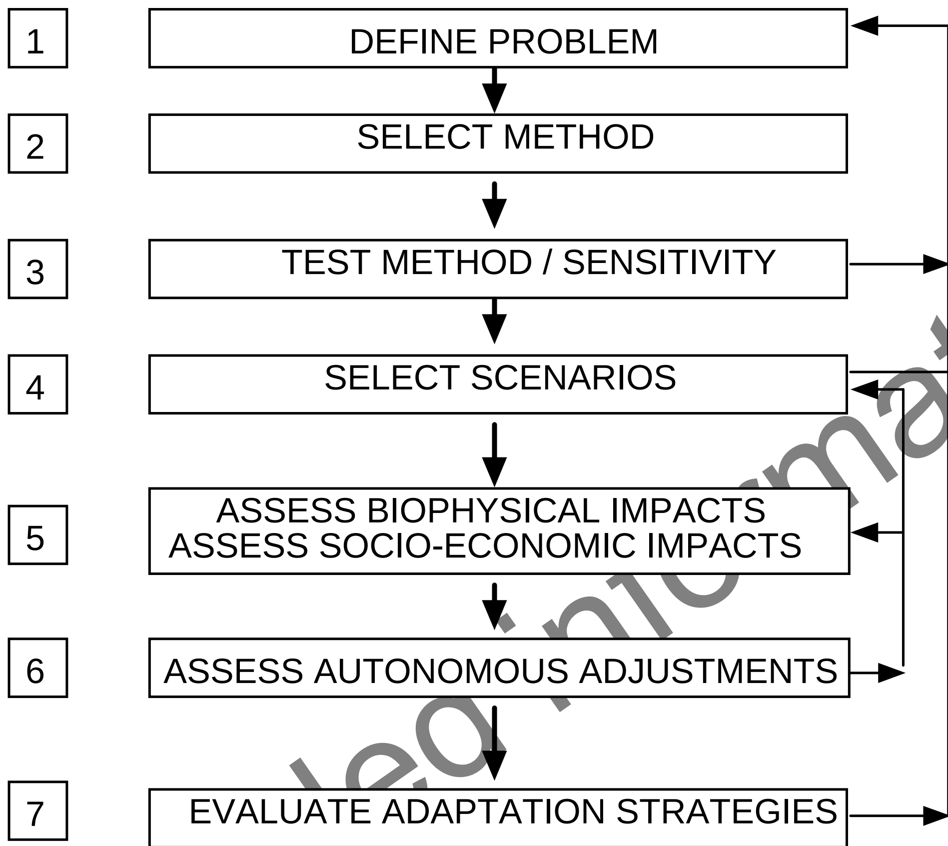
Appendix 1: General Methodology for Climate Change Effects and Impact Assessment



The diagram above shows the IPCC's seven steps of climate impact assessment (Carter et al 1994).

Note: Steps 1–3 are covered in Chapter 4 of this Guidance Manual (effects on local government functions and services). Step 4 is dealt with in Chapter 5 (constructing plausible scenarios) and draws on material from Chapter 2 (projections of future New Zealand climate). Steps 5 and 6 form part of Chapters 6 and 7 (risk assessment and how and where to use it). Step 7 (evaluation of adaptation strategies) will be covered later in separate publications.

Reference

Carter TR, Parry ML, Harasawa H, et al. 1994. *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. Geneva: Intergovernmental Panel on Climate Change.

Appendix 2: Scaling to Full IPCC Range of Emissions

A2.1 Introduction

The rates of anthropogenic greenhouse gas and aerosol emissions that influence future climate will vary according to changes in population and economic growth, technology, energy availability and national and international policies. The Intergovernmental Panel on Climate Change developed 35 different future emissions pathways, the so-called ‘SRES scenarios’ (Nakicenovic and Swart 2000), for consideration, with no evaluation of their relative probabilities of occurrence.

In order to drive detailed regional projections from such global emissions, it is necessary to use complex atmosphere-ocean global climate models (AOGCMs). These model simulations require months of supercomputer time for each forcing emissions (or concentrations) scenario, and hence the models were able to sample only a small subset of the possible scenarios within the timeframe of the IPCC Third Assessment process. To cover the full IPCC range of emissions, a simple globally-averaged model was tuned to mimic the AOGCM results for a standard emission pathway and then applied to each SRES scenario in turn. However, this simple model only provided values for globally averaged surface temperature and sea level change, and gave no regional information.

