International Civil Aviation Organization

MIDANPIRG Meteorology Sub-Group
Eleventh Meeting (MET SG/11)

(Cairo, Egypt, 14–15 November 2023)

Agenda Item 4: MET Planning and Implementation issues – Performance Framework for MET implementation in the MID Region

QUANTITATIVE VOLCANIC ASH (QVA)

(Presented by VAAC London)

This paper provides an overview of the new quantitative volcanic ash forecasting provision that is being introduced with Amendment 81 to ICAO Annex 3 – *Meteorological Service for Air Navigation.*

1. INTRODUCTION

1.1 In recent years the Volcanic Ash Advisory Centres (VAACs) have been developing their ability to produce probabilistic forecasts from their atmospheric dispersion models, including plumes of volcanic ash. Initial operating capabilities for Quantitative Volcanic Ash (QVA) were developed by the Meteorological Panel (METP) Working Group on Meteorological Information and Service Development (WG-MISD) Volcanic Ash and Sulphur Dioxide (VASD) Work Stream and handed over to the METP Met Operations Group (WG-MOG) for the International Airways Volcano Watch (IAVW) to work on implementation of the new QVA products.

1.2 SL.2023-1 (dated 26 January 2023) which concerned changes to Annex 3 and the introduction of the new PANS-MET contained changes that will enable the introduction of the new QVA provision.

1.3 QVA information offers operators the opportunity to move away from traditional discernible ash criteria and instead use certified engine susceptibility for flight route planning and inflight replanning. The QVA provision was agreed with a representative of ICCAIA[1] whose members are aerospace manufacturers and service providers.

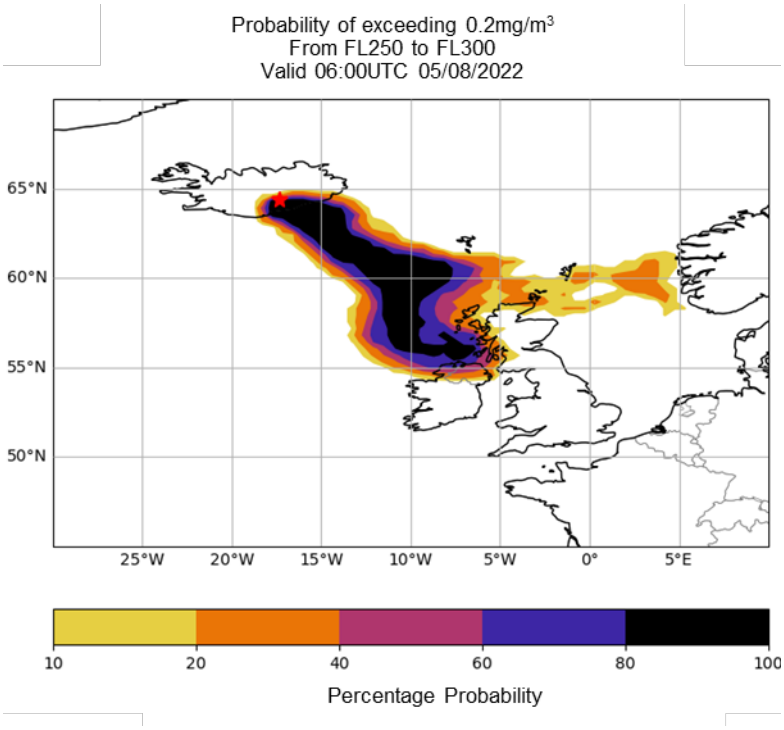
[1] International Coordinating Council of Aerospace Industries Associations.

2. INITIAL OPERATING CAPABILITY

2.1 The following thresholds and ranges were determined for the IOC:

Descriptor	Concentration thresholds and ranges
Very Low	<0.2 mg/m^3
Low	≥0.2 – <2 mg/m^3
Medium	≥2 – <5 mg/m^3
High	≥5 — <10 mg/m^3
Very high	≥10 mg/m^3

2.2 The probability of exceeding each of these thresholds will be provided for 5000FT slices of the atmosphere between the surface (FL000) and FL600, for three hourly intervals out to 24 hours. The gridded data output will be at a horizontal resolution of 0.25 degrees. An example of what this output could look like is shown below and further examples are included in **Appendix A**:



2.3 Forecasts will be updated at least every 6 hours, and it is expected that the first forecast will be produced within 60 minutes of the VAAC being notified of a new eruption.

2.4 The forecasts will geographically cover the entire extent of the ash cloud.

2.4.1 A definition of what constitutes a “significant volcanic ash cloud” will also be agreed to ensure that QVA forecasts are provided for ash clouds that pose a significant impact to aircraft operations and air navigation.

2.4.2 In addition to the probability QVA fields, a deterministic field will be provided that gives the expected ash concentration each grid point.

2.4.3 The deterministic data will also be turned into polygons/features in which everything inside of each one will exceed the specified concentration threshold. Each polygon/feature will also have attributes which indicate the base and top that it applies to. These are intended to allow users a simple way to visualize the key information about the volcanic plume, and has similarities to the way turbulence is presented in the World Area Forecast System SIGWX forecasts.

2.4.4 The diagram in **Appendix B** shows how polygons/features for each of the four threshold values could be stacked to produce the final visualization, as well as how they might relate to the traditional volcanic ash advisory products.

2.4.5 The polygons/features will be provided in a new IWXXM format, and the schema for this is already largely developed by the WMO Task Team on Data (who developed all the other IWXXM schemas).

2.4.6 The current volcanic ash advisories (VAA) and volcanic ash graphics (VAG) will continue to be produced for a number of years until the new QVA service is fully established.

3. DATA DISTRIBUTION

3.1 Recently the WG-MOG IAVW agreed on a common approach to distribute the QVA data which it is hoped that all VAAC's will be able to adhere to by November 2026.

3.2 This will be the Open Geospatial Consortium (OGC) Environmental Data Retrieval (EDR) framework https://ogcapi.ogc.org/edr/ (the same as is being used for the new SADIS API) to arrange the data into a series of collections (one for the deterministic output, one for the probabilistic output, and one for the IWXXM output) per volcano that is erupting. Alongside this will sit a notification service which will inform subscribers when new data has been published, and prompt them to download QVA data from the API. This suits the irregular nature of volcanic eruptions. Each VAAC's system will be SWIM compliant.

3.3 VAAC London is planning to implement their QVA API in November 2024 and it will use the framework described in 3.2 and will adhere to the EUROCONTROL SWIM yellow profile https://www.eurocontrol.int/concept/system-wide-information-management, and publish it in the SWIM registry https://eur-registry.swim.aero/services.

3.4 Unfortunately not all VAAC's, including Toulouse, will be able to adopt the OGC-EDR framework for their initial go live so a range of downloading protocols will be needed initially.

4. CONCLUSION

4.1 Development activities at VAAC London are already underway, and the QVA service is planned to become operational in November 2024 in line with ICAO Annex 3.

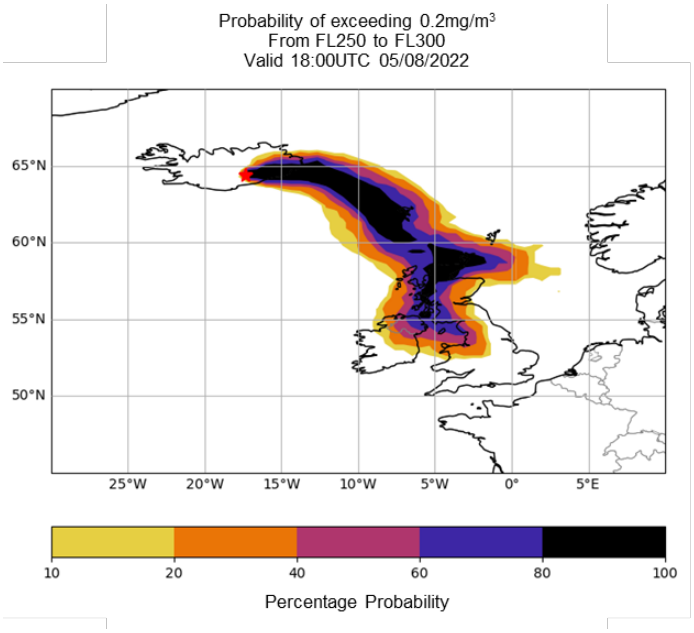
4.2 Attachment A contains a flyer which gives a summary of the QVA provision.

