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INFORMATION PAPER

ICAO Asia and Pacific (APAC)
Twenty-Sixth Meeting of the Meteorology Sub-Group (MET SG/26)

Online, 1 to 5 August 2022

Agenda Item 6: Research, development and other initiatives

VAAC DARWIN MANAGEMENT REPORT

(Presented by Australia)

SUMMARY

This paper presents an IAVW Management Report for the VAAC Darwin area of responsibility covering the period 1 July 2021 to 30 June 2022. It provides an update on current VAAC Darwin activities, significant operational changes, training and development, collaboration and stakeholder engagement.

There were 1702 advisories issued for the reporting period, the Hunga Tonga Hunga Ha'apai eruption provided a good test of operational procedures and will be used for forecaster training, and there are multiple backup tests coming in 2022.

1. INTRODUCTION

1.1 The report is contained in Attachment 1. The discussion below contains a summarisation of key topics.

2. DISCUSSION

Key topics from the report in Attachment A

2.1 VAAC Darwin issued 1702 advisories in financial year 21/22 (Note: a financial year runs from 1 July to 30 June the following year). Activity has been scattered amongst a number of volcanoes throughout this reporting period and there were four high impact events.

2.2 The activity per volcano has been summarised in Figures 1 and 2 in Appendix A.

2.3 Mt Hunga Tonga-Hunga Ha'apai is a volcano in Tonga that is activity monitored by VAAC Wellington. On 15 January at 0400 UTC, there was an eruption from the volcano which was initially issued to FL500 in the VAAC Wellington AOR. The stratospheric ash cloud was moving to the west, while an ongoing eruption continued above the volcano. The winds in the stratosphere easterlies which matched the westward-moving activity seen on satellite imagery and confirmed the intrusion into the stratosphere was higher than the initial assessment. The advisory was issued to FL630 which is the limit

in the software used to use VAA/VAGs even though the eruption was approximately 31 km (101,000 ft). As the volcanic ash was in the stratosphere, the particles would stay in the stratosphere and not fallout as it is above the cloud forming layer. The base of the ash cloud used varied from FL400 to FL450. The ash cloud passed from VAAC Wellington to VAAC Darwin AOR for which rebroadcast products were issued and ash cloud handover was conducted. The cloud continued to move over Australian FIRs from FL400/FL630 following the base of the stratosphere. As the ash cloud moved over the Indian Ocean, the collaboration and coordination started with VAAC Toulouse before the advisory was finalised on 22/2340 UTC.

2.4 The VAAC is creating new ways to train and assess forecasters' skills while they are gaining their competency including case studies for past real events. WMO will be looking at a review of the current VAAC competency framework with support from VAAC Darwin and VAAC Montreal to better align with AMF. Using the Hunga Tonga Hunga Ha'apai eruption as a training exercise for new staff members and refresher for other staff.

2.5 The new VAAC Washington backup arrangements with VAAC Darwin and VAAC Montreal have been finalised and MOUs have been signed. The service officially started on 1 November 2021. There was a live backup session conducted on 23 March 2022 to run through procedures and coordination between the VAACs. The two groups of forecasters worked together to issue products for active volcanoes. There is another live backup session scheduled for 3rd August 2022. Information regarding the new backup service will be included in the APAC SIGMET guide for reference.

2.6 The Bureau has a new Dispersion Ensemble Prediction System (DEPS) which provides probabilistic forecasts for volcanic ash to help with more accurate advisories. This new tool helps move away from a deterministic approach, to better capture the uncertainties involved. DEPS2 upgrade will be released soon which will bring improved sciences and inverse modelling, use of satellite retrievals and forecaster observations to improve forecast output. This system will support improved VAAC operation forecasts and future quantitative volcanic ash information services coming from the ICAO METP WG-MOG-IAVW/VASD (Met Panel Working Group on Meteorological Operations, International Airways Volcano Watch and Volcanic Ash and Sulphur Dioxide work streams).

2.7 VAAC Collaboration has strengthened between VAACs Darwin and Wellington as they look to harmonise services. The two VAACs have been working on operational processes and procedures, comparison of ash dispersion models, comparison of advisory and forecast creation, daily check-ins, and backup services and exercises. The collaboration work has continued throughout the year and the Hunga Tonga-Hunga Ha'apai event showed how well the two VAACs have been working together.

2.8 A backup test between VAAC Darwin and VAAC Wellington was conducted on 16 June 2022 to test out dissemination of VAAs between the two VAACs. There were 7 responses from users but it showed that the two VAAs were disseminated out to users. VAAC Darwin and VAAC Tokyo review backup procedures in May 2022 and plan to conduct a backup test on 21st July 2022. Both VAACs would like MWO to respond to the VAA sent out during the test.

2.9 VAACs Darwin and Wellington have been conducting standalone volcanic ash exercise, offline SIGMET testing and 60 days of SIGMET data collect to support Solomon Islands with Air Navigation deficiency (AP-MET-23). Most recent exercise was 20 April 2022, where Solomon Islands MWO correctly formatted and issued WV SIGMETs. There was 60 days-worth of SIGMET data collected which has been analysed and issues have been identified. A paper will be presented to the MET/SG 26 on this activity.

2.10 The METP WG-MOG-IAVW/VASD has been focusing on: key performance indicators to enhance consistency and accuracy of forecasts; elevation of the Volcano Observatory Notice for Aviation (VONA) status and discussions around aviation colour codes; and progression of the Roadmap and ConOps documentation. METP endorsed the Elevation of the Volcano Observatory Notice for Aviation (VONA) to recommended practice in 2023 in TAC and IWXXM formats and the removal of the aviation colour code from the Volcanic Ash Advisory (VAA) so it only appears in the VONA for consistency purposes. The group is now looking at IAVW updates, regional engagement activities, and guidance and educational materials.

2.11 The ICAO METP WG-MOG-IAVW/VASD is also looking at a potential operating capability for SO_2 services and having an initial operating capability (IOC) for the delivery of probabilistic quantitative volcanic ash (QVA) information services. The METP endorsed the provision of new QVA services from Volcanic Ash Advisory Centres (VAACs). The group is actioning several tasks which are directly related to the above endorsement which includes defining 'significant volcanic ash cloud', QVA IWXXM schemas, QVA data delivery, and guidance and educational material.

3. ACTION BY THE MEETING

3.1 Note the information contained in this paper.

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Appendix A

1. INTRODUCTION

1.1. The Volcanic Ash Advisory Centre (VAAC) Darwin is responsible for monitoring the area from the Andaman Islands (India) eastwards to the Solomon Islands, including the volcanically active Indonesian archipelago, Papua New Guinea and the southern Philippines. More than 150 active volcanoes lie within the area, some of which have given rise to the largest eruptions in human history. Areas within the region have poor communications and general infrastructure, incomplete volcanic monitoring and are characterised by moist tropical convection that makes remote sensing difficult for much of the year.

