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June 1988–December 1989

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Technical Report

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James R. Luyten, Chairman
Department of Physical Oceanography

Abstract

Forty freely drifting drogued buoys were tracked by satellite in the western tropical Pacific from June 1988 to January 1, 1990, as part of the Western Pacific Ocean Circulation Study (WEPOCS III). The data consist of buoy trajectories and sea surface temperature and velocity along trajectories. The main results presented here are the collection of figures which show trajectories and time series data in the South Equatorial Current, the North Equatorial Countercurrent, the Mindanao Current, and the North Equatorial Current. One striking result is that we obtained the first quasi-synoptic map of surface velocity in this region that shows the major currents and their interconnections.

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1 Introduction

This report describes results from freely drifting drogued buoys that were tracked by satellite in the western tropical Pacific over an 18 month period from June 1988 to January 1990. The drifters are part of the Western Pacific Ocean Circulation Study (WEPOCS). Thirty-five of the drifters were launched from the WEPOCS III cruise on the *R/V Moana Wave* from 18 June–31 July 1988. Other cruise observations included 117 CTD–O_2 casts plus bottle samples for tracers (including tritium and freon), XBTs, and acoustic Doppler current profiles along the cruise track. Five additional drifters were launched from the *R/V Xiangyanghong #14* in October 1988.

The overall objective of WEPOCS III was to measure the low latitude boundary currents of the Pacific Ocean, their connection with the equatorial circulation, and their water mass properties. A specific objective was to measure how the South Equatorial Current and Mindanao Current merge and form the North Equatorial Countercurrent and Indonesian Seas throughflow. The drifters component of WEPOCS is closely related to the Pan Pacific Surface Current Study in which drifters are being deployed (more sparsely) to measure aspects of the tropical velocity and temperature fields across the whole Pacific.

The WEPOCS current profiles along the ship's track and the drifter trajectories and velocity series were found to be highly complementary. The combined data provide a quasi-synoptic picture of the dominant circulation over a wide region of the western tropical Pacific including the swift narrow currents along the western boundary. In addition some aspects of the seasonal variation of velocity and higher frequencies are revealed by the drifters. A summary of preliminary results from the drifters and other components of WEPOCS III has been described by Lukas *et al.* (submitted).

2 Buoys

Thirty-four of the buoys were Low Cost Drifters (LCDs) made by Draper Laboratory in Cambridge, Massachusetts (see Dahlen, 1986), and six of the buoys were mini-Tristar buoys made by Technocean Associates in La Jolla, California (see Niiler *et al.*, 1987). Both buoys consist of a small surface float with a thermometer and drogue sensor and both have a large attached drogue centered at a depth of 15 m. The ratio of the drogue drag area to that of the tether plus buoy hull is around 50:1 which means the buoys are well coupled to the water. The LCD float is 0.37 m in diameter, 0.2 m high and contains a Toyocom transmitter and a strain-gauge drogue sensor; the drogue is a holey sock 0.41 m in diameter and 12.5 m long, connected to the float with a 1 cm diameter polypropylene line containing a 0.16 cm diameter wire rope core. The mini-Tristar float is a 0.28 m diameter sphere containing a Telonics transmitter; the drogue consists of three intersecting planes like a radar reflector, each plane being 2.6 m square. Since most buoys were LCDs and since the six mini-Tristars have already been described (Carpenter, 1989), this report concentrates on the LCDs.

Buoys were launched in three general areas (Figure 1):

1. thirteen (8 in June, 5 in October 1988) in the South Equatorial Current north of New Guinea between 1.5N and 2.5S and along 141.5E and 143E,

2. ten in the North Equatorial Countercurrent, Halmahera Eddy and South Equatorial Current along a line from Palau toward Tobi Island near Halmahera (7N to 2.5N),

3. seventeen in the vicinity of the Mindanao Current off the coast of Mindanao from 5N to 10N (two died at launch and never worked).

