An overview of the UK Met Office's Meteorological Monitoring System and on key future challenges facing the network.

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Abstract
The UK Met Office owns and operates a network of over 280 automatic weather stations (AWSs). The entire network was upgraded between 2008 and 2010 to a new Meteorological Monitoring System (MMS). Key benefits of the new MMS network include making greater use of measurements by transmitting all minute resolution data to a central location, allowing end-to-end system monitoring and control from a central location, and crucially a greater overall flexibility.
Recent changes to the network, taking advantage of this flexibility, include integration of new sensors, and a series of upgrades required to achieve certification against the UK Civil Aviation Authority standards for use on civil airfields.
This paper provides a brief description of the UK network including details of the MMS solution. It will also consider some of the challenges that the network faces over the coming years, including the increasing demand for higher spatial and temporal resolution observations, requirements for new data types, and the constant challenge for delivering cost savings.

Automatic surface observations in the UK
In the 1970s, the Met Office operated a surface observing network consisting of approximately 100 stations. Observations were transmitted hourly, and all observations were manual. The network distribution was uneven, with large data sparse areas in Scotland, the English Lake District, Wales and Northern Ireland (see Figure 1).

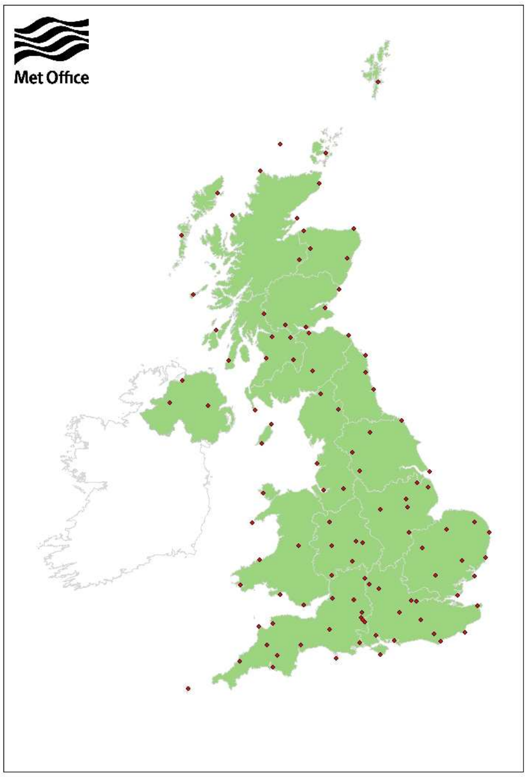

Figure 1: Met Office synoptic network as on 01/01/1970. (© Crown Copyright, the Met Office)

For comparison, Figure 2 shows the Met Office's synoptic network as on 1st January 2010. The red dots in Figure 2 are sites that were open in 1970, and still operating in 2010. The maps clearly illustrate the expansion of the synoptic network over this period, which has only been possible due to the introduction and development of automatic weather stations.

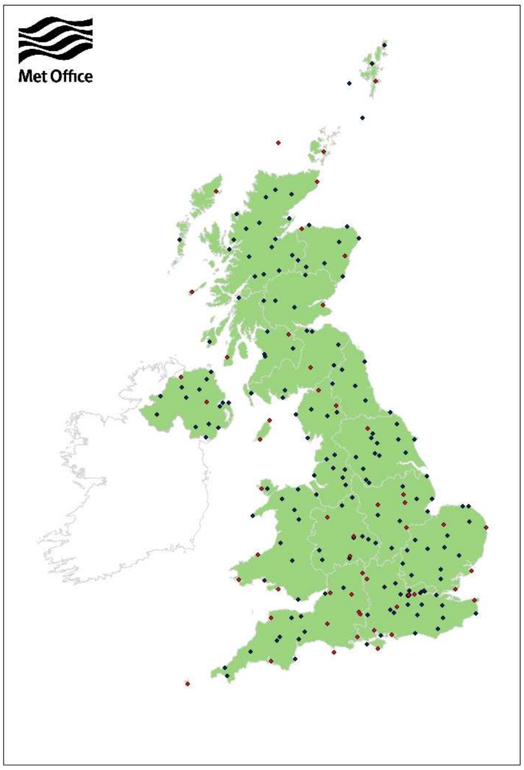

Figure 2: Met Office synoptic network as on 01/01/2010. (© Crown Copyright, the Met Office)

