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Commission for Aeronautical Meteorology
Fifteenth Session

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REPORT ON AGENDA ITEM 2

*(All Agenda Items considered conjointly with the
Fifteenth Session of the Commission for Aeronautical Meteorology
of the World Meteorological Organization)*

This report will be subject to review by the Air Navigation Commission and the Council of ICAO, and the Executive Council of WMO. The decisions of these bodies on the recommendations of the Meeting will be set forth in a Supplement to the Report of the Meeting, which will be issued in due course.

Agenda Item 2: Improving the safety and efficiency of international air navigation through enhanced meteorological service provision

2.1: Enhancement of existing meteorological service provision to support current strategic, pre-tactical and tactical operational decision-making (including ASBU Module B0-AMET)

2.1.1 The meeting considered proposals relating to the enhancement of the existing world area forecast system (WAFS), aspects of the aeronautical fixed service (AFS) and progress made in other areas since the last Meteorology Divisional Meeting in 2002 (MET/02). In addition, the meeting noted nine information papers related to this sub-agenda item.

Aeronautical meteorological service at aerodromes and in the terminal area, including OPMET information

2.1.2 The meeting was pleased to note the significant progress made since MET/02, particularly relating to the automation of aerodrome observing and the introduction of aerodrome forecasts up to 30 hours at selected aerodromes.

The world area forecast system (WAFS), the aeronautical fixed service satellite distribution system and the Internet-based services

2.1.3 The meeting noted with appreciation that since MET/02 significant enhancements within the WAFS programme had included the increased temporal and spatial resolution of WAFS upper-air gridded global forecasts (including a transition from 6-hour output time steps to 3-hour output time steps, transition from a 1.25 degree thinned horizontal grid to a 1.25 degree regular (un-thinned) horizontal grid and increased vertical resolution particularly at cruise altitudes) and the development and operational implementation of WAFS gridded global forecasts for icing, turbulence and cumulonimbus clouds.

2.1.4 The meeting agreed that changes to the WAFS during the 2013 to 2018 timeframe should be focussed around improvements to the WAFS gridded global forecasts for icing and turbulence. In this regard, the meeting reviewed and agreed the principles to be used (in the form of deliverables) as the basis for future development of the WAFS in support of module B0-AMET of the aviation system block upgrade (ASBU) methodology. The meeting formulated the following recommendation accordingly:

Recommendation 2/1 — Development of the WAFS in support of the ASBU methodology through to 2018

That ICAO, through an appropriate expert group, use the principles outlined by the deliverables included in Appendix A as a basis for the future development of the world area forecast system (WAFS) in support of module B0-AMET of the aviation system block upgrade (ASBU) methodology contained in the *Global Air Navigation Plan* (GANP) (Doc 9750).

2.1.5 With regard to the AFS satellite distribution system for information relating to air navigation (SADIS) used to disseminate or make available global OPMET information and WAFS forecasts to States and authorized users, the meeting noted the significant developments since MET/02 which had led to the SADIS second-generation satellite broadcast (SADIS 2G) and/or the Internet-based Secure SADIS FTP service used operationally by more than 180 authorized users in almost 110 States in

the ICAO European (EUR), Middle East (MID), Africa-Indian Ocean (AFI) Regions and the western part of the Asia-Pacific (APAC) Region. The meeting agreed that, as a fully cost recoverable service, there was a need to ensure that SADIS continued to operate in line with user expectations, and further developed in a manner consistent with the evolving GANP and the ASBU methodology contained therein. Furthermore, the meeting agreed that such development, as well as that of the WAFS Internet file service (WIFS) serving the Americas and the eastern part of the Asia/Pacific region, should be aligned to the future system-wide information management (SWIM) environment and the work of other ICAO expert groups responsible for the development of SWIM. The meeting formulated the following recommendation accordingly:

Recommendation 2/2 — Operation and further development of the aeronautical fixed service satellite distribution system and the Internet-based services

That an appropriate ICAO expert group be tasked, as a matter of urgency, to ensure that the operation of the aeronautical fixed service (AFS) satellite distribution system for information relating to air navigation (SADIS), and the Secure SADIS FTP and WAFS Internet File Service (WIFS) Internet-based services, continue to meet user expectations and further develop in a manner consistent with the *Global Air Navigation Plan* (Doc 9750), including:

- a) consideration of the role of SADIS and WIFS within the future system-wide information management (SWIM) environment underpinning the globally interoperable air traffic management system; and
- b) alignment with future activities to be undertaken by ICAO in the information management domain.

2.1.6 With regard to the future of the SADIS 2G satellite broadcast beyond 2015, the meeting concurred with an expressed expert opinion of the Satellite Distribution System Operations Group (SADISOPSG) that SADIS 2G should be extended beyond 2015 but only until November 2019, and concluded that it would not be viable to invest in an enhancement of the system in the interim. The meeting formulated the following recommendation accordingly:

Recommendation 2/3 — Withdrawal of the SADIS 2G satellite broadcast and formal testing of the exchange of global OPMET information and WAFS forecasts on the AMHS

That ICAO, through an appropriate expert group, be tasked to:

- a) undertake steps necessary to ensure that the SADIS 2G satellite broadcast be extended beyond 2015 but not beyond November 2019;
- b) urge States/users concerned who have not already done so to migrate to operational use of the Secure SADIS FTP service in the intervening period described in a) above; and
- c) undertake, as a matter of urgency, formal testing of the exchange of global OPMET information and world area forecast system (WAFS) forecasts on the ATS message handling system (AMHS) with a view to determining the capability and minimum specifications required to distribute such data to States/users in the future.

The international airways volcano watch (IAVW) and related matters concerning the release of radioactive material into the atmosphere and space weather

2.1.7 The meeting noted significant enhancements since MET/02 within the international airways volcano watch (IAVW) which included improvements in the real-time or near real-time observation, detection and reporting of volcanic eruptions and volcanic ash in the atmosphere, and in the forecasting of volcanic ash transport and dispersal therein. The meeting also noted that some of these advances had been prompted by, in particular, significant volcanic eruptions such as Eyjafjallajökull and Grimsvötn in Iceland in 2010 and 2011 respectively, and Puyehue-Cordón Caulle in Chile in 2011. The meeting noted that ICAO, in close collaboration with WMO, had established an International Volcanic Ash Task Force (IVATF) that worked in a complementary capacity between 2010 and 2012 to the extant International Airways Volcano Watch Operations Group (IAVWOPSG) to assist in expediting action on a number of the scientific, technical and operational issues that had been highlighted by these eruptions. In addition, the meeting was pleased to note that a World Meteorological Organization (WMO)/International Union of Geophysics and Geodesy (IUGG) Volcanic Ash Scientific Advisory Group (VASAG) had been established in March 2010 immediately prior to the Eyjafjallajökull eruption and that the VASAG had been instrumental in providing scientific inputs to the IVATF and IAVWOPSG.

2.1.8 The meeting noted that the IAVWOPSG had undertaken the development of a roadmap for the IAVW, as well as concepts of operation concerning information on the release of radioactive material into the atmosphere and space weather, all intended to aid the understanding of how service provision was expected to evolve over the coming years to support the emerging global air traffic management system.

Information on hazardous meteorological conditions, including en-route hazards

2.1.9 The meeting noted that the main task of the Meteorological Warnings Study Group (METWSG), established by ICAO in 2007, had been to review Annex 3/Technical Regulations [C.3.1] concerning the content and issuance of SIGMET information in order to meet the evolving needs of flight operations and in view of resolving long-standing SIGMET implementation difficulties encountered by many States. In this regard, the meeting was pleased to note that the METWSG had undertaken a trial in 2011 of the provision of SIGMET advisory information in the AFI Region and part of the APAC Region, with the significant contribution of China, France and South Africa that had served as SIGMET advisory centres during the trial. In view of the positive outcomes of the trial, the meeting noted a proposal for the establishment of a regional hazardous weather advisory system (addressed under Agenda Item 2.2).

2.1.10 In addition, the meeting noted other related developments arising from the METWSG, including a proposed amendment to Annex 3/Technical Regulations [C.3.1] intended to particularly improve the preparation of SIGMET and AIRMET information concerning hazardous meteorological conditions, including en-route hazards (addressed under Agenda Item 5.1).

Agenda Item 2: Improving the safety and efficiency of international air navigation through enhanced meteorological service provision

2.2: Enhanced integrated meteorological information to support strategic, pre-tactical and tactical operational decision-making from 2018 (including ASBU Module B1-AMET)

2.2.1 In the context of enhancing aeronautical meteorological service from 2018, the meeting considered proposals relating to the enhancement of the world area forecast system (WAFS) and the international airways volcano watch (IAVW) and the provision of information on space weather, release of radioactive material and toxic chemicals and other hazardous meteorological phenomena. In addition, the meeting noted fourteen information papers related to this sub-agenda item.

General considerations for the development of future requirements for aeronautical meteorological information

2.2.2 The meeting supported, in principle, the evolution of the existing WAFS and IAVW, and the further development of provisions for space weather information, release of radioactive material and toxic chemicals and other hazardous meteorological phenomena. However, the meeting was of the view that additional consideration should be given to the overall evolution of aeronautical meteorological service provision in the context of a changing air transport environment and on the development of a provisions framework of local, sub-regional, regional, multi-regional and global service. Within such a framework, the meeting noted that the provisions could support the concept of having user communities at different levels, such as individual airspace users, airline operations and various air traffic services or functions, while at the same time ensuring the exchange of performance-based MET information that is cost-effective, proportional and agile to its operational use and to meet Block 1 of the aviation system block upgrade (ASBU) methodology contained within the *Global Air Navigation Plan (GANP)* (Doc 9750) and other associated objectives. The meeting agreed that it was imperative that the future management and governance of the aeronautical meteorology system serving international air navigation be assessed, with required changes clearly identified. It was further noted that while the development of technology was an integral component of expected future services, it would continue to be important for service delivery to remain collaborative and inclusive. The meeting formulated the following recommendation accordingly:

Recommendation 2/4 — Review of MET information service provision framework to reflect GANP objectives

That ICAO, through an appropriate expert group and in close coordination with WMO, in support of overarching safety and efficiency objectives, be urged to:

- a) review the existing MET information service provision framework as laid down in Annex 3 — *Meteorological Service for International Air Navigation*, in consideration of the emerging needs from users, including air traffic services/air traffic management, for consistent, coherent, accurate, authoritative and fit-for-purpose MET information as specified in performance requirements in support of the overall objectives of the *Global Air Navigation Plan (GANP)* (Doc 9750);

- b) ensure that the initial priorities of the review, which should be concluded by 2016, are a consolidated effort together with the:
 - i) future development of the world area forecast system (WAFS), the international airways volcano watch (IAVW), and provisions for information concerning space weather and the release of radioactive material into the atmosphere;
 - ii) development and implementation of a regional advisory system for select en-route hazardous meteorological conditions for States where there are SIGMET-related deficiencies;
 - iii) MET support for trajectory-based operations in general and collaborative decision making, including at the airport and network levels; and
 - iv) development of guidance for States concerning how their ICAO obligations may be met in the context of local, sub-regional, regional, multi-regional and global MET, including cost recovery and governance considerations;
- c) ensure that outcomes of the referred review are considered when updating the GANP and relevant aviation system block upgrade (ASBU) modules; and
- d) ensure that guiding principles respecting the mandates of both ICAO and WMO are developed for States to facilitate inclusive MET service provisions to be done locally, sub-regionally, regionally, multi-regionally and globally when required and local, sub-regional, regional, multi-regional and global user communities could use this information in their operations.

2.2.3 In addition to the foregoing, the meeting gave consideration to the needs of pilots, specifically in the context of the user needs during and upon the transition to the provision of aeronautical meteorological information in digital form, as envisioned by the GANP. In this regard, the meeting noted a number of issues, particularly related to the visualization of such information, which would be considered further in the context of automation and human factors considerations (addressed under agenda sub-item 2.4).

World area forecast system (WAFS)

2.2.4 The meeting noted the work that had been carried out in the development of a roadmap to facilitate the future requirements for the WAFS. In line with the future evolution of the GANP, the meeting noted that it was to be expected that the roadmap would evolve through the coming years to

ensure that service levels fulfil current and future needs. The meeting therefore agreed that it was vital, as part of a holistic approach to future service provision, that the WAFS continue to evolve in line with the GANP in a cost-effective manner through appropriate governance. In addition, the meeting agreed that the information produced within the framework of the WAFS should be integrated into the future system-wide information management (SWIM) environment, including the interoperable data formats to be used based on the ICAO meteorological information exchange model (IWXXM).

2.2.5 The meeting agreed that changes to the WAFS during the 2018 to 2023 timeframe of Block 1, and additionally those in the 2023 to 2028 timeframe of Block 2, should be focussed around the principles provided in Appendix B. In this regard, the meeting reviewed and agreed the principles to be used as a basis for future WAFS developments. The meeting formulated the following recommendation accordingly:

Recommendation 2/5 — Further development of the WAFS

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to:

- a) further develop the requirements for the world area forecast system (WAFS) consistent with the *Global Air Navigation Plan* (Doc 9750), including the integration of the information produced by the WAFS into the future system-wide information management (SWIM) environment underpinning the globally interoperable air traffic management system; and
- b) use the principles outlined by the deliverables included in Appendix B as a basis for the future development of the WAFS in the timeframes of Blocks 1 and 2 of the aviation system block upgrade (ASBU) methodology.

International airways volcano watch (IAVW)

2.2.6 The meeting noted the significant enhancements of the IAVW since the Meteorology Divisional Meeting (2002) (MET/02) including the development of a roadmap to facilitate the future requirements for the IAVW. The meeting noted that, in line with the future evolution of the GANP, it was to be expected that the roadmap for the IAVW would evolve through the coming years to ensure that service levels fulfil current and future needs. The meeting therefore agreed that it was vital that the IAVW continue to evolve in line with the GANP and that the information produced within the framework of the IAVW should be integrated into the future SWIM environment. The meeting agreed that the roadmap provided in Appendix C should be used as a basis for the development of the future requirements of the IAVW. The meeting formulated the following recommendation accordingly:

Recommendation 2/6 — Further development of the international airways volcano watch (IAVW)

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to further develop the requirements for the international airways volcano watch (IAVW) consistent with the Global Air Navigation Plan (Doc 9750), including the integration of the information produced by the system into the future system-wide information management (SWIM) environment underpinning the future globally interoperable air traffic management system using, as a basis, the roadmap provided at Appendix C.

Space weather

2.2.7 The meeting noted the recent work carried out by the International Airways Volcano Watch Operations Group (IAVWOPSG) to develop draft initial provisions for inclusion in Annex 3/Technical Regulations [C3.1] to meet the requirements for information concerning space weather, involving the establishment of space weather centres. Additionally, the meeting noted the complementary development of a concept of operations for space weather information services which, as a living document, would be expected to evolve in line with the GANP, which explicitly included space weather as agreed by ICAO's Twelfth Air Navigation Conference in 2012 (AN-Conf/12), and that space weather information should be integrated into the future SWIM environment.

2.2.8 Taking into account the advice of WMO, including the WMO Inter-Programme Coordination Team on Space Weather (ICTSW) and others concerned, the meeting was of the view that space weather information services which serve international air navigation should be organized through the establishment of an optimal number of global centres (for solar radiation storms and solar flares, as well as for geomagnetic storms and ionospheric disturbances at the predictive stage) augmented by an optimal number of regional centres (for geomagnetic storms and ionospheric disturbances at the observation stage). The meeting agreed that the roles, requirements and capabilities of the global and regional centres (together with the optimal number of centres) had not been fully elaborated. The meeting agreed therefore that further consideration should be given to the aforementioned, including the development of a process for the designation of global and regional centres, their governance (including cost recovery for provision of service and competency standards) and duration of mandate. Furthermore, the overall understanding of how space weather information would be used needed to be elaborated in detail and appropriately reflected in appropriate documentation for space weather.

