WORLD METEOROLOGICAL ORGANIZATION

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

CONJOINT

SIXTH WMO VAAC "BEST PRACTICE" WORKSHOP (VAAC BP/6)

AND

EIGHTH WMO/IUGG VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/8)

Wellington, New Zealand

5-9 November 2018

FINAL REPORT

TABLE OF CONTENTS

LIST OF ANNEXES

GROUP PHOTO

[Not pictured: Messrs Clarkson, Griffin, Jenkins, Lunny, Rennie and Webster, and Mmes Fitness, Gnjidic Vuksa, Madden and Parkes]

Conjoint session – VAAC BP workshop and VASAG meeting

1. OPENING AND ATTENDANCE

1.1. The conjoint sixth WMO Volcanic Ash Advisory Centres "Best Practice" workshop (VAAC BP/6) and eighth WMO/IUGG Volcanic Ash Scientific Advisory Group meeting (VASAG/8) - hereinafter referred to as the 'conjoint session' – was opened at 09:00 a.m. on Monday 5 November 2018 at the headquarters of the Civil Aviation Authority of New Zealand in Wellington by Mr Ian Lisk, president of the WMO Commission for Aeronautical Meteorology (CAeM) and moderator of VAAC BP workshops.

1.2. Mr Lisk welcomed all participants and thanked the Civil Aviation Authority of New Zealand (CAA NZ) and the Meteorological Service of New Zealand Limited (MetService) for their willingness and ability to host the conjoint session. In view of a number of areas of common interest, Mr Lisk acknowledged that this was the first time that a VAAC BP workshop and a VASAG meeting had been convened as a conjoint session, and was consistent with the expressed wishes of both communities at their preceding sessions held in 2017.

1.3. The opening of the session was also addressed by Mr Peter Lennox, Chief Executive of MetService, Mr Graeme Harris, Director General of CAA NZ and Mr Peter Lechner, Chief Meteorological Officer of CAA NZ and Chair of the International Civil Aviation Organization (ICAO) Meteorology Panel (METP).

1.4. Dr Andrew Tupper of the Australian Bureau of Meteorology (BoM) and Dr Larry Mastin of the United States Geological Survey (USGS), in their capacity as co-chairs of the WMO/IUGG VASAG, also welcomed all participants and briefly outlined their aspirations for the week ahead.

1.5. The conjoint session was attended by 37 participants. The full list of participants is given at Annex 2 to this report. Outcomes/actions arising from the conjoint session are given at Annex 5 of this report.

2. AGENDA, OBJECTIVES AND WORKING ARRANGEMENTS

2.1 The conjoint session followed an agenda (order of business) as given at Annex 1 to this report.

2.2 Mr Lisk, with support from Dr Tupper and Dr Mastin, outlined that the objective of the conjoint session was to exchange information between managers/representatives of the nine VAACs, the members of the VASAG and other invited experts/observers on:

a) the current operational practices in monitoring and detecting volcanic eruptions, observing and forecasting volcanic ash in the atmosphere; and

b) recent scientific and technological advancement and research-to-operations scenarios

in order to identify collaborative opportunities leading to a more harmonized model of quality service delivery to aviation stakeholders.

2.3 Mr Lisk noted that the week would be a blend of conjoint and parallel discussions (Monday to Wednesday) followed by thematic open day discussions (Thursday and Friday) where other invited stakeholders would be present.

2.4 Mr Lisk emphasized that outcomes of the conjoint session would, in many instances, help inform the work being undertaken by working groups of the International Civil Aviation Organization (ICAO) Meteorology Panel (METP), notably:

a) the Working Group on Meteorological Operations Groups (WG-MOG) international airways volcano watch (IAVW) work stream; and

b) the Working Group on Meteorological Information and Service Development (WG-MISD) volcanic ash sulphur dioxide (VASD) work stream.

It was noted that meetings of both of these working groups/work streams were convening in Wellington in the week immediately following this conjoint session (specifically 12 to 14 November 2018).

2.5 Appropriate working arrangements for the conjoint session were formulated. As alluded to at 2.3 above, the week was arranged as follows:

2018	Monday 5 November	Tuesday 6 November	Wednesday 7 November	Thursday 8 November	Friday 9 November
Morning	Conjoint session	Parallel sessions	Parallel sessions	Thematic open session	Thematic open session
Afternoon	Conjoint session	Parallel sessions	Conjoint session	Thematic open session	Thematic open session

2.6 Messrs Lisk, Tupper and Mastin chaired proceedings in an alternating manner throughout the week based on the discussion topics while Mr Greg Brock with the assistance of Prof Alexander Baklanov provided the necessary WMO secretariat support.

2.7 All presentation and report materials associated with the conjoint session were made available at URL:

https://www.wmo.int/aemp/VAAC-BP-6-VASAG-8

3. 'INS AND OUTS' MODELLING TABLES UPDATE

3.1 It was recalled that VAAC BP/4 (2016) Outcome VW4-O-03 concerned investigations and reports on numerical weather prediction (NWP) errors/performance relevant to volcanic ash modelling taking into account region specific issues, e.g. the tropics, and a review of VAAC 'Ins and Outs' modelling tables which were to be updated and shared once every 2 years.

3.2 In the context of the VAAC 'Ins and Outs' modelling tables, Dr Matthew Hort and Dr Claire Witham of the UK Met Office (VAAC London) presented a review of the tables including potential opportunities for expanding their content, highlighted similarities and differences across the nine VAACs within the various fields of the tables, and considered some of the near and longer term developments with potential implications on the future content and structure of the tables.

3.3 During the discussion, it was highlighted that there would be value in elaborating certain field entries, particularly to explain why a VAAC (or VAACs) operationally applied a particular modelling approach versus the approach(es) taken by other VAACs. In view of the expressed demand of aviation users for globally consistent, harmonized information from the VAACs on the existence and extent of volcanic ash in the atmosphere, the conjoint session agreed that it was important to identify and understand where and why differences in

approach to modelling exist, to articulate these differences such that they are well understood, and to pursue efforts to close gaps wherever they exist. In respect of the near and longer term developments, it was acknowledged that as part of continuous improvement – an integral component of a quality management system (QMS) – there was a need to ensure that the VAACs appropriately integrate scientific and technological advances, particularly in observations and dispersion modelling.

3.4 To conclude, it was agreed that the modelling tables should continue to evolve as a 'living document' and should, therefore, continue to be reviewed on a periodic (typically two-year) basis. It was agreed that VAAC BP/4 (2016) Outcome VW4-O-03 should remain open as a recurrent activity.

4. VAAC STRENGTH OF EVIDENCE CHECKLISTS

4.1 It was recalled that VAAC BP/5 (2017) Outcome VW5-O-07 and VASAG/7 (2017) Action Agreed 7/1 both concerned discernible ash strength of evidence checklists used by the VAACs. More specifically, the VAACs had been tasked to undertake further trials with checklists presented in 2017 – both a conventional 'tick-box' style checklist and a more expansive graphical 'pyramid' style checklist – and to seek expert input/scientific advice from the VASAG. In this connection, the conjoint session considered presentations by Dr Jarrad Denman and Mr Tristan King of VAAC Darwin and by Dr Michael Pavolonis on behalf of the VASAG.

4.2 Consultations with VAACs, led by VAAC Darwin, had determined that the strength of evidence checklists were currently being used by some but not all VAACs – despite the fact that they demonstrate a good QMS practice – and that some VAACs would evaluate their utilisation in the 2019 timeframe. It was acknowledged that the strength of evidence checklists served as one valuable (prescriptive) tool to aid VAAC forecasters but that other objective and, at times, subjective considerations were also part of the decision-making process. Regardless of which tool or technique was used, the VAACs acknowledged that it was important to keep an appropriate record of the judgements – objective or subjective – that led to a decision on the presence and evolution of a volcanic ash cloud since this was valuable evidence for post-event analysis, training and aviation inquiries (if needed).

4.3 In respect of a Volcanic Ash Strength of Evidence Assessment (VASEA) tool, VAAC Darwin reported that this had transitioned within BoM from a concept and design phase in 2015 through development (2016) and operational trials (2017) to operational implementation in 2018. It was highlighted that VASEA was currently (2018) being enhanced through higher spatial resolution and an extension of the confidence assessment, and that information generated through VASEA was being disseminated to aviation users, as a BoM supplementary product, via a dedicated web portal. VAAC Darwin reported that as a result of the improved availability of the VASEA information, the number of direct enquiries made by aviation users to BoM during eruptions in the VAAC area of responsibility had reduced thereby allowing the forecasters to dedicate more time to the main task at hand – i.e. monitoring and forecasting the evolution of the volcanic ash cloud.

4.4 In respect of general feedback on the two types of strength of evidence checklists, it was VASAG's opinion that both types have value. Dr Michael Pavolonis, on behalf of the VASAG, provided specific feedback on the checklists for the consideration to the VAACs, including aspects worthy of additional consideration and incorporation, to enable the checklists to mature further. In particular, it was noted that the inclusion of quantitative information, such as cloud growth characterization, could potentially add considerable value. On the BoM VASEA

tool, comments included a suggestion to clarify the meaning of coloured polygon boundaries (e.g. do they convey uncertainty about the cloud's location or its existence?).

4.5 At the conclusion of the discussion it was agreed that preceding VAAC BP/5 (2017) Outcome VW5-O-07 and VASAG/7 (2017) Action Agreed 7/1 could be considered complete and replaced by the following new outcome:

VAAC BP/6 Outcome WV6-O-01:
a) All VAAC Managers encouraged to introduce, as soon as possible, operational use of the strength of evidence checklists within their respective forecast office (and non-operational use for training purposes where appropriate) and to provide feedback to VAACs Tokyo and Darwin (as focal points) on the utility of the checklists, including suggestions for improvement, by 30 June 2019;
b) Taking into account the feedback received from a) above as well as that received from the VASAG in 2018, VAACs Darwin and Tokyo (Jarrad Denman and Kazuki Ito) to further improve the checklists methodologies and to present progress reports in this regard on a biennial basis (next report in 2020).

5. VONA AND AVIATION COLOUR CODES

5.1 It was recalled that VAAC BP/5 (2017) Outcome VW5-O-04 and VASAG/7 (2017) Action Agreed 7/3 both concerned the Volcano Observatory Notice for Aviation (VONA) and aviation colour codes. As follow-up to VAAC BP/5 Outcome VW5-O-04, a proposal had been made to the ICAO METP WG-MOG/5 (IAVW) meeting that the aviation colour code be removed from the volcanic ash advisory (VAA) and that the status of the VONA be elevated to a recommended practice and (eventually) a standard. This proposal had been subsequently discussed and endorsed by the WG-MOG (IAVW) and the working group was undertaking the necessary development of a proposed amendment to ICAO Annex 3 provisions and associated guidance material. In this connection, through VASAG/7 Action Agreed 7/3, Drs Schneider, Engwell and Barsotti were providing assistance to the WG-MOG (IAVW) ad hoc group. In view of the progress, it was agreed that both VAAC BP/5 (2017) Outcome VW5-O-04 and VASAG/7 (2017) Action Agreed 7/3 could be considered complete.

5.2 Each VAAC presented an overview of their interactions with State Volcano Observatories (SVOs) within their area of responsibility, the progress made and the challenges often faced in obtaining information from SVOs.

5.2.1 The information presented by the VAACs demonstrated that while interactions between VAACs and SVOs had improved in some regions/sub-regions over recent years, notably through advances in communication technologies (e.g. text or instant messaging, email, mobile phone communication and internet-based web portals), the situation was far from uniform across all regions/sub-regions and that a number of shortcomings remain in some areas.

5.2.2 Some VAACs and SVOs have made significant progress in recent years in improving communication. Some VAACs, SVOs and other stakeholders have, for example, established memoranda of understanding (or similar) to formalize coordination, collaboration and communication arrangements, and are routinely involved in conducting regular volcano ash exercises (table top simulations) to test operational response procedures in a non-operational setting. Lessons learned and experiences gained from such exercises feed back into improving

the operational procedures. Several VAACs emphasized that the collaborative sharing of information (reciprocal information flows such as radar and satellite imagery) between the VAACs and the SVOs had proven beneficial, even crucial, in building relationships, building trust and was ultimately yielding a more timely response to a volcanic eruption and higher quality output (VONA and VAA/VAG).

5.2.3 Prevailing challenges within the SVO community include limitations in real-time monitoring of active or potentially active volcanoes, frequent power loss or internet outages (particularly those in geographically challenging, remote locations), language barriers between the SVO and their associated VAAC, an absence of a consistent, reliable funding stream to ensure 24/7 operational coverage, lack of on-call capability outside of normal working hours, lack of clarity within some States as to which agency has responsibility to issue warnings, and information overload brought about through social media misuse and spam emails. In addition, some SVOs lack awareness, understanding or misinterpret the (ICAO) aeronautical requirements for pre-eruptive and eruptive volcanic information yielding an inconsistent application of the VONA and the aviation colour code therein. Some VAACs were of the opinion that the aviation colour code assigned by some SVOs does not appropriately correspond to the volcanic activity evident from satellite imagery or other reliable sources. The sharing of information between VAACs and SVOs, alluded to above, was therefore considered important to help close this gap.

5.2.4 Notwithstanding the challenges faced, it was highlighted that SVOs generally possess dedicated, conscientious and pragmatic staff, albeit often in very limited numbers, and that during a volcanic eruption the priority of the SVO was often focussed on the protection of life and livelihoods within the local community. The needs of the aviation community may, in some areas, therefore be a secondary consideration until such time as SVO capacity is improved.

