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Abstract

Beach change on Stanwell Park beach has been linked to sea-level fluctuations and annual rainfall such that a 1-cm rise in sea-level and a 100-mm increase in rainfall results respectively in 0.45m and 0.8m of beach retreat. Both variables are related to the Southern Oscillation, which has worldwide climatic teleconnections. Research in NSW and elsewhere indicates that the 11- and 22-year sunspot cycles and 18.6-year MN lunar cycle may affect some sea-level and rainfall records. None of these astronomical variables was found to relate to beach retreat at Stanwell Park more than any of the meteorological or oceanographic variables.

Keywords

beach change, New South Wales, Australia, sunspot, 18.6 year lunar tide

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Sunspot and M_N Tidal Effects on Stanwell Park, NSW, Beach Change, 1895-1980

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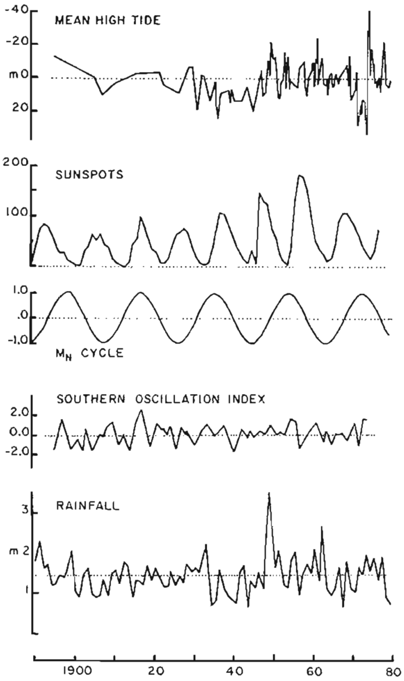
Beach change on Stanwell Park beach has been linked to sea-level fluctuations and annual rainfall such that a 1-cm rise in sea-level and a 100-mm increase in rainfall results respectively in 0.45m and 0.8m of beach retreat. Both variables are related to the Southern Oscillation, which has world-wide climatic teleconnections. Research in NSW and elsewhere indicates that the 11- and 22-year sunspot cycles and 18.6-year M_N lunar cycle may affect some sea-level and rainfall records. None of these astronomical variables was found to relate to beach retreat at Stanwell Park more than any of the meteorological or oceanographic variables.

In recent papers Bryant (1983b, 1984) found a significant correlation between beach change on Stanwell Park beach, NSW, and both sea-level and rainfall between 1895 and 1980. A 1-cm rise in sea-level accounted for a 0.45-m retreat in average high-tide position, while a 100-mm increase in yearly rainfall above 1670mm led to 0.8m of retreat. Currie (1976) detected in the Sydney sea-level record (30km north of the study area) an 11.8-year, 13-mm and a possible 21.1-year, 16-mm amplitude oscillation which he attributed to the 11- and 22-year sunspot cycles respectively. Compared to the long-term variations in sea-level of 10-12cm (Bryant, 1983b) these variations are small, but they would theoretically cause a horizontal change of 0.65-0.80m in average beach high-tide position at Stanwell Park. Regionally Stevenson (1980) drew a correlation between the 11-year sunspot cycle minima and coastal storm frequency in NSW. Currie (1981b, 1982) also found the 22-year sunspot cycle imprint as well as an 18.6-year M_N lunar cycle imprint in sea-level and rainfall records in the northern hemisphere. The 18.6-year M_N tide relates to the periodicity in the longitude of the ascending node of the moon. Even though this component is 3.6% as strong as the daily lunar component, its maximum effect occurs over several years and it can induce amplification of atmospheric planetary waves, especially in the northern hemisphere (Currie, 1981a; Pittock, 1983). This paper examines the statistical relationship of Stanwell Park beach change with the 11- and 22-year sunspot cycles and the 18.6-year M_N lunar tide, and demonstrates that it is much weaker than with meteorological and oceanographic variables.

