Guidance for State Volcano Observatories: The International Airways Volcano Watch

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Front cover: Eruption of Manam Volcano, Papua New Guinea, 24 October 2004, as seen by NASA's Aqua/MODIS. The scene shows an ash-rich lower level plume streaming to the northwest (brown), an overlying gas and ice-rich upper level cloud (white), and normal meteorological cloud (bright white).

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International Civil Aviation Organisation References:

- ICAO Annex 3 -Meteorological Service for International Air Navigation, Chapters 3, 4, 7 and 9 and Appendices.
- ICAO Handbook on the IAVW - Operational Procedures and Contact List (Doc 9766)
- ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds (Doc 9691)
- ICAO Manual of Aeronautical Meteorological Practice – Doc 8896
- ICAO Policy on Charges for Airports and Air Navigation Services – Doc 9082
- ICAO Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services - Doc 9377

1. Introduction

Volcanic ash suspended in the atmosphere is a great danger to aviation, especially to turbine powered aircraft. This paper is adapted from a resource originally written for States in the SE Asia and South Pacific regions to assist them to meet their international and domestic obligations in the mitigation of volcanic ash risk to civil aviation.

The paper also sets out the areas where there is most to be done in these regions; particularly the monitoring and communication of volcano activity status and the provision of the requisite formal warnings in the international aviation system.

Importantly, the paper also provides guidance and examples on how the costs of such services can be legitimately recovered from the aviation community.

2. The Danger

Volcanic ash in the air is composed of fine pulverised rock and is accompanied by a number of gases which are then converted into droplets of sulphuric acid and other substances. It is potentially deadly to aircraft and their passengers. The most critical effect is caused by ash melting in the hot section of turbine engines, and then fusing into a glass-like coating on components further back in the engine, causing loss of thrust and possible "flame out" (engine failure). In addition there is an abrasion of engine parts, the airframe and parts protruding from the aircraft, and possible clogging of the fuel and cooling systems. Sulphur dioxide, another product of volcanoes which is also carried within the ash clouds following an eruption is corrosive to aircraft that fly through it.

When flying at night, ash clouds are not visible to pilots; in addition they do not show on aircraft radar. Even when flying in daylight, the ash cloud may not be identified due to its mixing with water vapour or its light colouration.

19 September 1994 Rabaul eruption (Papua New Guinea)
showing a typical downstream fanning of the plume at a high altitude. Courtesy NASA (Space Shuttle)

Examples of incidents include:

✈ A British Airways Boeing 747 lost power to all four engines in 1982 over Indonesia after an eruption of Mount Galunggung and three weeks later the same thing happened to a Singapore Airlines 747, which lost two engines. Both made a successful emergency landing.

✈ A KLM Boeing 747 lost power to all four engines in 1989 over Alaska after an eruption of Mount Redoubt but was able to recover enough power to make a successful landing in Anchorage.

✈ The 2000 Miyakejima eruption in Japan where two international aircraft suffered damage requiring complete engine replacement,

✈ An unusual 2006 incident over Papua New Guinea where a Gulfstream lost power to both engines from what appears to have been a diffuse volcanic cloud.

✈ The 2008 eruptions of Chaiten Volcano, Chile, which caused five aircraft encounters (one resulting in engine replacement), and also caused significant disruption.

Such encounters, if survived, will inevitably cause the write-off of substantial parts, if not all of the aircraft. One of the biggest lessons learned over the last decade is that volcanic ash plume trajectories can extend for many thousands of kilometres and there is evidence that some plumes have completely circumnavigated the planet. This is of very significant importance to aviation world-wide. Plumes many days old are now thought to have caused (minor) damage to aircraft – for example in late 2002 some minor abrasion and a blocked pitot tube north of Papua New Guinea is believed to have been caused by a cloud from a South American eruption 20 days earlier.

The complex interaction between volcanic clouds and the atmosphere is still being explored. For example, the height to which a volcanic plume may rise is greatly influenced by the atmospheric characteristics (such as convective instability, the wind shear and tropopause height). An eruption in an unstable tropical atmosphere, for example, could potentially rise well above cruising levels, but the same eruption during a polar winter may only rise a few kilometres. A water/ice rich volcanic cloud might contain much less ash than a drier volcanic cloud due to particle aggregation, but the cloud might be much more difficult to detect as being volcanic due to the presence of the ice.

3. Mitigation

To address the aviation hazard, co-operation between the volcanological, meteorological, and aviation communities has been necessary to address the problem. As aviation and meteorology communities are highly organised under two effective and efficient UN specialised agencies, this co-operation has substantial potential to assist operational volcanology across the world achieve its aims.

Following the 1982 British Airways incident it was recognised by the international aviation community that volcanic ash was a danger to commercial aviation and that the only way to ensure that there would be no loss of an aircraft was to alert pilots in a timely manner to divert their flight around the ash cloud or plume.

Since those early incidents, a major international effort has been underway to track and warn aircraft of volcanic ash cloud. Quite apart from the safety consideration, volcanic ash has caused very expensive damage to aircraft; most estimates cite costs to aviation of well over $250 million since 1982. The KLM incident in 1989 alone cost over US $80 million. Therefore, international airlines are willing to undergo extensive and very expensive re-routing if there is any possibility of contact with volcanic ash on their regular routes.

