The Low-Frequency Drift of Paroscientific Pressure Transducers

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ABSTRACT

Sea Data pressure gauges were used in 1985 and 1986 in the central equatorial Pacific Ocean to record subsurface pressure. These gauges were equipped with Paroscientific Digiquartz pressure transducers which suffered mechanical failures leading to severe drifts in the records. Independent data are available to make direct determinations of these drifts for six out of a total of seven deployments. This note documents these drifts to provide a model of the drift characteristics for records where no independent data are available. The best model is a linear drift. The onset of the drift appears to be nearly coincident for all instruments, but the slopes vary considerably.

1. Introduction

As part of the Line Islands Array (LIA) project, Sea Data pressure gauges equipped with Paroscientific 0–100 psia Digiquartz transducers (model 2100-ASG) were deployed from February 1985 to June 1987 at four of the Line Islands (Fig. 1) to observe sea level variations. During these deployments, however, the pressure transducers suffered severely from drifts of between 0.3 and 0.6 dbar. The drifts were apparently caused by a mechanical failure of seals within the transducers that allowed diffusion of moisture into the evacuated interior of the sensor (Paros, personal communication 1988). The particular sensors that suffer from this problem can be recognized from the "ASG" designation.

One of the main objectives of the LIA project is to observe seasonal and interannual variability; the first 2 years of deployment cover the initial phases of the 1986–1987 El Niño/Southern Oscillation (ENSO) event, and it is critical to estimate the drifts accurately so that the records can be correctly compensated. Fortunately, independent data exist that can be used to estimate the drifts for six of the total of seven records.

This paper documents the drift removal done for the Line Island records. Its purpose is twofold. We would like to establish in the literature how the drifts in the Line Islands dataset have been removed, and that the drifts do not affect the high frequency variability. We also wish to document the functional form of the drifts to provide some justification for assuming drift functions where no independent checks exist. In addition to the LIA project, we had two Sea Data gauges exhibiting similar drifts deployed in the western Pacific under the WEPOCS program, and no independent data exist for these records.

Independent estimates of subsurface pressure were available at Palmyra Island from an inverted echo sounder record of dynamic height, at Fanning Island from a tide gauge record of sea level, and at Jarvis Island from an Aanderaa record of subsurface pressure. In addition, we estimate the drift at Malden Island from a GEOSAT altimeter record of sea level (Miller, personal communication 1988).

The drifts observed in these records tend to be linear (see section 3), agreeing with tests made by Paroscientific and several of their customers (Young, personal communication 1987). Where no independent measurement of a drift exists, one might thus estimate the drift from the linear trend in the record. Consequently, we test how well our measured drifts match the linear trends in the records. (We make the distinction here between the actual drifts of the instruments, and the trends in the records, which may also be affected by sea level changes.)

2. Uncorrected data

Figure 2 shows all seven LIA shallow pressure time series; the two deployments are denoted here as the 1985 and 1986 deployments, respectively. The series have been low-pass filtered with a Gaussian filter having 40 db attenuation at 24-hour periods. Least-squares fits of a trend having zero initial value and a constant slope after some onset time were made to each record, as shown. Two parameters are fit: the time of onset of the trend, and its slope as summarized in Table 1.

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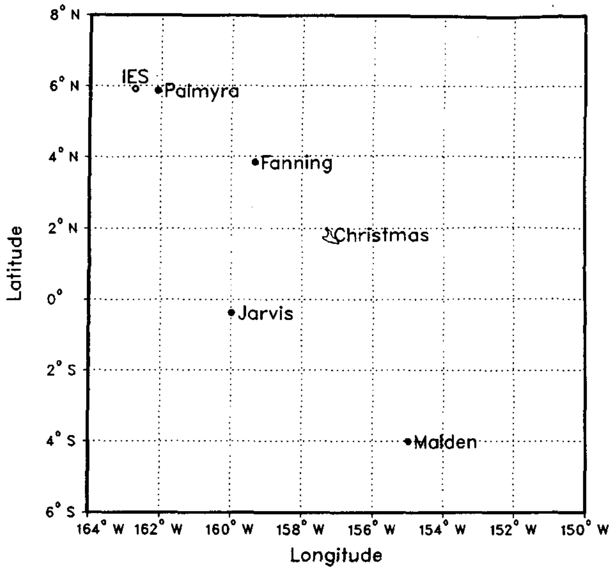

FIG. 1. Map showing locations of the Line Islands and 6°N IES (open circle).

