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The Effects of Compass Calibration on Aanderaa Current Meter Records

A. M. G. Forbes and J. A. Church

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THE EFFECTS OF COMPASS CALIBRATION ON AANDERAA CURRENT METER RECORDS

A.M.G. Forbes and J.A. Church

CSIRO Division of Fisheries and Oceanography
P.O. Box 21, Cronulla, NSW 2230

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Abstract

The results of a series of calibration trials of ten Aanderaa current meter compasses are presented. After all precautionary measures were taken to reduce contributors to non-linear compass response, there remained a stable repeatable calibration curve for each meter. Errors introduced by assuming linear compass calibration in the calculation of residual currents and Reynolds stresses are assessed, and found to be potentially large. Progressive vector diagrams are compared for selected field data, using linear and non-linear calibration equations, and the resulting long-term drifts found to be significantly different.

INTRODUCTION

Current meter measurements are an integral part of many studies of ocean circulation. Measurements at selected locations are used to support or suggest possible large scale circulation patterns and to estimate fluxes of mass and momentum. In areas where oscillatory signals (e.g. tides, inertial motions and longer period waves) are of importance, the mean velocity over several cycles is often considerably smaller than the instantaneous velocities. Gould (1973) showed that in such situations non-linearities in the direction sensor of current meters may result in contamination of the mean by the fluctuating component. Keenan (1976), in a study of one commonly used make of current meter (the Aanderaa RCM4), found compass errors in excess of the ± 5° error band (in the 5 to 100 m s^{-1} speed range) quoted by the manufacturer. He found that departures from the linear calibration of from 8 to 18° were due to:

(i) magnetisation of the pressure case,

(ii) the magnetic field generated by the electro-mechanical encoder,

(iii) the Savonius rotor and following magnets and

(iv) a residual error which remains constant over time.

In this report, the results of a series of calibrations of Aanderaa (RCM4) current meter compasses and the effect of these calibrations on the results of field programs are discussed.

THE CALIBRATION METHOD

The direction sensor of the Aanderaa (RCM4) current meter consists of a magnetic compass which is clamped against a potentiometer each recording cycle. The resulting signal is digitised with a resolution of ± 0.35° and recorded on magnetic tape. To calibrate the compass, the meter was

Table 1. Aanderaa current meter compass calibration trials (Frequency governed by meter availability)

Serial Number	5.9.78	8.12.78	1.3.79	7.6.79	7.6.79 Case degaussed	3.9.79 Case degaussed	25.10.79 Pressure = 1023
571	√	√					
572		√		√		√	√
580	√			√	√	√	√
583	√						
586	√					√	√
1247	√	√					
1731	√		√	√	√	√	
1736	√		√				
1733	√		√				
1734		√	√				

mounted on a rotating wooden table and aligned relative to accurately known trigonometric points. Two 360° rotations of each meter were performed, one clockwise and another anticlockwise, triggering the encoder to operate at intervals of 45°. As a precaution against compass friction, the meters were vibrated slightly before each encoding cycle. To minimise the error introduced by the Savonius rotor and following magnets, movement of the rotor was maintained during the calibration trials. The meter orientation accuracy of each calibration trial was better than $\pm 1°$.

Ten meters were calibrated on the dates indicated in Table 1. Degaussing of meter cases was not performed until June 1979, but each meter was assembled in a fixed orientation relative to its case, so that any case-induced error would be repeatable. All but one meter (No. 583) were equipped with pressure sensors. During calibration the error from the encoding of the pressure word should be at its maximum compared to errors induced in the field (Keenan 1976). In field operations, the higher ambient pressure would result in a smaller but more variable error.

RESULTS

Data for each 45° interval were averaged from the recordings of the clockwise and anticlockwise rotations. There were no significant differences between the two sets, except for a trial where the meter was not vibrated. In this case, the two sets differed by an average of 16°. The lack of significant difference between the clockwise and anticlockwise data sets means that friction in the compass was eliminated as a significant source of error in the calibration trials. Vibration in the mooring line would also eliminate this source of error in the field. Departure from linearity was plotted against true direction for each calibration trial for each meter. In contrast to the results of Keenan (1976), calibrations prior to and subsequent to degaussing the case were not significantly different. In fact, even when the cases from different meters were interchanged there was no significant effect. Similarly, when the pressure circuit was altered (as suggested by Keenan (1976)) such that the error from this source was removed, there was negligible change in the calibration curve.