2.2.9 In view of the foregoing, the meeting agreed to not include the draft initial provisions mentioned above in the draft Amendment 77 to Annex 3 (addressed under agenda item 5.1) in view of the need for the further development of service requirements and capabilities and any additional related guidance material. However, the meeting agreed that ICAO should work towards enabling space weather services for aviation by developing Annex 3 provisions for inclusion in 2018 (i.e. Block 1). The meeting formulated the following recommendation accordingly:

Recommendation 2/7 — Development of provisions for information concerning space weather

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to develop provisions for information on space weather to international air navigation consistent with the *Global Air Navigation Plan* (Doc 9750), including the integration of the information produced into the future system-wide information management (SWIM) environment underpinning the future globally interoperable air traffic management system, specifically addressing:

- a) requirements for space weather information services consistent with the draft concept of operations for space weather information services;
- b) selection criteria and associated capability for the designation of global and regional space weather centres, including the optimum number thereof;
- c) appropriate governance and cost recovery arrangements for the provision of space weather information services on a global and regional basis; and
- d) considerations on the use of space weather information and the various impacts space weather events could have on international air navigation.

Release of radioactive material

2.2.10 The meeting noted the significant developments since MET/02 to introduce provisions in Annex 3/Technical Regulations [C3.1] regarding the dissemination of information on the release of radioactive material into the atmosphere and the development of a global database to assist the WMO regional specialized meteorological centre (RSMC) co-located with VAAC London (designated as focal point) in the direct notification to affected area control centres in the event of a release of radioactive material. Additionally, the meeting noted the development of a concept of operations for information concerning the release of radioactive material into the atmosphere which, as a living document, would be expected to evolve in line with the GANP and that such information should be integrated into the future SWIM environment. The meeting formulated the following recommendation accordingly:

Recommendation 2/8 — Further development of provisions for information on the release of radioactive material into the atmosphere

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to further develop provisions for information on the release of radioactive material into the atmosphere consistent with the evolving *Global Air Navigation Plan* (Doc 9750), including integration of the information produced into the future system-wide information management (SWIM) environment underpinning the future globally interoperable air traffic management system.

Other hazardous meteorological phenomena

2.2.11 The meeting was pleased to note the significant progress made since MET/02, particularly by the Meteorological Warnings Study Group (METWSG), intended to resolve longstanding implementation issues in the provision of SIGMET information by some States, which was an impediment to continued safe and efficient flight operations. The meeting agreed that the implementation of a regional advisory system for select hazardous meteorological conditions, as proposed by the METWSG, should be actively pursued so as to provide a long-term solution to the difficulties encountered in this regard.

2.2.12 In addition to the technical challenges involved in the establishment of such a regionalized advisory system, the meeting emphasized that a number of non-technical issues would need to be addressed before any implementation could occur, including governance and equitable cost recovery arrangements. To these ends, the meeting reviewed a strategic assessment of the modalities for the implementation of a regional hazardous weather advisory system and an assessment of the associated governance and cost recovery arrangements as provided at Appendices D and E, respectively. Additionally, the meeting agreed that the development of such a regional hazardous weather advisory system should evolve in line with the GANP and that the information produced within the framework of the system should be integrated into the future SWIM environment.

2.2.13 The meeting noted that there had been long-standing SIGMET deficiencies in some States and expressed requirements from users for harmonized, phenomenon-based hazardous weather information. In this regard, there was an urgent need demonstrated by aviation users for the establishment of regional hazardous weather advisory centres (RHWACs) to assist meteorological watch offices (MWOs) with the provision of SIGMET information for select hazardous meteorological conditions that included, as a minimum, thunderstorms, icing, turbulence and mountain waves, but which excluded volcanic ash and tropical cyclones (given the existing volcanic ash and tropical cyclone advisory systems). The meeting agreed that an initial phase of issuing advisories to MWO would serve as a precursor to the next two phases of further regional hazardous weather advisory provision development as indicated in the referred Appendix D.

2.2.14 Taking into account such users' requirements, the meeting fully concurred that a regional hazardous weather framework should be implemented expeditiously, while considering the development of a governance and cost recovery framework.

2.2.15 The meeting agreed that the development of such a regional hazardous weather advisory system should be supported by appropriate guidance material for:

- a) ICAO planning and implementation regional groups (PIRGs) providing technical background and capabilities of meteorological centres in States able to serve as RHWACs taking account of cost-effectiveness such as the utilization of existing capabilities; and
- b) user States and service provider States on the processes for the preparation and dissemination of the advisory information, mutual cooperation and sustainability of the existing meteorological infrastructure and use of local expertise.

2.2.16 The meeting formulated the following recommendation accordingly:

Recommendation 2/9 — Implementation of a regional advisory system for select en-route hazardous meteorological conditions

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to:

- a) expeditiously develop provisions supporting the implementation of a phenomenon-based regional advisory system for select en-route hazardous meteorological conditions consistent with the evolving *Global Air Navigation Plan* (Doc 9750), in considering users' long-standing requirements, especially in those States where notable SIGMET-related deficiencies persist using, as appropriate, the strategic, governance and cost-recovery assessments provided in Appendices D and E;
- b) integrate the information produced by the referred system into the future system-wide information management environment underpinning the future globally interoperable air traffic management system; and
- c) develop appropriate guidance material to support the selection criteria of regional hazardous weather advisory centres taking account of cost-effectiveness, the processes for the preparation and dissemination of the advisory information, mutual cooperation, sustainability of the existing meteorological infrastructure and use of local expertise.

Note.— Select hazardous meteorological conditions in this context includes, as a minimum, thunderstorms, icing, turbulence and mountain waves, but excludes volcanic ash and tropical cyclones.

Meteorological service information for the terminal area

2.2.17 In a related issue, the meeting reviewed a proposal to include meteorological service for the terminal area in Block 1 of the ASBU methodology. The meeting also noted work undertaken in one State to develop ATM-tailored meteorological information that highlights potential weather-related impacts on air traffic flow and a need to develop guidance on verification methodology toward the continuous improvement of meteorological information for ATM. The meeting agreed that it would be important that specific mention be made of the meteorological requirements to support ATM in the terminal area in Block 1 modules, including B1-AMET of the ASBU methodology, noting that such an addition could only be made as part of a periodic review of the GANP as a whole. The meeting noted a potential study to be conducted by relevant WMO projects on the development of meteorological service for the terminal area which would include the impact of weather on different airports around the world. The meeting agreed that the experience gained from such work would indeed be valuable. In addition, the meeting noted that there were other studies underway to determine the needs of ATM service providers and operators for meteorological service information in the terminal area. Noting the discussion above, the meeting formulated the following recommendation:

Recommendation 2/10 —Development of meteorological service for the terminal area

That ICAO, in close coordination with WMO, be tasked to:

- a) include meteorological service for the terminal area and other relevant operational requirements in Block 1 and subsequent blocks of the aviation system block upgrade methodology to highlight potential related impacts on air traffic flow in consideration of air traffic control and air traffic management (ATM);
- b) develop ATM-tailored meteorological service for the terminal area to meet future ATM requirements identified by the *Global Air Navigation Plan* (Doc 9750) and reflect the appropriate functional and performance requirements in the relevant provisions, noting outcomes from ICAO expert groups on meteorology, ATM and flight operations.;
- c) develop guidance on verification methodology toward the continuous improvement of meteorological information to ATM; and
- d) integrate the information concerning meteorological service for the terminal area into the future system-wide information management environment underpinning the future globally interoperable ATM system.

2.2.18 The meeting was pleased to note significant enhancements related to the establishment of an air traffic meteorology centre of the Japan Meteorological Agency to support ATM. In particular, the meeting noted the development of a new system to provide tailored weather information which could be

used to indicate the likelihood of weather-related impacts on air traffic flow. The system has the potential to be used as a future index to measure the degree of weather-related impact on the ATM system.

2.2.19 Additionally, the meeting was apprised of a case study to illustrate how cumulonimbus clouds within the approach area of Tokyo International Airport significantly impacted ATC flow and how the air traffic meteorological centre helped the ATM centre to conduct efficient and effective ATM highlighting the importance of the information on meteorological conditions within approach control areas.

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2.3: Enhanced integrated meteorological information to support strategic, pre-tactical and tactical operational decision making from 2028 (including ASBU Module B3-AMET)

2.3.1 Notwithstanding that module B3-AMET of the aviation system block upgrades (ASBU) methodology contained in the Global Air Navigation Plan (GANP) was due to be implemented from 2028, the meeting noted that the complexity of the technology involved, particularly flight management systems and data link communications, meant that potentially significant changes to existing and short-term systems and services needed to be planned well in advance of the expected implementation period envisaged by Block 3 (i.e. 2028 and beyond).

2.3.2 The meeting agreed therefore that consideration of the technological requirements and service capabilities contained in ASBU Block 3, in particular module B3-AMET and those other modules relating to system-wide information management (SWIM), needed to be given many years in advance of the expected implementation date of 2028. The meeting formulated the following recommendation accordingly:

Recommendation 2/11 —Advanced planning relating to the aeronautical meteorological component of ASBU Block 3

That an appropriate ICAO expert group, in close coordination with WMO, be tasked to undertake advanced planning, in the 2015 to 2020 timeframe, of the technological requirements and aeronautical meteorological service capabilities needed to support the implementation by 2028 of module B3-AMET of the aviation system block upgrades (ASBU) methodology and the meteorological components of other ASBU modules related to system-wide information management contained in the *Global Air Navigation Plan* (Doc 9750).

2.3.3 The meeting reviewed proposed changes to the world area forecast system (WAFS) in the Block 3 timescale, which were to be focussed around the principles provided in Appendix F. Having completed its review, and appreciating that it was particularly challenging to fully envisage the future state of the aviation system (and the WAFS component) in the 2028 timeframe, the meeting agreed to the principles to be used as a basis for future developments of the WAFS in support of module B3-AMET of the ASBU methodology. The meeting formulated the following recommendation accordingly:

Recommendation 2/12 —Development of the WAFS in support of the aviation system block upgrades (ASBUs) beyond 2028

That ICAO use the principles outlined by the deliverables for en-route operations included in Appendix F as a basis for the future development of the world area forecast system (WAFS) in support of module B3-AMET of the ASBU methodology.

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2.4: Collaborative decision making and common situational awareness — automation and human factors considerations

2.4.1 The meeting noted expected benefits that would arise from the application of collaborative decision making (CDM) in an information-rich operating environment. In this regard, CDM was considered a fundamental aspect of how the global air traffic management (ATM) system would mature, ensuring that decisions were informed, understood by all and based on a shared evaluation of the underlying information. It was also noted that since aeronautical meteorology was an integral component of the total available information from which operational decisions would be taken in a collaborative manner by the ATM community, it followed that aeronautical meteorology would be a key enabler to common situational awareness.

2.4.2 The meeting emphasized that in such a collaborative environment there was a strong need for governance, including quality management and data standardization for which there were prescribed data formats that were common across all information domains within the future system-wide information management (SWIM) environment of global ATM.

2.4.3 The meeting noted that the expected transition from product-oriented to information- or data-oriented service provision would inevitably mean less interaction with the aeronautical meteorological information (on the part of the providers and the users) due to increased automation. In addition, given such an automated operating environment and being cognizant of the uniqueness of users' operational decisions, the meeting agreed that it would be advisable to not be prescriptive in terms of visualization standards of the commonly available aeronautical meteorological information, since each user would have their own, often unique operational needs and capabilities.

2.4.4 The meeting noted that in the interest of maximizing interoperability and easing the implementation process, air navigation service providers (ANSPs), as a key ATM community member, would play an integral role in the aeronautical meteorology and ATM communities transition to an information-oriented environment.

2.4.5 The meeting agreed that the transition to a more collaborate operating environment and increased automation would require changes to how aeronautical meteorological information was made available to and applied by users, and that governance was a prerequisite. In addition, there was a need to ensure that human factors considerations remain integral to aeronautical meteorological service provision during and upon such a transition. The meeting formulated the following recommendations accordingly:

Recommendation 2/13 —Development of provisions for aeronautical meteorological information services in the context of CDM and common situational awareness

That ICAO and WMO ensure the development of provisions for aeronautical meteorological information services that promote collaborative decision making (CDM) and common situational awareness among the air traffic management (ATM) community.

Recommendation 2/14 — Human factors considerations for the development of aeronautical meteorological service provisions

That ICAO and WMO ensure that human factors considerations are central to the development of aeronautical meteorological information services.

2.5 **Statement by the Delegations of China and the Russian Federation**

World Area Forecast System (WAFS)

2.5.1 The development of WAFS should be put in their proper historical perspective. It is understood that the establishment of WAFS in 1982 was based on the then situation that not all States had numerical weather prediction (NWP) and satellite dissemination capabilities. However, during the past three decades, the global situation has changed significantly in that many States now operate NWP models with high spatial and temporal scales out to a week or more. At the same time, satellite dissemination technologies are no longer cost-effective compared to the Internet. Therefore, apart from the WAFS model forecasts, there are many different global model forecasts which could be available for use, for en-route flight planning purpose, provided that they meet a required level of performance and internationally designated.

2.5.2 With tremendous air traffic growth around the world, in particular in the Asia-Pacific region, there is an increasing demand from the users for better forecasts and more timely amendments of the SIGWX information to respond to the rapid changes in weather such as significant convection which have not been forecast by the existing global centres. Furthermore, in future SWIM environment where there would be greater dependence on gridded forecasts to support ATM and TBO, it is not clear if the existing WAFS structure is meeting the future needs of users. To support inevitable growth in air traffic, the centres need to address the growing demands from users which might not be best served by the existing arrangement of having only two global centres. It is felt feasible to reconsider the place and role of WAFS in the new context of the GANP and ASBU methodology. As such, in considering the global centres, considerations in respect of performance, equity and sustainability including backup arrangements should be taken into consideration. Users should be given a choice as to the global model that best meets their operational needs.

2.5.3 Furthermore, Annex 3 and future PANS-MET should regulate on the provision of meteorological service, including WAFS forecasts, i.e. setting up the required performance standards each service should meet, not the agencies that provide such service.

2.6 **Statement by the Delegations of Bahrain, Kuwait, Qatar and United Arab Emirates**

To the Secretary General of ICAO and WMO

2.6.1 With reference to ICAO MET Divisional Meeting -14 supporting the “One Sky” concept as it relates to the Global Air Navigation Plan (GANP) and the meteorological component of the Aviation System Block Upgrade (ASBU) methodology. The Sub-regional representative presence at ICAO MET Divisional Meeting -14 are (Bahrain, Kuwait, Qatar, and United Arab Emirates) wish to put forward the following concerns for your consideration.

2.6.1.1 Reference to the Draft recommendation item 2.5.6, MET/14-WP/6|CAeM-15/Doc. 6, with regard to the Implementation of a regional advisory system for select en-route hazardous meteorological conditions and reference to Appendices B and C, we would like to bring to your attention that the implementation of a regional advisory system to serve SIGMET information would have impact on:

- a) sub region role on providing SIGMET warning as service providers, and organizational viability of sub- region NMHSs;
- b) the accurate manner as sub-region are fully compliance, and skilled since 1960 in providing SIGMET warning;
- c) current and ongoing investment on human resources, and meteorological systems; and
- d) annual fee collection reference to item 5.2.1.3, and 5.2.1.4 from MET/14-WP/6|CAeM-15/Doc. 6 Appendices C.

2.6.2 To conclude all above mentioned countries request both the ICAO and WMO to consider recommendations proposed above by the sub regional, as it will have effects on the governing role as single regionalized providers to international controlled system. All of the above mentioned member countries are providing valuable, quality and efficient meteorological services to aviation communities in terms of early weather warning for more than a decade. Our sub-region invested in meteorological systems in providing SIGMET service through their assigned FIRs with ongoing investment plans towards the contribution of composite RADAR Mosaic, high resolution NWP in both atmospheric & ocean domains, satellite data reception and sub-regional redistribution. After all these investments, we are in jeopardy of maintaining and sustaining these infrastructures in view of the new regionalized SWIM environment and forced to a position that we may lose our visible role among other members and also the support from the government.