3. Drift removal

a. Palmyra Island

Also as part of the LIA project, we deployed an inverted echo sounder (IES; Chaplin and Watts 1984) about 70 km from Palmyra Island. The IES measures the round-trip acoustic travel time from the sea floor to the sea surface, and variations in this travel time have been demonstrated to reflect changes in dynamic height (e.g., Watts and Rossby 1977). Chiswell et al. (1988) use the 1985 Palmyra Island records to estimate the calibration between travel time and dynamic height for this location; they obtain a calibration slope of −65 dyn m s^{-1} for the synoptic scale fluctuations (periods 20 to 40 days) and based on available CTD casts, state that this value is also valid for variability with longer time scales. We converted travel time to dynamic height using this value. This dynamic height was then subtracted from the Palmyra Island records to obtain the drifts; this is equivalent to assuming that there is a level of no motion at some depth deeper than the pressure gauges.

The resulting drifts for the Palmyra Island records (Fig. 3) appear linear, and least-squares fits were made to each drift as shown. The trends in the pressure series (i.e., those plotted in Fig. 2) have also been plotted for comparison. Travel time is primarily sensitive to baroclinic processes and the high frequency variability seen in the drifts is caused by barotropic signals (mostly the M_f tide), as well as the 70 km separation of the IES and pressure gauge.

The linear fits indicate that the 1985 drift started on 9 September 1985, and that the 1986 drift ended near 16 January 1987. The slopes of these drifts are statistically different from each other, but not different from the slopes computed from the trends (Table 1). The drift in the 1985 record would have been reasonably well estimated from the trend, although the onset would be wrong by about 1 month. The 1986 trend does not represent the 1986 drift well, illustrating how real low-frequency signals in the trend can mask the drift.

During the changeover in 1986, the new gauge was placed in the same container as the old one, so that the −0.15 dbar initial value of the 1986 drift indicates that the pressure gauge had drifted this amount before deployment. Extrapolating the 1986 drift backwards in time until it intersects zero drift suggests that the gauge began to fail about 1 month later than the 1985 gauge. The 1986 drift appears to have reached a maximum value of about 0.6 dbar.

b. Fanning Island

Figure 4 shows the drifts computed for the Fanning Island records using sea level measured from a tide gauge (installed as part of the Pacific sea level network, Wyrtki 1979), located 9 km from the pressure gauge. The approximately 0.05 dbar peak-to-peak high-fre-

TABLE 1. Least-squares fits to pressure trends and observed drifts.

			Pressure trends		Observed drifts	
		Depth (m)	*Slope* (10^{-3} dbar/day)	*Onset*	*Slope* (10^{-3} dbar/day)	*Onset*
Palmyra	85	3.9	2.82 ± 0.12	16 Oct 85	2.76 ± 0.04	8 Sep 85
	86		1.32 ± 0.04	6 Aug 86	1.27 ± 0.01	18 Oct 85*
Fanning	85	4.5	2.70 ± 0.11	27 Oct 85	2.00 ± 0.02	9 Sep 85
	86		1.94 ± 0.06	22 Dec 86	0.72 ± 0.01	14 Sep 85*
Jarvis	85	5.9	1.83 ± 0.04	9 Sep 85	n/a	
	86		0.95 ± 0.03	29 Sep 86	1.24 ± 0.01	—
					0.56 ± 0.01	30 Jul 86
Malden	86	7.6	1.99 ± 0.02	9 Oct 86	1.45 ± 0.02	24 Jul 86

* Extrapolated back in time (see text).

