AN INDUSTRIAL PLACEMENT AT THE MET OFFICE

INTRODUCTION

Many aspects of life are influenced by the weather and climate. The weather is the changing state of the atmosphere around us, and both individuals and industries rely on accurate forecasts in order plan their activities. The climate can be described as the long-term state of the weather, defined by average conditions as well as extremes and variability. The climate has a natural variability, but it is thought that human activity can heavily influence its future average state. There are many components of the climate system, which combine in a complex way, so an understanding of these is needed in order to predict our future climate so that we can asses the effects of human influence and hopefully employ more efficient and clean use of resources in the future.

The Met Office is a world leader in both short-term weather prediction and in climate research. It provides world-class forecasts for those who need them, and is also recognised as a centre of scientific excellence in the field of climate research, including the prediction of the future climate, and the understanding of all components of the climate system. The staff develop computer (climate) models using their expertise and knowledge of the physical processes and they use them to make predictions into the future, which play an important role in policy making for related environmental issues.

This report intends to show how the work I have been and will be undertaking during my placement year at The Met Office contributes to the organisation as a whole and fulfils the objectives of the climate change group.

THE MET OFFICE

The Met Office is an executive agency of the Ministry of Defence (MoD) and is a globally recognised centre of scientific excellence. It is the UK's national meteorological service, carrying out roles from predicting the direction of spread of the 2002 foot and mouth outbreak and the recent record breaking summer temperatures, providing objective analyses for policy making.

There are two research departments with expertise in computational modelling: The Hadley Centre for Climate Prediction and Research, and the Numerical Weather Prediction division (NWP). The NWP is responsible for producing numerical data from the forecast model, which is used to provide forecasts to a world-wide customer base. I work as part of the Climate Change group at The Hadley Centre for Climate Prediction and Research. The Hadley Centre is internationally renowned for its work on both natural and anthropogenic climate change on a large time-scale. It was formed in 1990, with an aim to understand the behaviour of the climate system in order to predict climate change centuries into the future. The work of the Climate Change group achieves this by using the understanding of all the scientific processes in the climate system, developing models to represent them and simulating the climate variability over past centuries. Predictions are then made into future climate states. This work plays an important role in the development of national and international policy. The Hadley Centre also researches themes such as Climate Variability, Quantifying Uncertainty and Ocean Applications.

Figure 1: Met Office logo

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THE CLIMATE SYSTEM

The climate system is a complex flow and cycle of energy, linking together the atmosphere, oceans, cryosphere (ice sheets), biosphere (living organisms) and geosphere (soils and rocks). Mankind is another more recent component with influence over the climate system. Through utilisation of the world's resources, humans have altered the energy balance of the system, causing an increase to the Earth's natural greenhouse effect. This is known as the anthropogenic component. The behaviour of each component plays a major role in this system, determining the balance of solar and terrestrial radiation and therefore the overall state of the global climate.

The Earth's climate system generally exists in equilibrium as a stable balance of incoming and outgoing radiation controlling all the climate components and any change to the combined components of the system resulting in climate change is produced by forcing agents. As the balance between this radiation alters, the global climate heats up or cools down in attempt to restore equilibrium. The adjustment to one part of the climate system cascades through all the components and is modified in character or scale. This process is known as feedback, and in some cases the initial effect is amplified (known as positive feedback) or reduced (negative feedback). For any one initial radiative forcing, a series of feedback effects will follow, which need to be considered in order to understand the change to the global climate.

While feedback from an initial forcing mechanism can decide the response of the climate (i.e. the resulting climate change), how much and how quickly depends on the climate sensitivity. It is effectively a "Measure of the strength of various feedback processes which determine the response of the climate system to any change in radiative forcing" [3]. To understand the present and future climate, it is necessary to be able to quantify the processes occurring, using observations and by constructing time series of climate data. Various measurements of individual climate elements at specific locations and times are used, with the most common diagnostic being temperature. The climate cannot be measured as a whole, so these individual elements are used when studying the present climate and predicting future changes.