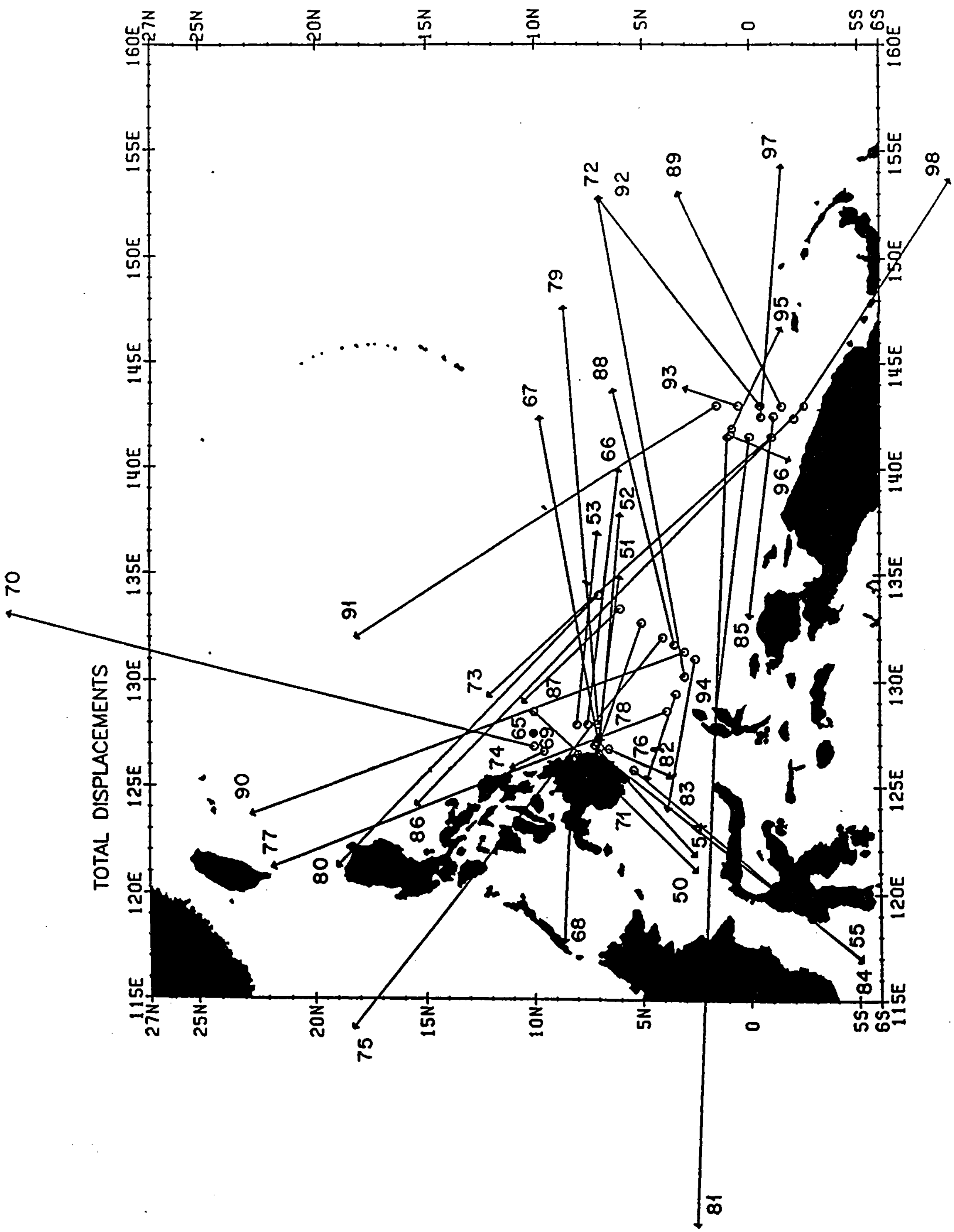

Figure 1: Total displacement vectors for all drifters.

All but the 5 launched in October 1988 were launched within a 32 day period from June 23 to July 25. During the first 2–3 months of drift, these buoys swept out a large portion of the western tropical Pacific giving a good picture of the dominant circulation patterns (Figures 2 and 3).

The useful lifetime of drogued buoys at sea depends on the transmitter continuing to transmit in order to track the buoy and the drogue remaining attached to couple the buoy to the water. A summary of launch information and lifetimes is given in Table I. Seventeen of the LCDs died at sea (2 at launch), 14 grounded, and 2 were stolen at sea. Some buoys that died could have been stolen or vandalized at sea. The average transmitter lifetime of the buoys at sea up to the end of March 1990, and including the two buoys that quit at launch and three buoys still transmitting on March 31, 1990, is 306 days (Table I, Figure 4). The LCD drogues remained attached for a minimum of 234 days and an average of 337 days (Figure 5). The average useful lifetime of the LCD buoys at sea that were not stolen or did not ground is 226 days (Figure 6). The primary failure mode for lifetimes less than 260 days is transmitter failures; the primary failure mode for lifetimes longer than 260 days is the drogues falling off. Overall the mean useful lifetime of all LCD buoys in WEPOCS is 201 days.