5.3 In a related matter, it was recalled that VASAG/7 Action Agreed 7/4 had requested ICAO to remind Contracting States with active or potentially active volcanoes of their State volcano observatory responsibilities under ICAO Annex 3, 3.6 and the supporting operational procedures contained within ICAO Doc 9766. It was noted that follow-up action by ICAO in this regard (e.g. issuance of a State letter) was still pending, hence it was agreed that VASAG/7 Action Agreed 7/4 should remain open.

5.4 Dr Samantha Engwell of BGS and Dr David Schneider of USGS presented insights from an analysis of volcanic ash advisories (VAA) issued by all VAACs between 2009 and 2018, including the use of the aviation colour code as a proxy for the VONA. The analysis demonstrated that, when viewed as an entire (nearly 10-year) dataset, a majority of VAAs had been issued *without* an aviation colour code. For those where an aviation colour code *had* been included, a majority of VAAs were associated with aviation colour code 'orange' (decode: *volcano is exhibiting heightened unrest with increased likelihood of eruption or volcanic eruption is underway with no or minor ash emission*). There was, however, significant variance in these findings when considering the VAA issuance of each VAAC individually. Some VAACs would always include the field entry, other VAACs would never include it. On discussion, it was noted that these differences were usually related to availability of information, in particular VONAs, from SVOs.

5.5 The conjoint session further acknowledged the work underway within ICAO to remove the aviation colour code field entry from the VAA and to elevate the status of the VONA to a recommended practice, potentially in the 2022 timeframe, and eventually (post-2022) a standard with the ICAO Annex 3 provisions. In this connection, it was appreciated that, in the longer term, the aviation colour code as a sub-set of the VONA may not be entirely suited to

aviation users' demand for improved pre-eruption information and that other solutions may come to fruition over the coming years in the transition to information services within the system-wide information management environment of global air traffic management. In the meantime however, while the VONA and its aviation colour code exist, efforts will likely be required to build the capacity and capability of SVOs in the issuance of the VONA (guidance, training and outreach). If changes to the aeronautical requirements come to fruition through ICAO channels, further such efforts would be required.

5.6 The conjoint session revisited VONA issues later in the proceedings – section 31 below refers.

6. VOLCANIC HAZARD MONITORING AND OBSERVING CAPABILITIES

6.1 The conjoint session discussed advances in volcanic hazard monitoring and observing capabilities, in particular from the perspective of State volcano observatories. Drs Schneider and Engwell presented an overview of the progress and challenges associated with the forecasting, detection, characterization and communication of volcanic eruptions.

6.2 During the discussion, it was emphasized that the improved detection of volcanic eruptions can go some way towards filling the gap in knowledge caused by a continued absence of ground-based monitoring of some volcanoes, and that the fusion of observational data from multiple sources is yielding improved confidence in the status of a volcano and often an improved timeliness of notification when an eruption occurs.

6.3 Following on from earlier discussions on the strength of evidence checklists for VAACs (see section 4 above), views were expressed that the development of a similar checklist scheme for SVOs could prove beneficial to support the issuance of the VONA. In addition, it was re-emphasized that community collaboration and the sharing of information between the VAACs and SVOs, as alluded to at 5.2.2 above, was crucial for an improved response to a volcanic eruption. It was noted that these considerations, and others, would be further addressed later in the week (see section 27 below).

Parallel session – VAAC BP workshop

7. STATUS OF OPEN VAAC BP OUTCOMES (2016 AND 2017)

7.1 VAAC managers/representatives undertook a review and update of the status of *open* outcomes from the VAAC BP workshops held in 2016 and 2017, specifically VW4-O-03 and -16 and VW5-O-01, -03, -07, -08 and -15

7.2 In respect of VW4-O-16 and VW5-O-15, it was agreed that these outcomes could now be considered complete. In respect of the remaining outcomes, it was noted that these would be addressed during the course of this conjoint session, with a determination made in each case as to whether to keep the outcome open, to replace it, or to mark it as complete.

7.3 Upon the conclusion of the conjoint session, the 2018 status of follow-up of open VAAC BP outcomes from 2016 and 2017 was as given in Annex 3 to this report.

8. SATELLITE INTER-COMPARISONS OF DISCERNIBLE ASH

8.1 It was recalled that VAAC BP/5 (2017) Outcome VW5-O-08 concerned satellite inter-comparisons of discernible ash. More specifically, the VAACs had been tasked, where feasible, to conduct a comparison between the old and new generation of satellite products within each VAAC and to conduct a comparison of the new generation of satellite products across all VAACs.

8.2 Several VAACs presented their inter-comparison analyses. The analyses highlighted that the latest generation of satellite imagery from GOES-16 and Himawari-8 had had noticeable positive impacts on VAAC capabilities but had also had some corresponding side effects.

8.2.1 Positive impacts included improved detection of small eruption events and of obscured or dissipating/distal volcanic ash clouds, and an improved ability to see (often subtle) directional changes in a volcanic ash cloud. For those VAACs in a position to make use of the higher temporal and spatial resolution, multi-spectral satellite imagery from GOES-16 and Himawari-8 can now, in many instances, offer an increased level of confidence in the presence of discernible ash, and can detect the presence of volcanic ash and sulphur dioxide more rapidly following an eruption and, thus, provide an improved quality of service to aviation users when compared with the use of the preceding generation of imagery.

8.2.2 Side effects included increased operational workloads for VAAC personnel due to an increase in the number of available images requiring monitoring and interpretation as well as an increase in the number of VAAs issued[1] with consequential downstream implications on end-user workloads. In addition, the new generation of satellite imagery was rendering a renewed demand for VAAC forecaster training in satellite interpretation methods.

8.2.3 The foregoing positive impacts and side effects were foreseen to apply with the introduction of the Meteosat Third Generation satellite imagery in the 2021 timeframe, and therefore VAACs London and Toulouse, in particular, would need to take due account of these considerations in their operational practices as the enhanced Meteosat imagery becomes operationally available.

[1] Some increases may be attributable to more active period of volcanic eruptions in some parts of the world.

8.3 Taking the foregoing into account, the VAACs discussed how to take the satellite inter-comparison efforts forward. It was agreed that further cross-VAAC satellite inter-comparison efforts were highly desirable – as a minimum, on a bilateral basis between a VAAC and their designated backup VAAC – to ensure that all VAACs become better positioned to make optimal use of the new satellite capabilities through a collaborative, shared learning experience. It was also acknowledged that such VAAC collaboration could, potentially, be beneficial for the inter-comparison of atmospheric transport dispersion model (ATDM) output of volcanic ash in the atmosphere. A linkage of these cross-VAAC collaborations with the subsequent discussion concerning collaboration tools (see section 10 below) was noted.

Note. — In parallel, initiating some form of inter-comparison, amongst the VAACs, of ATDM output was discussed during the standalone VASAG session – section 17 below refers.

8.4 To conclude the discussion, it was agreed that VAAC BP/5 (2017) Outcome VW5-O-08 could be considered complete and replaced by a new outcome as follows:

VAAC BP/6 Outcome WV6-O-02:
Strongly encourage the VAACs to continue or to commence satellite inter-comparisons of the old and new generation of satellite imagery – as a minimum between a VAAC and its backup centre – and to consider the feasibility of establishing similar inter-comparison efforts for ATDM output for volcanic ash in the atmosphere.
Progress report by all VAACs on a biennial basis (next report in 2020).

Post-script remark by Drs Pavolonis and Tupper — Recognizing that Meteosat Second Generation (MSG) can be considered, for all practical purposes, as the first next (newer) generation satellite, and that all VAACs are now using MSG, GOES-16 and/or Himawari-8, emphasis could be placed by the VAACs on the uptake of the new capabilities.

9. FORECAST VERIFICATION AND VAAC KEY PERFORMANCE INDICATORS

9.1 It was recalled that VAAC BP/5 (2017) Outcome VW5-O-05 concerned VAAC key performance indicators (KPIs). More specifically, an initial set of KPIs had been reported to the ICAO METP WG-MOG/5 (IAVW) and the VAACs had been subsequently tasked, by the ICAO working group, to trial the KPIs. It was recalled that the KPIs initially developed in 2017 were considered a 'minimum specification' and that some VAACs were required to meet more stringent KPIs under the direction of their national authorities.

9.2 Mr Mark Seltzer of VAAC London presented an analysis of the trial application of the timeliness and compliance KPIs across the nine VAACs. The analysis, based on VAA/VAG issuance since 1 January 2018, indicated that all VAACs were achieving or were close to achieving the initial set of KPIs. In the specific cases of VAACs London, Montreal and Toulouse it was acknowledged that the VAA/VAG issuance sample size was very small when compared with the other six VAACs and thus the metrics were not entirely representative or suitable for these centres.

9.3 While reviewing the metrics and the KPI definitions, the VAACs noted that there was some ambiguity in the precise application of the KPIs – for example: *When should the timeliness metrics of 20 minutes for the initial VAA/VAG and 75 minutes for the first forecast VAA/VAG be activated, and upon what consistent basis? Does the 75 minute metric for the first*

forecast VAA/VAG include or is it subsequent to the initial 20 minutes? Similarly, there were question marks over the use of the term 'sufficient evidence' in the KPI definition, and that a more suitable term might be 'information from a credible source'. It was noted, for example, that a 'credible source' could be information received from an SVO whereas 'sufficient evidence' could relate to the application of the strength of evidence checklists (see section 4 above) – a process which could extend beyond 20 minutes especially for challenging volcanoes with little or no ground-based monitoring or where unfavourable meteorological conditions prevail. It was also acknowledged that a 'source' initially considered to be 'credible' might turn out to lack credibility once other investigations have concluded. Similarly, the strength of evidence checklists may determine the situation to be a false alarm. In both scenarios, a first forecast VAA/VAG would not be issued, therefore rendering the second KPI (75 minutes for first forecast VAA/VAG) redundant.

9.4 In terms of the compliance KPI initially developed – where the subsequent forecast VAA/VAG is to be issued not later than the time stated in the 'next advisory' element of the VAA/VAG until there are 'no further advisories' – the VAACs considered that this was associated more with *timeliness* (i.e. the preceding KPI metric) than with *compliance*. The VAACs felt that it may be more suitable to formulate a KPI pertaining to compliance via a quality check (e.g. whether the VAA/VAG conforms to the ICAO Annex 3 templates) or an accuracy assessment (e.g. whether a T+0 observation in a new VAA/VAG verifies well with the T+6 forecast in the previous VAA/VAG). It was remarked that reducing subjectivity and increasing objectivity in any such compliance assessment could be challenging but that, through the ICAO METP WG-MOG mechanism, there may potentially be opportunities for inspiration to come from an understanding of how the world area forecast centres (WAFCs London and Washington) have, say, introduced objective verification schemes for WAFS forecasts. It may be possible to adapt such schema or to generate similar schema for the verification of VAA/VAG.

Note 1. — In a related discussion later in the VAAC BP session, it was proposed that an additional timeliness KPI could or should be developed for the issuance of re-broadcast VAA (section 12 below refers).

Note 2. — Later, more informal discussion in and around the conjoint session also discussed the concept of an 'eruption to action' type KPI, where the time from the actual eruption to effective action being taken by users would be examined. No conclusions were made in this regard.

9.5 Having completed its review of the initial set of timeliness and compliance KPIs, noting the progress made in trialling the KPIs across all nine VAACs, where improvements could be made, and highlighting the foregoing issues to be brought to the attention of the ICAO METP WG-MOG (IAVW), the VAACs agreed that VAAC BP/5 (2017) Outcome VW5-O-05 could be considered complete and replaced by a new outcome as follows:

VAAC BP/6 Outcome WV6-O-03:
VAAC London (Mark Seltzer) to forward to ICAO the feedback obtained on the trial application of the initial set of KPIs and the suggestions for improvement developed during VAAC BP/6 in 2018 for further consideration at the ICAO METP WG-MOG/8 (IAVW) meeting.

10. VAAC COLLABORATION TOOL

10.1 It was recalled that VAAC BP/5 (2017) Outcome VW5-O-01 concerned a VAAC collaboration tool whereby a functional needs analysis formulated at the 2017 workshop was to be finalized and VAACs with appropriate capability were to collaborate in the development of a suitable, single web-based platform (with basic functionality to start as necessary).

10.2 In this regard, Mr Dov Bensimon of VAAC Montreal presented a progress report summarising the background to this issue over the past several years (since at least 2013) and the formulation in 2017 (VAAC BP/5) of a list of basic information-sharing requirements. It was noted that although several VAAC collaboration tools had been explored over the years, none had transitioned into a viable, operational, single solution for use by *all* VAACs, often due to a lack of resources within the VAACs or technical/procedural limitations (e.g. prohibited use of social media websites on operational infrastructure).

10.3 To serve as inspiration of the feasibility and potential benefits to be gained from the development and use of a collaboration tool, several VAACs demonstrated operational tools already utilized within their national meteorological services – for example, Japan Meteorological Agency (VAAC Tokyo) demonstrated an online collaboration tool for VAAC operations based on an already existing SIGMET coordination tool in South-East Asia, UK Met Office (VAAC London) demonstrated a web-based application to support the collaborative issuance of WAFS significant weather charts by the world area forecast centres, and the United States National Weather Service (VAACs Washington and Anchorage) demonstrated a web-based chatroom facility. In addition, an online demonstration was given by MetService (VAAC Wellington) of a MetConnect Pacific portal as part of a severe weather forecast and disaster risk reduction demonstration project.

