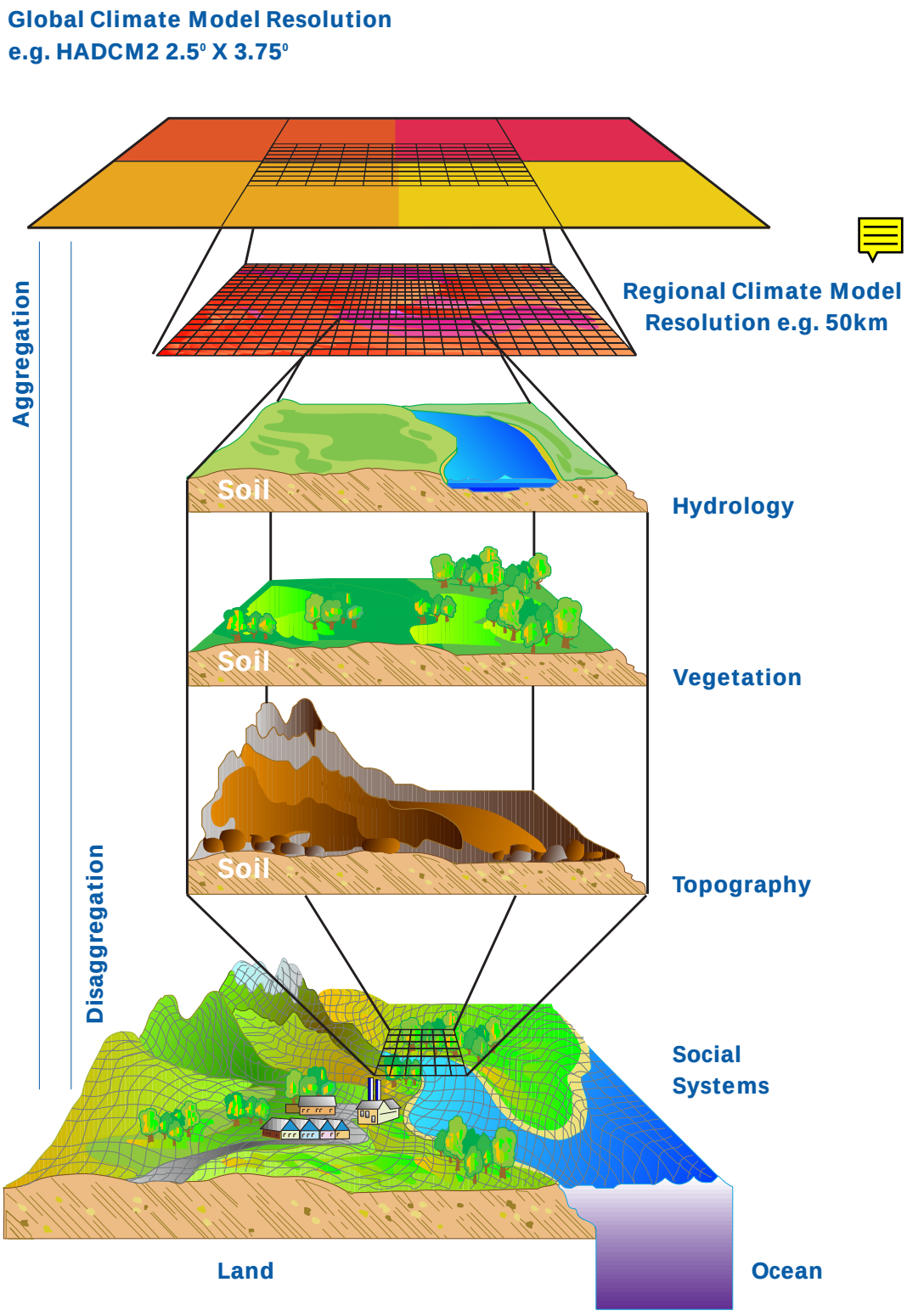
UEA NORWICH

DEPARTMENT OF THE ENVIROMENT, TRANSPORT AND THE REGIONS

The Climate Impacts LINK Project:

Applying Results from the Hadley Centre's Climate Change Experiments for Climate Change Impacts Assessments



David Viner
Mike Hulme
December 1997
Published by Climatic Research Unit,
UEA, Norwich
ISBN: 0 902170 10 4

Contents

Acknowledgments

- The UK Department of the Environment, Transport and the Regions (Global Atmosphere Division) which provides the funding for the Climate Impacts LINK Project.

- The staff of the Climatic Research Unit, in particular Elaine Barrow, Tim Osborn, Olga Brown and Julie Jones.

- The Hadley Centre for Climate Prediction and Research, especially Jean-Christophe Thil, Geoff Jenkins and Tim Johns.

- Climatological normals for the UK were provided by the UK Met. Office.

