ENVIRONMENTAL METROLOGY AND THE USE OF GIS – RESULTS FROM THE EC METROPOLIS PROJECT

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ABSTRACT

This paper presents the results of an investigation of current practices and gaps in the use of Geographical Information Systems as a tool for analysing and presenting environmental monitoring data in Europe. This work has been conducted as part of the Metropolis project. Metropolis is a metrology thematic network funded under the EC 5th framework, with the aim of improving the performance of environmental measurements and monitoring systems in support of EU policies. The Metropolis network is composed of 6 scientific work packages, which have examined many aspects of metrology with respect to environmental monitoring. This has included bio monitoring techniques, methods in analytical chemistry and reference materials, on-line measurements and data transfer, quality assurance and uncertainty assessment, standarisation and communication of results and support to decision making. The work discussed in this paper has been undertaken as part of work package 3 'On line data measurements and data transfer'.

To identify good practice and gaps in GIS use within environmental monitoring, members of the Metropolis network and beyond have been surveyed about GIS usage. This has included asking what data and software platforms they use, the type of data they collect or hold, examples of GIS applications and if they do not use GIS, the reasons why not. The survey has been conducted via a dedicated discussion forum on the Metropolis website (https://extranet.metropolis_network.net) and also via additional email and telephone contact. The results of the survey have been used to inform a GIS guidance document that is available on the Metropolis website. The guidance document provides a review of current standard GIS use in the environmental monitoring field, examines the perceived gaps in use and other uses of GIS in this field, discusses data access, maintenance and sharing issues and also wider European GIS issues. The GIS element of Metropolis has examined issues that relate closely to a number of other EC projects, including INSPIRE, GINIE and GMES, and has been used as an opportunity to discuss issues such as data standardization and interoperability within the Metrology community. A summary of the main points of the guidance document will be presented in this paper.

The results of the Metropolis GIS work have illustrated that there is still a gap in the level of communication between the data creators (metrologists) and the data users (the scientific community, decision and policy makers and the public). Therefore, an additional aim of the work has been to inform metrologists, analysts and decision makers how a GIS can help to plan a monitoring programme and to analyse, display and understand the results of measurements, and to promote the use of GIS in the metrology community and amongst policy and decision makers.

The results from the Metropolis GIS survey will be presented in this paper, along with a discussion of the main points covered in the Metropolis GIS guidance document. The paper will also present a discussion of how metrologists can be encourage to make the data they produce more accessible

by considering metadata and interoperability issues and how the wider GI initiatives already underway within Europe, such as INSPIRE, may impact on the Metrology community.

KEYWORDS: GIS, Environmental Metrology, EC project

BACKGROUND TO THE METROPOLIS PROJECT

Metropolis is a multidisciplinary thematic network funded under the EC 5th framework programme. The main aim of the Metropolis network is to improve the performance of environmental measurements and monitoring systems in support of EU policies. It is widely recognised that reliable, comparable and useable measurement results are the key component to effective environmental monitoring and successful sustainable development policies. The Metropolis initiative grew from the conclusions of the EU funded conference on 'Environment, Health and Safety: a challenge for measurements' held in Paris in June 2001. Here it was recognised that there was a need to create a thematic network in order to pursue three main objectives that were identified in the field of environmental metrology. These objectives were:

- To improve the performance of environmental measurement systems and their harmonization at EU level,
- To foster the dialogue between those who provide measurement methods and associated services and the users of measurement results,
- To prepare for further integration of research expertise and resources in environmental monitoring across Europe, by establishing communication and liaison arrangements between European research bodies.

The Metropolis network started in July 2002 and brings together 17 countries and 38 participants and is coordinated by INERIS of France. The Metropolis network has gathered experts from key research institutes and universities dealing with environmental metrology in Europe, in order to identify gaps and needs for future research in environmental metrology to support EU policies and improve the transfer of knowledge from researchers to the "end-users".

