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Workshop Abstracts

WIND-REMOBILISATION PROCESSES OF VOLCANIC ASH

Bariloche, 23 – 26 October 2019

INVITED TALKS

23 October – Day 1

THEME 1 - Physical description I: examples from Argentina

M. Elissondo and J. Kaufman (SEGEMAR, AR)

"Sources of remobilized pyroclastic material associated with the volcanism of the Argentine-Chilean Andes"

The Andean Cordillera extends from Colombia to Tierra del Fuego along the western margin of South America. Different subduction geometries along the margin define four zones with active volcanism (Northern, Central, Southern and Austral volcanic zones) separated by volcanic gaps (Ramos and Aleman, 2000; Stern, 2004). The Global Volcanism Program (2013) lists 174 active volcanoes for the entire Andes. The Argentine-Chilean Andes (22-55°S) includes volcanoes from the southern portion of the CVZ, the SVZ and the AVZ. These three zones include 115 active volcanoes, with at least 40 volcanoes having erupted during historical times (since XVI Century). This portion of the Andes records many large to moderate volcanic eruptions during the past centuries (Quizapu, 1932; Hudson,1991; Láscar, 1993; Chaitén, 2008; Cordón Caulle, 2011; Calbuco, 2015) and very large Holocene to Postglacial eruptions (Cerro Blanco, Laguna del Maule, Villarrica, among others). The purpose of this study is to compile those Holocene explosive volcanic events from the Argentine-Chilean Andes that produced pyroclastic deposits, which could subsequently be remobilized by aeolian activity. The position of the Andean Cordillera with respect to the dominant wind direction causes, in most of the cases, tephra dispersion toward the east, resulting in widespread tephra fallout deposits in Argentina. The semi-arid to arid conditions east of the Andes promotes the remobilization of tephra by wind, which has been reported after large historic eruptions (Hudson, Cordón Caulle), however remobilization appears to be also a common phenomenon in smaller and frequent eruptions (Copahue, Peteroa).

M.H. Easdale (on behalf of the colleagues from INTA Bariloche) (IFAB-INTA Bariloche – CONICET)

"*Assessments and responses of INTA Bariloche to the volcanic ash fall from the Cordon Caulle eruption*"

Volcano eruptions are a key disturbance factor in Patagonian rangelands, with impacts in livestock production and rural communities, through deposits of ash over large areas. This was the case of the 2011 Cordon Caulle eruption, which occurred in the context of a long-lasting drought. The actions of INTA Bariloche are revisitied considering three aspects: i) Zonification (inmediate and ex-post) to inform and orient public policy about regional differences in terms of the affected areas, ii) Recommendations during emergency and actions developed in the rural areas to mitigate the impact, iii) Productive and biophysical assessments (ex-post), with respect to direct impact on livestock (e.g.

animal death and productivity, animal wool quality, tooth wear, animal dietary shifts), impact on soil conditions, ecosystem (wetlands) and forage grasses responses, and impact on insects (Orthoptera). A final comment will be developed with regards to the shifts in logics behind technological innovation (R+D) and agricultural management, which are one of the main legacies of this ash impact in the rural areas of North Patagonia.

L. Dominguez[1]*, C. Bonadonna[1], P. Forte[2], P. Jarvis[1], R. Cioni[3], L. Mingari[4], E. Rossi[1], D. Bran[5] and J.E. Panebianco[6]

"Aeolian transport and deposition mechanisms of tephra remobilisation"

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Although volcanic eruptions represent short periods in the whole history of a volcano, the large amount of loose pyroclastic material produced, combined with aeolian processes, can lead to continuous, long-lasting reworking of volcanic products, lasting from years to millennia after the eruption. These phenomena result from a complex combination of meteorological conditions, surface properties and the intrinsic features of the primary volcanic deposits. We investigate aeolian processes of the 2011 Cordón Caulle (Chile) tephra-fallout from two perspectives: first, based on a comprehensive analysis of field observations and particles features (i.e. grainsize and shape), we characterize the main types of secondary deposits observed in the Patagonian steppe: i) deposits associated with non-erodible surface roughness elements (e.g. vegetation and rocks), and ii) deposits associated with pre-existing dunes or similar erodible bedforms. Secondly, based on a systematic collection of airborne material from 2011 to 2016, we investigate the temporal variation over which ash-remobilisation occurs. Two contrasting time-scales are identified: i) a first period of about 7 months after the eruption with a fast remobilised mass decay (~59 to 77 days); and a second period till 2016 with a slow mass decay (~445-775 days).

