***International Civil Aviation Organization***

**NINTH MEETING OF THE COMMUNICATIONS/NAVIGATION/SURVEILLANCE AND METEOROLOGY SUB-GROUP OF APANPIRG (CNS/MET SG/9)**

Bangkok, Thailand, 11–15 July 2005

**Agenda Item 10: ICAO Warning Systems:**

**1) review implementation of International Airways Volcano Watch (IAVW)**

# VOLCANIC ASH ISSUES IN THE REGION OVER 2004-2005

(Presented by Australia)

**SUMMARY**

This paper gives a brief discussion of developments and continuing volcanic ash challenges in the region.

## 1. Introduction

1.1 The meeting will already be aware of issues regarding the implementation of the International Airways Volcano Watch in the Asia-Pacific, including the relatively low rate of SIGMET compliance in the region, and the ICAO special implementation project to address these issues.

1.2 This paper is designed to briefly highlight developments and volcanic ash issues in the region over the past year.

## 2. Developments

2.1 In December 2003, the Australian Bureau of Meteorology introduced a new volcanic ash workstation, which is operational in the Darwin Volcanic Ash Advisory Centre, and the back-up centre, the National Meteorogical and Oceanographic Centre in Melbourne. During the 2004/05 period, the system has been steadily developed and substantially improved. The system has greatly simplified the issue of volcanic ash advisories in text and graphical format, and feedback from users has been very positive. A paper presenting the system in more detail is attached here as an Appendix.

2.2 To support the activities of ICAO in this regard, a strong effort has been made by Australia to improve communications and understanding on volcanic ash matters through the region. Activities have included liaison visits to the Philippines, Indonesia, and Papua New Guinea. An AusAID funded Bureau of Meteorology initiative with Geoscience Australia to improve volcanic

monitoring in Flores, Indonesia, has attained practical completion, and it is anticipated that a further project will commence shortly. Geoscience Australia are also managing a long-running joint project with the Rabaul Volcano Observatory, and the Australian Bureau of Meteorology, the Papua New Guinea National Weather Service and Air Niugini have been discussing information exchange and pilot reporting.

2.3 In addition, Australia has maintained an active research programme, including study of events recorded on infrasonic microphones (Geoscience Australia), interactions between volcanoes and tropical convection (Bureau of Meteorology), and new infrared techniques for monitoring volcanic clouds (CSIRO).

2.4 Aviation related volcanic ash issues are also addressed through the Vulcan-Aus Group which comprises representatives from Airlines, Asia/Pacific Vulcanological Agencies, Geoscience Australia, Airservices Australia, research institutes and the Bureau of Meteorology.

2.5 As a result of all these efforts and the other efforts by regional partners, we believe that the operations of the IAVW in the region are being steadily improved. However, we would like to remind the meeting of ongoing issues affecting the implementation of the IAVW in the region, and encourage all participants to continue working on the problems.

## 3. Concerns

3.1 The major eruptions in the Darwin VAAC area of responsibility came from Manam volcano, but there were many minor eruptions around the region. In all these eruptions, it has been evident that some SIGMETs are still not being issued or, if they are issued are not being widely received. One possible approach to this problem, from the volcanic perspective, is for VAACs to provide, with prior agreement, draft SIGMETs on volcanic ash for issue by MWOs during volcanic events. However this would only work as an MWO-initiated (rather than VAAC-imposed) initiative.

3.2 Volcanological agencies in the region are still not able to monitor volcanoes to the extent demanded by the IAVW. We continue to emphasise that every opportunity should be sought to promote appropriate funding for volcanological agencies, and to seek to increase communication and goodwill between volcanological agencies and the meteorological and aviation communities.

3.3 We believe that, despite some recent successes, pilot reporting of eruptions could still be significantly improved, and we urge that every airline implement robust procedures to ensure that pilot reports are disseminated widely, including to ACCs, MWOs, and VAACs. We also urge that airlines be pro-active in post-analysis of events that have significantly affected their operations and include the relevant VAACs and MWOs in their analysis of these events.

## 4. Conclusion

4.1 The meeting is invited to note the information in this paper, and if possible to provide some comments on the concerns raised above.