3 Data

The buoys were tracked by Service ARGOS at the Centre National d'Études Spatiale in Toulouse, France. Buoy positions were calculated from their Doppler shifted signals received by polar orbiting NOAA satellites. On average, around 6 fixes were received per buoy when it transmitted all day. The LCDs were programmed to transmit continually for the first 90 days, then every other day in order to save on tracking costs. To make sure the data fell into one ARGOS

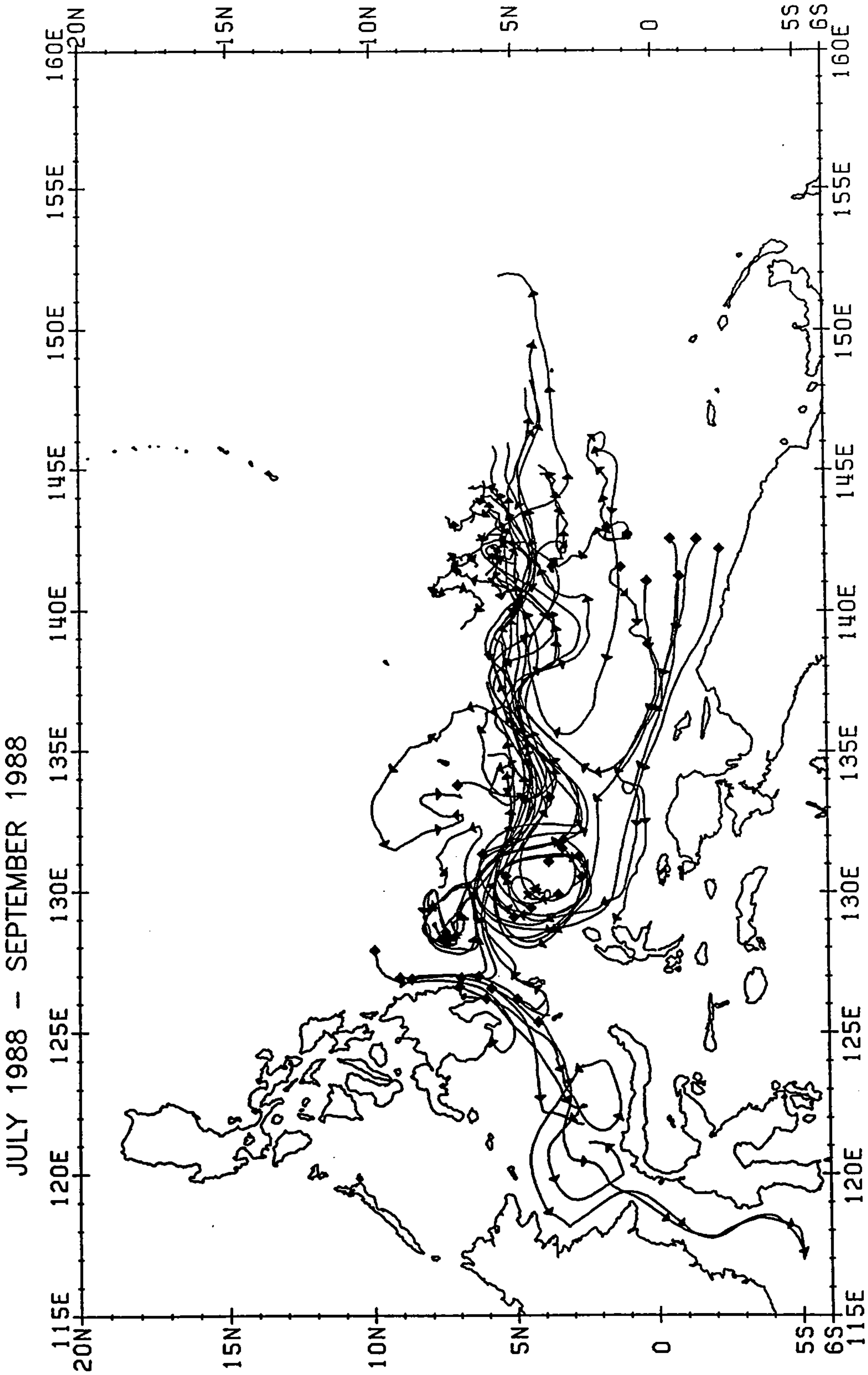

Figure 2: Drifter trajectories during the first three months.

