SIO REFERENCE SERIES

74-11

SWAINS ISLAND TIDE MEASUREMENTS

April-May 1970

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1 May 1974

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Sponsored by:

The State of California through the University of California's
Marine Life Research Program

and

NOAA Office of Sea Grant, Department of Commerce
under grant #USDC 2-35208 to the University of California.

*research conducted while at Scripps Institution of Oceanography

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Tide records of about 30-day duration were obtained at Swains Island, an atoll located at 11°03'S 171°05'W. This atoll rises from the deep ocean and has an average slope greater than 45° for the upper 2000m. Two Gulf General Atomic STG/100 in situ pressure gauges (Filloux, 1970) were diver-placed in 13m of water. One gauge (GA6) obtained a record for the period from 0600 (GMT) 26 April to 2200 11 May and from 2200 12 May to 2100 26 May; while the other instrument (GA5) recorded from 0600 26 April to 2000 8 May 1970.

This tide data was high-passed and analysed for the M_2, S_2, N_2, K_1 and O_1 frequencies. No attempt was made to further split the lines. The results are presented separately (Table 1) for the two instruments. It is felt that the longer GA6 record is more accurate and a rough error estimate is given with those results. The method of analysis and a breakdown of the error analyses are presented in following sections.

Table 1. Amplitude (cm) and phase, G (degrees), for GA6 and GA5. (Error estimate included for GA6.)

	M_2	S_2	N_2	K_1	O_1
GA6					
amplitude	39.72±.39	9.60±.25	8.82±.13	4.53±.14	3.47±.12
phase	159±0	139±0	149±1	72±1	69±1
GA5					
amplitude	38.99	11.24	8.45	4.56	3.85
phase	160	138	137	74	75

DATA ANALYSIS

The data analysis is presented diagrammatically in steps A through F of Fig. 1. The discussion which follows will correspond to the steps outlined in the figure.

A. The pressure records on the analog readout from the STG/100 gauge were digitized at one-inch intervals (about 1 hr). Time calibration information at the beginning and end of each time series was used to time-correct the digitized data assuming a linear response of the drive mechanism.

B. The analog record of the recording barograph was likewise digitized at approximately one-hour intervals and then time-corrected.

C. These digitized barograph readings were then straight-line interpolated to the times of the STG/100 data and the barometric component of the "tide" record was removed. In this case the atmospheric correction was only a few percent of the ocean tide.

D. The discontinuity of gauge GA6 was connected by fitting both segments of the record to the sinusoidal function:

$$y(t) = \sum_i A_i \cos(w_i t + \phi_i) \qquad (1)$$

where the tide lines M_2, S_2, N_2, K_1, O_1 and P_i were arbitrarily chosen for the W_i. In addition to the sinusoidal function, a variable C was added to the second half of the fit. The A_i, ϕ_i and the constant C were then calculated in a least squares sense. This gave a displacement, C, which best related the two segments of record.