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# THE DARWIN VAAC VOLCANIC ASH WORKSTATION

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## Introduction

The Darwin VAAC has been operating since March 1993 providing advice on volcanic ash for the aviation industry in accordance with arrangements established as part of the ICAO IAVW (ICAO, 2001). The Volcanic Ash Advisories (VAA's) are based on an initial report of an eruption, an analysis of satellite data to identify and track the ash cloud, and a forecast of the movement of the ash derived from upper level winds and an atmospheric dispersion model. The VAA message is prepared in the agreed format and disseminated to the aviation industry. This process must be completed in a timely manner so that aircraft likely to be affected by the ash cloud can take appropriate avoidance measures.

There are a number of complex issues in the preparation of warnings relating to volcanic ash. There are numerous volcanoes in the Darwin area of responsibility and most are remote and not routinely monitored. As a result, advice of volcanic eruptions or ash clouds may be delayed. Current satellite data has proved of considerable value for detection of volcanic eruptions and the detection and tracking of ash clouds and there have been improvements in the utilisation of these data to support the volcanic ash warning service. However, the discrimination of volcanic ash from water/ ice clouds and delineation of the observed ash boundary remains problematic with current data and processing techniques. This necessitates intensive manual analyses of satellite data with resultant time and resource implications. Ash dispersion models provide useful guidance on the expected movement of an ash cloud but there are uncertainties in the wind field in the underlying atmospheric model and the source term for initialising the dispersion model. Moreover, the concentration of ash that presents a risk to aircraft, either for safety reasons or maintenance impacts, is not well known. Hence delineation of the forecast 'threat area' is also problematic. Finally the preparation of the VAA can be manually intensive and during busy operational periods this can cause undue pressure for operational staff. All these factors cause delays and increase the potential for errors in the provision of advice that is of critical importance to aircraft operating in regions where there are active volcanoes.

With these issues in mind there is ongoing effort in the Bureau that is designed to improve the efficacy of the advisory service that is provided. This includes improvements in the use of satellite data for detecting volcanic eruptions and ash clouds, improvements in the utilization of the volcanic ash dispersion model and streamlining the warning preparation process. In this paper we briefly examine the operational uncertainties, using the Indonesian Ruang eruption of 25 September 2002 as a case study, and then describe efforts directed at using available guidance in a more integrated and streamlined way for preparation of the volcanic ash advisory and a corresponding graphical product.

## Ruang volcano eruption of 25 September 2002

The Ruang volcano is located in the Sangihe Islands of Indonesia at 2.28°N 125.425°E and around 0345 UTC, 25 September 2002, the volcano erupted to a height of approximately 20 km in clear conditions. The evolution of the ash plume was observed in hourly GMS5 satellite data and other satellite data (Tupper etal, 2004). Winds over the volcano at the time of the eruption were from the east in the layer up to 18 km and most of the ash plume moved to the west. A thin layer of ash and $SO_2$ in the layer 18-20 km did move to the east but for the purposes of this discussion is not considered further.

Fig.1a shows the IR1 ($BT_{11}$) image from GMS5 at 1230UTC and Fig. 1b shows the corresponding IR1-IR2 ($BT_{11}$-$BT_{12}$) channel difference image, with negative differences in orange and red indicating the possible presence of ash. It was possible to track the boundary of the ash cloud up to this time from a loop of the hourly visible, IR1 and IR1-IR2 images and Fig 1a also shows a manually analysed boundary for the ash plume. Discriminating ash from water/ice clouds and defining its boundary as it disperses can be difficult in visible and IR imagery, and although the IR1-IR2 image may show a well-defined ash signature it does not identify the full extent of the ash as shown in Fig 1. For this event the IR1-IR2 data showed the presence of ash for around 40 hours following the eruption but delineation of the ash boundary, or threat area, became problematic after just 9 hours. When there is active convection in the area and extensive water/ice cloud present, uncertainties in delineating the analysed threat area increase greatly.

Guidance on the dispersion of volcanic ash clouds is provided by the Hysplit dispersion model (Draxler and

