

Statistics for Environmental Evaluation

A two-week training course with the above title was organised recently by Marian Scott of the Department of Statistics, University of Glasgow and Ron Smith of CEH, Edinburgh as part of the NERC/EPSRC Environmental Mathematics and Statistics programme.

The rationale for the course is that Environmental Science is facing a number of challenges in the new millennium. The models developed to understand ecosystem behaviour are being extended and linked to simulate whole earth system responses, encouraged by the developments in computer technology, but the quantification of environmental responses to change remains a major challenge. Technology has also encouraged a massive increase in data collection through automated monitoring, satellite images, etc. and, especially with a scientific focus on the effects of climate change, the value of archived data and long run datasets is again appreciated. Simultaneously with these developments, governments and industry have recognised that good environmental management has a major economic impact and are requiring rigorous justification of this expenditure in relation to other fiscal pressures.

Statistics can provide the necessary rigour to answer these questions. However a broad range of modern statistical methodology is required to tackle these substantive environmental problems and these methods are not generally available within environmental science departments. With complex questions such as

- (a) how has climate changed in the past?
- (b) how can time series of proxy indicators from different locations be reconciled?
- (c) what relationships exist between precipitation change, river flow and floods?
- (d) what trends there are in extreme sea-levels?

statistical modelling will help in finding satisfactory solutions. However, in most cases, there will not be a single statistical technique which can be applied 'off-the-shelf'.

The training course was designed to provide a quite detailed overview of some modern statistical methods along with discussions of their application (potential and otherwise) to environmental problems supported by substantive examples and a number of case studies. The statistical analyses, wherever possible, were presented using freely available software such as R and WinBugs so that participants could perform future analyses after the course. Practical sessions followed most of the lectures and participants were able to have hands-on experience of some of the methods met in the earlier lecture.

The main target audience for the course was environmental scientists at postgraduate (second or third year) or postdoctoral level. Course participants came from Earth and Environmental Sciences, Biological and Life Sciences, Geography, Geology, Meteorology and several other scientific disciplines. They were statistically numerate, having had some previous exposure to statistics training, and some had developed expertise in particular statistical techniques used in their field of study. The course was substantially over-subscribed, with more than 60 applicants, and 40 scientists were selected to attend the course from research institutes and universities around the country.

For each week, there were close on 10 lecturers, who ran specific themed sessions on their speciality but also participated in the practical session for all other themes. This was particularly important since it meant that the 'students' got to know the lecturers and vice-versa, which engendered a good atmosphere and also encouraged the less formal discussions.

As well as these more formal sessions, there were a number of informal discussion and question and answer sessions. One highlight was during the first week of the course, when participants introduced their own work and highlighted specific questions they had, and the breadth of the environmental issues being tackled impressed everyone.

Logistically, the course was run over two sessions, each divided into a number of themed modules. The format for each session was the same with the two sessions approximately 6 months apart. For each themed module within the session, there was an expository lecture on the statistical methodology followed by a series of case studies covering more advanced material with the opportunity to discuss the techniques.

The statistical themes covered were extensive, including many general modern statistical methods such as advanced parametric and non-parametric regression modelling, multivariate methods (for the study of complex inter-relationships), sampling and monitoring (both the design issues and analysis of the data), extreme value modelling, and Bayesian methods. There was also a specific emphasis on spatial methods, modelling time series data, and the more complex recent developments in space-time modelling. Model evaluation, sensitivity and uncertainty analysis were also covered, as was the use of statistics in developing and evaluating environmental policy. These statistical themes were all mapped to environmental applications including detection and quantification of environmental trends potentially related to climate change, modelling and predicting environmental extremes (floods and storms), determining environmental gradients for species change, analysing complex environmental responses (including quantifying spatial patterns across oceans and dimension reduction for meteorological data), exploring causes for changes in animal population cycles, and assessing both environmental and health-related impacts of environmental pollution.

A number of special sessions were organised and these included Professor Peter Guttorp of the University of Washington who in March gave a session on spatio-temporal modelling, and in September, Dr Campbell Gemmill, CEO of the Scottish Environment Protection Agency and Dr John Custance, chief statistician of the Environmental Protection Statistics & Information Management Division of DEFRA both gave presentations on policy issues.

Participants and lecturers alike found the course hard-work, but worthwhile, rewarding and extremely stimulating. An e-mail list for the course participants has been created to encourage further dialogue and it is hoped that there will be further initiatives planned to foster collaborations.