Remarkable progress has been made in the intervening years, and the aviation industry has participated in all of the initiatives and development processes. However, much more work on mitigation participation and the science is required before the aviation community has a near fail-safe warning system:

3.1 International Airways Volcano Watch (IAVW)

On behalf of the international aviation community the International Civil Aviation Organisation (ICAO- a United Nations Technical organisation), in conjunction with the World Meteorological Organization (WMO), and in consultation with the International Union of Geodesy and Geophysics (IUGG[1]), has developed and implemented a system for the detection and warning of volcanic ash. This is known as the International Airways Volcano Watch (IAVW) and its operation and further development is managed by the International Airways Volcano Watch Operations Group (IAVWOPSG).

This initiative was undertaken under the auspices of the Convention on International Civil Aviation signed in Chicago in 1944 and its Annex 3- *Meteorological Service for International Air Navigation*. The great majority of countries in the world, or more properly 'States' in UN terminology, are signatories to the Convention.

The IAVWOPSG has the following responsibilities, amongst other things:

(a) provide advice and guidance to the secretariat concerning the operation of the IAVW and its effectiveness in meeting current operational requirements;

(b) develop proposals for the development of the IAVW in order to ensure that it continues to meet evolving operational requirements;

(e) assist the Secretariat in the development of appropriate guidance material both for operations with volcanic ash in the atmosphere and also operations with volcanic ash deposited on aerodromes;

(f) develop specific proposals for the provision of warnings for aerodrome management for deposition of volcanic ash on aerodromes; and

(g) provide advice and guidance to the Secretariat and the Volcanic Ash Advisory Centres (VAACs) regarding the future IAVW and existing VAAC Web sites, respectively.

The IAVWOPSG comprises representatives from States providing the VAACs, representatives from ICAO, the International Atomic Energy Agency (IAEA), the International Air Transport Association (IATA), the International Federation of Air Line Pilots' Associations (IFALPA), the International Union of Geodesy and Geophysics (IUGG) and the World Meteorological Organization (WMO).

There are four core aspects in the IAVW system:

(a) The **Volcanic Ash Advisory Centres** (VAAC) - issue of warning guidance material

(b) The various **Volcano Observatories** in each State – provision of volcanic event information

(c) The **Meteorological Watch Offices** (MWO) in each State – provision of warnings to aviation

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[1] The IUGG has as one of its members the International Association of Chemistry and Volcanology of the Earth's Interior (IAVCEI): the World Organisation of Volcano Observatories (WOVO) is a Commission of IAVCEI.

(d) **Pilots and aircraft operators** – provision of reports of eruptions and volcanic clouds/plumes.

A simplified schematic of the IAVW system is set out in Appendix 1. A full explanation of the IAVW system can be found in the ICAO:

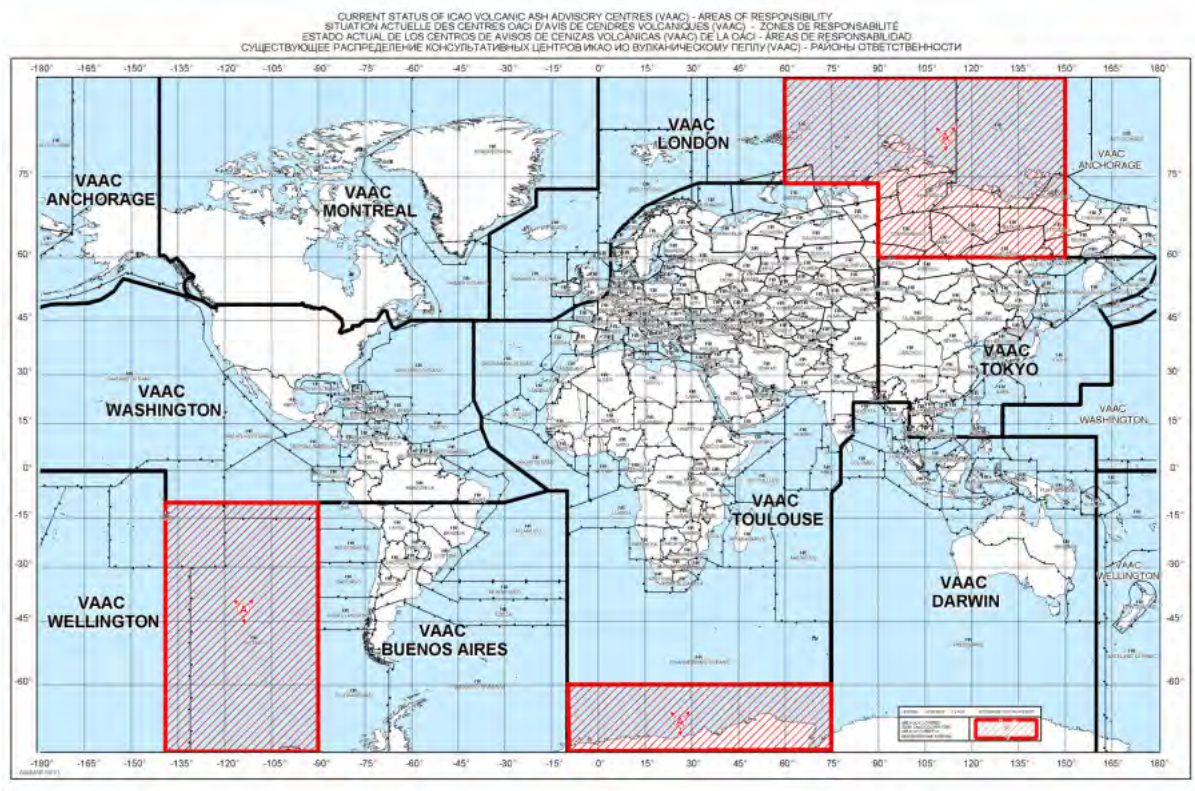
- ✈ Handbook On The International Airways Volcano Watch (IAVW) - Doc 9766
- ✈ Manual on Volcanic Ash, Radioactive Material, and Toxic Chemical Clouds - Doc 9691