Pablo Forte[1], Lucia Domínguez[2], Costanza Bonadonna[2], María Clara Lamberti[1,3], Chris E. Gregg[4], Donaldo Bran[5]

"Wind remobilization impact associated with the Cordon Caulle eruption"

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[5] Institute of National Agricultural Technology-INTA, Argentina

The 2011 Cordón Caulle eruption emitted about 1 km^3 of rhyodacitic tephra. Dominant westerly winds in the region caused most of the primary tephra to deposit in Argentina. In addition to the impact of widespread dispersal and fallout of primary tephra during the eruption, a vast area of the Argentinian Patagonia was also affected by wind-remobilization of ash. In this mixed study, we characterize the phenomenology and assess the impacts associated to this aeolian process by combining tools of natural and social sciences. We focus our analysis in two contrasting farming communities showing different environmental, socio-economic and primary tephra deposit characteristics. Our study areas

included the farming community of Villa La Angostura, located in the Andes Range at ~50 km from Cordón Caulle and Ingeniero Jaccobacci, located in the Patagonian steppe ~250 km from the vent. Our findings show the primary importance of wind, rainfall and ash availability —and the influence of pre-existing local conditions— in controlling the occurrence and persistence of this long-lasting secondary hazard and in its associated impacts. We demonstrate that massive wind-remobilization events can exacerbate the negative impact of primary tephra fallout events from the time of deposition to many years after the eruption.

C. Stewart[1], T. Wilson[2], G. Leonard[3], V. Outes[4], G. Villarosa[4], P. Baxter[5], J. Cole[2] and H. Craig[2]

"*Wind remobilization impact in Argentina*"

1 Massey University, New Zealand
2 University of Canterbury, New Zealand
3 GNS Science, New Zealand
4 CONICET/INIBIOMA, Universidad de Comahue, Argentina
5 Cambridge University, UK

Our New Zealand-based team, with international collaborators, has conducted a sustained programme of volcanic ash impact assessment field visits over the past 25 years, across most volcanically active regions of the world. For understanding impacts on agricultural systems, we have had a particular focus on recent eruptions in northern Patagonia, because of similarities to the New Zealand climate and landscape. This presentation will summarise key insights from impact assessment field trips for four recent Patagonian eruptions: the 1991 Hudson eruption; the 2008 Chaitén eruption, the 2011 Cordón Caulle eruption and the 2015 Calbuco eruption. Valuable lessons about the importance of wind remobilisation of ash have been learned, particularly from our 2008 field visit to the depositional area of the Hudson eruption 17 years after the eruption. Slow recovery of agricultural systems has been a feature both in proximal areas, due to burial by very thick tephra and lapilli deposits, and in distal areas where wind remobilisation caused continuing impacts for at least a decade. We have used hazard intensity measures and impacts across three eruptions to develop fragility functions for agricultural systems, to inform emergency management and loss modelling for future eruptions.

G. Toyos (CONAE, AR)

"*Wind resuspension of volcanic ash from space*"

This talk will provide an overview of the possibilities of space-borne remote sensing for detecting resuspended volcanic ash with a special focus on a cloud observed near Cordón Caulle volcano, Chile. On 14-Dec-2013, the Cooperative Institute for Meteorological Satellite Studies (United States) reported an ash cloud apparently emitted by the volcano and indicated its cause was probably resuspension. Thus, a series of tests was designed in order to identify the cause of this event by using remote sensing technology. Volcanic ash satellite products enabled the confirmation of the presence of volcanic ash and observations on the MODIS based cloud-integrated water path provided evidence in favor of a small and short-lived eruption. Thus, a volcanic eruption would constitute an explanation for the cloud of 14-Dec-2013, but it was not possible to discard resuspension. On the other hand, we found out that the water path product could constitute useful ancillary data to identify the origin of this kind of processes. The set of observations presented constitutes a good initial point towards the

identification and subsequent development of decision support tools for the mitigation of the hazards posed by volcanic ash resulting from volcanic eruptions and resuspension.

Elian Wolfram, SMN and UNIDEF; Juan Pallota, UNIDEF; Facundo Orte, UNIDEF; Sebastian Papandreas, SMN; Raul D'Elia, UNIDEF

"New insights into wind remobilisation from surface remote sensing"

