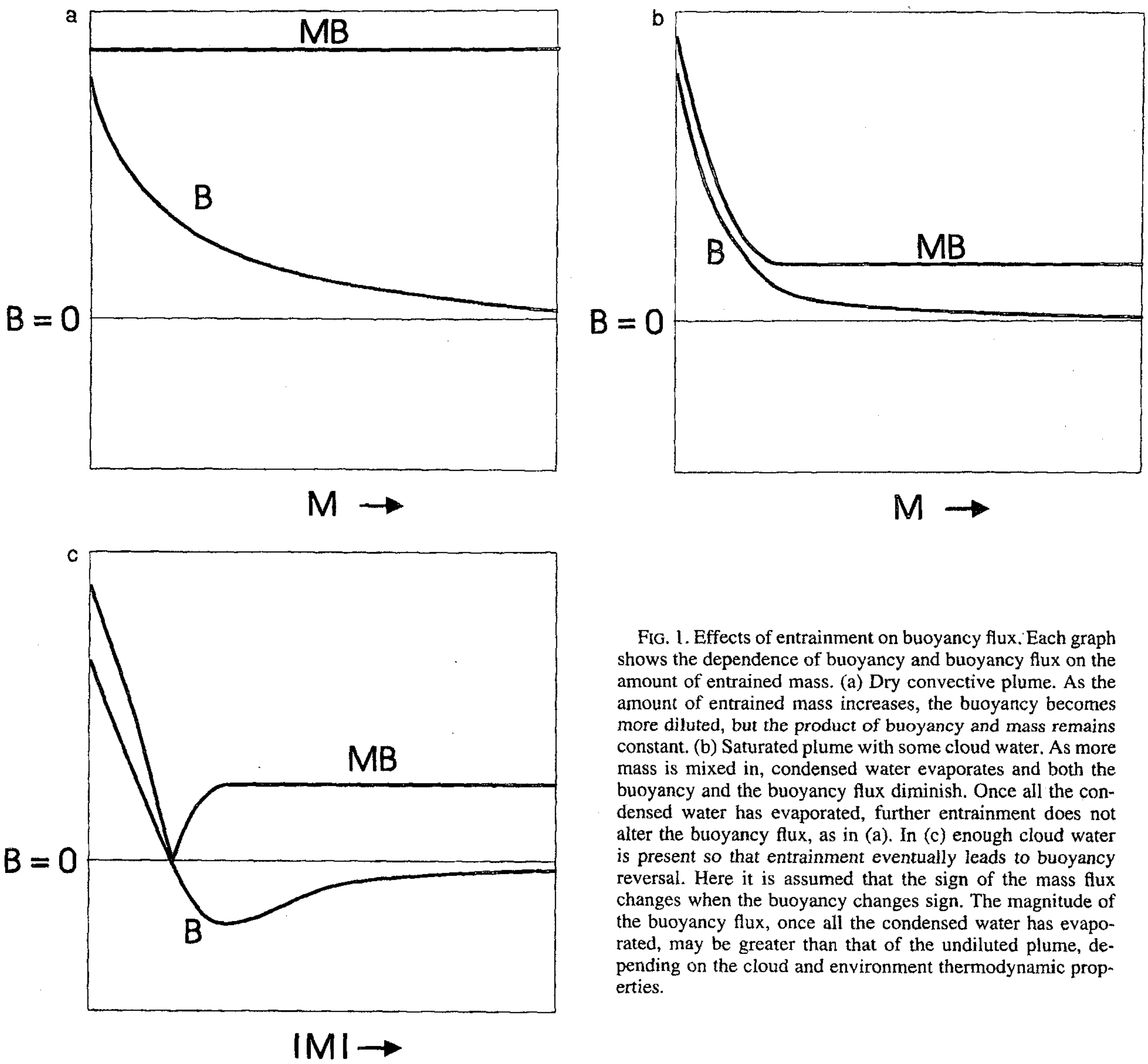

FIG. 1. Effects of entrainment on buoyancy flux. Each graph shows the dependence of buoyancy and buoyancy flux on the amount of entrained mass. (a) Dry convective plume. As the amount of entrained mass increases, the buoyancy becomes more diluted, but the product of buoyancy and mass remains constant. (b) Saturated plume with some cloud water. As more mass is mixed in, condensed water evaporates and both the buoyancy and the buoyancy flux diminish. Once all the condensed water has evaporated, further entrainment does not alter the buoyancy flux, as in (a). In (c) enough cloud water is present so that entrainment eventually leads to buoyancy reversal. Here it is assumed that the sign of the mass flux changes when the buoyancy changes sign. The magnitude of the buoyancy flux, once all the condensed water has evaporated, may be greater than that of the undiluted plume, depending on the cloud and environment thermodynamic properties.

flux. Unless substantial cloud water has been lost by precipitation, the buoyancy can actually change sign (Fig. 1c). If the buoyancy does change sign, its minimum value is reached when just enough environmental air has been entrained to evaporate all of the condensed water (e.g., see Emanuel 1994). Further entrainment diminishes the magnitude of the negative buoyancy but, as before, does not further alter the buoyancy flux.

On this basis, we make a few qualitative deductions about the relationship between the buoyancy flux in actual clouds and the buoyancy flux of undilute air. First, in situations in which much of the condensed water precipitates, entrainment will diminish the buoyancy flux but may not lead to actual buoyancy reversal or, if it does, to small buoyancy reversal. In this case, we may expect that $\Sigma_i M_i B_i < M_u B_u$. In circumstances in which little water precipitates, buoyancy reversal may happen more commonly and penetrative downdrafts may form. As the mass flux in these downdrafts is also negative, it is possible that $\Sigma_i M_i B_i > M_u B_u$ in this case.

Let us take, as a particular case, an example in which $\Sigma_i M_i B_i = M_u B_u$. Then (18) may be written

$$\int_{\mathrm{cl}} M_u B_u = M_u \int_{\mathrm{cl}} B_u dz = M_u(\mathrm{CAPE})$$

$$\approx \bar{Q}_A \bar{T}_{\mathrm{irr}} \left(\frac{1}{T_s} - \frac{1}{\bar{T}} \right), \quad (21)$$

where CAPE is the convective available potential energy. The undilute mass flux, M_u, is not a function of