- Dr Nigel Arnell, Department of Geography, University of Southampton and Nick Reynard, Institute of Hydrology, Wallingford for the Case Study which was funded by the UK Water Industry Research Ltd (UKWIR) and the Environment Agency

The Climate Impacts LINK Project:

Applying Results from the Hadley Centre's Climate Change Experiments for Climate Change Impacts Assessments

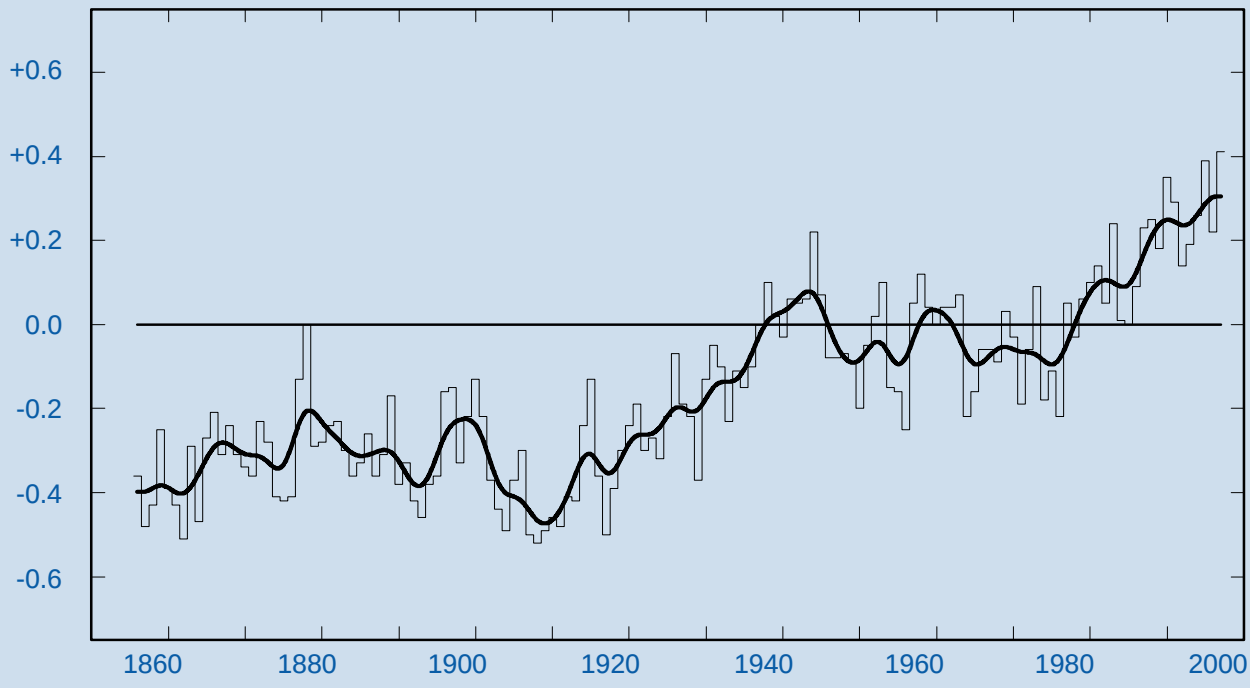
The Department of Environment, Transport and the Regions (DETR), formerly (DoE), is responsible for leading the development of United Kingdom Government policy in response to the threat of climate change. It is essential that such policy should be underpinned by sound science. The DETR therefore commissions policy-relevant research, drawing where possible on the wider national and international research base. The DETR also commissions research on climate prediction, most notably through the Hadley Centre for Climate Prediction and Research, together with research on climate impacts and response strategies.

The Hadley Centre Programme is a key component of the approach taken for improving our understanding of climate change. It is well recognised, however, that our assessment of the potential effects of climate change is relatively undeveloped. The Climate Impacts LINK Project was conceived to encourage research on impacts and to ensure that the most recent results from the Hadley Centre would be made available to a wider community in an effective and consistent manner. Since 1991 the Climatic Research Unit at the University of East Anglia has hosted the Climate Impacts LINK Project and has disseminated the results of the Hadley Centre's climate change experiments to hundreds of researchers throughout the UK and elsewhere.

This booklet provides an overview of the scope of the Climate Impacts LINK Project and guidance on making use of climate scenarios for impacts studies.

Figure 1

Combined land, air and sea surface temperatures relative to 1961- 90 averages



1

1. Climate Change, the Greenhouse Effect and International Activities

From the start of the industrial age (i.e., since about A.D.1750) to the present day there has been a rise in the global-mean surface air temperature of approximately 0.6°C (refer to Figure 1). It is unlikely that this change is entirely natural in origin. At least part of this warming has been brought about by increasing atmospheric concentrations of the greenhouse gases, most notably carbon dioxide (CO^2), methane (CH^4), nitrous oxide (N^2O) and the halocarbons. This climate warming is due to the 'enhanced greenhouse effect', an effect that is conceptually described in Figure 2. Continued growth in atmospheric concentrations of these gases is likely to lead to further climate change. To assess the scientific understanding of climate change, the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) established in 1988 the Intergovernmental Panel on Climate Change (IPCC). The IPCC reported its First Assessment in 1990 and its Second Assessment in 1996. This Second Assessment Report concluded that the balance of evidence suggests that there has been a discernible human influence on the global climate.

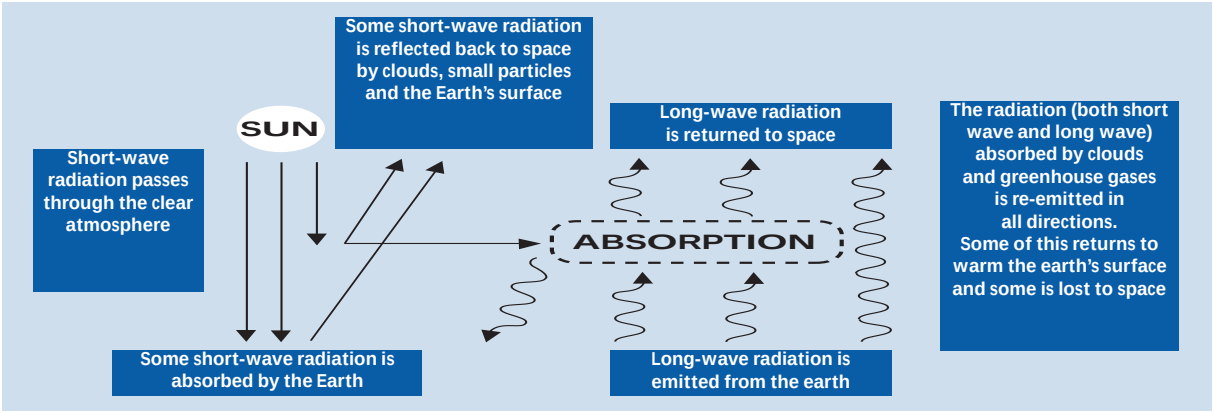
To begin to consider our global response to climate change the UN Framework Convention on Climate Change (UNFCCC) was signed by over 150 countries in June, 1992. The ultimate objective of the UNFCCC set out in Article 2 is:

"...the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the global climate system. Such a level should be achieved within a time frame to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner..."

The United Kingdom is a party to the UNFCCC and has an obligation under Article 4 (along with other developed countries) to return emissions of CO^2 to 1990 levels by the year 2000.

In addition to increases in atmospheric concentrations of greenhouse gases and global-mean temperature, greenhouse gas-induced climate change has the potential to produce other significant effects upon the climate system at all scales (local, regional, continental and global). Examples include rise in sea-level, changes in seasonality, altered atmospheric circulation and changes in the frequency and magnitude of extreme events. Such changes will manifest themselves in a variety of ways, some may be beneficial, but many may be damaging. On a local scale, there may be migrations or extinctions of individual populations of flora and fauna. At a regional level agricultural practices may be forced to adapt to a different climate and new crops introduced. The response to climate change at a global scale will be more difficult to ascertain because of the complex links and feedbacks that exist between component systems, both natural and socio-economic.

Figure 2
A simplified diagram illustrating the greenhouse effect



2

2. The Climate Change Research Programme of the Department of the Environment, Transport and the Regions

The United Kingdom is committed to scientific research aimed at improving our understanding of the response of the climate system to the enhanced greenhouse effect and of the impacts of climate change.

A key component of the Department of the Environment, Transport and the Regions' (DETR) climate programme is the Climate Prediction Programme at the Hadley Centre for Climate Prediction and Research, which was established at the UK Meteorological Office in 1990. It is the aim of the Hadley Centre to understand processes which control the climate system, to represent these processes in models and to reduce the uncertainties surrounding the prediction of the response of the climate system to anthropogenic forcing. The Hadley Centre is recognised as one of the world's leading climate modelling centres and its work has had an important influence on the conclusions of the IPCC.

An important research priority is to increase our understanding of the potential future impacts of climate change on the UK. In 1990, the Department of the Environment established the UK Climate Change Impacts Review Group which reported in 1991 and again in 1996. It also commissioned a study of the economic impact of the hot summer and unusually warm year of 1995, which was published early in 1997.

More recently, the DETR has established a UK Climate Impacts Programme (UKCIP) to co-ordinate an integrated assessment of climate change impacts in the UK and to disseminate the results of such assessments to a wider community. In defining the research agenda of this Programme, UKCIP will interact with a wide range of companies and organisations likely to be affected by climate change. Through also involving researchers and policy makers, the objectives of this Programme are to:

- establish the risks associated with climate change.

- inform strategic decisions related both to the mitigation of climate change and to the need for adaptation.

3

3. The Aims and Role of the Climate Impacts LINK Project

In 1991 the DoE established the Climate Impacts LINK Project to act as the interface between the climate modelling activities of the Hadley Centre and the wider UK climate change impacts research community. Such a Project was needed to ensure that more effective use could be made of results from the Hadley Centre's climate change experiments. Consequently, the LINK Project co-ordinates a two-way channel of data and information flow between the Hadley Centre and the national impacts research community and disseminates appropriate climate data and accompanying scientific and technical advice.

Over time, the focus of the LINK Project has moved from supporting national UK impacts research to supporting international impacts research. This has occurred partly as a result of the high profile the Hadley Centre climate change experiments have received and partly due to the success of the Climate Impacts LINK Project in making results available and providing a user support service. An ever-increasing number of research projects, institutes and individuals rely upon the easy availability of the Hadley Centre's results for use in research projects. To date over 100 research projects and programmes have used data provided by the Climate Impacts LINK Project. These include among many others: the IPCC; the US Country Studies Programme; component projects of the European Commission's Climate and Environment Programme; the UK Terrestrial Initiative on Global Environmental Research (TIGER) Programme; and SILMU (Finnish Research Programme on Climate Change).