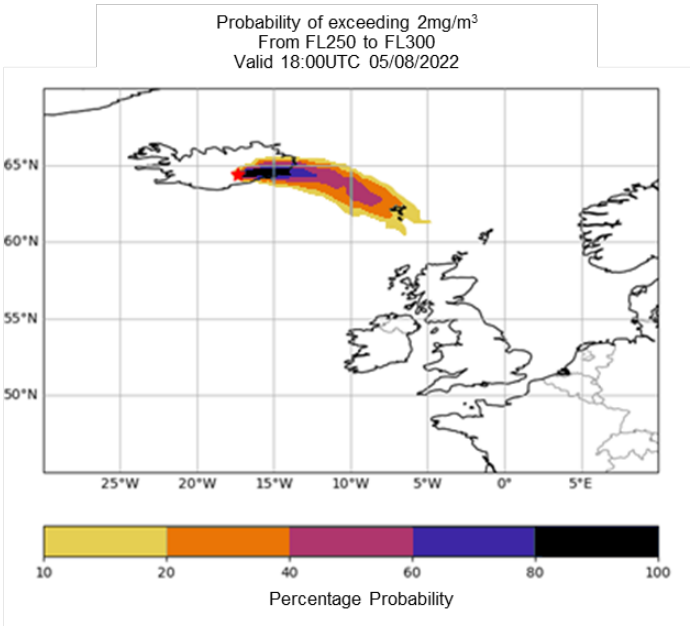
5. ACTION BY THE MEETING

5.1 The meeting is invited to:

a) note the information contained in this paper; and
b) discuss any relevant matters as appropriate.

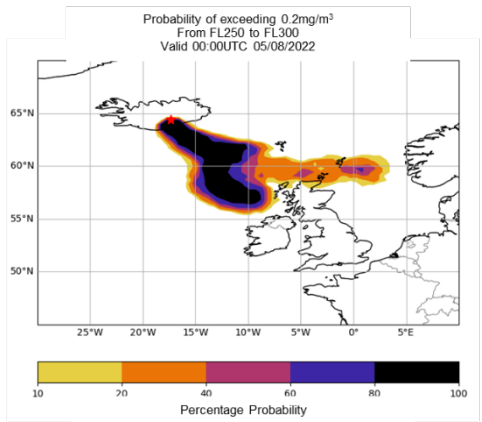
Appendix A – Example QVA probabilistic data

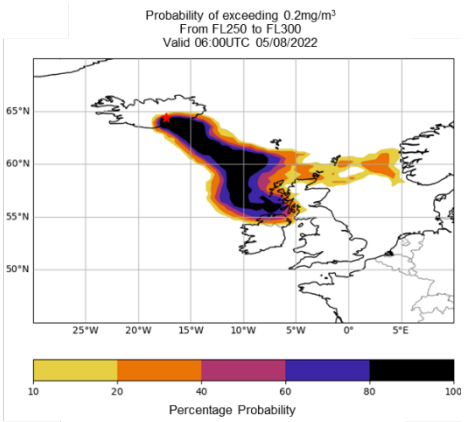


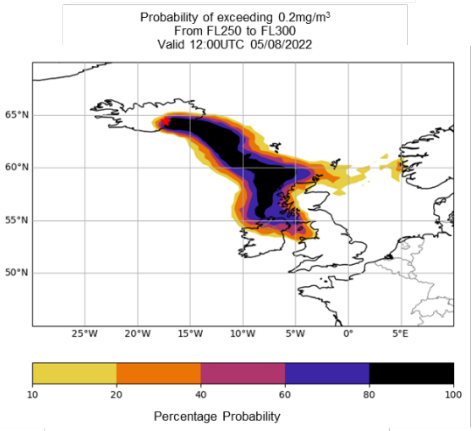


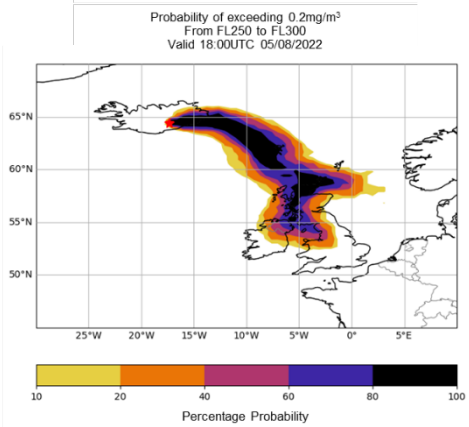
Plots of this type can be created from the probabilistic QVA data sets. The plot on the left shows the probability of the ash concentration exceeding 0.2mg/m^3 whilst the plot on the right shows the probability of the ash concentration exceeding 2mg/m^3

In example time series for the plume exceeding 0.2mg/m^3 is shown below.









Top left: 00UTC (T+0)

Top right : 06 UTC (T+6)

Bottom left: 12UTC (T+12)

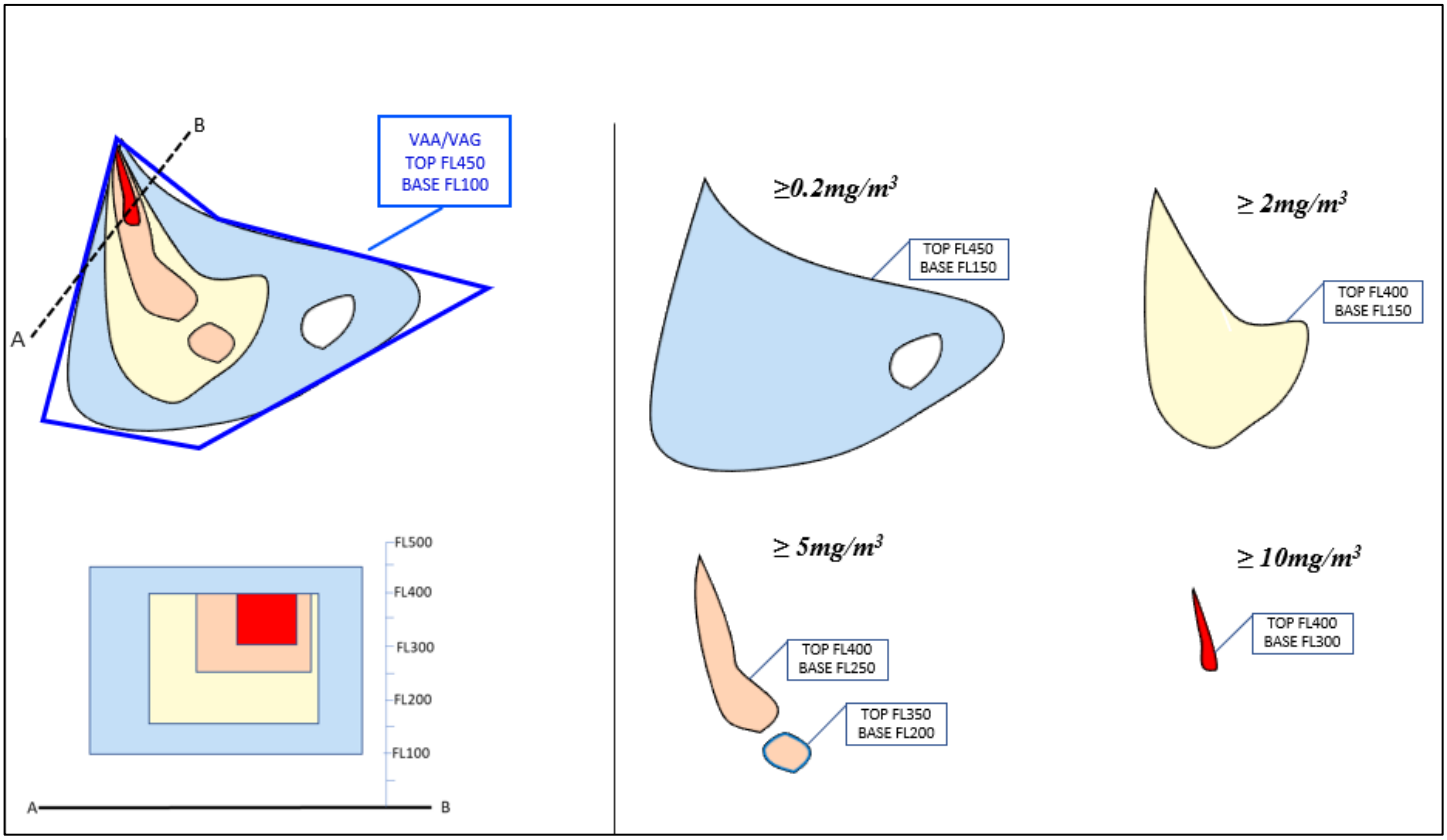
Bottom right: 18 UTC (T+18)

Appendix B – QVA polygons/features

Top left: this shows a top-down view of each polygon/feature, including the area that would be described in the traditional volcanic ash advisory.

