INTERNATIONAL VOLCANIC ASH TASK FORCE (IVATF)

THIRD MEETING

Montréal, 15 to 17 February 2012

Agenda Item 2: Progress reports of the science sub-group (SCI SG)
2.6: Quantifying the detectability of 'visible ash'
Agenda Item 3: Progress reports of the airworthiness sub-group (AIR SG)
3.1: Operationally applicable characteristic(s) that can be used as a threshold for the concept of 'visible ash'
Agenda Item 5: Progress reports of the international airways volcano watch coordination group (IAVW CG)
5.1: Enhancement of VAAC products

ATTACHMENT VAA02 TO IVATF/3 PPT/05

(Presented by the Project Manager of the IVATF IAVW Coordination Group)

SUMMARY

This attachment is associated with the deliverable of IVATF task TF-VAA02 concerning enhancements of VAAC products, as well as task TF-SCI03.1 concerning the quantification of detectible *visible ash* and task TF-AIR01 concerning operational applicable characteristic(s) that can be used as a threshold for the concept of *visible ash.*

The IVATF is invited to note the content of this attachment and, as necessary, develop a recommendation or further tasking for the consideration of the task force.

Noting the challenges in progressing the ash concentration issue, and in the context of VAAC best-practice discussions, this Attachment to IVATF/3 PPT/05 proposes:

a) an agreed set of consistent ash analysis and forecasting rules for VAACs to use (essentially recording the IAVW practices that have contributed to aircraft safety, and supporting an evidence-based approach);
b) that, until more information is available on aircraft exposure thresholds to ash, these rules continue to form the basis of Volcanic Ash Advisory and SIGMET issuance;
c) that carefully judged supplementary information (satellite imagery, concentration charts, explanatory briefing material and so on) be understood as relevant, necessary, and cost-recoverable for the IAVW, particularly during major events; and
d) that the IAVWOPSG be tasked with further developing guidance for refining this material and integrating it into operations.

Note.— The strategies proposed here do not replace the long term need to develop better information about potential system effects should ash be encountered (Ref: Volcanic Ash Challenge Team outcomes)

1. INTRODUCTION

1.1 IVATF/2 WP/08 contained the following commentary:

> *With respect to human observation* — Ash clouds with mass concentration between 0.01 mg/m^3 and 2 mg/m^3 often will be visible to the human eye (during the day with a blue sky background) as long as the geometrical extent of the cloud along the line of sight is greater than 5 km. Ash clouds with concentration of 2-5 mg/m^3 will likely be visible to the human eye (during the day with a blue sky background) when the geometrical extent of the cloud along the line of sight of the observer is larger than 0.5 km. Ash clouds with a mass concentration of 5-10 mg/m^3 should be visible to the human eye (during the day with a blue sky background), unless the ash particles are large and the cloud is small (geometric extent of the cloud along the line of sight is less than about 300 m). "Pure" ash clouds (e.g. no significant ice and liquid water content) with mass concentration greater than 10 mg/m^3 should always be visible to the human eye (during the day with a blue sky background). These guidelines assume a viewing distance for airborne observers of roughly 50 miles (80 km) or less.
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> *With respect to satellite detection* — Ash concentrations as low as about 0.06 mg/m^3 can be detected using satellite-based thermal infrared measurements when the satellite is viewing the cloud in a near vertical manner (nadir) and under certain prerequisite conditions (e.g., volcanic ash is the highest cloud layer, the underlying surface is warmer than the ash cloud, the ash cloud is semi-transparent)[1]. Lower concentrations are likely detectable when the satellite is viewing the ash cloud at much larger angles, such as a geostationary satellite observing a polar eruption. Concentrations of 2 mg/m^3 reliably can be detected using infrared measurements when the cloud layer along the satellite's line of sight is at least 0.5 km thick and the effective particle radius is smaller than 10 µm (and, again, ash is the highest cloud layer).

1.2 Further to this, a case study presented to the third meeting of the WMO-IUGG Volcanic Ash Science Advisory Group[2] (23-24 January 2012, New Orleans) has further suggested that an instrumental detection limit of ~0.2 mg/m^3 (or, in order of magnitude terms, 0.x mg/m^3) is reasonable in ideal conditions.

