Deep-Sea Research Part I 137 (2018) 20–29

Contents lists available at ScienceDirect

Deep-Sea Research Part I

journal homepage: www.elsevier.com/locate/dsri

Water following characteristics of Global Drifter Program drifters with and without subsurface float

Dong-Kyu Lee[a,*], Luca Centurioni[b]

[a] Department of Oceanography, Pusan National University, Busan, Republic of Korea
[b] Scripps Institution of Oceanography, La Jolla, CA, USA

ARTICLE INFO

Keywords:
Global Drifter Program drifter
Wind-driven current
Cross-spectral analysis
Ekman current, vector regression

ABSTRACT

In the Northeast Pacific (40–50°N, 135–180°W), the angle between the wind friction velocity (u_*) and the current observed by drifters with subsurface float (Global Drifter Program Version 1; GDP-V1) was found to be consistently 10–15° larger at all frequencies than the angle observed by drifters without subsurface float (Global Drifter Program Version 2; GDP-V2). To investigate the cause, cross-spectral analysis and vector regression between the wind and current were performed after carefully screening drifter tracks to study the wind-driven currents observed by drifters with different configurations. Vector regression analysis between the wind and current revealed that the angle of wind-driven current observed by GDP-V1 drifters was 10–13° larger for $u_* < 1.5\,\mathrm{cm\,s^{-1}}$ compared to that observed by GDP-V2 drifters. One possible explanation for a smaller angle between wind and current from drifters without subsurface float is the shallowing of observed depth due to the shrinking of the holey sock drogue induced by surface wave action. The depth of the current observed by GDP-V2 drifters during the winter was estimated using the observed angle and the e-folding depth calculated from the angle at 15 m by GDP-V1 drifters. In the winter, the mean depth of the wind-driven current observed by GDP-V2 drifters, which have been deployed since the early 2000s, was approximately in the range of 8–10 m depending on the estimation of the e-folding depth either from the angle change or from the amplitude decay in the Ekman layer. Except for the friction velocity exceeding $1.5\,\mathrm{cm\,s^{-1}}$, a nearly constant amplitude between surface current and friction velocity at all friction velocity ranges is another finding in our study.

1. Introduction

Satellite-tracked drifters have been used to measure near-surface currents in the ocean for over 40 years, and more than 1000 drifters equipped with various sensors are deployed annually. Niiler et al. (1995) indicated that TRISTAR drifters (Niiler et al., 1987) and drifters with holey-sock drogues exhibit similar water-following characteristics. Since then, drifters with holey-sock drogues have been extensively used for the Global Drifter Program (GDP) because shrinkable holey-sock drogues make shipping, storage, and deployment easier. The first-generation GDP drifters with a holey-sock drogue (hereafter GDP-V1 drifters) were configured with a subsurface float to reduce the effects of surface waves (Fig. 1). Since the early 2000s, smaller-sized holey-sock drogues without a subsurface float have been used for most second-generation GDP drifters (hereafter GDP-V2 drifters). Because the synthetic rubber hydraulic hose reinforced with steel wire on the inside was used between the surface and subsurface float, removing the subsurface float reduced costs considerably, and increasing the number of drifters with limited funds was important at the time. All drifters exhibit the same drag area ratio. However, existing studies have not examined the water-following characteristics of the smaller holey-sock drogues, especially under high-wave-sea conditions. The drag area ratio (Niiler et al., 1995) corresponds to the ratio of the drag area of the drogue to that of the other components of the drifters (e.g., surface buoy, wire, and attached sensor).

Studies on wind-driven current using GDP drifters have been performed in several regions (Ralph and Niiler, 1999; Niiler and Paduan, 1995; vanMeurs and Niiler, 1997) and in the global ocean (Rio and Hernandez, 2003). However, fitting the observed data to the Ekman wind-driven current model produced differences in these studies' results. Climatological maps of the near-surface current were produced by Lumpkin and Johnson (2013) using all drogued drifter data, and by Laurindo et al. (2017) using all available drifter data including the slip-corrected undrogued drifter. The currents they mapped are the total (geostrophic and wind-driven) currents observed by GDP drifters from several manufacturers with various configurations. Thus, if differences in the behavior of drifters with different configurations exist, it is important to find these differences for processing and analyzing the

* Corresponding author.
E-mail address: dglee@pnu.edu (D.-K. Lee).

https://doi.org/10.1016/j.dsr.2018.05.003
Received 1 December 2017; Received in revised form 5 May 2018; Accepted 5 May 2018
Available online 07 May 2018
0967-0637/

