# Research Note

# Magnetic Daily Variations Compared Between the East and West Coasts of Australia

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*Summary*

A study of magnetic daily variations shows their vertical component to be enhanced at the west coast of Australia, just as previous work had showed it to be reduced at the east coast. The anomalous contributions appear most likely to be due to induction by the onshore horizontal component of the daily variation field. The Australian data may also indicate regional differences in the structure of the continent.

## 1. Introduction

The coast effect in geomagnetic fluctuations of periods about one hour has been recognized since the work of Parkinson (1959). The evident correlation of vertical fluctuations near coast lines with fluctuations in the onshore horizontal magnetic field component has led to interpretations that the latter induce the former, (Schmucker 1964; Hyndman & Cochrane 1971; Lilley & Bennett 1973).

At the longer periods of the daily variation the position has been less clear. Less data have been published than for fluctuations of period about 1 hr, and at any given station daily variations tend to be repetitive, so that the range of horizontal field changes upon which the determination of a Parkinson vector depends is not easily observed. Furthermore, at the longer periods of the daily variation a substantial regional (or ' normal ') contribution is present in the vertical component of magnetic field; this must be known and subtracted from fluctuations observed at a coastal station, before an estimate of the coast effect can be obtained.

There are then several possible contributions to the coast effect at daily variation periods. Two of these are (i) induction by the onshore horizontal component at the ocean-continent interface, as for the coast effect at periods of about 1 hr, and (ii) induction by the regional vertical component of fluctuations, especially in the oceans. This latter effect has been estimated by Bullard & Parker (1970) and Richards (1970). A third possibility is that of induction by oceanic tides moving in the Earth's steady magnetic field. Where such an effect has been detected, (Larsen 1968), it has been small; however it must be remembered as a possible mechanism.

Bennett & Lilley (1973) examined the coast effect for south-east Australia at long periods, and found the anomalous vertical fields to correlate more consistently with the onshore horizontal components than with Richards' anomalous field estimates, implying that induction by the onshore horizontal field at the ocean–continent

interface might be the dominant effect. They examined also the coast effect at long periods evident in Schmucker's (1970) data for the Californian coast, with a similar result.

It is of interest to augment Bennett and Lilley's East Australia–California comparison with data from either an east coast in the Northern Hemisphere, or a west coast in the Southern Hemisphere, as there is the possibility that the 'mirror-imaging' of the daily-variation source current systems between the two hemispheres (Matsushita 1967) still allows the anomalous vertical components of east Australia and California to correlate with the normal vertical fields of the Southern and Northern Hemispheres respectively. One such station, on a west coast in the Southern Hemisphere, is the Gnangara observatory near Perth, Australia, operated by the Bureau of Mineral Resources.

This note reports an analysis of a quiet day at Gnangara, and its comparison with the coast effects of east Australia and California.

## 2. The west Australian data

The position of the Gnangara observatory is shown in Fig. 1. To obtain data from an inland control station, a single quiet day has been chosen for analysis (1970 October 9, local time), when an array of variometers was operating across South
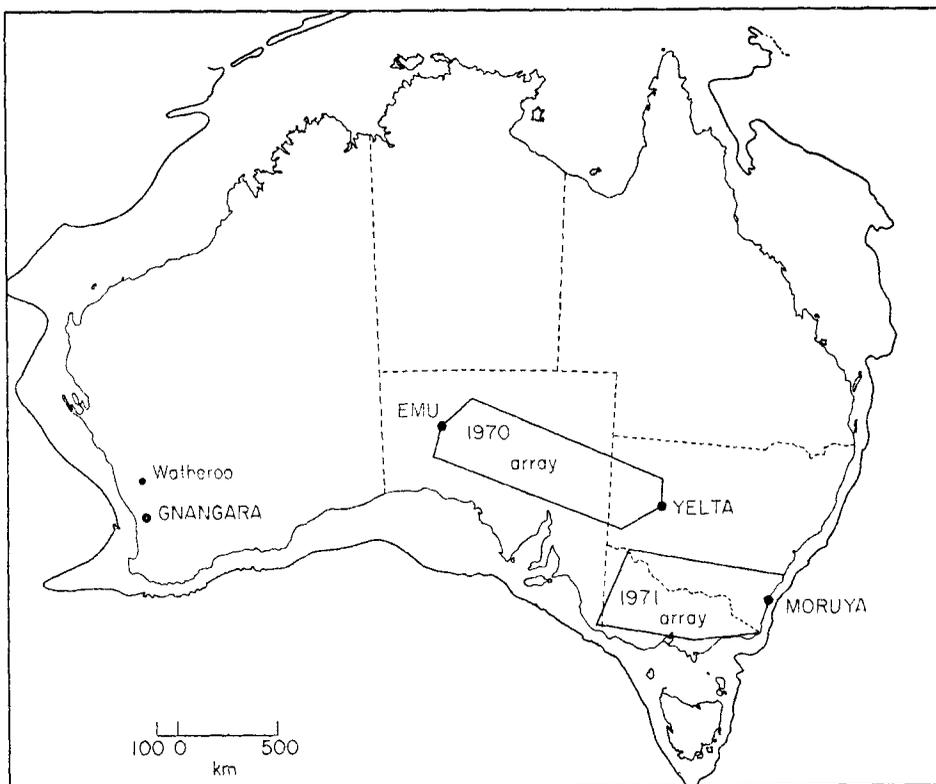