The problem, then, is that we have New Zealand projections for a number of GCMs, but all with the same forcing scenario of a 1% per annum compounding CO_2 concentration, which lies near the middle of the IPCC range. These local GCM changes need to be scaled appropriately, in order to produce robust quantitative scenarios of change for New Zealand that encompass the full IPCC emissions range. The approach we take is to expand the GCM global temperature projections to cover the full IPCC range, and then to rescale the local New Zealand changes in the same proportion as the adjustments required for the global temperatures. This assumption of a relationship between the global temperature change and a local change (in temperature, precipitation, etc) is a very common one in integrated assessment modelling (Kenny et al 2001).

A2.2 Scaling methodology

Figure A2.1 shows the IPCC Third Assessment Report global temperature projections that we want to match in order to develop a ‘robust’ scaling for New Zealand climate changes. In compiling this figure, IPCC used a simple model (known as MAGICC)[56] to reproduce the global projections of seven different AOGCMs. The coloured lines represent the seven-member ensemble-average global warming for selected IPCC emissions scenarios. The dark shading in Figure A2.1 shows the range of the 7-AOGCM average over all 35 SRES emission scenarios. The light shading shows the full range over all AOGCMs individually and all emission scenarios. Thus, the ‘robust’ or ‘full’ IPCC range of global temperatures incorporates not only the range of radiative forcing from the different emission scenarios, but also the different responses that can occur in state-of-the-art climate models. The full IPCC range of global warming from 1990 to 2100 is 1.4 to 5.8°C.

[56] Model for the Assessment of Greenhouse gas Induced Climate Change, developed at Climatic Research Unit, University of East Anglia (http://www.cru.uea.ac.uk/~mikeh/software/magicc.htm).

Mullan et al (2001) used statistical downscaling to produce projections for New Zealand. The analysis was based on simulations from six AOGCMs all having a common “1%/annum compounding CO_2 plus sulphate” emissions scenario, which is similar to the mid-range IPCC scenario known as SRES A1. The projections were applied to future 30-year ‘climatological’ periods 2020–2049 (referred to as the ‘2030s’ in brief) and 2070–2099 (‘2080s’).

Figure A2.2 shows the global temperature changes from 1990 for these six AOGCMs, to which have been added the IPCC extremes of Figure A2.1. Note that some of the models exceed the IPCC upper extreme prior to about 2030. This occurs because the models assume an idealised 1% per annum compounding greenhouse gas concentration from 1990 onwards, whereas all the IPCC emissions scenarios have an absolute decrease in emissions in the mid-1990s to better represent observations. Two of the models downscaled (GFDL, MPI) only used data up to 2050 (Mullan et al 2001). Note also that the model temperature curves represent smoothed values: the actual global average, as simulated, exhibits ‘natural’ variability and the global temperatures do not increase monotonically.

Table A2.1 shows the global temperature changes relative to 1990, calculated from Figure A2.2. For consistency with the work of Mullan et al (2001), the future 30-year periods (2020–2049 and 2070–2099) are retained. However, the changes are adjusted relative to 1990, as is the IPCC custom. In order to match the IPCC extremes, the model changes would need to be scaled by the following factors:

- for 2030s: scale from 0.509 (lowest model Hadley matches 0.510°C) to 1.104 (highest model GFDL matches 1.567°C)
- for 2080s: scale from 0.546 to 1.438.

The New Zealand downscaled changes of Mullan et al (2001), for all models, are multiplied by these factors (both the lower and upper limits) for the appropriate future period. The changes are then ranked, and the extreme low and high values extracted. The resulting range is what we term the ‘full’ or ‘robust’ IPCC range for New Zealand. Note that this approach of scaling local changes by changes in global temperature is a common way of deriving local changes in the absence of climate model simulations with the desired emission scenario. One difficulty with this method is that model changes at the regional level are quite often not linear with respect to the global average temperature change.

Chapter 2 also describes ‘mid-range’ IPCC projections. These projections are obtained by applying a scaling factor exactly mid-way between the lower and upper limits of Table A2.1. The scaled local changes are then averaged over the available GCMs (six for the 2030s, four for the 2080s).

Table A2.1: Global temperature changes for six AOGCMs and IPCC extremes, for the indicated periods

Model	1990 to 2030s change	1990 to 2080s change
CCC	1.104	3.423
CSIRO	1.090	2.418
Hadley	1.002	2.365
Japan	1.250	2.643
GFDL	1.420	
MPI	1.115	
IPCC low extreme	0.510	1.292
IPCC high extreme	1.567	4.921
Scaling factors	0.509 to 1.104	0.546 to 1.438

Note: The last line shows the scaling range required to make the GCM changes match the IPCC extremes, as described in the accompanying text.

