

*International Civil Aviation Organization*



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**INFORMATION PAPER (IP/15)**

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(MET SG/28)

Bangkok, Thailand, 8 to 12 July 2024

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**Agenda Item 6: Research, development, and other initiatives**

**COMBINED APAC VAAC MANAGEMENT REPORT**

(Presented by Australia, Japan and New Zealand)

**SUMMARY**

This paper presents an International Airways Volcano Watch (IAVW) consolidated management report describing activities for all 9 Volcanic Ash Advisory Centre's (VAAC) prepared by the Meteorology Panel (METP) Working Group Meteorological Operations Group (WG-MOG) IAVW workstream for the period 1 January 2023 to 31 December 2023. Additional information is provided by the three APAC VAACs Darwin, Tokyo, and Wellington to the APAC region covering the period 1 January 2024 to 31 May 2024.

**1. INTRODUCTION**

1.1 This paper presents the consolidated VAAC Management report prepared by the nine VAACs for the METP MOG-IAVW workstream. The information in the report covers all products issued during the 1 January 2023 and 31 December 2023 period, key performance indicators, operational improvements, competency, stakeholder outreach, volcanic events of interest, collaboration, and steps towards Quantitative Volcanic Ash (QVA).

1.2 The three APAC VAACs Darwin, Tokyo and Wellington have also provided additional updates that cover from 1 January 2024 to 31 May 2024 which would be important for operators and other stakeholders in the APAC region.

**2. DISCUSSION**

2.1 The consolidated VAAC management report for 2023 has been submitted as a separate PDF file linked to this paper.

[2024 update from VAAC Darwin](#)

2.2 As of the 21 March 2024, there was a change to VAAC Darwin policy where they will now issue Volcanic Ash Advisory (VAA) when ground reports (such as VONA etc) indicate an eruption has taken place, even if the VA is not visible on satellite imagery. In this instance the plume and affected area may need to be estimated based on dispersion modelling and this is indicated in the advisory by EST rather than OBS. This change in policy will support decision making, volcanic ash SIGMET generation and enabling safer operations near volcanoes.

2.3 For a discrete or short eruption in the VONA, there will be an estimated observation and possibly a T+6 forecast as these eruptions usually dissipate quickly. For a continuous eruption in the VONA, there will be an estimated observation and forecast (examples in Appendix A).

2.4 Note that the VAAC will not issue a new VAA for every VONA, as such when there is already a VAA issued that covers the activity in the VONA. If there is no VAA issued or the VAA does not cover the information in the VONA then the VAA will be updated.

2.5 On 17 April 2024, Ruang located in Sangihe Islands in Indonesia had a significant eruption to approximately 80,000 feet with stratospheric injection. The volcanic ash that reached the stratosphere moved quickly to the west but there was large amount of volcanic ash that reached the tropopause which was moving radially out in all directions above the volcano. Himawari-9 visible, split window and RGB imagery was used to continuously track the volcanic ash as it was providing strong ash signatures as well as glaciated volcanic ash but also large volumes of sulphur dioxide (SO<sub>2</sub>).

2.6 The volcanic ash and gases continued to move west over Borneo until the ash signal was no longer discernible as it moved over the South China Sea. The volcanic ash at the volcano continue to spread in all directions as it slowly dissipated impacting the local airports with ash fall. The high-level volcanic ash from the eruption was below discernible levels two days after the initial eruption (Appendix B - Figure 1).

2.7 On 29 April 2024, Ruang had a second significant eruption to approximately 80,000 ft. This eruption showed strong stratospheric injection as the ash was moving to the west but slower than the previous event. On Himawari-9 true colour imagery the brown ash signature was visible, and it was well above the tropospheric meteorological clouds. The ash produced in the 29 April eruption moved slower than the previous event, but still moved across Borneo. 30 hours after the initial eruption, the volcanic cloud moving west was still providing a strong ash signal but had passed over many tropospheric thunderstorm clouds. The volcanic ash that was being tracked was in the stratosphere and there were no reports of ash fall at airports. The base of the volcanic ash was estimated to be 45,000 ft as our analysis suggested the cloud of volcanic ash was trapped above the tropopause, which was consistent with no observed ash-fall. The base was flight levels just below the stratosphere.

2.8 VAAC Darwin reached out to MWOs for PIREPs but there were no reports of volcanic ash. Aviation operators continued to operate under the stratospheric ash cloud like during the Hunga Tonga Hunga Ha'apai eruption back in 2022. Around four to five days after the initial eruption, the volcanic ash moving west was no longer discernible by satellite imagery and was finalised (Appendix B - Figure 2).

#### 2024 update from VAAC Tokyo

2.9 The Japan Meteorological Agency updated its supercomputer system in March 2024. While some scripts were modified, the same high level of information quality remains.

2.10 VAAC Tokyo is reconsidering its approach to the issuance of VAAs on volcanic ash cloud not discernible in satellite imagery. Even where such cloud is not observed, or is expected to dissipate imminently, the potential presence of volcanic ash should be highlighted.

2.11 On May 29th, VAAC Tokyo reported on the progress of QVA development at an academic meeting in Japan, noting its evaluation as a practical consideration based on volcanology. VAAC Tokyo now plans quantitative verification via satellite-based retrieval.

#### 2024 update from VAAC Wellington

2.12 On 2 April 2024, the tool that VAAC Wellington uses to create and issue Volcanic Ash Advisories and Graphics (VAA/VAG) was upgraded to a newer version. As part of our change management plan, we issued a TEST VAA following the upgrade, and requested RODB Brisbane to confirm receipt to prove a successful connection. This upgrade also removes an issue we had previously identified related to volcano names with a forward slash included e.g. Whakaari/White Island.

2.13 VAAC Wellington has implemented a temporary procedure to help with the current information gap related to increased unrest of a volcano in the wider South Pacific. In cases where the Aviation Colour Code (ACC) is increased to yellow or higher (with no ash identified), and no NOTAM for unrest is issued, a one-off VAA is issued to highlight the ACC change for broader awareness. This is a temporary measure until either NOTAM for volcanic unrest is implemented or use of VONA becomes a recommended practice. VAAC Wellington utilised this procedure in May 2024 for a period of increased unrest at Tofua.

2.14 VAAC Wellington, GNS Science NZ and Tonga Geological Survey (TGS) continue to collaborate to refine our processes and communication around VONA and VAA issuance. Next steps are for VAAC Wellington is connect with TGS via Teams, to allow for more seamless and timely coordination.

### **3. ACTION BY THE MEETING**

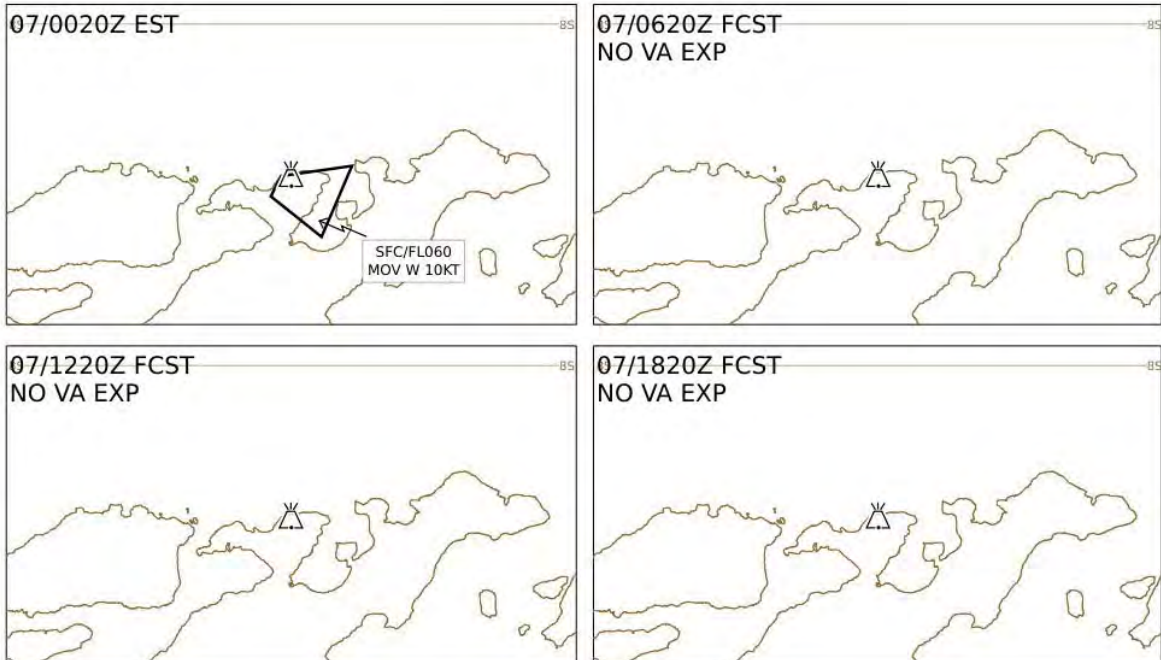
3.1 Note the information contained in this paper.