10.4 Having considered the demonstrations, the VAACs were of the firm belief that in the interest of ensuring and improving the level of consistency in operations and output across all nine VAACs, a suitable, single web-based platform remained a desirable and necessary deliverable from the best practices effort and was entering the realm of possibility given advances in web-based technologies. Recalling the initial functional needs analysis stemming from the VAAC BP/5 (2017), the VAACs believed that the tool demonstrated by JMA (VAAC Tokyo) could potentially serve as an excellent foundation upon which to build and ultimately introduce a single, operational collaboration tool for use by *all* VAACs. Many of the functional needs appeared to already be addressed within the JMA tool and there appeared to be opportunities to close existing gaps and to consider the introduction of new functionalities (e.g. the inclusion of GOES-16 and Meteosat satellite imagery in addition to Himawari-8).

10.5 To conclude the discussion, the VAACs agreed that VAAC BP/5 (2017) Outcome VW5-O-01 could be considered complete and replaced by a new outcome as follows:

VAAC BP/6 Outcome WV6-O-04:
VAAC Tokyo (Kazuki Ito), with the assistance of VAAC Wellington (Marcel Roux) and in coordination with the other VAACs, encouraged to lead the further development and operational introduction of a VAAC collaboration tool consistent with the basic functional needs identified in 2017 and taking into account the feedback at VAAC BP/6 in 2018.
Progress report not later than 2020.

11. IWXXM DEVELOPMENTS

11.1 It was recalled that VAAC BP/5 (2017) Outcomes VW5-O-02 and VW5-O-03 concerned the ICAO meteorological information exchange model (IWXXM). More specifically, Outcome VW5-O-02 sought to clarify the differences between IWXXM versions 2.1 and 3.0 and when IWXXM 3.0 would be available, while Outcome VW5-O-03 proposed that IWXXM-compliant volcanic ash advisory/volcanic ash graphic (VAA/VAG) should be made available on the respective websites of the VAAC initially and the extended AMHS[2] eventually.

11.2 In respect of Outcome VW5-O-02, VAAC managers/representatives were pleased to note that Mr Patrick Simon of VAAC Toulouse had obtained the necessary clarification on the IWXXM 2.1 to 3.0 change, and had shared this via email with the VAACs on 14 June 2017. VAAC BP/5 (2017) Outcome VW5-O-02 had been consequently marked as complete.

11.3 In respect of Outcome VW5-O-03, Mr Dov Bensimon of VAAC Montreal presented a progress report summarising the background and the latest IWXXM developments, including the relevant outcomes of an ICAO Meteorology Panel (METP) Working Group Meteorological Information Exchange (WG-MIE) meeting in May 2018. It was observed that some VAACs were already producing IWXXM-compliant VAAs based on IWXXM version 2.1.1 and that the new schema (IWXXM version 3.0.0) was under development with Release Candidate 2 (RC2) available via URL: http://schemas.wmo.int/iwxxm/index.php?dir=/3.0.0RC2

11.4 The VAACs were reminded that the ICAO Annex 3 requirement for the issuance of the VAA in an IWXXM-compliant format would become a Standard in November 2020, and that this was part of a wider package of aeronautical meteorological "products" to be available in the IWXXM format. It was noted that the prevailing abbreviated plain language VAA and graphical VAG would continue to be a requirement in parallel with the IWXXM information for several years beyond 2020 (potentially until 2026 given an outcome of the ICAO METP/4 meeting in September 2018).

11.5 Since the VAA in an IWXXM compliant format was part of a wider package of IWXXM-related developments taking place within national meteorological services, all the VAACs present at the conjoint session indicated that they were, to a greater or lesser extent, progressing towards meeting the November 2020 deadline.

11.6 The VAACs agreed that the follow-up to VAAC BP/5 (2017) Outcomes VW5-O-03 could be considered complete and replaced by a new outcome as follows:

VAAC BP/6 Outcome WV6-O-05:
All VAACs are encouraged to continue to pursue the introduction of the IWXXM schema for the VAA/VAG in readiness for November 2020 applicability of associated ICAO Annex 3 provisions. Progress report not later than 2020.

11.7 To supplement the preceding discussion, Mr Kazuki Ito of VAAC Tokyo highlighted key points that VAACs should be mindful of when undertaking the development and issuance of the VAA using the IWXXM schema. Some of these points required clarification from the WMO task team currently responsible for developing the IWXXM schema on behalf of ICAO (namely the Task Team on Aviation XML, TT-AvXML). On this latter respect, an additional outcome was formulated as follows:

[2] ATS Message Handling System (of ICAO).

VAAC BP/6 Outcome WV6-O-06:
VAAC Toulouse (Patrick Simon) encouraged to consult with WMO TT-AvXML on the IWXXM-related VAA/VAG issues identified by VAAC Tokyo at VAAC BP/6 in 2018 and to report on the outcomes of those consultations at the earliest opportunity.

12. ADDITIONAL VAAC DISCUSSIONS

Re-broadcasting of VAA

12.1 Further to the preceding discussion concerning the issuance of the VAA/VAG in an IWXXM-compliant format, the VAACs discussed prevailing issues surrounding the re-broadcasting of VAA. More specifically, it had been identified that, on a few occasions, some VAACs had issued a re-broadcast VAA before a primary VAA (from a neighbouring VAAC) had been issued. It was noted that these situations, albeit rare, were inconsistent with the VAAC operational procedures contained in Appendix C of the *Handbook on the International Airways Volcano Watch* (ICAO Doc 9766).

12.2 The VAACs agreed that they should *all* be following the procedure within ICAO Doc 9766 – i.e. the primary VAA should be issued *before* the re-broadcast VAA – and that any deviations from this procedure were regrettable. It was noted, for example, that the re-broadcasting of a VAA was often a trigger for end-users to seek the primary VAA and that if the primary VAA had not yet been issued this was problematic and an inconvenience.

12.3 Recognizing the foregoing discussion on KPIs (section 9 above refers), the VAACs agreed that there would be merit in considering the introduction of an additional timeliness KPI pertaining to the re-broadcasting of VAA.

VAAC backup arrangements

12.4 The VAACs discussed the formalized backup arrangements within the IAVW. It was noted that all VAACs were backed-up by at least one other VAAC, *with the exception of* VAAC Washington, as follows:

Lead VAAC	Backup VAAC(s) or other provider
Anchorage	Washington
Buenos Aires	Washington
Darwin	N of 20S: Tokyo S of 20S: Wellington
London	Toulouse
Montreal	Washington
Tokyo	Darwin
Toulouse	London
Washington	557th WW-USAF
Wellington	Darwin

12.5 In the case of VAAC Washington, it was noted that their backup provider was the 557th Weather Wing of the United States Air Force (USAF). VAAC Washington indicated that they were keen to explore whether one or more of the other VAACs could alternatively serve as their backup, particularly in the interest of ensuring continuity of operations across multiple VAACs within the framework of the IAVW (see paragraph 12.7 below). Several VAACs

expressed a potential willingness and ability to serve as the backup for VAAC Washington, but that some technical limitations (including access to appropriate coverage satellite imagery) and non-technical considerations (including senior management approval) would have to be resolved first.

12.6 Appreciating the significant area of responsibility of VAAC Washington and noting the foregoing remarks, it was expressed that it may be desirable to sub-divide the VAAC Washington backup arrangements across multiple VAACs (in a manner similar to how VAAC Darwin's area of responsibility is sub-divided at 20S and covered by VAACs Tokyo and Wellington in backup mode).

12.7 Furthermore, it was noted that VAAC Washington itself was backup to three other VAACs (Anchorage, Buenos Aires and Montreal) and that this presented: 1) a significant operational risk within the IAVW should there be a failure of VAAC Washington (given support from the 557th WW USAF to the other VAACs may be impossible or impracticable); and 2) a potentially significant workload for VAAC Washington if two or more of the other centres requested backup support at the same time.

12.8 To conclude this discussion, the following outcome was formulated:

VAAC BP/6 Outcome WV6-O-07:
VAAC Washington (Jamie Kibler) to:
a) work with other VAACs, particularly but not necessarily exclusively those in the Americas, to seek the establishment of a more viable VAAC backup arrangement for their operations; and
b) consider whether serving as the primary backup centre for three other VAACs (Anchorage, Buenos Aires and Montreal) is entirely suitable given the operational risk this represents within the IAVW during periods when VAAC Washington itself is unserviceable. Alternative proposals to be investigated accordingly.
Progress report not later than 2020.

Review of the IAVW arrangements

12.9 The VAAC managers present at the conjoint session held an 'in camera' (closed) session to discuss a request emanating from the fourth meeting of the ICAO Meteorology Panel (METP/4 held 10 to 14 September 2018) for a holistic review of the international airways volcano watch (IAVW) (METP/4 Recommendation 4/1 refers).

Parallel session – VASAG meeting

13. STATUS OF OPEN VASAG ACTIONS (2015 AND 2017)

13.1 VASAG members undertook a review of the status of open action items from the VASAG meetings held in 2015 and 2017. It was noted that many open action items were to be directly addressed during this conjoint session, with a determination made of whether to keep an action item open, to replace it, or to mark it as complete.

13.2 In respect of open action items *not* directly addressed by the agenda of this conjoint session, the following was agreed:

- Action Agreed 6/10 on the use of radar data for volcanic ash applications training: Ongoing effort, therefore keep open. Possible linkage with and topic for the proposed IWVA/8 in 2020 (section 19 and section 21 below refers); and
- Action Agreed 7/8 on the next meeting of the VASAG: Can be marked as complete since it refers to this meeting.

13.3 Upon the conclusion of the conjoint session, the 2018 status of follow-up of open VASAG action items from 2015 and 2017 was as given in Annex 4 to this report.

14. ERUPTION SOURCE PARAMETER DATABASE FOR RESTLESS VOLCANOES

14.1 It was recalled that VASAG/6 (2015) Action Agreed 6/6 concerned a global volcano eruption source parameter database for restless volcanoes and work to make a web-based version of the ESP database available for VASAG review. The status of progress had been discussed at the VASAG/7 (2017) meeting, where it had been noted that the ESP database was continuing to be improved by the British Geological Survey (BGS) with inputs from the VASAG and VAACs. It had been agreed at VASAG/7 to keep Action Agreed 6/6 open.

14.2 Dr Samantha Engwell and Dr Larry Mastin presented information on the latest ESP database developments, wherein volcanoes are characterized by their type and historical activity and key inputs for tephra dispersal models based on well-known examples are derived. It was noted that, of the 392 eruptions at 152 volcanoes reported since 2007 by the Smithsonian Institute Global Volcanism Programme, 91% of the volcanoes had historical activity and around 97% were in the database. In respect of changes to the database, it was highlighted that volcano numbers were now consistent with the Smithsonian numbering schema, that 'ice-covered' had been added as a binary field, that five submarine volcanoes had been added, that datum on eight volcanoes had been adjusted to reflect recent historical activity, and that the database was being progressively finalized in readiness for a soft online launch. The presentation also detailed areas of ongoing work to improve the database and areas of ongoing research as well as collaboration efforts with, for example, EUROVOLC (European Catalogue of Volcanoes) to collate eruption information and investigate ways to define scenarios.

14.3 The VASAG thanked Dr Engwell and the wider BGS team for the tremendous progress being made to prepare the ESP database for online publication. The VASAG encouraged BGS to continue taking steps in this regard and agreed that Action Agreed 6/6 should remain open.

15. AIRCRAFT VOLCANIC ASH ENCOUNTERS DATABASE AND SEVERITY INDEX

15.1 It was recalled that VASAG/7 (2017) Action Agreed 7/5 concerned an aircraft volcanic ash encounters database and severity index. More specifically, in direct response to a request emanating from the ICAO METP WG-MOG/5 (IAVW), Dr David Schneider had been tasked to lead efforts regarding changes to Appendix F to ICAO Doc 9691 with new data on aircraft encounters and any agreed-upon modifications to an encounter severity index.

15.2 Dr Schneider presented a progress report to the VASAG where it was noted that work had remained ongoing to reach consensus (within VASAG) on the proposed changes to the severity index criteria used in the aircraft volcanic ash encounters database. Next month (December 2018) a quality check on all entries in the database against the new criteria was to be performed while in January 2019 an update of the database to include 2010-2016 data would be performed in advance of its publication. Simultaneously, a review and update of Appendix F to the Handbook on the International Airways Volcano Watch (ICAO Doc 9766) is planned.

15.3 The VASAG discussed the ash-encounter severity index and formulated a new proposal, as given at Annex 6 to this report, for subsequent consideration at the ICAO METP WG-MOG/8 (IAVW) meeting. In view of the further work still required to finalize the database and the associated activities outlined at 15.2 above, it was agreed that Action Agreed 7/5 should remain open.

16. SATELLITE ADVANCEMENTS

16.1 Dr Michael Pavolonis presented the latest advances in satellite remote-sensing of volcanic ash clouds and gases. The presentation gave information on:

a) access to satellite products, including the latest multispectral false colour imagery, and their use by the VAACs;

b) recent satellite launches, including NOAA-20, Sentinel-5P and GOES-17, and their operational capabilities;

c) recent scientific developments;

d) new projects including EUNADICS-AV and a NOAA JPSS volcanic hazard initiative; and

e) the progress of a WMO Sustained Coordinated Processing of Environmental Satellite Records for Nowcasting (SCOPE-Nowcasting) volcanic ash pilot project.

16.2 In respect of e), Dr Pavolonis highlighted the major project milestones of 2018 and 2019 that were either completed or upcoming. He also reported on the outcomes of a WMO SCOPE-Nowcasting workshop held in Catania, Italy from 8 to 12 October 2018 which had addressed an inter-comparison of satellite-based volcanic ash retrieval algorithms. In this connection, Dr Pavolonis summarised the major outcomes of the pilot project as well as the major challenges that prevail. Dr Pavolonis concluded by giving an outline of the proposed structure of a SCOPE-Nowcasting final report and a proposed 2019 paper for the Bulletin of the American Meteorological Society (BAMS).