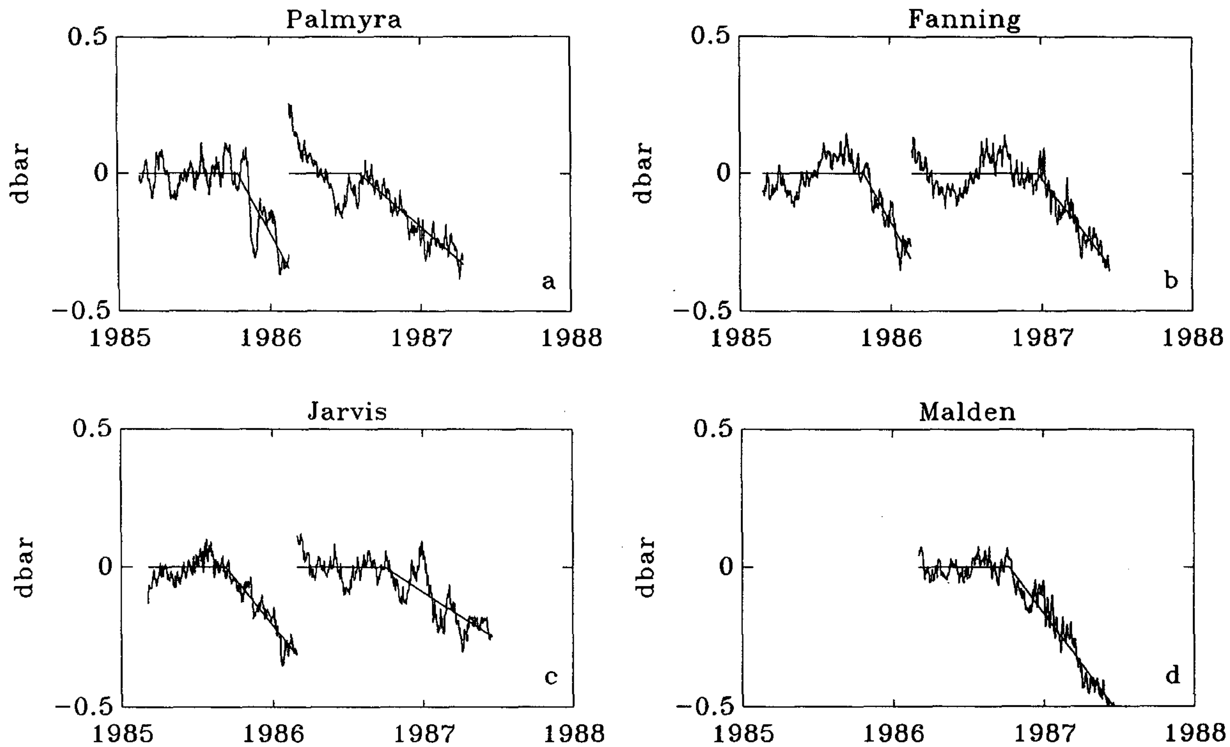

FIG. 2. Twenty-four hour low-pass filtered time series of pressure from the four Line Islands Array sites. Least-squares fits of a trend with constant slope after some time have been superimposed on each time series. Each series has been offset so that the trend has zero initial value.