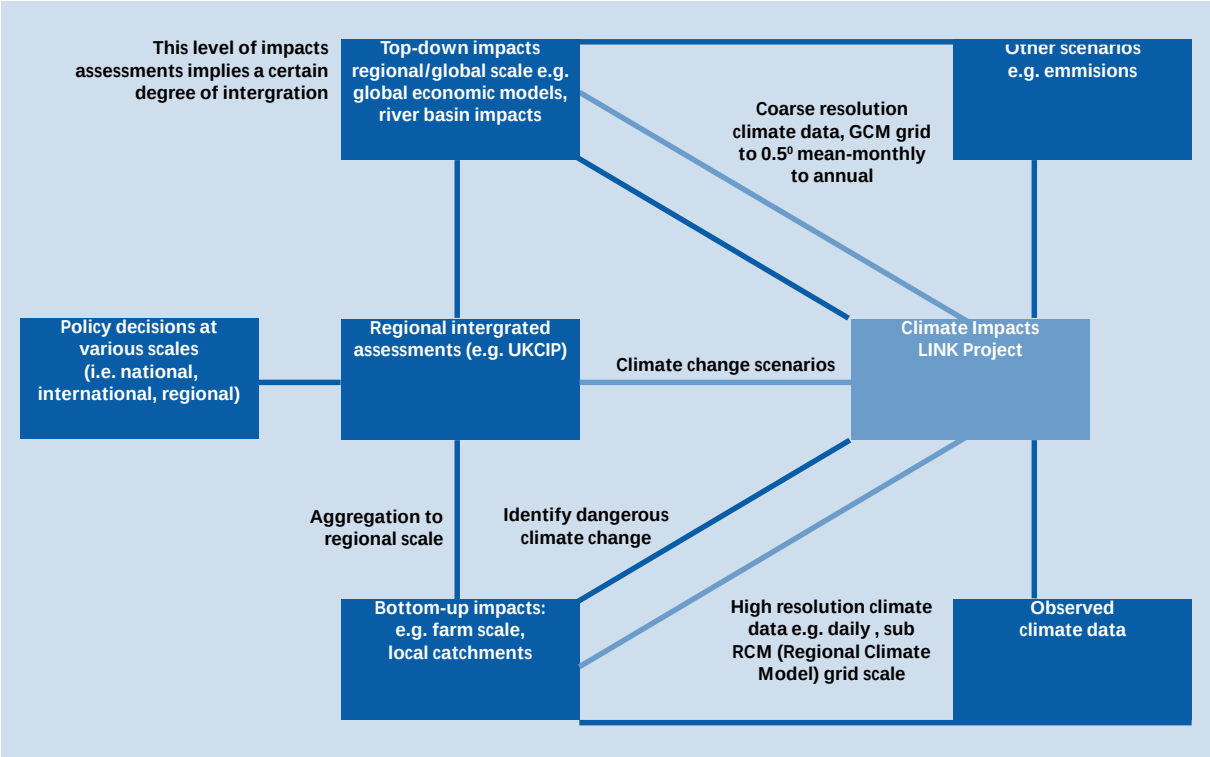


Figure 3
Data flow within the climate change impacts research community

The Climate Impacts LINK Project continues to evolve to provide the results of the Hadley Centre's climate change experiments in the most appropriate way to meet the requirements of the impacts community. For example, when the Project was first established in the early 1990s the largest climate model datasets consisted of two integrations of only ten years in length. Advances in supercomputing technology have now resulted in numerous multi-century climate change integrations from which to archive data sets. The Climate Impacts LINK Project is now established as a major focal point for the provision of observed and model-generated climate datasets. This can be seen schematically in Figure 3.

The main aims of the Climate Impacts LINK Project are:

- to make results from the Hadley Centre's climate change experiments and a variety of observed climate datasets available to the international climate change research community in forms that are easy to use and interpret.

- to provide a supporting role to the climate change impacts community to help ensure that the climate change scenarios are employed in an appropriate and consistent manner.

- to provide information to the international climate change research community about the nature of the Hadley Centre's climate change experiments and other relevant modelling and scenario activities.

4

4. Climate Models and Climate Change Scenarios

Climate change impacts assessments are diverse in nature, both in the areas studied and in their spatial and temporal scales. The primary aim of such impact studies is the assessment of the response of complex global and regional systems to climate change. To assess the impacts of climate change there is a clear need for consistent representations of future changes in climate, so-called 'climate change scenarios'.

There are two broad methodologies available for climate change scenario construction: empirical methods and process-based models. Empirical methods include instrumental analogues, palaeo-analogues or spatial analogues for climate change, while process-based models consist of a hierarchy of mathematical models of the climate system. The IPCC have recommended that process-based climate models are the most suitable methodology for the construction of climate change scenarios. Climate models fall into a number of categories and these are described in Table 1.

Table 1
The characersitics of different generic types of climate model

	Advantages	Disadvantages
Single GCM	Simulates the climate system in three-dimensions in a consistent manner	Requires large computing resources
Simple Models	Simulates the response of the climate system to a wide range of emissions scenarios and climate sensitivities. Computationally efficient	Models the climate in one-dimension only
Regional Climate Models	Simulates the regional climate response at a high spatial resolution	Driven by the results from GCMs. Computationally inefficient

4.1 Global Climate Models

Global Climate Models (GCMs) are the most complex of climate models, since they attempt to represent the main components of the climate system in three-dimensions. The characteristics of GCMs determine the nature of the climate change experiments that can be performed with them. These characteristics are determined by our scientific understanding of the way in which the climate system works and also in supercomputing technology. The historical evolution of GCMs and the nature of climate change experiments performed using them are therefore inextricably linked. This evolution can be viewed through the IPCC reporting process as described in Table 2 (opposite). Coupled ocean-atmosphere GCMs combine three-dimensional representations of the atmosphere, cryosphere and ocean components of the climate system. Figure 4 (below) shows the conceptual structure of one such coupled ocean-atmosphere GCM - HADCM2 - that has been used for performing climate change experiments at the Hadley Centre in recent years. Climate change experiments performed using GCMs can be split into two generic types: equilibrium and transient (see Box 1 opposite).