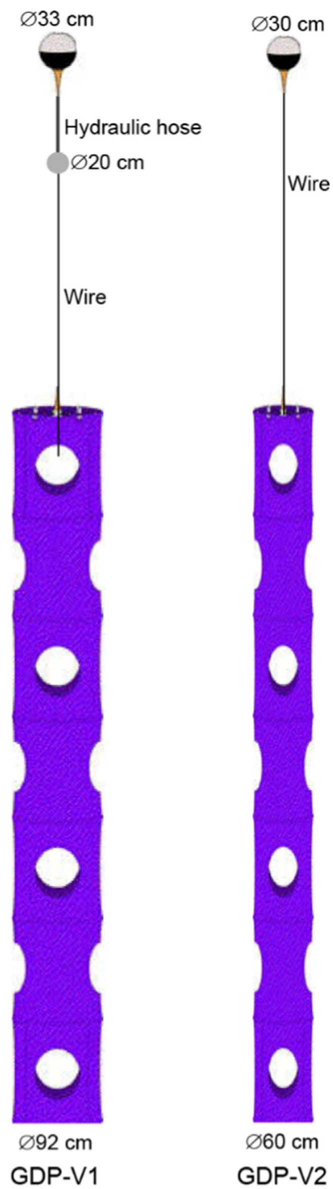

Fig. 1. Schematics of drifters with subsurface float (GDP-V1) and without subsurface float (GDP-V2).

drifter-observed current.

The aim of this study is to investigate the difference in wind-driven currents using reanalysis winds, and currents observed by drifters with or without subsurface buoys. For this purpose, all historical drifter data in the Northeast Pacific (40–50°N, 135–180°W) are examined. To obtain consistent data in different drifter configurations, properly functioning drifters are selected after individually examining the vector regression coefficients between the currents and winds observed by drifters. The cross-spectral analysis and vector regression analysis between the drifter-observed currents and collocated winds are used to identify the differences in water-following characteristics between drifters with and without subsurface float.

2. Data

2.1. Drifter and wind data

This study used drogue attached drifter data from the Global Drifter Program (GDP), obtained from the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration (AOML/NOAA, ftp.aoml.noaa.gov/phod/pub/buoydata). Velocities from GDP were calculated at 6 h intervals from 12 h centered differencing of the drifter positions interpolated by kriging at 6 h intervals (Hansen and Poulain, 1996). Niiler (2001) described the processing of location data from the drifters and Lumpkin et al. (2013) discussed the quality control including drogue status checking. The 10 m wind velocity fields were from the European Center for Medium-Range Weather Forecasts (ECMWF, apps.ecmwf.int/datasets/data/interim-full-daily/levtype = sfc) ERA-Interim reanalysis at 6 h intervals on 0.75° × 0.75° horizontal grids (Dee et al., 2011).

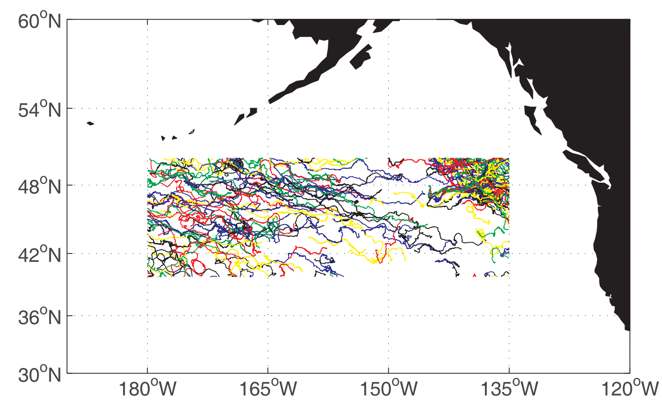

Fig. 2. Drifter trajectories used in this study.

2.2. Selection of study area

The latitude band of 40–50°N in the Northeast Pacific (Fig. 2) was selected to investigate the differences between the wind-driven currents observed by the drifter with subsurface float (GDP-V1) and without subsurface float (GDP-V2). The reasons for choosing this particular area for study are as follows. (1) A large number of GDP-V1 drifters continuously transmitted for location fix in the selected area (Paduan and Niiler, 1993). Most GDP-V1 drifters were programmed to collect location data only one third of the time (one-day-on and two-days-off) to save satellite transmission costs. The difference between analyzing continuously sampled data and interpolated data during transmitter-off days is described in the Section Data. Those continuously sampled GDP-V1 drifters were deployed from 1987 to 1992 when sea level anomaly data from the satellite altimeter was not yet available; therefore, it is necessary to consider ways to remove geostrophic current. Ralph and Niiler (1999) used geostrophic current from climatology for obtaining mean ageostrophic current. The vector correlation analysis used in this study estimates the mean response of the current to the changing wind over time and the most wind-driven currents are found in the frequency band of 0.05–1.0 cycle per day (cpd) (Rio and Hernandez, 2003). Thus, the cross-spectrum and vector correlation between wind and current in that frequency band will not be affected by subtracting the monthly climatological geostrophic currents from the drifter observed currents. Fortunately, eddies were rarely observed in the selected area (Chelton et al., 2011) and high-pass filtering with a cut-off frequency of 0.17 cpd (period of 6 d) removes the eddy-induced geostrophic currents for vector correlation analysis shown in Section 4. Rio and Hernandez (2003) found that the most coherence between wind and current comes from the motions with a period of 1–6 d at latitudes above 30° and that the decrease in coherence due to the geostrophic current becomes large in the period of 7 d or more. The shortest time scale of eddy in the study area is about 7 d estimated from an eddy amplitude of 5 ± 2 cm (Cheng et al., 2014) with a baroclinic Rossby radius of deformation of 25 − 30 km (Chelton et al., 1998).