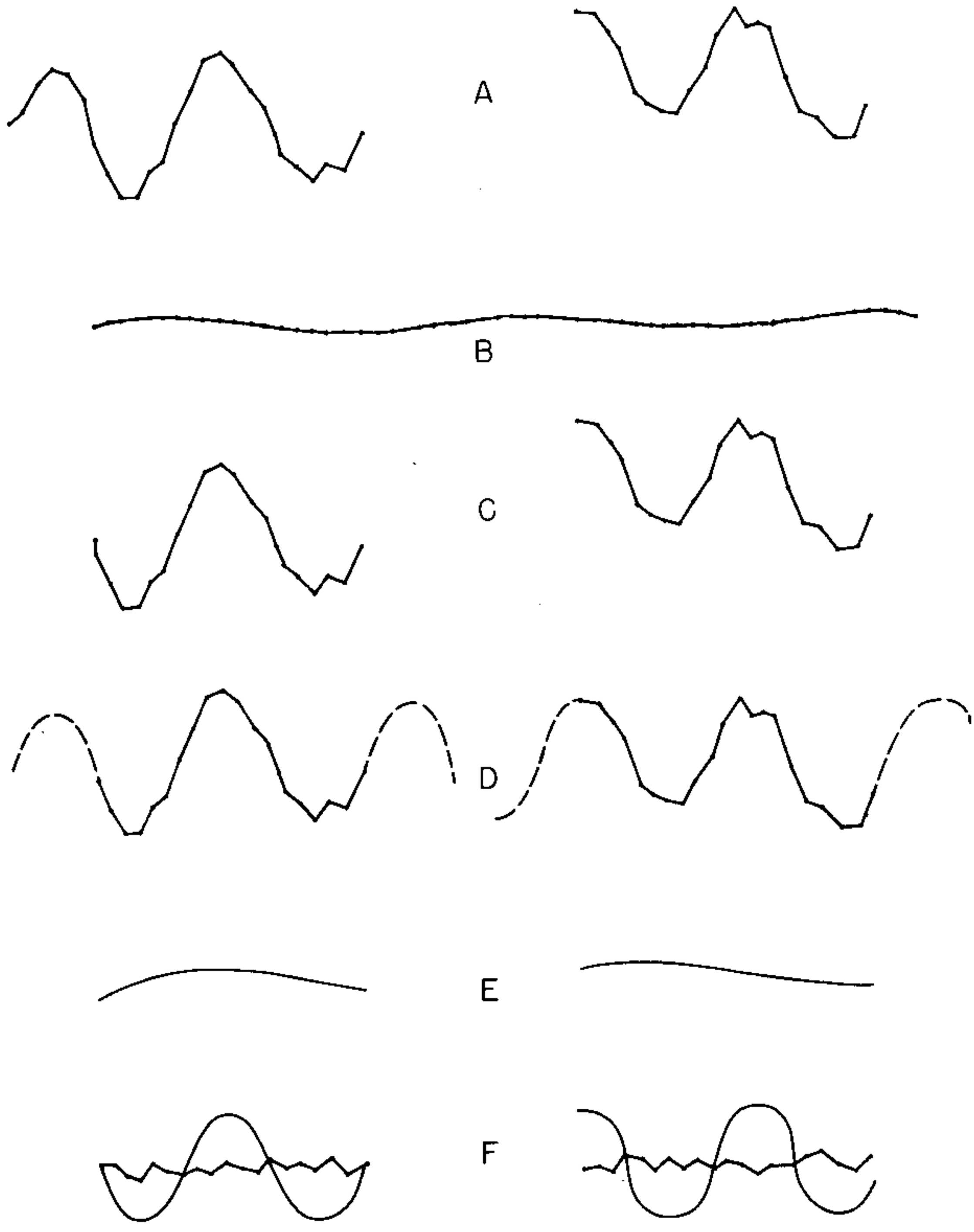

Figure 1. Schematic of tide analysis procedure.

The tide records were then extended 12 hours at all end points and missing internal data was patched by a least square harmonic fit to M_f, M_2 and S_2.

E. This extended and patched record was then low-pass filtered with a 25-hour (25 point) running mean filter to yield a low-passed record of the same length as the original one.

F. The low-passed signal was subtracted from the unextended, non-patched record to give a high-passed signal. This was then given a least square harmonic fit to the five tide frequencies, M_2, S_2, N_2, K_1 and O_1, to yield amplitude and phase lag predictions for those lines. The predicted curve was subtracted from the high-passed data.

Figure 2 shows the barograph record, the unfiltered tide data, and the high-passed data along with the residuals after the M_2, S_2, N_2, K_1 and O_1 fit has been removed.

Power spectra of the edited (but not patched, extended or high-passed) data for GA5 and GA6 are shown in figures 3 and 4.

ERROR ANALYSIS

Errors in the calculated amplitudes and phases are due to errors in recording the water level and errors introduced in analyzing the record.