1.3 It is important to consider what this might mean in terms of VAAC operations and the continuing importance placed on the term 'visible ash'.

2. BACKGROUND – 'VISIBLE ASH' IN VAAC OPERATIONS

2.1 ICAO provisions within Annex 3 – *Meteorological Service for International Air Navigation* and the *Handbook on the International Airways Volcano Watch* (Doc 9766) emphasise an evidence-based approach on the presence of ash, together with use of trajectory and dispersion models to assist in estimating current dispersion and likely future dispersion. For example, Volcanic Ash Advisories are issued *"until such time as it is considered that the volcanic ash cloud is no longer identifiable from*

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[1] The UK has suggested a more cautious wording of this sentence, along the lines of "*Ash concentrations as low as about 0.06 mg/m^3 could just about be detected using satellite-based thermal infrared measurements when the satellite is viewing the cloud in a near vertical manner (nadir) and under certain prerequisite conditions (e.g., volcanic ash is the highest cloud layer, the underlying surface is warmer than the ash cloud, the ash cloud is semi-transparent, the ash cloud is geometrically rather thick, the ash cloud is very high/cold)*."

[2] Prata, in review.

satellite data, no further reports of volcanic ash are received from the area and no further eruptions of the volcano are reported" (Doc 9766, 4.5.1e) refers).

2.2 In practical terms, VAACs also form a professional judgement about whether the 'visibility' of ash is inhibited by other factors such as cloud obscuration, ice content of volcanic clouds, or (for visible wavelength detection) nightfall. Procedures are more conservative in these situations, and have also been influenced by the historical 'zero tolerance' approach to ash. For example in the case of ambiguous or obscured signals, Darwin VAAC procedures are as follows:

> *If ash has recently ceased to be detectable, but the forecaster feels there is a possibility that ash may still be present, then extrapolated ash boundaries may be given instead of the winds above the volcano. Situations where the* ***extrapolation of ash boundaries*** *would be recommended include:*
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> - *Up to 24 hours from the point where ash from a significant eruption above FL150 ceases to be detectable;*
> - *Overnight, between visible images if ash was detectable on visible imagery late in the day (this especially applies to the case of continuing eruptions at the volcano).*

2.3 In essence, VAACs will use extrapolation, dispersion modelling and trajectory guidance to assist in guiding their analysis and forecasts during a marginal situation, until the decision to cease advisories is made. In the case of extremely long-lived plumes, such as the Cordon Caulle eruption of June/July 2011, these marginal situations may be very long lived as the clouds slowly (and non-uniformly) dissipate.

2.4 The implication of IVATF/2 WP/08 is that these 'marginal' visible conditions will actually span a great range of actual concentrations, from (taking the satellite example) roughly 0.06-2 mg/m^3 in good conditions, and potentially greater in conditions of uncertain viewing.

2.5 Thus, although formally VAACs use 'ash/no ash' as the basis for operations, much of VAAC operations is spent dealing with marginal situations and classifying marginal areas into 'ash' or 'no-ash'.

2.6 Importantly, as there are no universal decision-making rules around this decision-making process, a great deal of inconsistency between VAACs *resulting from this issue alone* is possible, and is indeed observed.

2.7 It should be noted that volcanic clouds are neither uniform during an event or between events. The 'pulsing' of an eruption, changes in eruption style or ash characteristics, increases in explosive intensity, and gas and ice content can all vary rapidly. When injected into an atmosphere that also strongly affects the column characteristics (for example, with wind shear, stratification, moisture, instability, and number of inversions) and that will be changing over time, a great variety of results are possible, and many of these will not be easily describable in modelling detailed analysis, or simplified graphical warning products. What may be represented as semi-uniform ash might in reality be clear air punctuated at irregular intervals with multiple thin layers of ash, themselves not uniform but appearing in clumps, whirls and swirls, areas of gas-rich stink, precipitating aggregates or innocuous-looking ice-rich aggregates. One aircrew flying through the area may observe nothing at all, while another slightly lower or on another track might have a serious ash exposure.

2.8 What the VAACs represent on Volcanic Ash Advisories is not an ash concentration (ash will be encountered within a set concentration range) but a threat area (there is some sort of reasonable risk that ash will be encountered).