The South-Patagonian region in South America is the southernmost habitable area in the world, and the inhabitant of this region directly suffers the influence of volcanic ashes spread from the Andes volcanoes that cause serious damages on agriculture, live stocks, forestry, tourism, and daily life near the volcanoes and make traffic jams of airlines over much larger area. In the period 2013-2018, Argentina, Chile and Japan run the SAVER-Net, South American Environmental Risk Management Network Project. In the frame of it, a ground based remote sensing network was developed, with different kind of instruments, like aerosols lidars, solar photometers and radiometers and particle counter that offer and ideal set of instruments to monitor the ash remobilization in the Patagonia region. The SAVER-Net network counts with of seven LIDAR systems, as independent measurement nodes, strategically emplaced in different locations of the country, to measure a variety of aerosol and atmospheric parameters. Five of them are installed at the airports of Río Gallegos, Comodoro Rivadavia, Neuquén, San Carlos de Bariloche and Aeroparque (SMN). The remaining two lidars are located at North part of the country, in the Observatories of Pilar – Córdoba and Las Talitas – Tucumán. The products obtained from the LIDAR network provide environmental sensitive information. In this work, the instrumental capabilities of SAVER-Net network will be described and a couple of different events of ash remobilization and dust transport will be presented as an example of ground based monitoring capabilities in Argentina.

THEME 2 - Physical description II: examples from other regions

N. Varley (Universidad De Colima, MX)

"Wind remobilisation in Mexico"

Of the 26 active volcanoes of Mexico, two have been regular sources of ash in recent years. Both Popocatépetl and Volcán de Colima have had regular Vulcanian eruptions and have had multiple episodes of dome growth. Episodes of ash-fall have been sufficient to close nearby airports on numerous occasions. Hazard maps have been recently produced for both volcanoes, which include simulations of ash production and its distribution for different eruptive scenarios and wind conditions. One of the more notorious ash-producing eruptions of the last century was El Chichón; wind remobilization of its ash has up to now not been considered as a hazard. At Volcán de Colima, the largest eruption in over 100 years occurred in July 2015. The generating mechanism for this event was unusual, no clear explosive phase was identified in the seismicity, and the eruption column did not extend to any significant altitude. A relatively large pulse of magma ascended the system, and was efficiently fragmented, resulting in large pyroclastic density current (PDC) generation, in two main pulses separated by almost 16 hours. The collapse of juvenile magma was accompanied by some older deposits on the crater rim. The PDC reached over 10 km, but fortunately did not take any lives.

Remobilization of the finer ash of these events did impact several local communities. Winds were relatively strong on the day, and ash accumulated up to thicknesses of 2 cm. Initial measurements of remobilized ash have been made in Colima, where large exposures can affect farm workers. No large tephra falls have occurred recently, but the debris avalanche deposits that cover the region to the south are ready sources of large volumes of ash. Clearly more work is needed to characterize the hazard.

M. Encalada (IGEPN, EC)

"*Wind remobilisation in Ecuador*"

In the last 20 years, Ecuadorians have witnessed explosive eruptions at five different volcanoes: Guagua Pichincha (1999-2001), Tungurahua (1999-2016), Reventador (2002-ongoing), Sangay (at least 2000-ongoing) and Cotopaxi (2015). During those eruptions, volcanic plumes and ash fallouts have been the most common phenomena and wind remobilization of the volcanic ash has been a common secondary phenomenon associated to high amounts of extremely fine grained ash. Wind remobilization at a more local scale is also been a factor of atmospheric contamination wherever there are large quarries in volcanoclastic deposits (i.e. Chimborazo DAD in Riobamba, Pululahua ignimbrite in San Antonio de Pichincha, Chalupas Ignimbrite in Latacunga). In Ecuador, this phenomenon has been clearly seasonal with much higher impact during the dry season between June and September.

Wind remobilization affected the visibility in large cities such as Quito (Pichincha 1999, Reventador 2002) and main roads such as the Panamerican highway (Cotopaxi 2015). It also greatly increased the atmospheric contaminant residence time during the Tungurahua and Cotopaxi volcanic crisis, causing chronical health diseases and impacting crops and livestock. In the future it is important to study in more details the conditions to produce wind remobilization of volcanic ash and their characteristics in order to limit its impacts on the society.

C. Chun (INSIVUMEH, GT)

"*Wind remobilisation in Guatemala*"

In Guatemala there are 39 volcanoes of which 4 are active, however, INSIVUMEH monitors 3 of these, which are: Fuego, Pacaya and Santiaguito. The Tacana volcano does not yet have equipment. One of the main threats is the fall of ash, in eruptive events it is transported by the wind, mainly affecting nearby towns and cities. The Fuego volcano is 40 km from the city of Guatemala and the Pacaya volcano 35 km from that city, so there has been an ash fall in the city and the La Aurora International Airport has also been closed; the Santiaguito volcano is 15 km from the city of Quetzaltenango however several flight lines have been affected by ash columns. The ash has been transported in several directions and for several kilometers; ash fall has been reported in other neighboring countries such as: Mexico, El Salvador and Honduras.

