Environmental Modelling

د/ دعاء عادل الامام

مدرس العلوم البيئية

قسم العلوم البيئية

كلية العلوم – جامعة دمياط

Email: doaa_elemam17@yahoo.com
doaa_alemam@du.edu.eg

Mobile: +201148748730

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Introduction/definition

Environmental modelling

- **Environmental modelling** is the creation and use of mathematical models of the environment. Environmental modelling may be used purely for research purposes, and improved understanding of environmental systems, or for providing an interdisciplinary analysis that can inform decision making and policy.
- Environmental modelling involves the application of multidisciplinary knowledge to explain, explore and predict the Earth’s response to environmental change, both natural and human-induced.
- Environmental modeling deals with representation of processes that occur in the real world in space and time. The processes that transform the environment through time are mostly described by dynamic models based on differential equations.

Environmental modelling

The spatial interactions and topological rules are mostly managed by geographic information systems (GIS). The data models can include description of real objects such as sources of pollution separated in dependence on their shape to point, line and area features, and other objects including buildings, roads, rivers, railways, and monitoring networks arranged in layers. Recently in environmental modeling, GIS has been used to provide input variables required by simulation models and yield visualization and analysis of output data.

Environmental modelling

Environmental models can be used to study many things, such as:

- **Climate.**
- **Coastal changes.**
- **Hydro-ecological systems.**
- **Ocean circulation.**
- **Surface and groundwater.**
- **Terrestrial carbon.**
- **The behaviour of enclosed spaces.**
- **The behaviour of spaces around buildings.**

Environmental modelling

According to the Environment Protection Agency (EPA) (2009a), a model is defined as:

A simplification of reality that is constructed to gain insights into select attributes of a physical, biological, economic, or social system. A formal representation of the behaviour of system processes, often in mathematical or statistical terms. The basis can also be physical or conceptual.’

Environmental modelling

Models can be used to improve understanding of natural systems and their reactions to changing conditions. They can also help inform decisions and policy.

Models are becoming increasingly sophisticated as computational power increases and our knowledge of processes and behaviours improves, but they will never completely replicate the full complexity of environmental system, and must be based on simplifications of, and assumptions about, environmental processes. Despite these limitations, models can be invaluable tools in helping diagnose what has taken place, to examine the causes of behaviour and to forecast outcomes and future events.

Environmental modelling

Before beginning modelling, it is important to identify the limitations and boundaries of available models, or models that can be created, how they can be applied and to which systems and situations.

When developing a model the following questions should be considered:

- What are the processes that the model is attempting to reproduce or include?
- What is the time scale for these processes?
- What is the spatial scale of these processes?
- How reliable will the results be?
- How will the results be used?
- Do the benefits of modelling outweigh the cost?
- Is an alternative means of assessment available?

Types of model

Types of model

There are a number of different kinds of model, including:

•**Empirical**: Relying on observed relationships in experimental data.

•**Mechanistic**: Including the underlying mechanisms and processes between the variables.

•**Deterministic:** Changes in model outputs are due to changes in model components, meaning that repeated tests under constant conditions will produce consistent results.

•**Probabilistic**: Utilising the entire range of input data to develop a probability distribution of model output rather than a single point value.

•**Dynamic**: Predict the way a system may change over time or space.

•**Static**: Predict the way a system may change as the value of an independent variable changes.

Model life-cycle

Model life-cycle

The model life-cycle may include a number of stages.

1. Identification:

Determine the correct decision-related questions and establish the modelling objectives.

Define the purpose of the modelling activity.

Specify the context of the model application.

2. Development:

Develop the conceptual model that reflects the underlying science of the included processes.

Develop the mathematical representation of that science.

Model life-cycle

3. Evaluation:

Peer review.

Formal testing to ensure the correct encoding of model expressions.

Comparison with empirical data to test model outputs.

4. Application:

Run the model and analyse the outputs.

Model availability

Model availability

- Modelling complex systems has in the past been carried out by experts who have a sound understanding of the processes involved, and a good grasp of the sort of input data that is required and the outputs that are likely to be generated. In effect, the model would, to a certain extent, simply confirm what they already expected. If the model produced unexpected results, they would re-assess the inputs, the model and the outputs to understand why.
- As computers have become increasingly powerful, more data has become available, and software developers have begun to give models more user-friendly front ends, and visually attractive outputs, modelling has become accessible to non-experts. Whilst this can be positive, in that it allows greater use of sophisticated analytical tools, it can also be very dangerous, as the inexperienced modeller is more likely to accept model outputs as 'facts' rather than simply a contributing part of a wider analytical process that should be regarded with healthy scepticism.

Data quality

Data quality

It is important that data upon which environmental modelling is based is of a high quality. Data which is of poor quality will not yield model results of a higher quality.

Some of the indicators of data quality include:

Precision.

Bias.

Representativeness.

Comparability.

Completeness.

Sensitivity.

Integrated Environmental Modeling

Integrated Environmental Modeling

Integrated modeling is a systems analysis-based approach to environmental assessment. It includes a set of interdependent science based components (models, data, and assessment methods) that together form the basis for constructing an appropriate modeling system. The constructed modeling system is capable of simulating the environmental stressor-response relationships relevant to a well specified problem statement.

Integrated Environmental Modeling

Integrated multimedia and multidisciplinary approaches are increasingly needed to address our most pressing environmental challenges. The Ecosystems Research group of EPA defines Integrated Environmental Modeling in the following way:

Integrated environmental modeling (IEM) is a new paradigm for conducting environmental assessments. The complexity of modern environmental problems, decisions and policies requires EPA scientists to consider the environment in a holistic manner.

Integrated Environmental Modeling

Integrated environmental modeling allows scientists to use cross-disciplinary science and computer capabilities to characterize problems by:

•Geographic scale

•The dynamic and interdependent nature of chemical and physical stressors and their impacts on humans and the environment

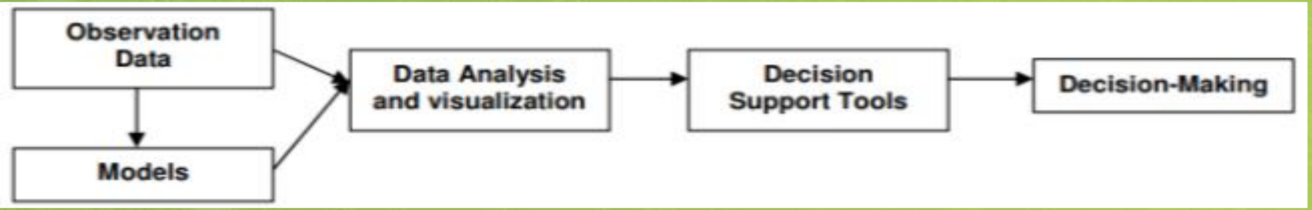
•Stakeholder diversity at local, state and national levels

•Social, economic and political issues fundamental to making sustainable decisions

Integrated Environmental Modeling

Environmental decision-making often relies on analysis of quantitative information from both monitoring and modeling to support assessments of both the state of the environment and the consequences of alternative environmental policies

Models represent our understanding of how the world works and play an important role in the conduct of both research and regulatory decision-making. In the conduct of research, models facilitate the development and testing of our understanding, while in the context of decision-making, models provide a means for applying our understanding to solve real world problems.



Analytical process to support decision making

Thank You !