Recording errors include time keeping, time and height digitization, barograph errors and calibration errors. All except calibration errors are considered random. The random noise was estimated (Lam 1971) and this estimate compares favorably with the power spectrum of the residual after

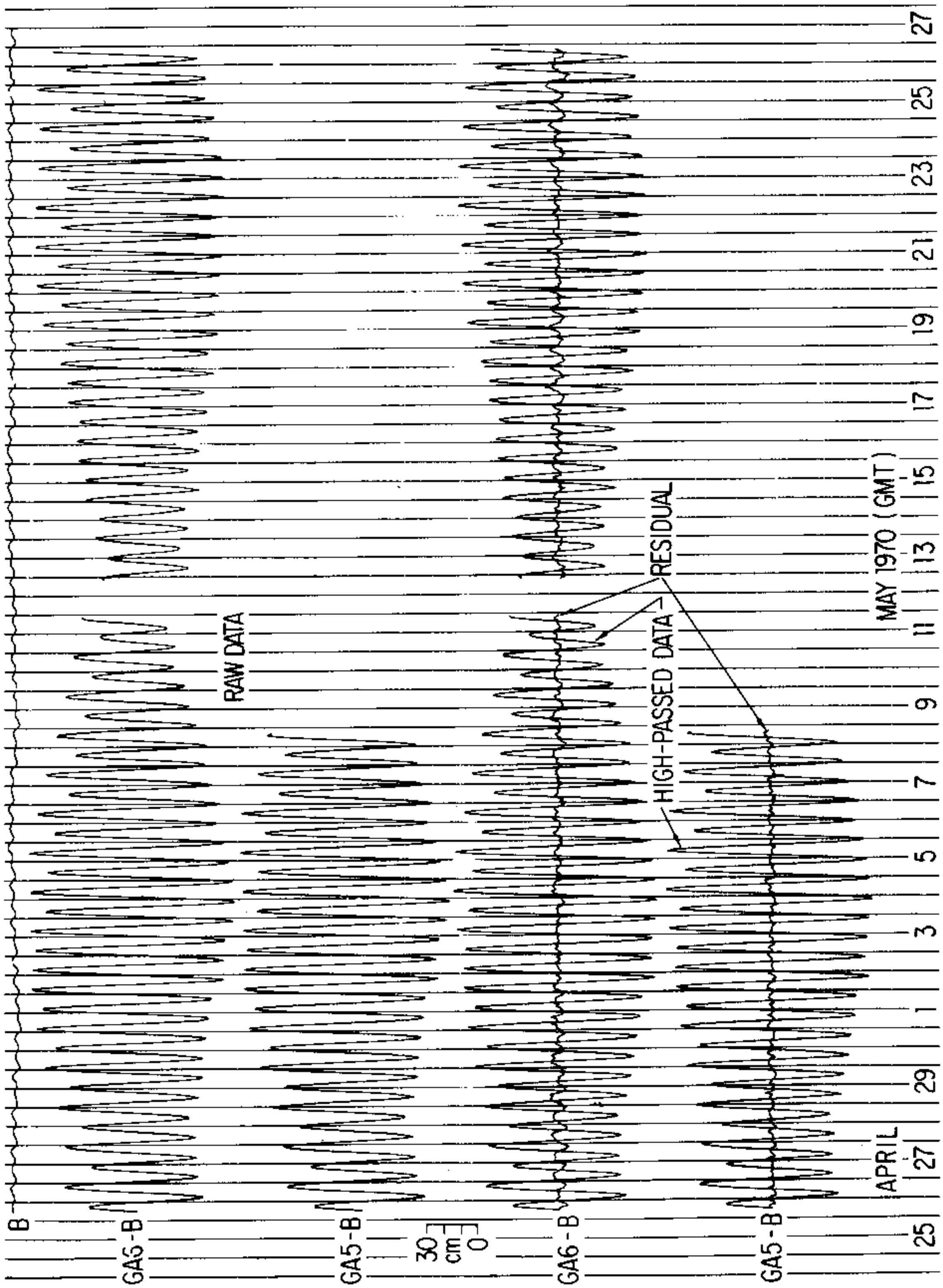

Figure 2. Time series in equivalent height of seawater of barograph record (B), of unfiltered (raw) tide data with atmospheric pressure removed (GA6-B and GA5-B), and of the high-passed data and residuals (also GA6-B and GA5-B).

