MANAGING DIFFUSE ERUPTION CLOUDS - THE EXPERIENCES OF 2010-11, AND THE RESULTS OF THE INTERNATIONAL VOLCANIC ASH TASK FORCE

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Abstract

The 2010 and 2011 eruptions of Eyjafjallajökull, Cordón Caulle, and other volcanoes have thrown a spotlight on the challenges of having a global volcanic cloud warning system for aircraft. Less obvious have been the many successes; in a short time, we have moved from the dramatic discovery of the hazard in the early 80s to a warning system that has brought two sciences (meteorology and volcanology) together with aviation to, so far, successfully mitigate against any fatalities.

The outcomes of the International Civil Aviation Organisation's International Volcanic Ash Task Force, which finished its work in June 2012, have resulted in there being no requirement for ash concentration charts globally. Much now rests on a consistent evidence-based approach to volcanic ash analysis and forecasting being developed by the nine worldwide VAACs, in close consultation with industry. As part of that, it is essential that work continues on understanding in what situations and in what concentrations ash causes significant damage to aircraft.

The discussions of the Task Force have been useful in practice. For example, the June 2011 eruption of Cordón Caulle was the first major hemispheric-scale ash cloud event in the Southern Hemisphere since 1991, and the first such since the creation of the International Airways Volcano Watch. Coming just over a year since Eyjafjallajökull, the eruption served to bring a sharp focus to the issue of dealing with 'old ash' that was nevertheless still discernable. On its first circuit of the globe in mid-June, southern Australia had diffuse parts of the cloud linger for several days, while the main body of ash moved over New Zealand in the jet stream. Subsequently, a deep low pressure system on 21 June brought ash over all the major cities of south-eastern Australia, to the intense frustration of airlines and passengers.

Aided by the discussions within the Task Force, the eruption was generally handled by southern hemisphere nations in a different manner to how Europe had dealt with Eyjafjallajökull. In Australia and New Zealand, for example, there was no public issuance of modelled ash concentration charts, and rather than wholesale airspace closures, airlines generally made their own decisions on how they would manage the risk. Evidence-based analysis was greatly assisted by many pilot reports, which made a critical difference to operations. It is most important that for this and all future major eruptions, a post-event 'wash-up' makes a strategic-level assessment of any damage or wear caused by ash encounters.

1 Introduction

The three aircraft encounters with volcanic ash from the eruptions of Mt Galunggung, Indonesia, in 1982, brought the hazard posed by volcanic ash to aviation dramatically to the world's attention [1]. Since then, reported encounters have occurred at a rate of about two per year, of varying severity:

"The effects observed by flight crews and extent of aircraft damage vary greatly among incidents... Of the 129 reported incidents, 94 incidents are confirmed ash encounters, with 79 of those having various degrees of airframe or engine damage; 20 are low-severity events that involve suspected ash or gas clouds; and 15 have data that are insufficient to assess severity. Twenty-six of the damaging encounters involved significant to very severe damage to engines and (or) airframes, including nine encounters with engine shutdown during flight… Most of the damaging encounters occurred within 24 hours of the onset of ash production or at distances less than 1,000 kilometers from the source volcanoes." [2]

1.1 Lessons from low-severity encounters

Closer examination of particular encounters illustrates some of the general rules that appear to apply to events:

