Dispersion of Floatables in Lake Currents

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ABSTRACT

A group of ten sub-surface drogues were released in a cluster in the epilimnion 15 km offshore near Oshawa, Lake Ontario, and the subsequent drift and horizontal spread were followed for 72 h using the radar/decca navigation system of the Canadian Survey Ship *Limnos*. Experimental data suggest periodic shrinking and expansion of the drogue group at approximately 16–18 h corresponding to the local inertial period. This is attributed to the generation of convergence and divergence flow fields as the inertial currents are modified by the sloping shore line or a sloping thermocline. Thus, mesoscale motions such as convergence and divergence of the flow field as well as turbulent dispersion due to random eddies are important considerations in the kinematics of floatables.

1. Introduction

In recent years, the practice of dumping man-made effluents into oceanic and lacustrine waters has led to considerable interest in the study of turbulent diffusion processes in such environments. Most existing experimental evidence on turbulent transport and diffusion of effluents in the oceans and the Great Lakes refers to dissolvable substances, providing a reasonable basis for estimating effluent concentrations downstream of sources. On occasions, however, waste effluents consisting of floatables are discharged into the surface layers of the oceans and the Great Lakes. Another related problem is the dispersal of accidental oil spills in navigable waters. Except for some limited experimental (Csanady, 1963, 1970; Okubo and Farlow, 1967; Chew and Berberian, 1971; Reed, 1971) and theoretical (Okubo, 1970) results, there is very little information on this practically important problem. An experiment was designed and carried out to study the dispersal mechanism of floatables in surface layer of Lake Ontario during the International Field Year for the Great Lakes as part of an overall program to study turbulent diffusion processes.

2. Experiment

The experiment was carried out during 18–21 July 1972, 15 km offshore near Oshawa, Lake Ontario. A group of ten drogues were released in a cluster in the surface layer and the subsequent drift and spread of the drogues was followed using the ship's radar/decca navigation system. The drogue group dispersion data was quite interesting showing some striking peculiarities.

A wide variety of drogues, drift cards and drift bottles have been successfully used as tracers to measure large-scale horizontal circulation and diffusion in the oceans and the Great Lakes (e.g., Csanady, 1963; Okubo and Farlow, 1967; Palmer, 1972). In this study, roller-blind drogues were used to simulate the dispersal of floatable particles. These drogues with their large area ratio of drogue assembly to surface appendage (50:1) respond to the changes in the surrounding water movements quite well and have been used successfully for Lagrangian measurements. The drogues were calibrated in the field under a variety of wind conditions to estimate the wind drift due to surface appendage. The drift was found to be less than 1 cm s^{-1}. The use of marked drogues or similar floating objects for studying turbulent diffusion has a number of limitations; floatables because of their density are constrained to move in a horizontal plane and respond only to the horizontal components of essentially three-dimensional flow field. Thus the drogues provide no information on vertical transport and mixing. Another limitation is the so-called "filtering effect" meaning smaller scale turbulent eddies are

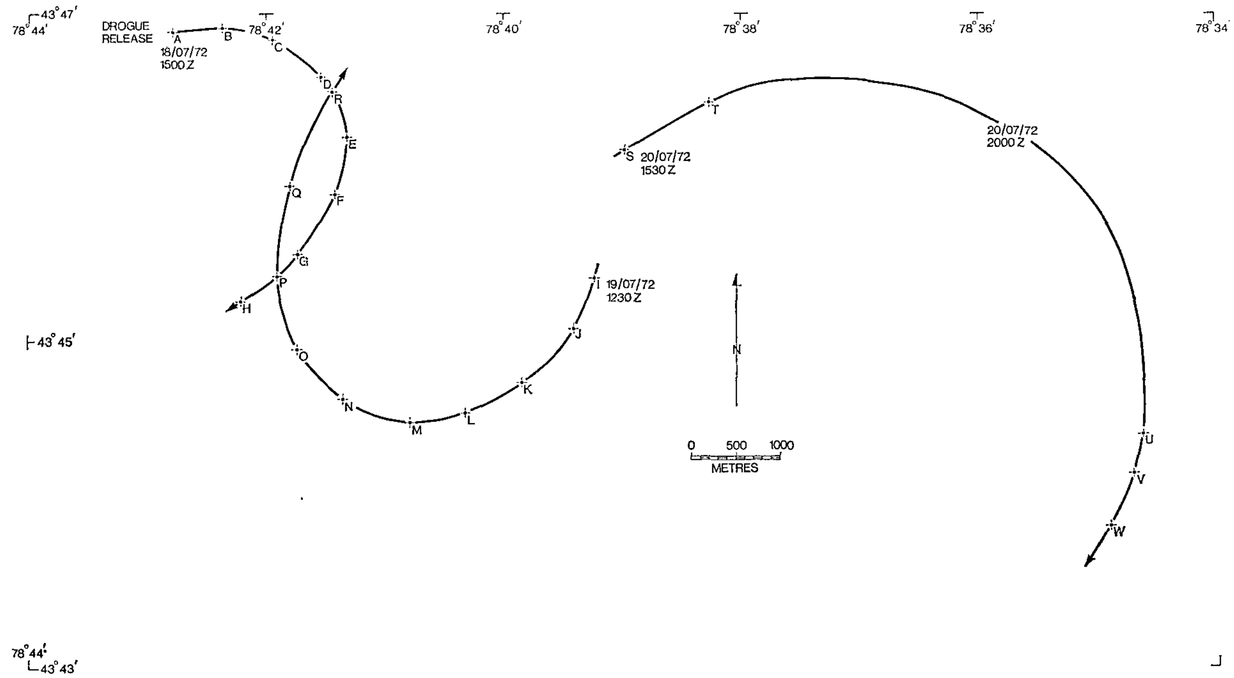

FIG. 1. Movement of center of gravity of drogue group.