R. Aguilar (INGEMMET, PE)

"*Wind remobilisation in Peru*"

During the last years, in southern Peru, explosive activity of composite volcanoes has produced emission of tephra disturbing the daily lives of people and caused damages in the infrastructure and economic activities. The ongoing eruptive cycle of Sabancaya which started on November 6th 2016 has been affecting villages and agriculture along the Colca valley. During its major activity, it was recorded more than 100 explosions per day, whose products were dispersed as far as 70 km from the vent. Three eruptive cycles of Ubinas volcano have affected agriculture, livestock and has forced the

authorities to evacuate people around ~10 km from the vent. The last eruptive event of Ubinas has occurred on July 19th 2019 and has emitted tephra which has reached as far as 200 km to the east. The ongoing eruptive cycles of Sabancaya and Ubinas are characterized by vulcanian-type eruptions. Considering the altitude and the weather conditions of the areas where these volcanoes are placed, ash remobilization is a frequent phenomenon. Dust-devils are very common in the highland and resuspended material is then transported by wind to the lower-altitude zones affecting the populated areas. Even if ash remobilization occurs frequently, very few studies or strategies have been developed to enface this process in Peru.

M.L. Monsalve (SGC, CO)

"*Wind remobilisation in Colombia*"

Ash wind remobilisation and its effects is not a phenomenon studied or well known in Colombia. This has been recently observed in the Nevado del Ruiz volcano (NRV), and dune geoforms in the vicinity of the volcano, confirm the occurrence in its eruptive history. Since 2012, more than 1500 ash emissions have been confirmed in the NRV, most of them of very small volume, which have deposited material, less than 10 km (W–NW) from the vent. On 12/14/2018, the VAAC reported the emission of ash originating from the NRV, which generated the notification of "eruption" of the volcano in the "Disaster Alert" application. A similar situation was presented on January 2, 2019. On these dates, the SGC–Vulcanological Observatory of Manizales (OVSM), confirmed that there was no seismic activity related to ash emissions and, through the webcams around the volcano, was observed a phenomenon of material remobilization from the upper parts of the volcano toward the W sector, due to strong winds in the area. The phenomenon deposited ash particles with thicknesses <1 mm and sizes between 2–4 phi, mixed with non-volcanic material, in cities 25 km NW away from the volcano, causing confusion and alarm in the population. Future analysis of this phenomenon would imply the study of the geological record of active volcanoes with VEI> 3 in Colombia.

C. Jorquera and A. Amigo (SERNAGEOMIN, CL)

"Wind remobilisation in Chile"

Ash remobilization has been documented several times in the last decade in Chile, although the dynamic of the process, timing, frequency and impacts are not well understood. Documented events have been usually reported some weeks after large recent explosive eruptions, such as Calbuco in April 2015, and Cordón Caulle in June 2011. For the latter, ash remobilization has been reported even few years after the eruption. On the other hand, some events have been linked to remobilization from tephra fall and PDC deposits. For instance, during two days in March 2019, the Geological and Mining Survey of Chile (SERNAGEOMIN), detected ash transport from 1932-deposits of Quizapu volcano to the highly populated central valley. The high concentration of ash in the atmosphere was enough to accumulate a thin layer (millimetric) more than 100 km from source, and the averaged particulate size was between 50 and 80 um. Despite the relevance of this event, this is the only case analyzed so far by SERNAGEOMIN, mostly because it reached thousands of people in Chile. In summary, there is increasingly concern about ash resuspension at populated regions and therefore a better understanding on the physical origin of the process, impacts on both people´s health and environment are needed. In addition, the developing of reliable forecasting tools as well as a new sampling system must be planned in order to get a rapid ash characterization of ash, which allow to determine its potential impact.

M. Butwin (IMO, IS)

"*Wind remobilisation in Iceland*"

