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Drivers of Rainfall Variability in Melbourne and the Murray Darling Basin

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This article is based on my submission to the House of Representatives Industry, Science and Innovation Committee enquiry into long-term meteorological forecasting in Australia.

In my submission, I documented my finding that rainfall in Melbourne and the Murray Darling Basin is quite strongly influenced by the 18.6 year lunar node cycle. Discussions I have had with researchers since then indicate that this **not** a factor which has been or is being considered as a driver of rainfall cycles – despite my finding that this is a major driver and that it is predictable with a high degree of accuracy long into the future.

Since that submission, I have now quantified the impact of another major influence on rainfall in Melbourne and the Murray Darling Basin. This is the Indian Ocean dipole and this submission extends the previous document to include the results of this analysis. This is a factor which explains large annual variations in rainfall. It is only a partial explanation of the intensification of the drought since 2005 and so the search for another factor must continue.

The lunar node cycle forces decadal variations in rainfall while the Indian Ocean dipole influences annual rainfall variations. Understanding the combined effect of these two factors (and others) opens up the potential for both improved seasonal rainfall forecasting and longer-term rainfall forecasting.

This documented will be updated from time to time as my research progresses.

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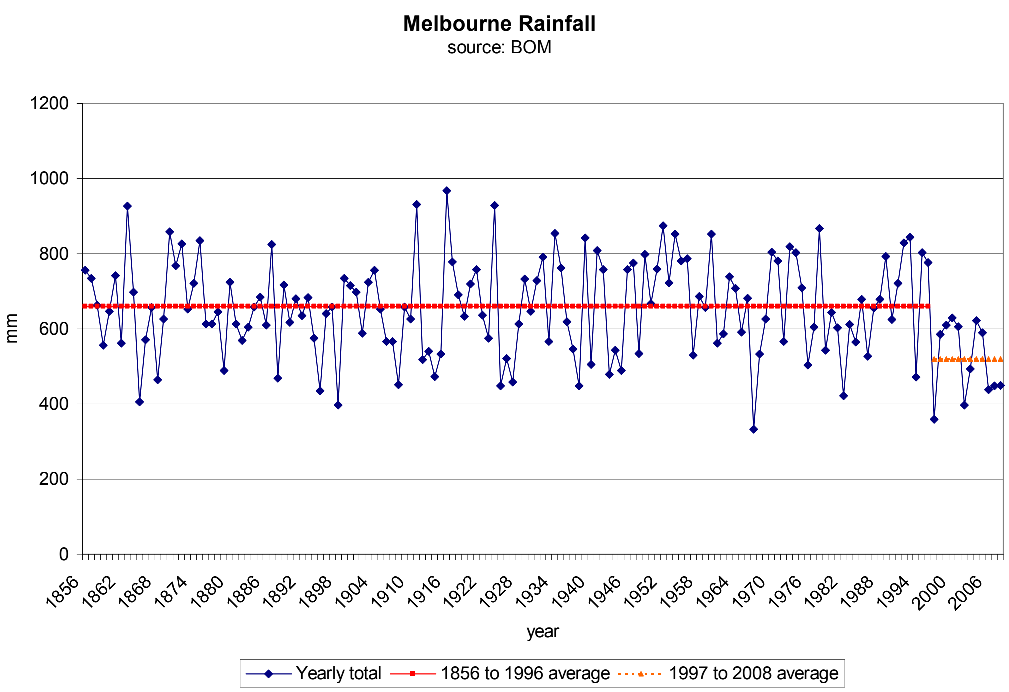
Overview of Melbourne's rainfall data

By the end of 2002, Melbourne had simultaneously endured both its driest six years on record and it's hottest. My 2003 analysis of this data can be read at www.foreseechange.com/melbourne.htm. Since then, the drought has intensified and temperatures have also risen.

Unfortunately, this prepared the bush land around Melbourne for the tragic fires of 7 February 2009. It has also caused losses to farmers in much of Victoria and led to urgent action to secure water supplies as Melbourne's dams reach record lows.

Melbourne's rainfall seems to have suffered an abrupt drop (of 21%) from 1997 and again (by 32%) from 2006 (Chart 1).