Figure 4
The conceptual structure of a coupled ocean-atmosphere Global Climate Model

This figure is available at:

http://www.cru.uea.ac.uk/link/3DGCM.html

Table 2

The evolution of the Hadley Centre's GCMs and climate change experiments

Model Name and Experiments	Year	IPCC Report	Ocean	Resolution lat. x long.
UKLO Equilibrium 10 year integrations	1987	Pre-IPCC	Slab -Ocean	5.0 x 7.5
UKHI Equilibrium 10 year integrations	1990	First Assessment Report	Slab -Ocean	2.5 x 3.75
UKTR Transient - cold-start Multi-decadal integrations	1992	Supplement to the First Assessment	20 layer full Ocean	2.5 x 3.75
HADCM2 Transient - warm-start Historically forced Aerosols included Multi-century integrations Multi-century ensembles	1995	Second Assessment Report	20 layer full Ocean	2.5 x 3.75
HADCM3 As HADCM2 but including improvements in parameterisations Sulphur Cycle Model	1998	Third Assessment Report	20 layer full Ocean 1.25° x 1.25° Resolution	2.5 x 3.75

Box 1

Equilibrium Climate Change Experiments (e.g. UKHI)

The first generation of climate change experiments using GCMs were performed to simulate the equilibrium response of the climate system to an instantaneous increase (usually a doubling) of the atmospheric CO^2 concentration. The absence of a coupled ocean GCM enabled these experiments to be performed relatively quickly on the computers available at the time in the 1980s and early 1990s. The major drawback of these experiments was that the resulting equilibrium doubled CO^2 climate assumed that the component parts of the climate system were in a steady state. In reality, however, this is unlikely to occur since there are unquantifiable and unequal lags between the component parts of the climate system. Furthermore, the results from such experiments could not be interpreted in terms of calendar years.

Transient Climate Experiments (e.g. UKTR)

Transient climate change experiments are performed with coupled ocean-atmosphere GCMs. The first generation of coupled ocean-atmosphere GCMs in the early 1990s benefited from increases in computing power and were used to perform multi-decadal (up to 100 years) transient climate integrations. As a result of the inability at the time to perform long spin-up integrations (required to obtain a steady-state between the ocean and atmosphere systems), these experiments suffered from the 'cold-start' problem and, in many case, from serious climate drift. As with equilibrium experiments, these problems also prevented calendar years from being attached to the results of such transient experiments. Results from these first transient experiments were consequently treated in much the same way as those from the earlier equilibrium climate change experiments.

The second generation of transient climate change experiments (e.g. those performed with HADCM2) have been used to examine the response of the climate system to the historic forcing of greenhouse gases and sulphate aerosols that has occurred since the early industrial period. These so-called 'warm-start' experiments have longer control integrations and a longer spin-up period so do not suffer so badly from climate drift (although they may still require flux adjustments to be made). Results from these warm-start experiments can be interpreted in terms of calendar years.

4.2 The Hadley Centre's Climate Change Experiments

Since 1991 the Climate Impacts LINK Project has distributed results from three major climate change experiments that have been performed at the Hadley Centre: UKHI, UKTR and HADCM2. As a result of improvements in both computing power and our understanding of the climate system, the Hadley Centre's climate models continue to evolve. So do the characteristics of the climate change experiments performed with them (see Box 1).

Increases in the computing resources available for climate change experiments have led to increases in the length and number of integrations being performed. Initially, an experiment such as UKHI comprised only of two ten-year integrations from which a small number of climate variables were archived. For HADCM2 there have been numerous multi-century integrations performed from which over forty variables have been archived. There are three primary integrations using HADCM2 which are important to climate change impacts research:

- HADCM2CON, the control integration in which atmospheric forcing is kept constant. This simulates a period over 1000 years in length.

- HADCM2GHG, the greenhouse gas integration, in which the greenhouse gas forcing is increased gradually to represent the observed changes in forcing due to all the greenhouse gases from 1860 to 1990 and then from 1990 to 2100 uses a 1 per cent per year compounded increase in concentrations
(a rather larger forcing scenario than is represented by the IS92a emissions scenario).

- HADCM2SUL, the sulphate aerosol and greenhouse gas integration, in which the forcing includes not only the greenhouse gas forcing described above but also the direct radiative effect of historic sulphate aerosol concentrations from 1860 to 1990 and a scenario of sulphate aerosol concentrations from 1990 to 2100 derived from the sulphur emissions in the IS92a scenario.

In addition to these integrations there have also been performed:

- HADCM2GHGd, the same as HADCM2GHG but the greenhouse gas concentrations from 1990 to 2100 are equivalent to a 0.5 per cent per year compounded increase (roughly equivalent to IS92d, a low IPCC emissions scenario).

- HADCM2SULd, the same as HADCM2SUL but the sulphate forcing from 1990 to 2100 is derived from the IS92d scenario.

In order to identify the climate change signal more clearly twelve further integrations were performed, each integration introducing the forcing at a different year of the control run. These further integrations yielded four-member ensembles for each of HADCM2GHG, HADCM2GHGd, HADCM2SUL and HADCM2SULd.

4.3 Climate Change Scenarios

To address some of the limitations of GCMs and GCM experiments, results from such experiments are often modified to allow the construction of climate change scenarios. The Climate Impacts LINK Project uses a conceptual framework for climate scenario construction that is summarised in Figure 5. This framework employs existing methods and techniques and allows climate scenarios to be constructed for a specific impacts model or application. It is the mismatch in spatial (and sometimes temporal) scale between GCMs and impacts studies that presents the biggest challenge for successful climate change scenario construction and application.