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**APPENDIX A**

An example VAA of estimated observation based on a VONA for discrete eruption but it is not observed on satellite imagery:

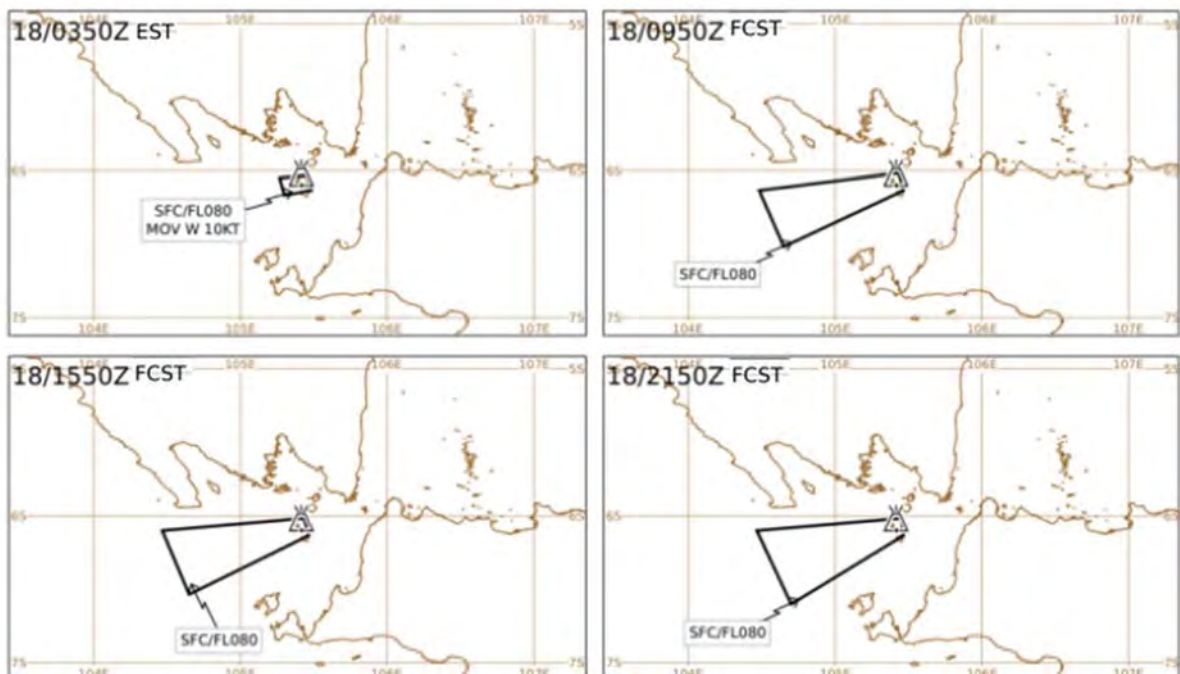
FVAU03 ADRM 070035  
VA ADVISORY  
DTG: 20240407/0035Z  
VAAC: DARWIN  
VOLCANO: LEWOTOLOK 264230  
PSN: S0816 E12330  
AREA: INDONESIA  
SUMMIT ELEV: 1423M  
ADVISORY NR: 2024/59  
INFO SOURCE: CVGHM, HIMAWARI-9  
AVIATION COLOUR CODE: ORANGE  
ERUPTION DETAILS: VA REPORTED TO FL060 AT 07/0004Z  
EST VA DTG: 07/0020Z  
EST VA CLD: SFC/FL060 S0815 E12329 - S0814 E12336 - S0821  
E12333 - S0817 E12328 MOV W 10KT  
FCST VA CLD +6 HR: 07/0620Z NO VA EXP  
FCST VA CLD +12 HR: 07/1220Z NO VA EXP  
FCST VA CLD +18 HR: 07/1820Z NO VA EXP  
RMK: VA REPORTED TO 500M ABV SUMMIT AT 07/0004Z. VA NOT  
IDENTIFIABLE ON SAT IMG, OBS POLYGON ESTIMATED. VA EXPECTED  
TO DISSIPATE WITHIN 6HRS. VA HEIGHT BASED ON GRND RPT, FCST  
MOV FROM MODEL GUIDANCE.  
NXT ADVISORY: NO LATER THAN 20240407/0635Z=



MET SG/28  
Appendix A to IP/15

An example VAA of estimated observation based on a VONA for continuous eruption but it is not observed on satellite imagery:

VA ADVISORY  
DTG: 20240118/0410Z  
VAAC: DARWIN  
VOLCANO: KRAKATAU 262000  
PSN: S0606 E10525  
AREA: INDONESIA  
SUMMIT ELEV: 155M  
ADVISORY NR: 2024/1  
INFO SOURCE: VONA  
AVIATION COLOUR CODE: ORANGE  
ERUPTION DETAILS: VA REPORTED TO FL080 AT 18/0347Z  
EST VA DTG: 18/0350Z  
EST VA CLD: SFC/FL080 S0608 E10529 - S0610 E10518 - S0603  
E10516 - S0602 E10527 MOV W 10KT  
FCST VA CLD +6 HR: 18/0950Z SFC/FL080 S0608 E10528 - S0631  
E10439 - S0608 E10429 - S0601 E10526  
FCST VA CLD +12 HR: 18/1550Z SFC/FL080 S0608 E10528 - S0632  
E10439 - S0606 E10428 - S0601 E10526  
FCST VA CLD +18 HR: 18/2150Z SFC/FL080 S0608 E10528 - S0636  
E10442 - S0606 E10428 - S0601 E10527  
RMK: CONTINUOUS ERUPTION REPORTED BY SVO. VA UNIDENTIFIABLE  
ON SATELLITE IMAGERY DUE TO MET CLOUD. OBSERVATION, HEIGHT  
AND MOVEMENT HAVE BEEN ESTIMATED AND EXTRAPOLATED BASED ON  
VONA AND NWP GUIDANCE.  
NXT ADVISORY: NO LATER THAN 20240118/1010Z=



