3B.4 THE UK MET OFFICE ENVIRONMENTAL MONITORING AND RESPONSE CENTRE (EMARC)

Gareth D. Powell*
United Kingdom Met Office, Exeter, England

1. INTRODUCTION

The Environmental Monitoring And Response Centre, abbreviated to EMARC (pronounced ee-mark), is a weather forecasting position within the Operations Centre at Met Office Headquarters in Exeter, England, and is continuously manned 24 hours a day, 7 days a week, 365 days per year.

"Environmental monitoring" means we are not just watching the weather, but actively gathering information on a whole range of natural environment phenomena (including the weather), and using this information to predict how these different phenomena may combine to grerate natural hazards which might impact on society.

Then in response we produce operational services, warnings and advice for government, emergency responders, and the wider public, so that they can take prepatory and mitigating action as required.

2. EMARC BACKGROUND: 1980s and 1990s

EMARC began life in 1986 following the Chernobyl incident, following which the Met Office quickly set up a dedicated atmospheric dispersion service to forecast the spread of the radiological emissions and fallout, which of course was highly dependent on weather. Shortly after this, the Met Office also developed its first atmospheric dispersion model known as the Nuclear Accident Model (shortened to NAME).

Then in 1989 the Met Office was appointed as one of the first Regional Specialist Meteorological Centres (RSMC) by the World Meteorological Organisation (WMO) and the International Atomic Energy Agency (IAEA). The establishment of RSMCs around the globe was motivated by the Chernobyl incident, to provide dedicated early warning and forecasting services for nuclear accidents. The Met Office RSMC responsibility was hence delegated to EMARC.

Following this, in the early 1990s the Volcanic Ash Advisory Centres (VAACs) were established by the ICAO, and the Met Office was appointed as London VAAC, the responsibility of which was again delegated to EMARC. The RSMC and VAAC responsibilities thus made EMARC a permanent, specialist, atmospheric dispersion capability, and we continue to hold these two international responsibilities today.

3. EMARC EVOLUTION: 2000s

During the 2000s, the UK witnessed a series of high impact natural hazard events where weather was either the key driver or at least a major influence, such as the Foot and Mouth epidemic in 2001, the Buncefield oil storage fire in 2005, a Bluetongue outbreak in 2007, severe summer flooding in 2007, winter flooding in 2009, the series finally culminating in the eruption of the Eyjafjallajökull volcano in Iceland, which severely disrupted UK, European and trans-Atlantic aviation for several weeks. This series of events brought natural hazards to the attention of the general population, but also to the UK government.

In particular, after the 2007 summer floods, a 'lessons learned' review was commissioned by the UK government, known as the Pitt Review. Published in 2008, a key line from this review stated: "*The UK system of providing advice and warnings on potential natural hazards was too disjointed, and scientific information was not translated into useable and actionable information".* The review further recommended: *"...improving resource integration between scientific organisations, governmental departments, and emergency responders"*.

In essence, the report said that while the advice and actions of individual agencies was sound, there existed a need for a more joined up approach to natural hazard forecasting and responsive action. In the short term this led to the founding of the dedicated Flood Forecasting Centre, a partnership between the Met Office and the Environment Agency, which has greatly improved flood forecasting in the UK, and gave a model on which to base other partnerships.

The volcanic eruption in 2010 acted to confirm the findings and suggestions of the review, as overly-large areas of airspace were closed since the safe limits of ash concentration were uncertain. This was an inefficient response, but it also weakened public perception and trust in agencies involved, not least large numbers of the public thinking that the Met Office had closed the airspace!

* *Corresponding author address:* Gareth D. Powell, F1 Operations Centre, Met Office, FitzRoy Road, Exeter, EX1 3PB, United Kingdom;
email: gareth.powell@metoffice.gov.uk

4. NATURAL HAZARDS PARTNERSHIP

In response to the Pitt Review and the Icelandic eruption, a partnership of 13 UK government departments and public bodies was formed (later increasing to 17), including organisations with expertise in different aspects of natural hazards, the idea being to implement the Pitt Review recommendations by taking a more collaborative and integrated approach to predicting, responding to, and recovering from natural hazards, thereby improving UK resilience. This partnership is known as the Natural Hazards Partnership (NHP). Further information on the NHP can be found in Hemingway and Gunawan (2018).