2. VAAC STATISTICS

VAAC	Period of reporting	Total number of Advisories	High Impact Events*	
Darwin	1 July 2021 – 30 June 2022	1702	Manam	20 October 2021
			Semeru	4 December 2021
			Manam	22 December 2021
			Hunga Tonga-Hunga Ha'apai	15 January 2022
			Manam	17 April 2022

* Discernible or visible ash that is impacting or expected to impact aircraft cruising levels, international aerodromes, is of high media interest, or is deemed to be significant to aviation operations by the VAAC

2.1. A total of 1702 Volcanic Ash Advisories (VAA) and accompanying Volcanic Ash Graphics (VAG) have been issued for the Darwin area of responsibility this reporting period. (Note: a financial year runs from 1 July to 30 June the following year).

2.2. Figure 1 shows the number of advisories issued by VAAC Darwin (reported by volcano name) during FY 20/21. FY 20/21 has continued with low impact volcanic activity. In the VAAC Darwin area of responsibility (AOR), Mt Dukono, in northern Halmahera, Indonesia had been continuously erupting for many years but over the recent months the emissions have stopped or become so minor that there has been no ash observed during clear days. Other volcanoes have provided minor eruptions throughout the year so far. The volcanoes which have had high impact eruptions include Mt Manam in Papua New Guinea, Mt Semeru on Java in Indonesia and Mt Hunga Tonga-Hunga Ha’apai in Tonga which had the ash cloud pass from VAAC Wellington AOR to VAAC Darwin AOR. In

order to provide context, Figure 2 features the total number of advisories issued by VAAC Darwin (by FY) since 1993.

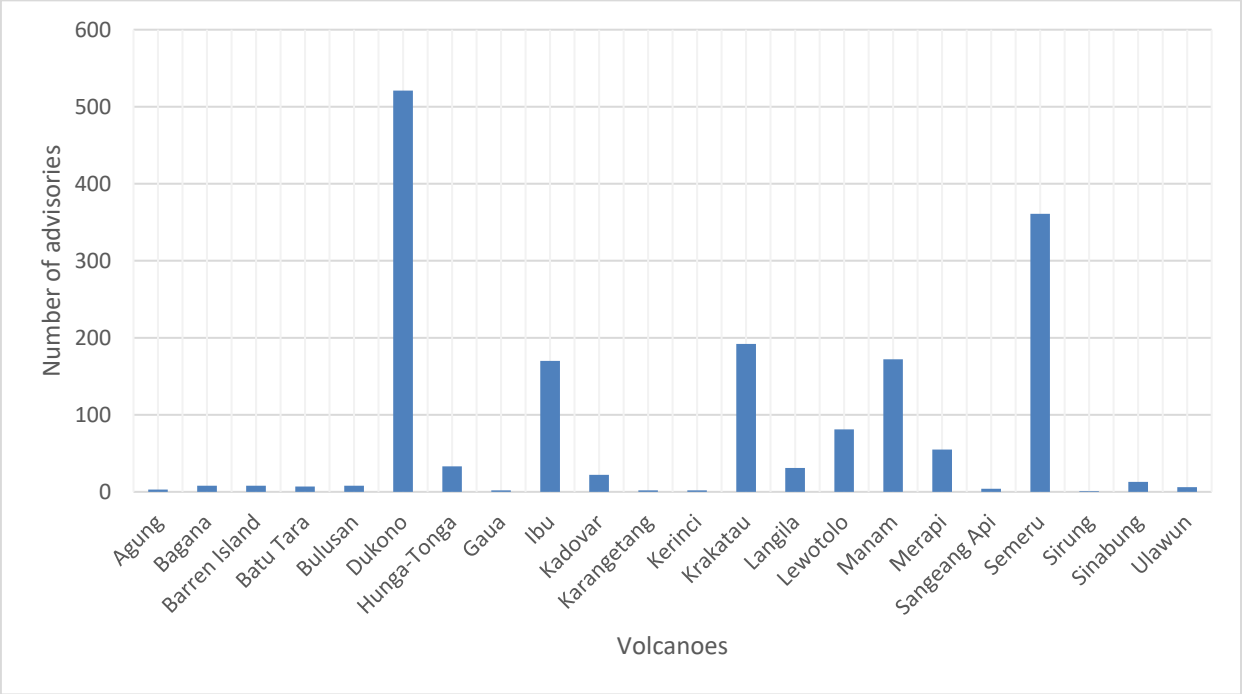

Figure 1 *- Advisories by volcano for the VAAC Darwin area of responsibility for 1 July 2021 to 30 June 2022.*

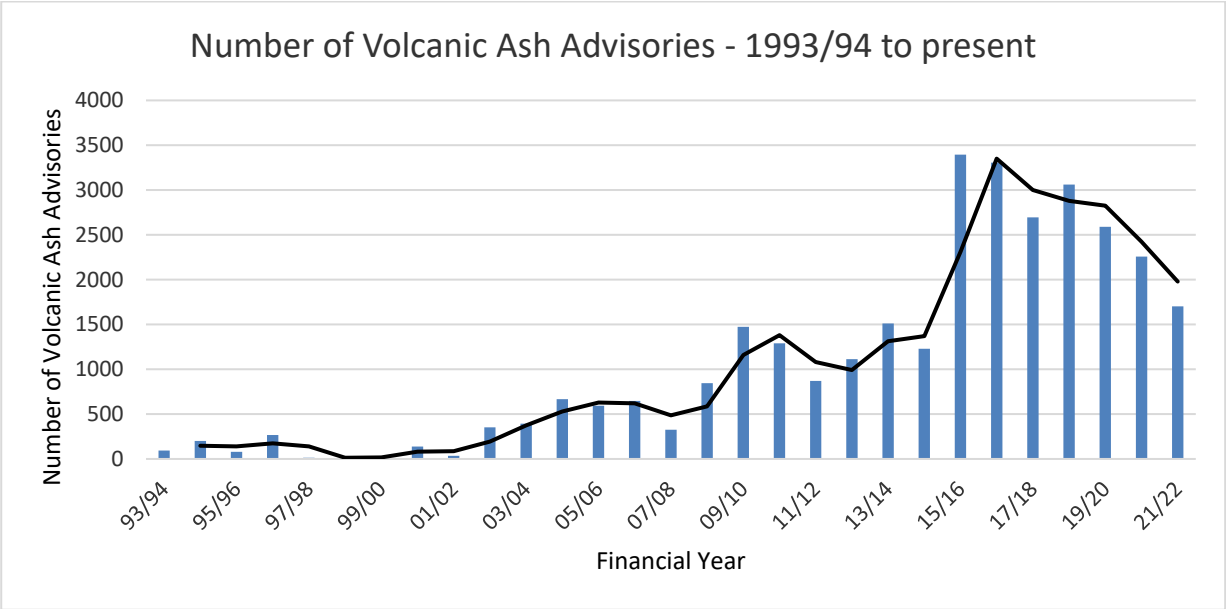

Figure 2 *- VAAC Darwin: Number of advisories for Financial Years 1993/94 - 2021/22*

3. HIGH IMPACT ERUPTIONS

3.1. Manam, Papua New Guinea – 20 October 2021

3.1.1. During the day on 20 October 2021 a thermal anomaly was observed on Himawari-8 satellite imagery and a weak emission from the summit to low levels. There was an advisory issued at 19/2230 UTC for this activity to FL070. There was a ground alert that came through for possible eruption and a rise in seismic activity at Manam at 19/2230 UTC. The eruption was observed on satellite imagery at the same time so the first advisory was issued to FL450 at 19/2240 UTC. As the eruption continued it was noted that the ash was moving in multiple directions so the advisory was quickly split into three levels: FL500, FL350 and FL150 to cover the spread in directions. There was a strong sulphur dioxide signal associated with the eruption which was clear on satellite imagery.