The 2010 eruption of Eyjafjallajökull produced volcanic ash that was mostly deposited to the south and east of the volcano with the thickest deposits closest to the main eruption vents. For months following the eruption there were numerous reports of resuspension of volcanic ash made by weather observers on the ground. A saltation sensor (SENSIT) and Optical Particle Counter (OPC) located on the southern side of Eyjafjallajökull measured post-eruptive particulate matter (PM) saltation and suspension events, some of which were also observable by satellite imagery. Visible satellite images and the saltation sensor shows that PM measured by the OPC originated mostly from the slopes of Eyjafjallajökull where ash from the 2010 eruption was deposited. PM events were only detected by this OPC when winds had a northerly component or coming from the slopes of Eyjafjallajökull towards the instrument. These PM events were likely dominated by the recently deposited volcanic ash and are therefore considered to be ash resuspension events. During the detected ash resuspension events, most of the particles were 1 µm and smaller. During the largest observed events, particles >10 µm were also suspended but in extremely low concentrations (< 1 particle/cm3); however, the saltation measurements show high concentrations of particles >100 µm in size. The weather conditions during the observed PM events were typically windy and dry. During the largest events, winds were at least 5 m/s with a relative humidity < 70%. Ground conditions in Iceland quickly change from unfavorable to favorable for the suspension of particles. With a period of saltation occurring before high concentrations of suspended particles. It is hypothesized that this is due to the overall porosity of the surface material allowing water to filter through quickly, as well as the fast drying time of surface material. The moist conditions of Iceland in terms of the atmosphere and the ground do not appear to be a deterrent for large PM events to occur, as they are in other world desert locations.

Kristi Wallace, Dave Schneider, Hans Schwaiger (USGS, USA)

"*Wind remobilisation in Alaska*"

Resuspension and transport of fine-grained volcanic ash from the Katmai National Park and Preserve region of Alaska has been observed and documented over the past several decades and has likely been occurring ever since the 1912 Novarupta-Katmai eruption. This eruption produced approximately 17 cubic kilometers of ash deposits and 11 cubic kilometers of pyroclastic material that filled nearby valleys, creating what is today known as the Valley of Ten Thousand Smokes. Pyroclastic deposits in this valley are up to 200 meters thick and the valley remains almost entirely free of vegetation. Resuspension into ash clouds occurs most often in the spring and fall when strong northwesterly winds blow over the snow-free, dry landscape. These clouds have been seen by individuals and in satellite imagery. Documented clouds are typically between 1–5 kilometers above sea level and extend up to 250 kilometers downwind over Shelikof Strait and Kodiak Island. Trace amounts of ash fallout (usually less than 1 mm) have been reported from communities on Kodiak Island. This fallout is composed primarily of glass shards. Clouds of resuspended volcanic ash are not well studied and little is currently known about the amount or sizes of ash particles in the clouds. Unlike many other wind-related erosion events in Alaska composed of non-volcanic sand and silt, these clouds are composed of volcanic ash and are similar to ash clouds generated from a volcanic eruption. Thus, dilute clouds may pose hazards to human health and aircraft operation. In 2015–2016, the Alaska Volcano Observatory deployed particulate monitors to Kodiak Island to: 1) assess the impacts to air quality during these

resuspension events, and 2) collect physical samples to assess grain size and composition of fallout. The Observatory has also provided community training on ash collection and observation reporting and is developing a model to forecast ash resuspension.

Kristi Wallace, Marcus Bursik, Steve Kuehn, Andrei Kurbatov (USGS, USA)

"*An overview of efforts toward standardization of tephra collection, analysis and reporting*"

Studies of explosive volcanic eruptions and the ash clouds and respective deposits they produce are becoming global in scope. Advances in research are therefore, becoming more dependent on the ability to identify and correlate tephra deposits across broad regions. These two factors, coupled with our growing knowledge of the limitations of analytical techniques and standard practices in tephra characterization and correlation, make it critical to seek interoperability of tephra datasets. Following the tephra workshops in 2014 and 2017 in Portland, Oregon (https://vhub.org/resources/3860), a working group has been established to hold focused workshops to take action on the outcomes and recommendations of those previous workshops. We seek to seed the implementation and use of cyber-based tools and technologies in tephra studies to enable global study and correlation of tephras. Specifically, our goals are to produce:

1. A consensus paper to draw attention to the demand, and to develop a coordination plan for creating datasets compatible across disciplines,
2. Multiple open access products, for example, best practice templates, data collection and processing templates with "end user" oriented minimum sets of essential data, and
3. Collation of databases and already built tools/code/software for data processing.

To accomplish these goals, a series of small, focused, international workshops are planned for 2019–2021. These workshops will bring together experts from multiple disciplines with the goal of accomplishing end-products. The 2019 workshop, held in Dublin Ireland, focused on completing templates for the collection, analysis and correlation of tephra deposits as well as a supporting consensus document. These efforts are directed so that the tephra community has the tools to work better together to make advances in tephra studies across the many disciplines and regions where tephra is important. The workshops will include small writing groups to work on a focused activity for 1 week each, resulting in a definitive product during the two-year period of the activity. Meetings are being held at research institutions on different continents to draw in researchers from volcanic regions of interest, and to capture differences in local perspective.