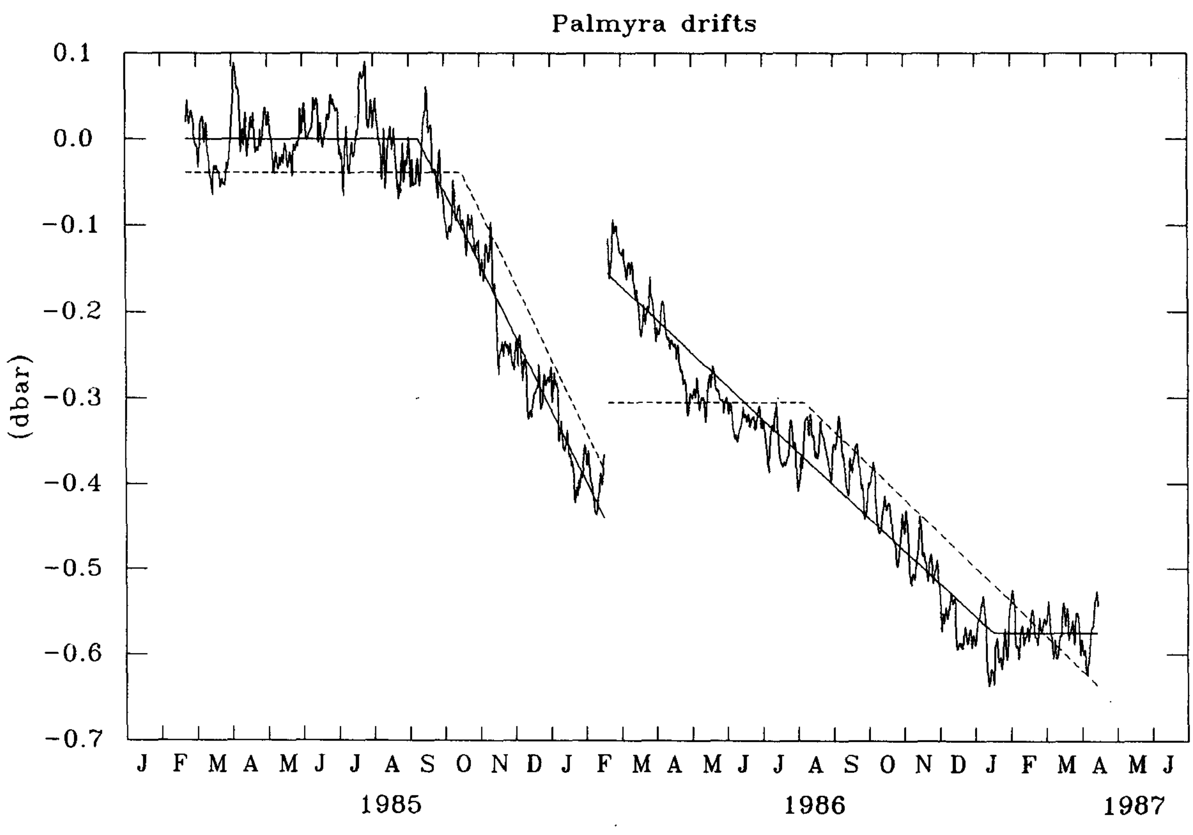

FIG. 3. Observed drifts of the Palmyra Island records, computed as the difference between the subsurface pressure and travel time from the IES scaled in accordance with Chiswell et al. (1987). Also plotted are the linear fits to the drifts (solid lines) and to the trends in pressure (dashed lines, also seen in Fig. 2). A constant pressure, equivalent to the mean depth of the pressure gauge, has been subtracted from each series so that the drift in 1985 has zero initial value.

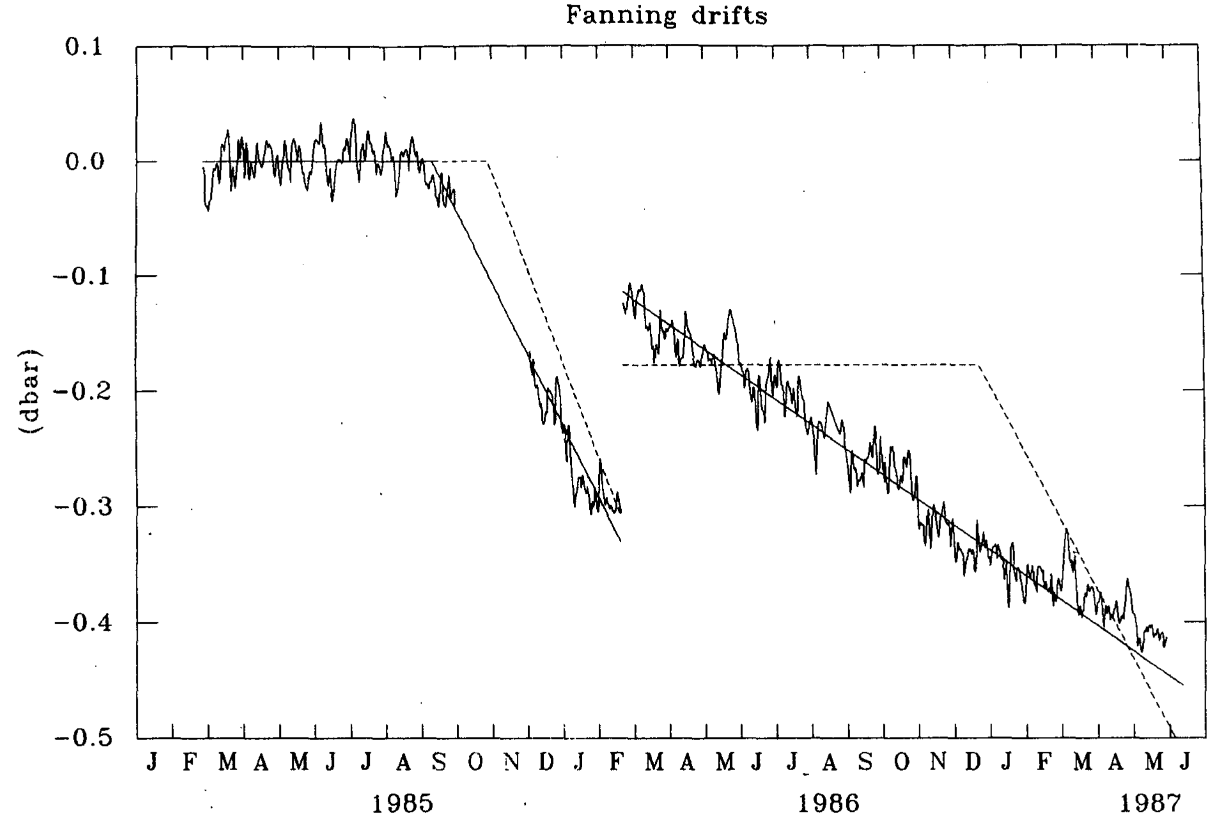

FIG. 4. Observed drifts of the Fanning Island records, computed as the difference between subsurface pressure and sea level from a nearby tide gauge. As in Fig. 3, linear fits to the drifts (solid lines) and to the pressure trends (dashed lines) have been plotted.