3.1.2. The high-level ash to FL500 and FL350 eventually dissipated leaving the ash to FL150 which eventually lowered to FL080 and continued until 21/0500 UTC when the final advisory was issued.

***Figure 3**. Mt Manam eruption on 20 October 2021 in Papua New Guinea. The image shows the ground report passed from Rabaul Volcano Observatory (RVO) (courtesy of Maryanne Kamon, St Aldof Sakaruau Primary School).*

3.2. Semeru, Java, Indonesia – 4 December 2021

3.2.1. Mt Semeru on Java in Indonesia has had many eruptions throughout FY 21/22 with 109 advisories issued. Typically, the activity has been observed as low-level and discrete which can dissipate quickly. Prior to the high-impact eruption, there was a significant thermal anomaly over the volcano and some minor eruptions to a few thousand feet over the volcano.

3.2.2. On 4 December 2021, there was an explosive eruption which was recorded on the Centre of Volcanology and Geo-Hazard Mitigation (CVGHM) seismograms and captured on Himawari-8 imagery at 04/0730 UTC. The advisory was initially issued to FL400 but quickly reassessed to FL500. There was convection in the area but the initial eruption was easily picked out despite the limited ash signal (Figure 4).

3.2.3. The ash continued to move to the southwest and by 04/1530 UTC, the ash was expected to enter the Melbourne FIR so the first WV SIGMET was issued for the eruption. There was significant media interest in this event with the VAAC getting many calls about the ash cloud. The event was finalised by 05/0330 UTC.

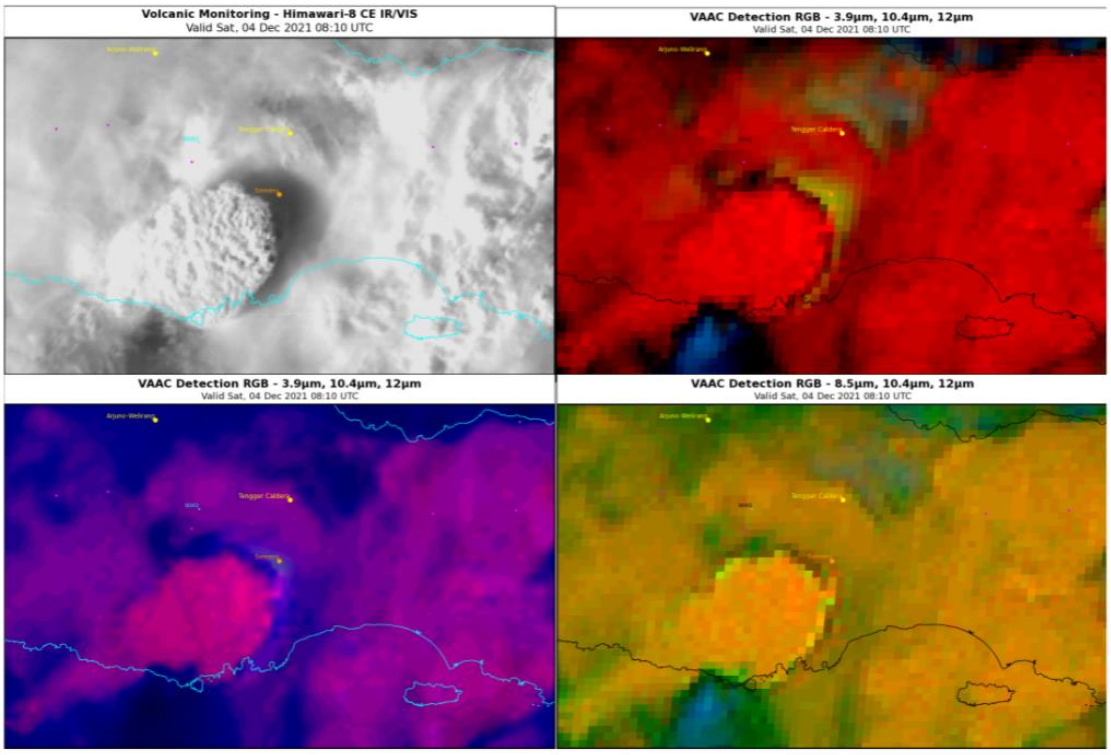

Figure 4. *Himawari-8 imagery on 4 December for the eruption at Mt Semeru. Top left is visible image, top right is RGB false colour image (bright red is volcanic ash), bottom left is RGB false colour image (bright pink is volcanic ash) and bottom right is RGB false colour image which highlights SO_2 as bright green.*

3.3. Manam, Papua New Guinea – 22 December 2021

3.3.1. On 22 December, Manam in Papua New Guinea was experiencing a large thermal anomaly indicating that there was volcanic activity occurring at the summit. At 21/1430 UTC, there was a discrete eruption observed from the volcano to FL350. There was discussion between VAAC Darwin and RVO about further evidence of the eruption and RVO provided RSAM data (seismic information) to say that it peaked around 1400 to 1600 UTC so there was potentially an eruption around that time. This gave the forecaster confidence that it was a volcanic eruption so they continued to issue the advisory. The event was finalised at 22/0640 UTC. There was good communication between the VAAC and the SVO for this event.

3.4. Hunga Tonga-Hunga Ha'apai, Tonga – 15 January 2022

3.4.1. There was activity at Hunga Tonga-Hunga Ha'apai in the weeks leading up to the eruption on 15 January which included a large eruption on 14 January. This activity was contained within VAAC AOR. At 15/0400 UTC the second major eruption was observed on satellite imagery by VAAC Wellington (Figure 5) and products were subsequently issued at 15/0439 UTC and 15/0519 UTC to FL500. There was discussion between VAAC Darwin and VAAC Wellington forecasters about the eruption where VAAC Darwin was providing as much support as possible. There were video calls and discussions occurring through the MS Teams channel throughout the initial stages of the eruption. There was a large volume of lightning recorded at the volcano location (Figure 6).

3.4.2. At 15/1424 UTC the two VAACs reassessed the situation and confirmed that the satellite imagery was showing the eruption was stratospheric since the Infra-red temperature reading was showing warmer cloud-top temperatures with a cold cloud layer appearing underneath. There was also supporting evidence from the Nadi sounding which showed winds in the stratosphere would be moving everything to the west but at the top of the tropopause the winds would move everything to the east. The upper-level ash was moving to the west which confirmed it had reached the stratosphere so the advisory was issued to FL630.

3.4.3. Volcanic ash in the stratosphere will stay in the stratosphere as it is above the cloud forming layers so nothing will wash the ash out. This lead to the decision to apply a base to the volcanic ash advisory so the ash was contained from FL450/FL630. Many pilot reports were received as airlines started to fly underneath the polygons. The pilot reports confirmed that there was no visible ash at FL350 but they could see a haziness at higher altitudes. This provided the confidence to continue with the base to the polygon.

