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To whom it May Concern:

This is a final report for ONR contract N00014-92-J-1185, "Development of a Mixed Layer Float", 11/1/91-10/31/92. The purpose of this grant was to finish development of a new type of neutrally buoyant float designed to accurately follow the three-dimensional motion of water parcels in the ocean mixed layer. This work was joint with David Farmer, of the Institute of Ocean Sciences, Sydney, British Columbia, Canada. This grant was responsible for the mechanical aspects of the float design. IOS/BC was responsible for acoustical tracking in three-dimensions.

Under this contract we finished construction of 2 new floats and took them on a cruise of the *CRV Parizeau* in October, 1991. The results from this cruise are summarized in Figures 1 and 2. Due to a failure of the ship's bow-thruster we could not work in the open ocean, and instead worked in Georgia Strait, a large sea inland of Vancouver Island. The top panel shows the wind stress, computed using meteorological data from a buoy which IOS/BC deployed. The wind is mostly rather weak, with two storms, the largest on November 24. The bottom panel shows the stratification from CTD casts. The depth of the mixed layer and the density surface 0.1 kgm^{-3} below the mixed layer are indicated by symbols. Smoothed versions of these indicate the mixed layer (white) and the depth of 0.1 kgm^{-3} more stratification (light grey). Superimposed on these are the depth-time trajectories of the two floats (dark lines). Before the storm, the floats, which have been ballasted slightly heavier than the mixed layer, rest on the top of the stratification and oscillate in the ambient internal wave field. As the wind picks up and the mixed layer deepens, the floats begin to move vertically through the mixed layer. This, I believe, is due to the turbulence which is actually deepening the mixed layer. More surprisingly, the floats seem to generally penetrate below the mixed layer into the underlying stratification. This, I believe, is the signature of mixed layer turbulence entraining water into the mixed layer.

We have compared these data with a numerical model of Langmuir Circulations, as embodied in the equations of Liebovich[1]. The model is two dimensional and is forced by the observed wind and wave fields at the height of the November 24 storm. Figure 2 shows the streamfunction (upper panels) and temperature (lower panels) from the simulation at 2 hours (left panels) and 6 hours (right panels) into the simulation. Quasi-periodic circulation cells fill the mixed layer and deepen it. Simulated floats (Figure 3) move freely through the mixed layer and penetrate the mixed layer base, just as seen in the data. A more quantitative comparison of the data and the model results shows remarkable agreement in vertical velocity, float time scale,

[1]S.Leibovich, 1977, JFM, 79,4,715-743

cell spacing and mixed layer deepening. We conclude that the mixed layer was deepened by Langmuir Circulations, as far as we can tell. This is the first quantitative test of the Liebovich theory.

Although this contract terminated with no follow-on, the floats have continued to yield wonderful data. Measurements in a convective mixed layer in February, 1993, show the first measurements of the predicted -2 spectral slope in the Lagrangian frequency spectrum. From these, we can estimate the kinetic energy dissipation and show that it agrees with what is expected in a convective boundary layer. The floats measure temperature along their paths. From this, we can compute vertical heat flux, using the correlation method, probably the first such measurements ever made in the open ocean. Finally, the spin of the float allows us to compute vertical vorticity, another quantity which is dynamically important, but seldom measured.

