For the purpose of numerical calculations, equations (8) and (10) are transformed into finite difference equations using the implicit Crank-Nicholson scheme [*Richtmyer and Morton*, 1967]. The vertical grid spacing is optimized to obtain high vertical resolution of the parameters near the water surface. The distance between computational grid points increases with depth according to a geometrical progression. The interval is 0.04 m at the surface and there were 300 levels down to a depth of 740 m. The time step is 15 min.

Experimental Data

The model described above was run using time series data obtained with multivariable moored systems (*Dickey et al.*, 1991, 1993). The measurements were carried out from April 13 through June 12, 1989, in the North Atlantic (59°29'N, 20°50'W) as a part of the Marine Light in the Mixed Layer program. The full details of the methodologies and the description of the data are given by Dickey et al. (submitted manuscript, 1993).

Boundary conditions for the model, including wind stress, heat flux, and incoming solar insolation were obtained from the meteorological sensors on the surface mooring (see *Stramska and Dickey*, 1993 for details). Wind stress was obtained using bulk aerodynamic formula [*Large and Pond*, 1982; *Geernaert*, 1990]. The heat flux was taken as a sum of the heat loss leaving directly from the water surface and the solar radiation absorbed within the water column. The heat loss is the sum of the latent, sensible and longwave radiative heat fluxes, which were estimated using standard bulk formulas [*Large and Pond*, 1982; *Geernaert*, 1990] and a net longwave radiation formula [*Bunker*, 1976]. The model was initiated using temperature and chlorophyll profiles constructed from the mooring data taken at the beginning of the experiment (day 103).

Results

Estimates of Primary Production

Estimates of carbon production obtained with the Kiefer-Mitchell model using four different parameterizations of light received by the cells (equations (3), (5), (6), and (7)) are given in Figure 1. Note that all these estimates fell within the range of values observed in the region at that time of the year [*Williams*, 1975; *Martin et al.* 1993; *Weeks et al.* 1993). However, the estimate based on the parametrization of E_o taken as an average PAR for the mixed layer (equation (6)) displays a clearly different pattern in vertical distribution than the other three estimates.

The column-integrated estimates of the production for the top 200 m of the ocean are shown in Figure 2. The estimates involving parametrizations by equations (3) and (5) gave very similar results, which suggests that the influence of turbulence on the light energy captured by cells had only a minor effect on the integrated production. While a significantly higher productivity estimate resulted from applying the daily integral of light (equation (7)), the lower estimate was obtained when the light was averaged over the MLD (equation (6)).

It is important to emphasize that our calculations cannot be used as a general quantification of the differences between various estimates of primary productivity. This is because the final results depend also on the vertical distribution of Chl a in the water column. Figures 1 and 2 only serve as examples,

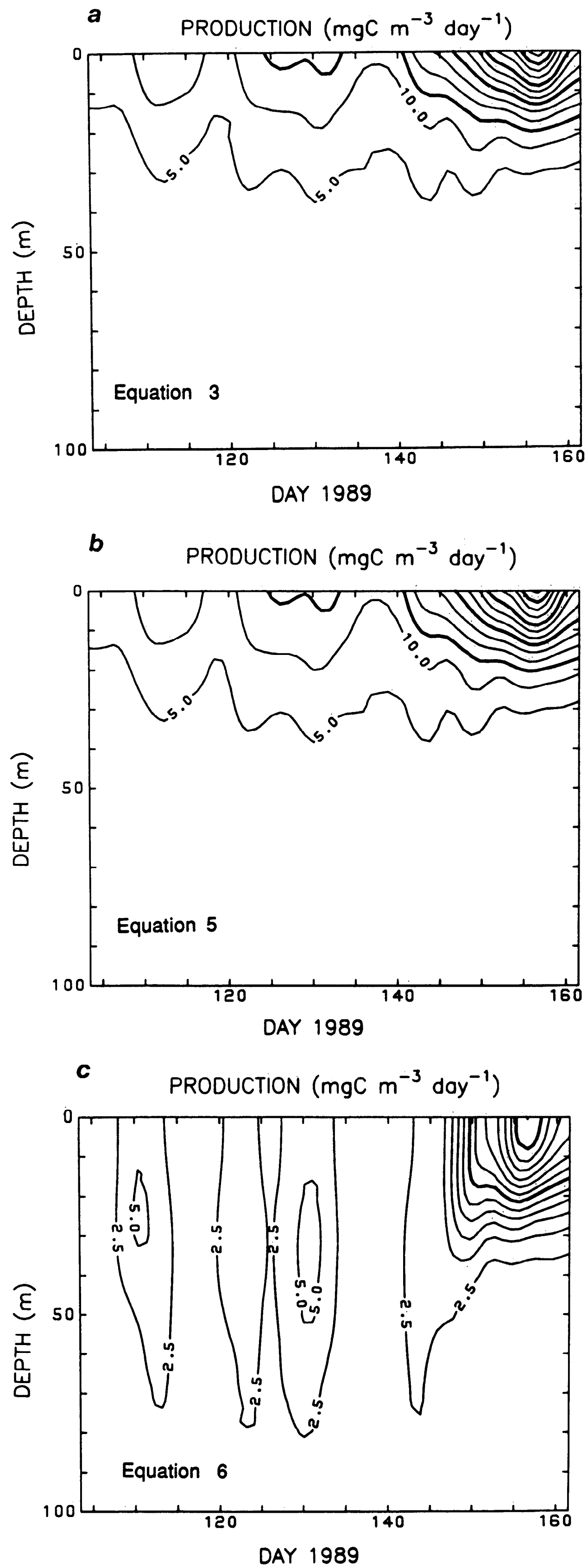

Figure 1. Contours of gross primary production estimated using Kiefer-Mitchel model [*Kiefer and Mitchel*, 1983], Marine Light in the Mixed Layer mooring data, and equations (3), (5), (6), and (7) to parametrize E_0. See explanations in the text.