What is Sustainability when on the Climate Roller Coaster?

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ABSTRACT:

This paper is about the identification of the changing world climate drivers and speculation concerning the future impact such drivers will have on countries in the southern hemisphere, especially Australia and New Zealand. A focus for the above is a case study of climate change which has induced severe hardships in the Bendigo region of Victoria, Australia. The authors are of the opinion this experience, in this extremely climate sensitive agricultural area, is a forerunner to what could occur to many regions in the southern hemisphere. The case study show the vulnerability of communities to instruments of governance establish during periods of stability and urges the urgent need for modified governance instruments during periods of rapid climatic change. The paper commences the discussion about the meaning, relevance and reality of sustainability for communities during times of climatic uncertainty.

1. INTRODUCTION

This paper initially focuses on and records the lessons learnt from an extensive study of the Lake Eppalock catchment and water consumption in the Bendigo region during a time of unprecedented drought and rapid climate change in south eastern Australia. The learning from this work is then applied to the Murray Darling Basin, Australia and New Zealand. The impact of global climatic uncertainty is then considered against the timetable of 500,000 years and Homo sapiens' emergence during a period which could be termed a 'climate roller coaster'. Finally some relevant issues concerning sustainability within rapid climate change are considered. There are seven conclusions.

2. LOCATION

Northern Central Victoria in shown in figure 1. This figure shows the extent of the irrigation area in northern Victoria. The Great Dividing Range runs from east to west in the bottom of the figure and the Murray River flows from east to west through the centre of the figure. The Eppalock catchment is located in north central Victoria on the Campaspe River which rises in the Great Dividing Range and flows north into the Murray River at Echuca. The Lower Murray Darling Basin extends north into New South Wales and is defined by the Lachlan and Murrumbidgee catchments in this paper.

Lake Eppalock's catchment is in a rain-shadow which is caused by the southerly proximity of the Great Dividing Range and the predominant directions of three weather systems which generally approach from a westerly direction. Weather which approaches from the north east, the fourth weather system, provides Lake Eppalock with most of its inflow. It is the combination of these four weather systems which determine the extent of inflow into the lake. I.e. during the El Niño years the weather originating in the north east is weakened or non-existent and provides little inflow to the lake. In the La Nina season all weather systems are operating so the inflow into Lake Eppalock is unseasonably large and this is the reason for the great variability of flow extremes in the Campaspe River.

The major storages in North Central/Eastern Victoria from west to east are Cairn Curran, Lake Eppalock, Waranga Basin, Lake Eildon, Lake Hume and Dartmouth Dam and with the application of the current drawdown bulk entitlement rules all these reservoirs will be empty by June 2007. Currently, Cairan Curran, Lake Eppalock, Waranga Basin are effectively empty with the remainder major resource being quickly drawn down to empty on the presumption that statistically there will be renewing rainfall in the 2007/8 irrigation year.

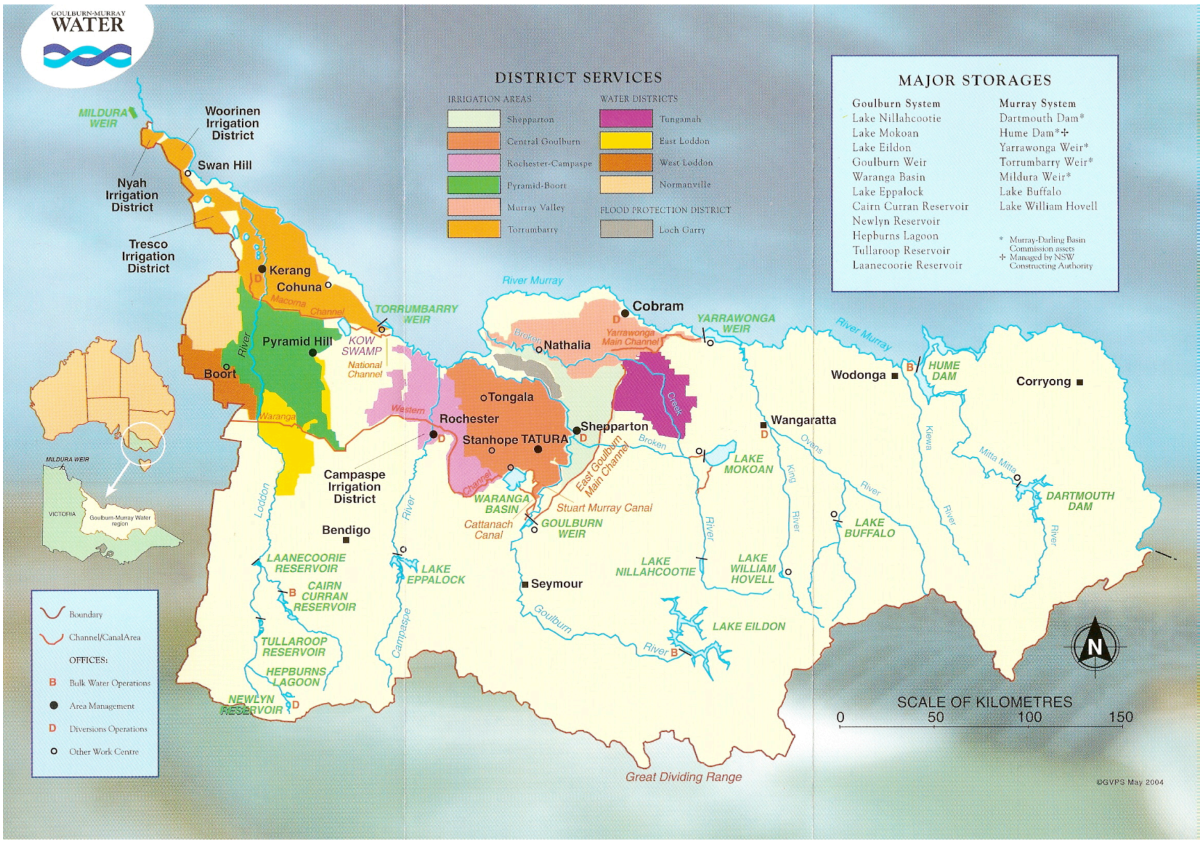


Figure 1 The Goulburn-Murray Water Region in North Central Victoria showing the Headworks and Extent of Irrigation. Map published by G-M Water

As shown in figure 2 the Murray Darling Basin extends from southern Queensland south through New South Wales and includes the portion of Victoria north of the great dividing range. The Murray Darling Basin is vitally important for Australia's agricultural production. The farm gate revenue is of the order of $20 billion of which approximately half can be attributed to irrigated activities. The agricultural exports from the Murray Darling basin accounts for approximately 5% of Australia's total exports and 2.6% of total employment.

The water diverted for irrigation purposes is of the order of 16,660,000ML per year and irrigates a total area of 2,000,506 ha which is approximately 1% of the world irrigated area.

The sustainability of the Murray Darling Basin's irrigated agriculture, dryland cropping, rural water supplies and urban water supply for the city of Adelaide is of strategic importance to Australia.

