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REPORT 50

CURRENT MEASUREMENTS IN THE GULF OF CARPENTARIA

By G. R. Cresswell

Marine Laboratory
Cronulla, Sydney
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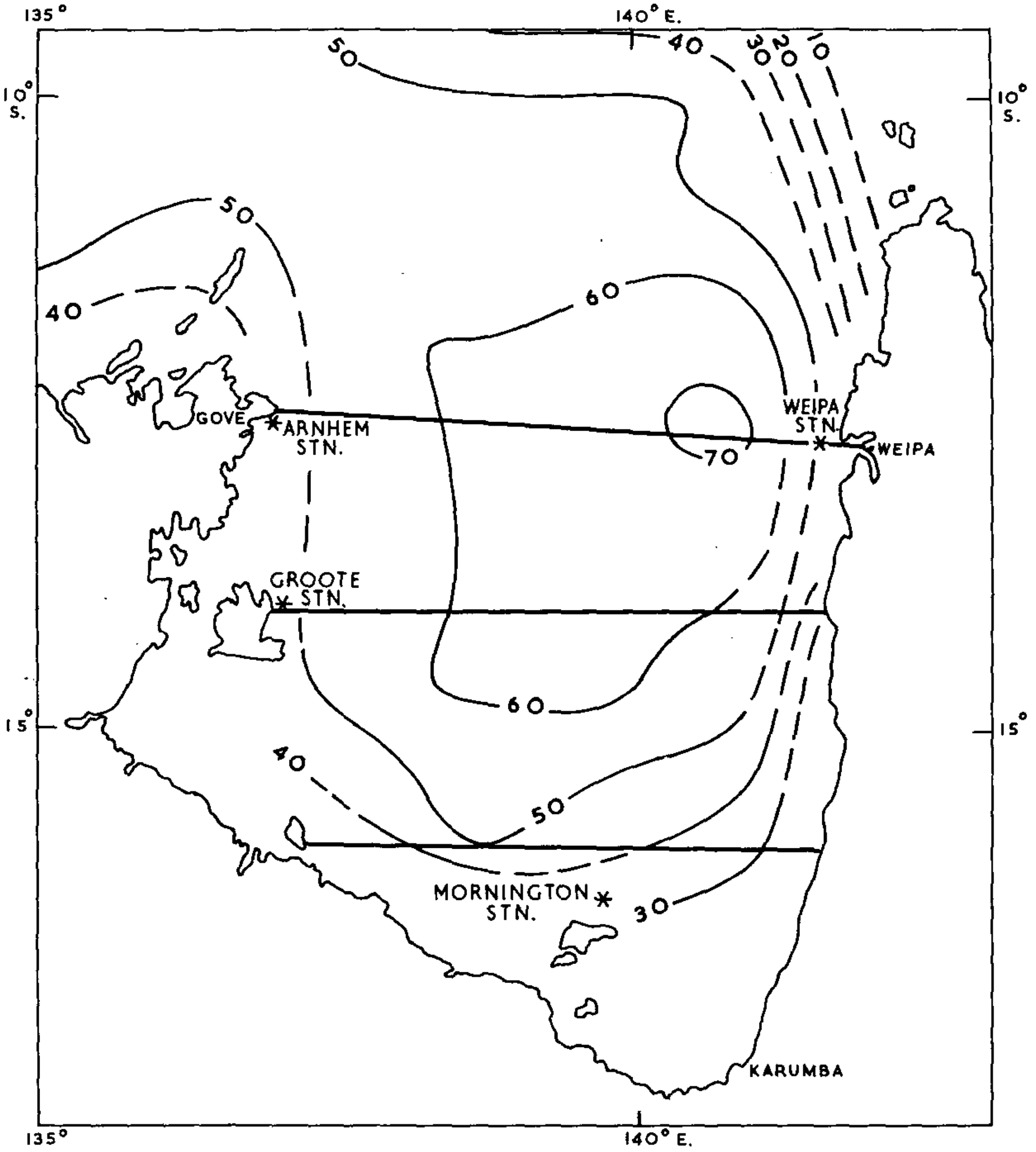

Fig. 1. A map of the Gulf of Carpentaria showing water depths in metres (after Rochford, 1966), the east-west cruise traverses, and the current meter stations.

CURRENT MEASUREMENTS IN THE GULF OF CARPENTARIA

Abstract

An exploratory phase of current measurements using moored recorders in the Gulf of Carpentaria has revealed both tidal and non-tidal current components. Support is given for the suggestion that the diurnal tidal wave travels clockwise around the perimeter of the Gulf pivoting on some as-yet-unknown amphidromic point within the Gulf. The tidal currents measured at several places and times in the Gulf showed a maximum value of 1.5 kt. Non-tidal current components determined for four occasions during a year on the eastern side of the Gulf showed a possible seasonal effect: values ranged from 4 miles/day northward in July to 1 mile/day southward in March with the former being during the S.E. trade wind period.

INTRODUCTION

The Gulf of Carpentaria is physically interesting and warrants study for a number of reasons: A tenth of the tidal energy dissipated on the earth is dissipated in its vicinity. It has a roughly geometrical shape and a relatively smooth bottom. For several months of the year it is influenced by strong and steady trade winds which drive its circulation. The circulating waters carry with them the future of the lucrative prawn fishery - the infant prawn larvae.

For these reasons the author participated in four bi-monthly cruises of ten day duration aboard the M.V. "Islander". This enabled some recently completed current meters to be moored for periods up to ten days.

The cruises consisted of three east-west traverses across the Gulf (Fig. 1) generally having the same start and finish port, Weipa. A certain amount of flexibility allowed for extra steaming to pick up moorings as long as each cruise did not exceed 10 days.

INSTRUMENTATION

The current meters used for the work were designed by Frassetto (1967) and ten copies were built by this Division under the supervision of Mr D. Lockwood. A Savonius rotor monitors the current speed while a shuttlecock assembly coupled to a compass monitors direction; both are recorded on chart. The charts are subsequently digitized on a chart reader at the Division and then computer processed.

The moorings employed two anchors (150-200 lbs of scrap iron) with a surface spar marker attached to a line from one anchor and a sub-surface float supporting a taut instrument line (4 mm hydrology wire) from the other anchor. All moorings were put down in approximately 35 metres of water and within radar distance (about 20 miles) of shore. When one meter was used it was positioned 11 metres from the bottom. When two were used on the one instrument line they were placed 11 and 22 metres from the bottom.

RESULTS

In all, nine meters and seven moorings were put down during the July, September and November cruises of 1970 and the March cruise of 1971 (Table 1).

TABLE 1

THE POSITIONS OF THE CURRENT METERS

	Locality			
	Weipa	Cape Arnhem	Mornington Is.	Groote Is.
July	1	-	-	-
September	1	-	-	-
November	2	1	1	-
March	2	-	-	1

The main instrumental faults were clock stoppage and compass assembly failure, the latter being the result of rough handling at the air freight terminals; during one mooring a chart recorder stylus became jammed. With the short duration of the moorings the clock stoppage proved to be an inconvenience only and the compass assembly failure caused the complete loss of only one record (Groote Is., March 1971).