Right: This shows individual polygons/features for each of the threshold criteria. The area inside of each polygon/feature (shown in colour) is where that threshold is exceeded. A base and top attribute is also provided to indicate the vertical extent.

Bottom left: shows a simple cross section of the plume along the line A-B



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METEOROLOGY PANEL

Quantitative Volcanic Ash (QVA) Concentration Information

First edition – 13 September 2022 (corrected 15 December 2022)

1 Introduction

This document describes the quantitative volcanic ash (QVA) concentration information (hereafter referred to as 'QVA information') that is planned to be provided by volcanic ash advisory centres (VAAC) as part of the International Civil Aviation Organization's (ICAO) International Airways Volcano Watch (IAVW). It is the first in a series of information "flyers" on QVA information.

Over the past two decades there were many requests by representatives of the IAVW, through various ICAO and World Meteorological Organization fora, for aircraft and engine manufacturers to provide information on the susceptibility of aircraft and their engines to volcanic ash. The specific desire was for ash concentration thresholds to be identified that did not pose a safety concern but could improve route efficiency. This need has led to the development of QVA information.

QVA information offers operators the opportunity to move away from traditional discernible/visible ash criteria and instead use certified engine susceptibility for flight route planning and inflight replanning. Visible ash is what an observer or flight crew member sees with their eyes. The lower limit of visible ash ranges from approximately 0.01 mg/m^3 to 10 mg/m^3, depending on many factors such as time of day, sky background, position of the sun to the observer (pilot) as well as the angle the ash cloud is viewed (e.g., viewed from the side). Discernible ash is what a satellite or other remote sensing instrument detects. Discernible ash from satellites has been used by the VAACs to define the observed area in the volcanic ash advisories (VAA) in both text and graphic form (VAG) over the past two decades. The lower limit of discernible ash from satellites is approximately 0.1 mg/m^3 to 0.2 mg/m^3, depending on the satellite and other factors.

QVA information will begin with an initial operating capability (IOC) that is planned to be implemented in three phases in the mid-2020s.

2 Initial operating capability (IOC)

The IOC for QVA will provide forecasts of ash concentration in two data formats for significant eruptions.

2.1 Format

QVA information will be provided in two file formats. Objects will be provided in ICAO's Meteorological Information Exchange Model (IWXXM) format. Gridded data will be provided in a file format which has yet to be determined but will probably be a binary format. The IWXXM format contains a subset of the entire gridded data file set.

2.2 Concentration thresholds and ranges

QVA information will consist of the thresholds and ranges shown in Table 1, which were formulated by ICAO's Meteorology Panel in coordination with ICCAIA[1]. The units for the ash concentration thresholds and ranges are in milligrams per cubic meter (mg/m^3).

Table 1: Thresholds and ranges

Descriptor	***Concentration thresholds and ranges***
Very high	$\geq$ 10 mg/m^3
High	$\geq$ 5 and < 10 mg/m^3
Medium	$\geq$ 2 and < 5 mg/m^3
Low	$\geq$ 0.2 and < 2 mg/m^3
Very low	< 0.2 mg/m^3

The QVA information in IWXXM form will be provided as 'objects' for the very high, high, medium, and low concentration ranges. An illustrated example of QVA objects is shown in Figures 1 – 6 on page 5. Figure 7 is an illustrated example of QVA objects compared to a VAG.

2.3 Resolution

During the IOC, QVA information will have the following horizontal, vertical, and temporal resolutions.

2.3.1 Horizontal resolution

Gridded QVA information will be produced with a horizontal resolution of 0.25 degrees latitude and longitude.

2.3.2 Vertical resolution

The vertical resolution of the gridded data will be in 5,000-foot flight levels (FL) from mean sea level to FL 600 (Table 2).

Table 2: Vertical resolution

Mean sea level to FL 50	FL 150 to FL 200	FL 300 to FL 350	FL 450 to FL 500
FL 50 to FL 100	FL 200 to FL 250	FL 350 to FL 400	FL 500 to FL 550
FL 100 to FL 150	FL 250 to FL 300	FL 400 to FL 450	FL 550 to FL 600

2.3.3 Temporal resolution

QVA information will be provided in the following three hourly valid time increments: 0, 3, 6, 9, 12, 15, 18, 21 and 24 hours. QVA information will be updated as necessary but at least every six hours until the volcanic ash cloud is no longer considered a hazard.

2.4 Significant volcanic ash clouds

During the IOC, QVA information will be issued for significant volcanic ash clouds. Significant in this context means an ash cloud that poses a widespread impact to aircraft operations and air navigation. The VAACs will use the following guidance criteria for issuing QVA information:

- an ash cloud with a vertical extent to at least FL 300, and/or

[1] International Coordinating Council of Aerospace Industries Associations.

- an ash cloud within (or expected to move within) approximately 100 nm of a commercial aerodrome, or
- when requested by area control centre (ACC) or airline operator.

At their discretion, VAACs may deviate from this guidance for special circumstances and quality control assessment of the event.

2.5 Probabilistic forecasts

The traditional approach to weather forecasting is known as deterministic, with only one forecast outcome. While this can provide good advice, deterministic forecasting may not provide users with a full understanding of the possible range of outcomes, or indicate the risk of encountering specific phenomena. Probabilistic information will be provided by combining information from multiple forecasts.

QVA information in gridded code format will include ensemble relative frequency of exceedance for volcanic ash concentration thresholds of 10, 5, 2 and 0.2 mg/m^3. This is simply the number of ensemble members with concentration above a threshold divided by the total number of members at each grid point. Figure 8 shows some examples of QVA information in gridded format for relative frequency of exceedance of ash concentration thresholds 2.0 and 0.2 mg/m^3.

QVA objects in IWXXM form will not include probabilistic information.

2.6 Implementation of QVA

In the IOC, QVA information is planned to be implemented in three phases in accordance with the provisions in ICAO's Annex 3 – *Meteorological Service for International Air Navigation*.

2.6.1 Phase 1 – planned for late 2024

In Phase 1, QVA information will be issued by those VAACs that have developed the capability to issue QVA information for significant volcanic ash clouds. These VAACs will continue to issue VAAs and VAGs for all ash clouds.

2.6.2 Phase 2 – planned for late 2025

Phase 2 is noted by a Recommended Practice in ICAO Annex 3 that all VAACs should issue QVA information for significant volcanic ash clouds. VAACs will continue to issue VAAs and VAGs for all ash clouds.

2.6.3 Phase 3 – planned for late 2026

It is expected with Amendment 82 to Annex 3 that QVA information will be a Standard for all VAACs for significant volcanic ash clouds. With QVA as a Standard, it is expected that the VAA and VAG will only be issued for those volcanic ash clouds that don't meet the criteria for a significant volcanic ash cloud.

3 Full operating capability (FOC)

Details for the FOC have yet to be determined. It is anticipated that QVA will be provided in finer vertical and temporal resolutions. Probability information may be added to the IWXXM objects.

With the FOC, it is anticipated that QVA information will be issued for all volcanic ash clouds (rather than for significant), which would lead to the retirement of the current versions of the VAAs and VAGs.

Implementation date of the FOC has yet to be determined but is not likely until the next decade.

4 Using QVA information

User education material is expected to be developed that will provide flight crew and other users with information on the subtleties, uses and limitations of the QVA information.