In recognition of weather being either the main cause, or a major influencer of many natural hazards, the Met Office took the lead for transforming much of the combined expertise of the partnership into operational services which could be delivered to responders, and again this responsibility was largely delegated to EMARC as we had long-establshed experience in collaborative working and producing operational output through our long-standing RSMC and VAAC roles.

As such, EMARC's portfolio of forecasting and advice services significantly expanded through the NHP, and an overview of the most high profile or high impact ones now follows, along with details of the key collaborators involved

5. INTERNATIONAL SERVICES

EMARC was born out of international-scale atmospheric dispersion forecasting, and these two main responsibilities, the RSMC for radiological events, and the VAAC for volcanic eruptions, continue to this day. These responsiblities extend beyond the NHP, but still involve collaboration with key international organisations to deliver operational services.

5.1 Regional Specialist Meteorological Centre

Real-life RSMC events are mercifully rare, but we rehearse the procedures through monthly global exercises with the IAEA and other RSMCs, and once per quarter we take the joint lead of these exercises with RSMC Tolouse at Météo-France.

We still use the NAME model for atmospheric dispersion forecasting, though it has since been rebranded as the Numerical Atmospheric-dispersion Model Environment (still abbreviated to NAME) to reflect the fact that it models far more than just nucelar releases. Unsurprisingly it is far more sophisticated than in 1986, and as well as the trajectory and dispersion of particles it can now model atmospheric chemistry processes (e.g. decay) and atmospheric physics processes (e.g. buoyancy and fallout).

In addition to sophistication, the modern NAME model also has the benefit of speed. The original deposition plume map for the Chernobyl incident was hand-drawn, based on nothing more than mean low-level winds and a 'dispersion factor', and yet must have taken hours to analyse and draw up. Converesely the modern NAME model can produce complex dispersion plumes, trajectories, doseage maps and deposition maps within a matter of minutes.

5.2 Volcanic Ash Advisory Centre

EMARC also continues as London VAAC, one of nine VAAC areas in the world. London VAAC may have one of the smallest areas of VAAC responsibility, but this area encloses a cluster of volcanos across Iceland, and is influenced by dynamic temperate weather patterns, meaning that the ash plume from an eruption can quickly spread far from the volcano and potentially become very complex. Hence the threat of significant disruptions to aviation remains very real.

For VAAC forecasting, EMARC collaborates very closely with the Icelandic Met Office, who are experts in volcanism and provide a volcanic monitoring and eruption risk service, as well as detailed information on eruption plume heights and composition when an eruption is underway, which is key information for accurately modelling an ash plume with NAME.

Icelandic eruptions are thankfully infrequent, but as with our RSMC responsibiltiy we conduct monthly exercises jointly with Iceland Met Office to rehearse VAAC forecasting procedures.

6. UK SERVICES

6.1 CHEMETs

These international atmospheric dispersion principles can be scaled down to a much more localised level, especially with high resolution NWP models widely available. Hence we can also provide local dispersion forecasts for smaller and much more common pollution events in the UK, such as building fires, chemical leaks, windborne biological agents, or minor nuclear releases, all on a much shorter timescale than VAAC or RSMC services, typically hours rather than days.

We produced local dispersion forecasts mainly for emergency services to assist with their immediate response to an event, so they can take action and advise the public accordingly.

For most incidents we will produce a CHEMET (short for CHEmical METeorology), along with an accompanying written forecast of the general weather. A CHEMET shows a map of the local area with a dispersion plume superimposed, and a variety of plume maps can be produced to provide different information. Most emergency services will be content with a basic plume showing low-level concentration levels near the surface, as this provides the key information from their point of view, i.e. where pollutants may be present at or near the surface.

