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The development of the EUMETNET OPERA radar data hub

Dawn Harrison, Robert Scovell, Huw Lewis and Stuart Matthews

The Met Office, Exeter (United Kingdom).

1 Introduction

The 2nd Operational Programme for the Exchange of Weather Radar Information (OPERA II) included a work package to establish a pilot European weather radar data hub (hereafter referred to as the Data Hub). This work package has been progressed by the UK Met Office. The overall aim of the Data Hub is to facilitate the production of Europe-wide high quality rainfall products for use in research and development activities, particularly Numerical Weather Prediction (NWP).

Fig. 1. Locations of weather radars in OPERA member countries.

The networks of weather radars in Europe currently consist of close to 150 operational installations (Huuskonen, 2006), with a further 20 radars planned. Figure 1 shows the location of radar sites within OPERA member countries. The Data Hub is scoped to handle data from up to 100 radar sites. Its specific functions are to (1) receive radar data from participating organisations; (2) perform agreed quality control and correction procedures; (3) maintain and operate a data storage and retrieval system; (4) disseminate data and products to participating members for use in research and development activities and (5) inform the specification of an operational data hub. The work package proposal defined two types of composite products. The first to be based on National or Regional composites, whose data have undergone prior processing. The second based on single site data, supplied in an ‘unprocessed’ form, which would be subject to a set of quality control and correction algorithms applied within the Data Hub system, prior to compositing.

Correspondence to: Dawn Harrison.
dawn.harrison@metoffice.gov.uk

2 Data Hub system configuration

The Data Hub shares hardware with the Met Office’s centralised radar data processing system (Radarnet). This is based on a Unix cluster, which was expanded from two to four processing nodes in May 2005 to create capacity required for the Data Hub. This system lies within the Met Office’s IT security firewall, so in order to provide access to products and monitoring information, a separate web-server, which resides outside this protective firewall, is utilised. Figure 2 shows a diagram of the systems, connectivity and data flow associated with the Data Hub.

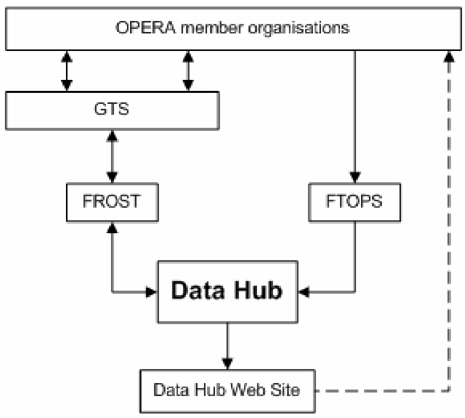

Fig 2. Diagram of system components and data flows associated with the Data Hub. FROST and FTOPS are the UK Met Office message switching and ftp server systems respectively. The dashed line indicates latest product download via the Data Hub web site.

Access to the imagery, products and monitoring information provided via this password protected web site is currently limited to OPERA delegates and colleagues working on radar data development and maintenance activities.

3 Data supplied to the Data Hub

In mid 2005 OPERA delegates from each member country were asked to specify what, if any, data and/or products they were prepared to supply to the Data Hub. Table 1 summarises the responses received and shows the current status of data supply. To date, most products, which were to be made available, are being routinely supplied to the Data Hub in near real time. There are a small number of organisations, who gave positive responses to the request for data, who have not been able to make data available to date for either technical or administrative reasons. It is anticipated that some of this additional data will begin being received routinely at the Data Hub during the remaining months of the OPERA II programme.

Table 1. Summary of data supplied to the Data Hub

Country	Data offered	Composite products		Single site products	
		Delivered	Available	Delivered	Available
Austria	N	0	0	0	0
Belgium	Y	0	0	2	2
Channel Isles	Y	0	0	1	1
Croatia	Y	0	0	2	2
Czech Rep.	Y	1	1	2	2
Denmark	N	0	0	0	0
Finland	Y	0	0	8	8
France	Y	1	1	0	0
Germany	Y	1	1	16	16
Greece	Y*	0	0	0	0
Hungary	Y	1	1	0	0
Ireland	Y	0	0	2	2
Italy	Y	0	0	4	5
Netherlands	Y	1	1	2	2
Norway	Y	0	0	5	5
Poland	Y	0	0	8	8
Portugal	Y	0	1	0	2
Slovakia	Y	0	0	0	2
Slovenia	Y	0	0	1	1
Spain	Y	1	1	0	15
Sweden	Y	0	0	12	12
Switzerland	Y	1	1	3	3
UK	Y	1	1	13	13
		8	9	**81**	101