24 October – Day 2

THEME 3 - Dynamics of wind remobilisation

J. Merrison (Aarhus University, DK)

"*Dynamics of wind remobilisation*"

In many cases the remobilization of volcanic ash by wind can be as dangerous to health and the environment as the initial deposition. The dynamics involved is complex, involving both aerodynamics and many-particle kinematics. Despite several decades of active research in wind driven soil erosion, describing the processes of remobilization is still challenging. This is especially true in the case of very fine ash (for example PM10). Specifically, here effects such as; particle aggregation/agglomeration,

saltation induced resuspension, electrification and the generation/destruction of crusts are still being investigated. Focus will be placed here on laboratory studies (in wind tunnels) and how these can be compared to field investigations and modelling.

J.A. Gillies[1], V. Etyemezian[2], G. Nikolich[2]

"*Laboratory experiments of volcanic ash resuspension*"

Division of Atmospheric Sciences, Desert Research Institute, Reno[1] and Las Vegas[2], NV, USA

Laboratory experiments were carried out to measure threshold shear velocities (u_{*t} m s^{-1}) and emission rates (F $mg \cdot m^{-2} \cdot s^{-1}$) of ash under different environmental conditions, including relative humidity between 25%–75% and simulated rainfall with subsequent drying. Ash was collected from deposits from the 18 May 1980 eruption of Mount St. Helens (MSH) Washington and the 1912 eruption of Novarupta, in Alaska's Valley of Ten Thousand Smokes (VTTS). Samples were conditioned in a laboratory chamber and prepared with bulk deposit densities of 1,300–1,500 kg m^{-3}. The deposits were subjected to different wind shear velocities using a modified PI-SWERL® instrument. Under a constant relative humidity of 50% and shear velocities 0.4–0.8 m s^{-1}, emissions of particles ≤10 µm (aerodynamic) diameter ranged from 10 to >100 $mg \cdot m^{-2} \cdot s^{-1}$. Addition of liquid water equivalent to 5 mm of rainfall had little lasting effect on MSH wind erosion potential, while the VTTS deposits exhibited lower emissions for at least 12 days. The results indicate that particle resuspension due to wind erosion of ash deposits potentially exceeds that of most desert surfaces and approaches some of the highest emissions ever measured.

E. Del Bello, J. Taddeucci, P. Scarlato, (INGV Roma, IT), J. Merrison, K. Rasmussen (Aarhus University, DK)

"*Experimental and field studies of the resuspension of volcanic ash by wind*"

The wind-induced resuspension of volcanic ash is a well-known source of hazard during and after eruptions at scales local to regional. Ash resuspension is modelled using appropriate values of the threshold friction velocity (U_{th}*), a parameter dependent on individual particle properties, deposit features, atmospheric humidity. So far, hazard-oriented models used literature parameters derived for non-volcanic particles, wind tunnel studies on volcanic particles being very limited and restricted to laboratory parameterizations, with in-situ effects not parameterized. The recent studies presented here are trying to fill this gap by providing much needed data on volcanic particles. First, we describe an experimental parameterization of U_{th}* of volcanic ash from Eyjafjallajökull (Iceland) and Campi Flegrei (Italy), performed in an environmental wind tunnel under controlled humidity conditions. We find that the currently adopted values of U_{th}* are only to be used for modelling the resuspension of volcanic ash in dry environments, whereas in wet environments, volcanic ash properties determine new, ash-specific values. Second, we present preliminary findings of an ongoing project in which we designed, calibrated and deployed a portable wind tunnel in the areas around Sakurajima (Japan) to characterize the wind-induced resuspension of volcanic ash deposits in the field.

A. Folch and L. Mingari (BSC, ES)

"*Theory and numerical modelling of ash remobilisation*"

Resuspension by wind of volcanic ash can persist for many years after its primary deposition on the ground. Periodic seasonal resuspension events deteriorate air quality and cause a variety of local impacts on the environment and communities, which can also encompass wider regions in the case of

large outbreaks able to transport ash away from the source regions. The occurrence of this phenomenon depends on a complex combination of factors involving meteorological conditions, properties and conditions of the soil, and physical characteristics of the deposited particles. In order to simulate the phenomenon and to forecast the subsequent ash dispersal, atmospheric transport models must include emission schemes that estimate the flux of particles at surface. Several parameterizations for emission exist for mineral dust and are typically extrapolated to volcanic ash. On the other hand, a second critical aspect is the model resolution at low atmospheric levels, particularly that of the driving meteorological model. Both aspects will be reviewed and illustrated using the FALL3D dispersal model.

