CLIMATE CHANGE SCENARIOS FOR THE AUSTRALIAN REGION

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Climate Impact Group, CSIRO Division of Atmospheric Research

Current scientific understanding predicts global warming in the next few decades with a high degree of probability. However, uncertainty in future greenhouse gas emissions, shortcomings in climate modelling, and difficulties in determining the regional implications of climate change from global estimates, mean that detailed and accurate predictions of future climate change at a regional level cannot be made yet. Therefore, *this is not a forecast.*

This set of scenarios is based on the best available science as at November 1992. Scenarios represent a multiplicity of plausible futures. They should *therefore be used as a guide for sensitivity studies only*. Users are advised to investigate possible impacts over the full range of the scenarios provided.

In constructing climate change scenarios there are many sources of uncertainty. Where possible these have been taken into account. Changes outside the ranges given here cannot, however, be ruled out, nor can confidence levels be reliably quantified.

This set of scenarios will be updated as new information comes to hand. For this and other reasons, users are advised to consult the Climate Impact Group (CSIRO Division of Atmospheric Research) before applying this set of scenarios to any particular problem. *This is a summary statement.* More detailed studies are available for a number of regions and topics, or can be done on a consultative basis.

All values given in this summary are relative to 1990 levels.

These scenarios differ from those previously prepared by the Climate Impact Group in two important respects: scenarios at two future dates are included, and uncertainties associated with emissions scenarios have been incorporated explicitly.

Greenhouse Gas Emissions

The IPCC supplement (IPCC, 1992) identifies a broad range of plausible future greenhouse gas emissions in the absence of emission policies beyond those already adopted. Figure 1 shows revised IPCC scenarios for CO_2 emissions (IS92a–f) compared to the IPCC 'business-as-usual' scenario (SA90) used in the original IPCC Scientific Assessment (IPCC, 1990). For other greenhouse gases, the IS92a–f scenarios contain a similar range of possible future emissions.

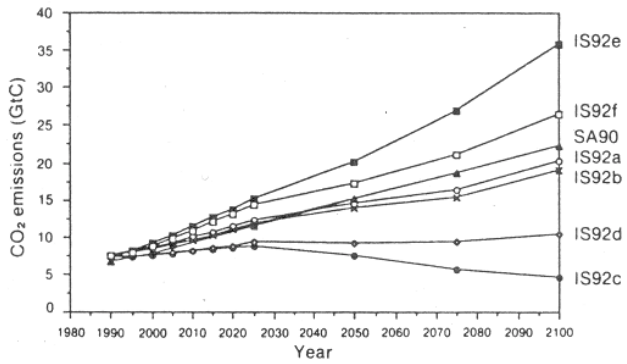

Figure 1 New IPCC scenarios for CO_2 emissions (IS92a–f) compared to the original IPCC (1990) single emissions scenario (SA90).

The regional climate change scenarios given below allow for these new estimates of the uncertainty associated with future greenhouse gas emissions.

Global Warming

The results of global climate models (GCMs) suggest that if the atmospheric CO_2 concentration instantaneously doubled from its pre-industrial level and the climate were allowed to come to a new equilibrium, the resultant mean surface air temperature increase would lie in the range 1.5–4.5°C. This warming value is known as the climate sensitivity. However, this describes a highly idealised situation. In reality CO_2 is increasing continuously, and is not the only greenhouse gas that needs to be considered. Furthermore, because of the large capacity of the oceans to absorb heat, changing greenhouse gas concentrations and global climate would not be in equilibrium.

New scenarios of future global warming that take into account the range of climate sensitivities as well as a range of future greenhouse gas emissions, have been produced by Wigley and Raper (1992). They used a simple model which allowed for the absorption of heat by the oceans. Figure 2 shows the range of future global warming they calculated. The upper limit of this warming corresponds to the highest emission scenario (IS92e) combined with the greatest climate sensitivity (4.5°C). The lower limit is based on IS92c and a climate sensitivity of 1.5°C.