16.3 In the discussion that followed Dr Pavolonis' presentation, the VASAG noted that most VAACs were utilizing satellite-derived alerting tools such as VOLCAT (Volcanic Cloud Analysis Toolkit) and that collaboration in the usage of such tools within and across the VAACs was increasing.

16.4 In the context of SCOPE-Nowcasting, the VASAG commended the progress made by the pilot project and appreciated where challenges remain. The VASAG also suggested that the SCOPE-Nowcasting outcomes would help direct priorities for future research efforts. In this connection, the VASAG indicated that consideration could be given to exploring further collaborative work on near-real-time experimental satellite products and model integrations across the VASAG, GAW APP SAG and SCOPE-Nowcasting teams.

17. MODELLING ADVANCEMENTS

17.1 Dr Larry Mastin delivered a presentation on the latest advances in the numerical modelling of volcanic ash clouds and gases. The presentation detailed how:

a) models have improved and where some of the derived benefits are being realized;

b) technology is allowing the community to better constrain some of the eruption source parameters that are a key input to the numerical models;

c) advances in model physics (such as the representation of umbrella clouds) are leading to new functionality and a better understanding of model input influences

d) quantitative satellite data has allowed for automatic comparisons with models in order to improve forecast accuracy in areas such as inversion modelling, data insertion and ensemble techniques; and

e) new datasets and techniques for comparing models to observations are aiding accuracy assessments (which is essential for qualitative and quantitative applications).

17.2 Dr Mastin's presentation highlighted that: the improvements in model accuracy are constrained by the availability of data with which to test the numerical models; most new datasets have come from satellites; and advanced modelling techniques (such as inversion modelling) are progressing well in the non-operational domain but remain generally untried and untested in the operational domain.

17.3 In light of the latest developments, the VASAG considered whether a new model inter-comparison and validation study that makes use of new observational datasets should be undertaken It was indicated that this could be a worthwhile consideration at the proposed IWVA/8 in 2020.

Note. — In parallel, initiating some form of inter-comparison, amongst the VAACs, of ATDM output was discussed during the standalone VAAC BP session – section 8 above refers which led to VAAC BP/6 Outcome WV6-O-02).

18. PUBLICATIONS AND OUTREACH

18.1 It was recalled that VASAG/6 (2015) Actions Agreed 6/2 and 6/7 concerned publications and outreach. More specifically, Action Agreed 6/2 pertained to the VASAG contributing to an update to IAVCEI guidelines (available here) and the promotion of conformance with these guidelines; while Action Agreed 6/7 concerned the further development of graphically-based information brochures and a website to underpin and complement the priorities and themes of the periodic science workshops. At VASAG/7 (2017) both of these actions had been marked as 'ongoing'.

18.2 In respect of Action Agreed 6/2, the VASAG decided to close this action due to a lack of specific progress since 2015. In respect of Action Agreed 6/7, it was noted with appreciation that the VASAG had contributed to volcanic-ash-related outreach and publications over the intervening period, including *Observing the Volcano World: Volcano Crisis Communication* published by Springer in 2018, and the WMO GAW SAG-Aerosol *Aerosol Bulletin No. 3*, published in 2017 in English, French and Spanish. The VASAG consequently agreed that VASAG/7 (2017) Action Agreed 6/7 could be marked as complete.

18.3 In the context of new or renewed efforts to facilitate and promote outreach within the community of the scientific and technological developments taking place in support of the IAVW, the VASAG first noted the potential for being involved in an article on the status and future of volcanic ash forecasting. A similar article on the status and future of numerical atmospheric aerosol prediction with a focus on data requirements had been initiated by the GAW Aerosol and APP SAGs (available here).

18.4 General discussions highlighted the following considerations (in no particular order and non-exhaustive):

- ***Where to publish:***
  - (for example) Atmospheric Chemistry and Physics (ACP), Aviation Week or other professional publications
  - Community factsheets and community science engagement sites, such as The Conversation
  - Other publications, e.g. ICAO Journal

- ***Themes for publication:***
  - Progress and challenges
  - Prevailing gaps and priorities
  - Research and development needs

- ***The 'hook':***
  - Air travel has continued to increase. "*What will happen during the next Pinatubo?*" Show statistics on increases in air travel and increase in the number of VAAs. Re-project today's air traffic over the map of the Pinatubo cloud, for example
  - "*It has been XXX years since YYY happened. How much progress have we made? We're in a new era. Etc.*"
  - Consider developing a 2020 publication providing a ten-year retrospective since the eruption of Eyjafjallajökull in Iceland

- ***Intended audience:***
    - SVOs, VAACs, NMHSs and other aeronautical meteorological service providers, CAAs, aviation users and other IAVW stakeholders
    - Governments and other influential bodies and development partners (e.g. World Bank) in order to influence funding priorities

18.5 Having considered the foregoing aspects, the VASAG formulated the following action:

VASAG/8 Action Agreed 8/1:
Andrew Tupper and Larry Mastin requested, in coordination with VASAG members and Matt Hort (representing GAW APP SAG), to:
a) lead further discussions and devise proposals on outreach in support of the IAVW;
b) specifically consider becoming involved with an ACP publication (Andrew Tupper); and
c) determine the feasibility of authoring a 2020 publication that provides a ten-year retrospective on the progress made since the eruption of Eyjafjallajökull in Iceland (Larry Mastin).
Progress report via correspondence by 30 June 2019.

19. INTERNATIONAL WORKSHOP ON VOLCANIC ASH PROPOSAL

19.1 It was recalled that VASAG/7 (2017) Action Agreed 7/7 concerned the development of a concept note for an eighth International Workshop on Volcanic Ash (IWVA/8) in the 2019 timeframe. The VASAG was informed of latest developments such that there had been a keen, informal expression of interest made by the Icelandic Meteorological Office (IMO) to host the IWVA/8 in the 2020 timeframe (not 2019), which would coincide better with the tenth anniversary of the eruption of the Eyjafjallajökull volcano in Iceland (April) as well as the centenary of IMO (September).

19.2 The VASAG agreed that, given the continued pace of scientific and technological advancement, the need to direct or otherwise better inform strategic decisions in this regard, and noting where gaps exist and the need to encourage capacity development, there continued to be a sufficient justification to convene an IWVA in the coming few years.

19.3 The VASAG consequently discussed the objective, format, etc. of the next IWVA and formulated the following outline:

- ***Objective:*** To demonstrate the progress made in supporting the scientific and technological advancement (research-to-operations, science-to-services) within the International Airways Volcano Watch over the past 10 years, to highlight where gaps and other limitations in capacity and capability continue to exist, and to proactively chart a path for scientific and technological advancement over the next 10 years and beyond in line with the evolving needs of aviation users.

- ***Timing:*** Circa September 2020 (avoiding direct conflict with ICAO METP/5 or other such international meetings).

- ***Duration***: Minimum 3 days, maximum 5 days (subject to available budget), with side meetings as required.

- ***Location/Host:*** Potentially Iceland/Icelandic Met Office (IMO) – based on informal expression of interest already received from IMO. Would coincide with the 10-year anniversary of the eruption of Eyjafjallajökull and the centenary of IMO.

- ***No. of participants:*** Approximately 100. Could be by 'invitation only' if required.

- ***Participation:*** Experts from NMHSs and other aeronautical meteorological service providers, SVOs and VAACs including scientific support staff, geophysical and geodetic members/affiliates of IUGG, scientific research institutes, universities and other academia, aviation user organizations/representatives and other industry stakeholders.

- ***Format:*** Plenary discussions, presentations, breakout groups, panel discussions and/or site visits. Could adopt an approach whereby plenary discussions are held on either side of weekend breakout groups or other activities (e.g. field trip).

- ***Responsible bodies:*** Local organizing committee (LOC) and scientific organizing committee (SOC) to be established.

- ***Other considerations:*** Exhibition space, sponsorship/fundraising, poster session, communication and outreach, and financial support for those experts otherwise unable to attend (e.g. from SVOs).

19.4 Taking the foregoing into account and noting the need to further mature a concept note, the VASAG agreed that Action Agreed 7/7 should be marked as complete and replaced by a new action as follows:

VASAG/8 Action Agreed 8/2:
David Schneider is requested, in coordination with VASAG members and Matt Hort (representing GAW APP SAG), to lead the development of an update to a draft Concept Note for a proposed IWVA/8 in the late-2020 timeframe.
Progress report via correspondence by 30 June 2019.

19.5 It was noted that the foregoing proposal would be presented to the VAAC managers under agenda item 21 (see here) upon the reconvening of the conjoint session.

Conjoint session – VAAC BP workshop and VASAG meeting

20. VAAC BP AND VASAG REPORTING FROM THE PARALLEL SESSIONS

20.1 Following-on from standalone VAAC BP workshop (sections 7 to 12 above refer), Mr Ian Lisk presented an overview of the VAAC discussions and the main outcomes. Similarly, following-on from standalone VASAG meeting (sections 13 to 19 above refer), Dr Andrew Tupper assisted by Dr Larry Mastin presented an overview of the VASAG discussions and the main outcomes.

21. IWVA PROPOSAL FROM VASAG

21.1 Following on from preceding discussions during the standalone VASAG meeting (section 19 above refers), Dr Tupper provided an outline, for all participants, of proposals for the convening of an eighth International Workshop on Volcanic Ash (IWVA/8). There was agreement with the proposal and the VASAG/8 Action Agreed 8/2 was noted.

22. WMO CONTITUENT BODIES REFORM AND IMPACTS ON CAeM GOVERNANCE AND STRUCTURES

22.1 In their respective capacities as Acting Chief of the Aeronautical Meteorology Division of WMO and president of the WMO Commission for Aeronautical Meteorology, Mr Brock and Mr Lisk presented an overview of the status of WMO Constituent Bodies Reform (hereinafter referred to as 'WMO Reform') and the impacts of WMO Reform on CAeM governance and structures.

22.2 In respect of the status of WMO Reform, it was highlighted that intense work was now underway in advance of the Eighteenth World Meteorological Congress (Cg-18) in June 2019 to prepare for the focussing and alignment of the activities of the Organization with the United Nations Sustainable Development Goals and the needs of society in general, and to transform the governance structures of the Organization, including the technical commissions structure, to make them more agile, cross-cutting and fit-for-purpose. It was highlighted that, subject to the outcomes of Cg-18, WMO Reform could be implemented by the time of the seventy-second session of the WMO Executive Council (EC-72) in May/June 2020.

22.3 In respect of the impacts of WMO Reform on CAeM governance and structures, it was highlighted that there would be significant implications on the Commission to the extent that the latest proposal was for CAeM (an intergovernmental body) to be decommissioned – along with all other technical commissions – and replaced by a Standing Committee on Aeronautical Meteorology (non-intergovernmental) reporting to a new Commission for Services and Applications (intergovernmental). This would have ramifications on how WMO conducts its business in the aeronautical meteorology domain, how members and other experts contribute to the work, and how WMO interfaces with partner organizations such as ICAO and IUGG.

22.4 It was highlighted that WMO was developing transition plans and communications strategies to foster the reform, and that broad consultation with Members, the community of expertise and other interested parties was now underway.

23. WRAP-UP AND CLOSE OF CONJOINT SESSION

23.1 Prior to the commencement of two days of thematic open sessions (section 24 onwards refers), the VAAC managers/representatives and VASAG members took the opportunity to wrap-up the proceedings of the conjoint session.

23.2 In considering whether the conjoint session had been productive and worthwhile, the overwhelming consensus of opinion was that it had been tremendously productive and worthwhile to convene the VAAC BP workshop and VASAG meeting conjointly whilst also allowing each community of experts a portion of time to convene, in parallel, as standalone sessions. It was emphasized that bringing the two communities together, in person, was highly beneficial for exploring and exploiting research-to-operations opportunities, community collaborations, and closing gaps in knowledge and capability.

23.3 As a lesson learned and for future consideration, it was indicated that during the standalone sessions there had been occasions where VASAG experts, say, could have actively contributed to discussions taking place within the VAAC BP (and vice-versa) and that the physical separation of the two venues (VAAC BP at MetService and VASAG at CAA NZ) had made this challenging. Therefore, if similar such sessions are held in the future, it may be worthwhile to consider convening parallel discussions at the same office, perhaps in adjacent rooms.

Thematic open session

24. OPENING AND ATTENDANCE

24.1 To conclude the week (Thursday and Friday), a thematic open session was held. As moderator, Mr Ian Lisk extended a warm welcome to all new participants and thanked the Civil Aviation Authority of New Zealand for hosting. The list of participants is given at Annex 2 to this report.

25. AGENDA, OBJECTIVES AND WORKING ARRANGEMENTS

25.1 The thematic open session addressed the following agenda:

a) VAAC personnel competency;

b) State volcano observatory skills, needs and capacity development;

c) Volcanic ash impacts on jet engines – an update;

d) Quantitative volcanic ash forecasts – progress and recommendations; and

e) Volcanic sulphur dioxide.

25.2 The objective of the thematic open session was to explore the foregoing topics in greater detail and to take advantage of the presence of other invited experts and stakeholders, including local staff from CAA NZ, MetService and GNS Science, as well as members/advisors residing on the ICAO METP working groups.

