Description and Performance of Finescale Drifters for Coastal and Estuarine Studies

RON GEORGE AND JOHN L. LARGIER

Scripps Institution of Oceanography, University of California, San Diego, San Diego, California

10 February 1995 and 24 May 1996

ABSTRACT

The authors have designed and built a differential Global Positioning System (DGPS)-positioned Lagrangian drifter system to study complex nearshore, estuarine, and inner shelf flows with strong gradients and small scales. Various measures of the accuracy of the positioning system were assessed experimentally, as were the windage effects of antennas and floats. The DGPS-indicated position of a fixed drifter has a standard deviation of less than 1 m (over 600 samples) at a distance from the base station of up to 20 km. Windage effects are linear with a slope of about 0.002 drift-to-wind velocity ratio, which is about half the theoretical value.

1. Design specifications

The small-scale flow structures found near fluid boundaries, such as the coast and strong fronts, are poorly described owing to a lack of adequate instrumentation. Similarly, away from such boundaries, the finescale structure of horizontal dispersion is poorly described. In response to this absence, we set out to develop a drifter system that would resolve small-scale, high-frequency coastal and estuarine flows. Following are our criteria for such a system.

The drifters must be inexpensive so that large numbers can be deployed simultaneously to provide both statistical reliability and spatial resolution over the domain of interest. The system must be self-contained, reliable, rugged, and easily transportable. The drifters are to be retrievable. The drifter package should be modular, allowing for the possibility of using different drogue, float, and visibility-device designs. The drifter should be easily adjusted for droguing at depths from 1 to 15 m for use in vertically sheared flow in a wide variety of applications. Positioning error must be small (less than 5 m) in order to resolve the small-scale structure of the flows of interest. Sample interval must be short (less than 10 s) and not dependent on the number of drifters deployed at one time. Position accuracy and sample rate must be maintained at distances of up to 20 km from the base of operations. In the presence of moderate wind and wave conditions, the water-following performance of the drifter must have errors that are known and a wind-induced-drift to wind speed ratio of no more than 0.005.

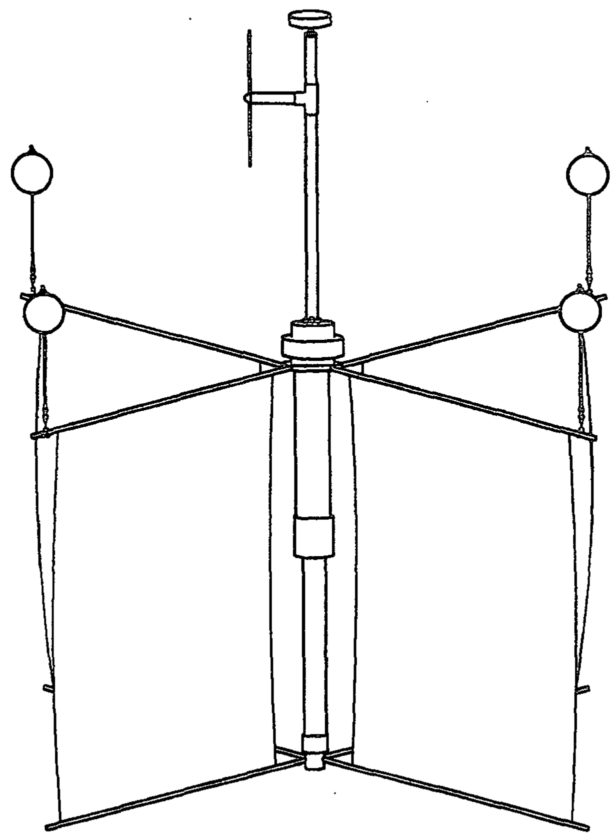

FIG. 1. GPS drifter body. The drifter consists of a central PVC tube housing the electronics package and batteries, an antenna structure, four coated-cloth vanes, and four plastic foam floats with tethers. The vanes are approximately 1 m high and 1.1 m in total width.

