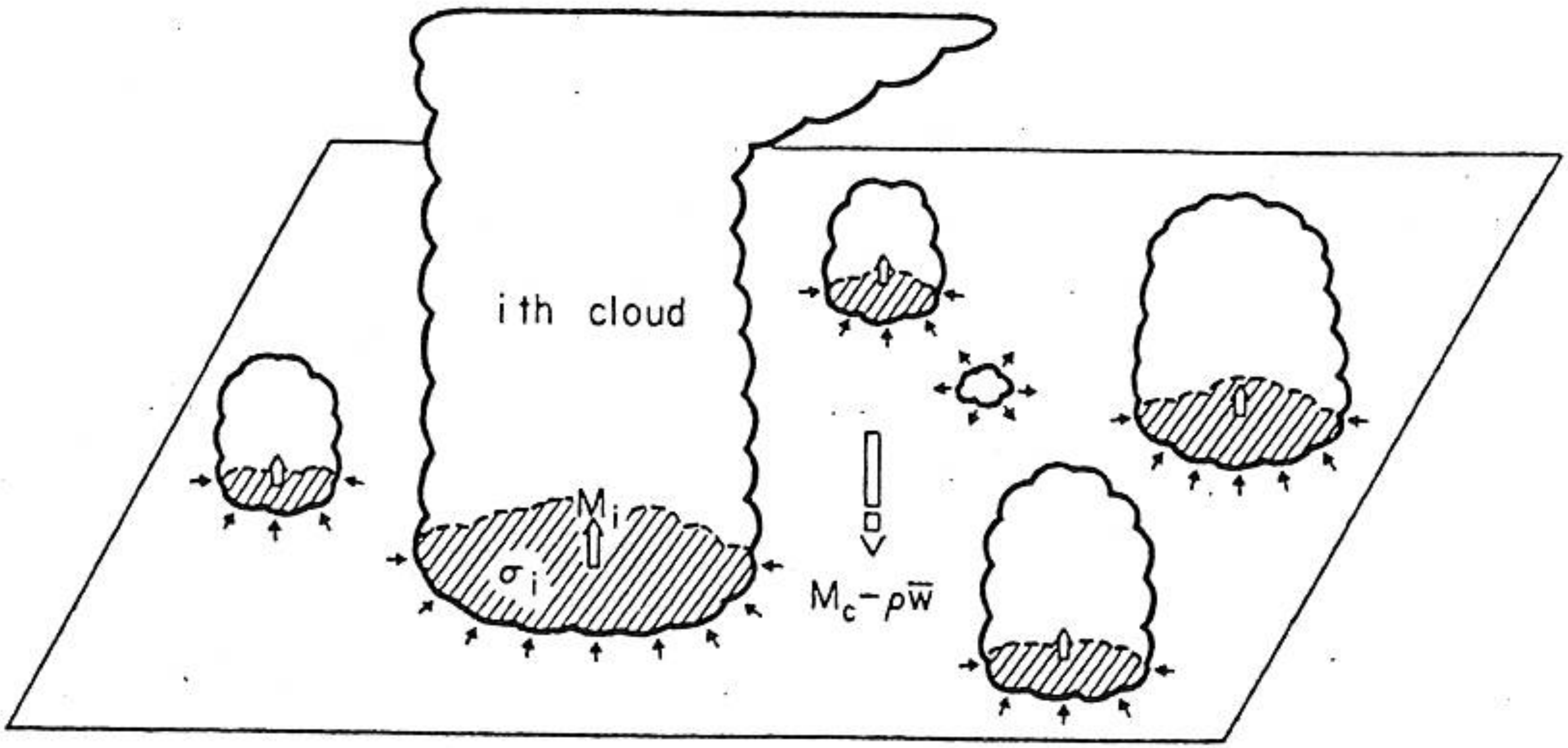



FIG. 1. A unit horizontal area at some level between cloud base and the highest cloud top. The taller clouds are shown penetrating this level and entraining environmental air. A cloud which has lost buoyancy is shown detraining cloud air into the environment.

Dry static energy: $s \equiv c_p T + gz$.

For adiabatic processes, $Ds / Dt \cong 0$.