Figure 2 The Murray Darling Basin

3. WEATHER

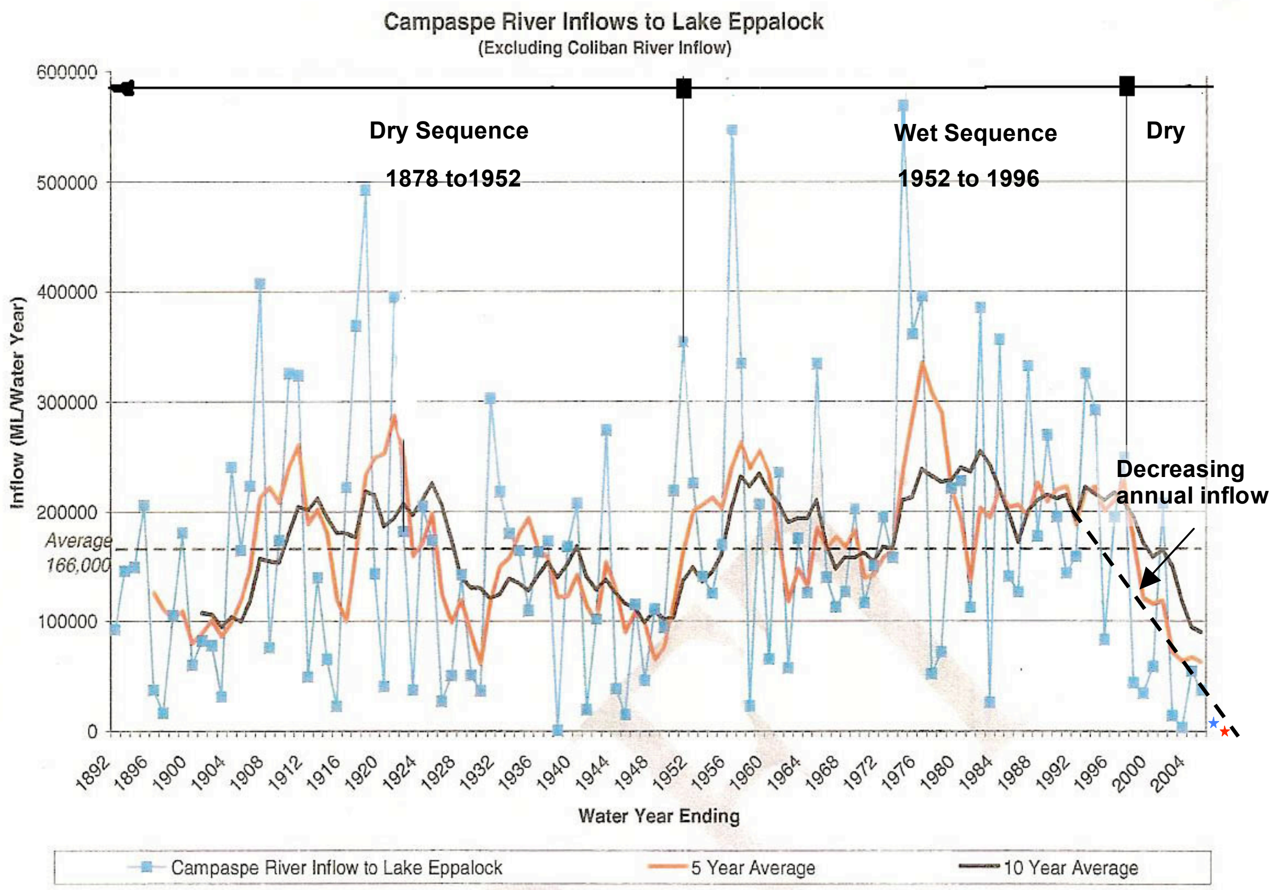
In this section weather and water is considered at the local, regional, national and global perspective.

3.1 Bendigo Region - Historical wet and dry sequences and the emptying of Lake Eppalock

History indicates that during the first 35 years of European settlement (1788 to 1823) drought conditions were the dominate feature of life on the land, however, it was during the above average seasonal conditions from 1824 to 1874 that Australia developed much of its agriculture and mining industries. Again a dry period prevailed from 1874 to 1952 where the average rainfall was 518mm; well below the long-term average of 540mm at Bendigo. The period 1952 to 1996 was a wet period similar to1824 to 1874 and was marked by above-average rainfall of 596mm. The wet and dry sequences over the last 140 years can be seen on figure 3.

Since 1992 to now there has been a steady decline in the average long-term rainfall and drought conditions have dominated since1997. The last 10 years have the lowest average rainfall on record. The CSIRO observed that the rainfall had flip-flopped from a long-term wet to a dry sequence in 1992. (Jones, 1997) Autumn rainfall averages in the Upper Campaspe Catchment have averaged 40% less over the last 14 years. (Burns, 2006:3) Autumn, winter and spring rains have been of less intensity and duration if they have come at all. Summer rains have been sporadic and heavy, usually unable to contribute to deep soil moisture deficiency during the hot summer months due to intense evaporation.

Figure 3 shows the Campaspe River flows for the last 144 years. The extreme differences between low and peak flows characterise the Eppalock catchment and its sensitivity to four influencing weather systems. The five and 10 year average inflows accentuate the wet and dry sequences. The predicted inflow for 2006 is shown in red at the extreme right of the figure. This inflow, as that the 19th of November 2006 has only amounted to a few hundred mega litres and the de-crease in the annual inflow over the last 10 years is also clearly shown.



Source: DOCS# 1743243

Figure 3 – Campaspe Inflow to Lake Eppalock. Source: G-MWater

The actual recorded inflow from the Campaspe River into Lake Eppalock for the period of May 2000 to October 2005 compared to the average inflow envelope for the wet sequence, 1954 -- 1996, is shown in figure 4 below. It will be noted that the heavy rainfalls over nine weeks in the months of September October and November (late heavy rains) were adequate to nearly fill the reservoir from a low-level.

The combined seasonal inflow and drawdown on Lake Eppalock for the last 10 years is shown in figure 5. This storage/drawdown trace captures the exceptionally high September October November inflows in 2002 and the subsequent drawdowns in the following years. The significant drawdowns were based upon the bulk entitlement operating procedures which are modelled on past rainfall events which by definition anticipate average rains in the following year. Such events had not eventuated and the yearly water allocations which were historically of the order of 190% during the wet sequence, were 39%, 31% and 0% for this year. In view of the known decrease in yield from the Eppalock catchment over the last 10 years the large drawdowns in the 2000/1, 2001/2 and 2002/3 were a gamble that did not pay off. Unfortunately the outlook for water allocations in 2007/8 is not encouraging with the conditions for a developing El Nino event becoming evident.

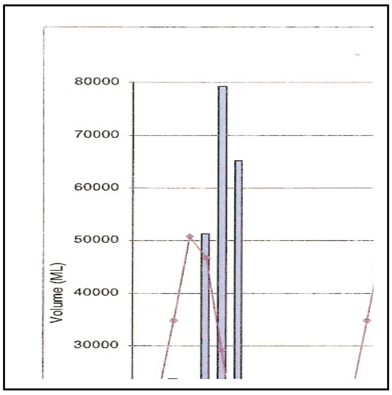


Figure 4 Eppalock Inflow Actual May 2000 to October 2005 and Average Inflow Envelope for Wet Sequence 1954 – 1996 (Near zero inflow for 2006 as at 19th November 2006)
Source :G-MWater

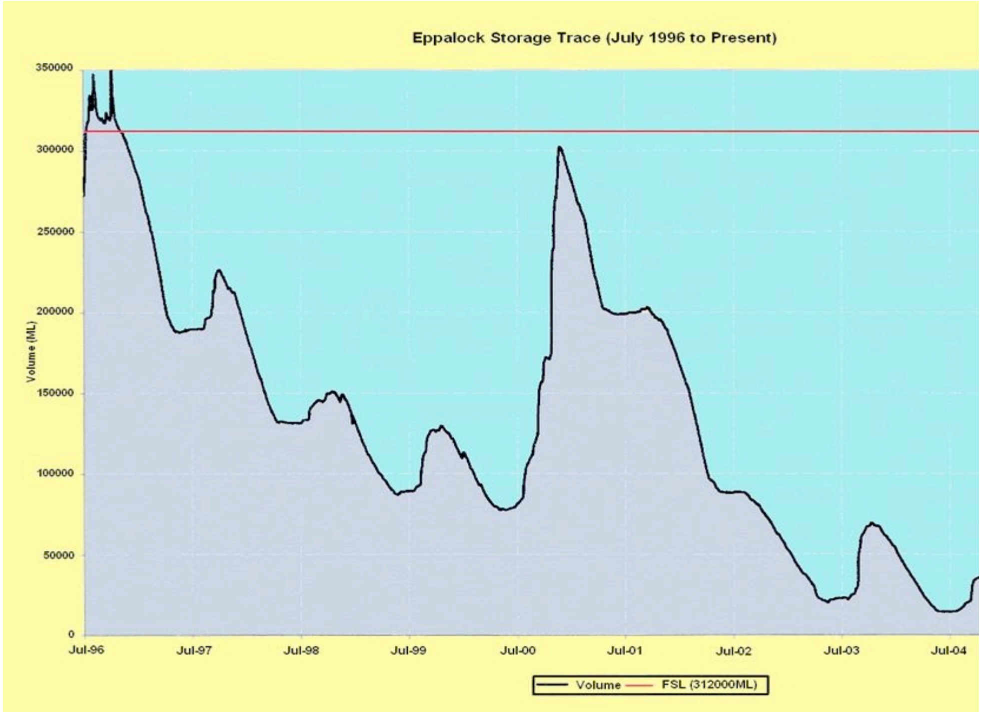


Figure 5. Shows the Combined Seasonal Inflow and Drawdown on Lake Eppalock from July 1996 to July 2006: In Hindsight a Gambol that did not Payoff. Source: G-MWater

3.2 Murray Darling Basin - Recent Trends

Figure 6 illustrates that the Murray Darling Basin is in rainfall deficit over the last three years when compared to the 1961 - 1990 base period. It must be remembered that this base period falls within an identified wet sequence from 1952 to 1996. The rainfall anomaly from -500 to -1000 mm of rainfall (yellow in the figure) covers the reliable high rainfall catchments of the Lower Murray Darling Basin. The rainfall deficit shown along the eastern coast of Australia is a characteristic of the El Nino phenomenon as it is the increase in rainfall in the north-west of Australia. Overall, the total rainfall on the Australian continent is not drastically changed. The rainfall anomaly from 0 to -250 mm of rainfall (grey) shown over the Murray River is a result of Jetstream activity bringing moisture from the north-west. For the last three years Jetstream moisture has petered out before it has reached the lower Murray Darling Basin catchments on the east side of the Great Dividing Range. The loss of rainfall over the last three years in the Bendigo area has been of the order of 160 mm per year. Such loss reduces the long-term average of 540 mm per year to 380 mm per year which explains why there is no effective rainfall in the area during these times.