Corresponding author address: Dr. Ronald A. George, Sontek, Suite D, 7966 Arjons Drive, San Diego, CA 92126.
E-mail: Ron@sontek.com

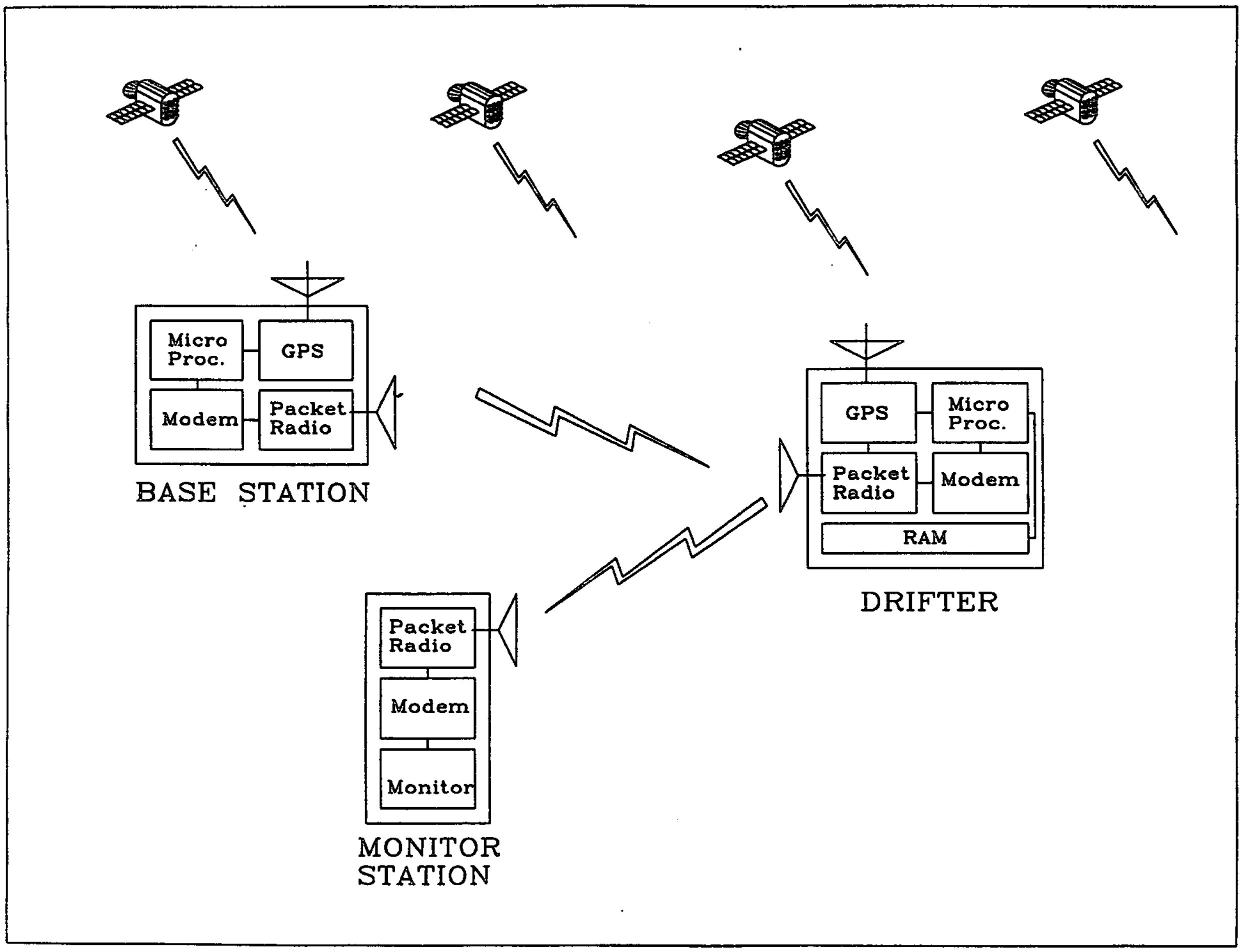

FIG. 2. General schematic of differential GPS drifter tracking and monitoring system. Signals are received from satellites by drifters and the base station; the base station determines corrections and transmits them to drifters, which then determine corrected position. Corrected positions are stored on board and occasionally transmitted to monitor station.

2. Description of instrument

a. Drifter body

A modification of an existing drifter body design used by Davis (Davis et al. 1982; Davis 1985) meets the physical requirements (Fig. 1). The projected area of the drogue is approximately 1 m^2, and the electronics package is carried in a central PVC (polyvinyl chloride) pressure case. This drifter has known surface-following characteristics in a wave field, low mass, and can be inexpensively constructed.

b. Positioning system

The drifter system as built consists of a base station, a fleet of drifters (18 at present), and a monitoring station located on the drifter tracking vessel. Figure 2 shows a general schematic of the system.