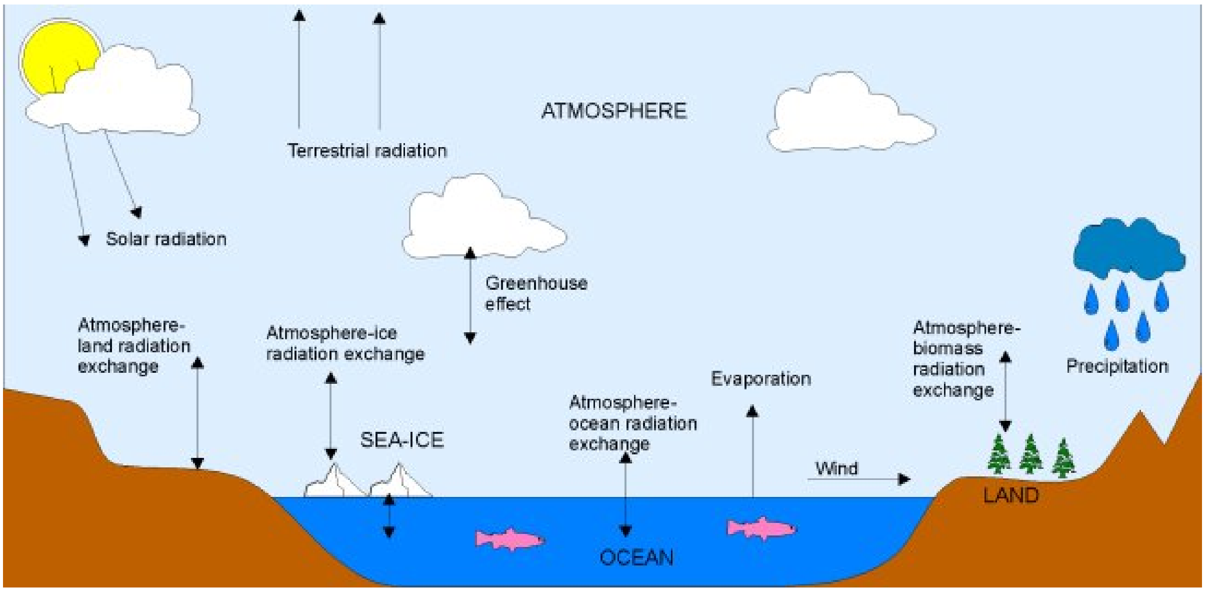

Figure 2: The global climate system and it energy transfers [2]

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Climate models are an extremely valuable tool in simulating the behaviour of the climate system with aim to understanding the key processes. Past climates are simulated and compared to observations and predictions made into the future. There are various types of model, which range from a globally averaged energy balance model (EBM) simulating the two most fundamental processes of the climate system (global radiation balance and latitudinal energy transfer) to the most sophisticated general circulation models (GCMs). These can simulate a three-dimensional climate system based on the fundamental laws of physics (conservation of mass, energy, momentum and the ideal gas law). All models represent the processes as a series of equations which satisfy basic laws and relationships within the climate system. These equations are usually solved using finite difference methods, therefore an important consideration is the resolution of the model in space and time.

The simplicity of a model is defined by both the number of spatial dimensions represented and the degree to which parameterisation occurs. This involves the inclusion of a process as a simplified function rather than an explicit calculation from first principles. Sub-grid scale phenomena such as thunderstorms and cloud formation are examples of parameterised processes which need to be simplified in order to reduce the amount of computation. The models aim to asses how the climate system will respond to any initial radiative forcing to restore equilibrium, therefore the role of feedback and climate sensitivity are also critical parameters.

MY ROLE

As an Industrial Placement student my primary role has been to assist the scientists by extracting suitable results from the archive of data produced by the model runs on the supercomputers, process this data, and present the results in graphical format. It is an important aspect of the Hadley Centre's work to make its results accessible to those people who need them, including government policy makers. The majority of my work is performed on a UNIX or LINUX platform, where I use a variety of software and programming tools. PV-WAVE (Precision Visuals Waveform Analysis and Visualisation Environment) is a script driven language used to graphically interpret data from the Hadley Centre's climate models, which runs various experiments to represent a number of different scenarios.

