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Woods Hole Oceanographic Institution

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TO 110 m DEPTH AT DEEPWATER DUMPSITE #106
USING ACOUSTICALLY TRACKED DROGUES
AND CONVENTIONAL CURRENT METERS

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TECHNICAL REPORT

*Prepared for the Department of Energy under
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Abstract

A system has been developed recently at W.H.O.I. for tracking nearsurface drogues equipped with sonobuoys using an acoustic navigation system. Surface and submerged drogues of mean depths ranging from 0.15 m to 4.88 m were tracked in the vicinity of deepwater dumpsite #106. A least squares linear regression technique was used to determine drogue velocities over 2 hour periods. Water velocities at depths from 8 - 110 m were measured using a ship-deployed current meter coupled with acoustic tracking of the ship. The results indicated very little velocity shear in the surface mixed layer. There were two regions of strong shear at greater depths, one associated with the main thermocline and the other presumably associated with a halocline.

1. Introduction

A quantitative description of the dispersive properties of an oceanic region requires a knowledge of the vertical shear of horizontal currents. During April of 1979 our research team participating in a cooperative field study of dispersion at deepwater dumpsite 106, measured nearsurface current profiles in the dumpsite region (see Figure 1 for location). Both Lagrangian and Eulerian methods of current measurement were employed.

Lagrangian velocity measurements at depths ranging from 0.15 m to 5 m were made by acoustically tracking Large Contact Surface (LACS) drogues equipped with sonobuoys. LACS drogues, recently developed at W.H.O.I. consist of matted packing material which provides a large contact surface between water and drogue, ensuring minimum slip.

Eulerian current measurements from 8 - 110 m were made utilizing a ship-lowered, rotor-vane type current meter coupled with acoustic tracking of the ship.

This report provides a general description of the equipment and techniques involved, and discusses the field data.

2. Method of Lagrangian Current Measurement Utilizing Acoustically Tracked Drogues

Acoustic Navigation System:

The acoustic navigation system has been used at W.H.O.I. for a number of years and is well documented. Hunt et al. (1974) and Peal (1974) have provided an overall description of the system's design and operation. Experiments involving the tracking of sonobuoys have been reported by Spindel and Porter (1974) and Spindel, Davis, Macdonald, Porter and Phillips (1974). The system will be briefly described here.

The geometry of the system as used at the dumpsite is presented in Figure 2. The fundamental components are:

- a towed body containing a transducer (acoustic fish)
- two expendable bottom mounted transponders
- a LACS drogue connected to a listening hydrophone and transmitting VHF antenna
- a receiving antenna aboard ship
- a shipboard master timing clock and microcomputer used to control the system's operation and to collect and process data.

Two phases of navigation, 'ship' and 'sonobuoy', are performed as separate cycles.

The ship cycle is initiated with the transmission of a pulse (7.5 khz, 10 msec) from the acoustic fish. Immediately following the detection of this pulse each bottom transponder generates a reply pulse at a specific frequency (12.5 khz for one, 11.5 khz for the other). These reply pulses are detected by the acoustic fish. The acoustic round trip travel times between the fish and each bottom transponder are thus determined and are logged by the shipboard computer. A formula relating

slant range to acoustic travel time (determined using the local sound velocity profile and ray analysis) is used to convert each travel time to the slant range between the fish and respective transponder. The position of the ship relative to the transponders is calculated using these slant ranges together with the known depth of the acoustic fish and the previously measured transponder net geometry (baseline length and transponders' depths).

The sonobuoy cycle also begins with a pulse transmission from the acoustic fish. The reply pulses from the bottom transponders are received by the sonobuoy of a LACS drogue and transmitted (via radio) to the ship. Assuming the travel time from the sonobuoy to the ship is negligible, the elapsed time between the initial pulse transmission and a reception at the ship is the acoustic travel time from the ship to the respective transponder to the sonobuoy. The travel time from each transponder to the sonobuoy is found by subtracting the ship to transponder travel time determined by the most recent ship cycle. These travel times are converted to slant ranges and used to calculate the position of the sonobuoy with respect to the transponders.

