THE INTERNATIONAL AIRWAYS VOLCANO WATCH (IAVW)

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1. INTRODUCTION

The definition of the IAVW is included in ICAO Annex 3 — *Meteorological Service for International Air Navigation* to the Convention on International Civil Aviation and reads as follows:

International airways volcano watch (IAVW). International arrangements for monitoring and providing warnings to aircraft of volcanic ash in the atmosphere.

[Note: The IAVW is based on the cooperation of aviation and non-aviation operational units using information derived from observing sources and networks that are provided by States. The watch is coordinated by ICAO with the cooperation of other concerned international organizations.]

2. HISTORICAL BACKGROUND

The IAVW was first established in 1987 with an amendment to Annex 3, which introduced a requirement for the international dissemination of information on volcanic ash to aircraft. This information was included in SIGMETs and NOTAMs. This amendment was developed with the assistance of the former Volcanic Ash Warnings Study Group (VAWSG), which had been created in 1982. For the initial detection and notification of a volcanic eruption and/or volcanic ash cloud, ICAO sought and received the cooperation of a number of other international organizations that administer vulcanological observatories, aircraft reports and satellite data. The responsibility for the issuance of SIGMETs and NOTAMs lay with the meteorological watch offices (MWOs) and aeronautical control centres (ACCs) through their NOTAM Offices (NOFs), respectively, both of which are designated by States to provide service for a flight information region (FIR).

It was clear from the outset that many MWOs, not having necessary tools, would have difficulty in providing accurate forecasts of volcanic ash extent and trajectory for the SIGMET and particularly for the required twelve hours, i.e. six to eight hours beyond the usual period of validity of SIGMETs. Steps were taken by ICAO, therefore, to designate, on advice from WMO, centres having the capability to provide advisory information on volcanic ash to the MOWs. At the conjoint ICAO/WMO Communications/Meteorology/Operations (COM/MET/OPS) Divisional Meeting (1990), it was agreed that information on forecast trajectory covering 12 hours beyond the validity period of a SIGMET should be included in an "outlook". Information to assist MWOs in preparing SIGMETs for volcanic ash, and especially the "outlook", was to be provided by designated meteorological centres, which henceforth were known as volcanic ash advisory centres (VAACs). The designation of VAACs was accomplished one by one, as Provider States concerned agreed to accept the responsibility. The designations are reflected in the relevant ICAO regional air navigation plans. Due to the fact that the development of the IAVW involved coordination with other international organizations not hitherto linked to civil aviation, the operational procedures were largely based upon experience, and were tested as guidance material first before being included as formal ICAO Annex provisions.

Recent developments of the IAVW include the introduction of a new format for volcanic ash advisories and templates for SIGMETs for volcanic ash for data link purposes in 2001 (Appendix A). During the ICAO MET Divisional Meeting (2002), in order to face the problem of the lack of implementation (e.g. SIGMETs are not issued by certain States), a set of measures were recommended, including the review of the ICAO regional SIGMET guides. A requirement was also introduced for maintenance of a 24-hour watch by the VAACs. In view of flight safety considerations, the requirement for information from selected State volcano observatories was introduced in ICAO provisions in order for the ACCs MWOs and the VAACs to receive from these selected observatories messages on volcanic activity. All the provisions endorsed by the MET Divisional Meeting (2002) will become applicable in November 2004 as part of Amendment 73 to Annex 3.

In order to assist States exposed to volcanic eruptions, specific special implementation projects on the issuance of SIGMETs with emphasis on volcanic ash have been undertaken by ICAO in a number of ICAO Regions during recent years. Special implementation projects involved visits to States; in each State visited the ICAO expert met with officials from three areas involved in the implementation of the IAVW; ATS authorities/providers; MET authorities/providers and vulcanological agencies. In some of the States, representatives from the airlines were also available during the meetings. These projects were considered very successful by the States concerned and ICAO, and resulted in noticeable improvements in the local procedures.

The MET Divisional Meeting (2002), recognizing the need for a reliable operation of the IAVW and its impact in flight safety, recommended the establishment of an operations group in order to coordinate and oversee the development of the IAVW. In 2003, the International Airways Volcano Watch Operations Group (IAVWOPSG) was established; it held its first meeting in Bangkok, Thailand, in March 2004. It formulated twenty-eight conclusions and five decisions related to the operation and development of the IAVW.

3. OPERATION OF THE IAVW

The IAVW comprises an observing part to detect volcanic eruptions and volcanic ash and a warning part concerned with the issuance of volcanic ash advisory information in both alphanumerical and graphical format, SIGMETs, NOTAMs (and the special series NOTAM called ASHTAM designed specifically for volcanic eruptions/ash). This section deals with the recent developments of the IAVW.

3.1 Observing component of the IAVW

The observing part depends upon initial notification of volcanic eruptions/ash cloud to MWOs, ACCs and/or VAACs by vulcanological agencies, meteorological observing networks, United Nations Disaster Relief Organization field officers, national networks such as police, military, border guards, forestry personnel etc; pilot reports and satellite data. Substantial efforts have been made to ensure that personnel from the foregoing organized networks understand that if they see or learn of a volcanic eruption in their area they are to inform the nearest civil aviation or meteorological contact point. These contact points and channels of communication are organized nationally in those States having active volcanoes in the FIRs for which they are responsible. Ultimately, the notification of a volcanic eruption/ash cloud has to reach the ACCs, MWOs and VAACs to permit the issuance of the necessary advisory information, SIGMETs and NOTAMs.

3.2 Ground-based observations

The ground-based observing part of the IAVW, which used to be dependent on voluntary cooperation, is by no means 100 per cent effective. In this regard, the MET Divisional Meeting (2002) was informed that difficulties were being experienced by some vulcanological agencies in obtaining the necessary funding for sending messages on volcanic activity to ACCs, MWOs and the VAACs in their region. These additional funds most often involved staffing and communications costs. In order to face this issue, the requirement for information from selected State volcano observatories is being introduced in ICAO provisions. This requirement means that the role of the volcano observatories, which are the front line of alert of the IAVW, will be formalized.

3.3 Observations from air-reports

The provision of special air reports on volcanic eruptions/ash cloud by pilots is in general operating well, and on many occasions such reports have provided the initial notification of an eruption. However, at the IAVWOPSG/1 Meeting it was recognized that there are still certain areas where further work is necessary. With regard to the implementation of the existing provisions concerning the reporting, recording and post-flight reporting of aircraft observations related to volcanic activity, there is a reluctance by some airlines in providing the special air report of volcanic activity form. According to the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), special air-reports containing volcanic activity shall be recorded on the special air-report on volcanic activity form. Information contained in this form is considered of particular importance to the successful operation of the VAACs due to the fact that the details related to the eruption can be deducted from the report. Therefore, the IAVWOPSG/1 concluded that airlines should be encouraged by ICAO to adhere to the existing provisions regarding the reporting, recording and post-flight reporting of aircraft observations of volcanic activity.

3.4 Space-based observations

The space-based component using satellite data is critical for the VAACs in assessing the existence and extent of volcanic ash cloud, and in detecting the initial eruption. The space-based observations have the potential for the largest scope for improvement in the future. The MET Divisional Meeting (2002) had noted with satisfaction the work being done in some States in order to improve satellite-based techniques for the detection of volcanic eruptions and volcanic ash clouds. The additional capabilities that would assist future research offered by the second-generation of METEOSAT satellites launched by EUMETSAT was also noted. The MET Divisional Meeting (2002) called for WMO to encourage VAAC Provider States to continue and, if possible, to accelerate research on the detection of volcanic ash. During the Third International Workshop on Volcanic Ash (organized by Meteo-France in 2003, in cooperation with WMO and ICAO) the latest developments on the detection of volcanic eruptions and volcanic ash by remote sensing techniques were discussed. In this regard the METEOSAT second generation satellites and the potential use of the moderate resolution imaging spectroradiometer (MODIS) and the ground-based infrared detection (G-bIRD) were highlighted. During the same workshop all parties involved in the IAVW were encouraged to continue to develop modelling technologies with the enhancement of various models.

3.2 Warning component of the IAVW

3.2.1 Areas of responsibilities of the VAACs

Each Provider State of the VAACs undertook responsibility for an area for which they generally had access to high-resolution satellite information. There are some exceptions to this, but on the whole, this was the basic principle to which most Provider States adhered. For obvious reasons, the main international air routes were covered first which still left some areas of the world uncovered. In the evolving air navigation systems, the emphasis will be on "major traffic flows" from one "homogenous area" to another, and so-called "free flight", which in theory, at least, will permit aircraft to flight plan off air routes for any flight level and routing which is considered economically attractive. It will be necessary, therefore, to ensure that the "major traffic flows" are adequately covered and eventually, most areas of the globe, in order to protect future "free flight" operations off air routes. In the actual concept of "organized tracks" the VAACs are providing adequate coverage, however, this may not be the case for the evolving ATM systems. In this regard, in response to a conclusion by the IAVWOPSG/1 Meeting, VAACs Toulouse and Washington agreed to extend their areas of responsibility in order for the IAVW to reach a quasi-global coverage. The current VAAC areas of responsibility are given in Figure 1.

3.2.2 Advisory information in graphical format

The alphanumerical and graphical formats for volcanic ash advisory information have existed for a few years. All VAACs issue volcanic ash advisory messages, but not all VAACs have implemented graphical advisories. The IAVWOPSG is currently developing a future format for graphical volcanic ash advisories to be issued by VAACs. The issuance of advisory messages in alphanumeric format continues to be essential for all VAACs because it provides a reliable means of addressing individual "offices or units" via the ICAO Aeronautical Fixed Telecommunication Network

(AFTN); graphical advisories cannot be disseminated over the AFTN. Graphical advisories are disseminated on the International Satellite Communication System (ISCS) 1 and 2 and the Satellite Distribution System for Information Relating to Air Navigation (SADIS) satellite broadcasts; however, their reception cannot be guaranteed.

3.2.3 Distribution of NOTAMS for volcanic ash

The distribution of NOTAMs for volcanic ash and ASHTAMs on the SADIS and ISCS broadcasts, was tested in July 2001. The test was successful and proved that it is, in principle, possible to route these types of messages to SADIS provided that a WMO abbreviated header is added thereto. However, in an operational environment, adding such dummy headers is not feasible and the NOTAMs will have to be processed as they are. The IAVWOPSG had agreed that ASHTAMs and NOTAMs for volcanic ash be required for uplink on the ISCS and SADIS; and that a draft amendment to Annex 15 — *Aeronautical Information Services* be developed.

3.2.4 Advisory information for airlines

Advisory information is also disseminated to airlines through an AFTN address provided specifically for this purpose. The introduction of this requirement was based on the fact that, in many cases, the first warning of the existence of an ash cloud came from the volcanic ash advisory message.

4. EFFECTS OF RECENT VOLCANIC ERUPTIONS

There has been no respite in the recent past from the occurrence of violent volcanic eruptions producing ash cloud that warranted the issuance of advisories, SIGMETs and/or NOTAMs. Since the Pinatubo eruption in 1991, the volcanoes that have caused the most difficulty for civil aviation were probably Soufriere Hills in Montserrat, Popocatepetl and Colima in Mexico, Sakurajima and Suwanosejima in Japan, Etna in Italy, Tungurahua and El Reventador in Ecuador, Sheveluch, Karimsky, Klyuchevskoi, Cleveland and Anatahan in the North Pacific Ocean and Semeru, Ruang, Dukono and Ulawun in Indonesia, some of them continue to be active. There have, however, been numerous other eruptions that have caused temporary problems, especially over the North Pacific; and there have been few weeks when the IAVW has not been activated at least somewhere in the world.

In addition to its potential to cause a major aircraft accident, the consideration of the economic cost of volcanic ash to international civil aviation is staggering. This involves numerous complete engines changes, engine overhauls, different aircraft repairs, loss of revenue due to the aircraft down-time, cost of rerouting and delays, clearance from airports and damages to equipment and buildings on the ground. On average, various estimates made calculated the costs to aviation to be well in excess of US$ 250 million between 1982 and 2000.

5. SPECIFIC PROBLEMS TO BE ADDRESSED

The following are the main issues, to be addressed within the IAVW:

- lack of sufficiently reliable and timely notification of volcanic eruptions to ACCs, MWOs and VAACS;
- communication difficulties between observing sources and ACCs, MWOs and VAACs and also between the ACCs/MWOs/VAACs themselves; and
- extension of VAAC coverage over all future “major international air traffic flows” and, eventually, all areas to support “free flight” or “dynamic aircraft routing”.

6. GUIDANCE MATERIAL

Extensive guidance has been prepared by ICAO to assist States and Users. Two documents were published by ICAO, in close cooperation with the IAVW, during the last few years. One is the *Handbook on the International Airways Volcano Watch (IAVW)* (Doc 9766) in 2000, updated in 2004, and the other is the *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691) published in 2001.

The handbook on the IAVW is an operational publication for the daily use by operational staff in the ACCs, NOFs, MWOs, VAACs and contains information regarding active volcanoes, VAACs and their responsibilities, useful websites, IAVW procedures and finally it provides the IAVW contact list. The handbook is available and kept up-to-date at the ICAO website: http://www.icao.int/anb/iavwopsg .

The main purpose of the manual is to assist States and international organizations involved in the IAVW by gathering together in one document information on the problem of volcanic ash, and to provide guidance regarding what each of the parties in the IAVW is expected to do and why. Currently ICAO, with the assistance of the IAVWOPSG, is in the process of updating the manual. It is expected that the new edition will be available in early 2005.

Additionally, ICAO produced training aids designed to support the implementation of the Standards and Recommended Practices (SARPs) related to volcanic ash. They consist of a video entitled Volcanic Ash Avoidance, and a poster entitled *Warning — if you inadvertently enter a volcanic ash cloud*.

Finally, as an example of excellent international cooperation, the *World map of volcanoes and principal aeronautical features* was issued in 1995. This world map was published by the USGS in a conjoint effort with Jeppesen Sanderson, Inc., ICAO, various US federal agencies, international organizations and individual experts involved in volcanic ash issues.

7. FUTURE DEVELOPMENTS

The most urgent issue for the IAVW in the interest of air safety is how to ensure the reliable and timely notification of volcanic eruptions. In this regard, ICAO is working closely with WMO regarding the infrasonics and seismic network established by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) to support the verification procedures. The idea is to study the feasibility by

IAVW of gaining real-time access to the CTBTO infrasonic and seismic networks to detect volcanic eruption "signatures". ICAO has been exchanging letters with the CTBTO Secretariat in this regard for the last year in support of the IAVW and in the interests of air safety. Currently the CTBTO is undertaking an assessment on the usefulness of seismic and infrasonic data from the CTBTO observing networks to the IAVW; it is expected that the final report will be sent to ICAO during the next few months.

Recently during a meeting of a working group of the WMO Commission of Basic Systems, it was indicated by the CTBTO that a potential existed as far as the use of the CTBTO network for IAVW was concerned; however, the results were preliminary with a number of unknowns.

8. CLOSING REMARKS

It can be said that, given the safety and economic implications of volcanic ash to aircraft operations, it is necessary to maintain the IAVW in much the same way that the aerodrome fire services are maintained; in constant readiness but with the fervent hope that it rarely has to be used.

APPENDIX 5. TECHNICAL SPECIFICATIONS FOR SIGMET AND AIRMET MESSAGES AND SPECIAL AIR-REPORTS

(See Chapter 7 of this Annex)

Table A5-1. Template for SIGMET and AIRMET messages and special air-reports

Key: M = inclusion mandatory, part of every message
C = inclusion conditional, included whenever applicable
= = a double line indicates that the text following it should be placed on the subsequent line

Note.— The ranges and resolutions for the numerical elements included in SIGMET/AIRMET messages and in special air-reports are shown in Table A5-2 of this appendix.

Element as specified in Chapters 5 and 7	*Detailed content*	*Template(s)*				*Examples*
		SIGMET	*SIGMET SST1*	*AIRMET*	*SPECIAL AIR-REPORT2*	
Location indicator of FIR/CTA (M)3	ICAO location indicator of the ATS unit serving the FIR or CTA to which the SIGMET/ AIRMET refers (M)	nnnn			—	YUCC4 YUDD4
Identification (M)	Message identification and sequence number5 (M)	SIGMET [nn]n	SIGMET SST [nn]n	AIRMET [nn]n	ARS	SIGMET 5 SIGMET A3 SIGMET SST 1 AIRMET 2 ARS
Validity period (M)	Date-time groups indicating the period of validity in UTC (M)	VALID nnnnnn/nnnnnn			6	VALID 221215/221600 VALID 101520/101800 VALID 251600/252200
Location indicator of MWO (M)	Location indicator of MWO originating the message with a separating hyphen (M)	nnnn				YUDO4 YUSO4
Name of the FIR/ CTA *or* aircraft identification (M)	Name of the FIR/ CTA7 for which the SIGMET/AIRMET is issued *or* aircraft radiotelephony call sign (M)	nnnnnnnnnn FIR[/UIR] *or* *nnnnnnnnnn CTA*		*nnnnnnnnnn FIR[/n]*	*nnnnnn*	*AMSWELL FIR*4 SHANLON FIR/UIR4 AMSWELL FIR/24 SHANLON FIR4 VA812
IF THE SIGMET IS TO BE CANCELLED SEE FOR DETAILS AT THE END OF THE TEMPLATE						
Phenomenon (M)8	Description of phenomenon causing the issuance of SIGMET/AIRMET (C)	OBSC9 TS [GR10] EMBD12 TS [GR] FRQ13 TS [GR] SQL14 TS [GR]	MOD TURB11 SEV TURB ISOL15 CB16 OCNL18 CB FRQ13 CB GR	*SFC WSPD nn[n]KMH (SFC WSPD nn[n]KT)* *SFC VIS nnnnM (nn)*17 ISOL15 TS[GR]10 OCNL18 TS[GR] MT OBSC	TS TSGR SEV TURB SEV ICE SEV MTW	SEV TURB FRQ TS OBSC TS GR EMD TS GR TC GLORIA VA ERUPTION MT ASHVAL LOC S15 E073 VA CLD

		TC nnnnnnnnnn SEV TURB11 SEV ICE19 SEV ICE (FZRA)20 SEV MTW21 HVY DS HVY SS VA[ERUPTION] [MT nnnnnnnnnn] [LOC Nnn[nn] *or* Snn[nn] Ennn[nn] *or* Wnnn[nn]] VA CLD	VA[ERUPTION] [MT nnnnnnnnnn] [LOC Nnn[nn] or Snn[nn] Ennn[nn] *or* *Wnnn[nn]] VA CLD*	BKN CLD nnn/[ABV]nnnnM (BKN CLD nnn/[ABV]nnnnFT) OVC CLD nnn/[ABV]nnnnM (OVC CLD nnn/[ABV]nnnnFT) ISOL15 CB16 OCNL18 CB FRQ13 CB ISOL15 TCU16 OCNL18 TCU16 FRQ13 TCU MOD TURB11 MOD ICE19 MOD MTW21	HVY SS VA CLD [FL nnn/nnn] VA [MT nnnnnnnnnn] MOD TURB11 GR10 CB16	MOD TURB MOD MTW ISOL CB BKN CLD 120/900M (BKN CLD 400/3000FT) OVC CLD 270/ABV3000M (OVC CLD 900/ABV10000FT) SEV ICE
Observed or forecast phenomenon (M)	Indication whether the information is observed and expected to continue, *or* forecast (M)	OBS [AT nnnnZ] FCST OBS [AT nnnnZ] AND FCST			OBS AT nnnnZ —	OBS AT 1210Z OBS OBS AND FCST OBS AT 2245Z
Location (C)	Location (referring to latitude and longitude (in degrees and minutes) *or* locations or geographic features well known internationally)	[N OF, NE OF, E OF, SE OF, S OF, SW OF, W OF, NW OF] [Nnn[nn]][Wnnn[nn]] or [N OF, NE OF, E OF, SE OF, S OF, SW OF, W OF, NW OF] [Nnn[nn]][Ennn[nn]] or [N OF, NE OF, E OF, SE OF, S OF, SW OF, W OF, NW OF] [Snn[nn]][Wnnn[nn]] or [N OF, NE OF, E OF, SE OF, S OF, SW OF, W OF, NW OF] [Snn[nn]][Ennn[nn]] or [N OF, NE OF, E OF, SE OF, S OF, SW OF, W OF, NW OF] nnnnnnnnnnnn			NnnnnWnnnnn or NnnnnWnnnnn or SnnnnWnnnnn or SnnnnEnnnnn	S OF N54 N OF N50 N2020 W07005 YUSB4 N2706 W07306 N48 E010
Level (C)	Flight level *and* extent22(C)	FLnnn *or* FLnnn/nnn *or* TOP FLnnn *or* [TOP] ABV FLnnn *or*[TOP] BLW FLnnn *or*23 CB TOP [ABV] FLnnn WI nnnKM OF CENTRE (CB TOP [ABV] FLnnn WI nnnNM OF CENTRE) or CB TOP [BLW] FLnnn WI nnnKM OF CENTRE (CB TOP [BLW] FLnnn WI nnnNM OF CENTRE) *or*24 FLnnn/nnn [APRX nnnKM BY nnnKM] [Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] (FLnnn/nnn [APRX nnnNM BY nnnNM] [Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]])			FLnnn	FL180 FL050/080 TOP FL390 BLW FL200 TOP ABV FL100 FL310/450 CB TOP FL500 WI 270KM OF CENTRE (CB TOP FL500 WI 150NM OF CENTRE) FL310/350 APRX 220KM BY 35KM FL390

Movement or expected movement (C)	Movement or expected movement with reference to one of the eight points of compass, or stationary (C)	MOV N [nnKMH] *or* MOV NE [nnKMH] *or* MOV E [nnKMH] *or* *MOV SE [nnKMH] or* MOV S [nnKMH] *or* MOV SW [nnKMH] *or* MOV W [nnKMH] *or* MOVNW[nnKMH] *or* *(MOV N [nnKT] or* MOV NE [nnKT] *or* MOV E [nnKT] *or* MOV SE [nnKT] *or* MOVS[nnKT] *or* MOV SW [nnKT] *or* MOV W [nnKT] *or* MOV NW [nnKT]) *or* *STNR*			—		*MOV E 40KMH* *(MOV E 20KT)* *MOV SE* *STNR*
Changes in intensity (C)	*Expected changes in intensity (C)*	*INTSF or* WKN *or* NC			—		WKN
Forecast position (C)22	Forecast position of volcanic ash cloud *or* the centre of the TC at the end of the validity period of the SIGMET message (C)	FCST nnnnZ TC CENTRE Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] *or* FCST nnnnZ VA CLD Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]]			—	—	FCST 2200Z TC CENTRE N2740 W07345 FCST 1700Z VA CLD S15 E075 TO S15 E081 TO S17 E083 TO S18 E079 TO S15 E75
Outlook22 (C)	Outlook providing information beyond the period of validity of the trajectory of the volcanic ash cloud and positions of the tropical cyclone centre (C)	OTLK nnnnnn TC CENTRE Nnnnn *or* SnnnnWnnnnn *or* Ennnnn nnnnnn TC CENTRE Nnnnn *or* SnnnnWnnnnn *or* Ennnnn *or* OTLK nnnnn VA CLD APRX [Flnnn/nnn]25 Nnn[nn] *or* Snn[nn] Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] nnnnnn VA CLD APRX Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]] [TO Nnn[nn] *or* Snn[nn]Wnnn[nn] *or* Ennn[nn]]					OTLK 260400 TC CENTRE N28030 W07430 261000 TC CENTRE N3100 W07600 OTLK 212300 VA CLD APRX S16 E078 TO S17 E084 TO S18 E089 TO S19 E081 TO S16 E078 220300 VA CLD APRX S17 E81 TO S18 E86 TO S20 E92 TO S21 E84 TO S17 E81
OR							
Cancellation of SIGMET/ AIRMET26 (C)	Cancellation of SIGMET/AIRMET referring to its identification	CNL SIGMET [nn]n nnnnnn/nnnnnn	CNL SIGMET SST [nn]n nnnnnn/nnnnnn	CNL AIRMET [nn]n nnnnnn/nnnnnn	—		CNL SIGMET 2 101200/10160026 CNL SIGMET SST 1 212330/22013026 CNL AIRMET 151520/ 15180026

Notes.–

1. Only for transonic and supersonic flights.
2. Automated special air-reports also include information on wind and temperature which does not need to be uplinked to other aircraft in flight.
3. In cases where the airspace is divided into a flight information region (FIR) and an upper flight information region (UIR), the SIGMET is identified by the location indicator of the air traffic services unit serving the FIR; nevertheless, the SIGMET message applies to the whole airspace within the lateral limits of the FIR, i.e. to the FIR and to the UIR. The particular areas and/or flight levels affected by the meteorological phenomena causing the issuance of the SIGMET are given in the text of the message.
4. Fictitious location.
5. Corresponding with the number of SIGMET/AIRMET messages issued for the FIR/CTA since 0001 UTC on the day concerned.
6. Special air-reports are to be uplinked for 60 minutes after their issuance.
7. Or a sub-area thereof in the case of AIRMET messages.
8. Only one of the weather phenomena listed should be selected and included in each SIGMET.

