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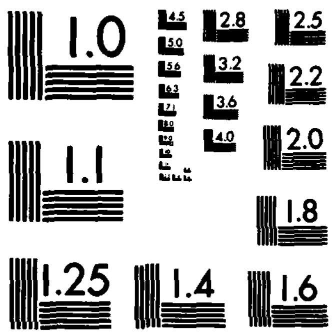

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REPORT NO. CG-D-16-85

AN EVALUATION OF CASP DRIFT PREDICTIONS NEAR THE NEW ENGLAND SHELF/SLOPE FRONT

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JANUARY 1985
INTERIM REPORT

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

OFFICE OF RESEARCH AND DEVELOPMENT
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This report is the nineteenth in a series that documents the Improvement in Probability of Detection in Search and Rescue (POD/SAR) project at the U.S.C.G. R&D Center.

In June 1984 a series of experiments was conducted

16. Abstract

During June 1984, the U.S. Coast Guard Research and Development Center, Commander, International Ice Patrol, and the University of Delaware conducted a series of experiments in which the drift predictions of the Coast Guard's operational search planning computer model (CASP) were evaluated. Three satellite-tracked drift buoys and a life raft were released and tracked for two 3-day periods at the New England Shelf/Slope Front. Their movement was compared with CASP drift predictions for simulated PIW's and a life raft for two sets of environmental data: historical currents and large-scale winds versus locally measured data. For the historical data, the observed drift errors were two to four times larger than drift errors calculated by CASP. The use of on-scene environmental data improved the predictions for PIW's to near the CASP-calculated drift errors, but not for the life raft. Significant differences in the surface currents occurred over 20 nautical miles and 3 to 5 days, which were not accounted for by the historical surface current files, and therefore increased the error in the drift prediction of CASP.

17. Key Words
Search and rescue; surface currents; fronts; satellite-tracked buoys; ocean circulation; drift prediction

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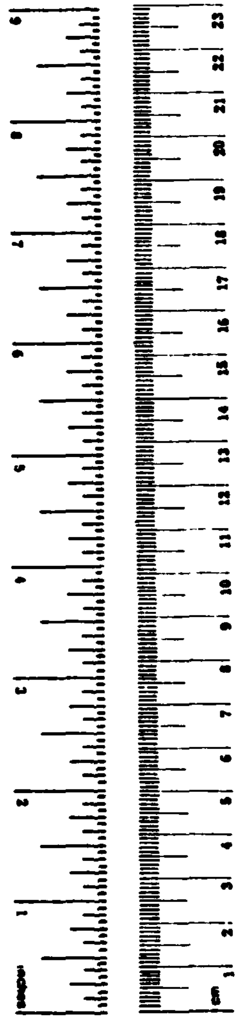
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

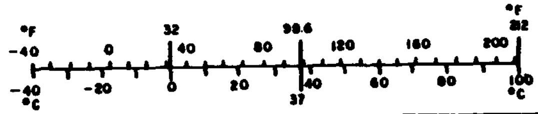
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CONTENTS

ILLUSTRATIONS

TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

No matter how thorough the search or how sophisticated the search platform, the probability of detection (POD) of a search object is zero if it is not in the search area. As a result, establishing an accurate datum (probable location of search object) is essential to the success of a search.

This report describes the preliminary results of a search and rescue (SAR) drift experiment conducted from 11 June to 26 June 1984 near the edge of the continental shelf (Figure 1-1), approximately 170 kilometers (~90 nautical miles) south of Block Island, Rhode Island. The objectives were two fold: first, to test the accuracy of the drift predictions of the Computer Assisted Search Planning Program (CASP) for the study area and, second, to investigate how the accuracy changes when on-scene wind and current data are used in CASP. The experiment was a cooperative effort between the Coast Guard Research and Development Center (R&DC), Commander, International Ice Patrol (CIIP), and the University of Delaware (UDel).

The study area contains the Shelf/Slope Front of the Middle Atlantic Bight, a permanent water mass boundary extending about 1000 kilometers along the shelf break from Cape Hatteras to Georges Bank. It separates the relatively cool, fresh water of the outer continental shelf from the warmer, saltier North Atlantic Slope water inshore of the Gulf Stream. Its surface expression is readily seen in the surface temperature distribution except during the summer when seasonal heating masks this feature. The details of the circulation in this region are not well known and were the subject of the UDel oceanographic study.

The UDel study, funded by the National Science Foundation, involved the deployment and tracking of 90 radio-tracked buoys as well as intensive hydrographic measurements in the vicinity of the Front. These data are being analyzed and will be provided to the Coast Guard upon completion. Although the oceanographic environment cannot yet

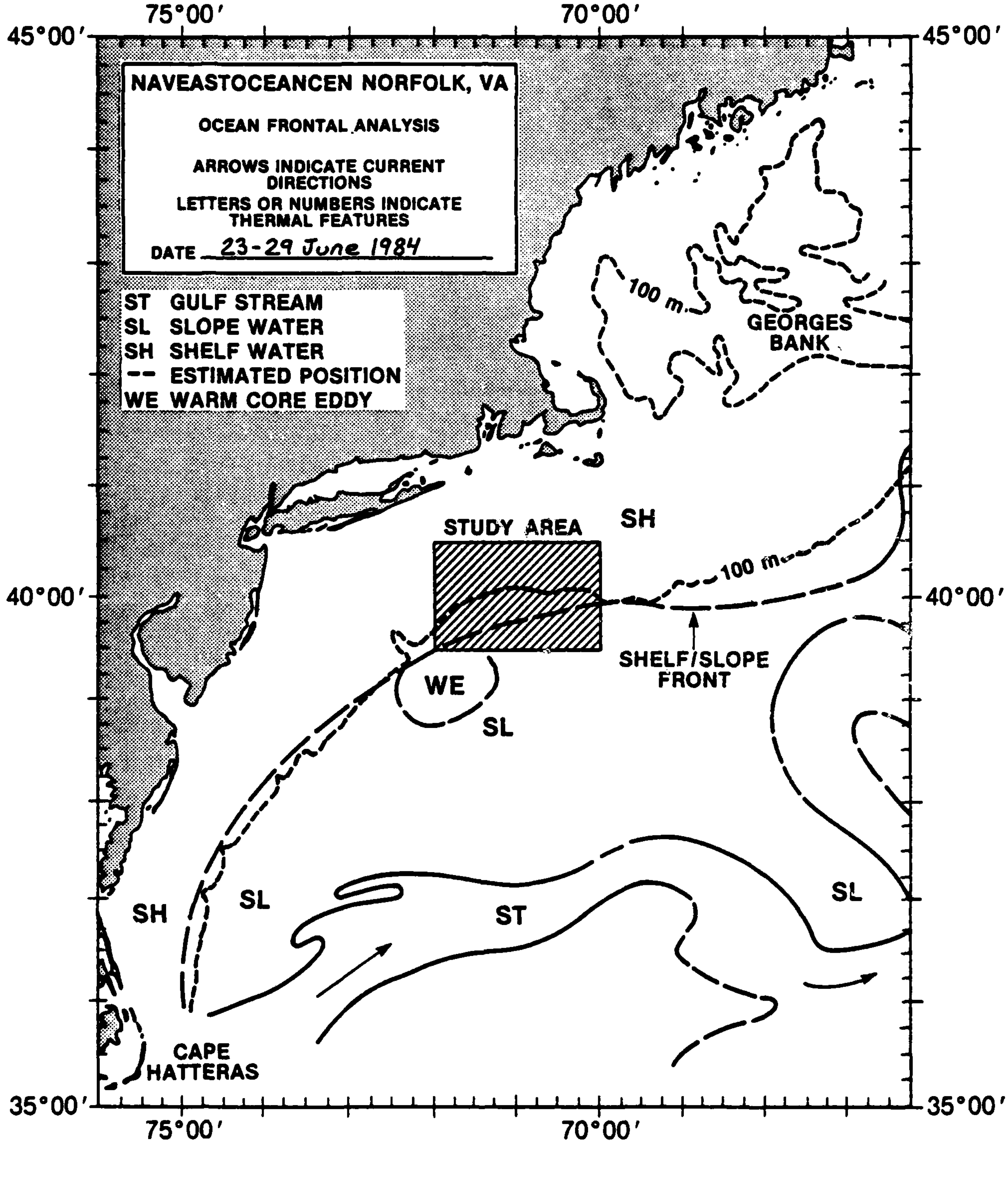


Figure 1-1. Approximate Location of June 1984 Experiment. (Ocean Frontal Analysis provided by U.S. Naval Eastern Oceanography Center, Norfolk, Virginia)

be evaluated completely, the data collected by the Coast Guard are sufficient for a CASP evaluation and a preliminary study of the use of on-scene wind and current measurements in CASP.

The R&DC deployed simulated SAR targets (three satellite-tracked buoys and one life raft) from the UDel vessel, R/V CAPE HENLOPEN. After deploying the targets, CAPE HENLOPEN made hydrographic measurements while continuously circuiting the study area. As a result, the wind data taken aboard CAPE HENLOPEN represent data expected from a surface SAR unit. In addition, the Coast Guard buoys can be used, not only as simulated SAR targets, but also to develop real-time current data for CASP. Thus, the results described in this report are a preliminary evaluation of a system that uses on-scene environmental data for CASP drift predictions.

1.2 CASP

The accuracy of CASP, the Coast Guard's operational SAR model since 1982, depends primarily on the quality of the wind and current data used in the drift predictions.

Wind Data. The wind data, provided to the Coast Guard by the U. S. Navy Fleet Numerical Oceanography Center (FNOC), are the result of large-scale meteorological observations and are reported on a very coarse (5° x 5°) grid. Forecasts are provided for 36 hours and, as observations are made, the FNOC computes observed (analysis) winds, which then replace the forecast winds. In CASP, the analysis winds are referred to as System winds and the forecast winds are called Predicted winds.

Current Data. The primary CASP sea current file for the area, the Wagner file, is based on historical ship set and drift data and varies monthly; it is reported for a 1° x 1° grid. The sea current data in the study area for the month of June are shown in Figure 1-2. For most of the study area (40° N to 41° N and 70° W to 71° W), the currents are zero or very weak.

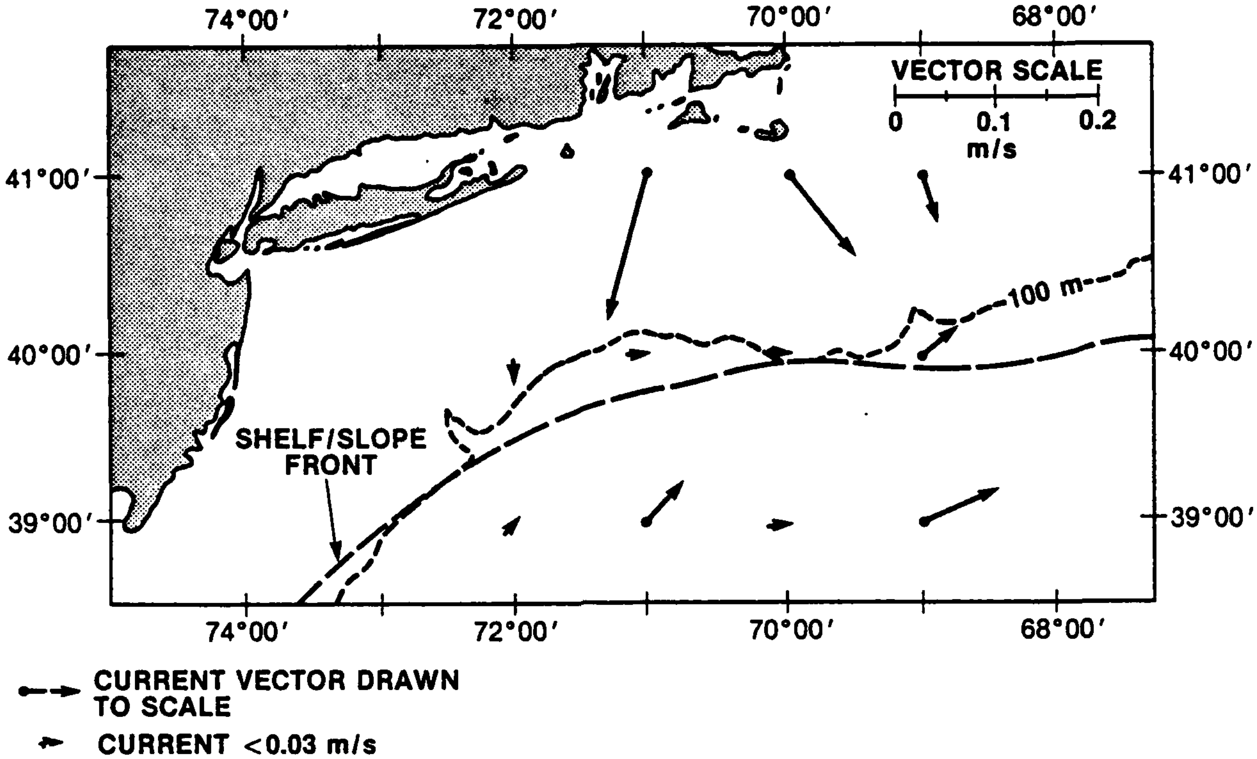


Figure 1-2. CASP Sea Current Data for June

The difficulty in making hourly or daily drift predictions for a specific site using such data inputs is clear. The 5° x 5° wind grid is reasonable for large-scale atmospheric dynamics, but, with a grid spacing of up to 550 kilometers (300 nautical miles), it is not adequate for the regional drift predictions required for SAR. The current files have two major limitations. The first is the fact that they are based primarily on set and drift data, which suffer from several well-known errors including navigational errors. In addition, set and drift data contain, to an unknown extent, the effects of vessel leeway and wind-driven current. The second limitation is that the space scale of the 1° x 1° grid and the monthly time scale fail to resolve important current fluctuations on shorter scales that can dominate the flow field, and which are critical to SAR cases.