It should be noted that in most operations a net of three transponders is employed. The third transponder, used to increase tracking range and to resolve the ambiguity as to which side of the baseline the tracked vehicle is on, was deemed unnecessary for this application.

The baseline length and transponder depths are determined by a minimization algorithm using travel times collected during several baseline crossings. Geographic positioning of the transponder net is determined using the ship's navigation system. Typical tracking accuracy relative to the transponders is in the order of 5 - 10 meters.

The normal tracking procedure of alternating between "ship" and "sonobuoy" cycles yields a drogue position every 20 - 30 seconds. The present system can concurrently track 16 drogues in this fashion.

The shipboard system has the additional capability to accept and log current meter measurements while simultaneously tracking the ship (as described in Section 3). A schematic for the entire shipboard unit is presented in Figure 3.

Acoustic Drogue Assembly:

The acoustic drogue assembly, recently developed at W.H.O.I., consists of three principal components: LACS drogue, sonobuoy electronics, and float-antenna assembly.

The drogue is constructed of a wire 1" x 2" mesh frame molded into a 1' x 2' x 2' block. A padding of 2" thick densely wound, simulated horsehair is fastened to the exterior. With appropriate counterweights the drogue constitutes a slightly negative buoyant, stable body with extremely high drag. A typical assembly of a "deep" drogue is diagrammed in Figure 4. For shallower drogues the bridle immediately above the drogue is of reduced size. The drogue depth is specified as the distance between the center of the support float (which is presumed to be at the water's surface) and center of the LACS drogue.

The electronics consist of a modified Magnavox AN/SSQ41B sonobuoy. The boards and alkaline batteries have been packaged into an 18" long by 5" diameter sealed aluminum housing which is incorporated into the interior of the drogue. The piezo-electric ceramic hydrophone (2" length x 1.75" dia.) has an omnidirectional pattern and is suspended 1' below the counterweight by its original compliance cable and shock absorber assembly. The present alkaline battery package yields an operating life of 9 hours at a transmitting power of 1 watt.

The float-antenna assembly consists of a support float for the drogue connected by 4' of antenna wire to an antenna bearing float. Both are made from 4" dia. x 6" long toilet bowl floats and drift with approximately 3" above the water surface. The antenna carrying float (Figure 5), designed to freely ride the waves, is stabilized by a 4" long rod with attached zinc counterweights. The VHF electronics have been modified to permit the use of a 1/4 wave antenna (0.063" dia. x 16" length).

3. Method of Eulerian Current Measurements

Eulerian current measurement was accomplished using Marine Advisors, Inc. (subsidiary Bendix Corp.) Model O-15 current meters. The O-15 current sensor (Fig. 6) is a bidirectional ducted impeller which is directed into the current by a 1 m boom and connected vane. The sensor is interconnected through a pivot shaft to a potentiometric direction transducer and gimbal mounted compass.

The current meter output is directed at a 10 sec sampling rate to the shipboard computer where a running vector average is computed using an exponential filter (first order lag) of time constant, $\tau = 60$ sec. The results are logged onto a magnetic disk or tape. This data along with the simultaneous ship tracking data is later input to a computer program which subtracts the ship drift components from the current measurement.

For this application two current meters were employed. One continuously monitored the current at a depth of 10 m (approximately 2 m lower than the ship's keel); while the other measured the current at specific levels below. The lower current meter was held at each measurement level for approximately 5 minutes, a time sufficient for transients due to the lowering of the meter to decay and for a statistically meaningful average.

4. Results

Drogue deployment began at approximately 1840 GMT (all times in this report are GMT) on April 19 with the release of a 1.22 m drogue. Initially there was considerable difficulty in tracking this drogue which was eventually linked to noise generated by the ship's engines and propellers. At about 1900 the ship's engines were completely shut down enabling successful tracking of the drogue. Soon after four additional drogues of depths: 15.2 cm, 30.4 cm, 2.84 m and 4.88 m were released.