Sincerely,

Eric A. D'Asaro

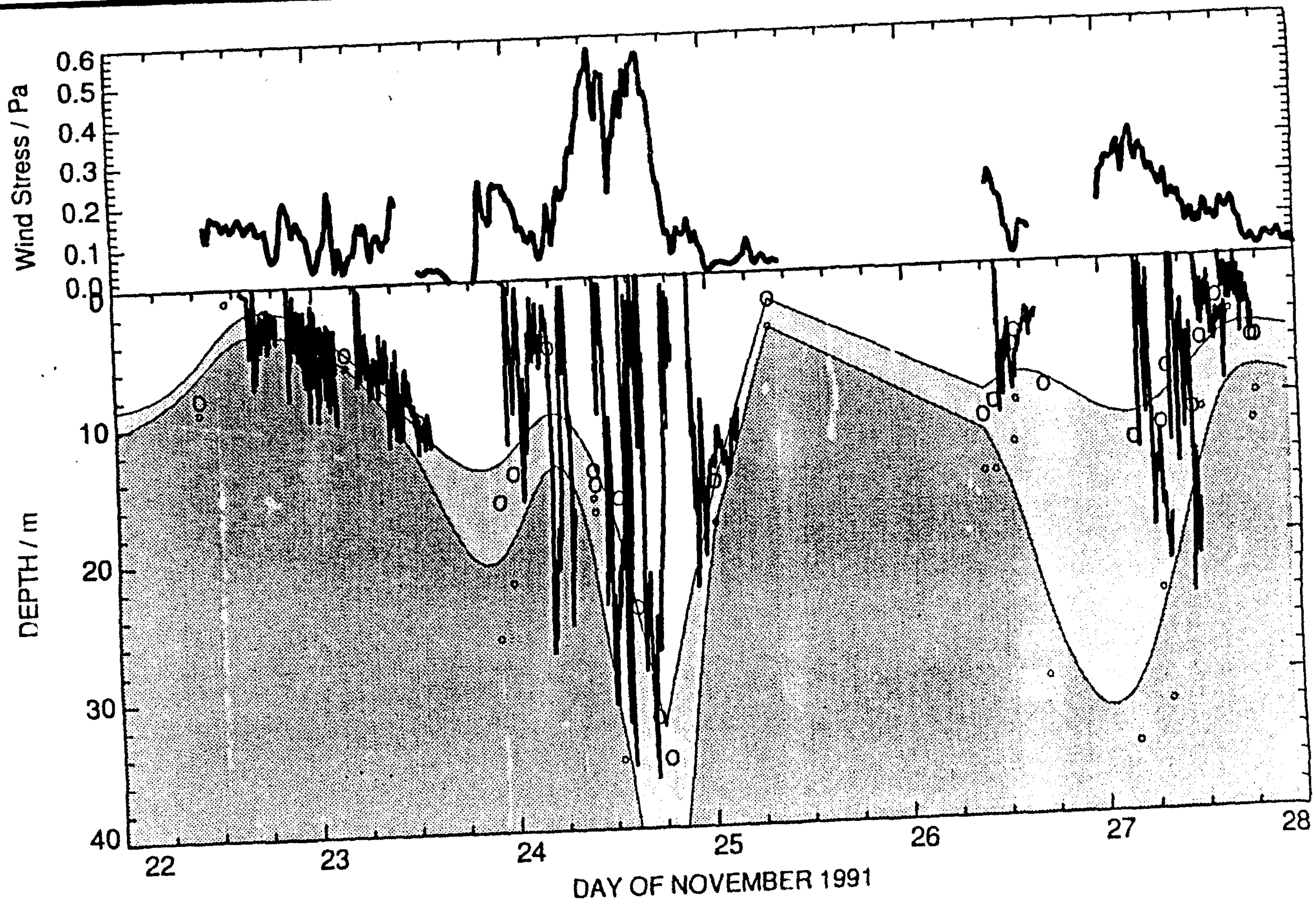
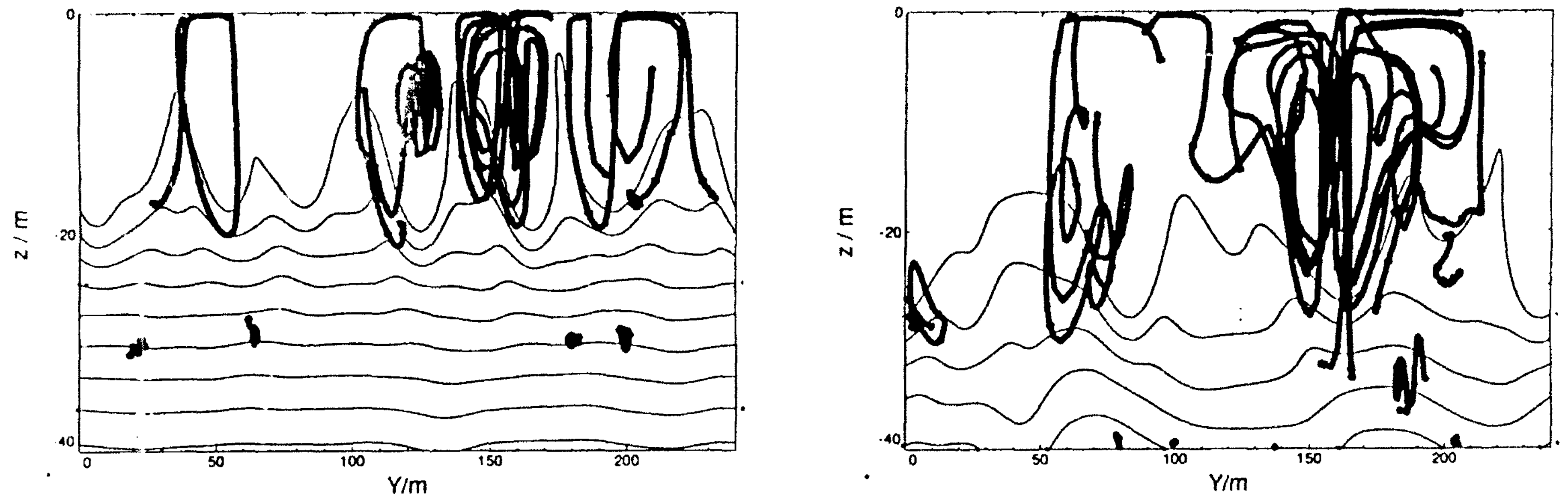