The Metropolis network is composed of six scientific work packages (WP) and a seventh coordinating WP. Each of the WPs deals with a different aspect of environmental monitoring, from the definition of measurement strategy, collection of data, harmonization and evaluation of uncertainty issues to the interpretation of the results by policy and decision makers. The network is committed to a series of actions and deliverables for each of the three objectives. These include:

- The preparation of reports, guidance documents and databases,
- The organisation of workshops, seminars and discussion fora on the Internet,
- The participation in organised expert groups in support of EU environmental policy,
- The presentation of research projects within the 6th Research Framework Program.

The documents produced under the Metropolis project and additional information about the project can be found on the web site[1].

GIS AND METROPOLIS

The use of GIS for analysing and presenting environmental monitoring data across Europe has been one of the aspects investigated by the Metropolis project. With the aim of identifying good

practice and gaps in the usage of GIS. WP3 of Metropolis entitled 'On line measurements and data transfer' has undertaken this work.

Location plays a crucial role in facilitating information sharing by providing a link among disparate data sets, allowing analysis of information in a way that would otherwise be impossible. The collection and analysis of information about the environment has been one of the driving forces behind modern GIS development. A GIS can provide a way to manage and exchange information more effectively and ultimately provide an improved and more cost effective service to the public. It can also provide an invaluable tool for understanding and assessing the impacts of government policy on the public. Sharing information within and across different governments is vital, for the development of EU policy and its implementation and to help to visualise the wider picture necessary to deal with complex issues.

In order to explore the current and potential uses of GIS in environmental monitoring and to increase the use of GIS as a working tool in the future, WP3 of Metropolis were tasked with the production of a GIS guidance document. GIS can be used to aid the whole metrology process from data specification and collection to data storage and management through to data manipulation and presentation. The guidance document aims to illustrate how GIS can be used to help plan an environmental monitoring programme and to analyse, display and understand the results of measurements to metrologists, analysts and decision makers who may not be fully aware of its potential. The main points from the guidance document are discussed in this paper and the full document is available on the Metropolis website[1].

THE METROPOLIS GIS SURVEY

In order to examine the extent and type of GIS use in the environmental monitoring field within Europe, the Metropolis partners, plus other key institutions in environmental monitoring, were contacted and asked to complete a GIS survey. The results of this survey have been used to inform the GIS guidance document and are discussed in this paper. The Metropolis group are aware that there are a number of other EU funded projects examining a range of GIS issues within Europe, some of which included undertaking surveys of GIS related information. To ensure Metropolis did not duplicate other EU funded work in this area, WP3 were in contact with DG ENV and members of the GINIE and INSPIRE EU projects.

The survey has been used to exchange information about the types of datasets that are collected across Europe (e.g. background mapping, meteorological data, results of analysis, sampling location, soil type, industrial sites, etc) the format of these datasets and how they are used and the maintenance and updating of this data. In addition, the survey has also attempted to examine the difficulties institutions currently have in implementing and using GIS. The following is a summary of the questions that were included in the survey:

Question 1 Do you currently use a GIS for environmental monitoring?

If so

- What data do you collect and in what format?
- What software do you use?
- Is your GIS PC-based, networked, and available over the web?
- What datasets do you use, other than your own?

If you do not use a GIS

- What is stopping you

Question 2 What do you use GIS for at present?
Question 3 What would you like to use a GIS for?
Question 4 What problems, if any, do you associate with the use of GIS in environmental monitoring?

GIS survey results

The survey showed that a large number of the Metropolis partners were from institutions that currently use GIS, although not usually in the same department as the metrologists. The type of data that is collected and used in a GIS includes a range of soil, water and air pollutant data and also epidemiology data. At present GIS is currently used in the following types of areas: pollution mapping, risk estimation work, in combination with models for geostatistical analysis and interpolation and for more general mapping, presentation and resource management.

The survey also asked how metrologists would like to use a GIS and many respondents highlighted areas such as predictive mapping, linking GIS further with economic, health and population data and the provision of internet and real-time automated mapping services. The survey also highlighted the fact that the cost of a GIS, both in terms of the hardware and software and the time taken to train staff, is still a barrier to its use. GIS is still seen as expensive and time consuming. Problems with data, such as interoperability, cost, availability and maintenance issues are also given as obstacles to GIS use within the environmental monitoring field. The survey also reinforced the view that metrologists and GIS experts are most commonly in separate departments without a clear line of communication set up between them. These issues are discussed in more detail in the following section and in the Metropolis GIS guidance document[1], which also has a full summary of the results from the GIS survey.

