Background

GIE EUMETNET (the network of European Meteorological Services) coordinates a number of collaborative European meteorological activities and represents the collective Membership of 26 European Met Services at a European level.

Collaboration enables economies of scale, consistency of approach, common methodologies, and allows for optimisation of efficiency in operating the European infrastructure required for monitoring and forecasting.

A primary activity coordinated by EUMETNET is the EUMETNET Composite Observing System (EUCOS), a key component of our European infrastructure, providing an optimised, quality controlled in-situ network of observations for weather prediction and monitoring the atmosphere and oceans. EUCOS is an operational programme with the following components:

- Ground based site specific observing systems;
- Ground based remote sensing observing systems (e.g. radar, radiosondes, windprofilers, measurements from aircraft);
- Ocean based site specific observing systems;
- Ocean based remote sensing observing systems.

The UK Met Office and Météo-France which operate the 2 Volcanic Ash Advisory Centres (VAACs) in Europe are also Members of EUMETNET. The majority of EUMETNET Members have also been using their own dispersion modelling capabilities to add additional support and advice to national authorities and governments.

The capabilities provided by EUMETNET and its Members are designed to complement those available through EUMETSAT and ECMWF. In Europe the combination of space observations from meteorological satellites and the ground based network of observing systems are designed to be collectively optimal in providing the best value real time data for weather monitoring and forecasting.

EUMETNET works within the framework of policies and programmes set by WMO and coordinates its activities with WMO.

What is needed?
The impact of the Eyjafjallajokul eruption on civil and military aviation has highlighted 3 needs:

1. Observing the Source.
   The need for continued improvements in monitoring and measuring the material and gases erupting from the volcano in order to further improve the accuracy of the models.

2. Observing the Plume.
   The need for enhancements to observing system to enable improved monitoring and verification of the dispersing ash and gaseous plumes (over possibly many days).
3. **Forecasting the Dispersion of the Airborne Material and Gases.**
The need to maintain leading edge operational dispersion modelling capability that can be run in real time.

These needs were met through the ICAO agreed operational IAVW and VAAC responsibilities which have been delegated to National Meteorological Services; in this case, the Icelandic Meteorological Organisation and UK Met Office. However, it has become clear that the needs of aviation are changing in light of the Eyjafjallajokul eruption. A review of these changing requirements and recommendations for improvements to satisfy them is timely, and will enable greater confidence in decision making by the aviation authorities and airlines.

**What is being done?**
Taking each of the 3 areas in turn.

1. **Observing the Source**
The Icelandic Meteorological Organisation (a Member of EUMETNET which also incorporates in its mission the monitoring of seismic activity and providing advice to Icelandic citizens) took the lead in providing the necessary source data about the volcano. IMO worked very closely with the UK Met Office to coordinate their two key responsibilities. IMO was able to mobilise resources to provide enhanced monitoring information directly from the volcano and in real time. Changes in the source term led to updates in the model forecasts. Work is now underway to explore enhancements to the monitoring systems available including the deployment of additional seismometers in the area of Eyjafjallajokul and Katla volcanoes and the relocation of a Doppler radar from Italy.

2. **Observing the Plume**
The EUMETNET community, working with the academic research community were able to respond quickly during the start of this volcanic event to provide access to non-operational sources of data gathered from observational systems (for example LIDAR and research aircraft). Similarly, the research community which operates the research aircraft did an excellent job in releasing aircraft in coordination with the National Meteorological Services (NMSs) to enable monitoring of the ash plume.

3. **Forecasting the Dispersion of the Airborne Material and Gases**
The EUMETNET community, led by the UK Met Office and Météo-France, maintain leading edge dispersion modelling capabilities. During the event there was considerable cooperation between the various VAACs surrounding the North Atlantic, comparing output and verification information.

**What more does EUMETNET propose?**
Taking each of these 3 areas in turn.

1. **Observing the Source**
While in Iceland and Italy, Volcanoes are very well monitored and eruptions typically reported immediately, the most critical phase from an aviation point of view is the onset of the eruption which may go unnoticed for several hours, and pose the greatest safety threat for aircraft entering the plume at night or in IMC. Over Iceland where for several months darkness prevails for most of a 24-hour day, there is a need to ensure that IMO is appropriately resourced for alerting the VAAC and the authorities in the case of an overnight eruption given that many transatlantic routes are very close to the volcanoes there.
IMO has proposed to ICAO that a radar is placed on NE-Iceland for eruption monitoring. IMO see this as a vital warning tool for volcanoes in N-Iceland, which are not currently covered by radar. This is especially important to give warnings of an ash cloud when an unexpected eruption starts, and this does happen. IMO plan to raise this with ICAO again later this summer.

Further research into the use C- and X- Band Doppler radar to monitor eruptions could be undertaken to better understand the reflectivity signal in relation to the ash content.

As noted below, dropsondes and UAVs also offer potentially exciting opportunities for enhancing the monitoring and measurement of the source, but much more research is needed.

