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Position

11POS01

Volcanic Ash Operations

Executive Summary

Dealing with hazards is inherent to aircraft operation. Like icing conditions, wake turbulence or microburst, volcanic ash introduces operational risks that can be identified and dealt with in order to achieve a safe flight.

Aircraft are not specifically designed nor certified for flight into volcanic ash simply because airworthiness requirements have not been specified with regard to volcanic ash. There is presently no clear threshold for the composition and concentration of ash that is hazardous to aviation, so the ICAO recommended practice is to avoid all volcanic ash (zero-tolerance). Current regulations and guidance for volcanic ash operations (including measurement and certification), i.e. those that resulted in the widespread airspace closure in Europe in April and May 2010, do not fulfil all operational and safety needs. This has led to devastating economic consequences. Under this pressure, the Council of European Union Transport Ministers adopted a value of 2 mg/m3 as acceptable provided that certain risk mitigating measures were implemented. IFALPA believes that such a value needs a scientific basis and this has not yet been demonstrated.

ICAO specifies that the position of the 'ash cloud mass' should be forecast, but does not define any threshold limits for ash concentration. Threshold ash concentration values vary over the world with no clear relationship between threshold values and aviation hazards. A continued zero-tolerance policy is probably not realistic therefore acceptable levels of exposure to defined ash-concentrations and appropriate risk mitigation measures must be established.

Volcanic Ash is first of all an operational problem as it affects the aircraft and its safe operation. The solution depends on new or revised specifications for acceptable tolerance levels from engine and airframe manufacturers which can be related to scientifically validated measurements. ICAO should establish or revise global Standards for refined threshold values for exposure to volcanic ash concentration which must be based on hazards to the aircraft and people; a so-called hazard threshold.

Furthermore flight operational and maintenance procedures must be adapted or developed and subsequently implemented. Taking into account scientifically proven aviation limits (hazard thresholds) the airlines/operators should be able to bear the responsibility for planning and executing safe flights.

The necessity of avoiding Volcanic Ash creates a problem for the Air Traffic Services (ATS). They play a significant role in the information distribution and have to prevent collisions between aircraft and to maintain an orderly flow of air traffic (ICAO Annex 11, Objectives of the Air Traffic Services), even in situations where Volcanic Ash restricts operations in large portions of airspace. ATS Contingency Plans addressing all aspects of Air Traffic Management for Volcanic Ash situations should be available for all regions of the world and be based on the needs of aircraft in flight.

Civil aviation has developed a 'safety-first' principle which should not be abandoned as a result of the economic pressures caused by the recent airspace closures. This means that the current principle of conservative avoidance should be maintained unless demonstrably safe hazard threshold criteria can be applied. These include accurate modelling or measurement of the hazard and certification criteria for flight in the hazard area that includes mitigation measures catering for longer term effects.

Finally, the ultimate responsibility for the safe conduct of a flight rests with the Pilot-In-Command. The Pilot-In-Command must therefore be given adequate tools, training information and guidelines to deal with volcanic ash.

This position paper addresses these topics.

Volcanoes and Flight Operations

Of the more than 1,330 volcanoes worldwide that have demonstrated activity over many thousands of years, approximately 500 have recent histories of activity, resulting in 55 to 60 eruptions per year (an average of more than one a week) . However constant seismic monitoring is only available on 174 volcanoes.

Hazardous substances

Each volcano creates its own specific eruption content. From a geophysical standpoint, it is likely that the hazard threshold would vary according to plume altitude, ash composition and mean particle size. From an aviation standpoint, the duration of exposure of aircraft engines to ash and their thrust settings at the time of the encounter have a direct influence on the hazard threshold.

In general the following hazardous substances can be identified:

- Dust/rock particles
- Glass particles
- SO2 (Sulphur Dioxide)
- HCl (hydrochloric acid)

In their gaseous form the latter two constituents of the volcanic ash cloud are thought not to cause significant harmful effects to aircraft. However, following the eruption oxidation and hydration of the SO2 forms H2SO4 (sulphuric acid) droplets which are quite a different matter. The resulting ash/acid mix is highly corrosive and can cause damage to jet engines and pitting of windscreens. This may well present a long-term maintenance expense for aircraft operating regularly in airspace contaminated with even relatively low concentrations of such ash/acid.
Volcanic aerosols also provide a catalyst for ozone depletion.

Aircraft Hazards

Several short-term and long-term hazards can be identified and have been encountered in real life in relation to ash encounters. The hazards that warrant most attention are those affecting aircraft engines and airspeed sensors.