25.3 Appropriate working arrangements for the thematic open session were formulated.

26. VAAC PERSONNEL COMPETENCY

26.1 To open this session, Mr Lisk drew reference to quality management system (QMS) as a driver for continuous improvement within the service delivery domain. Recognizing ICAO Annex 3 requirements for a properly implemented QMS for aeronautical meteorological service provision, and with the competency and qualification of service personnel forming an integral part of demonstrating a properly organized QMS, it was incumbent upon WMO to ensure that the competency and qualification of meteorologists, including aeronautical meteorological personnel, was addressed. In this connection, it was highlighted that in 2013 WMO had introduced a Standard into *Technical Regulations* (WMO-No. 49), Volume I, *General Meteorological Standards and Recommended Practices* requiring Members to ensure that an Aeronautical Meteorological Observer (AMO) and Aeronautical Meteorological Forecaster (AMF) comply with a series of competencies. At the same time, WMO had introduced a Recommended Practice into WMO-No. 49, Volume I recommending Members ensure that an AMF has successfully completed a Basic Instruction Package for Meteorologists (as defined in Appendix A to WMO-No, 49, Volume I). This Recommended Practice had been subsequently elevated to a Standard in 2016.

26.2 Given this background, noting that the delivery of a VAAC service can involve personnel with meteorological backgrounds and, often, non-meteorological backgrounds (e.g. volcanologists, geologists, atmospheric scientists, etc.), and noting that no well-defined competency or qualification requirement currently exists within the WMO framework for personnel performing operational duties within a VAAC, participants discussed whether there was a need and a way to utilise the AMF top-level competencies and/or second-level competencies such that they could be tailored to meet VAAC needs, thus potentially offering a uniform VAAC personnel competency framework across all nine VAACs.

26.3 The session welcomed presentations given by Mr Chris Webster of MetService on the generic WMO AMF education, training and competency standards and how to develop a competency framework utilising the WMO *Guide to Competency* (WMO-No. 1205). In addition, the VAAC managers each gave thought-provoking presentations on how, at a local level, they were each addressing the competency assessment and training of VAAC forecasters, and how VAAC forecaster qualifications link with the BIP-M qualification requirement for AMF.

26.4 The presentations by Mr Webster demonstrated that the foundations and building blocks for the development of a VAAC forecaster personnel competency assessment framework already exist given the existing framework for AMF. The presentations by the VAAC managers demonstrated that while all VAACs had, to a greater or lesser extent, training programmes and other related initiatives in place to ensure, to the extent practicable, the competence of VAAC forecasters, there was presently a non-uniform, non-standardized approach across the nine VAACs.

26.5 During the discussions, the following key points arose:

a) The VAAC forecast production process benefits tremendously from a blend of expertise from across the meteorological *and* non-meteorological domains;

b) Not all VAACs are the same in respect of their size and commitments. Some VAACs handle eruptions very infrequently (e.g. there may be years between an operational response). This can generate an imbalance in opportunities for VAAC forecasters to gain hands-on, real-time experience and challenges when designing and conducting training;

c) In most VAACs, forecasters are often cross-trained to perform other duties/functions. On the one hand this can allow surge capacity to be available to the VAAC at times of need (e.g. during the response to an eruption) while at other times it can also take capacity away from the VAAC position (e.g. when supporting other emergency response activities such as wildfires and chemical spills);

d) The resources at some VAACs are such that little or no surge capacity exists. Some VAACs often function with SPOFs (single points of failure), although noting that back-up arrangements are in place as discussed earlier. Implementing a competency framework for VAAC forecasters should allow junior (least experienced) personnel to become operationally ready more quickly, thereby reducing a reliance on senior (most experienced) personnel;

e) The pace of scientific and technological advancement and the transfer of these new capabilities into VAAC operations through the hands-on training and build-up of experience is challenging amongst the VAACs and often hindered by resource constraints and significant workloads (associated with the points at c) and d) above);

f) During quieter operational periods, opportunities should be taken to conduct VAAC forecaster training, even if only for short periods. VAAC forecasters should be actively encouraged to practice their forecasting skills during such quieter periods using, for example, eruptions taking place in other VAAC areas of responsibility, past case studies or hypothetical cases. Regular participation in multi-lateral volcanic ash exercises should also be encouraged provided that the surge capacity outlined at c) above exists;

g) Akin to the implementation of QMS, the establishment and maintenance of a competency assessment framework for VAAC forecaster personnel should not be viewed as an onerous task. The framework should work for the VAACs, not against. While it may be challenging at first, over time the maintenance of the framework should become more self-sustaining, effectively 'business-as-usual';

h) The competency assessment of VAAC forecasters should become, if not already, a formal part of the staff performance review/appraisal process; and

i) The absence of an appropriate cost recovery scheme or other reliable funding stream for the provision of the VAAC service remains a critical issue for some VAACs. In some instances, the absence is inhibiting the availability of sufficient resources to support 24/7 operations and the pace of pull-through of research-to-operations/science-to-services.

26.6 To conclude the discussion, Mr Lisk invited the VAACs to respond to the following questions:

Questions	Nature of the response from participants
Should a VAAC forecaster's basic underpinning qualification by the BIP-M?	• Ideally yes, however the reality is that performing VAAC operations demands a blend of meteorologist and non-meteorologist expertise. • Performing the VAAC forecaster function should be viewed as a specialist extension of being an AMF, not a subset. • Meteorology is an important underpinning skill, an enabler, but treated in isolation is insufficient for fulfilling the VAAC function.
Can the second-level competencies for an AMF be applied for VAAC forecasters without amendment? Or, could they be amended such that they could be applied for VAAC forecasters while noting that the top-level competencies for an AMF may have to be amended too?	• A new set of second-level competencies for VAAC forecasters appears desirable and necessary. It could take inspiration from the existing second-level competencies for AMF personnel. • The existing top-level competencies for AMF may only require minor adjustment (see next) to make it broader and more suitable for application to specialist domains such as a VAAC forecaster. • Terminology such as 'the weather situation', 'meteorological phenomena' and 'meteorological information' should be reviewed and, where necessary, amended to ensure suitability for broader (non-meteorological) domains.

Questions	Nature of the response from participants
If the top- and/or second-level competencies for an AMF are going to be amended such that they can be applied for VAAC forecasters, who is going to initiate and lead this work?	• The CAeM Expert Team on Education, Training and Competency (ET-ETC) should be tasked to initiate and lead this work in consultation, as necessary, with VAAC managers/representatives and VASAG members (see below).

In respect of the last bullet point, the following outcome was formulated:

VAAC BP/6 Outcome VW6-O-08:
Ian Lisk, in his capacity as president of CAeM, to task the CAeM Expert Team on Education, Training and Competency (ET-ETC) to initiate and lead work on amending the top- and/or second-level competencies for AMF such that they can be applied for VAAC forecasters. This work should be undertaken in consultation with VAAC managers/representatives and VASAG members as necessary.
Progress report via correspondence by 30 June 2019.

27. STATE VOLCANO OBSERVATORY SKILLS, NEEDS AND CAPACITY DEVELOPMENT

27.1 As evidenced by discussions that have taken place during this conjoint session as well as previous VAAC BP workshops, VASAG meetings and elsewhere (e.g. ICAO meetings), the State volcano observatories (SVOs) are a critical component within the entire international airways volcano watch (IAVW). Often an SVO is the first responder to a change in the status of a volcano and, therefore, the first step in a sequence of steps that lead to the issuance of VAA/VAG by VAACs and SIGMET for volcanic ash by meteorological watch offices. However, in many parts of the world with active or potentially active volcanoes, there continues to be a lack of capacity or capability amongst SVOs to fully implement the ICAO Annex 3 provisions. Any SVO deficiencies, major or minor, are an impediment to the efficient and effective operation of the IAVW and, thus, present an increased risk to safe and efficient flight operations.

27.2 Given this background, and acknowledging that ICAO – through its METP WG-MOG (IAVW) – was in the process of elevating the status of a Volcano Observatory Notice for Aviation (VONA) to a Recommended Practice and (eventually) a Standard within Annex 3, participants discussed related issues surrounding SVO skills, needs and capacity development.

27.3 To support the discussion, the session welcomed an enlightening personal insight by Dr Natalia Deligne, Duty Officer of GNS Science – the State volcano observatory of New Zealand. Dr Deligne's presentation addressed volcano observatory goals, how volcano monitoring is prioritized and conducted, what is considered a "well-monitored" volcano, the bare minimum monitoring needs, SVO challenges, governance/peer network expectations, and issues surrounding the VONA and aviation colour code.

27.4 Dr Deligne's presentation was followed by an additional personal insight from Dr Larry Mastin of USGS. Collectively these insights led to a discussion on how to overcome the long-standing reality that many SVOs around the world, particularly but not exclusively those in the developing world, simply lack the capacity and capability, even at a basic level, to fulfil the ICAO Annex 3, Chapter 3.6 requirements and the supporting IAVW/SVO procedures contained in the *Handbook on the IAVW* (ICAO Doc 9766).

27.5 The discussion emphasized several key points, including aspects raised earlier in the conjoint session, as follows:

a) there is a tremendous dependency between the VAACs and their associated SVOs (and vice versa) in respect of the provision of high-quality services to aviation;

b) a sustainable cost recovery mechanism or other such reliable funding stream remains elusive for many SVOs yet must be realized to build capacity, capability, resilience, etc. and thereby ensure the needs of international civil aviation are fulfilled;

c) elevating the status of the VONA to a Recommended Practice and (eventually) a Standard within ICAO Annex 3 will demand financial and capacity-building support at the level of the SVO. It will also demand bilateral and multilateral interactions between all concerned stakeholders (e.g. national civil aviation administrations, national meteorological services, VAACs and SVOs) since, in addition to their often very pressing responsibilities for managing local ground-based hazards, many SVOs presently lack an awareness and appreciation of the needs of aviation; and

d) in the longer term there may be a need to look beyond the VONA towards a more viable, more sustainable service delivery model for pre-eruption/pre-eruptive information for aviation.

27.6 Dr Tupper noted that the *Handbook on the IAVW* (ICAO Doc 9766), as mentioned earlier, contains extensive guidance for States on responsibilities for volcanic monitoring; however little, if any, coordinated effort has been undertaken recently to proactively develop compliance to these provisions (although several individual efforts have been made). Doc 9766 itself, whilst up-to-date in terms of its guiding provisions, contains outdated contact details for SVOs in its Appendices, and discussion during the week highlighted that, in some cases, the SVO designations themselves remained problematic. It was considered that ICAO's attention should be drawn to these issues. The meeting noted that VASAG Agreed Action 7/4 (issuance of a State letter regarding SVO arrangements) remained open as discussed earlier, but that additional outreach work into the volcanological community would also be required.

27.7 Additionally, it was noted that a 'plain language' summary of provisions put together by the World Organization of Volcano Observatories (WOVO, a commission of IAVCEI) in the *Guidance for State Volcano Observatories: The International Airways Volcano Watch* had not been updated since 2009. The following action was formulated accordingly:

VASAG/8 Action Agreed 8/3:
David Schneider and Sara Barsotti to lead a review and, as necessary, update of the WOVO *Guidance for State Volcano Observatories: The International Airways Volcano Watch* (available at URL: http://www.wovo.org/assets/docs/gvo2009s.pdf).
Progress report via correspondence by 30 June 2019.

28. VOLCANIC SULPHUR DIOXIDE

28.1 At the VAAC BP/5, METP WG-MISD/3 (VASD) and VASAG/7 meetings between June and August 2017, discussions had taken place on volcanic sulphur dioxide (SO_2). Stemming from a request at the METP WG-MISD/3 (VASD) meeting, the VASAG had been tasked to assist an ad hoc group of WG-MISD in the conducting of a review of the state of science related to volcanic

SO_2 that poses a threat to aircraft occupants and to investigate possible impacts to the aircraft[3]. The VASAG/7 had, consequently, formulated Action Agreed 7/6 in this regard.

28.2 To support a discussion on this topic, the session welcomed presentations by Dr Claire Witham (VASAG Member), Mr Dov Bensimon (VAAC Montreal), Mr Marcel Roux (VAAC Wellington) and Mr Rory Clarkson (ICCAIA/Rolls-Royce).

28.2.1 The presentation by Dr Witham demonstrated that many tens of hundreds of volcanic eruptions each year generate SO_2 clouds that can be tracked using satellites – some with significant emissions, others with lesser amounts – and that some eruptions produce SO_2 but no volcanic ash, some eruptions produce both SO_2 *and* volcanic ash where the two can often co-exist as separate 'clouds', SO_2 often has a longer range transport in the atmosphere compared with discernible volcanic ash, and some long duration, effusive eruptions can produce discernible SO_2 on an ongoing basis for many months (with implications on the design of a future service delivery model for aviation users). The presentation also demonstrated that there have been recorded aircraft encounters with SO_2 dating back to the 1980s and that, as alluded to at paragraph 28.1 above, the issue was progressing both through ICAO and WMO channels at present.

28.2.2 Mr Bensimon's presentation was a demonstration (proof of concept) of tools and techniques used within Environment Canada to detect, track and forecast the presence of volcanic SO_2 in the atmosphere. It was noted that information (data) on the presence of SO_2 in the atmosphere that is used to initialise and calibrate the Environment Canada atmospheric transport dispersion model (ATDM) comes from a Support to Aviation Control Service (SACS) of the Royal Belgian Institute for Space Aeronomy - a non-operational[4], European-funded scientific research effort within EUNADICS-AV. During a discussion that followed the demonstration, it was highlighted that the latest generation of meteorological satellites (GOES-16 and Himawari-8) had multispectral capabilities enabling SO_2 in the atmosphere to be identified and tracked, and potentially serving as an additional or alternative input for ATDM simulations. In respect of the ATDM model itself, it was noted that the EC model did *not* currently take account of chemical reactions, an important factor in determining how an SO_2 cloud may evolve in the atmosphere over time.