Figures 2 to 9 give the north-south and east-west velocity components and the progressive vector diagrams for all the recordings excepting that from Groote Is. The progressive vector diagrams generally show tidal ellipses superimposed on steady non-tidal currents. In November (one day's record only) and March the meters at 26 m depth at Weipa were accompanied by meters at 15 m depth on the same instrument line. The ones closer to the surface showed larger currents.

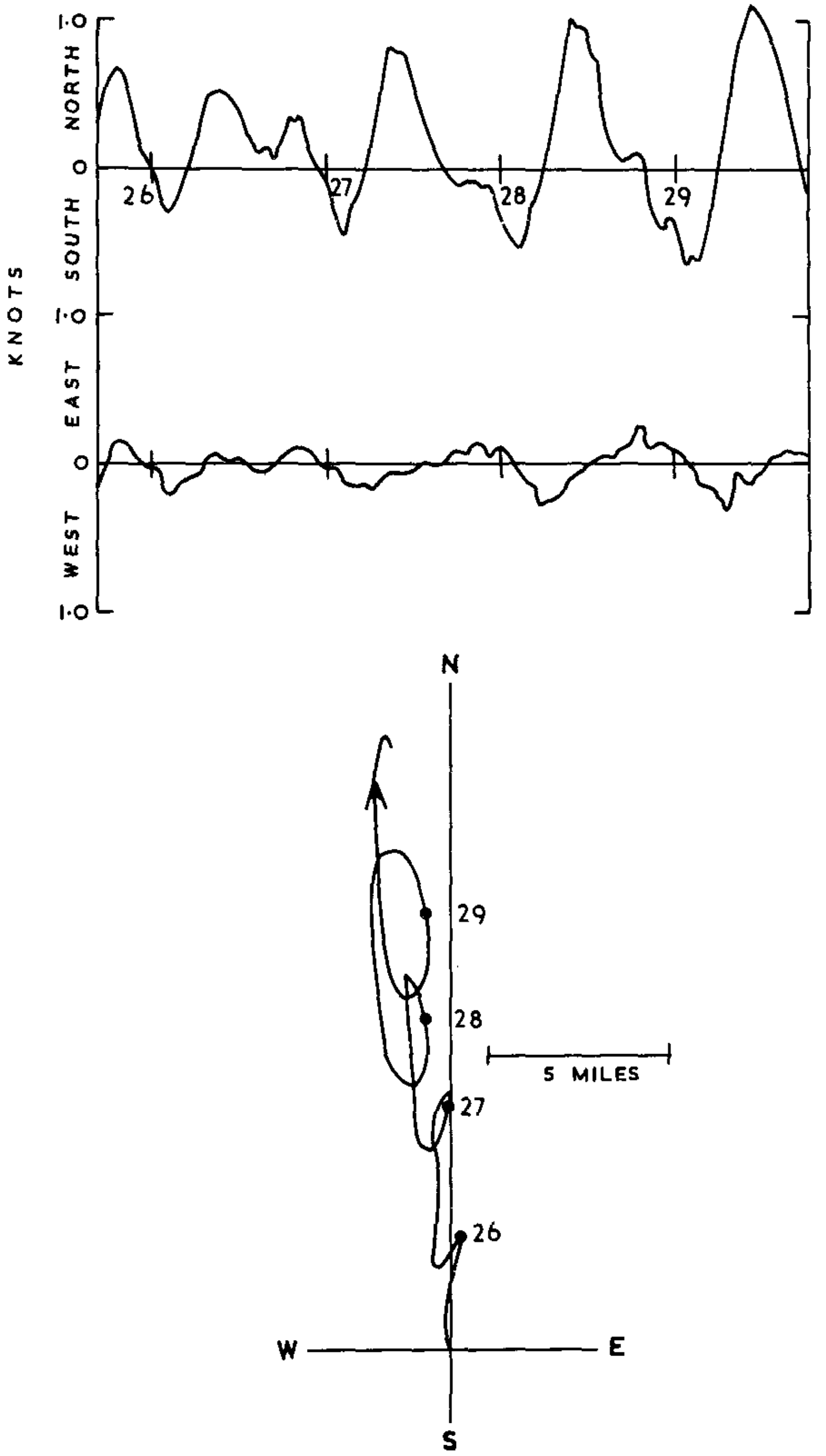

Fig. 2. Weipa station current velocity components and progressive vector diagram for the period 1600 25.7.70 to 1800 29.7.70 Water depth: 37 m; current meter depth: 26 m.