At the time of introducing the new Meteorological Monitoring System, the Met Office surface observing network consisted of ~200 sites, and five different automatic systems. The different systems in use were aging and becoming more difficult and costly to enhance, manage and maintain. They relied heavily on local on-site data processing, leading to major expense when introducing upgrades, and were not all able to interface to modern instruments. Although the sensors and certain parts of the processing software were able to cope with continuous data flows, they were fundamentally linked to hourly reporting and transmission of data using old alpha-numeric coding conventions (such as FM-12) which have been in existence since observations were produced manually without any automatic aids. This was not ideal given the growing demands of nowcasting systems, and developments in numerical weather prediction (NWP) model data assimilation which require more frequent, flexible reporting of observations, and new data types such as precipitation drop size distribution, not easily encoded within FM-12.
In order to address the varying needs of the many users of land based observations, the Met Office required a more versatile and scalable observing infrastructure, one where expansion or contraction of the network and/or the range of sensors at a given site, attracts minimal marginal costs. It was envisaged that this would be best achieved by taking full advantage of electronic sensing (by getting best value out of sensors which provide virtually continuous measurements), and by carrying out far more data processing centrally.

Various options were considered, including continuing with the existing network, designing a new system in-house, or purchasing a new system from a third party supplier. The third option was selected. This option had the benefit of combining the data telemetry and Supervisory Control And Data Acquisition (SCADA) expertise of the supplier, the data logging expertise of their subcontractor, with the meteorological expertise of the Met Office.

The Meteorological Monitoring System (MMS)

The Meteorological Monitoring System (MMS) is supplied by CSE Servelec and is based on SCOPE-X, their well established data telemetry and SCADA suite of software. SCOPE-X consists of a resilient real-time database, seamlessly united to an Oracle long-term historic database, and features flexible data interfaces. SCOPE-X is currently widely used within the water and utility sectors for other wide area applications, with many other current UK users including the Environment Agency, National Grid Gas, Severn Trent Water, and Trinity House.

The core of the solution comprises of two sets of central server computers acting as a duty/standby pair located in primary and backup computer halls. This arrangement ensures that if one server or computer hall has technical problems the system will continue to operate seamlessly and data will remain available to downstream systems and users. MMS also contains a pair of database servers, providing a 12 month rolling archive of minute resolution data from all sensors at all sites, and web servers which enable desktop users to access information within the real time and historical databases.