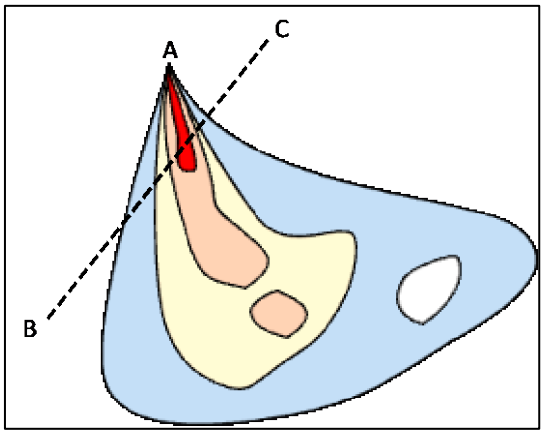
QVA information provides users with a high-resolution four-dimensional representation of a volcanic ash cloud, providing a more realistic depiction of the ash cloud. The 3-hourly timesteps of QVA information provides users with more accurate forecast positions of the ash cloud, compared to the 6-hourly timesteps of the VAA/VAG.

QVA information will likely have its greatest utility with ash cloud events that have a widely dispersed ash cloud with mostly lower levels of ash concentration. Operators with approval and procedures/practices, e.g., maintenance for planned flight into select thresholds of ash concentration, will be able to use QVA information to fly more efficient routes in accordance with their safety management program.

Probabilistic QVA information is intended for use in operator's flight planning and decision support systems. Operators will use probabilistic QVA information in conjunction with their safety management program to optimise airspace and plan more efficient routes during significant volcanic ash cloud events.

Visual illustrations of QVA information IWXXM objects

Colour legend: White = <0.2mg/m³, Blue = ≥ 0.2mg/m³, Yellow = ≥ 2mg/m³, Orange = ≥ 5mg/m³, Red = ≥ 10mg/m³. Note that colours were randomly chosen and do not infer any visualization guidelines.



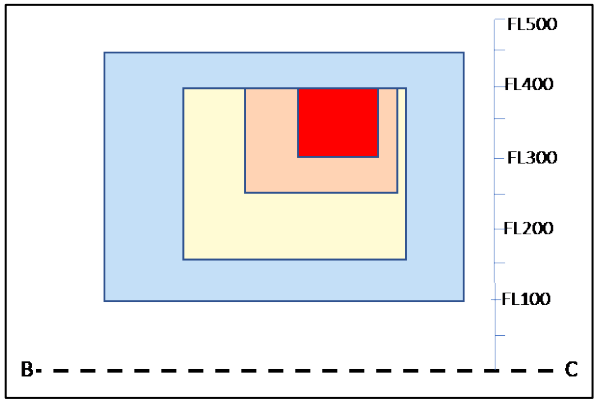


***Figure 1 (left)**. IWXXM objects showing all QVA thresholds depicted in the horizontal from a fictitious volcano located at A. The vertical depiction along line B-C is shown in **Figure 2 (right)**.*

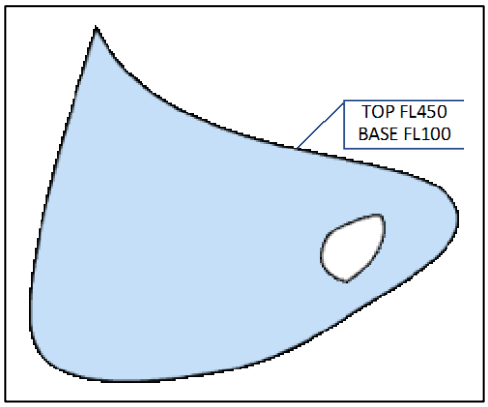


Figure 3.

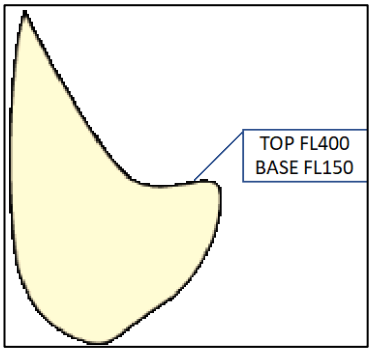


Figure 4.

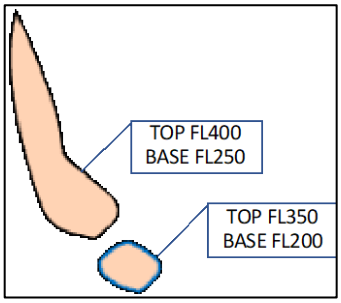


Figure 5.

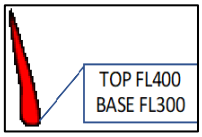


Figure 6.

Figures 3 through 6 depict the individual IWXXM objects from Figure 1. Figure 3 is IWXXM object ≥ 0.2mg/m³ (the "hole" is ash <0.2mg/m³). Figure 4 is IWXXM object ≥ 2mg/m³. Figure 5 is IWXXM object ≥ 5mg/m³. Figure 6 is IWXXM object ≥ 10mg/m³.

Visual illustration of QVA information IWXXM objects and volcanic ash advisory in graphic form (VAG)

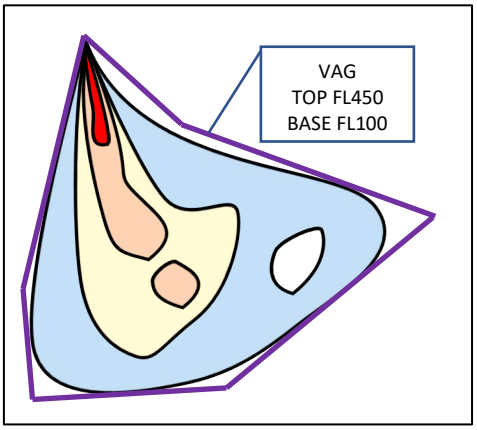


Figure 7. *Same as Figure 1 but overlayed with the VAG (purple polygon).*

Visualized examples of QVA grid point probability information

(Provided by VAAC Buenos Aires using FALL3D model and correspond to the exercise of 10 December 2021)