The base station consists of a Motorola PVT6 six-channel differential Global Positioning System (GPS) engine, a Motorola UHF packet radio, a Paccom packet modem, an Onset Model 5F datalogger/processor, and UHF and GPS antennas. Total cost of components was approximately $1,400. The GPS engine in the base station receives precise timing and satellite position information from the constellation of GPS satellites and calculates its distance (pseudorange) from each satellite. The differences between the known and calculated distances (pseudorange corrections) for each satellite are broadcast over the UHF packet radio.

Each drifter has an electronics package similar to the base station. The drifter GPS engine is configured to receive the satellite messages, generate the local pseudoranges, receive the UHF-broadcast pseudorange corrections from the base station, and calculate its cor-

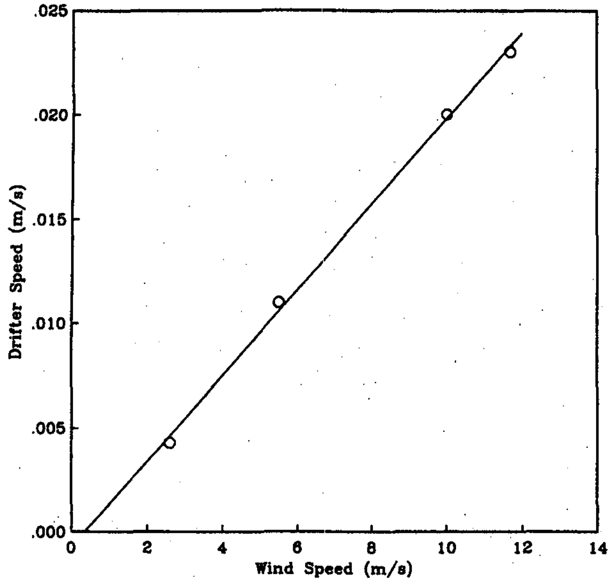

FIG. 3. Wind-induced drift speed as determined through wind-channel testing. Best-fit slope is 0.002.

rected position. The corrected positions are then recorded in onboard memory. The frequency of positioning can be as fast as 1 Hz.

The relatively small size of the drifters precludes storing enough batteries on board to continuously telemeter data back to a land station. However, to aid in the recovery of the drifter fleet, each drifter broadcasts its position at a programmable interval. A monitor station on board the tracking vessel receives and displays the position of the drifters as they sequentially report their positions.

3. Performance testing

a. Drifter body

1) WAVE FIELD RECTIFICATION

A surface drifter may rectify the wave velocity field—a positively buoyant drifter proceeding in the same direction as long waves and a near-neutrally buoyant drifter proceeding opposite to the direction of small waves (Davis et al. 1982). As our drifter body