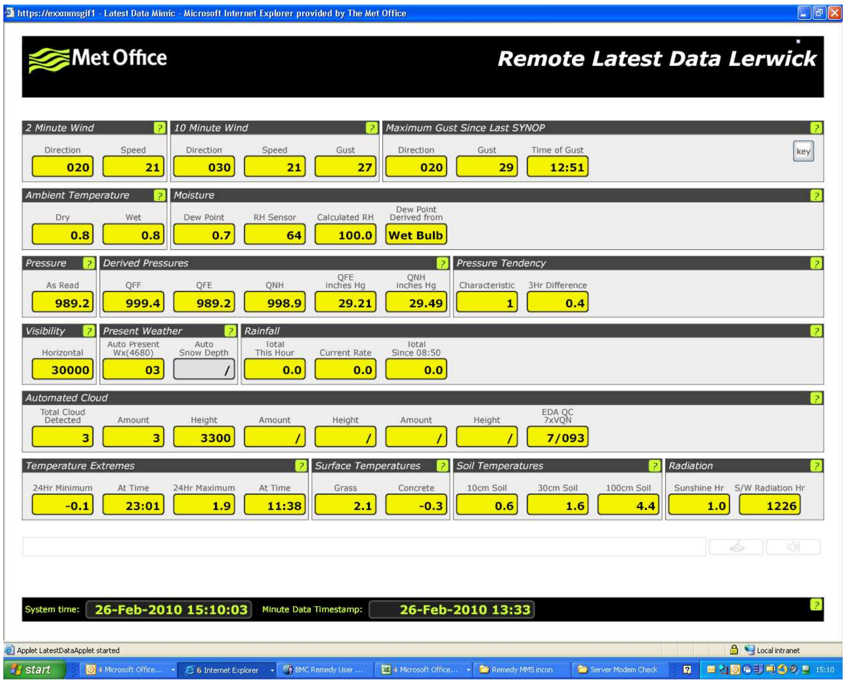

Figure 3: MMS latest observations display. (© Crown Copyright, the Met Office)

The central servers provide extensive data monitoring, automatic alarms, calculation of derived values from embedded and basic user-definable algorithms, and various facilities for implementing centralised automatic control. Statistical functions and consequential alarm generation are also standard features of the SCOPE-X system. Alarms may be generated from any values within the system, including raw data, derived data, and statistical results.

The system caters for configurable scheduling and prioritisation of data logger communications, and the automatic polling of loggers utilises existing Met Office communications infrastructure, a mix of IP, PSTN and GSM.
Campbell Scientific are sub-contractors to CSE Servelec. Campbell Scientific have over 30 years of meteorological experience, and their equipment has proven reliability in the field. Their new generation of data loggers offer a powerful and flexible programming interface which enable them to be readily interfaced with the SCOPE-X central system. The loggers interface with all existing sensors, and are flexible enough to accomodate the addition of new sensors in the future. The loggers collect, process and store data from all sensors, which are then retrieved by the central servers in Exeter where they are further processed centrally to generate and transmit the hourly FM-12 coded messsages. A major difference between MMS and previous systems is that MMS retains the high resolution data which are of considerable value to various users (for example forecasters, research scientists, engineers, and quality control staff). Data sampling is actually carried within the loggers at a variety of sub-minute frequencies in line with WMO recommendations, before storing minute values for all sensors from all sites, along with associated quality indicator flags, within the data archive. Further numerous quality control checks are applied within the central system prior to producing and transmitting the FM-12 coded messages.

