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A comparison of vertical drift-envelopes to conventional drift-bottles[1,2,3]

Abstract—A comparison of the recovery sites of vertical drift-envelopes and of ballasted drift-bottles released simultaneously at common locations in Nantucket Sound off Cape Cod substantiates a preliminary conclusion, based on small tank experiments and simple calculations, that vertical envelopes move more rapidly through the water due to direct wind influence than do ballasted bottles. The bottles therefore provide a truer indication of surface currents than do the envelopes.

Many types of surface floats have been advocated for use as lagrangian indicators of surface currents. Setting aside the dozens of drogue system designs (Monahan and Monahan 1973*b*) where the drogue-buoy's position is monitored frequently during the drift, and considering only those small surface drifters that are released in clusters, one still has at least a dozen distinct designs to choose among (Monahan and Monahan 1973*a*). Two of the currently most popular surface drifter designs are the ballasted drift-bottle and the vertical drift-envelope. The drift-bottle has been in use as a surface current marker since 1763 (Carruthers 1956; Gakkel' and Samsoniya 1961), while the vertical drift-envelope has been introduced since the close of the Second World War. Before comparing these two types of surface drifters we must state specifically the criteria to be used in evaluating them.

Clearly it is impractical in any measurement program to use a drifter type that does not net a significant number of postcard returns for the number of drifters released. Thus any acceptable drifter must be able to survive at sea for an extended period, must be able to reach the shore through the surf, and once stranded, must be of such a nature that it attracts attention.

A good drifter must not only satisfy these practical criteria, but must move in unison with the surface current. Here one has to decide what the term "surface current" means in the particular context. In a study of the transport of surface film material "surface current" might mean the horizontal motion characteristic of the upper millimeter or less of the water column: for such a study horizontal drift-envelopes (Olson 1951; Duncan 1965) or horizontal drift-cards (Duncan 1965; Stander et al. 1969) should be considered. The selection of ballasted drift-bottles and vertical drift-envelopes for our study reflects our interest in the average horizontal advective velocity of the upper meter or so of the water column and accords with the more common usage of the term "surface current."

While surface currents are usually wind induced, a good surface drifter (if it is to move with the surface current) must suffer minimal direct wind influence, and thus must have a very small ratio of sail area (area exposed to wind) to drogue area (area exposed to current). An initial esti-

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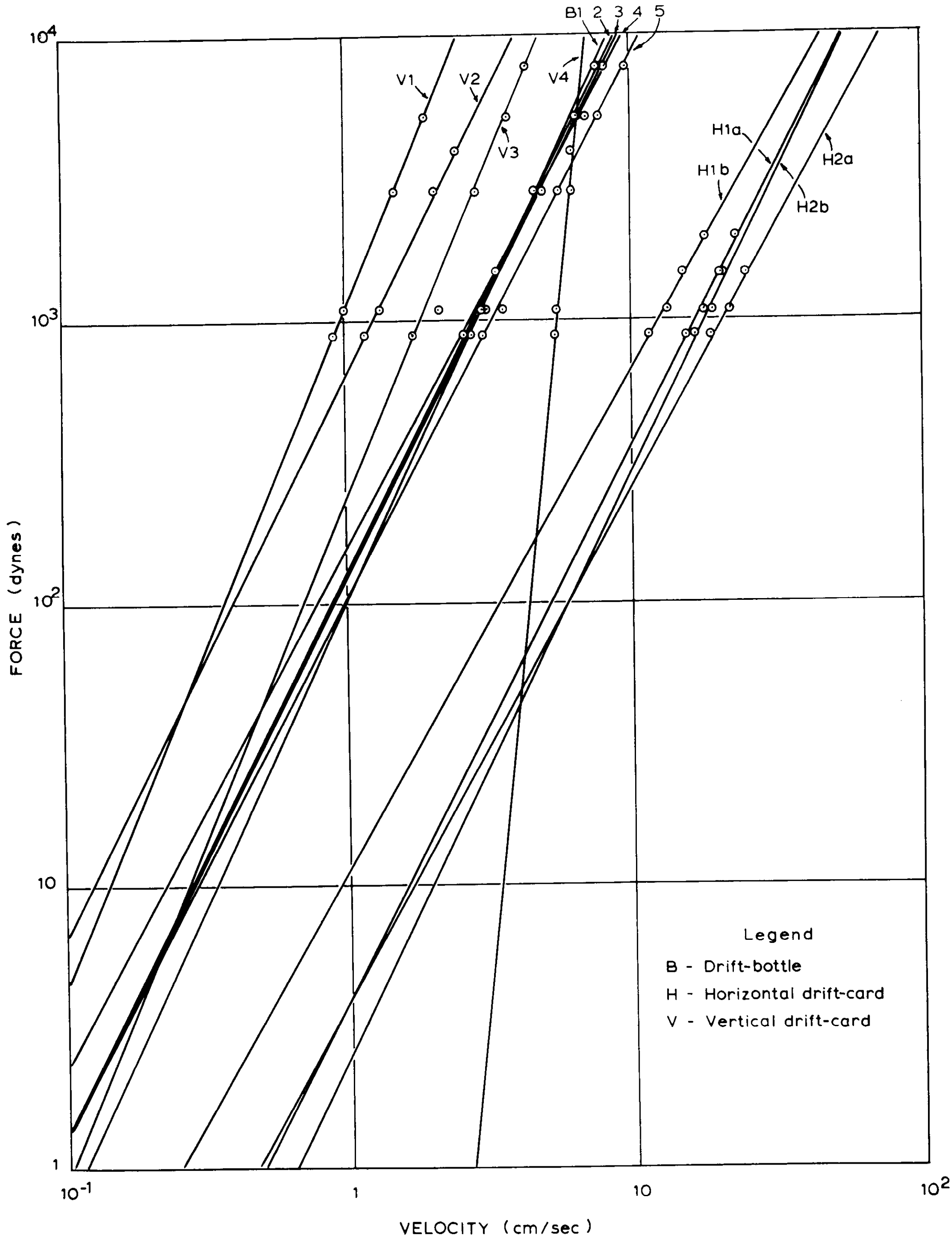