I have spent my time locating and retrieving the required data from the archives and using PV-WAVE to manipulate it, with the end results being plots and animations, which have been used by Hadley Centre staff in presentations and appeared in brochures and reports.

Perhaps one of the largest projects I have carried out so far has been for work on the Conference of the Parties (COP) report and conference which was held in December in Milan. The conference is an annual gathering of ministers and members of the parties to the United Nations Framework Convention on Climate Change with aim to evaluating and adopting policies which will tackle emissions issues relating to climate change. My role in this was to produce a variety of plots and figures to appear in the Hadley Centre's annual report on recent results, as well as a series of animations, which would be taken to the COP conference. I was using results from the Hadley Centre coupled ocean-atmosphere general circulation model (HadCM3). I used the SRES scenario experiments to produce a series of plots showing the predicted changes over time for some climate change diagnostics including temperature, precipitation and soil moisture. The SRES (Special Report on Emissions Scenarios) experiments are a series of scenarios using estimates of future greenhouse gas emissions running up to the year 2100. The HadCM3 model has run experiments using five of the SRES scenarios. Figure 3 which I produced for the brochure is shown below and shows the range of possible values for anthropogenic carbon dioxide emissions according to these scenarios. Carbon dioxide is the most abundant greenhouse gas, so changes to its concentration in the atmosphere would have a significant effect on the climate. The predictions of all future greenhouse gas emissions were decided by the IPCC (Intergovernmental Panel on Climate Change), taking into account economic changes and population.

