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Woods Hole Oceanographic Institution

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IN CAPE COD BAY USING SIGHTED DROGUES

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TECHNICAL REPORT

*Prepared for the Department under Grant DE-
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Approved for Distribution

Valentine Worthington, Chairman
Department of Physical Oceanography

Abstract

During July 16-19, 1979 currents in Cape Cod Bay from the very near surface to 1.8 m were measured by taking simultaneous bearings on submerged drogues from two anchored vessels. The error in drogue position as a function of location with respect to the two vessels was examined in detail and was used for rejecting or accepting velocities from particular sightings. From the final results well defined velocity shears, nearly parallel with the wind, were evident. From these velocity fields surface stress coefficients, equivalent sand-grain roughness coefficients, and the near surface gradients of relative (to the surface velocity) velocity were calculated.

I. Introduction

During the period of July 16-19, 1979 we undertook to measure nearsurface current in Cape Cod Bay. The experiment had two primary objectives. The first was to test and evaluate the relatively simple experimental technique which involved taking simultaneous bearings of drogues from two anchored vessels. The second was to apply the resulting current field together with the wind field to existing theory of wind-driven water transport.

II. Method

The drogues were constructed of an interwoven horsehair-like material. They either floated with their top at the sea surface or were weighted to equilibrate at a specific depth. The submerged drogues were attached by string to a colored ping-pong ball which floated at the surface. The surface drogues, slabs of horsehair, had total depths of 1", 2", 4", and 8". The submerged drogues assumed a mean depth of 12", 24", 48", and 72". Photographs of a 2" slab and 12" submerged drogues are displayed in Figure 1.

The vessels involved were the R/V Asterias of W.H.O.I. and a 12' Boston Whaler. Prior to a release of the drogues both boats were anchored at a distance of 50-100 m from each other. The crew of each boat took a bearing on the other and measured the distance of separation with a telescoping range finder. These measurements established the baseline which is used in the calculation of the drogue's positions.

On order from the whaler stop watches on each vessel were started. The drogues were then released from the whaler in order of increasing depth. From 3 - 7 of each depth type were deployed. The approximate time of release of each type

was recorded. With all drogues in the water compass sightings from both vessels commenced. Generally these sightings were made simultaneously; however, occasionally, when the drogues could no longer be seen from the whaler, sightings were taken from only the Asterias.

At least once during each run the wind speed and direction were measured from the deck of the Asterias using a hand held anemometer (Belfort Inst. Co. #6052). The height at which this measurement was taken varied between 7 and 15 ft.

At the completion of a run the drogues were retrieved. On some runs, as the whaler picked up a group of drogues its range and bearing were sighted from the Asterias.

III. Calculation of a drogue's position from sightings and the baseline

Figure 2 diagrams the geometry of a particular sighting. A, W and D represent the positions of the Asterias, whaler and drogue respectively. ω_1 and ω_2 are the sighting bearings from the whaler and the Asterias. WA is the baseline length and β is its bearing as measured from the whaler.

The distance of the drogue from the whaler, WD, can be found by noting that:

$$\frac{WD}{\sin(\pi - \omega_2 + \beta)} = \frac{WA}{\sin(\theta)} \quad (1)$$

It can be readily shown that:

$$\theta = \omega_2 - \omega_1$$

so that

$$WD = WA \frac{\sin(\beta - \omega_2)}{\sin(\omega_2 - \omega_1)} \quad (2)$$

If the origin of the coordinate system is at W then the coordinates of the drogue are:

$$\begin{aligned} x &= \text{east} = WD \sin(\omega_1) \\ y &= \text{north} = WD \cos(\omega_1) \end{aligned} \quad (3)$$

IV. Experimental error

The three primary sources of experimental error are uncertainty in the baseline distance, compass bearing and stopwatch time errors.

The range finders used to measure the baseline have an accuracy of about 10%. As can be seen from Eqs. (2) and (3) this results in a 10% error in drogue position. This error influences only the magnitude (not direction) of the drogue's velocity; and, for a particular run, all magnitudes are affected in the same proportion.

The stopwatch error is at most 10 sec. Because the bearings never changed by more than a degree in 10 sec, the stopwatch error can be ignored.

The magnitude of compass error is dependent on sea and weather conditions. During high seas it is about $\pm 5^\circ$; in calm weather it is about $\pm 3^\circ$. The effect of compass uncertainty on the drogue's position is a function of the drogue's bearings. This can most easily be demonstrated by expressing the sighting angles with respect to the baseline as shown in Figure 3. In this figure α_1 and α_2 are the sighting angles from the whaler and Asterias.