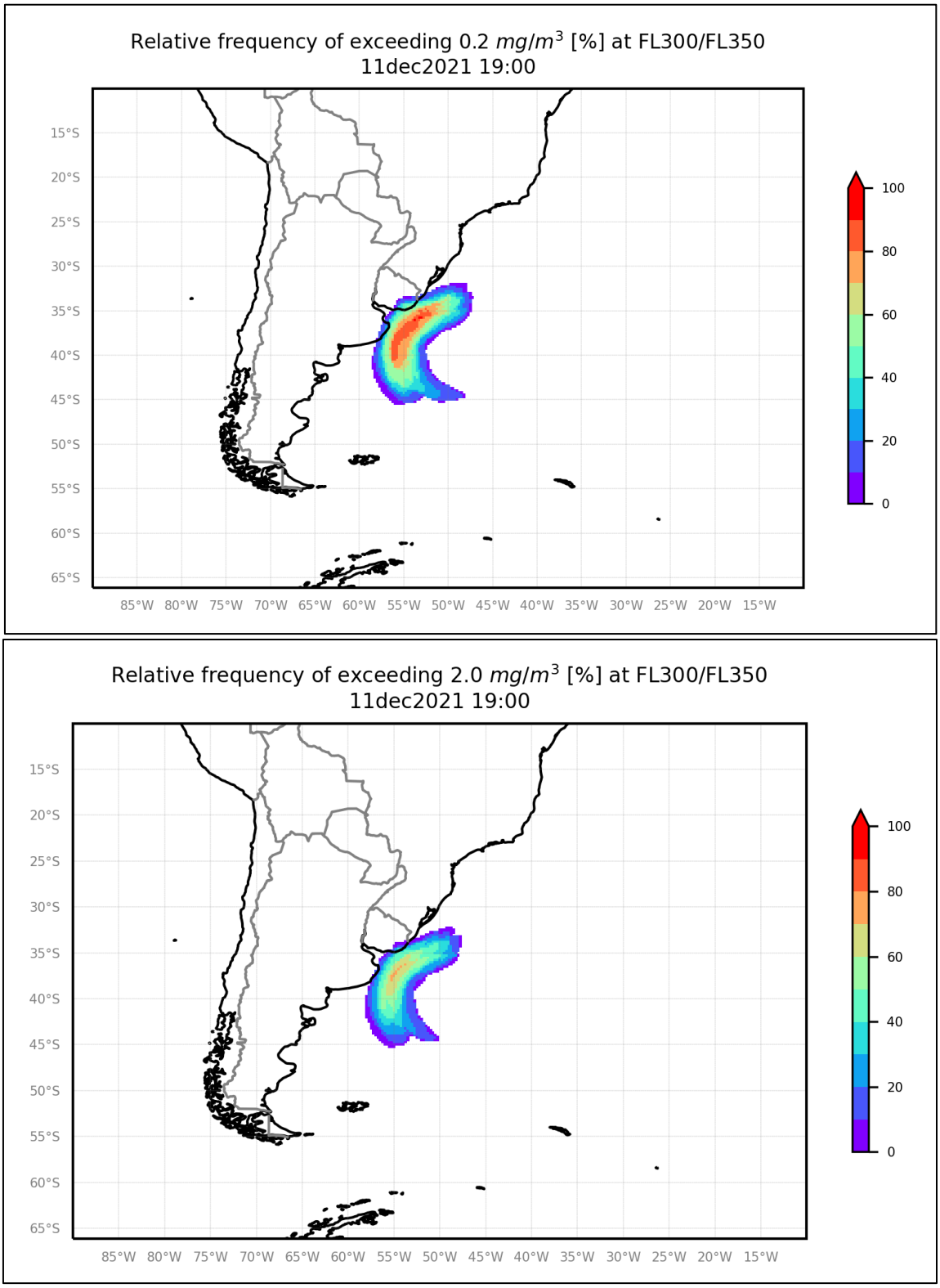


Figure 8. *Visualized examples of QVA grid point probability information from FL 300 to FL 350. Upper frame is the probability of exceeding 0.2 mg/m³. Lower frame is the probability of exceeding 2 mg/m³.*

-END-

METEOROLOGY PANEL

Introduction of Quantitative Volcanic Ash (QVA) forecasts November 2024

INTRODUCTION OF QUANTITATIVE VOLCANIC ASH FORECASTS - AMENDMENT 81 TO ANNEX 3 ….

- The Volcanic Ash Advisory Centres have been developing their capability to produce probabilistic forecasts from their atmospheric dispersion models.
- A work stream under the ICAO panel has been defining the requirements for a new quantitative volcanic ash (QVA) information service.
- QVA information offers operators the opportunity to move away from traditional discernible ash criteria and instead use certified engine susceptibility for flight route planning and inflight replanning.

- The new QVA forecasts will be provided alongside the traditional Volcanic Ash Advisory messages and graphics for the time being.

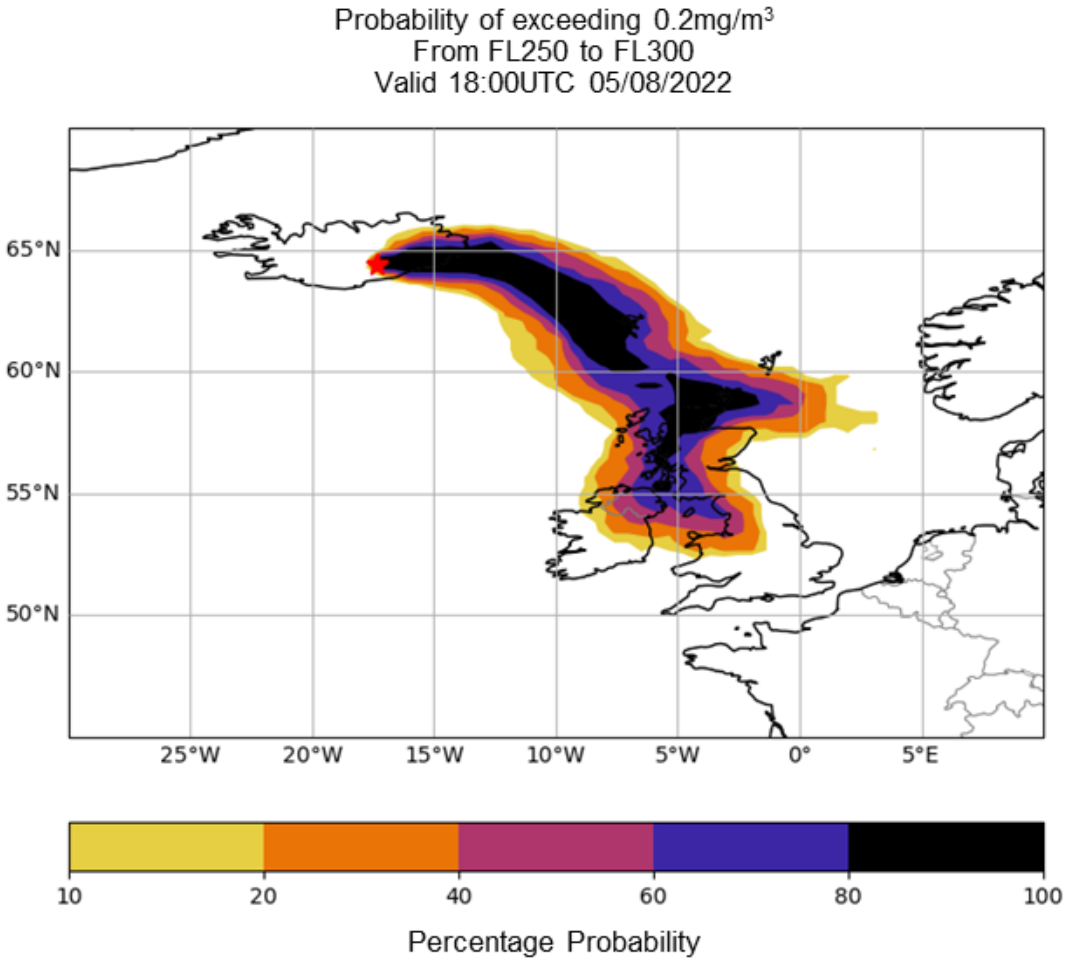
QVA FORECASTS – Initial Operating Capability

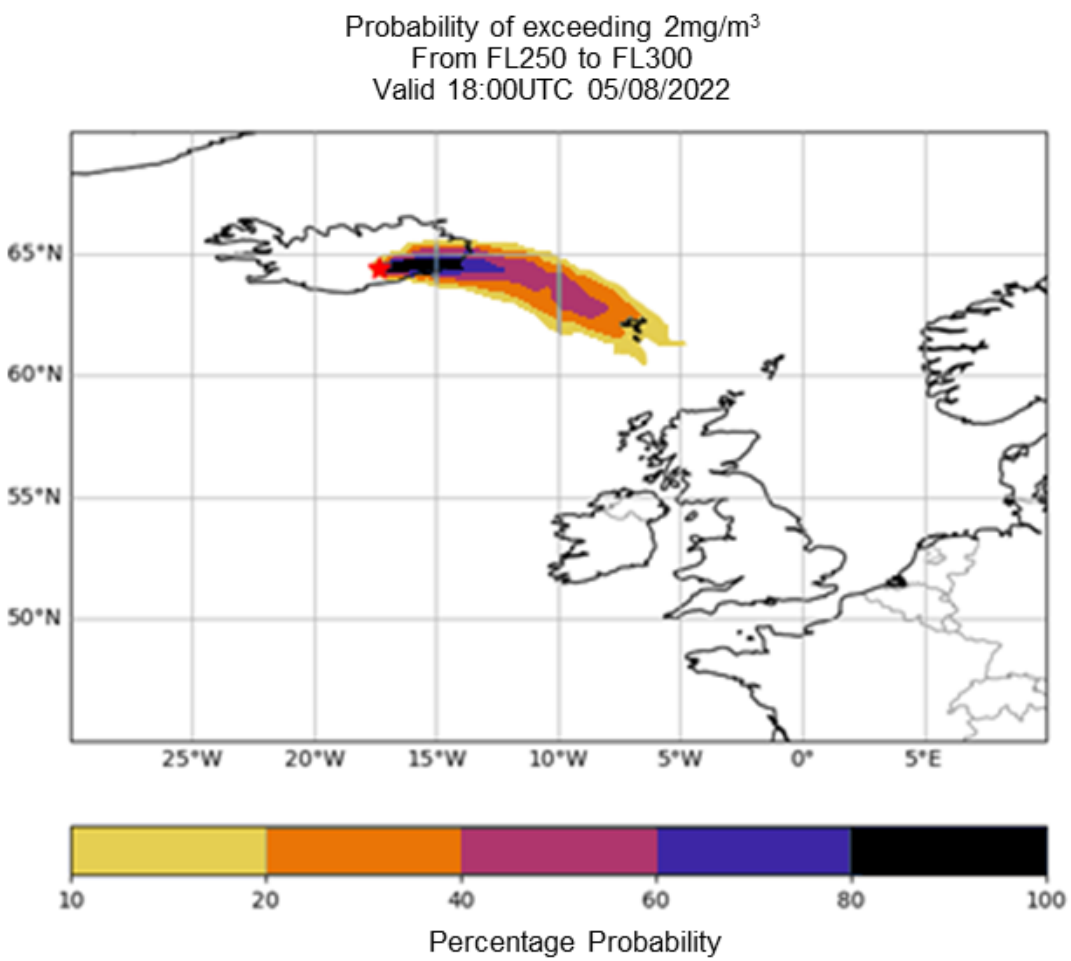
- The probability of exceeding each of the thresholds will be provided for 5000ft slices of the atmosphere between the surface and FL600