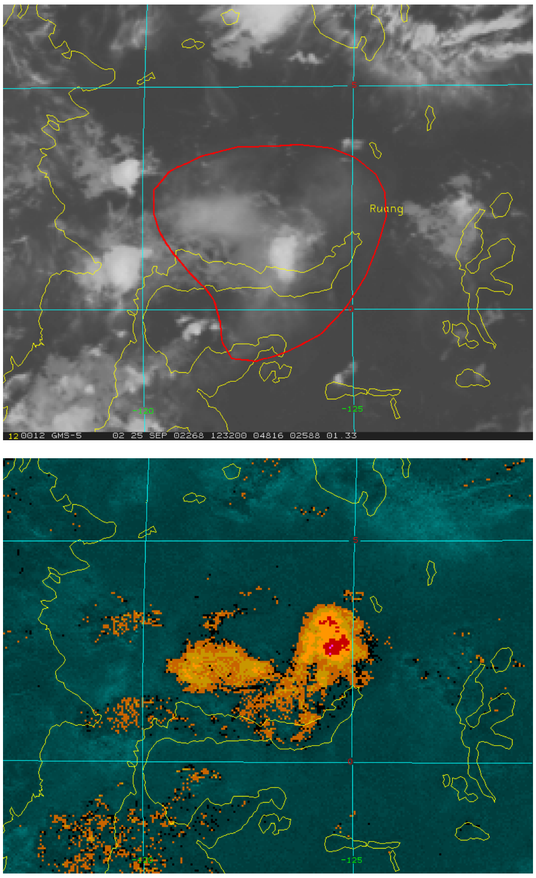


Figure 1. GMS-5 satellite imagery for 1230 UTC, 25 Sep 2002, showing Ruang eruption cloud. (a) IR1 image with manually analysed boundary of ash plume, and (b) image of brightness temperature difference (IR1-IR2) with blue indicating positive differences and orange/red indicating negative differences.

Hess, 1998) and Fig.2 shows model output for the Ruang eruption for the same time as that shown in Fig 1. This figure shows the integrated concentration from the surface to 18 km. Comparison of the boundary shown in Fig. 1a with that in Fig. 2 shows general agreement but the extent of the analysed ash is significantly greater. Such differences can arise because the forecast wind field from the underlying NWP model is not representative. There are also uncertainties in the source term for initialising the dispersion model, including the height of the eruption plume and the mass distribution. Many dispersion models assume a line source but in reality there is horizontal spreading of the plume in the early stages due to internal dynamics of the eruption. This will contribute to greater spreading of the plume than models predict. Finally the nominal ash concentration that presents a risk to aircraft is not well known. These issues lead to uncertainties in delineating the forecast threat area.

These uncertainties mean that the forecaster must use satellite data and dispersion model output in an integrated way to provide the best assessment of the analysed and forecast ash boundary or threat area.

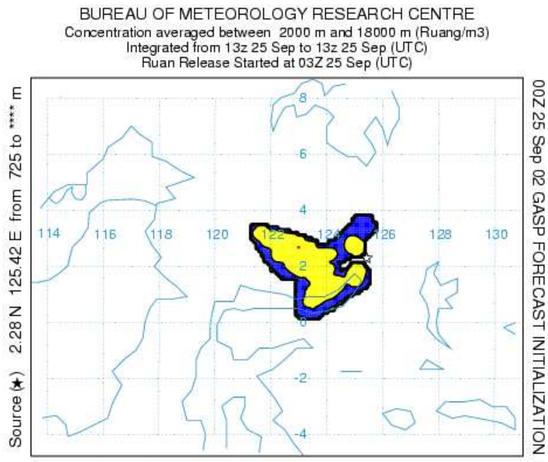


Figure 2. Hysplit dispersion model forecast for 1300 UTC, 25 September 2002 based on eruption at 0345 UTC.

**The Darwin Volcanic Ash Warning Preparation System (VAWS)**

The Volcanic Ash Warning Preparation System (VAWS) has been developed to enable more integrated use of available satellite data and dispersion model output and to streamline the generation of the text and corresponding graphical volcanic ash products. The system also provides a stable framework that should simplify the operational implementation of improved analysis and prediction components that are underway.

The VAWS interface includes a map window that shows coastlines and all volcanoes in the region, a table for the display of relevant volcano details, a layer manager and a toolbar, as illustrated in Fig 3. Full roam and zoom capabilities are available in the map window and the user can select the volcano of interest, using the mouse or a text based search, and add the volcano to the volcano table. The operator defines the analysed and forecast threat areas for 0 hr, +6 hr, +12 hr and +18 hr using the mouse and the VAA products are then generated in a two-step process. The operator selects the 'Advisory' icon on the toolbar and this generates a text dialogue that shows all the required fields for the VAA. Most fields are filled automatically using details

derived from the graphical interface and the few remaining fields, such as the information source, are completed manually. The output products are then previewed and submitted for dissemination. The products include the VAA in text format and a corresponding graphical product (Fig 4) that was developed in liaison with regional aviation industry representatives. The output products are archived together with system files that store relevant information for each advisory and for the system status.