The error in WD due to uncertainty in the sighting angle from the Asterias can be found by differentiating WD with respect to α_2 . Equation (1) can be reexpressed as:

$$\frac{WA}{\sin(\alpha_3)} = \frac{WD}{\sin(\alpha_2)} \quad (4)$$

where $\alpha_3 = \pi - (\alpha_1 + \alpha_2)$

so that:

$$WD = WA \frac{\sin(\alpha_2)}{\sin[\pi - (\alpha_1 + \alpha_2)]} = \frac{WA \sin(\alpha_2)}{\sin(\alpha_1 + \alpha_2)} \quad (5)$$

For most releases α_1 is constant to within 4° . It can thus be held constant while differentiating with respect to α_2 :

$$\left. \frac{d(WD)}{d\alpha_2} \right|_{\alpha_1} = \frac{WA \sin(\alpha_1)}{\sin^2(\alpha_1 + \alpha_2)} \quad (6)$$

Figure 4 displays the above function vs. the angle between the Asterias's sighting line and the drogue's path (α_3), for various values of α_1 . The functional values are in units of baseline distance, i.e. $\frac{d(WD)}{d\alpha_2} \frac{1}{WA}$. Each curve encompasses a range from $\alpha_2 = 0.1^\circ$ to a value of α_2 such that $WD = 2 WA$ (In practice the drogue can seldom be tracked for more than twice the baseline distance.). The error in drogue position can be found by multiplying the value of the graph by the baseline distance and by the compass error. For example, at $\alpha_1 = 60^\circ$ and $\alpha_3 = 90^\circ$ ($\alpha_2 = 180 - \alpha_1 - \alpha_3 = 30^\circ$)

the functional value is 0.015/deg; for a baseline of 100 m and a compass error of 3° this corresponds to a drogue position error of 4.5 meters. At $\alpha_1 = 5^\circ$ and $\alpha_3 = 170^\circ$ ($\alpha_2 = 5^\circ$) the functional value is 0.15/deg which for the above parameters corresponds to a position error of 45 meters.

Note that for all curves the error is a minimum at $\alpha_3 = 90^\circ$, i.e. when the Asterias's sighting is normal to the drogue's path. For smaller values of α_1 the variation of error is larger. The error is exceptionally high when the sighting angles from both vessels are close to the baseline. This information was used when taking data and for rejecting questionable sightings.

Figure 5 displays $\frac{d(WD)}{d\alpha_2} \cdot \frac{1}{WA}$ as a function of drogue distance from the whaler. Close examination of the figure will reveal that the values of α_1 which have the greatest range of low position error are between 30° and 45°.

In addition to measurement uncertainties there are experimental difficulties (movement of the vessels during a run and inconsistency between the two compasses, for example) which also contribute to the error in the drogue's position. These will be discussed in detail later.

With regard to the wind measurement, the error in direction is roughly 10%; the uncertainty in magnitude is unavailable but is believed to be 5% or smaller.

V. Results

The first day of the experiment, July 16, 1979, was primarily devoted to developing and perfecting the technique; little useful data resulted. During the second day data collection was hampered by high seas. What little data we managed to take had relatively high error of bearings and

baseline range. On the third and fourth days, July 18-19, we encountered relatively calm seas and moderate, shear producing winds and were able to conduct several good runs. Analysis has been restricted to data from those two days.

Program PRPL (listings in Appendix) was used to calculate the positions and velocities of the drogues using equations (2) and (3). This program reads a data file consisting of the baseline bearing and distance, times of drogue releases, compass sightings, and times of the sightings. The drogue positions at all sightings are calculated as well as the velocities since the time of release and from sighting to sighting. Positions and velocities are also calculated for those occasions when the Asterias's crew took the bearing and range of the whaler while retrieving drogues. A plot is generated displaying the positions of the whaler and Asterias and of each type of drogue at each sighting.

Initial processing of the data produced some positions which were grossly incorrect. This was especially true for instances in which both the drogue's path and the sighting from the Asterias were close to the baseline. Close examination of the data revealed that the baseline bearing as measured from the Asterias was almost always greater (more clockwise) than that taken from the whaler. This is demonstrated by Table 1. The implication is that the compasses were not aligned.

