On the influence of ENSO indicators on autumn rainfall in Sydney and the Central Tablelands

Introduction

The phenomenon of El Nino has been extensively researched by climatologists and numerous studies exist of its influence on rainfalls in various parts of the world. This study seeks to explore whether or not there are any apparent relationships between El Nino and station rainfalls in the greater Sydney area and the elevated escarpments to its immediate west.

Rainfall in this part of NSW is quite variable. The wettest parts are in the coastal areas, particularly the elevated locations north of Sydney Harbour and the Blue Mountains. It tapers off to the west and southwest. In autumn the climate is often dominated by maritime air masses from the neighbouring Tasman Sea, especially in March. There is a tendency for major rain events to occur in certain years, due to various combinations of east coast lows, troughs in the easterlies, 'northwest cloud bands' and upper cold pools. However, tropical influences are usually starting to decline.

El Nino often 'resets' in autumn, usually from a negative to a neutral phase and, less frequently, from neutral to positive. Reversals from a neutral stage to a negative stage are also not uncommon. The reliability of forecasts of El Nino in autumn for this region is also relatively good.

Data and methodology

A 'bird's eye' view of sea surface temperatures and rainfall may not necessarily disclose any more than a vague relationship. So it is desirable to separate the meaningful data from 'noise' and other things that might distort the true picture. There might also be autocorrelation in the data when ideally the observations should be independent of one another thus ensuring true randomness. Most stations in the Bureau of Meteorology's rainfall observing network have missing data, due to temporary closures, the observer sick or on holidays, plain carelessness on the part of observers, or their deaths. Stations also change localities from time to time.

For this study, the average autumn rainfalls for 1940 to 2009 were examined for 42 stations in Sydney and the central tablelands to its west. Stations with more than 10% of data missing were removed. Further refinement was then made by removing a few stations that were geographically very close to one another. These adjustments reduced the final number of stations to 27.

Principal components analysis (PCA) was then used to categorise the stations into groups. This has the effect of reducing the size of the dataset to a smaller number that nevertheless would account for much of the features of all the station rainfalls. This was also done with the ENSO indicator data, which were for the same period as the rainfalls. It also takes care of dependent data through rotation of the variances of the components and allows for the effect of missing data. This means that the components extracted are totally and completely independent of each other, and so therefore, the individual observations contained in them.

There are a number of theories that discuss the best 'cutoff point' beyond which the data contain random 'noise'. I chose a minimum eigenvalue of 0.7 for the rainfall and 0.5 for ENSO, so as to 'trap' a reasonably comprehensive extraction. The data were standardised before the analysis by subtracting their means and dividing by their standard deviations. This stabilises the data somewhat.

Initially, the following ENSO indicators were tested:

1. The Southern Oscillation Index
2. The Pacific Decadal Oscillation Index
3. The Nino 12, Nino3, Nino3.4 and Nino3.4 indices
4. The Indian Ocean Dipole
5. The Southern Annular Mode
6. The Atlantic Multidecadal Oscillation Index

The last three were found to have no significant correlation on the rainfall data selected. However results for the IOD have been shown below for comparison.

The next step was to correlate the factor scores of the rainfalls and ENSO data. These scores are a measure of the components that explain most of the data's variance. While it is clear that correlation does not imply causation, the fact that many rainfall data are indeed correlated with ENSO parameters suggests that there are links there, even though further research into their cause is still needed. Finally, the rainfall data themselves are correlated with the ENSO scores that had significant correlations with the rainfall scores (at the 95% level of significance), and moving averages of the correlations over 25-year periods were taken in order to show the degree to which the apparent relationships varied, removing those rainfalls for stations in which no significant correlations were detected.