All drogues were tracked until about 2120 when it became apparent that the ship had drifted out of tracking range. The

ship then steamed back towards the transponders. Tracking resumed at 2250 and continued until 0100 on April 20.

Figure 7 displays the wind record from the ship's weather log with the tracking periods included. On this graph phase 1 refers to the time between the initiation of tracking and the loss of the ship's navigation; phase 2 represents the time between the resumption and completion of drogue tracking.

The ship's positions and all drogue positions are displayed in Figure 8. Individual drogue tracks are shown in Figures 9-13. All drogue tracks are divided into two obvious groups corresponding to tracking during phase 1 and during phase 2. During each phase the trajectories of all drogues form nearly straight lines. For most drogues, however, there is an apparent difference in bearing between the trajectories of each phase. For this reason the drogue tracks of each phase have been analyzed separately.

The east and north velocity components of each phase have been determined by computing the slope of the least squared linear relationship between east and north position and time. The least squares fits to the east and north position components of the 15.2 cm drogue during phase 1 are graphically displayed in Figures 14 and 15. Table 1 lists the velocities as well as the standard errors of the linear regressions.

Velocity vectors of phases 1 and 2 together with the ship measured wind vectors at the beginning and end of each phase are displayed in Figure 16. Drogue speed and direction vs. depth is shown in Figure 17. Note that the velocity of the 1.22 m drogue, which was released first and was about 2 km from the others during tracking, was markedly different from that of all other drogues. This difference is most likely due to horizontal rather than vertical shear.

The last column of Table 1 indicates that the trajectories of all drogues were more clockwise during phase 2, whereas the ship's bearing was more counterclockwise. Note from Figure 8 that the ship and drogues were in totally different localities

during phase 2. This would suggest that the difference in trajectories between the two phases was, to a large extent, due to horizontal variation.

Discounting the 1.22 m drogue the tracking results show only a slight shear in the upper 5 m. XBT profiles before and after tracking (Fig. 17) indicate that all drogues were traveling in a vertically mixed layer.

Current Meter:

At 0420 GMT on April 19 the current meters were deployed. Both meters were maintained at 8 m depth for about 5 minutes. The average current measured by the meters differed by 1.1 cm/s and 8° , both figures within instrument accuracy.

At approximately 0500 the ship drifted out of tracking range. The current measurements continued, however, and were completed by 0640. While being tracked the ship was moving at a velocity of 72.2 cm/s at 157.8° with standard deviations of 0.4 cm/s and 0.4° . This velocity was used to correct all current meter measurements. The resulting current profile together with the corresponding stationary current meter record is presented in Figure 18.

Note the ostensible change in current as measured by both meters between 0544 and 0616. The change in the stationary current meter's record is likely an artefact of an undetected deviation of ship drift. The lowered current meter values subsequent to 0544 were corrected for this presumed change in ship drift by subtracting the vector difference between concurrent stationary current meter measurements and the stationary current meter value prior to 0544 (28.3 cm/s at 135°). This corrected profile together with a coincident XBT temperature record is presented in Figure 19.

Two separate regions of vertical shear are apparent. The upper region, from 10-30 m, coincides with the main thermocline. The lower region (70-100 m) is within a thermostad. This region

could, however, correspond to a halocline produced density front. Hydrographic transects in close proximity of the dumpsite (Ketchum and Corwin, 1964) have displayed halocline associated density fronts of slope water in the thermocline beneath the main thermocline.

Conclusions

The drogue results indicated that the shear in the nearsurface mixed layer was relatively slight. The current meter measurements showed two regions of moderate shear, one associated with the main thermocline and the other presumably linked to a halocline.