Descriptor	Concentration thresholds and ranges
Very Low	<0.2 mg/m^3
Low	≥0.2 to <2 mg/m^3
Medium	≥2 to <5 mg/m^3
High	≥5 to <10 mg/m^3
Very high	≥10 mg/m^3

- This gridded data will be provided at a 0.25-degree horizontal resolution, for 3 hourly intervals out to 24 hours.

The probability of exceeding 0.2 mg/m^3 and 2.0 mg/m^3 for the FL250-FL300 level.





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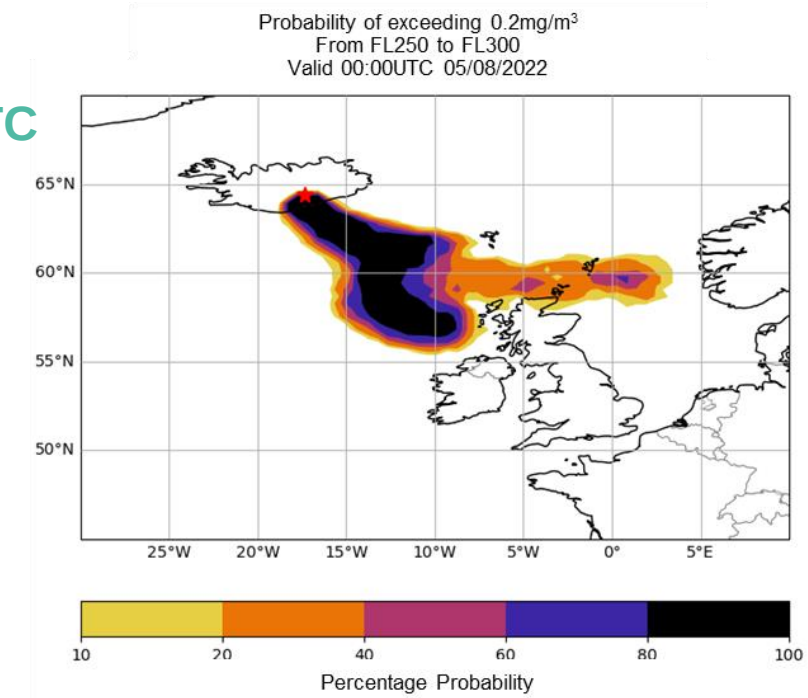

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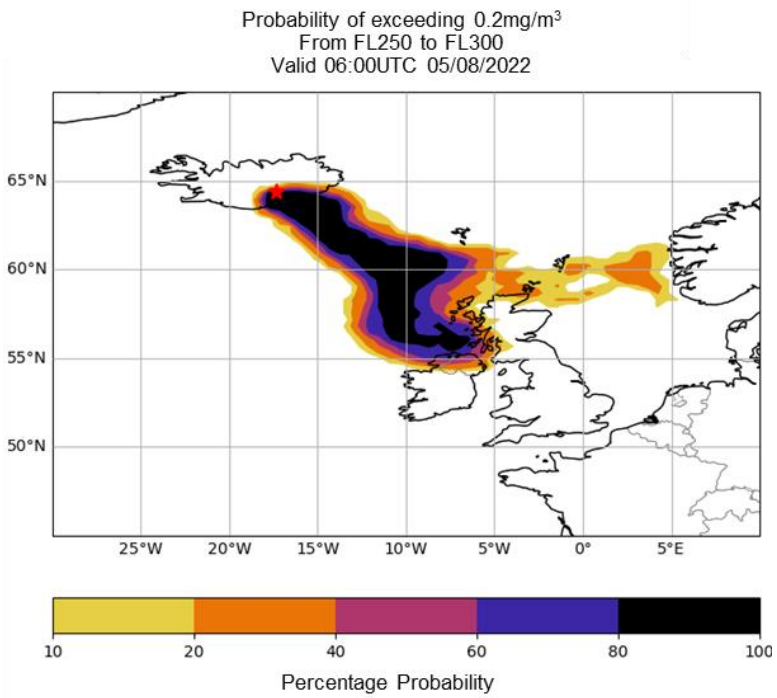

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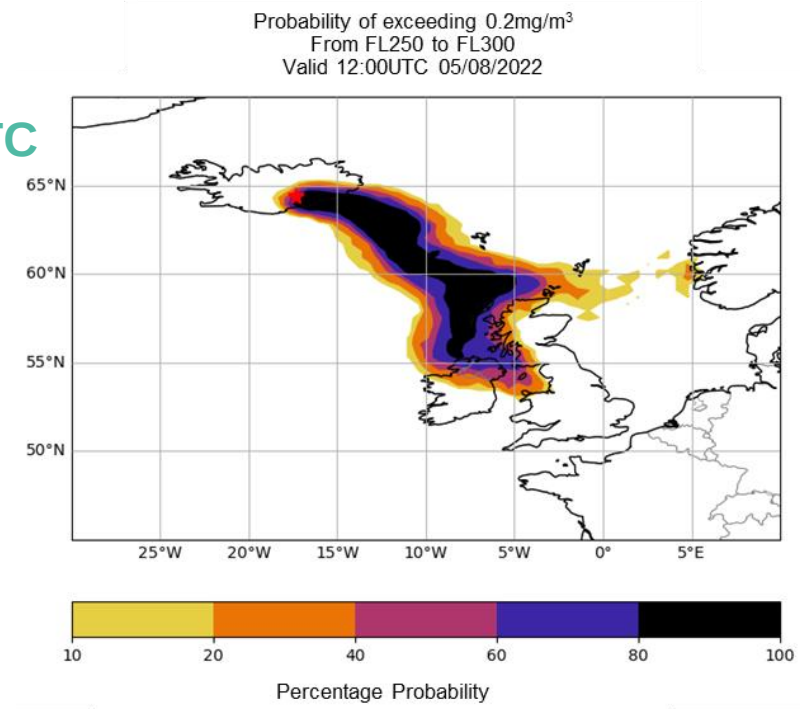