28.2.3 Mr Roux presented a brief case study of the eruption of the Aoba volcano in Vanuatu on 26 and 27 July 2018 where, in the absence of significant meteorological cloud, there had been a clear, unrestricted view of multiple volcanic ash clouds *and* SO_2 clouds using the Himawari-8 satellite imagery.

28.2.4 Dr Clarkson presented an outline of known previous and ongoing studies on the presence of volcanic SO_2 in the atmosphere and its potential impact on the aircraft and/or the aircraft occupants. The presentation revealed that while there was known to be (or, at least, considered to be) a wealth of data on volcanic SO_2 and a general understanding of the impacts, gaining authorized or unrestricted access to the data was a challenge that was inhibiting the speed of scientific and technological progress. The presentation also emphasized that cabin air quality – where the SO_2 issue is of great interest, particularly given the potential health effects on aircraft occupants – was a highly complex issue and that defining internationally-accepted air quality standards and contaminant thresholds remained challenging.

[3] ICAO METP WG-MISD/3 (VASD) Action 3/1 refers.

[4] Non-operational in the context of ICAO regulated services to support international civil aviation.

28.3 At the conclusion of the discussion, participants strongly encouraged the cross-community (i.e. meteorological community and industry community) sharing of data on volcanic SO_2 and aircraft encounters with volcanic SO_2 as a means to further advance and expedite scientific and technological progress. Noting that WMO, through mechanisms such as the VASAG, would continue to assist ICAO on volcanic SO_2 matters, and given the information presented, it was agreed to close VASAG/7 Action Agreed 7/6.

29. VOLCANIC ASH IMPACTS ON JET ENGINES – AN UPDATE

29.1 Following-on from information presented at the VAAC BP/5 workshop in June 2017, Dr Rory Clarkson of Rolls-Royce presented an update on the latest progress in understanding the impacts of volcanic ash on jet engines. In his presentation, Dr Clarkson highlighted the susceptibility of engines and other airframe components to encounters with volcanic ash, the latest guidance and regulatory requirements, the latest airframe and engine original equipment manufacturer (OEM) positions on these issues, and recent technical developments.

29.2 Dr Clarkson also gave a comprehensive insight into and a demonstration of a DEvAC (Duration of Exposure versus Ash Concentration) chart devised by Rolls-Royce. The DEvAC chart was an evidence-based approach enabling Rolls-Royce, and potentially other engine OEMs, to better understand and quantify the risks posed by exposure to volcanic ash and the implications in respect of flight safety as well as exigent damage and long term damage to airframe/engine components. It was noted that there was sufficient evidence to suggest that the DEvAC chart/methodology could be applied to other atmospheric/aerosol components such as sand, dust and ice crystals. In the case of sand and dust, it was indicated that emerging evidence was suggesting that the immediate and longer-term impacts of sand and dust ingestion by engines was far more complex than volcanic ash ingestion due, in part, to complex reactions within the 'hot' part of the engine leading to changes in the chemical composition of the sand and dust.

29.3 Dr Clarkson summarised by stating that:

a) all available evidence still indicates that the dose approach (i.e. quantified ash concentration *and* duration of exposure) is appropriate and that most engine types currently in operation in the worldwide commercial airliner fleet would cope, from a flight safety perspective, with a dose of up to 14 g sm^{-3}. In addition, in some quarters, industry is becoming increasingly confident that performing operations in higher dose values (threshold yet to be specified) has no flight safety implication;

b) there are delays in getting the dose approach rolled-out across Rolls-Royce's other two-shaft engine types (i.e. non-RB211 and Trent engines);

c) there is no obvious indication yet that other engine OEMs will follow the Rolls-Royce approach, although some airframe OEMs and military operators appear interested;

d) given the latest body of evidence and the advanced scientific and technological understanding based on the evidence, investigations have commenced within Rolls-Royce and its UK partners including the Met Office and Civil Aviation Authority to determine the suitability (or otherwise) of the ash concentration thresholds instituted in Europe in the immediate aftermath of the eruption of Eyjafjallajökull in 2010; and

e) it remains entirely appropriate for the IAVW community, including the VAACs and aviation end-users, to be shifting focus towards quantitative volcanic ash forecasts which support the risk-based, dose approach.

29.4 During the discussion that followed Dr Clarkson's enlightening presentation, it was highlighted that the recent and foreseen future advancement in satellite imagery – with higher spatial and temporal resolutions and improved multispectral capabilities – will likely demand a review of the 0.2 g m^{-3} threshold applied for the detection of discernible ash. More specifically, the existing estimate of the lower limit of satellite-based detection could (subjectively at the present time) be an order of magnitude too high, at least under certain conditions.

29.5 Participants recognized that this was a critical and potentially far reaching development that would require close monitoring within the satellite applications area, the VAACs, airframe and engine OEMs, operators and other industry bodies, since lower concentrations of volcanic ash in the atmosphere posed, according to the DEvAC chart, a more benign, less significant risk to aviation. Therefore, unless there was a future review of the discernible ash concentration threshold presently used within the IAVW and applied by the VAACs, there was a risk that the areas of volcanic ash represented in the VAA/VAG could (subjectively at the present time) be an order of magnitude too high at times.

30. QUANTITATIVE VOLCANIC ASH FORECASTS – PROGRESS AND RECOMMENDATIONS

30.1 At the VAAC BP/5, METP WG-MOG/5 (IAVW) and VASAG/7 meetings held in June and August 2017, discussions had taken place on quantitative volcanic ash contamination information. Stemming from a request at the WG-MOG/5 (IAVW) meeting, the VASAG was tasked to undertake, in coordination with ICCAIA, a state of science review regarding the global development and use of quantitative volcanic ash contamination information and forecasts[5].

30.2 Dr Larry Mastin, on behalf of the VASAG, presented an overview of a state of science review paper (hereinafter referred to as the 'review paper') that had been completed by the VASAG, with input from ICCAIA, in October 2018 and duly submitted to the ICAO METP WG-MOG (IAVW) for consideration. Dr Mastin summarized several of the key developments taking place in the following areas addressed by the review paper:

a) current and foreseen future satellite characterization capabilities;

b) advances in modelling from the perspectives of improvements to source parameters, automated integration with observations, improved model physics, better numerical weather prediction models and better coupling with dispersal models; and

c) state of engine susceptibility science.

30.3 During the discussion that followed the presentation of the review paper, the following points of relevance to scientific progress were noted (in no particular order):

[5] ICAO METP WG-MOG/5 (IAVW) Action 5/12 refers.

a) Since the Eyjafjallajökull volcanic eruption in 2010, through scientific and technological advancement, progress has definitely been made to improve the community's state-of-the-art understanding of what is possible/not possible and what risks exposure to volcanic ash clouds and gases in the atmosphere pose to aviation. There is growing justification to revisit the 'ash concentration' issue that arose in 2010 provided that any areas of existing and foreseen future uncertainty are well-communicated and well-understood by all those involved in the IAVW service delivery chain.

b) Advances in the numerical modelling of volcanic ash in the atmosphere have, to a great extent, been enabled by access to enhanced observations (particularly satellite imagery) that allow better model calibration. Constraining the uncertainty (or error) in numerical model output is progressing in the right direction. Uncertainty is generally reducing, although remains high in some contexts and will always be present.

c) Transitioning to a situation where quantitative volcanic ash information is routinely derived and then supplied to users is not, in and of itself, entirely sufficient. Conveying (bounding) uncertainty *and* confidence are important factors in equal measure. Uncertainty will always exist while confidence will vary.

d) The 'pull-through' from scientific research into meteorological operations ("R2O") can be challenging and requires resources, including financial resources. Transitioning from a limited-scope research effort into a fully-operational solution supporting VAAC operations, say, that performs consistently and reliably on a 24/7 basis demands investment. Qualitative improvements are often realized faster than quantitative improvement. Quantitative improvement is often incremental.

e) Notwithstanding point c) above, data output from non-operational systems that may be accessible to VAAC forecasters, say, can be of value. It is important, however, that the users of the data fully understand the limitations in use and do not become heavily or solely reliant on the data (or their associated tools) for operational service delivery.

f) Non-operational trials that are 'open' in nature tend to generate problems in the community at large, since they often raise expectations to a point that is beyond what is considered scientifically sound or reasonable. Non-operational trials that are 'closed' in nature are often the preferred approach.

g) There is a clear demarcation between the functions performed by VAAC and those performed by end-users (e.g. airline operators). It is important that one does not try to perform the function of the other. End-users only expect to receive the highest quality, most reliable information from the VAACs. End-users will base *their* decisions on *their* business rules and *their* appetite for risk. The VAACs should not attempt to do this for them.

h) It is generally the case that the exploitation of scientific and technological advancement is often best achieved during 'peacetime', and that exploitation during emergency or crisis response can yield unintended consequences.

i) Since all nine VAACs are subsets of national meteorological services (NMS) that each possess, to a greater or lesser extent, a research facility or access to a research facility (e.g. within academia), and given the time it can take to transition research into operations, VAACs should be encouraged to make plans now (if not already) to harness

the recent and foreseen future scientific and technological advancements in support of the IAVW.

j) Following on from i) and recognizing that internal forcing within a VAAC or an NMS, say, can often be insufficient to drive or expedite change in service delivery, external forcing has an important role to play too. Every effort should be made to exploit internal and external opportunities as they arise, to help drive the entire community forwards.

30.4 To conclude the discussion, it was the consensus view and thus recommendation of the VAAC managers and VASAG members present that the quantitative volcanic ash contamination issue that was paused in 2012 as a result of the outcomes of the International Volcanic Ash Task Force (IVATF) of ICAO (2010-2012) should be revisited on the understanding that while there has been noteworthy scientific and technological advancement since IVATF concluded, and with a proviso that continued scientific and technological advancement demands sustained investment to enable research-to-operations pull-through, uncertainty will always prevail (albeit to a generally decreasing extent over time).

31. VONA ISSUES

31.1 Further to preceding discussions during the conjoint session (see section 5 and section 27 above), Dr David Schneider led a closing discussion on the Volcano Observatory Notice for Aviation (VONA). Dr Schneider presented an overview of the content of the VONA and recent examples from the Alaska Volcano Observatory. The presentation highlighted that the information to be included in the VONA can be open to misinterpretation or otherwise be vague, while the recent VONA examples demonstrated that the aviation colour code assigned to a volcano can often be highly variable, particularly when the volcano is experiencing heightened or episodic unrest.

31.2 During the subsequent discussion, communication and collaboration between SVOs and VAACs was highlighted as an enabler to the production and issuance of the VONA. However, it was recognized that both aspects remained challenging in some regions. Where electronic means of communications are difficult or impossible, telephone calls are often the only (essential) bridge.

31.3 Participants were encouraged to provide additional feedback on the utility of the VONA directly to Dr Schneider.

32. WRAP-UP AND CLOSE OF THEMATIC OPEN SESSION

32.1 Mr Lisk drew the thematic open session and the conjoint session as a whole to a close. He acknowledged the significant contribution that all participants had made to the week and the spirit of camaraderie that had prevailed. He thanked the staff of CAA NZ and MetService of New Zealand for the use of their facilities and for the hospitality shown throughout the week. He emphasized the outcomes of the week were of direct relevance to the work being undertaken by the ICAO METP and its working groups, and that the outcomes of the conjoint session would be fed to the WG-MOG (IAVW) and WG-MISD (VASD) meetings that immediately follow (12 to 14 November 2018). In respect of the next meetings or a conjoint session of VAAC BP and VASAG, Mr Lisk indicated that, following consultation with Dr Tupper and Dr Mastin, the target timeframe was late-2020 to coincide with the proposed IWVA/8 (discussed at section 19 above). However, should there be a specific issue demanding special

attention and a face-to-face meeting, consideration may be given to convening at an earlier point in time.

32.2 The closing of the meeting was also addressed by Dr Tupper and Dr Mastin on behalf of the VASAG, Mr Brock on behalf of the WMO Secretariat, and Mr Lunny and Mr Lechner on behalf of MetService and CAA NZ respectively.