The Stanwell Park data are based upon measurements of the high-tide position taken from 128 photographs, averaging one every four years between 1895-1920, one every two years between 1920-1933 and more than one per year thereafter. Photographs were accurately dated to the nearest season and year. High-tide was measured to within ±2.5m using a direct linear transformation of photo co-ordinates to a ground co-ordinate system (Bryant, 1983a). Deviations from the mean record for the whole beach are shown in Figure 1. Throughout the record storms have had a consistent magnitude and frequency, and have been superimposed on a period of accretion between 1929 and 1948 and of erosion since then. Also plotted is the Zurich sunspot number and the 18.6-year lunar cycle for the same period. The solar and lunar cycles were cross-correlated with high-tide position using Pearson product-moment correlation (Table 1) for

FIGURE 1

Changes at varying periods 1895-1980 in average high-tide position for Stanwell Park beach (values measure deviations from mean record), Zurich annual mean sunspot number, M_N lunar cycle, Southern Oscillation index (values measure pressure difference between Tahiti and Darwin standardised to a value of 1), and mean annual rainfall at Helensburgh, 4km from Stanwell Park.



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Lag in years	a	b	c	d	e
11	−0.091	0.056	−0.032	---	---
10	−0.099	0.029	−0.073	−0.163***	0.064
9	−0.090	0.050	−0.103	−0.156***	−0.131
8	−0.095	0.076	−0.117	−0.158***	−0.182
7	−0.076	0.062	−0.118	−0.136**	0.194*
6	−0.100	0.068	−0.107	−0.091	−0.188*
5	−0.066	−0.002	−0.085	−0.064	−0.180
4	0.012	−0.082	−0.054	−0.018	−0.149
3	−0.008	−0.073	−0.017	0.020	−0.075
2	−0.054	−0.051	−0.023	0.046	−0.003
1	−0.081	−0.039	0.063	0.094	−0.069
0	−0.035	−0.046	0.095	0.121**	0.118
−1	−0.042	−0.026	0.116	0.121**	0.141
−2	−0.051	−0.097	0.125	0.117**	0.150
−3	−0.070	−0.074	0.065	0.131**	0.176
−4	−0.091	−0.071	−0.041	0.093	0.162

* .10 level of significance
** .05 level of significance
*** .01 level of significance

TABLE 1

Correlation coefficients between (a) beach change and Zurich sunspot number, 11-year cycle, (b) beach change and Zurich sunspot number, 22-year cycle, (c) beach change and 18.6-year M_N lunar tide cycle, (d) Southern Oscillation index and 18.6-year M_N cycle, and (e) rainfall at Stanwell Park and 18.6-year M_N lunar cycle.

lags up to 11 years. In order to perform correlations with the 22-year sunspot cycle, sunspot numbers for alternate minor cycles were converted to negative numbers.

Statistically the results are not highly significant. There is a tendency ($r=-0.100$, 0.26 level of significance) for erosion to peak 6 years, or half of the 11-year sunspot cycle, after sunspot maxima, and for accretion to peak 6 years after sunspot minima. The timing of erosion concurs with Stevenson's (1980) study in which he linked periods of enhanced anti-cyclonic blocking in the Tasman Sea at times of sunspot minima to increased storm activity and beach erosion. However the statistical relationship defined in our study is not between times of erosion and sunspot minima, but between times of erosion and sunspot maxima 6 years previously. Stevenson's (1980) study defines only the timing of erosional periods within the sunpot cycle; causal relationship lies with the previous sunspot maximum. While blocking patterns in the Tasman Sea may correlate with sunspot minima, there is as yet no explanation presented in the literature to account for this pattern. There is also a weak tendency ($r=-0.097$, 0.28 level of significance) for erosion to occur two years before double sunspot maxima. The relevance of this correlation must be discussed in relationship to the 18.6-year lunar cycle.