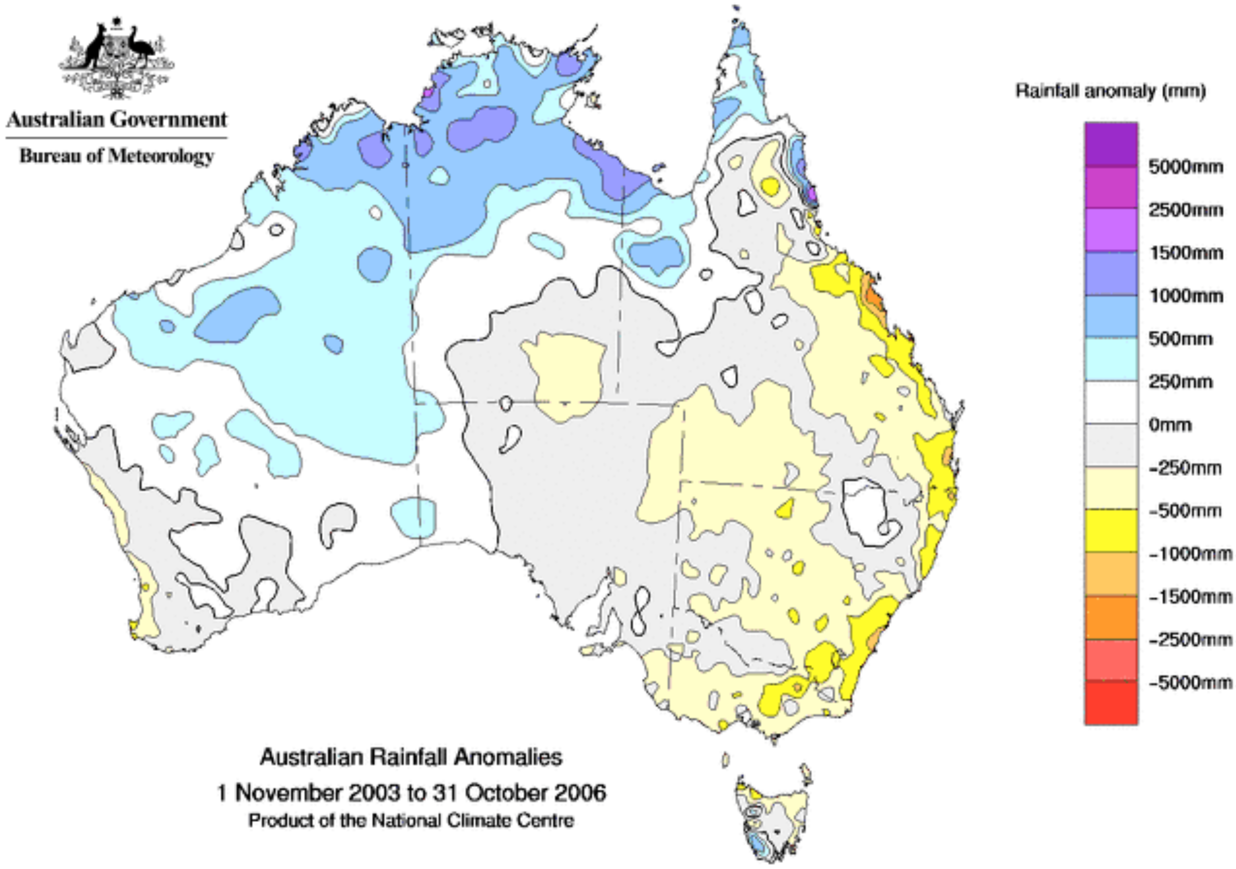


Figure 6 Australian Rainfall Anomalies – 36 months. Departures from the 36 month mean (1961 – 1990 base period)

On the 7th of November 2006 David Breverman, General Manager of the River Murray Water, Murray Darling Basin Commission presented the First Ministers Briefing titled, "River Murray System Drought Operation and Planning 2006/07 and Beyond". This was the first occasion the dire water crisis existing in the Murray Darling Basin was made public. The following three figures graphically demonstrate the grave drought situation, the availability of current water resources and the outlook for the 2007-08 irrigation season. The briefing discussed operational planning contingencies for 2007-08 in the event of continuing extreme dry weather.

The three worst drought periods in the last 114 years are shown in the figure below together with the unprecedented minimal inflow which has occurred in 2006. It should be noted that significant wildfires (Early 2003) in the critical reliable high yielding catchments of the Lower Murray Darling Basin catchments would have been a contributing factor in reducing system inflows.

Inflows to River Murray System (including the Darling River) are 10% of the long-term average and an outlook for 2007-08 has been selected at 20% providing, as a maximum, an average 20% of diversions over the entire system.

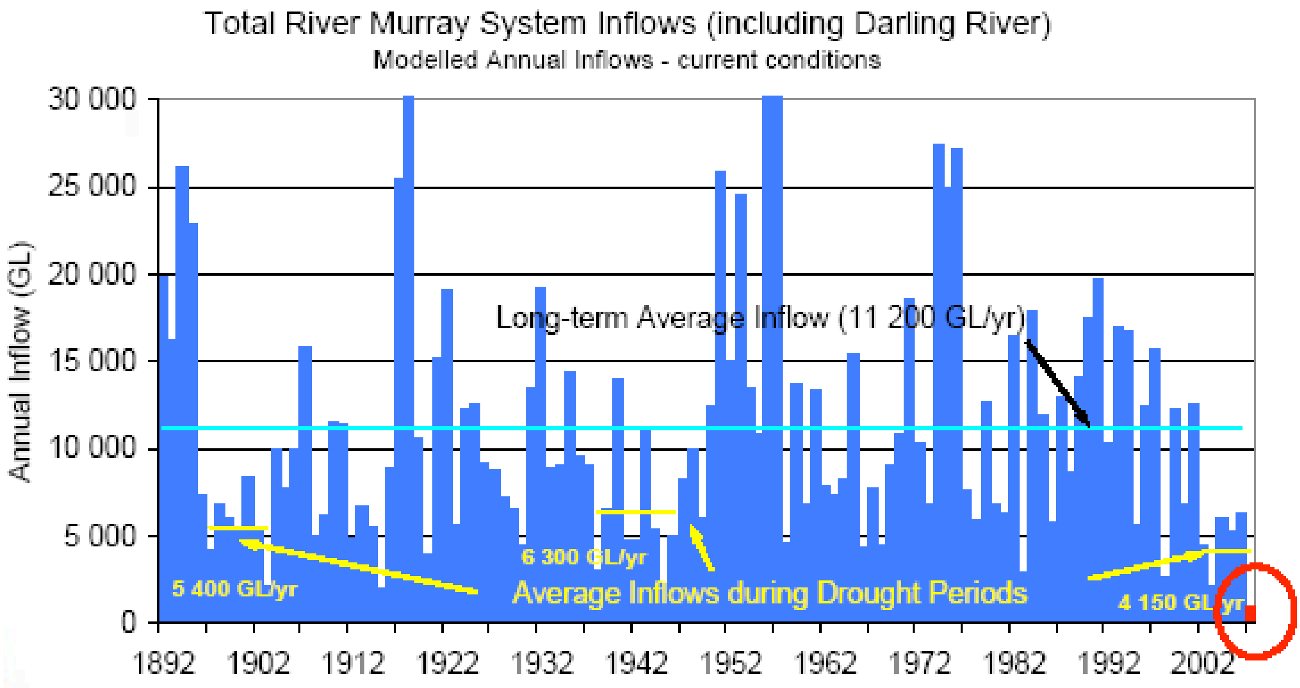
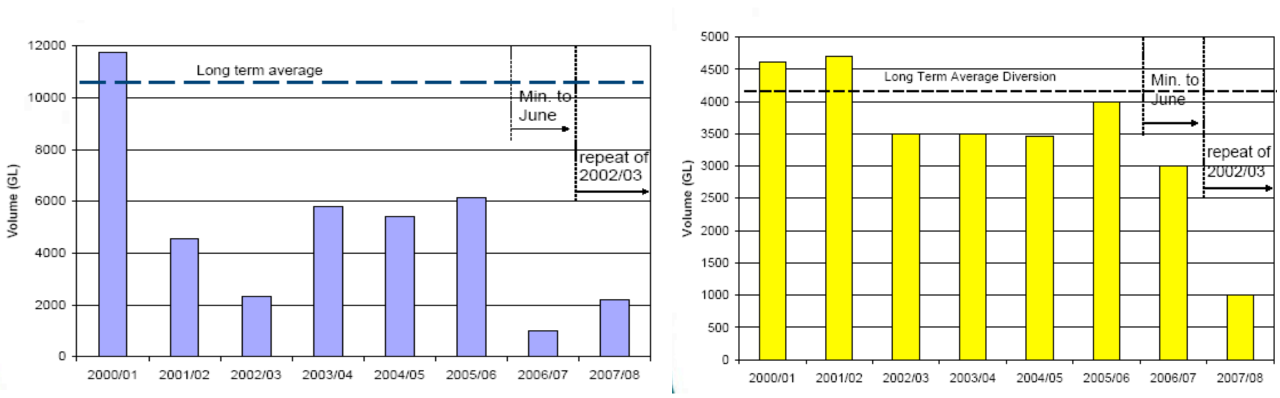