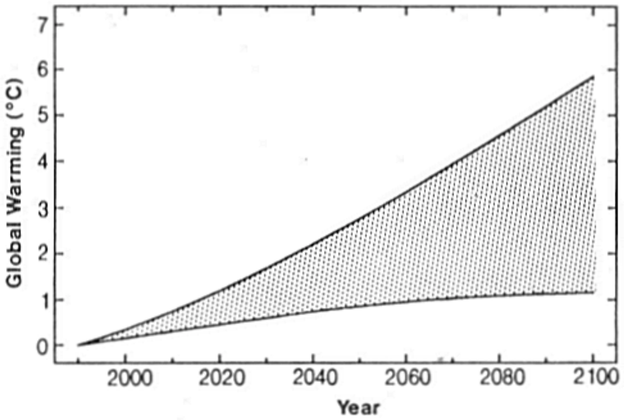

Figure 2. Scenarios of future global warming fall within the shaded region of the graph.

These curves indicate an average global warming in the range 0.6–1.7°C by 2030 and 1.0–3.9°C by 2070. The regional scenarios given below are based on these scenarios of global warming.

The scenarios do not take into account the possible effect of sulfate aerosol or CO_2 fertilisation. These factors are not well understood at present but are being actively researched. Calculations by Wigley and Raper (1992) based on their 'best guess' of the magnitude of these effects suggest reductions in estimates of future global warming of 20–30%. However, any reduction due to sulfate aer`osol may not be as great in the southern hemisphere, where the concentration of sulfate aerosol is less than in the northern hemisphere. Depending on the development of the science, we may incorporate these factors into future scenarios.

Climate Change for Australia

Temperature and rainfall

The following scenarios of regional changes in temperature and rainfall are based on:

- global warming scenarios as outlined above, which provide information on the magnitude of the climate response
- the regional results of five recent GCM equilibrium experiments analysed by CSIRO, which provide information on the regional pattern of the climate response.

The GCM results are used to produce plausible ranges of local temperature and rainfall change per degree of global warming. These values are multiplied by appropriate global warming values to obtain ranges of local temperature and rainfall change for particular times in the future.

This approach assumes that the pattern of regional climate response at any time in the future will be in proportion to the pattern of response for equilibrium conditions. It also does not allow for possible changes in El Niño–Southern Oscillation (ENSO) behaviour—an important climatic feature not simulated in current GCMs.

Within the ranges given in the following tables, there are some combinations of temperature and rainfall change that are not mutually consistent. Most of the lower limits of possible change in the tables assume the lowest climate sensitivity, but where rainfall may decrease the highest climate sensitivity must be assumed to obtain the lower limit. It is not possible to deal adequately with this problem in a summary document. Therefore we ask users to consult us, to ensure that they use the most appropriate climate change information in their studies.

Table 1 Scenarios of temperature change for locations in the Australian region. Values for 2030 are rounded to the nearest half degree and those for 2070 to the nearest degree.

Region	*Local warming per degree global warming (°C)*	*Warming in 2030 (°C)*	*Warming in 2070 (°C)*
Northern Coast (north of about 25°S)	0.3 – 1.0	0 – 1.5	0 – 4
Southern Coast (south of about 25°S)	0.8 – 1.2	0.5 – 2.0	1 – 5
Inland (more than about 200 km from coast)	0.5 – 1.4	0.5 – 2.5	1 – 5

Temperature

Table 1 gives scenarios of temperature changes for the Australian region. Ranges of local warming per degree global warming are given for three regions. These ranges represent differences amongst GCMs, and seasonal variation (although the latter was small). Using these values and the information from Figure 2, we then calculate the ranges of warming for 2030 and 2070. The scenarios for these dates incorporate the additional uncertainty associated with estimating global warming, namely: the range of climate sensitivities, and the range of plausible future emission scenarios.

Compared to the scenario issued in 1991, the above ranges for 2030 represent a downward revision in the warming scenarios for the Australian region. This is due to significant improvements in the method used to construct regional scenarios for particular dates in the future from GCM data, the availability of new GCM data, and the adoption of the Wigley and Raper (1992) global warming scenarios which are a little less than those given in IPCC (1990).

Rainfall

Scenarios of rainfall change are given in Table 2. In the summer half-year (November to April), the same ranges are given for locations throughout Australia, but in the winter half-year (May to October) separate values are given for locations within three different parts of the continent (sub-regions) (see Figure 3). These sub-regions were determined by the spatial pattern of rainfall change as simulated by the five GCMs used. In the winter half-year, no rainfall scenarios are given for the regions with very low rainfall in central and northern Australia.