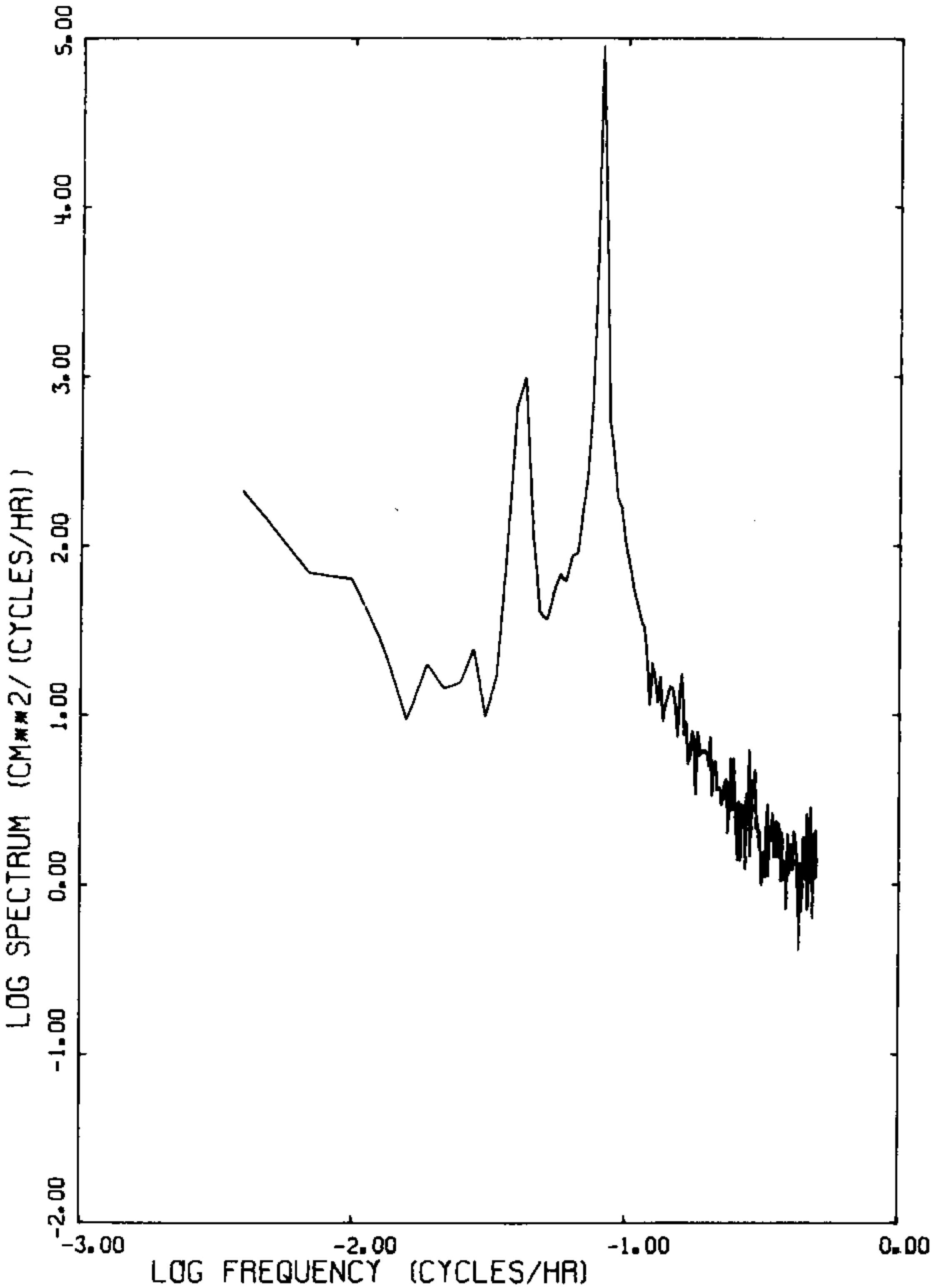

Figure 3. Power specturm of GA6 tide height. 6 degrees of freedom.