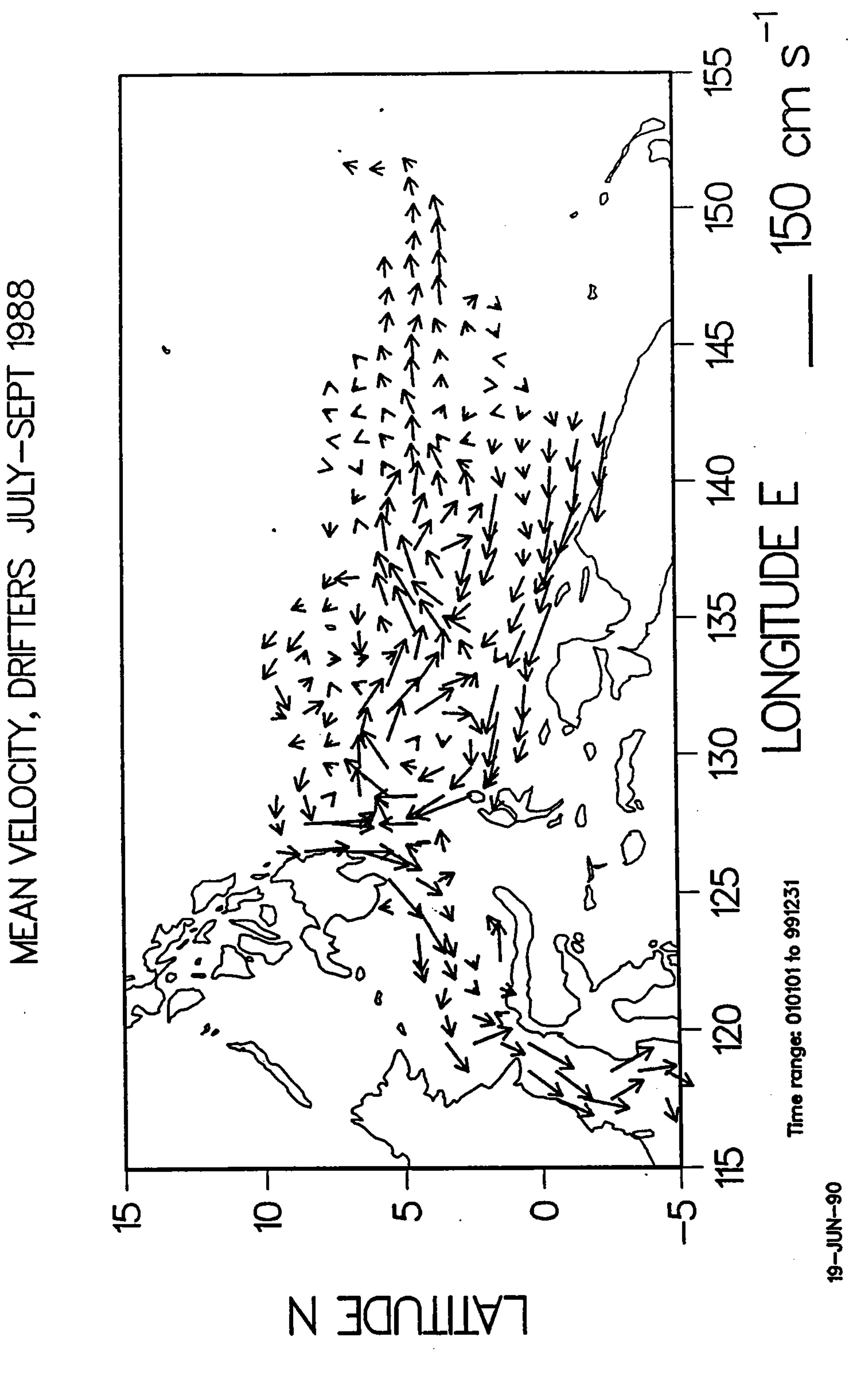

Figure 3: Average velocities in 1° × 1° bins from drifters during first three months.