3.4.4. VAACs Darwin and Wellington decided to both issue active advisories for this event as it started to become overly large for a single VAAC to monitor. At 16/1500 UTC both VAACs issued a coordinated VAA for the whole situation. This continued until 17/0300 UTC when VAAC Darwin became the primary VAAC responsible for the ash cloud as the volcano had stopped erupting and the entire ash cloud was moving towards the VAAC Darwin AOR. VAAC Wellington continued to issue rebroadcast VAAs.

3.4.5. The ash cloud continued to move to the west and over the Australian mainland from FL420/FL630 with the base being determined as the base of the stratosphere. There were strong SO_2 signals but the volcanic ash was difficult to detect (Figure 7). At sunrise and sunset the Himawari-8 true-colour visible imagery had a brown tinge which indicated the presence of volcanic ash but it was not being picked up by standard techniques. It could have been very fine

ash particles or not discernible. There were many pilot reports being sent to VAAC Darwin as aviation operations continued underneath the ash cloud and all reports mentioned haze at high levels and clear at cruising altitude with no evidence of volcanic ash or smell of SO_2.

3.4.6. The eruption was observed on the NASA CALIPSO LIDAR to 31 km (well into the stratosphere) on 16 January as it passed over the coral sea towards Australia. The data showed two different ash cloud heights but with all the volcanic material being in the stratosphere. The CALIPSO LIDAR data is delayed and only becomes available two day after the capture so was seen on 18 January (Figure 8). This also gave forecasters added information that the ash cloud was all in the stratosphere.

3.4.7. As the ash cloud passed over Australia and moved over the Indian Ocean, VAAC Darwin and VAAC Toulouse started to discuss the ash cloud and compare imagery as it was approaching the VAAC Toulouse border.

3.4.8. VAAC Darwin stayed the primary VAAC while VAAC Toulouse issued rebroadcast advisories. There was continuous discussion and information sharing that occurred on a daily basis through e-mails until eventually the event was finalised at 22/2340 UTC.

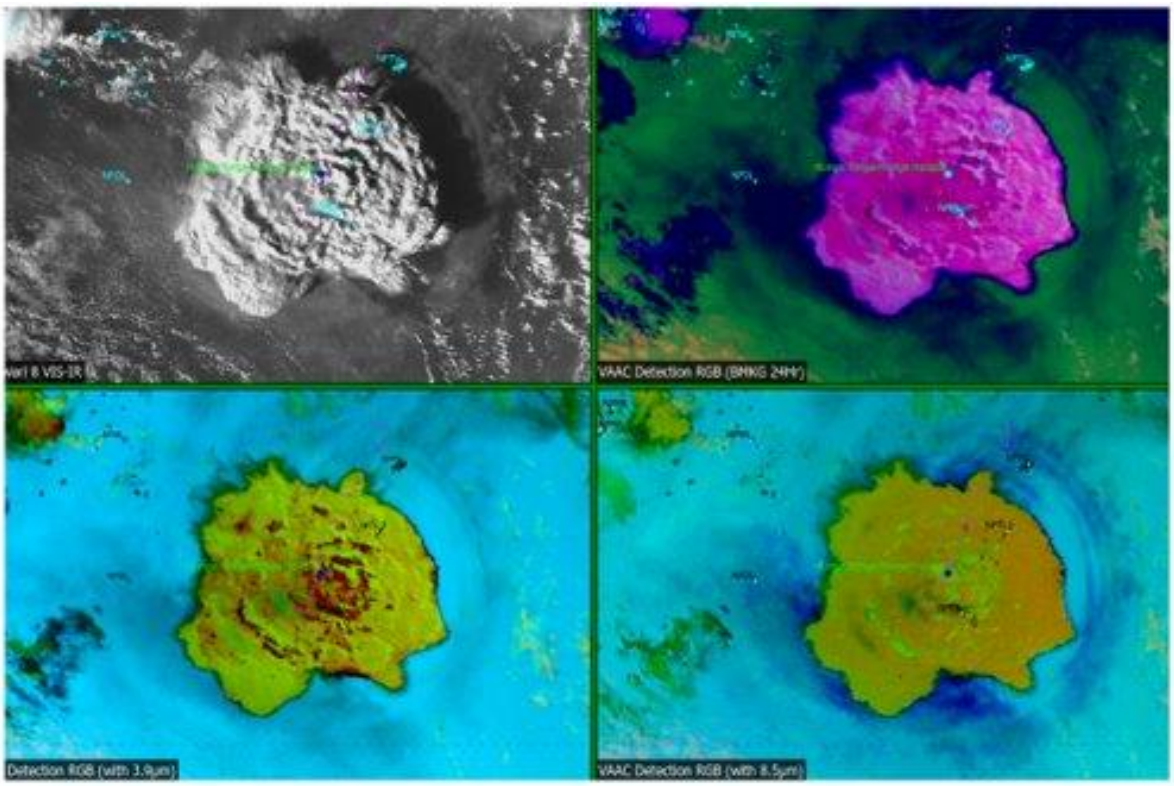

Figure 5*. Himawari-8 imagery on 15 January for the eruption at Mt Hunga Tonga-Hunga Ha'apai in Tonga. The volcano is in the VAAC Wellington AOR. Top left is visible image, top right is RGB false colour image (bright red is volcanic ash), bottom left is RGB false colour image (bright pink is volcanic ash) and bottom right is RGB false colour image which highlights SO_2 as bright green.*

0205-007	Haruj	Africa-N	Volcanic field	27.250	17.500	0	9	0205-007.kml
0300-03-	Golan Heights	Syria	Volcanic field	33.100	35.970	0	28	0300-03-.kml
0301-071	Kishb, Harrat	Arabia-W	Volcanic field	22.800	41.380	2	99	0301-071.kml
0301-072	Birk, Harrat al	Arabia-W	Volcanic field	18.370	41.630	0	4	0301-072.kml
0301-07-	Rahat, Harrat	Arabia-W	Volcanic field	23.080	39.780	0	2	0301-07-.kml
0302-01-	Damavand	Iran	Stratovolcano	35.951	52.109	2	88	0302-01-.kml
0303-013	Ankaizina field	Madagascar	Cinder cones	-14.300	48.670	0	22	0303-013.kml
0303-014	Itasy Volc field	Madagascar	Scoria cones	-19.000	46.770	7	129	0303-014.kml
0303-015	Ankaratra field	Madagascar	Cinder cones	-19.400	47.200	0	122	0303-015.kml
0303-02-	Fournaise, Piton de la	Indian O.-W	Shield volcano	-21.231	55.713	1	162	0303-02-.kml
0403-011	Unnamed	Tonga-SW Pacific	Submarine volcano	-21.150	-175.750	683	27335	0403-011.kml
0403-01-	Unnamed	Tonga-SW Pacific	Submarine volcano	-21.380	-175.650	657	21898	0403-01-.kml
0403-03-	Unnamed	Tonga-SW Pacific	Submarine volcano	-20.850	-175.530	1327	29886	0403-03-.kml
0403-04-	Hunga Tonga-Hunga Ha'apai	Tonga-SW Pacific	Submarine volcano	-20.570	-175.380	9322	21356	0403-04-.kml
0403-05-	Falcon Island	Tonga-SW Pacific	Submarine volcano	-20.320	-175.420	2136	27955	0403-05-.kml
0403-061	Kao	Tonga-SW Pacific	Stratovolcano	-19.670	-175.030	428	12043	0403-061.kml
0403-06-	Tofua	Tonga-SW Pacific	Caldera	-19.750	-175.070	497	17036	0403-06-.kml
0403-07-	Metis Shoal	Tonga-SW Pacific	Submarine volcano	-19.180	-174.870	3	3055	0403-07-.kml
0403-08-	Home Reef	Tonga-SW Pacific	Submarine volcano	-18.992	-174.775	0	1547	0403-08-.kml
0403-091	Unnamed	Tonga-SW Pacific	Submarine volcano	-18.325	-174.365	0	5	0403-091.kml
0403-09-	Late	Tonga-SW Pacific	Stratovolcano	-18.806	-174.650	0	424	0403-09-.kml
0403-101	Tafahi	Tonga-SW Pacific	Stratovolcano	-15.850	-173.720	1	0	0403-101.kml
0403-102	Curacoa	Tonga-SW Pacific	Submarine volcano	-15.620	-173.670	0	1	0403-102.kml
0403-10-	Fonualei	Tonga-SW Pacific	Stratovolcano	-18.020	-174.325	0	2	0403-10-.kml
0404-03-	Upolu	Samoa-SW Pacific	Shield volcano	-13.935	-171.720	0	7	0404-03-.kml
0404-04-	Savai'i	Samoa-SW Pacific	Shield volcano	-13.612	-172.525	0	6	0404-04-.kml
0405-01-	Taveuni	Fiji Is-SW Pacific	Shield volcano	-16.820	-179.970	0	6	0405-01-.kml
0405-02-	Koro	Fiji Is-SW Pacific	Cinder cones	-17.320	179.400	0	22	0405-02-.kml
0405-03-	Nabukelevu	Fiji Is-SW Pacific	Lava domes	-19.120	177.980	0	1	0405-03-.kml