THE METROPOLS GIS GUIDANCE DOCUMENT

The aim of the GIS guidance document produced by WP3 of Metropolis was to examine current GIS use within the environmental monitoring arena and to explore the gaps that currently exist and the new potential uses of GIS, to increase the use of GIS as a working tool of the future. In order to do this the guidance document examines issues that were raised with the GIS survey and discusses the following:

- The current standard use of GIS within environmental monitoring
- Perceived gaps and other uses of GIS
- Data access and maintenance issues
- European GIS issues

The main points from each of the guidance document sections are presented here.

Current standard GIS use

A GIS has sophisticated data presentation capabilities that can be used to display mapping data, charts, graphs and tabular data. Contouring, hot spotting and surface mapping are also features of a GIS. Due to the spatial nature of environmental data, a digital mapping framework is the ideal format for its presentation. By presenting multiple datasets together, insights into a problem are often provided. Current, standard uses for GIS in the environmental monitoring field include:

- Presentation of results on a map, in a clear concise and accessible way
- Combining and presenting results from different analyses

- Web based applications for dissemination of information to the public.

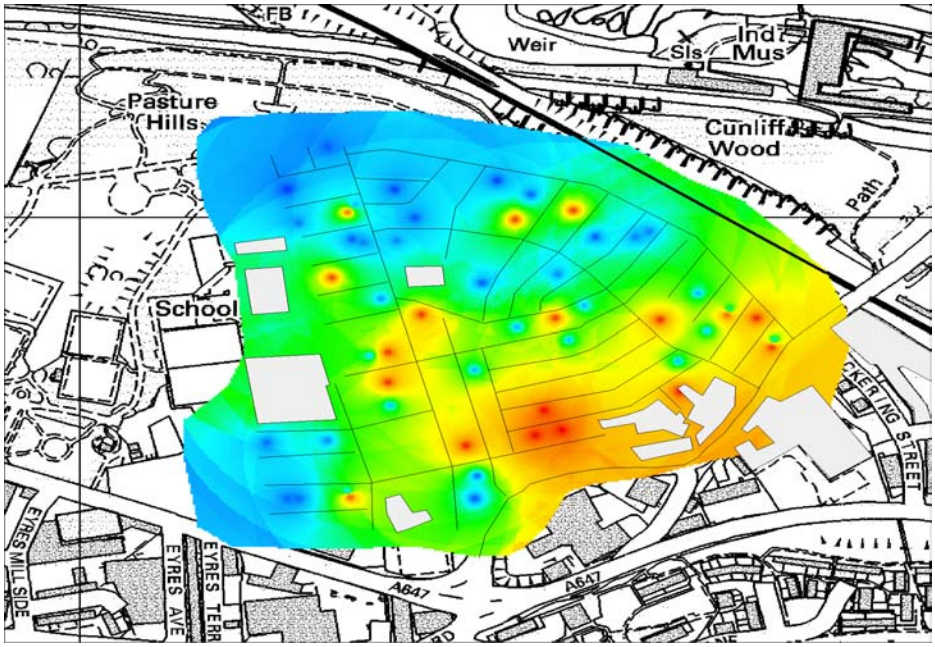

Figure 1: *Extent of asbestos contamination in an urban area. The red areas represent higher levels of asbestos and the blue areas lower levels*

Combining datasets in a GIS may shed new light on a problem, which may be valuable for providing feedback to the environmental monitoring process. Examples of GIS use for environmental mapping are shown in figures 1 and 2. Figure 1 illustrates asbestos pollution measurements from an urban area in the UK. The data are displayed using colour coded concentration measurement levels to illustrate the extent of the spread of the pollutant from the source. Using this type of data representation it is easy to identify the homes of people exposed to the pollutant at work, as these form 'hot spots' of pollution in the surrounding area.

Figure 2 is an example from a study of the population exposed to potential hazards from a chemical plant. All the data is fictitious in this example, however, it illustrates how the population exposed to different levels of risk can be easily identified and how sensitive populations, such as the young, old or hard to evacuate, can be identified and targeted if necessary.