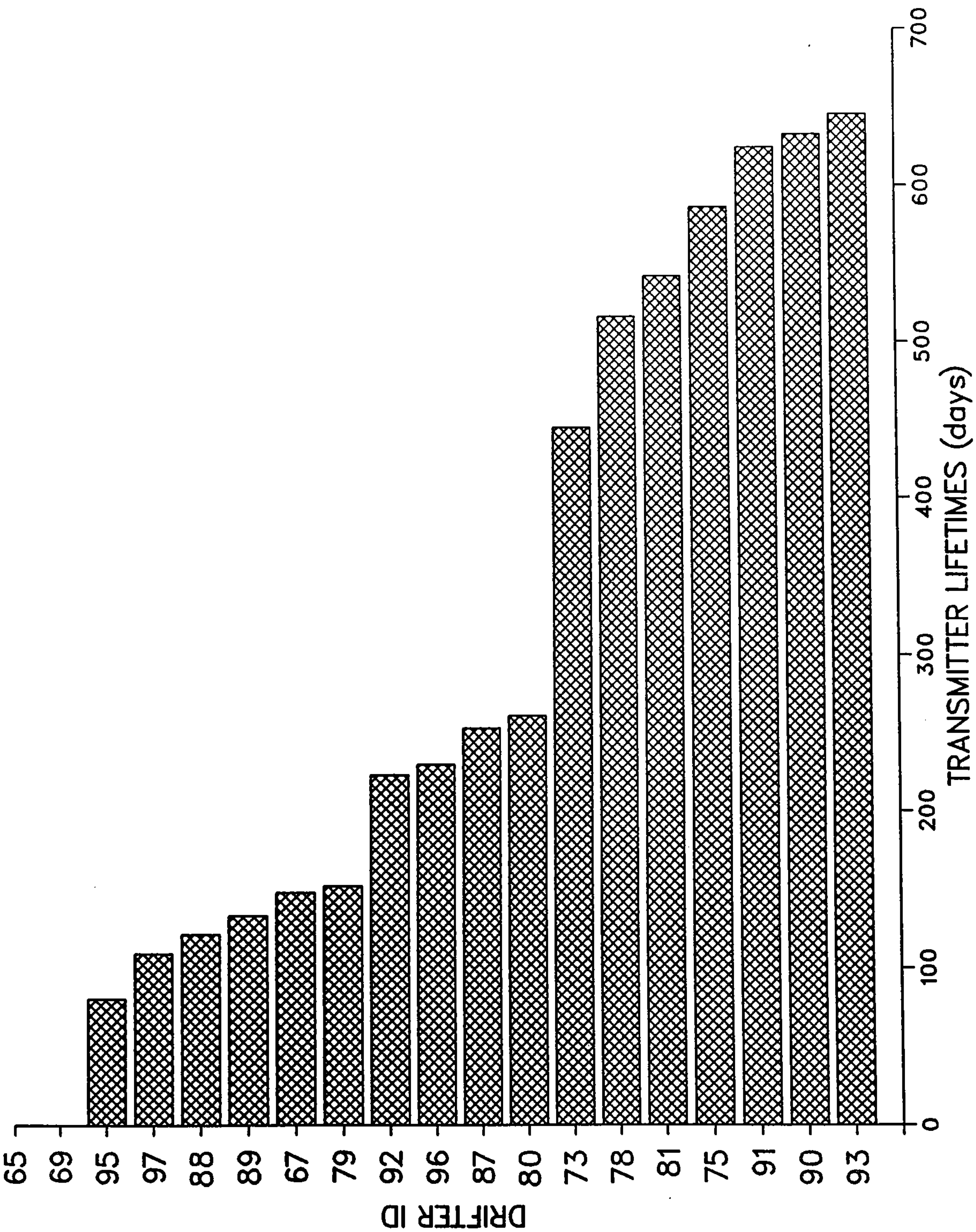

Figure 4: Lifetimes of transmitters that failed at sea.