2.6.3 In addition to the circumstances in our region, we request both ICAO and WMO to clarify clearly the regulations (with regards to bilateral agreements) and rules to be drawn up when, and before assigning the regional SIGMET service provision

APPENDIX A

WORLD AREA FORECAST SYSTEM DELIVERABLES IN SUPPORT OF ASBU BLOCK 0

- Implement improved turbulence algorithms including the replacement of turbulence potential with turbulence severity (i.e. eddy dissipation rate (EDR))
- Implement improved icing algorithms including the replacement of icing potential with icing severity
- Global and regional verification of WAFS forecasts by utilizing data provided by States and user organizations

APPENDIX B

WORLD AREA FORECAST SYSTEM DELIVERABLES IN SUPPORT OF ASBU BLOCKS 1 AND 2

Changes intended during the time frame of Module B1-AMET — *Meteorological Information Supporting Enhanced Operational Efficiency and Safety* (2018-2028) are:

- 2018-2023:
 - Implement cumulonimbus cloud ensemble based prediction system
 - Implement turbulence type forecasts (e.g. convection, jet-stream shear, terrain) utilizing eddy dissipation rate (EDR)
 - Implement finer grid resolution for WAFS data
 - Implement calibrated probabilistic forecasts for icing, turbulence and cumulonimbus cloud
 - Provide partial dataset of meteorological information suitable for integration into flight planning, flight management and air traffic management (ATM) decision support systems for en-route weather
 - Implement significant weather forecasts (SIGWX) in XML/GML format as a replacement to SIGWX in BUFR format
 - Make available WAFS data via the System Wide Information Management (SWIM)
- 2023-2028:
 - Provide increased dataset of meteorological information suitable for integration of meteorological information into flight planning, flight management and ATM decision support systems for en-route weather

Improved algorithms

Improvements by the WAFCs include, but are not limited to:

- Cumulonimbus cloud:
 - Improvements linked to convection scheme and use of ensemble based forecasts
 - Change output parameters to provide more useful calibrated values

- Turbulence:
 - Characterization of turbulence type, e.g. convective, upper level wind shear or terrain induced
 - Calibrated probabilistic output utilizing EDR
- Icing:
 - Calibrated probabilistic output

APPENDIX C

Roadmap
for
International Airways Volcano Watch (IAVW)
in
Support of International Air Navigation

21 November 2013

Version 1.0

Revision	Date	Description
0.1	29 July 2013	Initial draft. Based on draft ConOps for the IAVW in response to IAVWOPSG Conclusion 7/17. Aligns with <i>Meteorological Information Supporting Enhanced Operational Efficiency and Safety</i> from ICAO's Aviation System Block Upgrades (ASBU).
0.2	27 September 2013	Revised draft based on comments from IAVWOPSG ad hoc group.
0.3	24 October 2013	Revised draft based on comments on version 0.2 from the IAVWOPSG ad hoc group.
0.4	10 November 2013	Revised draft based on comments on version 0.3 from the IAVWOPSG ad hoc group
1.0	19 November 2013	Submitted to IAVWOPSG Secretariat
1.0 rev	21 November 2013	Revised to include additional comments from WMO

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Preface

At the first meeting of the International Volcanic Ash Task Force (IVATF/1), held at ICAO Headquarters in Montréal from 27 to 30 July 2010, it was recognized that there was a need to further promote and improve the services provided by Volcanic Ash Advisory Centres (VAAC) and Meteorological Watch Offices (MWO). It was agreed that a global Concept of Operations (ConOps) for volcanic ash should be developed that would cut across all service fields from a perspective of the providers of information to the users/operators of that information in support of both tactical and strategic decision making. This resulted in IVATF Task TF-VAA10, *Development of a Concept of Operations for the International Airways Volcano Watch (IAVW)*.

A draft version, and follow-on revisions, of the ConOps for volcanic ash were presented to the IVATF at their subsequent meetings. At the IVATF's fourth meeting the IAVW Operations Group (IAVWOPSG) was tasked with developing a version 1.0 of the ConOps, and this was subsequently presented to the seventh meeting of the IAVWOPSG (Bangkok, Thailand, 18-22 March 2013). At that meeting the group recognized the inherent value of the ConOps document and agreed to use the material included in the ConOps for the development of an IAVW roadmap to be consistent with the outcomes of ICAO's 12th Air Navigation Conference (Montreal, Canada, November 2012) and formulated Conclusion 7/17 which states:

Conclusion 7/17— Development of an IAVW roadmap

That an ad-hoc group consisting of Canada, China, France, Germany, New Zealand, United Kingdom, United States (Rapporteur), IATA, ICCAIA, and WMO to be tasked to:

- a) develop an IAVW roadmap for the provision of information services in support of the aviation system block upgrade (ASBU) methodology to be included in ICAO's Global Air Navigation Plan, taking into consideration the draft concept of operations for the IAVW as presented in Appendix J to this report; and
- b) provide a draft of the roadmap called for by a) above by 29 November 2013 for onward consideration at the IAVWOPSG/8 meeting and the proposed ICAO MET Divisional Meeting in July 2014.

This roadmap replaces the ConOps as originally proposed and is a living document that will evolve as the science and technology improves, and as operational requirements evolves.

1.0 Introduction/Scope

The roadmap for the International Airways Volcano Watch (IAVW) is based on the draft Concept of Operations (ConOps) for the IAVW which was presented at the seventh meeting of the IAVW Operations Group (IAVWOPSG/7). This roadmap replaces the ConOps.

The roadmap is not intended to provide detailed descriptions on all the areas presented in the document, rather it presents a high-level overview for the user.

1.1 Purpose

This document is intended to provide international air navigation users and providers of information under the IAVW with a roadmap that defines improved services including the integration of volcanic meteorological information into decision support systems for trajectory based operations (TBO).

This document provides a plan for the development and implementation of volcanic meteorological information for modules *B1-AMET* and *B3-AMET*, time frames 2018 and 2028 respectively¹.

Module *B0-AMET*² of ICAO's Aviation System Block Upgrades (ASBU), titled *Meteorological Information Supporting Enhanced Operational Efficiency and Safety*, describes the baseline of meteorological information provided in Block 0 of the ASBU which is defined as beginning in 2013. The IAVW element is included in module *B0-AMET* and describes the information services provided by State Volcano Observatories (VO), Meteorological Watch Offices (MWO) and Volcanic Ash Advisory Centers (VAAC).

1.2 Background

The Eyjafjallajökull volcanic eruption of April and May 2010 highlighted issues relating to all aspects of volcanic ash service provision including underpinning science and observational capabilities. Eyjafjallajökull brought direct attention to the need for a better understanding of volcanic ash information and the use of that information in Air Traffic Management (ATM) and flight operations. In addition it was recognized that there were no measureable certificated tolerances for volcanic ash for safe and permissible aircraft operations.

While the provision of contemporary volcanic ash information has served the international community well for many years, especially in areas where the airspace is not congested and operators have greater flexibility in avoiding airspace identified with ash, the application of this operational procedure did not work well in congested airspace. This was evident from the Eyjafjallajökull volcanic ash episode in April and May of 2010. During this time period, volcanic ash of mostly unknown concentrations, were detected visually and/or by satellite imagery at times over parts of Western Europe and parts of the North Atlantic. This was due to the

¹ Module *B1-AMET* encompasses the timeframes of Block 1 (2018) and Block 2 (2023).

² Advanced Meteorological Information (AMET).

prevailing meteorological conditions and the prolonged period of eruption. The busy and congested air routes over Europe were significantly impacted and issues also arose with the many Air Navigation Service Providers (ANSP) and MWOs serving a multitude of Flight Information Regions (FIRs). At one time during the Eyjafjallajökull eruption, more than 40 volcanic ash SIGMET messages were in effect.

The limited ability to identify observed areas of volcanic ash as well as forecast areas of volcanic ash concentrations hazardous to aircraft was another significant factor in the resultant closing of airspace, especially during the first few days after the initial eruption.

Aviation users (i.e. ANSP, operators and pilots) need to know the location, size and vertical extent of a given volcanic cloud, and where it will be located in the future. Ideally, the precise location and future location of the volcanic ash cloud would be known with great accuracy and confidence and over time scales ranging from minutes to days. However, the current science for observing and forecasting volcanic ash cannot provide that precision or accuracy.

Currently there are no requirements to observe and forecast volcanic gases, such as sulphur dioxide (SO₂), thus these observation and forecasts do not exist. However, Grímsvötn (2011) highlighted shortfalls in our understanding of and service provision for possible SO₂ impacts.

Aviation users need to know how much volcanic ash is in the atmosphere and if those amounts pose a threat to the aircraft's engine(s) and system(s). However, there are no agreed values of ash which constitute a hazard to an aircraft.

In addition, many volcanoes are not monitored despite continued efforts from the International Union of Geodesy and Geophysics (IUGG), ICAO and WMO. The lack of this monitoring contributes to uncertainty in the model output in that the source data from the eruption is based on an estimate.

1.3 Problem Statement

Explosive volcanic eruptions eject pulverized rock (volcanic ash) and corrosive/hazardous gases high into the atmosphere. Depending on the energy and duration of an eruption, there is potential for an ash cloud to cover a wide area for timescales ranging from hours to days.

Volcanic eruptions represent a direct threat to the safety of aircraft in flight and present major operational difficulties at aerodromes and in airspaces located proximal to volcanoes. Currently there are no agreed values of ash loading metrics (amount and rate of ash ingestion) that represent quantified hazard to aircraft or gas turbine engines. The exposure time of aircraft or engines to the ash, type of ash and the thrust settings at the time of the encounter, both have a direct bearing on the threshold value of ash loading that may constitute a hazard. Hence, the current globally recommended procedure is to avoid any volcanic ash, regardless of the level of ash contamination. Many years of service have demonstrated this to ensure safe operation.

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

If demonstrated to be beneficial and without compromising safety, it may be desirable to agree to standards on where and for how long aircraft can operate in specified concentrations. Until those standards are established, if indeed they can be, considerable effort is required to establish rigorous and well understood practices and products provided by the VAACs.

1.4 Identification

This roadmap is expected to provide the guidance on services tasked by the IVATF and the ICAO challenge team and identified in the ICAO's ASBUs. This document will be updated as required as procedures changes or as technology warrants a change to take advantage of new state of the art capabilities to detect, monitor, and forecast ash.

This document is intended to complement the ICAO *ATM Volcanic Ash Contingency Plan*, ICAO Doc 9974 *Flight Safety and Volcanic Ash*, ICAO Doc 9691 *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds*, and ICAO Doc 9766 *Handbook on the International Airways Volcano Watch*.

2.0 Current Operations and Capabilities

During a volcanic event the coordination and flow of information regarding the location and forecast position of the volcanic cloud is the primary concern. It involves cooperation among all information providers in support of operational decision makers. Providers of information primarily include MWO, VAACs, and VOs. Users of information are ANSPs that include Aeronautical Information Services (AIS), Air Traffic Control (ATC) and Air Traffic Flow Management (AFTM) units, flight crews, and airline operations centers (AOC). The cooperation between operators and civil aviation authorities (CAA) using the information provided by the providers is essential for the purpose of supporting the pre-flight process, and the in-flight and post-flight decision-making process, as part of the risk mitigation in accordance with ICAO Doc 9974 *Flight Safety and Volcanic Ash*.

2.1 Description of Current Operations

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 the volcanic ash in the atmosphere, (3) forecasting the expected trajectory and location of the ash cloud, and (4) communicating the information to the users.

2.1.1 Monitoring the threat, onset, cessation, dimensions and characteristics of an eruption

The ability to provide an advanced warning of an imminent eruption and the onset of the eruption rests with the VOs which are loosely organized under the banner of the World Organization of Volcano Observatories (WOVO) of the International Union of Geodesy and Geophysics (IUGG). These VOs provide guidance on the magnitude of the eruption, including dimensions and characteristics, which are then used in support of numerical dispersion and transport models.

Pre-eruptive activity may come from several sources, including, but not necessarily limited to: seismic monitors, physical observations of deformation, hydrologic activity, gaseous activity, steam explosions, or debris flow. The international aviation community has established a four-level color code chart for quick reference to indicate the general level of threat of an eruption for a given volcano. The color codes identify the state of the volcano (i.e. pre-eruptive vs. eruptive stage)³ and not to ash in the atmosphere. While the international community has developed the color code chart, it should be noted that these codes are not assigned to all volcanoes for various reasons.

In 2008, the IAVWOPSG agreed to implement a message format to assist volcanologists in the provision of information on the state of a volcano in support of the issuance of volcanic ash advisories (VAA) by VAACs, and the issue of SIGMET information by MWOs, and the issuance of a Notice to Airmen (NOTAM) for volcanic ash by Air Traffic Services (ATS). The message, referred to as Volcano Observatory Notice for Aviation (VONA), was introduced into the ICAO *Handbook on the International Airways Volcano Watch*, Doc 9766. The VONA should be issued by an observatory when the aviation color code changes (up or down) or within a color code level when an ash producing event or other significant change in volcanic behavior occurs. The VONA allows the volcanologists to provide a succinct message on the state of volcano to MWO, VAAC, and ACC which as noted above assists in the issuance of SIGMET, VAA and NOTAM respectively.

For safety purposes, operators have stated the importance of having available pre-eruption activity for situational awareness. Some VOs and a VAAC⁴ currently provide information the volcanic activity within their area of responsibility. This is expected to be extended so that all volcanic areas have improved activity reporting for aviation and is a task being looked at by the IAVWOPSG⁵.

³ In the aviation volcano color code; Green denotes a non-eruptive state; Yellow denotes a state of elevated unrest; Orange denotes a state of heightened unrest with the likelihood of eruption, or minor eruption underway; and Red denotes a forecast of imminent major eruption, or that major ash-producing eruption is underway.

⁴ The Darwin VAAC provides a daily volcanic activity summary on the volcanoes in their area of responsibility.

⁵ IAVWOPSG Conclusion 7/13 refers.

2.1.2 Volcanic ash-cloud monitoring

Depending on many variables, an ash cloud can be detected from the ground, air, or from satellite. A large number of different ground and air-based instruments are available to monitor volcanic ash clouds, including lidar, ceilometers, sun photometers, radar, imaging cameras and aerosol sondes. However, none of these are yet designed, networked or quality controlled for operational use and many are operated in ad-hoc research mode only⁶. Satellite-based sensors are used to locate ash cloud and aid in discerning the perimeter of ash clouds. Ash clouds can be detected on visible satellite imagery, but only during the day. Single and multi-spectral infrared imagery and applied techniques can be used both day and night, and can provide a means of estimating the top of the ash cloud and in the case of the multi-spectral Meteosat SEVERI sensor ash cloud composition characteristics including mean particle size and ash mass loading estimates. Both visible and infrared imagery have limitations when meteorological clouds (e.g., cirrus, etc.) are present depending on the thickness and height of the meteorological cloud cover. Infrared measurements can only detect volcanic ash if the ash is the highest cloud layer, regardless of the level of ash contamination.

Until recently, what was detected by satellite was assumed or interpreted by many to be the “visible ash cloud.” This term was also used to refer to ash clouds seen by pilots in the air and people on the ground. To avoid further confusion and misuse of terms, the IAVWOPSG formulated Conclusion 7/16 which defined “visible ash” and “discernible ash”. According to Conclusion 7/16:

- visible ash be defined as “volcanic ash observed by the human eye” and not be defined quantitatively by the observer
- discernible ash be defined as “volcanic ash detected by defined impacts on/in aircraft or by agreed in-situ and/or remote-sensing techniques”

It is noted that there is no single quantitative threshold value for ‘visible ash’. Discernible ash agreed in-situ and/or remote-sensing techniques are based on the findings and recommendations of the IUGG/WMO Volcanic Ash Scientific Advisory Group.