Short-term operational hazards:

- Engine failure
  - Multiple engine malfunctions, such as surge, stalls, increasing Exhaust Gas Temperature (EGT) and torching
  - Slow or no engine restart
  - In case of loss of all engines there is a high risk of loss of most electrical, hydraulic and pneumatic components with the ensuing flight control problems and cabin pressurization failure
- Pitot-static instrument failure
- Communication failure
- Electrical failures
- Impaired vision caused by damaged windows
- Degraded landing performance
- Limited ground operations
- Degraded integrity of composite structure

Long-term operational hazards:

- Abrasion of fan-blades, engine inlet, and compressor blades
- Partial or complete occlusion of turbine blade cooling channels leading to blade overheating with a corresponding reduction of blade life and premature blade failure
- Abrasion or contamination of pneumatic ducting
- Damage to aircraft exterior e.g. windshields, wing leading edge, landing lights
- Contamination of pitot tubes and static ports
- Health risks to operating crew and passengers
- Corrosion of exterior
- Corrosion of interior

Health hazards:

- Impaired breathing
- Impaired vision (physically)
- Long term exposure health risks to operating crew and passengers

From 1980 to 2005, more than 100 turbojet aircraft have sustained volcanic ash damage, with repair costs in excess of $250 million dollars. Seven of these encounters caused temporary engine failure, and three of the aircraft involved temporarily lost all engine power. Whereas most documented engine failure events have occurred in the overhead plume relatively close to the eruption, some engine failures took place in downstream ash clouds as far away as 600 miles from the erupting volcano.

IAVW

The International Civil Aviation Organisation (ICAO) established in 1991 an international system for volcano watch called IAVW, the International Airways Volcano Watch, responsible for a coordinated monitoring, detection, tracking and alerting service for aviation. The IAVW comprises observations of volcanic ash from selected observatories and other organisations, from satellites and from pilot reports.

Nine selected Volcanic Ash Advisory Centres (VAAC) around the world are responsible for advising Meteorological Watch Offices (MWO) and international aviation via the Aeronautical Information Services (AIS) of the location and expected movement of clouds of volcanic ash. Based on this advice, the MWO issues warnings in the form of SIGMET[1] messages and the AIS issues NOTAMs or ASHTAMs containing longer term forecasts of VA dispersion as well as information on the establishment of a volcanic ash danger area and associated airspace restrictions or closure.

The 2010 Eyjafjallajökull eruption

The application of the EUR and NAT contingency plans resulted in gradual closure of most of the European airspace in April 2010. The enormous consequences of the almost complete shutdown of air transport in Europe resulted in a demand for revised procedures. The European Union's Transport Ministers adopted a short-term solution on April 20th:

Volcanic Ash at a concentration of up to 2 mg/m^3 was considered acceptable for safe flight operations provided that adequate risk mitigation measures (e.g. frequent maintenance inspections) were applied in context of a safety management process.

Accordingly the States concerned established a limited "No-Fly Zone", based on forecasts of ash concentration higher than 2 mg/m^3 from the VAAC. EUROCONTROL was tasked to provide the data and the forecast to States every six hours.

Aircraft Operators were permitted to operate outside this zone. Their decision as to whether to fly in airspace considered to be contaminated by volcanic ash up to 2 mg/m^3, had to be based on safety risk assessments under the oversight of their competent Safety Oversight Authority supported by shared data including expert advice from the scientific community (meteo, volcanic ash proliferation etc.).

ICAO reacted by establishing the EUR/NAT Volcanic Ash Task Force to review and update the EUR and NAT contingency plans, and the International Volcanic Ash Task Force (IVATF) to review global provisions.

Recommendation 1:
New SARPs and Guidance Materials are needed to ensure safety and minimise disruption to air travel in case of future eruptions. Revised procedures shall be based on data from scientific research; global volcanic ash standards (composition, concentration, etc); certified engine and airframe operations; reliable and fast (ideally real time) information on the hazards; etc.

ICAO Provisions

The Annexes to the ICAO Convention require the implementation of a State Safety Program and Safety Management Systems for all aviation "service providers". Within this context the term "service provider" includes approved training organizations that are exposed to operational safety risks during the provision of their services, aircraft operators and approved maintenance organizations, organizations responsible for type design and/or manufacture of aircraft, air traffic service providers and certified aerodromes, as applicable.