The compass used on the Asterias was the ship's compass. It was thus impossible to calibrate the two compasses together in conditions similar to those of the experiment without taking the Asterias out of port. It was therefore decided to assume that the compass of the whaler was accurate and to correct the sightings from the Asterias by the

difference between the two baseline bearings (Table 1; for July 19, Run 1 no correction was applied).

Figures 6-13 display drogue positions for all processed runs of July 18-19. In these figures each drogue is represented by a unique symbol which is listed in Table 2. The position of the whaler is at the coordinate system origin, and the Asterias's location is marked by a cross with an A. The averaged velocities since release are tabulated in Tables 3-9. Not all positions shown in Figures 6-13 have been used in these averages. The velocities were filtered by considering the error curves of Figures 4-5.

It will be instructive for the reader to examine each run of July 18-19.

Run 1 of July 18 was aborted due to unfavorable drogue trajectories (they were traveling away from both the whaler and Asterias).

Run 2 was completed successfully after which the Asterias's crew took ranges and bearings on the whaler during drogue retrieval. All positions are shown in Figure 6. The magnitude of the velocities calculated from the pickup sightings were generally at least 3 standard deviations different from those velocities calculated from the other sightings. They have therefore not been included in the averages of Table 3. Figure 7 displays the drogue locations of only the simultaneous sightings. The angles of the drogue's paths from the baseline were between 30° - 45° , the low error region of Figure 5. This justified including the velocities from all these sightings in the averages.

After Run 3 the whaler was again sighted while picking up the drogues. As for Run 2, the velocities calculated from these retrieval sightings differed from the others by more than 3 standard deviations and were not included in the

averages (Table 4). Figure 8 depicts the locations of the simultaneous sightings. The drogue paths were between 28° - 40° from the baseline, again in the region of small error.

During Run 4 the crew of the Asterias had difficulty making sightings. Very little data was recorded and thus this run was not processed.

The drogue paths of Run 5 of July 18 were close to the baseline (6° - 21°) and therefore of highly variable error (Figure 5). In this run each type of drogue was sighted as it passed abeam of the Asterias at 30° (magnetic). As can be seen in Figure 9 these sightings were nearly perpendicular to the drogues' trajectories and thus have very small error. The velocities calculated from these sightings were therefore used as a basis for rejecting other velocities in computing the averages of Table 9.

During Run 6 sightings were again taken as the drogues passed abeam of the Asterias. The drogue trajectories were either coincident with or very close to the baseline (0° - 10° , Figure 10). The only reliable velocities were those calculated from the abeam sightings and these are given in Table 6.

The weather conditions of July 19 produced very interesting results. As we steamed to the experimental region there was absolutely no wind. During the first run, however, a slight breeze commenced, and the wind continued to increase and change in direction throughout the day.

The slight breeze which picked up during Run 1 caused the vessels to move on their anchor lines producing some change in the baseline. The bearing and range measured from the whaler varied from 76° - 80° and 82-89 m (76° and 87 m were used in the processing). The varying baseline was certainly, in part, responsible for the curved appearance of the drogues' trajectories shown in Figure 11. All drogue trajectories and

most *Asterias* sightings were close to the baseline and thus many were not included in the averages of Table 7.

During Run 2 the wind strengthened considerably causing the baseline to vary from 90° - 100° and 66-88 m. This run was not processed.

Run 3 was aborted because the drogues were traveling away from both the *Asterias* and the whaler.

During Runs 4 and 5 the wind and baseline were fairly steady, and, as can be seen in Figures 12-13, the shear was pronounced.

The wind and averaged current vectors for July 18 and July 19 are shown in Figures 14 and 15. The current vectors measured by the slabs are labeled by the slab depth in inches (1,2,4, and 8). It should be noted that these vectors actually represent the current integrated from the surface to that depth. For all runs a well defined shear with depth is clearly evident and the direction is nearly parallel with the wind direction.

Note that the 1 inch drogue generally does not fit into the pattern of the others. The dimensions and composition of the drogue may be responsible for this discrepancy. The surface area of the 1 inch drogue is 36 square inches as compared with roughly 64 square inches for all other slabs. The fibers of the 1 inch drogues are woven much less densely than those of the other slabs. The 1 inch drogue is therefore more susceptible to slippage relative to the surrounding water. Its smaller size also makes the 1 inch drogue more influenced by waves. The wave-induced rotational tumbling motion may dissipate a portion of the drogue's translational energy.