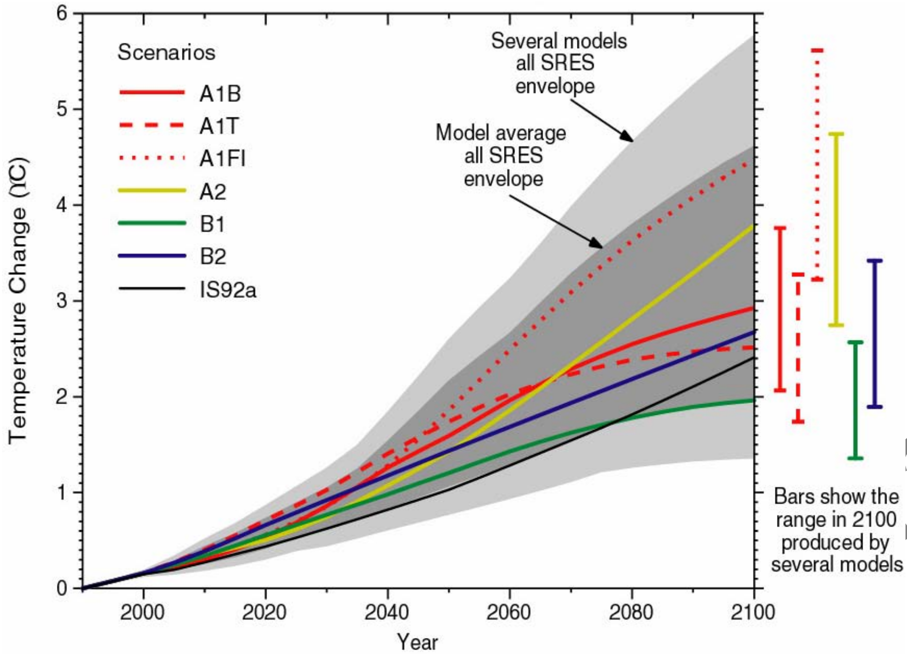
Source: Mullan et al (2001); Figure 9.14 of Cubasch et al (2001).

A2.3 Probability distribution of climate projections

The IPCC did not assign relative probabilities of occurrence to the SRES emissions scenarios, and therefore, by default, they are all equally likely. However, this does not imply that there is an equal likelihood (or uniform distribution) over the entire range of projected climate changes for New Zealand. Firstly, of the 35 SRES scenarios, different socioeconomic assumptions can still end up producing very similar emissions and hence temperature changes. The GCMs, too, often tend to 'bunch' in terms of their projections, with similar results from several models but with one or two 'outliers'. Of course, it is difficult to justify probabilities on these factors since new emissions scenarios could be produced (e.g. emissions constrained by the Kyoto protocol), and climate models are being continually improved.

However, even if there is a uniform distribution of global change over a range of emission scenarios, and a uniform distribution of GCM projections for a specific scenario (such as the 1% compounding CO_2), then the scaling approach we have used will still result in a non-uniform distribution for the robust range. (This phenomenon is well-known as the Central Limit Theorem in statistics). This characteristic is illustrated schematically in Figure A2.3. The product (global scaling times local projection) ends up with a preferred mode rather than a flat uniform distribution across the range. This arises because there is only one way to get the lowest (highest) projection – as the product of the lowest (highest) scaling and the lowest (highest) local change. However, intermediate projections could occur from more than one combination of possibilities.

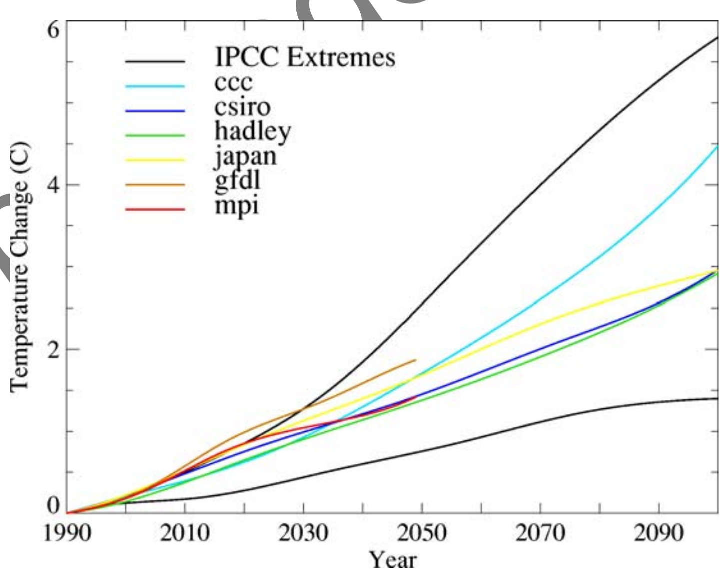
Figure A2.1: Global mean temperature change for six illustrative SRES scenarios (plus one IS92 scenario) using the MAGICC model tuned to seven AOGCMs



