INTEGRATED ENVIRONMENTAL MODELING – THE NEW DREAM FOR GEOLOGICAL SURVEYS

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Abstract

This paper summarises the British Geological Survey (BGS) plans for the development of integrated environmental models to address the grand challenges that face society. It describes a vision for an Environmental Modelling Platform (BGS 2009), that will allow integrated models to be built and describes case studies of emerging models in the United Kingdom. After an initial scoping phase (Giles et al. 2010), this activity is now being carried out under the DREAM (Data and Research for Environmental Applications and Modelling) cross-cutting project.

The Context

There is now a growing realisation in the environmental and social sciences that to address the grand challenges that face the world a whole system approach is required. These challenges including climate change, natural resource and energy security and environment vulnerability raise multi- and inter-disciplinary issues that require integrated understanding and analysis. Not only must we model the whole physical Earth system, bringing together climate, ecological, hydrological, hydrogeological, and geological models to name but a few, we must link them to socio-economic models. This may well be the only adequate way to provide the necessary framework in which decisions concerning prediction and planning can be most appropriately made.

Vision

The BGS vision is to provide scientists with the data, tools, techniques and support to address trans-disciplinary environmental questions impacting on human society. We plan to achieve this by being a leading member of an open community that will share data, applications and environmental models, thus enabling collaboration and achieving sustainable solutions.

Building an Environmental Modelling Platform

Many scientific disciplines have been modeling during the past 5 to 10 years in order to best understand and analyse the processes and conditions within their areas of interest. This has led to a multitude of discipline specific models, modeling system software and workflows with greater or lesser success depending upon the quantity and sources of data and complexity within the scientific discipline concerned.

This has become most apparent within the British Geological Survey (BGS) from the wide variety of differing geoscience models generated in the past few years that need to be interlinked to fully understand the subsurface.

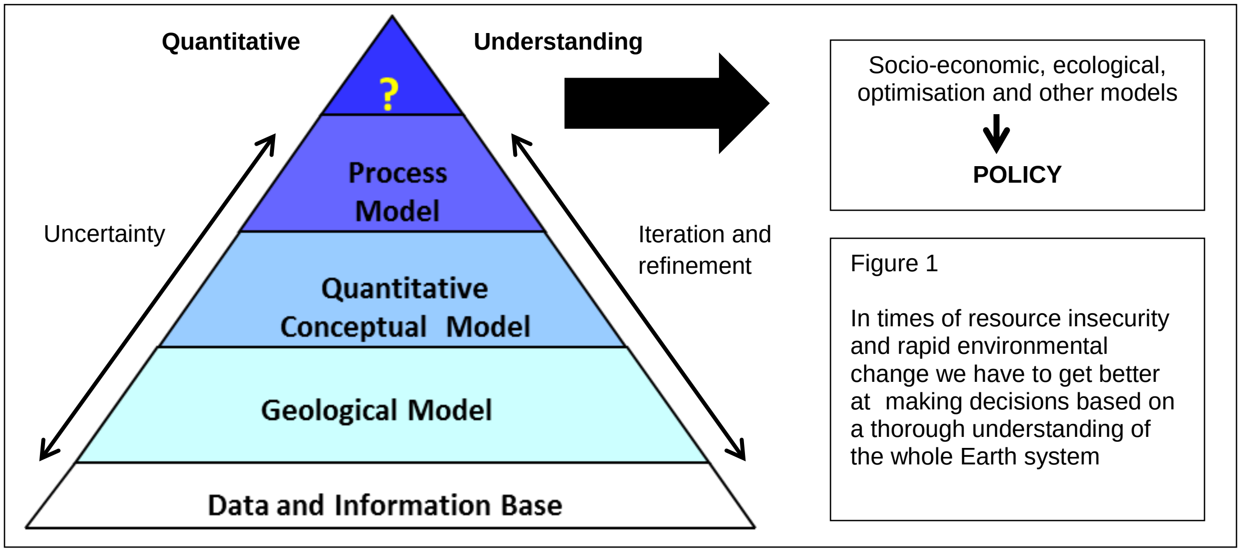

Figure 1

In times of resource insecurity and rapid environmental change we have to get better at making decisions based on a thorough understanding of the whole Earth system

To this end a scoping study was commissioned to assess the current situation and make some preliminary recommendations in order to take steps towards a more joined up and semantically harmonized future in environmental modeling. The recommendations are embodied in the DREAM Report (Giles et al. 2010). The concept of the platform is summarised in Figure 1.

This Environmental Modelling Platform will be founded on the data and information that BGS holds. This will have to be made as accessible and interoperable as possible to both the academic and stakeholder decision making community. The geological models that have been built in an adhoc way over the last 5-10 years will be encompassed in a National Geological Model which will be multi-scaled, beginning with onshore United Kingdom and eventually including the offshore continental shelf. This initiative began in 2010 and has been embedded in the BGS science in recent months as the major plank of our Landscape and Geology programme. The future will be characterised by the routine delivery of 3D model products from a dynamic multiscaled 3D geological model of the UK. The deployment of this model will generate further significant requirements across the Information and Knowledge Exchange spectrum, from applications development (database, GIS, web and mobile device), data management, information product development, to delivery to a growing number of different end-users and stakeholders.