9. Obscured (OBSC) indicates that the thunderstorm (including, if necessary, cumulonimbus cloud which is not accompanied by a thunderstorm) is obscured by haze or smoke or cannot be readily seen due to darkness.
10. Hail (GR) may be used as a further description of the thunderstorm as necessary.
11. Severe and moderate turbulence (TURB) refers only to: low-level turbulence associated with strong surface winds; rotor streaming; or turbulence whether in cloud or not in cloud (CAT) near to jet streams. Turbulence is not required to be used in connection with convective clouds. Turbulence is considered:
   a) severe whenever the turbulence index is between 15 and 27 (i.e. the peak value of the eddy dissipation rate (EDR) exceeds 0.5); and
   b) moderate whenever the turbulence index is between 6 and 14 (i.e. the peak value of the eddy dissipation rate (EDR) exceeds 0.3 while not exceeding 0.5).
12. Embedded (EMBD) indicates that the thunderstorm (including cumulonimbus cloud which is not accompanied by a thunderstorm) is embedded within cloud layers and cannot be readily recognized.
13. Frequent (FRQ) indicates an area of thunderstorms within which there is little or no separation between adjacent thunderstorms with a maximum spatial coverage greater than 75 per cent of the area affected, or forecast to be affected, by the phenomenon (at a fixed time or during the period of validity).
14. Squall line (SQL) indicates thunderstorm along a line with little or no space between individual clouds.
15. Isolated (ISOL) indicates an area of individual cumulonimbus and/or thunderstorms with a maximum spatial coverage less than 50 per cent of the area affected, or forecast to be affected, by the phenomenon (at a fixed time or during the period of validity).
16. The use of cumulonimbus, CB, is restricted to AIRMETs and SIGMETs related to SST flight during transonic and supersonic cruise; the use of towering cumulus, TCU, is restricted to AIRMETs.
17. The weather phenomenon causing the reduction in visibility in brackets; choose one from the following list: DZ, RA, SN, SG, PL, IC, GR, GS, FG, BR, SA, DU, HZ, FU, VA, PO, SQ, FC, DS or SS.
18. Occasional (OCNL) indicates an area of well-separated cumulonimbus and/or thunderstorms with a maximum spatial coverage between 50 and 75 per cent of the area affected, or forecast to be affected, by the phenomenon (at a fixed time or during the period of validity).
19. Severe and moderate icing (ICE) refers to severe icing in other than convective clouds.
20. Freezing rain (FZRA) refers to severe icing conditions caused by freezing rain.
21. A mountain wave (MTW) is considered:
   a) severe whenever an accompanying downdraft of 3.0 m/s (600 ft/min) or more and/or severe turbulence is observed or forecast;
   b) moderate whenever an accompanying downdraft of 1.75–3.0 m/s (350–600 ft/min) and/or moderate turbulence is observed or forecast.
22 Only for SIGMET messages for volcanic ash cloud and tropical cyclones.
23. Only for SIGMET messages for tropical cyclones.
24. Only for SIGMET messages for volcanic ash.
25. Up to four layers (or levels) to be included in the SIGMET outlook for volcanic ash.
26. End of the message (as the SIGMET/AIRMET message is being cancelled).

General Note.— Severe or moderate icing and severe or moderate turbulence (SEV ICE, MOD ICE, SEV TURB, MOD TURB) associated with thunderstorms, cumulonimbus clouds or tropical cyclones should not be included.

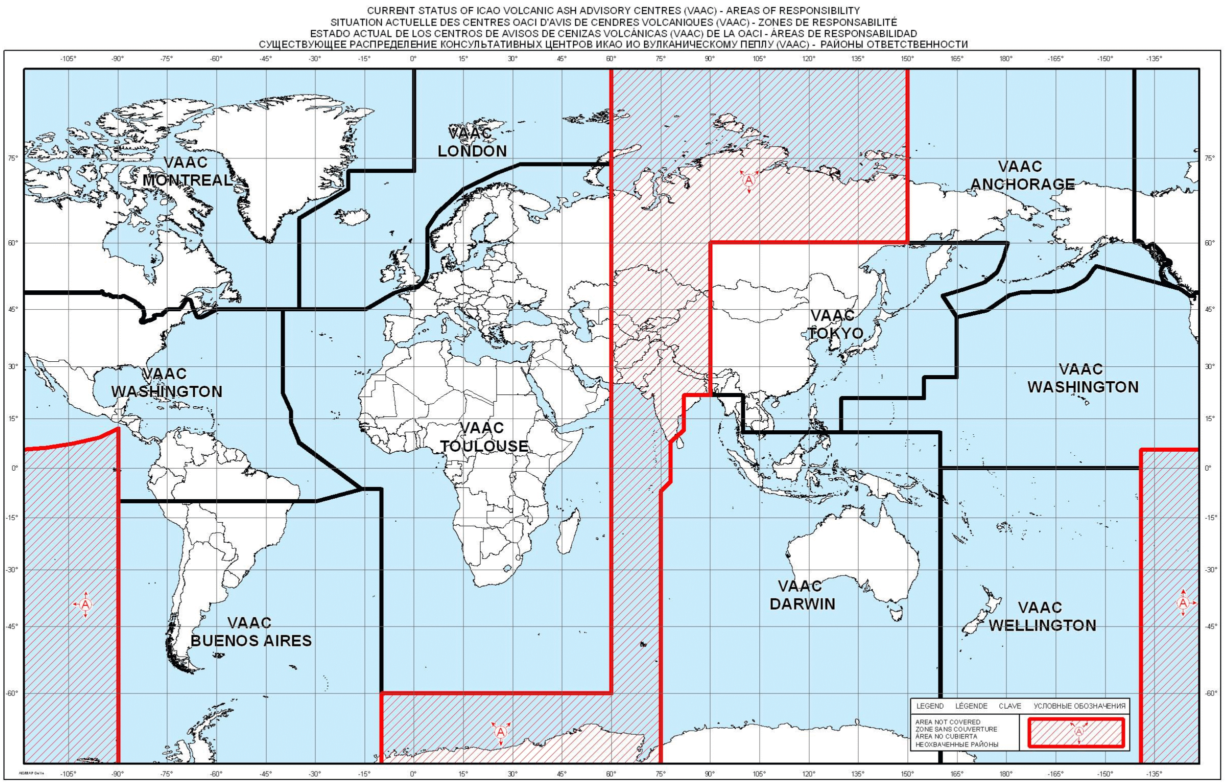
ADVISORY MESSAGE FOR VA

VOLCANIC ASH ADVISORY
ISSUED: 20000402/0700Z
VAAC: TOKYO
VOLCANO: USUZAN 805-03
LOCATION: N4230E14048
AREA: JAPAN
SUMMIT ELEVATION: 732M
ADVISORY NUMBER: 2000/432
INFORMATION SOURCE: GMS JMA
AVIATION COLOUR CODE: RED
ERUPTION DETAILS: ERUPTED 20000402/0614Z ERUPTION OBS ASH TO ABV FL300
OBS ASH DATE/TIME: 02/0645Z
OBS ASH CLD: FL150/350 N4230E14048-N4300E14130-N4246E14230-N4232E14150-N4230E14048
SFC/FL150 MOV NE 25KT FL150/350 MOV E 30KT
FCST ASH CLD + 6 HR: 02/1245Z SFC/FL200 N4230E14048-N4232E14150-N4238E14300-N4246 E14230
FL200/350 N4230E14048-N4232E14150N4238E14300-N4246E14230
FL350/600 NO ASH EXP
FCST ASH CLD + 12 HR: 02/1845Z SFC/FL300 N4230E14048-N4232E14150-N4238E14300-
N4246E14230 FL300/600 NO ASH EXP
FCST ASH CLD + 18 HR: 03/0045Z SFC/FL600 NO ASH EXP
NEXT ADVISORY: 20000402/1300Z
REMARKS: ASH CLD CAN NO LONGER BE DETECTED ON SATELLITE IMAGE

SIGMET FOR VA

YUDD SIGMET 2 VALID 211100/211700 YUSO-
SHANLON FIR/UIR VA ERUPTION MT ASHVAL LOC E S1500 E07348 VA CLD OBS AT 1100Z
FL310/450 APRX 220KM BY 35KM S1500 E07348E TO S1530 E07642 MOV ESE 65KMH FCST 1700Z VA
CLD APRX S1506 E07500 TO S1518 E08112 TO S1712 E08330 TO S1824 E07836
OTLK 212300Z VA CLD APRX S1600 E07806 TO S1642 E08412 TO S1824 E08900 TO S1906 E08100
220500Z VA CLD APRX S1700 E08100 TO S1812 E08636 TO S2000 E09224 TO S2130 E08418

FIGURE 1


CURRENT STATUS OF ICAO VOLCANIC ASH ADVISORY CENTRES (VAAC) - AREAS OF RESPONSIBILITY
SITUATION ACTUELLE DES CENTRES OACI D'AVIS DE CENDRES VOLCANIQUES (VAAC) - ZONES DE RESPONSABILITÉ
ESTADO ACTUAL DE LOS CENTROS DE AVISOS DE CENIZAS VOLCÁNICAS (VAAC) DE LA OACI - ÁREAS DE RESPONSABILIDAD
СУЩЕСТВУЮЩЕЕ РАСПРЕДЕЛЕНИЕ КОНСУЛЬТАТИВНЫХ ЦЕНТРОВ ИКАО ИО ВУЛКАНИЧЕСКОМУ ПЕПЛУ (VAAC) - РАЙОНЫ ОТВЕТСТВЕННОСТИ
VAAC MONTREAL
VAAC LONDON
VAAC ANCHORAGE
VAAC TOKYO
VAAC WASHINGTON
VAAC TOULOUSE
VAAC WASHINGTON
VAAC DARWIN
VAAC BUENOS AIRES
VAAC WELLINGTON
LEGEND LÉGENDE CLAVE УСЛОВНЫЕ ОБОЗНАЧЕНИЯ
AREA NOT COVERED
ZONE SANS COUVERTURE
ÁREA NO CUBIERTA
НЕОХВАЧЕННЫЕ РАЙОНЫ

THE WORLD METEOROLOGICAL ORGANIZATION (WMO) ACTIVITIES RELATED TO VOLCANIC ASH

Mr. Saad Benarafa, World Meteorological Organization,
Geneva, Switzerland

ABSTRACT

This paper provides the main thrusts of the World Meteorological Organization (WMO) activities related to volcanic ash. The WMO Emergency Response Activities (ERA) Programme objectives are presented and the involvement of the WMO designated Regional Specialized Meteorological Centers (RSMCs) is highlighted. The excellent cooperation with the International Civil Aviation Organization (ICAO) regarding the international airways volcano watch is also highlighted

The World Meteorological Organization (WMO) is one of the various stakeholders involved in volcanic ash and aviation safety. The WMO Emergency Response Activities (ERA) Programme is being implemented to assist National Meteorological and Hydrological Services (NMHSs), other relevant agencies of WMO Member countries and international organizations to respond effectively to environmental emergencies related to large-scale transboundary air pollution, caused in particular by major nuclear accidents, volcanic eruptions, and land fires. This programme is implemented through the provision of specialized Global Data Processing and Forecasting System products by 29 designated WMO Regional Specialized Meteorological Centers (RSMCs). This programme also includes the development and implementation of procedures for the provision and exchange of specific observational data, and related training support for users. The WMO Fourteenth Congress (Cg-XIV) held in May 2003, decided to expand the ERA Programme to include, in particular, chemical accidents.

Through the ERA Programme under the auspices of the World Weather Watch and the Global Atmospheric Watch Programme (GAW) being implemented under the Atmospheric Research and Environment Programme (AREP), WMO will continue to support its Members to develop the appropriate environmental prediction tools to prepare and strengthen their capability to advise Member countries relevant national authorities when required. In this regard , the “ensemble” approach for predicting the atmospheric transport and dispersion of tracers is being explored for emergency response applications and WMO constituent bodies are encouraging RSMCs to further develop and test new technologies such as ensemble methods, new products to satisfy growing requirements and the use of the Internet for the information exchange.

In line with its excellent cooperation with ICAO regarding aviation safety, WMO has been actively participating in activities undertaken by the ICAO International Airways Volcano Watch Operations Group (IAVWOPSG). In this context, ICAO has been benefiting from results of the specialized atmospheric transport modeling of airborne volcanic ash conducted under WMO auspices. Products generated from transport models are essential for supporting the operations of the International Airways Volcano Watch Programme

In response to Recommendation 1/18 of the Conjoint WMO CAeM Session/ICAO/Meteorology Divisional Meeting (2002), related to the completion of the assessment of the usefulness of seismic and infrasonic data from the Comprehensive Test Ban Treaty Organization (CTBTO) monitoring networks detecting explosive volcanic eruptions, a report on this assessment, that will not include a definitive conclusion, is expected to be sent by CTBTO to ICAO and WMO in the near future. If the assessment concludes that the provision of CTBT data is of use to the IAVW and thus worth implementing operationally, it would be necessary to prepare a "road map", which would lead to the implementation of operational arrangements between CTBTO, ICAO and WMO.

NOAA'S NWS VOLCANIC ASH PROGRAM: CURRENT STATUS AND PLANS FOR THE FUTURE

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Operationally, the National Oceanic and Atmospheric Administration (NOAA) plays an important role in the worldwide volcanic ash network through the operation of two of the world's nine Volcanic Ash Advisory Centers (VAACs) and four Meteorological Watch Offices (MWO). The operational responsibilities of these two VAACs are defined in the International Civil Aviation Organization (ICAO) Annex 3. The Washington VAAC is jointly managed by the National Environmental Satellite, Data and Information Service (NESDIS) Satellite Analysis Branch and the National Weather Service's (NWS) National Centers for Environmental Prediction (NCEP). The Anchorage VAAC is managed by the NWS' Alaska Aviation Weather Unit. Together, these centers are responsible for providing volcanic ash advisories and ash dispersion forecasts for a wide area ranging from the Pacific Ocean eastward over the U.S and much of the Atlantic Ocean. Research and development efforts in support of those operations include (but are not limited to) assets from NOAA's NCEP, NESDIS, Forecast Systems Laboratory, Air Research Laboratory and U.S. Geological Survey. With regards to policy, NOAA's Volcanic Ash Program has a responsibility to meet both U.S. and international customers' needs by ensuring product content, dissemination and coordination procedures remain consistent and compatible with ICAO standards. This presentation will examine NOAA's NWS Volcanic Ash Program, discussing the current status and future plans in the areas of operations, research/development, and policy development.

VOLCANIC ASH IMPACT ON INTERNATIONAL AIRPORT OF MEXICO CITY (AICM), DUE TO EMISSIONS OF POPOCATEPETL VOLCANO

Humberto Rodríguez, DMTA of SENEAM, México, D. F. México.

ABSTRACT

Since 1995, the CAPMA of SENEAM, which is the main office of the Aviation Weather Service in Mexico, has been issued SIGMETS of volcanic ash. At present, most of the SIGMETS were issued due to emissions of Popocatepetl volcano. Since that time Popocatepetl volcano has had several erupted events some of them have threatened the safety of the aviation . In this work we are going to comment two important eruptions: (1) The event occurred on June 30, 1997, where the AICM was closed for about 10 hours and (2) The July 19, 2003 event. The collaboration from VAAC of Washington, CENAPRED in Mexico City and The Air Traffic Service (ATS) of SENEAM has been essential to alert the pilots and flight dispatchers about volcanic ash plumes. However, we still have lack of tools and techniques to track more efficiently the volcanic ash plumes.

INTRODUCTION

Since December 21, 1994, Popocatepetl volcano started another eruptive stage. This obligated authorities of Civil Aviation, AICM (Aeropuerto Internacional de la Ciudad de Mexico - International Airport of Mexico City), and SENEAM (Servicios a la Navegación en el Espacio Aéreo Mexicano), among others entities, to restrict flight operations around 10 NM from volcano crater. Also, a contingency plan was issued to prevent and minimize the threat of volcanic ash plumes. The CAPMA (Centro de Análisis y Pronósticos Meteorológicos Aeronáuticos - Analysis and Forecasting Meteorological Center for Aviation) of SENEAM, which is the main meteorological office of the Aviation Weather Service in Mexico was designated the responsible to gather information of volcanic activity an also responsible to issue the volcanic ash SIGMETS. The CAPMA receives information and reports from CENAPRED (Centro Nacional de Prevención de Desastres - National Center for Disaster Prevention), Weather Observers, Controllers, Pilots, Civil Protection and VAAC of Washington. The coordination between the VAAC of Washington and CAPMA is so important and it has been improved since we had the June 30, 1997 event. CAPMA of SENEAM has a procedure, which is followed carefully when a volcanic ash plume is reported. This is important because we can alert with more opportunity to airlines and pilots. In this work we try to discuss two cases related with volcanic ash that have impacted the AICM and emphasize the roll of aeronautic meteorology in the prevention of these phenomena. Also, to show the economic impact they caused to aeronautical operations in Mexico.

POPOCATEPETL VOLCANO FEATURES

- It is located about 35NM (64.8km) southeast of International Airport of Mexico City. See Fig. 1.
- It has an age of 700,000 years (CENAPRED, 1995)
- Its geographical position is: 19.0°N and 98.6ºW
- Popocatepetl means “Smoking Mountain”
- Elevation: 5,465 m (17,930 ft).

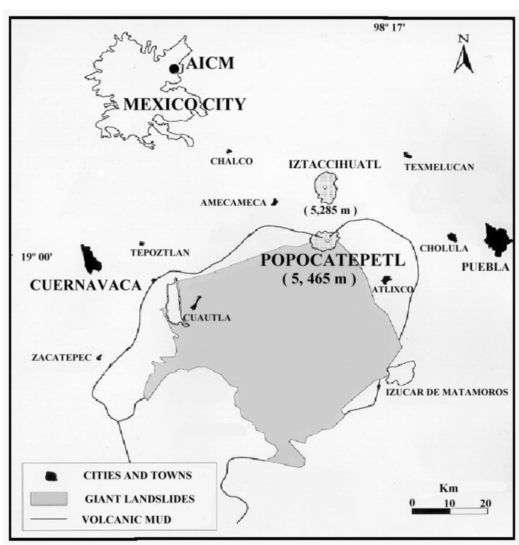

Fig. 1: Location of Popocatepetl volcano (source: CENAPRED).

AICM FEATURES

- About 830 operations take place daily.
- In 2003 about 21 million passengers used the AICM.
- It is located in the Northeast Mexico City area, at 35NM northwest of Popocatepetl volcano.
- Elevation: 2,229m (7,316 ft).
- Geographical location: 19°25'N and 99°05'W.

THE JUNE 30, 1997 CASE

Popocatepetl volcano is so close to Mexico City and consequently close to the "Benito Juarez" International Airport of Mexico City (AICM). This means the constant threat of volcanic ash plumes due to summer circulation which has a East/Southeast (E/SE) wind component in the low and middle levels of the atmosphere, between May to October months of each year.

There are no records in the history of AICM that indicate the volcanic ash has impacted the Airport of Mexico City like the case we are going to discuss. As we pointed before, Popocatepetl volcano started with some important activity at the end of 1994. During the years of 1995 to 1996 occurred some considerable eruptions. However, in the evening of June 30, 1997 a big one was present. At 19:26 hrs. LT (0026 UTC), the crew of AVIACSA airline reported that a large volcanic ash plume from Popocatepetl was moving to Mexico City. This was the first report received in the CAPMA of SENEAM. Few minutes later, at 19:30 hrs. LT (0030 UTC), a report from CENAPRED, confirmed the eruption indicating the ash column reached, in few minutes, a high of 8km from volcano crater (De la Cruz-Reyna and Quaas, 1997). That means the ash column reached an altitude of more than 40,000 ft.