2.1.3 Volcanic ash forecasts

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. Most of the numerical models utilized by VAACs depend on meteorological input (e.g. wind speed and direction) as well as input regarding the eruptive parameters at the volcanic source (Eruption Source Parameters - ESP). ESPs include (1) plume height, (2) eruption duration or start/stop time, (3) mass eruption rate, (4) fraction of fine ash particles, and (5) the vertical distribution of mass with height above the vent. Uncertainty or

⁶ In 2012 WMO had established the GALION activity as a network (see also www.dwd.de/ceilomap) with a focus also on operational volcanic ash monitoring. This European network already now consists of several thousand systems, for which algorithms have been developed to get quantified volcanic ash information in a quality much better than (passive) satellite observation, although the location of systems is certainly restricted to continental (land-surface) stations.

inaccuracy in any of the various sources can result in large errors in the resultant volcanic ash forecasts.

Forecasters provide value added input to the model output as required before issuing a VAA and VAG. This work is dependent on real-time verification of the ash cloud model output against a range of observational resources, principally, remote sensing by satellite.

Today's two primary volcanic ash forecast products are the VAA and the SIGMET. The VAA is produced and issued by the VAAC, and the SIGMET is produced and issued by the MWO. 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 on the trajectory of the ash cloud and the associated flight levels that may be affected. The VAAs are produced and issued by nine VAACs across the world, each with a defined geographical area of responsibility, as shown in Figure 1. MWOs issue volcanic ash cloud SIGMETs based on the guidance provided by the associated VAAC. These SIGMETs are valid for up to six hours and describe the location and expected location of the ash cloud within the FIR or area of responsibility of the MWO.

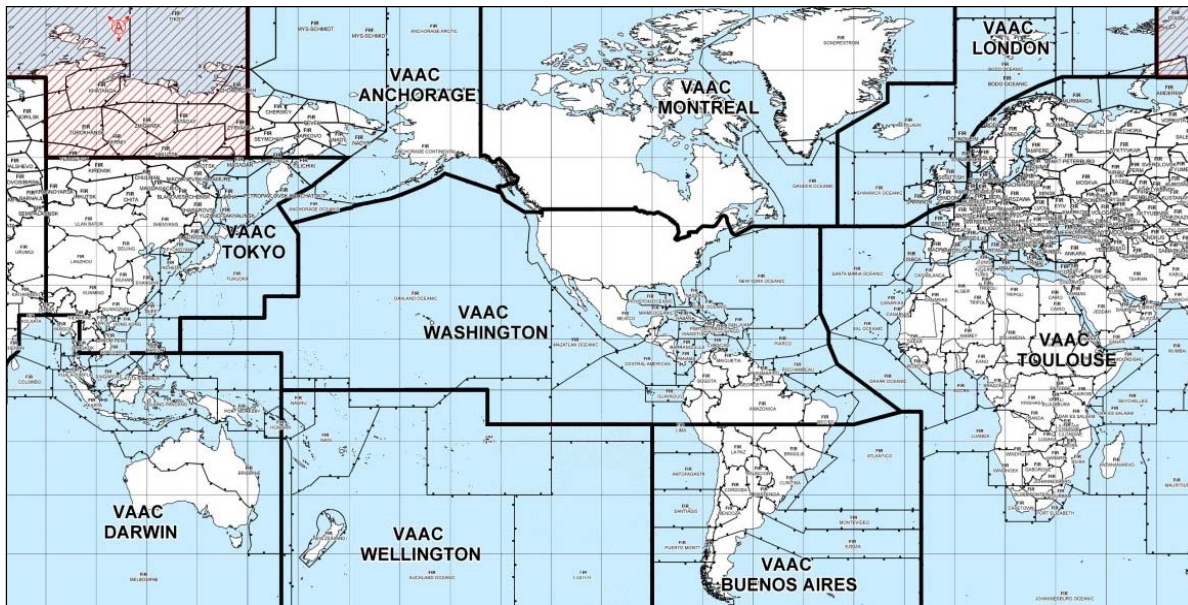


Figure 1. Areas of responsibility for the nine VAACs.

As a supplementary service, meteorological (MET) offices collocated with the EUR/NAT VAACs are required by regional documentation to issue forecast ash concentration charts. Such charts, depicting forecast ash concentration were first provided to users in April 2010 in response to the Eyjafjallajökull volcanic event. It is important to note that there are no globally agreed standards and procedures for the production and provision of such information. Despite lack of global requirement and large uncertainties the ICAO EUR/NAT Volcanic Ash Contingency Plan still includes the provision and use of such charts to underpin the current airlines volcanic ash safety risk assessments.

2.1.4 Communicate volcanic ash information to users

In the simplest terms, MET services are required to provide volcanic ash information to airline operators and ANSPs who then pass the information to aircraft and pilots. Figure 2 depicts an example of information flow following a volcanic eruption. The Figure identifies participants in the provision of contemporary volcanic ash cloud information. The lines between the providers in the diagram do not imply one-way communication, or communication relationships. The lines represent the distribution of information over aeronautical fixed services, with the exception of the VONA⁷. The box colors do not represent significance; rather they help distinguish the information products (e.g., observations and forecasts) (red) from the providers/users (shades of blue, purple and green).

The initial report of volcanic ash can result in many products being delivered to the end user. In most cases, information about a volcanic ash cloud will be provided to the pilot, either in-flight, or during pre-flight planning, in the form of a SIGMET, NOTAM or ASHTAM⁸, Special AIREP, or VAA. Each of these products is unique in format and content, but all provide information regarding the location of the volcanic ash. It is critically evident that all of these products must be consistent in their overall message.

⁷ VOs disseminate the VONA via facsimile or e-mail.

⁸ ASHTAM is a special series NOTAM for a volcanic eruption and/or volcanic ash cloud.

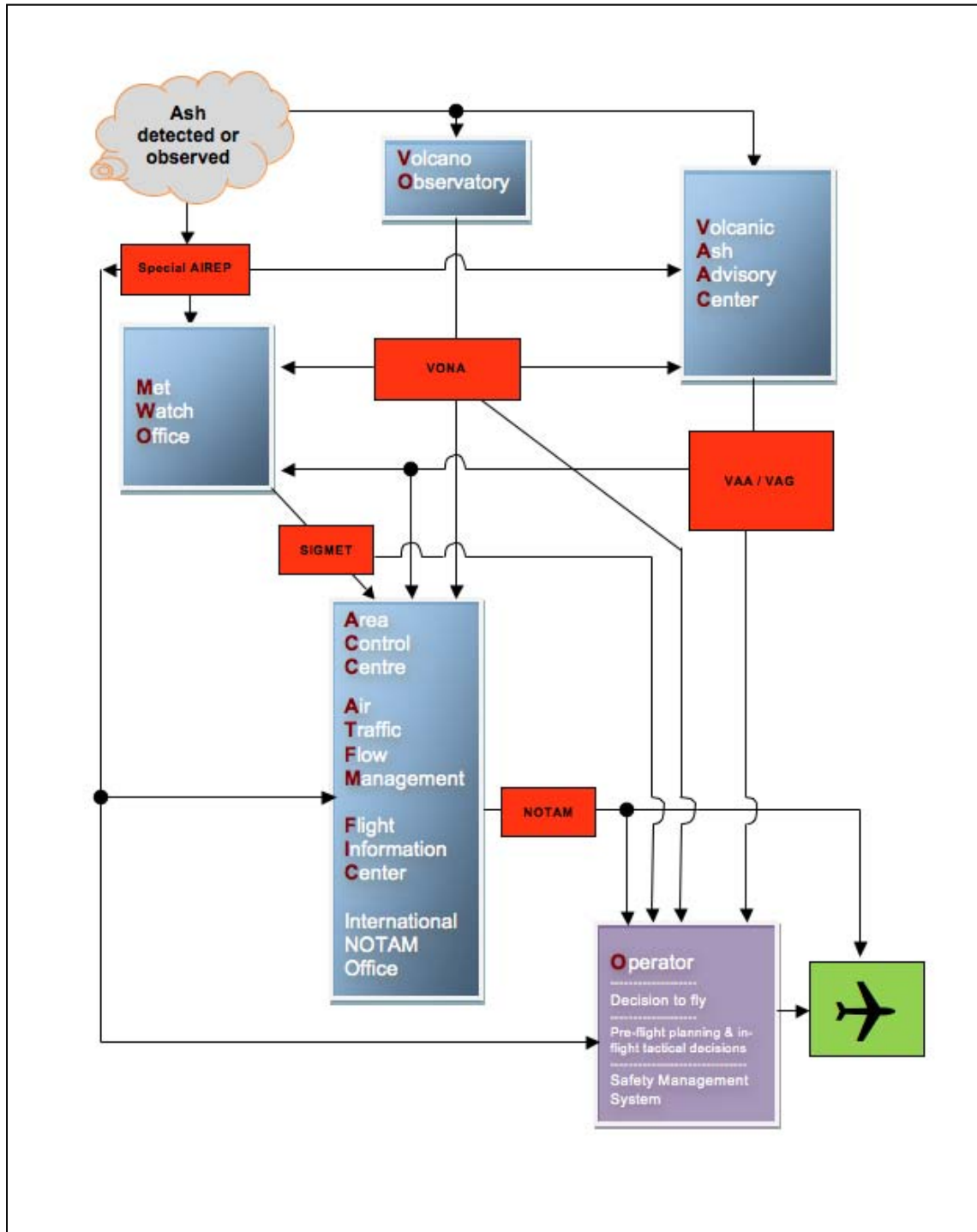


Figure 2. High-level information flow diagram between the users and providers of contemporary volcanic ash cloud information. The lines represent the distribution of information over aeronautical fixed services, with the exception of the VONA. The box colors do not represent significance; rather they help distinguish the information products (e.g., observations and forecasts) (red) from the providers/users (shades of blue, purple and green). It should be noted that there are other distribution networks and information sources that may be unique to different States which are not depicted in the diagram.

2.2 Current Supporting Infrastructure

Table 1 outlines service providers and their functions with respect to volcanic cloud information. The exact role of each provider depends on various circumstances that are not exhaustively described in the table.

Current Services and Providers		Functions for:			Information	
		Pre-Eruption	Eruption ⁹	Volcanic Ash ¹⁰	Information Received and Used	Information Provided (shared)
Volcano Observatory (VO)		Monitor volcano, report changes in status. Pre-eruption activity for situational awareness	Monitor eruption, report changes in status.	Monitor and report	Data from ground-based, air-based and satellite-based observing networks.	VONA
MET Service Provider	Met Watch Office (MWO)		Provide location and notice of eruption	Provide location and dimension of volcanic ash	AIREP, VONA (report from VO), VAA/VAG, METAR/SPECI, NOTAM. Data from ground-based, air-based, satellite-based observing networks. Input from VAACs and other research institutes.	SIGMET
	Aerodrome Met Office and Stations	Report pre-eruption activity	Report	Report		METAR/SPECI. Aerodrome Warning
	Volcanic Ash Advisory Center (VAAC)	Pre-eruption activity for situational awareness.	Initial analysis including dispersion model (initialization), forecast and coordination.	Determine and predict location and dimensions of airspace impacted by volcanic ash	VONA (report from VO). Data from ground-based, air-based, satellite-based observing networks. Input from other VAACs and other research institutes.	VAA and VAG
	Other State, Research, University, Commercial Services (including research modeling centers)	Coordinate with VO and VAACs	Initialize dispersion model. Operate aircraft and sondes for airborne sampling of ash. LIDAR etc for ground based sampling.	Produce model derived predictions of volcanic ash. Operate aircraft and sondes for airborne sampling of ash. LIDAR etc for ground based sampling.	Data from ground-based, air-based, satellite-based observing networks. ESP.	Deliver model derived predictions

⁹ Known as the “Start of Eruption” cycle in Doc 9974 - ICAO Doc 9974 *Flight Safety and Volcanic Ash*.

¹⁰ Same as the “Ongoing Eruption” cycle in Doc 9974 ICAO Doc 9974 *Flight Safety and Volcanic Ash*.

Current Services and Providers		Functions for:			Information	
Service Provider		Pre-Eruption	Eruption ⁹	Volcanic Ash ¹⁰	Information Received and Used	Information Provided (shared)
Air Navigation Service Provider (ANSP)	Air Traffic Control Units (Area, Approach, Aerodrome)	Identify appropriate areas ¹¹ within airspace to outline hazard	Identify appropriate areas within airspace to outline hazard. Reroute traffic as necessary	Identify appropriate areas within airspace to outline hazard. Reroute traffic as necessary	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA or report from VO, VAR (Special AIREP)	IFR clearances. FIR's sector capacity. Affected aerodrome arrival and departure acceptance rate
	Air Traffic Management (ATM)	Maintain communications links and ATS monitoring systems	Implement contingency plans	Lead CDM process for adjusting traffic capacity and routes	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), VAR (Special AIREP, other ¹²)	FIR traffic capacity
	Flight Information Center (FIC)	Maintain communications links and ATS monitoring systems	Provide preflight and in-flight information about eruption	Provide preflight and in-flight information about volcanic cloud	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), Special AIREP	SIGMET, NOTAM/ASHTAM VAA/VAG, VONA (report from VO), Special AIREP
	International NOTAM Office (NOF)	Maintain communications links and ATS monitoring systems. Provide notice of pending hazard.	Provide notice of hazard	Provide notice of hazard	SIGMET, VONA (report from VO), Special AIREP	NOTAM/ASHTAM
Aerodrome		Maintain communications links and monitoring systems	Address ash contamination on runways, taxiways, ground equipment, planes	Address ash contamination on runways, taxiways, ground equipment, planes	Aerodrome Warning	Information for the NOTAM/ASHTAM
Operator	Airline Operations Center (AOC)	Maintain communications links and monitoring systems. Reroute aircraft around volcanoes identified in a pre-eruption state.	Reroute aircraft away from eruption.	Apply agreed SMS processes to adjust routes. Provide information to flight crew. Plan for reroute.	SIGMET, NOTAM/ASHTAM, VAA/VAG, VONA (report from VO), ash or SO2 report from flight crew, or ANSP (ATS, FIS, AIS).	Route/altitude selection, fuel, go/no-go decision, in-flight route/destination change.
	General Aviation Operators	Maintain communications links and monitoring systems	Appropriate decisions per SMS for operators of Large and Turbojet Aeroplanes.	Appropriate decisions per SMS for operators of Large and Turbojet Aeroplanes.	SIGMET, NOTAM/ASHTAM, VAR (Special AIREP), ash or SO2 report from ANSP (ATS, FIS, AIS)	Special AIREP, VAR

¹¹ In accordance with the *ATM Volcanic Ash Contingency Plan*

¹² Ash concentration forecast (if provided)

Current Services and Providers		Functions for:			Information	
		Pre-Eruption	Eruption ⁹	Volcanic Ash ¹⁰	Information Received and Used	Information Provided (shared)
Service Provider	Pilot / Flight crew (Commercial and General Aviation)	Maintain communications links and monitoring systems	Report eruption	Report volcanic ash, sulphur	SIGMET, NOTAM/ASHTAM, VAR (Special AIREP), ash or SO2 report from AOC or ANSP (ATS, FIS, AIS)	Special AIREP, VAR
	Original Equipment Manufacturers (OEM) or Type Certificate Holder (TCH)	Guidance and information to operators	Advice and information to operators	Advice and information to operators	Engineering and operations reports from operator.	Technical information about aircraft operation in volcanic ash, future/ongoing maintenance information requirements, details of inspection requirements

Table 1. Current service providers and their functions with respect to volcanic cloud information.

3.0 Description of Changes

Future services center on a number of changes that are intended to match the time frames of the Blocks of the ASBUs.