Major challenges for BGS will be three-fold:

1. The deployment of 3D modeling in an acceptable, understandable product form, from a dynamically constructed 3D geological framework model.

2. The parameterisation of this framework model with physical properties and later chemical properties, with error and uncertainty bounds defined for line-work, lithostratigraphy and properties.

3. The use of this Environmental Modelling Platform with partners to provide the knowledge base for modeling Earth System processes at all scales is not the end. This requires linkages to climate models, surface process models, hydrological and hydraulic models and so on. But to achieve impact and value for society coupling to social, economic and financial processes and models will be necessary.

We have commenced the first of these activities and can reasonably see forward to the production of realistic and serviceable deliverables. Figure 2 shows an image of progress to date.

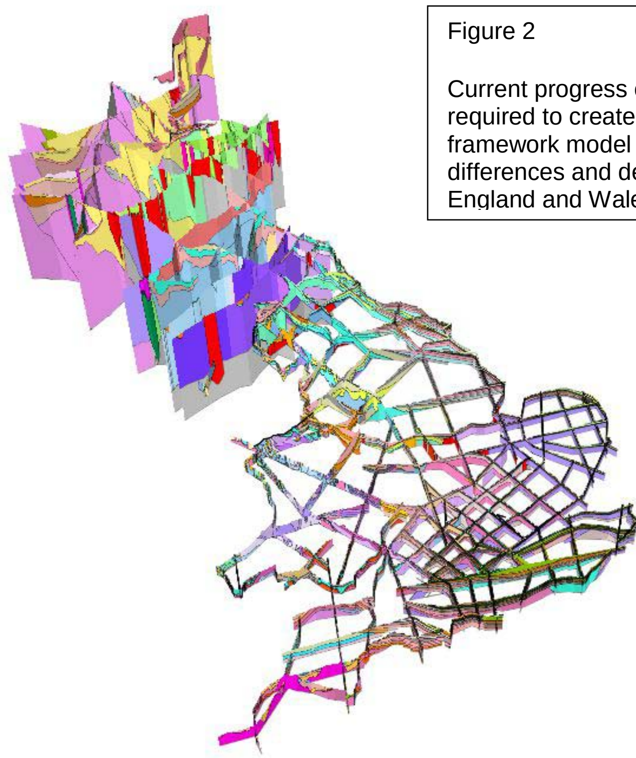

Figure 2

Current progress on developing the cross sections required to create a GSI3D (Kessler et al. 2009) framework model of onshore Britain. Note the scale differences and depths included, between Scotland and England and Wales

The second activity is more difficult, given t[...] of incorporating geological process understanding in u[...]res linkage to other data and modeling technologies and working and modeling of disparate disciplines.

Figure 2

Current progress on developing the cross sections required to create a GSI3D (Kessler et al. XXXX) framework model of onshore Britain. Note the scale differences and depths included, between Scotland and England and Wales

Integrated Environmental Modeling

The concept of Integrated Environmental Modeling (IEM) is certainly not new and a variety of initiatives have developed in the US and Europe in recent years. IEM is about linking computer models simulating different processes to help understand and predict how those processes will interact in particular situations. There are currently numerous examples of global initiatives that require international science collaboration on a very large scale. For example the OneGeology project to make digital geological map data available across the internet; the Global Earthquake Model funded by governments and the insurance industry to develop common standards and understanding of earthquake risk; the GSI3D consortium to take forward the international development of geological 3D models and a new initiative called the Global Volcano Model to develop common data, knowledge and understanding of volcanic risk. It is clear that IEM crosses all these initiatives, is a global issue and an international approach might be taken. BGS and the OpenMI Association (Gregersen et al. 2007) successfully won funding to hold an international workshop to discuss IEM and ways forward globally (see Figure 3). The current BGS favoured route for model linking is to use the OpenMI standard and to promote its use in environmental modeling. This approach has been endorsed by the start of the process of adoption of the OpenMI as a standard with the Open Geospatial Consortium.

