METEOROLOGY PANEL

Concept of Operations

for

Volcanic Hazard Information

for

International Air Navigation

in

Support of the Global Air Navigation Plan

and the

Aviation System Block Upgrades

06 November 2015

draft Version 2.0

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0.1	15 April 2011	Internal draft. New Document.
0.2	06 May 2011	Initial draft. Presented to IAVW coordination group of IVATF.
0.3	13 July 2011	Initial draft. Presented to IVATF/2 (Working Paper 04).
0.4	08 February 2012	Revised draft. Complete rewrite based on comments received on initial draft.
0.4.1	10 February 2012	Minor revision. Minor edits. Presented to IAVW coordination group at IVATF/3.
1.0	14 December 2012	Draft version for IAVWOPSG/7. Format and structure changed to harmonize with other ConOps being developed. Considered and/or incorporated comments received in response to IAVWOPSG Memorandum 56.
2.0	Xx November 2015	Based in part on the *Roadmap for International Airways Volcano Watch (IAVW) in Support of International Air Navigation*, 21 November 2013, version 1.0, ICAO Doc 10045 *Meteorology (MET) Divisional Meeting (2014)*, Appendix C. New format and structure changed

Contents

1.0 Introduction.

This Concept of Operations (ConOps) document describes the **need for** and **use of** volcanic hazards information for operational decisions, in qualitative and quantitative terms, from the perspective of the end user and relevant to an operator's Safety Management System (SMS). This ConOps is not intended to describe **how** future volcanic hazard information is to be provided or by **whom** the future information is to be provided.

This ConOps complements the *Roadmap for International Airways Volcano Watch (IAVW) in Support of International Air Navigation*, Version 1.0 (21 Nov 2013), which is Appendix C to ICAO Doc 10045 *Meteorology (MET) Divisional Meeting (2014)*, and is a living document that is intended to evolve as the science and technology improves, and as operational requirements evolves.

1.1 Information Identification

(A high-level description (e.g., Executive Summary) of the information described in greater detail in the ConOps document)

This ConOps presents the future use of volcanic hazard information for international air navigation in support of International Civil Aviation Organization (ICAO) Global Air Navigation Plan (GANP) and associated Aviation System Block Upgrades (ASBU). Specifically addressed are ASBU Blocks 1 and 2, in their respective timeframes of 2018-2023 and 2023-2028.

Performance Improvement Area 2 from the GANP calls for, inter alia, *enhanced operational decisions through integrated meteorological information*, with *meteorological information supporting both air and ground automated decisions support aids for implementing weather mitigation strategies*[1]. This ConOps describes how improved information on the hazards from volcanoes will help meet the need called for in the GANP.

There are three improvements presented in this ConOps. Two are new information services, while the third is the integration of these services into decision support systems.

First is the development of three-dimensional representation of the current or near-current volcanic hazard boundaries, referred to in this document as a "now-cast[2]". Now-cast information would be made available via the System Wide Information Management (SWIM) system and extracted by the user. Volcanic hazard information providers would update the information at a high frequency, to provide a more realistic assessment of the location and extent of the hazard (e.g., volcanic ash cloud).

Second is the provision of probabilistic forecasts of the volcanic hazard. The purpose of a probabilistic forecast is to provide decision makers an assessment of all the likelihoods of a volcanic cloud's (i.e., ash, gas) risk of exceeding a defined threshold. Probabilistic forecasts

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[1] *Global Air Navigation Plan 2013-2028,* ICAO Doc 9750, fourth edition 2013
[2] Now-casts is a term used by the ICAO's Air Traffic Management Requirements Performance Panel to describe the current state.

allow multiple decision makers to use the same information, but apply their own operational constraints to determine risk to their operation.

Finally, neither now-casts nor probabilistic forecasts will meet the needs of the GANP without integration into decision support systems for trajectory-based operations. Decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds. Integration into decision support systems also allows users to control the amount of information received on the volcanic hazard so that they receive the correct amount of information, per their Safety Risk Assessment *(*SRA), to complete their operation.

1.2 Information Overview

(A high-level overview of how the information will be used by aviation decision-makers)

An aviation user must know if a hazard will affect them or their operation, and if so, what actions to take in order to mitigate the risk in accordance with SMS practices.

A provider of aviation hazard information needs to determine if a hazard exists, or is expected to exist, in their area of responsibility. The provider compiles information about the hazard into format(s) that can be used by the aviation user. The provider makes available information about the hazard for users to access to mitigate the risk.