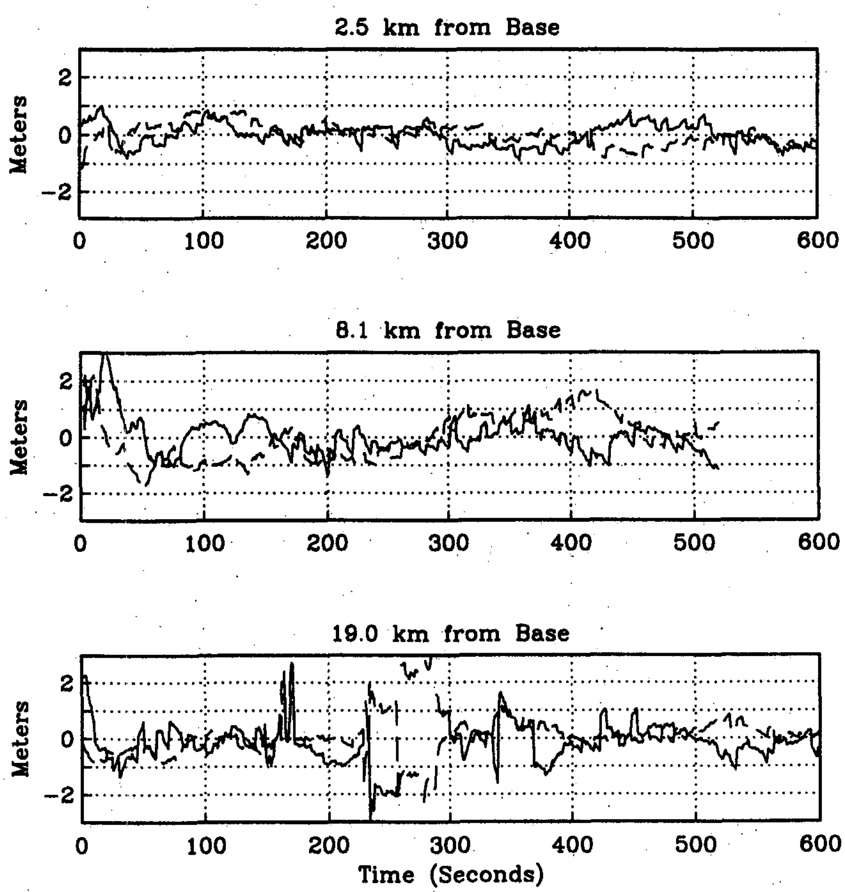

FIG. 4. Time series of DGPS position for a fixed drifter located at three different distances from the base station.

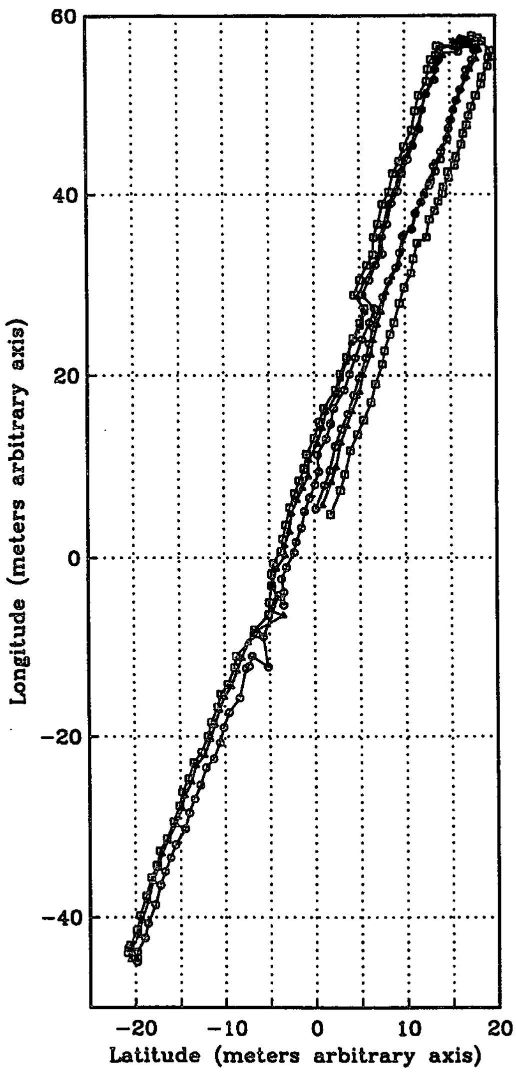

FIG. 5. Tracks of three drifters as they are moved first in a straight line; the group rotated 180° and then returned halfway to the starting point.

is similar except for the float configuration to that tested by Davis et al. (1982), we expect that the influence of waves will be no worse than found by Davis et al.

2) WIND DRAG

Wind drag may be relevant, even though the drogue is designed with a cross-sectional area 40 times that of the above-water components. The small wind deflections accumulate over time and the drifter may move into a different water mass (a 0.01 m s^{-1} slip results in an offset of 900 m in a day).

Drifter windage was tested in a wind-wave channel at various wind speeds. Because the wind produces currents in the channel water, the drifter being tested was deployed alongside a reference drifter that was designed to monitor, independently of the wind, the water currents. The reference drifter had no antenna structure and was ballasted so that its floats barely penetrated the surface.

As shown in Fig. 3, a linear dependence of drifter speed (the difference between the speeds of the test drifter and the reference drifter) on wind speed was found with a slope of 0.002 (i.e., a slip of 0.01 m s^{-1} in a 5 m s^{-1} wind). The values are about half those predicted by Murray (1975), when Murray's calculation is corrected for a sine–cosine transposition and applied to our drifter and antenna projected areas. The drifters were deployed near the upwind end of the channel, where waves were small, to minimize any wavefield rectification by the reference drifter.

b. Positioning system

1) GPS COVERAGE

GPS coverage is the surface area in which the signals are adequate to provide the required positioning accuracy (U.S. Departments of Transportation and Defense 1992). We report on a simple test of the approximate coverage of the system in the next section.