More detailed plumes are available for more thorough analysis, such as total deposition, absolute air concentrations, total column load, wet deposition, etc, and these might be used after an event to see if there is any contamination of, for example, water sources or food sources. CHEMETs are our most common ad hoc service, on average we produce around 300 per year, though this can vary greatly, for example we issued 600 CHEMETs over summer 2018 alone due to multiple wildfires.

So EMARC's atmospheric dispersion origins can be applied to the domestic scale as well as the international scale. But now with the Natural Hazards Partnership in place, EMARC has branched out into forecasting other high-impact natural hazard events where weather is a key driver. Most of these are done in collaboration with at least one other member of the partnership, and some examples now follow.

6.2 Air Quality

Air quality is a subject of increasing interest around the world. Since 2012, EMARC has produced a daily air quality forecast in collaboration with DEFRA, the Department of the Environment, Food and Rural Affairs. A specialist air quality model is used, along with weather patterns and information on long-term pollution sources such as busy roads or industrial sites, to predict episodes of poor air quality in the UK. This model can predict general particulate concentrations of PM10 and PM2.5, but also specific atmospheric chemicals such as ozone and nitrous oxide. A network of air quality sensors around the UK are then used to monitor real-time pollution levels and verify the forecast and the model.

In addition to locally-produced pollution, pollutants can be brought in from outside the UK too, for example Saharan dust, or even smoke from wildfires on other continents, so monitoring is required much further afield, using satellite imagery and global-scale dust models.

6.3 Wildfires

The UK does experience wildfires, these are much smaller scale than those witnessed in the USA or Australia for example, but they can still have an impact on health if they are located close to populated areas, and there are in fact very few parts of the UK further than a few tens of miles from populated areas, so this is often a risk. EMARC forecasts wildfire risk based on various surface parameters like soil moisture, presence of dry fuel sources like dead plant material, which combine to give an overall fire potential across the UK. Once fires are underway, EMARC can produce CHEMET plumes for the spread of smoke

6.4 Temperature Health Alerts

EMARC issues temperature health alerts for heat in summer and cold in winter. "Extreme" temperatures are very rare in the UK, but Public Health England (PHE), in partnership with the National Health Service (NHS), have identified temperature thresholds, both hot and cold, beyond which hospital admissions rise significantly for certain health problems, like heat stroke or pneumonia. Hence issuing temperature alerts allows health authorities to prepare for a potential increase in admissions. This is done on a regional basis, with slightly different thresholds for each region, and on an escalating scale based on the probability of thresholds being reached, rather than the severity of the temperature.

6.5 Daily Hazard Assessment (DHA)

Much of the collaborative work of EMARC is consolidated into a daily forecast called the **Daily Hazard Assessment**, which is an at-a-glance overview of current and forecast natural hazards across the UK, summarised in maps and text, with links to further information as required. The different hazards covered are: Significant Weather, Flooding, Volcanic Ash, Space Weather, Landslides, Wildfires, Temperatures, Air Quality, Earthquakes, Drought, and Space object re-entry(!).

This document is sent to central government daily, currently to around 14,000 different recipients, and is the most visible service coordinated and delivered by the Natural Hazards Partnership. It can sometimes be very complicated if multpile natural hazards are ongoing or anticipated, or can be very simple.

6.6. Civil Contingency Advisors (CCAs)

EMARC also provides support to a network of Met Office "Civil Contingency Advisors" (CCAs) located

around the UK. The CCAs are meteorological advisors who provide regional weather advice direct to emergency responders and local governments, and have expert local knowledge of their geographical areas and their customers. EMARC, being 24/7, can provide resilience to the advisor network by providing cover out of hours (nights and weekends), or as an extra node in this network during high-impact events when there are multiple demands on the advisors.

EMARC also channels expert advice to the advisors on ongoing or forecast natural hazard events, so that they are able to brief customers and answer questions with confidence. So in this way too, specialist information from natural hazards partners can be transformed into operational services to recipients who can use it to take actions.

7. RESPONSE AND RESILLIENCE

With a diverse range of services, inevitably EMARC forecasters will be met with conflicting demands if multiple hazardous events occur simultaneously, so prioritisation becomes a key part of the response to natural hazard events.