Moist static energy: $h \equiv s + Lq = c_p T + gz + Lq$.

For moist adiabatic processes, $Dh / Dt \cong 0$.

Saturation moist static energy: $h^* \equiv c_p T + gz + Lq^*$,

where $q^*(T, p)$ is the saturation mixing ratio.

When air is saturated and remains so, $Dh^* / Dt \cong 0$.

It can be shown that $\dfrac{\partial h^*}{\partial z} \leq 0$ as $\Gamma \geq \Gamma_m$ and vice versa.

where the moist static energy $h$ is defined by

$$h \equiv s + Lq \equiv c_p T + gz + Lq. \tag{53}$$

The moist static energy is approximately conserved by an individual air parcel during moist adiabatic processes.

We assume that the air is saturated in the clouds. Then $q_i = q^*(T_i, p_i)$, where the asterisk denotes the saturation value. If the effect on $q^*$ of a pressure difference between the cloud and the environment is neglected,[3] then

$$\begin{aligned} q_i &\approx q^*(T_i, \bar{p}), \\ &\approx \bar{q}^* + \frac{1}{c_p}\left(\frac{\partial \bar{q}^*}{\partial \bar{T}}\right)_{\bar{p}} (s_i - \bar{s}). \end{aligned} \tag{54}$$

Here $\bar{q}^* \equiv q^*(\bar{T}, \bar{p})$, and

$$s_i - \bar{s} \approx \frac{1}{1+\gamma}(h_i - \bar{h}^*), \tag{55}$$

$$q_i - \overline{q^*} \approx \frac{\gamma}{1+\gamma}\frac{1}{L}(h_i - \bar{h}^*), \tag{56}$$

where

$$\gamma \equiv \frac{L}{c_p}\left(\frac{\partial \bar{q}^*}{\partial \bar{T}}\right)_{\bar{p}}. \tag{57}$$

The symbol $\bar{h}^* \equiv \bar{s} + L\bar{q}^*$ is the saturation value of moist static energy of the environment; $\partial \overline{h^*}/\partial z \gtreqless 0$ defines, respectively, the moist adiabatically stable, neutral, and unstable lapse rates of the environment.

$$q_i \approx \bar{q}^* + \frac{\gamma}{L}(s_i - \bar{s})$$

$$\boxed{s_i - \bar{s} = (q_i - \bar{q}^*)\frac{L}{\gamma}}$$

$$h_i = s_i + Lq_i + gz$$

$$\bar{h}^* = \bar{s}_{\cancel{i}} + L\bar{q}^* + gz$$

$$h_i - \bar{h}^* = L(q_i - \bar{q}^*) + s_i - \bar{s}$$

or $\boxed{L(q_i - \bar{q}^*)} = h_i - \bar{h}^* - (s_i - \bar{s})$

so

$$s_i - \bar{s} = \frac{h_i - \bar{h}^* - (s_i - \bar{s})}{\gamma}$$

or $\boxed{s_i - \bar{s} = \dfrac{h_i - \bar{h}^*}{1+\gamma}}$

To include evaporation of detrained liquid water, need eq. for $l_c$:

$$0 = -\frac{\partial}{\partial z}(M_c l) + C - R \qquad \text{(entrainment)}$$

$$0 = -D\hat{l} - \frac{\partial}{\partial z}(M_c l) + C - R \qquad \text{(detrainment)}$$

R: rate of conversion to rain per unit height.

---

Skip CISK.

---

Spectral representation of the cumulus ensemble.

Cu effects depend on:

(1) $M_c(z)$
(2) $D(z)$
(3) $\hat{l}(z)$

Detrainment at different levels is due to different types of clouds. To find $D(z)$, we must find the distrib. of mass flux of clouds which detrain (i.e., lose buoyancy) at different levels. Assume a single parameter, $\lambda$, can characterize a cloud type. Choose the fractional rate of entrainment as $\lambda$.

---

$$M_c(z) = \int_0^{\lambda_{max}} M_B(\lambda)\, \eta(z,\lambda)\, d\lambda$$

↑ Need this.