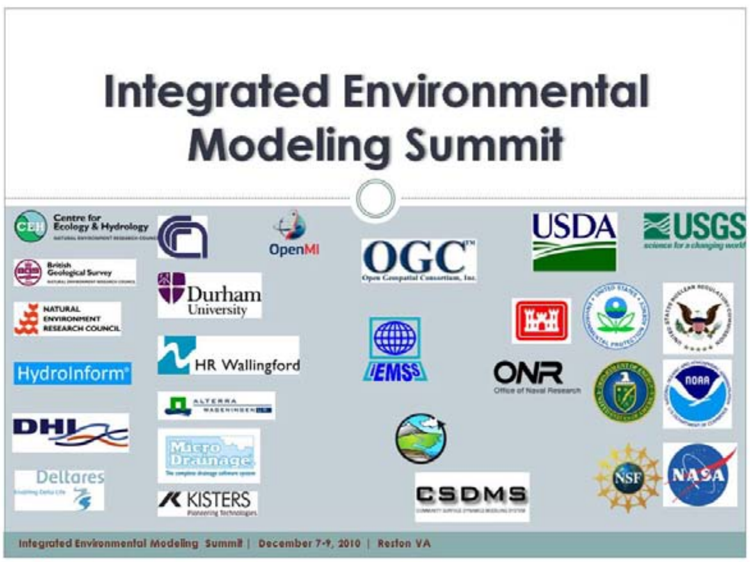

Figure 3

The IEM summit brought together 57 scientists and managers from 10 US federal agencies and academic and non-governmental organizations, European agencies, universities, companies and International organizations. Summit participants discussed what is needed to advance the science, technology and application of integrated environmental modeling worldwide. This was funded by the UK Foreign and Commonwealth Office, BGS and the OpenMI Association

Many fruitful opportunities for collaboration leading to projects were identified. Agreement was reached to produce a roadmap setting out how to achieve the IEM vision. The meeting offered a clear consensus that with greater collaborations, the rewards offered by IEM for society and for industry would be enormous. At the highest level, the challenge was then to turn IEM from its present state, essentially something used by researchers, into an operational tool useable by anyone. (IEM Summit, In Press).

The development and implementation of the roadmap was recognized to be key to the future of IEM. This is a work in progress but it will be essential to implement projects to enhance communication, co-ordination and collaboration in the IEM field and to establish the presence of the IEM community with research organizations (the science funders like the UK Natural Environment Research Council, the US National Science Foundation), national regulatory agencies, national governments, the European Commission and industry (particularly IT and Re-Insurance).

Progress

Recent research into the importance of groundwater in flooding in Oxford has allowed the development of the integration of groundwater levels into a GSI3D geological model (see Figure 4). In addition, through Fluid Earth, the

ZOOM3QD (Jackson and Spink, 2004) OpenMI compliant groundwater model has been linked to the HR Wallingford river model, Infoworks RS to explore the benefits of OpenMI and IEM. Fluid Earth is an HR Wallingford initiative bringing together a community of specialists with the aim of researching and implementing integrated modeling approaches to the understanding of environmental systems (Fluid Earth, 2011)

Similar work in Morayshire in Scotland has enabled the development of an understanding of flooding in the coastal region near Forres. A new research project investigating the impacts of extreme events on the hydrological system in the Thames catchment is leading to the development of a series of distributed, partially distributed and lumped groundwater models to a model of the River Thames, upstream of the tidal region.

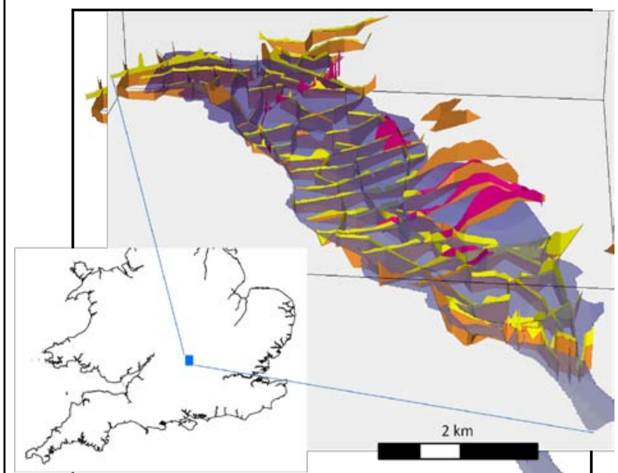

Figure 4 3D geological model and predicted groundwater levels integrated in one model

Major challenges

The DREAM project is a vast undertaking and for BGS to have the temerity to think it can achieve this vision without international partnership, when it is but one player of many, would be foolish. Nevertheless it is at the core of our strategy for the next few years and will be the focus of our attention. The problems and difficulties we face are numerous but the prize of properly serving society is great. The DREAM report identifies a number of challenges. They include:

selecting the most appropriate software, alignment of ontologies and semantics between discipline, dealing with scale, heterogeneity and complex systems, taking account and understanding uncertainty, ready access to interoperable data with appropriate metadata, making use of existing model investments, having accepted and appropriate international standards, easily interpreted visualization of data and model results, reduction of inherently chaotic nature of modeling multidisciplinary systems and issues to ordered repeatable processes.

Most importantly they require a major cultural change from the innately competitive nature of science research to a more collaborative endeavor between and within disciplines and reaching out to the stakeholder community to a degree not often achieved to date.

What does this mean for Geological Survey Organisations?

Geological Surveys of the future must respond to the needs of society to provide the geoscience understanding to allow solutions to the grand challenges mentioned earlier. They must change themselves to become increasingly relevant as they reach out to integrate with others. How many people can read a geological map, or understand the language of lithostratigraphy? People, society, decision makers all need useable relevant information. Integrated Environmental Modeling is our future not just our DREAM.

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