Climate Changes and the Effect on Horticultural Production in New Zealand

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Summary:

1. **New Zealand's climate is very variable.**
2. **To understand climate change we need to understand the natural climate dynamics.**
3. **The Greenhouse Effect is natural and makes the world habitable.**
4. **Human activity is enhancing the Greenhouse effect (IPCC).**
5. **This makes the world warmer and the weather system dynamics much more extreme in many ways.**
6. **The Southwest Pacific has experienced many more tropical cyclones.**
7. **New Zealand has seen progressive warming, especially in winter. This increases the risks of insects and fungal diseases,**
8. **The east coast of New Zealand, especially the South Island, is experiencing a highly significant growing season drying trend.**
9. **El Nino's and La Nina's are more extreme in terms of length and strength.**
10. **The Sub-Tropical Ridge (STR) is a climate indicator for New Zealand.**
11. **The STR has moved progressively further south and has a higher center pressure, consistent with global warming enhancing the strength of the Australasian Hadley Cell.**
12. **The last few years have been dominated by anticyclonic droughts in the South Island.**

13. **Low South Island Hydro Lakes are continuing, raising the cost of electricity.**

14. **Spring and autumn anticyclones have the potential to bring early and late season more extreme frosts, especially following a cold southerly event.**

Global Warming:

The Intergovernmental Panel of Climate Change (IPCC) produced the data presented in Figure 1. The warmest temperature in the Interglacial period was 1.4°C, 14,000 years ago. On average, for nearly 14,000 years we have been cooling at 0.1°C per 1000 years. The same has occurred for most of the last 1000 years, until 150 years ago when the temperature trend reversed.

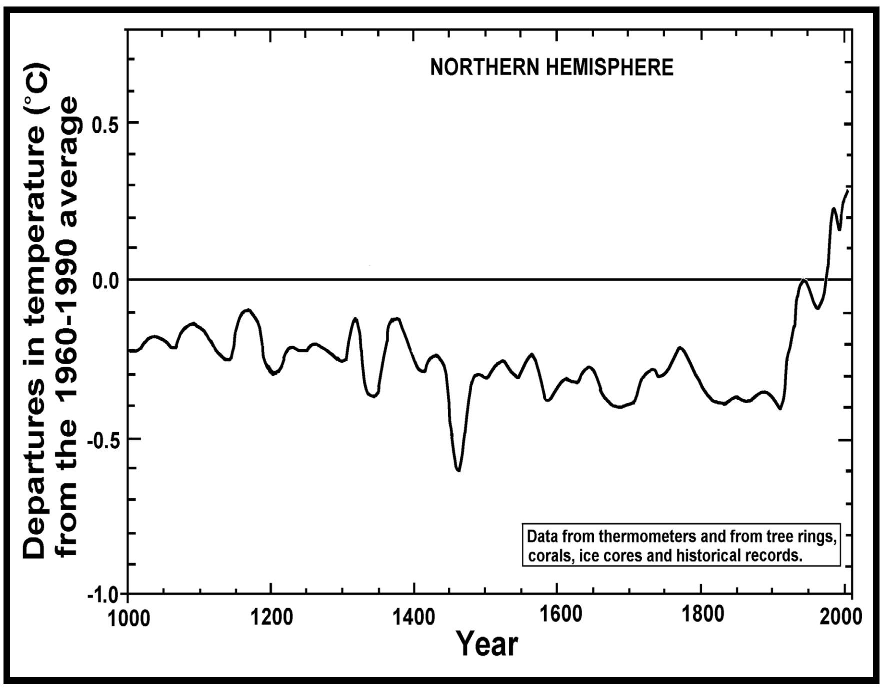

Figure 1: IPCC graph of global mean temperature change over the past 1000 years.

Despite the trend towards an ice age, with 0.1°C cooling per 1000 years, as shown for the first 850 years of this millennium, we have experienced a 0.6°C warming in the past 150 years, as a result of human induced global warming.

New Zealand Warming:

The West Coast glaciers have retreated significantly with the occasional small advance due to heavy snowfall in the high Southern Alps, e.g. in the early 1990's.

Note that despite the rising trend the coldest year was 1992. This was the combination of El Nino and the volcanic eruption of Mt Pinatubo.

Climate change is much more complex that trends in temperatures. The weather has a major role to smooth out the gradients in pressure and temperature. This is accomplished by the formation and movement of synoptic weather systems, anticyclones and depressions with their associated fronts.