From the graphs of Figures 14-15 approximate velocities relative to the velocity of the 2 inch drogue have been

determined. Plots of these velocities vs depth for 5 of the runs are shown in Figs. 16 and 17. In these graphs the velocities measured by the slabs have been considered to be at half the total depth of each slab.

From each of the curves of Figs. 16-17 the velocity gradient at 2.5 cm was determined by evaluating the slope of a quadratic function fit to the values at 2.5, 5.1 and 10.2 cm. These gradients are listed in Table 10.

It has been suggested that the following equation can represent the current shear due to surface wind stress:

$$\frac{u_r}{u_*} = 2.5 \ln(z/\gamma) + 8.5 \quad (7)$$

where:

- u_r = velocity relative to the surface velocity
- z = water depth
- u_* = surface stress parameter (friction velocity)
- γ = equivalent sand grain roughness parameter.

Figures 18 and 19 present the relative velocities of Figs. 16-17 vs the log of depth.

For equation (7) to be applicable to our data these points should lie roughly on a straight line. (Note that the velocity of the 2 inch drogue is considered to define a "surface" velocity.)

For July 18 the linear relation holds for all depths, whereas for July 19 the linear fit applies to only depths shallower than 60 cm. This discrepancy may be due to the fact that the time variation of the wind was much greater during July 19. The mechanism represented by equation (7) may not have had sufficient time to penetrate to deep water for the particular value of wind stress. u_* and γ have been calculated from the lines shown in Figs. 18 and 19 and are tabulated in Table 10.

VI. Conclusion

This experiment has demonstrated that the technique employed gives results which are consistent with intuitive expectations and with existing theory. The attractive features of this technique are that it requires only simple and inexpensive equipment and very little preparation time. One of the obvious disadvantages is that data cannot be obtained during high seas or periods of limited visibility. This technique also requires four sharp-witted, seaworthy persons with good intercommunication to take and record the simultaneous sightings.

A few obvious improvements have been suggested by these results:

Both compasses should be calibrated to each other at the experimental site.

To avoid ship sway during sightings two anchors should be dropped from each vessel (especially important when the wind is variable).

The drogues should be released at 30° - 45° from the baseline; and, sightings need not be taken at drogue locations of high error.

All of the slab type drogues should have the same dimensions of the horizontal cross-section to ensure consistency of results.

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Table 1

Baseline Bearings Taken from the Asterias and Whaler

Date	Run	Bearing from Whaler B_W	Bearing from Asterias $\pm 180^\circ$ B_A	Difference $B_A - B_W$
July 18	1	210°	211°	+1°
July 18	2	268°	275°-285°	+7° - +17°
July 18	3	285°	290°	+5°
July 18	4	305°-310°	312°	+2° - +7°
July 18	5	290°	293°	+3°
July 18	6	292°	295°	+3°
July 19	1	76°-80°	74°	-2° - -6°
July 19	3	26°	34°	+8°
July 19	4	218°	224°	+6°
July 19	5	216°	222°	+6°

Table 2

Key to Symbolic Representation of Drogues
in Figures 5-12

<u>Droque</u>	<u>Symbol</u>
1 inch slab	⊙
2 inch slab	△
4 inch slab	+
8 inch slab	×
12 inch submerged	◆
24 inch submerged	↑
48 inch submerged	⌘
72 inch submerged	z

Table 3

Averaged Drogue Velocities for July 18, Run 2

Drogue	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	2	32.94	1.09	-76.5	1.4
2"	1 ^τ	36.08	-	-75.5	-
4"	2	34.46	0.84	-74.5	1.4
8"	2	32.62	2.67	-72.5	1.4
12"	2	29.90	1.70	-68.5	0.0
24"	2	29.87	0.45	-67.5	0.0
48"	2	27.89	1.73	-66.5	0.0
72"	2	28.39	1.08	-63.5	0.0

τ - First sighting deleted due to very questionable sighting
from whaler

Wind: 8 knots from 84.5°

Table 4

Averaged Drogue Velocities for July 18, Run 3

Drogue	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	2	33.89	1.48	-64.5	1.4
2"	2	36.00	1.67	-67.5	1.4
4"	2	35.58	1.70	-66.5	2.8
8"	2	35.18	0.05	-61.5	1.4
12"	2	31.61	0.21	-60.0	0.7
24"	2	31.21	0.01	-59.5	0.0
48"	2	29.73	1.97	-57.5	0.0
72"	1	28.71	—	-56.5	—

