THIRD INTERNATIONAL WORKSHOP ON VOLCANIC ASH

Organised by Météo-France, co-sponsored by WMO and ICAO

Toulouse, France,
29 September to 3 October 2003

FINAL REPORT

i.1 INTRODUCTION

I.1.1 The first two volcanic ash workshops were organized by the World Meteorological Organisation (WMO) and the International Civil Aviation Organisation (ICAO) respectively in Darwin, Australia, in September 1995 and in Toulouse, France in May 1998. To maintain the momentum developed by these workshops WMO and ICAO agreed to convene this third workshop kindly hosted by Météo-France in its International Conference Centre in Toulouse, France, from 29 September to 3 October 2003.

i.2 AGENDA, OFFICERS, AND ORGANISATION OF THE WORKSHOP

i.2.1 The agenda for the workshop included the six following items:

1) Opening of the workshop
2) Detection of volcanic eruptions and volcanic ash by remote sensing techniques.
3) Initialisation and operation of trajectory and dispersion models.
4) Model output presentation used for volcanic ash advisories in message and graphical format.
5) Coordination and cooperation between VAACs on technical issues.
6) International Airways Volcano Watch: current status.

i.2.2 Moderators for the agenda items were:

Agenda item 2: Mr Jeffrey Osiensky (USA)
Agenda item 3: Mr Andrew Tupper (Australia)
Agenda item 4: Mr Philippe Husson (France)
Agenda item 5: Mr Saad Benarafa (WMO)
Agenda item 6: Mr Raul Romero (ICAO)

i.2.3 Papers for each agenda item were presented followed by a round table discussion. At the end of the workshop, conclusions reached on each of the agenda items were prepared and agreed on after the meeting through an e-mail discussion. Final conclusions are given in the Annex 1 to this report.

i.2.4 The list of participants with their phone numbers and email addresses is given in Annex 2.

i.2.5 In addition to this report, the papers and slides presented to the workshop have been issued as a separate document and in CD ROM support.

i.3 WORKING LANGUAGE

i.3.1 The working language of the workshop was English.

1. AGENDA ITEM 1 :

OPENING THE WORKSHOP

The workshop was opened by Mr S. Benarafa on behalf of WMO, in the presence of Mr Bernard Strauss Director of Weather Forecast Service of Meteo-France and Mr Raul Romero (ICAO). A list of participants is given in the appendix.

2. AGENDA ITEM 2 :

DETECTION OF VOLCANIC ERUPTIONS AND VOLCANIC ASH BY REMOTE SENSING TECHNIQUES.

2.1 Last developments on the Meteo France algorithm for the detection of ash from MSG (Emmanuel Legrand)

2.1.1 Emmanuel Legrand presented general characteristics of Meteosat Second Generation (MSG). It was recalled that even if volcanic ash monitoring is not the primary goal of MSG, the combination of geostationary orbit, high frequency, relatively good resolution and numerous channels may be particularly useful for monitoring Mediterranean volcanoes (Etna, in particular) and central-Africa volcanoes. The main limitations, common to visible and infra-red passive imagery, are the difficulties of seeing ash underneath atmospheric clouds, and assigning ash cloud height. However MSG is not meant to replace the other information sources but just to complement them. Various methods developed related to produce a volcanic ash flag in the cloud mask product, cloud type, cloud top height were presented.

2.1.2 The Meeting agreed that the use of probability function should be an important issue for the future investigations with the MSG.

2.2 A system for automatic satellite detection of volcanic eruptions (Helen Watkin)

2.2.1 Helen Watkin presented the volcanic eruption detection system set to be implemented in the London VAAC next year. It consists in developing a remote sensing system that can automatically detect ash-producing volcanic eruptions. The presentation included detection algorithm and performance statistics of the eruption detection system that uses infrared images from Meteosat and will be upgraded to use SEVIRI (Spinning Enhanced Visible and Infrared Imager) images from Meteosat Second Generation (MSG).
The Workshop was also presented with an illustration showing the identification of a candidate cloud, and the testing of the conditions for that cloud, using among others the location, the contrast, and the temporal tests for the eruption of Hekla in Iceland on 26 February 2000.

2.2.2 The workshop noted that several checks are carried out to improve the confidence that the cloud is an eruption cloud and rule out as many false alarms as possible. The workshop considered that the development of some common framework to archive maximum information for each eruption was needed.

2.3 A Ground-based InfraRed Detection (G-bIRD) system for volcanic ash and sulphur dioxide (Fred Prata)

2.3.1 Fred Prata, presented the first results from a commercial system for detecting the presence of hazardous volcanic ash and sulphur dioxide gas using a novel ground-based infrared imaging camera. The system, G-bIRD (Ground-based InfraRed Detector), consists of an uncooled focal plane infrared array detector (320 x 240 elements), a wide-angle lens, automatic 5-position filter wheel and calibration shutter. The device operates unattended by acquiring spectral images within the 7–14 μm wavelength band, calibrating and processing them and transferring product files to a dedicated web-server using the Iridium satellite network. A proprietary alarm algorithm is used to efficiently and accurately determine the nature of the hazard in the imagery (e.g. ash, SO_2 or water/ice cloud) and warn the operator of its presence. The alarm has flexible thresholds and a statistical basis that permits an assessment of the degree of hazard detected (e.g. none, low, medium, severe). Images can be viewed on any compatible computer with access to the world-wide-web, or by using a 'roving' hand-held palmtop device supplied with the system. The 5-position filter wheel separates infrared radiation into narrow bands within the 7–14 μm region and specialised algorithms are used to determine the unique spectral signatures of volcanic ash, sulphur dioxide gas, water/ice clouds or clear skies. A broadband filter is used to indicate the height of the base of opaque clouds.

2.3.2 The G-bIRD system can be configured to operate with multiple cameras and has the flexibility to include other detectors (e.g. UV or CCD cameras). Because G-bIRD uses passive infrared radiation it consumes low power, emits no hazardous radiation and can operate during the day and night. A live demonstration of G-bIRD operating at a remote volcano was provided.

2.3.3 The workshop noted the difficulties posed by the lack of consensus on what ash concentrations are operationally significant for aviation safety.

2,4 Monitoring of infrasonic waves generated by volcanic eruptions : contribution to aircraft traffic safety (Bernard Massinon)

2.4.1 Bernard Massinon presented a monitoring system using distant miniarrays of infrasonic sensors of high sensitivity and reliability that have been designed by laboratories as CEA/ DASE to study and monitor the origin and propagation of infrasound in the atmosphere. He also presented examples of automatic detection and localization of infrasound generated namely by active volcanoes.

2.4.2 The distant miniarrays of infrasonic sensors are very sensitive pressure sensors capable of measuring 0,1 Pascal, with high dynamic ranges and operating from DC to 27 Hz. They also take advantage of an acoustic filter to optimize the signal upon noise ratio. Four of these sensors assembled in an equilateral triangle with three km length and one sensor at the center, constitute the basis for an acoustic antenna of high sensitivity.

