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CURRENT PROFILES

by Ted Pochapsky and Frank Malone

Unexpectedly strong echoes upset the simple procedures used to measure the distances of free floats from bottom-anchored transponders in the 1972 experiments off R/V Eastward at 28°N 68°40'W (Hot Line News No. 15). Analyses have been confined to determining horizontal displacements of floats over fairly large depth intervals during the ascent and descent of floats. No correction was made for the variation of sonic velocity with depth. Certain features of the results suggest more thought on possible experimental errors. Nevertheless, these preliminary results are at least a good approximation to actual conditions and so are useful to know at this time.

The horizontal trajectroies are illustrated in Figure 1. Depths, in km, are marked along the plots. Only two transponders, 3.9 km apart, were used. Floats descended at a rate near 1 km per hour; ascent speeds were a little higher. Drops 1 and 2, made on 23 August, returned prematurely. The former went to a depth of only 490 m and then returned to the surface; points shown in the figure for this are 1 minute, or approximately 20 m in depth, apart. Similarly, dense points are shown for the first 500 m depth of drop 2. Data for the ascent of drop 2 were obtained only during the initial portion of the ascent. The other three drops went to the sea floor at 5300 m; only drop 3 of these yielded data on ascent. Data points in these

(continued page 2, column 1)

CORRELATIONS BETWEEN INTERNAL WAVES AND MEAN CURRENTS

by Peter Müller

Frankignoul[1] and McWilliams[2] found correlations between internal wave energies at stations far separated whereas they found no correlations--at these separations--in amplitude. There are two explanations for these findings. Either they tracked single internal wave events or the internal wave field interacts with and is modulated by a larger scale field. In the latter case, the modulating field can be detected by correlating the high-frequency internal wave energy with low-frequency fields (bispectral analysis).

Several models for wave-current interactions exist. The theory reported by the author in Hot Line News No. 32 is one. The general result of this theory is that the modulation of the internal wave field is a linear non-local functional of the spatial gradients of the mean flow.

(continued page 2, column 2)

SECOND MODE LEG OF R/V TRIDENT

by Rich Scarlet

Trident Leg II departed Bermuda on 9 May with 2 computers, 3 STD's, 4 Rossette samplers, 75 reversing thermometers, and 100 Niskin and Nansen bottles. Sixty-six successful density stations were taken in and around the MODE area with all equipment working well.

Trident returned to Bermuda on 1 June, having completed her work for MODE-I.

CURRENT PROFILES (continued)

latter drops were selected at ten-minute intervals, or 150 to 200 m apart in depth. The quality of the data hastily extracted from drop 4 was poor relative to that for the other drops. Otherwise, times were correct to better than a millisecond. Drops 3, 4, and 5 were made on 24, 25, and 26 August, respectively; the ascent of drop 3 occurred early on 25 August.

The average velocities for all the trajectories--to ten percent or so--over large depth intervals are:

depth range (km)	velocity (cm/sec)	direction
0 - .25	36	SE
.25 - .50	45	SE
.50 - 1	19	SE
1 - 2	7.7	S
2 - 3	6.5	SW
3 - 4	5.8	SW
4 - 5	8.0	WSW
5 - 5.3	13	WSW

At a depth of 4800 m the negative temperature gradient started to increase pronouncedly, and temperatures near the sea floor were approximately 0.1°C lower than would be present if the gradient did not increase--a manner of behavior in this region already noted by others. Such a character at lower latitudes is associated with north-flowing Antarctic Bottom Water (AABW). In the present case there is an appreciable increase in the current at lowest depths, but the flow was directed almost due west during these tests.

Below a depth of 1 km, currents were approximately 7 cm/sec. A hasty comparison with Tom Rossby's results over much longer times near a depth of 1.5 km indicates that his values varied typically from 2 to 6 cm/sec with directions changing abruptly at times.