Two previous studies have documented inaccuracies in CASP drift predictions. Murphy et al (1982) compared the movement of 12 satellite-tracked buoys released in the Gulf Stream east of Florida with the drift predictions of the computerized Search And Rescue Planning (SARP) system, the CASP predecessor. They found that, for 24-hour predictions, the search target was in the area in 9.1 percent of the cases evaluated. As expected, the errors increased with longer prediction times. They found no discernible difference between drift predictions made with predicted winds and those made using analysis winds. They concluded that the sea current files used by SARP were the cause of the errors; most of these files are still used by CASP. They also concluded that the drift error factor, used by SARP to estimate the error in the drift of a target, seriously underestimated the actual drift error. The drift error factor (DEF) is defined as the ratio between the total drift error and the total predicted drift. SARP used a DEF of 1/8 (0.125), but Murphy et al (1982) computed the ratio using the observed error and found the DEF was 0.96. This means that the drift error was approximately as large as the total predicted drift. CASP presently uses a DEF of 3/8 (0.375).

Anderson (1984) evaluated CASP drift predictions in the North Atlantic using the movement of satellite-tracked buoys deployed in support of IIP operations during the 1983 iceberg season. He established dynamic and non-dynamic regions based on the average buoy drift speeds. He then tested the accuracy of the CASP drift predictions using several combinations of environmental inputs:

1. System winds and system currents,
2. System winds and zero currents,
3. System winds and geostrophic currents from the IIP data base (from historical hydrography), and
4. No winds and system currents.

He found that, in both areas and in all cases, the errors grew with increasing prediction time and that the errors did not change substantially regardless of the wind and current inputs. He also determined that the drift error factor used by CASP underestimated the drift errors. The ratio between observed drift error and the total observed drift was 0.7. Although he used the observed total drift rather than the total predicted drift to calculate this value, the results are much the same as Murphy et al (1982).

These two studies investigated the drift predictions of SARP and CASP using forecast and analysis winds, and a wide variety of current data (all historical). In all cases, the errors were unacceptably large with drift errors on the order of 70 to 100 percent of the total drift. Both previous studies recommended that CASP evaluations be conducted in areas where real-time environmental measurements were being taken in the study area.

This report describes a CASP evaluation using on-scene environmental measurements and extended (up to four-day) drifts of a realistic SAR target. The location of the study area is important from both the SAR and oceanographic standpoints. The New England Shelf/Slope Front is well known as an active fishing site and, thus, is a high traffic area. The study area contains two distinct oceanic regions, the shelf and the slope, and a major oceanic front. Hence, there are rapid variations in the strength and direction of the currents over short distances (30 kilometers) and time periods (2 to 3 days), which are critical to SAR cases.

Chapter 2 describes the simulated SAR targets, their deployment, and drift tracks. It also presents the CASP options that were tested and the methods used to calculate the errors. Chapter 3 discusses the errors in the CASP drift predictions based on the input options: system winds and currents, predicted winds, and on-scene winds and currents. Finally, Chapter 4 presents the conclusions and recommendations.

CHAPTER 2
METHODS

2.1 INTRODUCTION

This chapter describes the data acquisition and computational methods used in the study. It presents:

1. The types of simulated SAR targets and the positioning system used in the study,
2. The target deployment strategy, and
3. The inputs for the specific CASP runs.

2.2 TARGETS

Two target types were used in the experiment. The first (Figure 2-1) was a TIROS Oceanographic Drifter (TOD) and the second (Figure 2-2) was a Givens Buoy 6-person life raft containing an ARGOS Data Acquisition Platform (ADAP). The ADAP, designed to be deployed onto sea ice, contains the same electronics as the TOD, but is packed in a much smaller case. Both target types were tracked by the polar-orbiting NOAA/TIROS series satellites and the data were received from the ARGOS tracking system. The ARGOS system provides a position accuracy of approximately 300 meters and, for the latitude of the experiment, three to five fixes per day (Bessis, 1981).

The three TOD's used in the study served the dual roles of a simulated person-in-the-water (PIW) and a current measuring device. TOD's have very little leeway, particularly when drogued; therefore, TOD's are most appropriately represented in the CASP model as PIW's. All the TOD's were deployed with a window-shade drogue attached to the buoy with a tether that included a shock cord to help maintain drogue depth, even in rough seas. Two of the drogues were 10 x 2 meters; the third was 6 x 2 meters.

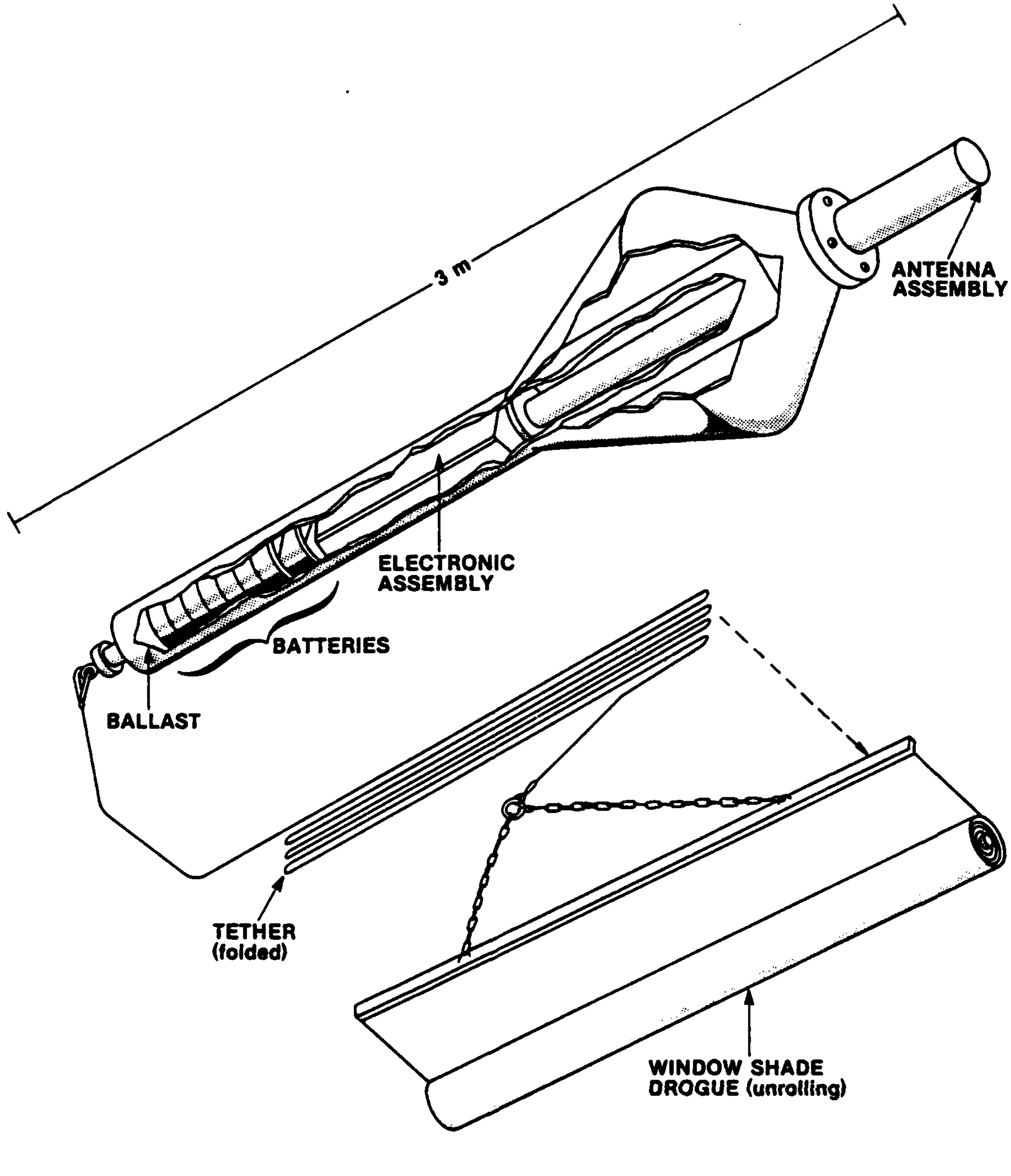


Figure 2-1. TIROS Oceanographic Drifter (TOD)

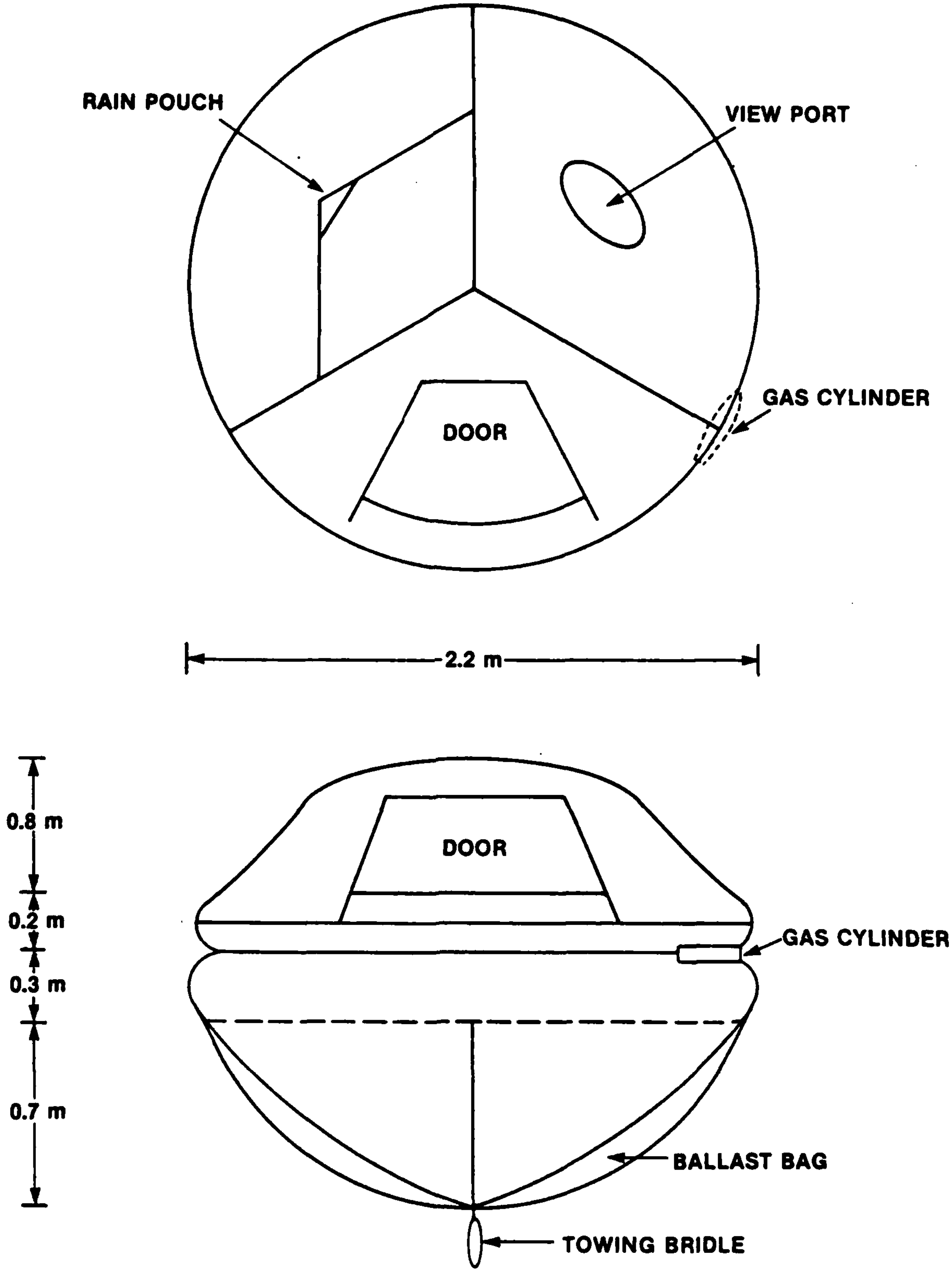


Figure 2-2. Givens Buoy 6-Person Life Raft

The Givens Buoy life raft has a canopy and a hemispherical ballast system. The top of the canopy is approximately 1.3 meters above the unloaded waterline, and the ballast system extends to a depth of approximately 0.7 meters. For this experiment, the raft was deployed with only the ADAP aboard. Fully loaded, the draft would increase to about 1 meter and the height of the top of the canopy would decrease to about 1 meter. These changes (about 0.25 meter in height and draft) are small, and are assumed to be negligible for this study. In all cases, the life raft was deployed without a drogue.