Changes outside the ranges given in the table and large local variations from place to place could occur, particularly in locations where topography strongly controls rainfall patterns (such as along the southern and eastern coasts).

These scenarios of rainfall change would have the effect of extending southwards the region where summer rainfall is dominant.

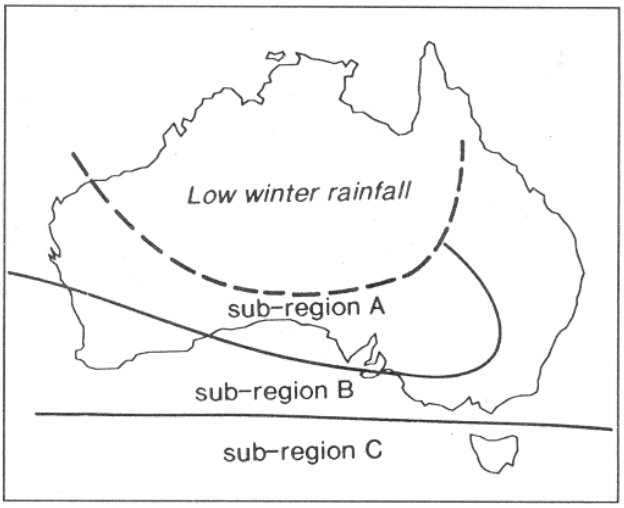

Figure 3 Key to sub-regions used for winter half-year rainfall change.

A general increase in rainfall intensities, and in the occurrence of heavy rainfall events, is also plausible. This change is difficult to quantify at present.

There is a possibility of longer dry spells in southern Australia associated with a reduction in the number of days on which rain falls.

Table 2 Scenarios of rainfall change for locations in the Australian region. Sub-regions are as defined in Figure 3. 2030 and 2070 values are rounded to the nearest 10%.

Season	Region	Response per degree global warming	Change in 2030	Change in 2070
Summer half-year (Nov. to April)	Any location	0 – +10%	0 – +20%	0 – +40%
Winter half-year (May to Oct.)	Locations in sub-region A	0 – -5%	0 – -10%	0 – -20%
	Locations in sub-region B	-5 – +5%	-10 – +10%	-20 – +20%
	Locations in sub-region C	0 – +5%	0 – +10%	0 – +20%

Extreme events

Extreme events are likely to change in magnitude and frequency more rapidly than the averages. This, together with other changes indicated by current research, implies more very hot days, fewer frosts, more floods and dry spells.

El Niño—Southern Oscillation (ENSO)

In northern and eastern Australia, El Niño years are generally dry, whereas in anti-El Niño years heavy rain often occurs. Future behaviour of ENSO is uncertain. In the absence of evidence to the contrary, El Niños and anti-El Niños can be assumed to continue, with consequent drought and flood years.

Tropical cyclones

These important, but small-scale events are difficult to model and are a major research priority. Present indications are:

- Region of origin likely to remain unchanged
- Change in intensities and southward extent still uncertain
- Preferred paths may alter
- Location and frequency affected by ENSO.

Alpine snowcover

Higher temperature is expected to reduce the duration of alpine snowcover, and any increases in precipitation are unlikely to be sufficient to compensate for this. The extent of the reduction will depend on the magnitude of local warming. The reduction is likely to be quite marked for any local warming in excess of 2°C. Impact will be greater at lower elevation.

Winds

- Possible strengthening of monsoon westerlies of northern Australia and in the south-east trade winds during summer.
- Change in mid-latitude westerlies not yet clear.

Cloud

Direction of change expected to correspond to that of rainfall. Quantitative estimates await further investigation.

Evaporation

2–4% increase in potential evaporation per degree of local warming.

Sea level

The scenarios of global mean sea level change for 1990–2100 are shown in Figure 4. These are calculated by Wigley and Raper (1992) and are based on their calculated range of global warming given above in Figure 2. The curves indicate sea level rises above the 1990 level of 5–35 cm by 2030 and 10–80 cm by 2070. The 2030 range is slightly greater than the original IPCC (1990) and earlier CSIRO estimates, because allowance has been made for the range of possible emission scenarios, as given above.

Local variations due to changes in weather and ocean currents, especially affecting the magnitude and frequency of extreme events, such as storm surges, waves, and estuarine flooding, should also be taken into account.