CORRELATIONS BETWEEN INTERNAL WAVES AND MEAN CURRENTS (continued)

The cross-spectrum, Γ_{ij}, of the internal wave field can be written as a function of frequency, ω:

$$\Gamma_{ij}(\omega) = C_{ij}(\omega) - iQ_{ij}(\omega)$$

$$= \int_{-\infty}^{+\infty} d\tau < u_i(t)\, u_j(t+\tau) > e^{-i\omega\tau}$$

The spectrum can be estimated with values of u, corresponding to velocity or temperature components from moored current meter and temperature records. Here, the complex cross-spectrum, $\Gamma_{ij}(\omega)$ is composed of the co-spectrum, $C_{ij}(\omega)$ and the quadrature spectrum, $Q_{ij}(\omega)$. Note that i and j take the values 1, 2, or 3, corresponding to the three cartesian axes.

The theory proposes that there will be correlations between the spatial gradients of the mean current, $\bar{u}$, and some of the cross-spectral components. The correlations are derived under the assumption that the mean internal wave field is horizontally isotropic and that the mean flow is geostrophically balanced. We expect to find correlations between:

(i) $C_{11} - C_{22}$ and $\partial_1\bar{u}_1 - \partial_2\bar{u}_2$

(ii) C_{12} and $\partial_1\bar{u}_2 + \partial_2\bar{u}_1$

(iii) C_{13}, Q_{23} and $\partial_3\bar{u}_1$

(iv) C_{23}, Q_{13} and $\partial_3\bar{u}_2$

All other co- and quadrature spectra, especially $C_{11} + C_{22}$, should not correlate with the mean flow. The correlations should be better with smaller relaxation time.

References

[1]Frankignoul, C. J. and E. J. Strait Correspondence and vertical propagation of the inertial-internal wave energy in the deep sea. Mémories Soc. Roy. Sci. de Liège (in press).

[2]McWilliams, J. (1972) Observations of kinetic energy correspondences in the internal wave field. Deep-Sea Res., 19, 793-811.

THE INTERNAL WAVE EXPERIMENT (IWEX)

by Mel Briscoe

MODE-I is an experiment to look at sub-inertial-frequency motions. The Internal Wave Experiment (IWEX) is designed to study a higher frequency range. A goal of the experiment is to obtain a four-dimensional energy spectrum (in frequency and three components of vector wavenumber) for the internal motions between inertial and Brunt-Väisälä frequency, primarily in the main thermocline in the MODE-I region.

MODE-I and IWEX are symbiotic: IWEX is attempting to describe those motions which will be parameterized from the point of view of MODE-I, whereas MODE-I gives excellent information on the large-scale environment external to the inertio-gravity waves.

A three-legged mooring will be set near the MODE-I site mooring from August through October of this year. The apex float will be at a depth of 600 m. Figure 2 is a schematic of the proposed geometry of the "tri-mooring". Vector-averaging current meters (VACM's)--modified to carry a vertical temperature gradient sensor in addition to the sensor for absolute temperature--are the main instruments on the mooring. Seventeen of these M-VACM's will be located in a three-dimensional array in the 600-m to 1000-m depth range. Horizontal and vertical instrument spacings will varry from about 2 m to 400 m. Other instruments, such as Geodyne Model-850 current meters, Wunsch/Dahlen pressure-temperature recorders, inclinometers, and tension meters are located at various depths to give engineering data on the dynamics of the tri-mooring.

The choice of wire rope sizes, buoyancy elements and distribution, and predicted motion/stability were based on a computer program (Skop and Kaplan) that was prepared after the Sea Spider mooring set in 1965. The final design for the tri-mooring is a light, compliant structure, rather than the heavy, rigid style of Sea Spider. It will be set from R/V Knorr using a supplementary surface mooring to tie off one leg until the others are implanted. An acoustic navigation system working from three bottom-mounted transponders will be used to assure precise relative positioning of the three anchors.

Much has appeared in the MODE Hot Line News about the effects of microstructure on moored measurements, especially of temperature. These studies are of importance in IWEX because the vertical current at each M-VACM will be estimated from the ratio of time derivative of temperature to vertical gradient of temperature. Numerical simulations of this procedure by Terry Joyce have shown that the technique is effective.

Nevertheless, prior to the late-October recovery of the tri-mooring, there will be about two weeks of on-site science from Knorr. During that period, several Voorhis-Webb vertical current meters (VCM's) will be deployed to provide a comparative estimate of the vertical currents.