Results

The following shows the grouping of the station rainfall components:

GROUP 1

LITTLE HARTLEY
BATHURST AGRICULTURAL STATION
BIGGA (BIRRELLAN
COWRA AG RESEARCH STATION
HILL END POST OFFICE
ORANGE POST OFFICE
SOFALA OLD POST OFFICE
SUNNY CORNER
TRUNKEY CREEK
MERRIWA
MUDGEE
RYLSTONE

GROUP 2

KATOOMBA
PROSPECT
RICHMOND
BEXLEY BOWLING CLUB
MIRANDA
NEWPORT
POTTS HILL
SANS SOUCI
SYDNEY (BOM)
TURRAMURRA

GROUP 3

BILPIN
BLACKHEATH
KURRAJONG
LAWSON
SPRINGWOOD

The table below shows the percentage estimates of the proportion of the variability in each variable attributable to the extracted factors (applied before removal of insignificantly correlated data):

Variable	Estimated communality
PROSPECT RESERVOIR 67019	0.905
RICHMOND - UWS HAWKESBURY 67021	0.902
BEXLEY BOWLING CLUB 66004	0.94
MIRANDA (BLACKWOOD ST) 66040	0.915
NEWPORT BOWLING CLUB 66045	0.828
POTTS HILL RESERVOIR 66050	0.925
SANS SOUCI (PUBLIC SCHOOL) 66058	0.941
SYDNEY (OBSERVATORY HILL) 66062	0.9
TURRAMURRA (KISSING POINT ROAD)	0.9
BILPIN (FERN GROVE) 63118	0.949
LITTLE HARTLEY (ROSCOMMON) 63267	0.828
BATHURST AGRICULTURAL STATION 63	0.911
BIGGA (BIRRELLAN) 63094	0.849
BLACKHEATH (LAWRENCE ST) 63009	0.934
COWRA AG RESEARCH STATION 63022	0.865
HILL END POST OFFICE 63035	0.853
KATOOMBA (MURRI ST) 63039	0.918
KURRAJONG HEIGHTS (BELLS LINE OF	0.864
LAWSON (WILSON STREET) 63044	0.912
ORANGE POST OFFICE 63064	0.908
SOFALA OLD POST OFFICE 63076	0.909
SPRINGWOOD BOWLING CLUB 63077	0.949
SUNNY CORNER (SNOW LINE) 63079	0.907
TRUNKEY CREEK (TRUNKEY (BLACK ST	0.877
MERRIWA (MERRY VALE) 62015	0.713
MUDGEE (GEORGE STREET) 62021	0.762
RYLSTONE (ILFORD RD) 62026	0.808

For example, in the case of Prospect Dam, 90.5% of the variance in its rainfall is accounted for by the combined factors extracted.

The following table shows how the ENSO indicators were grouped:

GROUP 1	GROUP 2
SOI	IOD
PDO	
NINO12	
NINO3	
NINO34	
NINO4	

The next table shows the correlations of the rainfall with the two principal components of the ENSO data shown above:

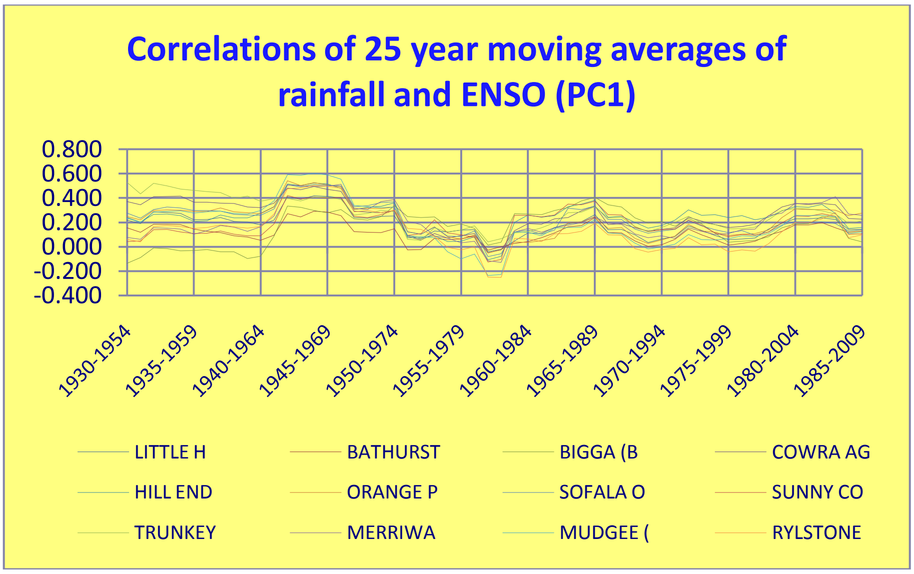
ENSO Group 1	Rainfall Group 1	Rainfall Group 2	Rainfall Group 3
Pearson correlation	31.44%	27.94%	30.59%
Probability correlation is not random	1.53%	3.21%	1.84%
ENSO Group 2			
Pearson correlation	9.35%	0.84%	2.54%
Probability correlation is not random	48.12%	94.97%	84.86%