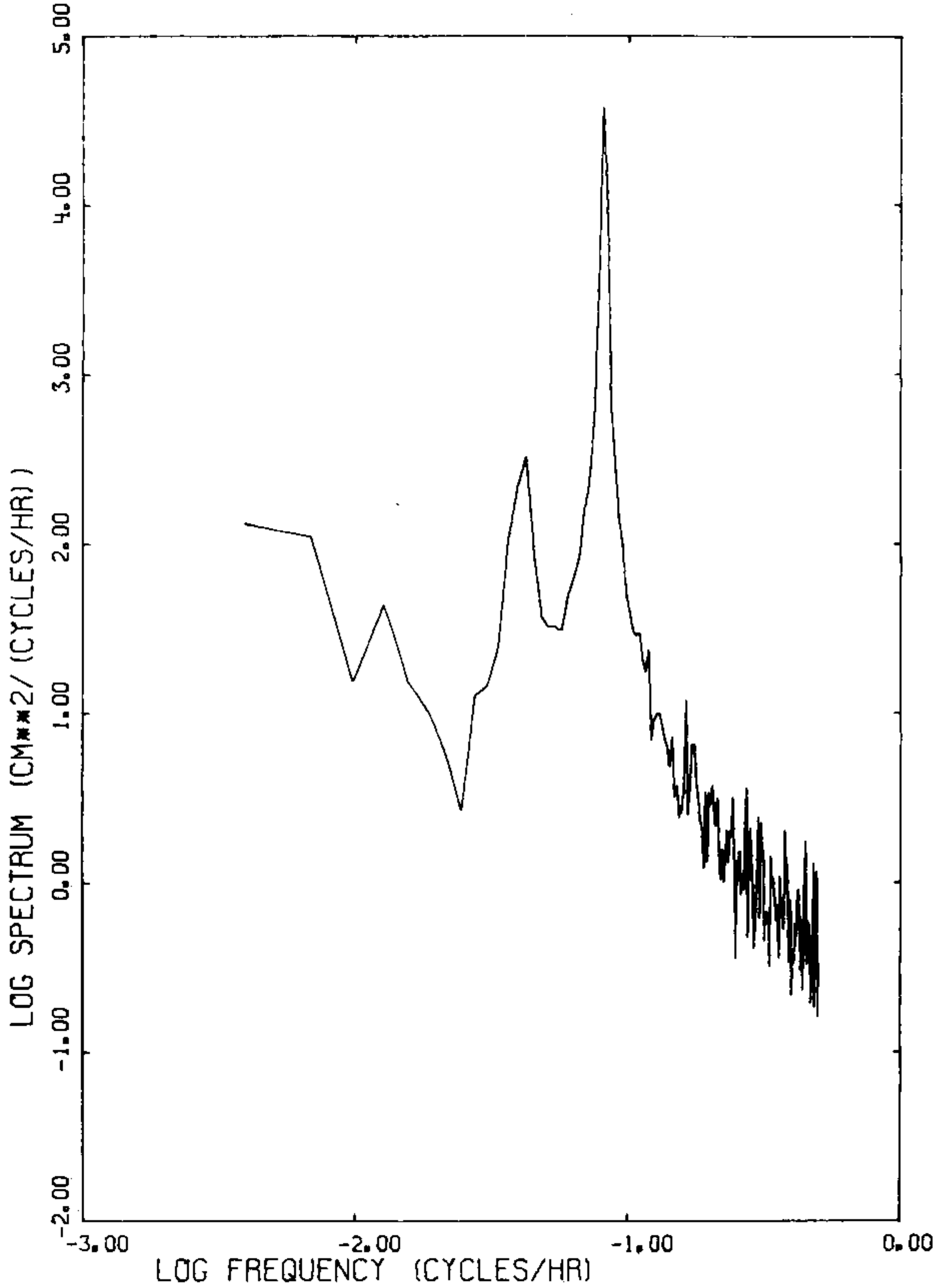

Figure 4. Power spectrum of GA5 tide height. 6 degrees of freedom.

the five tide lines had been removed from the record (Figs. 5 & 6). Normally distributed noise having a variance commensurate with the estimated noise was added to an artificial series composed of the five pure tidal lines. This series was refit. This introduced an error of at most one least-count unit. The effect of this on the final error estimate is negligible.