The data processing for IWEX will consist of standard analysis, culminating in extensive cross-spectra. The advanced analysis will consist of attacks on the inverse problem, culminating with a specification of the best-fit internal wave spectrum that gives the measured field of fluctuations. In many ways the analysis and ideology are similar to those used by Garrett and Munk to obtain their model spectrum for internal waves.

Within IWEX there is interest in self-interactions of the internal wave field and interactions with the larger-scale "mean" flow. IWEX is not expected to answer all these questions, but it is hoped that the design of future experiments to this end will be aided by the IWEX data set.

Reference

Skop, R. A. and R. E. Kaplan (1969) The static configuration of a tri-moored, sub-surface, buoy-cable array acted on by current-induced forces. NRL Report 6894.

NOTE

It is intended to set the IWEX array 40 km southwest of the MODE central point (28°N 69°40'W), although the precise position will not be decided until August.

Due to the complexity of the mooring, all ten AMF release receiver channels and all three commands on all of the channels will be used. If you intend to leave gear which uses AMF acoustic release equipment in the MODE area after 1 August, contact Don Moller, WHOI (617) 548-1400, ext. 458.

THIRD MODE LEG OF R/V HUNT

by Wendell Brown

The third MODE cruise of the R/V Hunt began on 8 May. The mission was to service many of the bottom instruments deployed during Hunt Leg I in March. In addition, Bob Harvey of the University of Hawaii was along to deploy his instrumentation for measuring the vertical component of the electric field gradient in the bottom 300 m of ocean. Others aboard the Hunt for the first time included Walter Munk (IGPP), Dick von Herzen (WHOI), Ken Yasi (WHOI), and Stan Wilson (ONR).

After a planned mid-morning rendezvous with Discovery to exchange laundry and mail, the Hunt proceeded towards the position of MODE mooring 20 where we expected to recover an SIO electric field instrument. As we came within five miles of the recovery site on 10 May, it became apparent that something was wrong because we could make no radio contact with the instrument, which should have been floating for nearly ten hours. It was raining during this time, and citizen band noise levels were higher than usual. The search was abandoned after a few hours, and the Hunt headed for the next scheduled station at the position of MODE mooring 11.

During the next five days six bottom instruments were recovered with the apparent loss of one SIO electric field instrument at MODE mooring 20 and one SIO magnetometer at MODE mooring 1. The IGPP capsule, EDIE, was recovered at MODE mooring 11 because both bottom pressure sensors had failed.* EDIE was deployed a day later in the same location. Another IGPP capsule, REIKO, was recovered to replace the bottom pressure sensor which had failed during the launch in March. REIKO was redeployed at MODE mooring 1. An attempt to recover IGPP capsule MERT at mooring 1 was made because we failed to make acoustic contact. Though this attempt failed, we should be able to recover MERT when the backup timer releases on 12 July during Hunt Leg V.

Dick von Herzen suffered an agonizing 2 hours between the time he commanded acoustic release of his magnetometer at mooring 5 and the time it finally left bottom. A post-recovery checkout indicated possible AMF release problems were associated with the delay. The captain, who serves as the radio operator aboard the Hunt, reported to the MODE Hot Line Center that "Dr. von Herzen held Sunday services for the thankful return of his magnetometer". In spite of these problems, data records were recovered from two IGPP capsules, three SIO electric field instruments, and the WHOI magnetometer.

Between 11 and 18 May, ten instruments were successfully deployed at moorings 1, 5, 11, and 20. Table 1 details these operations. Acoustic diagnostics indicated that all sensors were functioning aboard both REIKO and EDIE five days after launch. We will have to wait until Hunt Leg V to once again assess the results of these deployment operations. After a bottom survey of REIKO's position during 18 May, we returned to Bermuda.

*One pressure record is six days long; the other is 21 days long out of a possible 50 days.