Choosing the appropriate CASP target based on leeway characteristics of the life raft is not as easy as in the PIW case. CASP offers three choices: raft without a drogue, raft with a drogue, and user-defined leeway. At the time of the experiment, no generally accepted leeway characteristics for the Givens Buoy life raft were available. As a result, for all of the raft drift predictions two choices were run: raft without a drogue and raft with a drogue.

Further information on search target leeway characteristics, including those for the Givens Buoy raft, is presently being developed as part of an R&DC leeway investigation (Nash, 1985).

2.3 DEPLOYMENT STRATEGY

The experiment was divided into three separate drift periods, each of approximately three days' duration.

In the first period, one TOD, drogued at 18 meters (depth of the drogue center), was deployed (Figure 2-3). Its drift provided simulated PIW target movement and current information for preliminary CASP runs, as well as a test of the buoy location and recovery procedures aboard CAPE HENLOPEN. Using a combination of ARGOS position data, a radio direction finder (RDF), and visual search, the TOD was recovered without incident. Typically, the RDF began to receive the buoy signal at 9 kilometers, and at about 5 kilometers the signal was strong enough to provide a reliable relative bearing. The buoy was detected visually at 1 to 2 kilometers.

In the second and third periods, all three TOD's and the ADAP-equipped life raft were deployed (Figure 2-3). For both periods, the TOD deployment strategy was the same. Two TOD's, one drogued at 35 meters (2581) and the other drogued at 12 meters (2601), were deployed at the same location north of the Front. The third, drogued at 12 meters (2600), was deployed south of the Front. At the beginning of the second period, the raft was deployed with TOD 2600, south of the Front. During the third period, the raft was deployed north of the Front about 13 kilometers south of the launch location of TOD's 2581 and 2601.

CAPE HENLOPEN recovered all of the targets at the end of each drift period. Aside from the obvious advantage of allowing the reuse of the drifters, the recovery allowed the confirmation that the TOD drogues remained attached during the entire drift; neither Murphy et al (1982) nor Anderson (1984) could be certain of the fate of the drogues.

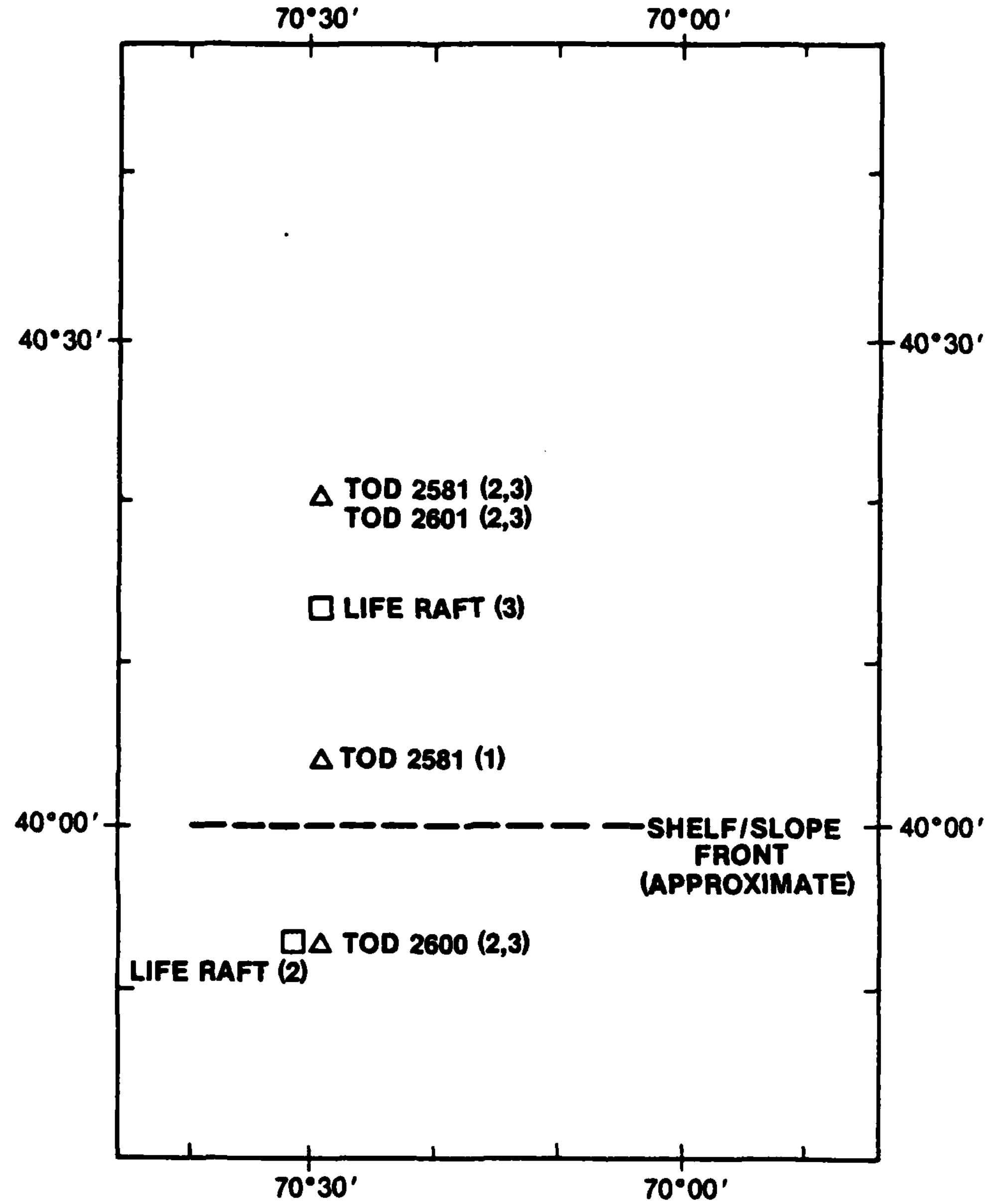
The deployment strategy described above permits the evaluation of CASP drift predictions for both the TOD's and the raft on both sides of the Shelf/Slope Front. In addition, the movement of two of the buoys was used to develop an observed current field, called case-dependent by CASP, north (2581) and south (2600) of the Front.

2.4 INPUTS TO CASP DRIFT PREDICTIONS

Each target deployment time and position was used as the incident date-time-group (DTG) and last known position (LKP) for CASP drift predictions of 12, 24, 36, and 48 hours. As additional platform positions became known, they were used to start a new set of CASP predictions. A minimum interval of 6 hours between new platform positions used for the CASP runs was established to avoid making predictions that were essentially duplicates.

Three CASP options were tested.

1. Environmental Files. This was the primary variable of the experiment. For all of the TOD and raft tracks in each of the three drift periods, CASP was run using system winds and system currents. Most of these runs were made



NOTE: THE NUMBERS IN PARENTHESES INDICATE THE DRIFT PERIOD.

Figure 2-3. Approximate TOD and Life Raft Deployment Locations for Each Drift Period after the experiment using the archived system (analysis) winds; however, some runs were made during the experiment using predicted winds.

For the second and third drift periods, observed wind and current data were used to create case-dependent environmental files for input to CASP. The wind data were measured aboard CAPE HENLOPEN at approximately 6-hour intervals and linearly interpolated in time to arrive at an evenly spaced wind record. The wind measured aboard ship was assumed to be representative of the wind in the entire study area. Even for the CASP runs made with case-dependent winds, some system winds were used because the wind current calculation in CASP requires 48 hours of antecedent winds; CAPE HENLOPEN was not always on scene 48 hours prior to the start of the CASP runs. Even though this leads to inhomogeneous wind input, it is a realistic SAR scenario because a SAR unit would not have been on the scene 48 hours before the case.

During the second and third periods, the drifts of TOD's 2581 and 2600 were used to create case-dependent sea current files north and south of the Front. Buoy speeds and directions were linearly interpolated to an evenly spaced current record with 6-hour intervals. The current file derived from the drift of 2581 was assumed to be representative of the currents in the entire area north of the Front; the record from 2600 for the area south of the Front. During the experiment, the raft and the TOD's never crossed the Front. TOD's 2581 and 2600 were not used as SAR targets for the case-dependent CASP predictions.

2. Datum Marker Buoy (DMB) Option. When a DMB is used during a SAR case, its motion can be used to calculate a case-dependent current file (assuming the buoy can be relocated after deployment). Because the buoy moves with the near-surface currents (<1 meter), the current determined from its motion is assumed to represent the contribution of both the sea current and the wind-driven current. CASP allows the user to choose a DMB option that disables the CASP wind-driven calculation, thus preventing the wind currents from being included twice.

In the experiment, all of the case-dependent CASP runs were made with and without the DMB option.

3. Leeway Characteristics. For all of the life raft CASP runs, two leeway options were used: raft with a drogue and raft without a drogue.

2.4.1 Error Computations

For each CASP run, the predicted target position was compared to the actual position as determined from the satellite fixes. Because ARGOS provides platform positions at irregular intervals, the TOD and raft position data were linearly interpolated in time to estimate a position to coincide with the time of the predicted datum. Rarely was it necessary to interpolate over an interval greater than 12 hours, and the datum times typically were no more than 3 hours from the closest satellite fix.

Two error computations were made to evaluate the accuracy of each CASP drift prediction. The first, the observed drift error, was the computed distance and bearing from the predicted position (datum) to the interpolated (actual) target position. This provided a direct indication of the magnitude and bearing of the error. The second computation, the drift error factor (DEF) was made by taking the ratio of the observed drift error and the total predicted drift (from the CASP output). The DEF provides a direct evaluation of the 0.375 value presently used by CASP to estimate the drift errors.

CHAPTER 3
RESULTS

3.1 INTRODUCTION

This chapter is divided into three parts. Section 3.2 describes the TOD and raft trajectories. The intent is to introduce the drift of CASP targets rather than to describe the oceanography of the area. Section 3.3 describes the CASP drift predictions made using system winds and system currents. In this section, all three TOD's and the raft are used as simulated SAR targets. Section 3.4 presents the results of two TOD's (2581 north of the Front and 2600 to the south) are used to compute an observed current field north and south of the Front. The remaining TOD (2601) and the raft are used as simulated SAR targets. The wind data are from the on-scene vessel. In Sections 3.3 and 3.4, nautical units are used so that the results can be related directly to the CASP outputs.