ICAO Doc 9691, Manual on *Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* explains the current status of aircraft hazard knowledge and the role of the IAVW, VAACs and the Air Traffic Services (ATM, AIS, ATC, MET). Current guidance compiled in ICAO Doc 9691 contains procedures covering observation and reporting of volcanic activity, eruptions and ash clouds, the issuance of warnings to aircraft, closure of airspace and pilot reporting.

ICAO Doc 9766, the *IAVW Handbook* provides guidance and procedures for the operation of the volcano watch.

Until 2010 global aviation standards and guidelines for volcanic ash particle measurements and acceptable limits for aviation were missing and regional procedures (especially in Europe) were inadequate. Aircraft and engine certification criteria for volcanic ash were missing. Common guidelines are to avoid volcanic ash since acceptable ash thresholds and aircraft certification requirements are not specified.

The *Volcanic Ash Contingency Plan EUR Region* (EUR Doc 019) and the *North Atlantic Volcanic Ash Contingency Plan* (contained in NAT Doc 006) that had been developed around 2004 were focussed on ATM and ATS procedures with little regard to the flight operational problems. They were based on the zero-tolerance principle.

Certification

There are no aircraft certification requirements for volcanic ash. Manufacturers have produced guidelines for avoidance and emergency procedures for escape. Recently Boeing and Airbus have published additional operator guidelines for flight in low ash

1. *According to ICAO Annex 3 SIGMETs have a maximum validity period of four hours, but SIGMETs for Volcanic Ash can have a validity up to six hours.*

concentration. Other aircraft manufacturers should be encouraged to update their recommended practices.

National Safety Oversight Authorities together with ICAO should set new criteria in cooperation with the engine and aircraft manufacturers. These criteria should meet the requirements of the operator and pilot for flight planning and execution, avoidance of unacceptable levels of volcanic ash and maintenance purposes.

Recommendation 2:
IFALPA strongly supports research to validate a safe and practicable boundary for acceptable ash concentration exposure. The introduction of standardised limitations must be based on a safety risk assessment.

Detection, Measurement and Standards

ICAO specifies that the position of the 'ash cloud mass' should be forecast, but does not define any limits for ash concentration. Relevant parameters to be measured or forecast are plume altitude, ash/gas composition, ash/gas concentration and mean particle size.

Present and near-future ground-based, airborne and satellite sensors are mainly based on Doppler radar, LIDAR and satellite imagery/spectrometer systems. These systems are designed for research, observation and model validation purposes; not for real-time onboard use. Verification flights must be conducted to validate the models in use.

The 2000 eruption of the Icelandic volcano Hekla demonstrated that even very low concentrations of ash, undetectable visually or by satellite sensors, can cause substantial damage to aircraft[2]. The terms 'visible' and 'visual' (implying detectable) ash cloud have been previously used to describe areas of volcanic ash to the aviation community. These slightly ambiguous terms should be used with care, as the ash cloud may be neither visible to the eye nor detectable by present remote sensing.

There is currently no consistency in the way that the VAACs define the ash-cloud boundary with thresholds depending variously on the source release rate used, availability of satellite data for comparison, and forecaster judgement. Neither is there a clear threshold for the concentration of ash that is hazardous to aviation so the current recommended practice is to avoid all volcanic ash.

Ash Cloud Modelling

Initial reaction to a volcanic eruption that affects aviation will be to establish a danger area of fixed, conservative dimensions with adequate safety margins in order to warn aircraft of the hazard. As soon as more information about the extent of the eruption becomes available and is validated by measurements, the VAACs will estimate the dispersion of the volcanic ash by use of scientific models.

Several models for volcanic ash dispersion are in place and used by the Volcano Ash Advisory Centres. Validity, accuracy and robustness of modelling efforts are still being refined. Validation of individual models requires observations of multiple eruptions, but these data can be scarce, particularly given the low frequency of volcanic eruptions, cost of the technologies and remoteness of the volcanoes.

The amount of ash that should be modelled, per source (eruption), for a given interval is not specified by ICAO and, in reality, will vary according to the specific eruption. This has resulted in very different values being used by the VAACs. Some VAACs have a fixed release rate for all eruptions (e.g. London, Washington), while others (e.g. Montreal) have a variable rate determined from the eruption magnitude.

The definition of volcanic ash (particle size and density) in a model will influence the dispersion results. Unfortunately, there are few actual measurements of in-plume ash particle size distributions, on account of the risks involved with such measurements.

In general it can be concluded that the modelling process is not yet robust enough with respect to its goal; to determine the hazard for an aircraft. It has been mentioned that the results of modelling are accurate only to +/- one order of magnitude.