Fig. 1. Results of laboratory tank tests performed on various drifter types. Drogue force, F_D, versus slip velocity, V. *See text and Table 1 for identification of drifter symbols.*

Table 1. The drag forces and slip velocities expected for the various drift-bottles and vertical drift-envelopes when the wind speed 10 m above the sea surface is 8 m sec⁻¹.

Drifter	Mass (g)	A_S Sail area (cm^2)	A_D Drogue area (cm^2)	A_P Plan area (cm^2)	C_D Drag Coeff.	F_S Sail force (dynes)	F_P Plan force (dynes)	V Slip velocity (cm sec^{-1})
Bottles								
B1	480	5.7	129.2	3.7	1.58	5.2	4.3	0.33
B2	467	3.8	126.5	5.2	2.43	5.3	6.0	0.30
B3	523	5.7	139.3	3.8	1.77	5.8	4.4	0.28
B4	456	6.9	133.3	3.8	1.91	7.6	4.4	0.24
B5	411	2.2	120.1	5.2	1.39	1.8	6.0	0.26
Vertical Envelopes								
V1	31.9	70.0	355.3	---	6.08	246	---	0.54
V2	32.5	121.1	244.8	---	5.11	357	---	0.76
V3	17.7	67.6	147.3	---	2.67	104	---	0.71

mate of the relative importance of direct wind influence in inducing motion through the water of ballasted drift-bottles and vertical drift-envelopes was obtained from a combination of laboratory tank experiments with simple drag calculations.

Five types of drift-bottles (including several soft drink bottles and the flint glass bottles used by W.H.O.I.) and three types of vertical drift-envelopes were tested. The laboratory experiments were conducted in a narrow tank, 150 cm long. The drifter to be tested was placed at one end of the tank, and a horizontal thread was run from the exposed portion of the drifter over a ring at the far end of the tank to an adjustable hanging weight. When this weight was released the drifter was initially accelerated toward the far end of the tank, reaching a terminal velocity after it had been towed a fraction of the way down the tank. Its time of travel over a 50-cm section was then measured. For each drifter the procedure was carried out for at least four different values of the hanging weight, with 20 runs conducted at each weight setting.