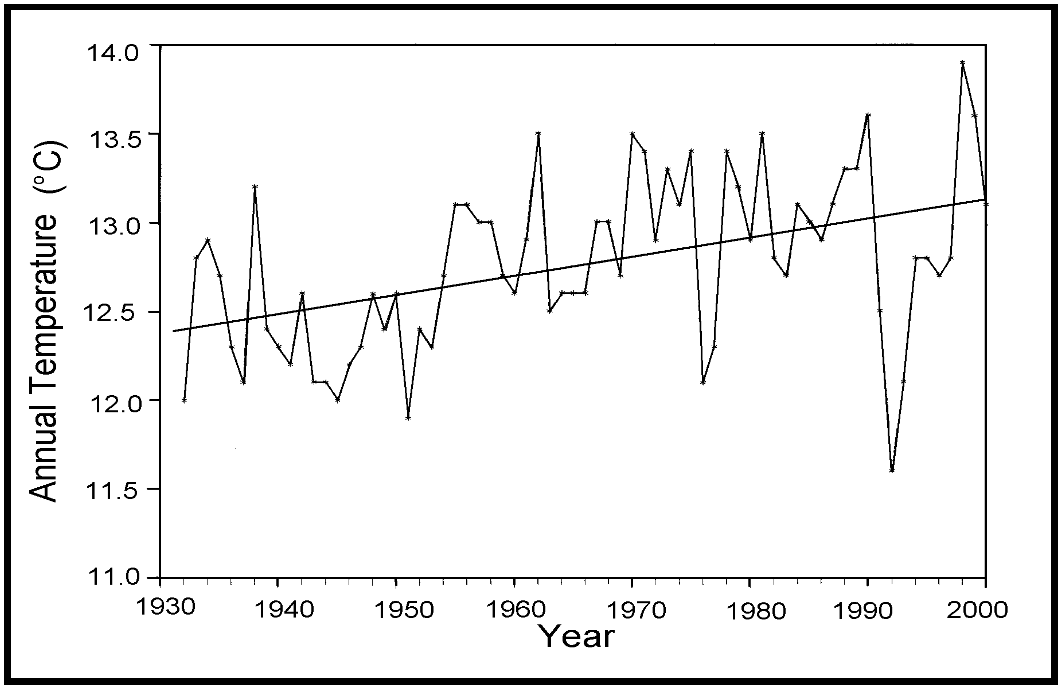

Figure 2: Annual mean temperature for Lincoln.

Since hurricanes are sensitive to the sea surface temperature, was the world warms we expected more frequent and more intense hurricanes. In the SW Pacific they are called Tropical Cyclones. Figure 3 shows the decadal incidence of SW Pacific Tropical Cyclones.

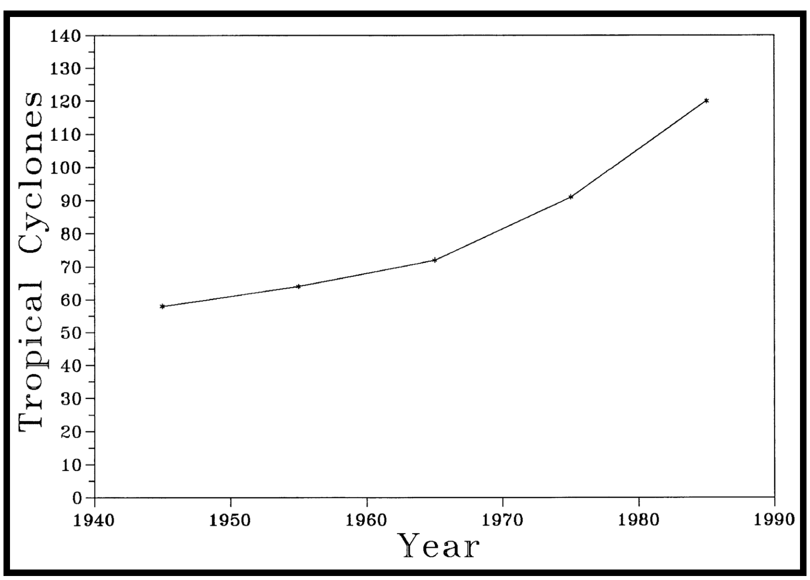

Figure 3: Decadal occurrence of Tropical cyclones in the SW Pacific Ocean.

New Zealand is located in the Southern Hemisphere between the Sub-Tropical Ridge and the Sub-Polar Trough, Figure 4.

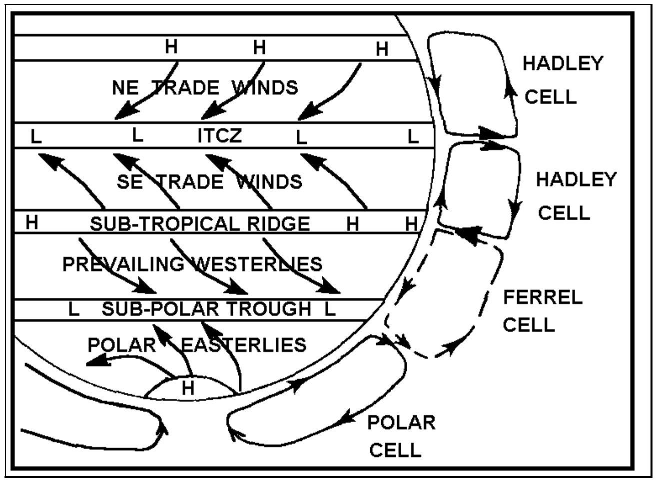

Figure 4: Southern Hemisphere Circulation pattern.