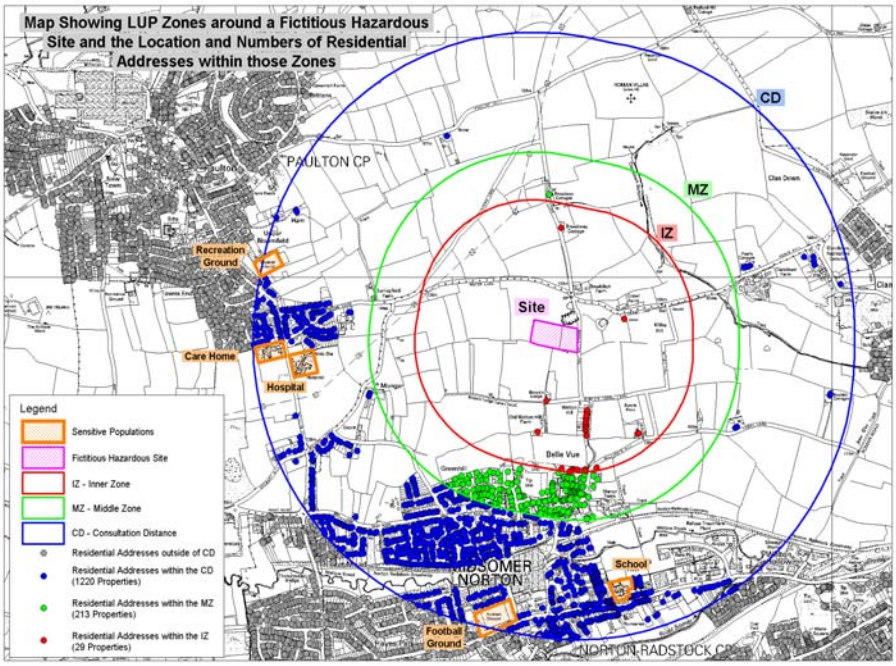

Figure 2: *Extent of contours of individual risk around a fictitious hazardous installation, for land use planning (LUP) decision making. Also shown is how the composition and density of the surrounding population varies.*

There are many examples of how GIS may be used for presenting environmental data on the Internet. This includes the UK Environment Agency [2], the British Geological Survey[3] and the UK Centre for Environment Fisheries and Aquaculture, CEFAS[4]. A good example from the Metropolis consortium can be found on the Swedish Environmental Research Institute Ltd, IVL, web site[5], where a range of pollution data are available to view online or to download from a database. This includes urban air quality data and continuously updated concentration measurements of ground level ozone.

Perceived gaps in usage and other applications of GIS

Environmental datasets are often extremely large, frequently updated and require a high level of management. These datasets might include for example: remote sensing images from aerial photography and satellite observations; thematic maps (maps with a single theme or subject) of vegetation cover, soil type or hydrological information; or topographical and geological maps. The current perception is that while GIS usage is becoming more widespread within environmental monitoring, the full potential uses of this tool have not been fully exploited. In particular the Metropolis work has highlighted that there is frequently separation between GIS specialists and measurement scientists, even within the same organisation. It is suggested that closer integration

of these specialists would allow the work of the measurement scientists to be more fully understood in an environmental context by policy makers and the public.

The Metropolis GIS survey highlighted areas where metrologists would like to implement GIS; the most commonly cited being to serve and access data via the Internet. Many metrologists also saw interesting potential uses of GIS, such as predictive modelling and extensions into health, economic and population work via the combining of datasets. Other applications of GIS use within environmental monitoring might include GIS being used to aid the location of experimental sampling sites. For example, by using a GIS during the experiment design stage, positioning of sample points may be made easier. Gaps in sampling locations can be highlighted and adjusted if necessary, whether in terms of site characteristics (e.g. range of different geology, proximities to industry, urban or rural) or merely spatial separation. The maintenance and monitoring of sampling location points, to ensure they are still in valid locations, can also be managed with a GIS.