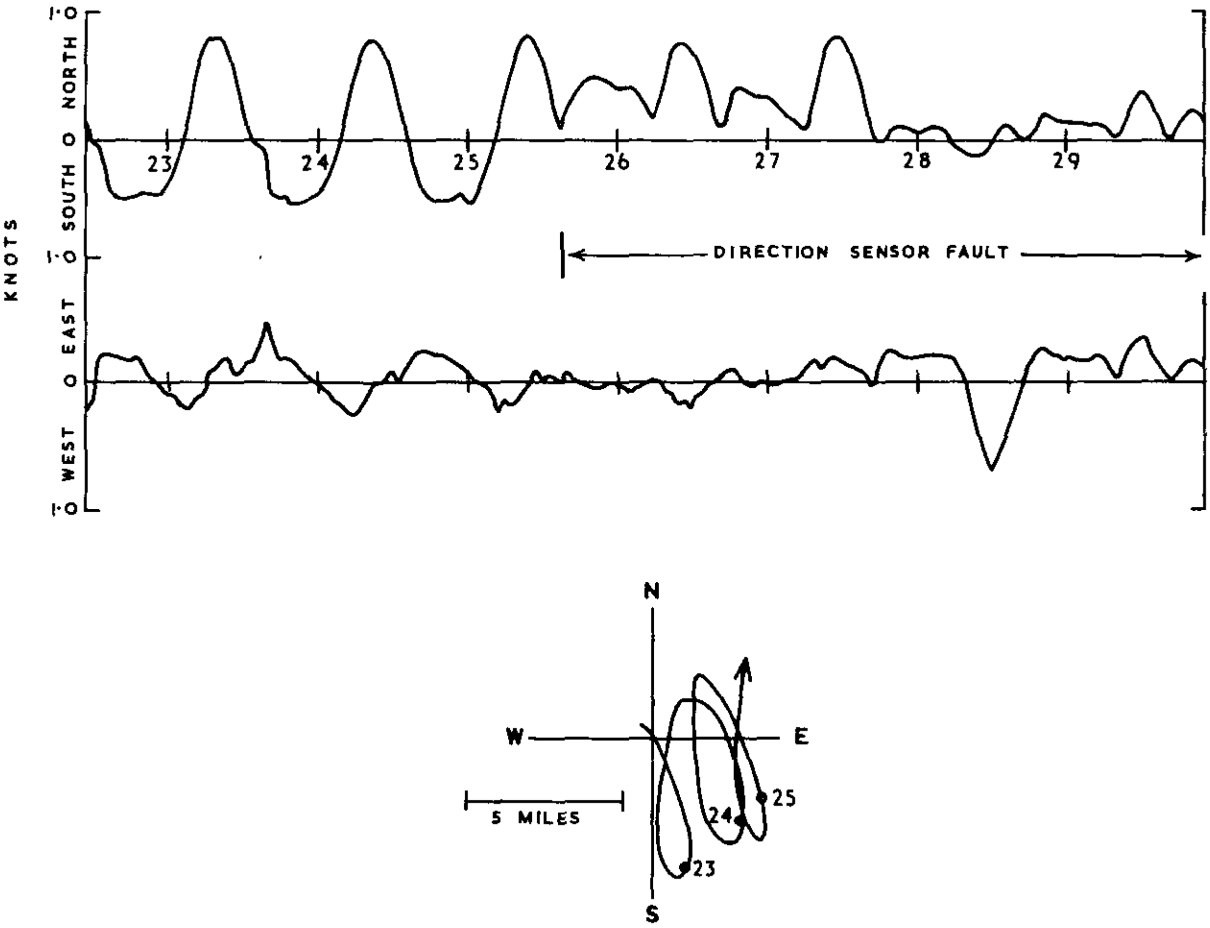

Fig. 3. Weipa station current velocity components and progressive vector diagram for the period 1100 22.9.70 to 2200 30.9.70. Water depth: 37 m; current meter depth: 26 m. The progressive vector diagram is for the period preceding the direction sensor fault.

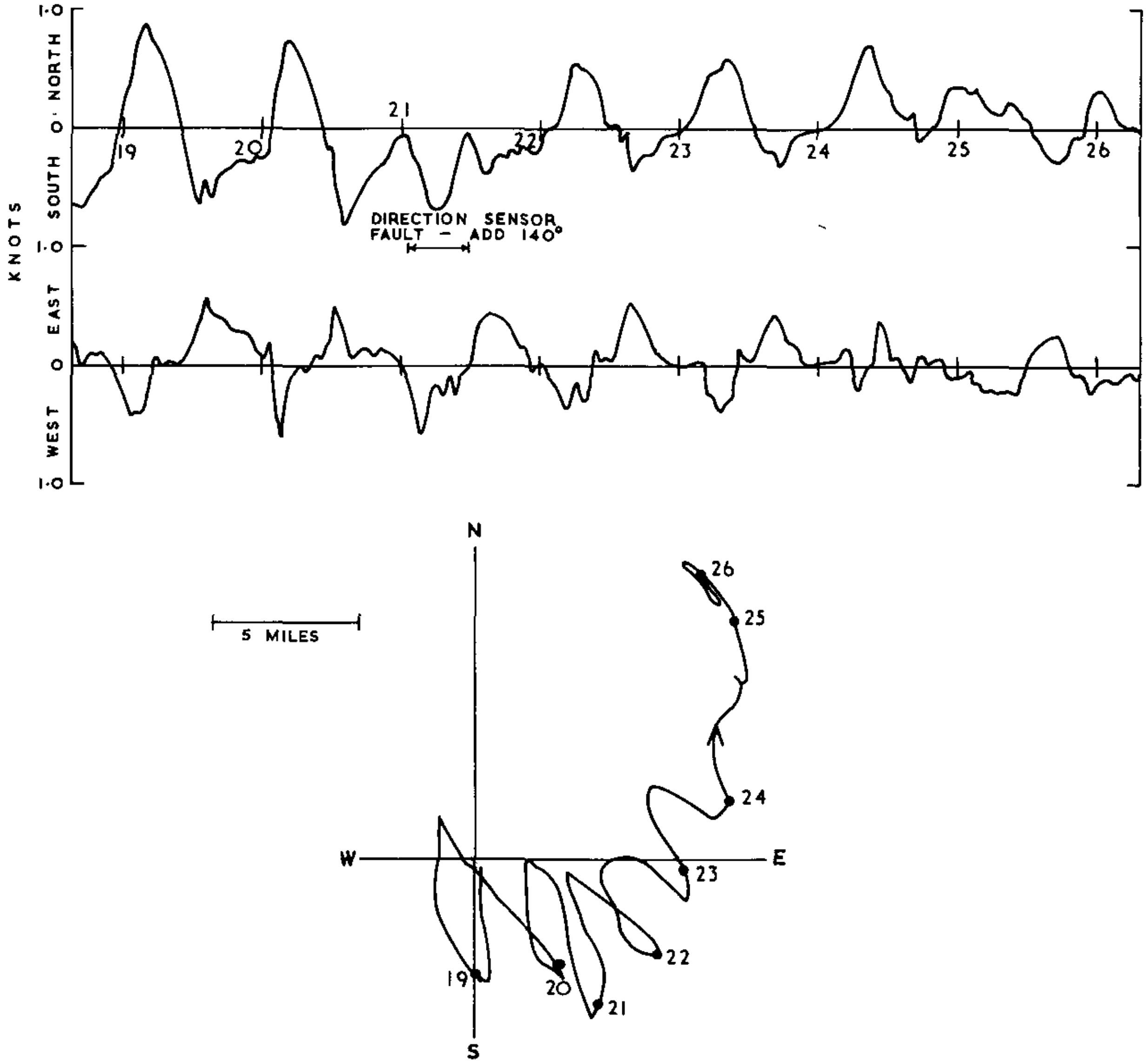

Fig. 4. Weipa station current velocity components and progressive vector diagram for the period 1500 18.11.70 to 0800 26.11.70. Water depth: 37 m; current meter depth: 26 m. The + 140° direction correction has been applied to the progressive vector diagram for the appropriate period.

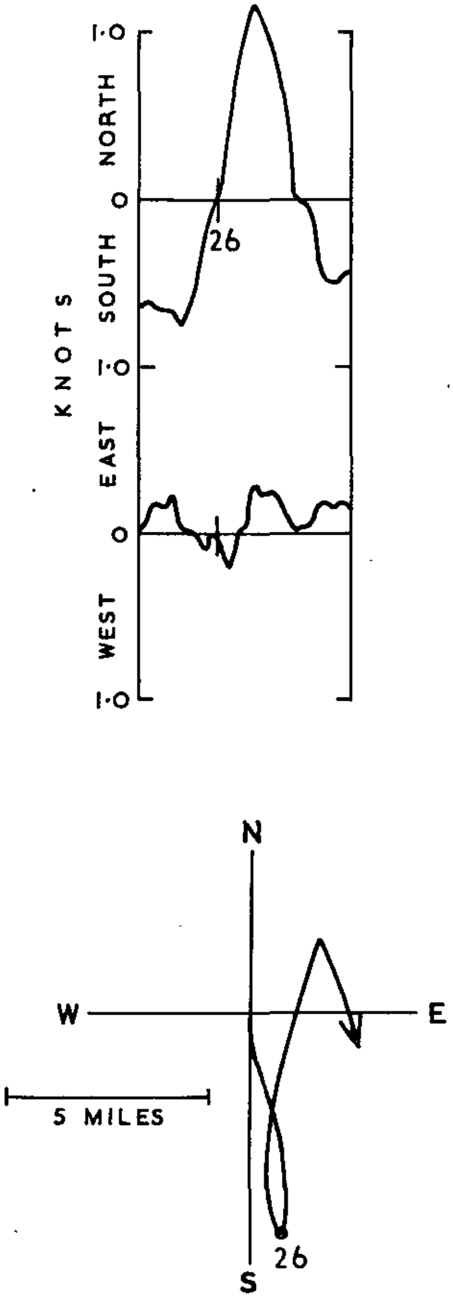

Fig. 5. Weipa station current velocity components and progressive vector diagram for the period 1500 18.11.70 to 1700 19.11.70. Water depth: 37 m; current meter depth: 15 m.

