



WORLD METEOROLOGICAL ORGANIZATION
INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

**6th meeting of the
Volcanic Ash Scientific Advisory Group
(VASAG)**

**Anchorage, Alaska, USA
23-24 October 2015**

FINAL REPORT



Attendees: LR Arnau Folch, Adele Bear-Crozier*, Sigrún Karlsdóttir*, Sara Barsotti, Barbara Stunder*, Dave Schneider*, Matt Hort*, Larry Mastin (co-chair), Andrew Tupper (co-chair), Mike Pavolonis, Tom Kiley*, Augusto Neri, Peter Lechner*, Ian Lisk (secretariat), Marianne Guffanti, Raul Romero*. Not pictured: Charles Holliday* (*observer).

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1. WELCOME AND APOLOGIES

The co-chairs welcomed attendees (listed above), including a healthy contingent of observers who had also attended the WMO 7th Workshop on Volcanic Ash and Aviation, held in Anchorage immediately prior to the VASAG meeting. It was noted that the availability of observers to attend and participate in the meeting provided an immediate resource for VASAG to draw on in its work.

Apologies were received from Dimitar Ivanov (WMO Secretariat), Hans Schlager, Claire Witham and Fred Prata. In the absence of Mr Ivanov, Mr Lisk agreed to act as the meeting Secretariat.

2. SCIENCE REVIEW

Discussion on scientific developments relating to ICAO International Airways Volcano Watch since previous meeting.

2.1 Debrief on WMO 7th International Workshop on Volcanic Ash, 19-23 October 2015

A separate workshop report is under preparation, which will cover the science aspects discussed. The group reflected on the overall success of the workshop, which was hosted by USGS and the National Weather Service in Anchorage, and was very well attended by a broad cross section of the International Airways Volcano Watch operations and science community. Overall, the feeling of the group was very positive, with several comments to the effect that the workshop was the best of the seven held so far. The issues were relatively minor. Specifically:

- The workshop felt very 'joined up' and collaborative - the panel discussion and poster sessions formats worked well and the stated theme stimulated excellent discussions. The discussion was mature (with occasional hilarity) and respectful, with a variety of strong opinions expressed in various areas but a demonstrated openness to considering different viewpoints. The discussion on volcanic ash impacts on aircraft was particularly notable in this respect given that it had previously been a 'difficult' area in which to achieve consensus opinion.
- There was a need for more discussion on engine tests and industry perspectives earlier in the conference. It was terrific to have industry there with lots of great input, but as not all aviation representatives were able to stay for the week, there is a need to think about how we take even more advantage of potential outreach activities e.g. hazard assessment schemes like the Volcano Observatory Notice for Aviation.
- Colocation with a VAAC and/or State Volcano Observatory was a great opportunity and should be considered next time, as should incorporating a training event that takes advantage of all the experts present.
- The research to operations theme worked really well but perhaps we need to think more about more formalized recommendations to focus future work.
- The relative time allocated to presentations versus.
- Panel discussion/questions was viewed as being about right (perhaps a little more discussion time next time) but perhaps we could have provided more guidance about how the panel sessions were structured and focussed.
- Downtime breaks were long enough to encourage off-line discussion.

- The workshop would have benefitted from some further explanation of ICAO and WMO processes and the functioning of the International Airways Volcano Watch at the start of the workshop, to help all delegates engage with relevant discussions on issues that have been previously dealt with.
- The number of workshop delegates, at around 100 'felt' about right and the VASAG agreed that a much bigger group would be difficult to manage.
- It is important to consider gender balance of groups for future workshops, particularly in regard to speakers. The VASAG recognises that aviation and to a lesser extent meteorology and (lesser again) volcanology are male dominated fields, but VASAG has the opportunity and responsibility to be proactive in considering the diversity of presenters and panelists. That said, there were very strong presentations given by both genders.
- VASAG was supportive of the current workshop frequency of once every 3-years with the Icelandic Meteorological Office suggested by Dr Karlsdóttir as one possible host in 2018.
- The group articulated a heartfelt thank you to Dr Mastin and Dr Schneider for leading the scientific and local organising committees respectively. The hard work, warmth and hospitality of the USGS, NOAA/NWS, and other local hosts was extremely appreciated and a critical factor in the success of the workshop.