The hazard may vary depending on the user. For volcanoes, the hazards to aviation include:

- Volcano that is erupting or expected to erupt
- Volcanic ash:
    - in the atmosphere greater than a specified threshold
    - on the runway/taxiway greater than a specified depth
- Sulphur dioxide (SO_2) and other gases greater than a specified threshold

Note: Specified threshold and depth refers to a defined metric that can vary depending on the user. For example, for ash in the atmosphere it can be 2 milligrams per cubic meter, or some other value (per a user's SRA).

Depending on the user, quantitative and qualitative information on the hazard will vary. A user may not need to know every detail regarding the hazard; only the information pertaining to their operation. For example, a flight crew must know if they will encounter the hazard during their route of flight. They may not need to know the entire extent of the hazard; just the portion of the hazard that may affect their planned route (including altitude) or revised route. However, the crew's need for detail and accuracy can be high for only that portion of the hazard expected to affect the flight route.

Information overload can occur for the user if too much information is provided that is not relevant to the hazard affecting their operation. To avoid information overload, users must be able to obtain the correct amount of information in order to successfully complete their operation (e.g., flight) efficiently.

1.3 References

(Documents used as references in this ConOps document)

- *Roadmap for International Airways Volcano Watch (IAVW) in Support of International Air Navigation*, Version 1.0 (21 Nov 2013), ICAO Doc 10045 *Meteorology (MET) Divisional Meeting (2014)*, Appendix C
- *Global Air Navigation Plan 2013-2028,* ICAO Doc 9750, fourth edition 2013, including:
    - *Aviation System Block Upgrades*, Appendix 2
- *Handbook on the International Airways Volcano Watch*, ICAO Doc 9766
- *Flight Safety and Volcanic Ash,* ICAO Doc 9974

2.0 Operational Need

(Describes the need for the information to be provided based on the needs identified by aviation decision-makers as part of mission/needs analyses. This section identifies the users (e.g., pilots, air traffic controllers, etc.) of the information to be provided)

Users need to know the current and future state of the hazard, including both location and extent. For volcanic ash clouds, today's advisories (i.e., volcanic ash advisory [VAA] and its corresponding graphical version [VAG], and SIGMET) provide information about the ash at the initial time of the product (i.e. T+0 hour), a forecast valid at T+6 hour (for both VAA/VAG and SIGMET), followed by T+12 and T+18 hour forecasts (VAA/VAG only).

These products are issued every six hours. Thus at two hours after T+0, users must interpolate between T+0 and T+6 in order to obtain an estimate of where the ash cloud boundary lies. Providing VAA/VAG and SIGMET at three-hour time-steps would help this issue, but more can be done with the transition to a digital information database for meteorological information, as part of the GANP and associated ASBUs, including volcanic ash.

2.1 User Need Identification

(Identify the users (pilots, Flight Operations Centers, Air Traffic Controllers, Aerodrome Operators), describe the operational decisions they make related to weather (human or automated decisions), and define qualitatively and quantitatively the weather information needed to make those decisions in terms of content, reliability, timeliness, accessibility, procedures, and man-machine interface)

In order to improve efficiencies in air transportation during volcanic events, high-quality, timely and consistent volcanic hazard information is essential to mitigate the safety risk of aircraft encountering volcanic ash. Education of all users is also needed to ensure proper use of volcanic hazard information within the operator's risk assessment process.

The following is a set of high-level operational needs of aviation users:

- Determine the onset of a volcanic event (i.e., especially pre-eruption warning)
- Determine if an eruption and any associated volcanic ash or gasses are a hazard to international air navigation based on any agreed-upon threshold values
- Determine what aerodromes and airspace are affected by the eruption and associated cloud
- Determine when the eruption has ended
- Determine when the volcanic ash or gases have dispersed below agreed-upon threshold values
- Determine when the aerodrome/airspace affected by the eruption and/or cloud is safe for continued operation in or through

2.2 Current Capability Assessment

(Describes qualitatively and quantitatively, currently available information (in terms of content, reliability, timeliness, accessibility, procedures, and man-machine interface) utilized by aviation decision-makers for operational decisions)

The initial report of volcanic eruption and resultant ash cloud can result in many products being delivered to the pilot. In most cases, information about a volcanic ash cloud will be provided to the pilot, both in-flight and during pre-flight planning, in the form of a SIGMET, NOTAM or ASHTAM, Special AIREP or Volcanic Ash Advisory (VAA). Each of these products is unique in format and content, but all provide information regarding the location of the volcanic ash but with varying degrees of quality and accuracy. The challenge is the need for consistency in their overall message.