3. IMPROVING THE INTERPRETATION OF 'VISIBLE ASH' IN VAAC OPERATIONS.

3.1 Much discussion at IVATF/2 centred on the difficulty on modelling ash concentrations, and the assessed uncertainty of an order of magnitude above and below a given value. Discussion on observational issues is, however, equally important.

3.2 Taking into account the evidence-based approach suggested in Doc 9766, the following 'analysis rules' are suggested:

1. 'Visible ash' is taken to mean that, in the professional opinion of the VAAC analyst, there is a moderate to high confidence that, within the volume of space defined by the VAAC, ash clouds exist that would in good visibility conditions be visible to aircrew, and hence must be actively avoided. In concentration terms, this will be assumed to translate to ash concentrations of 0.1-1 mg/m^3, although it might be lower if viewing conditions are exceptionally good.
2. A pilot observation of 'ash' be taken as an observation of visible ash (taking into account the effect of viewing angle on apparent concentration), unless the description given or other evidence suggests otherwise.
3. A nil-ash report or ambiguous satellite observation in good viewing conditions be taken as ash concentration of less than 'visible'.
4. An ash observation using multi-spectral or hyper-spectral techniques always be taken as 'visible ash' unless the sensitivity and confidence of the ash retrieval allows the analyst to confidently assert otherwise (ie., if remote sensing improves beyond current precision and beyond an accepted definition of 'visible ash', the VAAC may chose to not take remotely sensed ash as 'visible'). A contiguous volcanic plume visible by human eye should be treated as likely containing 'visible ash'. The VAAC should use remote sensing techniques or other information, such as advice from a volcanological authority, to seek to rule out the presence of 'visible ash'.
5. A satellite observation of sulphur dioxide does not necessarily imply the presence of ash. However, where evidence supports the detected sulphur dioxide was produced from an explosive volcanic eruption, and in conditions which are unfavourable for detecting ash, sulphur dioxide may be used to indicate areas of reasonable expectation of the presence of ash.
6. Where observations are inconclusive (e.g. previously detected ash becoming obscured by cloud), a dispersion model forecast may be used to define an area of reasonable expectation of the presence of 'visible' ash. However, dispersion model forecasts should not be used where observations clearly indicate ash is not 'visible'.
7. Forecasts in VAAs must be meteorologically consistent with the analysed area at 0hr.
8. There is no requirement for a VAA (and hence SIGMET) if analysts assess that ash is "invisible". It is understood and accepted that low-severity encounters with marginally 'visible' ash are still possible in this situation.

3.3 VAAs issued under these rules would continue to form the basis for the preparation of SIGMET, as per the Annex 3, 7.1.4 recommended practice.

4. SUPPLEMENTARY INFORMATION AND LOW-CONFIDENCE AREAS

4.1 Worldwide experience during 2010 and 2011 strongly suggests that, in order to inform risk management during a major ash event, supplementary data such as remote sensing observations and dispersion modelling output, and identification of 'low confidence areas' of ash are required. These data

are not currently formally part of the IAVW, are not easily issued in text-only form, and do not contribute towards the defining of the SIGMET by Meteorological Watch Offices. Because of the apparent usefulness of these data for operations during a major event, it is suggested that, with the lessons of recent events in mind, the requirement for these supplementary data in graphical form be promptly (but carefully) expressed in Annex 3 and the Handbook, and the IAVWOPSG be tasked with developing further guidance.

4.2 Hence, the IAVW community will be given additional information:

- where a VAAC believes that there is a possibility of ash associated with a known event (a low-confidence area of ash) but feels that there is insufficient evidence to justify a Volcanic Ash Advisory. This approach may also be used for gas-rich clouds, which will likely contain small amounts of ash;
- where extended period dispersion modelling will be useful in contingency planning;
- where particular observations (remote sensing, pilot reports, lidar etc) are particularly useful for a public understanding of the VAAC analysis;
- where the nature of an event demands further measures.

Note: in order to continuously improve VAAC services in this regard and ensure cost-effectiveness, a user feedback process should be incorporated into VAAC Quality Management processes.