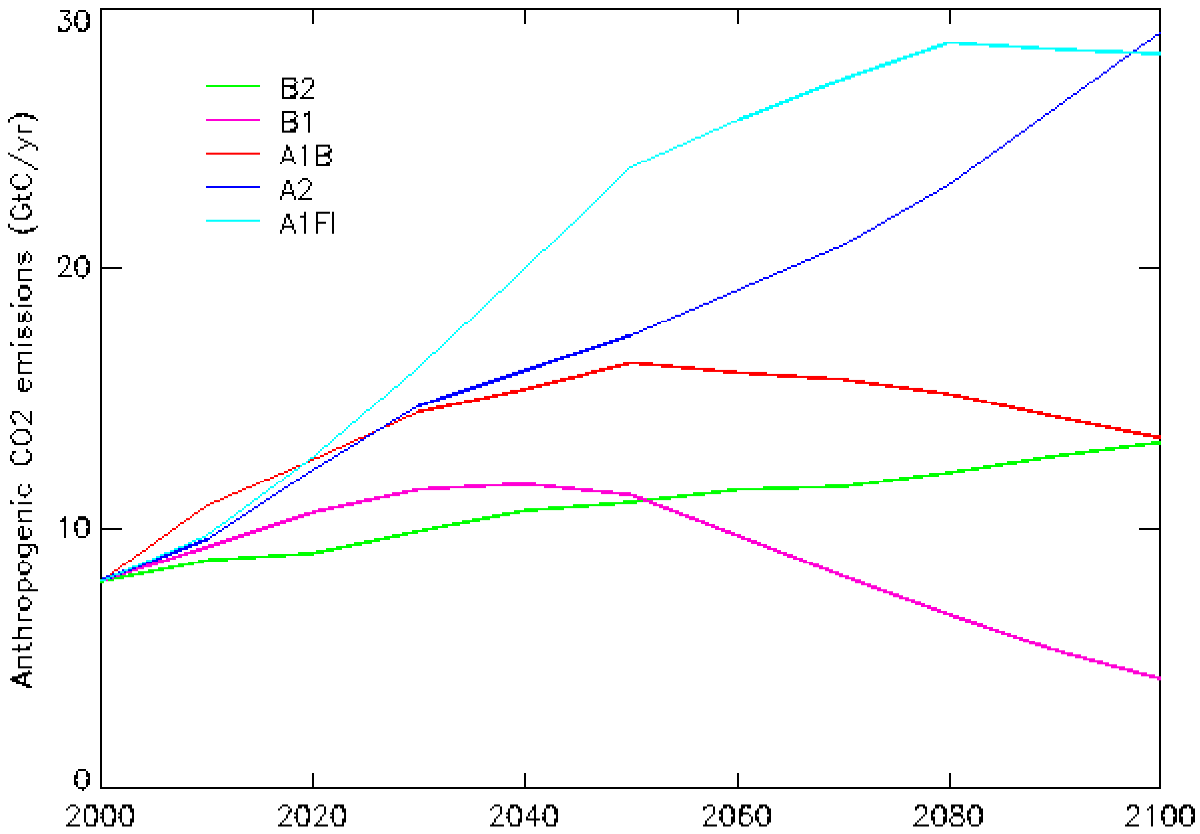

Figure 3: Anthropogenic carbon dioxide emissions for the SRES scenarios

The models use the emissions in each scenario to carry out their calculations to obtain future possible states of the climate system. The results from the SRES experiments predicted by HadCM3 show an increase in global average temperature of between 2ºC and 4.5ºC for the various emissions scenarios (see figure 4). This range between scenarios doesn't start to become evident however until about 2040, when the values start to diverge. This is due to the fact that carbon dioxide has a long atmospheric lifetime, and the climate system takes a long time to respond to changes (large thermal inertia), so emissions which take place now will have their effect on the climate decades into the future. As a result of a temperature rise, other climate elements will also change over time, including an increase in global precipitation, due to a more intense water cycle, and changes in soil moisture. Figure 5 shows the correlation between the global temperature changes predicted for each scenario by the model against the percentage precipitation change. For every 1ºC rise, the globally averaged precipitation increases by approximately 1%.