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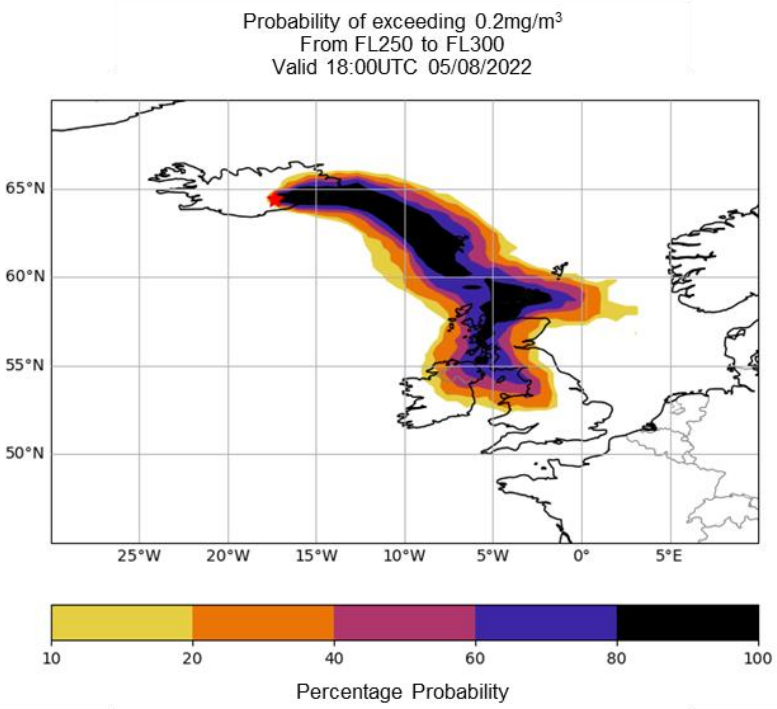
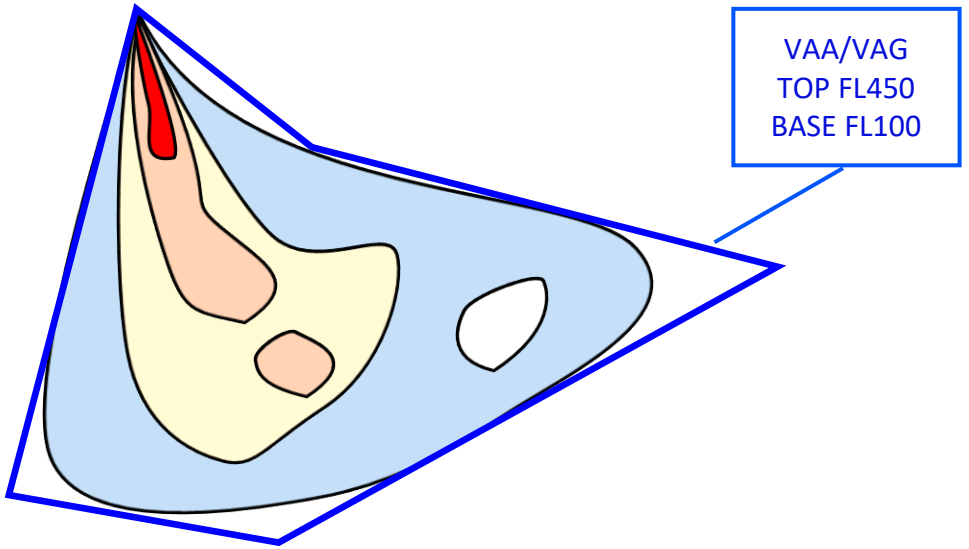


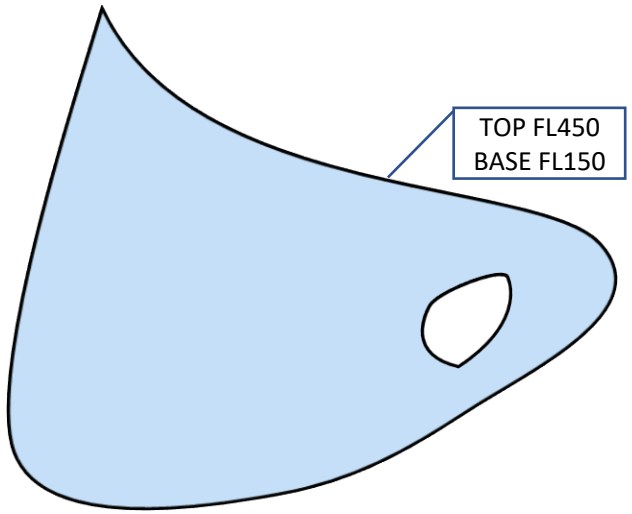
QVA FORECASTS – Initial Operating Capability

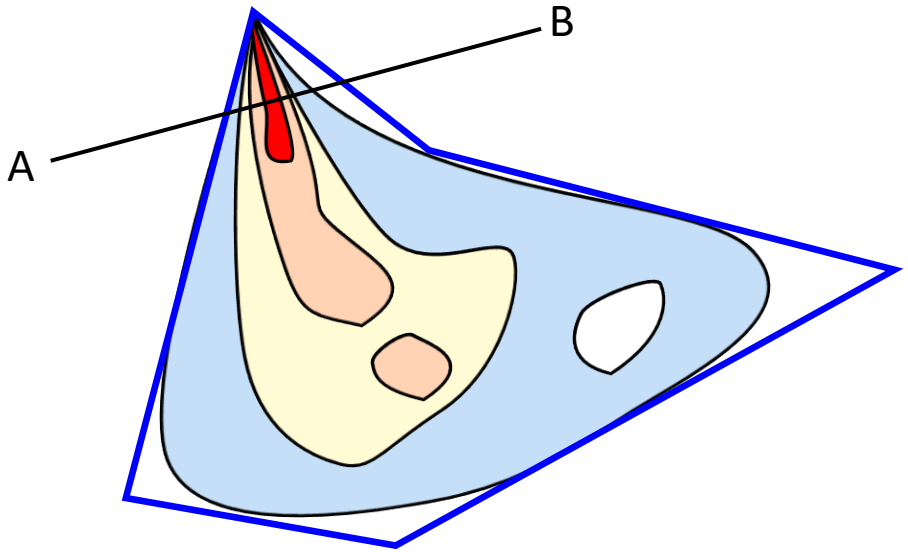
- A deterministic gridded QVA data set showing the expected ash concentration for each grid box.

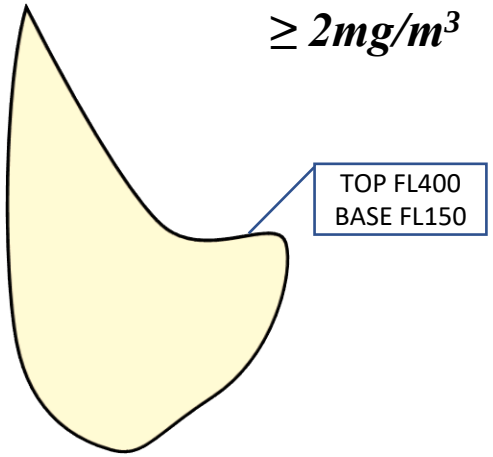
- Polygons/features will be created from the deterministic data, and these are intended to be used for situational awareness
- This will be provided in IWXXM format, using a specially created schema.

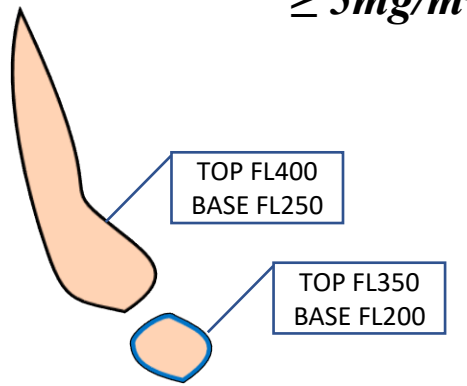


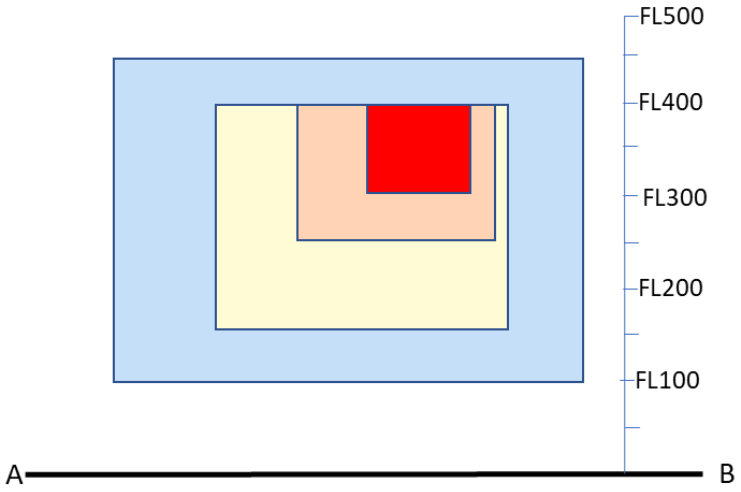
$\geq 0.2 mg/m^3$

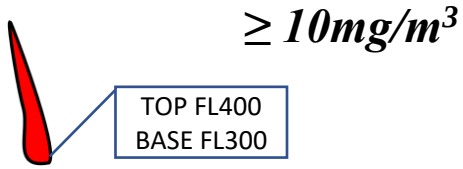



A
B


≥ 2mg/m³
TOP FL400
BASE FL150


≥ 5mg/m³
TOP FL400
BASE FL250
TOP FL350
BASE FL200


FL500
FL400
FL300
FL200
FL100
A
B


≥ 10mg/m³
TOP FL400
BASE FL300

QVA FORECASTS – Initial Operating Capability

- These forecasts will be provided for “Significant” volcanic ash clouds
- Exact definition still being determined by the VAAC’s but may include:
  - an ash cloud with a certain vertical extent
  - an ash cloud within (or expected to move within) a certain distance of an airport
  - Impact of ash on aviation operations