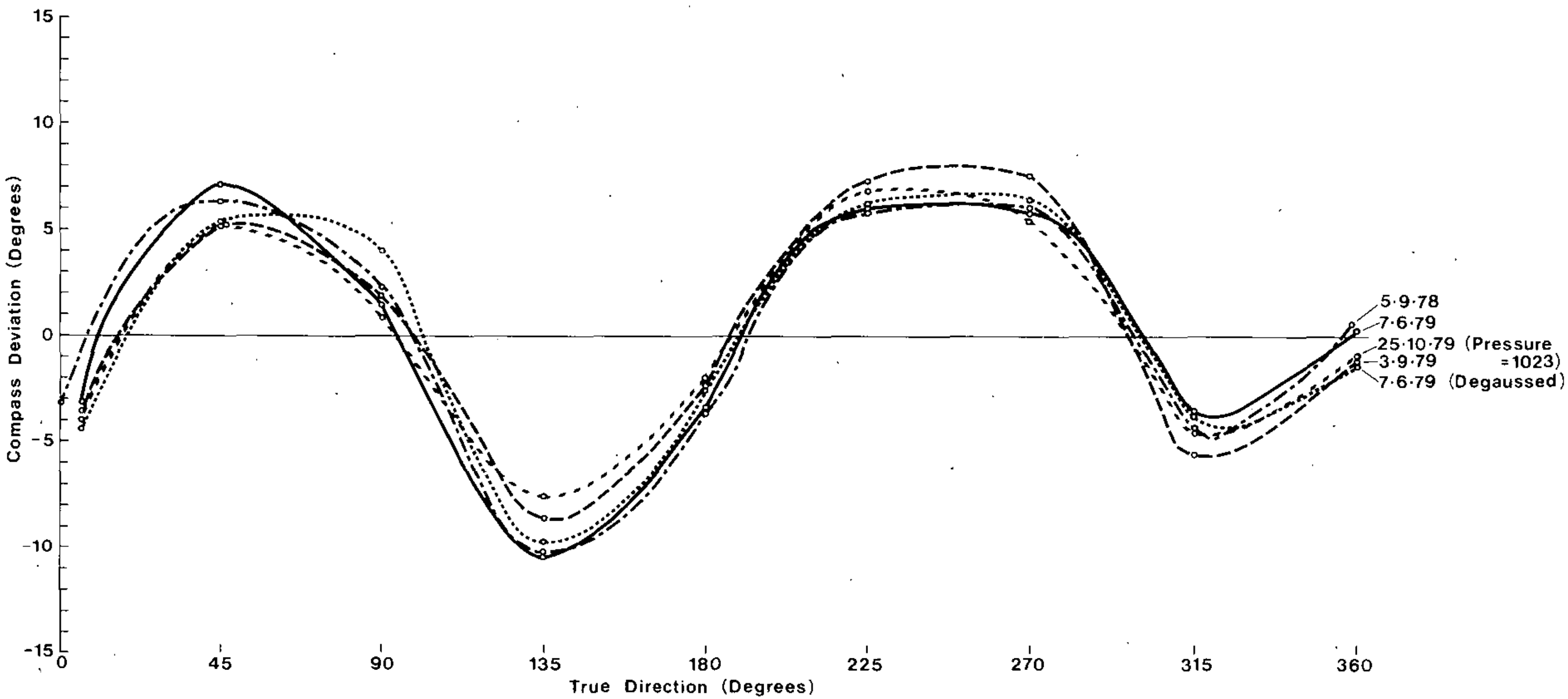

Fig. 1. Compass calibration curves for meter no. 580 over a 10 month period - Deviation from linear relationship vs. true direction.