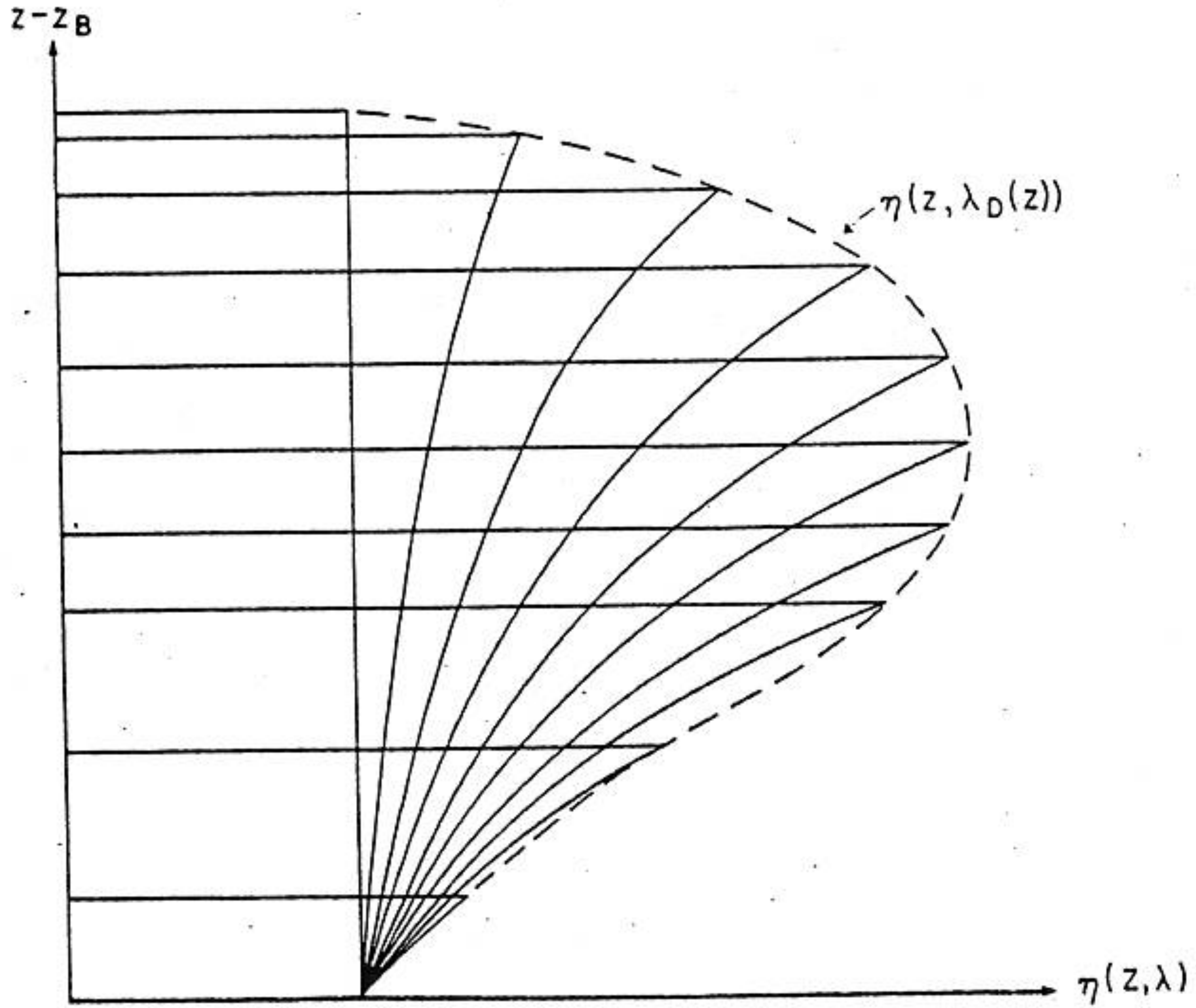



FIG. 5. Schematic profiles of the normalized mass flux $\eta(z,\lambda)$ for various $\lambda$. The envelope of these curves is $\eta[z,\lambda_D(z)]$.

