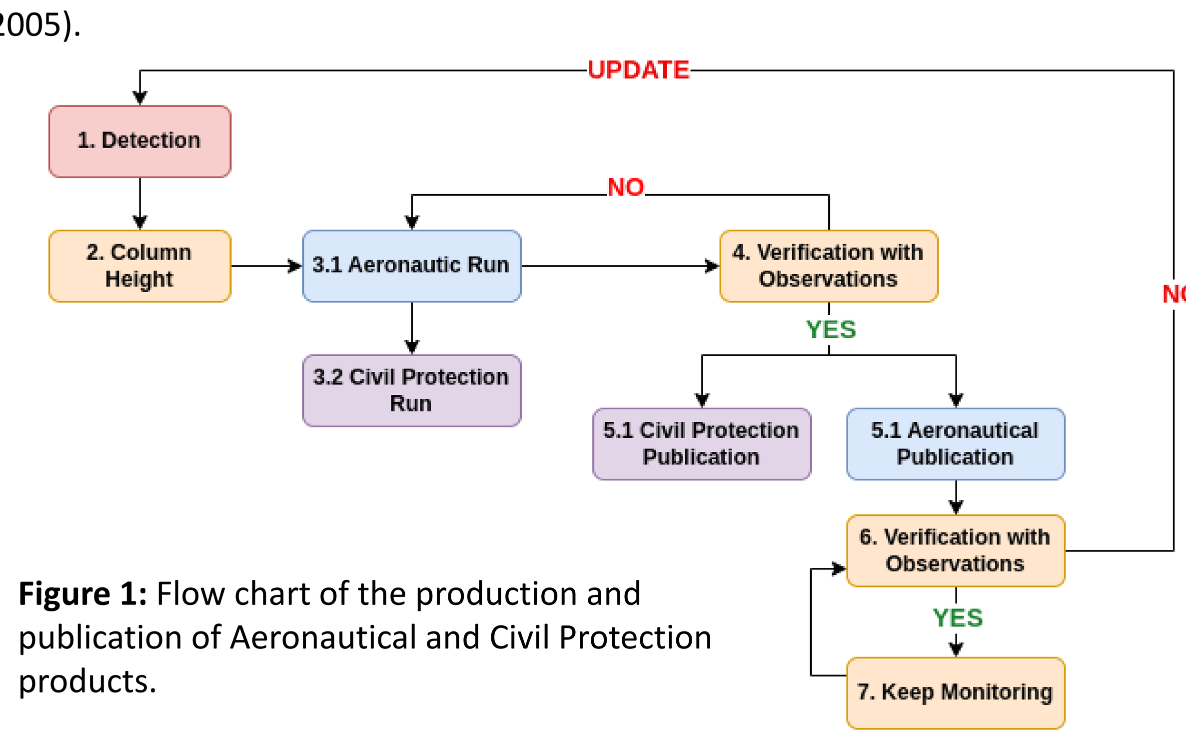


Figure 1: Flow chart of the production and publication of Aeronautical and Civil Protection products.

3. Design of the product

Volcanic ash fall can cause different impacts depending on the mass loading on the ground (Table I) and the concentration in the air can reduce visibility affecting ground transportation and producing health impacts.

To define the ground ash mass loading threshold used in the Civil Protection product, we used the impacts summarized in Biass et al. (2014) and defined three impact categories to help stakeholders identify the potential impact.

Table I: Ash mass load impact on ground (from Biass et al., (2014))

Impact	Threshold	Potential impact
1	1 kg m^{-2}	Electric flashover, closing airports
2	10 kg m^{-2}	Impact on road traffic, damage on crops
3	100 kg m^{-2}	Structural damageof weakest structures

The ash concentration is related to visibility, since the higher the concentration the lower the visibility. To estimate a range of visibility reduction we used the empirical relationship of Shao and Dong (2006) between total dust concentration and visibility. Three categories were identified based on this relationship, which are shown in Figure 2.

