Mediterranean Drifter Data Analyses

Pierre-Marie Poulain
Naval Postgraduate School, Code OC/Pn
Monterey, CA 93943
phone: (831) 656-3318 fax: (831) 656-2712 email: poulain@oc.nps.navy.mil

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http://www.oc.nps.navy.mil/~drifter

LONG-TERM GOALS

To contribute to the understanding of the dynamics of marginal seas such as the Mediterranean by collecting and interpreting accurate Lagrangian observations of currents and satellite measurements of water mass properties (e.g., temperature, salinity, chlorophyll concentration). In particular, to study the variability of the surface velocity and temperature/chlorophyll fields in selected basins of the Mediterranean at the meso-, seasonal and interannual scales and to assess the impact of the wind forcing and fresh water runoffs.

OBJECTIVES

1) To quantify the instrumental and sampling errors associated with velocity statistics derived from Lagrangian data sets. In particular, to assess the water-following characteristics of commonly-used surface drifters by making direct measurements of the relative flow around their body under various wind and wave conditions. To use advection-diffusion statistical models of trajectory prediction to estimate important sampling errors, such as the so-called "array" bias affecting the estimated mean flow. To find design criteria for optimizing drifter deployment strategies.

2) To describe the spatial characteristics and the temporal evolution of the surface circulation, the sea surface temperature (SST) and the surface chlorophyll concentration in selected basins of the Mediterranean, e.g., in the Ionian Sea, from meso- to interannual scales. To investigate some aspects of the response of the surface circulation and SST/chlorophyll to atmospheric (e.g., winds) and boundary (e.g., river runoffs) forcings. In particular, to study the characteristics of wind-driven currents (i.e., upwelling events).

APPROACH

1) Direct measurements of the relative water flow around surface drifters in various wave and wind conditions. Interpretation of the measurements using multi-variate regression analyses to find simple models of drifter slip versus wind speed and direction and versus wave significant height and direction.

2) Estimation of Lagrangian sampling errors, and in particular of the important "array" bias error, using statistical models. Assessment of the validity of Davis (1999)'s formula using numerically simulated drifter trajectories produced by a "random flight" model (Gaussian-Markov process). The use of the same model to seek an optimized drifter deployment strategy to map the mean flow and eddy variability and to quantify particle dispersion (Lagrangian statistics).

3) The analysis and interpretation of historical Ionian surface drifter data sets collected between 1990 and 1999 by various organizations, mostly by the SACLANT Undersea Research Centre (SACLANTCEN), by the Naval Oceanographic Office (NAVOCEANO) and by the Naval Postgraduate School (NPS). Eulerian and Lagrangian statistics of the Ionian surface circulation and SST are computed. Sampling random and bias errors on the mean flow estimates are estimated.

4) The use of satellite images concurrently with the drifter data to describe the variability of the surface currents, SST and surface chlorophyll fields in coastal areas of the Ionian Sea (Strait of Sicily and of Otranto, near the Cretan islands and along the African coast). AVHRR images archived by SACLANTCEN and processed by the Satellite Oceanography Laboratory of the University of Hawaii (Dr. P. Flament) are used to study the SST variability. SeaWiFS images downloaded from the Goddard DAAC are utilized to create maps of surface chlorophyll concentration during periods of large drifter concentration.

WORK COMPLETED

1) Two commonly-used surface drifters, the CMOD (without case) and the CODE, and a new drifter design (MICROSTAR) were equipped with acoustic velocimeters and with GPS receivers, without changing significantly their hydro-dynamical characteristics (e.g., size, buoyancy and drag area; see Fig. 1). The velocimeters measured the relative water flow at 1-2 locations near the body of the drifter with an accuracy of about 1 cm/s and with sampling frequency of 1 Hz. The GPS receivers provided high accuracy (~ 1 m) position data at 1 Hz. All the data were recorded on a datalogger and memory board inside the drifters. The three drifters were deployed in the vicinity of a waverider buoy in Monterey Bay on 5, 6, 7, 8, 11 and 12 December 2000. The waverider buoy provided significant wave height and wave direction data every 30 min. Each day, the drifters remained in the water for 3-5 hours before they were recovered. The ship used for the deployment/recovery operations was fitted with a meteorological station to collect wind data close to the drifters with a sampling interval of 10 min. Wind speeds when the drifters were in water ranged in 0.5 - 8 m/s whereas significant wave height varied between 0.8 and 2.5 m.