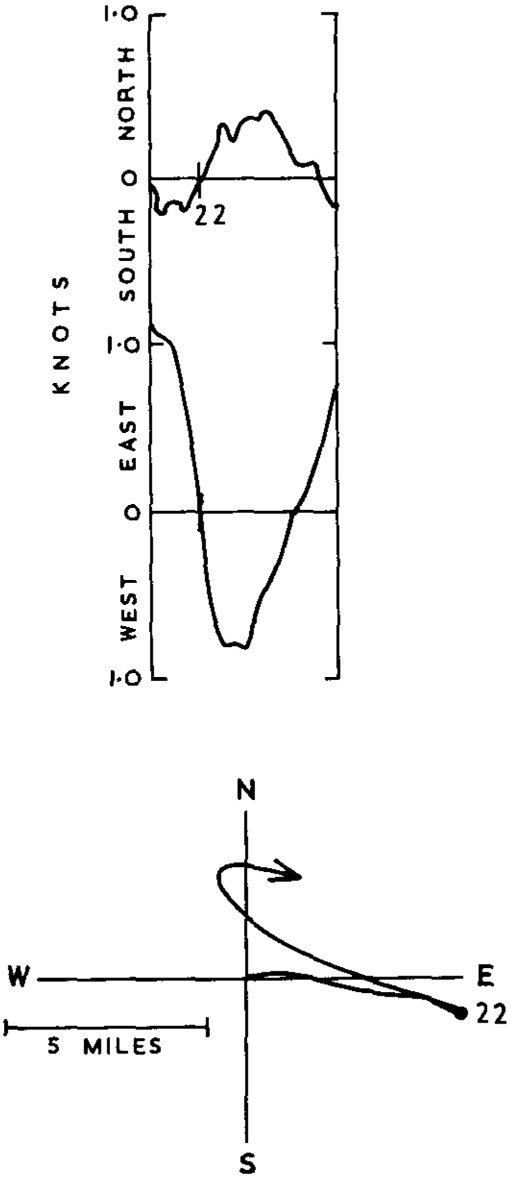

Fig. 6. Mornington station current velocity components and progressive vector diagram for the period 1800 21.11.70 to 1700 22.11.70. Water depth: 33 m; current meter depth: 22 m. Note that a surface drogue released when the mooring was put down returned to it (within 50 yards) 23 hours later.

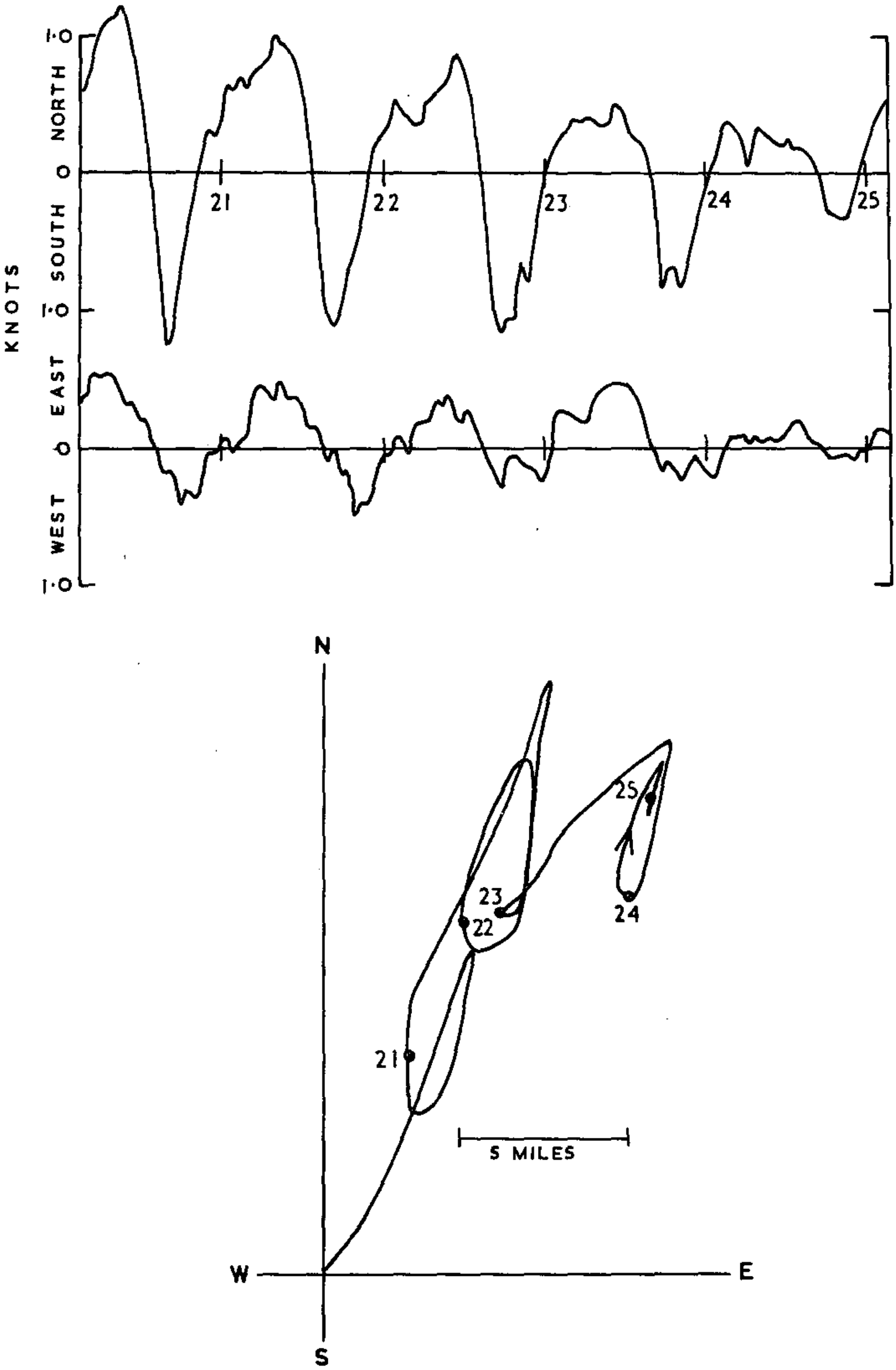

Fig. 7. Arnhem station current velocity components and progressive vector diagram for the period 0200 20.11.70 to 0300 25.11.70. Water depth: 37 m; current meter depth: 26 m.