**APPENDIX B**

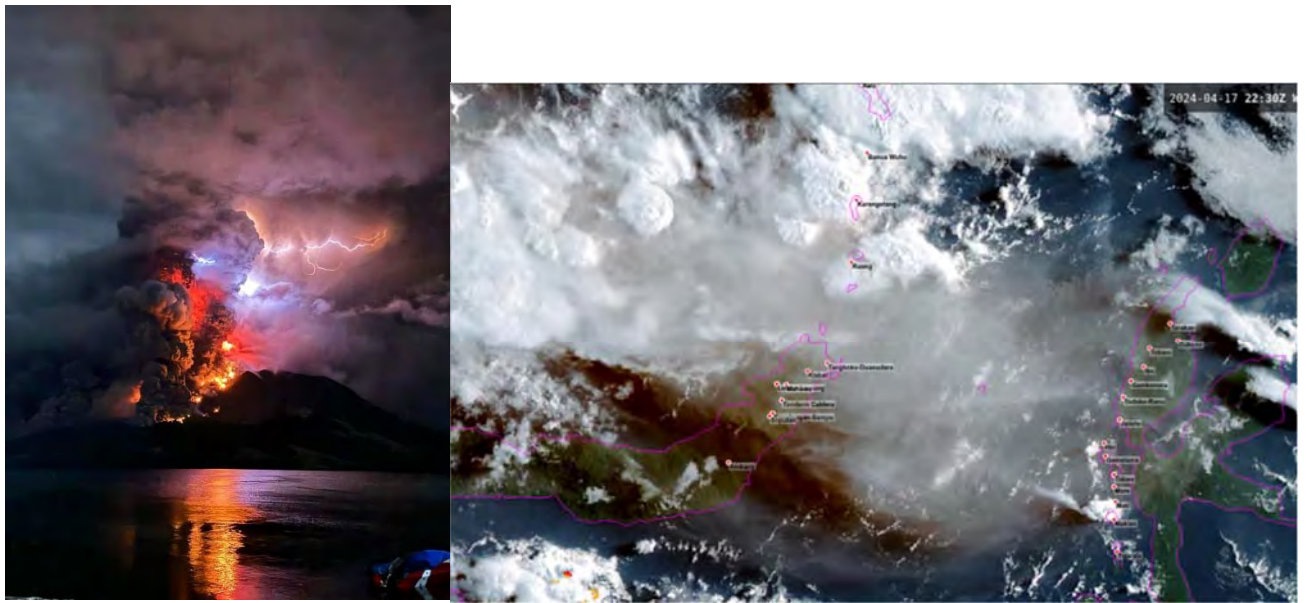


Figure 1. Left: Ground observatory image at the start of the 17 April eruption at Mount Ruang. Imagery Courtesy of CVGHM. Right: Visible Himawari-9 imagery 12 hours after the commencement of the eruption on 17 April.

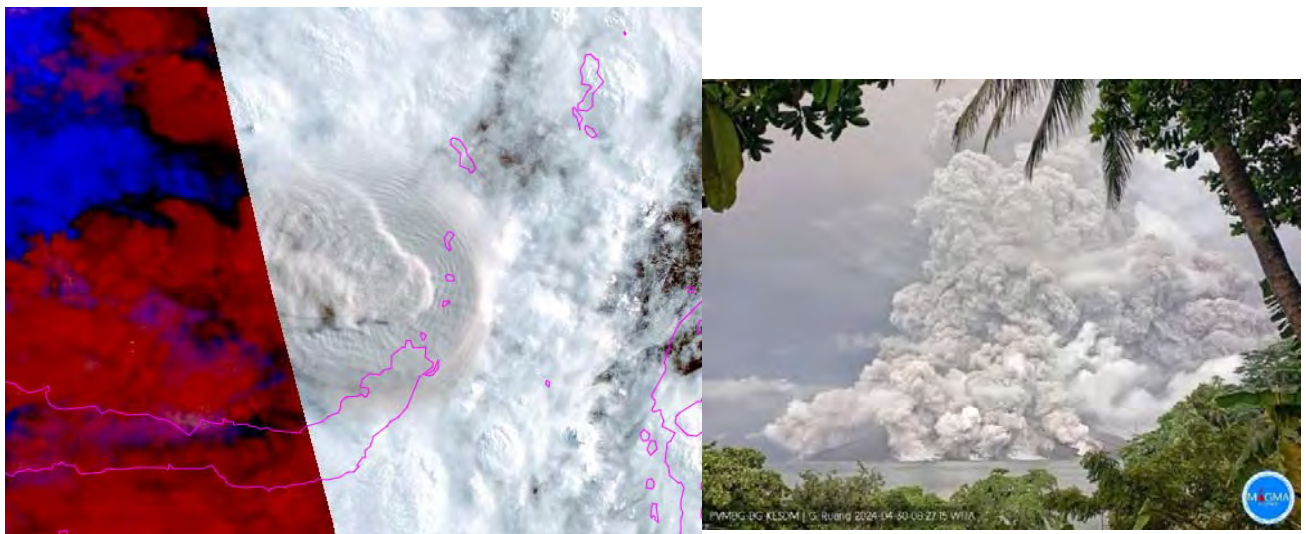


Figure 2. Left: Himawari-9 imagery showing a brown ash signature entering the stratosphere on visible channels at 2200 UTC on 29 April at Mount Ruang. Right: Ground observatory report for the eruptive activity on the 29 April. Image courtesy of CVGHM.

# Consolidated VAAC Management Report 2023

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# 1. INTRODUCTION

## 1.1 Introduction of World Volcanic Ash Advisory Centres (VAAC)

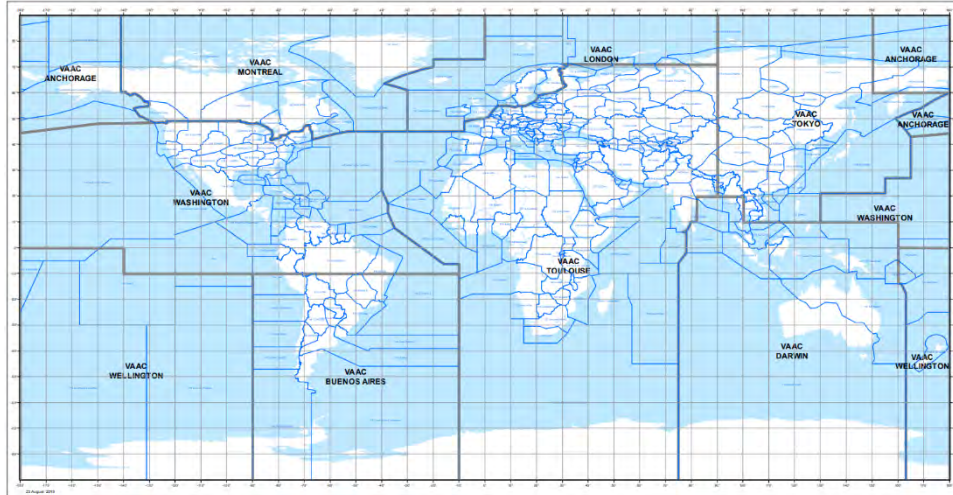


Figure 1: Area of Responsibility (AoR) for each VAAC (2019 version of map)

Since 2018, all nine VAACs produce a Consolidated VAAC Management Report.

This report covers the period from 1 January 2023 to 31 December 2023 (inclusive).



## 2 DISCUSSION ON OPERATIONS

### 2.1 Issuance of VAA and VAG for the period 1 January 2023 to 31 December 2023

2.1.1 The table below is a breakdown of the number of advisories issued by each VAAC, as well as a total. Note, the column “Volcanic Ash Advisory” includes nearly all advisories issued by the VAAC, including those for re-suspended ash, as well as re-broadcast and back up advisories. Note that advisories for re-suspended ash are also tallied in the column entitled “Re-suspended ash”. Only test and exercise advisories are not included in this column: they are accounted for in the “Test and exercise advisory” column.

Volcanic Ash Advisory Centre	Volcanic Ash Advisory	Volcanic Ash Graphic	Re-suspended ash	Test and exercise advisory	“False alarm” VAA
Anchorage	269	182	71	1	0
Buenos Aires	1868	1864	8	0	1
Darwin	3064	3064	0	5	0
London	4	4	0	24	0
Montreal	60	31	0	24	0
Tokyo	2181	800	122	3	0
Toulouse	42	42	0	11	0
Washington	5647	5610	50 <sup>1</sup>	10	0
Wellington	29	29	0	5	0
<b>Total</b>	<b>13164</b>	<b>11626</b>	<b>251</b>	<b>83</b>	<b>1</b>

Table 1 The total number of advisories issued by each VAAC including the number of test/exercise or back-up advisories for each VAAC between the period of 1 January 2023 to 31 December 2023 (inclusive).

Notes:

1. **VAAC Washington:** count is estimated.

## 2.2 Key Performance Indicators

2.2.1 An outcome from the VAAC Best Practice and Met Operations Group (MOG) meetings (New Zealand, 5-9 November 2018 and 12-14 November 2018 respectively) was that the currently agreed KPIs will be further clarified and future KPIs will be discussed by all VAACs and proposed at the next MOG. After consultation with all VAACs, the current KPIs are as follows.