32.3 The session closed at 4:40 p.m. on Friday 9 November 2018.

_____

AGENDA (ORDER OF BUSINESS)

(All times local)

MONDAY 5 NOVEMBER JOINT SESSION		TUESDAY 6 NOVEMBER PARALLEL SESSIONS			WEDNESDAY 7 NOVEMBER PARALLEL & JOINT SESSIONS			THURSDAY 8 NOVEMBER THEMATIC OPEN SESSION		FRIDAY 9 NOVEMBER THEMATIC OPEN SESSION	
0830	**Registration @ CAA NZ**	**—**	**VAAC BP @ MetService**	**VASAG @ CAA NZ**	**—**	**VAAC BP @ MetService**	**VASAG @ CAA NZ**	**0830**	**Registration for new participants @ CAA NZ**	**0830**	**Registration for new participants @ CAA NZ**
0900	Welcome, opening remarks [Ian] Objectives, working arrangements	**0900**	Status of open VAAC BP outcomes (2016 & 2017) [Ian]	Status of open VASAG actions (2015 & 2017) [Andrew & Larry]	**0900**	Additional VAAC discussions including IATA request for review of VAACs [Ian] (*VAAC managers only*)	Publications and outreach suggestions [Andrew] IWVA proposals [Andrew & Larry]	**0900**	Welcome, opening remarks [Ian] Objectives, working arrangements	**0900**	Welcome to new participants [Ian] Plan for the day
0930	INS and OUTS modelling tables update [Matt & Claire]	**0930**	Satellite inter-comparisons of discernible ash [Kazuki]	ESP database for restless volcanoes [Larry & Sam]				**0930**	VAAC Personnel Competency [Ian]	**0915**	Volcanic sulphur dioxide [Larry & Andrew]
1030	*Break*	***1030***	*Break*		***1030***	*Break*		***1030***	*Break*	***1030***	*Break*
1100	VAACs strength of evidence check-lists [Kazuki, Jarrad & Mike]	**1100**	Forecast verification and VAAC KPIs [Mark]	Encounters database and severity index [Dave]	**1100**	**JOINT SESSION @ CAA NZ** Parallel session reporting [Ian, Andrew & Larry]		**1100**	VAAC Personnel Competency [Ian]	**1100**	Volcanic Ash Impacts on Jet Engines Update [Rory]
1200	*Lunch / Group photo*	***1200***	*Lunch*		***1200***	*Lunch*		***1200***	*Lunch*	***1200***	*Lunch*
1330	VONA and aviation colour codes [Dave & Sam]	**1330**	VAAC collaboration tools [Dov]	Satellite advancements (including SCOPE-Nowcasting) [Mike]	**1330**	**JOINT SESSION @ CAA NZ** IWVA proposal from VASAG & feedback [Andrew & Larry] WMO Constituent Bodies Reform and impacts on CAeM governance/structures [Ian]		**1330**	VAAC Personnel Competency [Ian]	**1330**	Quantitative volcanic ash forecasts – progress and recommendations [Ian and Andrew]
1530	*Break*	***1500***	*Break*		***1530***	*Break*		***1530***	*Break*	***1530***	*Break*
1600	Volcanic hazard monitoring and observing capabilities [Dave & Sam]	**1515**	IWXXM developments [Dov & Patrick]	Modelling advancements (including probability & ESP) [Claire]	**1600**	**JOINT SESSION @ CAA NZ** Wrap-up and close [Ian, Andrew & Larry]		**1600**	State Volcano Observatory skills, needs & capacity development [Larry & Andrew]	**1600**	VONA issues [Dave] Wrap-up and close [Ian]
1700	**Close**	**1630**	**Close then 'Icebreaker' at MetService**		**1700**	**Close**		**1700**	**Close**	**1700**	**Close**

LIST OF PARTICIPANTS

1. VAAC MANAGERS (or Representatives)

VAAC AFFILIATION	NAME	E-MAIL
ANCHORAGE	OSIENSKY, Jeff	jeffrey.osiensky@noaa.gov
DARWIN	DENMAN, Jarrad	jarrad.denman@bom.gov.au
LONDON	SELTZER, Mark	mark.seltzer@metoffice.gov.uk
MONTREAL	BENSIMON, Dov	dov.bensimon@canada.ca
TOKYO	ITO, Kazuki	kazuki.ito@met.kishou.go.jp
TOULOUSE	HEREIL, Philippe	philippe.hereil@meteo.fr
WASHINGTON	KIBLER, Jamie M.	jamie.kibler@noaa.gov
WELLINGTON	ROUX, Marcel	marcel.roux@metservice.com

2. VASAG MEMBERS

AFFILIATION	NAME	E-MAIL
AUSTRALIA	TUPPER, Andrew	andrew.tupper@bom.gov.au
GERMANY	SCHLAGER, Hans	hans.schlager@dlr.de
UNITED KINGDOM	LISK, Ian	ian.lisk@metoffice.gov.uk
UNITED KINGDOM	WITHAM, Claire	claire.witham@metoffice.gov.uk
UNITED STATES	MASTIN, Larry	lgmastin@usgs.gov
UNITED STATES	SCHNEIDER, David	djschneider@usgs.gov
UNITED STATES	PAVOLONIS, Michael	mike.pavolonis@noaa.gov

3. OTHER PARTICIPANTS (OBSERVERS)

AFFILIATION	NAME	E-MAIL
BRITISH GEOLOGICAL SURVEY	ENGWELL, Samantha	sameng@bgs.ac.uk
BUREAU OF METEOROLOGY / VAAC DARWIN	KING, Tristan	tristan.king@bom.gov.au
MÉTÉO-FRANCE / VAAC TOULOUSE	SIMON, Patrick	patrick.simon@meteo.fr
UK MET OFFICE / WMO GAW SAG APP	HORT, Matthew	matthew.hort@metoffice.gov.uk
QANTAS / IATA	RENNIE, Graham	grennie@qantas.com.au
ROLLS-ROYCE / ICCAIA	CLARKSON, Rory	rory.clarkson@rolls-royce.com
UNITED STATES FAA / ICAO METP WG-MISD (VASD) COORDINATOR	FLOWE, Tammy	tammy.flowe@faa.gov
CAA OF NEW ZEALAND / ICAO METP CHAIR	LECHNER, Peter	peter.lechner@caa.govt.nz
CAA OF NEW ZEALAND	ACETHORP, Paula	paula.acethorp@caa.govt.nz
CAA OF NEW ZEALAND	MACKERSY, Keith	keith.mackersy@caa.govt.nz
CAA OF NEW ZEALAND	MADDEN, Kate	kate.madden@caa.govt.nz
METSERVICE OF NEW ZEALAND	LUNNY, James	james.lunny@metservice.com
METSERVICE OF NEW ZEALAND	WEBSTER, Chris	chris.webster@metservice.com

AFFILIATION	NAME	E-MAIL
METSERVICE OF NEW ZEALAND	DAVIS, Cory P.	cory.davis@metservice.com
METSERVICE OF NEW ZEALAND	GNJIDIC VUKSA, Tamara	tamara.gnjidicvuksa@metservice.com
METSERVICE OF NEW ZEALAND	PARKES, Ashlee	ashlee.parkes@metservice.com
METSERVICE OF NEW ZEALAND	GRIFFIN, Joshua	joshua.griffin@metservice.com
GNS SCIENCE (NEW ZEALAND)	DELIGNE, Natalia	n.deligne@gns.cri.nz
AIRWAYS (NEW ZEALAND)	JENKINS, Lewis	lewis.jenkins@airways.co.nz
AIRWAYS (NEW ZEALAND)	FITNESS, Julia	julia.fitness@airways.co.nz

4. WMO SECRETARIAT

TITLE	NAME	E-MAIL
ACTING CHIEF, AERONAUTICAL METEOROLOGY DIVISION	BROCK, Greg	gbrock@wmo.int
SCIENTIFIC OFFICER, RESEARCH DEPARTMENT	BAKLANOV, Alexander	abaklanov@wmo.int

_____

STATUS UPDATE ON THE OUTCOMES OF THE FOURTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/4) (2016)			
Outcome No.	**Description**	**Lead**	**Status at VAAC BP/6 (2018)**
VW4-O-03	**Modelling** - All VAACs in coordination with the relevant NWP provider(s), to further investigate and report on NWP errors/performance (taking into account region specific issues e.g. tropics) relevant to volcanic ash modeling and VAAC 'Ins and Outs' Modelling tables to be reviewed, updated and shared **every 2-years** (next update 2018).	VAAC London (Updated tables added to VAAC BP website by end of July 2016)	**Open.** Recurrent activity. [Section 3 refers]
VW4-O-16	**Volcanic hazard monitoring and observing capabilities** Volcanic ash AIREPS, in-situ, remote sensing and volcano monitoring information availability and dissemination processes need to be enhanced and better coordinated with associated guidance including operational application best practice updated/developed. (IAVWOPSG ref 7/23, 8/3, 8/21, 8/22) – METP WG-MOG paper	WMO. Routine VASAG updates submitted to MET-P WG-MOG meetings.	**Complete.** Reports to METP as routine. [Section 7 refers]

All other VAAC BP/4 outcomes were closed at the VAAC BP/5 workshop in 2017

STATUS UPDATE ON THE OUTCOMES OF THE FIFTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/5) (2017)			
Outcome No.	**Description**	**Lead**	**Status at VAAC BP/6 (2018)**
VW5-O-01	**VAAC COLLABORATION TOOL** 1) Finalize functional needs analysis for a VAAC collaboration tool; and 2) Upon completion of 1), VAACs with capability to collaborate in the development of a suitable, single web-based platform (basic functionality to start as necessary). **Progress report to next workshop.**	VAAC Montreal (Dov)	**Complete.** Replaced by new outcome. [Section 10 refers]

STATUS UPDATE ON THE OUTCOMES OF THE FIFTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/5) (2017)			
Outcome No.	**Description**	**Lead**	**Status at VAAC BP/6 (2018)**
VW5-O-02	**IWXXM VERSIONS** Seek clarification from ICAO METP WG-MIE and/or WMO CBS TT-AvXML on the differences between the current and next IWXXM versions (i.e. 2.1 and 3.0) and when the next IWXXM version (3.0) will be available.	VAAC Toulouse (Patrick)	**Complete.** Email comm. 14 June 2017. [Section 11 refers]
VW5-O-03	**IWXXM IMPLEMENTATION** IWXXM-compliant VAA/VAG should be made available on the VAAC websites (to start) and extended AMHS (eventually). **Progress report to next workshop.**	VAAC Montreal (Dov)	**Complete**. Replaced by new outcome. [Section 11 refers]
VW5-O-04	**VONA AND AVIATION COLOUR CODES ISSUES** Propose to the WG-MOG/5 (IAVW) meeting that the aviation colour code be removed from the VAA template and that the VONA be elevated to the status of a recommended practice and (eventually) a standard.	WMO (Greg/Ian)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-05	**KEY PERFORMANCE INDICATORS (KPIs)** 1) Proposed KPIs should be reported to the ICAO METP WG-MOG/5 (IAVW) meeting for consideration; and 2) Upon completion of 1), the KPIs should be trialled by all VAACs. **Progress report to next workshop.**	VAAC London (Anton)	1) **Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) 2) **Complete.** Replaced by new outcome. [Section 9 refers]
VW5-O-06	**'ASH'/'NO ASH' REPORTING** Feed ideas to the ICAO METP WG-MOG/5 (IAVW) meeting on the ways and means to improve the level of 'Ash'/'No Ash' reporting without significantly compromising the use of resources.	VAAC Darwin (Emile)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-07	**DISCERNIBLE ASH AND STRENGTH OF EVIDENCE CHECKLISTS**	1) WMO	1) **Complete.** Reported to

STATUS UPDATE ON THE OUTCOMES OF THE FIFTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/5) (2017)			
Outcome No.	**Description**	**Lead**	**Status at VAAC BP/6 (2018)**
	1) Inform VASAG of the discernible ash strength of evidence checklists to seek their expert advice in maturing the methodology; and 2) Further trial and mature the checklists amongst the VAACs, taking into account the advice of VASAG as appropriate. **Progress report to next workshop.**	(Greg/Ian) 2) VAAC Darwin (Adele) and VAAC Tokyo (Kazuki)	VASAG/7 in 2017. 2) **Complete.** Replaced by new outcome. [Section 4 refers]
VW5-O-08	**SATELLITE INTER-COMPARISON** Where feasible, 1) Conduct comparison between the old and new generation of satellite products within each VAAC; and 2) Conduct comparison of the new generation of satellite products across all VAACs. **Progress report to next workshop.**	VAAC Darwin (Adele) and VAAC Tokyo (Kazuki)	**Complete.** Replaced by new outcome. [Section 8 refers]
VW5-O-09	**RE-SUSPENDED ASH** Propose to the ICAO METP WG-MOG/5 (IAVW) meeting that some form of re-suspended ash indicator be introduced into Annex 3, Appendix 2, Table A2-1.	VAAC Tokyo (Yohko)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-10	**T+0 CONFIDENCE** Propose to the ICAO METP WG-MOG/5 (IAVW) meeting that the inclusion of T+0 confidence in VAA/VAG should be discontinued while other options are explored.	VAAC Darwin (Emile)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-11	**MODEL VAG AND MODEL SVA** Propose to the ICAO METP WG-MOG/5 (IAVW) meeting that two new examples *each* should be developed for the MODEL VAG and MODEL SVA with a view to their potential future inclusion in ICAO Annex 3.	WMO (Greg)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-12	**T+24 VAG TRIAL** Propose to the ICAO METP WG-MOG/5 (IAVW) meeting that the T+24 VAG trial be discontinued.	WMO (Greg)	**Complete.** Addressed at ICAO METP WG-MOG/5

STATUS UPDATE ON THE OUTCOMES OF THE FIFTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/5) (2017)			
Outcome No.	**Description**	**Lead**	**Status at VAAC BP/6 (2018)**
			(IAVW) in 2017.
VW5-O-13	**SUPPLEMENTARY PRODUCTS – CONCENTRATION CHARTS** Propose to the ICAO METP WG-MOG/5 (IAVW) meeting that the issue of volcanic ash concentration charts should be revisited in the context of the scientific and technological advances since 2010 and the latest engine-type tolerability information.	VAAC London (Anton)	**Complete.** Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-14	**SO2** Report to the WG-MISD/3 (VASD) that: 1) most but not all VAACs currently have SO_2 detection, monitoring and/or prediction capabilities and that, where any capability exists, this was in the research/non-operational area; and 2) the future establishment of an operational VAAC service for SO_2 based on a (yet to be determined) user requirement in ICAO Annex 3 would require additional VAAC resources to implement and therefore must be supported by appropriate cost recovery arrangements.	WMO (Greg)	**Complete**. Addressed at ICAO METP WG-MOG/5 (IAVW) in 2017.
VW5-O-15	**NEXT WORKSHOP** VAAC Wellington to work with the WMO Secretariat to confirm the offer of hosting the VAAC BP/6 workshop in New Zealand in 2018.	VAAC Wellington (Paula)	**Complete.** Conjoint meeting of 2018.