Figure 7 Showing the Total Average inflows into the MDB - Comparing Drought Periods. Current inflow for 2006 shown in red.
Source: First Minister's Briefing 7 November 2006 MDBC



Figures 8a and 8b. Showing the River Murray Inflows and Diversions for an extreme dry outlook.
Source: First Minister's Briefing 7 November 2006 MDBC

3.3 Australia, New Zealand and the Pacific Ocean – Recent Trends

The weather received by Australia and New Zealand is significantly influenced by the El Nino and La Nina phenomena as shown in the classical comparison shown below. When the sea surface temperature anomaly is positive (red) off the western coast of Peru and there is relatively cool water (blue) around Australia low rainfalls can be expected in Australia and New Zealand. This is the classic El Nino event. The opposite is the case for the La Nina event where the warm waters that surround Australia generate moisture and low pressure regions and sometimes cyclones which can penetrate the Australian Continent. During the El Nino events the lower sea temperatures off the north-west of Australia are less inclined to generate cyclones and consequential Jetstream moisture-laden air which can be precipitated over the usually reliable high rainfall catchments in the Lower Murray Darling Basin. During this period the cyclones generated off the coast of Peru in the warm water seldom travel into the proximity of eastern Australian and New Zealand, as can be seen in figure 10 below.

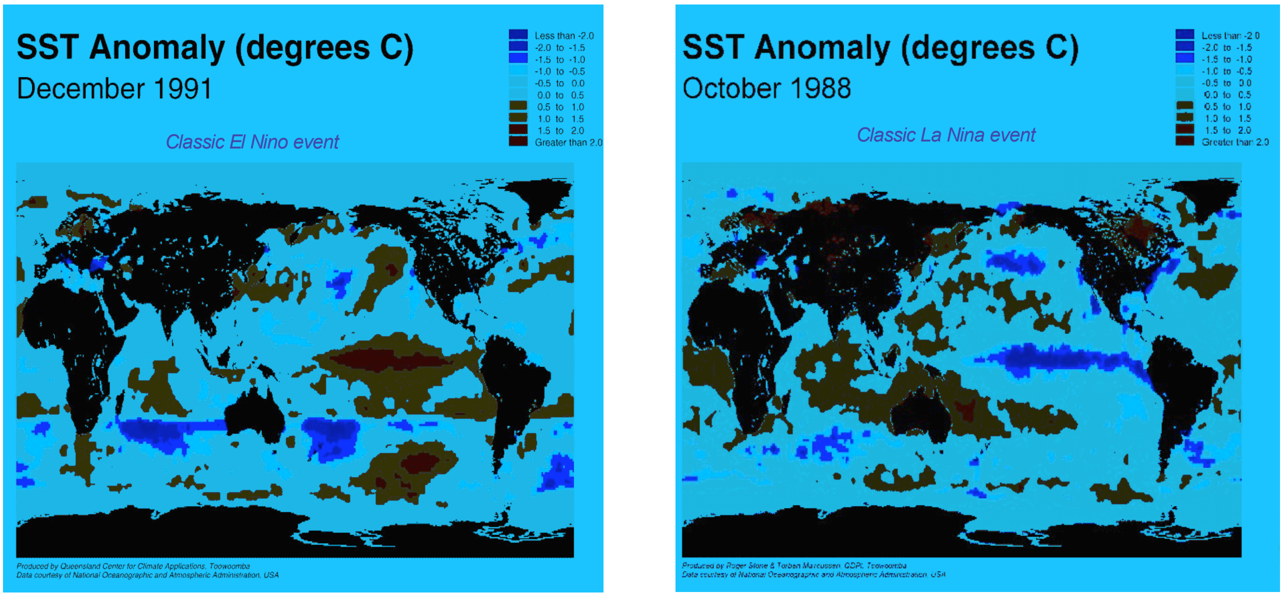


Figure 9 Comparison of Classical El Nino and La Nina Events

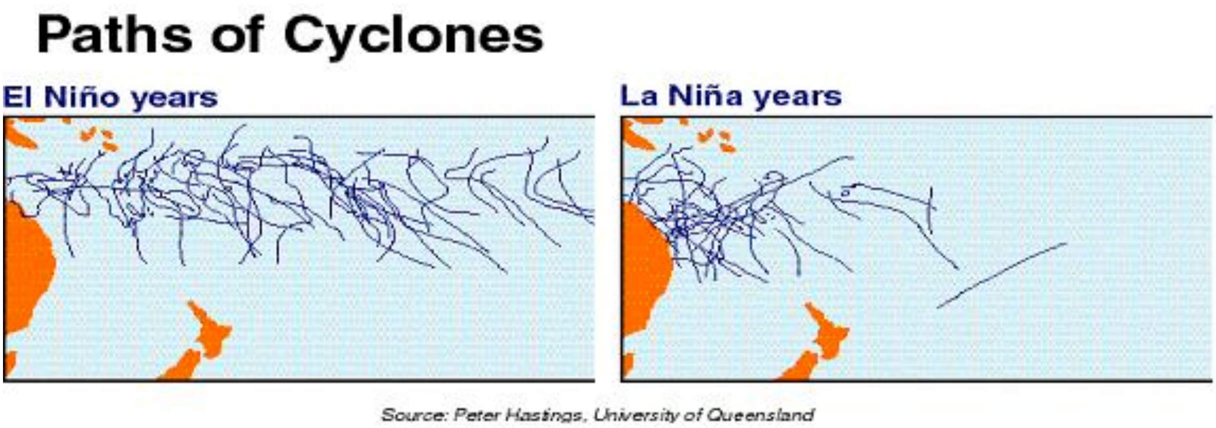


Figure 10 Classic paths of Cyclones resultant from either El Nino or La Nina Events

The incidents of the El Nino events are occurring more often with the increase in global temperature. (Refer to figures 18a and 18b.) The trend is clearly shown in the figure11. The significance or otherwise of this trend is captured in figure 12 which shows a market departure in the negative values of the Southern Oscillation Index.

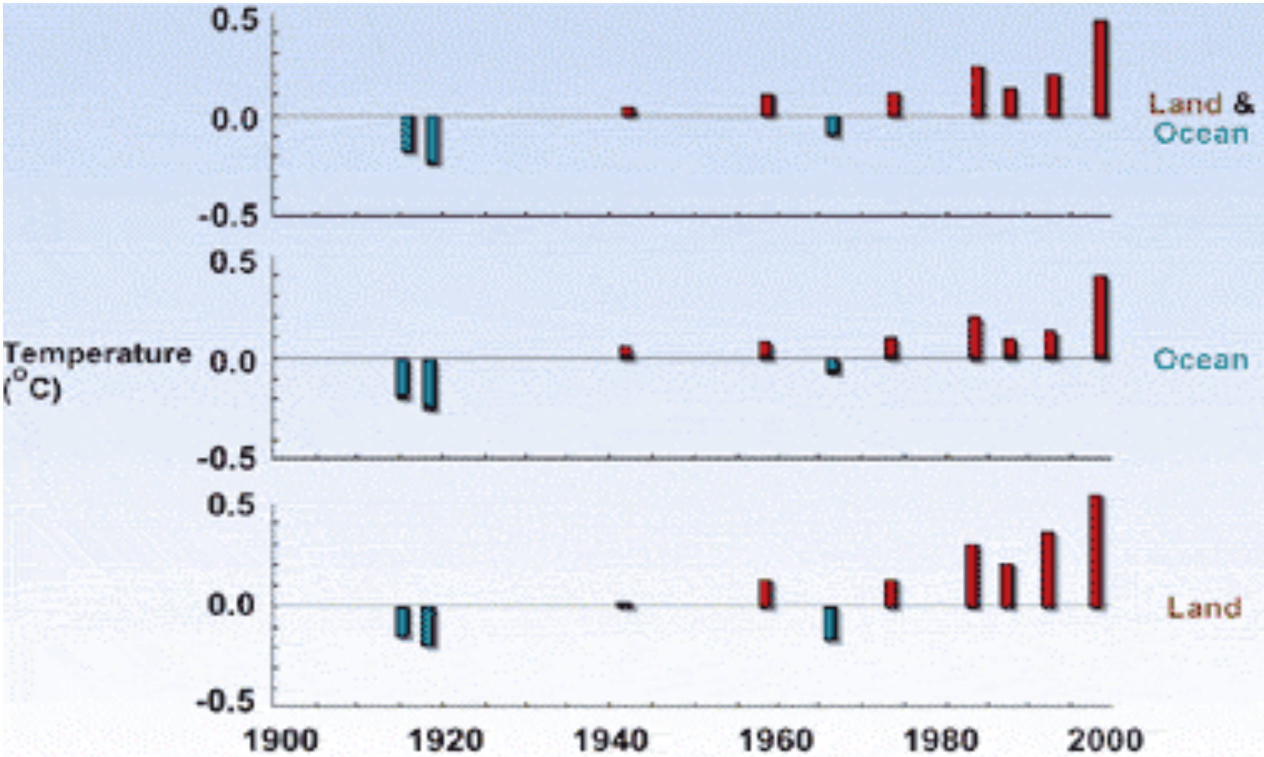


Figure 11 Top 10 El Nino Events of the Twentieth Century incorporating Global Surface Mean Temperature Anomalies
Source S.J. Crimp 2000 Department of Natural Resources. Queensland Government