A basic principle of science is that the simplest theory or hypothesis that explains a large amount of patterns in the data is the best scientific concept. For the regional global warming scenario I proposed many years ago that the simplest explanation was that warmer tropical temperatures would enhance the Hadley Cell over Australia, causing the Sub-Tropical Ridge (STR) to move further south and have a higher center pressure. Regional pressure data has been analysed and shows that this is exactly what has been happening, Figures 5 and 6.

Figure 5 shows the time series of the annual mean central pressure of the STR. It was lowest during the 1910 to 1920 period. Since then it has risen steadily and significantly, with a slight decrease in the 1950'sand 1970's which were slightly cooler global temperature periods.

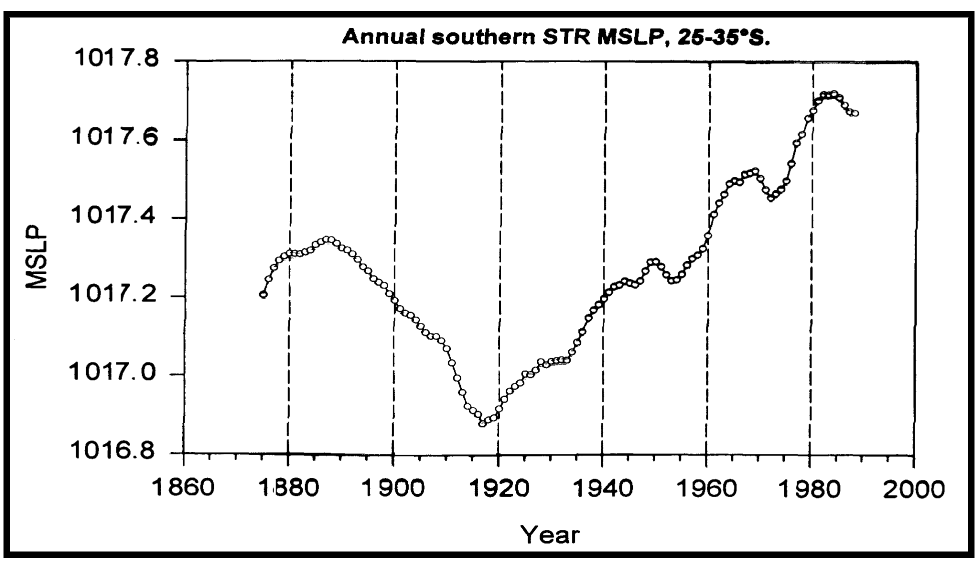

Figure 5: Annual central pressure of the Southern Sub-Tropical Ridge.

Figure 6 shows the latitude of the STR along the east coast of Australia. This is the departure point of anticyclones entering the Tasman Sea on their way towards New Zealand. There is a significant linear trend of movement towards the south with the mean latitude being 36° in 1910 and 36.45° in 1985.

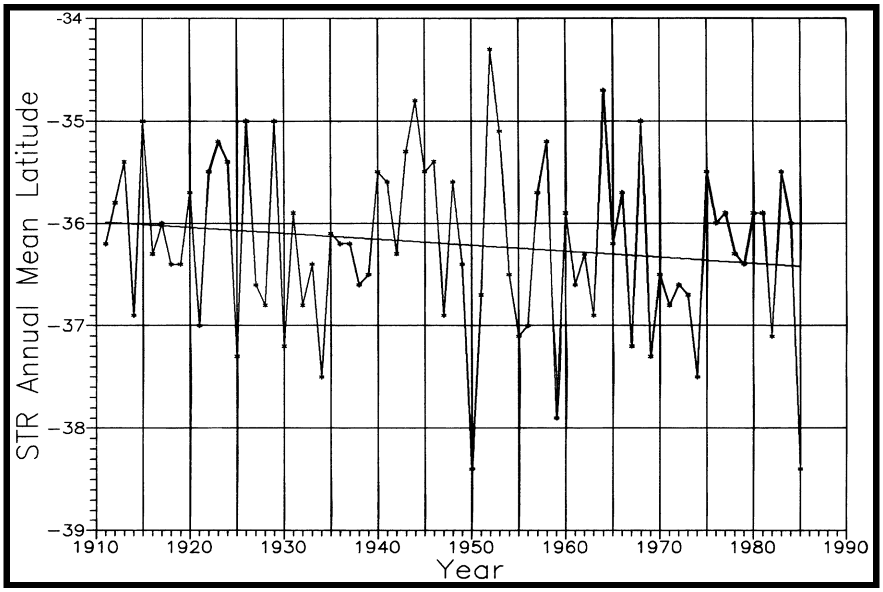

Figure 6: Annual mean latitude of the Sub-Tropical Ridge along the Australian east coast with a least squared fit trend line, trend $p<0.001$.

The synoptic weather pattern change between the beginning and end of the 20th Century shows for the summer season a stronger more southern anticyclone with a stronger ridge extending across the Tasman Sea to cover New Zealand with higher pressures in the range 0.2 to 0.3mb, Figure 7.