Another potential use of GIS is to assess the impact of certain regulations or EC directives. In particular, the combination of environmental monitoring results with social, health or economic information for example, can assist in assessing the consequences of pollution, or identifying or confirming relationships between pollution levels and other phenomena, such as weather, traffic levels or child health problems. For example, if measures are implemented under the Air Quality Framework Directive or the Water Framework Directive, that lead to a reduction in a pollution footprint, GIS can be used to demonstrate how many fewer people are now being exposed. This could be used to compare the social and human health impacts of different pollution reduction measures, and provide a new and more accessible method of informing the public about the effects of EC policy on their environment and their lives.

Figure 3 illustrates this by showing a hypothetical situation in the UK: a factory has emissions which measurements show as affecting the larger, yellow area. The number of people affected has been estimated based on the number of residential postal addresses within the yellow area. A proposed measure would reduce emissions, which it is estimated would then affect the smaller, green area. The number of people in this area has also been estimated and shows that the proposed measure would lead to a large reduction in the number of people affected by the emissions. In this case a large benefit is immediately apparent from the analysis and decision makers could use the population estimates in cost-benefit calculations. The figure also gives an immediate insight into the effects of uncertainty in the measurements and derivation of the zones: in the case of the yellow zone, a difference in the zone size would have a large effect on the population estimate, as the zone boundary crosses the middle of the main densely populated area in the figure. For the smaller, green zone, an overestimate in the efficiency of the proposed measure could have a large effect on the predicted benefit of the measure, because a larger green zone would then reach the main population centre in the figure.

These considerations could lead to a revised measurement strategy, such as more monitoring in the population centre. In a real example, the monitoring locations would be indicated which would also assist in judging the reliability of the measurement-based yellow zone.

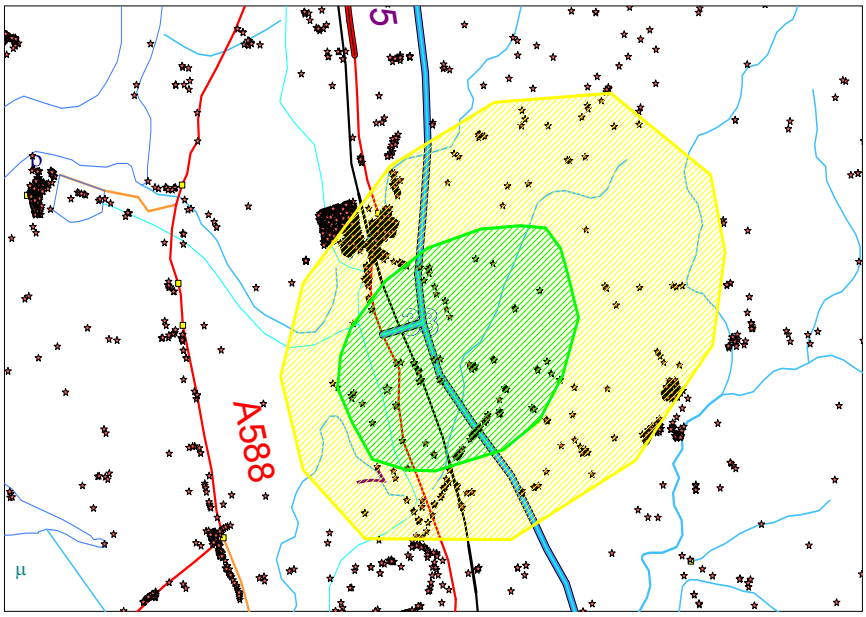

Figure 3: *Illustrative examples of pollution extent and population density. Red stars indicate postal addresses (real data), the red circle the hypothetical factory and the yellow and green zones the extent of the pollution. Estimated populations: yellow zone 2100; green zone 265.*

Data access and maintenance

To ensure a GIS is fit for purpose and able to add insight to the environmental measurement process, issues of data management and maintenance, resource and cost requirements and infrastructure also need to be examined. The full benefit of a GIS will only be gained when due considerations of scale, accuracy and intended use are taken.