Fig. 1. Map of Australia showing positions of relevant observing sites. Geographic co-ordinates are: Gnangara, (31°47′ S, 115°57′ E); Emu, (28°39′ S, 132°04′ E); Yelta, (31°56′ S, 143°39′ E); Moruya, (35°54′ S, 150°08′ E).

Australia (Gough, McEllhinny & Lilley 1974). Of the 25 stations of the array, two in particular (Emu and Yelta, the western and eastern extremes also shown in Fig. 1), are used in this analysis. Emu is closer to Gnangara, but Yelta is more nearly on the same geomagnetic latitude. These stations are not as satisfactory a control as would be a full simultaneous coastal array, but they should be reasonable on a quiet day during which the ionospheric current systems change little as the Earth rotates beneath them, from Emu to Gnangara.

For the Gnangara data hourly means were supplied by the observatory, and these are plotted in Fig. 2. For Yelta and Emu the records digitized at half-hour intervals were taken, (Lilley 1975), and these are also plotted in Fig. 2. Simple 24 hr, 12 hr, 8 hr and 6 hr Fourier harmonic amplitudes and phases for these records were then computed. While the analysis of one day may not give a reasonable estimate of the average daily variation at a single station, it may nevertheless be used to compare the response at two different stations.

Data thus obtained for the various periods at the different stations are plotted in polar form in Fig. 3 (left-hand column). The phase convention used is that an increase in the lead of a signal corresponds to the signal occurring at an earlier time. The estimates of anomalous vertical field $(Z_A)$ at Gnangara have been obtained by subtracting from the observed vertical variation $(Z_O)$ the mean of the vertical variation observed at Yelta $(Z_Y)$ and Emu $(Z_E)$, taking local solar time at all stations.