quency fluctuations in the drifts are mainly caused by atmospheric pressure variability. Unfortunately, a gap in the tide gauge data covers most of the period of the 1985 drift, although the drift appeared to start just before the break in data.

The two observed drifts are nearly linear. According to their least-squares fits, the 1985 record drift started within one day of the Palmyra Island drift. The 1986 drift started before the gauge was deployed; extrapolating it back in time indicates that it failed at the same time as the 1985 gauge (Table 1). The trend in the 1985 record approximates the drift, but the 1986 trend is substantially different, again due to the low-frequency content of the record.

c. *Jarvis Island*

At Jarvis Island, an Aanderaa subsurface pressure gauge was installed next to the Sea Data gauge. Unfortunately, the Aanderaa gauge failed in 1985, and we can only measure the 1986 drift.

The 1986 drift (Fig. 5) appears to consist of two linear segments, and started before deployment. The drift changed slope near 13 August 1986 and then appears to have stopped abruptly near 24 February 1987, reaching a maximum level of 0.579 dbar according to the post-deployment calibration. The drift is considerably different from the trend in the pressure record. It is not clear why the drift is two linear segments.

d. *Malden Island*

Laury Miller has provided GEOSAT altimeter data for a 8° long by 2° lat area centered around Malden Island. Figure 6 shows the Malden Island drift computed from this data. Again, the drift appears linear, but with large fluctuations having time scales from days to months. These fluctuations are probably a result of aliasing of synoptic-scale variability in the GEOSAT averaging. Unlike the other 1986 records, it appears that the drift at Malden did not start until after the gauge was deployed.

4. Corrected data

Figure 7 shows the corrected records and the independent checks, except for Jarvis Island, where we have shown the Christmas Island tide gauge record. This is because we have no check for the 1985 record, and historically, Christmas–Jarvis Island coherence is high (Wyrtki, personal communication 1988) so that the