QVA FORECASTS – Data Distribution

- VAAC's will be expected to provide a SWIM compliant method to give access to the data, but for some VAACs this may take some time to implement.
- VAAC London is trying to get all VAACs to agree to using the same data delivery mechanism to improve user experience. This would be the same OGC-EDR framework as is being used for the SADIS and WIFS APIs, however this may take some years for all VAACs to implement.

- It is also recognised that provision of QVA data sets would benefit from a "publish subscribe" service to notify users of new data due to the irregular nature of volcanic eruptions… particularly in the London VAAC!

QVA FORECASTS – Data Distribution VAAC London

- VAAC London will adhere to the EUROCONTROL SWIM yellow profile requirements and will be published in the SWIM registry.
- A notifications service will be provided that systems can “listen” to for alerts saying that new data is available.
- Information in the alert can be used to access QVA data on the API, which will be organised into collections according to the volcano number

https://{organizaton URL}/{CollectionID}/Locations/{LocationId}/{paramName}? {datetime}

QVA_probabilistic
QVA_deterministic
QVACI_IWXXM

Volcano number
E.g.
372030

Potentially used for the probabilistic output to split out data for the different concentration thresholds

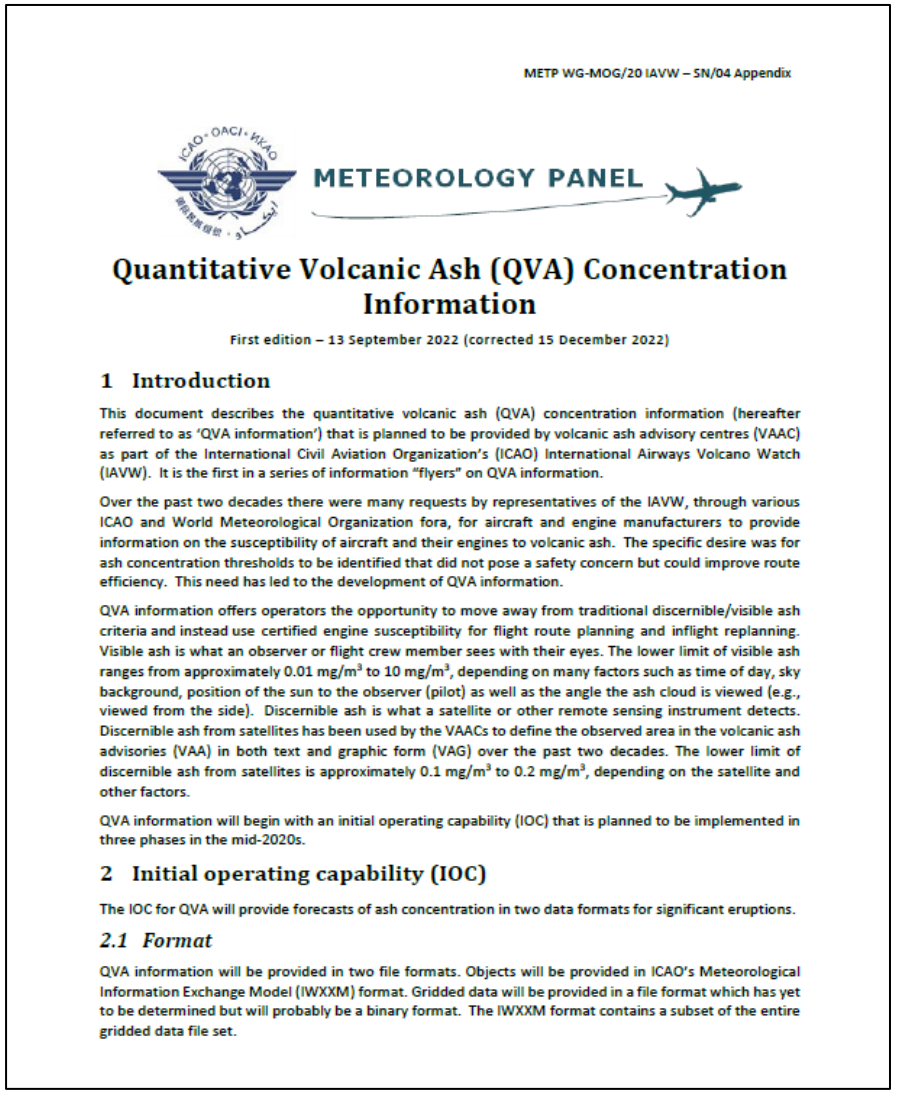
Allows choice of one/some/all available timesteps

QVA FORECASTS – Data Distribution

- The new QVA information services are expected to become operational by November 2024 for “those VAAC’s in a position to do so”.
- VAAC London is working towards a November 2024 release date
- Full operating capability for QVA will be developed and implemented several years later.

A flyer is available that describes the QVA information service.

Thank you for listening.



METP WG-MOG/20 IAVW – SN/04 Appendix

METEOROLOGY PANEL

Quantitative Volcanic Ash (QVA) Concentration Information

First edition – 13 September 2022 (corrected 15 December 2022)

1 Introduction

This document describes the quantitative volcanic ash (QVA) concentration information (hereafter referred to as 'QVA information') that is planned to be provided by volcanic ash advisory centres (VAAC) as part of the International Civil Aviation Organization's (ICAO) International Airways Volcano Watch (IAVW). It is the first in a series of information "flyers" on QVA information.

Over the past two decades there were many requests by representatives of the IAVW, through various ICAO and World Meteorological Organization fora, for aircraft and engine manufacturers to provide information on the susceptibility of aircraft and their engines to volcanic ash. The specific desire was for ash concentration thresholds to be identified that did not pose a safety concern but could improve route efficiency. This need has led to the development of QVA information.

QVA information offers operators the opportunity to move away from traditional discernible/visible ash criteria and instead use certified engine susceptibility for flight route planning and inflight replanning. Visible ash is what an observer or flight crew member sees with their eyes. The lower limit of visible ash ranges from approximately 0.01 mg/m^3 to 10 mg/m^3, depending on many factors such as time of day, sky background, position of the sun to the observer (pilot) as well as the angle the ash cloud is viewed (e.g., viewed from the side). Discernible ash is what a satellite or other remote sensing instrument detects. Discernible ash from satellites has been used by the VAACs to define the observed area in the volcanic ash advisories (VAA) in both text and graphic form (VAG) over the past two decades. The lower limit of discernible ash from satellites is approximately 0.1 mg/m^3 to 0.2 mg/m^3, depending on the satellite and other factors.

QVA information will begin with an initial operating capability (IOC) that is planned to be implemented in three phases in the mid-2020s.

2 Initial operating capability (IOC)

The IOC for QVA will provide forecasts of ash concentration in two data formats for significant eruptions.

2.1 Format

QVA information will be provided in two file formats. Objects will be provided in ICAO's Meteorological Information Exchange Model (IWXXM) format. Gridded data will be provided in a file format which has yet to be determined but will probably be a binary format. The IWXXM format contains a subset of the entire gridded data file set.