According to sounding of Mexico City of July 01, 1997 at 0000 UTC, at middle levels we had winds with a component of the east with 20knots (kt), meanwhile in upper levels (25,000 to 40,000 ft), the winds had a direction from southeast with an intensity of 15 kt. This sounding showed a deep layer of 7km of moisture (around 4.7km thickness). The weather reports (METAR) from AICM indicated a ceiling conditions of broken of low clouds, overcast of middle clouds and light rain. These weather conditions presented to observers a difficulty to evaluate what was going on that evening. On the other hand, the convective clouds covering Popocatepetl volcano did not allow us to observe the ash plume in the GOES-8 satellite infrared imagery. The ash started to fall around 0110 UTC over the AICM and ending at 0645 UTC. We recognize that this surprised event caused some confusing among the personal who work at the AICM because it was the first time we had an event like this. The Local Security committee of AICM determined to close the airport at 21:20 hrs. LT (0220 UTC).

The Air Traffic Services of SENEAM prepared 10 airports as alternative airports to receive the deflected flights. The AICM was closed for about 10 hours. At 07:13 hrs. LT (1213 UTC) of July 1, 1997 the International Airport of Mexico City started operations using the 05R runway. To clean up the runways was a difficult mater, we had to use brooms to sweep the dust and particles of volcanic ash from the runways surface. The aeronautical operations of AICM were recovering gradually. At 16:13 hrs LT (2113 UTC), the runway 05L was opened to air traffic (DGAC, 1997).

This event caused a lot of damage and losses to aeronautical industry in Mexico. Table 1, shows us the economic impact that emissions of Popocatepetl volcano caused on June 30, 1997. The experience left by this eruption was taking into account and it has allowed us to improve our contingency plans in order to face with more efficiency episodes like these, that can happen again at any time.

Table 1: Economic Impact at AICM, June 30, 1997.

CONCEPT	AMOUNT	LOSSES ($USD)
WINDSHIELD DAMAGED	22	132,000.00
ENGINE DAMAGED	3	2,588,417.00
PASSENGERS AFFECTED	19, 000	
DELAYS	15,957 minutes	515,781.00
LOSSES DUE TO AFFECTED PASSENGERS		588,643.00
AIRLINE LOSSES		1,351,994.00
CANCELED FLIGHTS	205	
DELAY FLIGHTS	284	
DEFLECTED FLIGHTS	19	
AIRPORT CLOSED	10 HRS.	

Source: DGAC, SCT, 1997.

THE JULY 19, 2003 CASE

In this case, as the previous one, the trade winds were the cause of volcanic ash plume moves to Mexico City. That day of July 19, 2003, CENAPRED reported the event started at 09:20 hrs LT (1420 UTC) with a dense volcanic ash column which reached an altitude of more than 28,000 ft (CENAPRED, 2003).

The sounding of Mexico City (MEX) of July 19, 2003 at 1200 UTC, showed a wind profile with an east component almost in all levels with 10 to 15 kt speed. Because of this circulation the ash plume was forced to move to central and south areas of Mexico City. Fortunately, with this situation the AICM was less affected than the event of June 30, 1997. This pattern of wind was determinant to carry out the volcanic ash, mainly to Mexico City. The volcanic ash arrived AICM at 13:25hrs. LT (1825UTC). In other scenery, with a wind pattern like shown by the sounding of MEX at 1200Z of July 20, 2003, the impact on AICM had been devastate due to the wind direction, it was from the southeast, in the middle and upper levels of the atmosphere, with an intensity of 15kt. Fortunately this circulation occurred the next day of the event, so that, no ash emission occurred

The weather observations (METAR) of MEX reported, almost for five hours, from 191825Z to 192203Z, light volcanic ash fallen on AICM. Even with this condition, the visibility was ranging between 5 to 6 statute miles. Also, these weather reports indicated the ash plume was moving westward . In comparison with the June 1997 case, in this event the AICM was working nearly in normal conditions. The International Airport of Mexico City was closed only for 6 minutes, between 191832Z to 191838Z (ATS of SENEAM records, 2003). The airline with more delays was AEROMAR (Lydia Robles, 2004, personal communication). Table 2 shows the economic impact caused by the eruption of Popocatepetl volcano. No damage to windshield and engine of aircrafts were reported.

Table 2: Economic impact at AICM, July 19, 2003.

CONCEPT	AMOUNT	LOSSES ($USD)
PASSENGERS AFFECTED	380	
DELAYS	70 minutes	
AIRLINE LOSSES		19,250.00
CANCELED FLIGHTS	1	
DELAY FLIGHTS	2	
AIRPORT CLOSED	6 minutes	

Source: Airlines and ATS of SENEAM, 2004

CONCLUSIONS

We have learned a lot from the experiences left by these two cases. After this events we have to improve and verify our procedures and contingency plans to prevent as possible, the threat and effects of volcanic ash plumes. Some of the most important conclusions are pointed below:

- The aviation safety must be our first priority.
- Alert Pilots and Airlines, as soon as possible, about volcanic ash plumes to mitigate negative impacts like those discussed here.
- The communication and coordination between CAPMA and VAAC of Washington, CENAPRED, ATS, and DGAC have been improved significantly, since the June 30, 1997 event.
- Maintain a permanent volcano watch.
- Improve our contingency plans.
- Continuos training for operational meteorologists.
- The need of appropriate equipment such as: Wind profiler, Doppler Weather Radar, Software to analyze satellite data, etc.

ACKNOWLEDGMENTS

I would like to thank the USGS, NOAA, OFCM among others entities for their support to participate in the 2nd. International Conference on Volcanic Ash and Aviation Safety. Also, to thanks Authorities of SENEAM who gave me the permission to attend this important meeting. And finally, thanks to Grace Swanson, from VAAC of Washington, who is the person we have received a great collaboration in this matter.

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THE DARWIN VAAC VOLCANIC ASH WORKSTATION

Rodney Potts[1], Mey Manickam[1], Andrew Tupper[2] and Jason Davey[2]
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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

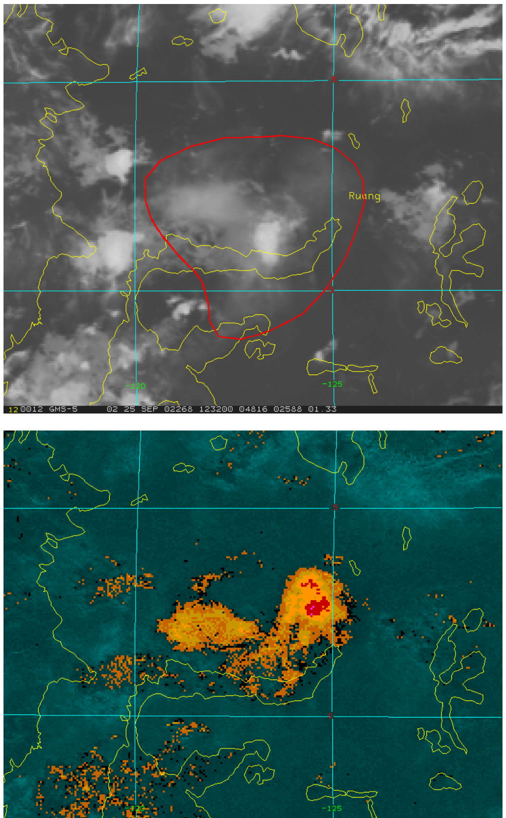

Figure 1. GMS-5 satellite imagery for 1230 UTC, 25 Sep 2002, showing Ruang eruption cloud. (a) IR1 image with manually analysed boundary of ash plume, and (b) image of brightness temperature difference (IR1-IR2) with blue indicating positive differences and orange/red indicating negative differences.

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.

The Darwin Volcanic Ash Warning Preparation System (VAWS)

The Volcanic Ash Warning Preparation System (VAWS) has been developed to enable more integrated 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 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

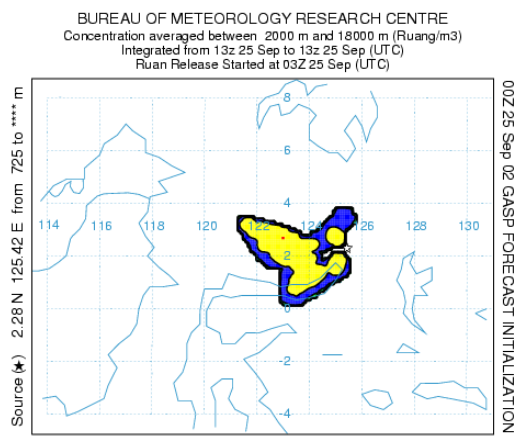

Figure 2. Hysplit dispersion model forecast for 1300 UTC, 25 September 2002 based on eruption at 0345 UTC.

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.

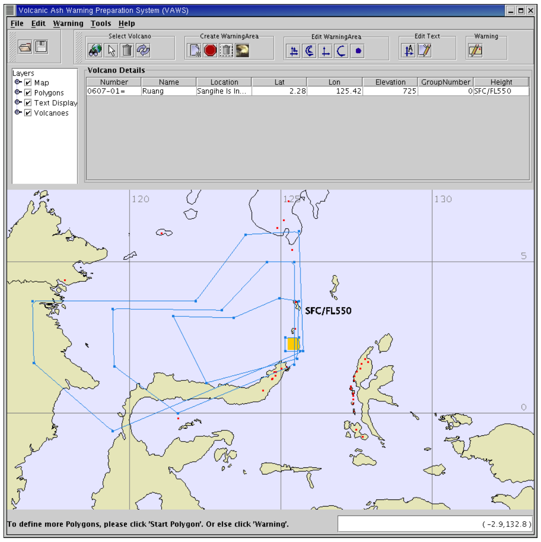

Figure 3. Graphical interface for Volcanic Ash Warning Preparation System.

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

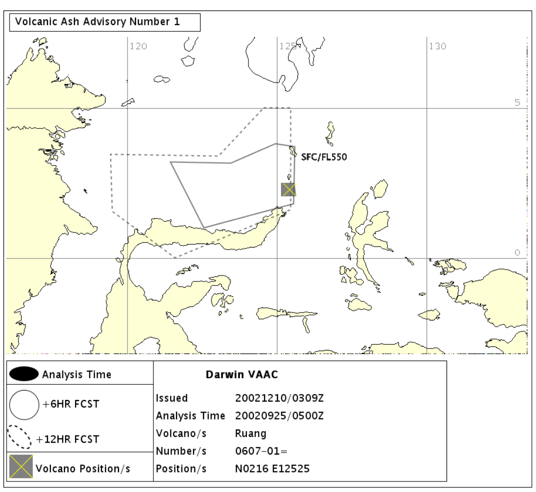

Figure 4. Volcanic Ash Advisory graphical product.

ash dispersion model using a concept of layers; and, the need to archive relevant information for training purposes and for ongoing research and development.

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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SHARED SITUATIONAL AWARENESS AND COLLABORATION THROUGH THE USE OF THE VOLCANIC ASH COLLABORATION TOOL (VACT)

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There are approximately 100 historically active volcanoes located in an area stretching from Alaska to the Northern Kurile Islands. Many of these volcanoes are located within close proximity to the major North Pacific (NOPAC) jet routes that traverse the Pacific Ocean. Aircraft flying at speeds of 500 mph or greater coupled with the close proximity of these historically active volcanoes to the jet routes, creates a potentially serious hazard to aviation with potentially rapid ash encounters. This situation requires a highly accurate and rapid response in volcanic ash plume forecasting to the aviation community. Several groups are responsible for monitoring and forecasting volcanic ash in the North Pacific area. It is imperative that all agencies speak with "one voice" with regard to plume height, aerial extent and movement. In order to facilitate real-time collaboration during North Pacific eruptions, a pilot project was instituted in 2003 to develop the Volcanic Ash Collaboration Tool (VACT). The VACT consists of workstations located at the Anchorage VAAC, the Anchorage Center Weather Service Unit, and the USGS Alaska Volcano Observatory, with shared access to satellite and meteorological data. The VACT allows for shared situational awareness by providing common views of the data sources, and by allowing all groups to view, enhance and annotate graphical data. The project team is continuing to define requirements for the system with implementation through rapid software updates. This presentation will provide an overview of the VACT, demonstrate some of its current and future capabilities, and propose how a system such as this could enhance collaboration between international agencies.

PERSPECTIVES ON OPERATIONAL VOLCANIC ASH WARNINGS

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ABSTRACT

MetService is directly involved in many aspects of volcanic ash warnings for a large part of the South Pacific Ocean and for New Zealand, and has a long history of involvement with the International Airways Volcano Watch (IAVW). MetService operates the Wellington VAAC and is the operational co-ordinator of the New Zealand domestic Volcanic Ash Advisory System (NZ VAAS). This is a local enhancement of the Wellington Volcanic Ash Advisory Centre (VAAC). MetService personnel have actively participated in the work of the ICAO ASIA/PAC Working Group on Volcanic Ash and successor groups. MetService undertakes a National Meteorological Service (NMS) role under contract to the New Zealand Government. It also provides a wide range of commercial services to the media, the general public, industry and to aviation. As a service provider in these roles, combined with a long and active involvement with ICAO and WMO, there have been lessons learned over many years and perspectives gained. This paper offers some of these perspectives in terms of international aspects of warning services, the structure of warning systems, development of customised services, what seems to work for users and what doesn't.

1. Introduction

The Meteorological Service of New Zealand in Wellington provides a Meteorological Watch Office (MWO) and a Volcanic Ash Advisory Centre (VAAC). As such we provide SIGMETs and Volcanic Ash Advisory (VAA) messages. Work is ongoing to improve these messages and warnings by increasing the quality of the information used to generate these messages, understanding the limitations associated with such information and gaining an understanding of user needs.

The Wellington VAAC area covers much of the Southwest Pacific Ocean. The area encompasses our own FIR along with parts of the FIR areas of Honiara, Nauru, Nadi and Tahiti. This, along with the fact that parts of our VAAC area are remote and some of the volcanoes are not monitored, presents a challenge that we work hard to face. High quality information about volcanic activity is available within New Zealand but it is sometimes difficult to obtain such information from the outer reaches of our VAAC area.

The VAA format, VA SIGMETs, our operational experience via a real example and lessons we have learned from interaction with the aviation industry will be discussed.

2. The Volcanic Ash Advisory format and VA SIGMETs.

It is fair to say that there is some ambiguity regarding the role of the VAA and it's content. In some cases the VAA seems to be used as a volcanic ash warning for aviation, thus extending its role beyond what was originally envisaged. Warnings for aviation, whether they pertain to severe icing, turbulence or volcanic ash have traditionally been disseminated as SIGMETs. MWO offices in some parts of the world do not always issue SIGMET warnings about volcanic ash. This problem has in some cases been addressed, by including information, which would normally be contained within a SIGMET, in the VAA.

The view of the MetService is that the VAA should remain a mechanism for sharing scientific information between VAA Centres and MWOs. Warnings for aviation should be contained within SIGMETs and if volcanic ash SIGMETs are not being issued for one reason or another, then steps should be taken to rectify that situation.

Also, it is our opinion that the current format can sometimes contribute to unrealistic expectations regarding the accuracy of the advisory. In many cases the ash envelope can not be specified 6,12 and 18 hours forward in time with great precision. It is easy for end users to gain the impression that if the ash envelope is specified by an area bounded by points in degrees and minutes of latitude/longitude, then this information can be trusted to the extent that flights can be planned directly adjacent to the forecast ash envelope area. This is a dangerous practice because of the uncertainties involved in forecasting the dispersion of an ash envelope. Information regarding the initial ash plume height may be missing or of poor quality and atmospheric forecast models do not always forecast winds correctly.

Given these facts the VAA format should be simplified and there should not be a demand for such precise forecasts of the ash envelope, 6,12 and 18 hours forward in time.

We should work to improve our capabilities but we should not imply that we are capable of something that we are in fact not.

2. The eruption of Lopevi in June 2003

Lopevi is one of many active volcanoes located in the Republic of Vanuatu in the Southwest Pacific. This region is important for international aviation since flight routes between the United States and Australia cross it. It lies within the Wellington VAAC area.

Vanuatu has few resources for monitoring volcanoes and timely, accurate and reliable observations can not be always be expected.

Lopevi is not monitored by seismographs and no warning or indication was received in the Wellington VAAC before the volcano actually erupted on the 8th of June 2003. An airborne observer at 5,000 feet made the initial observation and reported ash up to above 40,000 feet. "A massive rate of growth and a black/brown plume becoming white at high altitude".

This report raises the question, how did an observer at 5,000 feet estimate that the ash rose to above 40,000 feet? The actual height of the ash plume is of course a critical piece of information. This needs to be known with a fair degree of accuracy in order to be able to forecast the dispersion of the ash. Of course the height of the ash plume also needs to be known to ascertain the impact on aviation. Will it be possible to fly above the plume or must it be avoided altogether?

These can quickly become important questions from an operational point of view. Whether or not trans Pacific flights will have to be diverted or not may hinge upon the answers. One such diversion can easily cost more than $US 100,000. The cost would of course be much greater should a flight actually encounter volcanic ash, exposing passengers and crew to danger and making repairs necessary to aircraft costing tens of millions of dollars.

We were not able to verify the initial observation by using satellite imagery and we did not receive any other observations at the time. Therefore we had to base our assumptions on the initial observation being true.

During the 7 days this eruption lasted, we only received 7 direct observations and only two of these mentioned ash above 10,000 feet.

This example highlights the uncertainties and difficulties involved in forecasting ash dispersion from volcanoes in remote areas. VA advisories can sometimes give little more than rough estimates of ash envelopes. Specifying envelopes far into the future with high precision can be misleading. Computer models have achieved a high level of performance. It must however not be forgotten that when initial observations are of poor quality, then output from the models will reflect this.

It is important that end users know as much as possible about volcanic ash and its impact on aviation. They also need to understand what VA advisories are, and the limitations associated with them.

3. What could be improved?

The most important factor that contributes to being able to provide timely and accurate information about volcanic ash is close collaboration by all agencies involved. Civil aviation authorities, Geological and Meteorological services need to keep in contact in order to assure a smooth fast flow of information whenever the need arises.

If MWOs are unable to issue VA SIGMETs for some reason, then they need to be helped to do so.

Everyone needs education. Typical eruption patterns for major volcanoes, effects of volcanic ash, uncertainties involved in ash envelope forecasting, etc. need to be known by all involved.

Observations need to be improved. Advances in remote sensing need to be utilised. The importance of direct observations must not be forgotten. Reconnaissance flights by light aircraft are relatively inexpensive compared to many other means of observing volcanic ash, and should be exploited where possible.

4. The situation within New Zealand

A comprehensive system for monitoring and observing volcanoes and a system for interaction between agencies involved is in place in New Zealand. This is provided through interaction between aircraft operators, the Civil Aviation Authority of New Zealand, Airways Corporation New Zealand, the Institute of Geological and Nuclear Sciences and the Meteorological Service of New Zealand. Issues illustrated in the Lopevi case do not present problems within New Zealand.

5. Summary

Timely, simple, accurate and realistic warnings are what end users need and this is what we should strive to provide. Nothing is gained by unnecessary complication that can fuel unrealistic expectations and cause confusion.

Communications between all the agencies concerned with VA warnings need to be maintained and strengthened. Good working relationships should be developed. Advances in remote sensing must be monitored and utilised if they are to increase our ability to detect ash. A course of action that could lead to significant advances in volcanic ash forecasting is to improve monitoring, observations and contacts with people in areas outside New Zealand.

VOLCANIC CLOUD CONCEPTUAL MODELS FOR VOLCANIC ASH ADVISORY CENTRE OPERATIONS

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Abstract

Volcanic Ash Advisory Centre operations are hampered by limited ground-based monitoring, imperfect remote sensing, and few reliable direct observations. These issues are fundamental and must be addressed to improve the warning service. However, it is also essential to maximise our use of the information available. A basic approach to factual uncertainty in operational meteorology is to develop conceptual models and related procedures that allow fast diagnosis of the nature of an event, the degree of risk, and the action required. The height of rise of a volcanic cloud, concentration of maximum ash, detectability of the cloud, cloud evolution and rate of ash deposition are all highly dependent on the meteorological environment. Therefore, we must consider how, given an assumed level of volcanic activity, a volcanic cloud will develop in its meteorological context. Here, we use ground and aircraft based video observations from Japan and the Philippines, remote sensing of the Pinatubo 'Volcanic Thunderstorms' using particle radius measurement techniques, and results from the Active Tracer High Resolution Atmospheric Model to discuss modes of volcanic convection, relative particle concentrations, and plume dispersal. In mid-latitude winter and summer, and active and inactive periods of the tropical monsoon, conceptual models can be developed which allow implementation of pre-defined risk management strategies, and quick remote sensing and other report interpretation during an event. The further development of these models relies on continued close co-operation between the aviation, meteorological, and geophysical communities.

Introduction

Despite the rapid advances in remote sensing and ground-based monitoring of volcanic clouds, there are still large deficiencies in our observation system. Remote sensing of eruption clouds using meteorological satellites is severely hampered by the presence of overlying cloud or of water within the eruption cloud (Rose *et al.*, 1995: Tupper *et al.*, 2004a), human ground-based height observations are often severely limited, and instrumental monitoring for aviation purposes is patchy (Tupper and Kinoshita, 2003).

This is a difficulty primarily because the International Airways Volcano Watch is designed as a reactive system; warnings are issued (and airspace is closed) based on confident observations of volcanic ash, rather than on the possibility of volcanic ash. This contrasts with, for example, tropical cyclone or mid-latitude severe storm warning systems, where often patchy observations are coupled with increasingly sophisticated conceptual models to produce credible warnings. Warnings for volcanic clouds are relatively new, and so the application of conceptual models has been rather limited to the present.

Since the 1st International Symposium on Volcanic Ash and Aviation Safety, a great deal has been added to our understanding of volcanic cloud characteristics. The main variations on the basic eruption column conceptual models (Self and Walker, 1994) are the effect of wind and moisture on the development of eruption columns and on the observability of the eruptions with remote sensing.

In this paper, we give some examples of how particular understandings of volcanic cloud behaviour could affect the warning strategy for that event.