Considerable effort has therefore been made to increase the spatial resolution of results from climate change experiments at both global and regional scales. There are two main methods available: Regional Climate Models (RCMs) and time-slice integrations. For Regional Climate Models, the results of a coarse resolution global climate change experiment are used to provide the driving conditions for a high resolution (e.g. 0.5° latitude/ longitude resolution) regional climate model. The Hadley Centre has performed such experiments for Europe. In high resolution time slice integrations, the resolution of a GCM is increased (e.g. to that of an RCM), but the integrations are performed for only short time-slices (e.g. 10 or 30 years). In this case computing time is minimised because an atmosphere-only GCM is used, with the ocean boundary conditions taken from the results of the driving coarse resolution GCM climate change experiment.

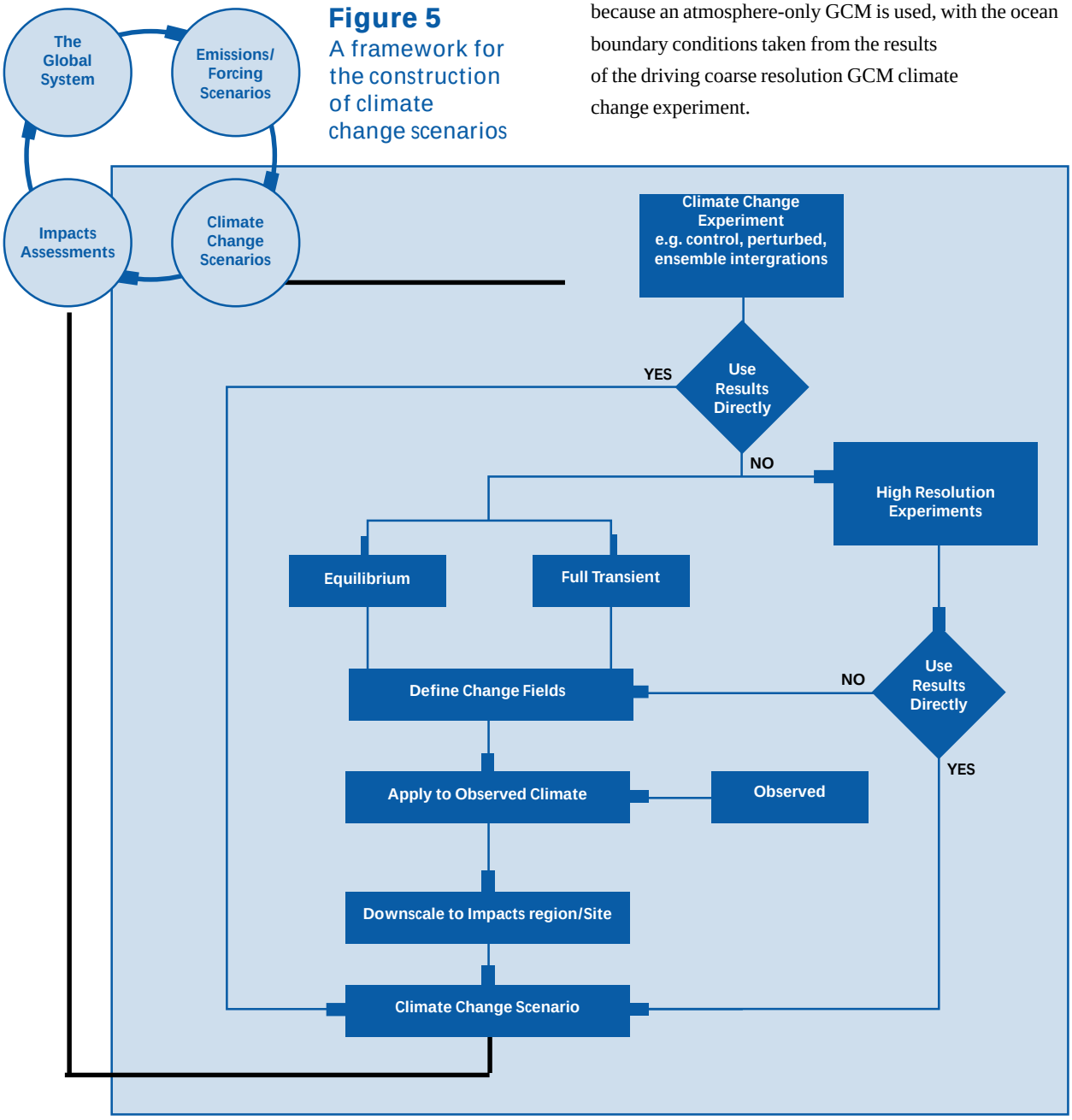


Figure 5
A framework for the construction of climate change scenarios

5

5. The Activities of the Climate Impacts LINK Project

5.1 The Provision of Climate Model Results

The increasing number of experiments and integrations by the Hadley Centre has led to the establishment by the Climate Impact LINK Project of an efficient infrastructure for the distribution of very large datasets. Results from GCM experiments that are needed for impacts assessments are now housed on-line by the Climate Impacts LINK Project on a dedicated storage system. Users can request access to any of these archived model results and these will be supplied to the user either via ftp or on tape. All users of Climate Impact LINK Project data are required to sign a Data Licence Agreement and are requested to leave a description of their research application with the Project office.

Table 3.
Observed Gridded Climatologies available through the Climate Impacts LINK Project.
Key:
P-Precipitation,
Tmin-Minimum temperature,
Tmax-maximum temperature,
Tmean- Mean temperature,
DT-Diurnal temperature range,
Sun-Sunshine Hours,
Cloud-Cloud Cover,
Pday-Raindays,
Vap-Vapour Pressure,
Fday-Frost Days and
Wind-Wind Speed.