2.4.3 This antenna is using the Progressive Multi Channel Correlation method (PMCC, Cansi, 1995; 1997) as a real time detector. PMCC processes in real time the acoustic noise and detects any front wave arrival by computing adequately propagation time differences from cross correlations between couples of sensors. Wave azimuth and apparent velocity are evaluated, and source location is obtained by simple azimuths intersection from couples of miniarrays. Knowledge of realistic propagation model and wind information might allow localizing the source area with only one miniarray.

2.4.4 It was highlighted that the global infrasound network going to be achieved as a part of the International Monitoring System for the verification of the Comprehensive Test Ban Treaty (CTBT) as other infrasonic stations might provide in the future an important contribution to the current volcanic eruption monitoring system in use.

2.5 Status of the implementation of the Comprehensive Test Ban Treaty Verification regime (Peter Chen)

2.5.1 Peter Chen provided recent information on the status of the Comprehensive Nuclear-Test-Ban Treaty Organization's (CTBTO) International Monitoring System (IMS) global infrasound monitoring network and on the possibility of supplementing stations to this network through the Treaty's Cooperative National Facilities mechanism. A possible concept of operations was also presented.

2.5.2 The Treaty provides for a global coverage IMS for the Verification Program, consisting of four technologies: Seismic, Infrasound, Hydro-acoustic, and Radionuclide. The Infrasonic Network is planned with 60 sites. As of December 2002, 48 site surveys were completed and 5 were in progress. The Entry into Force for the Treaty is not anticipated in the short term but the Verification system is currently being run operationally out of the International Data Center (IDC) as it evolves.

2.5.3 It is expected that the average time delay between the occurrence of an explosion and the provision of an IDC infrasound product would be 12 to 18 hours. Better response time could be achieved by adding supplementary infrasound stations. The Treaty provides for the possible enhancement of the IMS network through a Cooperating National Facilities mechanism (CTBT Article IV Section B).

2.5.3 The meeting was informed that Canada would plan a test to examine the feasibility of a possible concept for operation using one or more CTBT National Data Centre (NDC) with digital signal processing tools process raw data. This NDC could then provide notification to the VAACs.

2.6 Modelling volcanic ash transport and dispersion: Expectations and reality (Peter Chen)

2.6.1 Peter Chen highlighted significant improvements in the prediction of airborne volcanic ash through the use of volcanic ash transport and dispersion models (VATDM). He addressed the problem of timeliness and accuracy that are equally important for aircraft operations. Detailed description of the 3 distinct components namely: Volcanic ash source, Meteorology and Transport and dispersion, were given to determine accurately forecasting ash with VATDM.

2.6.2 A large number of uncertainties and limitations about the usefulness of the VATDM were also described. However, the qualitative verification of VATDM guidance based on satellite data and other tools has shown it to be of great value.
Finally, Peter Chen presented some of the key elements that should be improved in order to maximize the improvements in VAFTD guidance. These elements included Source term – eruption parameters, Source term and Transport / Dispersion and Source term - Remote sensing and detection of ash.

2.7 Airborne Asian dust: Case study of long range transport and implications for the detection of volcanic ash (Rene Servranckx)

2.7.1 Rene Servranckx recalled that the transport of fine-grained Asian dust from its source (*e.g.,* Gobi Desert, Mongolia) to North America is a common springtime phenomenon. Because of its chemical composition (Si, Fe, Al, Ca) and its particle size distribution (*e.g.,* mean aerodynamic diameter 2-4 µm), Asian dust produces a negative signal in the "split-window" T_4-T_5 algorithm, as does airborne volcanic ash.. Use of Total Ozone Mapping Spectrometer (TOMS) aerosol and sulfur dioxide indices, in conjunction with the "split-window" method, can mitigate the possibility of a false airborne volcanic ash alarm. Asian dust also is important for other reasons. Thus, meteorological agencies should monitor it because it can be transported thousands of kilometers from its source region.

2.7.2 Rene Servranckx presented the case study that appears in a Paper by *Simpson et al*, 2003 and 1) Reviews some satellite based retrievals of aerosol; 2) Presents a case study of two recent Asian dust events including detection from satellites and modeling of the atmospheric transport; 3) Examines the potential effects of desert dust on the performance of the operational "split-window" airborne volcanic ash detection algorithm; and 4) Suggests possible ways of differentiating dust from volcanic ash using satellite data.

2.7.3 The paper draws the following conclusions:

a. Asian dust events, especially in springtime, occur frequently. Chinese National Academy's records show that during the 17^{th} century, there were 0.3 to 1.0 sand storms in Inner Mongolia per year, but by 1990, the annual rate had increased to 3.0 to 5.0 per year. Multiple dust events occurred January to May during 1997 – 2002.

b. Satellite and lidar observations clearly show transport of dust to the North Pacific atmosphere and over North America. Model results corroborate this.

c. Large particles of dust do not reach North America due to gravitational settling.

d. Asian dust which reaches North America, typical aerodynamic diameter of 2-3 µm, is derived largely from crustal rocks and minerals dominated by : Si, Fe, Al, and Ca.

e. The particle size distribution and chemical composition of the Asian dust are near optimal to produce a strong negative signal in the "split-window" T_4-T_5 airborne volcanic ash detection algorithm used by most operational VAACs. An inverted arch characteristic of volcanic ash is also produced. Unless the VAAC meteorologists are trained to recognize and correctly interpret these characteristics of Asian dust, a false VAAS could be issued. The misidentification of lofted dust vs. volcanic ash has important operational impacts (potential false volcanic ash alert). Moreover, accurate and rapid detection of dust may help to warn flight operations in potentially affected airports about possible decreased visibility, especially in China, Korea, and Japan. It also has air safety (potential health) implications should dust get into the cabin.

f. Simultaneous use of TOMS aerosol and sulfur dioxide indexes with the T_4-T_5 "split-window" retrieval can help to distinguish Asian dust from volcanic ash. Unfortunately, TOMS data are only available during daylight hours and may not be received in "real-time" by some VAACs. The area covered by the negative T_4-T_5 signals may also help distinguish Asian dust from volcanic ash (very large relative to that of a newly erupted volcanic ash plume, at least in the early stage).

g. Meteorological and environmental agencies which share responsibility for “air quality” advisories need to monitor the distribution of Asian dust because of its potential public health hazard.

h. Analogous dust events occur in other hyper-arid regions (*e.g.,* Sahara).

i. The possible short- and long-term impacts of desert dust on aircraft should be examined and documented. Would these be significant enough to warrant the issuance of advisory messages by VAACs as is already the case for volcanic ash?

j. Experimental instruments (*e.g.,* MODIS) may prove useful, especially if TOMS data become unavailable.

2.8 Volcanic cloud monitoring issues at the Darwin VAAC (Andrew Tupper)

2.8.1 Andrew Tupper presented the historical development of IAVW in Indian Ocean and Southwest Pacific region and the remote sensing techniques used. Four Case studies, namely – Ruang, 25 September 2002 – Rabaul, 20 October 2002 – Mysterious Micronesian encounters and – Semeru, 1967 were described.

2.8.2 Major issues addressed included lack of information flow, (Pilot reports, NOTAMs, SIGMETs), No defined safe concentration of ash, little operational detection of SO_2 and inferred ash; low level plumes generally only sensed from polar orbiting satellites or high-resolution visible imagery and many volcanoes constantly in low-level eruption.