Wind Effects

The effect of wind on eruption columns, particularly weaker eruption columns, has been covered extensively in theory and observation (Ernst *et al.*, 1994: Sparks *et al.*, 1997: Woods, 1998: Graf *et al.*, 1999). For large eruptions, Graf et al. (1999) suggest a difference in the mean height of ash of as much 7 km between different wind regimes, although these results were based on a Cartesian formulation of the model and may be overestimated. Fig. 1 shows the effect that strong winds can have on a smaller volcanic plume in a summer situation – explosions that would normally be expected to rise to moderate altitudes shear immediately and barely rise above the volcano top. Ground based gas and ash measurement stations will record anomalously high values in the path of the plume and the plume will rapidly extend a great distance away from the volcano, possibly affecting airports and nearby shipping (Kinoshita *et al.*, 2003) but posing a relatively low risk to overflying aircraft.

Figure 1 - Explosions from Sakurajima, Japan are immediately 'blown down' over Sakurajima town in a lee wave, 3 August 1999, as a typhoon passes close to the area.

Where minor explosions are known to be a consistent feature of activity at a volcano but cannot be observed due to bad weather and lack of instrumentation, a strategy can be developed which allows appropriate NOTAMs and SIGMETs to be issued well in advance, based on forecast wind variations assuming continuation of the same volcanic activity level.

Moisture Effects

The effect of moisture on plume rise has been modelled by simple models for a range of plume sizes (Woods, 1993), and by the Active Tracer High Resolution Atmospheric Model (ATHAM) model for Plinean style eruptions (Graf *et al.*, 1999). The effect is difficult to show in observations because of the other variables involved; for example, the plumes of Satsuma-Iojima in sub-tropical Japan show a pronounced seasonality in height, but it is difficult to separate wind and stability influences (Matsui *et al.*, 2004). As a generalisation, however, moist convection can be coincident with, or induced by, volcanic activity, and can transport volcanic ash to any altitude within the troposphere or lower stratosphere. In other words, a large eruption is not required for transportation of volcanic ash to cruising levels, given the appropriate meteorological conditions.

Fig. 2 shows a typical (moist) summer situation over Sakurajima. On this day, the active vent (on the right) was emitting gas, steam and ash continuously without explosions, with the result that ash-bearing cumulus was forming continuously over the vent and dissipating to the north (left of picture), leaving fine ash at cloud-top levels. Discussions with observers in Japan, Indonesia and Papua New Guinea suggest that, in this common situation, the height of volcanic ash officially reported would be the base of the cloud, since the cumulus cloud is not regarded as being volcanic.

Figure 2 - Cumulus over Sakurajima, 12 Aug 2002, 0750 UTC. After Tupper & Kinoshita (2003).

A complex picture emerges when considering an active volcano interacting with the broader environment. Fig. 3 shows the mean brightness temperature measured over the Philippines, using hourly data for three and a half months following the climactic 1991 Pinatubo eruptions. During this period, smaller eruptions, secondary explosions and 'volcanic thunderstorms' were common over the area (Oswalt *et al.*, 1996), yet not one high level ash event could be explicitly detected using the split-window algorithm (Tupper *et al.*, 2004b).

The Pinatubo area was, however, the most active source of convection in the whole region during that period, as shown by the coldest mean brightness temperature (i.e. highest average cloud tops) in Fig. 3. Analysis of the diurnal variation (Fig.4) shows further that the diurnal cycle of convection remained dominant over Pinatubo, but that the cycle was shifted significantly earlier when compared to nearby topography, due to the convection initiation from lower level explosions and the heating of the denuded area around the mountain. Knowledge of these interactions can help to set warning policy; in the absence of any other information, deep convection near an erupting volcano should be assumed to contain at least trace levels of ash.

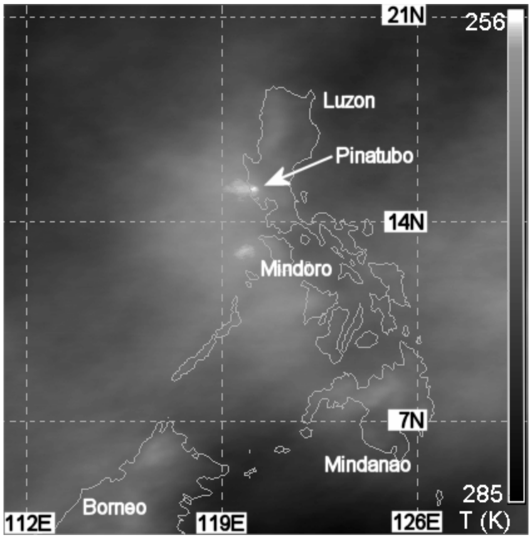

Figure 3 - Mean GMS-4 brightness temperature, 17 June - 30 Sept 1991 (excluding typhoon-cloud affected days), Philippines area.

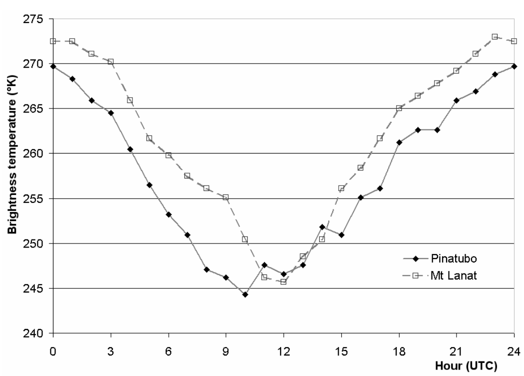

Figure 4 - Diurnal variation of mean GMS-4 brightness temperature above Mt Pinatubo (solid line) and nearby Mt Lanat area (dashed line), Luzon, 17 June - 30 Sept 1991. Values are for 20x 20 km boxes, using the same source data as Fig. 3.

Putting the volcanic activity within a large-scale meteorological framework also helps us with the warning strategy. Fig. 5 shows the situation six days after the climactic eruption at Pinatubo; at this stage, a southwest monsoon surge was affecting the Philippines, with maritime convection cloudiness at a maximum in the early morning. On this day, radar suggested Mt Pinatubo was venting to about 20,000 ft (6.1 km), but deep convection (16-17 km) was unusually strong in the Pinatubo area. Normally, in a situation so cloudy, there could be no direct evidence of the ash cloud. However, recent work has shown that ash contamination of an opaque cold cloud top can be detected by measuring the effective radius of the cloud top particles using NOAA/AVHRR data. The relative smallness of the particles is proportional to the amount of ash in the cloud, with ice-laden eruption clouds from Pinatubo having measured effective radii of around 15 µm, 'clean' cumulonimbus tops 30-35 µm or higher, and ash-contaminated cumulonimbus (with ash entrained at lower levels) in-between (Rosenfeld and Tupper, 2004). In the 21 June 1991 case of Fig. 5, cloud tops with a notably reduced effective radius of 20-25 µm were found in the high level 'return flow' extending at least 100 km southwest from the volcano (Tupper *et al.*, 2004b).

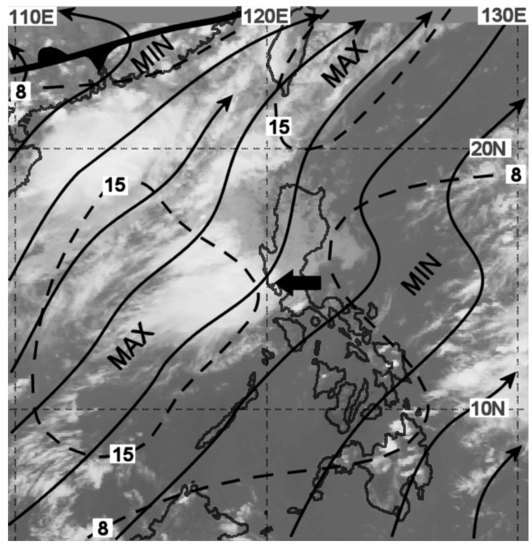

Figure 5 - 900 hPa streamline analysis overlaid on GMS-4 infrared image, 21 June 1991. The location of Mt Pinatubo, Philippines, is indicated by an arrow. Isotach values are indicated in m/s.

Warning seasonality

We now consider the effect on the International Airways Volcano Watch if assumptions about ash distribution are made on routine basis. Fig. 6 shows the consequences of the current system. There is a pronounced variation between wet season and dry season observation of ash, and therefore on the issue of volcanic ash advisories, for Semeru volcano in eastern Java, Indonesia. The increased warning incidence in the dry season is caused partially by the lack of cloud, but also by fresh dry winds causing low, long highly visible ash plumes. The actual activity at the volcano has not had any known seasonal variation over that ten-year period.

The current warning regime at Semeru is therefore focussed mainly on conditions that are relatively safe for flying. In the wet season, ash will rise higher and be hidden by extensive cumulonimbus cloud, so volcanic ash advisories are rarely able to be issued.

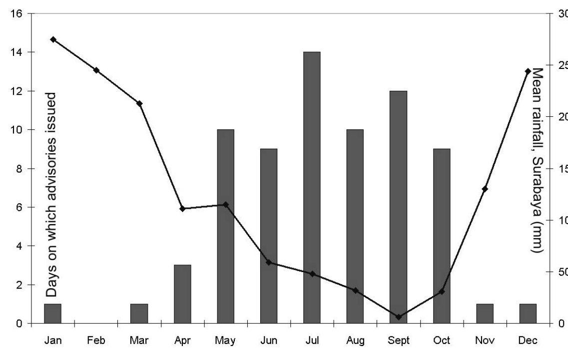

Figure 6 - Number of Volcanic Ash Advisories issued by Darwin Volcanic Ash Advisory Centre for Semeru by month (bars), against average rainfall from nearby Surabaya (black line), 1993-2003 (Davey *et al.*, 2003).

However, if the assumption of passive ash transport within cumulonimbus is made, there is a danger of substantial over-warning, as deep convection is very frequent around Indonesia's many active volcanoes. To reduce the possibility of over-warning, it will be necessary to a) define a warning threshold for ash concentrations, and b) examine ash dispersion and advection processes in the context of deep convection.

Ash removal processes

Given a warning threshold, how would we start to approach the ash dispersion problem?

Recent work with ATHAM (Textor *et al.*, 2003: Textor *et al.,* 2004a: b) has found a number of relevant results:

1) Hydrometeors are dominant in controlling many processes within the volcanic plume, even when a relatively dry lower troposphere leads to water evaporating from ash aggregates as they fall, thus giving the appearance of a dry ash cloud.
2) The collection efficiency of icy particles is sensitive to the amount of ice in the model, which is dependent upon the ambient humidity.
3) The initial size distribution of the erupted particles has a major influence on ash aggregation and sedimentation patterns.

Fig. 7 shows the mean height of particles in two size classes for a Plinean eruption, for the range of atmospheres described in Textor et al. (2003). With these ash-dominant, large eruption clouds, ice has a crucial role in the removal of particles from the atmosphere, but the small-sized particles of interest to aviation have a relatively long residence time.

Since the ash distribution over time is dependent on both the eruption and atmospheric characteristics, simulations would be necessary for a range of eruption types as well as atmospheres. More development work will be required to effectively model complex interactions such as those described for Pinatubo above.

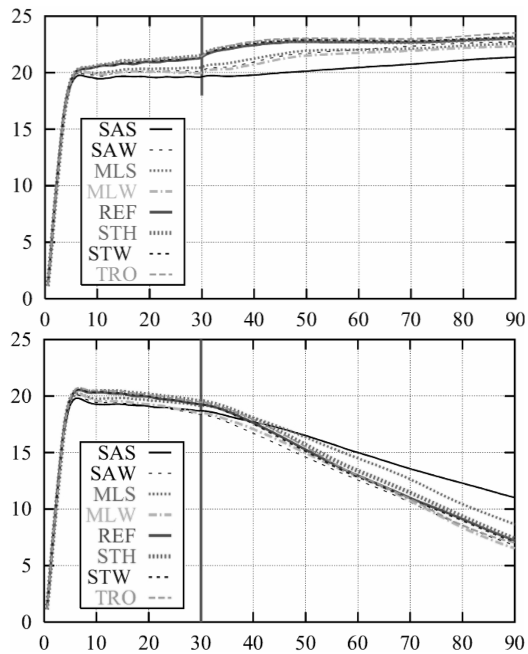

Figure 7 - Mean height (km) of small (top) and large (bottom) particle classes in Plinean style eruption clouds developing in a range of atmospheric conditions.

Conclusions

We believe that it is possible to integrate theoretical and observational knowledge of volcanic cloud interactions with the environment to develop useful conceptual models of volcanic ash cloud evolution, and then apply these models in an appropriate warning strategy. Marrying the complexity of volcanic clouds with the already challenging field of aviation meteorology is a formidable problem, but not impossible.

Basic understandings of wind, moisture, mesoscale and synoptic scale interactions can already be applied in a simple way to substantially alleviate the effect of incomplete observations. Advanced satellite techniques such as effective particle radius measurement will occasionally provide explicit evidence of ash affecting the microphysical processes in deep convection, and improve our conceptual models and warning confidence. Modelling using ATHAM-style models will eventually provide much greater insights into the processes within the cloud.

In order to make substantial progress in these areas, it is absolutely necessary to define a warning threshold of volcanic ash concentrations. The alternative will be substantial over-warning in situations where trace amounts of ash can be assumed to be present. Intensive investigation of aircraft encounters such as those described in this volume will aid these efforts.

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VOLCANIC ASH ADVISORY SUPPORT FOR THE U.S. DEPARTMENT OF DEFENSE

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ABSTRACT

The Air Force Weather Agency (AFWA) issues volcanic ash advisory products tailored for U.S. Department of Defense (DoD) support. AFWA's Meteorological Satellite Applications Branch (XOGM) monitors a variety of sources for volcanic ash plume activity, and creates both alphanumeric and graphic advisory products supporting DoD resource protection. In addition, AFWA serves as a hot backup for the Washington Volcanic Ash Advisory Center (W-VAAC).

BACKGROUND

Volcanic ash is a major concern to the DoD. Several U.S military installations stand within the shadows of active volcanoes in Asia, the Pacific, and the Mediterranean, while DoD aircraft regularly traverse regions susceptible to ash plumes from active volcanoes. Besides high altitude (>30,000 ft) transit of active volcanic chains, the DoD has localized operations in Southeast Asia, the Marianas Islands, and other regions. These areas frequently require sustained flight at much lower altitudes (<20,000 ft) near volcanoes increasing aircraft vulnerability to airborne ash.

AFWA at Offutt AFB, Nebraska provides volcanic ash advisory support for DoD customers. AFWA's XOGM issues a suite of text and graphical products tailored to DoD requirements for volcanic ash advice and forecasts. With U.S Forces operating worldwide, a standardized and consistent set of timely advisory and forecast products from one source is essential to DoD planners for both situational awareness and decision-making.

SATELLITE DATA

Satellite imagery plays a critical role in surveillance of recently active or potentially active volcanoes worldwide. In addition, it is used to verify and provide quality control for ash dispersion model forecast graphics output.

AFWA's operational global satellite database consists of five geostationary satellites providing frequent imagery refresh coverage of suspect areas. In addition, AFWA receives higher resolution global polar orbiter data over areas of interest via stored readout from two National Oceanographic and Atmospheric Administration (NOAA) and four DoD Defense Meteorological Satellite Program (DMSP) satellites.

XOGM augments the above imagery with data relayed from the Air Force MARK IVB network of tactical direct readout sites. This permits timely review of data over volcano regions at full resolution from both NOAA and DMSP satellites. In addition, the direct readout capability enables AFWA to leverage data from several older polar satellites for which stored readout is no longer possible.

XOGM uses the Satellite Image Display and Analysis System (SIDAS) to examine ash plume characteristics. This AFWA interactive graphics toolkit allows analysts to display, interrogate, and manipulate satellite imagery to maximize imagery data extraction.

SIDAS facilitates multi-spectral analysis including infrared channel differencing when meteorological cloud or darkness inhibits visual imagery inspection of ash plumes. In addition, data from other sources (conventional surface and upper air data, cloud drift winds, numerical analysis and prognosis fields) can be overlaid on the image to assist in the analysis of plume height or other features.

OTHER DATA SOURCES

Global monitoring of active volcanoes and airborne ash is an extensive task, and cannot be effectively accomplished with review of satellite imagery alone. Aircraft, surface reports, and alerts from volcano observatories often provide the first notification of an eruption.

A primary method to alert analysts to these reports is to use automated text filter capabilities to scan existing alphanumeric bulletin traffic across the DoD's Automated Weather Network (AWN). This XOGM developed software package interrogates Meteorological Aerodrome Report (METAR) observations, Pilot Reports (PIREPS), Significant Meteorological Information (SIGMET) bulletins, and civilian Volcanic Ash Advisories (VAAs). When ash is detected, the software alerts branch analysts and highlights the alphanumeric data for closer review and crosscheck with satellite imagery.

Although limited to a small number of volcanoes, AFWA leverages web cams as an additional method of monitoring. XOGM developed software provides a grid display of multiple volcano web cam sites with continuously updating animated image loops covering the last 30 min. This greatly assists the analyst in effectively managing limited time by eliminating the need to contact each web site for single image updates.

PRODUCTS

AFWA issues alphanumeric advisory and forecast graphic products when ash is detected or suspected. Bulletin updates on ash activity occur at six-hour intervals until the end of the event. As a measure of global activity for 2003, XOGM issued advisories for 450 initial eruptions from 38 volcanoes. Ongoing activity necessitated over 2,000 updates. Ash plumes below 20,000 ft accounted for 75% of the notices.

AFWA bases its forecast graphic products upon the University of Alaska, Fairbanks' volcanic ash dispersion model called PUFF (not an acronym) and wind fields from the National Weather Services' (NWS) Global Forecast System (GFS). The current PUFF graphical user interface version includes customization for AFWA by the Johns Hopkins University's Applied Physics Lab. PUFF run length is dependent upon the height of the initial ash cloud and the duration of the eruption. Low-level eruptions (<20,000 ft) have a six hour run period with forecast intervals of three hours. Maximum run lengths for higher-level eruptions may extend to 48 hours with forecast intervals of 12 hours. Forecast graphics include both animated and static products.

The animated forecast is a color graphic product with dynamic, optimized geographical boundaries to incorporate the entire ash cloud at its maximum forecasted extent. Ash is visualized using a consistent color scheme, with ash plotted in five thousand foot (Kft) bins from the surface (Sfc) to 55 Kft.

The static graphic product is a set of four-panel charts for forecast intervals extracted from the PUFF model run. This is a color graphic product with fixed geographic boundaries and ash plotted within four flight levels – Sfc-12Kft, 12-24Kft, 24-36Kft, and 36-55Kft.

In addition to actual eruption situations, AFWA also prepares forecast products in both animated and four-panel static format for hypothetical eruptions. These automated products assist DoD flight planners in route decisions near active volcanoes, particularly during exercises and contingency operations.

COMMUNICATIONS

AFWA disseminates alphanumeric ash advisories via the AWN. In addition, the bulletins are e-mailed to numerous customers who have a direct interest in the products. Air Force customers include the Tanker Airlift Control Center (Scott AFB, IL), Operational Weather Squadrons, and selected Base Weather Stations. Products are e-mailed to other DoD agencies as well, such as the Navy's Meteorological & Oceanographic Centers. For eruptions likely to directly impact DoD facilities, product submission is preceded by telephonic communication to ensure timely notification.

XOGM posts volcanic ash imagery and graphic forecast products on the Joint Air Force and Army Weather Information Network (JAAWIN) web site for ease of access for customers. JAAWIN is a web-based system which provides DoD customers access to over

800,000 products daily. These include all forms of meteorological data products – satellite, model output, radar, lightning, observations, charts, space environment, and a myriad of other products. The JAAWIN Environmental Events page features the volcanic graphic products divided into four regions around the globe – the Americas, Europe/Africa, North Pacific, and South Pacific. For each active volcano, customers have direct access to alphanumeric bulletins, satellite imagery, and both the animated and four panel PUFF graphics.

WASHINGTON VAAC BACKUP

AFWA provides backup for the W-VAAC to ensure continuity of operations during power failures, communications outages, or other contingencies. During backups, AFWA assumes the monitoring function for the W-VAAC and issues volcanic ash text and forecast graphic products on behalf of Washington. To ensure readiness, AFWA and the W-VAAC hold quarterly exercises to test the effective execution of these duties. During 2003, AFWA provided immediate "hot" backup five times due to communications difficulties.

SUMMARY

AFWA is the DoD focal point for volcanic ash advisory products including monitoring, forecasting, notification and product dissemination. This is a mission of global extent carried out 24/7 by AFWA's Meteorological Satellite Applications Branch (XOGM). These efforts ensure planners and flight crews have the information needed to ensure mission accomplishment and resource protection.

WEB ACCESS TO THE VOLCANIC ASH ADVISORY DATABASE

Paula Dunbar, National Geophysical Data Center, Boulder, CO, USA
Grace Swanson, NOAA Satellite Services Division, Camp Springs, MD, USA

Volcanic ash is a significant hazard to aviation and can also affect global climate patterns. To ensure safe navigation and monitor possible climatic impact, NOAA's Volcanic Ash Advisory Centers (VAACs) track volcanic ash eruptions and monitor surface weather observations, aircraft pilot reports, and satellite imagery for ash clouds. The NOAA Washington VAAC is part of the National Environmental Satellite, Data, and Information Service (NESDIS) and the National Weather Service (NWS). The Satellite Analysis Branch (SAB) of NESDIS and the National Centers for Environmental Prediction of the NWS share duties as the regional Washington VAAC located in Camp Springs, Maryland. The Washington VAAC area of responsibility includes the continental United States and southward through Central America, the Caribbean to 10 degrees South in South America, and the United States controlled oceanic flight information regions (FIRs). The NOAA Anchorage VAAC is part of the Alaska Aviation Weather Unit in Anchorage and is responsible for Alaska and Anchorage FIRs and a small portion of Russia north of the Kamchatka peninsula.

NOAA's VAACs issue two products after a volcanic eruption. The first product, the Volcanic Ash Advisory (VAA) statement, includes text describing current volcanic activity and ash cloud position. The second product (when appropriate), the Volcanic Ash Forecast Transport and Dispersion (VAFTAD) model, provides a forecast of ash location in the atmosphere for the next 48 hours. All of this information is provided to the Federal Aviation Administration, the U.S. Geological Survey, Meteorological Watch Offices, climate analysts, and scientists in other countries.