3.2 Volcanic Ash Advisory Centres (VAAC)

The nine Volcanic Ash Advisory Centres (VAACs) around the world are designated by ICAO. They are responsible for co-ordinating and disseminating information on volcanic ash that may endanger aircraft. The individual VAAC are run as part of the particular State Meteorological Authority responsibilities.

The function of the VAACs is to respond to reports of volcanic ash within their region and provide forecasts to the aviation community of ash cloud extent and movement. Observations may come from ground stations and volcano observatories, aircraft in flight or orbiting satellites.

In the map below, note that the hatched area in the south Pacific shown as uncovered in the diagram is now covered by VAAC Wellington (to ensure support for great circle flights from New Zealand and Australia to South America).



The specific output of each VAAC is the issue of Volcanic Ash Advisories (VAA). These are textual and graphical products that show the origin of the ash, and the expected trajectory and height of the ash cloud or plume over 6, 12 and 18 hours.

While the existence of an eruption and/or an ash cloud may come from satellite remote sensing information, it is more likely to come from aircraft observations or, more importantly, from volcano observatories (refer 3.3 below).

The VAA are primarily intended to inform meteorological watch offices so they can perform their obligatory warning function (see 3.4 below). However, VAA are also passed to air traffic control offices and, airlines as this information may well precede the issue of formal warnings by some time. Non-volcanically sourced observations coming into the VAACs are also potentially useful for assessment of general volcanic risk, and VAAC are encouraged to pass these observations to volcano observatories, in support of the Hyogo Framework for Disaster Risk Reduction.

3.3 Volcano Observatories

There are approximately 560 volcanoes for which there is evidence of an eruption during the past 500 years. Only about 170 active volcanoes are under continuous surveillance by volcano scientists.

Under Annex 3 to the Convention each State is required to provide information on volcanic activity to the VAAC Centre covering the particular regions. There are specific information requirements to be fulfilled in a timely manner. A template report has been developed for volcano observatories to pass this information to the VAACs, Area Control Centres (ACC) and Meteorological Watch offices (MWO) – the VONA template – Volcanic Observatory Notice to Aviation. A copy of the VONA template is attached in Appendix 3.

An undersea volcano erupts off the coast of Tonga, sending plumes of steam, ash and smoke up to 100 metres into the air, on March 18, 2009, off the coast of Nuku'Alofa, Tonga

3.4 Meteorological Watch Offices (MWO)

Each State Flight Information Region (FIR) has an associated Meteorological Watch Office (MWO) which operates as part of the States' Meteorological Authority obligations under the Convention. It is the responsibility of the MWO to issue formal warnings to aviation of various meteorological phenomena including volcanic ash and eruption activity.

The warnings take the form of information about significant en-route meteorological conditions which may affect the safety of aircraft operations. This information called SIGMET has a specific form and covers the actual reported event as well as a projection, in the case of volcanic ash, the expected conditions in 6 hours time. SIGMET are produced in both textual and graphical form and are passed to air traffic control offices and airlines.

Within the ICAO standards and recommended practices, SIGMET are the primary form of warnings on volcanic ash.

3.5 Area Control Centres

Each State Flight Information Region (FIR) has an associated Area Control Centre (ACC) which operates as part of the States' Meteorological and Air Traffic Management Authority obligations under the Convention.

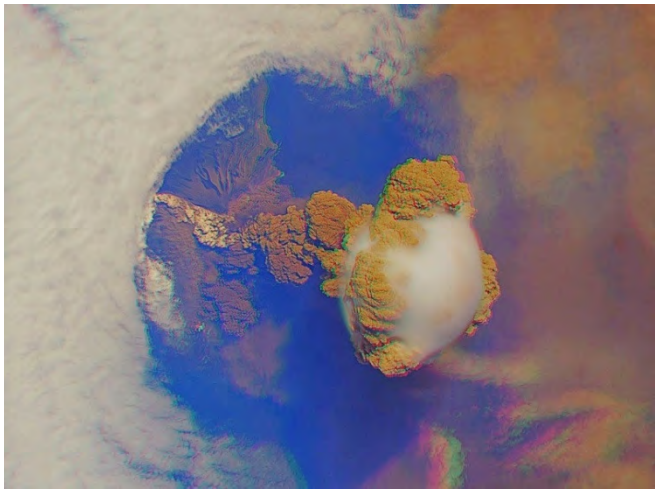
It is the responsibility of the ACC to receive and the various warnings and report on volcanic ash and transmit these to the appropriate parties – VAAC, MWO and aircraft in flight in the FIR.

3.6 Aircraft Operators and Pilots

VAACs and MWOs need strong support in two ways. Firstly, aircraft operators and pilots need to be proactive in promoting better monitoring in their own region. Secondly, in real time, VAACs need every sighting of volcanic ash reported in real-time to the local ACC, and preferably followed up with a written report after landing. Similarly, every encounter with ash or sulphur dioxide (a sharp, 'struck match' smell) should be also immediately reported and then followed up by the operator, preferably involving the relevant VAAC and MWO, in the process.