2.8.3 It was highlighted that there are still many IAVW issues to address, both procedural and scientific, that continued remote sensing research, expansion of remote sensing programmes, ground and air based detection, advanced together with procedural issues are still needed since the IAVW can only be built on consensus.

2.9 Case study of the February 2001 eruption of Mt. Cleveland, Alaska; identifying some gaps in R&D satellite detection and implications for potential future operational implementation (Peter Chen and Rene Servranckx)

2.9.1 Rene Servranckx presented the case study of 19 February 2001 Mt. Cleveland, Alaska eruption that appears in a Paper published by *Simpson et al*, 2002. The case study 1) Describes the meteorological conditions present when Mt. Cleveland erupted; 2) Identifies some of the difficulties associated with the real time detection and response to such an event; 3) Highlights some strengths and weaknesses of the currently available satellite remote sensing methods in detecting the ash cloud from Mt. Cleveland; 4) Documents several serious encounters of commercial aircraft with the volcanic ash plume; 5) Describes the meteorological operational response to the eruption and factors that affected it; and 6) Suggests specific areas of improvement for future events.

2.9.2 A large number of complex interactive issues that operational units face during a real time volcanic response and that have a direct impact on detection, rapid alert and timely delivery of reliable advice were highlighted. The challenges include:

a. Responding quickly and accurately while at the same time dealing with large uncertainties

b. Detecting volcanic ash with satellites

c. Assessing ash plume tops and bases with incomplete and at times conflicting information

d. Defining eruption parameters and initial conditions to run the dispersion model

e. Interpreting modeling results

f. Coordinating information between adjacent VAACs to ensure a smooth transition at the boundary between their respective areas of responsibility

g. Deciding on when to terminate warnings to aviation in the absence of pilot reports or satellite detection

2.9.3 Proposed recommendations that highlighted among others the need for more frequent and detailed volcanic ash pilot reports were noted.

2.10 Observations of volcanic cloud heights and ash-atmosphere interactions (Andrew Tupper)

2.10.1 Andrew Tupper recalled how the height of an eruption is a critical issue for volcanic ash dispersion forecasting and how changes in eruption height can make huge differences in how an event is handled. He presented satellite / ground height comparisons to describe the accuracy of the observations. He also provided analysis of the observed variation of volcanic cloud height with atmospheric conditions including effect of water vapour, infrasonic, seismic amplitude and convection above passive degassing.

2.10.2 For operational use, the most common method of height estimation is correlation of brightness temperatures with atmospheric profiles (Sawada, 1987, 2002), preferably supplemented with wind correlations (Holasek *et al.*,1996) to overcome underestimates caused by non-opaque clouds, overestimates caused by clouds having emissivity of less than unity, and height ambiguities caused by atmospheric inversions. In many cases, wind correlations alone are sufficient to give a reasonable estimate of cloud height. We are therefore able to achieve a reasonable level of accuracy using satellite techniques. However, the temporal resolution of most satellites means that we will usually be making our first dispersion forecasts for any major event using height information from ground or air based observers, assuming the eruption is observed and reported promptly. For eruptions obscured by overlying cloud or too small to be resolved by satellite sensors, ground or air based reports are the only available estimates of volcanic cloud heights. Such observations are consequently critically important affirm the need to know of minor eruptions and of old ash clouds.

2.10.3 In this context, the uncertainties of cloud height observation from the ground, and the knowledge of convective transport of ash particles, are critical issues. The current IAVW procedures (ICAO, 2000) place heavy emphasis on regarding each eruption as a discrete, observable event, with the role of volcanic observatories, VAACs, and Meteorological Watch Offices well defined.

2.10.4 Andrew Tupper concluded that here is great variation between volcanic cloud heights estimated from the ground or aircraft and satellite measurements. The development of observing systems, and observer/pilot education will improve the quality of observations, but IAVW methodology also needs to take into account the uncertainty associated with these observations.
Many observations show the variation

of volcanic cloud height with differing atmospheric conditions. In particular, ash transport should be assessed in the context of the convective regime around the source. IAVW participants can take account of this by improved satellite techniques, by detailed modeling to refine conceptual models and ash loading profiles, by research to better define dangerous ash concentrations of ash, and by extensions to the 'color code' system for aviation.

2.11 Transport of forest fire smoke above the tropopause by supercell convection (Rene Servranckx)

2.11.1 Rene Servranckx presented an information paper on a previously unreported mechanism that can quickly transport forest fire smoke to the upper troposphere / lower stratosphere and has many and interesting parallels to volcanic eruptions and the transport of ash in the atmosphere.

2.11.2 This mechanism was illustrated by a case showing the full evolution sequence of such an event triggered by a combination of intense forest fires and very dry, hot meteorological conditions that happened near Chisholm, Alberta, Canada (55N, 114W) in May 2001. It was indicated that a number of research groups have expressed interest in the Chisholm case and that it may turn out that this fire event will lead to modelling results that may eventually benefit the forecasting of volcanic ash.

3. AGENDA ITEM 3 :

INITIALIZATION AND OPERATION OF TRAJECTORY AND DISPERSION MODELS

3.1 New perspectives in ash dispersion modelisation on short distances (Christine Lac)

3.1.1 Christine Lac presented two tools used at Météo-France Toulouse VAAC to track airborne ash in near real-time following an eruption, for the purposes of hazard warning : an air mass trajectories software, describing the evolution of a neutrally buoyant particle in the wind field forecasted by the numerical weather prediction (NWP), and an eulerian off-line dispersion model, MEDIA, solving an advection-diffusion equation for a passive scalar. These tools mainly concern the long-range dispersion forecast.

3.1.2 At long range, Météo-France has developed a global three-dimensional Chemical Transport Model, MOCAGE, dedicated to the numerical simulation of the interactions between dynamical, physical and chemical processes in the lower stratosphere and in the troposphere. As MOCAGE takes into account dry deposition, scavenging of soluble gases by convective and stratiform rain, and fallout, it will be used to forecast ash movement in a realistic manner in the troposphere and in the lower stratosphere. It would benefit in the next years of the implementation of an aerosol model.

3.1.3 At local scale, the system PERLE, developed primarily for emergency response in case of an accidental release, is based on a meso-scale non-hydrostatic model for meteorological fields, Meso-NH, coupled to a lagrangian particle model for the dispersion. It will be concerned with the tracking of eruption clouds. In addition, the eulerian meso-scale meteorological model will also provide a regional description of the ash cloud given by a passive tracer. In the vicinity of an eruptive volcano, the system PERLE, developed for emergency response in case of accidental pollutant release, could be applied with minor modifications for VAAC purpose.

3.2 Progress in volcanic ash modelling at the MET Office (Helen Champion)

3.2.1 Helen Champion presented two tools developed by the London VAAC to provide information to forecasters. One is a product derived from AVHRR satellite imagery to aid forecasters in locating volcanic ash, and the other is an atmospheric dispersion model (NAME) which forecasters use to predict the dispersion of the ash.

3.2.2 The AVHRR satellite imagery tool uses the difference between channel 4 (10.8 µm) and channel 5 (12.0 µm) to show the location of volcanic ash, indicated by negative values (i.e. higher values for channel 5 than for channel 4). These images are operationally produced every 3 hours over Iceland and every 6 hours over the Mediterranean. They are available to forecasters within 30 minutes, covering 3 domains: Iceland, the full London VAAC area, and the Mediterranean.