The VAAC system had its roots in the 1980's when the NESDIS SAB began to provide the aviation and volcanology community real-time analysis of satellite products to support response actions to volcanic ash eruptions. In 1997, the Washington VAAC joined a global network formed by the International Civil Aviation Organization to provide worldwide coverage of volcanic ash events. Since the beginning of its volcanic ash monitoring program, the NESDIS SAB has maintained an archive of Volcanic Ash Messages, VAFTAD model output, and substantiating information. The substantiating information includes surface weather observations, pilot reports, volcanic observatory reports, news media reports, and satellite imagery for each event. The National Geophysical Data Center (NGDC) has had this analog archive scanned into image format and is now making it available on the web.

The digital archive, known as the Volcanic Ash Advisory Database (VAADB), currently consists of information from over 600 folders representing different eruptive episodes. Since the Washington VAAC originally had global responsibility for volcanic ash monitoring, the VAADB includes information on over 40 volcanoes from all over the world (Figure 1). The current database includes information from 1996 to 2001. It will eventually be extended back to the 1980's and will also include advisories issued after 2001 which are already in digital format. The VAADB images are being delivered over the Web using a geospatially-enabled relational database management system using a text-based search interface (Figure 2). Users can search the database using one or more of the following search parameters:

- Volcano name
- General location by description (region or country) or latitude-longitude entry
- Beginning date of the eruption
- Type of information (advisory or substantiating),
- Type of image (VAA, VAFTAD, Ash analysis graphic, Satellite imagery, Media report, Pilot report, Volcano Observatory report, Surface Weather Observation, etc.)

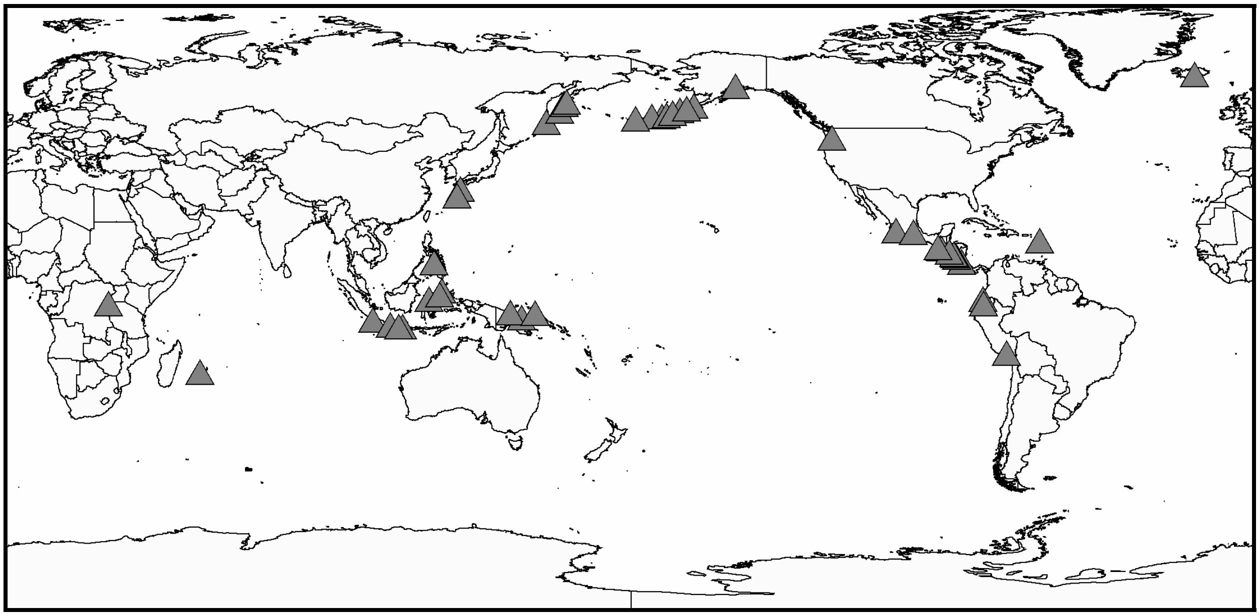


Figure 1. Volcanoes included in the Volcanic Ash Advisory Database.

Examples of the types of output and images currently available online are shown in figures 3-6. Figure 3 shows the result of searching the database for all images from Popocatepetl in Mexico. Figures 4-6 provide examples of advisory information for Popocatepetl during the March 1996 eruptive episode.

The VAADB will eventually be accessible via an interactive map interface and will be integrated into the NGDC Natural Hazards interactive map that provides Web-based GIS access to volcano, earthquake, tsunami, and auxiliary geospatial data. In addition, links will be provided to the Smithsonian's Global Volcanism Database, associated images in NGDC's natural hazards slide sets, and GOES imagery from the Comprehensive Large Array-data Stewardship System GOES active archive.

Volcanic ash modelers, climate analysts, and volcanologists will soon have web-access to a vast collection of data from past volcanic events. The VAADB website is listed below:
http://www.ngdc.noaa.gov/seg/hazard/vol_ash.html

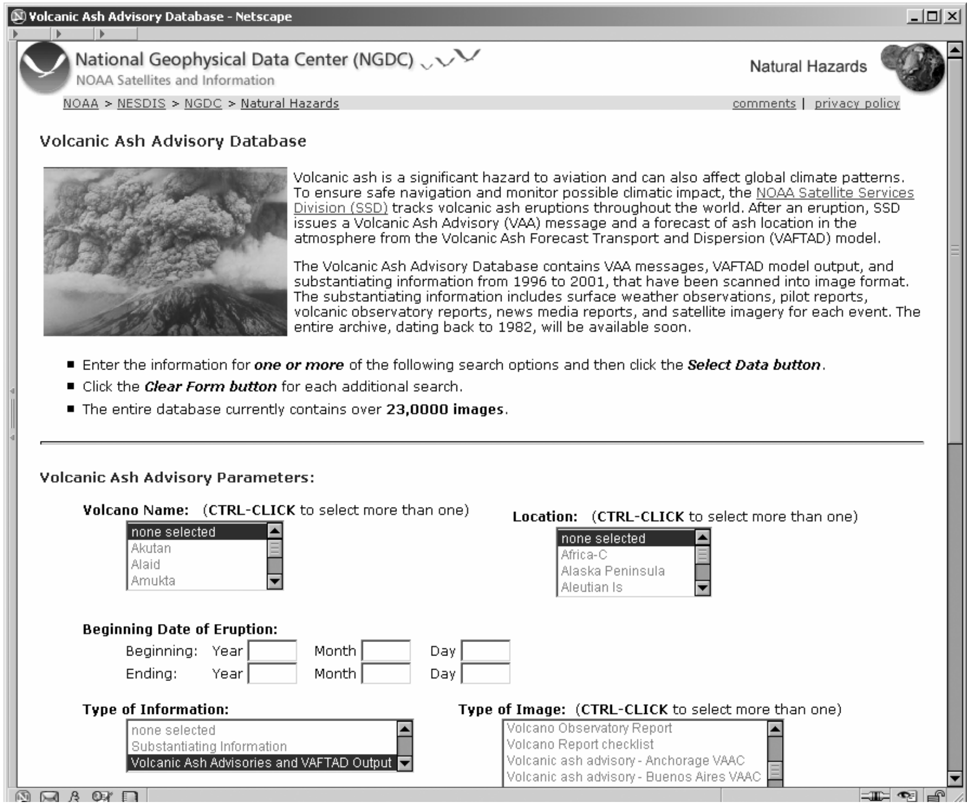
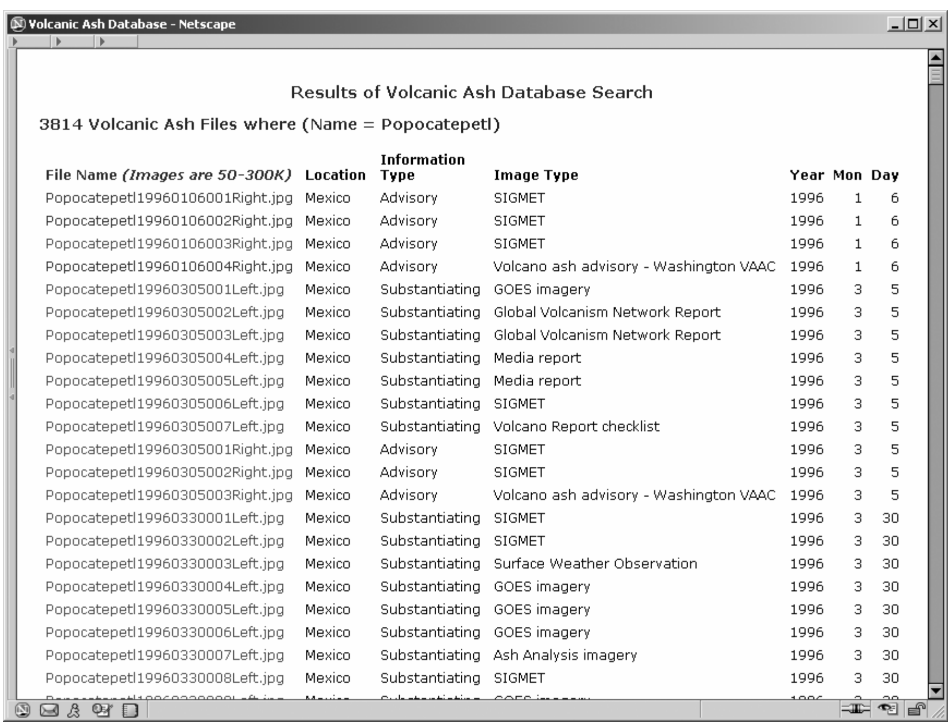
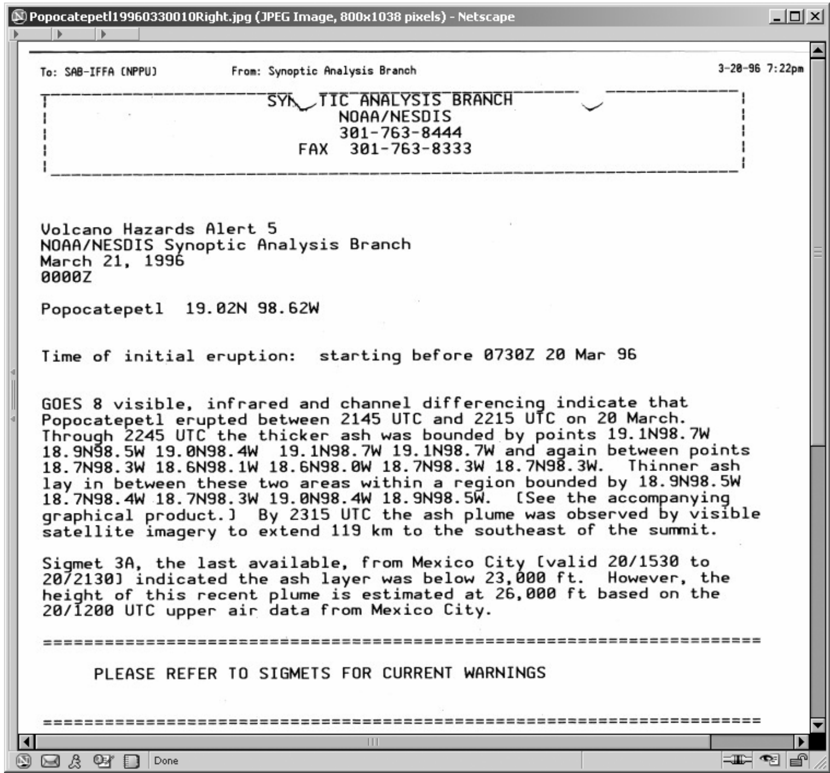


Figure 2. Search interface for the Volcanic Ash Advisory Database.



File Name *(Images are 50-300K)*	Location	Information Type	Image Type	Year	Mon	Day
Popocatepetl19960106001Right.jpg	Mexico	Advisory	SIGMET	1996	1	6
Popocatepetl19960106002Right.jpg	Mexico	Advisory	SIGMET	1996	1	6
Popocatepetl19960106003Right.jpg	Mexico	Advisory	SIGMET	1996	1	6
Popocatepetl19960106004Right.jpg	Mexico	Advisory	Volcano ash advisory - Washington VAAC	1996	1	6
Popocatepetl19960305001Left.jpg	Mexico	Substantiating	GOES imagery	1996	3	5
Popocatepetl19960305002Left.jpg	Mexico	Substantiating	Global Volcanism Network Report	1996	3	5
Popocatepetl19960305003Left.jpg	Mexico	Substantiating	Global Volcanism Network Report	1996	3	5
Popocatepetl19960305004Left.jpg	Mexico	Substantiating	Media report	1996	3	5
Popocatepetl19960305005Left.jpg	Mexico	Substantiating	Media report	1996	3	5
Popocatepetl19960305006Left.jpg	Mexico	Substantiating	SIGMET	1996	3	5
Popocatepetl19960305007Left.jpg	Mexico	Substantiating	Volcano Report checklist	1996	3	5
Popocatepetl19960305001Right.jpg	Mexico	Advisory	SIGMET	1996	3	5
Popocatepetl19960305002Right.jpg	Mexico	Advisory	SIGMET	1996	3	5
Popocatepetl19960305003Right.jpg	Mexico	Advisory	Volcano ash advisory - Washington VAAC	1996	3	5
Popocatepetl19960330001Left.jpg	Mexico	Substantiating	SIGMET	1996	3	30
Popocatepetl19960330002Left.jpg	Mexico	Substantiating	SIGMET	1996	3	30
Popocatepetl19960330003Left.jpg	Mexico	Substantiating	Surface Weather Observation	1996	3	30
Popocatepetl19960330004Left.jpg	Mexico	Substantiating	GOES imagery	1996	3	30
Popocatepetl19960330005Left.jpg	Mexico	Substantiating	GOES imagery	1996	3	30
Popocatepetl19960330006Left.jpg	Mexico	Substantiating	GOES imagery	1996	3	30
Popocatepetl19960330007Left.jpg	Mexico	Substantiating	Ash Analysis imagery	1996	3	30
Popocatepetl19960330008Left.jpg	Mexico	Substantiating	SIGMET	1996	3	30

Figure 3. Results of searching the VAADB for Popocatepetl.



Popocatepetl19960330010Right.jpg (JPEG Image, 800x1038 pixels) - Netscape

To: SAB-IFFA (NPPU) From: Synoptic Analysis Branch 3-20-96 7:22pm

SYN TIC ANALYSIS BRANCH
NOAA/NESDIS
301-763-8444
FAX 301-763-8333

Volcano Hazards Alert 5
NOAA/NESDIS Synoptic Analysis Branch
March 21, 1996
0000Z

Popocatepetl 19.02N 98.62W

Time of initial eruption: starting before 0730Z 20 Mar 96

GOES 8 visible, infrared and channel differencing indicate that Popocatepetl erupted between 2145 UTC and 2215 UTC on 20 March. Through 2245 UTC the thicker ash was bounded by points 19.1N98.7W 18.9N98.5W 19.0N98.4W 19.1N98.7W 19.1N98.7W and again between points 18.7N98.3W 18.6N98.1W 18.6N98.0W 18.7N98.3W 18.7N98.3W. Thinner ash lay in between these two areas within a region bounded by 18.9N98.5W 18.7N98.4W 18.7N98.3W 19.0N98.4W 18.9N98.5W. [See the accompanying graphical product.] By 2315 UTC the ash plume was observed by visible satellite imagery to extend 119 km to the southeast of the summit.

Sigmet 3A, the last available, from Mexico City [valid 20/1530 to 20/2130] indicated the ash layer was below 23,000 ft. However, the height of this recent plume is estimated at 26,000 ft based on the 20/1200 UTC upper air data from Mexico City.

==

PLEASE REFER TO SIGMETS FOR CURRENT WARNINGS

==

Done

Figure 4. Example of Volcanic Ash Message from the VAADB for Popocatepetl.

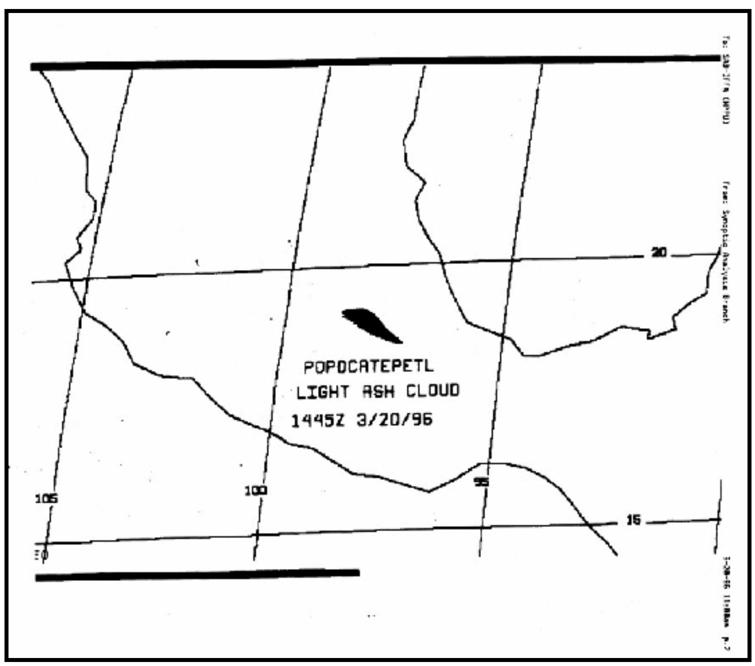


Figure 5. Example of Ash Analysis Graphic from the VAADB for Popocatepetl.

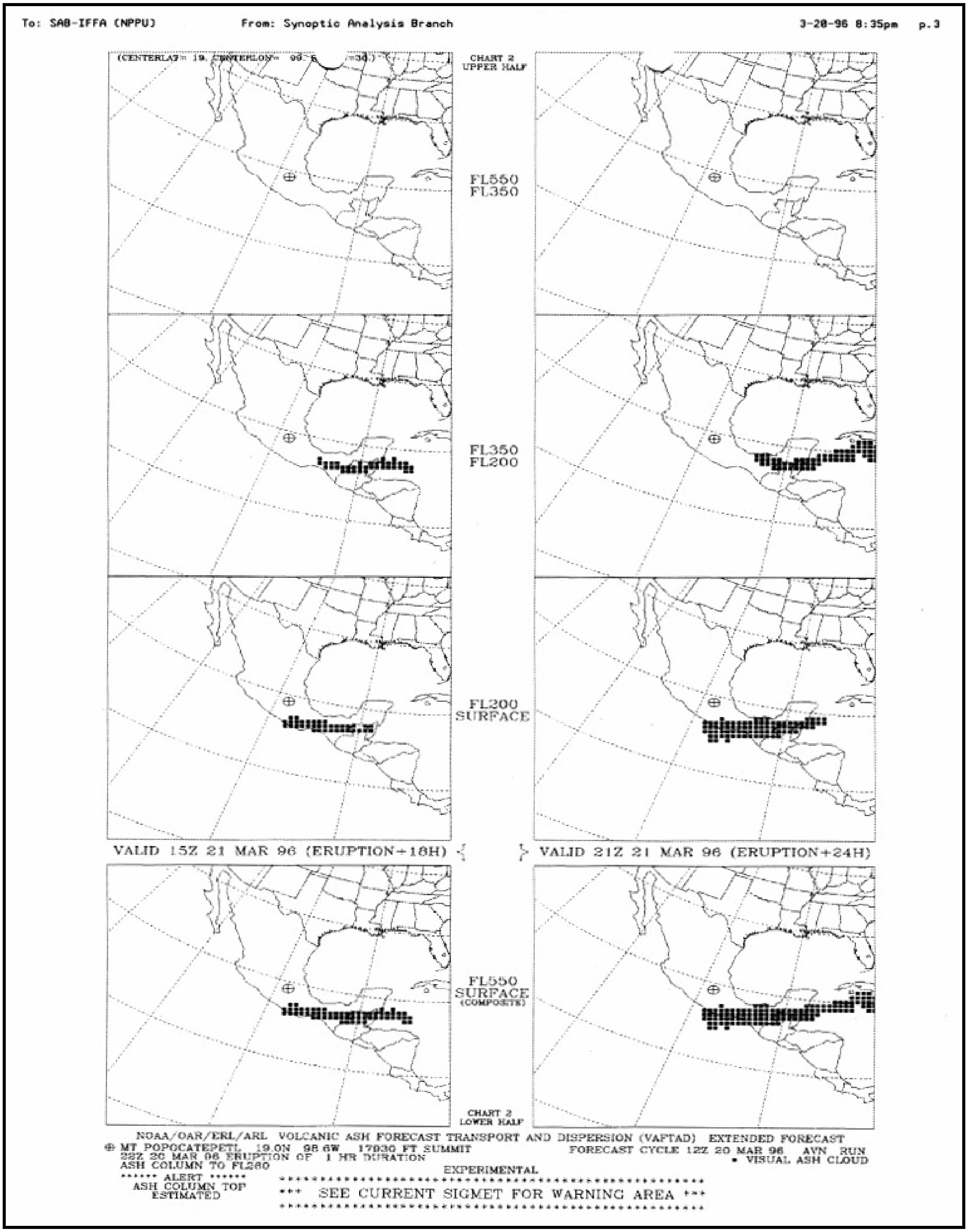


Figure 6. Example of VAFTAD output from the VAADB for Popocatepetl.

WASHINGTON VOLCANIC ASH ADVISORY CENTER (VAAC) OPERATIONS

Gregory M. Gallina and Davida Streett
Washington VAAC-NOAA/NESDIS/Satellite Services Division

Introduction

The Washington Volcanic Ash Advisory Center (VAAC) monitors and tracks airborne volcanic ash and disseminates text and graphical messages to the global aviation community. The Washington VAAC is part of a global network created by the International Civil Aviation Organization to provide nearly worldwide coverage of volcanic ash events. This network of centers includes VAACs, Meteorological Watch Offices (MWOs), and Area Control Centers (ACCs). VAACs provide ash information to MWOs (and vice versa) and the MWOs issue ash warnings for aviators by SIGMETs. VAACs also provide ash information to ACCs, and ACCs issue notices to in-flight aircraft via NOTAMs and ASHTAMs. VAAC information and products are also broadly disseminated to a variety of other users concerned about airborne ash (Fig. 1, not shown).