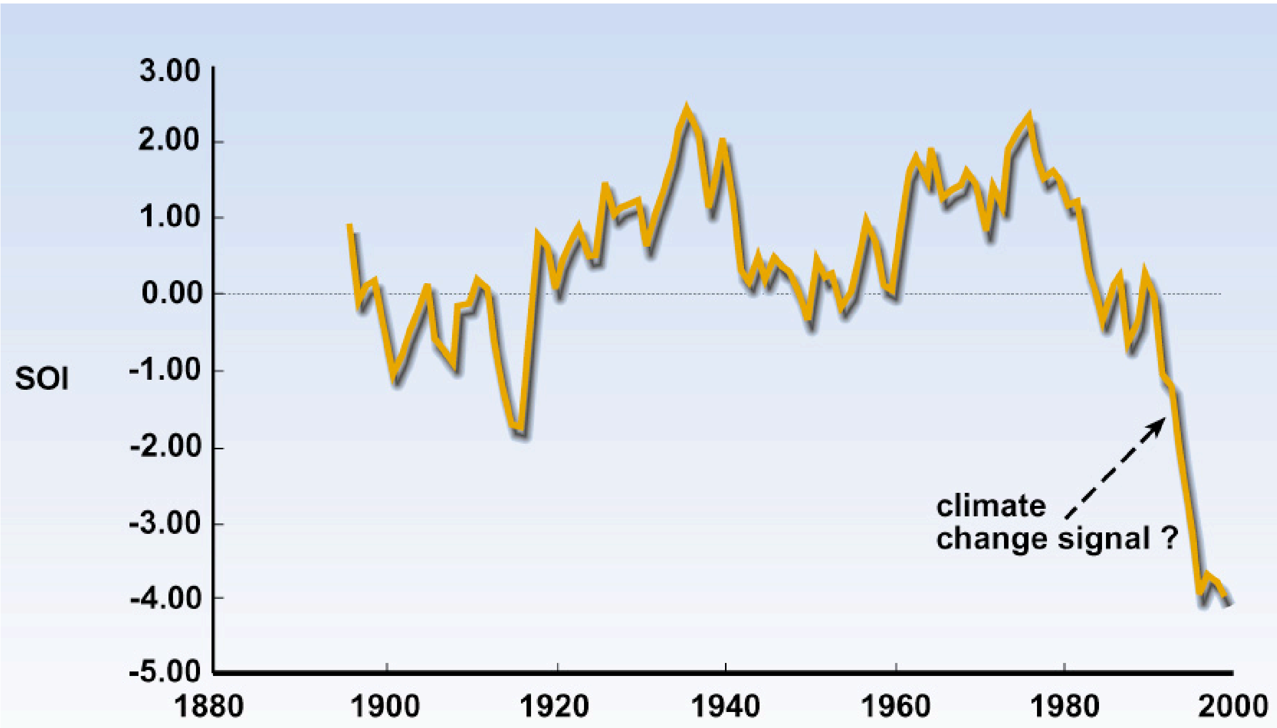


Figure 12 20 Year moving Average of Mean Yearly Southern Oscillation Index (SOI)
Source S.J. Crimp 2000 Department of Natural Resources Queensland Government

The trend in annual total rainfall from 1970 to 2005 for Australia is shown in figure 13. Again the significant shift of rainfall from the eastern to the western half of Australia can be seen. It must be noted that if the trend in annual total rainfall was taken from 1950 instead of 1970 the effect would appear less dramatic. This is because, particularly in the South Eastern Australia, there was a wet sequence from 1952 to 1996 which weighs the trend. The trend of the average loss of rainfall at Bendigo is shown in Table 1. Such rainfall losses are significant in a region where the long term average annual rainfall is only 540 mm. Such a loss can reduce the effective rainfall in such areas (on average) to zero and so impact inflow to existing reservoirs.

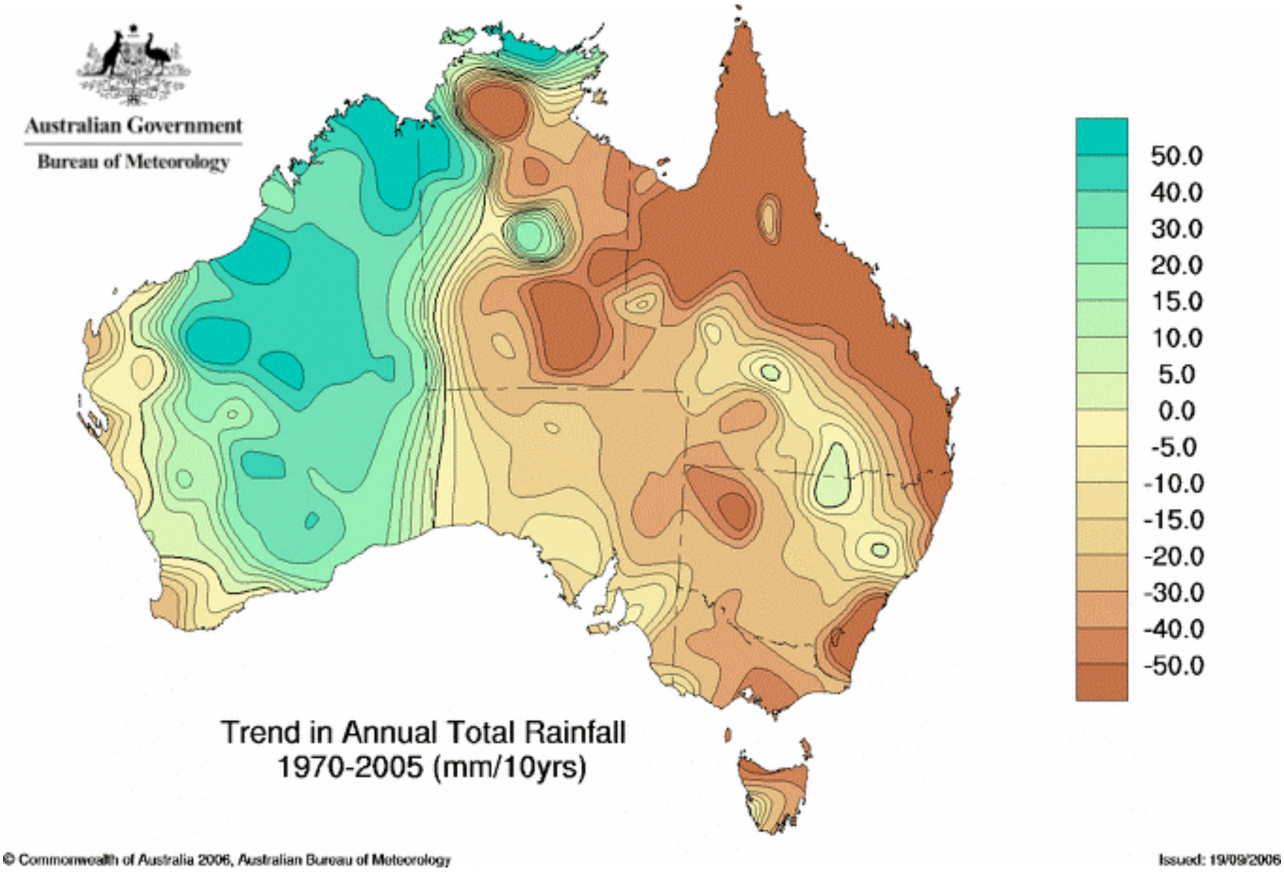


Figure 13 Trend of Annual Rainfall1970 - 2005 (mm/10years)

Table 1 Trend of Annual Rainfall Loss at Bendigo

Sample Span (Years)	Loss of Rainfall (mm/year)
1950 - 2003	110
1970 - 2005	140
2003 - 2006	160

4. GLOBAL WEATHER – RECENT UNCERTAINTY

Most world nations, in recent times, have expressed their concern and in some cases alarm at the level of uncertainty in the global weather patterns. There has been argument about the issue of global warming, its causes and implications. A consensus view appears to be emerging which identifies the burning of fossil fuel with the rising of the Earth's temperature; global warming. The evidence indicates that there has always been changes to the global temperature; however, the concern is over the unprecedented rate of temperature rise in recent years.