2.2 WMO SCOPE-NOWCASTING update

A presentation on work of the WMO SCOPE-NOWCASTING group had been given at the Workshop, with a focus on globally harmonised products for volcanic ash pilot project, exemplified by the recent volcanic ash remote sensing inter-comparison workshop which produced 22 recommendations. It was noted that the Workshop had accepted all potential algorithms, including some where data was offered quite late in the process, and that this had contributed to a very large workload. The VASAG welcomed the tremendous amount of work that had been done, congratulated those involved, and encouraged efforts to keep future relevant work reasonable and manageable, even at the expense of not including all possible algorithms in comparisons.

Action VASAG-6/1: VASAG's continued strong support for this project as an essential component in the science to services system should be expressed to the SCOPE-NOWCASTING panel (through Dr Pavolonis)

2.3 Relevant matters from VAAC Best Practices meeting

The report from the VAAC BP meeting in London during 2015 was presented at the WMO Workshop and is available at

<https://drive.google.com/file/d/0B50bTmQtOwH6TEtJMG5aekpqYkE/view?pli=1>.

A follow-up meeting between VAAC managers had been hosted by Anchorage VAAC immediately prior to the WMO Workshop, and had also been highly productive. The collaborative discussions between VAAC managers are resulting in significant improvement in coordination mechanisms and in reducing inconsistencies. The improvements had been noted by aviation representatives at the workshop. The BP process also attracted much discussion on strengthening coordination on underpinning numerical weather prediction and on the use of operational exercises (with the State Volcano Observatories).

2.4 Any other recent relevant conferences since December 2014

The IUGG General Assembly took place in Prague in June, an EGU special session on

Bardarbunga (in Iceland) was held in April, and an AMS special session was held in January on volcanic ash science, services and observing system updates. Each of those was considered useful by those who attended. The effort of maintaining a strong presence at AMS in the absence of significant recent events affecting the US was noted, with the VASAG preferring to target a variety of meetings and venues over different years rather than attempt to maintain a constant presence. The usefulness of connecting with the meteorological and volcanological research communities is well established and VASAG members (and observers) are encouraged to make every effort to promote the science → operations needs of the International Airways Volcano Watch at relevant events, in addition to those being specifically targeted.

2.5 Any relevant publications

The flowering of volcanic ash-related publications in recent years has continued, albeit with many of those papers being about a single eruption (Eyjafjallajökull in 2010). Peer reviewed papers in eruption cloud dynamics, ash dispersion and fallout processes and modelling, remote sensing, and aviation effects of ash continue to be published, with more known to be in preparation. A relevant book chapter (Springer: Volcanic Crisis Communication) is also nearing finalisation. Related efforts include work by DLR and USGS to update the volcanic ash encounter database, adding to our knowledge of significant incidents. In regard to aviation encounters, the sensitivity of some of the critical information around these incidents, and the maintenance of trust of information sharing between those involved, the group noted the long-standing practices of care and confidentiality used by those compiling such information (eg Casadevall, Guffanti et al), and encouraged that these practices be captured in relevant work by IAVCEI to update their guidelines to scientists for professional behaviour during volcanic crises.

Action VASAG 6/2: VASAG (through Ms Guffanti) to contribute as required to the updated IAVCEI guidelines at

<http://www.iavcei.org/documents/IAVCEI%20GUIDELINES%20for%20eruption%20hazards%20and%20risk%20management%20Giordano%20et%20al.%20May%202015.pdf>

and promote conformance to these guidelines.

3. PRESENTATION ON CHANGES TO ICAO MECHANISMS AND DISCUSSION OF THE ROLE OF VASAG WITHIN THIS FRAMEWORK

The Chair of the ICAO Met Panel, Mr Peter Lechner, gave VASAG a presentation about the structure of the new Met Panel and its subsidiary groups. This new structure had been raised by a variety of stakeholders, including aviation and operational representatives, in discussions during the WMO Workshop, with concerns centred on managing the risk inherent in changing management structures around critical operational issues, and the ability of the process to function effectively without support from a dedicated ICAO Met Section. VASAG, as the WMO-IUGG expert group charged with providing science and training advice on volcanic ash issues to ICAO, reaffirmed its strong commitment to continuing this work, and clarified its view that this advice should be formally directed to the Chair of the MET Panel. In addition to comments made during the Workshop, the VASAG noted an apparent potential for confusion or duplication of advice within the MET Panel process, as Panel members can themselves nominate advisors to the Panel on relevant subjects, including on volcanic ash. The VASAG appreciated the complexity of these structures, which are being refined, and was pleased to note the assurances of the Met Panel Chair and Mr Raul Romero, the ICAO Secretariat observer at the meeting, that in the face of the concerns expressed, all possible endeavours would be made to ensure efficiency, transparency, and efficacy of process.