Globally, there are nine VAACs (Anchorage, Buenos Aires, Darwin, London, Montreal, Tokyo, Toulouse, Washington and Wellington), each having responsibilities for volcanic ash eruptions within their ICAO-determined boundaries (Fig. 2, not shown). Most of the world's airspace is facilitated by one of the VAACs; however, there are some gaps, usually over oceans and areas without active volcanoes. Notice in Figure 2 that the Washington VAAC area of responsibility includes the contiguous U.S., Mexico, Central America, South America north of 10°S, parts of the Pacific (including Hawaii and the Southern Mariana islands) and Atlantic Oceans (including the Caribbean). Under normal circumstances, VAACs will only issue ash advisories and trajectory models when an eruption or ash occurs within their area of responsibility. Each VAAC ensures that ash products (described more in VAAC Products section below) are issued when an eruption or airborne ash occurs within their geographic area of responsibility and the appropriate MWOs are contacted/receive the information so warnings (SIGMETS) can be produced.

The Washington VAAC is a joint collaboration between the Satellite Analysis Branch (SAB) of the National Environmental Satellite, Data, and Information Service (NESDIS) and the NCEP Central Operations (NCO) of the National Weather Service. Although the Washington VAAC was chartered in 1997 by ICAO, NESDIS and the NWS have a long history of monitoring volcanic ash events. The NESDIS component, SAB, has had over 20 years of experience monitoring volcanic ash via satellite imagery. The NWS component, NCO has worked with volcanic ash by utilizing ash trajectory models for the past 10 years. Both organizations are part of the National Oceanic and Atmospheric Administration (NOAA).

Products and Services

When ash is reported or detected within the Washington VAAC boundaries, the person on-duty discontinues other operational activities and immediately begins gathering information about the ash/eruption. The VAAC analyst's first priority is to notify the affected MWO(s) to facilitate their issuance of a Volcanic Ash SIGMET. Next, the analyst prepares a text product known as the Volcanic Ash Advisory (VAA) (Fig. 3). A VAA is intended to provide the aviation community with all of the pertinent information that we have about the airborne volcanic ash. Ideally a VAA will contain information on the eruption, the location, height and amount of ash, the current movement(s) of the ash (noting when different areas of ash move in different directions) and other information. VAA are updated at least every six hours, but sooner if the ash situation changes substantially. In addition to the VAA, the Washington VAAC also issues two graphical products (an ash analysis and an automated forecast) and is preparing to issue a third product (a forecast created by a person). The VAA is distributed through many communication networks, such as: AFTN, AWIPS/N-AWIPS (NWS systems), GTS, WAFs, Family of Services, under the identification header FVXX## KNES (where ## denotes a number in the range of 20 to 27). Also, as a service of the Washington VAAC, a graphical analysis of the detectable ash drawn on a map background (Fig. 4) is issued but is currently available only on our website.

For flight planning purposes, an ash trajectory and dispersion model is also issued. This model, known as the VAFTAD (Volcanic Ash Forecast Transport and Dispersion), graphically depicts predicted ash location at 12, 24, 36 and 48 hours. It is based on the aviation or ETA numerical weather models and manual inputs of ash height, summit height, eruption duration, and an adjustment factor to modify ash amounts. At each time period, the forecasted ash is depicted at low, middle and high levels of the atmosphere, and there is a composite showing all atmospheric levels from surface to 55,000 ft. The VAFTAD is available via the VAAC website and satellite broadcast under bulletin headers PHBE10KWBC and PHBI10KWBC. In the future, a new product (the Volcanic Ash Graphic) will be issued that represents a VAFTAD with its output adjusted and hopefully improved by a forecaster. A variety of current GOES satellite imagery over selected volcanoes can be viewed on our website (Fig. 5, not shown) at www.ssd.noaa.gov/VAAC/. We also expect to soon have available on our website, a Geographic Information System (GIS) based display of ash as seen in MODIS (Moderate-Resolution Imaging Spectroradiometer) satellite imagery using a special optimized multi-spectral algorithm. Although this should provide an excellent snapshot of the ash at a given instance, it will not be nearly as current or frequent as the GOES imagery.

Washington VAAC is staffed 24 by 7; however, its personnel are multi-tasked, performing a number of meteorological tasks unrelated to volcanoes. In the event of a Washington VAAC outage, the United States Air Force Weather Agency serves as the Washington VAAC backup and will create and disseminate the VAA and VAFTAD.

FVXX22 KWBC 112209Z
VOLCANIC ASH ADVISORY
ISSUED: 2003MAY11/2200Z VAAC: WASHINGTON

VOLCANO: ANATAHAN 0804-20
LOCATION: N1621E14540 AREA: MARIANA ISLANDS

SUMMIT ELEVATION: 2585 FT (788 M)
ADVISORY NUMBER: 2003/007

INFORMATION SOURCE: GOES-9 IMAGERY. GFS MODEL WINDS FORECAST. GUAM MWO.

ERUPTION DETAILS: ERUPTION OCCURRED AROUND 10/0730Z AND EMISSIONS CONTINUE TO OCCUR

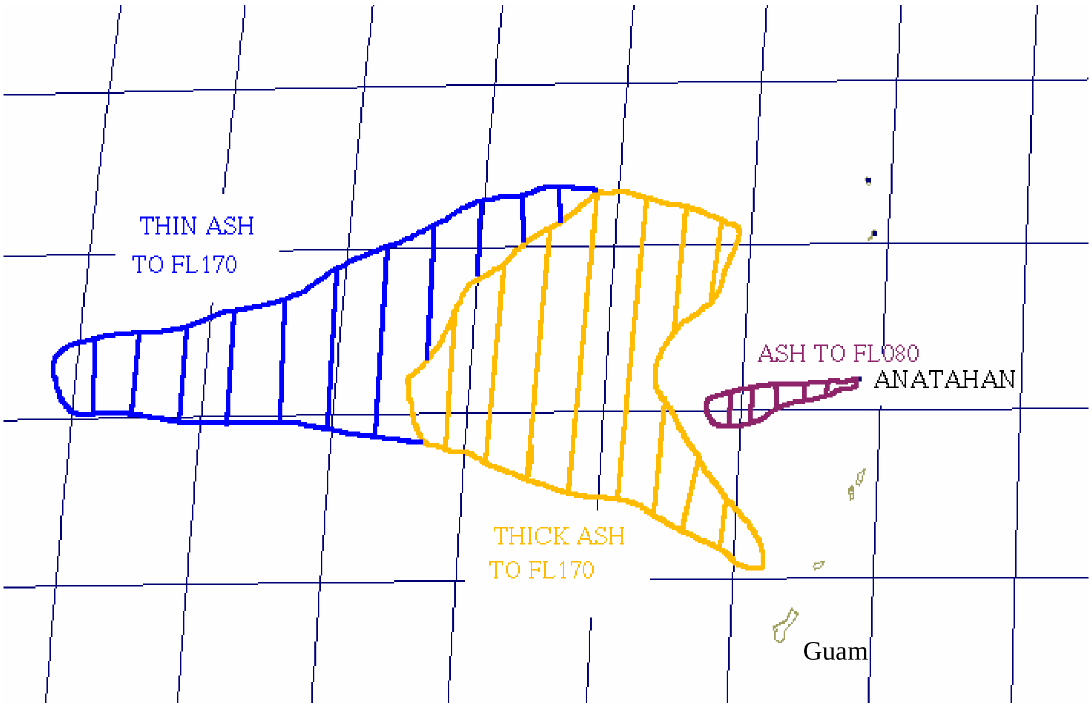
OBS ASH DATE/TIME: 11/2118Z

OBS ASH CLOUD: SFC/FL170 N1621E14256 - N1800E14417 - N1900E14200 - N1706E13403 - N1559E13340 - N1339E14423 - N1428E14502 - N1621E14256 MOVING W 15 KNOTS.
SFC/FL080 17 NM WIDE LINE OF ASH BETWEEN N1621E14540 - N1611E14326.
ASH IS MOVING WEST 20 KNOTS.

FCST ASH CLOUD+06H: NOT AVBL
FCST ASH CLOUD+12H: NOT AVBL
FCST ASH CLOUD+18H: NOT AVBL

REMARKS: A LARGE AREA OF MID-LEVEL ASH IS MOVING WEST WITH THE THICKEST OF THIS ASH BETWEEN 140E AND 143.5E. FAINTER ASH EXTENDS TO ABOUT 134E. IN ADDITION A NARROW LOW LEVEL ASH PLUME CAN STILL BE SEEN EXTENDING FROM THE SUMMIT TOWARD THE WEST.

NEXT ADVISORY: WILL BE ISSUED BY 12/0400Z.



Figures 3 and 4: Example of VAA Text Product and associated Graphic. Example from May 2003 Eruption of Anatahan in Southern Mariana Islands.

Ash Detection Methods

Viewing ash in satellite imagery provides ash location, height and speed information that is useful in creating VAA. The Washington VAAC relies primarily on GOES satellite imagery since it is available every 15 or 30 minutes, throughout most of the VAAC area. Polar orbiting satellites with their high spatial resolution provide supplementary information, but do not have the temporal resolution of GOES imagery.

Satellite detection algorithms using a variety of visible and infrared wavelengths and combinations of wavelengths ("multispectral" imagery) are optimized to enhance ash detection and help discriminate ash from weather clouds. In Fig. 6 (not shown), each panel is an example of GOES satellite imagery used in ash detection: Visible, 10.7 mm Infrared (IR), 3.9 mm "shortwave" IR, Principal Component Imagery (PCI) 3, a multi-spectral technique created by CIRA, and Gary Ellrod's multi-spectral technique.

For volcanoes within the GOES-E footprint, the Washington VAAC primarily uses 2 forms of multispectral imagery that rely on fixed weighting and one form that varies with image content. The CIRA algorithm utilizes channels 2, 4, 2 and with fixed weighting designed to enhance ash versus weather cloud. Gary Ellrod's algorithm uses channels 2 4 and 6 with fixed weighting of the channels. Since late 1999, the Washington VAAC has relied heavily on the use of Principal component analysis of GOES imagery. According to Hillger and Ellrod 2003, the PCI technique "determines which part of the multi-spectral signal is common to all the images (or ... bands) and separates that information from other image information that is sensed only by image differences or multiple image combinations. Whereas the original images…[generally] contain redundant information, the…component images contain independent information separated out of the original images. This allows the image analyst to see the independent components in multi-spectral imagery." The VAAC uses PCI-3 (GOES-12 channels 2, 4, 6) and GOES-10 channels 2, 4, 5) for ash detection and discrimination of ash versus steam. The VAAC uses a split window technique for satellites (GOES 9, GOES 10, NOAA, MODIS) that have a 12 micron channel.

Besides satellite imagery, many other data sources provide crucial information necessary to an accurate VAA. Pilot reports (AIREPS), airline phone calls, surface weather observations (METAR/SPECI), volcanological observatories, SIGMETs, upper air observations (radiosondes), numerical weather models, and media reports are useful. To help find references to volcanic ash in the multitude of telecommunications traffic, the Washington VAAC uses an automatic alert notification program based on a keyword search engine. The program scans for "words" such as ASH, PLUME, VA, WV, FV, VOLCANO, VOLC, and CENIZA as well as some individual volcano names and whenever a message is found with these keywords, an e-mail alert is sent to the VAAC and an audible alarm sounds.

Six Year Statistics

On November 1st, 2003, the Washington VAAC celebrated six full years of service to the aviation community. Coincidently, a mile-stone was surpassed the same day as the 7500th VAA was disseminated. Figure 7 shows the annual distribution of VAA and graphical depiction of ash clouds during the six years of service.

During those six years, VAA were written for 26 volcanoes, 17 that are located inside the VAAC boundaries, as well as, for 9 volcanoes in support of other VAACs or ash that moved across into the Washington VAAC's airspace of responsibility. The majority of VAA have been written for 2 volcanoes: Tungurahua with 2677 VAA, followed by Soufriere Hills with 2589. Popocatepetl (812), Guagua Pichincha (397) and Anatahan (289) round out the top five.

Similarly, the graphical depiction of ash seen on satellite imagery has been produced for 16 volcanoes (13 within the Washington VAAC). Graphics were created mostly for Soufriere Hills (1176), followed by Tungurahua (492), Popocatepetl (275), Anatahan (162), and Colima and San Cristobal tied for fifth with 34 each.

Authors note: Due to the unavailability of color graphics, Figures 1, 2, 5 and 6 are available from the authors. Please contact them at Greg.Gallina@noaa.gov, Davida.Streett@noaa.gov or 301-763-8444 in Camp Springs, Maryland, USA.

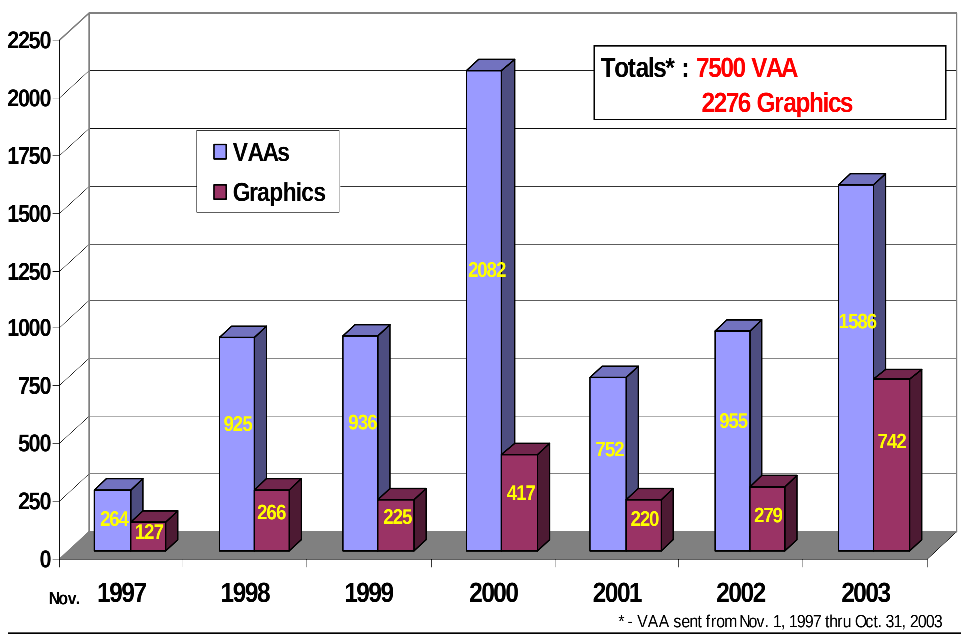


Figure 7: Number of Volcanic Ash Advisories (VAA) and Graphics for the six years since the VAAC was created in November of 1997 through October 2003.

IMPROVEMENT OF ASH CLOUD INFORMATION BY TOKYO VAAC

Takeshi Koizumi, Japan Meteorological Agency, Tokyo, Japan
Yoshihiko Hasegawa, Yasuhiro Kamada, Masamichi Nakamura

Introduction

The Japan Meteorological Agency (JMA) is operating Tokyo Volcanic Ash Advisory Center (Tokyo VAAC) that is responsible for monitoring volcanic ash clouds in Asia/Western Pacific area and issuing Volcanic Ash Advisories (VAAs), one of 9 VAACs are being operated in the world in order to mitigate or prevent disasters of airplanes caused by volcanic ash.

Tokyo VAAC monitors satellite imagery and gathers domestic and foreign reports on volcanic activities. When volcanic ash is likely to affect to any routes in the area of responsibility (Fig. 1), the Tokyo VAAC issues VAAs, which includes the present status and forecast information of volcanic ash clouds in the text and graphical format used by Meteorological Watch Offices, civil aviation authorities and other related organizations**.**

From March 1997 to May 2004, the Tokyo VAAC has issued 411 VAAs regarding volcanic eruptions and volcanic ash clouds within the area of responsibility.

Automatic Issuance of VAA for Volcanoes in Japan

JMA operates not only the Tokyo VAAC but also four Volcano Observations and Information Centers (VOICs) that cover all 108 active volcanoes in Japan.

The four VOICs, namely Sapporo, Sendai, Tokyo and Fukuoka are watching 26 major active volcanoes 24 hours a day, 7 days a week using, for example, seismometers, tilt meters, GPS networks, and television cameras. Quick response teams under the VOICs conduct regular observations for the rest of 82 volcanoes in 'moderate' activities. When eruption reports from VOICs arrive at the Tokyo VAAC, the computer system translates the messages into VAAs and issues them automatically in order to immediately inform the occurrence of eruption (Fig. 2).

The automation is performed taking advantage of the fixed format of eruption reports from the VOICs. The Tokyo VAAC has established several communication routes under cooperation with adjacent VAACs, airlines (e.g., pilot reports), volcano observatories (e.g., KVERT and PHIVOLCS) so that appropriate and accurate information about volcanic eruptions could be immediately and correctly acquired. Based on such information, though, VAAs are issued manually because the software used in the automatic transaction cannot cope with various 'free' format massages.

After the issuance of each VAA triggered by an eruption report, VAAs, which contain ash cloud dispersion, are issued manually when ash clouds are detected on satellite imagery.

Improvement of Forecast Precision of Volcanic Ash Cloud Dispersion

Based on the improvement of numerical weather prediction model for the area in and around Japan, the Tokyo VAAC developed a detailed Lagrangian model that takes the effect of vertical wind into account. The grid and time interval has been improved to 20 km from 100 km and 1 hour from 6 hours, respectively. The model has been available since November 2003.

When ash clouds are released from volcanoes in Japan and Kuril Is. area, the improved model above (New Model) is used to calculate ash cloud dispersion for the issuance of VAA. Because of the limited application area of the New Model, the previous model (grid interval: 100 km; time interval: 6 hours) takes over the calculation using the final forecasted area by the New Model as an initial when the forecasted area of ash clouds reaches the boundary of the model.

Open to Public using Website

The web-site of the Tokyo VAAC has been open to public since December 2003. The contents, though, have not included issued VAAs. The Tokyo VAAC is now conducting a revision to the web-site so that VAAs will be available by the end of next March. The URL of Tokyo VAAC web-site is:

http://www.jma.go.jp/JMA_HP/jma/jma-eng/jma-center/vaac/index.html

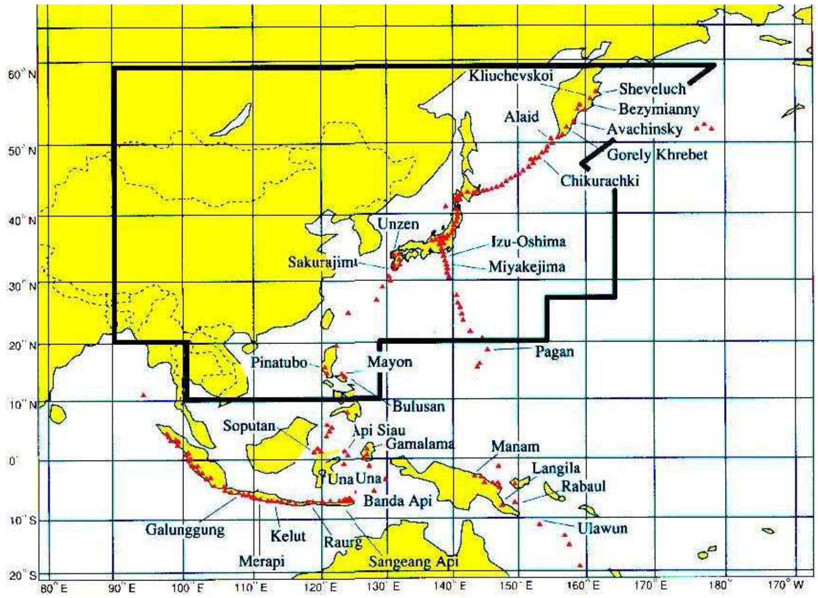


Fig.1 Area of responsibility of Tokyo VAAC (inside of the bold line)

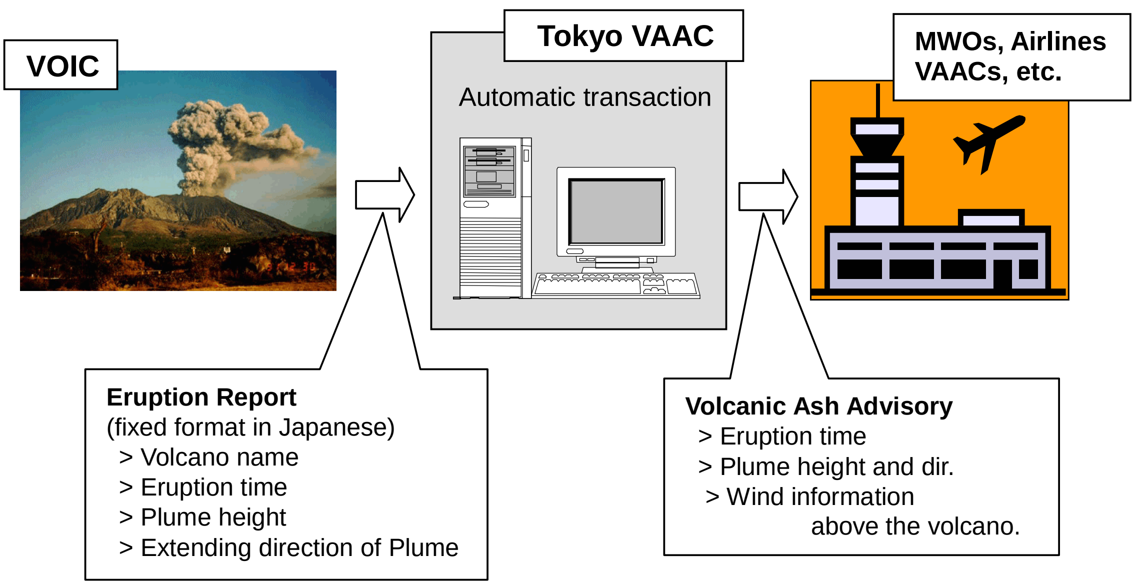


Fig. 2 Automatic issuance of VAA triggered by eruption report from Volcano Observations and Information Center (VOIC)

THE MONTREAL VAAC TOOLBOX: WHEN EVERY SECOND COUNTS

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Following the designation of the Montreal VAAC, the task of volcanic ash detection and forecasting was given to the 24/7 operational meteorologists of the Canadian Meteorological Centre (CMC). This was done so that, in the case of an actual volcanic eruption on Canadian territory, or in the case of inherited volcanic ash from neighbouring VAACs, a fast first response would be possible in order to support the Meteorological Watch Offices (MWOs) that issue SIGMETS, air traffic controls centres, flight dispatch centres, etc. To consolidate all the necessary monitoring and forecasting tasks into one place, a TCL based software known as the "Toolbox" was created which, since its inception, has undergone several revisions. It allows the on duty shift supervisor to continuously monitor various bulletins or pilot reports that may contain reference to volcanic ash and to track ash clouds with satellite data. The supervisor can also launch the CMC Trajectory Model and/or the CMC Canadian Emergency Response Model (CANERM) transport and dispersion Model. With the Toolbox, the results can be quickly posted on the public Montreal VAAC web-page or transmitted on national and international communications circuits as well as the WAFS. The toolbox also allows for the composition, transmission or re-transmission of volcanic ash advisory bulletins (FV). The latitude/longitude points of the ash cloud are extracted directly from the CANERM outputs with a few clicks of the mouse and automatically inserted in the FV, thus saving precious time.