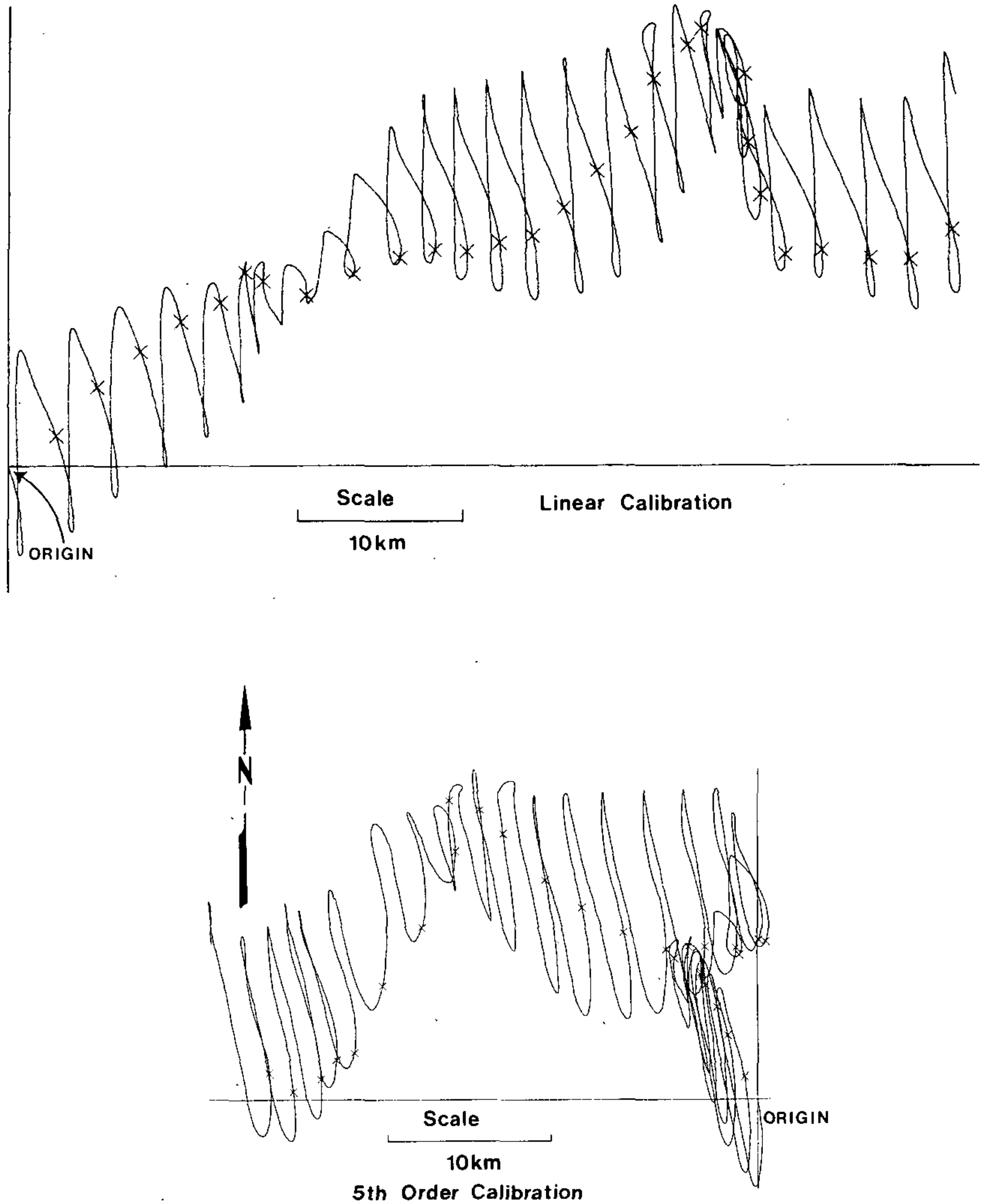

Fig. 2. Progressive vector diagrams for 29 days of data from meter no. 571. Upper diagram produced using linear compass calibration. Lower diagram produced using 5th order polynomial compass calibration on the same set of raw data.