Recommendation 3:
IFALPA believes that additional refinement of the model(s) will indicate more reliable and precise defined airspace volumes (3D) of ash hazards. Furthermore, whenever the dispersion of volcanic ash is forecast the extent of the airspace volume(s) estimated to be above the acceptable threshold concentration should be verified and validated by in-flight measurements otherwise a conservative safety buffer should be applied.

Airspace Management

Where unacceptable levels of hazardous ash exist, States may decide to close (parts of) their airspace. This should be based on unambiguous validated data and preferably done with uniform and internationally agreed 'closure criteria'. These regulations should be designed to minimise the amount of closed airspace. Over the High Seas, only danger areas can be established.

Since these hazardous levels are difficult to establish in general, a global approach is needed that accommodates local circumstances. Like other weather phenomena, volcanic ash is variable in time and place and its impact is dependent on the flying operations in the airspace concerned. Operators are primarily responsible for safe flight operations and thus general no-fly restrictions

2. See report on encounter of NASA DC-8 with volcanic ash from the eruption of Icelandic volcano Hekla in Feb 2000: (http://www.avweb.com/pdf/volcanic_ash_cloud_encounter_nasa_grindle.pdf) should be minimised and operations should be left subject to an operators' safety risk assessment.

IFALPA supports the definition of a "low contamination (or concentration) ash" airspace based on scientific research, which is not unrestricted but not closed either. In distinction from airspace containing unsafe volcanic ash concentration, low concentration airspace can support air traffic under special operational provisions. This will limit the consequences for air traffic efficiency and capacity. These areas should be clearly defined, and communicated in the same manner as a volcanic ash notification of the ICAO International Airways Volcano Watch.

The Air Navigation Service Provider (ANSP) is responsible for providing advice and information useful for the safe and efficient conduct of flights, to prevent collision between flights and to expedite and maintain an orderly flow of traffic (quote from ICAO Annex 11). A coordinated and effective airspace management should take place in case of a volcanic warning or eruption based on contingency plans established by Regional Air Navigation Agreement.

Recommendation 4:
IFALPA believes that a global approach is needed that allows for a tailor-made solution for any airspace concerned. Operators and flight crews are primarily responsible for safe flight operations and thus general no-fly restrictions should be minimised. Operations should be left subject to the operators' safety risk assessment that is acceptable to the overseeing national regulator (safety oversight authority). ANSPs should have contingency plans available, based on Regional Air Navigation Agreement.

Aerodromes

Volcanic ash may have a serious effect on aerodromes (both destination and alternates) located downwind of a volcanic ash plume, eventually requiring complete withdrawal of services. Additional factors pose an operational risk for the flight operations:

- Reduced availability of airport services
- Reduced runway friction
- Lower visibility
- Difficulty in reading signage and markings
- Changing winds
- Electro-magnetic interference
- Evacuation of an aerodrome or air traffic services facility (resulting in reduction or withdrawal of services; etc.

The planning of an alternate airport should be upwind of the ash cloud and should always avoid having to cross the ash cloud.

Recommendation 5:
Regional contingency plans should also consider potential effects of volcanic ash on aerodromes in the region.

Operator

The aircraft operator is responsible for safe flight operations, for an airworthy aircraft, for operational support facilities and qualified crew for the area and type of operation. Operators are required by ICAO Annex 6 to have a Safety Management System to minimize all hazards. The National Safety Oversight Authority has the responsibility to approve this SMS and to supervise its execution.

In concert with the aircraft manufacturer, operational procedures for intended flight in a low-concentration ash area must be specified and trained. These procedures must include an explicit guideline on identifying the presence of volcanic ash, the level of threat, the acceptable exposure times and ash concentration and escape/contingency procedures. Safety implications must be resolved by increased engine, airframe and systems maintenance inspections covering ash susceptible areas not routinely checked in normal situations and possibly earlier component renewal. Aircraft performance and systems data monitoring, inspection and maintenance checks should be adopted in order to prevent, monitor and mitigate possible damage related to volcanic ash.

For the high concentration ash encounter standard escape procedures are established. The escape manoeuvre is based on minimising the duration of exposure of the aircraft to ash and the thrust setting to avoid/limit hazards. With regard to planning, the general policy is to avoid volcanic ash.