Today's volcanic ash forecasts are basic textual and graphical products derived and produced using the output from dispersion and transport models validated and amended against available volcanic ash observations. The two primary volcanic ash forecast products are the VAA and the SIGMET information message.

VAAs are produced and issued by the nine Volcanic Ash Advisory Centers (VAAC) across the world, each with a defined geographical area of responsibility. The VAAC provides the VAA in a text and/or graphic-based format (the graphic version of the VAA is referred to as a VAG), that provides an analysis of the ash cloud and a 6-, 12- and 18-hour forecast for the trajectory of the ash cloud and associated flight levels that may be affected.

SIGMETs are produced and issued by the Meteorological Watch Office (MWO) based on the guidance provided by a VAAC. These SIGMETs are valid for up to six hours and describe in coarse terms the location and expected location of the ash cloud within the area of responsibility of the MWO, which is normally just one flight information region (FIR).

Services in support of the provision of meteorological information for volcanic events can be categorized in four areas: (1) monitoring the threat, onset, cessation, dimensions and characteristics of an eruption, (2) monitoring volcanic ash in the atmosphere, (3) forecasting the expected trajectory and location of the ash cloud, and (4) communicating the information to the users.

A detailed description of current service providers and their functions with respect to volcanic hazard information can be found in the *Roadmap for International Airways Volcano Watch (IAVW) in Support of International Air Navigation*, 21 November 2013, version 1.0, ICAO Doc 10045 *Meteorology (MET) Divisional Meeting (2014)*, Appendix C.

2.3 Anticipated Change Identification (Shortfall Analysis)

(Identifies and describes qualitatively and quantitatively the shortfalls in the current information relative to the needed information identified in the Users' Needs Analysis. Shortfalls include any deficiencies in reliability, timeliness, accessibility, procedures, or man-machine interface of the information)

VAA, VAG and SIGMET provide a simple outline of the ash cloud (observed and forecast), which often times is an over simplification due to the format requirements (limited number of vertexes/points). Also, base and top of the ash cloud is also a simplification. Temporal resolution of information in the VAA/VAG and SIGMET is 6-hours, which is very coarse and limits users' ability to determine the location of the hazard in various time frames (e.g., at 2 hours after issuance of a VAA/VAG and SIGMET).

SIGMETs are valid for only one FIR, whereas a VAA/VAG may cover multiple FIRs. At one time during the Eyjafjallajökull eruption of 2010, more than 40 SIGMET messages for the volcanic ash cloud were in effect. This resulted in information overload for many users, who needed to know consistent information about the extent of the ash cloud.

Today's SIGMETs and VAA/VAG are not issued for a specific threshold of ash. Although there are no agreed threshold values that constitute a hazard to jet aircraft engines, in time such thresholds will be developed which may allow safe flight through specified thresholds.

The VAA/VAG and SIGMET are currently issued for volcanic ash clouds. There is strong evidence that there is also a need to expand the volcanic hazard information services to include other toxic elements typically associated with volcanic eruptions. During volcanic eruptions, a number of toxic gases may be emitted in addition to ash; these include SO_2, hydrogen fluoride, and hydrogen sulphide among many others. Each of these gases has different atmospheric dispersion properties, and gas clouds may or may not be found coincident with ash clouds. Of these gases, SO_2 is of particular importance, as it may be emitted in large quantities and has potentially significant health effects.

3.0 Justification for Information to be Provided

3.1 Objectives and Scope

(Describes the objective (e.g., safety, efficiency, etc.) and the scope (e.g., global, regional, Flight Information Region, etc.) of the information to be provided)

3.1.1 Volcanic hazard now-casts

By the ASBU Block 2 timeframe, it is foreseen that a three-dimensional representation of current or near-current volcanic hazard boundaries, referred to as a “now-cast,” could be made available. Now-cast information would be made available via the System Wide Information Management (SWIM) system and extracted by the user. Volcanic hazard information providers would update the information at a high frequency to provide a more realistic assessment of the location and extent of the hazard (e.g., volcanic ash cloud).

As the volcanic ash moves or changes, now-casts are updated at a temporal frequency that meets user needs and service provider capabilities. Improved volcano eruption source parameters (ESP) and *in situ* measurements of the airborne volcanic ash (from ground-based, space-based, or airborne-based observing platforms) will be needed to provide now-casts that have a high level of accuracy and confidence.