Action VASAG 6/3: VASAG reaffirms its commitment to providing and supporting the METP with expert advice on volcanic ash issues. Co-chairs to convey this to the METP chair (completed).

4. REVIEW PROGRESS ON ACTIONS FROM PREVIOUS MEETING

4.1 Planning for 7th WMO Workshop on volcanic ash (VASAG5/6.1-6.3).

The meeting agreed that these actions had been concluded.

4.2 Aircraft ash encounter with ash from Kelud (VASAG 5/7.1-7.4)

Activity continues to occur in regard to the 2014 encounter of an aircraft with ash from Kelud volcano, which the former International Airways Volcano Watch Operations Group (IAVWOPSG) had particularly requested follow-up on. One published paper so far has used an inverse modelling technique to estimate volcanic ash concentrations. Other work has progressed on modelling the cloud and using remote sensing techniques to better define the cloud characteristics as it dispersed. Professor Michael Herzog (Cambridge) has been approached to coordinate the update of the ATHAM model to assist in further cloud modelling (reintegrating the microphysics scheme with the dynamical core), and Drs Alexa Van Eaton and Larry Mastin have agreed to assist in modelling the cloud with ATHAM and Ash3d. Resources have been identified to assist with the Cambridge element of the work. The bureaucratic process of getting those resources to Professor Herzog's team has been somewhat problematic.

The meeting recalled the earlier discussion on ash encounters in general, and how the analysis of such encounters might be encouraged, noting that this action item derives from a request from ICAO to the International Coordinating Council of Aerospace Industries Associations (ICCAIA) at IAVWOPSG/8. The active engagement of ICCAIA members since then has been warmly welcomed, and should be further encouraged from an institutional point of view. It was suggested, for example, that ICAO METP should be asked to promote the importance of sharing the outcomes of incident investigations with the science community to facilitate more focused research. Together with the earlier described work to update the ash encounters database and to produce relevant guidelines for scientists, this would be of assistance in filling the obvious gaps in the ash encounters analysis effort, at least for the more significant incidents.

Action VASAG 6/4: The ICAO METP to be asked to promote the importance of sharing the outcomes of VA-related investigations with the science community to facilitate more focussed research (Action: Dr Tupper / Ms Guffanti).

Action VASAG 6/5: Coordinate, through Dr Tupper, Dr Pavolonis, Dr Mastin, the further investigation of the Kelud encounter, and report back to the ICAO METP.

4.3 Global Volcano Eruption Source Parameter (ESP) database for restless volcanoes

Slow progress is continuing in collaboration with the British Geological Survey (BGS). Iceland Met Office (IMO) demonstrated the Futurevolc Icelandic volcano cataloguing capability at

<http://futurevolc.vedur.is/> which the VASAG endorsed as a model of best practice for this type of initiative. The meeting discussed how much additional information and other parameters e.g. particle size distributions (PSD), in addition to ESPs, could/should be added to the BGS hosted database.

Action VASAG 6/6: Encourage BGS to continue to work on making the web-based version of the ESP database available for VASAG review as soon as possible (Dr Mastin).

4.4 Infrasonic

VASAG was pleased to note the initiatives now being undertaken to pull through these capabilities into operations, e.g. collaborative work being done by CBTO and VAAC Toulouse, progress by the University of Hawaii, and continued work by AVO. The group considered that this application of infrasound technology is now maturing, and further specific action by the group is

not required at this stage.