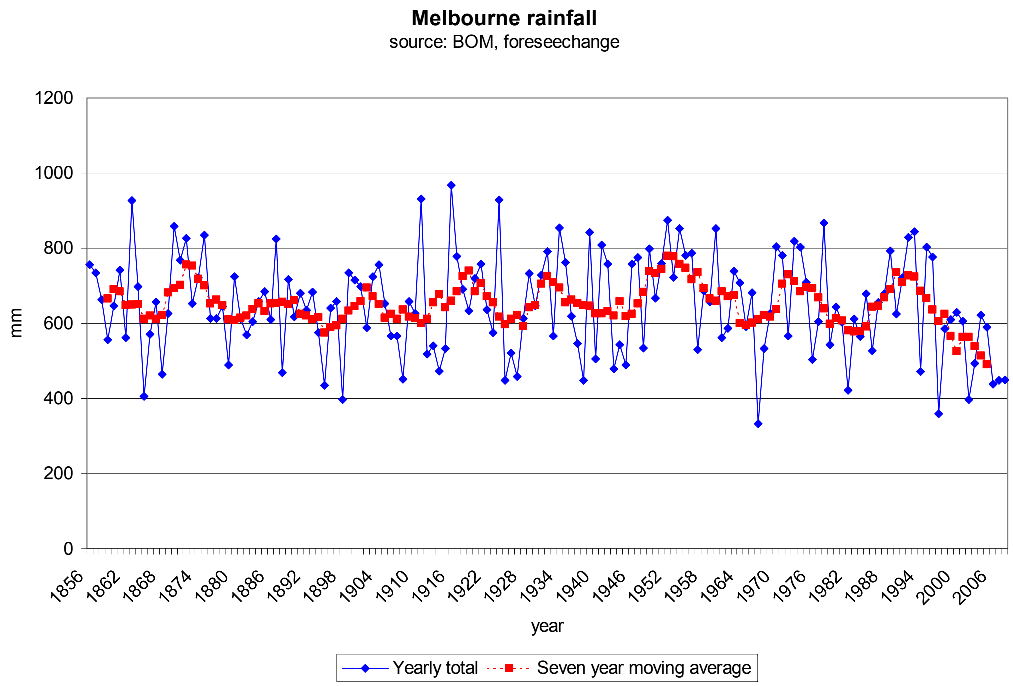
Chart 1



A cyclical pattern in Melbourne's rainfall

There is a cycle in Melbourne's rainfall. This is apparent by looking at moving average data as illustrated in Chart 2.

Chart 2



The period of the cycle appears to be about 19 years. The amplitude varies and there are individual years which vary substantially from the cycle. Also, there are a small number of periods of three or four years which are not synchronized with the cycle. However, it may be possible to explain, and in some cases predict, some of these variations.

Statistical analysis confirms that there is a significant cycle of about 18 years. These technical details (autocorrelation and spectrum analysis) have been omitted in the interests of brevity.

But what causes the cycle?

The lunar nodal cycle

The Sun's declination changes from +23.5° to -23.5° between the solstices due to the Earth's rotational axis being tilted at about 23.5° from the axis of orbital motion around the sun. The Moon also changes in declination by the same average amount over a period of four weeks, the period of the Moon's orbit around the Earth. But unlike the Sun, the maximum and minimum declination of the moon varies because the Moon's orbit around the Earth is inclined at 5° to the plane of the Earth's orbit around the Sun. The orientation of the 5° inclination relative to the tilt of the earth's axis rotates around the earth , due to the influence of the sun's gravity, over a period of 18.6 years. Thus, the maximum declination of the moon varies between 18.5° and 28.5° over an 18.6 year cycle.

The two points at which the Moon's path crosses the ecliptic are known as the nodes. These nodes slowly move around the ecliptic, taking 18.6 years to complete one cycle.

At a minor standstill, which last occurred in 1997, the declination of the moon varies from -18.5° to +18.5° over its month. At a major standstill, which last occurred in 2006, the declination of the Moon varies from -28.5° to +28.5° over its month.

This means that the Moon swings both further south and further north of the equator at a major standstill and its swings are closer to the equator at a minor standstill.

These variations are easily observed and have been known about since ancient times. The correlation of the lunar node cycle, and other lunisolar cycles, with variations in the weather has been suggested many times (see, for example, Charles D. Keeling and Timothy P. Whorf in "The 1,800-year oceanic tidal cycle: A possible cause of rapid climate change", Proceedings of the National Academy of Science USA, March 21 2000).