2.2.2 Following the receipt of information from a credible source of volcanic ash in the atmosphere within a VAAC AoR,

- the initial VAA/VAG product is to be issued within 20 minutes on 95% of occasions
- the first subsequent VAA/VAG (forecast, cancellation, or amendment) is to be issued within 75 minutes on 95% of occasions
- forecast VAA/VAG to be issued not later than the time stated in the 'Next advisory' element of the VAA/VAG, until no further advisories
- "Re-broadcast" of neighbouring VAAC's polygon information (within 555km/5deg of border) within 20 minutes of neighbouring VAAC's issue of the primary VAA.

2.2.3 **Compliance:** Both initial and forecast VAA to be Annex 3 compliant, where all fields of the VAA are correctly filled out (where information is available to do so), and appropriate time stamps and headers are used.

Volcanic Ash Advisory Centre	Initial VAA/VAG within 20 minutes	First subsequent VAA/VAG issued within 75 minutes	Subsequent VAA/VAG issues no later than 'next advisory' time	"Re-broadcast" of neighbouring VAA within 20 minutes (within 555km or 5 degrees of VAAC boundary)	Annex 3 compliance – All fields filled out correctly and appropriate time stamps and headers are used
Anchorage	100% <sup>1</sup> (31/31)	100% <sup>1</sup> (31/31)	93% (134/144)	88% (66/75)	87% (234/269)
Buenos Aires	80% <sup>2</sup> (28/35)	100% (22/22)	99% (1808/1830)	N/A	99% (1852/1868)
Darwin	95% (480/508)	100% (209/209)	99% (2530/2556)	N/A	97%
London	50% <sup>3</sup> (1/2)	N/A	100% (2/2)	N/A	100% (4/4)
Montreal	N/A	N/A	97% (30/31)	83% (24/29)	89% (75/84)
Tokyo	99% (1055/1057)	100% (464/464)	99% (657/660)	100% (6/6)	99% (2179/2181)
Toulouse	86% <sup>4</sup> (6/7)	100%	100%	N/A	100%
Washington	98% (497/508)	100% (2/2)	99% (5001/5060)	62% (32/52)	97%
Wellington	60% <sup>5</sup> (3/5)	100% (4/4)	100% (25/25)	N/A	100% (34/34)

Table 2 Percentage of advisories that meet the KPIs and the total number of advisories analysed for the period from 1 January 2023 to 31 December 2023. Volcanic ash advisories that are issued as part of tests and exercises are not included in this table.

N/A = not applicable, as none were issued, and all percentages rounded to the nearest whole number.

**Notes:**

1. **VAAC Anchorage:** All 31 initial VAA/VAG issuances contained forecast VA; subsequent 75-minute VAA/VAG N/A.
2. **VAAC Buenos Aires:** From 35 initial VAA/VAG, 7 of them were delayed.
3. **VAAC London:** 2 x effusive eruptions resulting in 4 advisories with no Ash. Issuance of initial VAA/VAG of the eruption at Fagradalsfjall in July was unnecessarily delayed due to awaiting confirmation of a RED VONA to arrive via email due to a coincidental local email exchange outage, even though we knew it had erupted and unlikely with any ash. Local procedural amendments to instructions have since been made to ensure that this doesn't happen again, and we don't wait on the SVO's written VONA to issue an initial VAA when we are certain something has erupted. Had this been an obvious ash eruption, we probably would have issued right away regardless but due to the uncertainty on how to treat an effusive eruption this invited a little ambiguity to the process.
4. **VAAC Toulouse:** Only 7 events. One was without any ash cloud in VONA neither ash to be detected on satellite picture. This situation let us in doubt, so we need more than 20 min to decide to provide a VAA/VAG.
5. **VAAC Wellington:** Of the 5 initial VAA/VAG, 2 were delayed due to difficulties confirming an eruption had occurred.

### 2.3 Significant satellite imagery, modelling or technical changes

*This section describes significant satellite, model or technical changes that influenced the performance of operations. The aim is to summarize how technology has been used to enhance the operational capability of the VAACs. Any new tools can be mentioned in this section.*

#### VAAC Anchorage

In concert with NASA, NOAA NESDIS, VIIRS Ash and SO2 Index products were made operational at VAAC Anchorage in late 2022. VIIRS is a Low-Earth-Orbit satellite (JPSS) instrument. In April 2023, they were used extensively during the Sheveluch eruption and subsequent VA clouds over the Bering Sea and Gulf of Alaska/SE Alaska. In a few instances during the Sheveluch event, the products greatly improved VA analysis and forecaster confidence to safely reduce warning/advisory areas when used in conjunction with geostationary satellite false color imagery.

#### VAAC Buenos Aires

VAAC Buenos Aires is using FALL3D dispersion model. This model was upgraded to its version 8.2. which improves the calculation speeds and includes the capability to perform deterministic as well as ensemble ash concentration dispersion forecasting. FALL3D is an Eulerian model, and it is configured to be run in different domains based on the intensity of the eruption, with higher resolution for small emissions and coarser resolution for bigger eruptions. The VAAC model setup is described in the VAAC Model Setup Tables.

#### VAAC Darwin

Looking to create new satellite imagery maps based on conversations with the APAC VAACs and recent case studies.

The Bureau of Meteorology is updating its supercomputer in 2024.

#### VAAC London

London VAAC still uses the now mature VAIT (Volcanic Ash Intervention Tool) within the Visual Weather package, with a few annual updates to fix bugs/known issues.

Technical design preparations and work are underway for the upcoming QVA provision. Our NAME Dispersion Model now produces deterministic and probabilistic QVA output which can be used in upcoming dissemination and service systems. The probabilistic forecast represents the uncertainty on the weather data, determined using ensemble meteorology. Currently we are using the QVA deterministic data to drive VAIT (replacing the original NWP data in Autumn 2023) after testing showed that this data was very comparable to the non-QVA datasets. With this, QVA deterministic data (12 levels/3 hourly) is repackaged to inform the current 3-level 6-hourly concentration charts and ultimately the VAA/VAG products.

In the coming years, VAIT is likely to be replaced by another system designed by the same provider, and work has begun specifying this with the new QVA provision. Until then, we continue to use VW VAIT to deliver the current concentration charts and VAA/VAG.

The system designed to provide QVA information streams to the aviation community (un-intervened) is currently in design and currently expected to be ready for trial in November 2024. A sizable project board involving multiple teams across the Met Office (London VAAC included) is meeting regularly to work on this.

### VAAC Montréal

In 2023, VAAC Montréal started using the same software used in forecast offices across Canada for its operations. This software includes RGB images designed to highlight volcanic ash.

A new version of the in-house software used by VAAC Montréal to produce volcanic ash advisories and graphics was implemented in June 2023. It includes several features that make drafting advisories easier and quicker.

### VAAC Tokyo

The Japan Meteorological Agency plans to update its supercomputer system in March 2024. While some scripts will need to be modified, information quality will remain unchanged.

### VAAC Toulouse

A new numerical system Flexpart, with local area, is adapted to small eruption, which is more precise than the global model Morage.

Implementation of QVA continues. Tests with VAAC London allow comparison of the model and results. As we back each other up, we want to test the compatibility our QVA systems.

### VAAC Washington

In 2023, the Washington VAAC continued to transition to the Advanced Weather Interactive Processing System version 2 (AWIPS-2). Software changes have been added based on Washington VAAC requests several times over the last year. Final testing of these changes will be done in February 2024. After that dissemination transition and testing will take place. Complete transition is hopeful by the end of 2024.

NOAA's Air Resource Laboratory (ARL) continued to work with the Anchorage VAAC and Washington VAAC on gaining the ability to create and disseminate Quantitative Volcanic Ash information streams. Two QVA tabletops were conducted in 2023 and future ones in 2024 to help figure out the workflow, creation and dissemination of QVA.

### VAAC Wellington

A new prototype for our internal VOLCAT suite has undergone an upgrade to make it run more efficiently. There are plans to further develop various postprocessing tasks.

We are looking at options to host a 'VONA portal' to help SVOs disseminate VONA as part of the proposed elevation of VONA to a recommended practice.

Extensive testing of a new version of the tool we use to create and send VAA/VA SIGMETS. The new version contains a bug fix related to issues identified with volcano names with a "/" (eg Whakaari/White Island).