The purpose of this paper is not to enter into the argument about global warming but to place on record findings in climate change as they relate to the Bendigo region and the impact upon the economic livelihood of those who depend upon regular rain and irrigation water in the region including the Lower Murray Basin and most probably New Zealand. The major factors influencing the rapid temperature change include;

1. The level of net radiation flux reaching the earth from the sun
2. global dimming due to air-travel
3. global pollution of particulates smaller than 2.5 micron
4. global warming gases due to human activity and
5. the rapid changing of carbon sinks. I.e. loss of forests, reduction of soil carbon etc.

The major symptoms resulting from the above include;

1. A weakening of trade winds
2. melting of glaciers, permafrost, Arctic and Antarctic ice
3. slowing of the Gulf-stream
4. extremes in droughts, fires, floods
5. acidification of the oceans and
6. the maintenance of abnormally warm South China and Philippines Seas.

The increase in the incident and intensities of the El Niño phenomenon in the last 30 years, the unprecedented sea temperature anomalies and differential warming of the Earth's hemispheres are strong indicators of climate change and global warming. It is important to note that the mean surface temperature in the Northern Hemisphere is rising at twice the rate of that in the Southern Hemisphere over the last twenty years.

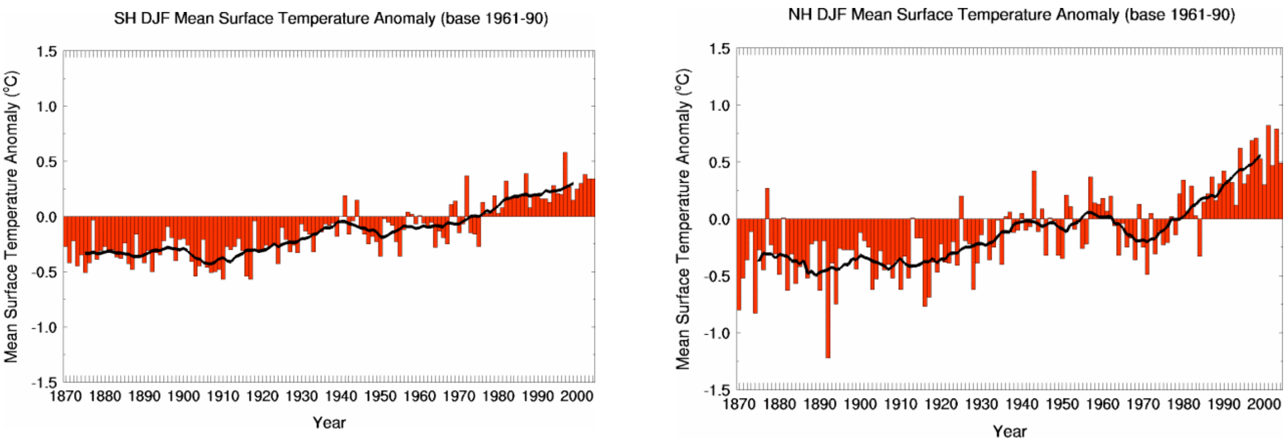


Figure 14a and 14b Showing the Southern and Northern Hemisphere Mean Surface Temperature Anomaly for the Months of December, January and February (Base 1961-1990)
Source: Commonwealth of Australia, Bureau of Meteorology

The trend of the temperature rise in the Northern Hemisphere from 1900 to 1950 is small compared to the significant rise from 1950 to 2005 as shown in figure 15. These higher temperatures appear to correlate with the reduced rainfall, see figure 16. Note. A comparison of such reduced rainfall of 0.5 mm per year is insignificant when compared to the reduced rainfall of approximately 160 mm per year lost at Bendigo.

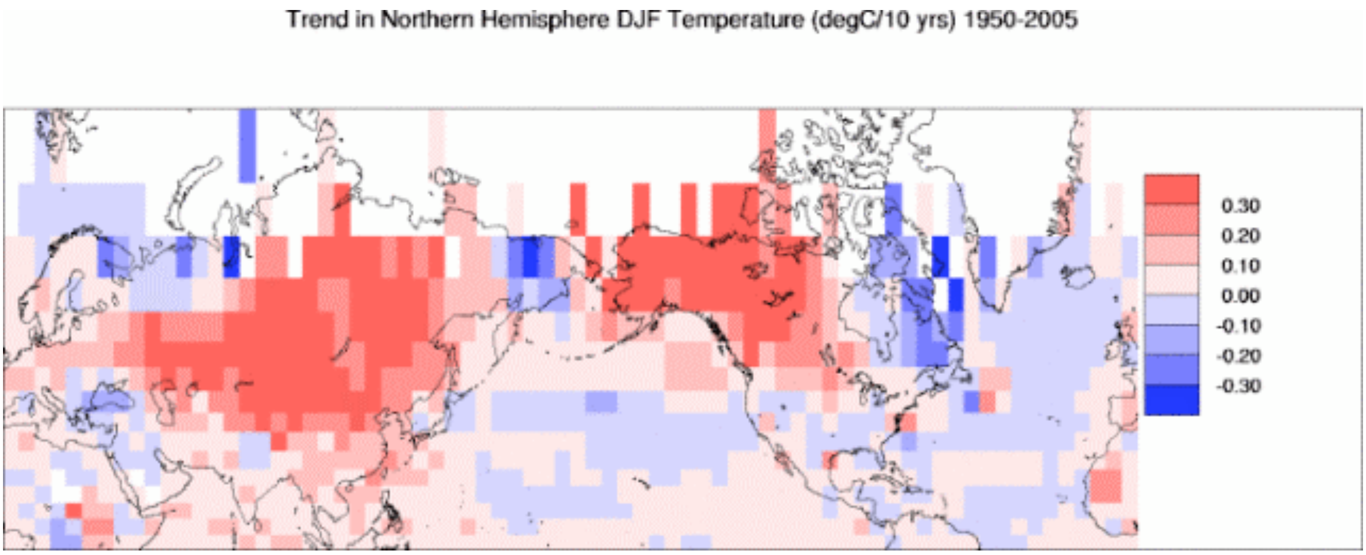


Figure 16 Trend in the Northern Hemisphere Temperature (degC/10yrs) 1950-2005 for the Months of December, January and February
Source: Commonwealth of Australia, Bureau of Meteorology

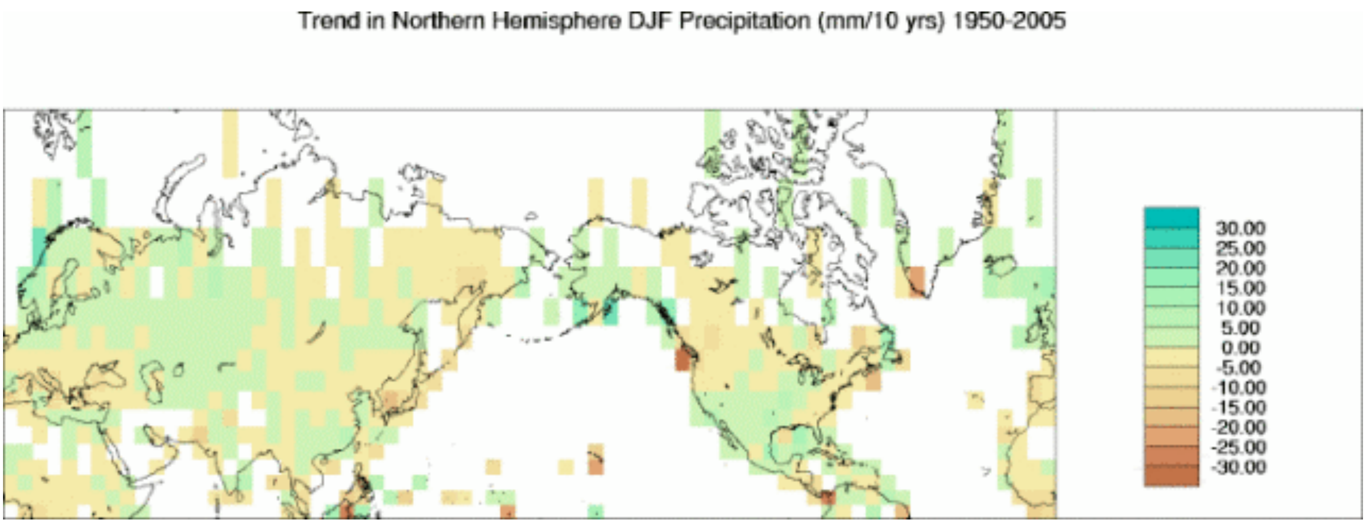


Figure 17 Trend in the Northern hemisphere Rainfall (degC/10yrs) 1950-2005 for the Months of December, January and February
Source: Commonwealth of Australia, Bureau of Meteorology

5. THE 'CLIMATE ROLLER COASTER'

Detailed scientific studies into global warming has shown that climatic change is a ongoing process and throughout recent history, the last 30,000 years, there has been major changes in the earth's climate, however, it is the unprecedented rate of rise of temperature that is causing anxiety. These changes have occurred in what could be called geological time and in most cases there has been adequate time for biodiversity adaptation, however, the challenge to the community in the Bendigo region is how to adapt to climate change when the rate of change is unprecedentedly fast and the economic resilience of the farming community is only a matter of a few years before the farming enterprises fail and the farmers walk off the land.