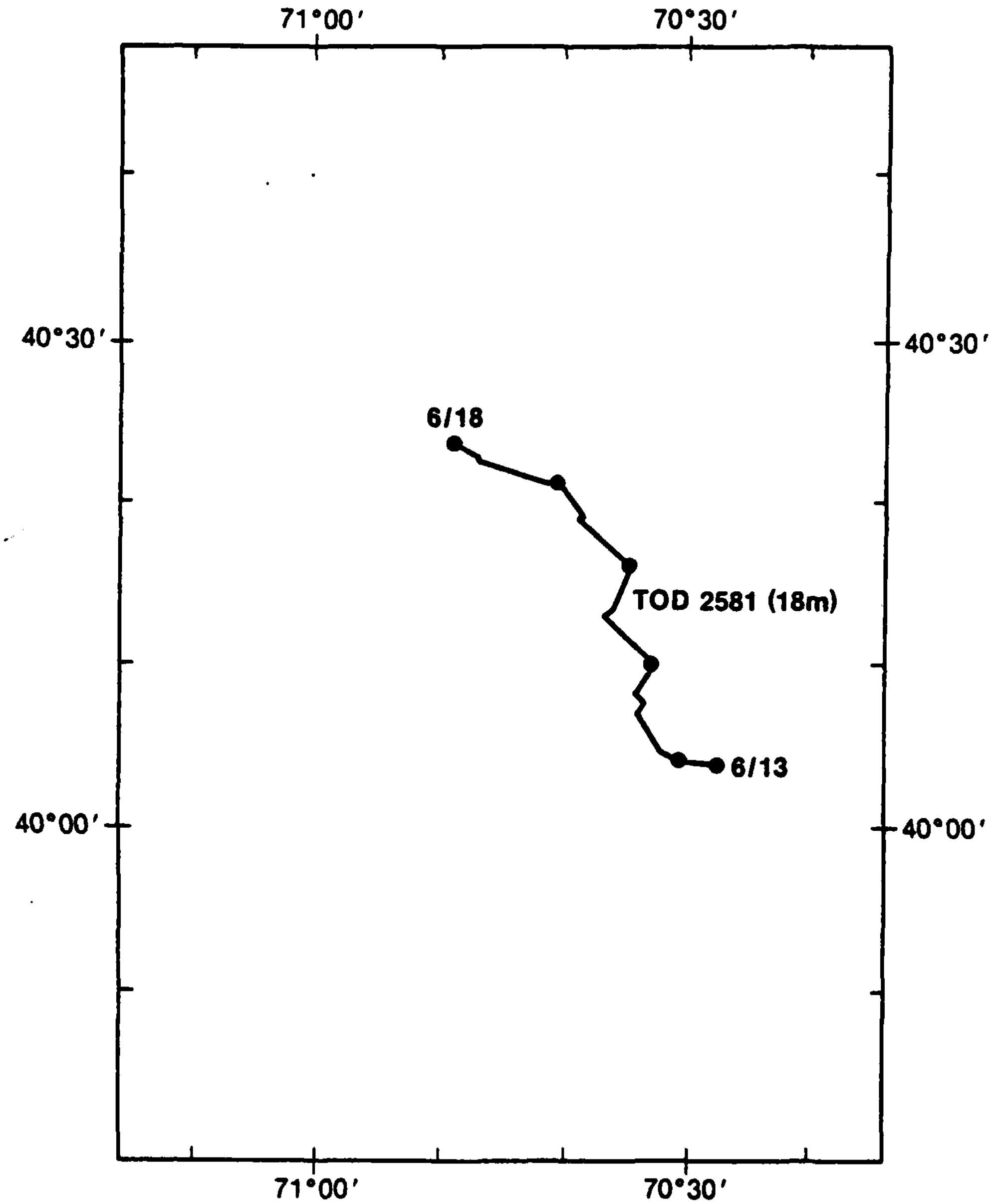
3.2 DRIFT TRACKS

Figures 3-1 through 3-3 show the trajectories of the TOD's and the life raft for all three periods.

In the first period (Figure 3-1) TOD 2581, drogued at 18 meters, moved persistently to the northwest after its deployment on 13 June; it was recovered on 18 June. Its net motion over the entire period was 0.10 meter/second toward 320°T.

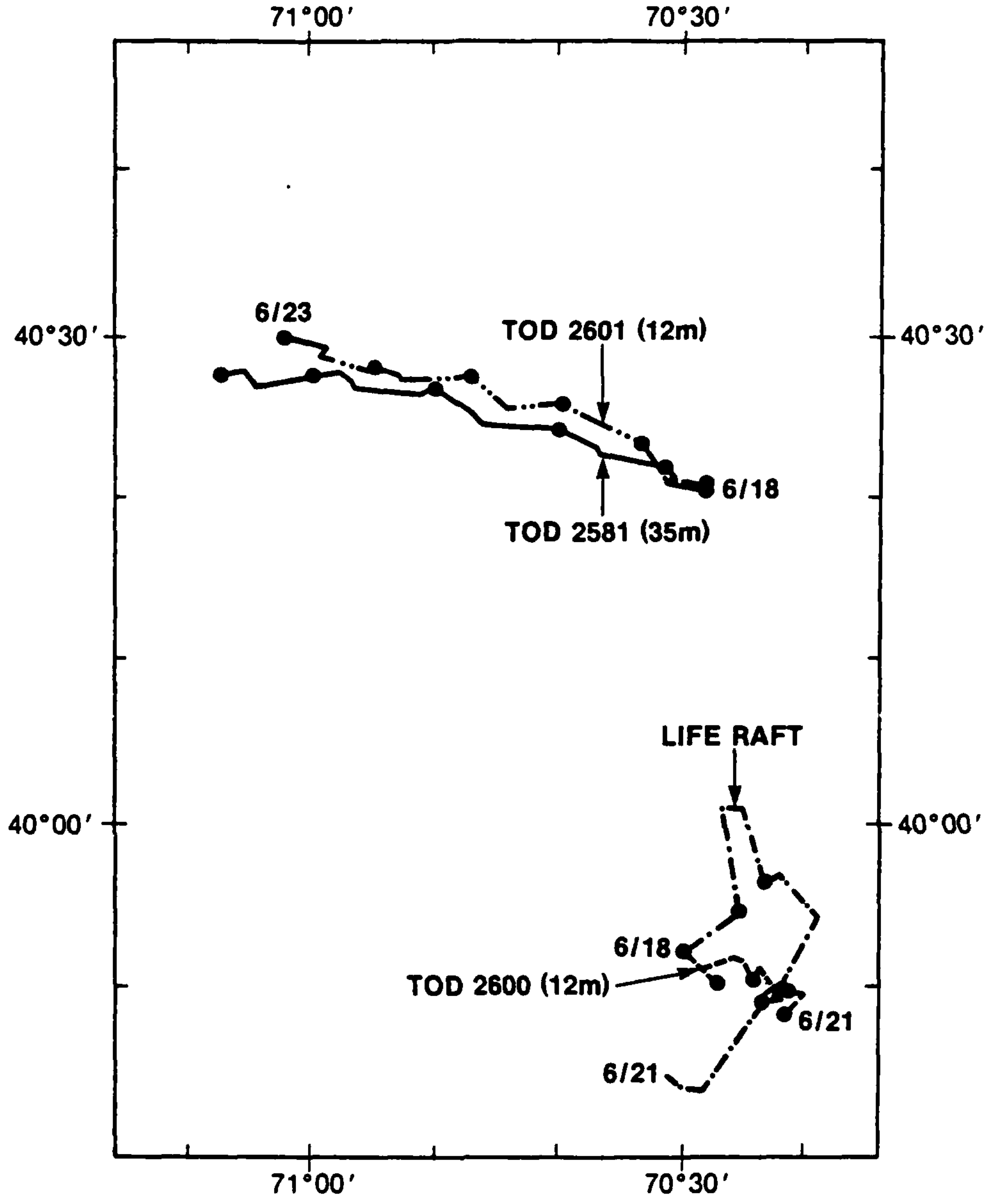
In the second period, the motions of the two TOD's deployed north of the Front were remarkably similar, despite being drogued at different levels (2601 at 12 meters and 2581 at 35 meters). From deployment on 18 June to recovery on 23 June, their net motion was toward 285°T at about 0.14 meter/second. The motion of TOD 2600, drogued at 12 meters, shows a more variable (albeit sluggish) current south of the Front. The raft, deployed with TOD 2600, showed even more direction variability, but higher speeds.

In the third period, the movement of the two buoys released north of the Front, was again, similar. From deployment on 23 June to recovery on 25 June, they moved



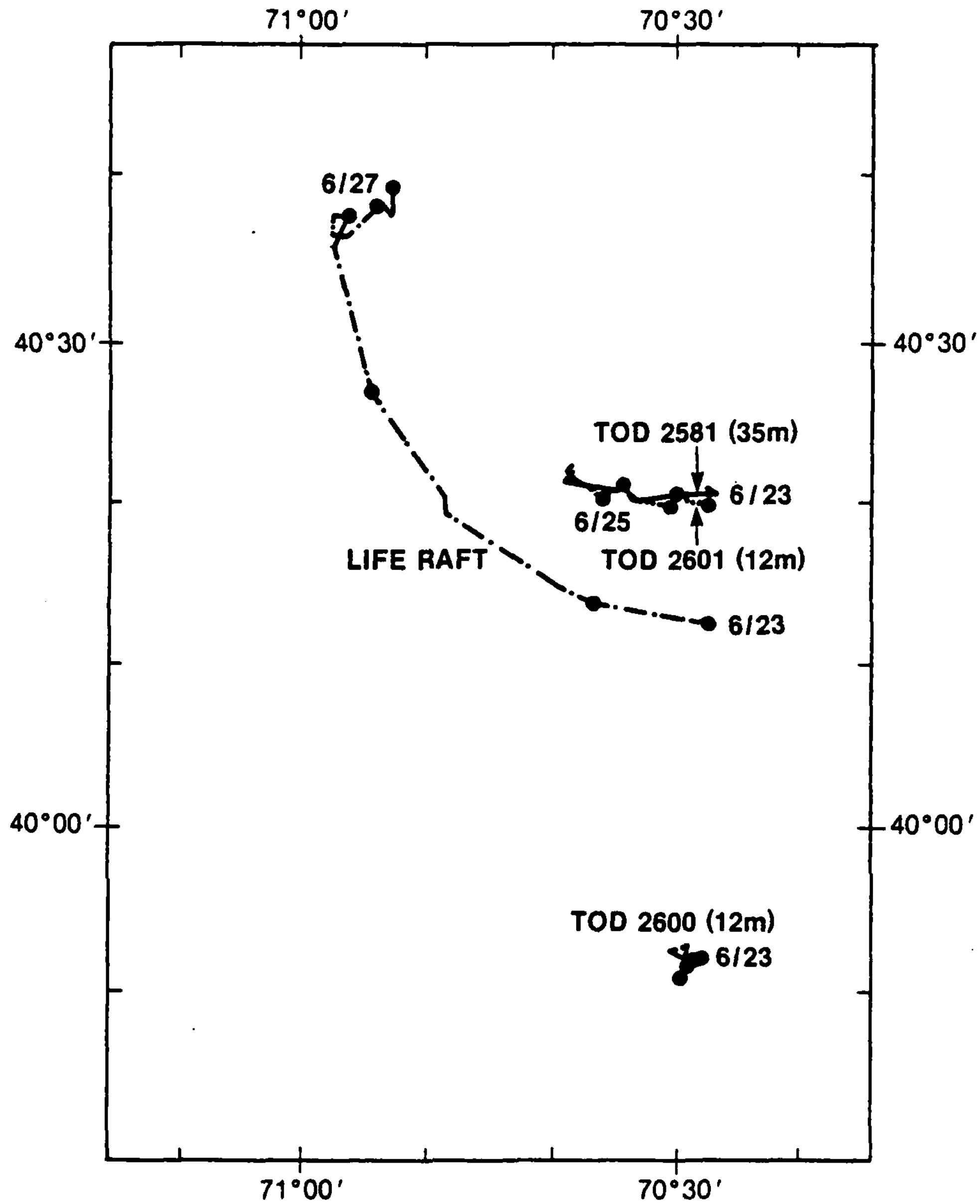
NOTE: DEPTH IN PARENTHESES INDICATES DROGUE DEPTH.

Figure 3-1. Trajectory of TOD 2581 from 13 June to 18 June 1984



NOTE: DEPTHS IN PARENTHESES INDICATE DROGUE DEPTHS.

Figure 3-2. Trajectories of TOD 2581 and TOD 2601 (both deployed north of the Front), and the Life Raft and TOD 2600 (deployed south of the Front) from 18 June to 23 June 1984



NOTE: DEPTHS IN PARENTHESES INDICATE DROGUE DEPTHS.

Figure 3-3. Trajectories of Life Raft, TOD 2581 and TOD 2602 (all deployed north of the Front) and TOD 2600 (deployed south of the Front) from 23 June to 25 June 1984 toward 285°T about 0.08 meter/second, the same direction, but somewhat slower net motion, than the second period tracks. TOD 2600, deployed south of the Front, showed little movement. The raft, deployed north of the Front, showed considerable northwestward movement.

The flow field that is indicated by the movement of the TOD's is dramatically different from the historical sea current file that CASP uses for the month of June (Figure 1-2). On the continental shelf north of the Front, the flow was toward the west and northwest at between 0.08 and 0.14 meters per second. Just 50 kilometers (30 nautical miles) to the south, the currents were weak and variable. The historical current data show no westward motion on the continental shelf; however, they do show weak currents at the edge of the shelf (40°00' N).

A direct comparison between the sea current file and the TOD trajectories is not possible because the TOD motions include the effects of wind-driven currents, which are calculated separately by CASP. However, the large differences between the TOD trajectories over a short space scale (50 kilometers) suggests that the wind-driven flow is not dominating the circulation in the study area. A detailed consideration of the oceanography of the area must be deferred until completion of the University of Delaware analyses.

3.3 SYSTEM AND PREDICTED WINDS/SYSTEM CURRENTS

Table 3-1 summarizes the magnitudes of the drift errors of the CASP predictions made with system winds and currents. The data represent an aggregate of all the CASP runs, including all three periods and both sides of the Front. In all cases, the mean drift errors grow with increasing drift interval. For example, the error in the TOD predictions grew from 3.6 nautical miles at 12 hours to 13.0 nautical miles at 48 hours, a nearly four-fold increase. In all cases, the scatter in the data is large as indicated by the standard deviation of the drift error which is approximately one third of the sample mean.

