7.4 Microburst downdrafts

Downdraft CAPE is the negative buoyancy integrated from cloud base pressure ($p_{\rm CB}$) to the surface pressure ($p_{\rm sfc}$):

$$\text{DCAPE} \equiv -\int_{p_{\rm CB}}^{p_{\rm sfc}} R(T-\overline{T})\, d\log p,$$

where T is the parcel temperature and $\overline{T}$ is the environment temperature. The parcel is assumed to have $T=\overline{T}$ and $T_d=\overline{T_d}$ at $p=p_{\rm CB}$.

Just below cloud base, the environment is slightly subsaturated. Rain that falls into this air evaporates and cools the air to its wet-bulb temperature. Due to the negative buoyancy, the parcel accelerates downward:

$$\frac{dw}{dt} = g\frac{T-\overline{T}}{\overline{T}} < 0.$$

Assume that as the parcel descends, evaporation of rain keeps it saturated, so that it remains on the saturation adiabat.

In"dry" microburst conditions, the rain totally evaporates a short distance below cloud base. Assume that the parcel remains saturated to this level, then continues to descend (if $w<0$) dry adiabatically below this level (the Sinking Evaporation Level, or SEL).

Let $\overline{T}(z)$ and $\overline{T_d}(z)$ be typical of a well-mixed boundary layer characterized by constant $\overline{\theta}$ and constant environment mixing ratio from $p=p_{\rm sfc}$ to $p=p_{\rm CB}=p_{\rm LCL}$, where LCL denotes the Lifting Condensation Level. DCAPE for such a sounding is shown by the shaded area in Figure 10.

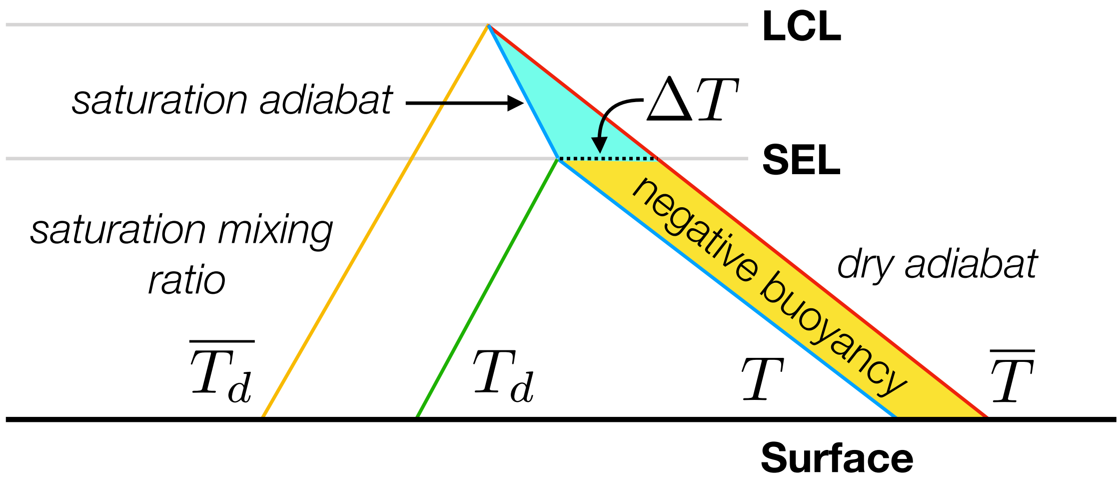

Figure 10: DCAPE (shaded area) for a dry microburst sounding on a skeleton skew-T log p diagram.

We can easily calculate DCAPE for the dry microburst sounding shown in Figure 10:

$$\begin{aligned}
\text{DCAPE} &= \text{DCAPE}_{\text{upper}} + \text{DCAPE}_{\text{lower}} \\
&= -\int_{p_{\text{LCL}}}^{p_{\text{SEL}}} R(T - \overline{T})\, d\log p - \int_{p_{\text{SEL}}}^{p_{\text{sfc}}} R(T - \overline{T})\, d\log p \\
&= -\frac{R\Delta T}{2} \log\left(\frac{p_{\text{SEL}}}{p_{\text{LCL}}}\right) - R\Delta T \log\left(\frac{p_{\text{sfc}}}{p_{\text{SEL}}}\right)
\end{aligned}$$

where

$$\Delta T \equiv (T - \overline{T})_{\text{SEL}}$$

and we used

$$\log x - \log y = \log\left(\frac{x}{y}\right).$$

The maximum downdraft speed achieved is

$$(w_{\text{down}})_{\text{max}} = \sqrt{2 \times \text{DCAPE}}$$

which occurs just above the surface. The maximum horizontal outflow speed $\approx (w_{\text{down}})_{\max}$.

With an environment lapse rate $< \Gamma_d$, negative buoyancy may not exist all the way from cloud base to the surface.

If the rainfall rate is large enough, $dw/dt < 0$ may occur due to the drag force of the rain drops, despite positive buoyancy ($T - \overline{T} > 0$).