Figure 6. *Lightning data from the WWLLN Global Volcanic Lightning Monitor for the 16 January (wwlln.net.USGS/Global/).*

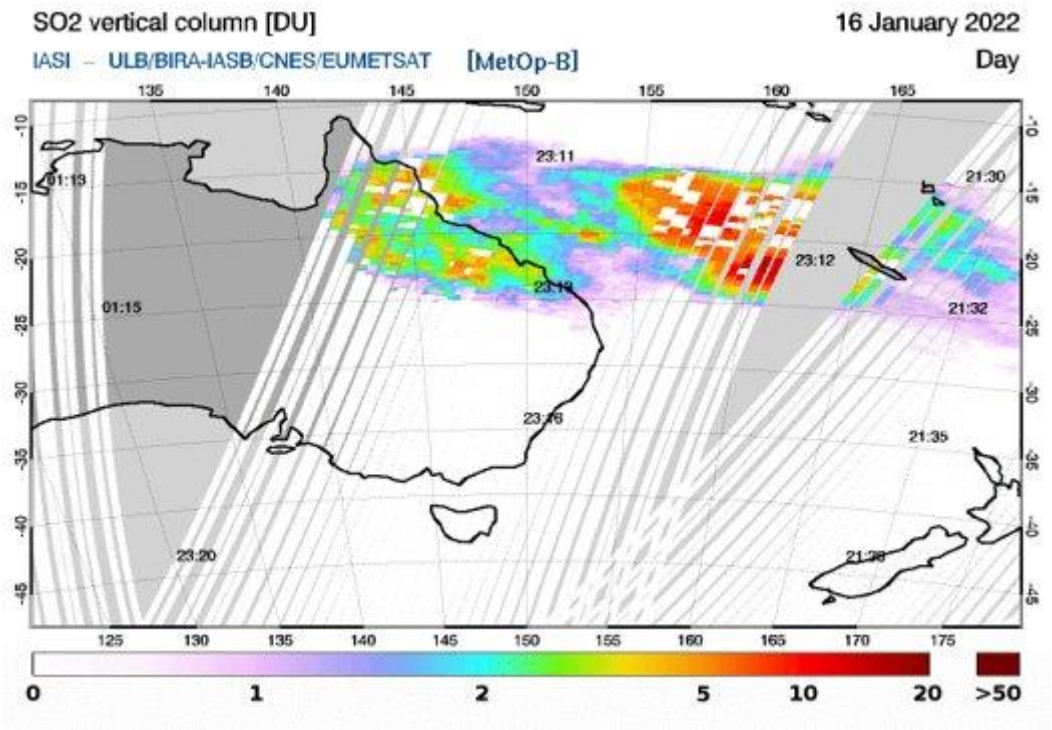

Figure 7*. SO_2 signal on 16 January on the IASI on the Support to Aviation Control Service (SACS).*

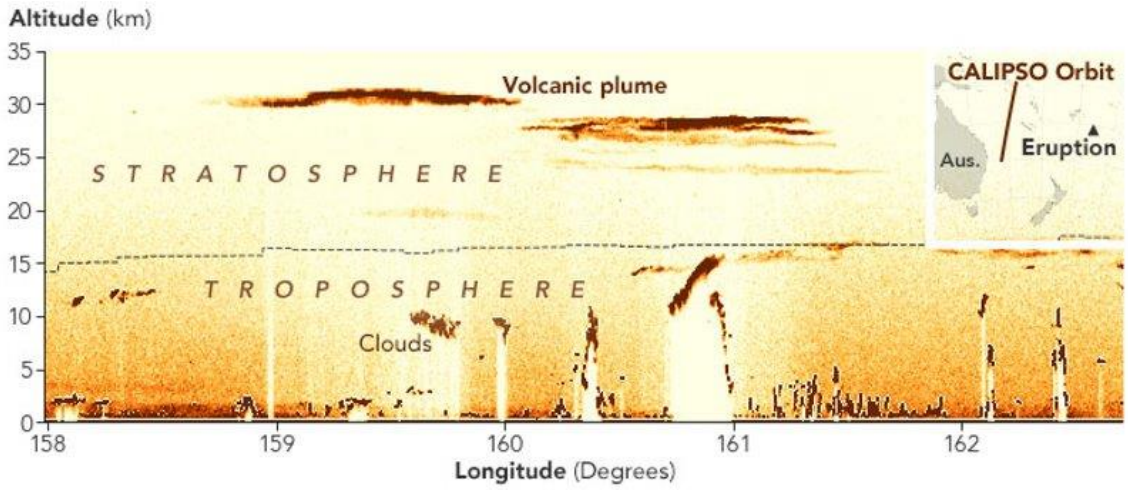

Figure 8. NASA CALIPSO LIDAR data as it passed over the Coral Sea next to eastern Australia and capture the volcanic cloud at 31km on 16 January.

3.5. Manam, Papua New Guinea – 17 April 2022

3.5.1. At 17/1958 UTC, the VAAC Darwin forecaster noticed something suspicious on satellite imagery and asked the Rabaul Volcano Observatory (RVO) if they have seismic data for Manam. Looking for further information to support evidence of an eruption or thermal activity.

3.5.2. At 17/2048 UTC, RVO e-mailed VAAC Darwin to advise that there was significant increase in seismic activity a few hours before and it suggests a volcanic eruption had occurred (Figure 9). The VAAC forecasters was able to confirm the eruption as it was thought that it was a thunderstorm. The initial advisory was issued at 17/2135 UTC.