The formal mechanism for the reporting of volcanic ash information is by special air report, in this type if instance it is referred to as a Volcanic Ash Report (VAR). The standards and protocols for pilots to make such reports are well document in various Annexes to the Convention.

Actual ash encounters should of course be fully investigated in their scientific and aviation contexts as soon as possible.



Sarychev Peak eruption (Russian Kuril Islands), 25 June 2009 from the International Space Station

4. Issues and Solutions

There are a number of significant remaining technical issues to ensure the IAVW system provides optimum volcanic ash risk mitigation information for international aviation. Broadly these include the need for:

1. Better remote sensing information from satellite based systems.
2. Better trajectory modelling, and initialisation.
3. Better and more timely volcano information and communications.
4. Better and more timely production of VA SIGMET by MWOs.
5. Better and more timely observation information from aircraft.

This paper contemplates issues 3, 4 and 5 only.

A further significant issue is the matter of the costs involved in States meeting their IAVW obligations. It is understood that many States may not have the capacity in their current agencies to perform the requisite functions and some may not have been historically able to allocate broad responsibilities that would cover the IAVW obligations. In either case the core issue is one of funding.

4.1 Communications

Only through intensive observations from volcano observatories can better definition of volcanic activity best inform the VAAC and MWOs thereby allowing them to perform their function in the IAVW.

It is therefore imperative that States with volcanoes in their territory, or in nearby international waters (submarine volcanoes), ensure that they have systems in place to pass any information they have on volcanic activity to the requisite VAAC, ACC and MWO. This does not necessarily mean that States must have a dedicated volcano observatory agency, but it does mean that some government agency is formally given the task of maintaining a 24/7 watch on volcanoes and providing activity and eruption information quickly to the requisite VAAC, ACC and MWO.

The IAVW system has recently completed work on the VONA (Volcanic Observatory Notice to Aviation – Refer Appendix 3) form in an attempt to guide observers through the kind of

information needed by the aviation community and the transmission of the VONA to the requisite ACC, VAAC and MWO.

It is understood that in many cases, this work will inevitably involve new costs to the State and this is covered in 4.4 below.

4.2 Meteorological Watch Office SIGMET Production

There are many Flight Information Regions (FIR) across the world. Each region has a designated Area Control Centre (ACC) and Meteorological Watch Office (MWO). While it is the responsibility of the MWO to issue volcanic ash warnings (VA SIGMET) on receipt of information (VAA) from the associated VAAC, this is not always achieved.

Some States have a chronic lack of capacity to meet their overall Annex 3 responsibilities. The problem is not unique to any one region but extends right around the world. Each region has different issues ranging from non-compliance in actually issuing VA SIGMET, non-functional or non-supportive MWO, through to providing VA SIGMET in incorrect formats.

Nevertheless, the issue is most clearly apparent in the failure of some States to issue VA SIGMET on the receipt of VAA guidance advisories from VAACs. Regular SIGMET tests conducted over the past four years in the Asia and Pacific regions have shown only a small improvement in reducing the deficiencies concerning the issue of such warnings including VA SIGMET.

Considerable effort has been made by ICAO and the World Meteorological Organisation (WMO) over the past several years to address the MWO deficiencies through conducting missions, Special Implementation Projects, seminars, and the publication of Regional Guides, handbooks and posters. Unfortunately there has been no material change in the performance of MWOs that have historically not performed well in issuing meteorological warnings including VA SIGMET.

The importance of SIGMET, and VA SIGMET in particular, cannot be over emphasised as they convey information about en-route weather phenomena, which may adversely affect the safety of aircraft operations. Clearly, the failure of some MWOs to issue timely and accurate SIGMETs is not conducive for the safe and efficient conduct of international air navigation.

States need to address such performance issues with their respective MWOs.

4.3 Reports from Aircraft

It is imperative that the IAVW system is informed of eruptions and volcanic ash in a timely manner by aircraft operators and pilots. There is a prescribed process in the ICAO system for the provision of meteorological reports from aircraft. In the case of volcanic ash and the like, the Volcanic Ash Report (VAR) template is promulgated in the aviation and air traffic control systems for this purpose.

Unfortunately there are many instances of volcanic activity where there has been no VAR furnished by aircraft operators even though operations took place in the vicinity of the volcanic activity. There are even incidences or even long term practices where a VAR is completed on the termination of the flight only to languish in internal records of the airline.

It is imperative that aircraft operators provide VAR in a timely manner to air traffic control units and for those ATC units to forward that information quickly to the MWO and VAAC and, where

appropriate, the volcano observatory. This is in fact a State responsibility under the Convention and States need to ensure the requisite processes and procedures are in place.

States need to promote the need for VAR amongst their respective aviation communities.

5.1 Costs

A difficulty in mainstreaming volcanic activity monitoring for aviation has always been that aviation users need information very quickly; some aviation user groups generally put a five-minute eruption notification time on their requirement for warnings. This has generally been outside the capacity of observatories mainly due to impracticality and the costs involved.

Similarly, some States are unable to fund any kind of volcano observation programme let alone one aimed at the specific needs of aviation.

To assist States solve such funding issues, ICAO has developed a new funding guideline for communications between volcanic observatories and VAACs, ACCs and MWOs, which represents a significant opportunity for volcanic ash information communications to be improved.