Wind: 7 knots from 84.5°

Table 5

Averaged Drogue Velocities for July 18, Run 5

Drogue	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	2	26.56	0.71	-79.5	0.0
2"	2	27.57	0.57	-79.5	0.0
4"	2	25.60	0.45	-78.5	1.4
8"	2	23.35	0.52	-75.5	0.0
12"	1	20.57	—	-70.5	-
24"	1	20.22	—	-69.5	-
48"	2	19.93	0.57	-65.5	0.0
72"	2	18.21	0.23	-64.5	0.0

Wind: 9 knots from 64.5°

Table 6

Averaged Droque Velocities for July 18, Run 6

Droque	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	1	23.19	-	-83.5	-
2"	1	22.91	-	-83.5	-
4"	1	22.91	-	-83.5	-
8"	1	21.46	-	-79.5	-
12"	1	19.12	-	-75.5	-
24"	1	18.08	-	-75.5	-
48"	1	16.17	-	-75.5	-
72"	1	15.60	-	-73.5	-

Wind: 9 knots from 59.5°

Table 7

Averaged Droque Velocities for July 19, Run 1

Droque	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	1	7.33	-	66.5	-
2"	1	7.32	-	68.5	-
4"	2	8.08	0.26	69.0	2.1
8"	2	8.25	0.36	68.5	0.0
12"	3	8.10	0.88	72.7	1.5
24"	3	7.68	0.79	73.5	1.0
48"	3	7.06	0.45	75.7	1.2
72"	3	6.53	0.72	75.7	1.2

No appreciable wind at the outset of the run, a very slight breeze near the end.

Baseline changed from 76-80° and 82-89 m during run.
76° and 87 m used.

All sightings from the Asterias within 10° of the baseline not included.

Table 8

Averaged Drogue Velocities for July 19, Run 4

Drogue	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	3	17.85	0.24	-113.7	2.3
2"	3	18.28	0.19	-113.7	2.3
4"	3	18.11	1.12	-115.3	2.1
8"	3	17.02	1.30	-119.3	2.1
12"	2	15.59	1.56	-128.5	1.4
24"	2	14.79	1.65	-135.0	2.1
48"	1	13.98	-	-153.5	-
72"	1	11.23 ^τ	-	-158.5 ^τ	-

Wind: 7.5 knots from 104.5°

^τ calculated from the release time and time of contact with
hull of Asterias

Table 9

Averaged Drogue Velocities for July 19, Run 5

Drogue	# of Sght	Speed cm/s	St.Dev. cm/s	Bearing deg	St.Dev. deg
1"	2	18.23	0.34	-109.0	0.7
2"	2	19.15	0.14	-109.0	0.7
4"	2	17.73	1.13	-108.0	0.7
8"	2	14.26	0.15	-113.5	0.7
12"	2	11.84	0.13	-126.5	1.4
24"	1	11.70	-	-131.5	-
48"	1	11.44	-	-149.5	-
72"	1	10.34 ^τ	-	-159.5 ^τ	-

Wind: 9 knots from 144.5° (measured 45 min after run)

First sightings not included

^τ calculated from the release time and time of contact with hull of the Asterias

Table 10

Friction Velocity and Roughness Coefficient

Date	Run	Friction Velocity u_* (cm/s)	Roughness Coeff. γ (m)	Velocity Gradient at 2.5 cm (/s)	Wind Vel. (m/s)
July 18	2	1.0	0.9	0.60	4.0
July 18	3	1.0	0.9	0.43	3.5
July 18	5	1.2	0.8	0.83	4.5
July 19	4	1.0	1.0	0.50	3.5
July 19	5	1.0	1.0	0.37	4.5

Figure 1. Photographs of the two types of drogues used in the experiment. (a) 2 inch slab; (b) 12 inch slab

Figure 2. Geometry of a drogue sighting

Figure 3. Geometry of a drogue sighting with the sighting angles referenced to the baseline

Figure 4. Scaled position error vs α_3 (of Figure 3)