* data not available on OPERA II programme timescale

Ideally, data supplied would consist of single site data in an 'un-processed' form and a composite product based on data that had undergone local quality control and correction. In practice, most of the single site data supplied have already undergone varying degrees of local processing and are supplied as either pseudo-CAPPI (constant altitude plan position indicator), surface rainfall intensity or column maximum reflectivity products. This makes deriving consistent quality surface precipitation products problematic. As a result, the quality control (QC) and correction steps available (see section 4.1-4.4) can be switched on or off for individual sites, as appropriate.

3.1 Format of data supplied

The OPERA programmes, and their predecessors (see Huuskonen (2006)), have worked to promote exchange of radar data in a common format, i.e. BUFR, and therefore input data were requested in the latest version of BUFR. However, a parallel OPERA II work package has been investigating alternative formats. The two formats being considered are HDF5 and GRIB2. As part of this activity, HDF5 decode software has been supplied to the Data Hub and data from the Swedish Meteorological and Hydrological Institute radars supplied in HDF5 format. This has served to demonstrate the potential of HDF5 as a format for radar data exchange and has also demonstrated the capability of the Data Hub to handle inputs in more than one format. A similar exercise could be undertaken for GRIB2.

3.2 Method of data reception

Exchange of radar data between OPERA members has traditionally made use of the World Meteorological Organisation's Global Telecommunications System (GTS). Much of the data supplied to the Data Hub are data that were already exchanged via the GTS. In these cases, all that was required was additional routing to the Data Hub system at Exeter, via GTS Regional Telecommunications Hubs (RTH). For a small number of countries, the capacity of the regional GTS circuit is insufficient to allow radar data to be routed to the RTH without adversely affecting the transfer of other critical data. Where this is the case, Internet File Transfer Protocol (FTP) has provided an alternative. BUFR files are sent to an FTP server at Exeter. This FTP server then forwards the files to the Data Hub system, as shown in figure 2. Currently, single site data from the Finnish and Norwegian Meteorological Institutes are received via this method. All other inputs are currently received via the GTS.

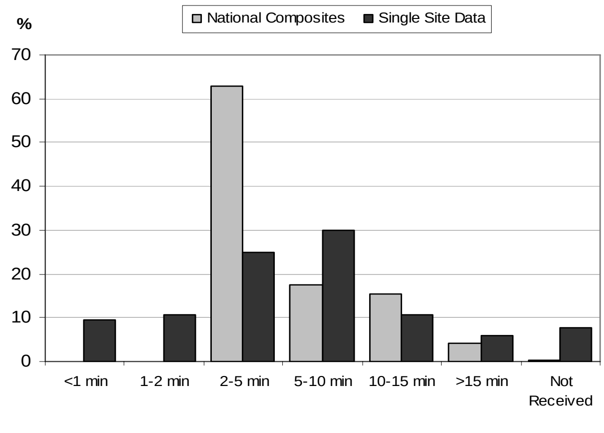

Fig. 3. Average timeliness of reception for single site data and national composites, May 2006.

3.3 Data availability and timeliness.

The Data Hub monitors the time of data reception for each incoming file. Logs of recent files received and daily and monthly statistics, for each site or national composite, are then made available via the Data Hub's web site. Timeliness statistics for May 2006 are illustrated in figure 3. This illustrates that most input data are received within 15 minutes of validity time. In the case of single site data, 86% of expected files were received within 15 minutes and just under 8% were not received at all. The main reason for missing data were a small number of sites with prolonged outages for maintenance/repairs, rather than intermittent missing inputs. This suggests that the communication links being utilised are reliable. Reception statistics for National composites are better still, with over 95% received within 15 minutes and less than 1% not received at all.