effectively damped out due to the finite physical size of the drogues and therefore do not contribute to the turbulent transport and diffusion (Ogura, 1952; Cederwall, 1971). Cederwall has demonstrated the "filtering effect" in laboratory channel flow by observing the dispersal of different size drogues. Smaller size drogues would have been more suitable for this study

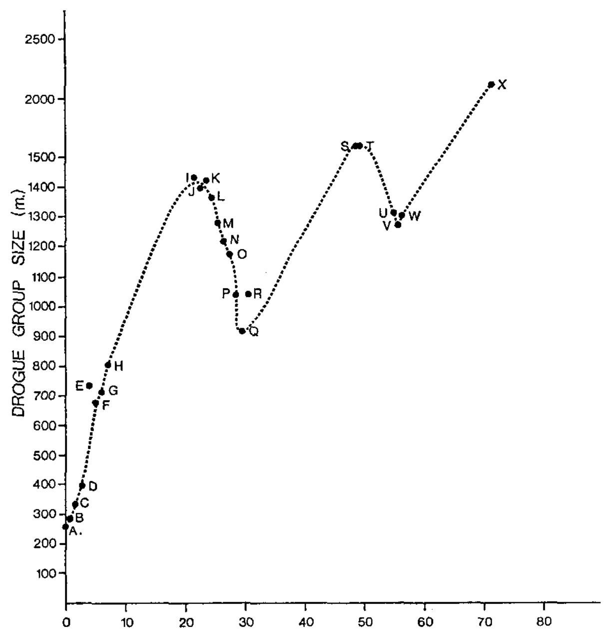

FIG. 2. Drogue group size vs elapsed time.

but practical considerations in the field dictated the use of roller-blind drogues. However, to simulate large-scale horizontal diffusion, these drogues were considered adequate, although smaller scale turbulence is averaged out due to the physical size of the drogues.

The experiment consisted of releasing a group of ten drogues set at 3 m depth in a cluster of approximately 100 m or so initial size. The drift and spread of the drogue group was followed every hour for about 72 h using the radar navigation system of the Canadian Survey Ship *Limnos*. Unfortunately, due to unforeseen field problems, there were gaps in the data. When bad weather seriously hampered the use of ship's radar navigation system for tracking the drogues, the decca navigation system was substituted, but the performance of the decca was also poor under such conditions. Some of the data were rejected for this purpose.

Temperature profiles taken from an electronic bathythermograph revealed a well-developed thermocline around 5 m depth during the entire period of the experiment. Thus the drift and spread of the drogue group refers to the epilimnion.

3. Discussion

The radar fixes were converted to displacements from which the center of gravity of the drogue group at successive intervals of time was calculated. The drift of the center of gravity of the drogue group exhibits typical inertial loops (Fig. 1). Root-mean-square separation of pairs of drogues, which is a measure of the group size, was also calculated at successive intervals of time. A plot of the group size versus elapsed time (Fig. 2) suggests periodic regrouping and subsequent dispersal of drogues at approximately 16–18 h corresponding to the local inertial period. To explain the observed horizontal spread of drogues, one has to invoke the generation of convergence and divergence flow fields by the inertial currents. Such a possibility exists when the inertial currents are modified due to the presence of the shore. For example, in the case of onshore flow, the shoreward component of the velocity must vanish at some point before reaching the shore and the water parcels must either sink or change direction or both to satisfy continuity. In any case, the net result is a convergence where floating debries collect. With an offshore flow a divergence is generated and the floatables disperse. A sloping thermocline can act much the same way as a sloping bottom and thus induce points of convergence and divergence in the flow field. A group of floatables around a point of divergence or convergence of the velocity field either grow or shrink with time. Okubo (1970) discusses this and other possibilities in some detail.

The growth of horizontal variance with time derived from the dispersion of a group of floatables has been used to calculate certain diffusion parameters notably horizontal eddy diffusivity (e.g., Okubo and Farlow, 1967). While these calculations appear to yield physically acceptable results for short-term duration experiments (say 4–8 h), such calculations would no doubt lead to misleading results for long-term experiments as the present data suggest. The convergence and divergence flow fields act as anti-diffusive agents undoing the dispersive action of random turbulent eddies.

Thus mesoscale motions such as convergence (or divergence) of the flow field as well as turbulent dispersion due to random eddies are important considerations in the kinematics of floatable clusters.

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