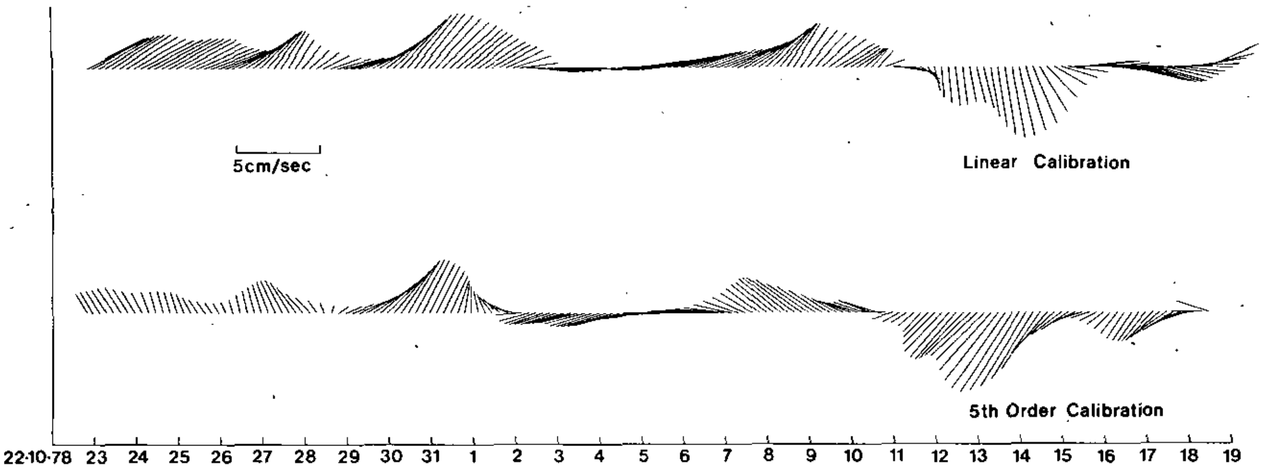

Fig. 3. Residual currents of 29 days of data from meter no. 571, plotted every four hours as stick diagrams. — Upper diagram produced using linear compass calibration. — Lower diagram produced using 5th order polynomial compass calibration on the same set of raw data.

For all meters, the calibration curve remained virtually unchanged with time. Figure 1 shows a series of calibration curves for one meter (no. 580) over a ten month period. Because of the consistency of the calibration curves and the above tests, the measured calibration curves must closely approximate the fundamental error curve of the compass. Least squares regression techniques were used to fit a 5th order polynomial to the calibration data. For all meters, a 5th order polynomial accounted for at least 99.9% of the variance.

Construction of the compass potentiometer is such that a dead zone of approximately 3° exists close to magnetic north. In this dead zone, the maximum value of 1023 is recorded on the tape. To account for this characteristic, a convention of assigning the mild point of the dead band to any recording of 1023 was adopted.

EFFECTS OF POOR CALIBRATION

As indicated by Gould (1973) compass non-linearities may affect mean current measurements. To illustrate the possible errors, 29 days of Aanderaa current meter data for a single instrument (no. 571) moored in the Gulf of Carpentaria were treated in two ways; first, using the linear calibration and second, using a 5th order polynomial derived from calibration data recorded prior to meter deployment. Progressive vector diagrams for the two cases are indicated in Fig. 2. Superimposed on the tidal signal there is a small residual drift to the east of 38.8 km in 29 days for the case of the linear calibration. However, when a 5th order polynomial was used, the same record indicated a net westward drift of 34.1 km.

Stick diagrams for the residual currents are shown in Fig. 3. These currents were obtained by applying Munk's "tide killer" filter (Hamon