The results of these tank tests are summarized on Fig. 1. Straight lines have been fitted through the data points on this log-log plot and extrapolated down to a lower range of velocities than were actually observed in the tests. All but one of the lines for the bottles (Bs) and the vertical drifters (Vs) exhibit slopes of about 2, indicative of a constant drag coefficient over the range of measurement. The exception, V4, is the case of a folded vertical card (Martin 1967), whose effective drogue area changes markedly with velocity. The other Vs all refer to vertical drift-envelopes, of the sort we subsequently used in the field intercomparison, while the lines (Hs) on the right are based on tests of horizontal drift-cards and envelopes, whose behavior will not be further discussed.

The drag coefficients, C_D, for the various drift-bottles and vertical drift-envelopes tested are given in Table 1, along with other measured properties of each drifter. The sail and drogue areas, A_S and A_D, are

Table 2. Drifter release (Rel.) and recovery (Rec.) information for combined clusters released at five stations in Nantucket Sound on 11 May 1972.

	Bottles			Vertical envelopes		
Stat.	Rel.	Rec.	Return %	Rel.	Rec.	Return %
A	15	8	53	15	10	67
B	10	5	50	5	4	80
C	15	3	20	15	5	33
D	10	2	20	5	2	40
E	10	6	60	5	5	100
Total	60	24	40	45	26	58