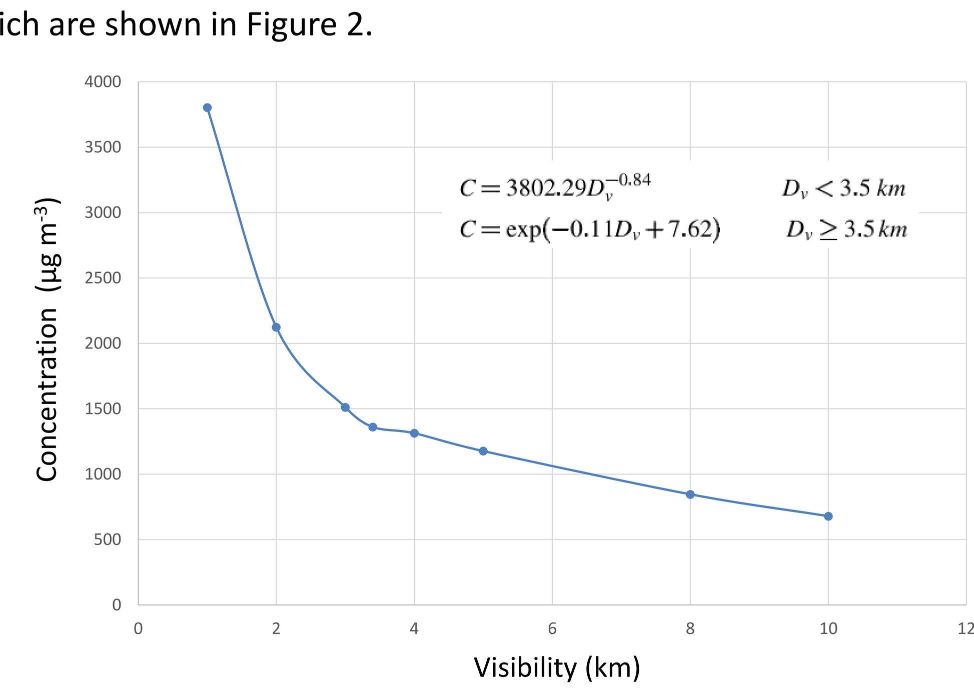


Figure 2: Concentration (C, μg m-3) as a function of Visibility (D_v, km) using Shao et al. (2006) empirical relation for dust events.

4. Example of the products

A hypothetical eruption of Lascar volcano (23.37°S;67.73°W, Chile at 5592 m a.m.s.l) with 15 km plume height on January 8, 2025 at 6:00 UTC. Figure 2 shows the 24-hour ash concentration forecast and the probability of exceeding 0.2, 2, 5 and 10 mg m^{-3} at FL350-FL400 for the Aeronautical community, and Figure 3 shows the Civil Protection products.