The lunar node cycle means that the Moon, which on average, swings as far south as the tropic of Capricorn (just south of Exmouth on the Western Australian coast) has periods when it doesn't reach Port Hedland and others when it is overhead as far south as Geraldton. During the nine years before a major standstill, it is presumably dragging warm water further south and during the nine years before a minor standstill, it would be pulling cool water further north.

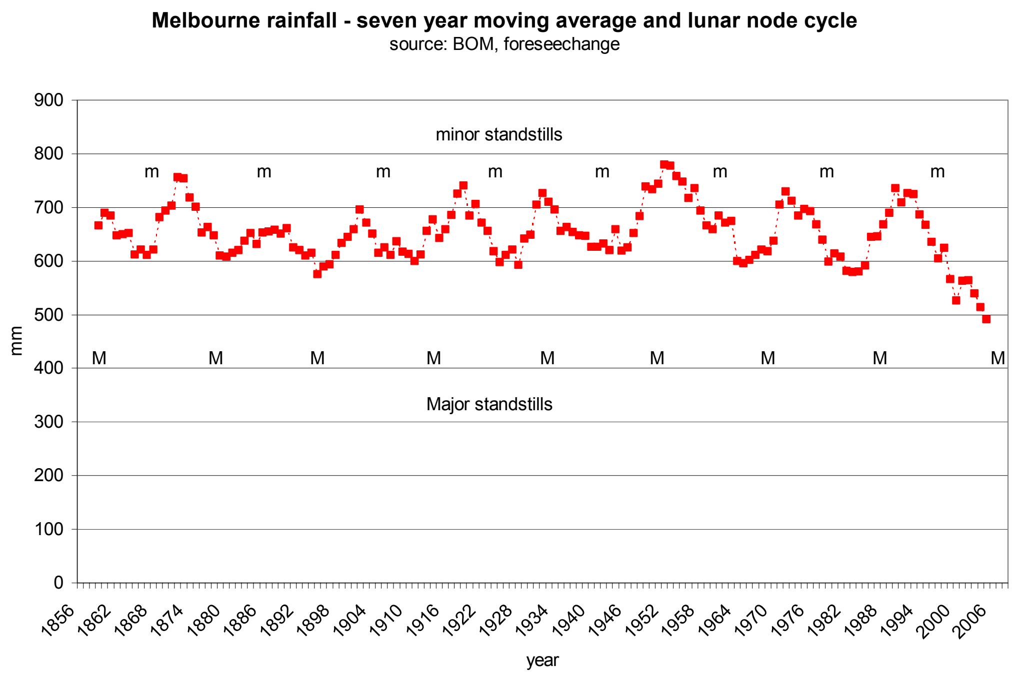
This, or some other mechanism such as variations in vertical mixing of water of different temperatures, could impact on the temperature and moisture of the air over the coast of Western Australia, thus affecting rainfall in Melbourne and elsewhere in the continent.

The Leeuwin current is considered to be a likely link between the lunar node cycle and Melbourne rainfall, and also between the Indian Ocean Dipole and Melbourne rainfall.

So is the 18.6 year lunar node cycle synchronized with the observed cycle in Melbourne's rainfall?

Chart 3 shows the moving average rainfall line against the major (M) and minor (m) standstills.