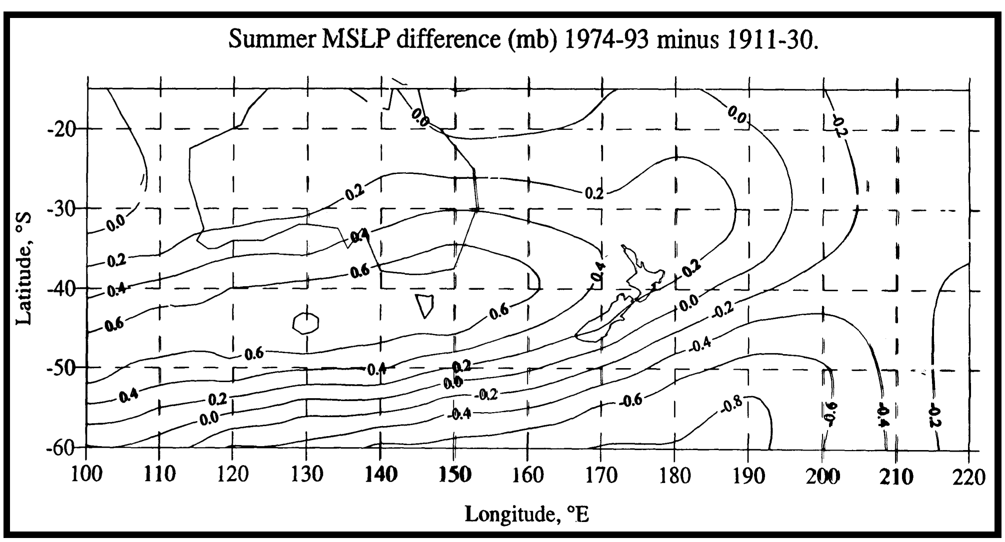

Figure 7: The sea level pressure difference between the 20 year period near the start of the 20th century, 1911-1930, compared with the 20 year period 1974-1993.

This gives stronger west-south-westerly winds still to the lee windward side of the Southern Alps, generating drier and warmer conditions by the cumulative effect of higher mean pressure (clearer, sunnier weather) and strong westerly winds against the Southern Alps giving drier conditions on their lee side.

This is associated with warmer and sunnier weather over the South Island, with longer growing seasons, drier growing seasons and longer drought periods and higher drought risks along the east coast of the South Island. Figure 8 shows that the result of this is a highly significant rising trend for annual dry soil days at Lincoln.

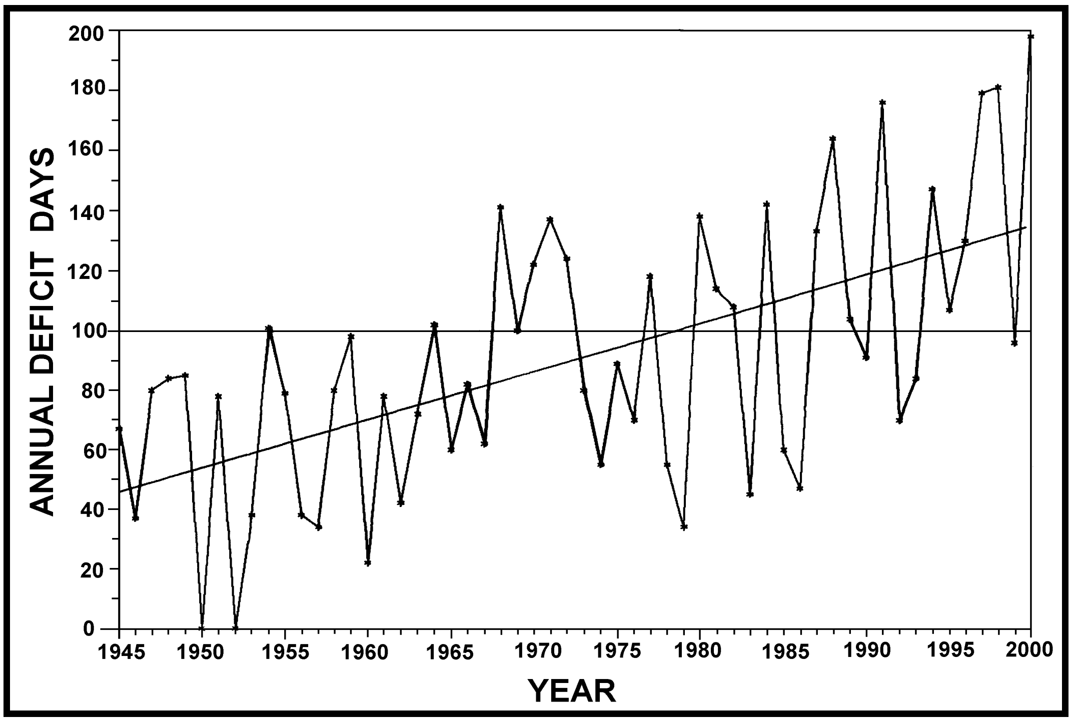

Figure 8: Growing Season dry soil days, Lincoln University. Trend $p<0.0001$.