The STG/100 gauges were calibrated by putting known changes of water pressure on the instruments and looking at the corresponding changes in the record. Eight readings for GA6 gave:

$$2.48 \pm .02 \ \frac{\text{cm of seawater}}{\text{chart division}} \qquad \text{(99\% confidence)}$$

and eight readings for GA5 gave:

$$2.35 \pm .03 \ \frac{\text{cm of seawater}}{\text{chart division}} \qquad \text{(99\% confidence)}$$

These percentage errors were assumed to apply to the tidal amplitudes of all constituents. To the extent that this is purely a height error, no errors are introduced in the phase.

Errors introduced in the analysis include neglected neighboring frequencies, neglected harmonics and low frequency effects. An estimate of the error introduced by neglecting neighboring lines with smaller energy was made by fitting successively greater numbers of tidal constituents and observing how the values of the lines of interest changed. A representative value for this error was taken to be the maximum deviation between the 5 component fit and fits up to 11 tidal lines. Because of its shorter record, GA5 became unstable for larger number of lines so that an accurate estimate of its error was difficult.

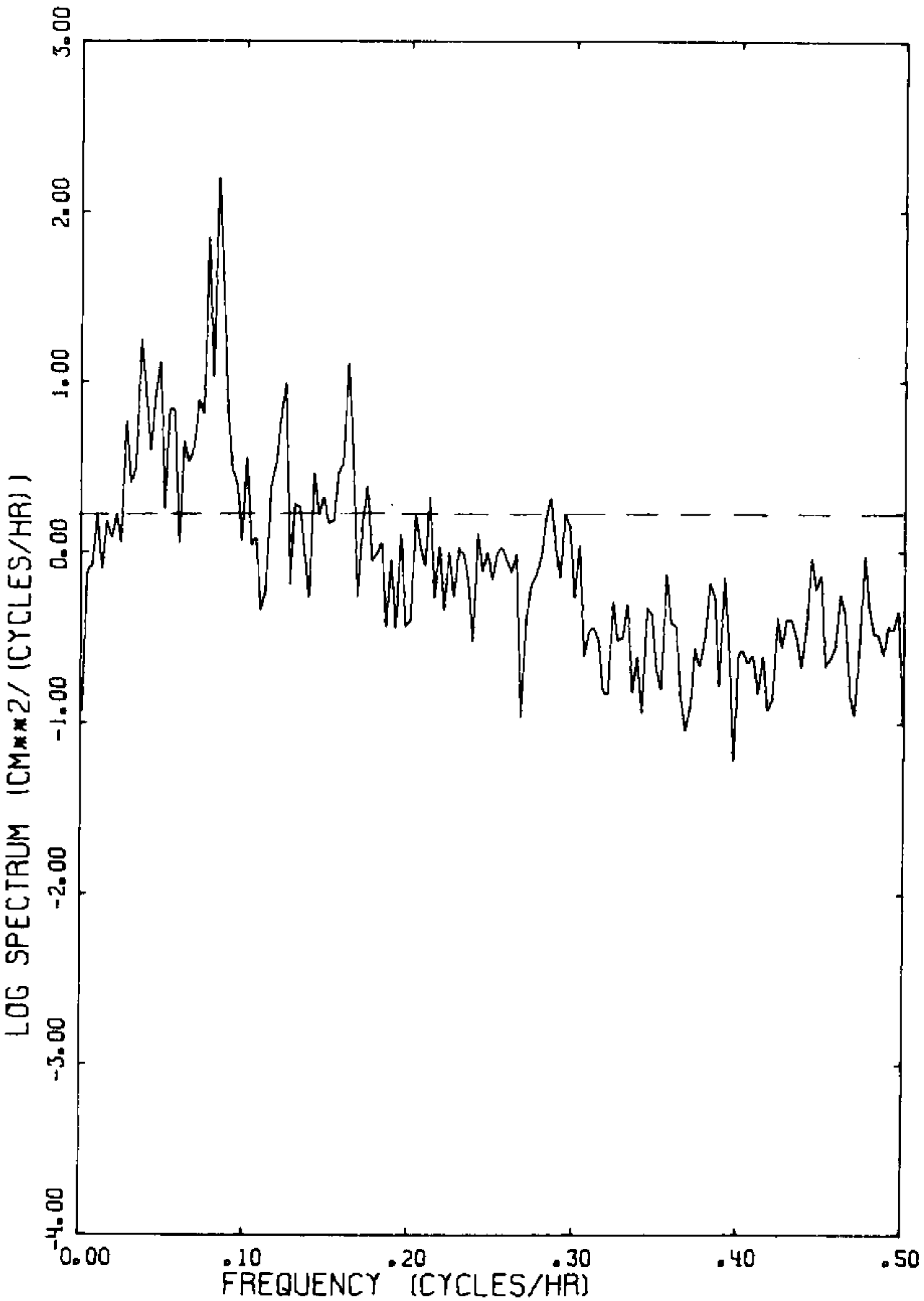

Figure 5. Power spectrum of GA6 residual. A 25-hr running mean and a M_2, S_2, N_2, K_1, O_1 fit has been subtracted from the data of Figure 3. 6 degrees of freedom. Dotted line gives the estimated random error.