The TOD predictions were much better than either of the life raft cases for all drift intervals. In many instances, the mean life raft drift errors were twice the TOD errors. The drogued raft computation produced consistently better results (in the mean) than the undrogued raft computation as is shown in Figure 3-4. This result seems reasonable because the ballast system should act like a drogue; however, the data prevent a clear separation of the means as is illustrated by the overlapping of the .95 percent confidence limits for the means.

For the TOD's, the CASP results computed using predicted winds were not significantly different from those made with the analysis winds (Figure 3-5). This result is consistent with the findings of Murphy et al (1982).

TABLE 3-1

DRIFT ERROR SUMMARY FOR CASP DRIFT PREDICTIONS
USING SYSTEM (S) AND PREDICTED (P) DATA INPUTS

PLATFORM	ENVIRONMENTAL INPUTS		DRIFT INTERVAL (hr)			
	WIND	CURRENT	12	24	36	48
TOD	S	S	3.6 (49)* 1.4	7.1 (42) 2.6	10.2 (34) 3.9	13.0 (26) 5.1
	P	S	4.2 (15) 1.7	8.0 (13) 2.6	--	--
RAFT (with drogue)	S	S	7.7 (13) 2.6	12.5 (12) 4.3	16.0 (10) 6.1	17.7 (8) 6.0
RAFT (without drogue)	S	S	9.9 (13) 2.6	16.6 (12) 5.4	21.5 (10) 7.8	23.6 (8) 9.3

*NOTE: Table format is $\boxed{\begin{matrix}\bar{X} & (N) \\ SD & \end{matrix}}$ where $\bar{X}$ and SD are the mean and standard deviation (in nautical miles), respectively, of the drift error. N is the number of observations.

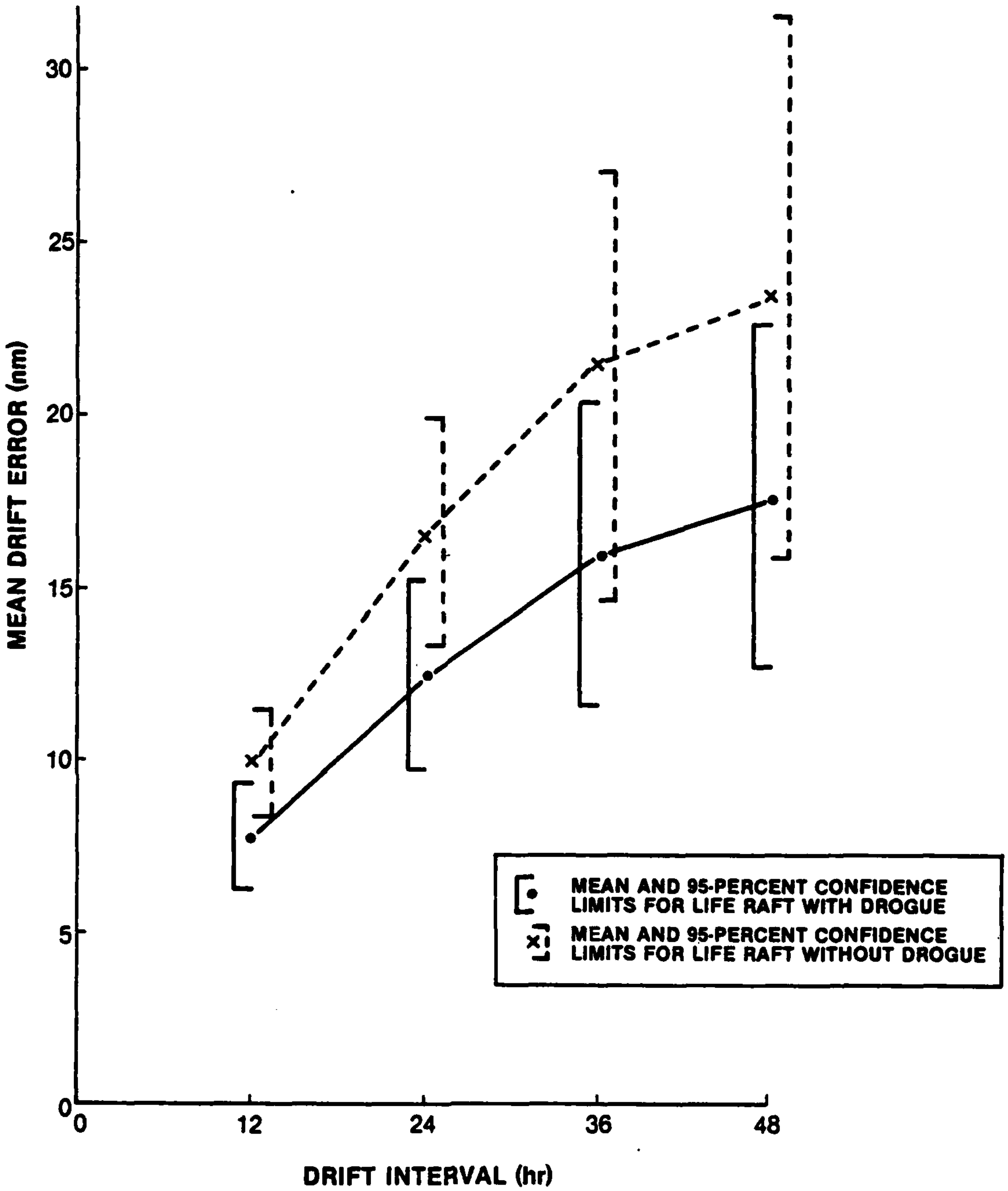


Figure 3-4. Errors for Life Raft Predictions for Drogued and Undrogued Cases

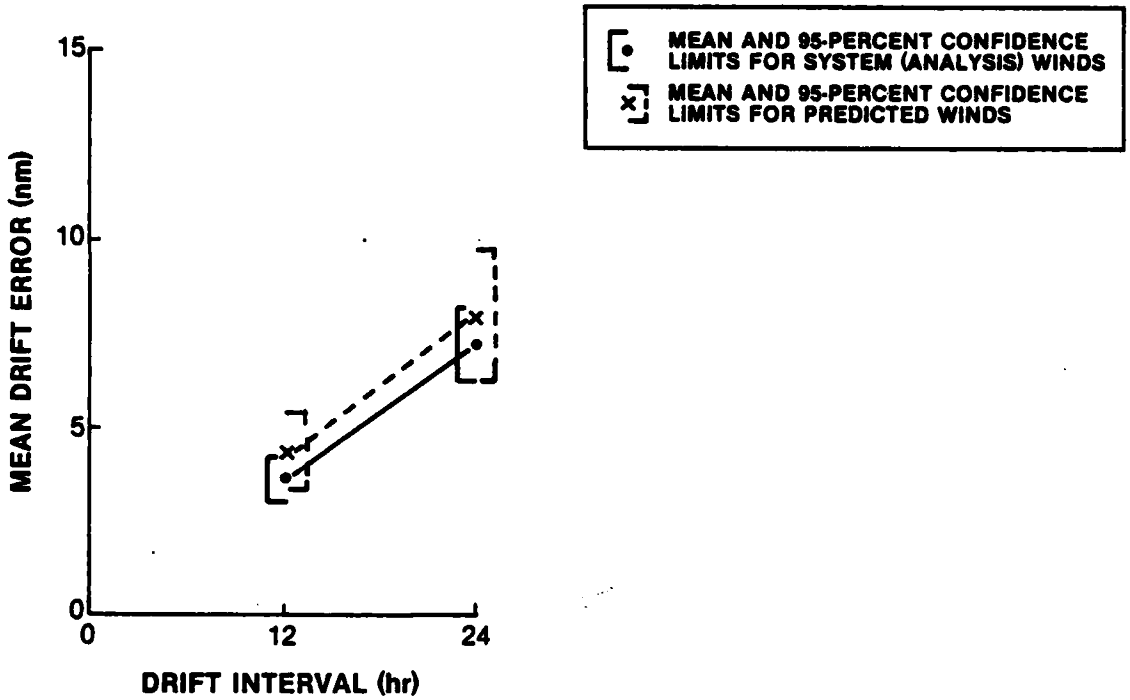


Figure 3-5. Errors for TOD Drift Predictions Using Predicted and Analysis Winds and System Currents

Table 3-2 summarizes the results of the computations of DEF, defined as the ratio of the drift error and the total predicted drift. Only the CASP results made using system winds and currents were included in the computation. For TOD's, the drift errors were consistently greater than the total predicted drift (indicated by a DEF greater than 1.0) and considerably larger than the 0.375 used by CASP to estimate the drift errors. The drift predictions for the TOD's south of the Front were consistently better than for those deployed to the north. In addition, the raft ratios were considerably lower than those for the TOD's. All the ratios should be used with the caution that the ratio is sensitive to the total predicted drift length. For smaller predicted drifts, even a small inaccuracy can lead to a large ratio.

The results presented thus far have focused on the magnitude of the errors without regard to direction. Figure 3-6 shows scatter diagrams of the observed drift errors for the aggregated TOD drift predictions made using system winds and currents. In the plots, the predicted position (datum) of the target is in the center and the actual buoy positions relative to that position are indicated by a "+". In all four intervals (12, 24, 36, and 48 hours), most of the data fall in the western two quadrants, which suggests a large mean error component toward the west. Is this error the same on both sides of the Front?

TABLE 3-2

SUMMARY OF RATIO OF DRIFT ERROR AND TOTAL PREDICTED DRIFT FOR CASP DRIFT PREDICTIONS MADE WITH SYSTEM WINDS AND CURRENTS

PLATFORM	DRIFT INTERVAL (hr)			
	12	24	36	48
TOD's (All)	1.63 (49)* 1.05	1.48 (42) 0.62	1.39 (34) 0.47	1.35 (26) 0.42
(North of Front)	1.79 (38) 1.14	1.63 (33) 0.61	1.53 (27) 0.40	1.49 (21) 0.32
(South of Front)	1.12 (11) 0.38	0.95 (9) 0.29	0.83 (7) 0.22	0.76 (5) 0.23
RAFT (with Drogue)	0.93 (13) 0.50	0.71 (12) 0.35	0.59 (10) 0.25	0.48 (8) 0.20

*NOTE: Table format is $\boxed{\begin{matrix}\bar{X} & N \\ SD & \end{matrix}}$ where $\bar{X}$ and SD are the mean and standard deviation (in nautical miles), respectively, of the ratio. N is the number of observations.

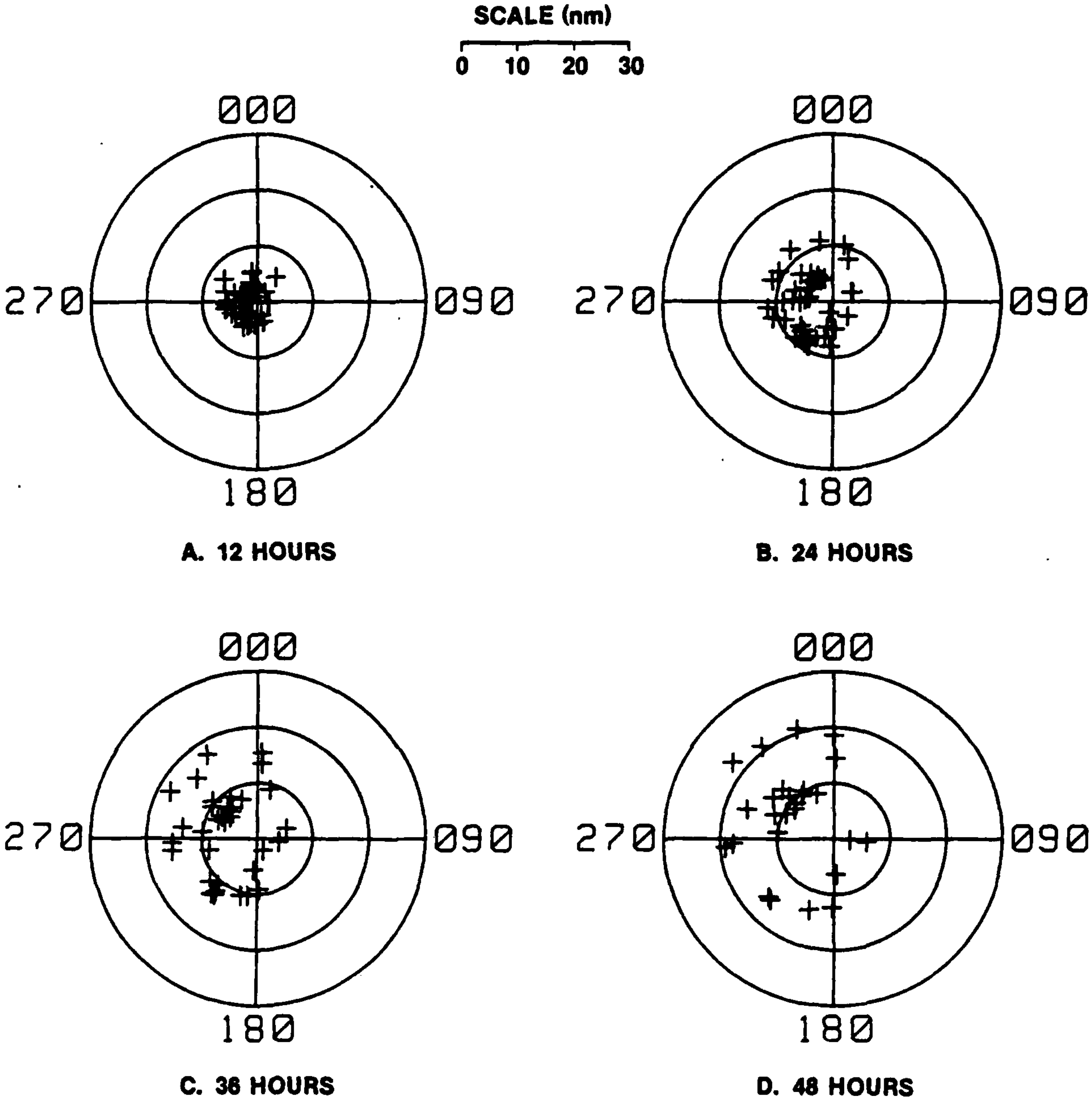


Figure 3-6. Magnitude and Direction of Drift Errors for Aggregated TOD CASP Drift Predictions Made Using System Winds and Currents

Figure 3-7 compares the errors of two buoys, one released north of the Front (2601) and the other to the south (2600); both were drogued at 12 meters. The northern buoy shows the strong westward bias, while the other does not.