Region	Resolution: Spatial, Temporal and Time Period	Variables
Great Britain	10km Mean Monthly 1961-1990	P, Tmin, Tmax, Tmean, DT, Sun, Cloud, Pday, Vap, Fday and Wind
Europe 35-68°N 15°W-60°E	0.5° x 0.5° Mean Monthly 1961-1990	P, Tmin, Tmax, Tmean, DT, Sun, Cloud, Pday, Vap, Fday and Wind
North America 22.5-52.5°N 125-65°W	0.5° x 0.5° Mean Monthly 1961-1990	P, Tmin, Tmax, Tmean, DT, Cloud, Pday, Vap, and Wind
South Asia 5-38°N 50-110°E	0.5° x 0.5° Mean Monthly 1961-1990	P, Tmin, Tmax, Tmean, DT, Pday, and Wind
Southern Africa 0-35°S 5-55°E	0.5° x 0.5° Mean Monthly 1961-1990	P, Tmin, Tmax, Tmean, DT, Pday, and Wind
Global	0.5° x 0.5° Monthly	P, Tmin, Tmax, Tmean, DT, Sun, Cloud, Pday, Vap, and Wind

5.2 The Provision of Observed Climate Data Sets

Accompanying the results from climate change experiments is an archive of observed gridded regional and global climatologies, details of which can be found in Table 3. These observed datasets have been used in many research projects requiring high quality climate information about current and historic climatic conditions. The combined observed and modelled sources of climatological data available through the Climate Impact LINK Project form the most extensive supported data archive that is available to the international climate change impacts research community for climate scenario applications.

5.3 Supporting Advice

Observed and modelled climate data are also accompanied by appropriate scientific and technical advice, which includes information about scenario construction techniques. The Climate Impacts LINK Project therefore facilitates the exchange of ideas regarding scenario construction and their application within impacts assessment. By providing data through a central node, which is in contact with both the climate modelling and climate change research communities, the Climate Impacts LINK Project encourages consistent use of results from the Hadley Centre and provides a support environment for researchers to make enquiries about the availability, interpretation and application of climate models and datasets.

The Climate Impacts LINK Project informs the climate change research community of ongoing developments within the component sectors of the impacts community and of new developments at the Hadley Centre by means of a regular newsletter, occasional reports and through a frequently updated World Wide Web site (see Appendix).

5.4 The International Role of the Climate Impacts LINK Project

To date, over 100 research centres worldwide have made use of the results from the Hadley Centre' s climate change experiments. This wide distribution of Hadley Centre results enables a degree of consistency to be achieved by many climate change researchers enabling results of impacts assessments to be more readily integrated. This key role played by Climate Impacts LINK Project in the provision of climate change scenarios has been recognised by the IPCC.

In 1994, the Climate Impacts LINK Project was commissioned to construct scenarios for the IPCC Working Group II 1995 Second Assessment Report. For the Third Assessment Report, the IPCC has established a Data Distribution Centre that will provide a core set of climate change scenarios to scientists that are involved in climate change impacts research. The Climate Impacts LINK Project was assigned joint responsibility with Deutches Klimarechenzentrum (DKRZ) for the running of this Centre. The Climate Impacts LINK Project is also involved in the Climate and Environment Programme of the European Commission through formal links with specific projects and through providing the framework for the ECLAT-1 and ECLAT-2 Concerted Action Initiatives. ECLAT-2 will run from 1998 to 2000.

6

6. Climate Change Impacts Assessment A Case Study: The effects of climate change on river flows and groundwater recharge

In order to assess the potential impacts of climate change on the water supply industry in the UK, a consistent methodoly is required. The ideal method would be to apply catchment hydrological models in each source catchment, and run the models with climate input data perturbed according to climate change scenarios. In practice, however, there are far too many source catchrnents for this to be feasible, and many do not have established, appropnate, catchment models. In order to overcome this problem, a "fast-track" procedure was developed, where factors were derived which could be applied to monthly river flows or annual groundwater recharge estimates, to reflect the effects of climate change.

A number of different options for climate change scenarios were initially considered, all based on the results from the Hadley Centre's climate change experiments. Four scenarios were finally selected, representing the range in the possible evolution of the climate. The first being 1996 Climate Change Impacts Review Group (CCIRG) scenario, derived from the UKTR experiment whilst the remaining three were developed from the HADCM2 experiments. The first of these used HADCM2GHG, and derived a scenario for 2025 by rescaling the change in the last 30 years of simulation to the IS92a estimate of global temperature change by 2025. The other two used the HADCM2SUL, one was rescaled in the same was as the HADCM2GHG resulrs, whilst the other was derived by extracting the 30 years around 2025 and comparing averages over this period with the baseline. Although the general pattern of the four scenarios was similar (ralatively wetter in the north), the local and regional details were very different.

The factors for river flows were produced by applying conceptual hydrological models in 60 catchments throughout the UK, simulating the effects of climate change scenarios on average monthly runoff and calculating regional average monthly changes. Factors for groundwater recharge were calculated using a simple recharge model applied to several aquifer units in Britain. Factors were derived for changes in average monthly river flow and average annual recharge, by region (based upon HADCM2 climate model grid cells) and for the four scenarios.

Glossary of Terms Used in this Report

Climate Change Experiment
A number of Simulations of the change in the climate system are performed using a Climate Model. There are two main types: Equilibrium Climate Change Experiments - a simulation of the climate system to a point where the individual components of the climate system have reached a steady state in response to an external forcing. These experiments are often performed with an atmospheric GCM coupled to a simple representation of the ocean. These have now been supperseeded by Transient Climate Change Experiments - a time-dependent investigation of the climate system to a change in external forcing. These experiments are performed with a Climate Model that can simulate (as a minimum) the three -dimensional atmospheric and ocean components.