Chart 3

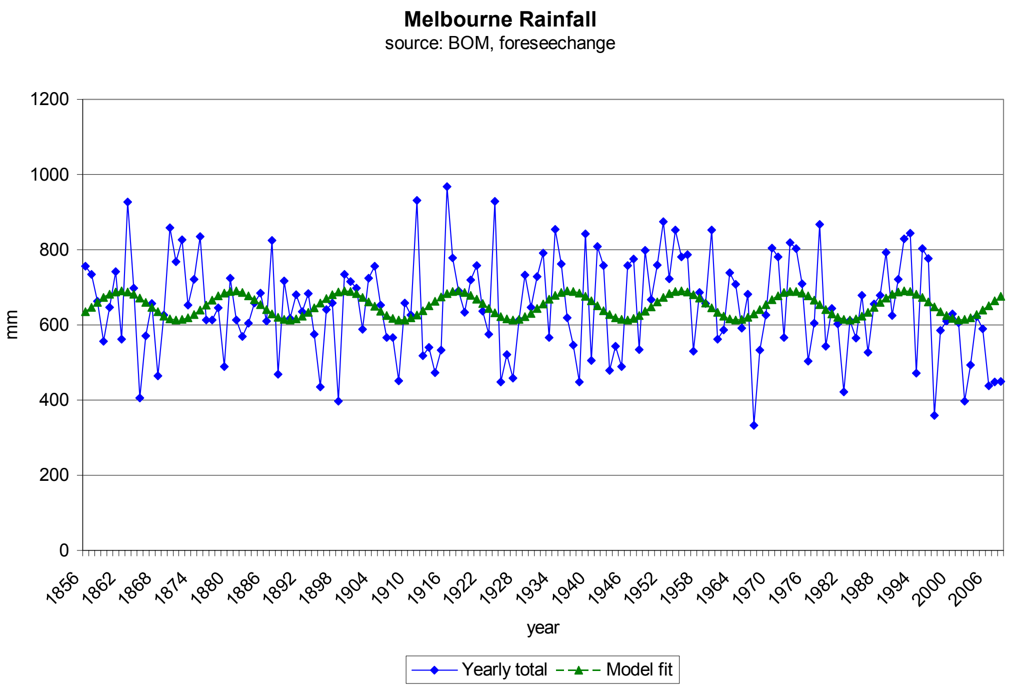


Wet periods, relative to the average, occur between the Major and minor standstills while dry periods occur between the minor and Major standstills. In other words, a switch towards dryer periods occurs after a minor standstill and a switch towards wetter periods occurs after a Major standstill (which is after the Moon is swinging most widely around the equator).

Lunar node cycle model of Melbourne Rainfall

Regression analysis shows that there is a statistically significant relationship between actual rainfall and a model constructed from the lunar node cycle, as illustrated in Chart 4.

Chart 4



The model indicates that rainfall varies by an average of 78mm from the peak to the trough of the cycle. There are large deviations from the model and these are of two types.

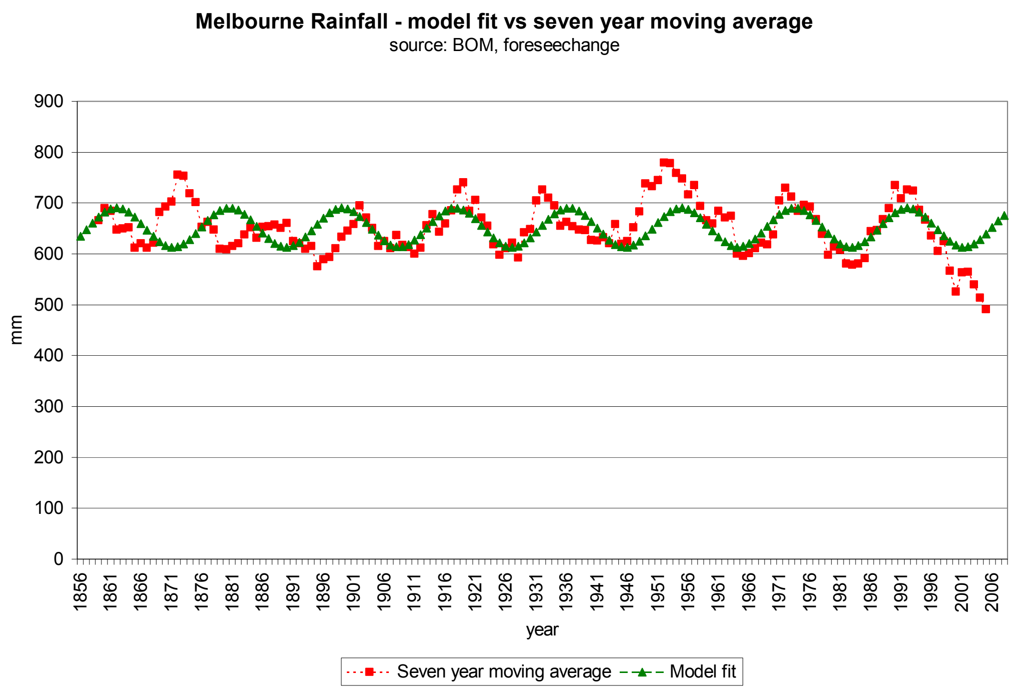
First, there are large variations in individual years. For example, the driest year on record is 1967 and the second-driest is 1997. As we show below, many of these short-term variations are associated with the Indian Ocean Dipole.