4 Quality Control and Correction

Single site data supplied to the Data Hub can undergo some, or all, of the quality control and correction steps outlined in sections 4.1 – 4.4. These are designed to address a number of known sources of radar errors. The techniques currently used have been applied within the UK's centralised radar processing system (Radarnet) for some time. It is recognised that, for some types of input data, these may not represent optimal processing techniques. However, their application in near-real time serves to demonstrate the capability of the Data Hub to carry out quality control and correction of radar data from a large number of different input sources. In future, a set of algorithms, which brings together techniques developed across a number of organisations, could be used.

4.1 Clutter identification

Currently, all data received at the Data Hub have undergone some prior processing to remove ground clutter. The techniques used tend to be based on Doppler filters or dynamic or fixed clutter maps. Identification of residual clutter is performed within the Data Hub. The probability of detection (POD), accumulated for a 3-month rolling time period, is used to identify pixels with permanent or semi-permanent echoes. Where the POD exceeds a specified threshold, pixels are set to a missing data indicator. Figure 4a shows an example of a POD image for the radar site at La Dole in Switzerland. Hot spots of residual clutter are shown as white. The extent and distribution of these permanent and semi-permanent echoes varies considerably from site to site.

4.2 Anaprop identification

The Data Hub makes use of a scheme originally described in Pamment and Conway (1998). This scheme doesn't specifically diagnose anomalous propagation, but identifies spurious radar echoes using a probability of precipitation (POP) product. This POP product is based on infra-red and visible imagery from Meteosat and elements of surface synoptic reports (present weather, cloud type and amount). Where the POP is lower than a specified threshold, the corresponding radar image pixels are set to zero precipitation rate. The threshold POP is set at such a level as to minimise the possibility of removing genuine precipitation.

4.3 Occultation identification

The Data Hub uses a method for identifying rays which are affected by occlusions or blockages to the extent that it is not beneficial to attempt any form of correction. This is based on the difference in frequency of detection (FOD) for gates along a ray from a 30˚ sector average FOD. Where a significant number of gates along a single ray have an FOD more than 30% less than the 30˚ sector average, then the pixels along this ray are flagged as occluded. For occlusions less than 2˚ wide, interpolation is performed, but for occlusions greater than 2˚, the data are set to missing values. Figure 4b shows the occlusions identified using this method for La Dole, Switzerland, and figure 4a shows the corresponding POD image. Occultation may originate from obstacles, blanked sectors or mountain ranges. For more details about radar visibility in the Alps see Germann et al (2006). Composites including data from this site would use data from another site (if available) in the areas that have been diagnosed as occluded.

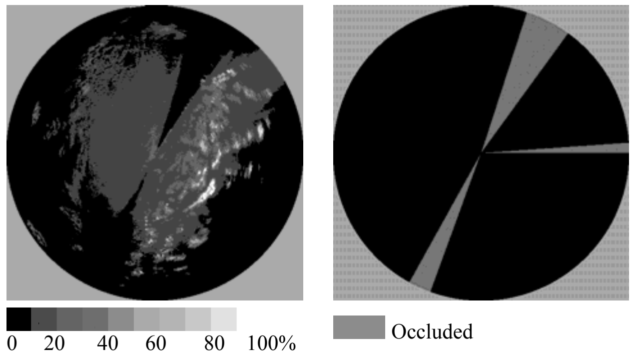

Fig 4 (a) Probability of detection (b) diagnosis of occultation for the radar at La Dole, Switzerland,

4.4 Adjustment for vertical profile effects

Several kinds of radar error (bright band, range, orographic growth) are all manifestations of variations in the vertical profile of reflectivity factor. The resulting errors can be very serious if left uncorrected. The Data Hub makes use of the scheme developed for the real-time processing of the UK radar data, described in Kitchen et al. (1994). This is a physically-based correction scheme in which an idealised vertical profile of reflectivity is diagnosed at each radar pixel. The idealised profile incorporates simple parameterizations of the bright band and orographic growth of precipitation over hills. The orographic element is based on the scheme outlined in Alpert and Shafir (1989). Data from both the UK Met Office's NWP models and Meteosat are utilised to determine the heights of turning points within this profile. Since the scheme requires an estimate of the height of the radar beam at each pixel, it cannot be applied beneficially to CAPPI data. It also should not be applied when radar data that have already had an alternative VPR type correction applied locally.