Low concentration ash can be completely unnoticeable to the pilot.[3] For low concentration ash encounters, long-term negative

3.The UK Flight Safety Committee estimated in a meeting in 2010 that at an ash density of $2mg/m^3$ a layer 1km thick would be semi-transparent when looking up or down through it. The wide variety of backgrounds, lighting conditions and associated clouds might make such a layer invisible. A thinner layer might be undetectable even in optimum conditions.

effects are significant: pollution, abrasion and corrosion of airframe, engine and ducting. These long-term effects constitute more an economical than flight safety aspect if proper maintenance and monitoring action is conducted. However, immediate and long-term effects on the health of aircraft occupants need to be considered.

Experience must be gathered and analysed of current findings and inadvertent ash encounters to adapt the procedures for flying through ash concentration. Data collection must never create additional risk for passengers and crew members.

Recommendation 6: The Aircraft Operations Certificate (AOC) holder must conduct a safety risk assessments prior to planned operations within or in the vicinity of volcanic ash. The risk assessment must include all affected stakeholders and must satisfy the acceptable level of safety prescribed by the safety oversight authority. The risk assessment must include clearly definable threat scenarios, actions, training and other mitigations.

Flight Planning/Flight Operations

The operator and flight dispatch are responsible for a safe flight plan free from significant ash hazards. This requires a tailor made risk assessment for the specific flight operation. Also contingency routes, alternate aerodromes (e.g. upwind) and decompression, engine and other failures (i.e. drift-down) must be considered.

At the planning stage comprehensive VA forecast information must be available in an easily understandable form to allow evaluation of the proposed operation. In flight significant changes to the forecast must be communicated to the crew in a timely manner. The flight crew must have continuous information of relevant NOTAMs/ASHTAMs and SIGMETs/AIREPs and, where possible, access to other information such as three dimensional map(s) reflecting the observed ash cloud location, extension and/or trajectory forecast, upper wind analysis and forecast at selected flight levels and satellite images.

Maintenance procedures and inspections required prior to and after operation in approved volcanic ash densities must be completed and notified to the crew. Specific MEL items must be serviceable. Extra contingency fuel should be considered. The Pilot-In-Command is ultimately responsible for safe flight and should therefore always have the best information available to determine the safest course of action.

The advent of operator's flight tracking services and seamless global communication enables dynamic flight planning to circumnavigate ash plumes.

During flight, the operator (dispatch, operational control personnel) and flight crews should continuously seek updates of the pre-flight information when en route. The flight crew should report any observation of volcanic activity to the appropriate Air Traffic Services unit. If an encounter with volcanic ash cannot be avoided the flight crew should immediately apply the procedure recommended by the aircraft manufacturers'/operator's documentation and notify the appropriate ATS facility if operational problems are encountered.

Conclusions

The zero tolerance policy on ash cloud is problematic; as it may restrict air operations to an unnecessary level. However, the lack of airframe/engine/systems certification criteria makes it unclear what an acceptable ash level and exposure would be. The lack of accurate modelling, detection and measuring/verification devices makes it impossible to clearly define three dimensional specific ash concentration areas.

The threats to human health due to exposure to volcanic ash during flight operations have to be studied and taken into account.

Several issues must be resolved to assure safe flight and avoid unnecessary complete airspace closure at the same time in case of a volcanic eruption. Subdivision of airspace according to ash type and concentration, minimising no-fly zones, dynamic flight planning and operator's risk assessment will provide relief.

The challenge will be to define three-dimensional airspace volumes with an unacceptable high ash hazard (black), volumes of no limitations (green) and volumes of an acceptable limited exposure to ash (e.g. grey, orange, yellow).

Uncertainties:

- Certification and ash tolerance/limitations for airframe and engine
- Measurement of relevant particle size and concentration and chemical (gases, aerosols, acid) contents
- Modelling
- Management of limited airspace

Recommendation 7:
IFALPA strongly believes that several issues must be resolved to guarantee safe flight in a volcanic ash environment with maximum flexible use of the available airspace. The underlying goal should always be to plan a flight path that will be free from significant ash hazards. To achieve this goal the following requirements shall be accomplished:

1. Identify the hazards.

a. Perform adequate research on the short and long term effects of volcanic ash on the entire aircraft and their occupants.

b. Conduct an in-depth risk analysis for the hazards of aircraft operation in VA.

c. Establish generic engine ash tolerance levels based on actual data and research for relevant ash parameters: content concentration, particle size/type/properties and acidity.