The positioning system was tested to determine the stability of the indicated position at varying distances from the base station. To accomplish this, the base station antennae were mounted 10 m above the beach and a drifter was moved on land to increasingly distant locations along the beach. Line-of-sight necessary for UHF radio communication was maintained due to cur-

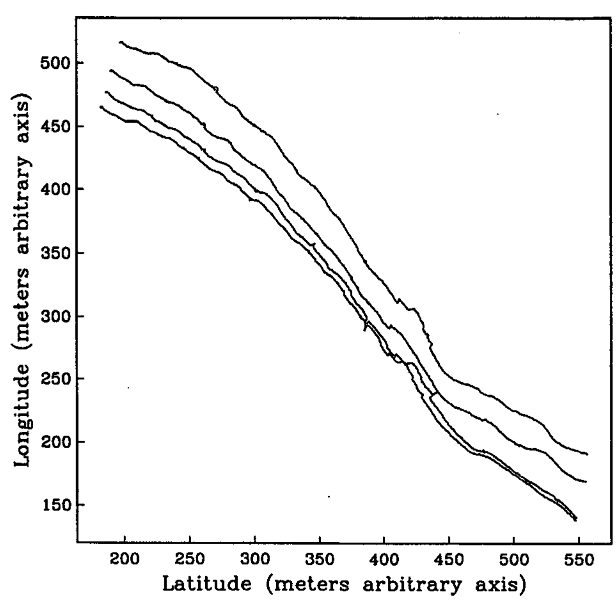

FIG. 6. Tracks of four drifters released in the nearshore.

vature of the shore. At each location, the drifter was held stationary and data were recorded for 10 min. The resulting standard deviation of position was less than 0.5 m at 2.5 km and increased to less than 1 m at 19 km from the base. The degradation with distance is most likely due to the drifter not receiving all pseudorange correction data because of the weak UHF signal (2 W) and low height of the base station. Figure 4 shows time series of position data at three of the locations. While this test is not as rigorous as a test over water, it gives a rough idea of the maximum coverage that could be expected. During actual deployments, the base station is much higher [O(150 m)] and the drifter antennae are much lower (less than 1 m).

2) ACCURACY

There are three types of accuracy that are generally used to describe radionavigation systems (U.S. Departments of Transportation and Defense 1992).

(a) Predictable accuracy: the accuracy of the system relative to the charted position. Predictable accuracy is important for surveying applications, but not critical for our uses.

(b) Repeatable accuracy: the accuracy with which a user can return to a position previously measured with the same system. Repeatable accuracy is not a primary concern in small-scale drifter studies.

(c) Relative accuracy: the accuracy with which a user can measure position relative to another user at the same time. Relative accuracy is our primary concern and we report on some simple tests to determine it.

To determine the relative accuracy of a group of drifters, three drifters were spaced 0.7 m apart and moved through a straight course 100 m long, then turned around as a group and moved back along a parallel but offset course. The tracks described by the drifters are shown in Fig. 5.

The data always indicated the correct orientation of the drifters to one another; the indicated distances between them varied from 0 to 1.4 m, and the paths are generally parallel, indicating that the errors are common to a small group at a particular time. The indicated offset at position (6, 29) in Fig. 3 occurred when the constellation visible to the base station changed. None of the recorded position offsets were larger than 2 m.

The drifters were also tested in the ocean as a qualitative measure of the relative accuracy under deployment conditions. Four drifters were deployed about 1 km from the shore. The resulting tracks are shown in Fig. 6. As in the land-based cohesion tests, the offsets that are synchronous at all drifters coincide with the base station's ungraceful handling of constellation changes.

Acknowledgments. We gratefully acknowledge support from the California Department of Boating and Waterways through interagency agreement 92-100-060-21. This paper is funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under Grants NA89AA-D-SG138 and NA36RG0537, Project Number R/CZ-121 through the California Sea Grant College System, and in part by the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies. The U.S. government is authorized to reproduce and distribute for governmental purposes.

REFERENCES

Davis, R. E., 1985: Drifter observations of coastal surface currents during CODE: The method and descriptive view. *J. Geophys. Res.*, **90**, 4741–4755.

——, J. E. Dufour, G. J. Parks, and M. R. Perkins, 1982: Two inexpensive current following drifters. Scripps Institution of Oceanography, Ref. No. 82-28, 54 pp. [Available from University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093.]

Murray, S. P., 1975: Trajectories and speeds of wind-driven currents near the coast. *J. Geophys. Res.*, **80**, 347–360.

U.S. Departments of Transportation and Defense, 1992: *Federal Radionavigation Plan.* U.S. Government Printing Office, 240 pp.