ERUPTION OF ANATAHAN VOLCANO: OPERATIONS AND OBSERVATIONS

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NOAA/National Weather Service Forecast Office, Barrigada, Guam

The first historic eruption of a volcano on the island of Anatahan, located in the Northern Mariana Islands in the western North Pacific Ocean, occurred on 10 May 2003 (Fig. 1, Fig. 2). Cooperation and coordination between the NOAA/National Weather Service Forecast Office on Guam, Washington VAAC, Saipan Emergency Management Office and the airlines were important for monitoring, processing and releasing information on the eruption. Imagery from polar-orbiting satellites proved to be an invaluable complement to imagery from the geostationary satellites for monitoring Anatahan's ash plume (Figs 3, 4, 5, 6, and 7).

Fig. 1 – Anatahan on May 11, 2003, the morning after the eruption began. This view is looking toward the southwest. The ash cloud reaches as high as 40,000 feet.

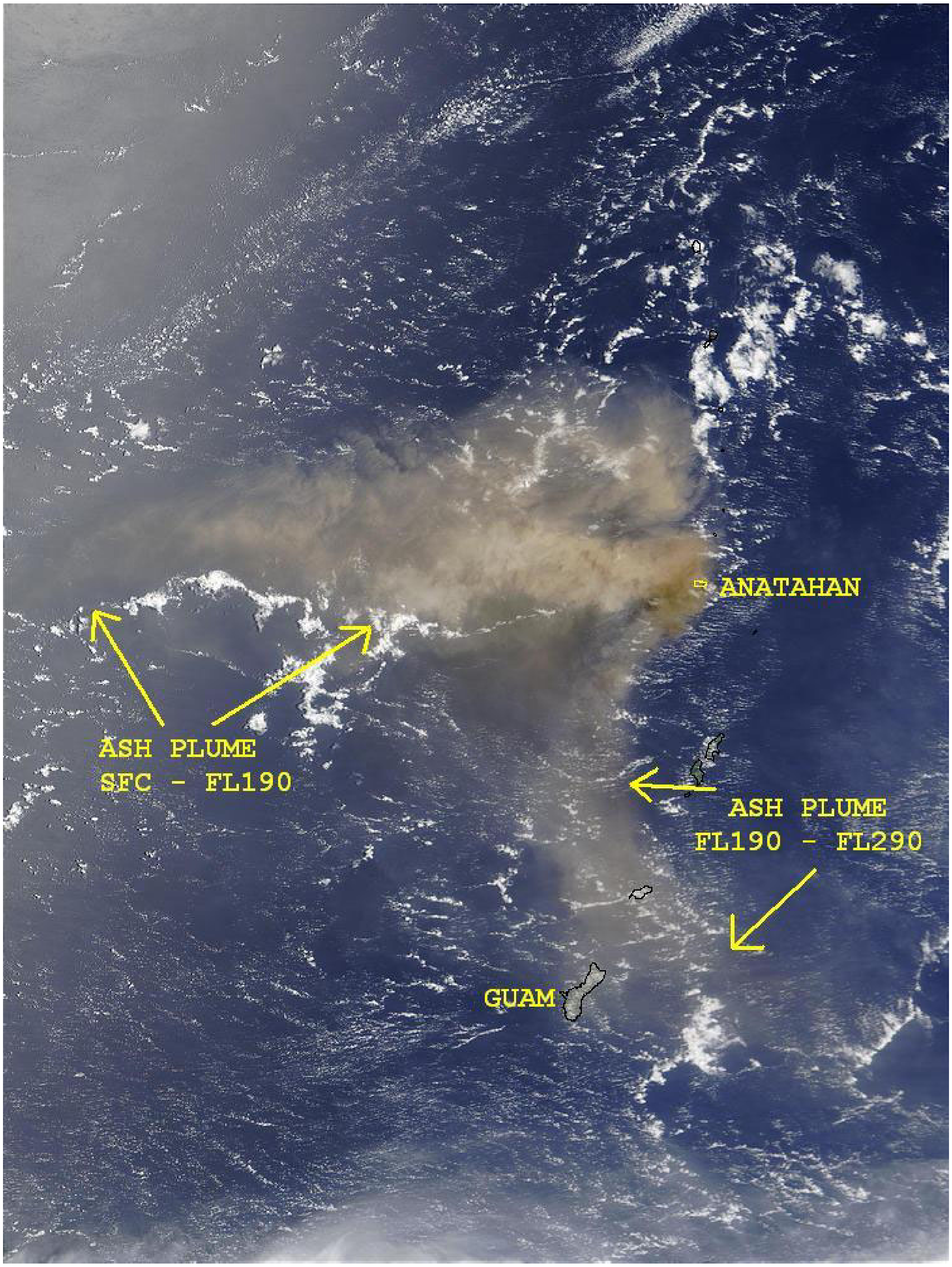

Fig. 2 – View from NASA's Terra satellite of Anatahan and its ash plume on May 11, 2003. The upper-level plume brought volcanic haze aloft to the skies of Guam and Rota.

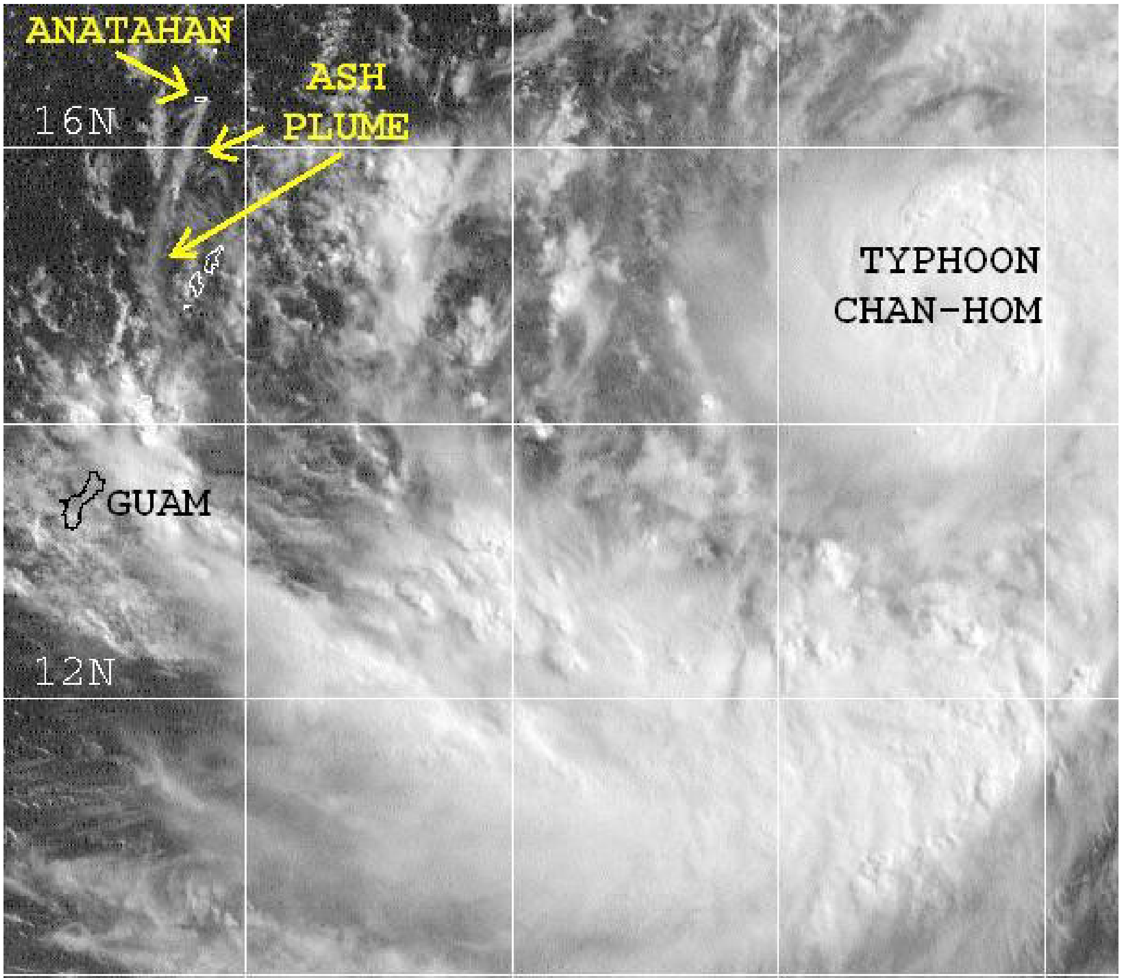

Fig. 3 – GOES-9 visible image for May 22 at 2213 UTC (May 23 at 8:13 a.m. Guam time). The circulation around Typhoon Chan-hom has brought the plume south-southwest over Guam and Rota. On Guam, a light dusting of ash fell, and there was a strong smell of sulphur. Because of the ash, Continental Airlines canceled six flights into and out of Saipan.

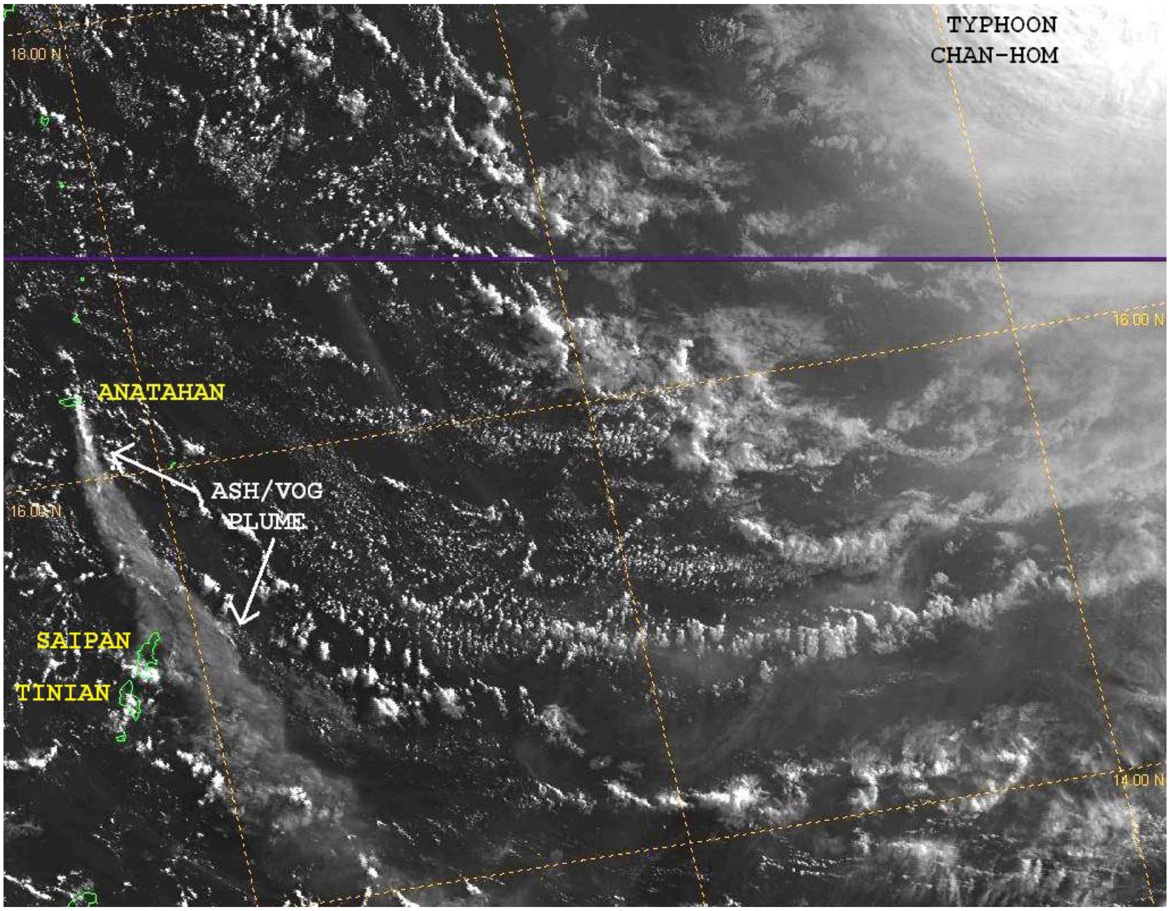

Fig. 4 – DMSP polar orbiter visible imagery showing the plume at 2034 UTC on May 23, 2003 (6:34 a.m. on May 24 Guam time). Ash fell on Tinian and Saipan, again prompting the cancellation of flights to and from Tinian and Saipan.

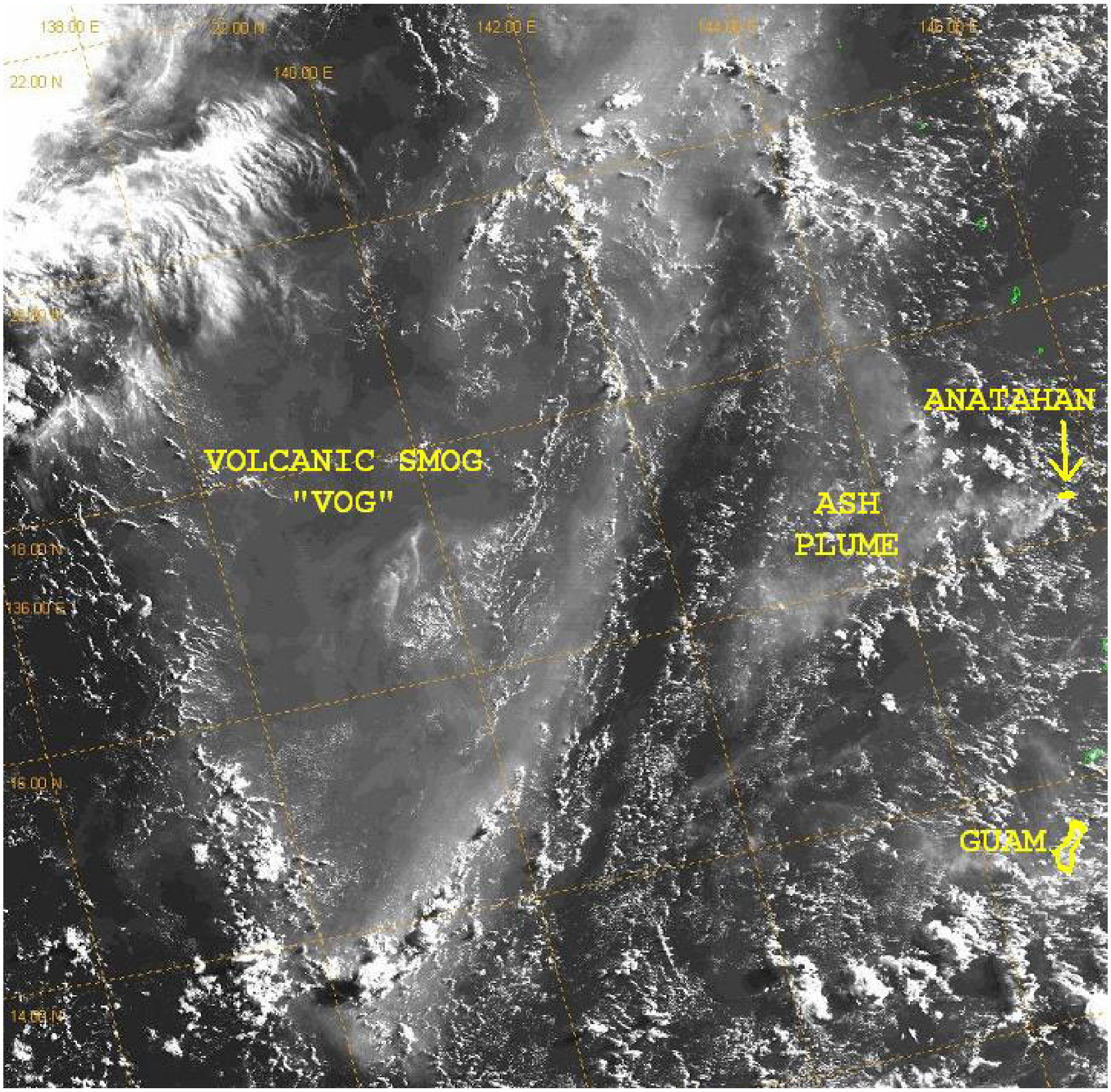

Fig. 5 – DMSP polar orbiter visible imagery from 2142 UTC on June 9, 2003 (7:42 a.m. on June 10 Guam time). In addition to the low-level ash/aerosol plume streaming west and northwest from Anatahan, volcanic smog or "vog" covers a large area further west. This vog is an aerosol that results from the chemical reaction between the volcano's sulphurous gas emissions, oxygen, and atmospheric moisture. Note the shadows cast by towering cumulus clouds onto the vog layer below.

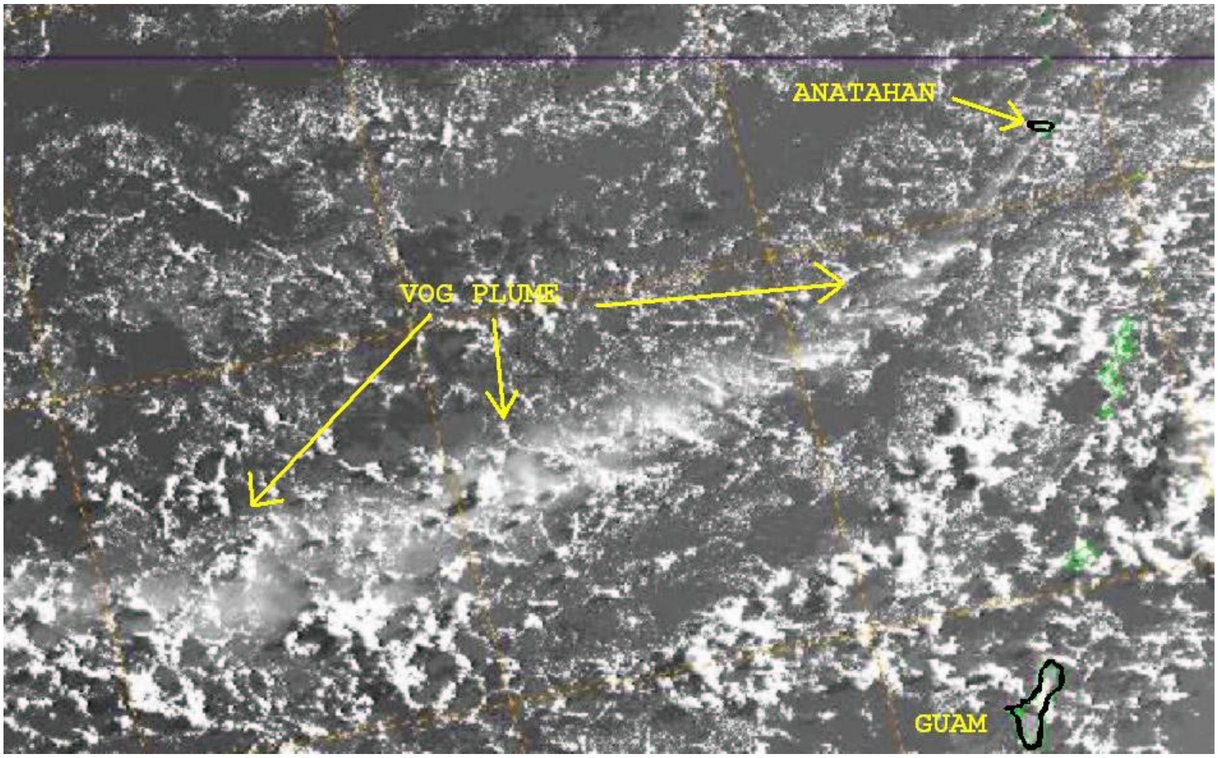

Fig. 6 – DMSP polar orbiter visible imagery from 2226 UTC July 9, 2003 (8:26 a.m. July 10 Guam time). The plume streams over 300 miles west from Anatahan. By this time, the plume is restricted to between the surface and about 8,000 feet, and it consists mostly of vog. The contrast in this image has been greatly enhanced to bring out the plume. Indeed, throughout July the plume was not visible in GOES-9 visible or IR imagery, and could only be seen under low sun-angle conditions by the DMSP satellite.