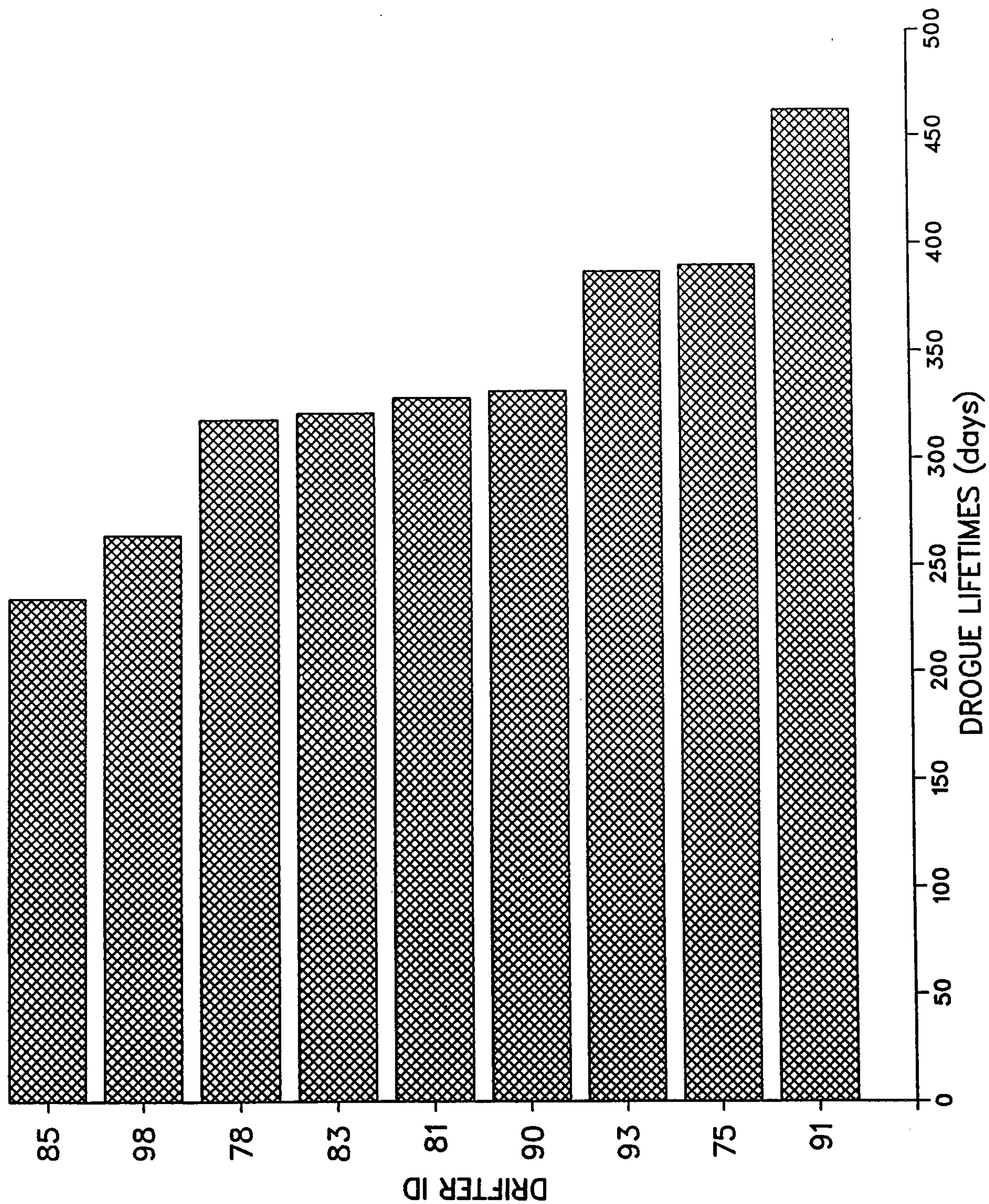

Figure 5: Lifetimes of drogues that failed at sea.