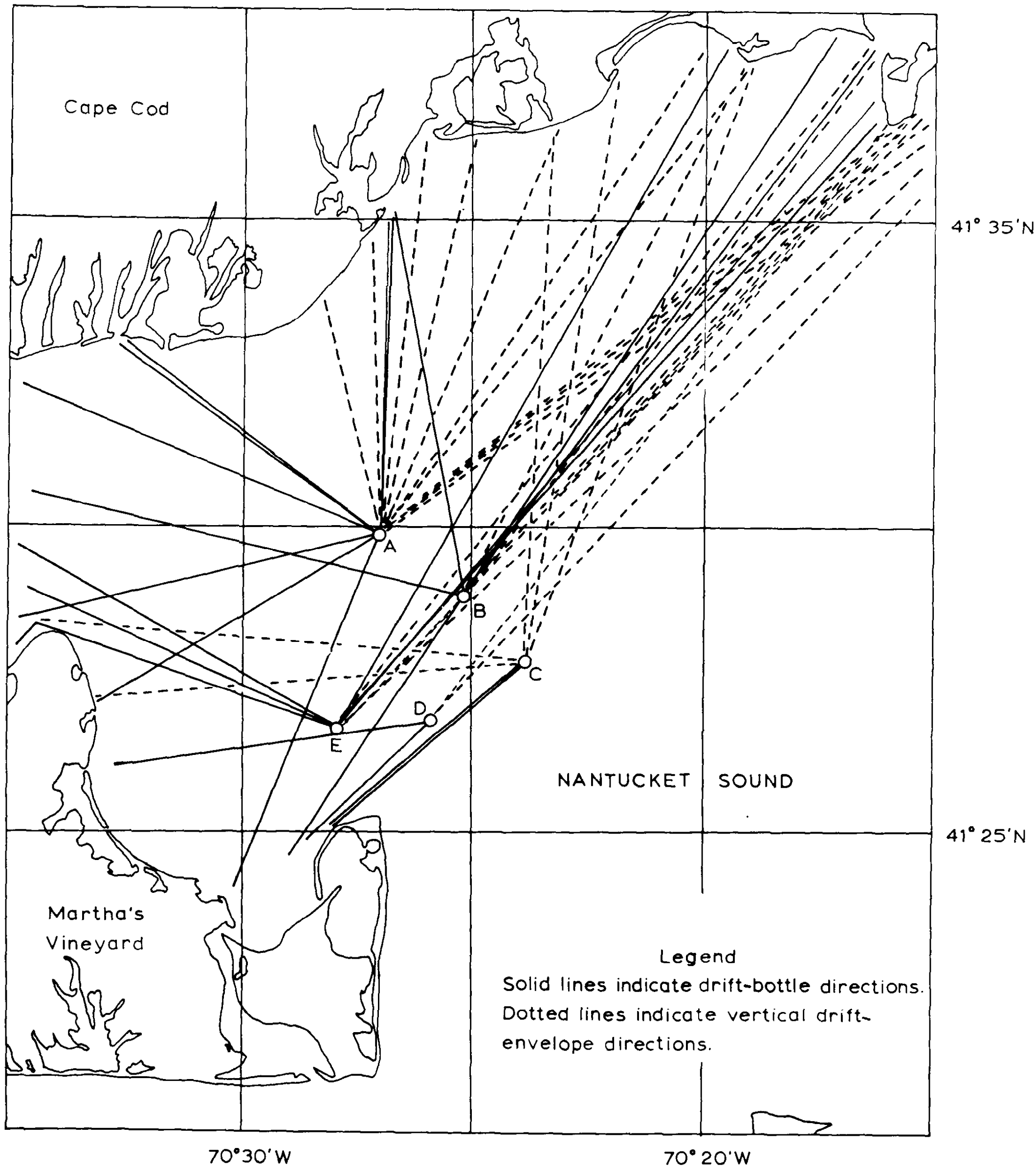

Fig. 2. Chart of Nantucket Sound and environs showing locations of drifter cluster release stations. Straight lines indicate direction from release location to recovery location for each drifter, not actual drifter trajectories.

based on the observed waterline of each drifter in freshwater at about 20°C. The plan area, A_P, is the horizontal cross-sectional area at the waterline. The sail force, F_S, to be expected when the wind speed at an elevation of 10 m (U_{10}) is 800 cm sec^{-1}, was calculated from the expression

$$F_S = \tfrac{1}{2}\rho C_D A_S U_*^2. \quad (1)$$

U_*, the friction velocity, was determined using

$$U_* = (\tau_0/\rho)^{\frac{1}{2}}. \quad (2)$$

τ_0, the surface wind stress, was in turn calculated from the relation

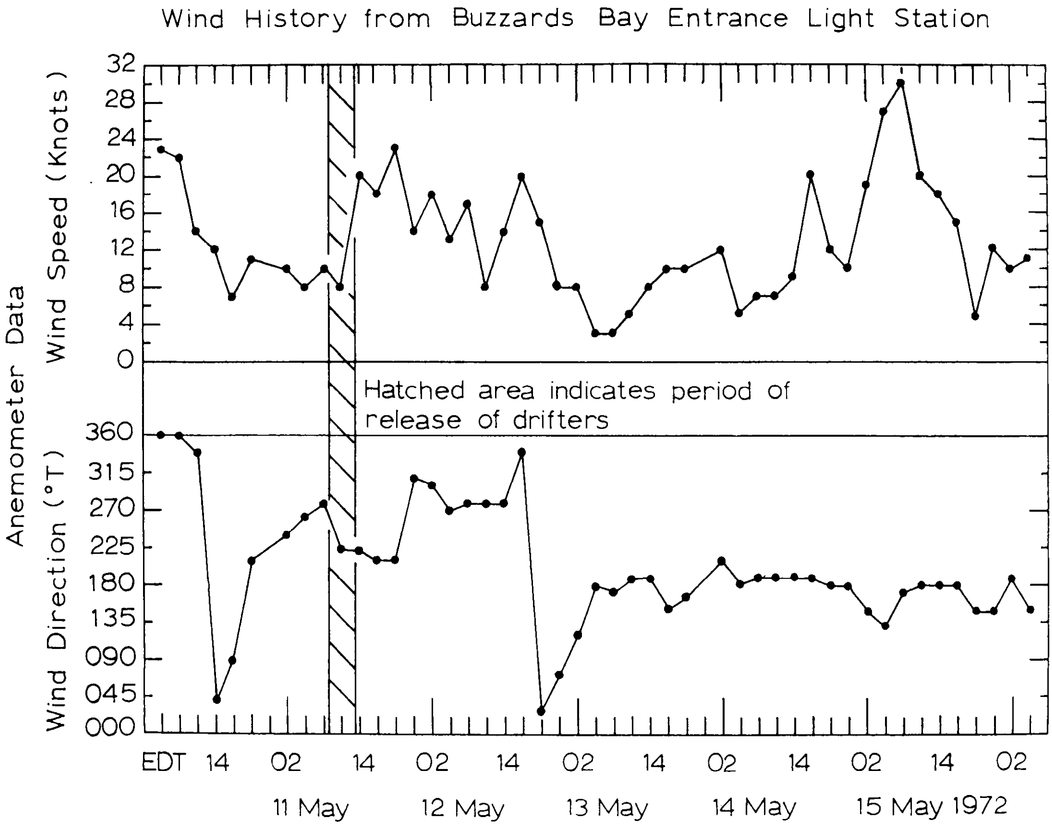

Fig. 3. Wind observations from the Buzzards Bay Entrance Light Station for the period covering the time of drifter cluster release and the next 4 days.