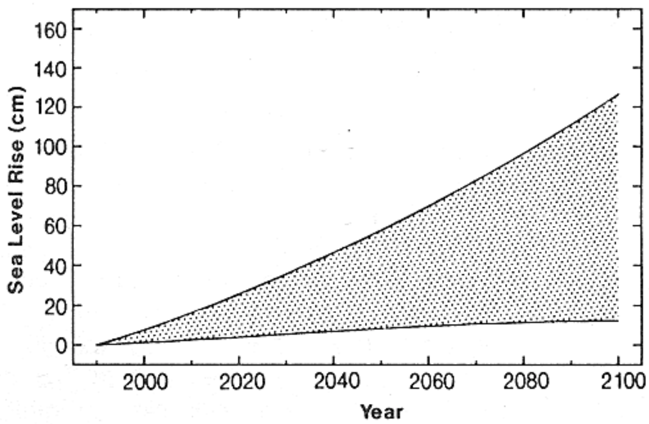

Figure 4 Scenarios of future rise in mean sea level.

Ozone Depletion

Ultraviolet radiation

While not due to the greenhouse effect, decreases in upper atmospheric ozone as a result of CFC and halon emissions are expected to increase the intensity of ultraviolet light. Assuming compliance with the 1990 Montreal Protocol for emission of ozone depleting substances, ozone depletion is estimated to be greatest around 2002. At that time, consequent ultraviolet light increases are estimated to be 5–10% or more over most of Australia. Ozone levels are expected to recover over the following half-century. Local ultraviolet exposure will be highly dependent on any changes in cloudiness, which are uncertain at present. An increase in ultraviolet exposure is expected to have deleterious effects on terrestrial organisms and near-surface marine organisms.

Direct CO_2 Effects

Increased CO_2 concentrations may significantly increase the growth rates of many plants. Figure 5 shows the range of future CO_2 concentrations calculated by Wigley and Raper (1992) for the IPCC (1992) emission scenarios (Figure 1). The curves indicate, the CO_2 concentration to be in the range of 450–500 ppmv by 2030 and 510–760 ppmv by 2070. These ranges do not include the effect of CO_2 fertilisation of the terrestrial biosphere, which may reduce these estimated concentrations.

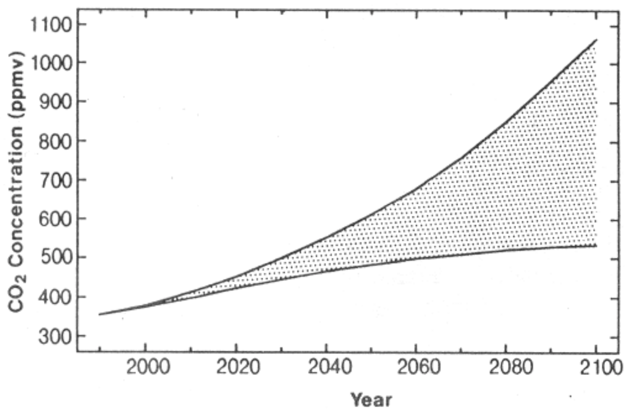

Figure 5 Scenarios of future CO_2 concentrations (after Wigley and Raper 1992).

The effect on plants of increased CO_2 should not be considered in isolation from the effect of likely future climate change, or other factors such as nutrient limitation.

Although plant water-use efficiency increases with increased CO_2 in controlled environments, the overall effect of increasing CO_2 concentration on water use in a competitive field environment is unknown.

Other Factors Affecting Climate

Volcanos

Major volcanic eruptions, such as that of Mt. Pinatubo in 1991, may lead to temporary coolings over land of the order of 0.2–0.5°C. After two or three years, temperatures should return to the interrupted warming trend.

Solar variation

There is no conclusive evidence that solar variability has had major effects on global climate over the last century, and no reason to expect warming or cooling due to such variations in the next 100 years large enough to significantly mitigate or amplify the enhanced greenhouse effect.

Ocean circulation

Possible changes in ocean circulation provide one of the major uncertainties about future climate change. At present this is a major topic of research. Such changes may explain some of the cooling in the Northern Hemisphere from the 1940s to the 1970s, and could lead to unanticipated regional changes in climate.

References and Further Reading

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