- *Distance matters.* As noted above, most damaging encounters happen close to the volcano, and when the eruption is relatively fresh. For example, in the 2000 Miyakejima eruption in Japan, of four encounters with the same eruption cloud where the location is known, the two damaging ones were the first, the third had ash indications but no damage, and the fourth had an SO_2 smell only [3].
- *Pilot actions matter.* In the NASA DC-10 encounter [4], the Micronesia encounters [5], and the twin-engine 'Gulfstream' flame-out over Papua New Guinea in 2006 [6], as far as is known the crew continued to fly through the cloud, sustaining minor damage or temporary failure (in the case of the flame-out, the failure was through an unusual mechanism, the engines restarted in flight, and no damage was noted to the aircraft). In the case of the 3rd encounter from the Miyakejima cloud [3], the aircraft had immediately exited the cloud and this might be the reason for the lack of damage (the aircraft was examined thoroughly).
- *Old ash at low concentrations can still cause minor damage.* Both the NASA and Micronesia encounters are instructive in this regard. Quoting from the account of the latter: *"In post-flight briefing, the aircraft crew reported intense St Elmo's Fire, and light white 'smoke' (ash) with 'burn smells' (most probably indicating the presence of SO_2 together with the ash). The report was not transmitted during the flight because the crew were unable to establish contact with either Port Moresby or Oakland; radio interference is another characteristic of volcanic ash encounters. The aircraft, an Airbus 340, had three Pitot probes replaced because of ash inside, some light abrasion on the engine air inlets but no damage on the windscreen or the nose. The encounter lasted about one minute at cruising speed (≈900 km/h), suggesting an area of distinct ash cloud of at least 15 km wide".* [5]

  The account above is significant, because the ash cloud in question was *not* discernable through standard satellite techniques at the time, and was found to almost certainly be around 20 days old [5].

1.2 Volcanic Ash Advisory Centre approach

With the background above and a 'zero tolerance' approach, the nine Volcanic Ash Advisory Centres have tended towards a conservative analysis philosophy, although a) not uniformly, and b) being limited by data available. In practical terms, it is difficult to sustain a warning for a cloud that cannot be discerned through remote sensing or seen by pilots. It would be expected that further low severity encounters would occur but without causing significant harm, and it would be hoped that unusual events such as the 'Gulfstream' double-flame out would remain rare and would be gradually eliminated through design changes.

Despite some obvious warning failures, the more serious of which have revolved around speed of notification of the initial eruption, the

International Airways Volcano Watch, the international warning system that has developed for ash clouds, has so far given us a fatality-free result.

2 The International Volcanic Ash Task Force

The ICAO International Volcanic Ash Task Force (IVATF) was formed in May 2010, in response to the disruptions of civil aviation that resulted from the eruption of the Eyjafjallajökull volcano in Iceland in April and May of the same year. The IVATF was tasked to assist in the urgent development of a global safety risk management framework that would make it possible to determine the safe levels of operation in airspace contaminated by volcanic ash [7]. The IVATF finished its work in June 2012.

2.1 Key outcomes and ongoing work of the task force

An important outcome of the IVATF was that a supplementary requirement for ash concentration charts, introduced in Europe during the 2010 crisis, was discontinued, particularly given the expert advice from the scientific part of the Task Force that the various concentration thresholds being applied in Europe were already likely to be a subset of the more general criterion:
'Avoid operations in visible or discernable ash. Discernable ash is ash that can be sensed by human sight, smell or other senses.' [8]
No additional warning criteria were agreed by the IVATF. In effect, the IVATF decided to continue the past practice of having VAACs define areas of potential ash hazard, but also noted a parallel process where the VAACs would agree on a 'best practice' consistent analysis and forecasting methodology.

2.2 Effect on VAAC approach

Although that part of the IVATF outcomes remains somewhat elastic, the implicit understanding that VAACs are *not* required to warn of ash that will not be visible or otherwise discernable has allowed the development of a more evidence-based approach – in other words, if the VAACs do not have sufficient evidence for analyzing or forecasting visible or discernable ash, then no products are necessary. This will include a situation where a VAAC judges that a modeled plume *will not be* or *is not* of sufficient concentration to be discernable.

In discussions in Montreal in June 2012, the VAACs arrived at the following definition for their best practice analysis and forecasting process:

"VAAC 'best practice' is the expert evaluation of the best available sources of meteorological and vulcanological information:

- *qualititative and quantitative satellite data*
- *model output*
- *ground and airborne based in-situ and remotely sensed observations*
- *pilot reports*

using (where possible) collaborative approaches, to derive authoritative, high quality, evidence based and globally consistent analysis and forecasts".