$$\tau_0 = \rho C_{10} U_{10}^2, \qquad (3)$$

where C_{10} was taken to be 0.0015 (Roll 1965) and ρ was assumed to be 1.2×10^{-3} g cm^{-3}. In taking U_*, which in this instance is 31.0 cm sec^{-1}, as an estimate of the effective horizontal velocity experienced by the sail of each drifter, a minimum possible value of F_S was calculated, since U_* represents a lower limit on the effective horizontal velocity. The effect of this assumption on the intercomparison of vertical envelopes and bottles is pointed out below. The planar drag force, F_P, for the assumed U_{10} of 800 cm sec^{-1}, was approximated by the expression

$$F_P = A_P \tau_0. \qquad (4)$$

The wind induced slip velocity, V, was obtained directly from Fig. 1, recognizing that the drogue force, F_D, at this wind speed, was simply

$$F_D = F_S + F_P, \qquad (5)$$

since each drifter, when traveling with its terminal slip velocity, must have no net horizontal force acting on it. It is apparent from Table 1 that the F_D values for the vertical envelopes, for which the F_P components are negligible, are more influenced by the low estimates of F_S associated with the velocity assumption mentioned previously than the F_D values for the bottles, for which the F_P components are significant. Hence it is to be expected that the actual slip velocities of the vertical drift-envelopes will exceed the actual slip velocities of the drift-bottles by even wider margins than are indicated in the last column of Table 1. Clearly, the vertical drift-envelopes can be expected to exhibit greater sailing before the wind than the drift-bottles.

It should be pointed out, in addition to the various assumptions previously discussed, that these calculations are based on observations made in still water. Thus the influence of waves in altering the effective sail area of drifters, in directly moving drifters horizontally through the water (Karwowski 1963), and, for drifters that lack cylindrical symmetry, in altering their aspect to the wind so that they do not sail directly downwind has not been taken into account.

To test in the field our preliminary conclusion that vertical drift-envelopes should show greater direct wind influence than ballasted drift-bottles, several large clusters each made up of a combination of the several types of drifters were released at selected locations in Nantucket Sound on 11 May 1972. The numbers of drifters released in five such clusters are presented in Table 2 with the number recovered from each release. The positions of the release stations are shown on Fig. 2; the largest combined clusters were released at stations A and C.

Although the influence of the oscillatory tidal component of the local currents is manifested by the wide scatter of recovery locations for both the bottles and the vertical envelopes released at each station, it is clear that the typical vertical envelope was found farther to the northeast than was the typical bottle. When these drifter return patterns are considered along with the wind data from the nearest regular recording location (Fig. 3), which indicate that the wind was out of the south and west for at least 4 days after the clusters were released, it is apparent that the vertical drift-envelopes, with their typically downwind trajectories, are indeed suffering greater direct wind influence than are the ballasted drift-bottles.

The field comparison tests thus substantiate our preliminary conclusion, based on the results of tank experiments and simple calculations, that vertical drift-envelopes are more liable to direct wind influence than are ballasted drift-bottles. The drift-bottles therefore give a better measure of the surface currents than do the vertical drift-envelopes.

Given the proximity to shore of the drifter release stations, and the prevalence of light surf and sheltered beaches, it is not surprising that a satisfactorily large fraction of the drifters released was found and reported (Table 2). These circumstances prevented an evaluation of the durability of either the envelopes or the bottles.

The vertical drift-envelopes that we used each had a foam flotation strip sealed in its upper end. The portion of the envelope enclosing this strip, and a further segment below this, were exposed above the sea surface, giving too large a ratio of sail area to drogue area for optimum performance. After completion of the Nantucket Sound study we got a shipment of vertical drift-envelopes without flotation strips. These envelopes have a sail to drogue ratio of 0.58, higher than the average ratio for the drift-envelopes listed in Table 1 (0.38), so there is reason to assume that the new envelopes will be even more subject to wind influence than those available at the time of the field study.

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