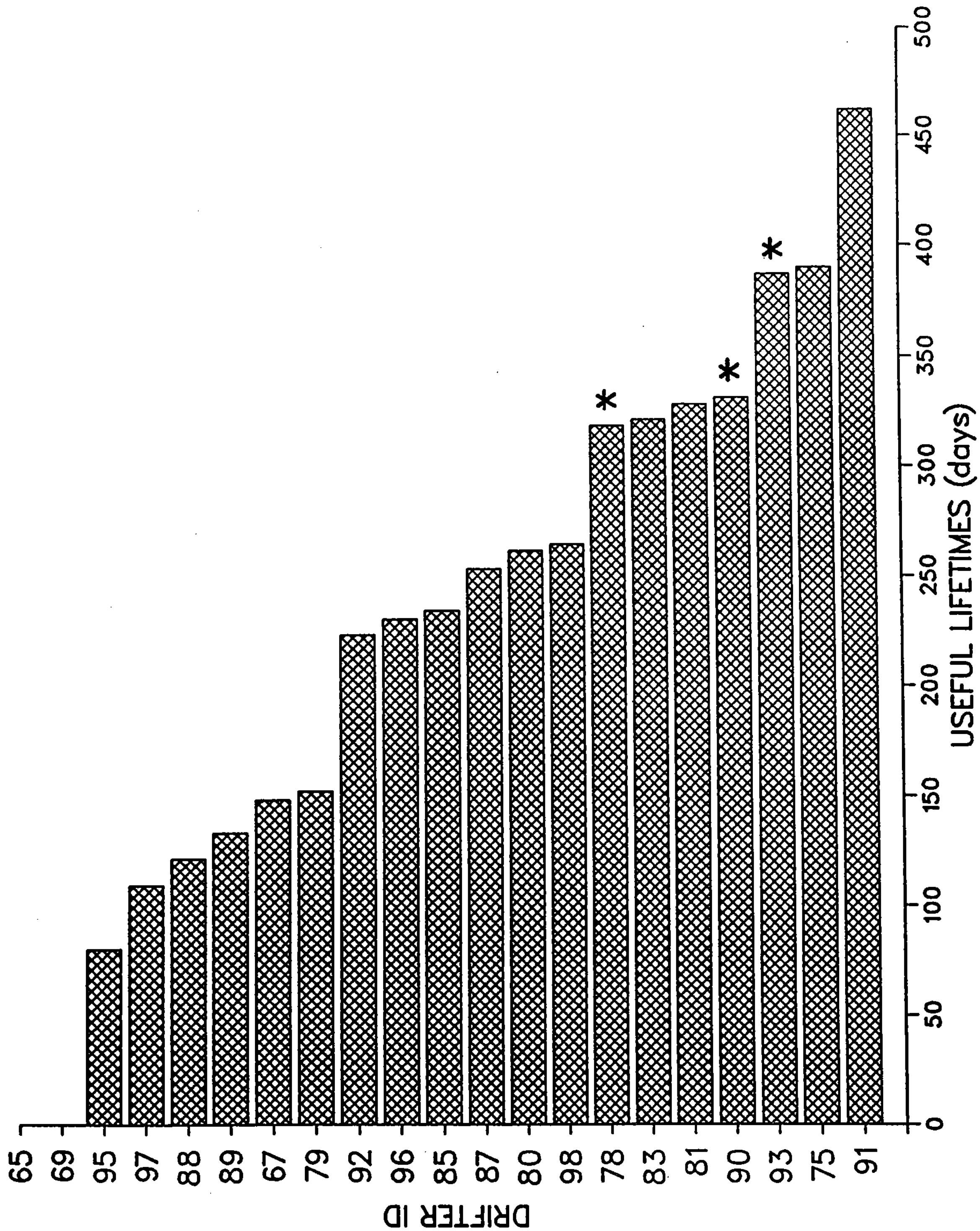

Figure 6: Useful lifetimes of drifters up to drogue or transmitter failure except for three shown by an asterisk (78, 90, 93) still operating as of March 31, 1990.

tracking day and also to conserve power, the buoys were programmed to transmit to satellite passes for around 8 hours every other day. After 90 days the original data contained daily gaps over which positions, velocity and temperature were interpolated as described below. Two gaps of 6–10 days occurred in the transmissions of buoy 88 and these portions of the trajectory are omitted (in the Halmahera Eddy).

Data were transmitted on the Global Telecommunications System (GTS) and were also obtained monthly on diskettes from Service ARGOS. D. Meldrum calculated polynomial fits to the LCD temperature calibrations and arranged to have the data on GTS. Processing the data consisted of the following steps:

1. Positions and temperatures were plotted and edited for obviously erroneous values.

2. All but the lowest temperature in each 24-hour period were removed.

3. Values of position and temperature were linearly interpolated in time at a 6-hour spacing.

4. Values were smoothed with a $\sigma = 0.5$ day Gaussian shaped filter to reduce high frequency oscillations and noise due to measurement errors. Portions of the beginning and end of trajectories were lost by this technique.