Aeronautical products

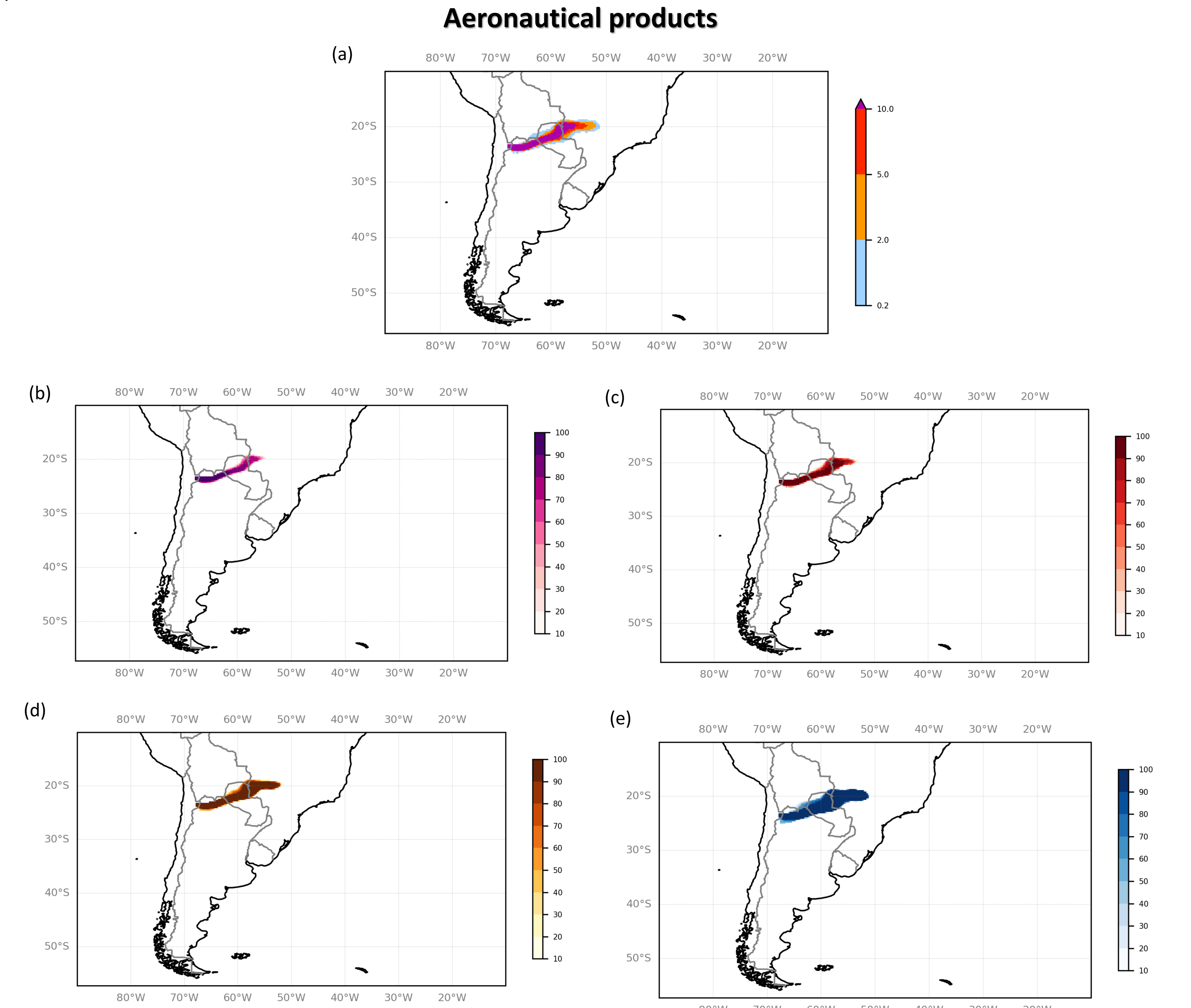


Figure 3: Forecast of (a) Ash Concentration (mg m^{-3}) and Probability (%) of exceeding (b) 10, (c) 5, (d) 2 and (e) 0.2 mg m^{-3} at FL350-FL400 after 24 hours of emission valid on 9th July at 6:00 UTC.

According to the product, high concentrations (>5 mg m^{-3}) are expected in the layer between 10668 m (FL350) and 12192 m (FL400) in northwestern Argentina.

Civil Protection products

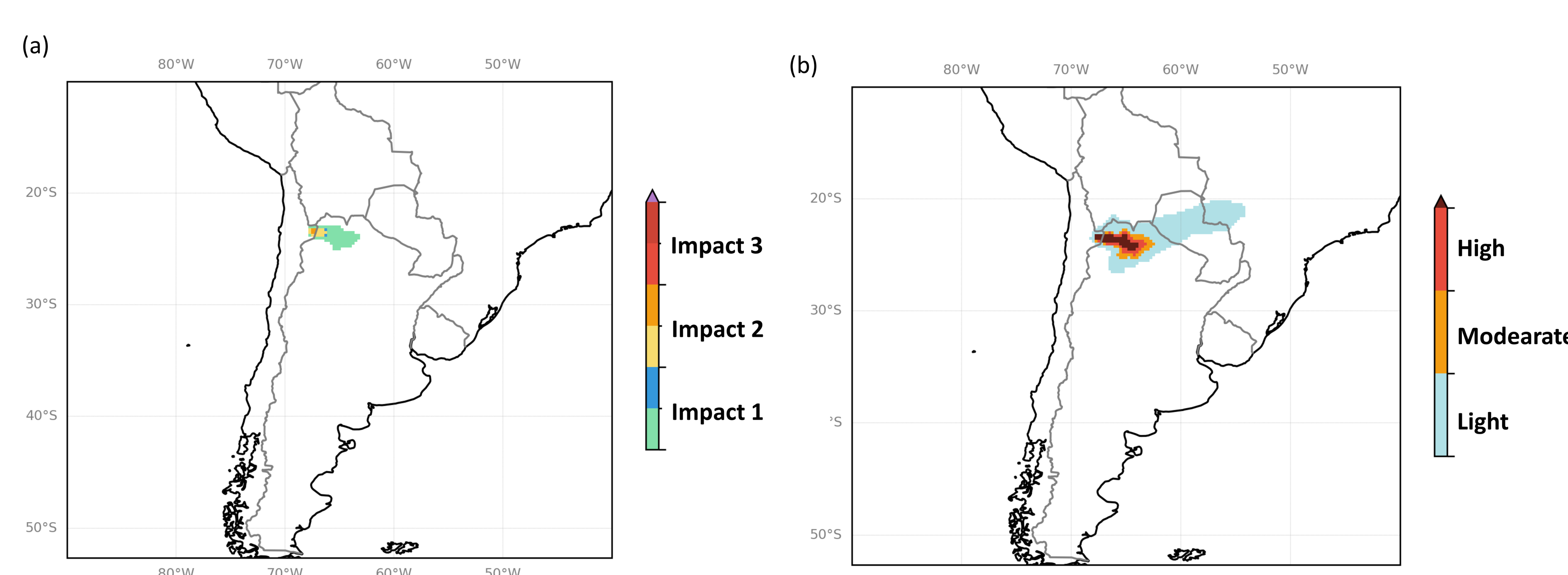


Figure 4: Forecast of (a) Ash Mass Load on ground impact and (b) estimated Visibility Reduction at ground level valid on 9th July at 6:00 UTC.

According to the product, the impact of ash deposition would be greatest near the border between Argentina and Chile. And visibility would be greatly reduced at ground level over a larger area over northwestern Argentina.

This information, in combination with the infrastructure layers, among others, will contribute to the decision-making process of the authorities to help and protect society in case of volcanic emergency.

5. Conclusions

- The aeronautical product, Quantitative Volcanic Ash Concentration Information, and the Civil Protection product in Argentina will coexist from Novembre 2026.
- A new design of the Civil Protection product was shown here as a collaborative work between the volcanological and meteorological organizations of Argentina.
- More work will be done with the Civil Protection users to improve the product.
- Some users will use the products independently, while others will have to use both. Training will be important to understand the differences
- In the near future, ensemble forecasts will be produced for Civil Protection as QVA is established and more computational resources become available.

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