Note: Lines are the ensemble average. The coloured bars to the right show the range of MAGICC results at 2100 for the seven AOGCM tunings for each illustrative SRES scenario. The dark shading represents the envelope of the MAGICC ensemble averages across the full set of 35 SRES scenarios. The light shading represents the envelope of all MAGICC results across all 35 SRES scenarios.

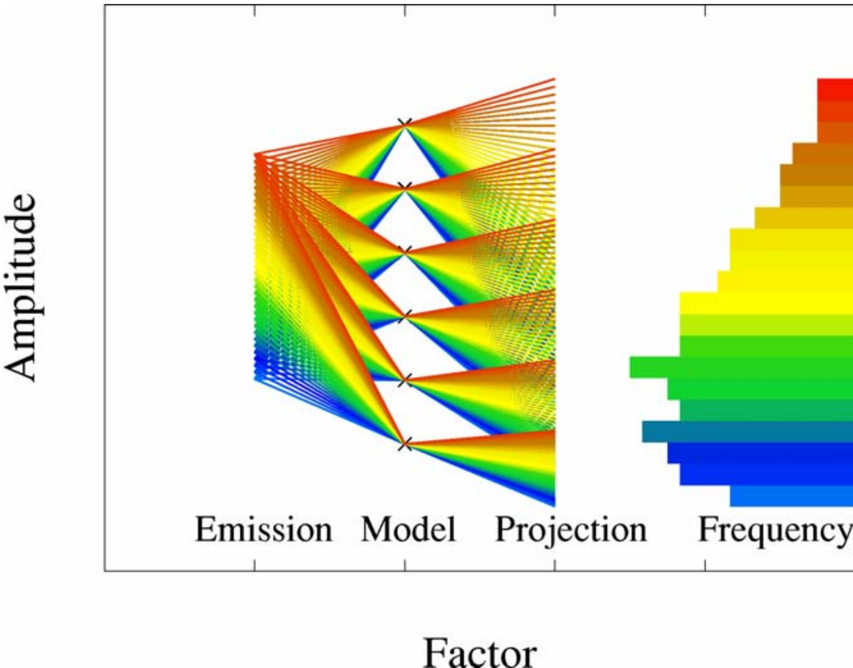
Source: Figure is variant of Figure 9.14 (page 555) from IPCC Third Assessment (Cubasch et al 2001).

Figure A2.2: Global temperature changes for six AOGCMs and the IPCC extremes



Source: Mullan et al (2001); Figure 9.14 of Cubasch et al (2001).

Figure A2.3: Schematic illustrating how projected extreme climate changes are less likely than mid-range values



A projected local climate change ('projection') is calculated as the product of each of 35 equally likely global scaling factors ('emission'), times the local (equally spaced) projections of each of six global climate models ('model'). The histogram at far right shows the frequency distribution of the 'projection' column results displayed in 20 equal bands.

References

Cubasch U, Meehl GA, Boer GJ, et al. 2001. Projections of future climate change. In JT Houghton, Y Ding, DJ Griggs, et al (eds) *Climate Change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York: Cambridge University Press, 525–82.

Kenny GJ, Harman JJ, Warrick RA. 2001. Introduction: The CLIMPACTS programme and method. In: RA Warrick, GJ Kenny, JJ Harman JJ (eds) *The Effects of Climate Change and Variation in New Zealand: An assessment using the CLIMPACTS system*. Chapter 1. IGCI, University of Waikato, 1–10.

Mullan AB, Wratt DS, Renwick JA. 2001. Transient model scenarios of climate changes for New Zealand. *Weather and Climate* 21: 3–34.

Nakicenovic N, Swart R (eds). 2000. *Emissions Scenarios: Special report of the Intergovernmental Panel on Climate Change*. United Kingdom: Cambridge University Press.