3.1.2 Probabilistic volcanic hazard forecasts

Current volcanic ash forecasts, such as the VAA/VAG, are deterministic forecasts. They are a yes/no forecast, with respect to the depiction of the airspace impacted by volcanic ash contamination. These forecasts are based on the definition of “discernible ash” as a fundamental criterion.

Volcanic ash transport and dispersion models can produce an array of solutions (e.g., forecasts) by varying the model input. Changes in meteorological parameters and ESP will result in different forecast outputs that affect the four-dimensional shape (three-dimensional shape and change of shape with time) of the cloud. The purpose of a probabilistic forecast is to provide decision makers with an assessment of all the likelihoods of a weather parameter’s risk of exceeding a defined magnitude/threshold. Probabilistic forecasts help multiple decision makers use the same weather information, applying their own operational constraints to determine risk to their operation.

From a high-level perspective, probabilistic forecasts are best provided via an ensemble approach. An ensemble is one way to account for some degree of uncertainty. For instance, the model can be run through several iterations, each one with a realistic variant of one of the uncertain parameters (e.g., ash amount, ash column height, eruption start time and duration, input meteorology dataset, with and without wet deposition, etc.). Taken as a whole, the variability of the ensemble members’ output provides an indication of the uncertainty associated with that particular ash forecast.

3.1.3 Integrate volcanic ash forecasts into decision support systems for trajectory based operations

One of the key elements in meteorological modules of the ASBUs is the integration of meteorological information into decision support systems. Future ATM decision support systems will need to directly incorporate volcanic hazard now-casts and forecasts, allowing decision makers to determine the best response to the potential operational effects and minimize the level of traffic restrictions. This integration of volcanic hazard now-casts and forecasts, combined with the use of probabilistic forecasts to address uncertainty, reduces the effects of volcanic hazards on air traffic operations.

3.2 Potential Benefits of New or Modified Information

(Describes the operational benefits (e.g., reduced pilot/controller workload, reduced cost, increased safety etc.) derived from use of the improved information)

The proposals for volcanic hazard information to be developed and implemented will provide users with volcanic hazard information that has greater confidence and utility. Moving from a product-centric environment to an information centric environment will meet the future operational needs of aviation decision-makers. Also, decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds. The integration of volcanic now-casts combined with the use of probabilistic forecasts to address uncertainty, will lead to more effective and informed decision making and planning for air traffic operations.

The application of probabilistic forecasts will best benefit high-density (congested) traffic areas, where decision makers can benefit from more than just a deterministic forecast. Also, decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds.

3.3 Description of Change in Operational Decision Environment that Produces the Benefits

(Describes changes in operational decision making environment in terms of procedures, standards, rendering and presentation (e.g., text to graphic, standalone versus integrated) and decision making mode (cognitive versus automated) that will be enabled by the information to be provided)

Future services center around a number of changes that are intended to parallel the time frames of the ASBU Blocks.

Module B*1-AMET - Enhanced Operational Decisions through Integrated Meteorological Information* enables the identification of solutions when forecast or observed meteorological conditions impact aerodromes or airspace. Full ATM-MET integration is needed to ensure that: MET information is included in the decision-making process and the impact of the MET conditions (e.g., volcanic ash) are automatically taken into account. Module B*1-AMET* improves upon current operations where ATM decision makers manually determine the change in capacity associated with an observed or forecast MET condition (e.g., volcanic ash), manually compare the resultant capacity with the actual or projected demand for the airspace or aerodrome, and manually devise ATM solutions when the demand exceeds the MET-constrained capacity value. Module B*1-AMET also* improves in-flight avoidance of hazardous MET conditions by providing more precise information on the location, extent, duration and severity of the hazard(s) affecting specific flights.

3.4 Assumptions and Constraints

(Describes any assumptions (e.g., system upgrades) or constraints (e.g., continued use of legacy systems) that impact the implementation of the information to be provided)

3.4.1 Assumptions

The proposed concept contained herein is based on the following assumptions:

- Now-casts and probabilistic forecasts of volcanic ash information will replace the need for today's SIGMETs and Advisories
- Now-casts are not a traditional alphanumeric coded product. This concept moves away from a product-centric environment to an information-centric environment.
- Probabilistic forecasts can be utilized by aviation decision makers
- Probabilistic forecasts are best suited for users in congested airspace, but can also beneficial for users in uncongested airspace
- Continuing user demand for phenomena based information, rather than FIR-based information
- Improved volcano eruption source parameters (ESP), *in situ* measurements of the airborne volcanic ash (from ground-based, space-based or airborne-based observing platforms) will be needed to provide now-casts and forecasts that have a high level of accuracy and confidence.
- There are acceptable thresholds of ash that may be a maintenance concern for an aircraft but do not pose a safety hazard for aircraft.
- Acceptable thresholds of ash may vary based on the type of aircraft and engine requiring the development of index levels.