Module *B0-AMET* of the ASBUs is the baseline services for Block 0. The following is taken from ASBU module *B0-AMET*:

VAACs within the framework of the International Airways Volcano Watch (IAVW) respond to a notification that a volcano has erupted, or is expected to erupt or volcanic ash is reported in its area of responsibility. The VAACs monitor relevant satellite data to detect the existence and extent of volcanic ash in the atmosphere in the area concerned, and activate their volcanic ash numerical trajectory/dispersion model in order to forecast the movement of any ash cloud that has been detected or reported. In support, the VAACs also use surface-based observations and pilot reports to assist in the detection of volcanic ash. The VAACs issue advisory information (in plain language textual form and graphical form) concerning the extent and forecast movement of the volcanic ash cloud¹³, with fixed time validity T+0 to T+18 at 6-hour time-steps. The VAACs issue these forecasts at least every six hours until such time as the volcanic ash cloud is no longer identifiable from satellite data, no further reports of volcanic ash are received from the area, and no further eruptions of the volcano are reported. The VAACs maintain a 24-hour watch. Argentina, Australia, Canada, France, Japan, New Zealand, the United Kingdom and the United States are designated (by regional air navigation agreement) as the VAAC provider States. Accordingly, VAACs Buenos Aires, Darwin, Montreal, Toulouse,

¹³ There is no requirement in Annex 3 – *Meteorological Service for International Air Navigation* to monitor, observe and forecast volcanic gases.

Tokyo, Wellington, London, Anchorage and Washington make available the aforementioned advisories on the ICAO AFS.

This baseline describes the services as they are for the beginning of Block 0 with the timeframe of 2013. During Block 0, several improvements are proposed and they are described in subsequent sections of this roadmap.

Module *B1-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 decision making process and the impact of the MET conditions (e.g., volcanic ash) are automatically taken into account. Module *B1-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 then manually devise ATM solutions when the demand exceeds the MET-constrained capacity value. Module *B1-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.

The aim of Module *B3-AMET - Enhanced Operational Decisions through Integrated Meteorological Information* is to enhance global ATM decision making in the face of hazardous MET conditions in the context of decisions that should have an immediate effect. Key points are a) tactical avoidance of hazardous MET conditions especially in the 0-20 minute timeframe; b) greater use of aircraft based capabilities to detect MET parameters (e.g. volcanic ash); and c) display of MET information to enhance situational awareness.

3.1 Changes intended through 2018:

Changes intended within the timeframe of 2013-2018 (i.e., Block 0 timeframe) to support Module *B0-AMET (Meteorological Information Supporting Enhanced Operational Efficiency and Safety)* are:

- Incorporate collaborative decisions and information sharing into volcanic ash cloud analyses and forecasts
- Increase the use of the aviation color-code alert system and provision of VONA by State VOs
- Develop confidence levels to aid decision makers as part of their safety risk assessment
- Improve ground-based, air-based and space-based observing networks to determine ESP and existing ash loading in the atmosphere
- Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

3.1.1 Collaborative decision analysis, forecasting and information sharing

The term Collaborative Decision Making (CDM) is a process used in ATM that allows all members of the ATM community, especially airspace users, to participate in the ATM decisions affecting all members. CDM means arriving at an acceptable solution that takes into account the needs of those involved. CDM for ATM is described in ICAO Document 9854 -*Global Air Traffic Management Operational Concept*, and Document 9982 – *Manual on Air Traffic Management System Requirements*.

A similar process has been proposed¹⁴ for volcanic ash and is called Collaborative Decision Analysis and Forecasting (CDAF). From a high level perspective and for an example, collaboration on the perimeter of the volcanic ash could be done, at a minimum, for events that affect high density traffic areas, or several FIRs and extend beyond the area of responsibility of one or more VAACs. This collaboration could be undertaken between predetermined partners, based on the event and extent. Table 2 lists some of the volcanic ash information needed by airspace users. As part of this process, information sharing between the partners is essential, so that all possible outcomes can be considered. Table 3 lists the partners for collaboration and information sharing as well as the expected role of the partners. The final decision (i.e., the location of horizontal/vertical airspace volcanic ash contamination boundaries) will depend on agreed upon guidelines that may vary depending on the size and scope of the volcanic event, but efforts should be made to ensure that the authority for the final decision concerning volcanic ash information resides with the designated Primary VAAC, otherwise the final output (e.g., forecast) may lead to inconsistency and hamper effective decision making by ATM and airlines. Once the decision is finalized it can be integrated into ATM decision tools for a CDM process by ATM decision makers and airspace users.

One of the challenges for the IAVWOPSG is to establish agreed procedures to support CDAF which have not been defined.

Need to know	Information Sharing	Output from a Collaborative Decision
Location of volcanic ash contamination boundaries.	Share data from ground, air, and space observing platforms	Current horizontal and vertical extent (perimeter) of volcanic ash contamination to be used in decision support systems and forecast products.
How the volcanic ash boundaries are changing and where will they be in the future.	Share various outputs of dispersion models	Forecast horizontal and vertical extent of the volcanic ash contamination and produce seamless products
If provided and available, multiple contours of ash contamination	Share various outputs of dispersion models	Forecast horizontal and vertical extent of multiple contours of ash contamination

Table 2. Collaborative decisions for volcanic ash cloud information

¹⁴ IVATF Recommendation 4/18, IAVWOPSG Conclusion 7/21 refers.

Partners	Role
Primary VAAC	Produces preliminary forecast and shares with rest of partners. Considers input and suggested changes from participating partners. Has the final decision on the forecast after considering information and input from partners.
Other VAAC(s)	Shares new information with participating partners.
VO(s)	Reviews preliminary forecast and provides suggested changes.
MWO(s)	
State’s NMHS	
University or Research Centers (dispersion modeling)	
Others (TBD), e.g., operators	Share information.

Table 3. Partners for the collaboration and information sharing and expected roles

3.1.2 Increase the use of the aviation color-code alert system and provision of VONA by State VOs

Not all State VOs issue a VONA, which provides a concise statement describing the activity at the volcano, as well as the specific time of the onset and duration of the eruptive activity. VONAs also contain a color code (see 2.1.1). As a form of “best practice”, this roadmap recommends that all State VOs use the VONA and its aviation color-code alert system for the provision of volcano information.

3.1.3 Develop confidence levels to aid decision makers as part of their safety risk assessment

In February 2012, the IATA met with the VAACs and discussed their need for levels of confidence in the volcanic analyses and forecasts (i.e., VAA/VAG). These confidence levels would be used or translated into the risk assessment conducted by operators to best determine the aircraft flight route or track.

The VAAC practices for presentation of ‘confidence’ must be consistent and be a well understood process to ensure a harmonized regional interoperability within the operator’s risk assessment process. Development of guidance material should be conducted in parallel with the development of the presentation of confidence.

Development of confidence levels are considered to be a key factor in improving the quality of information provided which will aid in the decision making process as part of an operators safety risk management plan.

3.1.4 Improve ground-based, air-based and space-based observing networks to determine ESP

Observation and forecasts information on volcanic ash will require continued improvement of observational capabilities globally, including volcano-monitoring networks, ground-based aerosol networks, satellite platforms and sensors, and airborne sampling.

3.1.5 Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

Scientific research in support of reducing risks from volcanic ash hazards should aim for tangible improvements in the detection and measurement of volcanic plumes and ash clouds during eruptions and in the accuracy of model forecasts of ash transport and dispersion. Research topics (both new and on-going) pertinent to these goals include the following:

- Characterizing volcanic plumes at/near the source
- Understand the evolution of volcanic ash and gas clouds in time and space
- Verification of the model forecasts

In addition,

- Develop an understanding of the impact of ash on aircraft and engines and provide enhanced guidance to operators
- Scientific research to support service delivery for volcanic ash hazard risk reduction

Since 2010 manufacturers have continued work on developing their understanding of the impact of volcanic ash. This will continue through a number of initiatives including involvement of the major manufacturers in the National Aeronautics and Space Administration (NASA) and United States Air Force (USAF) Vehicle Integrated Propulsion Research (VIPRIII) test programme and coordination between manufacturers through the International Coordinating Council of Aerospace Industries Associations (ICCAIA) Volcanic Ash working group. As this knowledge and understanding increases enhanced guidance to operators will be provided where possible.

Further description and discussion regarding research is detailed in Working Paper 14 from the fourth meeting of the IVATF.

3.2 Changes intended within 2018-2023:

Changes intended within the timeframe of 2018-2023 (i.e., Block 1 timeframe) to support Module B1-AMET (*Enhanced Operational Decisions through Integrated Meteorological Information*) are:

- Enhance the provision of SIGMETs in support of operational decisions
- Transition to all digital format for all volcanic ash information

- Further develop ATM for operations in or close to areas of volcanic ash
- Increase the VAA/VAG issuance frequency and time steps
- Provide additional information which reflects the forecast of volcanic ash beyond 18 hours
- Continued improvement in ground-based, air-based and space-based observing networks to determine ESP
- Continued scientific research in support of reducing risks from volcanic ash hazards

3.2.1 Enhance the provision of SIGMETs in support of operational decisions

A large volcanic ash cloud over congested, multi-States areas such as Europe could result in multiple SIGMET information messages, all being in effect at the same time. Each of these SIGMETs becomes a part of a jigsaw puzzle for the user to assimilate, in order to obtain a good understanding of the entire area of the volcanic cloud. As a result the International Air Transport Association (IATA) has stated that they have strong preference for the VAA vs. the SIGMET, i.e., that is one message covering a large region.

Since SIGMETs are, in most cases, based on the first portion of a VAA, that portion of the VAA/VAG could technically be elevated in status to serve as a SIGMET. Making the VAA/VAG's first six-hour portion (i.e., T+0 and T+6 hour) equivalent to the SIGMET would reduce the information overload experienced by users (pilots, operators, etc) who must currently track dozens of SIGMETs for their particular flight in congested areas.

Under today's operations each MWO is responsible for the provision of a SIGMET for their FIR in support of defining the location and forecast position of the ash cloud. However, many MWOs do not have the skill to provide this service and are dependent on the VAAC for this information via the VAA. Some MWOs have more advanced skill levels to provide value input. In those cases the MWO should coordinate with the VAAC and advise the VAAC that the information provided in the VAA is not necessarily reflective of conditions in their FIR. With the proposal to support CDAF this divergence of information should be minimized where the information provided in the VAA is consistent with the SIGMET or vice versa. If achievable this then begs the issue on whether there is a need to retain both products but rather provide a single high quality product to the operator and ANSP in support of integration of MET information into air traffic flow management (ATFM) systems for the routing of aircraft away from a hazard.

Proposed SIGMET enhancements are:

- The first six-hour portion of the VAA (i.e., T+0 and T+6 hour) is equivalent to the SIGMET for a volcanic ash cloud (with validity for one or more FIRs)
- MWOs should participate in the CDAF process and share information with the VAAC to ensure the VAA reflects the conditions in their FIR

- SIGMET *Information* messages should only be issued by a MWO for those cases where the VAA is not yet available or the VAA does not reflect the conditions in the FIR even after the CDAF process.

It is noted that IATA has formulated a set of requirements which were presented to the VAAC Best Practices Seminar of 12-13 June 2012 and expanded upon at IAVWOPSG/7. Those requirements will be considered in this enhancement process taking into account the issues of sovereignty, cost recovery and collaborating procedures among related States.

3.2.2 Transition to all-digital format for all volcanic ash information

Today's volcanic cloud products are primarily text-based (e.g., SIGMET information message), with some supplementation of graphic-based products (e.g., VAG). Future volcanic cloud information must be provided in a digital format in order to better serve aviation users and decision makers. The visualization of volcanic information must be capable of being displayed on moving maps, cockpit displays, radar screens, etc.

The IAVWOPSG, recognizing the need for digital information, formulated Decision 7/25 which calls for the development of a digital format of the VAA/VAG in an XML/GML format for implementation with Amendment 77 to Annex 3 – *Meteorological Service for International Air Navigation*.

The transition from text and graphic-based products to all-digital formats will take time, as there will continue to be a need for legacy text-based products for several years, especially in certain regions of the world.

3.2.3 Further develop ATM for operations in or close to areas of volcanic ash

In an effort to increase information exchange between ATM and operators, make available to affected ANSP's the outcomes of the operators risk assessment for their consideration, especially where applicable to ATFM.

3.2.4 Increase VAA/VAG issuance frequency and time steps

Operators need frequent updates of volcanic ash information especially in congested airspace and around constrained airports. The current VAA/VAG with its 6-hourly issuance and 6-hour time steps does not meet those needs.

The VAA/VAG presenting levels of certainty should be developed to include three hourly time-step information. There is a need to have the capability to increase the frequency of VAA/VAG for pre-defined operational conditions. This would be when ash is present in congested airspace and around capacity constrained airports.

3.2.5 Provide additional information which reflects the forecast of volcanic ash beyond 18 hours

Operators at IAVWOPSG/7 expressed an interest in having volcanic ash information beyond the current practice of T+18 hours for long-haul flight planning and management of airline operations. While it is understood that today's numerical models provide information for various meteorological elements out to several days, providing volcanic ash information beyond T+18 hours introduces a number of uncertainties into the forecast as a result of unknown or uncertain source terms and meteorology as well as inaccuracies in the physics of the dispersion/transport models. With this understanding, the goal is to provide additional information which can realistically reflect the forecast of volcanic ash beyond 18 hours.

3.2.6 Continued improvements in ground-based, air-based and space-based observing networks to determine ESP

Improvements to volcano-monitoring networks, ground-based aerosol networks, satellite platforms and sensors, and airborne sampling will continue in Block 1, building on the accomplishments from Block 0.

3.2.7 Continued scientific research in support of reducing risks from volcanic ash hazards

Scientific research in support of reducing risks from volcanic ash hazards will need to continue in Block 1 and build upon the area and topics listed in section 3.1.5.

3.3 Changes intended within the time frame of 2023-2028

Changes intended within the time frame of 2023-2028 (i.e., Block 2 timeframe), which is an extension of ASBU Block 1, to support Module B1-AMET (*Enhanced Operational Decisions through Integrated Meteorological Information*) are:

- Develop volcanic ash nowcasts
- Develop volcanic ash forecasts that include the use of probability

3.3.1 Develop volcanic ash nowcasts

Users need to know the current location of the volcanic ash. The VAA/VAG and SIGMET provide information about the ash at T+0, but these products are issued every six hours, thus at two hours after T+0, users must do some kind of interpolation between T+0 and T+6 to obtain an estimate of where the ash contamination boundary lies. Providing VAA/VAG at three hour time-steps will help this issue, but more can be done with the transition to a digital information data base for meteorological information, as part of the ASBUs, including volcanic ash.

In the Block 2 timeframe, it is foreseen that a three-dimensional representation of the current or near-current volcanic ash contamination boundaries, known in this document as a "nowcast", could be made available and extracted by the user. Nowcasts would be updated at a

high frequency and provide a more realistic assessment of the location and extent of the ash cloud.

3.3.2 Develop probabilistic volcanic ash 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 4-dimensional shape (3-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 occurrence exceeding a defined magnitude. Probabilistic forecasts help multiple decision makers use the same weather information, applying their own operational constraints to determine risk to their operation. Section 5.2 identifies those functions that could be provided in deterministic and probabilistic terms.

From a high-level perspective, probability forecasts may be based on an ensemble approach. An ensemble is one way to account for some degree of uncertainty. For instance, the model can be run many times, each time 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 gives an indication of the uncertainty associated with that particular ash forecast.

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.

For operators to effectively use ‘probabilities’ for specific time and space within the initial and ongoing risk assessments, a thorough understanding of the output from the VAAC is needed by operators and flight crew.

3.4 Changes intended by 2028 and beyond

Changes intended by 2028 (i.e., Block 3 timeframe) in support of Module B3-AMET (*Enhanced Operational Decisions through Integrated Meteorological Information*) are:

- Develop other volcanic derived contaminant forecasts, specifically SO₂
- Integrate volcanic ash forecasts into decision support systems for trajectory based operations

- Develop understanding of the impact of ash on aircraft and engines and provide enhanced guidance to operators
- Incorporate processes and procedures for the use of airborne detection equipment

3.4.1 Develop other volcanic derived contaminant forecasts, specifically sulphur dioxide

While the document has focused on volcanic ash there is strong evidence that there is a need to expand the services to other toxic elements that are typically associated with volcanic eruptions.