3.2.3 The atmospheric dispersion model, NAME, is used to generate volcanic ash forecasts up to 48 hours ahead, and can be run up to 6 days ahead. It produces graphical output showing the forecasted concentration of the plume. Recent improvements to NAME include the use of the New Dynamics version of the Unified Model (UM), which gives better vertical resolution, especially near the tropopause. The procedure for assessing the threshold concentration for a unit release has been automated, removing the need for manual input from the forecaster.

3.2.4 The London VAAC has started running daily volcanic ash forecasts to improve emergency response preparedness and response times. The NAME model is being used to generate 24 hour forecasts for hypothetical eruptions, using default emission scenarios, at 0, 6, 12 and 18Z every day. These are disseminated on an operational basis.

3.2.5 A detailed comparison of output from the satellite tool and the dispersion model showed good agreement throughout the period of the eruption of Mount Etna which began on 27 October 2002. One problem identified via the Etna case study is how to deal with orography which is poorly resolved in NWP models. Etna is an isolated mountain and, the modelled boundary layer can lie well above the modelled summit, when in reality it is below the peak while in this situation, the release is effectively taking place in the free troposphere, but the model releases the ash into the boundary layer instead, changing the dispersion of the plume. A process is required to cope with this issue for isolated volcanoes.

3.3 Status of satellite detection and numerical modelling technologies at the Montreal VAAC (Peter Chen and Rene Servranckx)

3.3.1 Peter Chen and Rene Servranckx presented a summary of the main changes and improvements that have been implemented in the operational version of the CANadian Emergency Response Model (CANERM) since the Toulouse meeting in 1998.These included

a) The introduction of a new vertical distribution function that allows for a constant distribution of the ash in the vertical. It is now used as the default for CANERM.

b) The possibility to change the horizontal grid size by the CANERM operator in real time. Also, the grid domain can now be moved prior to the execution of CANERM, in order to extend the grid in the downwind direction.

c) The production of automatic trajectories at two-hour intervals for a number of active volcanoes that could impact the VAAC Montréal area of responsibility within 48 to 72 hours of a major eruption. Also, at the request of other VAACs, automatic trajectories can be produced for any location in the world.

d) Automatic CANERM runs using a default eruption scenario can also be produced and posted on the internet when needed. This is done on a server that uses the CANERM version with a Gaussian distribution in vertical for the source term.

e) A Lagrangian dispersion model is currently under development and it will add to the capacity at Montréal VAAC

3.3.2 Considerable work has been done to make the VAAC Montréal products quickly available to the users. This included:

a) The VAAC Montréal VAAS, trajectories and CANERM outputs (either for a real eruption or in a watch / automatic mode) posted in real time on the internet (http://www.msc-smc.ec.gc.ca/cmc/eer/VAAC/index_e.html).

b) The first test WAFS broadcasts of the VAAC Montréal Volcanic Ash Advisory Statements (VAAS - FVCN) and the Volcanic Ash Graphical products (VAG - CANERM) were successfully in April 2000. First, a test transmission from Montréal to Washington was done for an uplink on WAFS. A second test was done using the direct link from Montréal to Bracknell for an uplink on SADIS .Regular testing is done.

3.3.3 With regard to satellite data, VAAC Montréal receives GOES 10 and 12 raw data as well as Environmental Satellites raw data (POES – NOAA). Since January 2000, POES raw data are also received in real time through a high speed terrestrial line. Work has begun to acquire real time POES data captured by a Department of Fisheries and Oceans antenna. All POES data are processed / displayed using Terascan / Teravision software from the Seaspace Corporation. These POES data provide high resolution coverage over Alaska, the Aleutians, Kamchatka, Canada, Greenland and the North Atlantic. Coverage over Iceland is marginal. Procedures established between the North-American VAACs and MWOs at the First North American Meteorological Operations Volcanic Ash Meeting held in Montreal on 30-31 March 1999 are applied. Regular testing for all VAAC Montréal meteorologists began in February 2000. Occasional tests with VAAC Anchorage and VAAC Washington are also conducted.

3.4 Volcanic Ash Dispersion Modeling in the U.S. using the HYSPLIT Model (Barbara Stunder)

3.4.1 Barbara Stunder presented some of the features of the HYbrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model for volcanic ash modelling developed at the NOAA Air Resources Laboratory (ARL) and upgraded from collaboration between ARL and the Australian Bureau of Meteorology (ABM). She highlighted the new features of the HYSPLIT system compared to VAFTAD showed example model output from both models for the Soufrière Hills eruption of December 1997. The ash reduction capability, in use for several years, was described and illustrated with example HYSPLIT output from two different meteorology datasets. The NWS is in the process of implementing the HYSPLIT dispersion model for volcanic ash forecasting.

3.4.2 HYSPLIT has several additional capabilities compared to VAFTAD. In general, better forecasts should result from finer model time steps and more up-to-date modeling algorithms. HYSPLIT can input meteorology on various grids or from various sources to suit particular applications or if one model's meteorology forecast appears better than another on a given day. Finer-scale and/or more near-term output may be created. Research into various volcanic ash modeling parameters, such as particle-size distributions and horizontal dispersion, is more feasible because of the HYSPLIT structure. Finally, since the HYSPLIT system is used for simulations of a variety of species, some current or future features developed for other applications may also prove useful for volcanic ash and aviation safety applications.

4. AGENDA ITEM 4 :

MODEL OUTPUT PRESENTATION USED FOR VOLCANIC ASH ADVISORIES IN MESSAGE AND GRAPHICAL FORMAT.

4.1The Darwin VAAC volcanic ash workstation (Rodney Potts)

4.1.1 Rodney Potts presented recent work that is being undertaken in the Commonwealth Bureau of Meteorology to implement a person-machine user interface that is being developed to streamline preparation of the VAA text product, automatically generate a corresponding graphical product, and enables satellite data and dispersion model outputs to be used in more integrated way to delineate analyzed and forecast threat areas. The system will also provide a stable framework that simplifies the operational implementation of improved analysis and prediction components developed in the future

4.1.2 The workshop was informed that 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. It was confirmed that when preparing required advice on volcanic ash for the aviation industry, uncertainties in the satellite analysis and output from the ash dispersion model make it essential for the forecaster to directly interact with interim products to generate the output products.

4.1.3 Rodney Potts highlighted ongoing effort in the Commonwealth Bureau of Meteorology that is designed to improve the efficacy of the advisory service that is provided, including improvements in the use of satellite data for detecting volcanic eruptions and ash clouds, and in the utilization of the Bureau volcanic ash dispersion model.

5. AGENDA ITEM 5 :

COORDINATION AND COOPERATION BETWEEN VAACS ON TECHNICAL ISSUES.