### 2.3.1 VAAC Modelling Tables

This Consolidated VAAC Management Report normally includes a link to the VAAC Model Setup Tables, which details the operational configurations of dispersion models used by the VAAC. These tables can now be found via this link:

Beckett, F. M., Bensimon, D., Crawford, A., Deslandes, M., Guidard, V., Hort, M. C., Jeoffrion, M., Kristiansen, N., Lucas, C., Nishijo, A., Osores, S., Renard, E., Servranckx, G., Snee, E., Trancoso, R., & Vazquez, E. (2024). VAAC Model Setup Tables 2023. Zenodo. <https://doi.org/10.5281/zenodo.10671098>

## 2.4 Competency, Training and Education

*This section highlights any noteworthy competency, training or education work undertaken at the VAACs during the reporting period. It is meant to include information such as:*

- *How many forecasters at each VAAC?*
- *Are there any changes to the VAAC Forecaster competencies?*
- *How the VAACs are going in terms of top-level and second-level competencies?*
- *Training ideas or additions that a VAAC would like to share with other VAACs*

### VAAC Anchorage

There are currently 13 Anchorage VAAC meteorologists. We hold quarterly staff meetings to review operations and timeliness of our products. Additionally, various events are reviewed for successes and areas for improvement.

### VAAC Buenos Aires

VAAC Buenos Aires staff is composed of 19 forecasters, 15 of them re-certified in competencies in May 2023 and the rest in training. Courses offered during this year to VAAC forecasters were atmospheric aerosol detection, communication to users, ash dispersion modelling including an introduction to QVA information and QMS.

### VAAC Darwin

VAAC Darwin has 18 VAAC competent forecasters working within the Hazardous Weather Unit (HWU). The staff rotate through the VAAC and an aviation desk so there are also 2 or 3 VAAC competency staff working a shift which gives greater support during a high impact eruption. All VAAC forecasters have the BIP-M qualification.

There have been many significant high impact events within the VAAC Darwin area of responsibility, and we are working on self-paced training exercises that new and existing staff can work through during support or project shifts. These case studies capture different processes that the forecasters need to understand.

We are currently reviewing all training materials at the Bureau of Meteorology, the VAAC training module is undergoing a refresher. During this process, we plan to include more on dispersion modelling to support the move towards Quantitative Volcanic Ash, and aviation response to volcanic ash.

### VAAC London

There are currently 18 multi-skilled Operational Meteorologists within the Hazard Centre team (of which the provision of VAAC London sits, including Space Weather, RSMC, other dispersion, health and specialist meteorological services). A steady stream of new entrants and leavers exist, so continual training and recruitment of new Meteorologists has occurred this year alongside time-served members. It is worth noting that the Aviation team sits separately to the Hazard Centre, where

corresponding SIGMETS are completed. These 18 forecasters of the London VAAC operational team undertake a regular VA competency assessment in line with AMF quality standards to ensure their continued proficiency. In addition, the team attend an annual VA training course led by our dispersion and observation science teams to ensure that they are up to speed and refreshed with volcanic dispersion and observational techniques. In 2024 (likely May/June) we will also introduce the forecasters to QVA in the training sessions. Since London VAAC rarely have to respond to ash eruptions in our area, daily VA response exercising is encouraged per-shift to ensure continued familiarity, tease out training and mentoring requirements, and to test the IT dissemination sequence at the same time so we are always ready.

### VAAC Montréal

There are 18 members of the VAAC Montreal team. Weekly tests are performed to ensure that staff practice components of the VAAC response and to ensure that the software required for this response is working correctly. A subset of the VAAC team has been trained to perform backup duties for VAAC Washington since 2019 and starting in 2023, this training was extended to all team members. Since all members of the VAAC team have other regular duties and since volcanic ash events requiring a response are rare, an important aim of this extended training is to increase staff's familiarity and comfort level with the VAAC response.

### VAAC Tokyo

Five VAA forecasters from the Volcanic Observation and Warning Center (VOWC) at JMA's Tokyo headquarters (responsible for mitigating ground-based eruption hazards) support the provision of VAAC Tokyo services. The Center runs five operation units for around-the-clock monitoring of volcanic activity, each employing three forecasters and two monitoring staff tasked with issuing VAAs, volcanic warnings/forecasts and ash fall forecasts.

All VAA forecasters meet the requirements of the Basic Instruction Package for Meteorologists (BIP-M). BIP-M-compliant Aeronautical Meteorological Forecaster (AMF) training is also provided toward development in the VAA forecasting field.

VAAC Tokyo holds monthly meetings between forecasters and management to encourage appropriate issuance based on the Quality Management System. Past volcanic ash events are also reviewed several times a year to enhance related operations and VAA products.

In the event that headquarters become incapacitated due to significant disaster conditions, operations are conducted in an internal back-up center. We had back-up drills at the center with several forecasters and updated workflow.

### VAAC Toulouse

4 new forecasters arrived this year in the department trained and practices to be able to provide VAA/VAG in case of an eruption.

They participated in VOLCAZO, VOLCAFI and VOLCEX exercises.



### VAAC Washington

There are 14 volcano analysts that run operations at the Washington VAAC. No new analysts were trained and certified in 2023. Quarterly reviews of operations are conducted if needed with each volcano analyst. Also, an End of Year review is conducted each year on topics that are found to be lacking and needed by volcano analysts. Finally, quarterly backups are scheduled with Darwin and Montreal VAAC along with members of the Washington VAAC team (not all analysts) to perform backup duties. Live backup events took place this year with Darwin and Montreal VAAC.

### VAAC Wellington

VAAC Wellington has a core group of 15 AMF competent forecasters, who are all able to produce both aviation and VAAC information. We have an additional pool of 14 AMF competent and 3 'VAAC only' competent forecasters, who can provide back up if required.

However, due to our shift/workload structure, it is a challenge to keep VAAC competent forecasters current, and this area will be reviewed in 2024.

Our forecasters work from our three main offices in Wellington, Auckland, and more recently, Paraparaumu, alongside work from home capability, providing good resilience for our operation.

## 2.5 Outreach for stakeholders and SVOs

*This section discusses any outreach events, meetings, triumphs, issues, concerns, new ideas, etc.*

### VAAC Anchorage

We participated in several meetings with the Alaska Volcano Observatory. The meetings were held for staffing familiarity, ways to foster collaboration using Slack and improving workflows.

### VAAC Buenos Aires

VAAC Buenos Aires held 4 user workshops to present the status of the current operations at VAAC Buenos Aires, the scientific advances in remote sensing and numerical modelling, the international work, introduce the elevation as a Recommended Practice of the volcano observatory notice for aviation (VONA) and the future of IAVW introducing the QVA Information. In the first workshop ACCs, OVMs, NOF and the SVO SEGEMAR-OAVV from Argentina participated, in the second one Airlines operating in Argentina, in the third one ACCs, OVMs and NOFs that operate in VAAC Buenos Aires's AoR, and in the last one airlines that operate in VAAC Buenos Aires AoR. More than 100 people participated in these workshops.

It was held from 30/10/2023 to 01/11/2023 the "NAM/CAR/SAM Workshop on the proposed PANS-MET Document - Procedures for Air Navigation Services - Meteorology (Doc 10157)". During this workshop the METP member nominated by Argentina with other colleagues presented the changes proposed for the restructuring of Annex 3 "Meteorological service for international air navigation", and the incorporation of the Air Navigation Procedures for Aeronautical Meteorology (PANS-MET). They included the changes proposed for the ICAO IAVW process related to QVA and VONA. Those new IAVW proposals were of great interest to the audience.

### VAAC Darwin

The Bureau of Meteorology held its annual Vulcan Working Group to discuss all things volcanic ash related. There were representatives from Australia, New Zealand, Japan and Indonesia. The group discussed operational matters, research and development, and Industry updates. Feedback on QVA will be passed to the relevant ad-hoc groups.

VAAC Darwin along with VAAC Wellington have supported Solomon Islands Meteorological Service (SIMS) with the removal of the long-standing ICAO Air Navigation Deficiencies for lack of SIGMETs. The work continues between the three agencies to strengthen the service. A similar approach is being started with Papua New Guinea including some volcanic ash exercises and review of processes.