This definition specifies an expert team approach relying on multiple sources of data, rather than on a single model or piece of information, such as a modeled concentration chart. In order to influence how 'conservatively' the expert team functions, a very important part of the continuous improvement mechanism will be the continued input of original equipment manufacturers.

3 Cordón Caulle

The June 2011 eruption of Cordón Caulle [9] (part of the Puyehue-Cordón Caulle volcanic complex) was the first major hemispheric-scale ash cloud event in the Southern Hemisphere since 1991's Cerro Hudson eruption, when some low severity ash cloud encounters occurred over southeastern Australia [10], and the first such since the creation of the International Airways Volcano Watch in the mid-1990s. Coming just over a year since Eyjafjallajökull, the eruption served to bring a further sharp focus to the issue of dealing with 'old ash' that was nevertheless still clearly discernable (the ash was detected visually by pilots and ground-observers, in infrared, visible, and true-color imagery, and by ground-based and satellite-based lidar). Consistent with the discussion above, the VAACs took a strong evidence-based approach.

3.1 Effect of the ash cloud on Australia

On its first circuit of the globe in mid-June, southern Australia had diffuse parts of the cloud linger for several days, while the main body of ash moved over New Zealand in the jet stream. Subsequently, a deep low pressure system on 21 June brought the dissipating, but still clearly discernable, ash over all the major cities of south-eastern Australia. As much of the ash was caught in the jet stream, its path was fairly predictable despite its longevity, allowing warning to airlines and the public (eg Fig. 1, for the second circuit of ash), and resulting in the cancellation of many flights. While this caused intense frustration of airlines and passengers, the forecasts were generally accurate, in particular for the critical event over Australia on 21 June, where the ash followed the forecast path almost exactly (Fig. 2).

Between and following these two major events, parts of the cloud affected various areas of southern Australia, and was observed extensively over the Southern Ocean.