4.5 Volcanic cloud thickness and stratification

This area of work (a referral from IAVWOPSG/7) is seen as critically important for developing refined volcanic ash avoidance strategies. Progress has continued, and the meeting noted the extensive database of lidar observation that has been developed in recent years, both from ground based lidars, and, in particular, from the operation of the CALIOP spaceborne lidar. VASAG highlighted the requirement for further research and remote sensing based technologies to support further progress in this field e.g. multi-channel space-based lidar to better understand how the layering mechanisms work both close to and at distance from volcanoes. Progress in this area will be reported as a standing agenda item in the future, until determined otherwise.

4.6 VASAG funding

VASAG warmly welcomed the formalization of the WMO governance, including some funding for the activities of the VASAG which have resulted in improved accountability, relevance and visibility for the group. It was noted at the meeting that this sustainable funding has significantly assisted in attendance at both VASAG and the WMO workshop.

4.7 Outreach

The VASAG has not been able to progress the proposed article detailing progress that has been made since 2010 for the AGS EOS publication. The VASAG recognised that outreach opportunities such as the further development of the VASAG website should continue to be pursued as important activities.

The group considered a suggestion to publish a book on 'Volcanic ash – progress made', but felt, on reflection, that the recent and ongoing publication of two relevant book chapters in Elsevier and Springer publications would most likely suffice for now. In discussion, an identified priority was a pamphlet and online equivalent to the basics of the volcanic ash problem and VASAG's role, for easy distribution in relevant fora. The excellent work of the Secretariat in developing the content on the current website was noted, and further development of the website will also be further welcomed.

Action VASAG 6/7: Further development of graphically-based information brochures and the website to underpin and complement the priorities and themes of the 3-yearly science workshops (Secretariat, with inputs from VASAG members).

4.8 Next generation geostationary satellite applications

As a result of discussion at the WMO Workshop, VASAG recognised the need for a significant amount of additional training and guidance material to support the pull-through, use of and further exploitation of the next generation of space-based data and products to provide improved services in support of international air navigation. Previous discussions had highlighted the prime responsibility of the VAAC Provider States in this regard, and this was reinforced by the group. The meeting noted that the 'Best Practice' meetings of VAAC operational managers might provide useful fora for providing training discussions, if relevant experts were present on an opportunity basis. Online resources, such as the WMO CAeM Expert Team on Education, Training and Competency (ET-ETC) website at <http://caem.wmo.int/moodle>, are also appropriate places to share material.

Action VASAG 6/8: Mr Lisk to liaise with the VAACs at the next VAAC Best Practice meeting to discuss how VAAC provider States can best be supported in undertaking their training opportunities.

4.9 'Volcano Desk' at WMO

Previous discussion, particularly prior to VASAG/4, had highlighted a gap in State Volcano Observatory coverage under UN treaty frameworks. Liaison with the GEO Secretariat in Geneva during VASAG/4, taking advantage of the presence of Dr Chris Newhall, representing the World Organization of Volcano Observatories, had identified potential placement opportunities for suitably funded volcanologists to work with the GEO Secretariat to begin to strengthen ties in this regard while a future direction is discerned, but progress since has been slow. Noting the critical role of State Volcano Observatories in the International Airways Volcano Watch, and the recent upgrade of ICAO provisions, including Annex 3 requirements and the provisions of the Handbook of the International Airways Volcano Watch, and the slow progress in implementing those provisions, VASAG reiterated the need to keep exploring this area.

Action VASAG 6/9: WMO Secretariat, with Mr Lisk, to make contact with the GEO Secretariat to explore options for future engagement.

4.10 Use of radar data for volcanic ash applications training

The WMO Workshop, like the previous workshop in Citeko, Indonesia, had discussed the great potential benefit from increased radar utilisation for volcanic cloud observation, noting increasing worldwide radar coverage in areas of active volcanism, and improving radar technologies for characterising volcanic cloud. Most operational radars are operated by National Meteorological and Hydrological Services, and are multi-tasked for other applications. In this regard, the VASAG was pleased to note the Icelandic Meteorological Office offer to coordinate with other interested parties, such as New Zealand Met Service and the USGS Alaska Volcano Observatory, on the development of training and guidance materials to support the use of radar data for volcanic ash applications and looked forward to receiving a progress report at the next VASAG. The VASAG also agreed that through best practice frameworks, the IMO should be encouraged to coordinate on how best to ensure these activities are shared, for example through the CAeM ET-ETC website at <http://caem.wmo.int/moodle>. ET-ETC is tasked with the identification of any training needs for aviation MET personnel and further development of relevant competency requirements, thus, it would be good to engage them in this action.