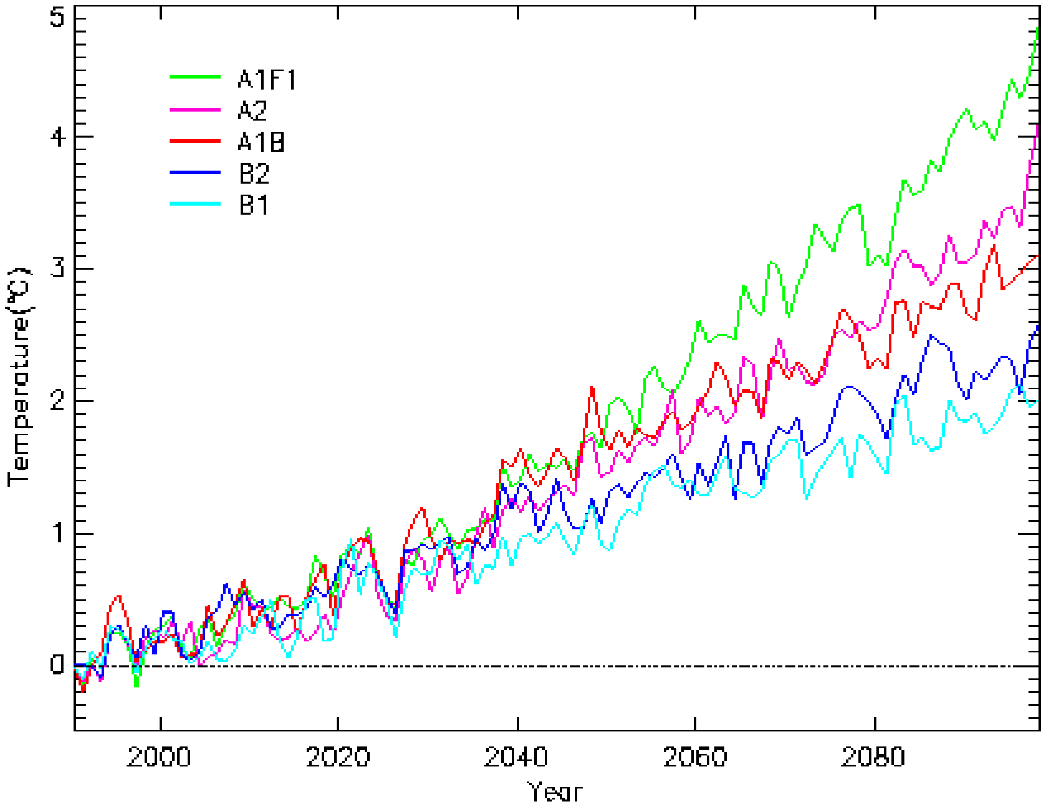

Figure 4: Global temperature rise for the SRES scenarios predicted by the Hadley Centre model

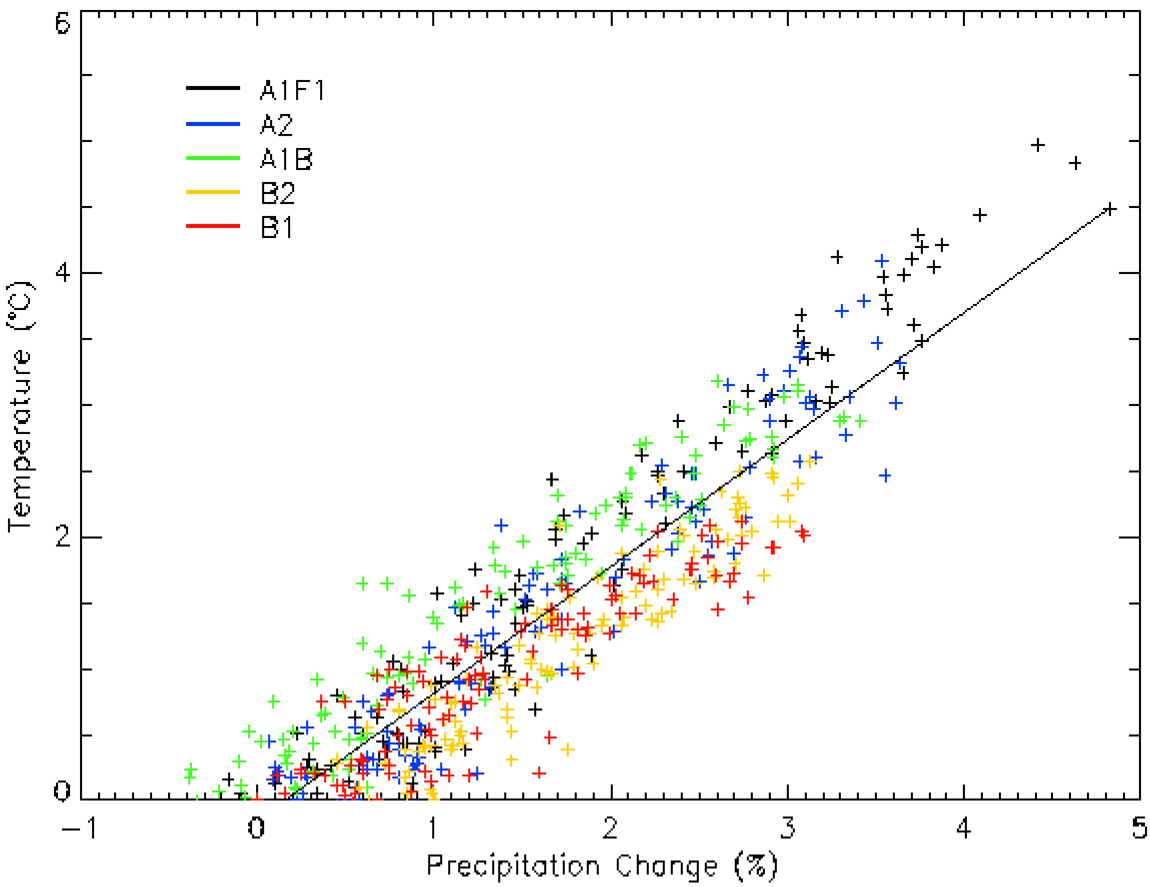

Figure 5: correlation between temperature rise and precipitation as predicted by the model