5.1 Volcanic Ash Coordination Tool (VACT) (Jeff Osiensky)

5.1.1 Jeff Osiensky presented the Volcanic Ash Coordination Tool (VACT) that is being developed by the U.S. National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL). VACT is based on FSL's FX-Connect (FX-C), a highly-interactive system that enables participants at various locations to view and interact with the same data in real-time. VACT enables persons who generate advisories and forecasts for volcanic ash to simultaneously view identical displays of critical observations and forecasts and *collaborate in real-time* with other decision-makers. VACT is also being an excellent vehicle for conducting regular coordination/response exercises among adjacent VAACs and meteorological watch offices.

5.1.2 In July 2003, initial VACT systems were implemented at the Anchorage Volcanic Ash Advisory Centre (VAAC), Alaska Volcano Observatory (AVO), and Anchorage Air Route Traffic Control Centre (ARTCC) Centre Weather Service Unit (CWSU). Among future activities, it is planned to implement capability to enhance satellite images and generate volcanic ash SIGMETs and Centre Weather Advisories efficiently via a complete end-to-end process. Jeff Osiensky indicated that implementing VACT in other countries if those countries express interest might also be explored.

5.2 A program for Research and Systems Integration to help Mitigate the Volcanic Ash hazard to Aviation. (David Johnson)

5.2.1 David Johnson started its presentation by a review of current volcanic ash products available to aviation users and a summary of qualitative descriptions of stated users needs. He presented an overview of the specific scientific and engineering plans and tasks that have been defined by the Oceanic Weather Product Development Team (OWPDT) in response to these formal user needs.
Some of the specific tasks the OWPDT has identified thus far include:

- Integration and display of VA SIGMET graphics and advisories on the OW web site (http://www.rap.ucar.edu/projects/owpdt/), representing an early capability.
- Ultimately, near-complete automation, with minimal mandatory human intervention.
- Capability to issue short-term pre-eruption advisories during episodes of potential volcanic unrest. Inclusion of geophysical data and input from the geosciences community.
- Improved detection of remote, unmonitored volcanic eruptions, possibly using a combination of teleseismic and satellite data.
- Incorporation of recently developed satellite interpretation technologies (e.g., multispectral analysis and channel splitting) to enhance ash cloud tracking. The OWPDT collaborates with several satellite centers of excellence with the goals of using current sensing technologies better, and identifying promising future technologies as well. For example (there are others),
- The Moderate Resolution Imaging Spectroradiometer (MODIS) data has demonstrated considerable potential for mapping several characteristic constituents of the ash cloud, including the ash particles, on the basis of distinct radiative properties in the thermal infrared.
- The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrumentation is ideal for detecting the thermal anomalies associated with volcanic eruptions. It has even been suggested that ASTER data may be used to identify regions of volcanic unrest, potentially allowing the forecast of an increased eruption risk. Although ASTER data has limitations that are inherently associated with the “on demand” nature of the instrument, the high spatial resolution of the data set may be extremely useful when available.
- The Multi-angle Imaging Spectroradiometer (MISR), which heavily emphasizes aerosol measurements, may provide additional capability to detect and monitor ash clouds of sufficient age that they are no longer thermally anomalous.
- The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) may prove useful for detection of young ash plumes when millimeter-sized particles may still be entrained. Data from this sensor may alleviate problems mentioned above in the detection of young ash plumes.
- Improvements to plume and ash cloud dispersion modeling, including high-resolution wind-field modeling and realistic particle size distributions. A fuzzy integration of several dispersion modeling systems, taking advantage of the strengths of each, could improve dispersion forecasts.
- Development of a global, high-resolution, satellite-derived wind field that can be integrated with the dispersion model system.
- Incorporation of “intelligent systems” capability, allowing the integration of a wide variety of input sources.
- Output will be graphical and generated in response to a user request, accessible even to airborne flight crews.
- Ash cloud characterizations will consist of detailed density contours, as opposed to the simple “visible cloud outlines” that are currently distributed.
- Task-oriented training for both meteorological and aviation user communities.

5.3 Warning Status for Volcanic Ash Advisories (Grace Swanson)

5.3.1 Grace Swanson pointed out difficulties for many Meteorological Watch Offices (MWOs) to perform their International Airways Volcano Watch (IAVW) functions due among others to severe resource shortages, lack of effective interactions with observatories and technological limitations. The effective absence of useful SIGMETs in many large, ash-prone parts of the world's airspace has given rise to suggestions that Volcanic Ash Advisories (VAA) be upgraded to warning status to better augment or even replace the Volcanic Ash SIGMET.

5.3.2 The meeting was informed that while acknowledging the compelling reasons to upgrade the status of the VAA to a warning, the Washington VAAC's management feels that in the absence of 24 x 7 single-tasked staffing, the danger and liability are too great. Conversely, in the unlikely event that the Washington VAAC is able to obtain enough additional staffing to have a 24 x 7 dedicated analyst, the VAAC would readily endorse warning status for VAA.

6. AGENDA ITEM 6 :

INTERNATIONAL AIRWAYS VOLCANO WATCH :
CURRENT STATUS.

6.1 Future modus operandi

6.1.1 The ICAO observer informed the workshop that the VAWSG has been recently replaced by the International Airways Volcano Watch Operations Group (IAVWOPSG) as recommended by the MET Divisional Meeting (2002). It was noted that the purpose of this new operations group was to coordinate and guide the development of the IAVW with a global perspective, in order to pursue coordination among the parties concerned and to develop the IAVW to ensure that the system continues to meet future requirements. The outstanding tasks of the VAWSG had been referred to the new group.

6.1.2 It was noted also that the ICAO Regional Planning and Implementation Groups (PIRGs) had sub-groups dealing with aeronautical meteorology, and some of these sub-groups had a task force specifically addressing the volcanic ash problem. These task forces had been very active in improving the implementation of the International Airways Volcano Watch (IAVW) in their respective regions and continued to play a crucial role as far as the implementation was concerned.

6.1.3 It was also noted that as a result of the establishment of the IAVWOPSG, a *modus operandi* between the IAVWOPSG and the PIRGs had been developed by ICAO with the purpose of establishing responsibilities regarding the IAVW and in order to avoid duplication of efforts between these bodies especially as far as planning was concerned. Currently the PIRGs were revising the work program of their task forces focusing their efforts on implementation issues.

6.1.4 It was expected that the IAVWOPSG will hold its first meeting in Bangkok in March 2004 and would convene future meetings every 18 months. It would be the body that would address all the operational aspects of the IAVW. It was noted that it would report to the Air Navigation Commission on the different conclusions and proposals, in order to ensure a smooth development of the IAVW.

6.2 Review of relevant outstanding issues from the Second Workshop on volcanic ash (Toulouse 1998) (Raul Romero)

6.2.1 The ICAO observer presented a report to the workshop on the actions taken regarding the outstanding issues from the Second International Workshop on Volcanic Ash (Toulouse, 1998). It was explained that a number of conclusions, not subject to formal follow-up, related to the IAVW had been referred to the disbanded VAWSG to facilitate appropriate action by ICAO. Most of the issues had been considered by the VAWSG/3 Meeting, held in Brisbane, Australia (2000).

Conclusion 2/2- Volcanic ash nephanalyses

6.2.2 Regarding this issue, the VAWSG/3 Meeting had suggested that including the initial state of the ash cloud at time "00" in an updated volcanic ash advisory in graphical format (model VAG) might cover the user requirement of a volcanic ash " nephanalyses". It had been agreed that the disbanded VAWSG should await the outcome of the validation of the user requirement by the United States FAA. The United States informed the workshop that the validation was finished and that the outcome would be sent to the ICAO Secretariat. The workshop agreed that this issue would be raised by VAACs or user States at the first meeting of the IAVWOPSG.