Annex 3 to the Convention now provides for identification of a 'Selected State Volcano Observatory' on the advice of State authorities:

> *3.6 State volcano observatories*
>
> *Contracting States that maintain volcano observatories monitoring active volcanoes shall arrange that selected State volcano observatories, as designated by regional air navigation agreement, observing:*
>
> *a) significant pre-eruption volcanic activity, or a cessation thereof;*
> *b) a volcanic eruption, or a cessation thereof; and/or*
> *c) volcanic ash in the atmosphere,*
> *shall send this information as quickly as practicable to its associated ACC, MWO and VAAC.*
>
> *Note - Pre-eruption volcanic activity in this context means unusual and/or increasing volcanic activity which could presage a volcanic eruption.*

Effectively this provides the international mandate for States to ensure timely VONA are provided to VAACs, ACCs and MWOs. A list of State and respective volcano observatories or authority, ACC, FIR and MWO, are set out in Part 5 of the *Handbook on the International Airways Volcano Watch (IAVW) - Doc 9766*.

The formalisation of a general agreement between the Volcano Observatory or authority, and the Meteorological Authority about information exchange (refer Appendix 2) would be useful to ensure all parties act in a concerted manner.

The ICAO policy on the charges for air navigation services, which includes, amongst other things, all services contemplated in Annex 3 to the Convention, is clearly set out in *ICAO Policy on Charges for Airports and Air Navigation Services – Doc 9082,* which states:

> *42. The Council considers that as a general principle, where air navigation services are provided for international use, the air navigation service providers may require the users to pay their share of the related costs...*

45. The Council observes that in determining the costs to be recovered from users:

i) Governments may choose to recover less than full costs in recognition of local, regional or national benefits.

ii) It is for each State to decide for itself whether, when, and at what level any air navigation services charges should be imposed, and it is recognized that States in developing regions of the world, where financing the installation and maintenance of air navigation services is difficult, are particularly justified in asking the international air carriers to contribute through user charges towards bearing a fair share of the cost of the services.

The ICAO document goes into great detail on how these charges and systems can be implemented by States, however, it is ultimately up to each State exactly how they go about this. The key point is that it is formally recognised by the international body (ICAO), working under the Convention, that States are at legitimate liberty to charge users of air navigation services, including all aviation meteorological services, for the cost of that provision.

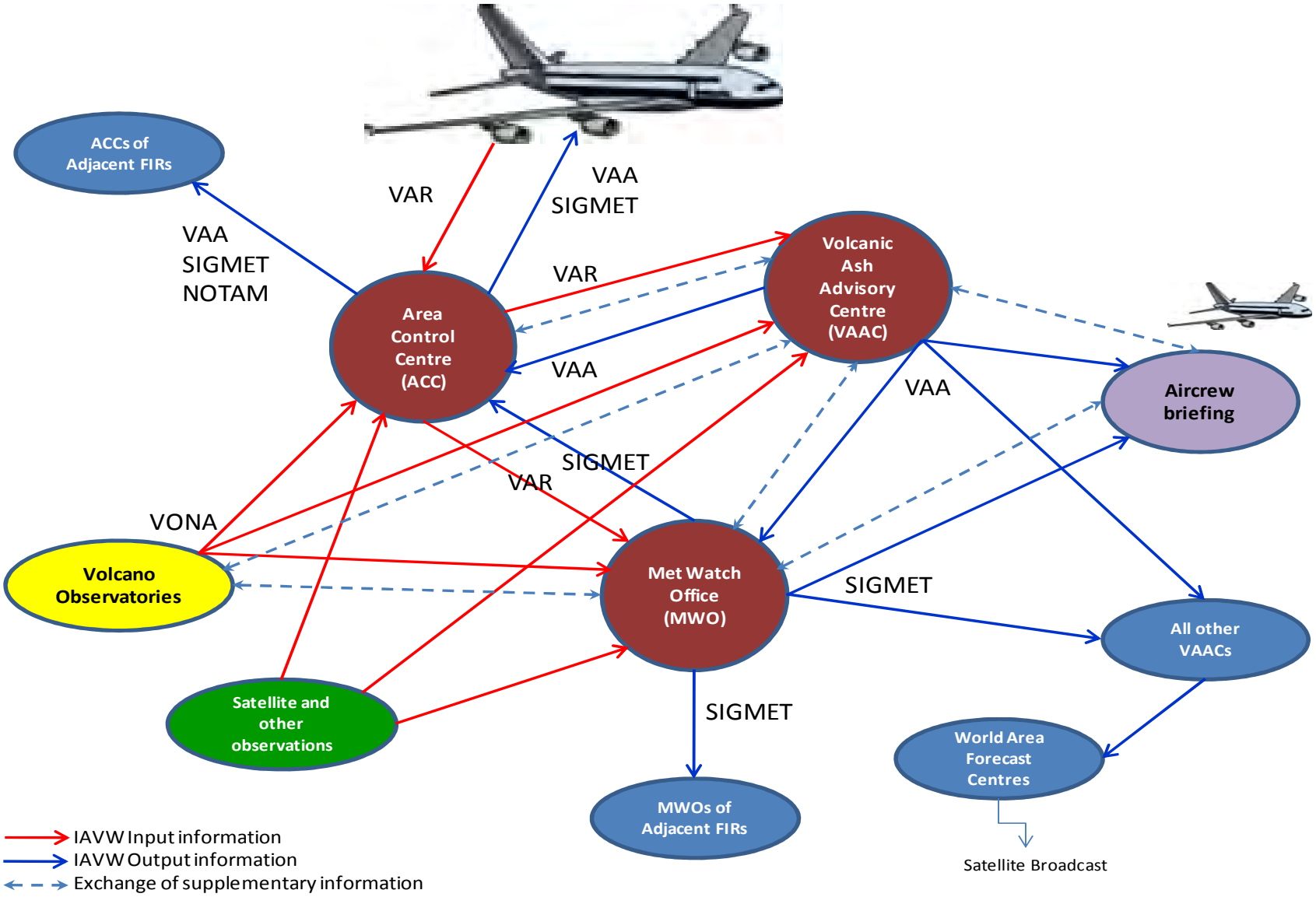
Translated into the context of the IAVW, the costs of providing VA SIGMET by MWO, the cost of providing VAAC services and communications, and the costs of providing volcano observatory information can be legitimately charged to international aircraft operators.