The diagrams in Fig. 3 for west Australia also show estimates of anomalous vertical field for Gnangara made from Richards' maps (1970), $(Z_R)$, after the method of Bennett & Lilley (1973). The central and right-hand columns of Fig. 3 present the east Australia and California data of Bennett and Lilley, for the purposes of comparison of west Australia with these other two coasts.
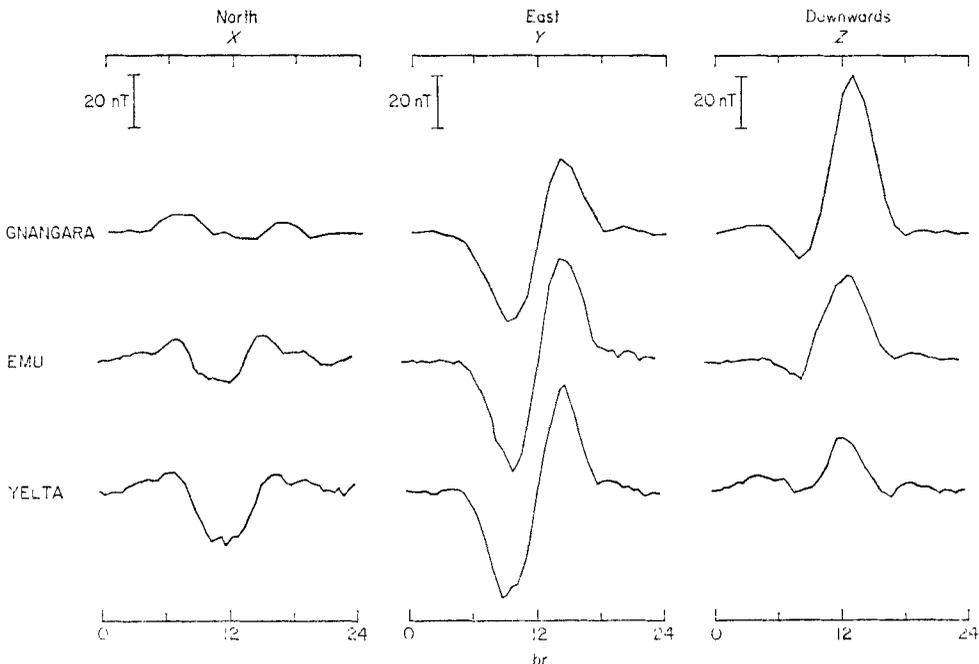


FIG. 2. Observations for the quiet day of 1970 October 9, taken from local solar midnight to midnight in each case.
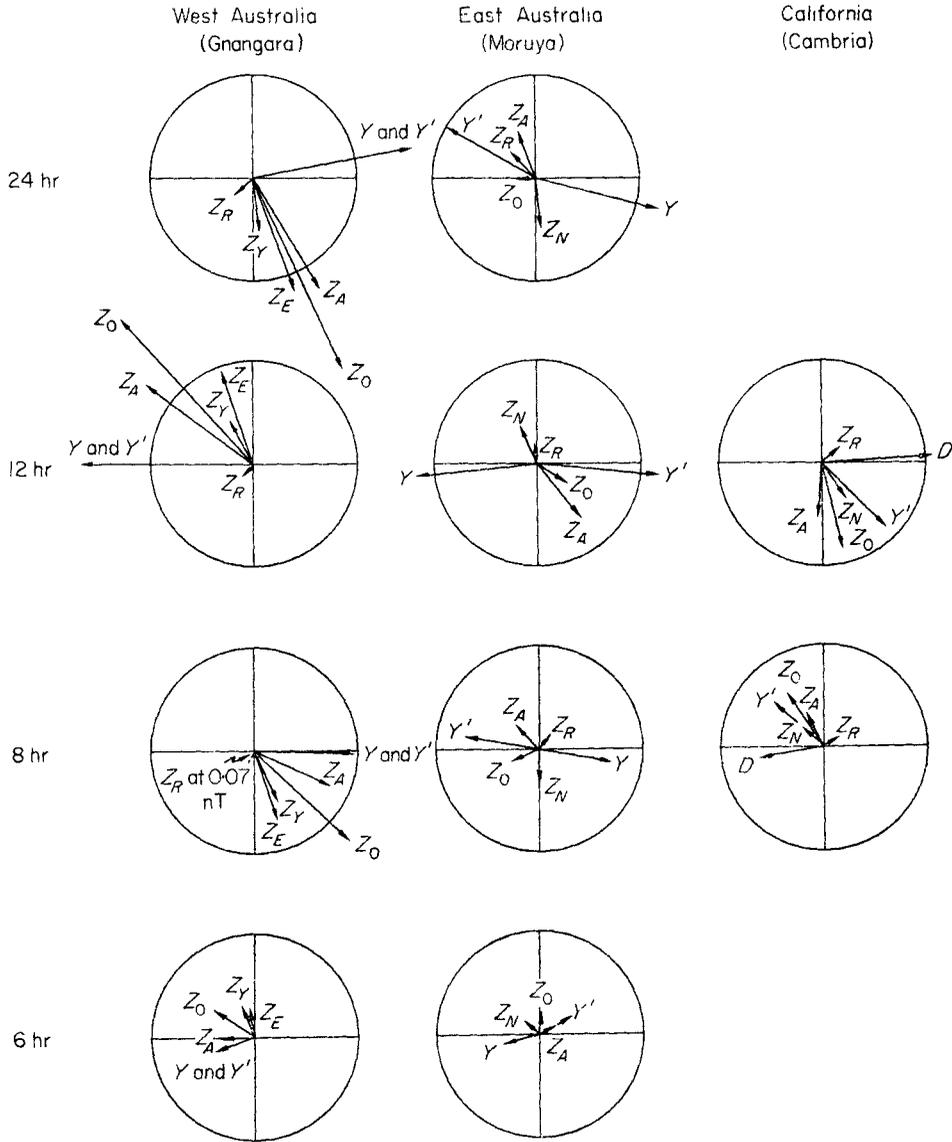
FIG. 3. Amplitude and phase polar diagrams for the various field components relevant to analysis of the coast effect. $Z_O$: observed vertical field; $Z_N$: regional vertical field; $Z_A$: anomalous vertical field; $Z_R$: vertical field estimate from Richards (1970); $Z_E$: vertical field at Emu; $Z_Y$: vertical field at Yelta; $D$: magnetic east horizontal field component; $Y$: geographic east horizontal field component; $Y'$: onshore horizontal field component. $Z_A$ can be seen to be the result of subtracting $Z_N$ from $Z_O$, (for Gnangara $Z_N$ is taken as the mean of $Z_E$ and $Z_Y$). Phase lead is zero at the top of each diagram, and increases clockwise. The radius of each circle represents an amplitude scale of 9 nT.
Note that in most cases the position taken by $Z_A$ is such that it leads $Y'$ in phase by about half a quadrant. Mean $|Z_A|/|Y'|$ ratios are 0·8 for Gnangara, 0·5 for Moruya, and 0·6 for Cambria.