In the 1940's and 50's the mean number of dry soil days was 50, with some years going down to zero and the highest, driest season having 100 dry soil days. A significant rising trend shows that by the end of the Century we were averaging over 120 dry soil days per growing season. The highest was 199 in the 2000/01 season.

Natural Weather Dynamic Factors:

The natural weather dynamics are strongly influenced by the solar activity as indicated by sunspot number and the Quasi-Biennial Oscillation (QBO). The sunspot activity modulates the annual latitude range of the STR. Normally the STR follows a month or two behind the annual solar latitude pattern with the sun coming south in our summer and going into the northern hemisphere for their summer. Thus the high pressure belt comes south for summer and goes north for winter, allowing more subtropical depressions to move south in summer and early autumn, and more sub-polar depressions to penetrate the New Zealand latitudes in winter and early spring. It was shown as early as 1925 that the seasonal amplitude of the anticyclone pattern was proportional to the sunspot number.

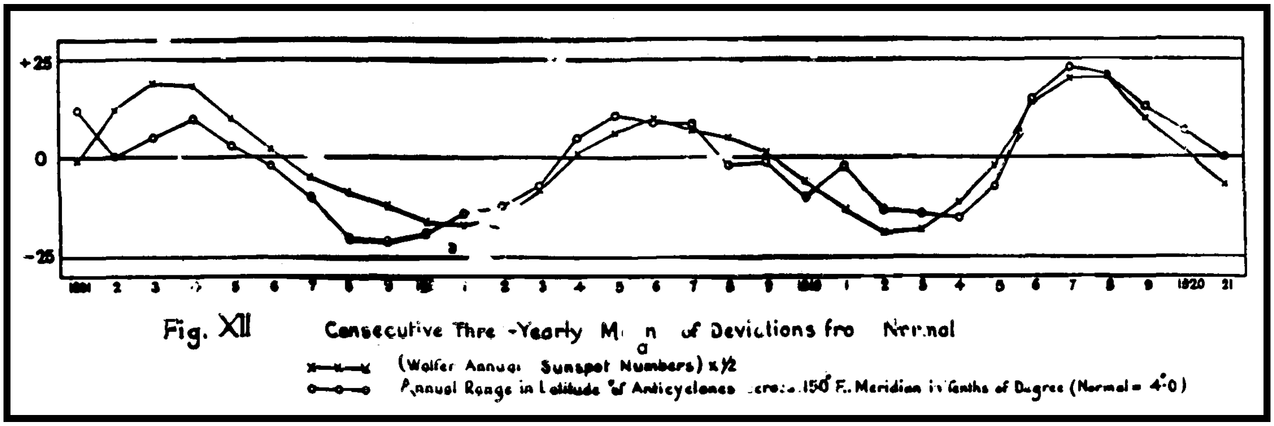

Figure 9: The 3-yearly sunspot number variation (times 0.5) and the departure from normal of the annual range of latitudes of anticyclones along the 150° meridian, Kidson (1925).

Dr Kidson describes this relationship as “remarkable” More remarkable is the ignorance or dismissing this by current climatologists. The effect is still happening in the 1980’s and 90’s.

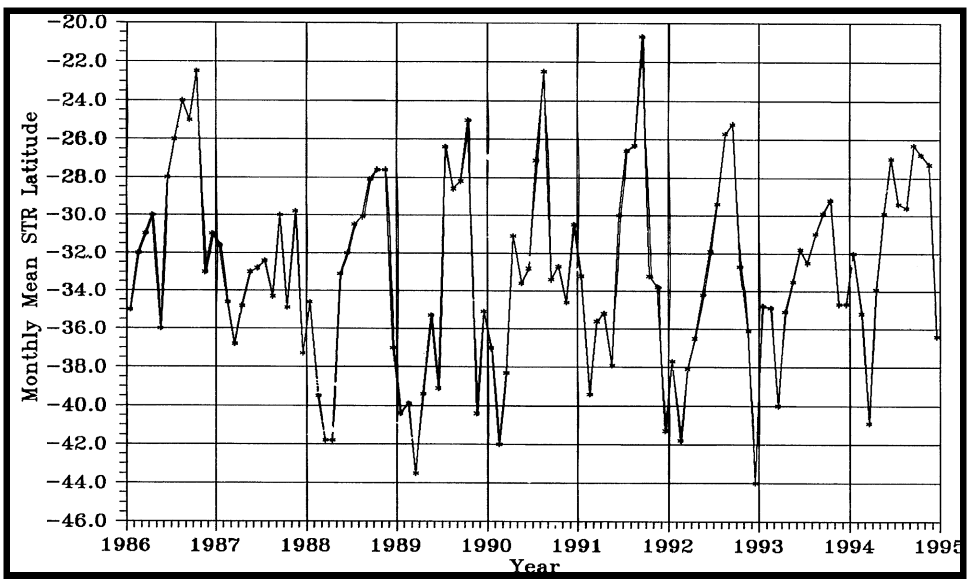

Figure 10: The monthly latitude of the STR leaving the Australia east coast with sunspot minimum in 1986/7 and 1993/4 and sunspot maximum in 1990/91.