2. Identify the contaminated airspace.

a. Improve modelling, measurement and/or sensing accuracy of ash particle size and density in volcanic ash clouds. Compile experience and data from present and past encounters and test flights.

b. VAAC must deliver relevant data in an accurate, timely and robust way by means of measurement, imaging, modelling and validation.

c. The appropriate safety oversight authority shall establish a danger area, where necessary.

d. Uniform global criteria for closure of (parts of) airspace should be applied in case of unacceptable hazardous ash concentrations (the no-fly black zone). Closure should be based on unambiguous validated data and executed in accordance with global 'closure criteria'.

e. Implementation of one or more intermediate levels of ash hazard/concentration with restrictive use and additional operating rules and maintenance requirements (e.g. red, orange zone) needs further study and validation.

3. Flight Operation.

a. Responsibility for flight operations should remain with the operators, except for hazardous high-density ash levels exceeding aircraft and engine tolerance limitations (black zone). The black zone should be defined by the National Safety Oversight Authorities responsible for regulating flight operations, not by Air Traffic Management authorities or Air Navigation Service Providers.

b. The operator must fulfil this responsibility for a safe flight and conduct a safety risk assessment prior to any operation in low-concentration ash (grey, red, orange zones) and get approval from his Safety Oversight Authority. The operators should effectively train crews for operation in these zones.

c. The Pilot-In-Command is ultimately responsible for safe flight and must therefore have insight in all relevant ash data and specific aircraft procedures. As the person ultimately responsible, the Pilot-In-Command must retain the final decision whether a flight can be conducted safely.

d. Operators should refrain from any disciplinary actions when flight crews exercise their flight safety responsibility not to fly in ash (i.e. delay departure or diversion).

e. VFR operations ("See and avoid") shall not be considered as a suitable method of conducting commercial air transport operations in, or near, ash. A restriction to fly in potentially or actually contaminated areas only under daylight VMC might be an adequate mitigation measure to avoid high ash concentration, but does not necessarily protect from low ash concentration that might still be hazardous.

References

ICAO Doc 7030 Convention on International Aviation

ICAO Annex 2 Rules of the Air

ICAO Annex 3 Meteorology

ICAO Annex 6 Operation of Aircraft

ICAO Annex 8 Airworthiness

ICAO Annex 11 Air Traffic Services

ICAO Annex 15 Aeronautical Information Services

ICAO Doc 9691 ICAO Manual on Volcanic Ash and Radioactive Material

ICAO Doc 9766 Handbook on the International Airways Volcano Watch

EASA Safety Information Bulletin 2010-17

NASA/TM-2003-212030 Engine Damage to a NASA DC-8-72

FSF publication Volcanic Hazards and Aviation Safety, may 1993

Comparison of VAAC atmospheric dispersion models, RMetS, 2007

Reducing the Risk from Volcano Hazards, US Dpt of Interior, 2009

Volcanic Ash Contingency Plan EUR Region, ICAO EUR Doc 019, September 2009 (plus amendment proposals 2010 stemming from EUR/NAT VATF and NATSPG)

IAVWOPSG, 2005

Appendix A

Recent (2010) developments of volcanic ash dispersion modelling include:

1. Dispersion model: A new version of MOCAGE (Large Scale Chemical atmospheric Model), developed for nuclear or chemical accidental releases, is currently operational. The volcanic ash dispersion version will be tested from summer 2008 and is planned to be fully operational from early 2009 to replace the current MEDIA model. The meteorological parameters are given by the French model ARPEGE or the model of ECMWF (European Centre for medium range Weather Forecast) on a global domain and at a resolution of 0.5 degrees. The range of forecast can reach 72h for ARPEGE and 180 h for ECMWF with two runs a day (00, 12 UTC)

2. MOCAGE, a semi-lagrangian model, integrates convection and 3D precipitations to calculate washing. Future developments include taking into account vertical and horizontal distribution of ash particles size.

3. PERLE is made of MESO-NH, a meso scale non-hydrostatic weather model, plus a high-resolution dispersion model SPRAY. It can provide data within the European geographic domain at a resolution of 8km on a 240/240 km area, centred on the volcano source. The dispersion model can be tuned to provide a final resolution of 1 km.

4. Météo France as a RSMC (Regional Specialized Met Centre) designated by WMO is involved in the project ‘Ensemble’ leaded by the Joint Research Centre in Italy. This European project launched in 2000 has now gained maturity. Designed for nuclear accident dispersion modellers, it provides a platform for any model comparison and even for multi-models production based on different single models. MEDIA, MOCAGE and PERLE outputs have already been provided for comparisons on the platform. It could be the place to continue model inter-comparisons as the one run after the Grimsvötn Icelandic eruption or to make tries on multi model prediction.