Each State (Country) decides how to fulfil its obligations to aviation. The principle is that the State must do its job, and may cost-recover from aviation. Volcanic observatories required to give information for aviation should negotiate how the cost of that is to be met.

How each State does go about this is determined by a number of factors, and there is no one 'correct' approach. For example, the United States does not choose to recover costs to volcano observatories in this manner, instead regarding services to aviation as an integral part of a federally funded service for the greater good. New Zealand, on the other hand, applies a cost recovery system. Appendix 5 describes how such volcano observatory costs are being met by airlines in New Zealand.

As part of the variation of approach, the definition of what costs are recoverable is left undefined, for good reason. Suppose, for example, that in one State a volcano would not be monitored at all, except for aviation purposes, and another volcano is near a densely populated area and needs to be monitored 24/7. It could then reasonably be argued that the entire cost of monitoring the remote volcano and only a small part of the cost of monitoring the volcano in the populated area could be charged to aviation – but this is up to the State concerned.

APPENDIX 1 – International Airways Volcano Watch (IAVW) Simplified Schematic



APPENDIX 2 – Sample Letter of Agreement

between Vulcanological Authority Meteorological Authority and Air Traffic Services

(from: Handbook On The International Airways Volcano Watch (IAVW) - ICAO Doc 9766)

OBJECTIVE

1.1 The objective of this Letter of Agreement between the [ATS authority]1, the [Meteorological authority] and the [Vulcanological authority] is to establish the directives for the necessary coordination between ATS units, meteorological watch offices and vulcanological observatories to ensure the provision of specific information on pre-eruption volcanic activity, volcanic eruptions and volcanic ash cloud required for civil international and national air navigation, in accordance with international agreements and [national air navigation regulatory documents].

1.2 This Letter of Agreement provides guidelines on the responsibilities of ATS units, meteorological watch offices and vulcanological observatories in relation to the mutual exchange of information related to volcanic ash.

1.3 This Letter of Agreement is in accordance with the Standards and Recommended Practices and Procedures of ICAO, contained in Annex 3 - Meteorological Service for International Air Navigation, Annex 11 - Air Traffic Services, Annex 15 - Aeronautical Information Services and in the Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM, Doc 4444), as well as the provisions contained in the relevant regional air navigation plan publications and in the aeronautical information publication of [State] (AIP-[State]). This Letter of Agreement is also based on the guidance material in the Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services (Doc 9377), the Aeronautical Information Services Manual (Doc 8126) and the Handbook on the International Airways Volcano Watch (IAVW) — Operational Procedures and Contact List (Doc 9766).

1.4 This Letter of Agreement includes 5 Appendices, regarding detailed national directives and arrangements pertaining to the use of the aviation volcano colour code, the ASHTAM format, abbreviations, list of contact points and means of communication, stations/offices and contact numbers, etc.

REVISIONS

1.5 When, for special or unforeseen reasons, a significant change in the co-ordination between the three parties involved or the services mentioned in this Agreement becomes necessary, the respective officers-in-charge, through mutual agreement, may effect temporary changes or amendments, provided that these changes are not intended to last more than 6 days.

APPENDIX 3 – Volcano Observatory Notice For Aviation (VONA), & aviation colour code

(1) VOLCANO OBSERVATORY NOTICE FOR AVIATION--VONA
(2) Issued: Universal (Z) date and time (YYYYMMDD/HHMMZ).
(3) Volcano: Name and number (per Smithsonian database at http://www.volcano.si.edu/world/)
(4) Current Aviation Colour Code: **GREEN, YELLOW, ORANGE, OR RED** in upper case bold font
(5) Previous Aviation Colour Code: lower case font, not bold
(6) Source: Name of Volcano Observatory (volcanological agency)
(7) Notice Number: Create unique number that includes year
(8) Volcano Location: Latitude, longitude in NOTAM format (N or S deg min W or E deg min)
(9) Area: Regional descriptor
(10) Summit Elevation: nnnnn FT (nnnn M)
(11) Volcanic Activity Summary: Concise statement that describes activity at the volcano. If known, specify time of onset and duration (local and UTC) of eruptive activity.
(12) Volcanic Cloud Height: Best estimate of ash-cloud top in nnnnn FT (nnnn M) above summit or AMSL (specify which). Give source of height data (ground observer, pilot report, radar, etc.). "UNKNOWN" if no data available or "NO ASH CLOUD PRODUCED" if applicable.
(13) Other Volcanic Cloud information: Brief summary of relevant cloud characteristics such as colour of cloud, shape of cloud, direction of movement, etc. Specify if cloud height is obscured or suspected to be higher than what can be observed clearly. "UNKNOWN" if no data available or "NO ASH CLOUD PRODUCED" if applicable.
(14) Remarks: Optional; brief comments on related topics such as monitoring data, observatory actions, volcano's previous activity, etc.
(15) Contacts: Names, phone numbers (voice and fax), email addresses.
(16) Next Notice: "A new VONA will be issued if conditions change significantly or the colour code is changes." Indicate if final notice for an event. Include URL of Web site where latest volcanic information is posted