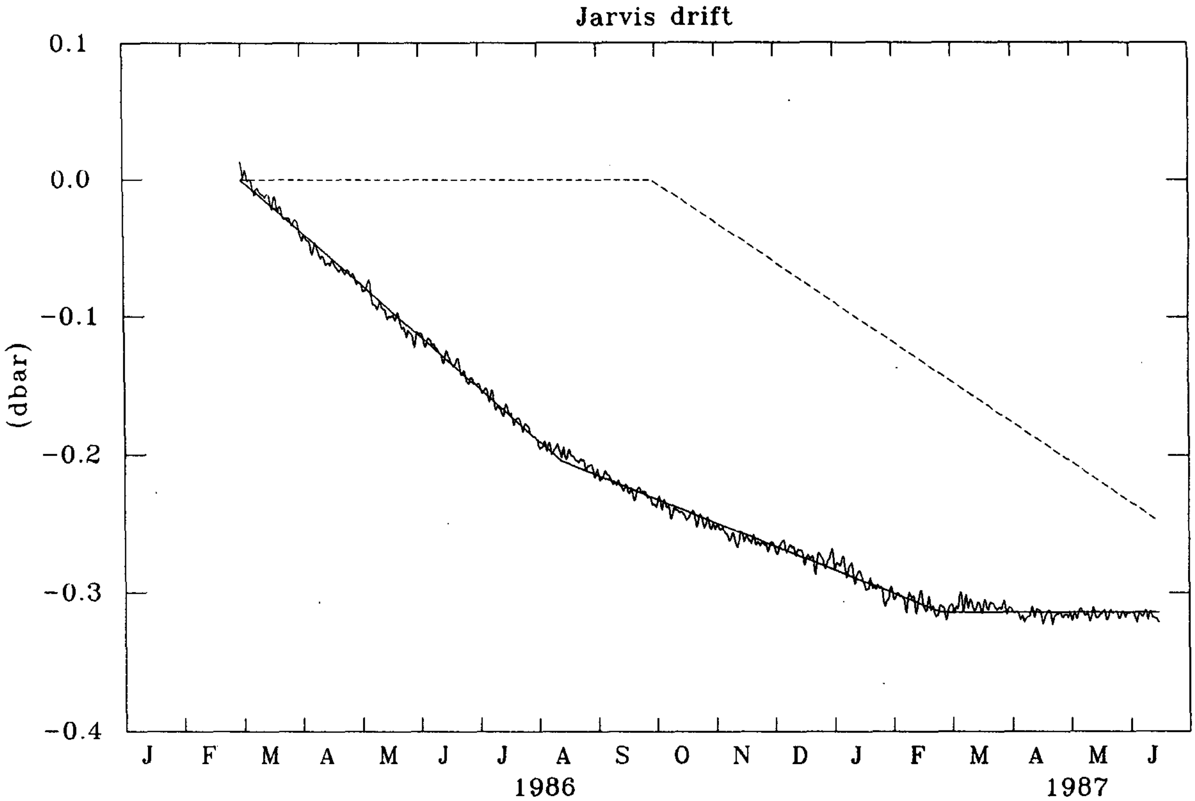

FIG. 5. Observed drift of the 1986 Jarvis Island record, computed as the difference between pressure measured by the Sea Data gauge and that from a nearby Aanderaa gauge. A least-squares fit with two linear segments has been made to the drift (solid line). Also plotted is the linear trend in the 1986 Jarvis Island record (dashed line).

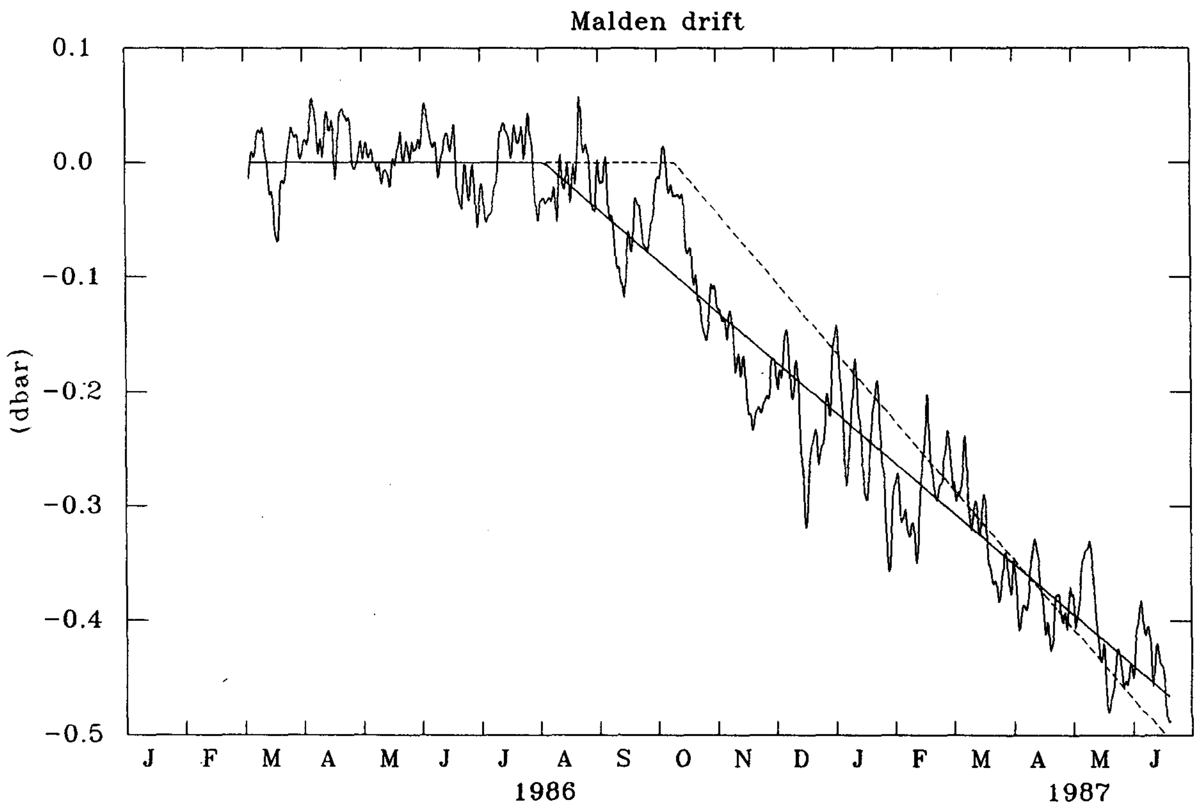

FIG. 6. The difference between the 1986 Malden Island record and sea level derived from GEOSAT altimeter data (Miller, personal communication 1988). The dashed line is the linear trend in the Malden Island record.