Figure 11 shows regional annual rainfalls series and sunspot numbers series. There is a significant correlation in each case for a high proportion of the rain rates from the sunspot activity. Similar relationships are seen in the inflows of the South Island hydro lakes and the Clutha and Waitaki Rivers.

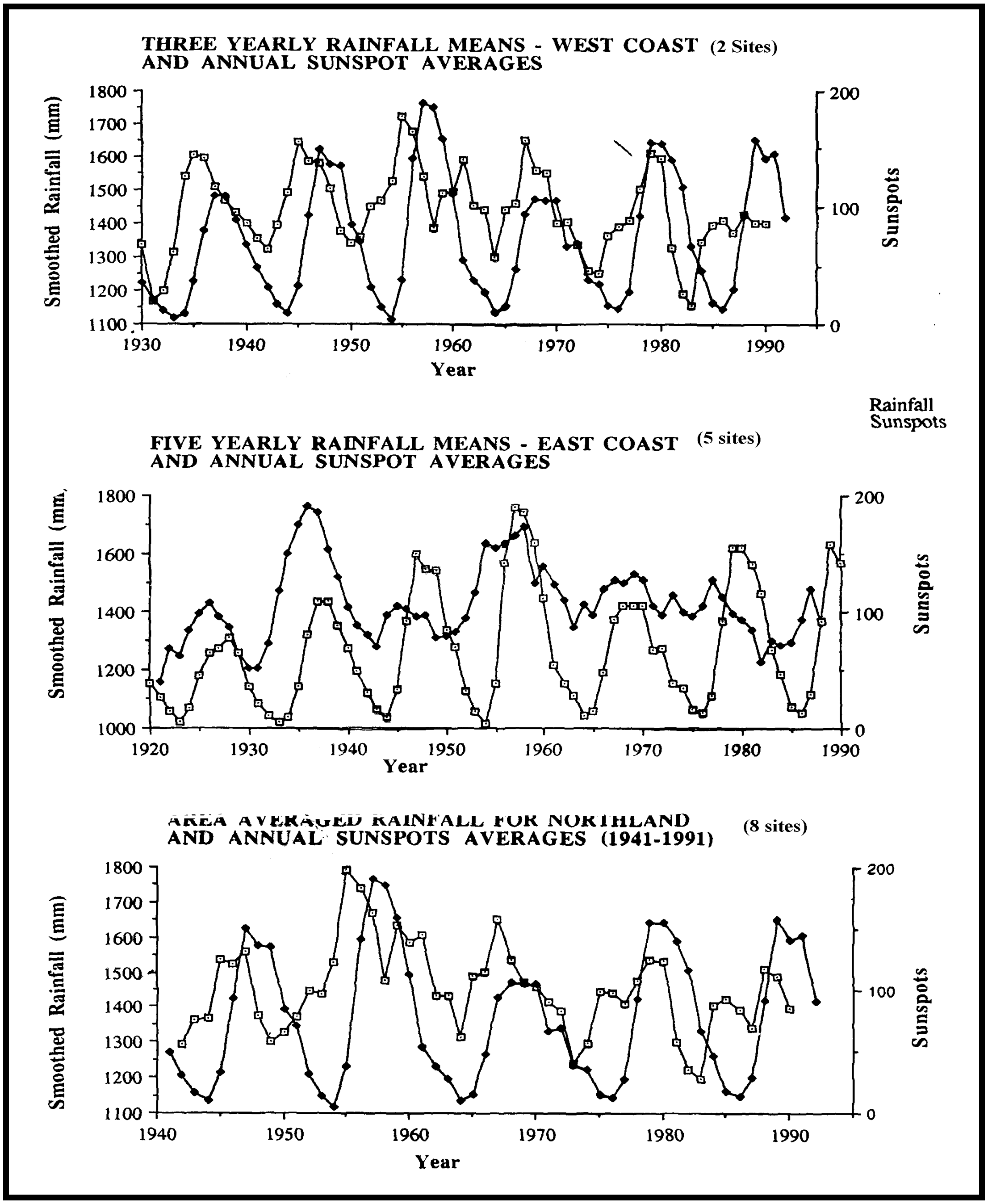

Figure 11: Annual rainfall and sunspot numbers for three regions, South Island West Coast and East Coast, and Northland.

The Quasi Biennial Oscillation (QBO) is produced in the stratosphere with the annual solar movement north and south over the equator heating the ozone layer. As it travels down the period gets longer and longer as the layers get less and less stable. Just above the equatorial troposphere its period is close to 2.3 years. Within the troposphere it modulates the westerly wind waves, Figure 12.

