International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 28, No. 3, September 2018, pp. 240–247; https://doi.org/10.17736/ijope.2018.ak29

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Statistical Analysis of Turbulent Dispersion in the Sea Surface Layer Based on Satellite-Tracked Drifter Data

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This paper deals with the analysis of drifter campaigns realized in two different domains, the Gulf of Mexico and the Mar Grande Basin (Italy). Relative dispersion, diffusivity, and velocity variance were estimated, identifying different growth regimes. An exponential growth of the dispersion process was detected during the initial phase of deployment, and empirical laws for horizontal diffusivity were inferred. Velocity variance and integral time scale of the turbulence were obtained by using different techniques capable of evaluating short-term dispersion phenomena and sub-mesoscale turbulence. A spectral analysis realized in accordance with Taylor's theory was used to estimate the Lagrangian time scale in domains strongly affected by inertial oscillations.

INTRODUCTION

Investigation of turbulence dynamics is very important for the understanding of dispersion and transport of pollutants in the marine environment. Specifically, at the surface boundary layer, dispersion phenomena are governed by the interaction of different forces (i.e., currents, waves, and winds) and are characterized by a wide range of temporal and spatial scales (Gallerano et al., 2016). Estimates of turbulence parameters able to describe the interaction of these different forces are required for an accurate prediction of pollutant pathways and concentrations. At present, turbulent dispersion simulations are mainly carried out by using Lagrangian particle models, alternatively based on a Wiener process or a Langevin scheme, which require as input data such turbulence parameters as diffusivity, velocity variance, and Lagrangian time scale (Monti and Leuzzi, 2010; De Dominicis et al., 2012). Besides, a new efficient approach is represented by kinematic chaotic models (Lacorata et al., 2014; Lacorata and Vulpiani, 2017). In numerous previous studies (i.e., LaCasce and Ohlmann, 2003; LaCasce, 2008; Corrado et al., 2017), the absolute and relative dispersion analyses of various data sets were conducted, providing some insight into dispersion dynamics for large spatial scales (mesoscale). On the contrary, the early phase of turbulent dispersion, which is fundamental in the planning of search-and-rescue activities in the case of the accidental release of pollutants, remains, at present, not completely understood, as most studies show estimates of horizontal diffusivity that vary by two orders of magnitude (see, e.g., Matsuzaki and Fujita, 2017). In this work, estimates of turbulence diffusion parameters, specifically referred to the marine surface boundary layer and the initial phase of deployment, are inferred from the analysis of two different drifter campaigns. The analysis was carried out by focusing on both relative and absolute dispersion to obtain turbulence parameters. Different techniques were used to estimate Lagrangian time scale and velocity variance. In particular, a spectral analysis realized in accordance with Taylor's theory of dispersion was used to estimate the Lagrangian time scale in domains strongly affected by inertial oscillations. Estimates of relative horizontal diffusivities are inferred and presented as well as results concerning relative dispersion parameters.

Received November 20, 2017; updated and further revised manuscript received by the editors January 28, 2018. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-seventh International Ocean and Polar Engineering Conference (ISOPE-2017), San Francisco, California, June 25–30, 2017.

KEY WORDS: Marine turbulence, Lagrangian transport, drifters, relative dispersion, absolute dispersion, horizontal diffusivity, Lagrangian time scale.

DATA

The analysis was conducted using two databases derived from GPS satellite-tracked drifter campaigns conducted in two different domains, the Gulf of Mexico (Grand Lagrangian Deployment or GLAD) and the Mar Grande Basin, Italy (Marine Rapid Environmental Assessment 14 or MREA14). Figure 1 shows maps of the considered areas.

Both campaigns were realized by using drifters designed to follow surface circulation in the presence of wind and surface waves. As these external factors are considered to affect horizontal diffusivity, the use of this kind of instrument is suitable for in-situ estimations of turbulent diffusion at the sea surface.

GLAD Campaign

One of the two databases analyzed in the present work is the publicly available data set (Ozgokmen, 2012) resulting from the GLAD experiment conducted by the CARTHE Consortium in the Gulf of Mexico in 2012. The GLAD campaign consisted of the nearly simultaneous release of approximately 300 GPS-equipped CODE-type drifters in the northern Gulf of Mexico in the area (De

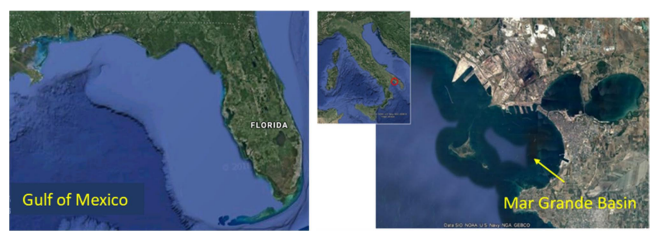

Fig. 1 Maps of the northern Gulf of Mexico (left) and of the Mar Grande Basin (right) and its location on the Italian territory (inset) (Map data © 2018 Google)