Conclusion 2/6 — VEI/Source term matrix

6.2.3 The Second International Workshop on Volcanic Ash (1998) had proposed that generic source term data, that could be applied as default values for typical eruptions when other more detailed information was not available, should be developed by the vulcanologists. When discussing this subject, the VAWSG/3 Meeting had been informed that the delay in progressing this task was due to the fact that one of the experts nominated by the Second International Workshop on Volcanic Ash to take the lead had retired. It was noted that related work had only been conducted for specific volcanoes in Alaska and Kamchatka. The disbanded VAWSG had felt that a generic source term matrix of typical volcano explosivity index (VEI) would still be useful and had referred the issue to the ICAO Secretariat. It was noted that no progress had been made on this issue and, therefore, it would be reconsidered by the IAVWOPSG/1 Meeting. The workshop felt that this project needed to be completed urgently.

Conclusion 2/7 — Rapid response trajectory models

6.2.4 When reviewing this issue, the workshop noted that the VAWSG/3 Meeting had noted that the rapid response model would be needed by meteorological watch offices (MWOs) in order to issue a more informative SIGMET for an eruption. Due to different considerations that had been made on the implementation of this proposal (e.g. the need for the model to access global upper wind fields, the complexity of the operation, the possible reluctance of a number of States in accepting responsibility for software maintenance), the VAWSG/3 Meeting had agreed to cease the work on this issue. Therefore, the task has been deleted from the work program of the group.

Conclusion 2/8 — Information on volcanic ash deposition

6.2.5 Concerning this issue, the ICAO observer informed the workshop that the VAWSG/3 had agreed (Conclusion 3/8 refers) that ICAO should ascertain from aerodrome experts if there was any interest for the inclusion of ash deposition data in the volcanic ash advisory information. Due to the fact that no progress had been made in this task, it has been included in the work program of the IAVWOPSG.

Conclusion 2/9 — Comparison trial of models

6.2.6 The VAWSG/3 Meeting had been updated on the progress in the conduct of comparison trials of the models used by the VAACs for forecasting volcanic ash movement in the atmosphere. It had been agreed that rather than having more trials, it would be far more productive to try to understand the differences between the models, calibrate the models and study the effect of different source term data on the model output. It had also been agreed that the VAACs should exchange detailed information on the transport and deposition models they were using, and future trials should focus on comparing model output between adjacent VAACs. The ICAO observer informed the workshop that this was an IAVWOPSG task which would be progressed in coordination with the VAACs.

Conclusion 2/10 — WMO abbreviated bulletin headings for volcanic ash advisories

6.2.7 The VAWSG/3 Meeting when reviewing this issue had noted that considerable progress had been made by the VAAC Washington on the compilation of a list of headers used by VAACs for the volcanic ash advisories and that this had been extended to include headers for SIGMET for volcanic ash. It had been noted that for standardization purposes, the geographical designator included in the header was important as it could be used to parse the message and allocate each message to its geographical area. In this regard it had been agreed that the use of Table C1-Part II of the WMO Manual on the GTS (WMO-No 386) had been particularly useful as it referred to regions rather than States. The ICAO observer pointed out that the disbanded VAWSG had agreed that the two WAFCs should have the same header data base for the uplink of messages on the three satellite broadcasts. The VAWSG/3 Meeting had formulated Conclusion 3/10 -WMO abbreviated header data base requesting the VAAC Washington to provide the Secretary with the abbreviated header data base in order to forward it to the WAFCs. The conclusion had also called for the Secretariat to undertake an analysis on standardization and to forward the results to the group. Due to the fact that no progress had been made the ICAO observer informed the workshop that this issue would have to be addressed by the IAVWOPSG at its first meeting.

Conclusion 2/12 — Handover of responsibility between VAACs

6.2.8 The ICAO observer informed the workshop that in Amendment 72 of Annex 3, the remarks section had been introduced in the volcanic ash advisory message format . Amendment 72 had also introduced in the volcanic ash advisory the information regarding next advisory which gave the VAACs the possibility to announce the handover of responsibilities between them. The workshop was also informed that the *Handbook on the International Airways Volcano Watch (IAVW) — Operational Procedures and Contact List* (Doc 9766), contained specific guidelines for VAACs in cases where the volcanic ash crossed the boundary between areas of responsibility. In conclusion the workshop agreed that the intent of the conclusion had been met and that there was no need to pursue this issue.

Conclusion 2/15 — Provision of temporary SATFONE to States

6.2.9 During the discussions at the VAWSG/3 Meeting a number of members had indicated that communication problems between volcanic ash observatories and ACCs/MWOs identified at the Second International Workshop on Volcanic Ash still existed. Most of these problems were organizational, for example, lack of permission from higher management for staff to use telephones for long distance calls to notify VAACs/MWOs/ACCs of a volcanic eruption. Conclusion 3/12 of VAWSG/3 had called for ICAO to consider ways and means to persuade relevant States to allocate sufficient resources required to ensure that observatories were permitted to make international telephone calls to notify the aviation community of volcanic eruptions. In order to address this issue, the MET Divisional Meeting (Montreal, 2002) (Recommendation 1/14 refers) had agreed to include a requirement for information from selected volcano observatories in Amendment 73 to Annex 3 and the meteorology part of the regional air navigation plans. Therefore the workshop agreed that action on this conclusion could be considered to be complete.

6.3 WMO activities resulting from the second international workshop on volcanic ash (Toulouse 1998) (Saad Benarafa)

6.3.1 The WMO observer provided information on WMO activities stemming from the following conclusions:

Conclusion 2/1 — Stakeholders on satellite sensor specifications should be made aware of the requirements of aviation for the timely detection of volcanic ash.

6.3.2 The workshop was informed that the Commission for Basic Systems Expert Team on Observational Data Requirement and Redesign (ETODRR) of the Global Observing System (GOS) has finalized in 2002 its four-year work plan and had been applying the Rolling Review of Requirements (RRR). In the WMO TD-992 — *Statement of guidance regarding how well satellite capabilities meet WMO user requirements in several application areas* published in 2000, it was highlighted among others that Geostationary capabilities for nowcasting volcanic ash do not meet minimal requirements, and that large expanses of the globe do not have routine multi spectral imagery required for volcanic ash detection. In many WMO for a concern had been expressed about the consequences of the change to the specifications for IR channels on the next series of US GOES satellites, as one of the techniques for determining ash cloud from water/ice cloud using Channels 4-5 split-window techniques. Further research of alternative techniques for using the available IR channels was encouraged.

6.3.3 In their fourth session held in Geneva, Switzerland (29 April - 3 May 2002), the Expert Team on Satellite System Utilization and Products (ET-SSUP) had agreed to a set of conclusions and recommendations that included alternative dissemination methods principles, potential benefits, a perspective from the satellite operators of the Coordination Group for Meteorological Satellites (CGMS), data dissemination concept, characteristics and preliminary user requirements.