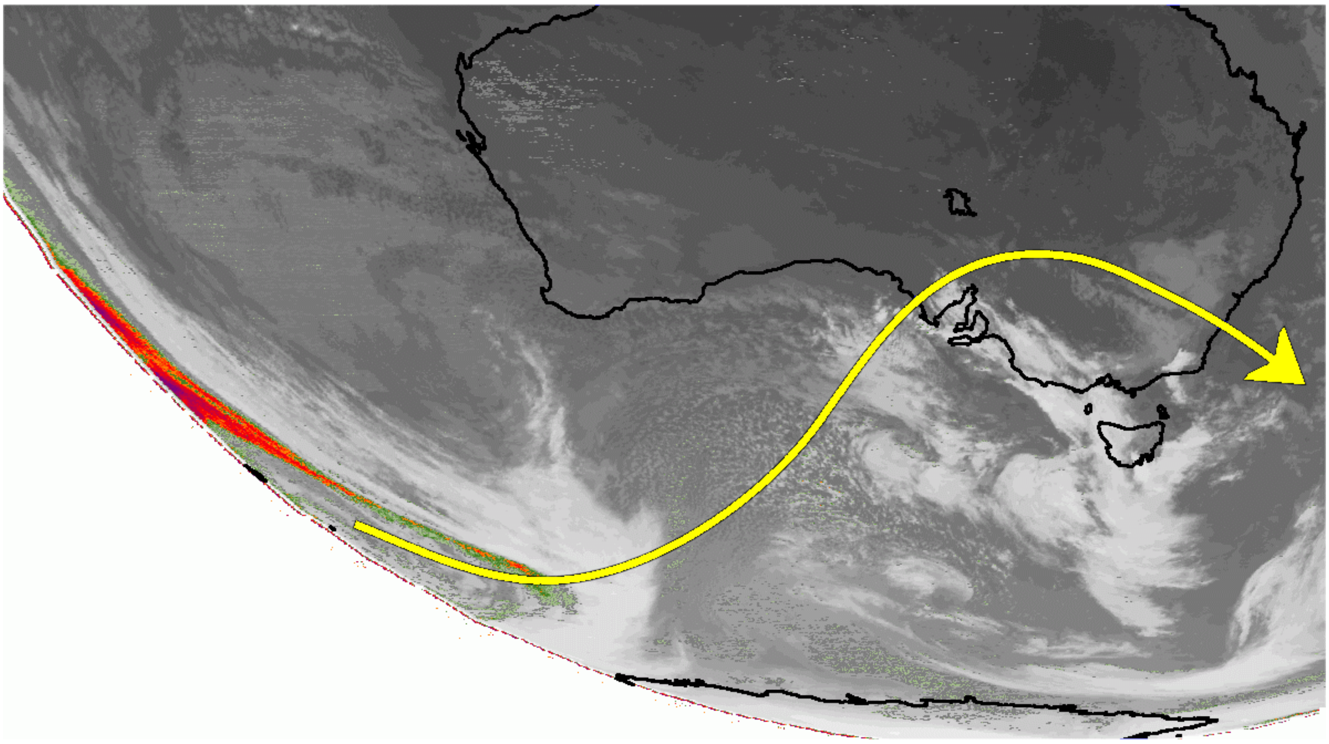

Fig. 1. Processed infrared satellite imagery for 20 June 2011, 0130 UTC, showing southern Australia and the Southern Ocean between Australia and Antarctica, with identified ash in false colour (shading from light green to red for weak to strong signals. Based on trajectory modeling, the expected path of the ash over Australia is indicated with a yellow arrow. This information was distributed to media on 20 June concurrently with news of widespread flight cancellations