The direction of the errors in the TOD drift predictions suggests the existence of a westward sea current north of the Front that is not recognized by the CASP system current file. The persistent westward motion of the 2581 and 2601 (Figures 3-2 and 3-3) strongly supports this suggestion. The data south of the Front are inconclusive. The fact that five of the seven TOD tracks were for the northern area explains why the aggregated TOD data show the westward error so strongly.

For the life raft, the direction of the observed drift errors showed an apparent random distribution, regardless of whether the tracks were north or south of the Front. Figure 3-8 shows the 24-hour errors for both life raft cases. In each case, the errors were distributed in all quadrants.

3.4 CASE-DEPENDENT WINDS AND CURRENTS

The case-dependent wind and current drift predictions were made using the winds recorded aboard CAPE HENLOPEN and current data derived from the TOD trajectories. The movement of TOD 2601, drogued at 12 meters, was predicted using current data from TOD 2581, drogued at 35 meters. All the TOD drift predictions were made for the area north of the Front, and all the data were collected in the second and third periods. For the raft, the second-period CASP predictions were made for the area south of the Front using a current file based on the drift of TOD 2600, drogued at 12 meters. During the third period, the raft drift predictions were made with current data from TOD 2581, drogued at 35 meters. Two cases were run for each CASP prediction. In the first case, the DMB option was specified. This means that the case-dependent currents were from the drift of a DMB; thus, the wind current computation in CASP was disabled. In the second case, the DMB option was not specified. This means that CASP calculated a wind-driven current and combined it with the case-dependent current file from the TOD's.

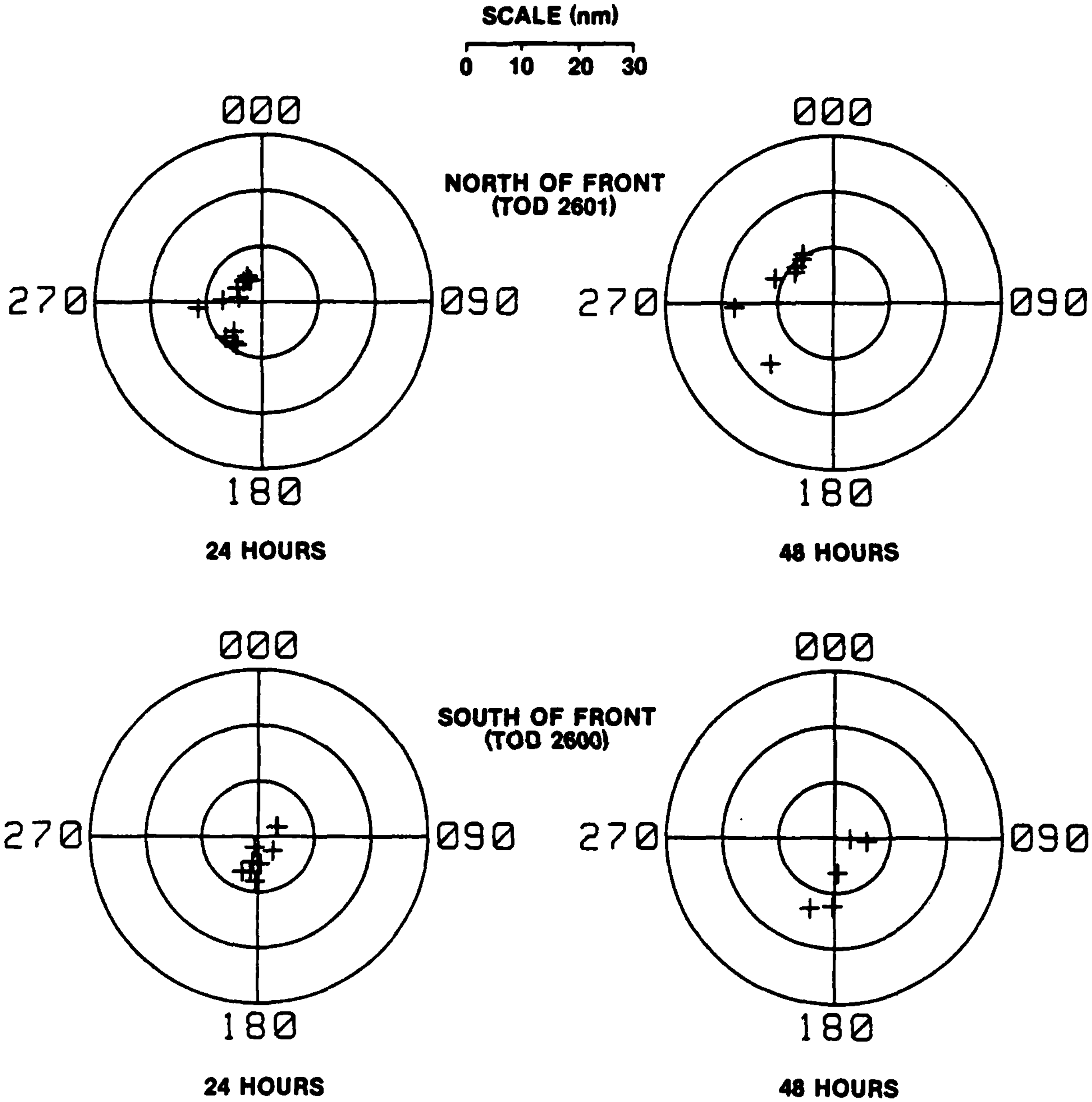


Figure 3-7. Magnitude and Direction of 24- and 48-Hour Drift Errors North of the Front (TOD 2601) and South of the Front (TOD 2600)

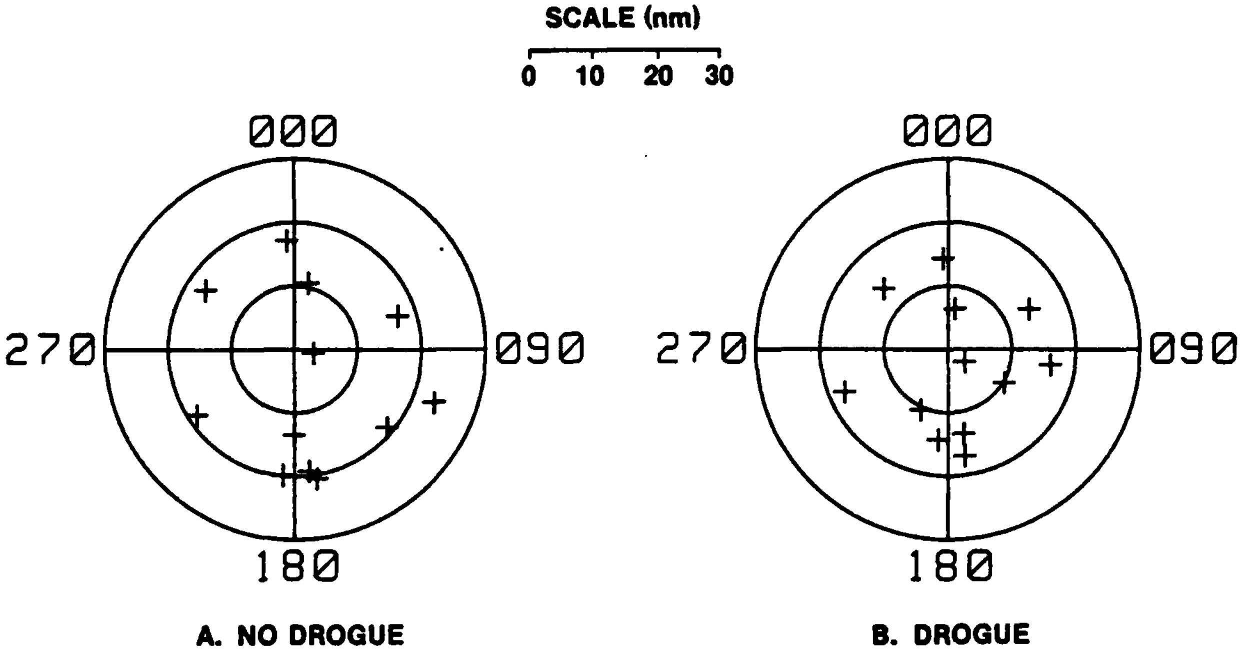


Figure 3-8. Magnitude and Direction of 24-Hour Drift Errors for Two Life Raft Cases

For the case-dependent runs, only two leeway targets were specified. The TOD's represented PIW's, and the raft represented a life raft with a drogue.

Table 3-3 summarizes the magnitude of the drift errors for the CASP drift prediction made using the case-dependent environmental data. The TOD data represent only the area north of the Front, while the life raft data include the results of one drift period north, and another south of the Front. In all cases and for all drift intervals, the number of observations is small.

From the results in Table 3-3, it is not possible to establish a clear distinction between the runs made using the DMB option and those made without it; however, the results for the TOD drift predictions (Figure 3-9) are promising. The mean errors are consistently smaller for the DMB cases, and for the two intervals (24 and 36 hours) are statistically distinguishable. For the life raft (Figure 3-10), the mean drift errors are consistently smaller for the DMB cases, but the large and overlapping 95-percent confidence limits on the means show that the means are indistinguishable.

TABLE 3-3

DRIFT ERRORS FOR TOD's AND LIFE RAFTS, WITH AND WITHOUT DMB OPTION

PLATFORM	DRIFT INTERVAL (hr)			
	12	24	36	48
TOD	2.5 (12)* 1.3	4.8 (10) 2.6	6.1 (7) 2.4	8.2 (6) 4.7
TOD (DMB)	1.5 (12) 0.7	1.8 (10) 0.6	2.3 (7) 1.1	3.2 (6) 2.2
RAFT	8.2 (9) 3.0	11.7 (8) 7.1	13.8 (6) 8.0	18.1 (4) 5.5
RAFT (DMB)	7.4 (9) 3.4	9.7 (8) 7.4	12.1 (6) 6.3	16.9 (4) 2.6

*NOTE: Table format is $\boxed{\begin{matrix}\bar{X} & (N) \\ SD & \end{matrix}}$ where $\bar{X}$ and SD are the mean and standard deviation (in nautical miles), respectively, of the drift error. N is the number of observations.

Because the case-dependent current data were derived from the drift of TOD's, the DMB cases should produce better results than those made without specifying the option. The movement of the TOD's includes the effects of the wind-driven current; therefore, allowing CASP to compute a wind current and adding it to the TOD-derived current should produce poorer results. Unfortunately, the data do not permit a clear answer.