Figure 5. Scaled position error vs distance from whaler

Figure 6. Drogue positions — pickup locations included

Figure 7. Drogue positions

Figure 8. Drogue positions

Figure 10. Drogue positions

Figure 12. Drogue positions

Figure 13. Drogue positions

Figure 14. Current and wind vectors of July 18

Figure 15. Current and wind vectors of July 19

Figure 16. Velocity relative to the velocity at 2.5 cm vs depth; July 18

Figure 17. Velocity relative to the velocity at 2.5 cm vs depth; July 19

Figure 18. Velocity relative to the velocity at 2.5 cm vs log of depth; July 18

Figure 19. Velocity relative to the velocity at 2.5 cm vs log of depth; July 19

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APPENDIX

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C      PROGRAM DRPL
C      PROGRAM DRPL CALCULATES DROGUE POSITIONS GIVEN
C      SIMULTANEOUS COMPASS SIGHTINGS FROM TWO SHIPS AND THE
C      BASELINE BETWEEN THEM. POSITIONS MAY ALSO BE CALCULATED
C      GIVEN THE RANGE AND BEARING FROM ONLY ONE SHIP.
C      VELOCITIES ARE CALCULATED FROM SIGHTING TO SIGHTING AND
C      SINCE TIME OF RELEASE. A PLOT IS GENERATED DISPLAYING
C      THE POSITIONS OF THE TWO VESSELS AS WELL AS THE POSITION
C      OF EACH DROGUE AT EACH SIGHTING.
C
C      DIMENSION NUMID(10),NUMSI(10),BEAR1(10,10),BEAR2(10,10),
& TIME(10,10),ITIT(5),XTIT(5),YTIT(5),IBUF(1000),
& X(10,10),Y(10,10),START(10)
C      INTEGER XTIT,YTIT
C      REAL NMIN,NMAX
C      DATA (XTIT(I),I=1,5)/'          EAST-M          '/'
C      DATA (YTIT(I),I=1,5)/'          NORTH-M          '/'
C
C      ESTABLISH CONVERSION FACTORS:  DEG TO RAD ; RAD TO DEG;
C      YARDS TO METERS.
C
C      PHI = 3.14159
C      DTOR = PHI/180.
C      RTOD = 1./DTOR
C      YTCM = 0.9144
C
C      MAGNETIC DEVIATION FROM TRUE NORTH
C
C      DEVM = 15.5
C      XMIN = XMAX = YMIN = YMAX = 0.
C
C      INPUT PLOTTING OPTION AND DIMENSIONS OF PLOT
C
C      READ(105,3) IPLOT,EMIN,EMAX,NMIN,NMAX,XAXL,YAXL
3      FORMAT(I1,4F6.0,2F6.2)
C
C      INPUT TITLE
C
C      READ(105,5)(ITIT(I),I=1,5)
5      FORMAT(5A4)
C      WRITE(108,6)(ITIT(I),I=1,5)
6      FORMAT(/////40X,5A4)
C
C      INPUT BASELINE DISTANCE AND ORIENTATION & CORRECTION
C      FACTOR FOR ASTERIAS BEARINGS
C
C      READ(105,10) BSL,BSLDR,CORR
C      WRITE(108,12)CORR
12      FORMAT(///' ASTERIAS BEARINGS CORRECTION',F5.0,' DEG')
10      FORMAT(3F5.0)
C      I = 0
C      J = 1
C      BSLDR = (BSLDR-DEVM)*DTOR
C      BSL = BSL*YTCM
C
C      INPUT DROUG #, TIME OF FIX AND BEARINGS, FIRST FIX ALSO

```