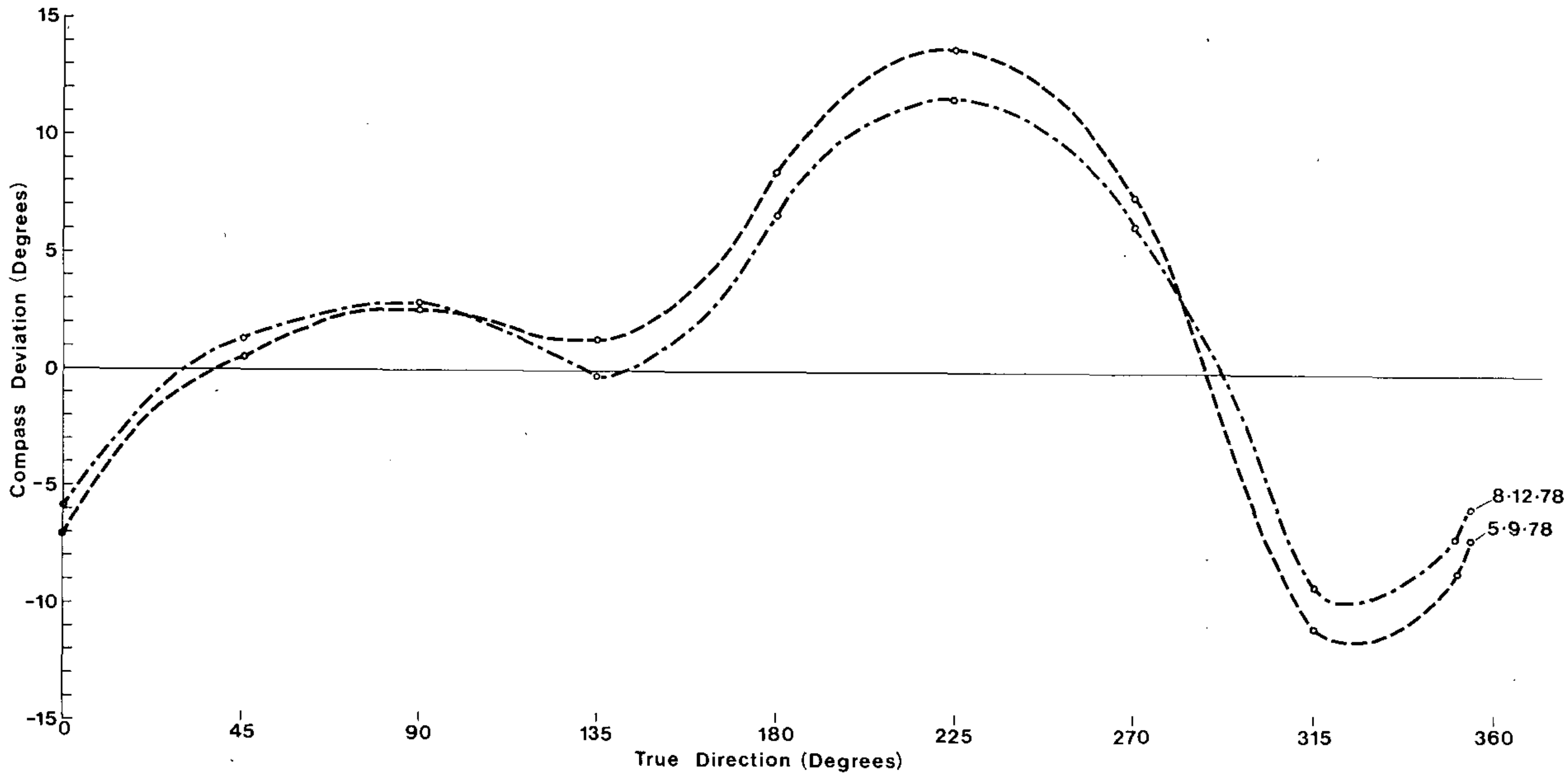

Fig. 4. Compass calibration curves for meter no. 571 over a 3 month period - Deviation from linear relationship vs. true direction.

Table 2. Comparison of component harmonic analysis of 29 days record using linear and 5th order polynomial calibration

Constituent	Easterly component				Northerly component			
	Amplitude ($cm\ s^{-1}$)		Phase (G) (degrees)		Amplitude ($cm\ s^{-1}$)		Phase (G) (degrees)	
	Linear calib.	5th order calib.	Linear calib.	5th order calib.	Linear calib.	5th order calib.	Linear calib.	5th order calib.
O1	1.62	2.08	167.8	153.2	21.42	21.66	347.2	347.3
K1	2.67	3.84	167.8	169.9	34.78	34.80	37.2	37.1
M2	3.18	1.84	34.2	46.6	3.37	3.43	265.4	261.2
S2	1.73	1.38	119.5	64.1	2.95	2.76	85.5	84.3
M4	0.08	0.24	170.4	33.6	0.18	0.14	148.4	170.5

(1977) to smoothed hourly data and then plotting every fourth value. The nature of the calibration curve for meter no. 571 (shown in Fig. 4) leads to a simple explanation for the widely different results discussed above. Suppose the tidal flow is north-south (a good approximation for the present case). Using a linear calibration will result in tidal currents 10° to the east of north and south (as indicated in Fig. 5). The mean speed ($\bar{v}$) over the 29 days was 18.1 $cm\ s^{-1}$, thus a linear calibration would yield an easterly component of approximately ($\bar{v}$) $\sin 10°$ = 3.1 $cm\ s^{-1}$. The difference between the mean currents in Fig. 2 is 3.7 $cm\ s^{-1}$, within 20% of this simple estimate.