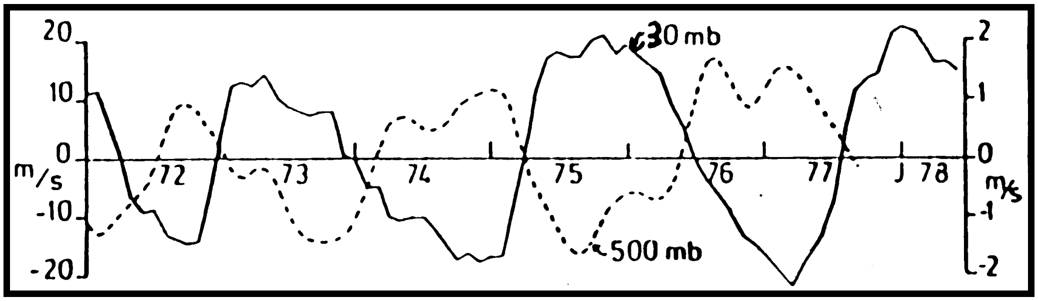

Figure 12: Showing the correlation between the QBO wind (30mb) and the mid-troposphere westerly wind speed (500mb). A positive (westerly) QBO produces weaker westerly winds and easterly QBO phases produce stronger westerly winds at 500 mb levels.

This produces modulation of the north and south surface wind analogies in the Tasman Sea, Figure 13.

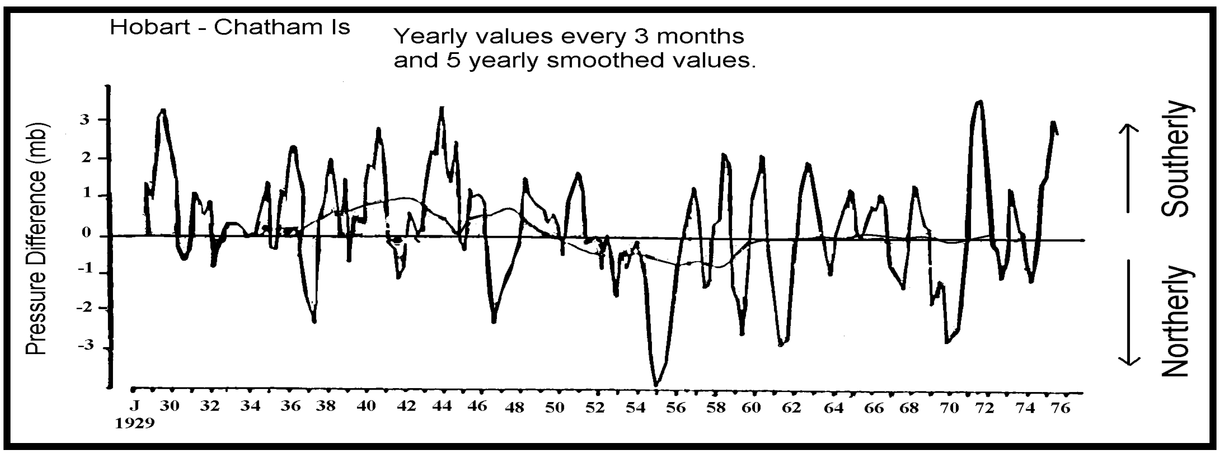

Figure 13: The north-south wind anomaly variation showing a close to QBO relationship, Trenberth (1976).

The years of 1972, 74, 76 have southerly dominating winds corresponding to easterly phases of the QBO. Easterly QBO phases support El Nino and westerly and southerly wind anomalies while westerly phases of the QBO favour La Nina and northerly and weaker westerly anomalies.

The main reasons for showing these relationships is that traditional approaches of the Meteorological Service and NIWA ignore this information even though they are from papers published by earlier NZ Met Service Staff, Dr Kidson and Dr Kevin Trenberth. A second reason is that these are consider to be very small and subtle factors but they have very strong effects on the dynamics of the Southern Hemisphere and Australasian weather systems.

Hence it shows that it is very strongly effects from the Greenhouse Effect because of the significant changes to the radiation balance by Greenhouse gases such as carbon dioxide, water vapour, methane, nitrous oxide and CFCs. The evidence above shows that New Zealand's weather is being strongly changed by the Greenhouse effect.

With the global warming pushing the anticyclones further south and La Nina occurring for three years also pushing the anticyclones southward, also being near the sunspot maximum, the last few years have been dominated by anticyclone dominated droughts. We are still in an anticyclone dominated situation and their movement north this winter was small and brief. The following weather map is from the Christchurch Press this last Monday. The region has far higher than average pressure and a weak low pressure cyclone with 1008 mb off the Australian coast, Figure 14.