VAAC Darwin has been participating in the Volcanic Ash Workshops hosted by Indonesia in 2023. The first workshop was an online discussion group on satellite utilisation for aviation services which was only Indonesia with a presentation from VAAC Darwin on 'Usage of satellite imager at VAAC Darwin'. The second was 'The Workshop on Volcanic Ash Impact Handling for Aviation' with attendees across the APAC region where VAAC Darwin presented on 'Overview of VAAC Darwin Processes and Responsibilities'. The sessions had presentations for all the different units within the IAVW and a discussion panel with a representative from each unit.

VAAC Darwin continues to improve its connection with Papua New Guinea with a more active communication channel between SVO and operational forecasters.

### VAAC London

VAAC Manager is in regular touch with our main SVO, Iceland Met Office, and sits in twice-a-year 2-day meetings with them which also include NCAS (National Centre for Atmospheric Science) and BGS (British Geological Survey), working on common-interest collaborative activities spanning operations and science surrounding the VAA provision.

Ongoing multi-stakeholder consultation internationally surrounding the VAA and QVA provision.

### VAAC Montréal

Following the eruption of Sheveluch on 10 April 2023 and its impact on Canadian airspace, VAAC Montréal held discussions with NAV Canada, Canada's Air Navigation Service Provider, to identify aspects of the VAAC response that worked well and others that could be improved for future responses.

A wider post-mortem of the multi-VAAC response to this eruption of Sheveluch was also conducted and shared with representatives from the aviation industry via ICAO's Meteorology Operations Group.

### VAAC Tokyo

From 13th to 15th November 2023, VAAC Tokyo representatives attended the Workshop on Volcanic Ash Impact Handling for Aviation in Yogyakarta, Indonesia. The contingent gave a presentation on the Center's dispersion model to promote understanding of VAA in the ASEAN region and received useful feedback from attendees on the Center's output.

VAAC Tokyo held a workshop for domestic and other stakeholders to promote usage of VAA and ash fall forecasts. The attendees understood the importance of the Center's products and expressed a desire for advanced information such as QVA.

VAAC Tokyo staff visited a domestic airline headquarters to observe operations, and engaged in discussions on how the airline utilizes VAAs.

### VAAC Toulouse

VAAC Toulouse contributed to the organisation of VOLCAFI exercise and participated.

### VAAC Washington

The Washington and Anchorage VAAC, following the Sheveluch eruption in April 2023, met with numerous users from the airline and aviation industry in May 2023. An overview of the VAACs,

operational procedures and products, and the response to the Sheveluch eruption were discussed. A very positive response from all groups came out of the meeting.

A rollout of the new NWSSChat 2.0 was completed in August 2023. In the rollout the Washington VAAC worked with users across their Area of Responsibility (AOR) and backup groups to help register and gain access to particular channels. NWSSChat 2.0 is used in discussion and exchange of volcanic ash information between the many users who collaborate on volcanic ash activity globally.

The Washington VAAC participated, provided several presentations, and led a panel discussion (that included Dov Bensimon of Montreal VAAC, Alice Crawford of NOAA's ARL, and the Geophysical Institute of Ecuador) for the WMO RAIV Aviation Workshop held in San Juan Costa Rica. Several topics of discussion were current products of the Washington VAAC, QVA, NWSSChat 2.0 and building relationships between the VAAC, MWOs, and SVOs across Central and northern South America. Overall, the workshop was a great success.

### VAAC Wellington

VAAC Wellington participated in the NZ-focused multi-agency 'Taranaki Mouna Volcanic Ash Exercise' led by CAA. The scenario for the exercise was designed to exercise how forecast and observed volcanic ashfall might be communicated across the aviation system, in coordination with the communication of ashfall through the civil defence and emergency management system. Taranaki was selected as the volcano, due to its location under domestic air routes, as well as near an airport and maritime port.

A presentation to the NAVAREA XIV Coordinator on the VAAC system – they have been looking into what volcanic hazard information exchange currently exists and potential applications to better support marine operations given the WMO Early Warning for All initiative. Following on from this presentation he signed up to receive VAA via email. Consequently, a VAA we issued for 'unrest' in Tonga (due to low awareness of VONA and lack of NOTAM), led them to investigate further and subsequently issue a marine hazard warning for that area.

VAAC Wellington Manager presented on 'QVA Concentration Information Service' at the APAC MET/SG in September 2023. This was recorded and is expected to be made available on the ICAO APAC website.

VAAC Wellington was invited to present at the 'Workshop on Volcanic Ash Impact Handling for Aviation' in Indonesia. We were unable to attend in person but did present online: '*How Early Collaboration Can Help During High Impact Events*' with a focus on the VAAC/SVO relationship during the Hunga Tonga – Hunga Ha'apai eruption.

A VAAC Forecaster presented at a New Zealand aviation industry webinar, alongside CAA and GNS – titled '*Accessing and Using VA Information for Pilots*'.

## 2.6 Volcanic events of interest

*This section highlights events of interest that VAACs wish to share. This can include summaries, analyses, insights, lessons learned, etc. This section can also point readers to more in-depth work.*

### VAAC Anchorage

The April 2023 eruption of Sheveluch on the Kamchatka peninsula had broad impacts across four VAAC areas of responsibility. Subsequent reports, both within the U.S. and those provided by the four VAACs to IAVW documented many lessons learned and insights into our processes. Additionally, both U.S. VAACs, U.S. FAA, took part in a presentation of findings and a question-and-answer session with Airlines for America, a forum with key stakeholders. This was the first time the VAACs have interacted with this forum and both groups felt it was positive and look forward to this venue for future collaboration.

Several eruptions of Shishaldin volcano on the Alaska Peninsula from July through September had notable impacts to carriers both locally and those traversing the north Pacific. One key finding along VAAC communications, is messaging with an off and on eruptive behaviour and addressing false reports of eruptions and VA clouds. In coordination with AVO and FAA, VAAC Anchorage is increasing its messaging response to address these situations.

### VAAC Buenos Aires

Sabancaya volcano continued erupting uninterrupted during the year, with variations in height and extension. During August we experiment the most intensive activity with eruptions reaching heights till FL290. VAAC Buenos Aires maintained daily communication with the Instituto Geofísico del Perú (IGP). During 2023, VAAC Buenos Aires emitted 1492 advisories with representing 80% of the total VAA/VAG issued during the year.

A re-suspended ash cloud event from the 2011 Puyehue-Cordón Caulle deposit took place on 23rd January 2023. The estimated ash cloud top height was FL090, and visibility reduction was registered in San Carlos de Bariloche's Airport for some hours. During that period some flights were deviated, and others cancelled.

### VAAC Darwin

There were a few events of interest in the VAAC Darwin area of responsibility. The eruption at Mt Ulawun on 20 November 2023 in Papua New Guinea. The highlight from this event is the connectivity with the Rabaul Volcano Observatory which sent a WhatsApp message to the operational forecaster at 0557 UTC and the first VAA was issued at 0624 UTC. The report indicated an eruption was underway to approximately 1000m above the summit, but the ash column was clearly stronger and hidden by the clouds in the image. The operational forecaster issued the first advisory to FL300 just as the 0600 UTC satellite image arrived in the forecasting software. The satellite imagery showed a growing ash cloud appearing above the meteorological cloud and the second VAA was revised to FL500 and issued at 0645 UTC. Later in the event there was another eruptive pulse which pushed the eruption to FL600 and just into the stratosphere. The eruptive period lasted for approximately 24 hours before the volcanic ash dissipated.

The eruption at Marapi on 3 December 2023 in Indonesia had similar timings. There was a WhatsApp message for a large eruption underway at the volcano with videos at 0827 UTC. There was no report with the video, but the official report came in at 0837 UTC as a VONA. The first advisory was issued at 0842 UTC to FL500. The follow up advisory was issued at 0900 UTC continuing the event to FL500. The eruption was short-lived, and the ash quickly dissipated as it moved to the south-west.

