MODEL APPLICATION FOR DECISION MAKERS AND POLICY EVALUATORS

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Contents

Summary

This paper describes the scale problems that underpin any model used for scientific research or decision making. The spatial and temporal problems involved in modeling are discussed. This then leads into a brief study of two models used in understanding and managing hydrological systems. More complex problems, such as modeling and managing sustainable development, are also described. This then leads into a brief discussion of scale, complexity and order in life support systems.

1. Introduction

Models are used in environmental sciences as a tool for assisting our understanding of a specific system of interest. Increasingly, models are used in environmental decision making and as an aid to the evaluation of past decisions and as a forecasting tool for future environmental impacts. Models are, however, like sharp tools and as any craftsperson knows a sharp tool can be most dangerous when it is applied incorrectly. Hence, if scientists and decision- makers are to use these tools as an aid to their investigations and decision making it is essential that these tools are used carefully. It is important, therefore, that model builders have a firm understanding of the different roles that scale problems have in our modeling endeavours as scientists; as well as appreciating the limits to modeling as an input to decision making.

The use of models in science (and in decision making) requires eternal vigilance. The purpose of this article is to examine model applications for decision makers and policy evaluation. This paper is divided into six sections. The following two sections examine the spatial and temporal domains of the scale problem. Then, in section four, an example of water flow through a hydrological system is used to illustrate the ways in which spatio-temporal dimensions of the scale problem can influence our modeling activity of life support systems.

Section five then discusses some of the implications of the scale problem. Included in this section is a brief description of the steady state model of sustainable development and some brief comments on the scale problems involved in Modeling these more complex systems Finally, some of the questions raised by an examination of the scale problem are addressed.

2. The Spatial Dimension

The problems associated with scale underpin any activity in the science and technology of life support systems. These scale problems can be readily identified but are difficult to resolve. Scale problems consist of three interrelated aspects namely the spatial extent of the study; the temporal duration used and the substantive stocks and flows that reside in or move through the specific system. The spatial extent implies an underlying geometry to any investigation. This geometry can be either absolute or relative.

An absolute geometry conceptualises space as a container of things, whereas in a relativistic concept of space it is the things that form the space. These two different views of space will be examined later. The geometry chosen also has implications for the methods used to investigate the problem. The temporal scale implies one or more time frames for the investigation. The obvious time scale is to determine how long the problem is supposed to endure. Other temporal problems reside in the solution time of any equations used in a model of the problem under investigation.

A solution time is an arbitrary temporal unit chosen to solve one or more different or differential equations that represent the system as a mathematical model. In many cases the model of the system may contain both fast and slow dynamics within it and then the so-called stiff equations have to be solved. The third aspect of the scale problem involves the amount of people, animals or other materials, energy, information or capital residing in or flowing through the system. When these different elements of the system represent finite quantities they are termed stock variables.

Alternatively, when some of these elements flow through the system they are referred to as flow rates or fluxes. The identification of stocks and flows depends entirely on the problem under investigation but are also an important and integral aspect of the scale problem. The scale problem will be examined with regard to the hydrological cycle and then, briefly, with regard to an early attempt to model sustainable development as a steady state. The hydrological cycle is an important life support system on Earth and, although other cycles could have been used, the hydrological cycle illustrates vividly many of the problems associated with the scale problem. The scale problems involved in modeling sustainable development, a more complex problem than hydrology, are also noted.

In any investigation of a life support system, for example, the ways in which an ecosystem functions or the ways in which hydrological systems operate there are *a priori* considerations of spatial scales which have to be considered. Any spatial scale implies an underlying geometry and there are at least two views about the appropriate geometry to be employed. The first view of space views space as an absolute container of things.

This view of space is derived from Kants' view of philosophy (Kant, 1781). Often the absolute concept of space is interpreted by using the well-known Euclidean geometry for any investigation. (Harvey, 1969). There are, however, relativistic concepts of space and these are derived from non-Euclidean geometry. The latter geometry developed with and alongside Einstein's theories of relativity. It could be argued that a third class of geometry namely topology is more general and this too has been used in many spatial studies.

2.1. Geometry

2.1.1. Absolute Space

The concept of absolute space regards space as an absolute container for all material objects. This idea of an absolutist space can be discerned in the Ancient Greek Atomists work and especially in the revised view of Kant. The real triumph of the absolute view of space came with the Newtonian synthesis of physics which Kant greatly admired (Kant, 1781). As Russell puts it absolute space "consists of a collection of points, each devoid of structure, and each one of the ultimate constituents of the physical world. Each point was everlasting and unchanging: change consisted in its being "occupied" sometimes by one piece of matter, sometimes by another, and sometimes by nothing" (Russell, 1948, 277).

At the time of Newton's writings only Euclidean geometry had been developed and this was the natural language to describe spatial relations. There is much to admire in the axioms and development of Euclidean geometry. For builders and engineers, for example, the idea of space described by Euclidean geometry seemed to accord to the world of the senses. Yet, for all its apparent successful applications, indeed because of its success, the development of other geometries was curtailed until the nineteenth century.

2.1.2. Relativistic Space

Theoretical developments in nineteenth century mathematics and in physics, especially in the examination of small scale and astronomical scale systems, led to the development of non-Euclidean geometry. The break from the absolutist concept of spatial relations, from a view where space was a container of things, to the adoption of a relativistic notion of space in some areas of intellectual enquiry was important. The importance of this change to a relativistic concept of space resides in the fact that the "space" is made up of the relationships between things rather than conceived as a container for things. Einstein's theory of relativity (special and general) was important for a variety of reasons.