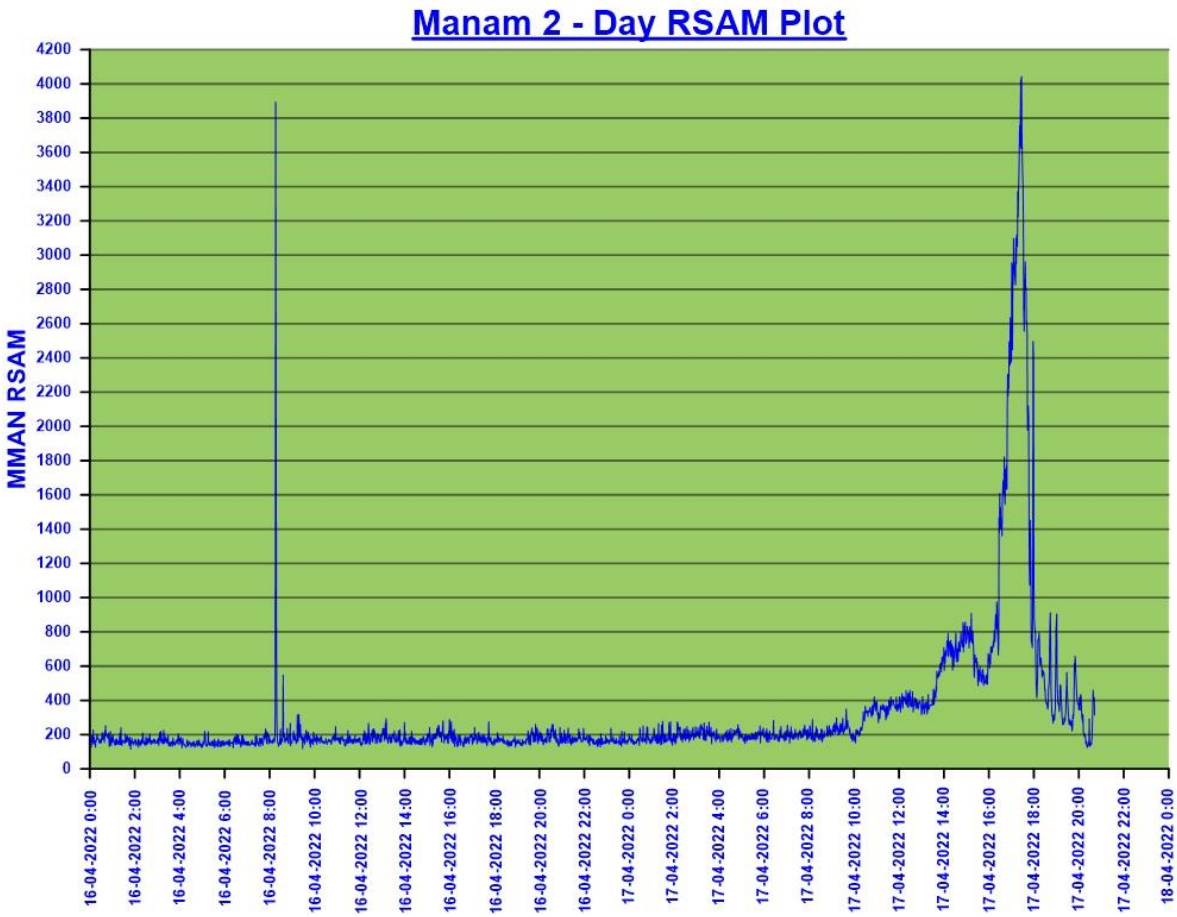

Figure 9. RSAM data provided by RVO in official e-mail at 17/2048 UT.

3.5.3. The advisory was issued to FL450 based on a -71ºC IR temperature. The volcanic ash was quickly dispersed into the surrounding meteorological cloud so became difficult to discern. The advisory was finalised at 18/0630 UTC. Looking at a way to gain more timely access to seismic data to support operations.

4. SIGNIFICANT OPERATIONAL CHANGES

4.1. VAAC Darwin Competency Program

4.1.1. VAAC Darwin has implemented a competency and training program for VAAC forecasters in line with quality management obligations and recent advancements in volcanic ash detection, monitoring and forecasting (i.e. next generation geostationary satellites, automated alerts (VOLCAT)), as well as implementation of improved strategies for delivering aviation briefings which can be scaled up or down based on the impact of an event and to meet the evolving needs of industry.

4.1.2. VAAC Darwin currently has 21 VAAC competent staff members. This is a significant increase in the number of competent technical staff available and able to respond to high impact volcanic ash events.

4.1.3. VAAC Darwin is developing in-house simulations and case studies to provide forecasters with a well-rounded training program so they can gain first-hand experience with many high impact eruptions. We will be using Ulawun (2019) and Hunga Tonga-Hunga Ha'apai (2022) as training cases for staff.

4.1.4. The World Meteorological Organization (WMO) Expert Team on Education, Training and Competency (ET-ETC) will be updating the top- and/or second-level competencies for aeronautical meteorological personnel to accommodate the role of VAAC forecasters and VAACs Darwin and Montreal will be assisting with the process. We are hoping that with VAAC Darwin's involvement we can have a consistent competency framework between all the VAACs. A separate VAAC competency framework has been developed to align with the AMF under the top-level competencies but have a separate set of second-level competencies. The new separate VAAC competency framework has been passed to WMO groups for review and approval process.

4.2. VAAC Washington backup

4.2.1. VAAC Darwin and VAAC Montreal have commenced backup support service for VAAC Washington. The service became live on 1 November 2021, from which point VAAC Washington may request backup support from VAAC Darwin and VAAC Montreal.

4.2.2. VAAC Darwin will backup the area consisting of Central America, South America to 10°S, the Northwest Pacific which includes the Marianas Islands and sections west of Central and South America in the Eastern and Central Pacific (Figure 9, green area). VAAC Montreal will backup the area consisting of the Continental US, Mexico, Caribbean, Eastern Atlantic and the Eastern and Central Pacific that includes Hawaii and west to 170°W. (Figure 9, yellow area).

4.2.3. There is a planned backup test organised between the three VAACs on 23 March 2022 to test out the coordination and dissemination with both VAACs at the same time. Further plans are being developed for this backup test.