The Bagana eruptions in July 2023 in Papua New Guinea highlighted the difficulty with detecting eruptions in the tropics. The eruption was covered in meteorological cloud with only the smallest signal visible on a few RGB channels for 2 to 3 images. The eruption appeared like a typical thunderstorm developing over a mountain with the surrounding thunderstorm activity. This case study has proved useful for the VAAC Darwin staff as there have been discussions with Aviation Industry around advisories for possible eruptions when there is enough evidence that something is occurring at the volcano but no confirmation.

### VAAC London

Volcanic activity within London VAAC's area of responsibility remains active (regular yearly or twice-yearly eruptions) but of low-key nature with no ash. In the year of 2023, there were two effusive eruptions in SW Iceland with the ongoing new peninsula activity. The first of which was the Fagradalsfjall system on 10th of July (3rd eruption since 2021) and the second in the nearby newly activated Reykjanes rift system on 18th December. Both locations are on the Reykjanes peninsula, close to the Keflavik International Airport and around 30 km southwest of Reykjavik.

The operational team at London VAAC remained in close contact with the team at Iceland Met Office (IMO) throughout these eruptive periods. For each eruption, London VAAC issued a preliminary (i.e. contained no forecast information) VAG/VAA product indicating that an (effusive) eruption had begun, but also indicated that no VA was visible. This preliminary VAG/VAA was followed-up with a final VAG/VAA product confirming that the eruption was effusive, that no significant VA had been observed and that no further advisories were expected to be issued.

Another eruption has happened outside of this reporting period (18th Jan 2024) in Reykjanes area, and with continuing likelihood of further effusive fissure eruptions in coming months.

### VAAC Montréal

An eruption of Sheveluch on 10 April 2023 led to volcanic ash entering Canadian airspace. VAAC Montréal responded to this event from 12 to 17 April 2023, issuing a total of 46 volcanic ash advisories. Half of these were re-broadcast advisories, but the total number of regular advisories issued established a new record for an event for VAAC Montréal. The preceding record of 16 advisories had been issued during the response to an eruption of Pavlof, from 28 March to 1 April 2016. VAAC Montréal was one of 4 VAACs to respond to this eruption of Sheveluch, along with the VAACs in Tokyo, Anchorage and Washington.

An eruption of Klyuchevskoy on 28 October 2023 led to volcanic ash entering Canadian airspace. VAAC Montréal responded to this event from 4 to 6 November 2023, issuing a total of 12 advisories for this event.

Montréal celebrated its 25th year of operations in 2023.

### VAAC Tokyo

On 10th April, an eruption at Mt. Sheveluch on the Kamchatka Peninsula sent an ash plume to an altitude of FL520. The eruption occurred at 1310 UTC and first appeared in satellite imagery at 1330 UTC, and VAAC Tokyo issued an initial forecast at 1349 UTC. With reference to Volcano Observatory Notice for Aviation (VONA) information from local observatories, issuance was continued for three days. A subsequent survey of stakeholders showed no significant disruption to operations, although some flight course changes were needed due to ash cloud covering North Pacific Route System (NOPAC) routes. Control of ash cloud that vacated VAAC Tokyo's area of responsibility was handed over to VAAC Anchorage. As VAACs refer to one another's information sources, VA height data showed some discrepancy. Subsequent reviews conducted in the IAVW community highlighted the importance of coordination with airlines and consistency with other centers.

### VAAC Toulouse

Very calm year with only a few eruptions.

### VAAC Washington

Several high-level eruptions occurred with the volcano Sangay in Ecuador with ash reaching over 40,000 feet. Also, with the volcano Popocatepetl in Mexico with ash reaching heights of 40,000 feet and extending nearly 1,000 miles from the volcano. Finally, and already mentioned, the eruptions of Sheveluch in April 2023 and Klyuchevskoy in October 2023 affected several VAAC (Tokyo, Montreal, and Anchorage VAAC) including the Washington VAAC.

### VAAC Wellington

It was a quieter year for VAAC Wellington with 5 'events' during 2023; all were considered low level/low impact.

We had a couple of unusual situations that we elected to issue VAA for:

- East Epi, Vanuatu – we were alerted to a social media post by the local VO about an eruption at East Epi (that wasn't identified via satellite imagery). We elected to issue a VAA, despite the few hours' time delay in spotting the report, as activity at this volcano was uncommon and no NOTAM was issued. We will continue to work with the local VO to inform us directly and will modify our procedures to include monitoring social media.
- Home Reef, Tonga – we received a VONA from Tonga which increased the ACC to yellow at Home Reef. We elected to issue a VAA to inform users of the increased risk in that area as the VONA is currently not widely received, nor was a NOTAM for unrest issued. We have now implemented a procedure around changes to ACC to help cover this gap until elevation of VONA to a recommended practice. Discussions continue with Tonga and NZ AIS staff (who have shared responsibility for the airspace, at different altitudes), in coordination with CAA NZ, on issuing NOTAM for volcanic unrest until VONA is a recommended practice and shared more widely.

## 2.7 VAAC collaboration

*This section mentions work done by VAACs on common tasks, visits, information exchanges, etc. Collaboration or efforts to develop working relationships with State Volcano Observatories can be included in this section.*

### VAAC Anchorage

We worked to improve collaboration and communication using Slack with the Alaska Volcano Observatory, United States Coast Guard, and the Federal Aviation Administration.

### VAAC Buenos Aires

During this year the collaboration with the SVOs of the region continued to strengthen, VAAC Buenos Aires participated in the 5th Volcano Observatory Best Practices Meeting (VOBP5) at Pucón, Chile. The focus of this meeting was the communication of volcano hazards. The VAAC Buenos Aires representative presented the IAVW messages exchange and the relevance of the rapid communication between SVOs and VAACs for air safety. The group was interested in learning more about the aeronautical messages (SIGMET, AIREP, VAA, ASHTAM) and valued the joint work between the SVOs and the VAAC Buenos Aires.

VAAC Buenos Aires continued the collaboration with the Instituto Geofísico del Perú (IGP), working on a project to automate the detection and characterization of volcanic plumes from a multi-parametric approach using video images, seismic and meteorological data from Sabancaya volcano. The results of this project are promising and expect to reduce the time of notification of volcanic eruptions in southern Perú.

### VAAC Darwin

VAAC Darwin is strengthening the connection with key stakeholders. VAAC Darwin and VAAC Wellington collaboration has been focused on the consistency and harmonisation of services. Looking at the coordination, quality, consistency, flexibility, and resilience of the service. The forecasters have been conducting shadow shifts where they get to check in on operational shifts and learn how each VAAC generates its forecasts and products. The MS Teams collaboration channel has made connective so much easier on a daily basis.

VAAC Darwin is looking to set up a similar MS Teams channel with VAAC Tokyo.

The Asia Pacific (APAC) VAACs have been having regular catchups to discuss operational matters, work related to the WG-MOG-IAVW and QVA.

The Japan Meteorological Agency (JMA) sent two VAAC Tokyo volcanic ash experts to the Bureau of Meteorology from 30 October to 3 November 2023 to discuss QVA and dispersion modelling, current and future operational procedures, VAAC Training, VAAC forecaster operational overview and the current Scheme of Cooperation between the two VAACs for back-up arrangements.

VAACs Washington, Montreal and Darwin have continued conducting live back-up tests to make sure the back-up arrangements are robust.



VAAC Darwin required operational back-up by VAAC Tokyo and VAAC Wellington for two planned outages in November and December 2023.

### VAAC London

As section 2.5 states, London VAAC continues to work closely with the Iceland Met Office (IMO), as the SVO for Iceland, with a Memorandum of Understanding (MoU) in place between IMO and Met Office, NCAS and BGS. This MoU ensures that both organisations work together to improve various services or work on scientific modelling development. Another manifestation of this relationship is the regular (monthly) testing regime, known as VOLCICE, that takes place in order to test the operational response of both IMO and London VAAC during an eruption.

### VAAC Montréal

VAAC Montreal acted as backup to VAAC Washington on 3 different occasions in 2023. These gave staff in Montréal an opportunity to become more accustomed to the tasks involved when backing up a neighbouring VAAC and strengthen ties to this VAAC as well. VAAC Montréal issued a volcanic ash advisory for Popocatepetl on behalf of VAAC Washington on 5 December 2023, a first since Montréal became backup to Washington in November 2021.