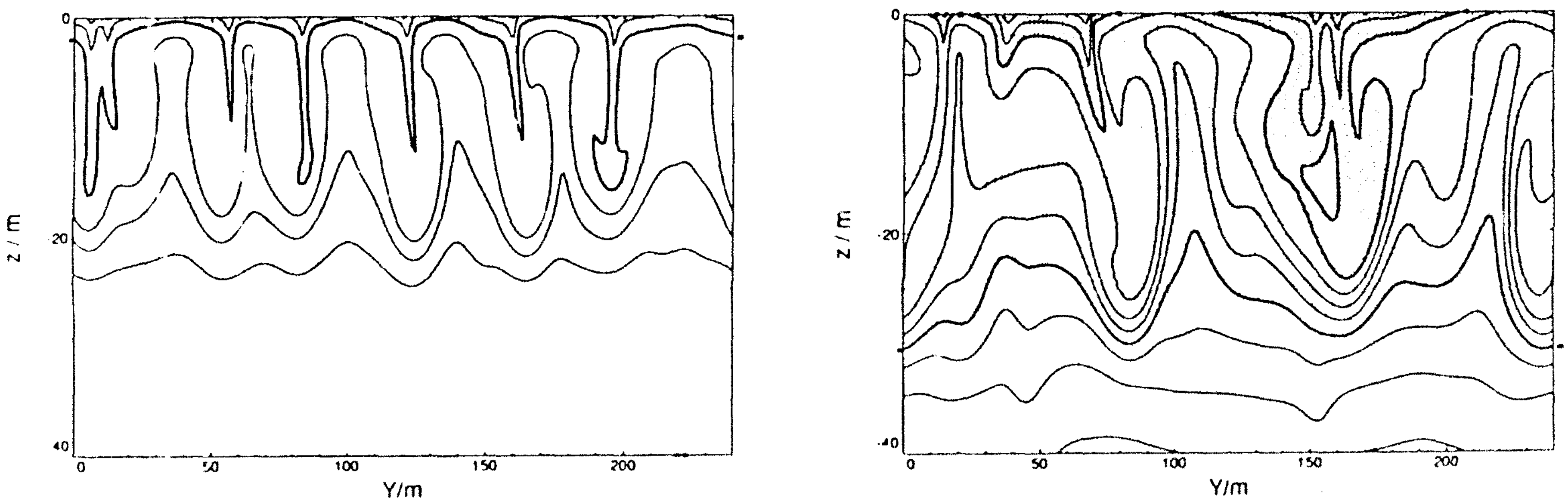
Figure 1. Summary of 1991 data. Top panel shows the wind stress. Bottom panel shows the stratification and float trajectories. Large symbols in bottom panel show the mixed layer depth while small symbols show the depth of a density 0.1 σ_t heavier. The light and heavy shaded regions are smoothed versions of these depths. During the two storms, the floats repeatedly transit the mixed layer penetrating into the mixed layer base.