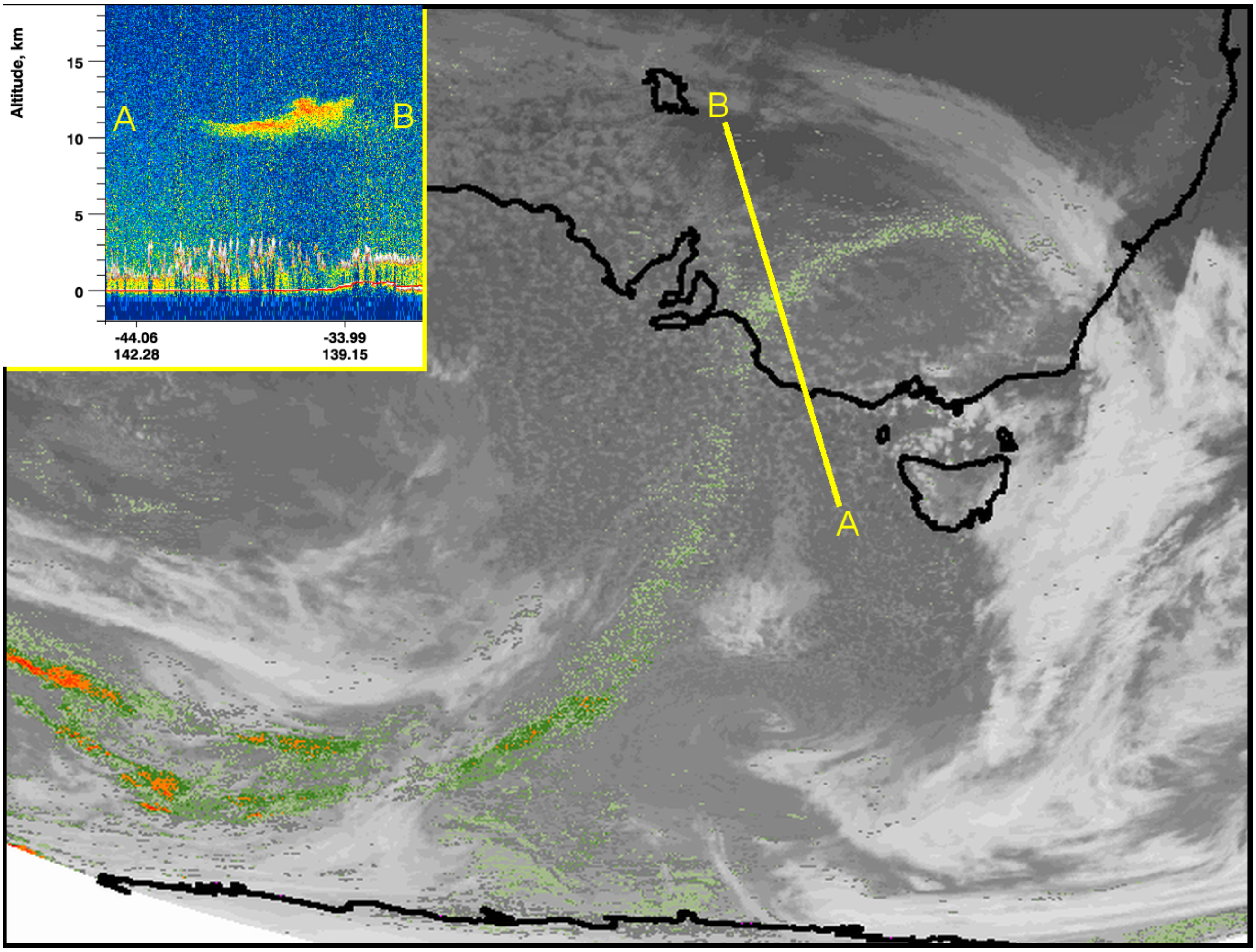

Fig. 2. Processed infrared satellite imagery for 21 June 2011, 0430 UTC, showing SE Australia and the Southern Ocean between Australia and Antarctica, with identified ash in false colour (shading from light green to red for weak to strong signals. Inset: NASA Calipso lidar showing ash identified at altitudes near 10 km amsl along the line A-B marked in the main figure.

4 Discussion: Treatment of 'weak' evidence

The decision of the VAACs on the weighting of marginal evidence is very important. It is not possible to extensively sample a plume on most occasions, and so great attention must be given to what data is collected. For this event, the discussions of the IVATF allowed the Darwin VAAC to refine its treatment of the information available to allow for the possibility of declaring a marginal area 'indiscernable' if the evidence was considered insufficient. Because of the sheer workload of dealing with such an enormous, circumpolar plume in real time, the areas of most attention in this regard were those most relevant to domestic air traffic.

If, as described earlier, an 'expert team' approach is taken, then it is essential to consider how the views of the team are developed. From the Australian point of view, Eyjafjallajökull demonstrated beyond doubt that it is counterproductive, divisive, and potentially unsafe to seek to shift a consensus during an event. During Cordón Caulle, there was a relatively high degree of harmony between the different players in the warning system. A post-event meeting including representatives from two VAACs, ICAO, and airlines involved in operations in the Australasian region was held in Melbourne immediately after the event, and this was followed shortly afterwards by an all-VAAC meeting with IATA in Montreal. These meetings were very useful for raising issues, and led to several important outcomes including a greater focus on the treatment of confidence in Volcanic Ash Advisories, and the communication of meta-data to industry.

So far, however, there has been relatively little round table discussion with the OEMs on the effects on aircraft of weak ash encounters, and their relationship with 'visible of discernable' ash. In order to advance our knowledge in this area and to influence the treatment of ash by the VAACs, it will be essential to implement a post-analysis process that includes the VAACs, aviation authorities, OEMs, and operators, and considers:

- What is known of ash 'discernability' at the time of every reported ash encounter.
- Whether the Volcanic Ash Advisories issued by the VAACs were appropriate,
- Whether the airline response strategy was adequate.

It is possible that, if we are not careful in introducing this process, then Volcanic Ash Advisories produced through an expert-driven 'best practice' process will tend to drift towards being more conservative as remote sensing and modeling technologies improve.

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