2) The same drifters were operated in the northern Adriatic in March 2001, in the vicinity of a waverider buoy just outside the Gulf of Trieste (12, 14, 20, 21 and 22 March 2001) and near the “Acqua Alta” oceanographic tower off Venice (26, 28 and 29 March 2001). The waverider buoy and pressure gauges at the tower provided significant wave height and wave direction data. The ship used for the deployment/recovery operations was fitted with a meteorological station to collect wind data close to the drifters with a sampling interval of 1 Hz. Wind and sea conditions were relatively calm, with wind speed smaller than 8 m/s and significant wave height inferior to 0.5 m.

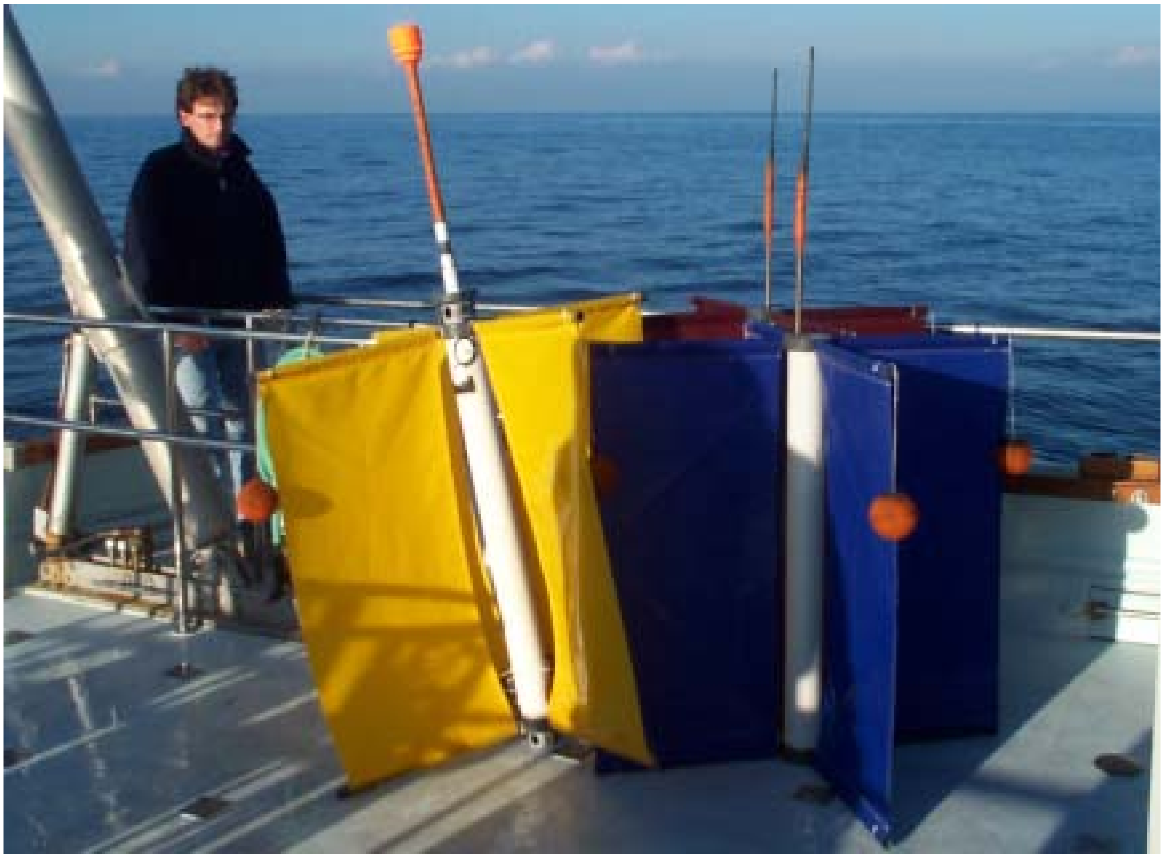


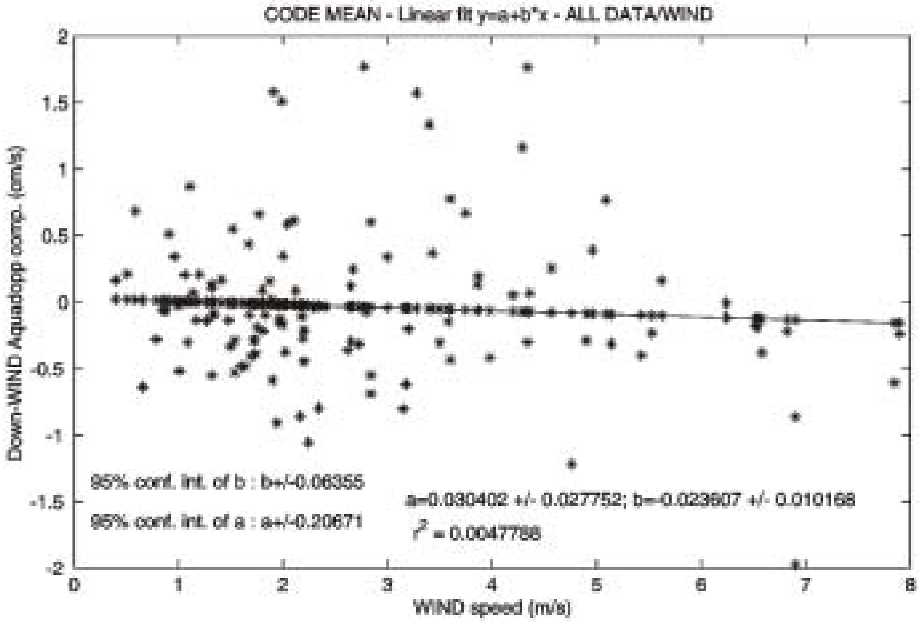
Fig. 1. CODE drifters ready to be deployed in Monterey Bay in December 2000: Two standard designs with Argos antenna are shown to the right (brown and blue); the drifter equipped with two acoustic velocimeters and GPS antenna is shown to the left (yellow).

RESULTS

1) Drifter tests, Monterey Bay, 5-12 December 2000

Over the 3-5 hour drift, the drifters deployed at the same location dispersed by less than 500 m (relative separation) with an obvious tendency of the CMOD to move more downwind that the others. The relative speeds measured by the acoustic velocimeters and averaged over 10 min intervals were as large as 10 cm/s for the CMOD with r.m.s. variability of about 15 cm/s. For the CODE and MICROSTAR drifters, the 10-min averaged slips were bounded by 5 cm/s and their typical r.m.s. variability was 5 cm/s. Substantial values of shear between the top and bottom of the CODE and MICROSTAR drifters (~ 1 m apart) were measured (up to 5 cm/s).

Regression were performed between the 10-min averaged relative flow data, the wind and wave observations. It was found that the CMOD drifter slips downwind (0.3% of wind speed) and to the right of wind (0.9%). The slip of the CODE (Fig. 2) and MICROSTAR drifters has no significant trend in the downwind direction whereas it increases like 0.1-0.2% of the wind speed in the cross-wind direction (to the right). The regressions of slip versus wave height did not provide significant linear trends, mostly because of the short range of wave heights and the dominance of wind effects, but a general tendency of upwave motion can be noted for the CODE/MICROSTAR drifters. Finally,