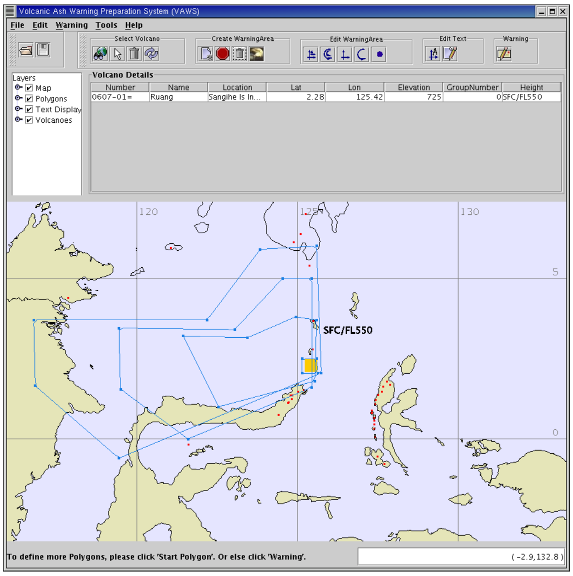


Figure 3. Graphical interface for Volcanic Ash Warning Preparation System.

In the development of the user interface several design criteria have been adhered to. These include platform independence; a responsive graphical interface; the need to integrate the system within the Bureau's operational infrastructure (Kelly, etal, 2004); the ability to display satellite data, NWP data and output from the ash dispersion model using a concept of layers; and, the need to archive relevant information for training purposes and for ongoing research and development.

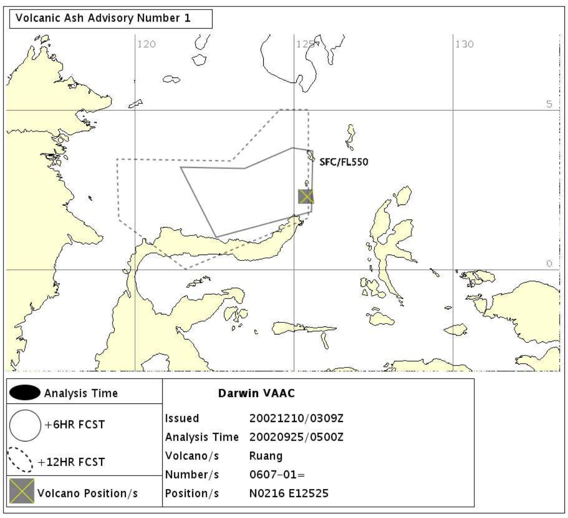


Figure 4. Volcanic Ash Advisory graphical product.

In the first stage of development the focus has been to streamline the preparation of the VAA message and to generate a corresponding graphical product. Future operational implementations of the VAWS system will allow for the display of satellite data and dispersion model output within the graphical interface and work on this is well advanced.

## Operational experiences

Operational use of the stage-one system started in December 2003 and over 200 VAA's have been generated and disseminated in the period up to 1 June 2004 with a text and graphical product for each. Following feedback from operational forecasters a number of upgrades have been provided to improve system operation and functionality. The system has streamlined the preparation of the VAA message, reduced the potential for errors, and feedback from forecasters has been positive. Feedback from the aviation industry on the format of the graphical product has also been positive. It is consistent with the text product and satisfies the need, expressed by flight planning personnel and pilots, for a concise and simple product that shows the variation of the ash boundary with time. The simple format also means the product remains legible when faxed to pilots at briefing stations that may have limited facilities.

## Conclusions

The Volcanic Ash Advisories (VAA's) issued by the Darwin VAAC are based on an initial report or detection of a volcanic eruption or ash cloud, an analysis of satellite data to identify and track the ash cloud, and a forecast of the movement of the ash derived from upper level winds and an atmospheric dispersion model. Uncertainties in delineating the analyzed and forecast ash boundary or threat area, requires intensive manual analysis and integrated use of available guidance by the forecaster when generating output products for the aviation industry. This process, together with preparation of the VAA, can be time consuming with resultant delays and potential for errors.

The Volcanic Ash Warning Preparation System (VAWS) is a person-machine user interface that has been developed to streamline preparation of the VAA text product and automatically generate a corresponding graphical product. It enables satellite data and dispersion model outputs to be used in a more integrated way to delineate the analysed and forecast

threat areas. The system should also provide a stable framework that simplifies the operational implementation of improved analysis and prediction components that will be developed in the future. The system has been in operational use since December 2003 and feedback from forecasters and the aviation industry has been positive.

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