Figure 17 displays the 'Climate Roller Coaster'. This figure depicts the cyclic variations of indicators (carbon dioxide, methane and infra red temperature) over the past 420,000 years. This unique record was derived from the Vostok Ice Core (Manning, 1990) and has intrigued scientists ever since. The frequency spectrum in figure 18a clearly shows a number of cyclic frequencies or beats occurring in the record. The major cycle or beat is approximately 100,000 years and is called a Milanovitch mechanism the largest of which relates to the elliptical passage of the earth around the Sun. It would appear that once in 100,000 years the elliptical variation could account for a seasonal variation of solar radiation intensity amounting to about 30%.(Sturman.A, 1996) The 100,000 year Milanovitch mechanism could be likened to a resetting of a switch where after the depths of an ice age the earth's surface temperature would rapidly warm and then progressively cool as a result of a multitude of factors until the depths of another ice age was reached after a cycle of about 100,000 years

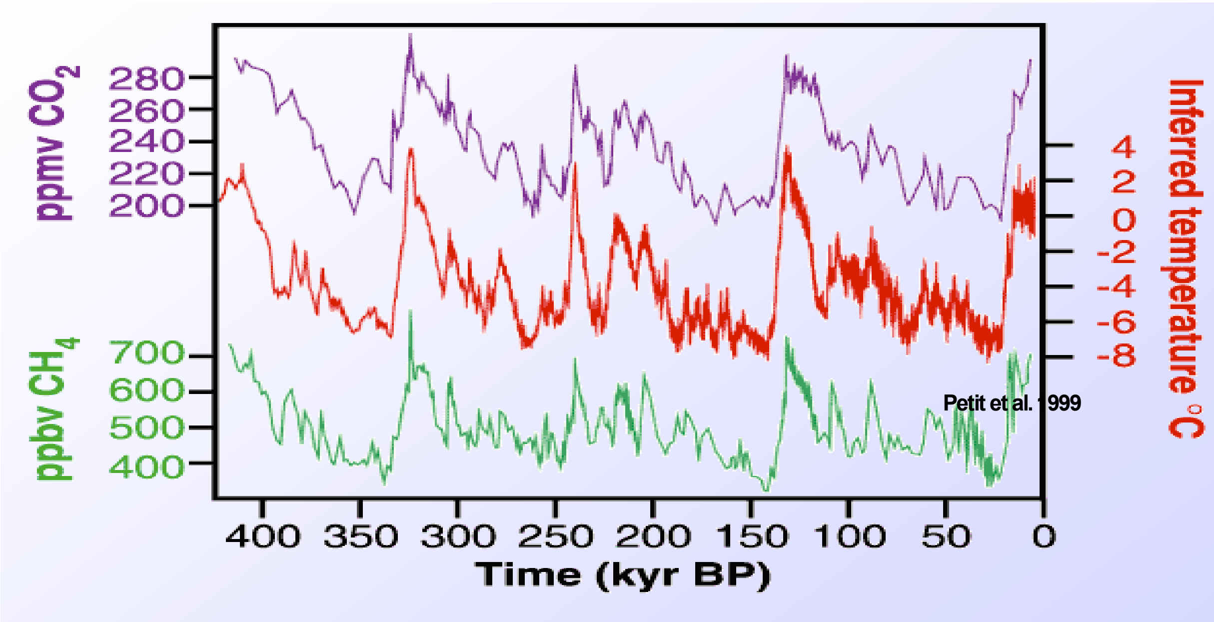
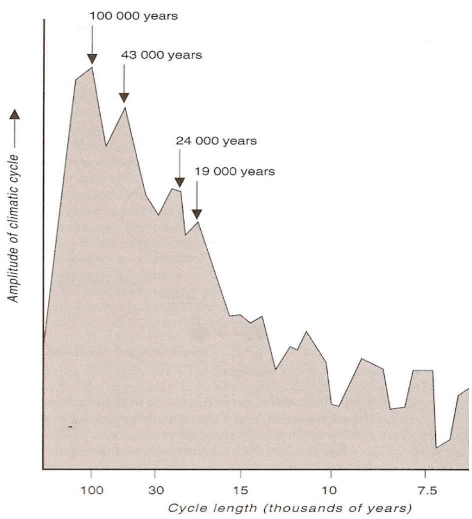


Figure 17 Showing the Cyclical Traces of Carbon Dioxide, Methane and Infra Red Temperature for the past 420000 years taken from the Vostok Ice Core where the Glacial-interglacial Cycling was measured. Note: Maximum CO_2 reading is approximately 300ppmv current reading is approximately 360ppmv.



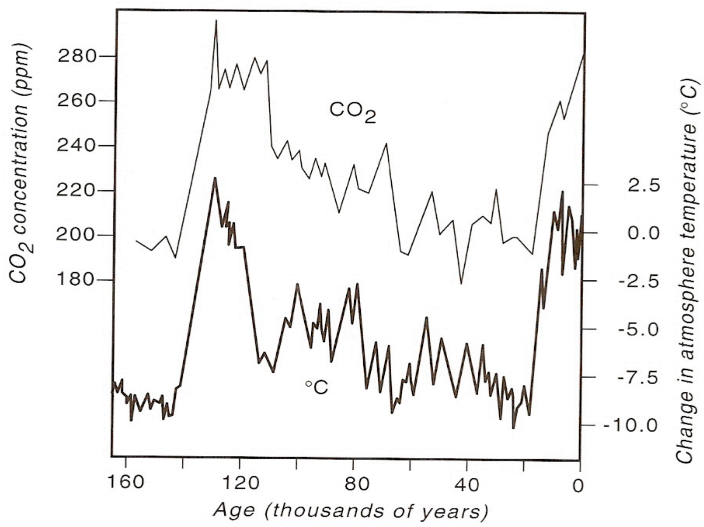


Figure 18a Showing a Spectrum of Cycle Frequencies up to 100000 years.

Figure 18b Showing the change in both and Atmospheric Temperature and CO_2 for the 100000year cycle. (After Manning 1990)
Note the relatively steady temperature for the last 10000 years which corresponds to farming, settlements and civilizations as we know them today.

It is truly remarkable that Neanderthal man and later Homo sapiens transversed this climate roller coaster and is possibly the reason why they roamed as hunters and gatherers until as recently as 10,000 years ago when relatively steady climate conditions prevailed and they could settle down and develop agriculture and civilisations. Refer to figure 18b where the last 10,000 years varies in atmospheric temperature only by a total of about 4 to 5° C°. Al Gore states in his recent book, “An Inconvenient Truth”, that the bottom of the temperature trace marks the depth of the last ice age that, "… represents the difference, in Chicago, between a nice day and a mile of ice over your head". The difference being about !0°C. Given the above what Homo sapiens have experienced over the last 10,000 years has been a degree of climatic sustainability not experienced before in the last 500,000 years.

It would appear from the temperature trace in figure 19 below that temperatures in the Northern Hemisphere have been in relatively steady for the past 1000 years with a recent maximum total variation of proximately 1°C. It raises the question that Homo sapiens have ‘never had it so good’ and if so what does it say for a sustainable future given our acquired dependence on climate stability and fossil fuels?.

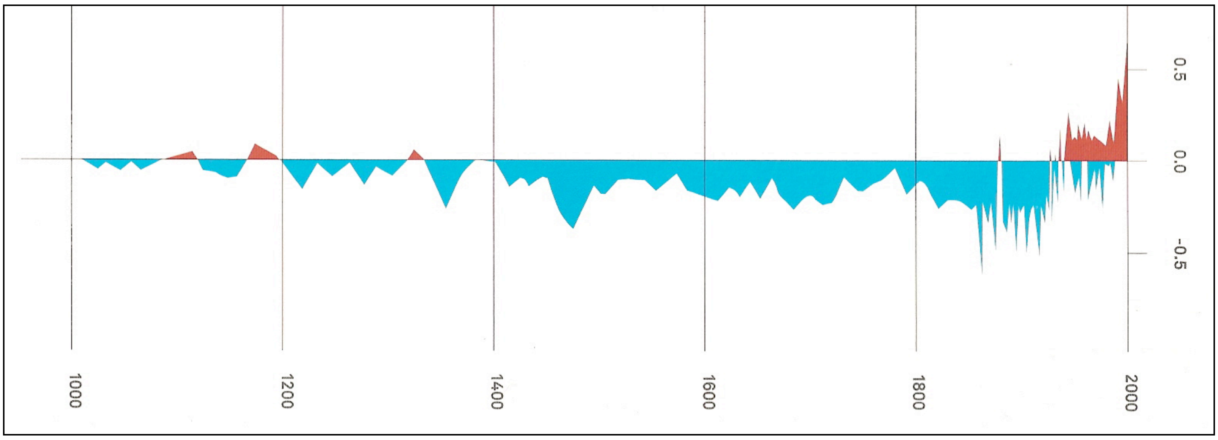


Figure 19 1000 years of Northern Hemisphere Temperatures in a Degrees Centigrade.