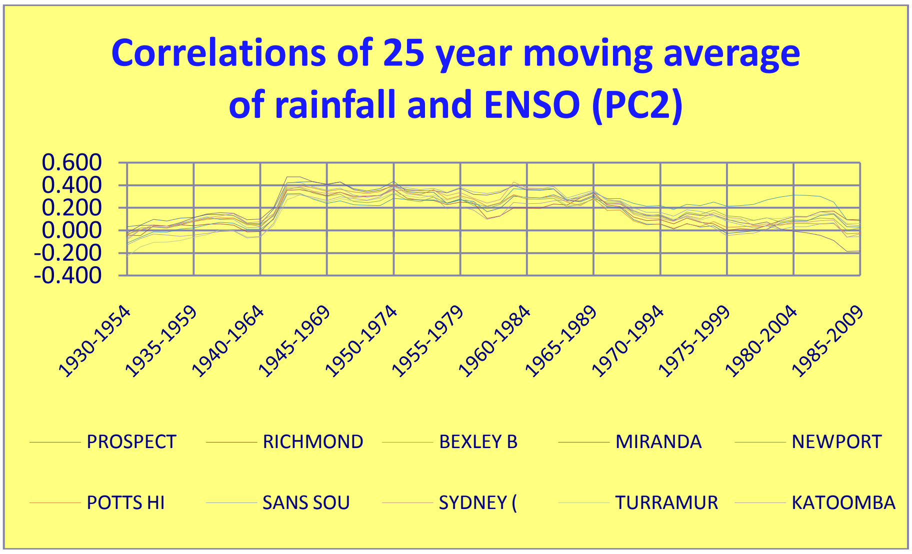
From the above we see that:

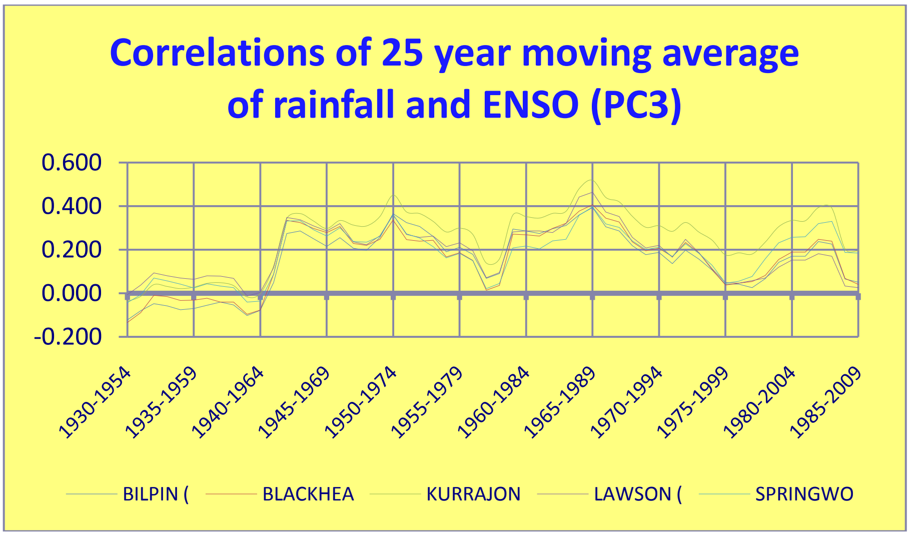
1. Stations in the north and west of the Central Tablelands form a single group, which has the highest correlation with the ENSO indicators listed in Group 1
2. Stations in Sydney's eastern and northern suburbs, which form the second group, have a similar but slightly lower correlation. The rainfall is similar to Katoomba (Blue Mountains)
3. Stations in other parts of the eastern (higher elevated) tablelands form the third group, again with a similar correlation.