THEME 4 - Modelling wind remobilisation

F. Beckett (UK-MetOffice, UK)

"Forecasting remobilised ash clouds at the London VAAC"

The London Volcanic Ash Advisory Centre (VAAC) are responsible for providing forecast guidance concerning the location of volcanic ash in the atmosphere (actual and forecast) within their area of responsibility, which covers Iceland, the northeast North Atlantic Ocean, the UK and Scandinavia. Traditionally this is thought of as forecasting plumes from an ash-rich eruption of a volcano, but also includes ash, which has been remobilised into the atmosphere from surface deposits during strong winds. We use our atmospheric dispersion model NAME to forecast remobilization events in Iceland, and track the onwards transport of the clouds of suspended particles. In this presentation, I will introduce the scheme used by NAME to model remobilization of surface deposits and show you the results from our ongoing work to improve our forecasts. This includes a study where we have used satellite-based measurements in combination with radiative transfer and dispersion modelling to quantify the total mass of ash resuspended during a significant remobilisation event in Iceland, and work to better understand the weather patterns conducive to remobilization.

M. S. Osores (VAAC-BA, AR)

"*Ash remobilisation observations and forecasting for BA-VAAC operations*"

To advise aeronautical users of the presence of airborne volcanic ash, Volcanic Ash Advisory Centers (VAAC) watch the atmosphere to detect these particles and produce advisory messages, including the observation and the forecasts of the ash plume dispersion. During the last years, VAAC Buenos Aires has experienced several ash remobilization events, with significant changes in the monitoring technology and modeling capabilities. Also, the experience of the forecasters in the identification of the synoptic situations that frequently trigger resuspension events has improved from year to year. But the variability on soil conditions and the partial knowledge on all the possible sources of ash remobilization in the region, introduce uncertainty in the advisory process. That is why the collaboration of the local State Volcano Observatory (SVO), to confirm the volcanic origins of the sources of remobilization, is very important for advisory production. In this work, we present an example of the advisories production process for volcanic ash resuspension, from the detection up to the advisory production, applied in VAAC Buenos Aires for ash remobilization events.

H. Schwaiger and K Wallace (USGS, USA)

"*Operational forecasts of the resuspension of volcanic ash deposits from the 1912 Novarupta eruption*"

The 1912 eruption of Novarupta-Katmai produced 17 km^3 of ashfall and 11 km^3 of pyroclastic-flow deposits that filled nearby valleys, creating what is today known as the Valley of Ten Thousand Smokes (VTTS). These deposits continue to pose hazards when strong winds in the region resuspend ash in times of suitable soil conditions (dry, exposed). Occasionally, the resuspended ash can be lofted to several kilometers altitude, extending to 250 km downwind, where it becomes an aviation hazard. Satellite observations and pilot reports indicate that such events occurred on a few dozen occasions since 2003, usually in autumn months of September and October. To forecast these events, we have modified the USGS ash dispersion model, Ash3d, to include resuspension of ash deposits based on boundary layer meteorological conditions using the 2.95 km North American Mesoscale (NAM) meteorological forecasts. The NAM meteorological model is evaluated for conditions (friction velocity, precipitation rate, snow depth, soil moisture) favorable for resuspension. When these criteria are met, an email message alert is sent to select AVO staff indicating that surface conditions are favorable for ash resuspension. If Ash3d models predicts resuspended ash, a text message is sent to alert staff of anticipated ash resuspension.

L. Mingari and A. Folch (BSC, ES)

"*Numerical simulations of ash resuspension using the WRF-ARW/FALL3D modelling system*"

Major explosive eruptions can inject large amounts of volcanic materials into the atmosphere, resulting in a large extension of the landscape covered by volcanic fallout deposits. Under favorable meteorological conditions, loose particles of the freshly deposited volcanic ash can be easily remobilized by wind. The recurrence of events of volcanic ash resuspension represents a collateral hazard derived from the primary volcanic activity with a long term impact on health, environment, and agriculture. Additionally, the presence of resuspended ash can affect aviation (flight cancellation, operational disruption at airports) and road transport networks. Although resuspended ash clouds can trigger substantial impact, only a few studies have attempted to model it and no systematic study of cases has been carried out. In this talk, I will examine the general characteristics of resuspension events in Argentina, including spatial distribution of sources, frequency, seasonal and diurnal variability, and transport patterns. For this purpose, I will summarize the main results of numerical simulations and observational data from meteorological networks, satellite imagery, lidar/ceilometer, and ground measurements of particulate matter concentration. The WRF-ARW/FALL3D modelling system is used to simulate the atmospheric transport and dispersion of wind-remobilized ash from both fresh and relic volcanic fallout deposits. The ability of the modelling approach to reproduce the observations will be discussed.