AVIATION COLOUR CODES RECOMMENDED BY THE INTERNATIONAL CIVIL AVIATION ORGANIZATION.	
GREEN	**Volcano is in normal, non-eruptive state.** ***or, after a change from a higher level*:** **Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.**
YELLOW	**Volcano is experiencing signs of elevated unrest above known background levels.** ***or, after a change from higher level*:** **Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.**
ORANGE	**Volcano is exhibiting heightened unrest with increased likelihood of eruption.** ***or,*** **Volcanic eruption is underway with no or minor ash emission.** ***[specify ash-plume height if possible]***
RED	**Eruption is forecast to be imminent with significant emission of ash into the atmosphere likely.** ***or,*** **Eruption is underway with significant emission of ash into the atmosphere.** ***[specify ash-plume height if possible]***

APPENDIX 4 – Volcanic Activity Report (VAR)

(note – arrangements for collation and redistribution from Darwin are currently being made)

OPERATOR:	A/C IDENTIFICATION: (as indicated on Flight Plan)

PILOT-IN-COMMAND:

DEP FROM:	DATE:	TIME; UTC:	ARR AT:	DATE:	TIME; UTC:

ADDRESSEE	AIREP SPECIAL

Items 1-8 are to be reported immediately to the ATS unit that you are in contact with.

1) AIRCRAFT IDENTIFICATION	**2)** POSITION
3) TIME	**4)** FLIGHT LEVEL OR ALTITUDE

5) VOLCANIC ACTIVITY OBSERVED AT
(position or bearing, estimated level of ash cloud and distance from aircraft)

6) AIR TEMPERATURE	**7)** SPOT WIND

8) SUPPLEMENTARY INFORMATION

a) SO2 detected Yes ☐ No ☐

b) Ash encountered Yes ☐ No ☐

(Brief description of activity especially vertical and lateral extent of ash cloud and, where possible, horizontal movement, rate of growth, etc)

After landing complete items 9-16 then send form to:
Darwin Volcanic Ash Advisory Centre

9) DENSITY OF ASH CLOUD ☐ (a) Wispy ☐ (b) Moderate dense ☐ (c) Very dense

10) COLOUR OF ASH CLOUD ☐ (a) White ☐ (b) Light Grey ☐ (c) Dark grey ☐ (d) Black (e) other _____

11) ERUPTION ☐ (a) Continuous ☐ (b) Intermittent ☐ (c) Not visible

12) POSITION OF ACTIVITY ☐ (a) Summit ☐ (b) Side ☐ (c) Single ☐ (d) Multiple ☐ (e) Not observed

13) OTHER OBSERVED FEATURES OF ERUPTION ☐ (a) Lightning ☐ (b) Glow ☐ (c) Large rocks ☐ (d) Ash fall out ☐ (e) Mushroom cloud ☐ (f) All

14) EFFECT ON AIRCRAFT ☐ (a) Communication ☐ (b) Nav systems ☐ (c) Engines ☐ (d) Pitot static ☐ (e) Windscreen ☐ (f) Windows

15) OTHER EFFECTS ☐ (a) Turbulence ☐ (b) St Elmo's Fire ☐ (c) Other Fumes

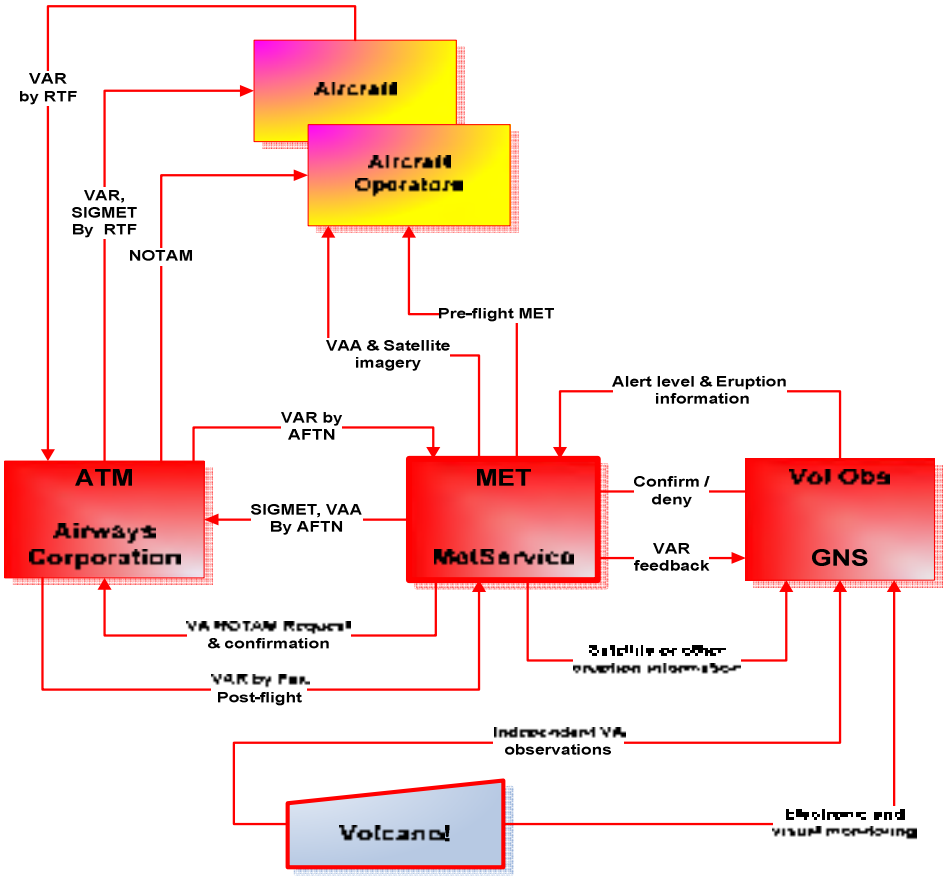
16) OTHER INFORMATION:
(Any information considered useful)