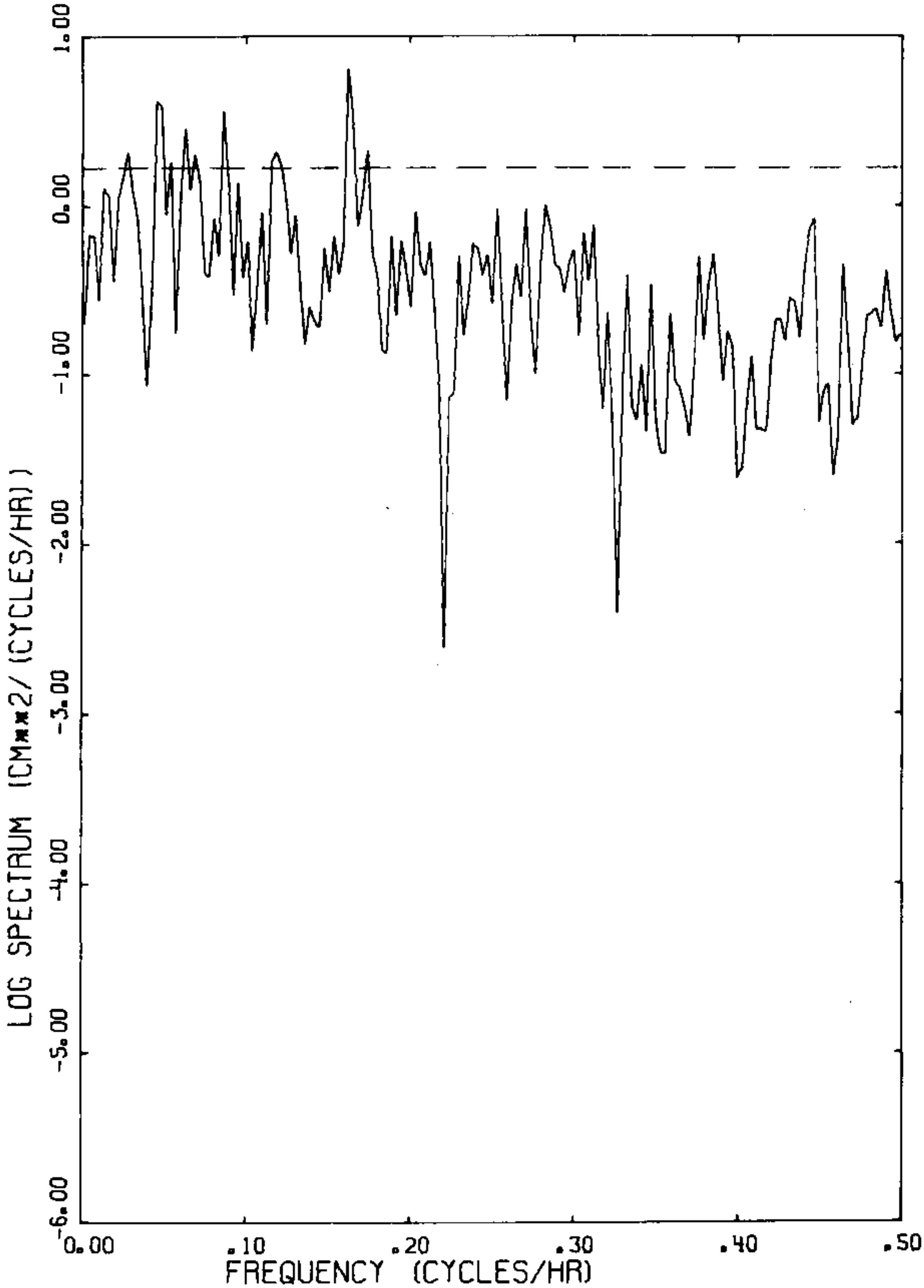

Figure 6. Power spectrum of GA5 residual. A 25-hr running mean and a M_2, S_2, N_2, K_1, O_1 fit has been subtracted from the data of Figure 4. 6 degrees of freedom. Dotted line gives the estimated random error.

Table 2. Error estimates of amplitude (cm) and phase (degrees) for GA6 and GA5. See text for discussion.

		Random errors		Calibration	Neighboring lines		Harmonics		Low frequency		Compound	
		amp	phase	amp	amp	ang	amp	ang	amp	ang	amp	ang
	M_2	0	0	.32	.11	0	0	0	.17	0	.39	0
	S_2	0	0	.08	.02	0	0	0	.24	.3	.25	0
GA6	N_2	0	0	.07	.08	.6	0	0	.07	.3	.13	1
	K_1	0	0	.04	.09	.6	0	0	.10	.6	.14	1
	O_1	0	0	.03	.11	.6	0	0	.05	.9	.12	1
	M_2	0	0	.44			0	0	.12	.3		
	S_2	0	0	.13			0	0	.21	.3		
GA5	N_2	0	0	.10			0	0	.10	1.2		
	K_1	0	0	.05			0	0	.17	.9		
	O_1	0	0	.04			0	0	.11	.6		

Energy in the harmonics of the 1 and 2 cycle for day tides, though real, enter the values of the fit as noise. Frequencies near 4, 5 and 6 cycles for day were added to the 5 frequencies of interest and the data refit. This introduced an insignificant change (Lam 1971).

The low frequency energy was removed from the record by using a running mean filter. This resulted in less variance in the residual than if the low frequency were removed with a decaying exponential. In order to estimate the possible error introduced by our particular method of removing the low frequency signal, results were compared between the two above methods and a case where the low frequency was left in. The compounded results, at 99% confidence, are used in the error analysis.

Table 2 is a tabulation of the errors for both gauges and the 5 tide lines, M_2, S_2, N_2, K_1 and O_1. The compounded error is also shown for GA6. In the case of GA5, inclusion of "neighboring frequency error" was felt to be unrealistic since that is a greater measure of the error due to the additional lines and not as good an indication of the error in the original 5 lines. Still, it is felt that the differences between the two instruments is due mainly to the instability of the shorter GA5 record.

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Filloux, J. H. 1970. Deep sea tide gauge with optical readout of Bourdon tube rotations. Nature, 226: 935-937.