2 hours FLOAT TRAJECTORIES and TEMPERATURE 1000s ticks 6 hours



DOWNWIND VELOCITY c.i.=0.05m/s

2 hours 6 hours



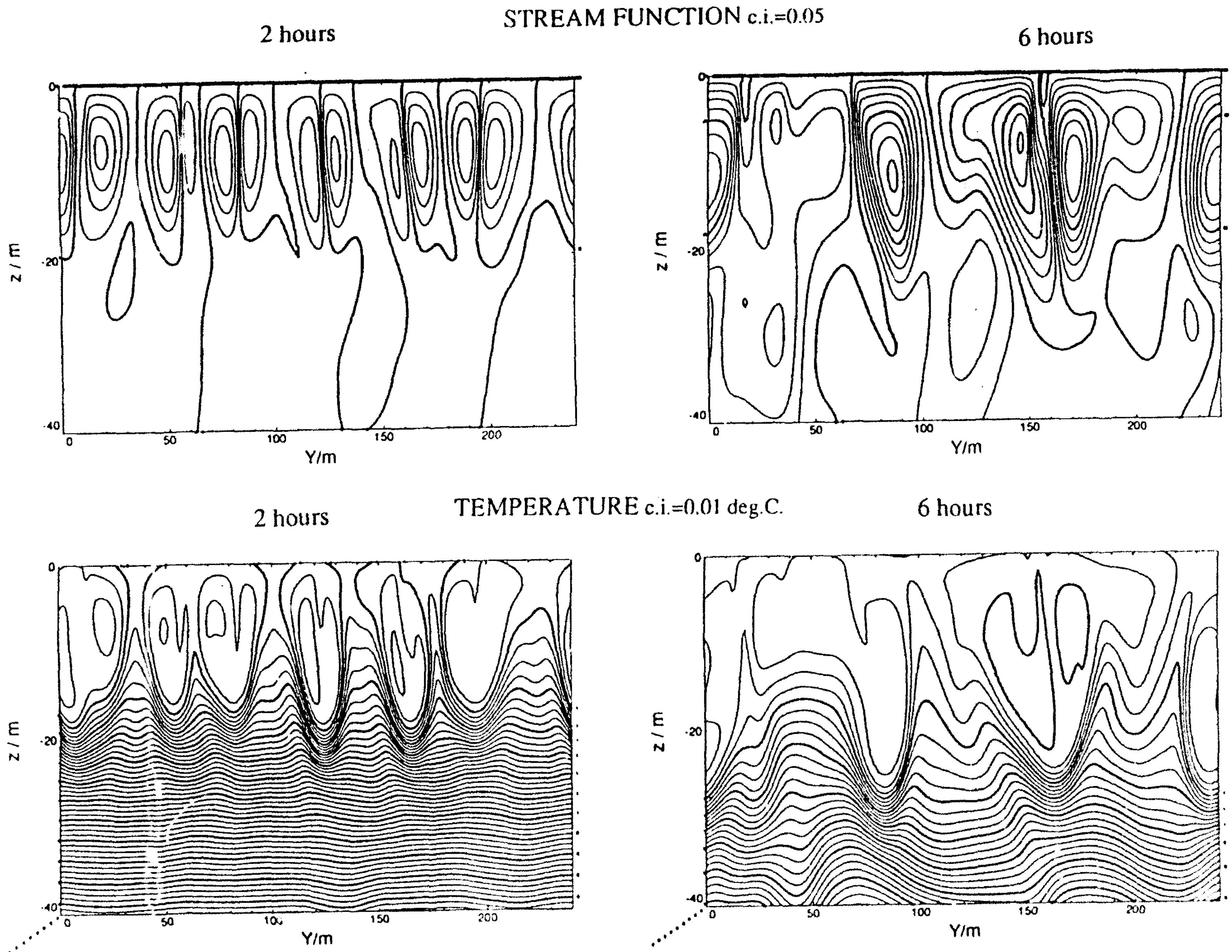


Figure 2. Simulation of mixed layer circulations during the November 24 storm using a two-dimensional model following Liebovich (1977). Panels show the streamfunction, temperature, downwind velocity and simulated float trajectories at 2 and 6 hours. The panels at 6 hours are at roughly the same time as the float data in Figure 8 and the image in Figure 2b.