2. Observing the Plume
There are 5 areas where enhancements could be realised (which could build upon and utilise EUMETNET coordinated programmes and systems):

a. Integrating EARLINET in to the operational observing network operated by EUCOS. A coherent LIDAR observing network could be enabled by linking EUMETNET’s experience in proven operational systems, infrastructures with the European Aerosol Research Lidar NETwork (EARLINET). Combining EARLINET R&D coordination with EUMETNET components provides an opportunity to develop a European wide atmospheric aerosol ground based remote sensing LIDAR network. Such a network would be a significant addition to the integrated observing network (satellite, aircraft, ground based site specific, and ground based remote sensing observations) required to monitor future volcanic ash cloud episodes in Europe. Rapid access to quality controlled, uniformly formatted data accessible to key customers through robust data portals would be a key added value components offered by EUMETNET to enhanced collaboration. It should be noted though that LIDAR systems work best in clear skies and other techniques are required to complement these systems.

b. In addition to these ground based LIDAR systems, aircraft mounted hyper-spectral Raman lidar systems offer the possibility to make calibrated measurements of ash volume concentration. These systems are in operation on the ground but also on aircraft (the new Research aircraft HALO of DLR, but also the DLR Falcon has a number of aerosol in-situ instruments on board). Such airborne systems also offer the benefit of being targeted and that they can get above or between cloud layers to measure ash that may not be visible from ground based systems. Further research should be conducted to investigate the true value of such systems as part of the composite volcanic ash monitoring system.

c. Ceilometers. The Meteorological community has operated ceilometers for many years in support of aviation for measuring cloud height. Ceilometers can be modified to enable them to detect suspended volcanic ash. Germany for example, operates a network of 50 such systems. LIDAR data (above) if the quality is assured, can be used to enable improvements in the calibration ceilometers. However, again, ceilometers do not work if cloud is masking the ash.
d. **Radiosondes equipped with aerosol sensors.** Again, radiosondes are a traditional observing technology for the meteorological community. Recent developments have enabled the addition of aerosol and gas sensors to the sondes. The benefit of these new technologies has yet to be proven, but they offer a further complementary capability in an integrated system, especially since it may be possible for these alternative sensors be deployed to remote locations which already launch radio sondes (for example the Faeroe Islands and the Shetland Islands).

e. **Drop Sondes.** Dropsondes are typically launched from aircraft via a parachute and have the advantage of being a observing system which can be targeted. We are currently exploring whether dropsondes can be developed to include aerosol instrumentation for a reasonable price and in a realistic time-frame to be launched from the high-flying research aircraft (Falcon, BAe146 etc.)

f. **UAVs.** Like dropsondes, UAVs have the potential advantage of being a system which can be targeted, either at monitoring the source or the plume. These systems are in early days of research but offer a potentially unique means of measuring the content and location of the ash plume without putting aircrew and scientists into harms way.

g. **Enhanced coordination of European Research Aircraft.** The FP7 EUFAR programme already offers a coordinated programme for optimising the European research aircraft fleet. This programme could be used as the foundation for exploring potential solutions for utilising these scarce and expensive resources in times of crisis. There is agreement to download inflight data in an agreed format onto a centralised data centre which can then be easily accessed. The agreed data centre is the BADC (British Atmospheric Data Centre) in the UK. It should be straightforward to link to the BADC and use this infrastructure for fast access. For example we are already in discussion with EUFAR about whether EUFAR could include on its website a "VA flight readiness" page that would allow at-a-glance information on which aircraft are currently operationally equipped and available for aerosol measurements.

h. To establish access to a coherent, operational portal for all volcanic ash observations in Europe, updated in real time.

3. **Forecasting the Dispersion of the Airborne Material and Gases**
There may be benefit though from enhancing these capabilities through a coordinated cooperation programme within Europe and globally to enable sharing of expertise and inter-comparison of techniques to ensure the best expertise is built in to these operational systems. Additionally we need to be sure our models handle the SO2 gaseous plume and the chemical processes involved since sulphuric acid is a hazard to aviation that has so far not attracted much attention. Such an activity will be coordinated with WMO and will feed through into supporting future agreed VAAC operational activities and responsibilities.
Summary
The EU and EUROCONTROL are now working towards a volcanic ash situation solution for the future which more strongly discriminates between "safety" and "damage to aircraft" issues. Engine loading to ash (concentrations and duration of exposure) is key, and to verify and predict exposure a 24/7 integrated observing system (for lifetime of future events) will be of increasing importance.

EUMETNET and its 26 Members wish to play an active role in identifying and delivering opportunities for wider cooperation with existing coordination activities. The focus will be to develop European wide collaborative in-situ monitoring systems to support volcanic ash cloud monitoring. EUMETNET has some experience with operationalising research networks (for example the European wind profiler network (E-WINPROF) is a combination of systems operated by the NMSs and by research organisations).

From experience we know it takes a big effort to make the data from research systems available on an operationally sustained basis. Therefore the NMSs and the research institutes must be given the resources to enable them to deliver the data for future events. EUMETNET can take the lead in coordinating available measurements at European level. The goal must be working towards operational available data, for this it is necessary to agree contracts with the research community (like EARLINET) to have access to data in cases of future volcanic eruptions.

There are two categories of coordination and cooperation in observations:
  a. Quick wins through enhancing existing NMS and research capabilities (for example making them more operationally available and understanding their quality)
  b. Coordinating or sponsoring research activity (e.g. in academia, COST and FP7) to fast track some of the systems with high value for this problem (e.g. dropsondes, cloud radar and UAVs).

EUMETNET and its Members should be invited to establish access to a coherent, operational portal for all volcanic ash observations in Europe, updated in real time. This would include, data currently made available through the EUFAR portal.

In addition, EUMETNET is well placed to enable coordination and cooperation in the field of dispersion modeling within the meteorological and research communities with the aim of ensuring the pull through of the best research in Europe in to the best operational modeling systems at the VAACs.

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