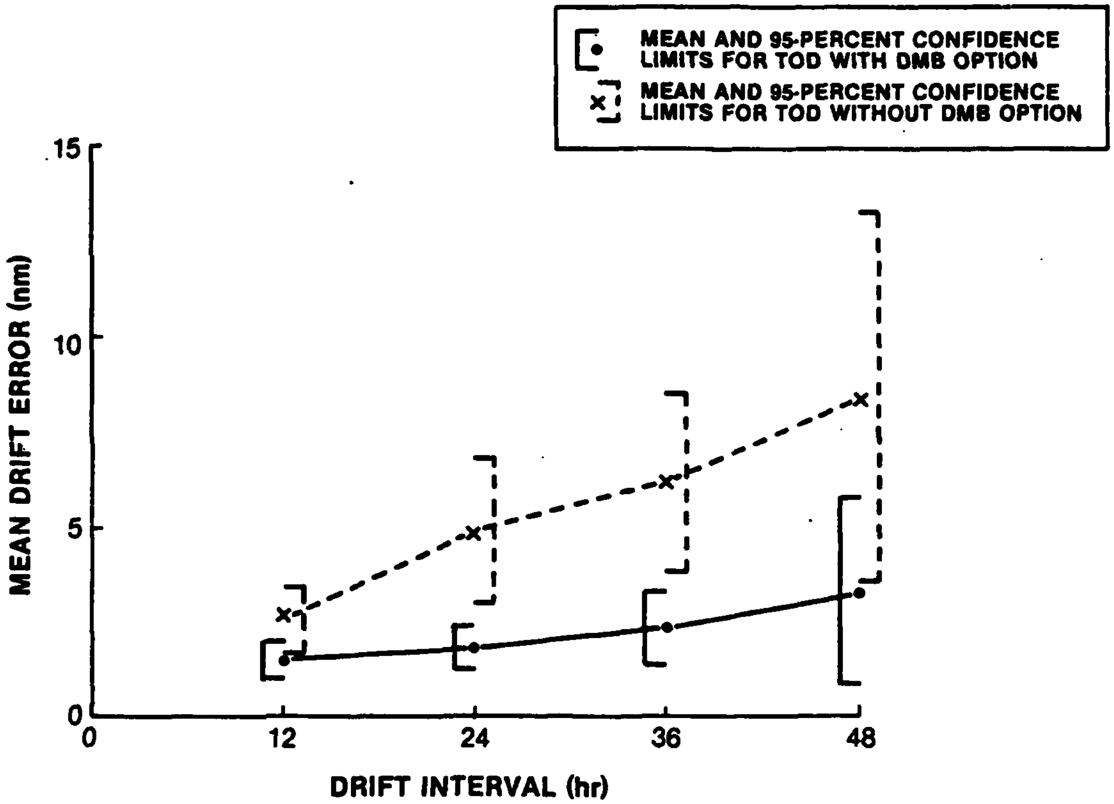


Figure 3-9. Drift Errors for TOD Case-Dependent Predictions With and Without DMB Option

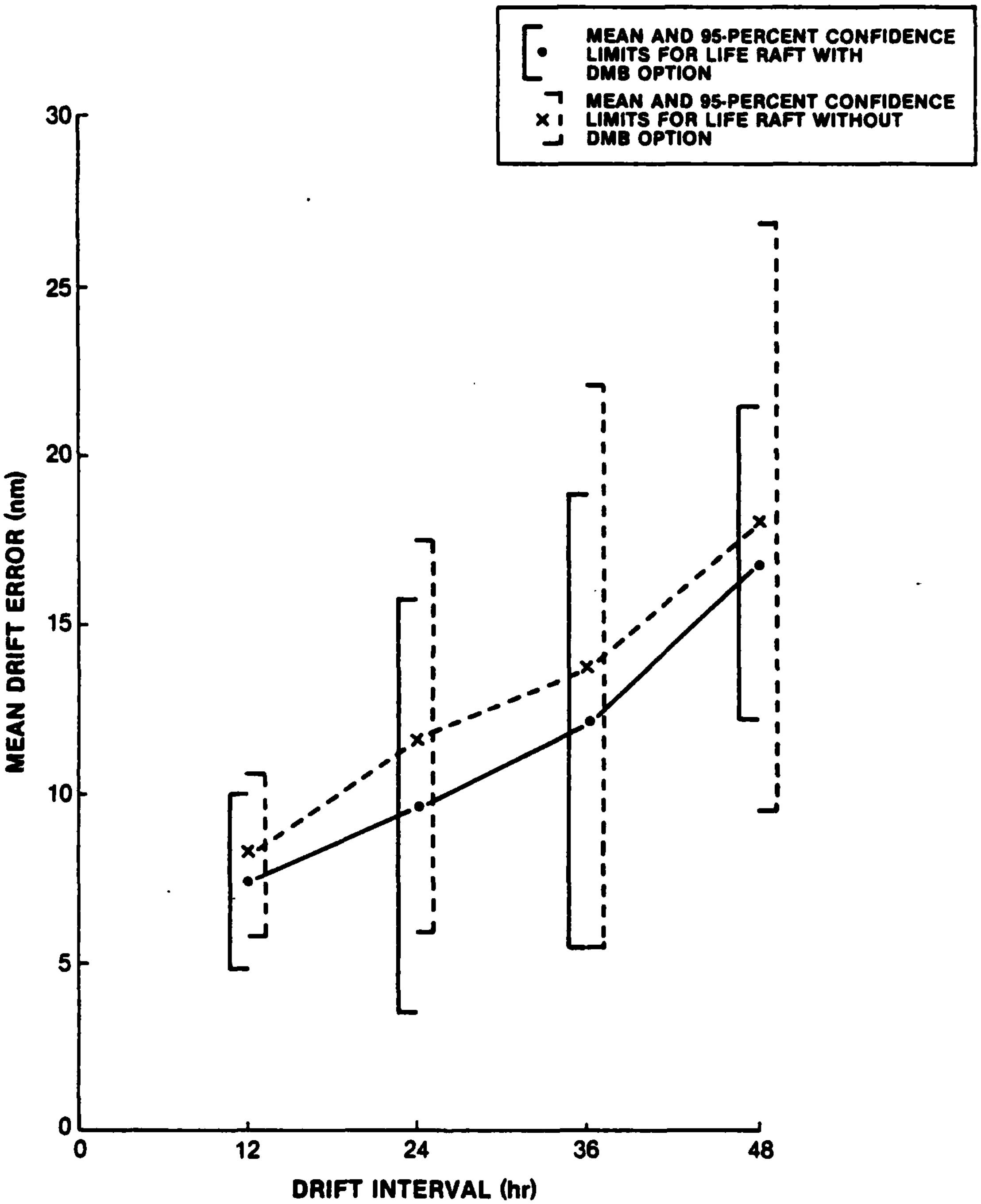


Figure 3-10. Drift Errors for Life Raft Case-Dependent Predictions With and Without DMB Option

The central question that this report seeks to answer is: Are the drift predictions made with the case-dependent environmental files better than those made using the CASP system files? Figures 3-11 and 3-12, which compare the mean drift errors for runs made using the two data sets, address this issue. For the case-dependent results, the DMB option is used.

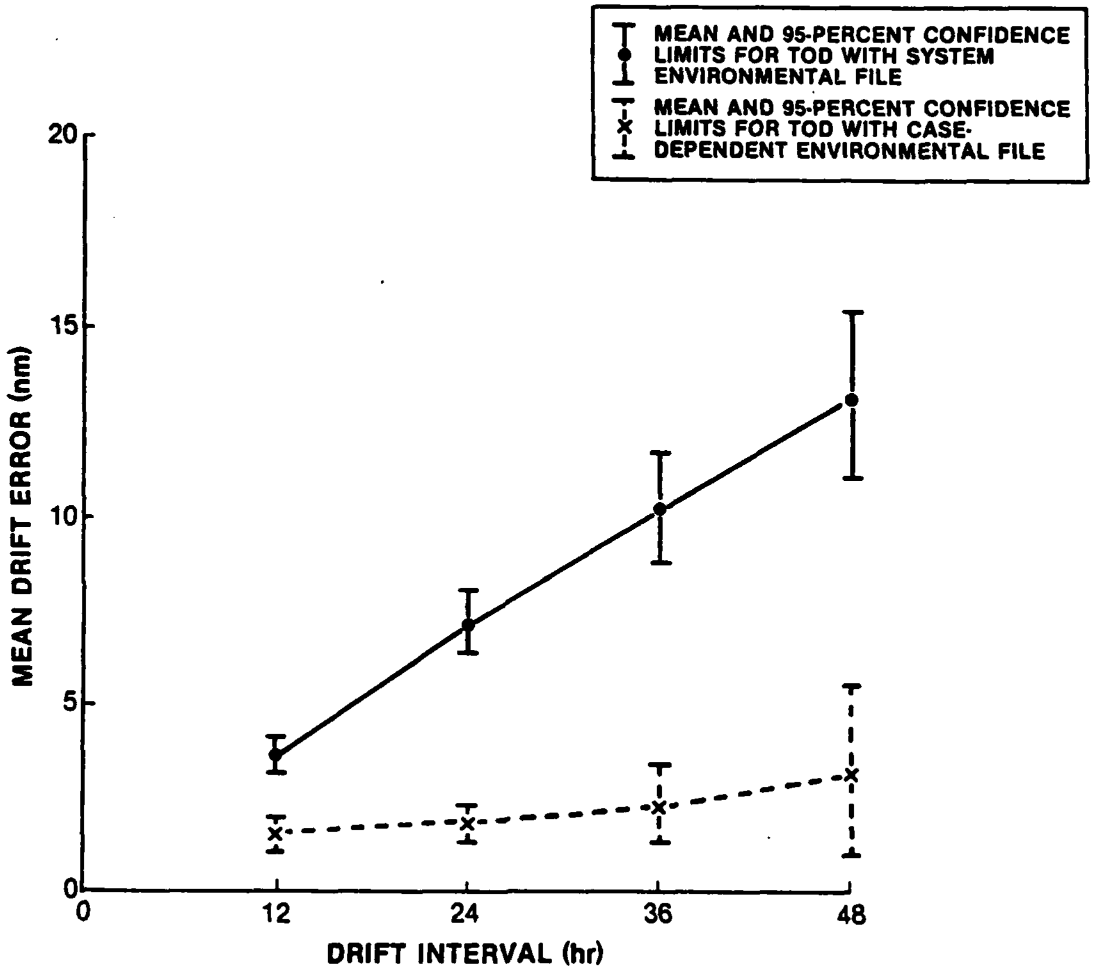


Figure 3-11. Drift Errors for TOD's with System and Case-Dependent Environmental Files

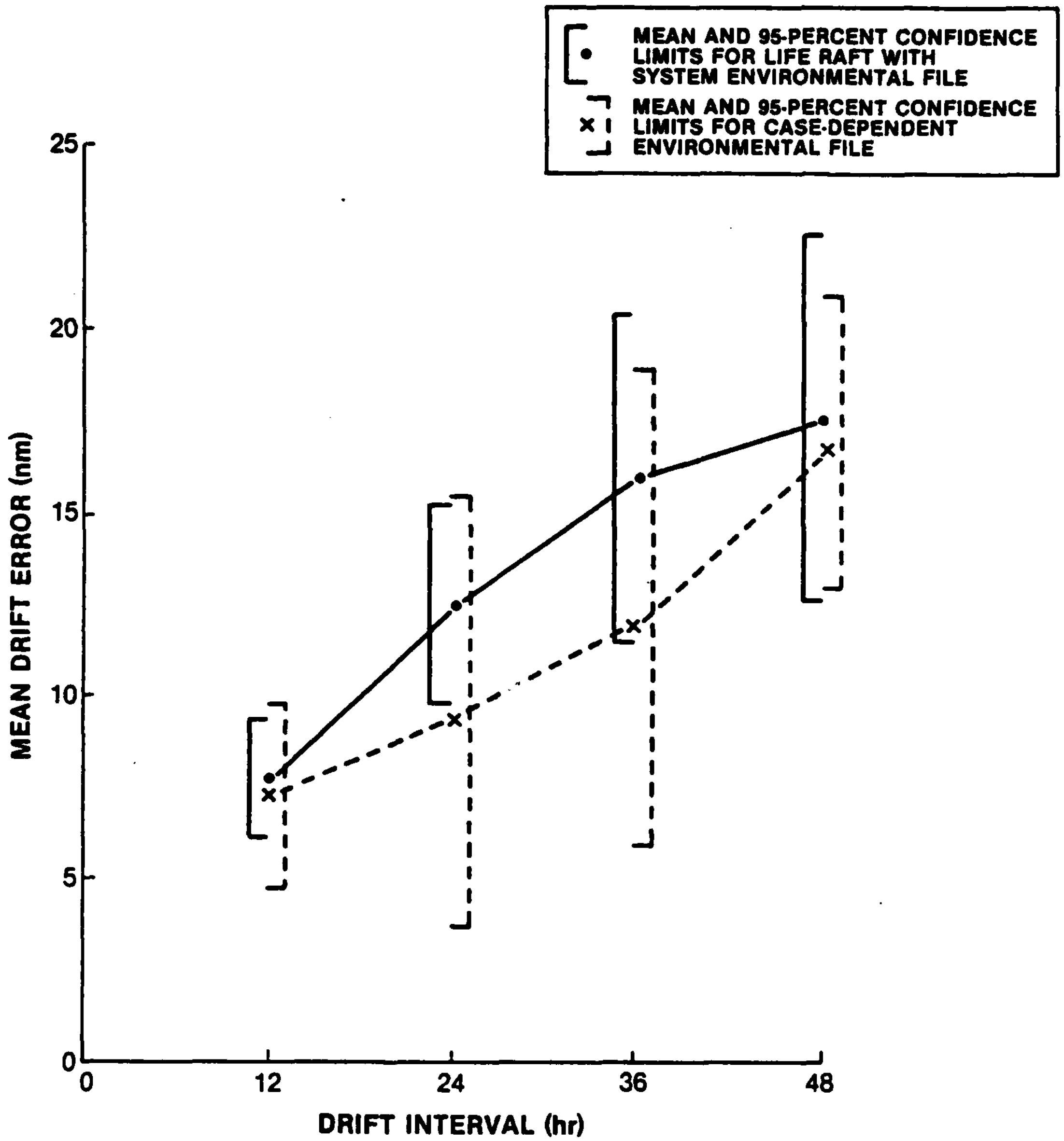


Figure 3-12. Drift Errors for Life Raft with System and Case-Dependent Environmental Files

For the TOD's (Figure 3-11), the case-dependent results are significantly better than the system file results. For example, the drift error decreased from 13.0 to 3.2 nautical miles for the 48-hour drift interval, a 75-percent decrease. This case represents the best possible case. The TOD from which the currents were derived was deployed at the same location as the simulated SAR target, and it never drifted very far away. In addition, the simulated target was another TOD, which has the same drift characteristics (except for the drogue depth).