Second, there are a few periods of several consecutive years where the model fits the data poorly. These include the dry period 2006 to 2008 and also 1912 to 1915 which was also much drier than expected although 1911 and 1916 were very wet. The period 1870 to 1875 had six wet years which would have been expected to be drier than average.

The second type of deviation seems unlikely to be driven primarily by the Indian Ocean Dipole and so the search for another driver must continue.

The model fit is shown against the seven year moving average in Chart 5. The fit is quite good throughout the 20th century. The period from 1949 to 1963 was consistent with the cycle in terms of timing but was much wetter than other wet phases. The last 30 years of the 19th century was inconsistent with the cycle, especially the period from 1870 to 1883.

Chart 5



The Indian Ocean Dipole has been found to explain much of the annual variation from the lunar node cycle model, at least since 1958.

The Indian Ocean Dipole

A recent Australian paper by Ummenhofer et al. ("What causes southeast Australia's worst droughts?" Geophysical Research Letters, Vol 36, 2009) claims that the Indian Ocean Dipole (IOD) is a major driver of rainfall over southeast Australia. On its own, this factor does not appear to adequately explain all droughts but my analysis shows that, in conjunction with the lunar node cycle, much of the annual variation in Melbourne's rainfall can be explained.

The Indian Ocean Dipole is a pattern of sea surface temperature variability occurring over the Indian Ocean, which has been linked to rainfall variability in Australia and elsewhere.

In a positive phase, water near Indonesia is cooler than average and water near India is warmer. This is the phase associated with drought in Melbourne. In a negative phase, water near Indonesia is warmer than average and water near India is cooler. The negative phase is associated with wet periods in Melbourne.

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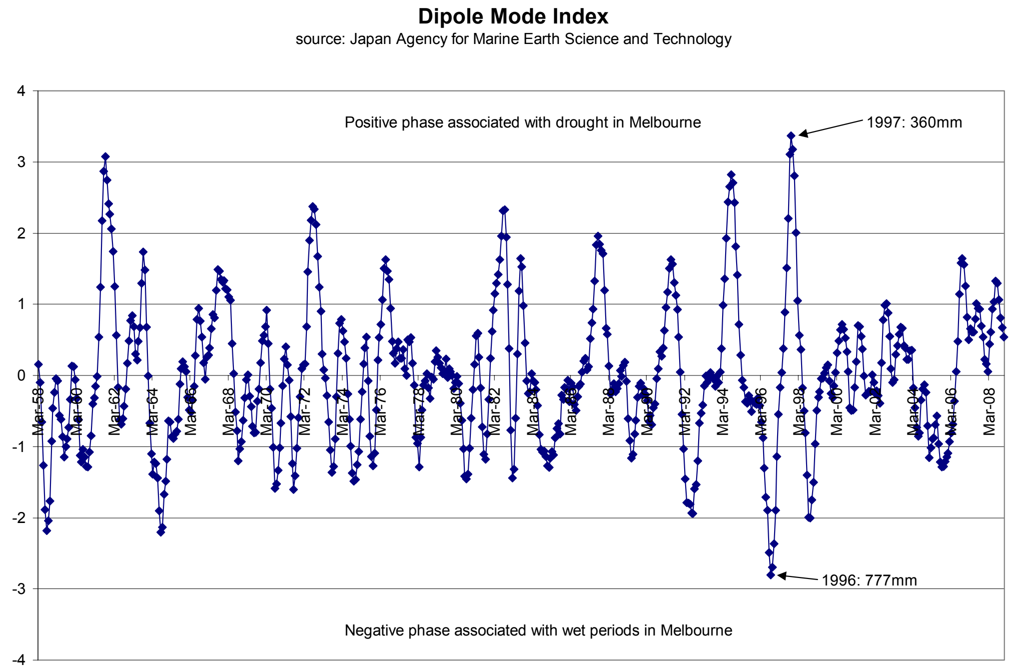
Monthly variations of the Indian Ocean Dipole, as represented by the Dipole Mode Index, since 1958 are shown in Chart 6.