Methods of storage should be considered to ensure consistency of data within an organisation. Key considerations are data backups, particularly of specialist data, storage capacity and the supply speed of the data over a network. In addition it is important that a standardised format is used for data, especially specialized data, and that metadata records are kept. Metadata, which is information about the data, is important for maintenance as it records the origin and specifications of the data. It can also help with updating datasets by ensuring that the correct parameters are used, such as the time and frequency of data collection and the correct units. Metadata can also be used to record the required frequency of updates and provide information about the history of the dataset. Another very important aspect of Metadata is that it can be used to compile a directory of available data, which can be searched and interrogated. Without this ability to search for data, data sharing is greatly restricted and effort may be duplicated.

An example of a metadata gateway is the UK government GI gateway site[6], which allows access to a wide range of government held data. Standardization and metadata are especially important

when sharing data with other organisations. Organisations need to consider how easy it is to share their data, in terms of the measurement technique used, the units of measurement, the location of the measurement and the data format used. As data exchange increases across the EC, these points will become more important.

An additional, pressing requirement for most data uses is the ability to interoperate with other systems. Currently, most GIS-specific formats are proprietary, however there is a trend towards interoperability encouraged by the Open GIS Consortium[7] (OGC), which sets common standards and formats for the GI industry. The EC is currently funding a number of projects to look at this area, the JRC GI and GIS project[8] is looking at interoperability and harmonisation with respect to pan European databases, and the INSPIRE (Infrastructure for Spatial Information in Europe) initiative[9] is also working towards standardization and interoperability in spatial data. It is advisable that organisations develop a data collection, format and storage strategy to ensure that a valuable asset is easy to manage, access and share within and beyond the organisation.

European GIS issues

There are currently a number of EC funded GI initiatives and projects and this area of the Metropolis guidance document closely relates to other EU funded work; in particular the INSPIRE, GMES and GINIE projects. The INSPIRE project[10] will impact on metrologists by eventually legally requiring them to make certain datasets available in a certain way. The GMES (Global monitoring for environment and security) project[11] will impact on metrologists by aiding the further integration of environmental data into European policies. And the GINIE (Geographic Information Network in Europe) project[12] will have implications for metrologists by requiring them to provide data to certain standards and to provide accompanying Metadata to ensure interoperability and cohesion across Europe. Details of all the current GI related work that is taking place in Europe and is funded by the EC can be viewed at the EC GI and GIS web site[13]

CONCLUSIONS

The results of the Metropolis WP3 work has shown that use of GIS within environmental monitoring organisations in Europe is not uniformly routine; in some organisations it is well established, in others not. At a simple level, GIS use may be just as an inventory of environmental information, for example, vegetation type and extent. More complex applications, however, may use the full analytical capabilities of a GIS to study environmental processes such as deforestation, water catchment areas and river responses for flood prediction or air quality and meteorological information for pollution monitoring.

The Metropolis GIS work and survey has highlighted that there is still a gap in the level of communication between data providers - the metrologists, and the data users - the scientific community, policy and decision makers and the public. The versatility of GIS makes it well placed to fill this gap. For metrologists a GIS can provide a system for storing, maintaining and analysing data to aid data interoperability and access. For the data user a GIS can provide an accessible, intuitive and robust data presentation system. To help promote GIS use within environmental monitoring, WP3 have produced a GIS guidance document for metrologists, which has been summarised in this paper. It is vital that Metropolis partners make their data accessible, to ensure that it is used to its full potential. WP3 identified the following points that may help this to happen:

- Metrologists need to fully identify and consider the issues around to whom, and how widely, data should be made available, and in what form it should be presented. From this an appropriate charging model can be identified (e.g. free, cost-recovery or a tiered system) and a suitable mechanism and format for data supply adopted.
- Consideration of interoperability and standardization issues at an early stage by metrologists, when determining how the geographic aspects of data are to be stored, will allow the spatial component of the data to be accessed at low additional cost.
- Introduction of metadata at an early stage will make data more retrievable and more useful to more people.

To promote the benefits of interoperability, metadata and the work of other EC GI initiatives, support is needed for GIS workshops for measurements scientists and their organisations. It is recommended that further work be carried out to promote understanding of the potential uses of GIS within environmental metrology at an organisational and wider level.

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