6. SUSTAINABILITY

6.1 Sustainability on the farms

The dryland cropping farmers north at Bendigo in the Wimmera Mallee area have farmed in a sustainable manner for the last 100 years. Sustainable meaning, not that environmental damage has not being done, but sustainable in the sense that in economic terms they have been able to survive through the good and the bad years. They could survive over a four-year cycle of one good year, to average years and one bad year. Now over the last 10 years and in more recent times the four-year cycle has escalated to one average year and three bad years forcing many of these farmers into bankruptcy since their finances are also so finely balanced.

A way to provide security for the growing season of plants is to supply irrigation water and this has been successful in the Lower Murray Darling Basin also for the past hundred years. Now, for the first time, as shown in the above sections the prospect of curtailing the amount of irrigated agriculture back to perhaps 10% of previous maximum development levels is becoming a reality.

Both the dryland crops farmers and irrigators have relied and survived what now has to be seen as a very stable climate with only subtle cyclic variations. Such stable climatic conditions over the last 1000 years hardly compare with the variations in climatic temperatures over the last 10,000 years not to mention the ‘climate roller coaster’. The prospect of rapidly moving towards the ‘climate roller coaster’ is daunting, to say the least.

For example figure 20 below shows the results from modelling the soil moisture deficit in North America arising from either the doubling or quadrupling the level of carbon dioxide in the atmosphere. Presumably in this modelling increased carbon dioxide levels in the atmosphere is coupled with temperature rise on the earth. As yet the temperature of the surface of the earth has not gone up in sympathy with the drastic increase in levels of carbon dioxide, however, the horrid thought is that once the latent heat of the ice caps is taken up sensible heat the temperature on earth will skyrocket unless there are other correcting circumstances.

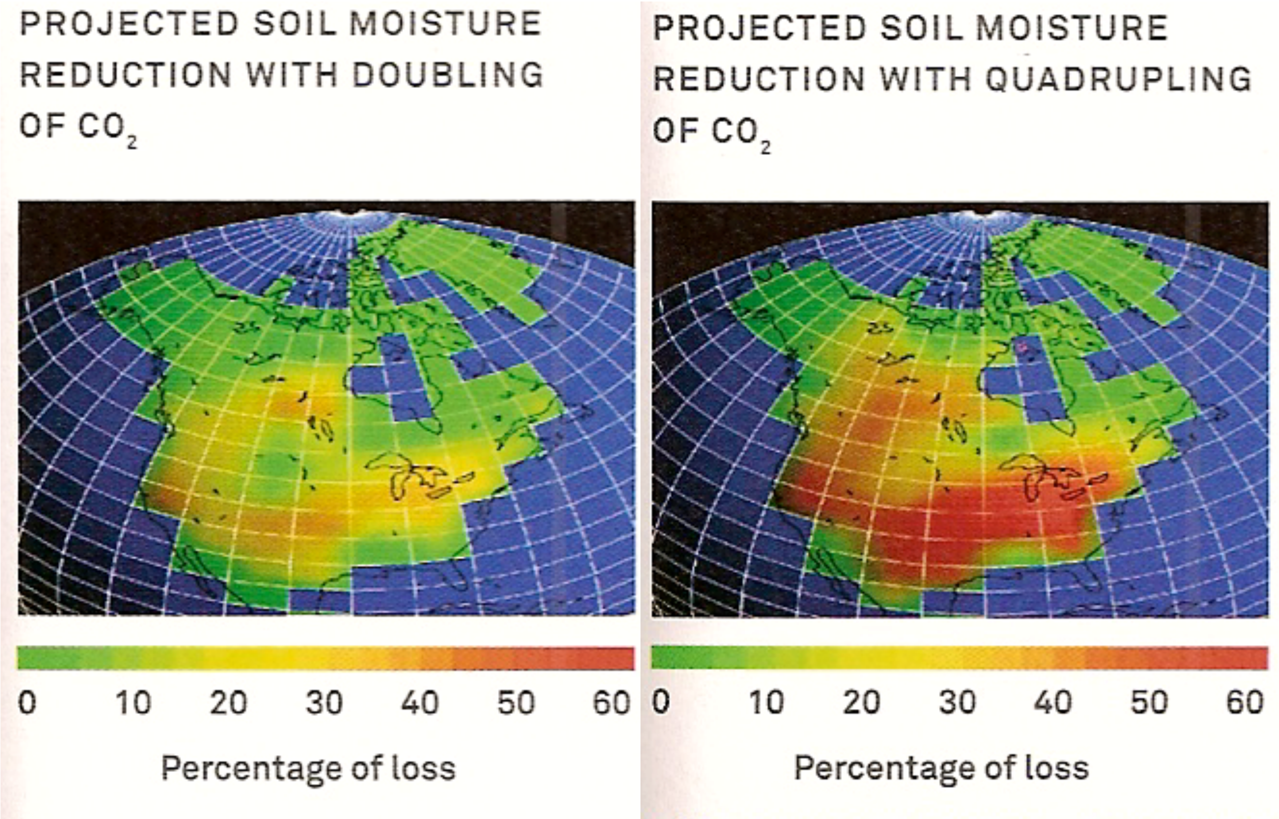


Figure 20 shows the projected Soil Moisture Reductions for Doubling and Quadrupling the level of Carbon Dioxide in the Atmosphere.

6.1 Sustainability Water in the Catchments

A detailed study of the Eppalock catchment showed that the ad hoc historical exploitation of water resources, the absence of an integrated natural resource management framework in the catchment, little institutional understanding of social aspirations and government agencies inability to recognise and adapt to climate change resulted in significantly less runoff from the catchment even when taking into account the drought conditions.

The future challenge for Landcare and the government agencies is how to integrate the management of the natural resources in the catchments so as to enhance the natural resources but simultaneously maintain the inflows to reservoirs during a time of decreasing effective runoff.

6.2 Sustainability - Water Governance and Paralysis

The development of the new water legislation in Victoria has come at a price. During the time it has taken to implement the Council of Australian Governments (COAG) water reforms Victoria has been in the grip of the worst drought on record and consequently the bulk entitlements governing the allocation and distribution of water have been tested and found inadequate. Unfortunately, water governance protocol have failed the Bendigo regional community and has caused them, and will continue to cause them, significant hardship until such time that the Minister directs that the bulk water entitlement be rewritten to accommodate the new climatic and hydrological conditions to ensure security of supply to regional communities. New water governance instruments are needed to address issues of future water security. Such instruments are to be focussed on actual water reserves and not probabilistic expectations.

7. CONCLUSIONS

It is concluded that:

1. The emptying of Lake Eppalock and the subsequent hardship caused to the communities in the Bendigo region is a result of the rapid changes to the multiple of influences that drive the global climate.
2. Existing water governance protocols and the lack of integrated catchment management practices have contributed to the premature emptying of Lake Eppalock.
3. The experienced at Lake Eppalock has been the forerunner to all the major water storages in the Murray Darling Basin which, on current predictions, will be empty by June 2007 if recent low seasonal rainfall persists.
4. The sustainability of the industries and communities in the Murray Darling Basin are under severe threat, both now and into the future, unless there is a return to a regular seasonal rainfall pattern (highly unlikely at present) or, a significant contraction of the irrigation sector together with the rewriting of the water governance protocols to secure water in reservoirs as a hedge against the uncertainties of rapid climate change.
5. The pattern of the increased occurrence of the El Niño phenomena in the Western Pacific will significantly reduce the amount of rainfall over South Eastern Australia and New Zealand for the foreseeable future.
6. The cyclic history of the climate changes over the last 500,000 years is best described as a 'Climatic Roller Coaster' on which the relatively steady state climatic conditions of the last 10,000 years rests.
7. Sustainable agricultural production and viable rural communities in Australia will become problematic if rapid climate change persists.

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Bendigo Advertiser for publishing the Bendigo Rainfall Chart 1863 to 2002

Mr Frank Hill, for access to his historical documents. Mr Hill is a lifetime resident and past councillor of Heathcote and lives on the eastern shore of Lake Eppalock.

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