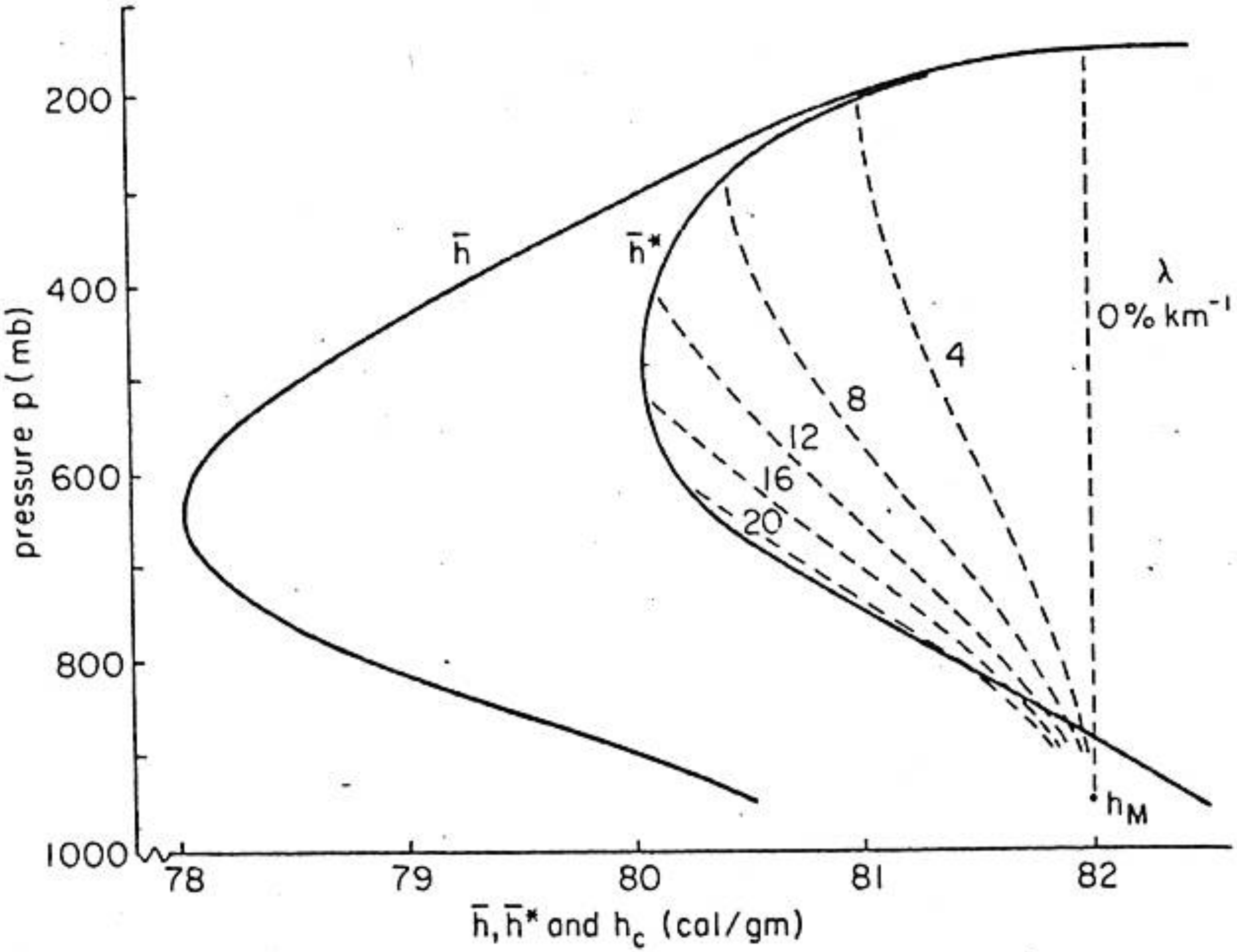