The international responsiblities, RSMC and VAAC, take priority over all domestic UK-centric services, and delivering these services would occupy the vast majority of an EMARC forecaster's time during radiological or volcanic events respectively. However, EMARC has built-in resillience to cover significant extra workload, as it is colocated with the Met Office Space Weather Operations Centre (MOSWOC), and all EMARC forecasters are also cross-trained in Space Weather, and vice versa, so there are always two EMARC forecasters on duty 24x7. Hence during major events, or otherwise busier times, the increased workload can be spread between two forecasters, ensuring that most services will continue to be delivered.

8. R2O AND O2R

As well as collaborating with external expert agencies, the Met Office also has its own in-house expert scientists in the Atmospheric Dispersion and Air Quality group (known as ADAQ), who undertake scientific research and development to improve understanding of dispersion processes and how to better model them using NAME. ADAQ also deal directly with some external customers for research and longer-term services, such as a bluetongue risk outlook for DEFRA.

ADAQ also work closely with EMARC to ensure their research and development is pulled through into operational services delivered by EMARC, and in turn EMARC provide ad hoc operational feedback on NAME performance and function. During major dispersion events, ADAQ also provide expert scientific support for using the NAME model, well beyond the day-to-day working knowledge of EMARC forecasters, such as refining the modelling of a dispersion source using more advanced techniques, or making adjustments to NAME programming.

EMARC forecasters also have regular refresher training on atmospheric dispersion, delivered by ADAQ scientists, which includes NAME updates, practice dispersion scenarios, and satellite imagery interpretation. The refresher training also provides a regular two-way forum in which EMARC forecasters can provide ADAQ scientists with feedback on NAME performance and functionality, and further training needs.

9. SUMMARY

From niche origins, the services provided by EMARC have grown to cover a full range of impact scales, from localised events which may cause minor disruption, up to international catastrophic events which can cause major economic losses and severely impact wider society, including potential loss of life.

The services delivered by EMARC utilise the combined expertise of the Met Office and our natural hazard partnership collaborators, and provide useable and actionable advice to responders and government, either directly through EMARC or via the civil contingencies advisors, all the while working with ADAQ to improve NAME modelling performance.

In this way, EMARC and the wider UK Met Office contribute to UK resilience to natural hazard events, while remaining ready to respond to international-scale events.

10. REFERENCES

Hemingway, R. and Gunawan, O. (2018) The Natural Hazards Partnership: A public-sector collaboration across the UK for natural hazard disaster risk reduction, International Journal of Disaster Risk Reduction 27, pages 499-511.

11. USEFUL WEB LINKS

11.1 General

Met Office Public Sector Services
https://www.metoffice.gov.uk/services/public-sector

Met Office Natural Hazards Services
https://www.metoffice.gov.uk/services/public-sector/emergencies

The NAME Model
https://www.metoffice.gov.uk/research/modelling-systems/dispersion-model

11.2 International Services

London VAAC
https://www.metoffice.gov.uk/aviation/vaac/

RSMC (very old!)
http://research.metoffice.gov.uk/research/interproj/rsmc/index.html

11.3 UK Services

General UK atmospheric dispersion response
https://www.metoffice.gov.uk/services/public-sector/cbrn

CHEMETs
https://www.metoffice.gov.uk/services/public-sector/chemet

Air quality forecasts
https://www.metoffice.gov.uk/guide/weather/air-quality

Cold weather alerts
https://www.metoffice.gov.uk/health/yourhealth/cold-weather-alerts

Hot weather alerts
https://www.metoffice.gov.uk/services/public/health/health-services/heat-health

Wild Fires
https://www.metoffice.gov.uk/public/weather/fire-severity-index/

Daily Hazard Assessment
http://www.naturalhazardspartnership.org.uk/products/dha/

Flood Forecasting
https://www.metoffice.gov.uk/services/public-sector/floodforecasting

The Natural Hazards Partnership
http://www.naturalhazardspartnership.org.uk/