Chart 6



It is important to note the change in the Indian Ocean Dipole between 1996 and 1997. At a time when the lunar node cycle was leading to falling average rainfall in Melbourne (refer to Chart 4) the Indian Ocean Dipole switched from a wet phase to a dry phase. These two factors combining is why Melbourne suddenly switched into drought (refer to Chart 1).

The Indian Ocean Dipole is at present not predictable, unlike the lunar node cycle, so this is an important direction for future research. However, it does display an approximately five year pseudo cycle, which may be a guide to improving predictability.

I have included the annual average Dipole Mode Index and the lunar node cycle in a model of Melbourne rainfall. The model fit over the period 1959 to 2008 is shown in Chart 7. The period 1959 to 2005 was used to calibrate the model and the years 2006 to 2008 are out of sample predictions given the Dipole Mode Index is known for these years.

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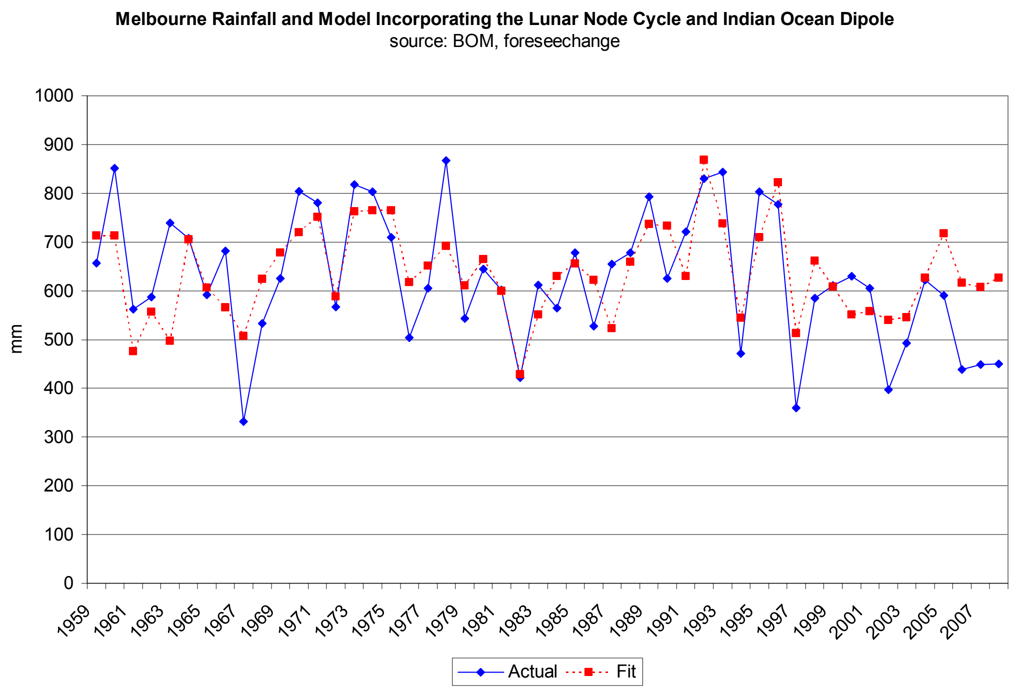
Chart 7



The model explains over 50% of the variation in rainfall. The lack of fit since 2005 indicates the existence of another factor which must be identified.

The fact that both the lunar node cycle and the Indian Ocean Dipole are significant factors suggests the importance of the Indian Ocean as a major connection to Melbourne's rainfall.

Connecting the driving forces to rainfall

Our hypothesis is that the Leeuwin current is the connection in the chain between both the lunar node cycle and the Indian Ocean Dipole as drivers and the rainfall in Melbourne as the effect.

The Leeuwin current is a band of warm, lower salinity water of tropical origin, which flows south from Exmouth to Cape Leeuwin and on to the Great Australian Bight. It is caused by warmer, low salinity water flowing through the Indonesian archipelago from the Pacific to the Indian Ocean being captured by the effect of the earth's rotation. Variations in the temperature, salinity, volume, and flow rate of this current are likely to impact on the moisture of the atmosphere flowing on to south-east Australia.