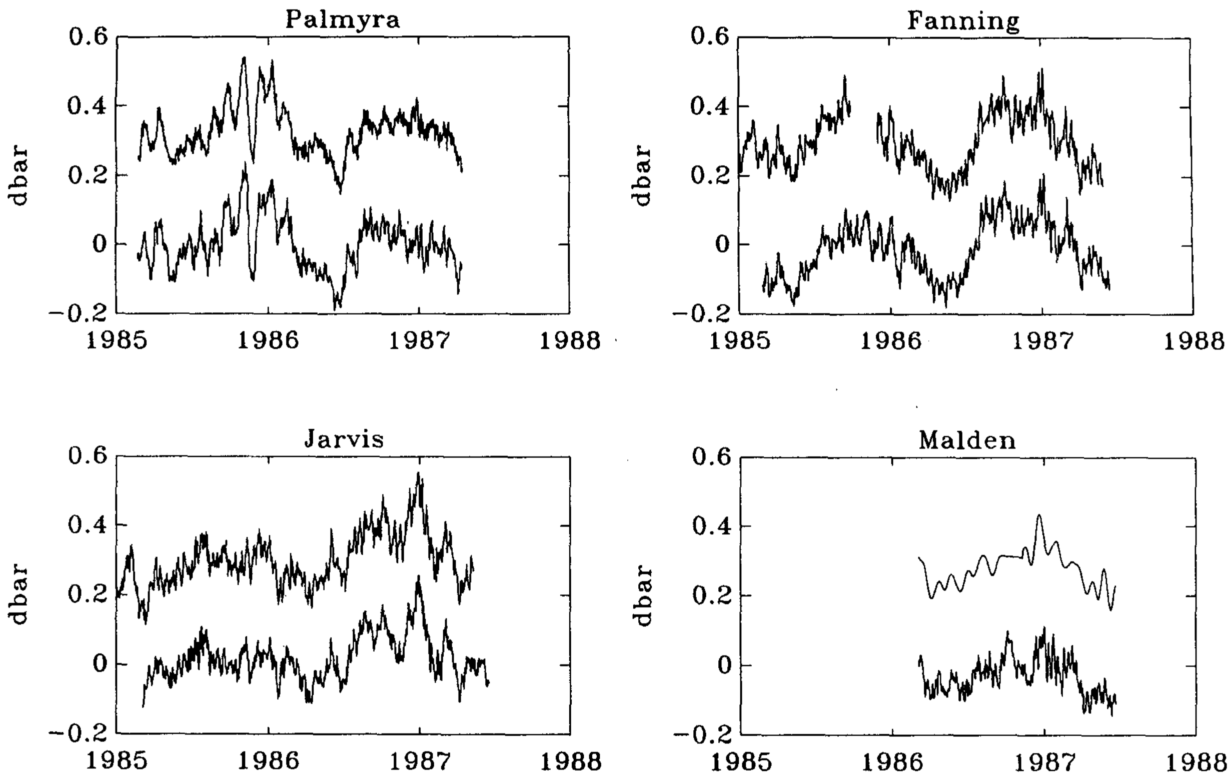

FIG. 7. Corrected pressure records. Also plotted, with 0.3 dbar offset (upper lines), are (a) at Palmyra Island, rescaled travel time; (b) at Fanning Island, sea level; (c) at Jarvis Island, Christmas Island sea level; and (d) at Malden Island, sea level derived from GEOSAT.