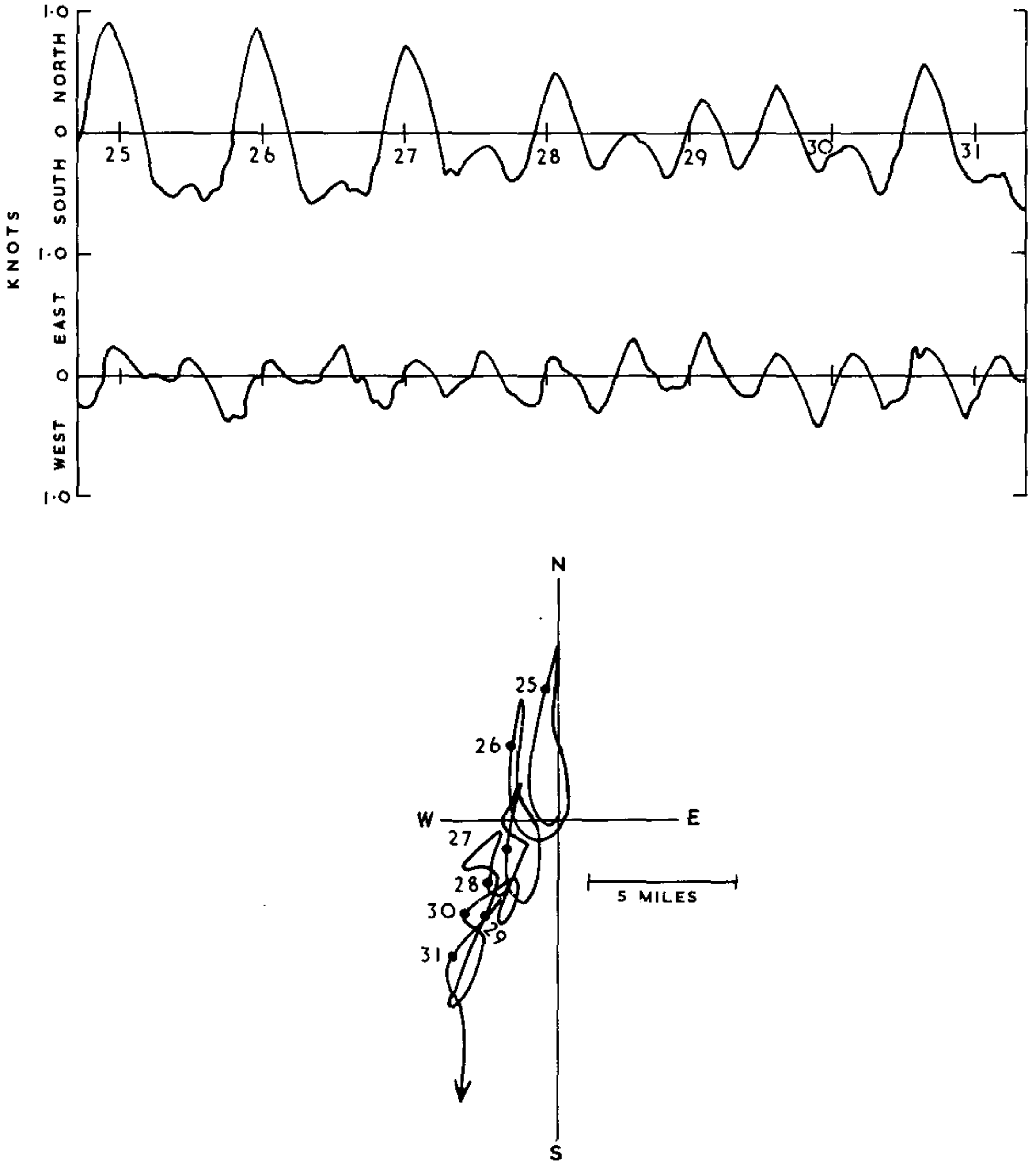

Fig. 8. Weipa station current velocity components and progressive vector diagram for the period 1700 24.3.71 to 1000 31.3.71. Water depth: 37 m; current meter depth: 26 m.