VAAC Montréal participated in a virtual volcanic ash workshop organized by the Meteorological Watch Office in Edmonton, Canada on 7 December 2023. This was the first such workshop to be held since December 2017, and the first to take place virtually.

### VAAC Tokyo

VAAC Tokyo representatives visited VAAC Darwin and VAAC London for technical interaction in 2023 to discuss QVA development status and VAAC operational expertise.

The annual backup test between VAAC Tokyo and VAAC Darwin was conducted on 28th June 2023.

Backup operations by VAAC Tokyo for planned outages at VAAC Darwin were conducted on 15th November and 4th December 2023.

VAAC Tokyo runs monthly VONA issuance drills with the Philippine Institute of Volcanology and Seismology (PHIVOLCS) to support prompt issuance in actual events. Drills were not held from June to December 2023 when Mt. Mayon was highly active.

On 30th August 2023, VAAC Tokyo representatives submitted a management report at a Vulcan Working Group Meeting held by Australia's Bureau of Meteorology.

### VAAC Washington

Several of these items have been discussed in other sections (WMO Aviation Workshop, rollout of NWSChat 2.0, Quarterly backup exercises, etc). Numerous domestic and international users (FAA, USGS, Aeormexico, Coast Guard, etc) visited the Washington VAAC throughout 2023. VAAC overview,

products produced today and information streams tomorrow and future collaboration between our groups were just some of the topics discussed during their visits.

### VAAC Wellington

#### GNS Science (NZ SVO)

- We continue to talk, via Teams, three times weekly with the duty volcanologist and 24/7 hazard monitoring team. We have started routinely providing them with MET information to support their gas monitoring flights in the vicinity of Whakaari/White Island, Ruapehu and Tongariro.
- Conducted two information sharing sessions and site visits.

#### Tonga Geological Service (TGS – Tonga SVO)/ Tonga Meteorological Service (assist in VONA email dissemination)

- Provided ongoing support/feedback on VONA issuance.
- Implementation of new procedure for ACC colour change to cover the gap till VONA is more widely disseminated.
- TGS visitors at MetService – VAAC presentation and session with forecasters (Dec 2023).
- Review of MOU for Reporting Volcanic Activities in Tonga.

#### VAAC Darwin

- Regular catch ups with VAAC Darwin (and VAAC Tokyo) to discuss matters related to QVA and IAVW.
- Ongoing discussions around approach for QVA.
- Trialled a 'Shadow Shift' for forecasters to share processes, tools, techniques, etc. This was well received by the forecasters, and we will look to hold more in 2024.

## 3 Future developments, steps towards Roadmap or ConOps for IAVW

*This section describes work that has been done towards progressing the future of IAVW such as Quantitative Volcanic Ash (QVA) forecasts, probabilistic forecast and concentration plot capabilities, information sharing capabilities (collaboration tool), etc. Both the IAVW [Roadmap](#) and [ConOps](#) are guiding documents for the work described in this section.*

### 3.1 QVA Progress

*Current progress and roadblocks/challenges towards progressing QVA.*

#### VAAC Anchorage

VAAC Anchorage, VAAC Washington, NOAA's ARL, and other collaborators continued the development of QVA for both U.S. VAACs. Two tabletop exercises were conducted in 2023 with future tabletops planned for 2024. Many questions still remain for QVA, what platform and the processes to produce and disseminate QVA are among them.

#### VAAC Buenos Aires

During the VAAC Buenos Aires user's workshops, QVA information was presented, and it was well received by the users. Many of them did not know about QVA information and others presented concerns about the verification of the product and the lack of information about the susceptibility of their engines.

VAAC Buenos Aires keep working on the development of QVA information workflow and IOC requirements. VAAC Buenos Aires modelers team participated in the VAAC modelers group meetings and shared some NetCDF examples to collaborate with the technical definitions of the grid files.

#### VAAC Darwin

The Bureau has deployed the Dispersion Ensemble Prediction System (DEPS) version 2 in September 2022. This new tool uses a probabilistic output which takes 18 current Numerical Weather Prediction (NWP) members and the previous 18 NWP members to create a lagged ensemble of 36 members to accommodate for uncertainties. Further science improvements and inverse modelling have supported improved parameterisation and the use of satellite retrievals and forecaster observations have improved forecast output. This system now supports improved VAAC operation forecasts and the future QVA information services. The next steps involve using DEPS2 against as many different eruptions and verify/validate the results.

The project team within the Bureau of Meteorology is working towards having DEPS2, forecasting software and the output data ready for the QVA timeframe. The current work is making sure the system outputs the concentrate thresholds and vertical layers as required by Annex 3. Considering how the data will be used to generate the QVA contours (control run, medium, mean or other solution). Currently exploring the workflow for staff and how they will review the data in the

forecasting software. The Bureau is currently using Visual Weather by IBL and looking at what changes would be required within the software to support issuance of QVA. The system and data output will be verified against all suitable events.

A separate team is working on the OGC-EDR API and deliverables of data.

#### VAAC London

QVA service development remains in progress and on target as per detailed in section 2.3, with our dispersion model capability element ready.

#### VAAC Montréal

VAAC Montréal began the development of QVA in 2023, adapting work that had been done to quantify uncertainty in the context of another project to that of a VAAC response.

#### VAAC Tokyo

VAAC Tokyo developed the NIKS-1D physical plume model, which estimates the amount of ash ejected into the atmosphere in the event of an eruption. Combination with the advection-diffusion model enabled clarification for the motion of airborne ash particles and quantitative forecasting with enhanced accuracy.

The Center plans to engage quantitative satellite retrieval for verification purposes and future operations. VOLCAT analytics have been tested for past events, and work is now underway on the development of VAAC Tokyo's proprietary OVAA satellite retrieval algorithm.

The technique of data insertion (with polygons of observed ash input as initial conditions) will be maintained for QVA. The bottom height distribution of ash cloud as derived from wind shear is used to estimate initial VA polygon concentration.

The format of tools developed by the Center for NetCDF output and deterministic QVA drawing can be modified to maintain consistency among VAACs. Probabilistic QVA generated from meteorological ensemble forecasts is currently under development, and perturbation for eruption source parameters will be examined in the future.

With an eye to providing QVA from OGC-EDR API on SWIM, discussions with other departments are now underway regarding the installation of an API system for JMA the agency. At the initial stage, QVA data will simply be uploaded to the organization's website.

Discussions have been held with airlines and area control center staff on QVA requests and usage. Such operators require actual expertise in this regard and requested ICAO guidelines as well as further research by parties other than Rolls Royce for advanced risk assessment with QVA.

VAAC Tokyo values verification to ensure that QVA services meet the needs and expectations of users in terms of accuracy, and domestic users need official guidelines based on such verification. As the scope of current methods is limited, collaboration with other centers is needed.

For VAAC Tokyo operation, back-up and handing-over of QVA operations is also an important consideration. The Center will continue to seek means of ever-more appropriate communication with surrounding VAACs.

#### VAAC Toulouse

VAAC Toulouse will provide QVA for familiarization during VOLCEX24.

#### VAAC Washington

The Washington VAAC, NOAA's ARL, the National Weather Service, and other collaborators continued the development of QVA for both VAAC. Two tabletop exercises were conducted in 2023 for potential workflow of each group. Future tabletops will take place in 2024. Within the development of QVA, the transition to AWIPS-2 is taking place as mentioned above. On AWIPS-2, VAA and VAG will be produced and disseminated. How and where QVA is created and disseminated is still in discussion.

#### VAAC Wellington

Limited resourcing continues to be a challenge – we are working closely with VAAC Darwin on an IBL approach.

We are waiting to engage with industry until we have a sample of model output. This is expected to happen early 2024.

We have started thinking about criteria for forecaster workflow changes and criteria for 'significant' eruptions.

### 3.2 Other Future Developments

*Anything else, eg VONA, etc*

#### VAAC Wellington

VONA Portal project, to provide a web-based platform for SVOs to use when issuing their VONA, ensuring ICAO compliant VONA created and disseminated as per any regional and local agreements. Currently in planning phase, subject to funding availability.