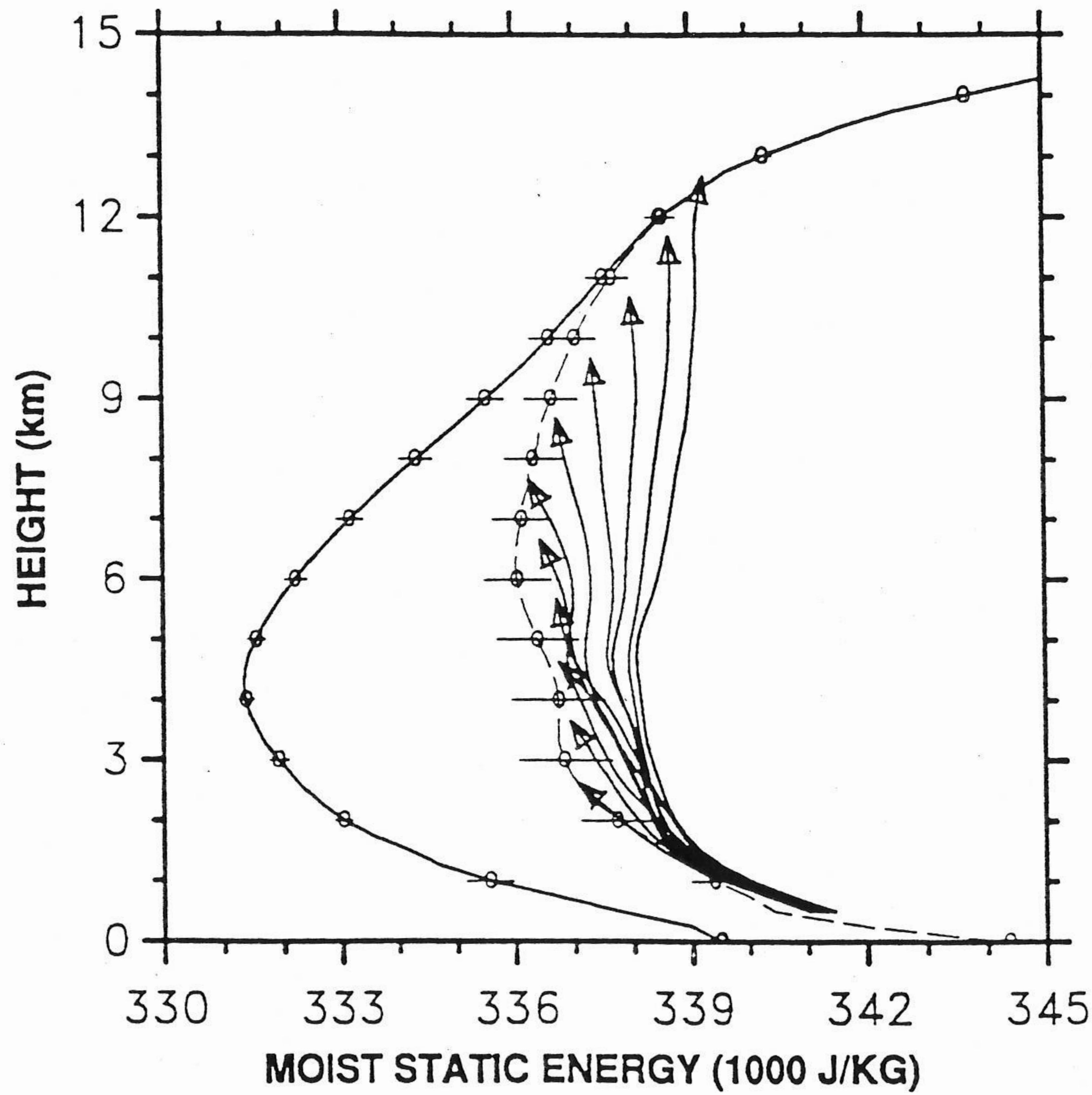