```

C      HAS RELEASE TIME (IOM,IOS)
C      NOTE:  ADD 9000 TO BEARING 1 (BEA1) IF SIGHTING RANGE AND
C      BEARING ARE FROM ONLY ONE SHIP.  FOR THESE CASES BEA1=RANGE
C      BEA2=BEARING
C
1      READ(105,15,END=100) NUMB,ITIMM,ITIMS,BEA1,BEA2,IOM,IOS
15     FORMAT(I2,2I3,2F5.0,2I3)
C
C      SORT BEARINGS AND TIMES INTO 2 COLUMN ARRAYS
C
      IF(J.EQ.1.AND.I.EQ.0) NUMID(1)=NUMB ; START(1)=IOM*60.+IOS
      IF(I.EQ.0) GO TO 50
      IF(NUMID(J).EQ.NUMB) GO TO 50
      NUMSI(J) = I
      J = J + 1
      I = 0
      NUMID(J) = NUMB
      START(J) = IOM*60. + IOS
50     I = I+1
      TIME(I,J) = ITIMM*60. + ITIMS
      BEAR1(I,J) = (BEA1-DEVM)*DTOR
      BEAR2(I,J) = (BEA2 -DEVM + CORR)*DTOR
      GO TO 1
100    NUMFL = J
      NUMSI(J) = I
C
C      CALCULATE COORDINATES OF FLOATS
C
      DO 200 J=1,NUMFL
      XVD = YVD = VD = AND = 0.
      WRITE(108,800) NUMID(J)
      DO 150 I=1,NUMSI(J)
CC     CALCULATION FOR RANGE AND BEARING FROM ONLY ASTERIAS
      IF(BEAR1(I,J).LT.10.) GO TO 110
      DISTA = (BEAR1(I,J)*RTOD +DEVM - 9000.)*YTOM
      XAS = BSL*SIN(BSLDR)
      YAS = BSL*COS(BSLDR)
      X(I,J) = XAS + DISTA*SIN(BEAR2(I,J))
      Y(I,J) = YAS + DISTA*COS(BEAR2(I,J))
      GO TO 120
CC     CALCULATION FOR SIMULTANEOUS SIGHTINGS
110    DEMS = SIN(BEAR1(I,J) - BEAR2(I,J))
      DIST = BSL*SIN(-BEAR2(I,J)+BSLDR)/DEMS
      DISTA = BSL*SIN(BSLDR-BEAR1(I,J))/DEMS
      X(I,J) = SIN(BEAR1(I,J))*DIST
      Y(I,J) = COS(BEAR1(I,J))*DIST
C
C      CALCULATE VELOCITY SINCE TIME OF RELEASE AND FROM
C      POINT TO POINT
C
120    DELT = TIME(I,J)-START(J)
      XVTOL = X(I,J)*100./DELT
      YVTOL = Y(I,J)*100./DELT
      VTOL = SQRT(XVTOL*XVTOL + YVTOL*YVTOL)
      ANTOL = ATAN(XVTOL,YVTOL)*RTOD
      IF(I.EQ.1) GO TO 125
      DELX = X(I,J)-X(I-1,J)
      DELY = Y(I,J)-Y(I-1,J)
      DELT = TIME(I,J) - TIME(I-1,J)
      XVD = DELX*100./DELT

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      YVD = DELY*100./DELT
      VD = SQRT(XVD*XVD + YVD*YVD)
      AND = ATAN(XVD,YVD)*RTOD
C
C      FIND RANGE OF POSITIONS
C
125   XMAX = AMAX(XMAX,X(I,J))
      XMIN = AMIN(XMIN,X(I,J))
      YMAX = AMAX(YMAX,Y(I,J))
      YMIN = AMIN(YMIN,Y(I,J))
C
C      PRINTOUT RESULTS
C
      WRITE(108,810) TIME(I,J),DISTA,X(I,J),Y(I,J),
& XVTOL,YVTOL,VTOL,ANTOL,XVD,YVD,VD,AND
150   CONTINUE
200   CONTINUE
      WRITE(108,820)
      OUTPUT XMAX,XMIN,YMAX,YMIN
C
C      IF IPLOT.NE.0 PLOT SIGHTINGS AND SHIP POSITIONS
C
      IF(IPLOT.EQ.0) GO TO 1000
      CALL PLOTS(IBUF,1000)
      SCALX = (EMAX-EMIN)/XAXL
      SCALY = (NMAX-NMIN)/YAXL
      XO = -EMIN/SCALX
      YO = -NMIN/SCALY
      CALL PLOT(XO,YO,-3)
      CALL PLOT(.1,0.,3)
      CALL PLOT(-.1,0.,2)
      CALL PLOT(0.,.1,3)
      CALL PLOT(0.,-.1,2)
      XAS = BSL*SIN(BSLDR)/SCALX
      YAS = BSL*COS(BSLDR)/SCALY
      CALL PLOT(XAS+.1,YAS,3)
      CALL PLOT(XAS-.1,YAS,2)
      CALL PLOT(XAS,YAS+.1,3)
      CALL PLOT(XAS,YAS-.1,2)
      CALL SYMBOL(XAS-.15,YAS-.15,.14,'A',0,1)
      CALL AXIS(-XO,-YO,XTIT,-20,XAXL,0.,EMIN,SCALX)
      CALL AXIS(-XO,-YO,YTIT,20,YAXL,90.,NMIN,SCALY)
      DO 300 J=1,NUMFL
      DO 250 I=1,NUMSI(J)
      IF(X(I,J).LT.EMIN.OR.X(I,J).GT.EMAX) GO TO 250
      XX = X(I,J)/SCALX
      IF(Y(I,J).LT.NMIN.OR.Y(I,J).GT.NMAX) GO TO 250
      YY = Y(I,J)/SCALY
      CALL SYMBOL(XX,YY,.07,J,0.,-1)
250   CONTINUE
300   CONTINUE
      YCCRN = NMAX/SCALY
      CALL SYMBOL(-XO+1.,YCCRN,.14,ITIT,0.,20)
      CALL PLOT(XAXL,0,999)
1000  CALL EXIT
800   FORMAT(////5X,' POSITIONS & VELOCITIES OF DROUG #',I5//
& ' TIME DIST FROM AST. EAST NORTH'8X,
& 'VEL SINCE REL-CM/S',16X,'VEL PT TO PT-CM/S'/
& ' SEC M M M',8X,
& 'VE',6X,'VN',6X,'VT',5X,'ANG',8X,'VE',6X,'VN',6X,'VT',