During volcanic eruptions, a number of toxic gases may be emitted in addition to ash; these include SO₂, hydrogen fluoride, and hydrogen sulphide amongst many others. Each of these gases has different atmospheric dispersion properties, and so gas clouds may be found coincident or separate from ash clouds. Of these gases, SO₂ is of particular importance as it may be emitted in large quantities and potentially has significant health effects. The documented experience to date of in-flight encounters with sulphurous gases suggests that SO₂ has never been a significant immediate safety hazard to an aircraft or health hazard to its occupants.

Through the work of the IVATF and IAVWOPSG¹⁵, it was determined that ICAO, through an appropriate expert group or groups, should determine a clear meteorological/atmospheric chemistry requirement (such as a critical level of SO₂ in the atmosphere that would be observed or forecast) that, after passing through the aircraft's ventilation system, could pose a health risk to the aircraft's occupants.

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

One of the key elements in Module B3-AMET of the ASBUs is the integration of meteorological information into decision support systems. Future ATM decision support systems need to directly incorporate volcanic ash nowcasts 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 ash nowcasts and forecasts, combined with the use of probabilistic forecasts to address uncertainty, reduces the effects of volcanic ash on air traffic operations.

3.4.3 Development of index levels for ash tolerances

Different aircraft and engine designs may be affected differently by volcanic ash. For example, modern turbofan engines ingest large volumes of air and their turbines run hotter than the melting point for volcanic ash constituents. They typically utilize exotic turbine component coatings that can be affected by volcanic aerosols such as sulfates and chlorides. They also use turbine nozzle cooling and blade cooling with passages that are vulnerable to ash blockage. Older turboprop or turbofan engines typically do not have these same features and have

¹⁵ IAVWOPSG Conclusion 7/34 and Decision 7/35 refers.

different vulnerabilities. These design and operational differences can significantly affect the engine's susceptibility to volcanic ash.

In the longer term the development of a volcanic ash index for ash tolerances of various types of engine/aircraft combinations may allow operators and ATM to take advantage of quantitative volcanic ash forecasts. It should be recognized that this may not be feasible due to the extensive testing and evaluation required to adequately cover the range of aircraft and engines in service.

3.4.4 Develop processes associated with airborne detection equipment

To allow operators to take advantage of tactical on-board volcanic ash detection equipment, ATM processes and procedures will need to be developed and incorporated into ATM Contingency Plans.

4.0 Proposed Roadmap

The proposed way forward will involve all the changes described in Section 3 above. Specifically:

Through 2018:

- Incorporate collaborative decisions and information sharing into volcanic ash cloud analyses and forecasts
- Increase the use of the aviation color-code alert system and provision of VONA by State VOs
- Develop confidence levels to aid decision makers as part of their safety risk assessment
- Improve ground-based, air-based and space-based observing networks to determine ESP
- Scientific research in support of reducing risks from volcanic ash hazards including understanding the impact of ash on aircraft and engines and the provision of enhanced guidance to operators

2018-2023:

- Enhance the provision of SIGMETs in support of operational decisions
- Transition to all digital format for all volcanic ash information
- Further development of ATM for operations in or close to areas of volcanic ash
- Increase the VAA/VAG issuance frequency and time steps
- Provide additional information which reflects the forecast of volcanic ash beyond 18 hours
- Continued improvements in ground-based, air-based and space-based observing networks to determine ESP
- Continued scientific research in support of reducing risks from volcanic ash hazards

2023-2028:

- Develop volcanic ash forecasts that include the use of probability
- Develop volcanic ash nowcasts

2028 and beyond:

- Develop other volcanic derived contaminant forecasts, specifically SO₂
- Integrate volcanic ash forecasts into decision support systems for trajectory based operations
- Development of index levels for ash tolerances
- Incorporate processes and procedures for the use of airborne detection equipment

4.1 Assumptions and Constraints

The proposed concept is based on the following assumptions:

- IAVW retains global legal mandate for volcanic ash service delivery
- The first six-hour forecast from the VAA (i.e., T+0 and T+6 hour) can be used equivalent to a SIGMET
- Probabilistic forecasts can be utilized by aviation decision makers
- Probabilistic forecasts are best suited for users in congested airspace, but can also be beneficial for users in uncongested airspace
- Before a probability can be derived from an ensemble, there is a need to “calibrate” the ensemble, as the number of elements in a “cluster” is not necessarily a reliable measure of probability if the variations of the initial states and ESP’s are not driven by a scientifically sound selection principle
- Index levels for volcanic ash tolerances can be developed
- Continuing user demand for phenomena based information rather than FIR based information

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

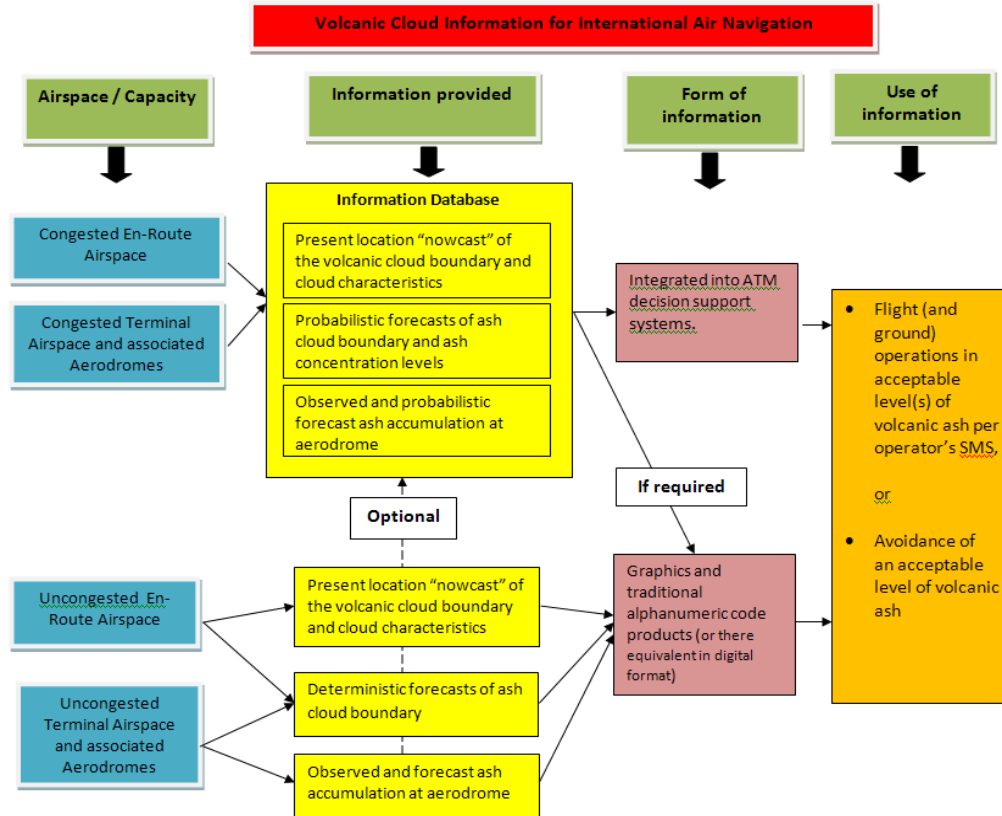
- The development of certifiable volcanic ash tolerances may take many years, or may not be feasible or beneficial to operators (if by 2028 the development is not possible then further work will be done to improve the avoidance of ash)
- Some States may not accept the VAA as equivalent to the SIGMET due to legal and political issues

4.2 Operational Environment

By 2028, volcanic cloud information will reside on a common information sharing platform and be part of the System Wide Information Management (SWIM) concept in support of global ATM.

4.3 Operations

Operations during a volcanic event depend on the information available as well as a function of



classification of airspace that being high density (congested) airspace versus low density (uncongested) airspace.

Nowcasts and deterministic forecasts may adequately serve the users of airspace that is not congested, and offers ample options for volcanic ash avoidance without great fuel penalties for the operator. But for congested airspace, the provision and use of probabilistic forecasts of the volcanic ash could be beneficial in order to achieve maximum efficiency of the air traffic system.

Figure 3 provides a high level schematic of meteorological service per airspace capacity. It should be noted that the provision and use of probabilistic forecasts is not restricted or limited to congested airspace, rather the "optional" block in Figure 3 denotes that operators in uncongested airspace, e.g., oceanic User Preferred Routes (UPR), can take full advantage of these forecasts.

Figure 3. Operations concept using volcanic cloud information per airspace capacity. Note that the "optional" box indicates that the Information Database and its probabilistic forecasts are available for users of uncongested airspace.

4.4 Supporting Infrastructure

In Blocks 0 through 2, the information on volcanic ash will continue to be product centric and be produced by humans in traditional alphanumeric text along with a graphical image. Production of these products will inevitably migrate from the MWOs to the VAACs.

In the Block 3, all relevant information on the volcanic clouds will reside on a common information sharing platform.

4.5 Benefits to be realized

The proposals for volcanic cloud information to be developed and implemented as noted in sections 3.1, 3.2, and 3.3 will provide users with volcanic ash information that has greater confidence and usability. 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 cloud forecasts, 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. Finally, if feasible, the development of a volcanic ash index for ash tolerances for various types of engine/aircraft combinations may allow operators and ATM to take advantage of volcanic ash concentration forecasts.

5.0 Needs and Goals

5.1 Operational Needs

The following is a set of high-level operational needs¹⁶ of aviation users for trajectory based operations in support of international air navigation:

- Determine the onset of a volcanic event (i.e., eruption)
- Determine if an eruption and any associated volcanic ash are a hazard to international air navigation based on any agreed threshold values of mass concentration
- Determine what aerodromes and airspace are affected by the eruption and associated cloud
- Determine when the eruption has ended
- Determine when the volcanic ash has dispersed below agreed threshold values
- Determine when the aerodrome/airspace affected by the eruption and/or cloud is safe to operate in or through
- Determine the cost of the event and stakeholder satisfaction

¹⁶ As determined by the author based on information from users at ICAO's IVATF.

5.2 Functional Goals

Table 4 lists a set of functional goals for volcano eruption and volcanic cloud information based on different types of airspace and aerodrome densities (i.e., capacity or congestion). An “X” in the table’s cell indicates that this function is needed for this airspace and aerodrome. A “P” or “D” indicates whether the forecast function is Probabilistic or Deterministic. A “D, P” indicates that both are provided.

Future Functional Goals for Volcano Eruption and Volcanic Cloud Information						
	Route operations		Terminal control area (TMA) operations		Aerodrome	
	Congested (high density)	Un-congested (low density)	Congested (high density)	Un-congested (low density)	High density	Low density
Volcano Eruption						
Detect an Eruption in all kinds of meteorological and day/night conditions (i.e., including tropical regions where convective activity is common)	X	X	X	X	X	X
Determine the height of the eruption plume	X	X	X	X	X	X
Determine the duration of the eruption	X	X	X	X	X	X
Detect, determine and report the heightened volcanic activity (pre-eruption)	X	X	X	X		
Volcanic Cloud						
Determine the perimeter, top and base of the volcanic cloud in all kinds of meteorological and day/night conditions	X	X	X	X		
Determine when the "volcanic cloud" is a hazard due to:	Ash	X	X	X	X	X
	SO2	X	X	X	X	X
	Electro-magnetic risks to avionics	X	X	X	X	X
	Other (TBD)					
Determine the perimeter of the lowest acceptable ash contamination level (ash cloud)	X	X	X	X	X	X
Determine the perimeter of the gaseous cloud	X	X	X	X	X	X
Determine the eruption source parameters	X	X	X	X	X	X
Forecast the perimeter of the lowest acceptable ash contamination level (ash cloud)	D, P	D, P	D, P	D	P	D
Forecast the top and base height of the lowest acceptable ash contamination level (ash cloud)	D, P	D, P	D, P	D	P	D
Forecast the movement of the lowest acceptable ash	D	D	D	D		

Future Functional Goals for Volcano Eruption and Volcanic Cloud Information						
	Route operations		Terminal control area (TMA) operations		Aerodrome	
	Congested (high density)	Un-congested (low density)	Congested (high density)	Un-congested (low density)	High density	Low density
contamination level						
Forecast the growth and decay of the lowest acceptable ash contamination level (ash cloud)	D, P	D, P	D, P	D		
Forecast the location of the gaseous cloud	D, P	D, P	D, P	D	P	D
Forecast the top and base height of the gaseous cloud	D, P	D, P	D, P	D	P	D
Forecast the movement of the gaseous cloud	D, P	D, P	D, P	D		
Forecast the growth and decay of the gaseous cloud	P	D, P	P	D		
Determine when the volcanic cloud is no longer a hazard	X	X	X	X		
Determine when the volcanic cloud is hidden or mixed with clouds, especially cumulonimbus clouds and cirrus clouds	X	X	X	X		
Forecast when the volcanic cloud is hidden or mixed with meteorological clouds	P	D, P	P	D		
Volcanic Ash Accumulation						
Determine the ash accumulation at the aerodrome					X	X
Forecast the ash accumulation at the aerodrome					D, P	D

Table 4. Future functional goals for volcano eruption and volcanic cloud information

6.0 Operational Scenarios

Two kinds of operational scenarios are envisioned, avoidance of the volcanic cloud, and planned flight into a cloud. The information for both scenarios is in the form of nowcasts and forecasts that are integrated into decision support systems.

Nowcasts

The three-dimensional representation of the current or near-current volcanic ash cloud, including depiction of the perimeter of the lowest acceptable level 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 nowcast provides users with the location of discernible volcanic ash. As the volcanic ash moves or changes, the nowcast is updated at a temporal frequency that meets user needs and service provider capabilities. For flight into acceptable levels of ash, volcano ESP, *in situ* measurements of the airborne volcanic ash (from ground-based, space-based, or airborne-based observing platforms) are required to provide a nowcast that has a high level of confidence of the ash concentration levels inside the cloud.

Forecasts

The four-dimensional representation of volcanic ash, including depiction of the perimeter of the lowest acceptable level of ash contamination, ash concentration levels and indices, in both deterministic and probabilistic terms, in a common exchange format that provides integration into decision making tools as well as offers a graphical depiction of the information. For both scenarios, the forecasts would be valid “X” hours and up to “Y” days, but 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 levels 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.

The Collaboration Process

Aligned with the above forecast process is the collaborative decision and information sharing process. In this scenario, collaboration on the nowcasts and forecasts will occur on a regular basis such that all users are afforded the opportunity to contribute information. Information will be shared and could be made available on an information database or web portal that is jointly run by the VAACs.

Civil aviation operators will then apply these new nowcasts and forecasts to their operations specifications per their Safety Management System (SMS) and any specific Safety Risk Assessments (SRA) for any operations other in areas of a volcanic ash cloud.

APPENDIX D

STRATEGY FOR THE FUTURE PROVISION OF INFORMATION ON HAZARDOUS METEOROLOGICAL CONDITIONS

Overall Objective

To develop a high-level strategic statement relating to the provision of information on hazardous meteorological conditions for international civil aviation, covering the period 2014 to 2025.

This strategic statement is expected to support recommended actions concerning aeronautical meteorological service provision arising from ICAO's 12th Air Navigation Conference (AN-Conf/12 held 19 to 30 November 2012), while recognizing that there is a need for shorter term action in some areas to rectify existing deficiencies in the provision of information on hazardous meteorological conditions to international civil aviation.

This strategic statement is intended to support and align with the programme and timing of the aviation system block upgrades (ASBUs)¹⁷ methodology contained in the Fourth Edition (2013) of ICAO's Global Air Navigation Plan (GANP) (Doc 9750-AN/963). The ASBUs provide target availability timelines for a series of operational improvements – technological and procedural – that will eventually realize a fully-harmonized global air navigation system.

Refer: Agreed Action 5/1, Meteorological Warnings Study Group (METWSG), 5th Meeting, Montréal, 20 to 21 June 2013.

Problem Definition

There is a significant and long standing issue regarding deficiencies in some ICAO Regions concerning the provision of SIGMET information and harmonization of such information within the current State meteorological watch office (MWO) flight information region (FIR)-based system¹⁸.

Deficiencies in SIGMET provision is a major concern, particularly given the programmed migration to performance-based air traffic management principles set out in the GANP. The need to provide better meteorological support for the safety and efficiency of international civil aviation is particularly important.

