8: Modelling Climate Change

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GCMs

Global Climate Models also known as General Circulation Models (GCMs) are the most complex of climate models, since they attempt to represent the main components of the climate system in three dimensions. GCMs are the tools used to perform climate change experiments from which climate change scenarios (possible representations of how the climate will evolve) can be constructed. The design and structure of an individual GCM determines the climate change experiments that can be performed. These characteristics are limited by our scientific understanding of the climate system and by the available computing resources.

The historical evolution of GCMs, computing resources, and the nature of climate change experiments, are inextricably linked. This evolution of the Hadley Centre models can be viewed in a historical context through as shown in Table 1.

Table 1: Evolution of the Hadley Centre GCMs (see text for explanation of the terms)

Model Name and Experiments	Year	Ocean	Resolution lat. x long.
UKLO Equilibrium 10 year integration	1987	Slab-ocean	5.0 x 7.5
UKHI Equilibrium 10 year integration	1990	Slab-ocean	2.5x3.75
UKTR Transient cold-start Multi-decadal integrations	1992	20 layer full ocean	2.5 x 3.75
HadCM2 Transient warm-start Historically forced Multi gas Multi-century integrations Multi-member ensembles	1995	20 layer full ocean	2.5 x 3.75
HadCM3 As HadCM2 but including gas life cycle models and early version of a biosphere model No flux correction	1998	20 layer full ocean at 1.25x1.25° resolution	2.5 x 3.75

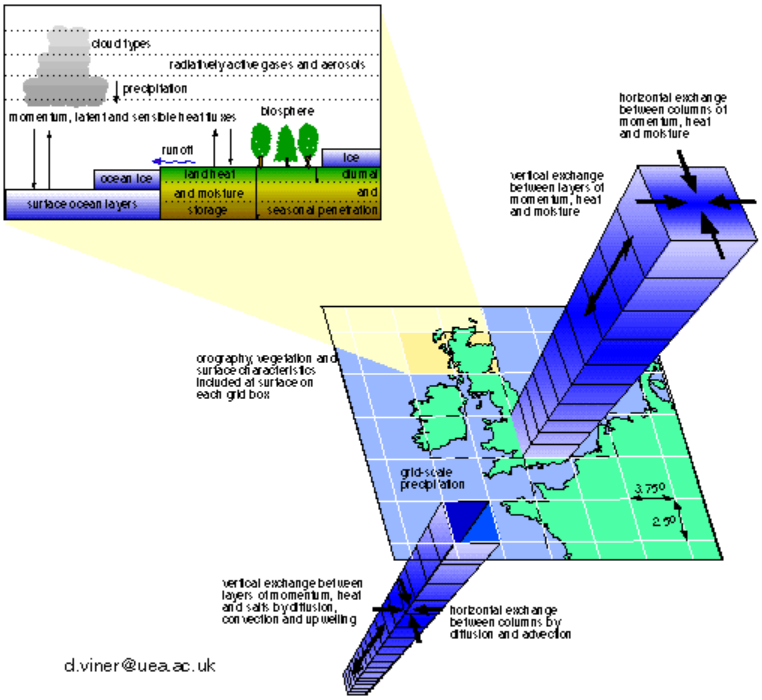
Note: For further details of the Hadley Centre's GCMs, climate change experiments and available data sets please see the Climate Impacts LINK Project

GCMs can be split into three main types:

1. Atmospheric GCMs coupled with a simple slab ocean (a single fixed layer representation of the ocean) and simple land-surface parameterisation schemes (e.g. UKLO and UKHI).

2. Atmospheric GCMs coupled to a three-dimensional representation of the the ocean system (one in which ocean currents and heat transport are represented) and with simple land-surface parameterisation schemes (e.g. UKTR).
3. Atmospheric GCMs coupled to a three-dimensional representation of the ocean and a three dimensional terrestrial biosphere model (e.g. HadCM2 and HadCM3).

Figure 1: A conceptual structure of a coupled ocean-atmosphere GCM



In order to develop a fully coupled ocean-atmosphere GCM and run climate change experiments with it, there is a need for very large high performance computing resources. As a result there are only a few centres around the world with the necessary facilities. For example, the Hadley Centre has access to two CRAY 3TE Supercomputers, both with over 900 processors each. Coupled to this there is the need for multi-terabyte data storage and processing facilities.