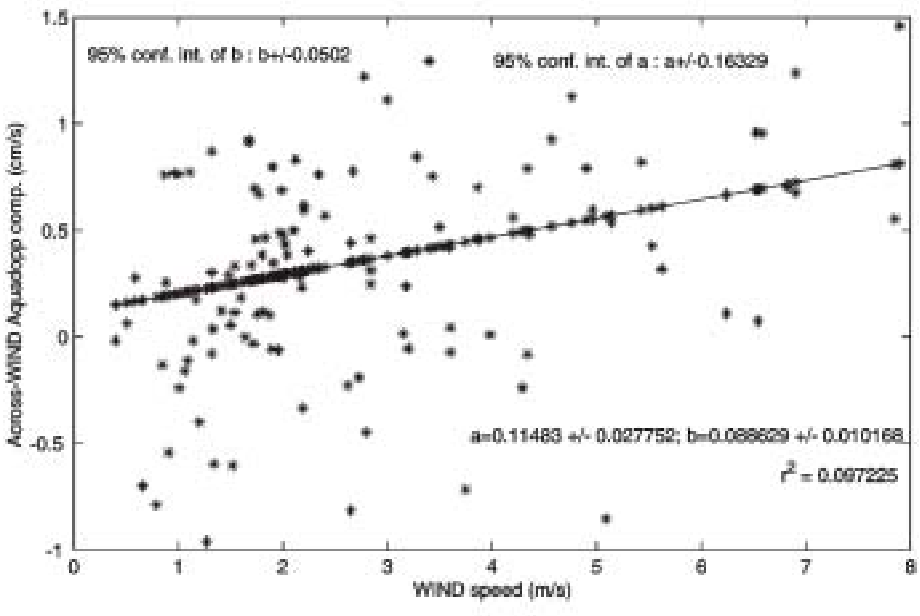


Fig. 2. Mean down-wind (top) and cross-wind (bottom; positive to the right) slip speeds versus wind speed measured for the CODE drifter in Monterey Bay (5-12 December 2000). Mean slips were obtained by averaging the relative flows measured by the acoustic velocimeters at the top and at the bottom of the drifter.

regressions of shear (velocity at the top minus velocity at bottom) versus wind and wave data revealed that the shear is downwind and to the right of the wind (compatible with Ekman spiral), and increases with wind speed with a slope of 0.3-0.5% of the wind speed. Regressions against wave data were inconclusive, although most estimates of shear were downwave (compatible with Stokes drift).

In brief, the CODE and MICROSTAR were demonstrated to follow relatively well the surface water with an accuracy of about 1 cm/s in 10 m/s winds. In contrast, the CMOD design (without case) was shown to slip downwind by about 0.3% of the wind speed.

2) Drifter tests in the Northern Adriatic

The data collected in the Northern Adriatic between 12 and 29 March 2001 are still at the processing/analysis stage. More measurements are scheduled near the "Acqua Alta" tower in November 2001.

IMPACT/APPLICATION

The scientific impact of this project will be to increase our understanding of the Mediterranean dynamics and of the major forcing mechanisms. Future application could be the assimilation of the drifter data into numerical models in the framework of the anticipated Mediterranean Forecasting System (MFSTEP). The assessment of the water-following capabilities of the surface drifters is important for future drifter experiments, e.g., the Lagrangian component of the Adriatic Mesoscale Experiment (AMEX) planned in 2002-2003.

TRANSITIONS

This program quantifies the water-following characteristics of the drifters that NAVOCEANO has been (and is currently) using to obtain environmental observations during sea operations (both CMOD and CODE). This information is also very helpful for various past, present and future scientific programs involving surface drifters.

It is planned to assimilate the drifter data (velocities and SST) into various numerical models of the circulation in the Mediterranean to improve forecasting skills.

RELATED PROJECTS

1) This project is strongly related to current and future drifter programs in which I am involved (Black Sea, Tyrrhenian Sea, Adriatic Sea).

2) The drifter data collected will be used by Drs. A. Griffa and T. Ozgokmen to validate their theoretical studies of particle dispersion (ONR supported project).

3) I have contributed to four chapters of an upcoming book on the physical oceanography of the Adriatic Sea ("Physical Oceanography of the Adriatic Sea – Past, Present and Future", by Cushman-Roisin, Gacic, Poulain and Artegiani, Eds.).

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