Table 1

Instrument	Launch Date	Position Latitude N	Position Longitude W	Timed release date (GMT)	
Hawaii electric field #1	11 May	27°08.5'	69°32.0'		8 Jul
IGPP capsule EDIE	12 May	26°27.8'	69°19.6'	1200	14 Jul
SIO magnetometer #2	13 May	27°50.6'	70°40.3'	1450	10 Jul
Hawaii electric field #2	14 May	27°57.4'	68°39.2'		5 Jul
IGPP capsule REIKO	14 May	27°58.6'	69°40.4'	1200	12 Jul
Hawaii electric field #3	15 May	27°50.7'	70°40.5'		6 Jul
SIO electric field #1	15 May	27°51.2'	70°40.0'	0600	6 Jul
SIO electric field #2	16 May	27°08.5'	69°32.7'	0600	8 Jul
WHOI magnetometer	17 May	27°08.9'	69°31.8'	1130	11 Jul
SIO electric field #3	18 May	27°57.8'	69°38.3'	0600	7 Jul

MODE LEGS I, II, AND III OF R/V RESEARCHER

by Ants Leetmaa

Leg I

Researcher left Miami on the morning of 7 March for the MODE area with four projects onboard: (1) STD program (AOML); SOFAR float program (WHOI/Yale); deployment of inverted echo sounders (IES) (Yale); and (4) deployment of deep-sea pressure gauges (AOML). Each project met with varying degrees of success.

The weather for the first half of the cruise was excellent. The two pressure gauge launches went well. Eight SOFAR floats were launched. Since the IES's were prototypes, one was launched for a two-day test. Only the STD system refused to work.

It took about a week to iron out the STD problems. The major sources of trouble were the cable length (7600 m) and the slip rings. The cable attenuated the depth signal to such an extent that the digitizer would not work. This problem was emphasized because two-thirds of the remaining signal was lost in the slip rings. Both these problems were solved in time. There remained a level-winding problem with the winch. Consequently, to save time, most casts on this leg went only to 3000 m.

Problems began to appear in the other programs. The test IES refused to surface on command. It was recovered two days later on its timed release. Several tests of it were conducted by lowering it beneath the STD. In its designed configuration, the IES could not hear the command signals. Subsequent reconfiguration took care of this problem. Four IES's were launched.

SOFAR float troubles started to appear on this leg. These did not become a major problem until the second leg. Careful preparation by the float group made launching of floats, even in rough weather, a smooth operation. The float and STD programs meshed fairly well.

Researcher returned to Miami on 29 March.

Leg II

The ship was to sail on the morning of 3 April. However, high winds forced postponement of sailing for two days. The ship's slip in Miami is such that any attempt to leave it at that time would have ended with the ship aground.

The weather during this leg was unpleasant, and time passed slowly. One AOML pressure gauge was successfully launched. It had been planned to drop two IES's during this leg. However, shore tests indicated problems with the test IES launched during Leg I. Consequently, no further drops were planned. Furthermore, two of the IES's implanted during Leg I were interfering acoustically with the MINIMODE floats. The ship had to be diverted to recover these instruments.

Major problems were encountered in the SOFAR float program. The bonding on the transducer end plates of the floats was giving away, causing the floats to stop transmitting prematurely. These floats had to be recovered. During this leg, 21 floats were recovered or launched. Two were searched for but could not be found.

About 80 STD stations were planned for this leg; of these only 52 were completed. The level-winding problem was solved with the acquisition of additional gears between Legs I and II. The biggest problem for STD work on this leg was the time lost to bad weather, IES, and SOFAR float work.

The ship's return to Miami on 26 April was eagerly anticipated by all.

Leg III

Researcher left Miami on the morning of 1 May. This leg would turn out to be unusual in that almost everything went well. The minor exceptions were that (1) our last basketball was lost overboard (a total of five lost) and (2) the condition of the ping pong table deteriorated rapidly with heavy use. The inclusion of two women in the scientific party made life more pleasant for the whole ship.

The weather was beautiful. Six IES's were launched. Little SOFAR float work was conducted. The participants in the float program had decided after the disastrous second leg that the transducer end plates had to be redesigned. Doug Webb stayed in Woods Hole during this leg to work on the redesign (Doug will bear four out of five Researcher legs!).

With good weather and little float work, the STD program blossomed. A total of 74 STD stations were taken; about 70 percent of these were deep casts. No major problems were encountered in the STD work.

The ship arrived in Bermuda on 23 May. A good time was had by all at the White Horse.

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If you have material of interest for this newsletter, please get in touch with either of the above at the Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543, Telephone (617) 548-1400.