Together the drogue and current meter techniques provide current measurement over a maximum vertical range. In the near-surface where current meter use is impractical due to interference effects of the ship's hull, drogue tracking is ideal. In deeper water the drogue method has serious drawbacks, but current meter measurements can be made with relative ease. Results of the two cannot, however, be combined without caution. One obvious problem is that drogues at different depths can be separated by large horizontal distances and are thus subject to horizontal variation, as the disparity of the 1.22 m drogue velocity demonstrated.

This experiment has shown both of these novel techniques to be viable and future implementation is planned.

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Table 1

Velocities of tracked drogues and ship with the standard errors of the linear regressions between position components and time

Drogue Depth m	Phase #	# of Pos	East Vel cm/s	Std Err cm/s	North Vel cm/s	Std Err cm/s	Speed cm/s	Direction deg	Bearing Shift Between Phases deg
0.15	1	21	13.72	0.13	-26.78	0.19	30.09	152.87	3.78
0.15	2	27	11.11	0.13	-25.74	0.20	28.04	156.65	
0.30	1	33	17.58	0.29	-29.64	0.69	34.46	149.33	16.55
0.30	2	20	6.51	0.28	-25.88	0.33	26.69	165.88	
1.22	1	24	3.90	0.55	-18.81	0.20	19.21	168.29	11.71
1.22	2	22	0.00	0.16	-21.61	0.23	21.61	180.00	
2.44	1	23	13.31	0.26	-20.52	0.16	24.46	147.03	18.39
2.44	2	30	5.84	0.28	-23.28	0.17	24.00	165.92	
4.88	1	15	10.46	0.23	-20.00	0.39	22.57	152.39	4.91
4.88	2	25	8.69	0.13	-20.77	0.12	22.51	157.30	
Ship	1	159	29.80	0.07	-51.00	0.14	59.07	149.70	-6.26
Ship	2	197	25.12	0.04	-33.87	0.03	42.17	143.44

Figure 1. DWD-106 (38°40' to 39°00'N and 72°00' to 72°30'W)

Figure 2. Geometry of a two transponder navigation net

Figure 3. Schematic of shipboard electronics for acoustic drogue tracking and current meter measurement.

Figure 4. A "deepwater" acoustic drogue. Shallower drogues have a smaller upper bridle.

Figure 5. Transmitting antenna and float. Numbered components are: 1. VHF antenna (16" long, 1/4 wave); 2. copper float (4" dia. x 6" high); 3. zinc counterweights; 4. antenna wire (RG 174/U).

Figure 6. Marine Advisors, Inc. Model Q-15 Current Meter

Figure 7. Wind speed and direction from the ship's weather log with the tracking periods (phases 1 and 2) noted.

Figure 8. Ship positions and all drogue positions. The x-axis points east, the y-axis is positive northward. Times of initial and final ship positions of each phase annotated.

Figure 9. Positions of the 15.2 cm drogue

Figure 10. Positions of the 30.4 cm drogue

Figure 11. Positions of the 1.22 m drogue

Figure 12. Positions of the 2.44 m drogue

Figure 13. Positions of the 4.88 m drogue

Figure 14. Least squares linear fit of east position coordinate vs time for the 15.2 cm drogue during phase 1

Figure 15. Least squares linear fit of north position coordinate vs time for the 15.2 cm drogue during phase 1

Figure 16. Drogue and wind velocities during phases 1 and 2. Drogue vectors are labeled by their mean depth in meters.

Figure 17. Drogue speed and direction during phase 1 (dots) and phase 2 (x's) plus two temperature profiles. The solid line temperature profile is from an XBT taken at 0457 GMT on April 19 at 200531N 720201W

Figure 18. Current speed and direction vs depth measured by the lowered current meter (solid line), together with the coincident stationary current meter measurement at 10 meters (dashed line).

Figure 19. "Corrected" current profile together with an XBT temperature profile taken at 04 57 GMT on April 19 at 38°52'N, 72°18'W.