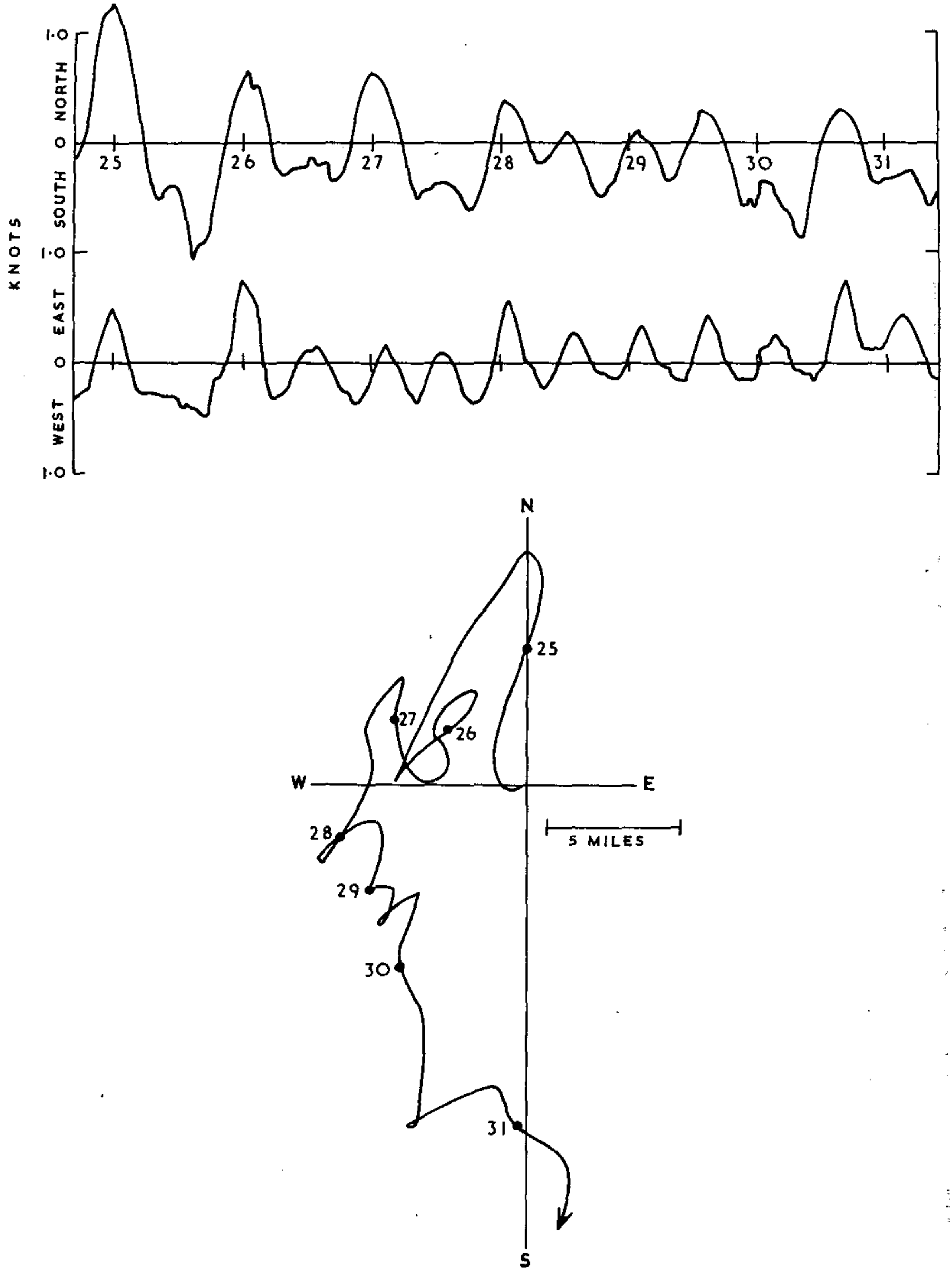

Fig. 9. Weipa station current velocity components and progressive vector diagram for the period 1700 24.3.71 to 1000 31.3.71. Water depth: 37 m; current meter depth: 15 m.

DISCUSSION

1. Tidal currents

Under the influence of the Coriolis force a progressive tidal wave that enters a terminated channel in the southern hemisphere - such as the Gulf - becomes higher on the left side facing the direction of travel and progresses clockwise around the terminated channel. This behaviour has been numerically modelled by Dr D. Webb of this Division.

A progressive wave has the property that at the crests the water motion is in the direction of progression while at the troughs it is opposite. The wave height and current can be represented by

$$H = A \sin(\omega t - kx) \qquad (1)$$

$$U = \frac{g}{\sqrt{h}} A \sin(\omega t - kx) \qquad (2)$$

Maximum tide height and current in the direction of progression are attained simultaneously.

On the other hand the wave height and current for a standing wave - resolvable into two progressive waves of the same amplitude and wavelength travelling in opposite directions - can be represented by

$$H = 2A \sin \omega t \cos kx \qquad (3)$$

$$U = -2 \frac{g}{\sqrt{h}} A \cos \omega t \sin kx \qquad (4)$$

The records of H and U versus time will show a $\frac{\pi}{2}$ phase difference, as long as neither are non-varying due to kx being a multiple of $\frac{\pi}{2}$. If the two progressive waves have different amplitudes (A and B) a standing wave and a progressive wave will result and the phase difference will not be $\frac{\pi}{2}$. An example would be an incoming wave encountering a smaller amplitude reflected wave.

In the November part of the present experiment it was possible to test the suggestion that the diurnal tidal wave progresses clockwise around the Gulf. On that cruise there was a single 24-hour period in which simultaneous current records were obtained in the eastern, southern, and western parts of the Gulf, i.e. from the Weipa, Mornington, and Arnhem stations respectively. Ideally one would like to have real tide height information from the same stations for a study of phase relationships. In this initial study such information was not available and predicted tide heights had to be used.

Fourier analysis was used to extract the diurnal and semi-diurnal components from the observed currents and predicted tides. What remained were the higher order components (8 hr, 6 hr periods), the mean, and the non-cyclic variation during the 24 hr sample. Figure 10 shows the harmonics from the analysis of the current record from Weipa and also the synthesized record from re-combining the harmonics, the mean, and the non-cyclic variation.

Figures 11 and 12 show the diurnal and semi-diurnal components of the tide height and current compared for the Weipa (eastern) and Arnhem (western) stations respectively; no tide prediction was available for the Mornington (southern) station. Because the diurnal component tide height and current are very nearly in phase at both stations both are experiencing primarily progressive waves, with the Weipa station having a southward-going crest and the Arnhem station having a northward-going crest at approximately the same time. Since we apparently have diurnal progressive waves entering the Gulf on the eastern side and similar ones leaving it on the western side we might conjecture that the waves travel clockwise around the Gulf. The tidal ellipses which are plotted in Figure 13 show that when the southward-going crest passes Weipa there is eastward flow at Mornington. It is suggested that this flow accompanies the trough of a westward-going wave. Since then at the one instant we have a crest at Weipa, a trough at Mornington, and another trough at Arnhem it seems likely that there will be another crest between Mornington and Arnhem.

The semi-diurnal components given in Figures 11 and 12 can be interpreted from their phase relationships to show a southward progressive wave with some standing wave at Weipa and nearly all standing wave at Arnhem.

2. Non-tidal currents

The non-tidal currents in the Gulf are probably wind-driven. In winter steady and strong SE trades blow; in summer there are NW monsoons and an occasional cyclone. Particularly in winter, the steady wind situation combined with the roughly geometrical shape of the Gulf could lead to a useful study of wind-driven circulation.