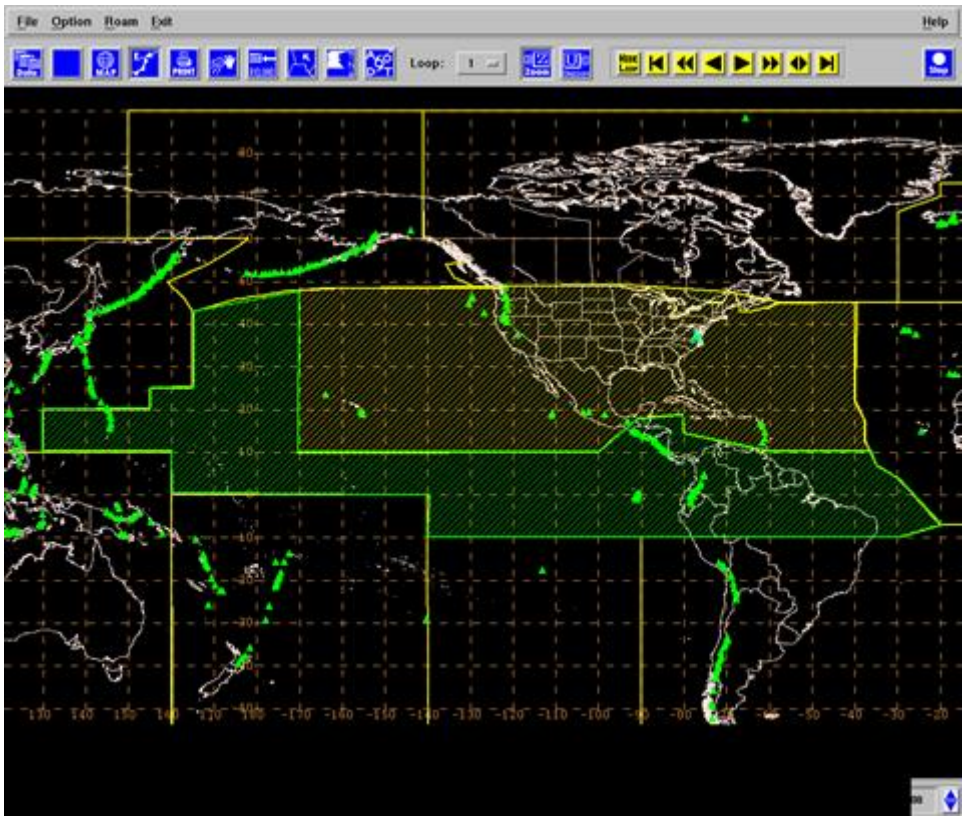

***Figure 9**. The VAAC Washington area split between VAAC Montreal and VAAC Darwin for backup support.*

4.3. VAAC Back-up testing

4.3.1. VAAC Darwin and VAAC Wellington conducted a backup test on 1 December 2021 to test newly reviewed procedures for the VAAC staff. The backup test was successfully carried out between the two VAACs. There was confirmed receipt of VAAs from a number of the updated AFTN addresses including Viet Nam and Sri Lanka. There was a backup test conducted on 16 June 2022 to test out the dissemination method for VAAC Wellington as there was a recent change. There were 7 responses from users about received the VAA issued by VAAC Wellington for the VAAC Darwin area of responsibility.

4.3.2. VAAC Darwin and VAAC Tokyo have finalised the backup processes and put the scheme of cooperation Appendices into operations in May 2022. To consolidate this, there will be a backup test conducted on 21 July 2022. The VAACs would like the MWOs to take note and make sure to participate in the upcoming backup tests.

4.3.3. VAAC Darwin, VAAC Montreal and VAAC Washington conducted a backup test in March 2022. This was a live backup where VAAC Darwin issued a product for the VAAC Washington AoR. There is another live backup session on 3rd August 2022. Backup information will be put into the APAC regional SIGMET guide of the new backup service.

4.4. VAAC Darwin webpage

4.4.1. The VAAC Darwin webpage will now display backup products issued by VAAC Darwin on behalf of other VAACs while under backup mode. So VAA/VAG products issued by VAAC Darwin for VAAC Tokyo, VAAC Wellington and VAAC Washington will be disseminated through AFTN and also appear on the VAAC Darwin webpage. This change was put into operations in October 2021.

4.5. Operational forecasting software

4.5.1. There have been many minor operational changes made to the forecasting software "Visual Weather" over the year to streamline processes, improve ability to issue backup products, combine product types such as SIGMETs etc. These minor operational changes come from operational VAAC staff, through exercises or post event reports when issues are found, introduction of new services or dispersion systems into the VAAC and left-over legacy systems where a process has changed.

5. Dispersion Ensemble Prediction System (DEPS)

5.1.1. The Australian Bureau of Meteorology transitioned its new dispersion model software to operations in 2020, which gave VAAC Darwin access to probabilistic forecasts and data for volcanic ash to help with more accurate forecasts in its advisories. The previous dispersion model capability was deterministic which provided a single output forecast for a volcanic eruption. The model could be run multiple times but only had limited atmospheric uncertainties as well as the eruption uncertainties.

5.1.2. The new DEPS provides 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. The output shows a probabilistic view of how many of the ensemble members suggest there is in any volcanic ash in a section of air space. Having an ensemble approach accounts for more of the uncertainties associated with the dispersion model process so it highlights that uncertainty in the output. This allows the VAAC forecaster to process the data and incorporate it into their advisories. It also puts VAAC Darwin in a good position to provide input into the international work by METP WG-MISD that is happening around quantitative volcanic ash and the future of volcanic ash services.

5.1.3. We are currently working towards a major upgrade to the DEPS system to include new features to be put into operations as DEPS2 in a number of months. The new features will include inverse modelling of the eruption to support improved parameterisation, an ingest of satellite retrievals to support more accurate eruption details including mass eruption rate, and the user defined polygon to tailor the eruption to start with specific area of coverage. These improvements will allow VAAC Darwin to work towards the new quantitative volcanic ash information services developed by the WG-MISD. The DEPS2 upgrade will happen in July 2022.

6. VAAC COLLABORATION

6.1. VAAC Wellington

6.1.1. VAAC Darwin and VAAC Wellington collaboration has been a major focus for the two VAACs to look at consistency and harmonisation of services. The VAACs have been considering coordination, quality, consistency, flexibility, and resilience. There are forecasters organising many activities which include looking into current capabilities and comparing ash dispersion models, looking into ways to incorporate daily collaboration activities, comparison of advisory and forecast creation, and sharing current activity or gaining insight into potential volcanic activity. With the increase in use of Microsoft Teams software due to the pandemic, a new Wellington-Darwin chat has been established which is allowing closer and more frequent collaboration.

6.1.2. We are having forecasters take on these responsibilities to further build up relationships between the two VAACs and to provide professional development for staff. We continue to work closely to organise, participate and review volcanic ash exercises to test out procedures and coordination. The coordination between the two VAACs was demonstrated during the Hunga Tonga-Hunga Ha'apai eruption where there was ongoing discussion, information sharing, video calls, and product coordination to make sure there was a seamless service across both VAAC's AORs.

6.1.3. VAAC Darwin and VAAC Wellington are continuing to support Solomon Islands with Air Navigation deficiency (AP-MET-23). The Solomon Islands FIR' Honiara' is split between both VAACs so a volcano from each VAAC area of responsibility was used for the exercise (Figure 10). There was another volcanic ash exercise on the 20 April 2022 where Solomon Island MWO showed a significant improvement in the WV SIGMETs issued. There was also 60 days worth of SIGMET data collected between 1 March to 30 April 2022. A few issues have been picked up but Solomon Islands have conducted workshops and refresher training to help resolve these issues. There were also some issues with some WV SIGMETs not reaching AFTN so some dissemination investigation is required with ATS and recording process times.