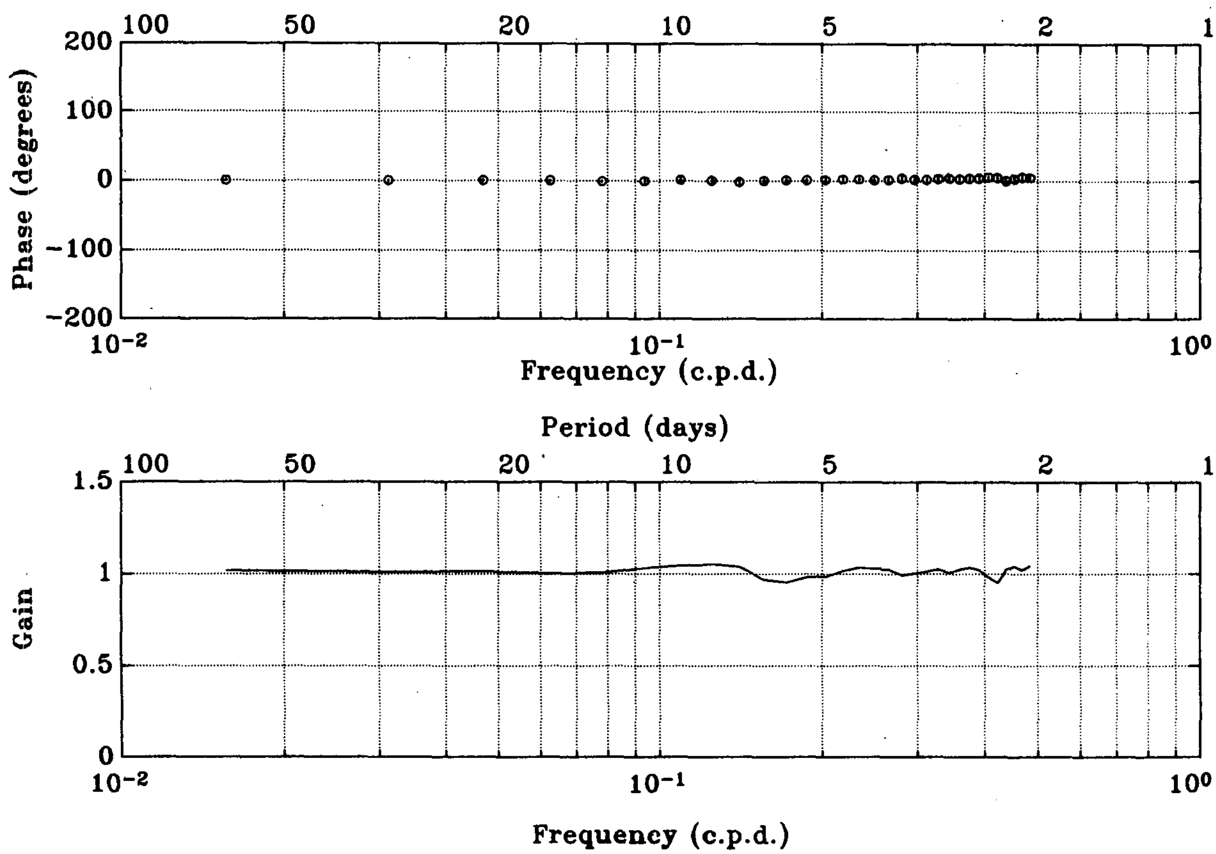

FIG. 8. Transfer function gain and phase computed between the corrected Sea Data record at Jarvis Island and the nearby Aanderaa record.

Christmas record provides a qualitative check on the dedrifting at Jarvis.

Post-deployment calibrations of the pressure sensors showed no measurable change in sensitivity, and this is well demonstrated by the transfer function (e.g., Jenkins and Watts 1968) computed between the corrected 1986 Sea Data record and the Aanderaa record (Fig. 8). The transfer function's gain is very close to one, and its phase is indistinguishable from zero degrees, indicating that the failures of the Paroscientific gauges have little, if any, effect on the sensors other than introducing a gradual change in level.

5. Conclusions

It is fairly clear that the failures of the ASG series transducers lead to linear drifts. The 1985 drifts are steeper than those in 1986, possibly because in 1986 the drifts had started before pressure was applied, but there is no apparent correlation between the slope of the drift and the applied pressure. With the exception of the Malden Island case, the onsets of the transducer failures show remarkable consistency. The 1986 Palmyra and Jarvis records show that the drift reaches a maximum value of about 0.6 dbar. The implications for correcting records where no independent checks exist are that a linear drift subject to a maximum value of 0.6 dbar can be fit with confidence.

The direct measurements of drift in 1985 agree reasonably well with the trends in the records, indicating that sea level itself had little trend from September 1985 to February 1986. Using the trend to correct the 1985 Jarvis Island record is thus reasonable, and the similarity between the corrected Jarvis Island and Christmas Island tide gauge records supports this. Of the seven Line Islands Array records, we have been able to remove the drifts accurately from six records, and have confidence that the drift removal done for the Jarvis Island record is valid.

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