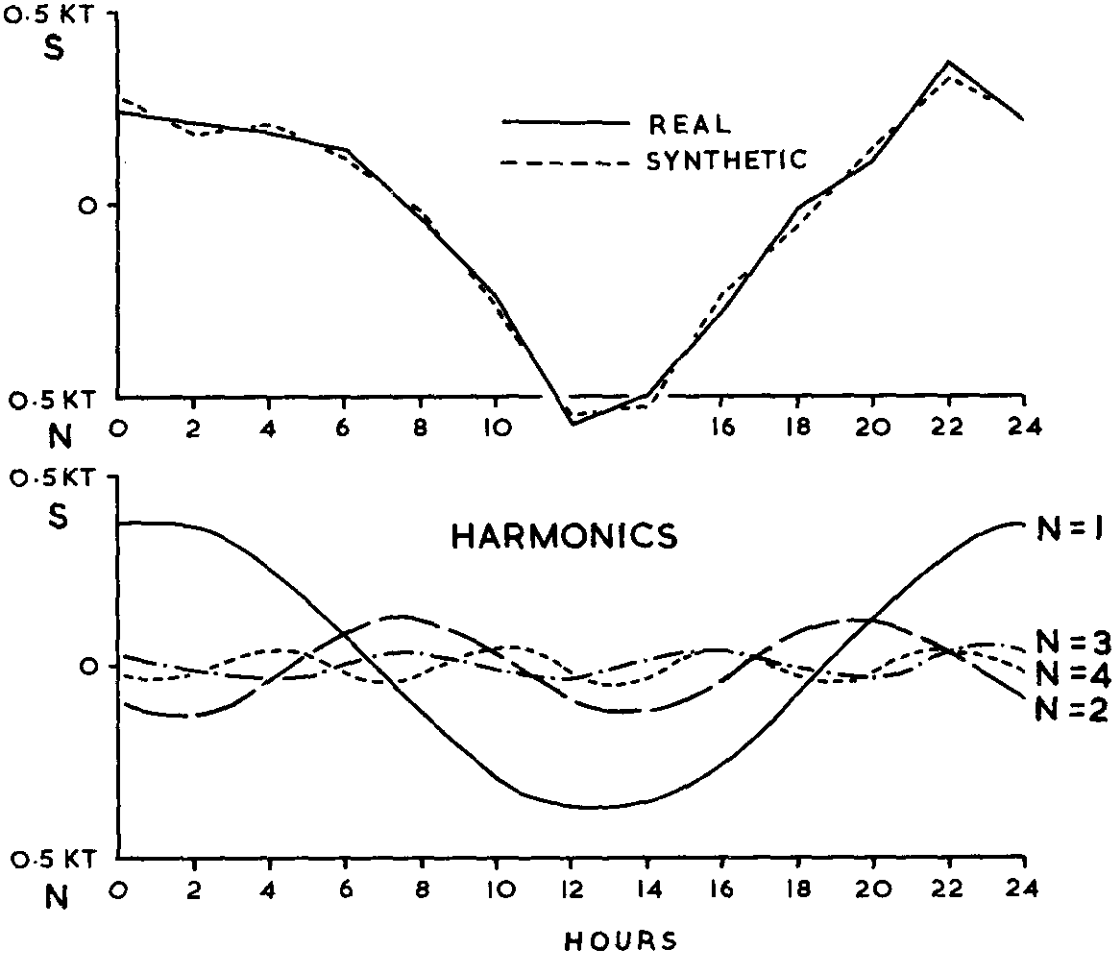

Fig. 10. An actual current record for a 24 hour period (Weipa *station*, 1800 21.11.70 to 1800 22.11.70) showing the harmonics derived from it and the synthetic record that they yield when recombined with the mean and non-cyclic variation.

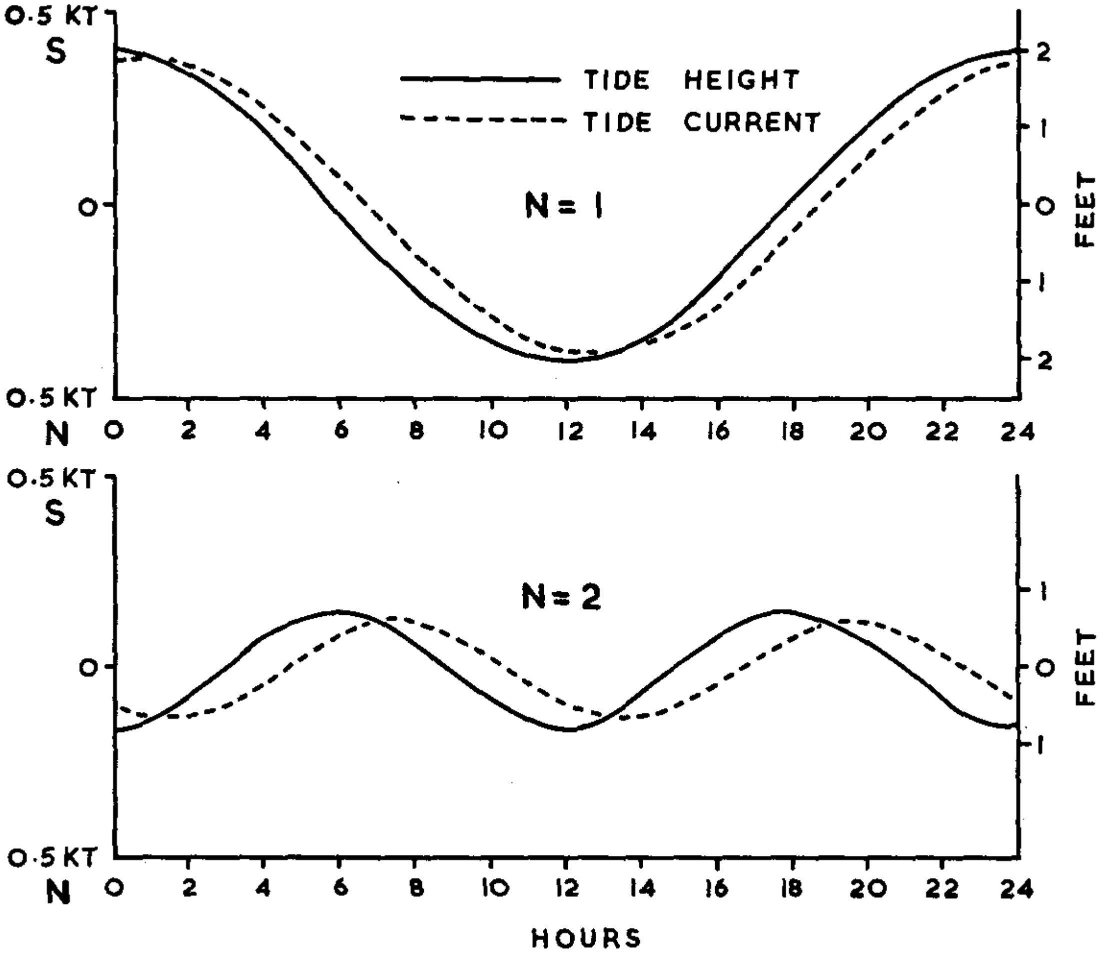

Fig. 11. The diurnal and semi-diurnal components of tide height and current for the Weipa station for the period 1800 21.11.70 to 1800 22.11.70.