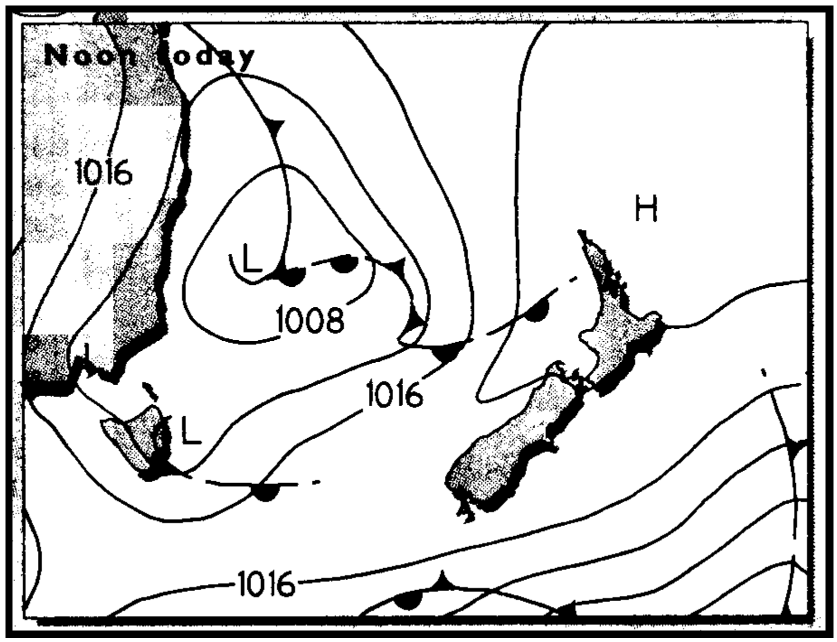

Figure 14 : Press weather map for Monday 12 November 2001.

Implications for Climate Change for Horticultural Production:

Horticulture is very dependent on rainfall, temperature and humidity for growth, maturation, and ripening, as well as for infection and for physical and biological damage.

With the significant and continuing warming the risk of insects and infection is increasing.

The much more highly variable climate makes planning and risk management more difficult.

Going through past records the usual frost-free season can be identified. However, with the greater variability and extremes, the risk of later frost in the Spring and earlier frosts in Autumn is increasing. The following weather map shows a typical anticyclonic situation which has clear skies, light to calm winds and radiative cooling causing ground and air frosts of –6.7°C and –3.8°C, respectively.

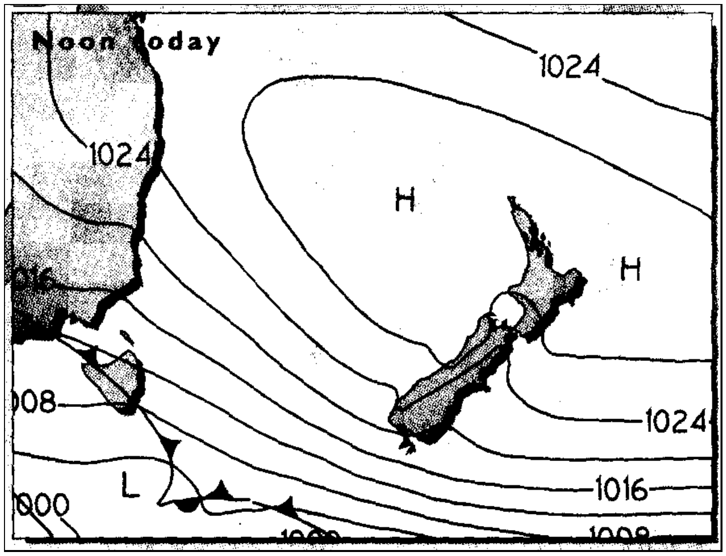

Figure 15: Noon forecast weather map from the Christchurch Press on 8th August 2000, associated with air and ground frosts in Christchurch.

Most likely the most extreme frost occurrence will be produced when there is a very cold southerly that cools the region and the ground to freeze with clear night skies and cold winds. As the depression moves away a strong and slow moving anticyclone comes in from the west giving a clear, dry, calm night with 6 to 9 degrees of radiative cooling.

This could be intensified by early evening katabatic winds bring very cold air down from the hills into the valley bring an advection frost. As the floor of the valley fills with cold dense air a stable layer is formed and subsequent katabatic airflows travel over the stable layer with brings the air speed down close to zero. Then the radiation causes more cooling and a very serious frost.

Seasonal forecasting:

With the extensive knowledge about the natural factors that alter the weather systems that ability to more reliably forecast the mean anomalies of seasons is significantly improved. With careful monitoring and watching how the trends changes from global warming are changing the dynamics of the weather systems, the reliability can be maintained and hopefully improved. One important fact must be taken into account. The Antarctic Circum-Polar Wave (ACW) must be used and followed. This produces a close to 4-year thermal and pressure cycle around the Antarctic Ocean and closely affects New Zealand, White and Cherry (1998).

With the demonstrated sensitivity of the Hadley Cell to the temperature gradient across Australia, as shown by the trend pushing the STR south over the last 100 years, this shows that El Nino's and La Nina's can be very different depending on whether the sea temperature as the ACW moves around, is above average and below average or near average, south of Australia. For example, El Nino brings colder than average water north of Australia. When the sea temperature to the south is colder than average then the temperature gradient across Australia is stronger than when the southern ocean is warmer than average. This will strongly influence the position and strength of the anticyclones in the STR.

With the many years that I have been working on seasonal forecasting for the electricity and primary production industry I have developed techniques that can be applied to specific regions and situations, provided long time series data is available to calculate the relationships and correlations to the many climate dynamic factors that affect the weather. Once the algorithms are identified then close following of the actual weather is used to refine the forecast system.

Frost Forecasts:

For frost forecasting a similar approach is used with different variables such as the 3pm temperature and dew point, the wind strength and direction and the time of year.

Forecasting is an important contribution to risk management but it must be continually refined and improved to make it more and more reliable.