## 3. Interpretation

(i) The basic result of the polar plots is that for Gnangara, as for the coasts of East Australia and California, $Z_A$ is evidently correlated with $Y'$, rather than with $Z_N$ or $Y$. This correlation carries the implication that of the mechanisms yet envisaged, $Z_A$ is most likely induced by the onshore horizontal field. Such knowledge is essential to the interpretation of coast effects in terms of electrical conductivity structure at ocean–continent boundaries.

It should be of interest to know whether the relationship holds also at other oceanic coasts, such as the Atlantic coast of North America, for which several results have been published at shorter periods, but none yet including daily variations.

(ii) The estimates of coastal anomalous vertical magnetic fields made from Richards' maps are crude, especially in amplitude. Even allowing for their approximate nature, however, they do not appear to account for a major part of the observations.

Induction in the oceans by the vertical component of the source field thus appears inadequate to account for the coast effect at Gnangara, as for East Australia and California. The possibility remains, however, that Richards' results would be different and might account more fully for the observations if a grossly different sub-oceanic conductivity structure were assumed.

(iii) The curious effects in the vertical component of the daily variation, especially its abnormal strength, noted for the west Australian observatory Watheroo (some 190 km north of Gnangara) by Malin & Winch (1968) and Green & Malin (1971), may well be accounted for as being a coast effect, like that here demonstrated for Gnangara.

(iv) Inspection of the Gnangara and Moruya data shows that the ratio $|Z_A|/|Y'|$ is consistently greater for the former than for the latter. Assuming the structures of the two offshore oceans to be similar, this contrast may reflect differences in the continental structure between west Australia, which is stable shield, and east Australia, which is younger and more tectonically active. Such an interpretation was also given by Everett & Hyndman (1967) when comparing shorter period magnetic fluctuation data between east and west Australia. The differences between east and west Australia may indeed be evident simply in the contrast between the vertical fields recorded at Yelta and Emu.

(v) Fig. 2 also shows differences in the amplitude of the $X$ component at the three stations. The amplitude at Emu may be expected to be slightly less than that at Yelta as Emu is a more northerly station; but then Gnangara is more southerly so that the $X$ amplitude should increase again. The Gnangara $Y$ amplitude is also slightly reduced relative to the other two stations. Such westward reduction in the amplitude of the horizontal components may also reflect varying conductivity structure beneath east and west Australia.

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