Action VASAG 6/10: Icelandic Meteorological Office, through Dr Barsotti and Dr Karlsdóttir, to consider potential approaches to radar training modules, in collaboration with other relevant countries and with CAeM ET-ETC.

4.11 Volcano risk and monitoring recommendations

The VASAG reflected on the related discussions and outcomes coming out of the seventh International Volcanic Ash Science Workshop in Alaska in October 2015 and agreed that further work was required to define, promote and share international best practices for volcano monitoring and eruption hazard risk assessments. This was further discussed later in the agenda, in the context of the venue for the next meeting.

5. DISCUSSION ON STANDING ICAO WORK REQUESTS ON

5.1 Reducing dispersion model output uncertainty (IAWOPSG 7/18)

The meeting agreed that progress in many areas related to this was evident, including further development of eruption source term understandings, aggregation/fallout processes, more sophisticated use of dispersion models, and (importantly) steadily improving input meteorology. Some major modelling inter-comparison exercises have also been undertaken by using 1D and 3D source plume models (a special volume of JVGR is in preparation about this activity). Nevertheless, volcanic clouds are extremely complex to model and to validate the results of modelling, and work will need to continue for some time (including improved modelling of source

plumes and umbrella cloud dynamics).

5.2 Benchmarking current and future satellite based retrieval schemes (IAVWOPSG 7/31)

The recent, and very substantial, SCOPE-Nowcasting activity (discussed earlier) has been a major effort towards this end. Discussions at the Workshop and at the VASAG meeting also indicated the need to carry satellite comparisons and techniques through into operations, as discussed earlier.

5.3 Scientific investigation into volcanic cloud thickness and stratification (IAVWOPSG 7/32)

Again, the meeting agreed that good progress, including the publication of many lidar papers, has happened in this area.

5.4 Appropriate methods for assessing aviation hazards and risk (IAVWOPSG 7/33)

Discussion on this recommendation recalled that it stemmed from the need to progress global volcanic hazard assessment. This remains a major challenge to be further addressed, although various projects such as the ESP effort, Global Volcano Model, WOVOdat, and such have made some progress. There has been no reported progress in rolling out the revised ICAO provisions on volcanic monitoring, and the patchy state of worldwide volcanic monitoring remains a major concern. In the context of poorly understood and often unmonitored volcanoes in many areas, efforts to assess risk necessarily remain incomplete.

In general, and reflecting the discussion of the Workshop, the science of volcanic ash monitoring has significantly advanced in the past 5 years, and the scientific community has collectively mobilised effectively towards this (and other) ends. Much remains to be done.

Action VASAG 6/11: The VASAG agreed to, under the leadership of the co-chairs, develop an information paper to present at the next meeting of the METP WG-MOG in 2016, based largely on the information provided to VASAG and relevant outcomes (including 'Ins and Outs' modelling tables update, other relevant comparison exercise outcomes, and so on) arising from the seventh International Volcanic Ash Science Workshop in Alaska in October 2015.

6. VASAG GOVERNANCE & MEMBERSHIP UPDATE (MEMBERS SESSION)

The meeting reviewed VASAG functionality, noting the recent endorsement of updated terms of reference by WMO Executive Council. The common practice for members of expert groups is that positions, including leadership positions will be refreshed at every relevant meeting of the appropriate commission, in this case the CAeM meeting expected in 2018. The group also discussed ways to keep the group membership well balanced, active, and productive in the interim in support of its terms of reference and the allocated budget. Resultant actions and decisions will be taken forward with the WMO Secretariat.

7. ANY OTHER BUSINESS

7.1 Visible / discernible ash (Follow up to IAVWOSPG Rec 8/3)

VASAG agreed that guidance material needs to be developed for inclusion in the 'Volcanic Ash, Radioactive Material and Toxic Chemical Clouds' (ICAO Doc 9691) to support the definition of 'discernible ash'. The VASAG noted that the UK Met Office (leading on behalf of the VAACs) proposed to make the draft guidance material available to the VASAG for review, ideally in time for submission to the next meeting of the ICAO METP WG-MOG.