5 Compositing

Compositing software has been developed and maintained by the Technical University, Graz, on behalf of OPERA. The software allows BUFR encoded radar data of any domain or resolution, in one of six permitted projections, to be composited. The composites currently generated by the Data Hub are 4 km resolution and on Lambert's azimuthal equal area projection. Figure 5 shows and example. The Data Hub produces 3 types of composite, based on: (1) single-site data only; (2) national composite data only and (3) all available data, the latter being produced to maximise the area of data coverage. The OPERA compositing software allows either the average or maximum of available inputs to be used as the basis for the composite. These both have the advantages of being simple techniques that can be applied to any sort of input data. However there are many drawbacks, particularly the tendency to maximise the extent of spurious echoes. A more preferable compositing technique would be one based on a measure of radar data quality (Donaldson (2002)), but this is only possible if such a measure is available for all inputs, in a consistent form. An OPERA II work package is looking at this requirement (see Holleman (2006)).

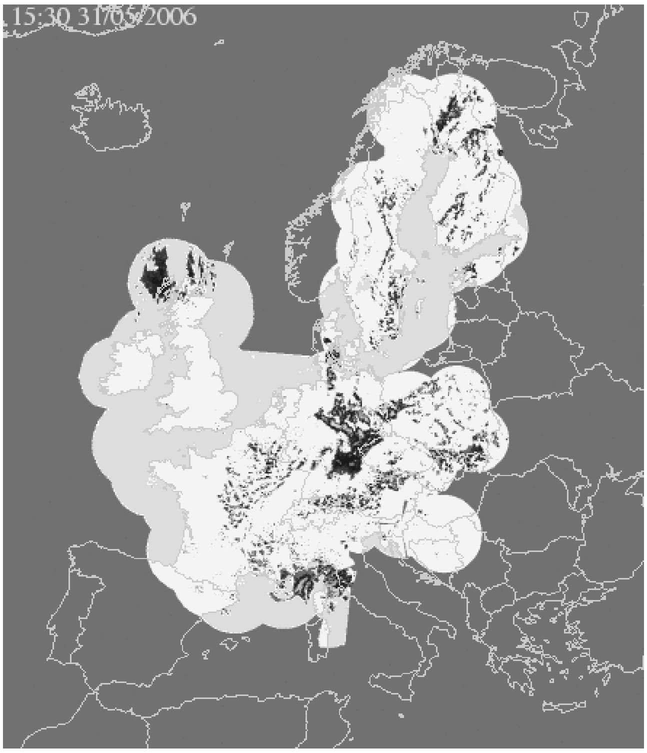

Fig. 5 Sample European domain surface precipitation intensity image, based on both single site and national composite inputs.

6 Product availability and the Data Hub web site

One of the most difficult issues facing the Data Hub relates to establishing terms and conditions for use of the inputs and products. A proposal was put to EUMETNET Council which detailed the benefits and issues relating to the use of European domain radar composites. A plan for introducing European composite products was suggested. This specified three levels of use for European composites:

(1) as a tool for radar data quality control
(2) for NWP model validation and assimilation
(3) for core services of National Meteorological Services and customers.

European domain composites are currently restricted to level (1) uses. To support this activity, the Data Hub makes its composite products available at T+1 hour from validity time, via its password protected web site.

7 Summary and future developments

The OPERA II pilot Data Hub project has been successful in demonstrating that radar data from across Europe can be reliably brought together in one place and composite products derived in near-real time. It has also been demonstrated that a set of processing algorithms can be applied in a central location, prior to compositing, although the benefits of doing this have not been quantified.

To date, the use of the Data Hub products has been very limited, and confined to use in radar maintenance and development activities only. For the benefits of the Data Hub to be realised it is essential that the quality of the composite products is verified and for wider use of the products to be permitted. For this to occur, issues around the Intellectual Property Rights of Data Hub products need to be resolved.

The next phase of the OPERA programme will work to establish a full scale operational facility. The specification for this system has yet to be determined but it will clearly need to take into account the outcomes of the pilot Data Hub project and developments elsewhere in the processing and application of radar based products.

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