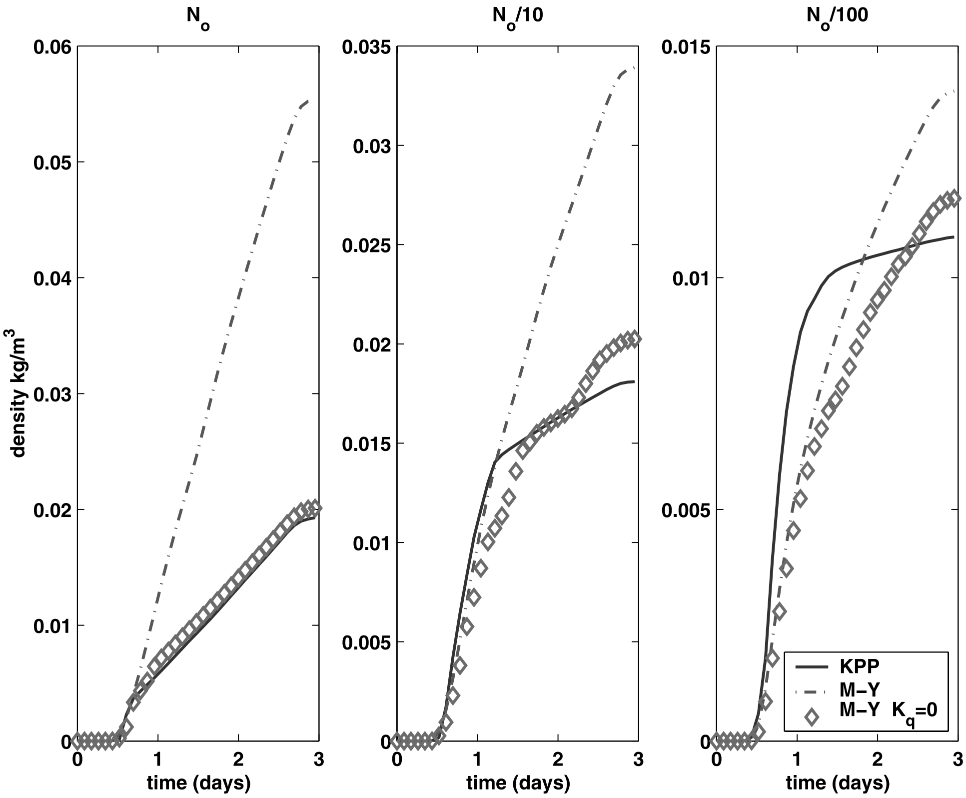

Figure 9. Time series of change in surface density with three different initial stratifications for simulations with the two mixing schemes and for the M-Y scheme with the vertical diffusion of turbulent kinetic energy and length scale excluded.

[56] Of course, stratification is not the only factor which determines which scheme entrains more even in simulations as idealized as these. If the same integrated wind stress is applied as a strong pulse lasting one-third the duration of the "steady" forcing examined above, the results differ. Figure 11 shows time series of surface density for simulations with stratifications of N_o, $N_o/10$ and $N_o/100$. While for the strongly stratified pycnocline M-Y still entrains more, for both $N_0/10$ and $N_o/100$ the reverse is true. The stronger wind stress in these simulations promotes stronger shear at the base of the surface boundary layer. The strong response of the shear mixing formulation of KPP exploits this more effectively for weaker stratification. The initial boundary layer deepening phase lasts for the duration of the wind event and KPP entrains more.

[57] The differences between the results given by these two vertical mixing parameterization in reality come from both algorithmic and numerical sources. The above section discussed in detail how differences in the formulation of the two schemes led to different results in the simulations. Here we briefly mention how the parameterizations are sensitive to some aspects of the numerics. In particular sensitivity to vertical resolution is examined.

[58] The $N_o/10$ experiment discussed in detail above, with a grid resolution of 0.5 m, was repeated at grid resolutions ranging from 0.25 m to 4 m. In Figure 12 the percent relative error in the surface density as a function of time and grid resolution is plotted. Error is measured relative to the 0.5 m vertical resolution base case. The K profile parameterization shows a much greater sensitivity to resolution than M-Y does. At low-resolution entrainment over the three day simulation can be reduced by as much as 40%. At very high resolution it is enhanced by 15 to 20%. The Mellor-Yamada parameterization, on the other hand, shows generally less than a 5 percent reduction in entrainment at both higher and lower resolutions.

[59] The significant decrease in entrainment at lower resolution with KPP can again be related to the gradient Richardson number mixing parameterization. Because of the finite resolution, shears and vertical gradients in the density field are not necessarily resolved. If the natural system tends to a state where shears and density vary sharply over a 2 m thick region at the base of the boundary layer, a simulation with only 4 m resolution will underestimate both the buoyancy and shear. Since the shear term is squared in the Richardson number calculation the underestimate in the denominator of Ri_g tends to be greater than the underestimate in the numerator. This results in a bias toward overestimating Ri_g as grid resolution decreases.

[60] Increasing the vertical resolution does alleviate this problem, but small grid spacing may also introduce a problem with KPP. The shear mixing scheme responds to low values of Ri_g with instantaneously strong mixing (on the order of 0.005 $m^2\ s^{-1}$) regardless of the vertical length scale over which the low Richardson number exists. This can result in very strong fluxes of density and momentum just above the pycnocline. At high resolution, this produces intermittent increases in the Richardson number within small portions near the base of the boundary layer which were previously well mixed. This process results in rapid