7.2 SO₂ monitoring

The group noted that the METP had received a 'job card' relating to human health effects of SO₂ and other toxic gases from volcanic clouds, with a view to defining a relevant warning service as required. VASAG noted that considerable work has been done on toxic gases on the ground, but more remained to be done. This ground-focused work should add considerably to our understanding of the hazard. In particular, the group noted the work of the International Volcanic Health Hazard Work, a commission of IAVCEI. VASAG also endorsed the VAAC Best Practice Workshop's recommendation that further research is required to better define potentially *hazardous gases* service development requirements to inform resource requirements and pull-through of existing research-based gas monitoring and prediction capabilities into any new services to aviation. (IAVWOPSG ref 7/34 refers).

Subsequent to this discussion, Dr Hort was able to provide a highly relevant consultant report to the group, entitled 'Effusive Eruptions Aviation Impacts Project – Final Report', which discusses the potential effect on aviation of SO₂. Further study of this report will help inform the group's views.

Action VASAG 6/12: The VASAG (Dr Witham leading, subject to confirmation) agreed to coordinate the gathering of hazardous gases health impact data and science to (potential) service capability assessments to support the delivery of a paper to the 2016 meeting of the ICAO METP WG-MISD (date to be advised later).

7.3 Future Space-based payloads

VASAG considered a NASA presentation submitted by John Murray and recognized the importance of submitting a supporting paper to help inform the US National Academies' decadal review activity. The paper would highlight the requirements of the volcanic ash science to services community to better characterise atmospheric aerosol composition and the resultant socio-economic benefits across a range of sectors. Discussion noted the very positive impact of various current polar-orbiting payloads launched as research instruments on NASA satellites, such as CALIOP (space borne lidar), and MODIS.

Action VASAG 6/13: VASAG (Dr Pavolonis leading) to coordinate the development of a paper to be submitted to the US National Academies' decadal review.

7.4 IAVW Roadmap

VASAG noted the continued development of the International Airways Volcano Watch 'Roadmap', and agreed to review this, and the relevant job cards, at the next meeting. In this regard, the group also noted ongoing discussion in the volcanic ash work stream regarding whether there was a need to produce a new volcanic ash Concept of Operations. While it is not necessarily desirable for VASAG to respond to procedural matters that are not yet resolved at MISG, the VASAG will monitor developments and respond as necessary.

Action VASAG 6/14: Co-chairs to ensure that sufficient discussion time is allocated at VASAG/7 to review the ICAO METP IAVW and SO₂ job cards and the ICAO IAVW Roadmap and to consider the opportunities to map these plans to the on-going and future science and research activities in preparation for a more detailed discussion at the next VASAG meeting. Co-chairs to raise any other related business for discussion between meetings as required.

8. DATE AND PLACE OF NEXT MEETING

According to the usual meeting cycle and preparatory discussions with the WMO Secretariat, the next meeting would be ideally in late 2016, or early 2017 at the latest, and

associated with a science conference. Given the extensive work to be done around risk assessment and promotion of better relationships with State Volcano Observatories, it was proposed to meet at the ninth 'Cities with Volcanoes (COV9)' meeting in Puerto Varas, Chile in late November 2016, with members to also participate in relevant natural hazard management, volcanic ash, and other relevant sessions. The area where the workshop will be held has been the source of several major recent eruptions affecting aviation and local communities. It was noted that, at several previous COVs, workshops on ash and aviation had been held to specifically connect with volcano observatories, and had been very successful. VASAG agreed in principle, pending confirmation of WMO support. The IAVCEI meeting in Portland, Oregon, USA, in early 2017 was raised as another potential opportunity although it was noted that this would then result in a third consecutive US-based VASAG meeting.

Actions VASAG 6/15:

- a) Co-chairs to discuss proposed meeting arrangements with WMO Secretariat;
- b) VASAG (Ms Guffanti) to contact other Scientific Organizing Committees to discuss possible relevant sessions;
- c) Consideration be given to updating the explanatory material on the IAVW previously prepared for SVOs (Dr Tupper).

9. CLOSURE OF MEETING

The VASAG again expressed its warm appreciation to the hosts at USGS, and closed the meeting at approximately 4pm on 24 October 2015.