The varying angular velocity of the moon caused by the lunar node cycle is considered likely to influence the volume and flow rate of the Leeuwin current and, in turn, the rainfall over south-east Australia.

The Indian Ocean Dipole is likely to be correlated with the temperature of this current and hence the moisture content of the air which flows over it.

There are, of course, several other patterns, such as the southern annular mode, which may be an intermediary and the relationships between such patterns and the drivers identified above should be part of any future research program. However, the priority should be other factors which may influence the Leeuwin current.

Such factors could include other cycles of the moon, such as the lunar apse cycle of 8.8 years, and discrete events, such as the boxing day 2004 tsunami off the west coast of Sumatra, Indonesia.

The orbit of the moon around the earth is elliptical and the orientation of the closest and furthest distance between the earth and the moon varies over a cycle of 8.8 years (lunar apse cycle). When the moon is closest to the earth at the time of the major standstill of the lunar node cycle, its influence would be greater than at the time when the moon is further away from the earth at the major standstill.

The boxing day 2004 tsunami is synchronistic in that Melbourne entered a very dry phase in 2005 (absenting the wettest day on record in February 2005) and that it occurred in what seems to be the very important part of the Indian Ocean which influences rainfall over Melbourne and the Murray Darling Basin. The tsunami would have significantly impacted the temperature and salinity of water which feeds the Leeuwin Current. This impact may last for up to five years given the pseudo cycle of an average of five years in the Indian Ocean Dipole (refer to Chart 6). It is likely that the impact has been one which is not captured in measurements of the Indian Ocean Dipole.

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Applicability to the Murray Darling Basin

Rainfall in the Murray Darling basin is also correlated with the lunar node cycle (Chart 8) and in this case the swing around the mean averages 33mm above and below. As with Melbourne, there are periods of poor fit. The Impact of the Indian Ocean Dipole is a significant influence on annual rainfall variation as shown in the combined model in Chart 9.

Chart 8

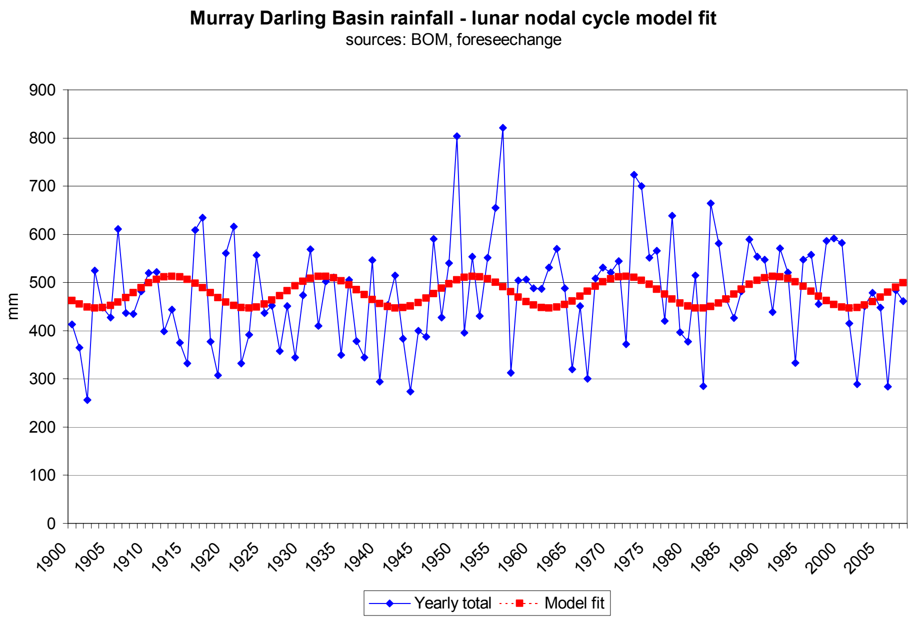
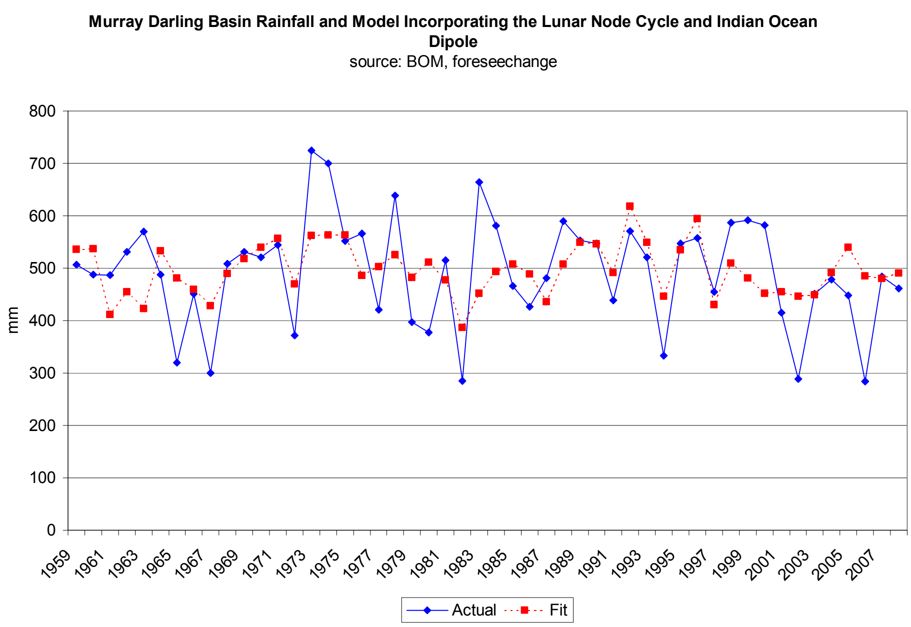