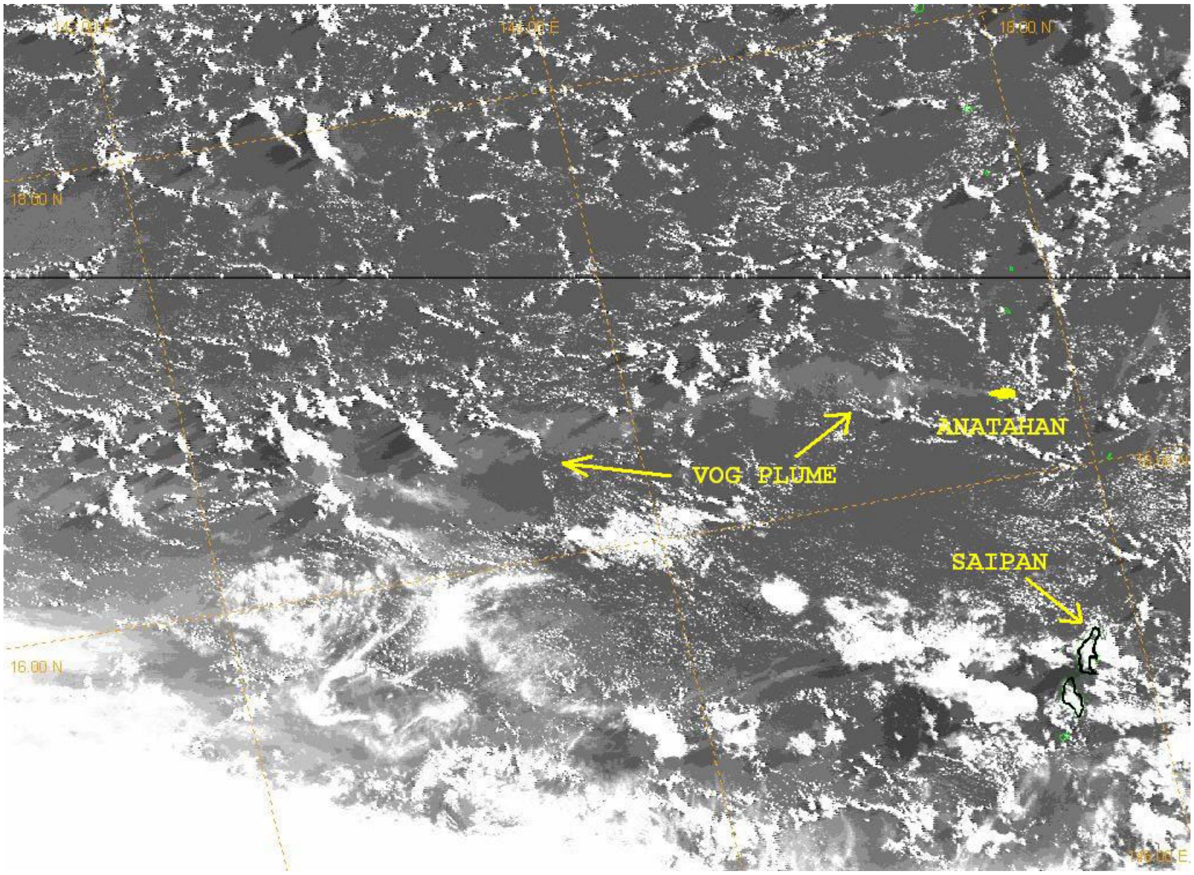

Fig. 7 – In this DMSP polar orbiter visible image from 2100 UTC on July 18, 2003 (7 a.m. Guam time on July 19), the vog plume is barely seen, even after greatly enhancing the image's contrast. At this point, the plume was judged to consist solely of vog. As a result, volcanic ash SIGMETs on the plume were discontinued the following day.

THE VOLCANIC ASH COLLABORATION TOOL (VACT)

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In order to facilitate real-time collaboration during North Pacific eruptions, a pilot project was instituted in 2003 to develop the Volcanic Ash Collaboration Tool (VACT). The VACT consists of workstations located at the Anchorage VAAC, the Anchorage Center Weather Service Unit, and the USGS Alaska Volcano Observatory, with shared access to satellite and meteorological data. The VACT allows for shared situational awareness by providing common views of the data sources, and by allowing all groups to view, enhance and annotate graphical data. This poster session will give participants the opportunity to gain hands-on experience with the VACT in order to explore its capabilities.

VOLCANIC ASH MONITORING AND FORECASTING AT THE LONDON VAAC

Sarah Watkin[1], Sigrún Karlsdóttir[2], Nigel Gait[1], Derrick Ryall[1] & Helen Watkin[1]
[1]Met Office, Exeter, U.K.
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Introduction to the London VAAC

The London VAAC (Volcanic Ash Advisory Centre) is responsible for monitoring and forecasting the movement of volcanic ash over the United Kingdom, Iceland and the north-eastern part of the North Atlantic Ocean (Figure 1). Although this is a relatively small area, it covers some of the busiest airways in the world. A volcanic eruption on Iceland can quickly affect a large area of airspace, as strong winds spread the ash downwind from the volcano. Air traffic control organizations need to react quickly to the forecasts issued by the VAAC so that aircraft can be diverted onto alternative safe tracks.

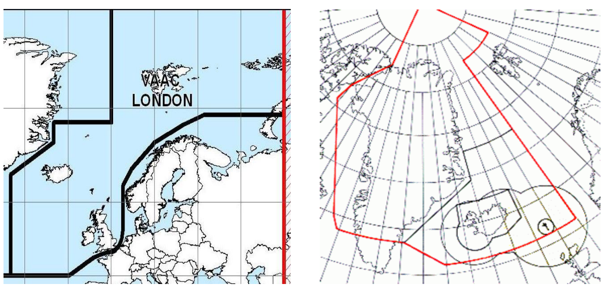

Figure 1: *The London VAAC area (on left) and the IOCA (on right in red).*

During a volcanic eruption on Iceland, the London VAAC liaises closely with forecasters at the Icelandic Meteorological Office (IMO), where monitoring of the Icelandic volcanic zone takes place. The London VAAC has access to the latest observational data as it emerges. This may be data from: seismic surveys, eye witness accounts (often from aircraft) of current plume behaviour or volcanic activity, or analysis of satellite pictures. During an eruption forecasters issue regularly updated Volcanic Ash Advisories Statements based on observational and forecast data about the current and predicted location of volcanic ash.

Volcano monitoring at the Icelandic Met Office

A volcanic eruption occurs in Iceland every four to five years on average. These eruptions can have a large impact on jet aircarft flying through the Icelandic Ocean Control Area (IOCA), which is one of the largest in the world (Figure 1). Approximately 250 jet planes cross the area daily and up to 500 utilize the area during favourable weather conditions (Sveinbjörnsson, 2001).

A monitoring system (Stefánsson et al., 1993) covers the active volcanic zone in Iceland, and data from this system are analysed continuously by the IMO. Currently (in July 2004), two Icelandic volcanoes show signs of an impending eruption. Those are Mt. Katla (63°59'N, 19°05'W), and Grímsvötn (64°41'N, 17°27'W). The last eruption of Mt. Katla was in 1918, hence a large eruption can be expected. Grímsvötn, on the other hand, erupted in 1998. In readiness for these eruptions, IMO receives two sets of images every day from the NAME model (see description below) run by the London VAAC. These images show the dispersal of volcanic plumes from hypothetical eruptions at the two locations, mentioned above (Figure 4). The height of the volcanic plume is an important input parameter into the model, and this information is based on research on previous eruptions at the same locations. This procedure makes it possible to issue a SIGMET indicating the forecast area of ash, only a few minutes after the onset of an eruption. Similar methods will take place when other volcanic areas show sign of impending eruptions.

When an eruption occurs in Iceland the following working procedure takes place. At the start of the eruption IMO informs the Icelandic Civil Aviation

Authorities and London VAAC about the eruption location and its estimated plume height. With this information the London VAAC calculates the spread of the plume with NAME, and the results are sent to IMO together with additional advisory information. During the eruption IMO and London VAAC forecasters monitor the volcanic plume via satellite images and with an Icelandic-based weather radar, which has shown to give valuable information (Lacasse et al., 2004) (Figure 2).

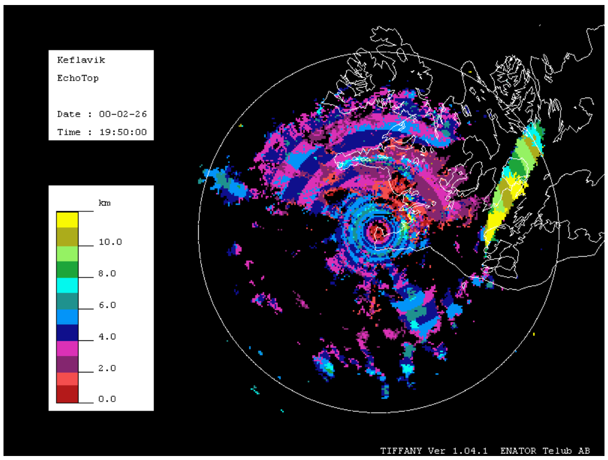

Figure 2: *C-band weather radar observations of the eruption plume from Mt. Hekla on 26 February 2000, approx. 1½ hours after the start of the eruption, showing the estimated height of the eruption plume.*

Eruption detection system

The Met Office has developed an automatic volcanic eruption detection system using Meteosat infrared images and forecast meteorological data. The system uses a shape-matching technique to search for suspected volcanic eruption clouds in the London VAAC area each time a new satellite image becomes available (every quarter of an hour with MSG).

Clouds are identified as possible ash clouds by checking for good correlation between the shape of the actual cloud and that which might be expected for an eruption cloud in the prevailing meteorological conditions. This shape is either circular, or a plume shape spreading downwind. The left image in Figure 3 shows the expected cloud shape that the system would have produced for Hekla at 1900Z on 26 February 2000 and used to search the image around Hekla for close shape-matches. The right image shows the Meteosat infrared image at that time. The cloud would have been detected in the outlined position 40 minutes after the eruption began.

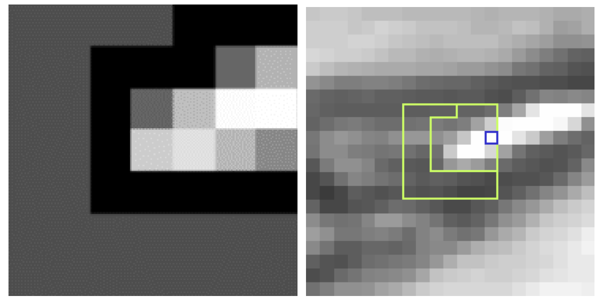

Figure 3: *Eruption of Hekla, Iceland on 26/02/00: the expected cloud shape produced by the detection system (left), would have detected the eruption in the 1900Z Meteosat IR image (right).*

The detection algorithm checks that the cloud that has been shape-matched exhibits other characteristics consistent with them being volcanic in origin:

Location - cloud top should be close to a volcano, or downwind of a volcano.

Contrast - cloud top brightness temperature should differ from the immediate surroundings.

Height - the cloud top height should be at the same height as the wind used for establishing the shape and location conditions.

In order to rule out as many false alarms as possible, the cloud must also pass the following checks to give sufficient confidence that it is not a meteorological cloud:

Temporal check - the cloud was not present upwind of the volcano in a previous image.

Grey level check - there are no other clouds in the vicinity at the same height.

Sudden appearance check - the cloud has suddenly appeared in the image.

Convective cloud check - no convective cloud has been forecast at that height.

The eruption detection system detected 12 of the 18 eruptions in the Meteosat field of view that were used to develop and test the system. The detection system was also tested on a month's data in order to investigate how many false alarms would be produced. A false alarm is when the eruption detection system detects a candidate cloud that passes all of the tests, but no eruption had actually occurred. These results show that the system could monitor the London VAAC's area of responsibility with the production of only a few false alarms each day. During 2004 the system will be upgraded to use MSG images. The performance of the system will be re-evaluated and a decision made regarding possible operational implementation.

Volcanic ash forecasting using NAME

NAME is the Met Office's medium-to-long range atmospheric dispersion model. It has evolved into an all-purpose dispersion model capable of predicting the transport, transformation and deposition of a wide class of airborne materials, e.g. nuclear material, volcanic emissions, biomass smoke, chemical spills, Foot and Mouth disease. It is a Lagrangian particle dispersion model which predicts 3D concentrations and deposition of airborne particles and covers horizontal scales from ~1km to many 1000s km. It uses detailed 3D meteorology from the Met Office's Unified Model (horizontal resolution of 60 km globally and 12 km over northwest Europe and the UK).

During an eruption, forecasters run NAME to predict the dispersion of volcanic ash particles up to six days ahead. Where possible the plume height and release duration are derived from observations (e.g. satellite, radar or pilot reports). A release quantity of 1g ash is used (1g per six hour period if the eruption continues for more than six hours). A look up table based on summit and ash cloud height is used to determine the concentration corresponding to a 'visual ash cloud'. If good observational data is available then the release rate can be adjusted to provide a better match between observed and modelled visual ash clouds. An assumed particle size distribution is used, with a continuous distribution between 0.1-50um.

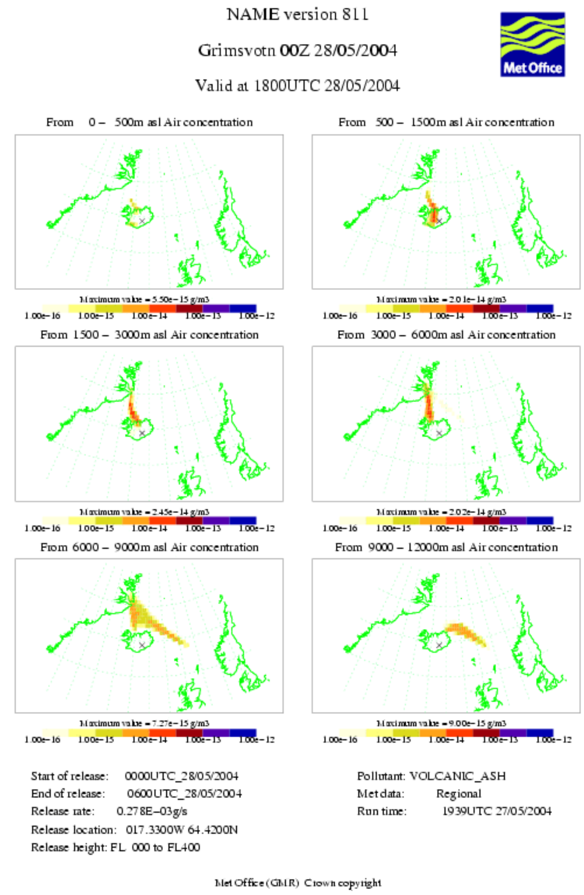

Figure 4: *NAME forecasted dispersion for a hypothetical eruption of Mt. Grímsvötn.*

The output from NAME is a graphic showing the extent of the visible ash cloud at three levels: surface-FL200, FL200-FL350, FL350-FL550 for the next 24 hours at 6 hour intervals. More detailed plots are available to forecasters, representing concentration maps over 6 layers. The NAME forecast forms the basis of the volcanic ash advisory issued by forecasters. They are validated by comparison in real-time with satellite observations (see Figure 5 and the next section). In addition to using NAME during volcanic events, it is run twice daily, as mentioned above, to provide guidance to the IMO about the dispersion of ash from two volcanoes, Mt. Katla and Grímsvötn (Figure 4).

There are several key modelling issues that remain. A clearer definition of a visual ash cloud is needed, along with a better understanding about what is hazardous to aircraft. Improved source terms are needed, particularly information about vertical extents and multiple or intermittent sources. Also, improvements in the NWP model that drives NAME in terms of the representation of orographic features are needed.

Volcanic ash tracking using satellite data

Once forecasters are notified about an eruption they need to track the transport of the ejected volcanic ash particles. Satellite observations offer the only possibility of tracking ash over large distances. However, discriminating between volcanic ash clouds and water or ice clouds can be difficult. The Met Office generates "volcanic ash images" routinely from Advanced Very High Resolution (AVHRR) data for regions covering the London VAAC area, Iceland and Mt. Etna (Watkin, 2003). These images are used by forecasters to discriminate between ash and water/ice clouds and enable them to track the ash and thus validate the NAME forecasts. The volcanic ash images show values of $BT_{10.8} - BT_{12.0}$. In general: $BT_{10.8} - BT_{12.0} < 0$ for volcanic ash, $BT_{10.8} - BT_{12.0} > 0$ for water/ice clouds.

These images have been used to study eruptions of Mt. Etna (there have been no Icelandic eruptions since their implementation in 2001). Figure 5 shows AVHRR $BT_{10.8} - BT_{12.0}$ images alongside NAME forecasts for two days during the eruption of Mt. Etna in 2002. This example demonstrates the usefulness of studying the two data sets in conjunction; e.g. the NAME forecasts confirm that the weak ash-signal (i.e. values are in a negative sense compared to surrounding clear-sky values) north-west of Sicily in the AVHRR image on 31 October 2002 is volcanic ash.

Meteosat-8 (Meteosat Second Generation) is a new geostationary satellite located at 0° longitude with a 15 minute imagery repeat cycle. The Spinning Enhanced Visible and Infrared Imager (SEVIRI) on board Meteosat-8 has 12 channels at: 0.6, 0.8, 1.6, 3.9, 6.2, 7.3, 8.7, 9.7, 10.8, 12.0, 13.4 μm and high resolution visible. Data from several of these channels could provide useful information about volcanic emissions (e.g. volcanic ash and sulphur dioxide).

Currently, SEVIRI data are operationally received and processed to generate nowcasting products and imagery, including "volcanic ash images" ($BT_{10.8} - BT_{12.0}$) every 15 minutes. The application of SEVIRI data offers a unique opportunity to advance satellite-based detection and retrieval of volcanic emissions. Work is underway to further exploit MSG data for volcanic emission monitoring.

Summary

The London VAAC provides a service to the aviation industry which advises about the presence of volcanic ash in a region encompassing Iceland, U.K. and the north-east Atlantic. To provide this service forecasters make use of a range of information: from the Icelandic Meteorological Office, from Icelandic radar, from NAME dispersion model forecasts and from satellite imagery. These information sources are supported by research into improving and extending the quality of the information. Research is currently underway in improving the NAME model for volcanic ash forecasting, in developing an eruption detection system and in the exploitation of Meteosat-8 (MSG) satellite data for volcanic ash and sulphur dioxide tracking. Close collaboration between the Icelandic Meteorological Office and the U.K. Met Office ensure that observational data about an eruption is transferred efficiently, that appropriate developmental work is undertaken and that Volcanic Ash Advisory Statements are timely and contain all available information.

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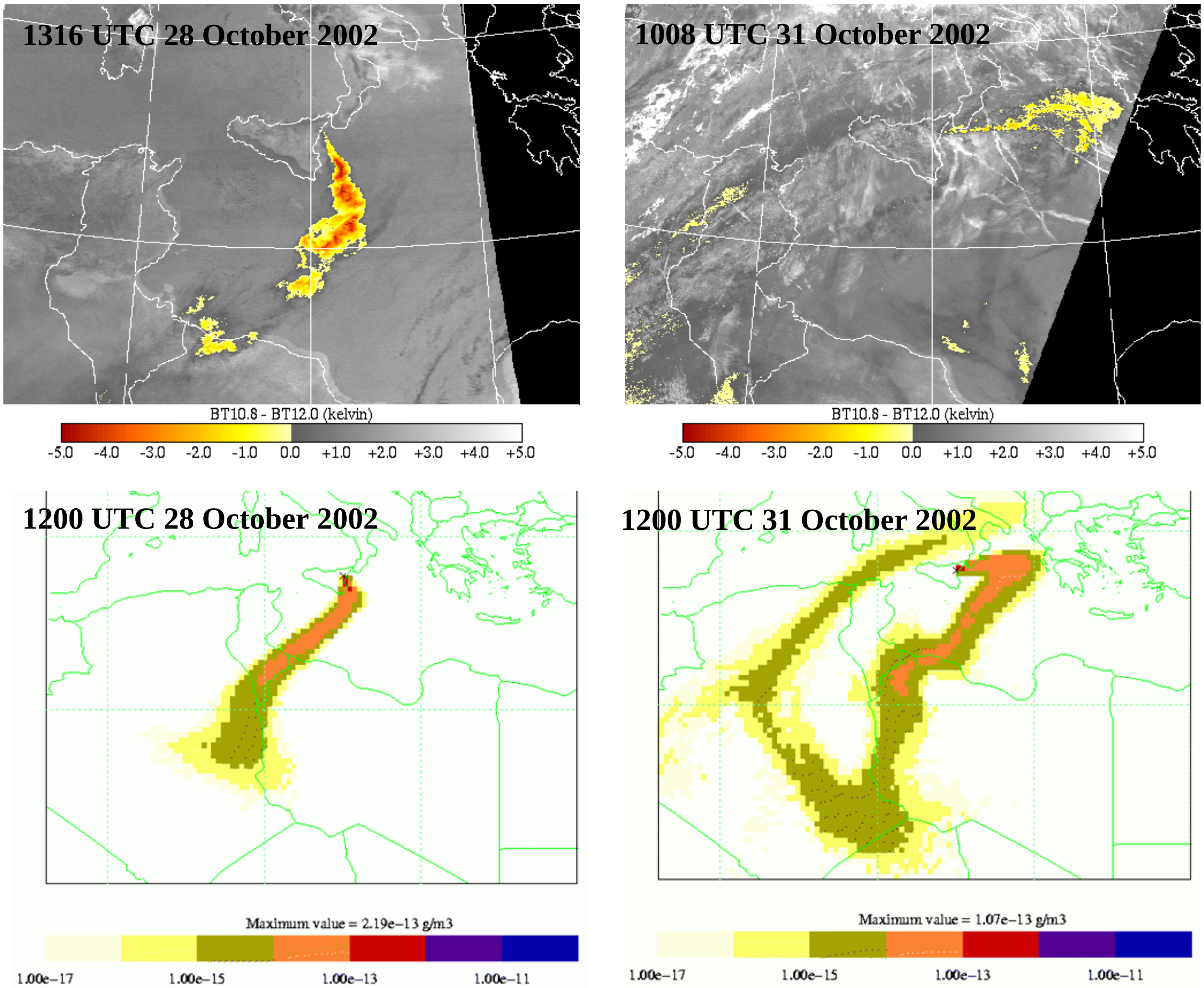

Figure 5: *Eruption of Mt. Etna in October 2002. Top: AVHRR $BT_{10.8} - BT_{12.0}$ images showing areas with negative values in red to yellow (indicating ash). Bottom: Forecasts from NAME showing show total column concentration (a continuous release rate of 0.278 mg/s from surface to FL200 was used).*

Web Access to the Digital Archive of VAA Messages and VAFTAD Model Output

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Grace Swanson, NOAA Satellite Services Division, Camp Springs, Maryland, USA

To ensure safe navigation and monitor possible climatic impact, NOAA tracks volcanic ash eruptions throughout the world and monitors all available satellite images for ash clouds. After an eruption, NOAA issues a VAA message and a forecast of ash location in the atmosphere from the VAFTAD model. The National Geophysical Data Center (NGDC) has digitized and archived 20 years of VAA messages, VAFTAD model output, and substantiating information for both foreign and domestic volcanoes issued by NOAA's Volcanic Ash Advisory Centers (VAACs) and collected by the NESDIS Office of Satellite Data Processing Division (OSDPD). The substantiating information includes surface weather observations, pilot reports, volcanic observatory reports, news media reports, and satellite imagery for each event. During the next year these data will be input into a geospatially-enabled relational database management system (RDBMS) and made accessible over the Web. The database will also include links to GOES imagery from the CLASS GOES active archive. This database will provide researchers with access to all of the information concerning a past volcanic event, facilitating model evaluation. A prototype of the new website will be presented and comments and suggestions for improvement will be solicited.

[This was given as an electronic poster.]