As Asimov puts it "the most important aspect of Einstein's theory was its denial of the existence of absolute space and absolute time" (Asimov, 1984, 357). Whilst the relativistic concept of space and time apparently defies common sense it should be noted that for extremely small phenomenon (e.g. inside the structure of an atom) or for exceedingly large problems (e.g. the evolution of galaxies) the absolute space time frame of Kant is replaced by a relativistic frame of reference to which events in the universe can be related. Either framework will be valid and we can simply choose the frame that is most convenient for the problem under investigation. It should, however, be emphasised that for many medium-sized Earth based problems an absolutist framework will suffice.

In recent decades interest in topological transformations of space has been explored. These transformations are concerned only with the continuous connections between points of a figure. This idea is based, in part, on Thompson's biological studies into growth and form (Thompson, 1954). The idea of distorting sketches of say a crab to illustrate the ways in which the same basic shape of carapaces of various crabs can be discerned but in each case it is embedded in a different co-ordinate system. The importance of topological transformations of space is not simply to show distortions of geographical areas but to allow researchers to test theories of earth systems which assume uniform density distributions which are not immediately apparent with the casual observations of the Earth's irregular features (Bunge, 1966).

The ideas of absolute or relativistic concepts of space have been developed and often rediscovered in other disciplines. Sometimes this discovery has been due to the idea that physics is the most advanced and basic of sciences so that many other subjects mimicked the development of classical Newtonian science. In fact, such mimicking has been dubbed "physics envy" (Massey, 1999).

Whilst there is some truth in Masseys assertion it is also true, a point acknowledged by Massey, that *contemporary* physcis is also concerned with both being and becoming (Prigogine and Stengers, 1982). In one sense the idea that we need to consider not just past patterns of empirical phenomena but also the ways in which they evolve is an important part of contemporary science.

The evolution of systems whether they are the movement of large Earth plates or the evolution of plants and animals or the development of societies in all their different manifestations is a point of profound philosophical concern. More complex problems such as modeling sustainable development within the life support systems of the Earth as an aid to decision making are also vitally important but raises even more profound problems such as justice and equity.

2.2. Scales of Measurement

So far this description of spatial dimension has concentrated on geometry rather than physical size. Yet, for any scientific study into physical phenomenon size matters. The measurement of any thing requires some agreement on the scales of measurement used and the units employed. Scales of measurement can be defined as one of four categories nominal, ordinal, interval and ratio. The nominal scale is a non-overlapping category into which an observation falls. Magnitude or quantity are not relevant. For example, the mineral is quartz or it is not. Households could be classified as car owning or non-car owning. In nominal scales of measurement magnitude or quantity are not relevant.

Ordinal scales are used when observations such as Moh's scale of the hardness of Minerals is used e.g. talc has a hardness of 1; quartz has a hardness of 7 and diamond has a hardness of 10. Again, a survey may ask if residents are 1 very satisfied, 2 satisfied, 3 neither dissatisfied or satisfied 4 dissatisfied or 5 very dissatisfied with, say, public transport in a city. Again, an interval scale is used. In interval scales the steps between the intervals are not necessarily by the same amount, so it would be wrong to do any arithmetic with the data. Talc is not ten times softer than diamond nor are two people satisfied with public transport equivalent to one person dissatisfied.

Interval scales have equal steps between successive intervals, so that arithmetic is possible -but an interval scale has no zero point to indicate the absence of a particular characteristic. When temperature is measured at 0 degrees Celsius it does not mean that no temperature exists but that the reading is equally spaced between -1 and +1 degrees. The zero is arbitrarily fixed (as the freezing point of water) we cannot say that 20 degrees C is twenty times warmer than 1 degree, but we can say that the difference in temperature between 20 degrees C and 0 degrees C is twenty times that of the difference between 0 degrees C and 1 degrees C.Ratio scales is the highest form of measurement as they have a true zero and equal increments between successive steps. A mass of 2 kg is exactly twice 1kg mass. Mass, Length and Time are all ratio scales (except when time is measured as AD or BC in the Western Christian tradition). The different scales of measurement allow more sophisticated statistical techniques to be performed on the data so that more penetrating analyses can be undertaken.

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Biographical Sketch

Dr. Ian Moffatt is a Senior Lecturer in the Department of Environmental Science at the University of Stirling, Scotland. He has BSc (London University) in geography and geology; a MSc in urban geography and a PhD in urban system modelling from the University of Newcastle Upon Tyne, England. He has been a lecturer at the University of Liverpool, England and a Senior Research Fellow at the Australian National University and a founder member of the Department of Environmental Science at the University of Stirling, Scotland. He has lectured extensively in Europe, North America, China and Australia. He has been involved in policy making into improving water quality in estuaries using regulative and economic incentive approaches as well as being a scientific adviser to the Northern Territory Governments Advisory Committee on the Greenhouse Effect (1990-1993). His main research interests are into sustainable development from an interdisciplinary perspective at different spatial and temporal scales. This research includes the development of dynamic simulation models for understanding and contributing to the management of environmental systems. He has published numerous scientific papers and six books, the last two are contributing to making development sustainable.