Climate Change Experiments

Climate change experiments performed with GCMs can be split into two generic types:

Equilibrium Climate change experiments

The first generation of climate change experiments were performed with atmosphere only GCMs. These were used to simulate the equilibrium response of the climate system to an instantaneous increase (usually a doubling) of the atmospheric carbon dioxide concentration. Because of the absence of an ocean component, and because only slow computers were available, these experiments could only be performed to simulate short periods (e.g. 10 years) and their results could not be fixed to calendar years.

Transient Climate change

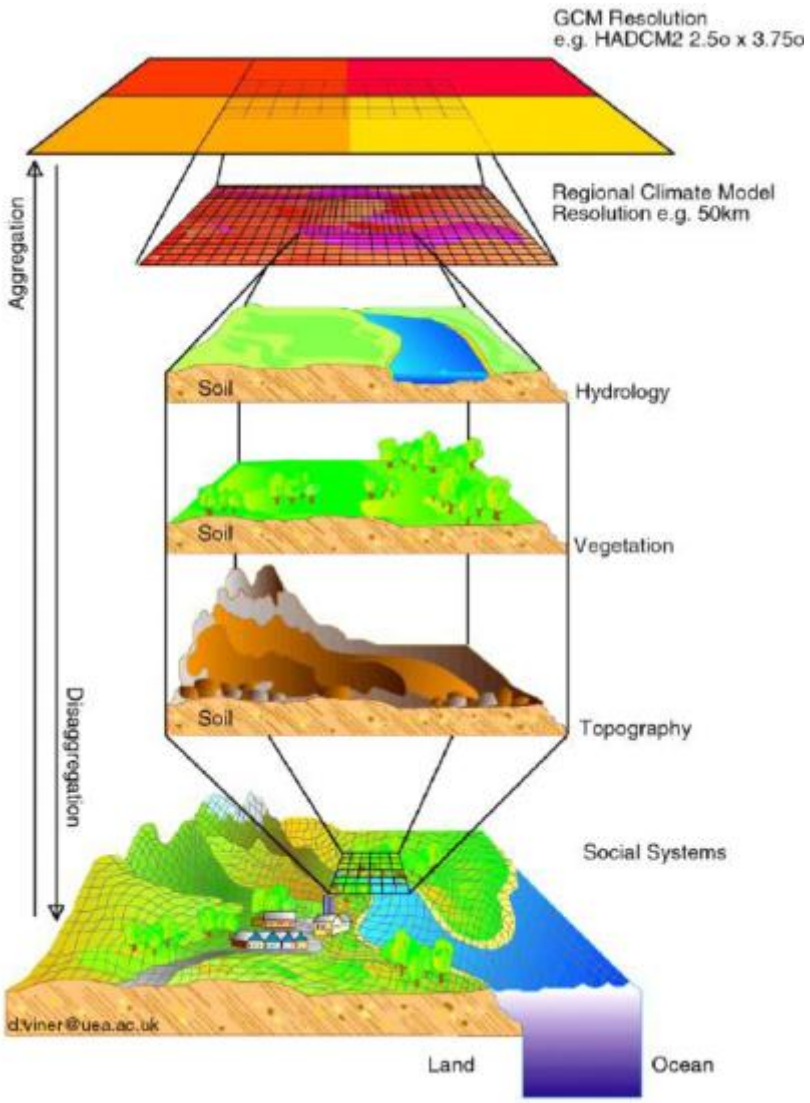
With the advent of more powerful computers, climate change experiments could be performed with coupled ocean-atmosphere and, more recently, coupled ocean-

atmosphere-biosphere GCMs. The most recent climate change experiments have consisted of multi-century ensembles of integrations which have been used to investigate the response of the climate system to different scenarios of radiative forcing. One of the major implications of these experiments was that results could be fixed to calender years.

Results and Application of the results from GCM Climate Change Experiments

The results of climate change experiments have been used widely to investigate how ecosystems and / or socio-economic systems will respond to an evolving climate. The spatial resolution of GCMs is relatively coarse, of the order of 2.5 latitude x 3.75 degrees longitude. This often leads to a mismatch, as the majority of impacts assessments are carried out at resolutions of 50km or less. To overcome this difference in scales (as indicated by Figure 2) there is a need to construct scenarios (see information sheet 9).

Figure 2



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