IATA and its member airlines continue to express concern over the safety and efficiency of operations in areas where SIGMETs are rarely, if ever, issued by MWOs.

Some States have a chronic lack of capacity¹⁹ to fully meet their Annex 3 – *Meteorological Service for International Air Navigation* responsibilities. In particular, some smaller developing States have difficulty with SIGMET provision. Some developed States also have significant problems in this area²⁰. These

¹⁷ Refer Working document for the Aviation System Block Upgrades, 28 March 2013.

¹⁸ Where a State has accepted the responsibility of providing air traffic services within an FIR (or control area), SIGMET information is to be issued by an MWO concerning the occurrence or expected occurrence of specified en-route weather phenomena which may affect the safety of aircraft operations. Such phenomena include severe turbulence, severe icing and others.

¹⁹ Capacity includes people, expertise and underpinning infrastructure.

²⁰ The acute lack of capacity of some States to meet many Annex 3 responsibilities regarding SIGMET issuance was emphasised during a SIGMET trial conducted by the METWSG in April to July 2011. This trial was aimed at testing the feasibility of regional SIGMET advisory centres (RSAC) assisting MWOs to issue SIGMETs by providing them with SIGMET advisory information.

difficulties result in particular MWOs not being able to issue SIGMETs in a timely, reliable, or accurate manner.

The problem is not unique to any one State or any one ICAO Region. The issues range from State non-compliance in actually issuing SIGMET, non-functional or non-supportive MWO, through to providing SIGMET in incorrect formats. The problem is compounded with the current FIR-based system of SIGMET provision also presenting co-ordination challenges, particularly over areas with small and irregular FIR boundaries, as well as in those ICAO Regions with many small FIRs.

Furthermore, IATA has noted that inconsistent cessation or change of hazardous meteorological conditions information at FIR boundaries, due to differences in methods and working practices between MWOs, creates significant and expensive flight management issues.

Any remedial developments must therefore align meteorological inputs to the evolving technical capacity of modern airline and aircraft operations and the increasing globalization of the civil aviation industry.

Statement of Strategic Intent

Reflecting its strategic objectives, and in an increasingly competitive business and technically advancing environment, ICAO recognizes:

- (a) the increasing demand from international civil aviation users for efficient and effective phenomena-based hazardous meteorological condition information, seamlessly covering the globe in a co-ordinated and harmonized way; and
- (b) the limitations, inconsistencies and gaps in the current production of hazardous meteorological conditions information (in the form of SIGMET) required to be produced by each MWO for its associated FIR.

To meet international civil aviation user demands, and make best use of resources (including technology), this strategy proposes to transfer the issue of defined²¹ regional hazardous meteorological condition information to appropriately resourced regional centres, supported by respective meteorological watch offices (MWOs) as may be determined, in a three phased approach and in support of the Aviation System Block Upgrades (ASBUs) methodology of ICAO's Global Air Navigation Plan (GANP), as follows:

1.1 **Phase One (2014-2017):** The first phase is the establishment of regional hazardous weather advisory centres (RHWACs) to assist MWOs with the existing provision of SIGMET information in those ICAO Regions in need of such support.

Explanatory note: Formal planning and development will begin with a mandate from the ICAO Meteorology Divisional Meeting in July 2014. All planning and arrangements will be in place with formal ratification of the scheme expected in Amendment 77 to Annex 3 (with intended applicability in November 2016), and parallel documentation in Regional Air Navigation Plans. The allocated RHWACs will commence operations at a date to be agreed but no later than December 2017.

1.2 **Phase Two (2016-2020):** The second phase (including the transition of the RHWACs) will cover the centralization of SIGMET-related responsibilities of MWOs to regional hazardous weather centres (RHWCs) supporting multiple FIRs. This may include the amalgamation of existing volcanic ash advisory

²¹ Part of the first phase would be the identification of exactly what constitutes hazardous meteorological conditions, excluding the contemporary work of VAACs, TCACs and pending the expected future work of space weather centres.

centres (VAACs) and tropical cyclone advisory centres (TCACs)²² into these RHWCs, and will include close liaison with users and detailed definition of all products to be supplied by the new centres.

Explanatory note: Formal planning and development will begin in 2016 with the completion of planning for Phase 1. All planning and arrangements will be in place with formal ratification of the scheme expected in Amendment 78 to Annex 3 (with intended applicability in November 2019), and parallel documentation in Regional Air Navigation Plans. Planning will include the development of suitable RHCW performance metrics to support Phase 3. The allocated RHWCs will commence operations at a date to be agreed but no later than December 2020.

1.3 **Phase Three (2020-2024):** This phase primarily covers the review of the performance of the regional hazardous weather centres, making any appropriate recommendations in this regard. The review will also include, inter alia, an evaluation of the efficacy, or otherwise²³, of consolidating, in a further phase (potentially a Phase Four), hazardous meteorological condition information issued from a few centres conjointly covering the globe²⁴, in or after 2025.

Explanatory note: The review will be undertaken in 2023 using performance data compiled for the years 2020 – 2022 inclusive. The review will include evaluation of operations, modelling, logistics, communications and science capability. A final report and recommendations will be provided by the end of 2023. If recommended, a reduced number of regional centres, or a few centres conjointly covering the globe, could be operating in 2025 if mandated in Amendment 80 to Annex 3 (with intended applicability in November 2025). It is noted, however, that any highly significant recommendations from this review process may need to go an ICAO Meteorology Divisional meeting around 2025/2026 for ratification, delaying implementation of any significant changes until after about 2026.

1.4 **Note**

Notwithstanding the strategic approach outlined above, and in accordance with Annex 3, Chapter 2, States can enter into bilateral arrangements at any time to obtain the support they may need to fulfil their MWO obligations with regard to SIGMET provision. As an interim arrangement, while Phase One of the strategy is implemented, such action is encouraged.

Supporting Considerations

This section references the areas of consideration taken into account in the derivation of the statement of strategic intent for the future provision of information on hazardous meteorological conditions.

1.5 **ICAO Strategic Objectives**

ICAO has established three strategic objectives for years 2011, 2012 and 2013:

- (a) Safety: Enhance global civil aviation safety.
- (b) Security: Enhance global civil aviation security.
- (c) Environmental Protection and Sustainable Development of Air Transport: Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment.

In years 2014, 2015 and 2016 the number of strategic objectives of ICAO will increase to five. Ten key air navigation policy principles²⁵ are contained in the GANP, intended to guide global, regional and State air navigation planning consistent with ICAO's strategic objectives.

1.6 **General Considerations**

²² VAACs and TCACs have been operating successfully in a regional capacity for the past several decades.

²³ It is accepted that the review may recommend slowing, delay, or postponement of further consolidation.

²⁴ There is a high level expectation of IATA for a better global hazardous weather scheme than exists today, consisting of only a few regional centres conjointly covering the globe, to be fully assessed and implemented in the mid-term.

²⁵ Refer Doc 9750-AN/963 — 2013-2028 Global Air Navigation Plan.

Those aspects contributing to the derivation of this document, not covered elsewhere, are:

- (a) Identification of hazardous meteorological conditions best managed in a consolidated manner;
- (b) Utilization of information within the envisaged data-centric environment²⁶ as part of the system wide information management (SWIM) concepts.
- (c) Need for evaluation of cost recovery schemes to support regional centres.
- (d) Need for evaluation of relevant airspace sovereignty, liability, and obligations of States - noting the range of political perceptions of regional and global change.
- (e) Need to ensure robust implementation of quality management system (QMS) and safety management system (SMS) principles and requirements in any new system.

1.7 Discussion

Article 28 of the ICAO Convention on International Civil Aviation (Doc 7300) and Annex 3 to that Convention defines meteorological services in support of international air navigation. Over the past six decades, amendments of Annex 3 have been largely centred on meteorological observations and forecasts rather than the nature of the underlying global systems structures.

In the 1980s the international community recognized technological advances and user demand changes (for example, increasing long-haul flights) with the establishment of the world area forecast system (WAFS). The WAFS initially provided global wind and temperature data with planning for significant weather forecasts (as currently provided). In the final phase of WAFS implementation, the WAFS replaced regional area forecast centres (RAFC) which had provided regional forecasts within their defined area of responsibility, operating within the limits of technology and communication networks of the times. The development of the WAFS hinged on global modelling capabilities, the advent of satellite remote sensing techniques, and satellite broadcast of WAFS products to States/users across the globe.

Other changes reflected this on-going development of international civil aviation. An example is the removal of the two-hour rule that restricted dissemination of METAR/TAF reports within a two-hour flying distance from the aerodrome. Just as it was recognized that this two-hour rule was obsolete then, the international civil aviation community recognizes now that future systems and the nature of meteorological information will need to meet new and different requirements within new and different contexts.

Reflecting this perspective, the future vision for aeronautical meteorological service practices was covered at the AN-Conf/12.

The international civil aviation community understands that meteorological conditions are not restricted to the boundaries of a flight information region (FIR) and that there is a need to provide a harmonized assessment of meteorological conditions irrespective of FIR boundaries. This perspective became most apparent in recent years with the provision of volcanic ash information; where there was a lack of information on the location of the hazard in some areas compounded by occasional inconsistency of information from different providers, covering adjacent areas. Within the international airways volcano watch (IAVW) these deficiencies have been well documented, with a wide array of remedial system changes implemented or being implemented. However, the international community has not yet

²⁶ Including inter-alia the achievement of a robust global network based on the principles of Service Oriented Architecture (SOA).

implemented the necessary system and product changes needed for other hazardous meteorological conditions.

If States are to respond to user demands for the provision of better aeronautical meteorological services, there is a need to change how these services are provided in support of the vision provided at the AN-Conf/12. For example, if States fail to recognize these changes, operators may look to other sources to obtain the necessary information to support their performance based operations. While it is recognized that fundamental services must continue to be provided by States, there is a need to identify which services belong to the State to support operations within their FIR, and which services are required for situations where meteorological conditions are transparent to FIR boundaries

1.8 Working Relationships

To ensure the success of the strategic plan there is a need to develop a co-ordinated working relationship with various organizations, service providers and users of services that includes but not necessarily defines all the stakeholders, including:

- WMO — World Meteorological Organization.
- IATA — International Air Transport Association.
- CANSO — Civil Air Navigation Services Organisation.
- IFALPA — International Federation of Airline Pilots' Associations.
- IFATCA — International Federation of Air Traffic Controllers' Associations.
- ISO — International Organization for Standardization.
- States in general (States in need of assistance, States able to host RHWACs, States likely to be able to provide other assistance, VAAC and TCAC host States)
- ICAO Regional offices.
- Particular States with capability and capacity to serve as a regional centre.

Discussion on Implementation

Consideration will be needed as to the assignment of an expert group to manage the process. This group may need to have overall management responsibilities for the system, reporting on a regular basis to the Secretariat or to the Air Navigation Commission (ANC). Its work will need to include the implementation of appropriate funding systems.

It is recognized that States will continue to have an important role in support of the operation of the intended regional hazardous weather centre concept. States will need to:

- (a) ensure that they provide, through their respective MWOs and requisite communications systems and protocols, local information²⁷ including special air-reports to the regional hazardous weather advisory centres, and eventually the regional hazardous weather centres, in a timely fashion;
- (b) continue to provide so-called flight following services through their respective MWOs, including the relay as appropriate of hazardous meteorological conditions information, monitoring of the

²⁷ Local information includes data and information from any remote sensing and satellite reception capabilities not directly accessible by the Regional Centres.

regional hazardous weather advisory centres and eventually the regional hazardous weather centre products with formal routine and special feedback to the centres²⁸;

- (c) where possible, provide routine evaluation of the hazardous weather information provided by the regional centres; and
- (d) continue to undertake the specified tasks required in the volcanic ash advisory and tropical cyclone advisory schemes.

MWOs would continue with all other specified requirements as currently set out in Annex 3.

In implementing the strategy care needs to be taken to ensure the voice of all States is represented on the referred expert group. In this regard, it is suggested that there be particular representation from a State or several States in each ICAO Region, and service provider and user representative bodies to supplement the expertise required (including WMO experts). The experience and capabilities of States involved in the development and operation of TCAC, WAFC and VAAC responsibilities should also be represented on the expert group either through membership and/or defined relationships.

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²⁸ Routine feedback to the Regional Centre would include the routine provision of validation and complementary real-time information. Special feedback would include real-time quantitative and qualitative advice on specific quality matters with regard to the Regional Centre products.

APPENDIX E

PLAN FOR THE COST RECOVERY AND GOVERNANCE SUPPORTING REGIONAL HAZARDOUS WEATHER ADVISORY CENTRES

Overall Objective

To develop a plan for the future governance and equitable cost recovery of a regional SIGMET advisory system for hazardous meteorological conditions for international civil aviation.

This plan and associated discussion is expected to support recommended actions concerning aeronautical meteorological service provision arising from ICAO's 12th Air Navigation Conference (AN-Conf/12 held 19 to 30 November 2012), and, importantly, the strategic statement relating to the provision of information on hazardous meteorological conditions to international civil aviation from regional advisory centres.

This paper details some of the issues relating to the future governance and cost recovery arrangements of the regional hazardous weather advisory centres (RHWAC) and provides an initial plan for development to assist discussion at the forthcoming Meteorology (MET) Divisional Meeting in July 2014.

The plan is intended to support and align with the programme and timing of the aviation system block upgrades (ASBUs)²⁹.

Refer: Agreed Action 5/3, Meteorological Warnings Study Group (METWSG), 5th Meeting, Montréal, 20 to 21 June 2013.

Problem Definition

Strategy Linkage

The concurrent strategic paper on the Future Provision of Information on Hazardous Meteorological Conditions (deriving from the Agreed Action 5/1, METWSG, 5th Meeting) sets out that there is a significant and long standing issue regarding deficiencies in some ICAO Regions concerning SIGMET provision and harmonisation within the current State Meteorological Watch Office (MWO) flight information region (FIR)-based system.

Some States have a chronic lack of capacity³⁰ to fully meet their Annex 3 – *Meteorological Service for International Air Navigation* responsibilities. In particular, some smaller developing States have difficulty with SIGMET provision. Some developed States also have significant problems in this area³¹. These difficulties result in particular MWOs not being able to issue SIGMETs in a timely, reliable, or accurate manner.

A three phased remedial strategy is proposed in response to long voiced concerns from users (IATA and others) regarding the safety and efficiency of operations in areas where SIGMETs are rarely, if ever, issued for hazardous meteorological conditions.

Key Issue

²⁹ ASBUs methodology contained in the Fourth Edition (2013) of ICAO's Global Air Navigation Plan (GANP) (Doc 9750-AN/963). The ASBUs provide target availability timelines for a series of operational improvements – technological and procedural – that will eventually realize a fully-harmonized global air navigation system.

³⁰ Capacity includes people, funding, expertise and underpinning infrastructure.

³¹ The acute lack of capacity of some States to meet many Annex 3 responsibilities regarding SIGMET issuance was emphasised during a SIGMET trial conducted by the METWSG in April to July 2011. This trial was aimed at testing the feasibility of regional SIGMET advisory centres (RSAC) assisting MWOs to issue SIGMETs by providing them with SIGMET advisory information.

There is currently no specific guidance or systems available through ICAO and WMO to assist in the funding or governance of regional centres providing advisory services on hazardous meteorological conditions.

The Plan

In direct relation to the *Statement of Strategic Intent* in the concurrent paper, *Future Provision of Information on Hazardous Meteorological Conditions*:

Assign an ICAO Expert Group by September 2014

The first objective will be to assign an ICAO expert group to have overall management responsibilities for developing the RHWAC scheme. The expert group would report on a regular basis to the Secretariat or directly to the Air Navigation Commission (ANC). Its work will need to include:

- (a) the development and implementation of permanent governance arrangements by mid-2015; and
- (b) the development and implementation of appropriate funding systems by mid- 2015.