POSTERS

A. S. Enriquez[1] and J. Six[2]

"*Immobilization of ash in soil aggregates*"

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Volcanism can be negatively perceived for human population and natural systems; however, it can derive in very rich soils and replenish particles in areas under strong wind erosion. After the Puyehue–Cordón Caulle Volcanic Complex event in 2011, we studied processes of soil aggregates formation at an early stage of the succession. Areas with concave topography, as meadow are, tend to accumulate ash (erodible material) relocated from convex areas (deflation), as surrounded steppes are. Five and half years after the eruption, we sampled topsoil (0-5 cm) in meadows of the East semiarid region, and examined the distribution of different size fractions of water-stable soil aggregates and their associated carbon (C) and total nitrogen (N) contents. While the free ash is still moving in the steppe, soil neoformation processes were detected in meadows through the presence of large (LM= 4%) and small (SM=21%) macroaggregates, although microaggregates (m= ~45%) and silt + clay (s+c= ~29%) - ash size - dominated the soil fractions. The C and N contents decreased in a sequence: LM > SM > m > s+c, highlighting the importance of soil organic matter in the formation of larger-size aggregates and their quality. The incorporation of the ash into the soil aggregates suggests dynamism in the immobilization-stabilization processes in meadows, despite the semiarid context.

V. Fernández-Arhex and A. L. Pietrantuono (IFAB-INTA EEA Bariloche)

"*Volcanic Complex Puyehue-Cordón Caulle: insecticidal role of volcanic ash*"

We evaluated the effect of volcanic ash on survival, motivation and use of habitat in different species of insects. Laboratory bioassays results have shown that the ash does not affect the species studied in the same way. Phloem-sucking insects are not strongly affected, actively choose their habitats for living and are capable of discriminate unfavorable habitats (i.e. presence of volcanic ash). Orthopteran species, the volcanic ash has a strong aversive and insecticidal effect similar to that of inert dust. The recovery of populations affected by ash in desert areas will be slower, and this will have long-term consequences for insect host plants, and on the development of populations of vertebrate insectivores. In humid regions will impact the ecosystem by the addition of nutrients, which in combination with water retention by the ash will lead to a recovery of the populations under favorable conditions. Therefore, the ashes could generate two types of responses on insects: direct (on individuals) or indirect (on individual-environment interactions).

J.F. Mejia[1], J.A. Gillies[1], V. Etyemezian[2], R. Glick[3]

"*A High Resolution (20 m) Measurement-Based Emissions and Dispersion Modeling Approach for Particulate Matter*"

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A high-resolution (20 m) dust emissions and transport model has been developed for particulate matter (PM). We demonstrate its effectiveness to model mineral dust emissions and downwind concentrations of PM from a coastal sand dune complex in California USA. This modeling system is applicable for modeling wind driven resuspended ash. The emissions grid is developed from measurements using the Portable In-Situ Wind ERosion Lab (PI-SWERL), which provides a well-determined PM emissions field as a function of time and space. Wind and turbulence fields are estimated using the CALMET meteorological model and constrained, in this case, with surface station meteorological data, upper air soundings, buoy data, and the North American Reanalysis data. Hourly, three-dimensional wind flow and instability objective analysis fields are developed at 20 m resolution. The dust dispersion component is a Lagrangian Stochastic Particle Dispersion Model driven by the CALMET output and the PI-SWERL time-space variable emissions. Results were tested at two downwind locations, with positive correlations for flow conditions (R2=0.89) and PM concentrations (R2=0.85). Evaluations against observations during mean flow conditions as well as for elevated dust events suggest that the model framework can capture the spatial and temporal characteristics of mean day-to-day and diurnal PM variability.

Raffo F., Ayesa J.A., Umaña F., Gaitán J.J., Bran D. (Remote Sensing and GIS Lab Natural Resources Area – E.E.A. INTA Bariloche)

"*Eruption of Puyehue-Cordon Caulle. Expedited methods used to determine the affected area and the thickness of the ash deposition*"

On June 4, 2011, the Puyehue - Cordón Caulle Volcanic Complex located in the Republic of Chile, near the border with Argentina, erupted. The eruption generated a column of gases and ashes that reached 14,000 m high, persisting for several days between 5,000 and 10,000 meters. The different human activities in the area were impacted based on the amount and type of accumulated ash. With the aim of zoning and quantifying the degree of affectation, different expeditious methods were used to map the distribution and the accumulated ash thickness. The delimitation of the affected area was performed using two satellite images where the different spectral response of the vegetation and ash was compared. The degree of affectation (ash thickness) was determined by geostatistical analysis of 300 field measurements.