IAPETUS

NERC DOCTORAL TRAINING

How can Landscape-Evolution Models be tested?

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Durham University, Department of Geography

In partnership with University of Newcastle, School of Geography, Politics and Sociology

Supervisory Team	
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Key Words	Modelling; Geomorphology; Sedimentology; landscape evolution; Validation

Overview

Landscape-evolution models (LEMs) are increasingly being used to investigate a wide variety of geomorphological questions. Since most of the existing models were developed for a specific purpose, and have defined parameters and calibration for very specific sets of boundary conditions, the utility of these models beyond their original intended use is, at best, limited. Choosing which model to use is fraught with difficulty. As yet there are no agreed benchmarks either for model performance (i.e. how well these virtual landscape models mimic real world examples) (Figure 1), or indeed for model-model comparison, i.e. how much they (dis-) agree with each other. As a consequence the model user community has little helpful information when considering which of the existing models is the most appropriate, or whether a new model is needed for their specific purpose. This project is designed to address these problems. This research aims to develop methods for evaluating LEMs against real-world data to enable effective inter-model comparisons to be made.

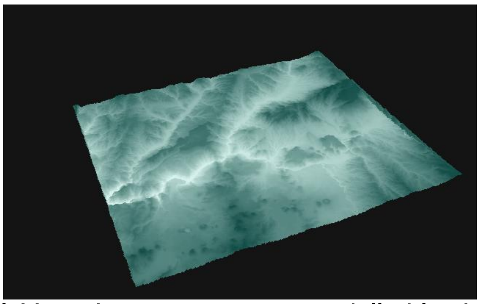

Figure 1 How do we compare a modelled landscape with a real landscape given constraints of available data and different types of data.

Methodology

To address the aim of providing robust means of testing LEMs, we will:

1. develop conceptual methods that produce model sedimentology so that direct comparisons with other aspects of field information can be made;
2. develop the PARALLEM model to enable the simulation of large catchments using high-performance computing techniques;
3. make comparisons with real-world datasets to evaluate our ability to simulate these large catchments based on studies of the Thames in the UK and the Allier in France; and
4. make comparisons with reduced-complexity models of landform evolution to see how much detail is required in a LEM to represent actual landform evolution.

Development of model code requires experience of programming in C and preferably some knowledge of CUDA, the environment developed by nvidia for programming GPGPUs. This computationally intensive model runs on a high-performance GPGPU cluster in Newcastle comprising multiple nodes, each with multiple GPGPUs. This work will require a willingness to engage in the use of MPI (message passing interface) protocols and other HPC techniques. Support for HPC model deployment comes from our collaborator Dr Stephen McGough, a parallel programming expert based in Computing Science in Durham.

The development of a model testing framework will involve two model-data comparison case studies. One of these will draw on the experience of the supervisor Maddy in the Upper Thames catchment, UK, where a large database of existing detailed sedimentological data is available covering the last interglacial-glacial cycle (126 ka-10 ka). These data can be compared against model-generated data, with data produced using PARALLEM in 'event-mode' (i.e. using a sub-annual flood, unsteady flow, event series) over the same timeframe. It is probable that in addressing this mismatch between model and sedimentary archive data, the need for new field observations will be identified i.e. new attributes of the archive will be needed, through new fieldwork, in order to facilitate the model testing. A second case study will consider the evolution of the Allier catchment, France and compare model outputs against its long-term sedimentary archive spanning the last 0.6 Ma. In this case PARALLEM will be deployed in its simpler 'annual mode' (i.e. using an annual, steady flow, event series). In this latter case model results can also be compared against existing cosmogenic isotopic erosion-rate data.

For both case studies PARALLEM results will also be compared with a range of increasingly reduced complexity models e.g. LAPSUS, CybErosion, and measures of relative model performance constructed to identify the range of appropriate usage for these models. In this way, we will establish a protocol for model benchmarking and the reporting of both model performance and inter-model comparison.

Timeline

Year 1 Background to LEMs and geomorphic processes; training in programming and means of developing PARALLEM in a team setting; literature review
Year 2 Fieldwork in the Thames basin; development of model sedimentary architectures; comparison against field data; paper 1
Year 3 Use of results from testing in the Thames to design and carry out fieldwork in the Allier; further model testing; carry out reduced complexity analysis; paper 2
Year 4 Thesis; definition of benchmarking approaches and relevant papers

Training & Skills

The proximity of Durham and Newcastle will enable a fully supportive research environment to be provided, allowing the student to interact with the broader research communities in both Departments, as well as the HPC facilities available at both. It is anticipated that the student will spend an equal amount of time in both institutions.
Key elements of the training the student will receive are:

1. advanced computational skills and implementation of numerical algorithms;
2. field techniques for the analysis and interpretation of sedimentary and geomorphic data;
3. statistical methods for model intercomparison and benchmarking;
4. how to present academic work in conferences and in articles for peer-reviewed publication; and
5. team-working and other transferable skills.

References & Further Reading

McGough *et al.* 2013 'Massively parallel landscape-evolution modelling using general purpose graphical processing units', http://ieeexplore.ieee.org/xpl/abstractAuthors.jsp?arnumber=6507488
Wainwright, J and M Mulligan (eds) 2013 *Environmental Modelling: Finding Simplicity in Complexity*. 2nd Edition. John Wiley and Sons, Chichester.
Gallagher, K, S Jones and J Wainwright (eds) 2008 *Landscape Evolution: Temporal and Spatial Scales of Denudation, Climate and Tectonics*. Geological Society Special Publication, London.
Maddy, D et al. 2005. An obliquity-controlled Early Pleistocene river terrace record from Western Turkey? *Quaternary Research* 63, 339-346.
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Further Information

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