The results of the life raft comparison (Figure 3-12) are quite different. Although the means of the drift errors are consistently smaller for the case-dependent environmental data, the results are statistically indistinguishable. There are several possible reasons. First, it is likely there are insufficient data to make the judgment. Second, in one of the drift periods, the raft was deployed 10 kilometers (6 nautical miles) from the TOD and this separation increased with time. It is possible, therefore, that there were unrecognized horizontal current gradients. Third, the TOD (drogued at 35 meters) measured currents considerably deeper than those that move the life raft (about 1 meter). Thus, vertical current gradients could also contribute to the uncertainty. Finally, it is possible that errors in the author's leeway computations for the life raft overwhelmed all other errors. These errors could be the result of an inadequate leeway model for the particular raft used in the study or of inadequate wind data. For the TOD's, leeway was not a problem.

To investigate whether the case-dependent currents had any effect on the life raft results, a series of CASP drift predictions was made using case-dependent winds and system currents. The results are compared to the case-dependent wind and current results in Figure 3-13. For the limited data presented here, there is no apparent improvement in life raft drift predictions made using observed current data.

The final subject to be addressed is how the DEF (ratio of the observed drift error to the total predicted drift) changes with the use of the on-scene environmental data. Table 3-4 compares the DEF's for the CASP runs made using the system and case-dependent environmental data. For the TOD's, the comparison is made only for the drifts north of the Front because it is the only area for which case-dependent data were available. The results show a substantial improvement (reduction) in the DEF for the TOD's, while the life raft results changed little. For example, the mean DEF for the

36-hour TOD drift interval decreased from 1.53 for the system winds and currents to 0.24 for the case-dependent runs. This means that, for the case-dependent runs, the observed drift error was 0.24 of the total predicted drift. This figure is well within the 0.375 value that CASP uses as an error estimate; however, it should be emphasized that it was calculated from CASP drift predictions using observed environmental inputs.

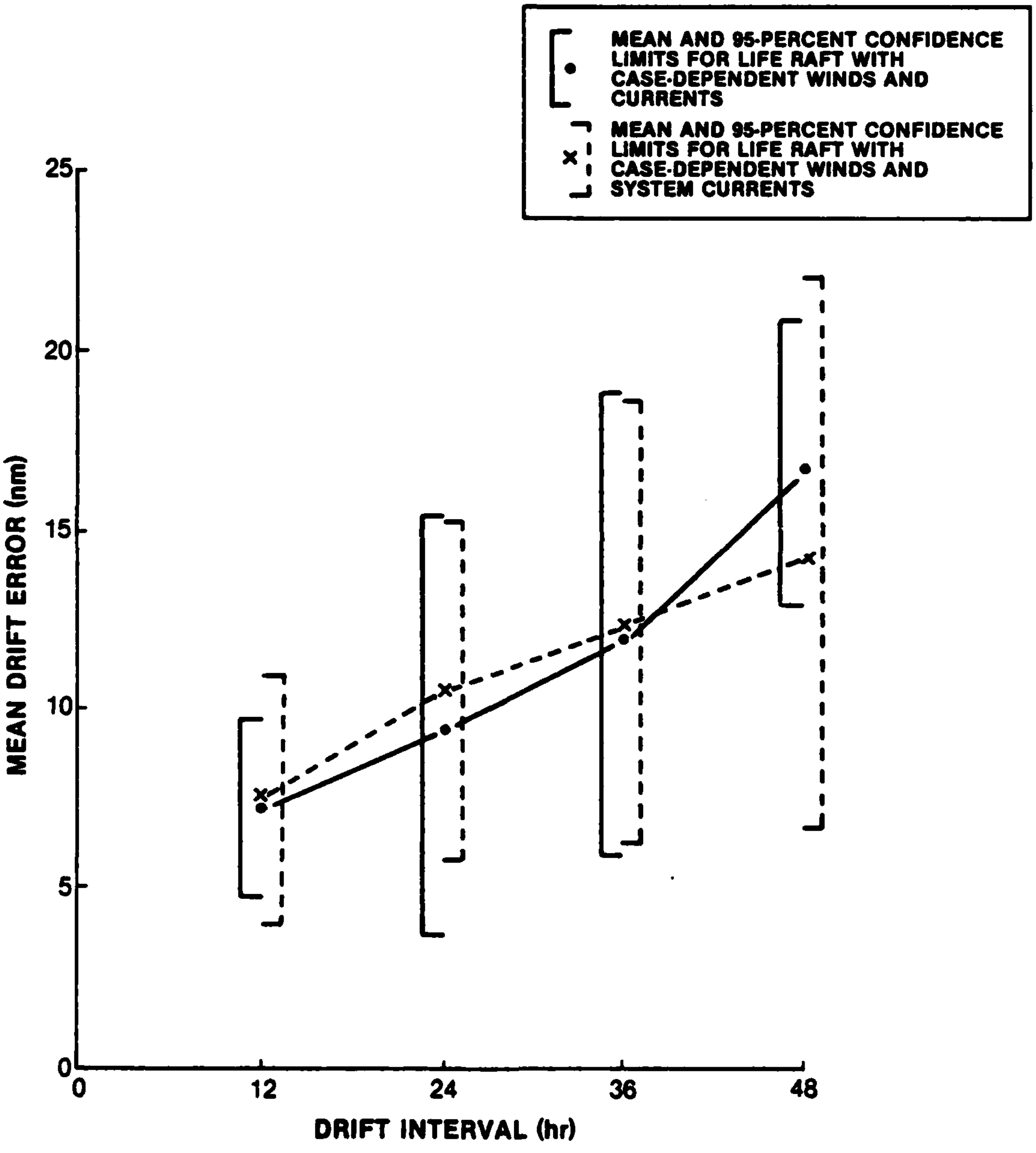


Figure 3-13. Drift Errors for Life Raft for Case-Dependent Winds and Currents, and Case-Dependent Winds and System Currents

TABLE 3-4

COMPARISON OF RATIO OF DRIFT ERROR AND TOTAL PREDICTED DRIFT FOR CASP PREDICTIONS MADE WITH SYSTEM (S) WINDS AND CURRENTS, AND CASE-DEPENDENT (D) WINDS AND CURRENTS

PLATFORM	ENVIRONMENTAL INPUTS		DRIFT INTERVAL (hr)			
	WIND	CURRENT	12	24	36	48
TOD (DMB)	D	D	0.55 (12)* 0.36	0.30 (10) 0.14	0.24 (7) 0.11	0.27 (6) 0.22
TOD (North of Front)	S	S	1.79 (38) 1.14	1.63 (33) 0.61	1.53 (27) 0.40	1.49 (21) 0.32
RAFT (DMB)	D	D	0.85 (9) 0.51	0.51 (8) 0.40	0.45 (6) 0.25	0.49 (4) 0.10
RAFT	S	S	0.93 (13) 0.50	0.71 (12) 0.35	0.59 (10) 0.25	0.48 (8) 0.20

*NOTE: Table format is $\boxed{\begin{array}{c}\bar{X} \quad (N) \\ SD\end{array}}$ where $\bar{X}$ and SD are the mean and standard deviation (in nautical miles), respectively, of the drift error. N is the number of observations.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions are based on the results presented in Chapter 3:

System Winds and Currents

CASP drift predictions made using drogued TOD's as simulated PIW's resulted in mean errors that ranged from 3.6 nautical miles for the 12-hour predictions to 13.0 nautical miles for the 48-hour predictions.

For the TOD's, there was no difference in the accuracy of predictions made using system (analysis) winds and those made using predicted winds.

CASP drift predictions made using a life raft as a simulated SAR target resulted in larger mean errors than the TOD cases. The errors ranged from 7.7 nautical miles for 12-hour drifts to 17.7 nautical miles for 48-hour drifts.

For both targets, the observed drift error factor (ratio of observed drift error to the total predicted drift) was larger than the 0.375 used by CASP as an error estimate. In the case of the TOD's, the mean DEF was consistently larger than 1.0, which means that the errors were larger than the total predicted drift.

The system current file did not recognize the persistent westward current measured by the TOD's on the southern New England continental shelf.

Case-Dependent (On-Scene) Winds and Currents

Using on-scene measured data improved the TOD drift predictions substantially, reducing the mean drift errors to 1.5 nautical miles for 12-hour drifts and 3.2 nautical miles for 48-hour drifts.

Choosing the DMB option resulted in smaller mean drift errors for the TOD predictions, but had no significant effect on the life raft results.

The life raft drift predictions showed no significant improvement when on-scene environmental data were used in CASP.

When on-scene data were used, the DEF's for the TOD's were near or within the 0.375 value used by CASP. CASP produced good results with good input data. The DEF for the life raft prediction showed no significant improvement.

4.2 RECOMMENDATIONS

1. Increase the CASP drift error factor.

   It is essential that the actual drift errors due to the use of the system current files be recognized and the DEF increased accordingly. A DEF of 0.375 does not estimate the drift error adequately; the DEF should be in the 0.5 to 1.0 range. The choice of this range is based, in part, on the results of Murphy et al (1982) and Anderson (1984). A larger DEF will result in larger search areas, and large search areas drain SAR resources; however, the goal is to locate the target.

2. Conduct a preliminary test of CASP Revision II using the data from the drift test reported here.

   Starting in early 1985, a new version of CASP (Revision II) will become operational. It is a major refinement of the CASP program, including changes in the method of computations and the environmental files. The system wind data will be presented on a finer grid (3° x 3°) than is presently available (5° x 5°) and predicted winds will be available for up to 48 hours (36 hours at present). For the first time, the results of a numerical ocean circulation model will be used for the CASP current files. FNOC will provide the model results on a 3° x 3° grid every 12 hours, including a 12-hour forecast. These model results will be combined with the historical data to form the major CASP current file.

3. Continue research into using near real-time on-scene environmental data for CASP drift predictions.

   The results presented here show promise, but the data set is small and there are many unanswered questions. Future SAR drift experiments should emphasize the use of realistic SAR targets and actual (or more realistic) DMB's. TOD's are neither a PIW nor a DMB. The targets should be loaded carefully to simulate real conditions. In lower latitudes, System ARGOS provides satellite-derived data that are too widely separated in time, which results in excessive interpolation intervals. More frequent position data are required.

4. Use the drift data described here to perform a preliminary test of the leeway coefficients developed for the Givens Buoy life raft.

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APPENDIX A
METRIC CONVERSION FACTS

1. <u>Feet to Meters</u>

1 foot = 0.3048 meters

Thus:

3- to 4-foot swells ≈ 1-meter swells,
a 16-foot boat ≈ a 5-meter boat, and
an altitude of 500 feet ≈ a 150-meter altitude.

2. <u>Nautical Miles to Kilometers</u>

1 nautical mile (nm) = 1.852 kilometers (km)

Thus:

10 nm visibility ≈ 18.5 km visibility, and
a 2-nm range ≈ a 3.7-km range.

3. <u>Knots to Meters per Second and Kilometers per Hour</u>

1 knot = 0.5144 meters per second
1 knot = 1.852 kilometers per hour

Thus:

a 10-knot wind speed ≈ a wind speed of 5 meters per second, and
a 10-knot search speed ≈ a search speed of 18 kilometers per hour.

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