5. EXAMPLES

5.1 A large explosive event is detected by a volcano observatory through seismic monitoring and the VAAC and MWO are informed prior to any observations being available. There is no direct observational evidence of ash in the atmosphere, but the volcano concerned has a history of large explosive eruptions. The tropopause height is FL600, and the duty VAAC meteorologist knows that a large eruption into that atmosphere will have no problem reaching that height. Based on this, the VAAC has sufficient evidence to immediately issue a VAA to at least FL600 and set the IAVW process into motion. At this stage, ash ‘visibility’ is not an issue.

5.2 Three hours into the eruption, a number of observations are available to the VAAC, including multiple pilot reports, satellite imagery, and a more detailed description of the eruption from the volcano observatory. Initial dispersion-model runs suggest that the cloud will shear and move in various directions. Ash concentrations are extremely uncertain, but the VAAC has updated the Volcanic Ash Advisory to show the expected shearing and dispersion. Observational confidence for the presence of ash is high, although parts of the plume are too opaque to show the ash in multi-spectral techniques. Resources have now been ‘spun-up’ in the VAAC, enabling some time to be spent feeding observations to IAVW participants and also media, thus supporting the public communications around the event in addition to the internal communications within airlines and agencies.

5.3 6 hours after the initial eruption, a more complex picture is emerging. The eruption is continuing and changing rapidly and inconsistently in intensity (i.e., eruption source parameters are variable). This is clearly communicated from the volcano observatory and as a result, all IAVW players, including Flight Dispatch, ACCs, MWOs, and the VAACs have agreed a conservative approach around the area of the volcano itself. However, one large high area of the cloud appears to be dispersing with little ash signal but a strong SO_2 signal. This is flagged in the Volcanic Ash Advisory (the area is included as ‘ash’ as there is some ash detected, but a plain language comment is included in the remarks), and an 18 hour forecast is made of ash dissipation for that part of the plume. In addition, the dispersion modelling is starting to become more precise in terms of the maximum height of the eruption and ash detrainment from the eruption column (most of the ash is spreading out in two umbrella clouds, at FL300 and FL650).

Adjusting the model source term results in a dispersion model output that looks more like the actual observations. With the assistance of the ACC and some flight dispatch centres, the VAAC has also had the opportunity to check some received pilot reports with the originators, resulting in some extra validating detail and in one case a significant correction. All of these actions result in a much higher confidence in the +18 hour forecast in the issued VAA, and as a result the forecast ash area is significantly reduced in some areas.

5.4 A major cold front crosses the area of the eruption, resulting in a loss of remote sensing and ground-based information. The VAAC switches to a strong reliance on dispersion modelling, using the best information available to make its best guess on where the ash is, and says as much in the plain language remarks in the VAA.

5.5 An aircraft has a low-severity ash encounter in an area thought to be ash-clear, and reports it immediately. The detail in the report convinces the VAAC to weigh it heavily, resulting in a significant reanalysis, and the VAA is adjusted accordingly with the associated reasoning given in the remarks. On the positive side, the SO_2-rich cloud now has no ash signal despite good satellite viewing conditions, and so the VAAC is able to drop it from the VAA. The cloud was above FL600 so aircraft weren't going to be flying through it anyway, but the confirmation that no ash is being detected gives operators enough confidence to fly underneath it.

5.6 The volcano observatory advises that the eruption is now settling down into a continuous venting stage and is more predictable in its behaviour. After discussion, the VAAC feels that it is scientifically valid and useful to make available extended-time dispersion model forecasts that assume a constant ash emission. These are made publicly available on the VAAC web site with the appropriate caveats. However, the formal warnings for the event, including SIGMETs, continue to depend on the evidence-based and quality controlled VAA.

5.7 Over another volcano, the VAAC spots a short, dark-coloured plume through a small break in the clouds on high resolution visible imagery. Multi-spectral evidence is ambiguous but this may be due to the poor viewing conditions. The VAAC takes a conservative approach and issues a VAA advisory for potential low-level ash, maintaining it for the next 18 hours of heavy cloud cover. On the next day, the volcano observatory confirms that the smoke plume appeared to be from a bushfire on the volcano, and the VAA is cancelled with explanation.

— END —