6.3.4 Furthermore, the conjoint WMO CAeM XII Session /ICAO MET Divisional Meeting held in Montreal, Canada, September 2002, recommended (Rec 1/19) "That, WMO be invited to encourage Provider States of the VAACs to continue, and if possible accelerate, research into the detection of volcanic ash from satellite data".

Conclusion 2/5— Infrasonic detection of volcanic eruption and the access to real time data on explosive volcanic eruption detected by the CTBTO infrasonic network

6.3.5 The workshop was informed that the conjoint WMO CaeM XII Session/ICAO MET Divisional Meeting recommended (Rec 1/18) that ICAO with the assistance of WMO invite the United Nation Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) to complete its assessment of the usefulness of global seismic and infrasonic data from the CTBTO treaty verification networks to the detection of volcanic eruptions under the IAVW, as soon as practicable. Consequently, a letter was sent to the CTBTO Preparatory Commission that and in its reply, the CTBTO expressed its readiness to undertake such a study.

6.3.6 The workshop was pleased to note that the WMO Fourteenth Congress adopted Resolution 9.1/1 (Cg-XIV) approving an agreement between the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization and the WMO. This agreement highlights specifically that the CTBTO and the WMO agree to cooperate closely with regard to meteorological measurements, the exchange of meteorological observations and transport modelling, and to establish specific procedures to that end.

Conclusion 2/7 — That ICAO VAWSG be invited to study the desirability/feasibility of ICAO/WMO providing access to rapid-response volcanic ash trajectory models to MWO

6.3.7 The workshop was pleased to note that WMO fourteenth Congress (paragraph 3.1.3.15) noted that some services were already able to issue special volcanic ash products and air pollution forecast for volcanic gas using the products based in part on atmospheric transport model using the tools of movable meso-scale models products. Congress agreed that Regional Specialized Meteorological Centers (RSMCs) with the operational capability to do so, should consider the development and application of such models with a view to responding to volcanic gas and other aspects of eruptions with impact on public health. Other information on this issue is addressed in paragraph 6.2.4 of this report.

Conclusion 2/12 — Handover of responsibilities between VAACs.
Conclusion 2/13 — Area of responsibility not covered

6.3.8 The WMO representative indicated that, as a result of the excellent collaboration between ICAO and WMO and the generosity of WMO Members, the WMO RSMCs in charge of the provision of transport model products for the Environmental Emergency Response have become the backbone of the ICAO VAACs. In this context, following a request from the WMO Secretariat, the United States as provider State of the Anchorage VAAC had kindly accepted to extend the western boundary of the area of its responsibility to longitude 150 west. In addition, the workshop noted that the kind offer of the Australian Bureau of Meteorology to extent the area of responsibility of the Darwin VAAC to cover the active volcano of Barren Island in the Andaman had been accepted by ICAO.

Conclusion 2/17 — Education and training in IAVW Operational procedures

6.3.9 The workshop was informed that the WMO publication No. 258 — *Guidelines for Education and Training of Personnel in Meteorology and Operational Hydrology* had been updated in 2002 with among others an input on volcanic ash and satellite matters. In addition, the workshop was informed that volcanic ash issues had been included in the program of training events on aeronautical meteorology organized by WMO, in particular, those held in cooperation with ICAO in Niamey, Niger in 2000 and in Bogota, Colombia in 2001.

6.3.10 Furthermore, the workshop was also informed that the CAeM XII Session had highlighted the issue of the issuance of volcanic ash advisories by VAACs and the issuance of volcanic ash SIGMETs by MWOs and the need to improve the accuracy, the consistency and the timeliness of these messages and that it was deemed essential that there be no misinterpretation resulting from lack of information. The workshop noted that the CAeM XII session had encouraged WMO to review existing practices and procedures to determine what additional guidance or guidelines would be required at VAACs and MWOs (paragraph 6.22 of the CAeM XII Report refers).

6.4 Volcano Observatories in Support of the VAACs (Mariane Guffanti)

6.4.1 The workshop noted that depending on the extent of its monitoring capabilities, volcano observatories can support volcanic ash advisory centers (VAAC) through detection and forecasting of eruptions, confirmation of the start of an eruption, characterization of the size and type of eruptive activity including production of ash plumes and provision of forecasts related to ongoing activity.

6.4.2 Useful information regarding action taken in the monitoring process of volcanic activity including pre-and post-eruption procedures was presented by the Alaska Volcano Observatory (AVO) which monitors 24 volcanoes along the North Pacific air routes.

6.4.3 The use of the aviation color code by all the entities involved in the IAVW was discussed and it was felt that the use was not yet fully implemented in the volcanic ash advisories (VAA) . Updated information regarding recent scientific and technological advances related to forecasting of eruptions was also discussed.. In that regard, the sophisticated seismic networks around active volcanoes, the forecast of eruption size by empirical methods, detection of ground deformation and the development of software packages to graphically integrate real time data were highlighted.

6.4.4 The workshop noted that due to gaps in the monitoring networks, it is not yet guaranteed that eruption information will reach aviation users in a timely manner.

6.5 Impact of Volcanic Activity on Airports (Marianne Guffanti)

6.5.1 It was noted that volcanic activity is not only an hazard to in-flight aircraft but it can also disrupt operations at aerodromes due to ash fall, reduction of visibility, structural damage, systems contamination, etc.

6.5.2 The extent of the hazard on airports was highlighted in a compilation of airport and volcanic data presented by the U.S. Geological Survey Volcano Hazard Programme and the Smithsonian Institution Global Volcanism Program.

6.5.3 It was noted from the analysis that operations at airports had been disrupted in 20 countries on 103 occasions by 34 different eruptions; and although the inventory was not complete (because incidents are not always reported) it could be considered as a good sample from different regions. It was also noted that about 50 per cent of the impacted airports were located within 100 km of the volcano, but operations at airports as far away as 500 to 1 700 km from the volcano had been disrupted.

6.5.4 Different methods used by airports in order to reduce operational disruptions like real time detection of explosive volcanic activity, the forecasts of ash plume paths and detection of approaching ash plumes using ground based Doppler radar were discussed. The efficiency of the warning using real time detection techniques and forecasting ash plume paths were highlighted. Unfortunately, the use of experimental ground based Doppler radar to track the direction and speed of ash plumes had not been proven as satisfactory for warning purposes.

6.5.5 The workshop concluded that airports located in areas of high risk of volcanic activity should continue to develop specific operational plans for ash fall events and evaluate appropriate systems of notification of volcanic ash activity.

6.6 User point of view (Noriyuki Todo).

6.6.1 An aircraft operator from the Asia/Pacific Regions presented an interesting evaluation on the current status of the IAVW in the Asia/Pacific Regions for the period 1998-2002.

6.6.2 The implementation efforts being done by the IAVW in these regions and the involvement of five of the VAACs (Anchorage, Darwin, Tokyo, Washington and Wellington) and a number of MWOs and ACCs in different States was recognized. The workshop acknowledged that from the aircraft operators point of view, the VAACs are performing very well and that VAAs are fully implemented in the Asia/Pacific Regions. However, it was also recognized that the performance of WMOs and ACCs in the regions need to be improved due to lack of implementation of SIGMETs and ASHTAMs/NOTAMs for volcanic activity.