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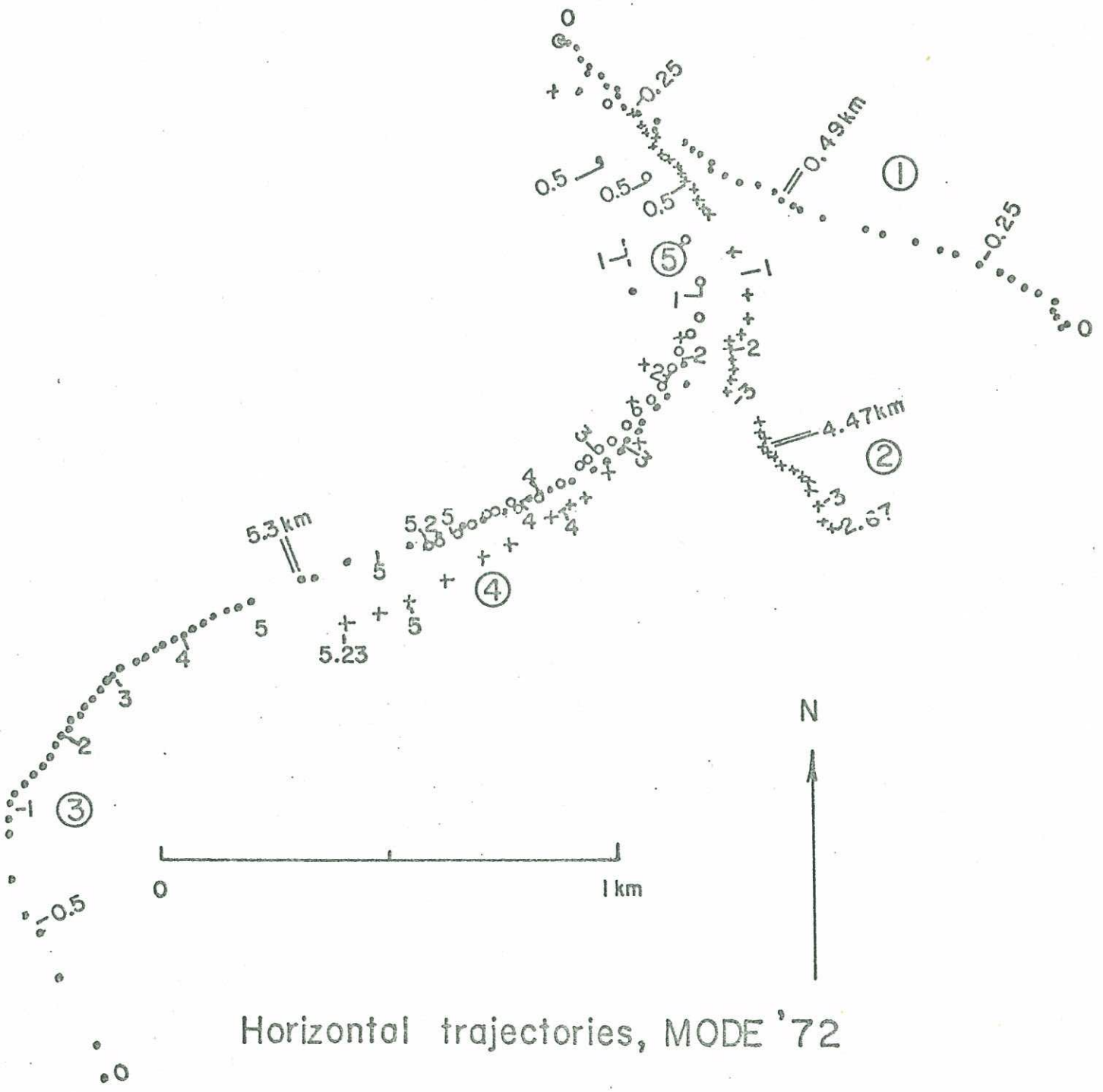
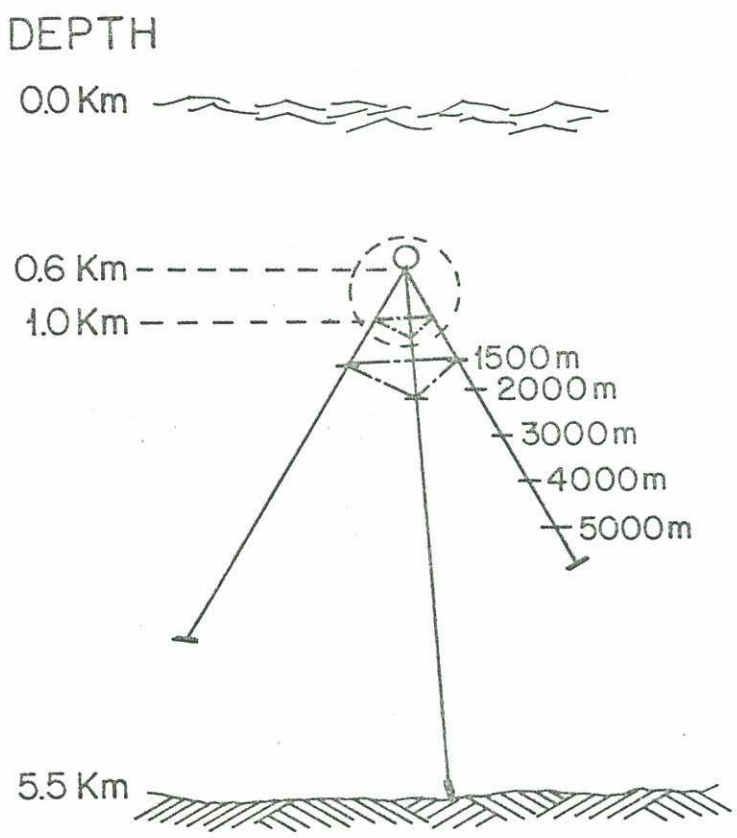