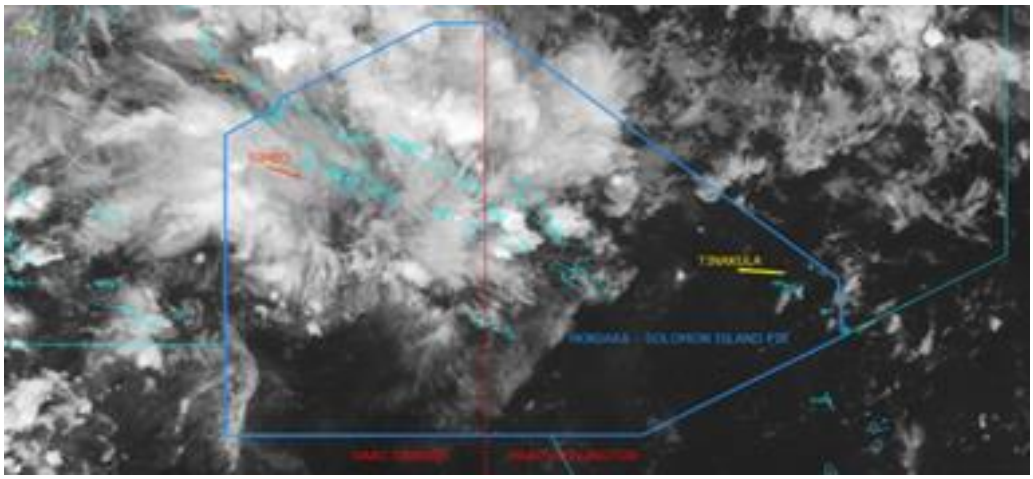

***Figure 10**. Map of the Honiara FIR, VAAC Darwin and VAAC Wellington Area of responsibility boundaries and Simbo and Tinakula volcanoes*

6.2. VAAC Tokyo Collaboration

6.2.1. VAAC Darwin and VAAC Tokyo are collaborating on a number of tasks to improve operational services and consistency between both centres. VAAC Tokyo have developed the JMA SIGMET Collaboration tool which will be expanded to include VAAC collaboration. The VAACs are looking to revise their backup arrangements and conduct a backup test in the next few months.

6.2.2. Both VAACs are looking to incorporate the collaboration tool into backup procedures as an easier way to communicate. VAAC Tokyo is also looking to join the MS Teams group to see if it is appropriate for operational use.

7. INTERNATIONAL STAKEHOLDER ENGAGEMENT

7.1. The Advisory Group on Volcanic Science for Applications (AG-VSA) replacing VAAC BP/VASAG

7.1.1. WMO has started up a new volcanic ash science group called the Advisory Group on Volcanic Science for Application. This group will be taking over the work conducted by the VASAG and support the METP WG-MOG-IAVW which will take on work of the VAAC Best Practice. The AG-VSA is currently working on the operating plan and terms of reference which should be finalised by the end of 2022.

7.1.2. The combined VAAC Best Practice and VASAG were looking at the information exchange for operational volcanic ash practices, which includes monitoring and forecasting, technology, backup services, new developments and ICAO compliance. There are a number of key actions that came out of the 2019 meeting which involve all VAACs or specifically VAAC Darwin and have been worked on over the last 12 months:

- WMO are reviewing top- and/or second level competencies for VAAC forecasters and VAAC Darwin will be heavily involved in the updates for consistent VAAC competencies.
- The VASAG is preparing for the eighth International Workshop on Volcanic Ash (IWVA) that was scheduled to be held in early 2023 but location is still being decided upon. The last workshop was held in 2015. The workshop is a chance for operational and scientific groups to talk about volcanic ash and the future. Next steps – to prepare agenda and finalise the concept note for the workshop.

7.2. ICAO Meteorological Panel Working Groups

7.2.1. The WG-MOG/IAVW and the WG-MISD/VASD have been merged into one group at the end of last year and the group is now WG-MOG-IAVW/VASD. The conjoint WG-MOG and WG-MISD meeting was held virtually in November 2021.

7.2.2. The WG-MOG-IAVW/VASD is responsible for operational oversight in the global system for volcanic ash, namely the International Airways Volcano Watch (IAVW) and developing future services for volcanic ash and sulphur dioxide. The IAVW work stream is working on the Concept of Operations to identify user needs, determining shortfalls, refining concept of operations, and defining functional and performance requirements for new information related to volcanic ash. The VASD work stream is looking at the requirements of SO_2 reporting and the future of volcanic ash products including concentration charts and graphics. The key action items for the new WG-MOG IAVW/VASD include:

- Timeliness and accuracy of key performance indicators to look at VAAC consistency, compliance and forecasts.
- Looking towards the future with the roadmap for the Concept of Operations and IAVW.
- The METP endorsed the elevation of Volcano Observatory Notice for Aviation (VONA) to recommended practice in 2023 in TAC and IWXXM formats and the removal of the aviation colour code from the Volcanic Ash Advisory (VAA) so it only appears in the VONA for consistency purposes. The group is actioning several tasks which are directly related to the above endorsement which includes
    - IAVW updates,
    - regional engagement activities, and
    - guidance and educational materials.
- The METP endorsed the provision of new quantitative volcanic ash (QVA) services from Volcanic Ash Advisory Centres (VAACs). The group is actioning several tasks which are directly related to the above endorsement which includes
    - defining ‘significant volcanic ash cloud’,
    - QVA IWXXM schemas,
    - QVA data delivery, and
    - guidance and educational material.
- Looking at the SO_2 requirements for the provision of a new service, with an emphasis on accessing user needs, determining information shortfalls, further refining the concept of operations, and defining functional and performance requirements for any new information elements related to SO_2.
- VAAC London provided an overview of a potential SO_2 service; the group will continue to work with this information on designing a new service.

7.2.3. The proposal was approved and the work with quantitative volcanic ash will go ahead and be put into Annex 3. The timeframe for QVA in Annex 3 will be:

a. Recommended Practice: all VAACs in a position to do so by November 2023 should issue forecasts of quantitative volcanic ash concentration information for significant volcanic ash clouds;

b. Recommended Practice: all VAACs by November 2025 should issue forecasts of quantitative volcanic ash concentration information for significant volcanic ash clouds; and,

c. Above becomes a Standard in November 2026.

Note: Significant volcanic ash cloud in this context means an ash cloud that poses widespread impact to aircraft operations and air navigation.

7.2.4. All nine VAACs are heavily involved in developing these capabilities. The next steps will involve looking at the service and consistency as well as education and guidance for users of the quantitative volcanic ash concentration information. Thresholds and forecast conditions will be placed in PANS-MET. Any delays to the Annex 3 update schedule could delay this work.

7.3. State Volcano Observatory engagement

7.3.1. Due to COVID, the State Volcano Observatory (SVO) engagement has slowed down since States have been responding to the pandemic. There has been outreach to States that have APAC Met deficiencies to see where the VAAC can provide support especially to deficiencies around volcanic ash services. VAAC Darwin will be supporting RVO with its current work to provide volcanic activity information and remove its deficiency. VAAC Darwin has also supported MWO Solomon Islands to remove some air navigation deficiencies and continues to support them for issuing volcanic ash SIGMETs.

7.3.2. With the elevation of the VONA by the ICAO WG-MOG IAVW/VASD, there will be follow on education for SVOs and customers. The SVOs in each region were consulted about the changes to the VONA and provided feedback to the WG-MOG IAVW/VASD. The VAACs will need to help with education around the changes and continue the discussion with SVOs now that METP has approved the changes to VONA.