The effect of compass errors on the tidal currents is less pronounced. The tidal constants for the four principal constituents from both analyses are given in Table 2. For the northerly component the effects are negligible, but for the easterly component they differ by as much as 60% in amplitude and 50° in phase. Small amplitude higher order constituents such as the quarter diurnal M4 are more sensitive to compass errors than K1 or M2.

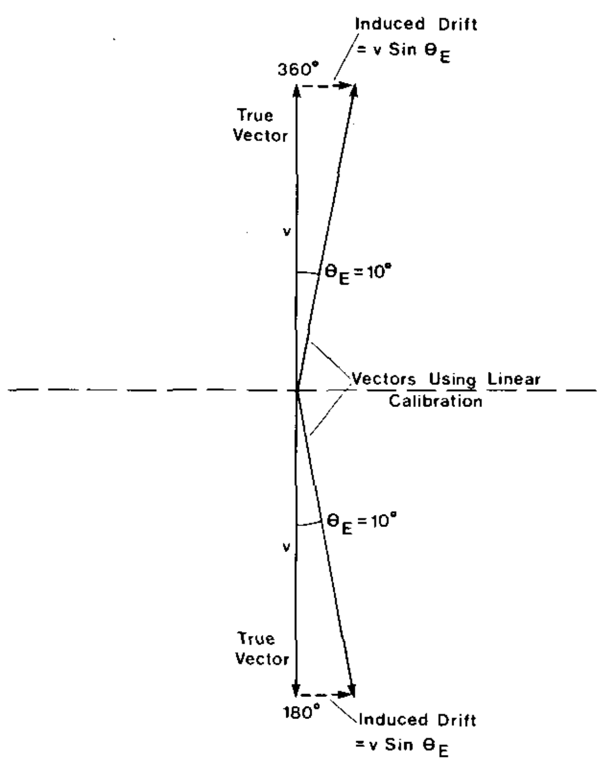

Fig. 5. Comparison of true north or south vector with vectors derived using linear compass calibration. The errors are labelled "induced drift".

A third area where compass calibration becomes important is in the estimation of the Reynolds fluxes $\overline{uv}$ where u and v are the two velocity components. For a current of magnitude r and bearing θ, the contribution to the Reynolds stress is $r^2 \cos\theta \sin\theta$. When a compass error θ_E exists, the corresponding contribution is

$$r^2\{\cos\theta \sin\theta (\cos^2\theta_E - \sin^2\theta_E)$$
$$+ \cos\theta_E \sin\theta_E (\cos^2\theta_E - \sin^2\theta_E)\}.$$

For cases when θ is small, as on a narrow continental shelf, the fractional error is approximately

$$(r^2 \cos\theta_E \sin\theta_E)/(r^2 \cos\theta \sin\theta) \approx \frac{\sin\theta_E}{\sin\theta}.$$

For topographic Rossby waves on the northern New South Wales shelf, a value of $\sin\theta$ of 0.074 is appropriate (Garrett 1979). Values of $\sin\theta_E$ can be of simular or greater magnitude if accurate calibration data is not available (e.g. for $\theta_E = 10°$, $\sin\theta_E = 0.17$) thus giving errors in measured momentum fluxes of over 100% in some circumstances.

CONCLUSION

The work completed indicates that the compass non-linearities are reasonably constant over a period of at least a year. Each compass was found to have its own characteristic curve which was not affected by degaussing the pressure case or by modifications to the pressure channel. Large errors in mean currents can result from compass non-linearities if the mean, or residual currents are small in comparison with the r.m.s. currents. Similarly, calculation of momentum fluxes can result in large errors if the mean flux is small in comparison with the r.m.s. flux.

For all future work using these meters, it is recommended that the pressure case be degaussed (to prevent permanent magnetism accumulating) and routine calibrations be made. For this work, a carefully designed and constructed table which could accommodate several meters would be desirable.

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CSIRO
Division of Fisheries and Oceanography

HEADQUARTERS
202 Nicholson Parade, Cronulla, NSW
P.O. Box 21, Cronulla, NSW 2230

NORTHEASTERN REGIONAL LABORATORY
233 Middle Street, Cleveland, Qld
P.O. Box 120, Cleveland, Qld 4163

WESTERN REGIONAL LABORATORY
Leach Street, Marmion, WA 6020
P.O. Box 20, North Beach, WA 6020