The comparison involving the 18.6-year lunar tide is also weakly significant ($r=0.125$, 0.16 level of significance) with erosion occurring 1-2 years before minimum phases. The result may be statistically fortuitous. Previously (Bryant, 1983b, 1984), Stanwell Park beach erosion was found to be related at the 0.05 level of significance to changes in rainfall ($r=0.35$), sea-level ($r=-0.192$) and to the Southern Oscillation index ($r=-0.192$). The latter measures the pressure difference in an atmospheric planetary wave between the equatorial east Pacific ocean and the Indo-Australian region. This wave oscillates in strength and phase every 2-3 years and has been linked to climatic phenomena worldwide (Angell, 1981; Horel and Wallace, 1981). Currie (1976) found no significant evidence of the M_N signal in Sydney sea-level records, so the M_N cycle does not affect Stanwell Park beach change through sea-level response. The 18.6-year lunar tide was cross-correlated with rainfall at Helensburgh, 4km from Stanwell Park, and with the Southern Oscillation index (Table 1). No significant relationship was found between the M_N tidal term and rainfall at the times of highest correlation between the tidal term and beach change; however, a significant positive correlation (0.05 level) exists between the SO index and the M_N lunar cycle. Positive SO indices, indicating stronger easterly air flow across the Pacific and increased rainfall in eastern Australia (Troup, 1965, Pittock, 1978), occur at times of M_N maxima. Such a result should be associated with beach erosion; however, our analysis indicates that accretion occurs at times of M_N maxima. Currie (1981a) and Pittock (1983) believed that in the northern hemisphere the 18.6-year lunar cycle was more important than the 22-year sunspot cycle; however, both cycles were associated with US droughts in the same manner – namely that drought periods occurred at times of lunar and double sunspot maxima. Such contemporaneous timing with beach change was not present at Stanwell Park. Both the 1936 and 1973 M_N maxima occurred at times of maximum accretion, and it is this association with only two lunar tide peaks which has produced the weak and spurious correlation.

TABLE 2

Stepwise multiple regression analysis between beach change and local rainfall, Sydney sea-level, Southern Oscillation index, 11- and 22-year sunspot cycles and 18.6-year M_N lunar cycle.

Variable	Multiple r	r^2	% change in r^2
rainfall	.352	.124	12.4
11-year sunspot	.383	.146	2.2
M_N cycle	.394	.155	0.9
22-year sunspot	.417	.174	1.8
Sea-level	.428	.184	1.0
SO index	.433	.187	0.4

The relative contribution of six variables – local rainfall, Sydney sea-level, the Southern Oscillation index, 11- and 22-year sunspot cycles and the 18.6-year lunar cycle – to beach change was evaluated using a stepwise multiple regression analysis (Table 2). Rainfall accounts for 12.4% of the data variance while all other variables account for less than 2.2% of the data variance. While the SO index and sea-level account for less variance than the astronomical terms, both are highly correlated with rainfall (Bryant, 1984). Compared to annual local rainfall, the 11- and 22-year solar sunspot cycles and 18.6-year $M_N$cycle account for minor percentages of Stanwell Park beach change. Relationships between these astronomical variables and beach change suffer from two additional faults. Firstly while the mechanism linking rainfall variation to beach change can be described (Bryant, 1984), the processes producing the astronomical associations are difficult to conceptualise. In the case of the 18.6-year M_N tide, correlation to beach change is dichotonous with that produced by meteorological variables. Secondly the lunar and sunspot cycles repeat too infrequently for random correlations to be eliminated. Our analysis was based on only eight single sunspot and four lunar cycles between 1895 and 1980. For that same period there have been 12 major and 10 minor Southern Oscillation cycles, and between 1930 and 1980 at least 17 erosional events evident in the Stanwell Park data, many of which can be associated with known storm or rainfall periods. At present the search for explanation of long-term beach change, at least for sections of the NSW coast, lies most fruitfully with research into meteorological and oceanographic variables rather than into sunspot or the M_N lunar cycles.

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