I produced a series of plots for each of the continents, using the middle SRES scenario (A1B) to show that these changes in temperature and precipitation vary considerably from location to location. This was also represented in the movie animations that I created by joining together a series of plots for each region using annual data. The temperature or precipitation was shown on a map of the region for each year, alongside a bar chart of the values for the region and globe. These showed that the Australian and African continents would have a lower temperature rise than the global average of 3ºC for this scenario, and parts of Europe, South America, Australia and Northern Africa having significant decreases in precipitation. Figure 6 shows the precipitation change in mm/day for the 2080s over South America with respect to the present day. This plot in particular shows a large decrease in precipitation, which would result in a significant loss in soil moisture, having impacts on agriculture and food production.

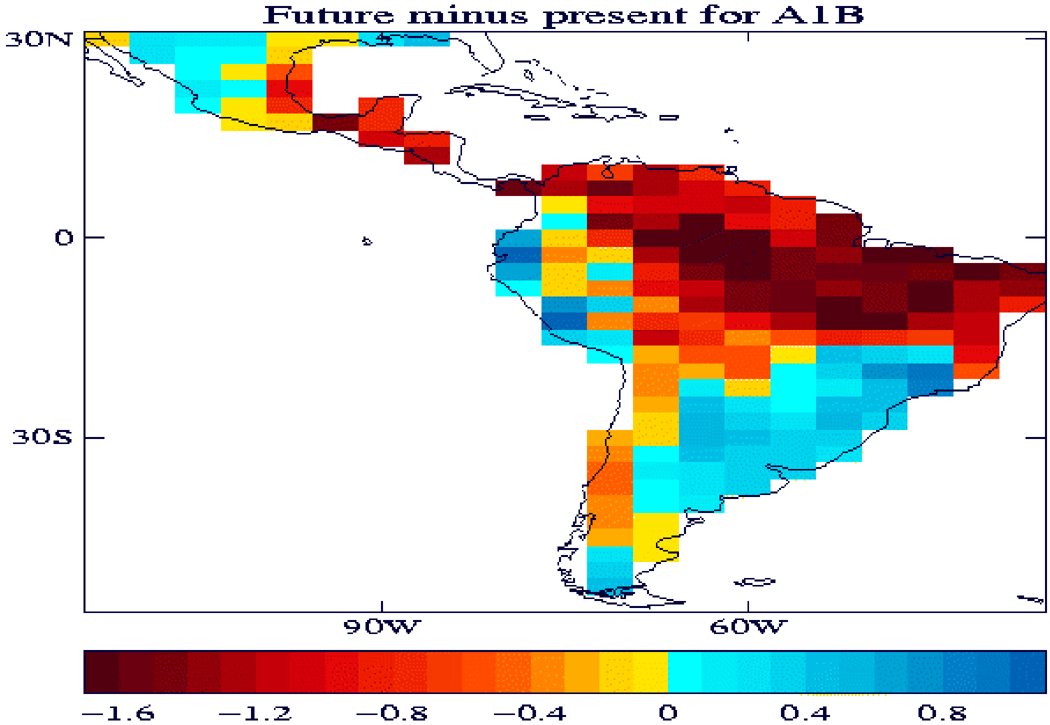

Figure 6: Precipitation change with respect to present day over South America for the A1B

Some other work I have been involved with is in making some predictions of temperature rise during the 22nd century. A new set of experiments have been run on the HadCM3 model, which continue on from two of the existing SRES scenarios (B1 and A1B). The aim is to see the effects on the climate up to the year 2200 from emissions in the 21st century, by stabilising the greenhouse gas and aerosol concentrations. Although unrealistic in practise, as it involves a sharp reduction in emissions, it is an interesting study to try and further understand the timescales of climatic responses. My involvement in this was initially to learn how to use a simple climate model (called Magicc), which produces globally averaged results, to produce plots of temperature and sea level rise for a version of the experiment which was then run on HadCM3. I was able to create a set of scenarios by entering a table of values for emissions of various greenhouse gases, and running them through the various stages of the model to create a time series of some output diagnostics. I used existing emissions values from the year 1990-2100 for the A1B and B1 scenarios, followed by constant concentrations up to 2200 in each case. I was able to then produce a plot of temperature rise and sea level. In addition to this I was recently able to retrieve the data from HadCM3 to produce a similar plot for these two scenarios, so figure 6 shows the results from both models. It is encouraging to see that the results from both models compare well, with the simple model reflecting the trend of the more complex GCM.