APPENDIX 5 – Cost and Charges in the NZ Volcanic Advisory Ash System

System Background

The CAA is responsible for ensuring a satisfactory means exists whereby civil aviation aircraft operations can be safely carried out near volcanic ash. To this end the CAA has facilitated the New Zealand Volcanic Advisory Ash System (VAAS). The VAAS is intended to inform civil aviation in New Zeeland of any volcanic ash risk using the standard ICAO standards and systems. The VAAS also covers New Zealand's implementation of its IAVW responsibilities.

A schematic of the NZ VAAS is shown below. A full description of the NZ VAAS can be obtained from the NZ CAA.



Briefly, under the NZ VAAS:

- The CAA is not responsible for providing any service to airlines to directly assist them with operations during volcanic events. The CAA remains a facilitator of the system.
- Meteorological Service of New Zealand Ltd (MetService) provide timely Volcanic Ash Advisories (VAAs) and Volcanic Ash SIGMETs and any other volcanic activity or ash information packages required pursuant to New Zealand's ICAO obligations. MetService has overall management responsibility for the VAAS.
- Airways Corporation (ATS provider and ACC operator) provide the NOTAM service, access to volcanic ash SIGMET and appropriate VAR information pursuant to New Zealand's ICAO obligations. It is also collects from aircraft VAR information and

disseminates this information immediately to MetService, GNS and accessible aircraft operators.

- The Institute of Geological Sciences (GNS) as the official volcano observatory keeps MetService informed as to any volcanic activity taking place in New Zealand, through the issue of formal communications including the VONA.
- Aircraft operartors are expected to ensure their aircraft do not operate in volcanic ash. They are also expected to provide Volcanic Activity Reports (VARs) when appropriate.

Funding Background

In New Zealand there is very little government funding applied or available for providing infrastructural services to civil aviation. The funding system is essentially one of user pays with a few small exceptions.

The CAA, as the Meteorological Authority under the Convention (Annex 3), contracts MetService to provide the meteorological products the State is obliged to provide. The CAA pays only a small amount for the provision of a few discrete services, the remainder and the large majority of MetService's cost in providing the requisite information is met by airlines through direct contracts (with MetService).

The provision of information on volcanic ash is a relative new-comer to the oversight responsibilities of the CAA and the operational responsibilities of MetService. Hence the funding is

Funding Structure

The funding structure of the VAAS/IAVW obligations is best shown in tabular form:

Service provider	Service	Funds provided by
MetService	Management of VAAS	Airlines contract
	Management of Wellington VAAC	CAA
	Evaluation of data - trajectory modelling	Airlines contract
	Communications with GNS	Airlines contract
	Provision of SIGMET	CAA
	Management of NOTAM	Airlines contract
	Provision of VAA	Airlines contract
Airways (ATS)	Communication of VAR	Airlines charges
	Communication of VAA	Airlines charges
	Communication of SIGMET	Airlines charges
	Filing and communication of NOTAM	Airlines charges
GNS	Monitoring of key NZ volcanoes 24/7	Government
	As possible, the provision of advice on other volcanoes in the Wellington VAAC area	MetService
	Provision of 24/7 advisory information to MetService including VONA and VAB	MetService
	Communication of advisory information	MetService

All of the costs generated by the Airways effort in the VAAS are met through the standard en-route charges on airlines and aircraft operators.

MetService has clauses in its contracts with all airlines operating in and to New Zealand that covers the provision of the VAAS and parts of its IAVW operations. The funds collected in this manner from the airlines are used to pay for the volcano observatory services provided by GNS and for MetService's own costs.

However, the bulk of the GNS volcano observatory costs are met through broad funding from the government. The basis of that funding is for the general protection and warning of the public. There are only marginal costs on this to make information available for the VAAS system and these are reflected in the charges to MetService.

As a general indication:

1. MetService collects a six figure sum from airlines to manage and operate its part of the VAAS, the majority of which it pays to GNS.

2. The CAA pays MetService a smaller amount for the provision of all types of SIGMET warnings including volcanic ash SIGMET and for the operation of the Wellington VAAC. Note that it is intended to shift these charges to airlines in the near future.

3. The funding from Government for the monitoring of New Zealand volcanoes is part of a ten year programme that is presently being reviewed.