ANNEX 4

STATUS UPDATE ON THE ACTIONS ARISING FROM THE SIXTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/6) (2015)		
Action No.	**Description**	**Status at VASAG/8 (2018)**
6/2	**Relevant publications** VASAG (through Ms Guffanti*) to contribute as required to the updated IAVCEI guidelines here and promote conformance to these guidelines. [*Changed to Dr Tupper at VASAG/7]	**Complete.** [Section 18 refers]
6/6	**Global volcano ESP database for restless volcanoes** 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).	**Open.** [Section 14 refers]
6/7	**Outreach** 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).	**Complete.** [Section 18 refers]
6/10	**Use of radar data for volcanic ash applications training** 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.	**Open.** [Section 13 refers]

All other VASAG/6 actions were closed at the VASAG/7 meeting in 2017

STATUS UPDATE ON THE ACTIONS ARISING FROM THE SEVENTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/7) (2017)			
Action No.	**Description**	**Lead**	**Status at VASAG/8 (2018)**
7/1	**Strength of Evidence Checklists** Agreement that Dr Pavolonis would collate feedback from the VASAG on the scientific perspectives of the discernible ash strength of evidence checklists and to provide feedback to VAACs Darwin and Tokyo (as the VAAC BP activity leads).	Pavolonis	**Complete.** [Section 4 refers]
7/2	**Quantitative VA contamination information and long-range forecasts** Agreement that Dr Mastin, assisted by other members and observers, would lead the VASAG follow-up of METP WG-MOG/5 (IAVW) Action Agreed 5/12.	Mastin	**Complete.** [Section 30 refers]

STATUS UPDATE ON THE ACTIONS ARISING FROM THE SEVENTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/7) (2017)			
Action No.	**Description**	**Lead**	**Status at VASAG/8 (2018)**
	Note. — This follow-up will entail leading a state of science review (by VASAG and ICCAIA) on the global development and use of quantitative volcanic ash contamination information and forecasts with a study note (or similar) to be prepared for the next WG-MOG (IAVW) in 2018.		
7/3	**Aviation colour codes and VONA** Agreement that Dr Schneider (for Ms Guffanti), assisted by Dr Engwell (for Dr Witham) and Dr Barsotti, would provide the VASAG support to the follow-up of METP WG-MOG/5 (IAVW) Action Agreed 5/10. *Note. — This follow-up will entail assisting WG-MOG (IAVW) in the development of a proposed updates to ICAO Annex 3 regarding VAA/VAG on VONA and supporting guidance material for ICAO Doc 9766.*	Schneider (for Guffanti), Engwell (for Witham) and Barsotti	**Complete.** [Section 5 refers]
7/4	**State Volcano Observatory responsibilities** Agreement that ICAO should be requested (through Mr Romero as the ICAO ex-officio VASAG member) to undertake efforts to remind ICAO Contracting States with active or potentially active volcanoes of their State volcano observatory responsibilities under ICAO Annex 3, 3.6 and the supporting operational procedures contained within ICAO Doc 9766, particularly in the context of the arrangements for the monitoring of such volcanoes and the preparation, dissemination and communication of the VONA.	Romero	**Open.** [Section 5 and section 27 refer]
7/5	**Aircraft encounters database and severity index** Agreement that Dr Schneider (for Ms Guffanti), assisted by other members, would lead the VASAG follow-up of METP WG-MOG/5 (IAVW) Action Agreed 5/7. *Note. — This follow-up will entail assisting WG-MOG (IAVW) in the drafting of changes to Appendix F of ICAO Doc 9691 with new data on aircraft encounters and any agreed-upon modifications to an encounter severity index.*	Schneider (for Guffanti)	**Open.** [Section 15 refers]

STATUS UPDATE ON THE ACTIONS ARISING FROM THE SEVENTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/7) (2017)			
Action No.	**Description**	**Lead**	**Status at VASAG/8 (2018)**
7/6	**SO_2 State of Science review** Agreement that, to the extent practicable, VASAG would assist ICAO in undertaking the SO_2 'state of science' review called for by METP WG-MISD/3 (VASD) Action Agreed 3/1.	VASAG members	**Complete.** [Section 28 refers]
7/7	**IWVA/8 Concept Note** Agreement that Dr Mastin and Dr Tupper, in coordination with Secretariat, would develop a concept note[6] for IWVA/8 (2019) for consultation with the wider VASAG membership.	Mastin and Tupper	**Complete**. [Section 19 refers]
7/8	**Next Meeting** Agreement that the Secretariat should identify where and when VASAG/8 will be held together with an indication of the extent of WMO funding that may be available to support members' attendance. *Note. — The VASAG agreed that there would be merit in convening a future meeting conjointly with a VAAC Best Practice workshop.*	Secretariat	**Complete.** Conjoint meeting of 2018.

[6] The concept note may address the workshop's theme and expected outcome, intended audience and expected level of participation, format, timing, duration and location plus co-sponsorship opportunities.

ANNEX 5

OUTCOMES OF THE SIXTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/6) (2018) AND ACTIONS FROM THE EIGHTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/8) (2018)			
VAAC BP/6 Outcome No. or VASAG/8 Action No.	**Description**	**Lead**	**Deadline**
VAAC BP/6 Outcome WV6-O-01	**VAAC Strength of Evidence Checklists** [Section 4 refers] a) All VAAC Managers encouraged to introduce, as soon as possible, operational use of the strength of evidence checklists within their respective forecast office (and non-operational use for training purposes where appropriate) and to provide feedback to VAACs Tokyo and Darwin (as focal points) on the utility of the checklists, including suggestions for improvement, by 30 June 2019; b) Taking into account the feedback received from a) above as well as that received from the VASAG in 2018, VAACs Darwin and Tokyo (Jarrad Denman and Kazuki Ito) to further improve the checklists methodologies and to present progress reports in this regard on a biennial basis (next report in 2020).	All VAACs with Tokyo and Darwin as focal points	a) 30 June 2019 b) 2020
VAAC BP/6 Outcome WV6-O-02	**Satellite inter-comparisons of discernible ash** [Section 8 refers] Strongly encourage the VAACs to continue or to commence satellite inter-comparisons of the old and new generation of satellite imagery – as a minimum between a VAAC and its backup centre – and to consider the feasibility of establishing similar inter-comparison efforts for ATDM output for volcanic ash in the atmosphere. Progress report by all VAACs on a biennial basis (next report in 2020).	All VAACs	2020
VAAC BP/6 Outcome WV6-O-03	**VAAC Key Performance Indicators** [Section 9 refers] VAAC London (Mark Seltzer) to forward to ICAO the feedback obtained on the trial application of the initial set of KPIs and the suggestions for improvement developed during VAAC BP/6 in 2018 for further consideration at the ICAO METP WG-MOG/8 (IAVW) meeting.	VAAC London	November 2018

OUTCOMES OF THE SIXTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/6) (2018)
AND
ACTIONS FROM THE EIGHTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/8) (2018)

VAAC BP/6 Outcome No. or VASAG/8 Action No.	Description	Lead	Deadline
VAAC BP/6 Outcome WV6-O-04	**VAAC Collaboration Tool** [Section 10 refers] VAAC Tokyo (Kazuki Ito), with the assistance of VAAC Wellington (Marcel Roux) and in coordination with the other VAACs, encouraged to lead the further development and operational introduction of a VAAC collaboration tool consistent with the basic functional needs identified in 2017 and taking into account the feedback at VAAC BP/6 in 2018. Progress report not later than 2020.	VAAC Tokyo	2020
VAAC BP/6 Outcome WV6-O-05	**IWXXM Schema Implementation** [Section 11 refers] All VAACs are encouraged to continue to pursue the introduction of the IWXXM schema for the VAA/VAG in readiness for November 2020 applicability of associated ICAO Annex 3 provisions. Progress report not later than 2020.	All VAACs	2020
VAAC BP/6 Outcome WV6-O-06	**IWXXM Schema Clarifications** [Section 11 refers] VAAC Toulouse (Patrick Simon) encouraged to consult with WMO TT-AvXML on the IWXXM-related VAA/VAG issues identified by VAAC Tokyo at VAAC BP/6 in 2018 and to report on the outcomes of those consultations at the earliest opportunity.	VAAC Toulouse	ASAP (2019)
VAAC BP/6 Outcome WV6-O-07	**VAAC Washington Backup Arrangements** [Section 12 refers] VAAC Washington (Jamie Kibler) to: a) work with other VAACs, particularly but not necessarily exclusively those in the Americas, to seek the establishment of a more viable VAAC backup arrangement for their operations; and b) consider whether serving as the primary backup centre for three other VAACs (Anchorage, Buenos Aires and Montreal) is entirely suitable given the operational risk this represents within the IAVW during periods when VAAC Washington itself is unserviceable. Alternative proposals to be investigated accordingly. Progress report not later than 2020.	VAAC Washington	2020

OUTCOMES OF THE SIXTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/6) (2018)
AND
ACTIONS FROM THE EIGHTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/8) (2018)

VAAC BP/6 Outcome No. or VASAG/8 Action No.	Description	Lead	Deadline
VAAC BP/6 Outcome VW6-O-08	**Competency Framework for VAAC Forecasters** [Section 26 refers] Ian Lisk, in his capacity as president of CAeM, to task the CAeM Expert Team on Education, Training and Competency (ET-ETC) to initiate and lead work on amending the top- and/or second-level competencies for AMF such that they can be applied for VAAC forecasters. This work should be undertaken in consultation with VAAC managers/representatives and VASAG members as necessary. Progress report via correspondence by 30 June 2019.	Lisk	30 June 2019
VASAG/8 Action Agreed 8/1	**Publications and Outreach** [Section 18 refers] Andrew Tupper and Larry Mastin requested, in coordination with VASAG members and Matt Hort (representing GAW APP SAG), to: a) lead further discussions and devise proposals on outreach in support of the IAVW; b) specifically consider becoming involved with an ACP publication (Andrew Tupper); and c) determine the feasibility of authoring a 2020 publication that provides a ten-year retrospective on the progress made since the eruption of Eyjafjallajökull in Iceland (Larry Mastin). Progress report via correspondence by 30 June 2019.	Tupper and Mastin	30 June 2019
VASAG/8 Action Agreed 8/2	**IWVA Concept Note** [Section 19 refers] David Schneider is requested, in coordination with VASAG members and Matt Hort (representing GAW APP SAG), to lead the development of an update to a draft Concept Note for a proposed IWVA/8 in the late-2020 timeframe. Progress report via correspondence by 30 June 2019.	Schneider	30 June 2019

OUTCOMES OF THE SIXTH VOLCANIC ASH BEST PRACTICE WORKSHOP (VAAC BP/6) (2018)
AND
ACTIONS FROM THE EIGHTH VOLCANIC ASH SCIENTIFIC ADVISORY GROUP MEETING (VASAG/8) (2018)

VAAC BP/6 Outcome No. or VASAG/8 Action No.	Description	Lead	Deadline
VASAG/8 Action Agreed 8/3	**Review and Update of WOVO guidance on the IAVW** [Section 27 refers] David Schneider and Sara Barsotti to lead a review and, as necessary, update of the WOVO Guidance for State Volcano Observatories: The International Airways Volcano Watch (available at URL: http://www.wovo.org/assets/docs/gvo2009s.pdf). Progress report via correspondence by 30 June 2019.	Schneider and Barsotti	30 June 2019

_____

ANNEX 6

ASH-ENCOUNTER SEVERITY INDEX

(proposal formulated at VASAG/8 in 2018 for submission to ICAO WG-MOG (IAVW))

Class	Criteria	***Nature of changes proposed by VASAG/8***
0	+ ~~sulphurous~~ sulfur odour noted in cockpit and/or cabin + anomalous atmospheric haze observed + electrostatic discharge (St. Elmo's fire) on windshield, nose, or engine cowls + volcanic ash reported or suspected by flight crew but no other effects or damage noted	*Addition of anomalous atmospheric haze and changes in wording to three other criteria.*
1	~~+ light dust observed in cabin~~ + volcanic ash ~~deposits~~ deposited on exterior of aircraft + fluctuations in exhaust gas temperature (EGT) with return to normal values + volcanic ash observed in cockpit and/or cabin	*Addition of anomalous atmospheric haze and changes in wording to three other criteria.*
2	~~+ heavy cabin dust ("dark as night") in cabin~~ ~~+ contamination of air handling and air conditioning systems requiring use of oxygen~~ + abrasion damage to exterior surfaces (wind screens, engine inlet and/or ~~compressor~~ engine fan blades) ~~+ pitting, frosting or breaking of windscreen or windows~~ ~~+ minor plugging of pitot-static system, insufficient to affect instrument readings~~ ~~+ deposition of ash in engine~~ + deposition of volcanic ash in engine + volcanic ash deposited in cockpit, cabin, and/or air systems + volcanic ash deposited in pitot-static system, insufficient to affect instrument readings	*Combined six criteria into four. Abrasion damage grouped, heavy cabin dust and contamination of air handling systems grouped into deposition within the aircraft. Minor edits regarding of pitot-static system.*
3	+ vibration or surging of engine(s) + plugging of pitot-static system to give erroneous instrument readings + contamination of engine oil and/or hydraulic system ~~fluids~~ + damage to electrical and/or computer systems + engine damage affecting engine performance + interference of navigation and/or communication systems	*Added criteria of interference to navigation or communication systems. Minor edits in wording in other criteria.*
4	+ ~~temporary~~ engine failure requiring in-flight restart or permanent shutdown of engine(s)	*Minor edit with addition of permanent shutdown of engine(s).*
5	+ engine failure or other damage ~~leading to crash~~ resulting in loss of aircraft	*Minor edit.*

— END —