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      & 5X, 'ANG' )  
810   FORMAT (F6.0, F10.3, F11.3, F9.3, 2X, 4F8.2, 2X, 4F8.2)  
820   FORMAT (////)  
      END
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<p>Woods Hole Oceanographic Institution WHOI-80-8</p> <p>MEASUREMENT OF NEARSURFACE CURRENT IN CAPE COD BAY USING SIGHTED DROGUES by James H. Churchill and Bert Pade. January 1980. 42 pages. Prepared for the Department of Energy under Grant DE-AC02-79-EV10005.</p> <p>During July 16-19, 1979 currents in Cape Cod Bay from the very near surface to 1.8 m were measured by taking simultaneous bearings on submerged drogues from two anchored vessels. The error in drogue position as a function of location with respect to the two vessels was examined in detail and was used for rejecting or accepting velocities from particular sightings. From the final results well defined velocity shears, nearly parallel with the wind, were evident. From these velocity fields surface stress coefficients, equivalent sand-grain roughness coefficients, and the near surface gradients of relative (to the surface velocity) velocity are calculated.</p>	<p>1. Current measurement, near surface</p> <p>2. Wind driver current</p> <p>3. Drogue studies</p> <p>I. Churchill, James H.</p> <p>II. Pade, Bert</p> <p>III. DE-AC02-79EB10005</p> <p>This card is UNCLASSIFIED</p>	<p>Woods Hole Oceanographic Institution WHOI-80-8</p> <p>MEASUREMENT OF NEARSURFACE CURRENT IN CAPE COD BAY USING SIGHTED DROGUES by James H. Churchill and Bert Pade. January 1980. 42 pages. Prepared for the Department of Energy under Grant DE-AC02-79-EV10005.</p> <p>During July 16-19, 1979 currents in Cape Cod Bay from the very near surface to 1.8 m were measured by taking simultaneous bearings on submerged drogues from two anchored vessels. The error in drogue position as a function of location with respect to the two vessels was examined in detail and was used for rejecting or accepting velocities from particular sightings. From the final results well defined velocity shears, nearly parallel with the wind, were evident. From these velocity fields surface stress coefficients, equivalent sand-grain roughness coefficients, and the near surface gradients of relative (to the surface velocity) velocity are calculated.</p>	<p>1. Current measurement, near surface</p> <p>2. Wind driver current</p> <p>3. Drogue studies</p> <p>I. Churchill, James H.</p> <p>II. Pade, Bert</p> <p>III. DE-AC02-79EB10005</p> <p>This card is UNCLASSIFIED</p>	<p>Woods Hole Oceanographic Institution WHOI-80-8</p> <p>MEASUREMENT OF NEARSURFACE CURRENT IN CAPE COD BAY USING SIGHTED DROGUES by James H. Churchill and Bert Pade. January 1980. 42 pages. Prepared for the Department of Energy under Grant DE-AC02-79-EV10005.</p> <p>During July 16-19, 1979 currents in Cape Cod Bay from the very near surface to 1.8 m were measured by taking simultaneous bearings on submerged drogues from two anchored vessels. The error in drogue position as a function of location with respect to the two vessels was examined in detail and was used for rejecting or accepting velocities from particular sightings. From the final results well defined velocity shears, nearly parallel with the wind, were evident. From these velocity fields surface stress coefficients, equivalent sand-grain roughness coefficients, and the near surface gradients of relative (to the surface velocity) velocity are calculated.</p>	<p>1. Current measurement, near surface</p> <p>2. Wind driver current</p> <p>3. Drogue studies</p> <p>I. Churchill, James H.</p> <p>II. Pade, Bert</p> <p>III. DE-AC02-79EB10005</p> <p>This card is UNCLASSIFIED</p>
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