Chart 9



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The Murray Darling Basin, being such a large area, is fed by more weather patterns than is Melbourne. Thus, the explanatory power of the model incorporating the two drivers is lower and as-yet unidentified factors are even more important.

Directions for further research

There are three streams of research needed in order to improve the reliability of rainfall forecasts based on my models.

One, it is necessary to establish the physical mechanism connecting the lunar nodal cycle, the Indian Ocean Dipole, and rainfall over Melbourne, central Victoria, much of the Murray Darling Basin, and other areas. This will be via analysis of ocean water temperatures, salinity, and perhaps other data. This would validate the correlations observed.

Two, a better understanding of the drivers of the Indian Ocean Dipole is needed in order to improve its predictability.

Three, reasons for variations from the model must be identified. These could include:

- The lunar apse cycle of 8.8 years which is associated with the elliptical orbit of the moon and the associated large variation in gravitational force. This is likely to alternately amplify and attenuate the impact of the lunar node cycle.
- The impact on the Indian Ocean of the 2004 boxing day tsunami off Sumatra.
- The influence of the Asian brown haze, which has been intensified recently by forest fires in Borneo. 1997, 2002, and 2006 were bad years for fires and were dry years in Melbourne. The Asian brown haze reportedly reduces solar energy reaching the Earth's surface by up to 15%, altering the Asian monsoon (New Scientist, August 12, 2002). If this proves to be an important factor, it would make sense for the Australian and Victorian governments to invest in preventing forest fires in Indonesia and extinguishing them if they start.
- Other weather patterns such as the southern annular mode.

Conclusions

I have demonstrated that there are long periods, in particular throughout the 1900's, where the lunar node cycle is a very good long-term predictor of rainfall in Melbourne and wide areas of Australia.

My analysis is important for long-term forecasting of rainfall, especially for several years and decades ahead. These are the horizons which are important for infrastructure decisions. A decision to build a new dam, or a desalination plant, or a pipeline has to be economically sound over a period of decades. Also, any decision to massively shift farming activity from one region to another must be made on the basis of an outlook for many years into the future.

I have also shown that the Indian Ocean Dipole is an important driver of annual variations from the longer-term cycle. The predictability of this factor is lower than for the lunar node cycle but may be amenable to improvement.

Beyond these two factors, there is at least one other important driver and this may well be associated with cataclysmic events such as the boxing day 2004 tsunami. This missing factor must be identified as soon as possible.

It is stating the obvious that there is an urgent need to adopt my models and further improve them. In doing so, I make two recommendations:

1. That investment into the analysis of historical data be at least maintained. I believe that I have demonstrated that there is much yet to be learned from such analysis.
2. That meteorological forecasting is too important to be left to the experts. We must encourage a much broader range of skills to be applied to this vitally important issue.