5. A cubic spline function was used to calculate velocity at final positions.

6. Trajectories and time series of velocity and temperature were plotted.

The LCD thermistor is located approximately 10 cm below the sea surface. Daily cycles in temperature up to 2–3°C were observed by both types of buoys suggesting that the near surface layer warmed during the day. Daily temperature cycles of a few degrees were also observed by other techniques in the western tropical Pacific by B. King and J. Godfrey (personal communications) which tend to confirm the buoy measurements. However, one can imagine that the surface float could have been heated in the strong tropical sun especially when the wind and waves were low, and this could have biased the measured temperatures. In order to test this hypothesis J. Dahlen conducted some laboratory tests at Draper in which he heated a LCD buoy with a 250 W heat lamp directly overhead and recorded internal and external temperatures. The LCD measured a temperature around 0.5°C higher than the nearby water temperature at 10 cm depth after 6 hours of heating, reaching a maximum of 0.6°C. Dahlen says that over the period of hours necessary to cause a significant error, the average solar power input would be much less than half of what he used in the test. The implications are (1) the 2–3°C daily cycle in observed temperature is not explained by the heating of surface float and (2) there is the possibility of a small (few tenths of a degree) but significant mid-day bias by the buoys. A calibration of buoy temperature at sea under high sun and low wind conditions is required to rule out this possible temperature error. Because of this possible error and because of the intermittent measurement of temperature every other day, we decided to retain the lowest temperature measured during each day as being representative of the upper mixed layer that day. The buoy time series plots show interpolated temperatures from the series of lowest values.

D. Bitterman detected a quantizing of temperatures between 29–31°C where resolution was degraded from the usual 0.02°C to around 0.35°C for these drifters. J. Dahlen traced this problem to the voltage-to-frequency converter which was locking on to certain discrete frequencies in this temperature range. This problem is being corrected on future LCDs.

Acknowledgements

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Summary of Figures

A summary of the WEPOCS drifting buoy data is shown in the series of figures which follows. The first set of figures (Figures 7–22) shows trajectories grouped in different ways. Arrowheads are spaced at 10-day intervals except for Figure 20 in which the spacing is 5 days. Trajectories are of drogued buoys unless monthly plots of all trajectories (dashed trajectories are undrogued). The final set (Figures 41–117) shows individual trajectories and time series of velocity and temperature for each buoy (including undrogued — “D” marks date of drogue loss).

Table I: LCD Buoy Lifetimes

Buoy ID	Launch Date	End Date	Drogue Off Date	Lifetime Buoy	Lifetime Drogue	Comments
65	88 07 25	88 07 25		0		Quit at launch
66	88 07 22	88 10 15		83		Stolen
67	88 07 16	88 12 13		147		Died at sea
68	89 01 21	89 04 12		81		Originally stolen after a few days at sea, ransomed, relaunched, grounded Palawan Island
69	88 07 09	88 07 09		0		Quit at launch
70	88 07 24	89 05 06		282		Grounded Japan
71	88 07 25	88 08 21		26		Grounded Mindanao
72	88 07 08	88 11 20		131		Grounded small island
73	88 06 27	89 09 15		445	?	Died at sea; bad values drogue & temperature
74	88 07 23	89 04 08		255		Grounded Philippines
75	88 07 07	90 02 13	89 08 01	586	390	Died at sea
76	88 07 08	89 05 30		326		Grounded Philippines
77	88 07 08	89 05 04		326		Grounded near Taiwan
78	88 07 06	90 03 31	89 05 20	633*	318	Dec. 90: three-week gap
79	88 07 21	88 12 23		152		Died at sea
80	88 07 05	89 03 26		261		Died at sea
81	88 06 27	89 12 21	89 05 21	542	328	Died at sea
82	88 07 16	88 07 26		10		Grounded Sangi Island
83	88 07 08	90 01 13	89 05 25	554	321	Grounded
84	88 07 09	88 08 31		52		Grounded Makassar Strait
85	88 10 29	89 09 24	89 06 20	330	234	Grounded north of New Guinea
86	88 06 25	89 03 04		249		Grounded Philippines
87	88 07 06	89 03 19		253		Died at sea
88	88 07 07	88 11 08		121	?	Died at sea, bad values drogue & temperature; one-week gaps in July '88 & Aug. '88
89	88 06 25	88 11 08		133		Died at sea
90	88 07 07	90 03 31	89 06 03	632*	331	
91	88 06 23	90 03 09	89 09 28	624	462	Died at sea; Sept. '89: two-week gap
92	88 06 24	89 02 07		223		Died at sea, found on Truk Island July '89
93	88 06 24	90 03 31	89 07 16	645*	387	Data after 89 09 30 missing during report preparation
94	88 06 27	88 08 23		56		Grounded Halmahera Island
95	88 10 27	89 01 17		80		Died at sea
96	88 10 28	89 06 15		230		Died at sea
97	88 10 28	89 02 17		109		Died at sea; Nov. '88: 10-day gap
98	88 10 29	89 09 18	89 07 20	324	264	Grounded Woodlark Island

* Still operating as of March 31, 1990.