End

ANNEX 1

Conclusions for the 3rd Intl Workshop on Volcanic Ash

(Toulouse 29 sep – 03 Oct)

Remote sensing

Conclusion 1: The Workshop expressed its support to the Volcanic Ash Advisory Centres, who have taken on a great part of the eruption monitoring load and devoted resources to the International Airways Volcano Watch (IAVW). This has contributed significantly to aviation safety.

Conclusion 2: The Workshop recognised that satellite derived volcanic ash detection technologies and methodologies have been developed further with some new avenues being explored including shape recognition. Various satellite platforms continue to provide useful imagery with future platforms expected to provide enhanced spatial, spectral and temporal resolution (Meteosat Second Generation for example).
The workshop encouraged all the stakeholders to continue the development of volcanic ash detection methods, and the exploitation of the newly-available imagery. The Workshop agreed that any technological advancement that might lead to a better quantitative estimate of airborne volcanic in the horizontal and vertical would have great benefits for volcanic ash modelling.

Conclusion 3 : Ground based detection technology continues to be advanced. Most notable are the continuing work being done by the CSIRO of Australia in conjunction with Tenix industries developing a marketable passive IR instrument for the purpose of detecting volcanic eruptions and the work being done on the development of relations with the Provisional Technical Secretariat of the Comprehensive Nuclear-Test-Band Treaty Organisation (CTBTO) for the possible sharing of global infrasound data for detecting and locating volcanic eruptions.

It was also recognized the work being done by ICAO, with the assistance of WMO, in order to complete the assessment of the usefulness of global seismic and infrasonic data from the CTBTO observing network to the detection of volcanic eruptions, as recommended by the Conjoint MET Divisional Meeting/ twelfth Commission for Aeronautical Meteorology Session (Montreal, September 2002). In that matter, the Workshop recognized the importance of appropriate infrasonic data processing and station site sensitivity to qualify the infrasound technology for the purpose of detecting volcanic eruptions. The efforts of the Alaska Volcano Observatory to greatly expand seismic coverage in the Aleutian Islands are also noteworthy. The Workshop encouraged all the stakeholders to continue the development of holistic multi-sensor approach for ground air satellite based observation and to reaffirm the vital importance of remote sensing through education and diplomacy.

Modelling

Conclusion 4 : The Workshop encouraged all the stakeholders to continue to develop modelling technologies with the enhancing of various models including VAFTAD, CANERM, MOCAGE, PERLE, HYSPLIT, NAME and PUFF.

Conclusion 5 : The Workshop recognised that new work was being developed in the use of ensemble methodologies to enhance ash plume and transport predictions and suggested that some measurement of confidence be included in the use of these ensemble methodologies.

Conclusion 6 : The Workshop recognizes that dispersion models used in real-time forecasting cannot accurately calculate volcanic ash concentrations because of uncertainties in the source term, one of which is the amount of ash in the eruption column. Since all dispersion models would benefit from the consistent use of a standard table of eruption-source terms, the Workshop urged that research toward that goal continue to be undertaken, despite the recent retirement of key people previously tasked with the project. Volcanic Ash Advisory Center (VAAC) Montréal (René Servranckx) in collaboration with NOAA ARL (Barbara Stunder) and VAAC Darwin (Andrew Tupper) have offered to contact the appropriate organizations and research groups to try to achieve this objective. In the mean time, the Workshop encouraged the VAACs to work towards a consistent approach in this area.

Conclusion 7 : The workshop recognized that even if dispersion models could fully describe the source term, and concentrations could be accurately calculated, threshold volcanic ash concentrations delineating acceptable concentrations, compared to concentrations known to impact an aircraft in terms of safety and maintenance, are unknown. The "visual ash cloud" concept recommended in ICAO Annex 3/ WMO Technical Regulations (C.3.1) instead provides a simple means of indicating the presence of volcanic ash. Furthermore, developing a quantitative definition of "visual ash cloud" and related quantitative definitions of ash density / risk ratios is important but these are unlikely to be achieved in the foreseeable future given the large uncertainties (eruption parameters, deficient quantitative data on the 3D structure of the airborne ash, etc.). However this current perspective should not preclude any endeavor or co-operation to achieve these quantitative definitions, and in the mean time, the Workshop encouraged the VAACs to work towards a consistent approach in this area,

Conclusion 8 : The Workshop expressed the need to continue to promote, in coordination with ICAO and WMO, national and international support of detection, modelling and operational warning development for volcanic ash emission and transport and that further consideration be given to the phenomena of dust and smoke being transported high into the atmosphere should this be of any safety or economic risk to aviation.
"The Workshop encouraged VAACs to address the issue of model-intercomparison at the next IAVWOPSG meeting, particularly as a means to prepare for instances of ash traveling across VAAC boundaries."

Coordination and cooperation

Conclusion 9 : The workshop expressed its concern with regard to standing difficulty in getting data and information on some volcanic events in real time from various parts of the globe.

Conclusion 10 : The workshop expressed its concern with regard to the lack of reporting of in-flight encounters by airlines as well as to the general lack of pilot reports during some eruptions. As reporting requirements are not universal, this was considered as both a scientific and operational issue. As a result the Workshop was of the opinion that ICAO should investigate ways to improve the reporting rate of aircraft encounters, prior to the first meeting of the IAVW Operations Study Group (IAVWOPSG).

Conclusion 11 : The Workshop noted with some concern that the use of colour code in the text of VAAs is not yet the object of a consensus of opinion from the IAVW participants.

Conclusion 12 : The group recognizes that a system such as Volcanic Ash Collaboration Tool (VACT) would be beneficial to facilitate coordination and collaboration between the VAACs. It would benefit the VAACs in providing a heightened situational awareness, data sharing, and a means to provide efficient "handoff" of products from one VAAC area of responsibility to another. The VACT Concept of Operations is currently being tested in Alaska and the assessment of its usefulness will be referred to ICAO's IAVWOPSG.

Conclusion 13 : The Workshop was of the opinion that special attention should be given to airports in vicinity of active volcanoes as the immediate contamination makes them particularly vulnerable. In this regard it was noted the interesting work that is being done in some States regarding forewarning of imminent volcanic activity in order to reduce operational disruptions at airports.

Conclusion 14 : The Workshop considered that it would be advantageous for WMO and ICAO, in their promotion and enhancement of the VAAC regime, to continue developing a working relationships, at National and international levels, with WOVO and its parent organisation, IAVCEI. The workshop noted that one VAAC has joined WOVO.

Conclusion 15 : The Workshop agreed that the open and constructive investigations of known aircraft encounters with ash by IAVW participants and their mutual co-operation are one of the keys for future improvement of the IAVW.

Conclusion 16 : The Workshop endorsed the convening of a 2nd International Symposium on volcanic ash and aviation safety in Washington DC planned to be held in 2004, and welcomed the proposal by the US representative to seek WMO involvement in administering travel grants to be made available by the USA to WMO to achieve broad representation at the symposium from VAACs and MWOs worldwide. The Workshop also welcomed plans for a regional workshop in Iceland in 2005.

ANNEX 2

Workshop on Volcanic Ash, Toulouse France 29 Sept -03 Oct

List of participants

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