3.4.2 Constraints

The following constraints may impede the implementation of the proposed concept:

- The ability to actually measure ash in the air remains difficult
- The development of certifiable thresholds of ash, based on aircraft and engine, may take years, or may not be feasible or beneficial to operators
- Some States may not accept now-casts and probabilistic forecasts of volcanic ash as replacement to the SIGMET due to legal and political issues

3.5 Operational Policies and Constraints

(Describes any policies required for the implementation and utilization of the information to be provided. Describes any constraints that may limit the utilization of the information to be provided)

Moving from a product-centric environment to an information-centric environment with integration into decision support systems require changes in policies for flight documentation as well as retention of information by the provider. Currently, products are artifacts that can easily be provided for flight documentation and then archived for future reference (e.g., accident investigation). With the implementation of probabilistic forecasts along with integration into decision support systems, the concept of flight documentation changes. A database of information will replace a folder with charts and text reports and messages. Policies relating to system storage capacity for data retention (archival) will need to be visited. This need could vary depending on State's legal requirements.

It is expected that these issues will be addressed with the implementation of the system wide information management system (SWIM) concept, which is part of the GANP and associated ASBUs.

4.0 Operational Scenarios

(Describes how the information to be provided will be utilized by aviation decision-makers for different operational decisions (e.g., fuel loading during pre-flight planning, course deviation during en route operation, etc.). (Note: Depending on the information to be provided, a single gate-to-gate operational scenario may be sufficient to describe all the intended uses of the information to be provided)

Two kinds of operational scenarios are envisioned: 1) avoidance of the volcanic hazard, and 2) planned flight into an ash cloud that has contamination thresholds below an operator's SRA. The information for both scenarios is in the form of now-casts and forecasts that are integrated into decision support systems.

Now-casts

The three-dimensional representation of the current or near-current volcanic hazard, including depiction of the perimeter of the lowest acceptable threshold of ash contamination, in a common exchange format that provides integration into decision making tools, as well as offers a graphical depiction of the information. In the avoidance scenario, the now-cast provides users with the location of volcanic ash. As the volcanic ash moves or changes, the now-cast is updated at a temporal frequency that meets user's needs and service provider's capabilities. For flight into acceptable thresholds of ash, volcano eruption source parameters (ESP), *in situ* measurements of the airborne volcanic ash (from ground-based, space-based or airborne-based observing platforms) are required to provide a now-cast that has a high level of confidence of the ash contamination levels inside the cloud.

Forecasts

The four-dimensional representation of volcanic ash, including depiction of the perimeter of the lowest acceptable threshold of ash contamination in both deterministic and probabilistic terms, in a common exchange format that provides integration into decision making tools. Forecasts would be valid *x* hours and up to *y* days, and would contain finer temporal resolution in the near time frame. Forecasts would also be provided in terms of uncertainty (use of probability). For flight into acceptable thresholds of ash contamination, volcano ESP, quantitative measurements of the airborne volcanic ash (from ground-based, space-based or airborne-based observing platforms), would be needed to enable accurate validation of ash contamination to support airline decision-making.

5.0 Impact

5.1 Impact of Current Operations

(Describes the effect of the information to be provided on current operations)

Moving away from a product centric environment to an information centric environment will meet the future operational needs of aviation decision-makers. Decision support systems can use the probabilistic information to provide route and altitude selections based on user's acceptance thresholds. The integration of volcanic cloud forecasts, combined with the use of probabilistic forecasts to address uncertainty, reduces the effects of volcanic clouds on air traffic operations.

5.2 Organizational Changes Required

(Describes any changes necessary in the various user organizations (e.g., airlines, air traffic control, air traffic management, etc.) necessary to implement the information to be provided)

No changes are foreseen for user organizations.

Appendix A. Glossary and Acronyms

(Defines any key terms used in the ConOps document will not be commonly known to the readers. Provides a list that spells out any acronyms used in the ConOps document)

<TBC>

Appendix <X>. <TBD>

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