None of the stations examined had any significant correlation with the Indian Ocean Dipole. Stations that come closest to this are those in the northern and western parts of the central tablelands.

The apparent relationship between the rainfall and ENSO is by no means constant. In fact, it appears to follow distinct cycles over time. The following graph plots demonstrate this:





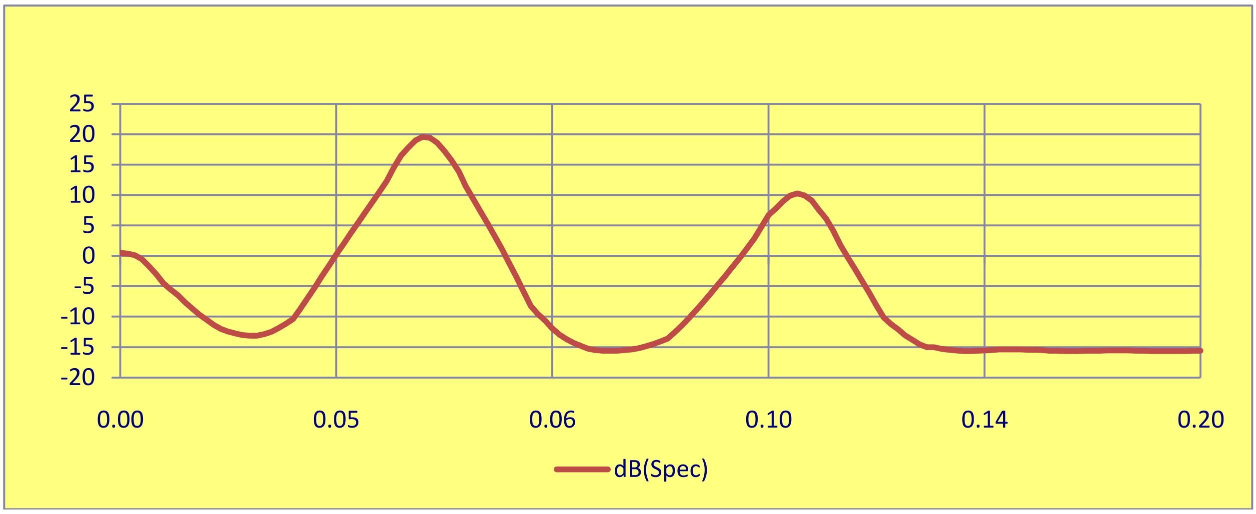


Correlations of the first principal component of ENSO parameters with autumn rainfalls, based on 25 year moving averages of the data. Each chart in succession relates respectively to the 1st,2nd and 3rd rainfall groups (see above).

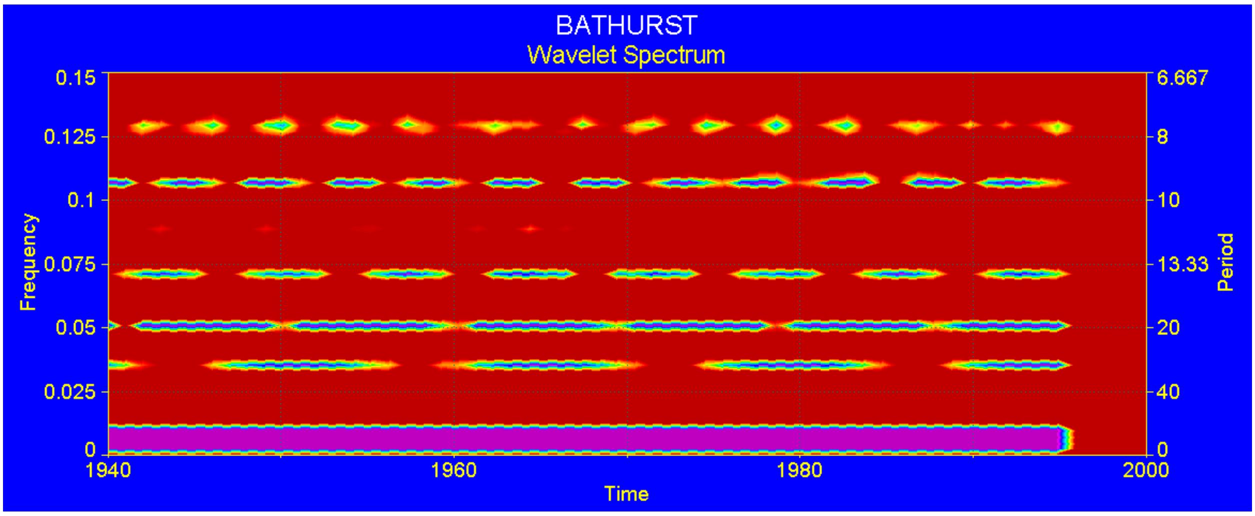
We also see two other features:

1. A sharp jump in the moving average from around 1940;
2. A narrowing of differences in correlations between some stations in wetter years, especially in Chart 1 from 1940 to 1964.

All three charts show similarities in the fluctuations of the correlations over time however it is clear that this is somewhat less pronounced in the case of stations west and north of the Blue Mountains (chart 1) and in Sydney (chart 2). Cycles are evident in all rainfall groups especially in the case of the 5 remaining stations in or near the Blue Mountains. The following chart shows the frequency spectrum of the correlations of the rainfall of Bathurst (Central Tablelands):

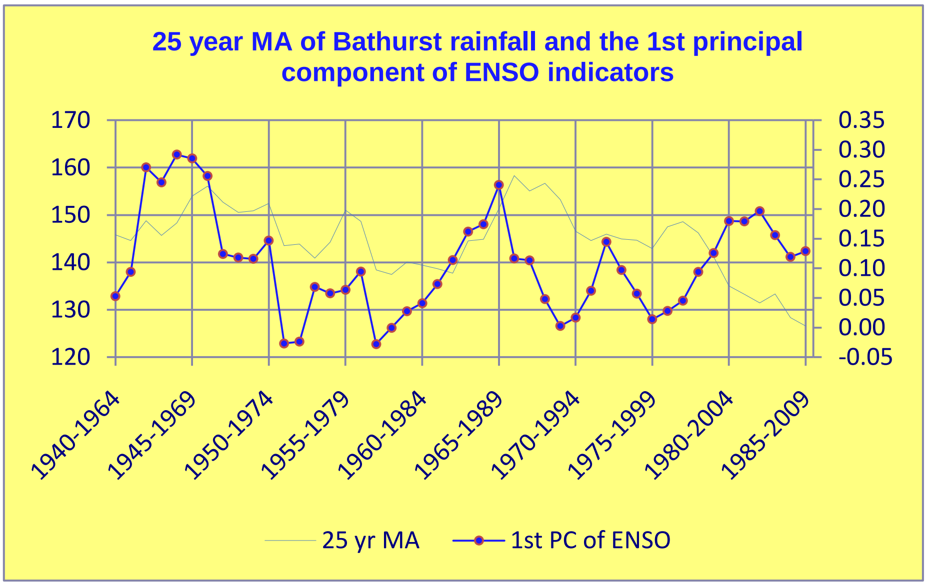


It shows peaks at cycles of approximately 20 and 10 years. One appears to be a harmonic of the other. There's even more:



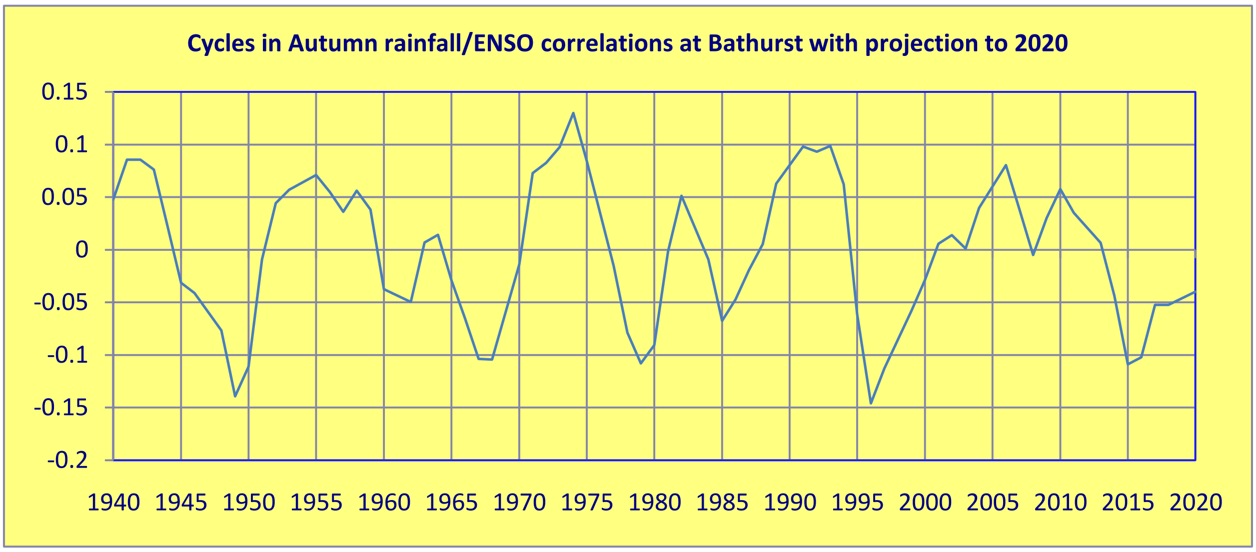
This is a wavelet analysis of the same data. There are 5 distinct wavelengths at just under 8 years but also more notably at 9-10 ,14, 19-20 and 33 years. The approximate 10-year and 19-year cycles are known to be respectively related to sunspot and solar tidal activity.

Taking data from Bathurst again and putting it into a wider context, we see how the correlated ENSO indicators compare with the 25 year moving average of the rainfall itself:



Even though there is only a 31% or so correlation, parallels exist with the rainfalls, although clearly the relationship almost disappears, gets out of step or even goes into reverse.

It is of course natural to wonder how the rainfalls will eventuate in future years. The following chart shows a sinewave reconstruction of the 1st principal component of the rainfall (again, taking Bathurst as the example):



Because the chart is based on 25 year averages it filters out smaller fluctuations and so should be taken only as a broad indication of future rainfalls. The years shown are the starting years of the 25 year average. So for example, looking at 1985 (1985-2009), we have reached a low point and we should therefore expect rainfall to be higher in coming years. However this is not to be taken as an attempt to make a detailed projection.

Conclusion

There is clear evidence that rainfall across Sydney and adjacent mountain areas is not only strongly correlated with the combined influence of various ENSO indicators, but that there are cycles in both the indicators and the rainfalls. These relationships are stronger in the case of some indicators than of others. The strength of relationships depicted by the first principal component of the ENSO indicators analysed, which all relate to measures of sea surface temperatures in the Pacific Ocean as well as the Southern Oscillation Index, is likely due to the displacement southward of the sub tropical high pressure belt, allowing warm moisture-laden air to penetrate deeply into the region.

It is worth mentioning in passing that the influence of the Indian Ocean Dipole, though very weak and insignificant, nevertheless was stronger by far in the westernmost parts of the region, away from the coast and higher escarpments. This is likely an indication that the influence of maritime airmasses from the east is starting to diminish, and other influences are beginning to override them. There is also strong evidence that solar activity has a direct influence on the strength of the ENSO signals that show up.

The enhanced clarity of rainfall cycles in the high parts of the Blue Mountains is almost certainly related to elevation above sea level.

The main purpose of this discussion has been to highlight the apparent, even if circumstantial, connection between rainfall and the complex phenomenon of El Nino/La Nina, and the identification and prediction of cycles in that connection. It is not meant to make a forecast of future rainfall events; that will require a separate analysis.

However the known effect of El Nino and its variation from season to season and place to place all over the world, hopefully makes analyses such as this a very useful exercise.