The voice of key States should be represented on the expert group. In this regard, it is suggested that there be particular representation from a State or several States in each ICAO Region, and service provider and user representative bodies to supplement the expertise required (including WMO experts). The experience and capabilities of States involved in the development and operation of tropical cyclone advisory centre (TCAC), world area forecast centre (WAFC) and volcanic ash advisory centre (VAAC) responsibilities should also be represented on the expert group either through membership and/or defined relationships. The ICAO Secretariat will need to ensure that relevant ICAO financial and economic expertise is available (such as from within the Air Transport Bureau).

Develop and Implement Governance Arrangements by mid-2015

In developing robust governance arrangements, the expert group will need to consider, taking into account those matters considered in this paper:

- (a) all technical management issues in establishing the RHWACs;
- (b) establishment of formal governance processes within the ICAO framework, documentation and reporting;
- (c) product validation/verification processes and routine assessment and reporting; and
- (d) financial management relationships, accounting and reporting procedures.

Develop and Implement of Appropriate Funding Systems by mid-2015

In developing robust funding systems, the expert group will need to consider taking into account those matters considered in this paper:

- (a) all possible alternatives, including those set out in this paper;
- (b) current cost recovery systems and guidance from both ANSPs and NMHSs that cover FIRs outside respective State territories;
- (c) extensive consultation and discussion with key stakeholders and possible third party assistance (for example, World Bank, Regional Development Banks);
- (d) the most expeditious method for accounting, reviewing and reporting on revenue and allocation to the RHWACs; and
- (e) the most expeditious method for RHWACs to report financial estimates, budgets and financial performance.

Complete all arrangements by the end of 2015

The target for ensuring good governance and funding systems are in place is the end of June 2015. It is expected that this will enable the first RHWACs to be established on a firm foundation within the time-scale set out in the *Statement of Strategic Intent* for regional centres – i.e. by the end of 2015.

As other regional centres are progressively developed they will have an already operating governance and financial system to engage, making the process straight forward and largely of a technical nature.

Background Considerations

This section sets out background information taken into account in the derivation of the plan for funding and governance of the future provision of advisory information on hazardous meteorological conditions.

ICAO Strategic Objectives

ICAO has established three Strategic Objectives for years 2011, 2012 and 2013:

- (a) Safety: Enhance global civil aviation safety;
- (b) Security: Enhance global civil aviation security; and
- (c) Environmental Protection and Sustainable Development of Air Transport: Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment.

In years 2014, 2015 and 2016 the number of strategic objectives of ICAO will increase to five. Ten key air navigation policy principles³² are contained in the GANP, intended to guide global, regional and State air navigation planning consistent with ICAO's strategic objectives.

Existing International Guidance

Extensive ICAO guidance on cost recovery is provided in *the Manual on Air Navigation Services Economics* (Doc 9161). This detailed manual sets out the ICAO policy on cost recovery and provides a robust array of perspectives that need to be taken into account in designing cost recovery systems. Appendix 3 of Doc 9161 details the guidance for determining the costs of aeronautical meteorological services. Additionally, ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082) provides guidance on cost recovery.

WMO provides a *Guide to Aeronautical Meteorological Services Cost Recovery: Principles and Guidance* (WMO Publication No. 904). This publication contains additional information on the principles of cost allocations for National Meteorological Services and other providers of meteorological services to aviation, but currently does not provide guidance on multi-State/multi-FIR based cost recovery mechanisms.

Existing Regional Schemes

At present, within the ICAO framework there are:

- (a) nine volcanic ash advisory centres (VAACs) (namely Anchorage, Buenos Aires, Darwin, London, Montreal, Tokyo, Toulouse, Washington and Wellington) as part of the international airways volcano watch (IAVW)
- (b) seven tropical cyclone advisory centres (TCACs) (namely Darwin, Honolulu, La Réunion, Miami, Nadi, New Delhi and Tokyo), and

³² Refer Doc 9750-AN/963 — 2013-2028 Global Air Navigation Plan.

- (c) two world area forecast centres (WAFCs) (namely London and Washington) as part of the world area forecast system (WAFS)

In addition, there is the ICAO Satellite Distribution System (SADIS) that provides OPMET information and WAFS forecasts to States/users in the ICAO EUR, AFI, MID and western part of the ASIA/PAC Regions.

With the exception of the SADIS, which has a governance and cost recovery arrangement in place, there are no regional cost recovery arrangements in place for any of the other regional or global centres referred to above.

Currently the IAVW, WAFS and SADIS all have a governance structure in place by way of ICAO operations groups – namely the IAVWOPSG, WAFSOPSG and SADISOPSG – which report to the Air Navigation Commission and/or Planning and Implementation Regional Groups (PIRGs) of ICAO on a routine basis. These operations groups consist of, inter alia, the provider States, States who make use of the services provided, airline users represented by IATA, and flight crew users represented by IFALPA. ICAO provides the Secretariat support for these operations groups.

These operations groups currently meet on a 12- or 18-month cycle and each has a similar agenda that includes:

- (a) review of associated regional and/or global ICAO provisions;
- (b) operation of the centres or systems;
- (c) development of the centres or systems; and
- (d) long term development and implementation issues.

WMO arranges for the governance for the TCACs. A technical co-ordination meeting involving all of the TCAC provider States currently takes place once every three years, however a number of regional committees (within the construct of the WMO Regional Associations) take place during the intersession period. There are no airline or flight crew user representatives on these particular WMO groups, however the ICAO Secretariat attends where resources allow.

Known Issues

Each State is responsible for the provision or facilitation, and funding of its meteorological service. Some States contract out the work and rely on those contractors to recover costs through third party mechanisms. Others meanwhile fund service directly from taxes or through air traffic services (ATS) and airspace levies and charges. In many cases, airlines and operators have little input into how the State delivers the service and how it is funded, leading to a general lack of transparency.

Currently States that provide regional and global meteorological centres (such as the TCACs, WAFCs and VAACs alluded to above) have taken responsibility for funding and resourcing. Where cost-recovery takes place, airspace users receiving en-route air navigation services (ANS) within the particular State's FIR(s) may be charged directly by the ATS provider or indirectly through other charging mechanisms bearing on airline operations. There is no international or regionally common scheme for the collection of revenue to support regional and global meteorological centres.

The demands on providing more accurate regional or global forecasts require constant improvements to the provider State's capability. This includes increasingly expensive computing capability for numerical weather prediction (NWP), data post-processing, as well as more sophisticated production software development. In this regard, States providing regional and global meteorological centre operations have generally noted that that there is increasing scrutiny being applied to these costs by operators.

The additional costs of providing such services for aviation can no longer be considered marginal or just a bi-product of the routine activities. Staff resources and infrastructure costs to provide these often complex and demanding services are needed; in addition, they also have to be tested and exercised on a regular basis.

An important aspect for any regional centre is the need to share information with neighbouring States and other centres³³. Operationally meeting this requirement, let alone the cost, may well be above and beyond what the provider State would normally be required to undertake if it was not a regional centre.

Generally speaking, airlines/operators overflying the regional centres area of operation but not the provider State FIRs currently do not contribute to the cost of the provision of the particular service. In a regionalised scheme, this highlights that current cost State/FIR-based recovery methodologies would be materially inequitable.

Discussion

Management and Governance

It is considered that similar arrangements of governance to the existing regional and global centres alluded to above could be utilised for the RHWACs - a global group of experts advising ICAO on the operation of the service and its effectiveness in meeting user requirements.

Careful consideration is needed as to the makeup of the ICAO expert group(s) that would oversee the work of the RHWACs, noting the need for a variety of expertise not just in meteorology but airline operations, air traffic management (ATM) and cost recovery. The expert group would need to ensure best practices are developed and shared between the RHWACs.

More local discussions relating to the day-to-day operation of the RHWACs should take place at the ICAO regional MET sub-group meetings (or equivalent) of the PIRGs, since these meetings would also allow States and users within the ICAO Region to have the opportunity to influence the development of the service and to propose changes to the requirements to particular or all RHWACs.

Governance structures must be in place to manage the establishment of the RHWACs. These governance structures (expert group(s)) would need to;

- detail the specific regional requirements (based on global ICAO provisions);
- arrange appropriate user consultation, produce guidance and usability guides for the products being provided;
- set out the performance indicators as agreed with the users;
- detail the meteorological information required from States (for example, observations);
- ensure there is a transparent costing, budgeting and long term investment plan in place;
- assist in the running (or development) of a cost recovery scheme; and
- review of performance, based on the performance indicators.

During implementation, governance could reside with a more local group (for example, a PIRG) that assists the State providing the RHWAC by providing guidance on policy and strategy during its initial operation. However, recognising the need for harmonized practices it is suggested that during the implementation phase a number of best practices workshops are held for the RHWACs.

The alternative is for a global expert group to oversee the establishment of the RHWACs as currently defined and as may be requested by the PIRGs.

³³ Including, for example, pilot reports, satellite information and other observations.

It is noted that users have expressed a need for consistency between RHWACs, one aspect of the governance expert groups is to ensure that the advisory products are provided uniformly and in a similar manner and that change management principles are applied. Also critical to the work of the RHWACs will be the development and subsequent agreement of a common set of key performance indicators (KPIs) to ensure that the RHWACs meet the quality standards required by users.

It is considered that there are no additional liability issues for a State since all the information provided by the RHWAC is provided as guidance material only.

Funding

While in theory it can be relatively easy to determine what type of cost recovery system should be in place, practically this is not the case. There are complicated political considerations and administration arrangements that would need to be put in place and any such scheme also needs to be fair and enforceable.

The following excerpt from ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082) provides details for the charges for air navigation services used by aircraft when not over the provider State. A similar policy could be developed for provision of meteorological services.

"53. The Council observes that the providers of air navigation services for international use may require all users to pay their share of the cost of providing them regardless of whether or not the utilization takes place over the territory of the provider State. Accordingly, wherever a State has accepted the responsibility for providing route air navigation services over another State, over the high seas, or in an airspace of undetermined sovereignty (in accordance with the provisions of ICAO Annex 11 — *Air Traffic Services* to the *Convention on International Civil Aviation* and *Regional Air Navigation Agreements* approved by the Council), the State concerned may levy charges on all users for the services provided. A State may delegate to another State or to an organization the authority to levy such charges on its behalf.

54. The Council also notes that the collection of air navigation services charges in cases where the aircraft does not fly over the provider State poses difficult and complex problems. It is for the States to find the appropriate kind of machinery on a bilateral or regional basis for meetings between provider States and those of the users, aiming to reach as much agreement as possible concerning the facilities and services provided, the charges to be levied, and the methods of collecting these charges."

Whilst the direct costs of provision will be relatively straightforward to identify, the allocation of additional core costs (i.e. infrastructure and underpinning services) will be more difficult. It is likely that additional guidance on the subject would need to be provided to assist States in order that a standardised allocation of costs is undertaken by the RHWAC provider States. This guidance would need to ensure States undertaking the operation of an RHWAC understand the need for transparency in determining the associated core costs.

Conversely, it is recognised that if an RHWAC were to have multiple functions, for instance if they were responsible for tropical cyclone, volcanic ash and other hazardous phenomena, this would reduce costs for training/competencies, administration for recovering costs, staff costs, data transfer, etc.

5.2.1 Cost Recovery Options

Creating a cost recovery arrangement for the RHWACs will provide an opportunity for users to influence the development work and have knowledge of the quality of information being provided. This will also allow users to compare the output from the RHWACs and see which provide quality services in a cost effective manner whilst recognising that the costs of providing the RHWAC service will vary due to the cost of living and other factors.

While the prospect of no cost recovery mechanisms is not ideal, this does not mean that a State hosting (providing) an RHWAC must cost recover. An RHWAC provider State could elect to meet costs from its own internal budgetary process.

5.2.1.1 No Regional Cost Recovery

In the past, when the provision of regional based advisory services were considered part-and-parcel of the National Meteorological Service (NMS) it could be argued that the costs of provision were relatively low and therefore the costs were “*de minimis*” (i.e. the effort to collect the charges does not justify the means since its effect on the en-route rate was low). However, as noted above, the costs of provision of regional and global meteorological services are increasing. The other possible concern to consider is that while it might be perfectly feasible for a large or well-developed State to bear this cost, this might not be the case for smaller or developing States. This could result in discouraging important investment in capability.

5.2.1.2 Airspace Users / States contract directly with the State providing the regional service

Airline operators that conduct flights through a region being supplied with SIGMET advisories from a RHWAC would contract directly with the State providing the RHWAC service. In addition, there would be a facility for States within the region to make contractual arrangements with the RHWAC provider State in order that the NMS and other agencies (e.g. the ANSP) could receive the information.

This option is complex in that the role of contract Law between the RHWAC provider State and the airlines / users could be quite fraught, and expensive to administer. There is also the likelihood that either non-State based operators are denied access to the services or that a number of users do not pay but receive the information from other sources.

5.2.1.3 Regional Cost Recovery Scheme

The SADIS cost recovery scheme alluded to above is a good example of a regional cost recovery scheme, whereby each year the provider State establishes the costs of providing the service; this cost is then shared by the States that make use of the service according to usage information provided by ICAO. Such a model could be used for regional cost recovery of RHWAC. It is noted that countries designated by the United Nations as a Least Developed Country are not required to pay any share of the costs. A similar model is used in Europe for the central collection of en-route charges for regional institutions (i.e. Eurocontrol).

This option requires the support of all States in a given ICAO Region and would be open to argument as to the acceptance and/or proportionality of charges levied on each State.

5.2.1.4 Fee Collection

In the contemporary systems, the administration, record keeping and fee collection arrangements form a critical element for the success of such a scheme. In addition, any user - be it State or operator - that refuses to pay would almost certainly be able to receive the information from other sources. If substantial numbers of users do not pay then it is likely that the services provided from the RHWAC would be of lower quality since the resources and investment to maintain the service delivery at sustainable levels would not take place.

5.2.1.5 Third Party Alternative

From the discussion in this section it is clear that any State-based scheme to fund the RHWACs will be difficult to implement and manage due to complexity of relationships and State Law. An alternative to that approach is to use a method of third party funding. ICAO successfully administers the contributions from States (recovered from airlines) to fund the provision of certain international services through its joint financing program;

- Air Navigation Services in Greenland and Iceland (DEN/ICE),
- North Atlantic Height Monitoring System (HMS)

5.2.2 Summary

Any future cost recovery mechanism should ensure that there is:

- clear description of objectives and benefits;
- identification of facilities and services to be jointly financed;
- definition of the responsibilities of the different partners;
- simplicity and flexibility of the arrangements; and
- equitable recovery of costs through charges consistent with ICAO's policies on charges
- alignment with the principles of *ICAO's Policies on Charges for Airports and Air Navigation Services* (Doc 9082)

5.3 Working Relationships

To ensure the success of the strategic plan there is a need to develop a co-ordinated working relationship with various organizations, service providers and users of services that includes but not necessarily defines all the stakeholders, including:

- WMO — World Meteorological Organization.
 - IATA — International Air Transport Association.
 - CANSO — Civil Air Navigation Services Organisation.
 - IFALPA — International Federation of Airline Pilots' Associations.
 - IFATCA — International Federation of Air Traffic Controllers' Associations.
 - ISO — International Organization for Standardization.
 - States in general (States in need of assistance, States able to provide RHWACs, States likely to be able to provide other assistance, VAAC and TCAC provider States)
 - ICAO Regional Offices.
 - Particular States with capability and capacity to serve as a regional centre.
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APPENDIX F

**WORLD AREA FORECAST SYSTEM DELIVERABLES
IN SUPPORT OF ASBU BLOCK 3**

- Fully integrated multi-member ensemble hazard forecasts
 - Implementation of the WAFS-database, populated with meteorological information from appropriate models to produce ensemble forecasts of global meteorological information
- Implementation of high spatial and temporal resolution models resulting in improved representations of meteorological information
- Provide full dataset of meteorological information covering en-route weather suitable for integration into flight planning for en-route operations, flight management and air traffic management (ATM) decision support systems
- Fully automated gridded and significant weather forecast (SIGWX) output
- Full implementation of system wide information management (SWIM) for access to WAFS data
- Retirement of legacy WAFS products and dissemination systems

— END —