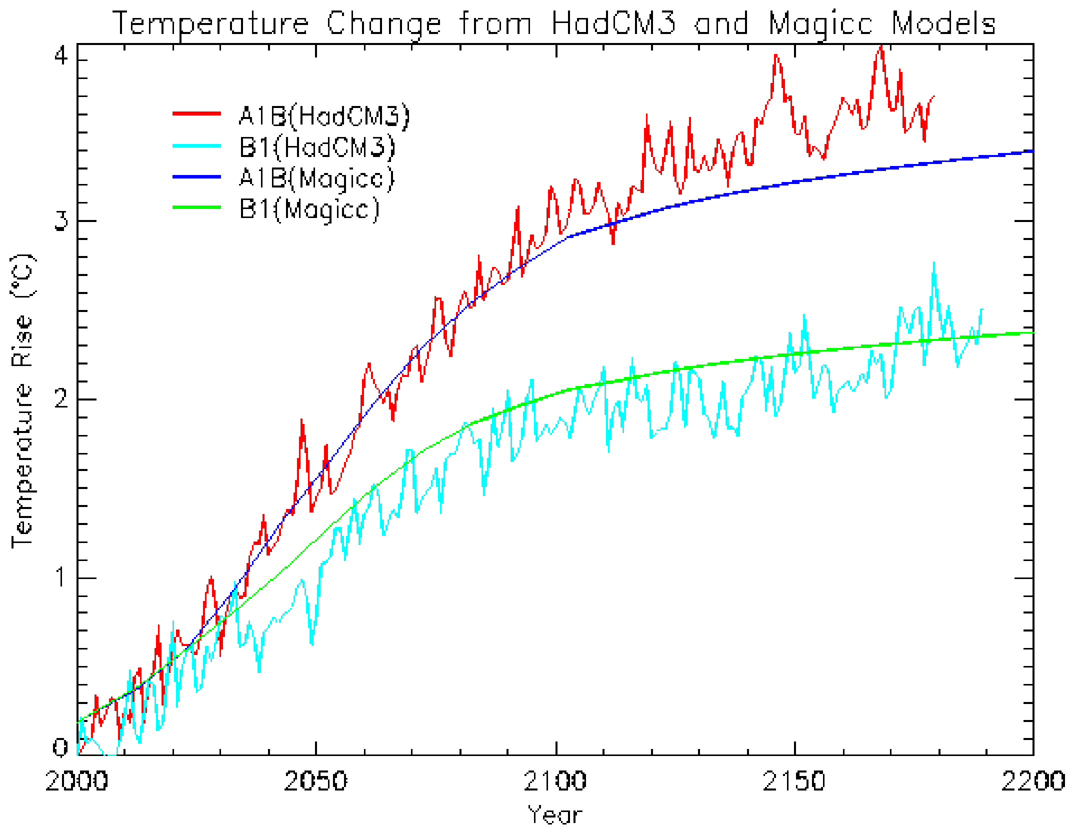

Figure 7: Comparison of models for temperature change using stabilised greenhouse gas emissions after 2100

Over the coming weeks I expect to be using more data from the new HadCM3 experiments in order to compute various other climate diagnostics such as ocean heat content and sea level, which I also hope to compare with Magicc model data. The plots that I have and will produce for this project have contributed to the work of the Hadley Centre by visually representing the first estimates of the climate system during the 22nd century for these scenarios and will provide a good base for further study in the future.

ACKNOWLEDGEMENTS

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2. http://www.doc.mmu.ac.uk/aric/gccsg/contents.html

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