FIG. 6. Vertical profiles of $\bar{h}(p)$, $\bar{h}^*(p)$ and $h_c(p,\lambda)$; $h_c(p,\lambda)$ lines are dashed and labeled with the value of $\lambda$ in percent per kilometer. Profiles of $\bar{h}$ and $\bar{h}^*$ were obtained from Jordan's (1958) "mean hurricane season" sounding. The top $p_B$ of the mixed layer is assumed to be 950 mb; $h_M$ is assumed to be 82 cal gm$^{-1}$.

EXP A10      09:00-28:00



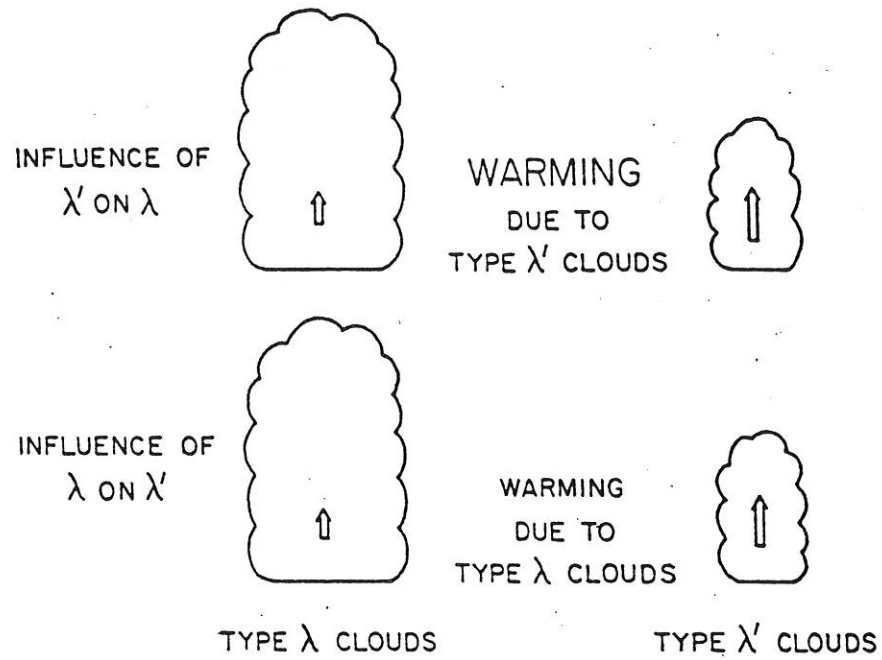



FIG. 11. A schematic diagram of the mutual influence of a sub-ensemble pair through the first part of the vertical mass flux kernel. The arrows inside the clouds show the normalized vertical mass fluxes $\eta(z,\lambda)$ and $\eta(z,\lambda')$; $\eta(z,\lambda')>\eta(z,\lambda)$ because $\lambda'>\lambda$. In the upper part of the figure, the warming of the environment due to type $\lambda'$ clouds is shown, and in the lower part of the figure, the warming of the environment due to type $\lambda$ clouds is shown. Note that (warming due to type $\lambda$ clouds)$\times\eta(z,\lambda')$ = (warming due to type $\lambda'$ clouds)$\times\eta(z,\lambda)$ holds for $z_B<z<z_D(\lambda')$, which is the entire depth of the mutual influence.

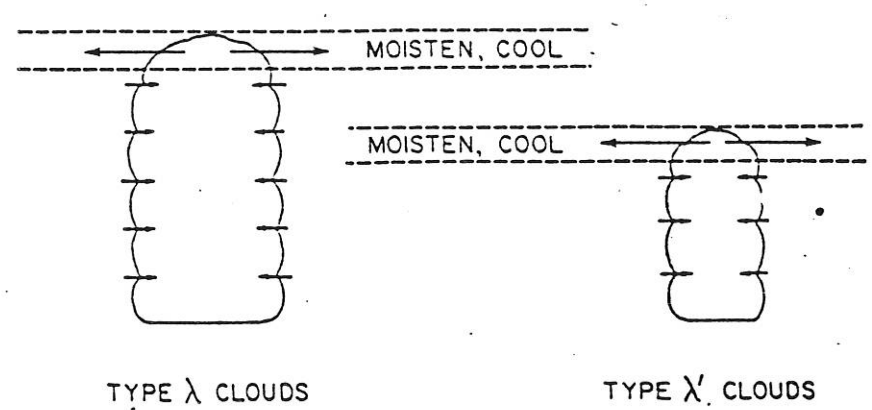



FIG. 12. A schematic diagram of the influence of type $\lambda'$ clouds on type $\lambda$ clouds through the detrainment process. The detraining air is saturated and contains liquid water. The detrainment moistens and evaporatively cools the environment. Type $\lambda$ clouds have no influence on type $\lambda'$ clouds but type $\lambda'$ clouds have a co-operative influence on type $\lambda$ clouds.