Climate Change Integration/ Simulation
A single realisation of the climate that forms one component of a Climate Change Experiment - for example the control integration.

Climate Change Scenario
An internally consistent description of future climate change, that has been constructed from methods based upon sound scientific principles. Such scenarios can be constructed from the results of a Climate Change Experiment.

Climate Model
A mathematical representation of the climate system that is used as a tool to perform climate change experiments. Climate Models can range from simple one-dimensional models to complex coupled ocean-atmosphere GCMs.

Climate Sensitivity
The fully realised steady-state globally averaged surface air temperature change following the response of the climate system to a doubling of atmospheric CO_2 concentrtaion.

General Circulation Model (GCM)
A three dimensional representation of the climate system that can vary in levels of complexity and that can be used as a tool for performing Simulations of the climate system. Examples are: an atmospheric GCM coupled to a simple representation of the ocean (often called a Slab-Ocean); and a Coupled Atmosphere-Ocean GCM which is a complex three dimensional representation of the coupled ocean and atmospheric components of the climate system. These will sometimes be linked to other three dimensional components of the climate system, for example, the biosphere.

Climate Prediction
The ultimate goal of climate change research is the ability to make probablistic statements about the future climate and conditions on a sub-regional scale. This goal has not yet been reached.

Climate Projection
This is the term used by the IPCC to describe an integration of a climate model forward in time. This is not a prediction because it acknowledges that the model and the characteristics of the climate change experiments have major limititations and that it is not possible, therefore, to attach a probability to the results of such a description.

Appendices

Further Reading

CCIRG 1996 *Review of the Potential Effects of Climate Change in the United Kingdom. Report* Prepared for the UK Department of the Environment. Publ HMSO 247pp.

Department of the Environment **1996** *Water Resources and Supply: Agenda for Action.* Publ. The Stationery Office, London.

Harvey *et. al.*, **1997** *An Introduction to Simple Climate Modles Used in the IPCC Second Assessment Report. IPCC Technical Paper II* Eds. Houghton J.T., Filho L.G.M., Griggs D.J. and Maskell K.47pp

IPCC WGI 1995 Climate Change 1995: *The Science of Climate Change, Contribution of the WGI to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. (Eds. Houghton J.T., Meira Filho L.G., Callander B.A., Harris N., Kattenberg A., and Maskell K.) Cambridge University Press

IPCC WGII 1995 *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change Scientific and Technical Analyses,Contribution of the WGII to the Second Assessment Report of the Intergovernmental Panel on Climate Change.* (Eds. Watson R.T., Zinyowera M.C. and Moss R.H.) Cambridge University Press

Mitchell J.F.B. and T.C. Johns T.C. , **1997**. On modification of global warming by sulphate aerosols, *J. Climate*, 10 (2), pp 245-267

Palutikof J.P., Subak S., and Agnew M.D. 1997 *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995*. Report prepared for the UK Dept. of the Environment. 178pp

The Climate Impacts LINK Project's Web Site at:
http://www.cru.uea.ac.uk/link
The Climate Impacts LINK Project E-mail List:
link-users@uea.ac.uk

Viner D. and Hulme M. 1994 The Climate Impacts LINK Project: Providing Climate Change Scenarios for Impacts Assessment in the UK. Report prepared for UK Department of the Environment. 24pp

No.1 1993a The UK Met. Office High Resolution GCM Equilibrium Experiment.

No. 2 1993b Construction of Climate Change Scenarios by Linking GCM and STUGE 2 Output.

No. 3 1993c What Carbon Dioxide Concentration Should be used with Climate Change Scenarios? Climatic Research Unit, Norwich 12pp.

No. 4 1993d The UK Met. Office High Resolution GCM Transient Experiment (UKTR).

No. 5 1994 Construction of Climate Change Scenarios for the British Isles from GCM Transient Climate Change Experiments.

No. 6 1994 Climate Change Scenarios for the IPCC Working Group II Impacts Assessment.

No. 7 The 1996 CCIRG Scenario of Climate Change and Sea-Level for the UK.

The Climate Impacts LINK Newsletter, distributed to those on the Climate Impacts LINK Porject Mailing List.

Further copies of this report and details about the Climate Impacts LINK Project are available from

Climate Impacts LINK Project
Climatic Research Unit
University of East Anglia
Norwich, NR4 7TJ. UK
Tel: +44 (0)1603 592089
E-mail: d.viner@uea.ac.uk
Web Site: http://www.cru.uea.ac.uk/link

Further information regarding the Hadley Centre contact:

Head, Climate Prediction Programme
Hadley Centre
London Road
Bracknell, RG12 2SY, UK
Tel: +44(0)1344 856653
E-mail: gjjenkins@meto.gov.uk
Web Site: http://www.meto.gov.uk/

Further information regarding the Department of the Environment Transport and Region's Integrated Assessment contact:

Dr Merylyn MacKenzie-Hedger
Programme Co-oordinator
UK Climate Impacts Programme
Environmental Change Unit
University of Oxford
Mansfield Road
Oxford OX1 3TB
Tel: +44 (0) 1865 281193
Fax: +44 (0) 1865 281188
E-mail: merylyn.hedger@ecu.ox.ac.uk
Web Site: http://www.ecu.ox.ac.uk/ukcip.html

ISBN:

0 902170 10 4

Published by the Climatic Research Unit, University of East Anglia, Norwich, UK

Design and Production: Shorthose Russell Ltd, Norwich. Telephone 01603 785765