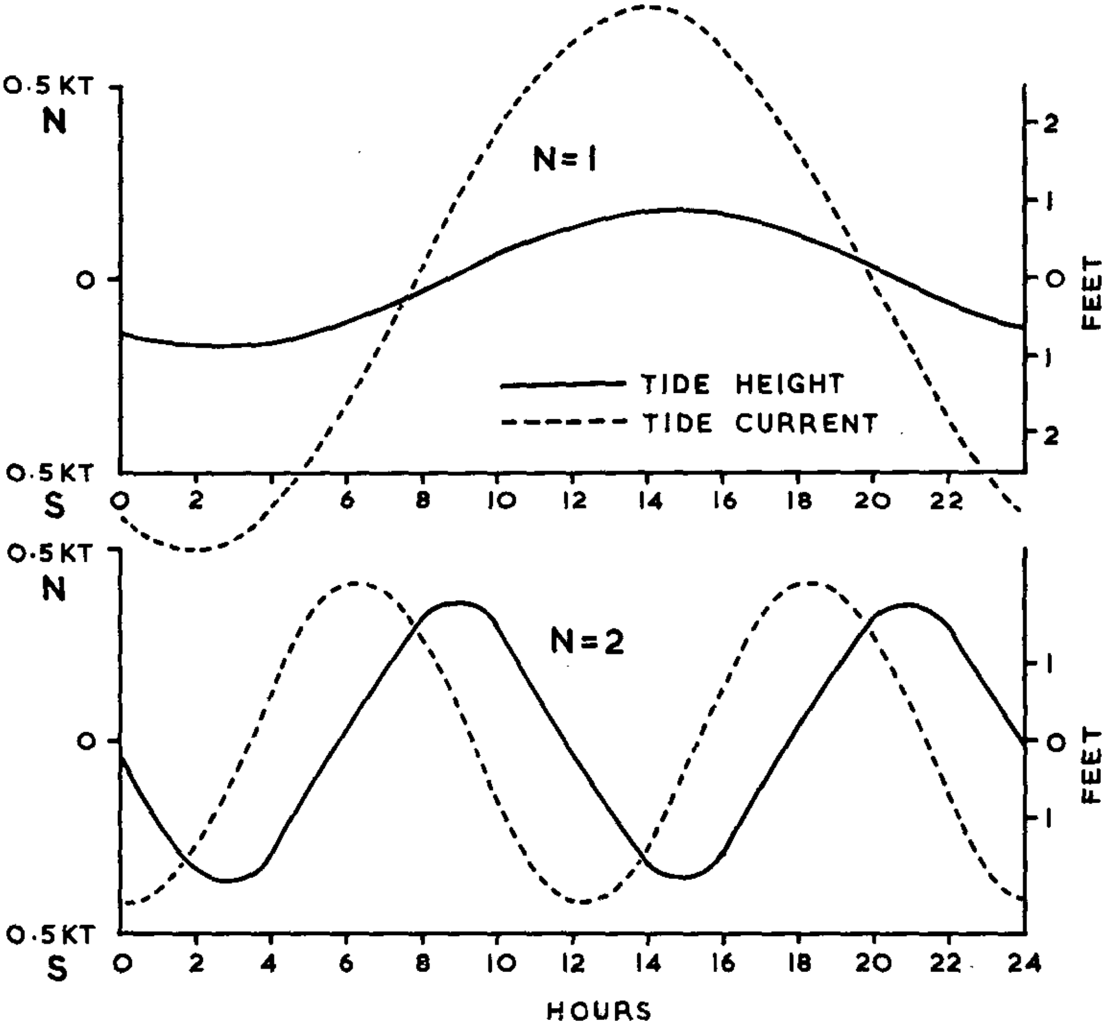

Fig. 12. The diurnal and semi-diurnal components of tide height and current for the Arnhem station for the period 1800 21.11.70 to 1800 22.11.70.

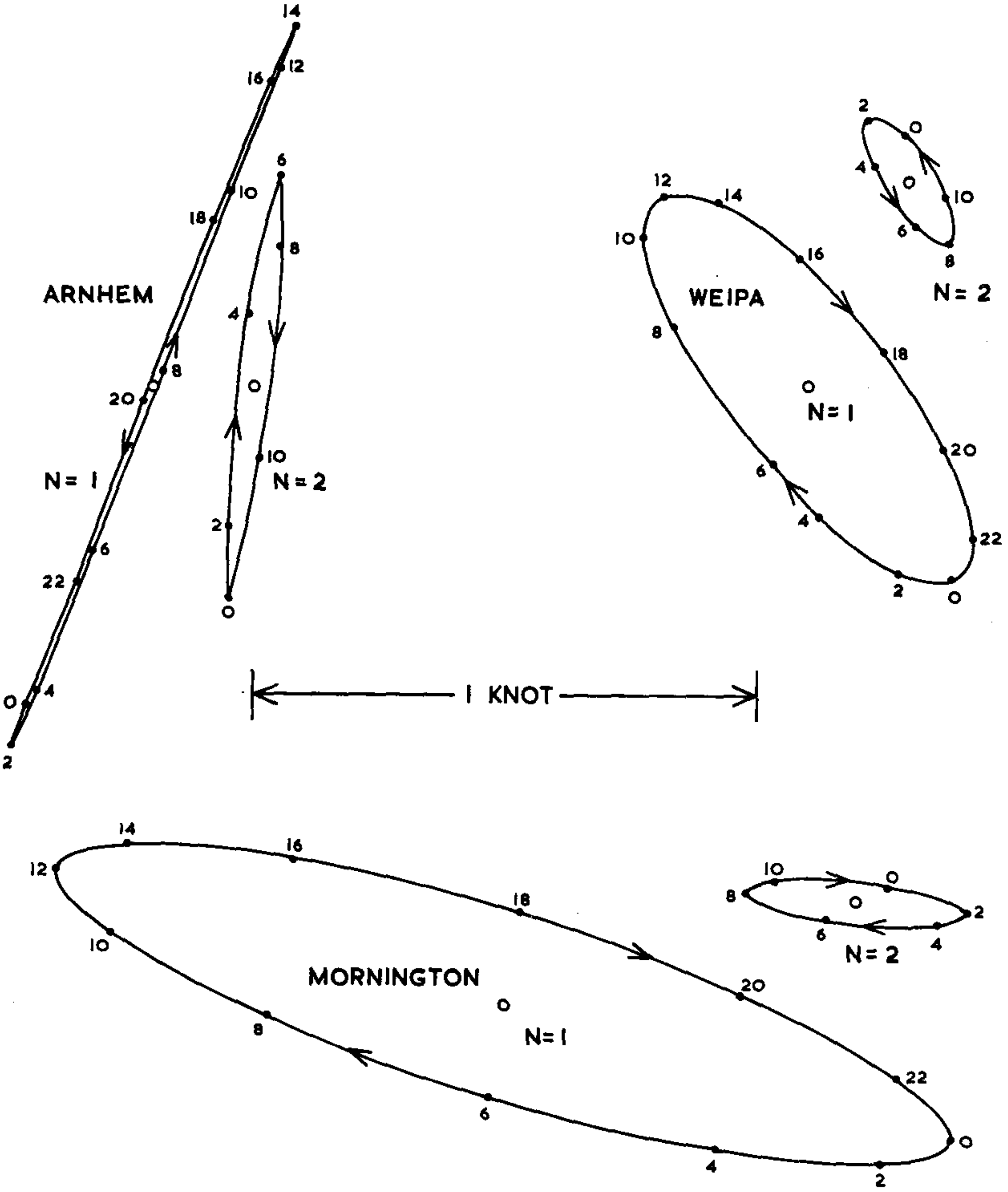

Fig. 13. The diurnal and semi-diurnal tidal current ellipses for Arnhem, Weipa and Mornington for the period 1800 21.11.70 to 1800 22.11.70.

In the present exploratory study current measurements made at the Weipa station for several days each in July, September, November, and March can be examined for possible seasonal effects. The progressive vector diagrams (see Figs 2, 3, 4, 8) reveal the following: in July, at what seemed to be the end of the trade wind season, the non-tidal current was 4 miles/day northward; in September this current was very small; in November it slowly changed; and in March it was 1 mile/day southward. Any measurements in the future would be of great value.

Changes in non-tidal current appeared to occur at both Weipa and Arnhem on November 23rd when increasing winds were encountered on the cruise.

CONCLUSIONS

This exploratory study has revealed interesting aspects of the tidal and non-tidal currents in the Gulf. To extend the tidal work it would be desirable to have each current meter mooring include a bottom mounted tide recorder for unambiguously determining phase relationships. For the non-tidal wind-driven currents more measurements are needed to determine if a seasonal effect exists in the circulation. This can then be linked with prawn larvae migrations. The mooring surface markers would benefit from the addition of a radio location beacon to enable the moorings to be moved our beyond radar distance of land. Also on the surface markers the addition of an anemometer would aid in the interpretation of the wind-driven currents.

ACKNOWLEDGEMENTS

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