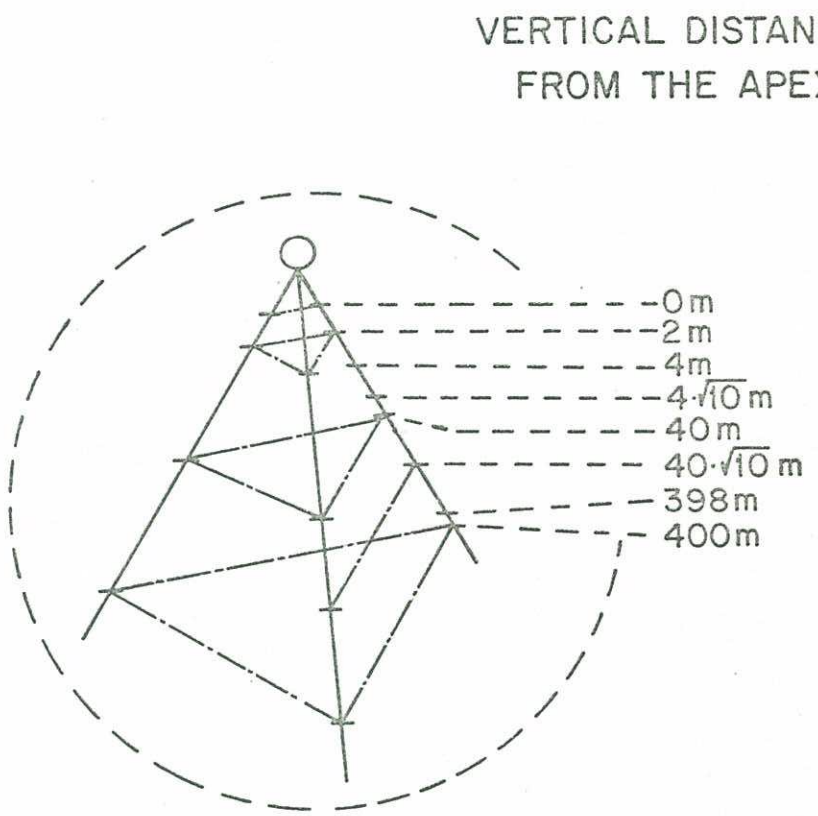
Horizontal trajectories, MODE '72

Figure 1
(Pochapsky & Malone)

GEOMETRY OF THE PROPOSED MOORING



GEOMETRY OF MOORING



ARRANGEMENT OF CURRENT METERS

Figure 2 (Briscoe)