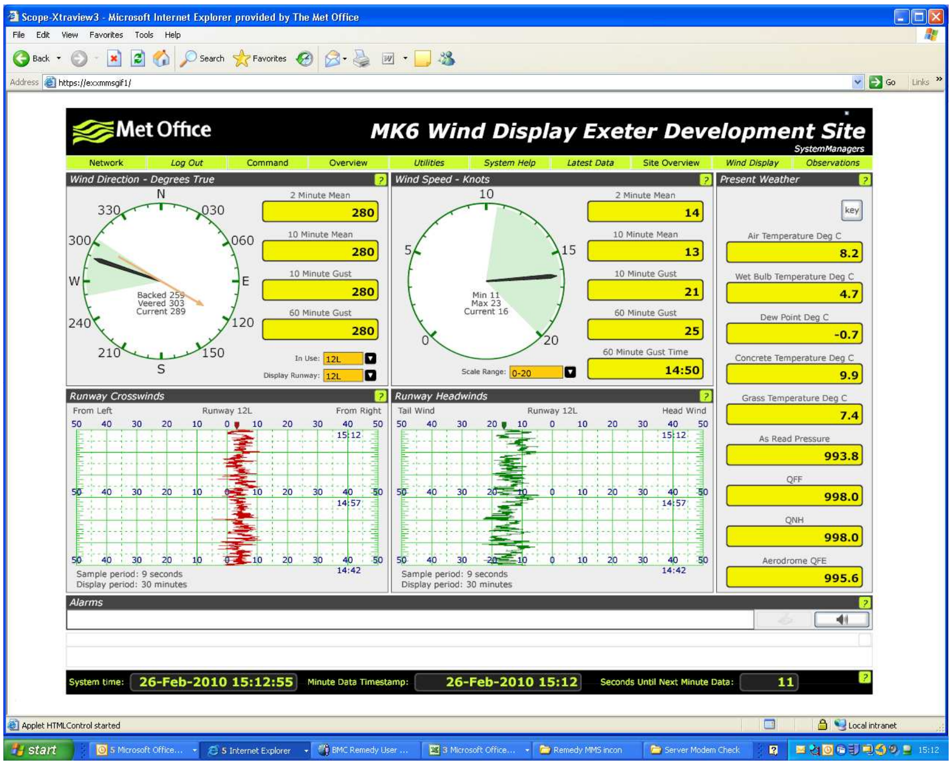

Figure 4: MMS wind display. (© Crown Copyright, the Met Office)

MMS also enables trained observers to manually enter supplementary data (such as cloud type) via a PC, and to apply quality control to automatic observations. The user workstations are high resolution colour PCs, running a web-browser based user interface within a standard Windows operating environment. The application utilises all of the standard tools within a web-browser (such as backward, forward, printing, favourites and multiple windows) while still retaining the speed and stability of a standalone application. A uniform appearance and operation is provided throughout

all windows (see Figures 3 and 4), providing a consistent means of access, interface and operation, and an easy to use interface for all MMS users.
In accordance with the GCOS Climate Monitoring Principles the impact of the introduction of this new observing system was carefully assessed prior to implementation, including long-term side-by-side trials with previous systems.

Future challenges

There are many challenges facing the network over the coming years. As numerical weather prediction models increase in resolution (for example, the UK's new 70 level, 1.5km resolution model), there is a corresponding demand for increasing resolution observations for initialisation and verification purposes.
Likewise, with developments in data assimilation techniques, there are also requirements for higher temporal resolution observations, with the assimilation of sub hourly data now possible. These requirements for increasing temporal and spatial resolution data have many implications for the network, including increased demands on data storage, data processing, maintenance and communications costs.
Another challenge is the rapidly growing demand for new types of observations. The users and requirements for surface meteorological observations are extensive and varied. Observations are of fundamental importance to the work of National Met Services, essential to the forecasting process since they are required to initialise weather and climate prediction models. Observations are also used to verify the performance of these models and to help forecasters monitor the current meteorological situation in near real-time, helping increase the accuracy of forecasts for the next few hours ('nowcasting'). However, the users of observations include not only forecasters and climate scientists, but the academic, defence, health, media, and transport communities, as well as the general population and the many commercial organisations impacted by weather and climate.
We face these major challenges during an extremely difficult financial period and under continuous pressure to deliver cost savings. These challenges can not be met simply by trying to work more effectively and efficiently (although this is always important to strive for). One important approach will be to seek out ways to develop the network with new sensors and new capabilities to meet the emerging and varied requirements for observations. For example, during 2011 MMS was enhanced to meet stringent criteria laid down by the UK Civil Aviation Authority (CAA) to enable it to be used as the primary observing system at UK civil airfields. Funding from operating such sites will help offset costs caused by the increasing costs of running an expanding network.

Summary

This paper has presented a brief introduction to the UK Met Office automatic surface observing network, and the Meteorological Monitoring System (MMS).
In summary, MMS has replaced the previous diverse data logging systems with a new single-system network, with a more uniform set of sensors and data processing algorithms. The new system provides increased flexibility to adapt to new sensors in the future. Manned sites have the functionality to display and interact with automated measurements. The new SCADA software is located within a highly resilient central system at the Met Office headquarters in Exeter. This central system enables data collection, monitoring and control at frequencies capable of being adapted to meet changing operational requirements. The system is designed to be easily scalable, allowing the number of sensors at sites, and the number of sites themselves, to be increased or reduced as necessary. The scalability of MMS will be important in meeting the growing challenges of delivering increased spatial and temporal resolution surface observations. While the flexibility to add new sensor types and modify system outputs will help us to meet the new and evolving requirements of the extensive range of users of surface meteorological observations.