Parcel Model

- Goal is to predict how the properties of a parcel change due to various processes.
- The processes include dry adiabatic vertical displacements, condensation/evaporation, precipitation formation, entrainment and mixing, and radiative heating/cooling.
- Buoyancy and vertical acceleration can be calculated if the environmental profile of virtual potential temperature is known.

Parcel Model

$\begin{align*}
\text{State 1} & : p_1, \theta_1, w_1 \\
\text{State 2} & : p_2, \theta_2, w_2 \\
\text{thermodynamic process} & \\
\text{dry adiabatic vertical displacement} & + \\
\text{other physical processes} & 
\end{align*}$
Parcel Model

\[
\begin{align*}
p_2 &= p_1 + dp \\
\theta_2 &= \theta_1 \\
w_2 &= w_1
\end{align*}
\]

dry adiabatic vertical displacement

Parcel Model: Buoyancy

\[
\begin{align*}
p_2 &= p_1 + dp \\
\theta_2 &= \theta_1 + d\theta \\
w_2 &= w_1 + dw
\end{align*}
\]

dry adiabatic vertical displacement + other physical processes

Parcel Model

\[
\begin{align*}
p_2 &= p_1 + dp \\
\theta_2 &= \theta_1 + d\theta \\
w_2 &= w_1 + dw
\end{align*}
\]
isobaric processes

Parcel Model: Buoyancy

\[
\begin{align*}
p_2, \bar{p}_2, w_2 & \quad \text{(environment)} \\
p_1, \bar{p}_1, w_1 & \quad \text{(environment)}
\end{align*}
\]

\[
\begin{align*}
W &= \frac{dz}{dt} \quad \text{(vertical velocity)} \\
\frac{dW}{dt} &= -\frac{1}{\rho} \frac{\partial (p - \bar{p})}{\partial z} + g \frac{\theta - \bar{\theta}}{\theta_v} \quad \text{(vertical p.g.f.) (buoyancy)}
\end{align*}
\]
\[ \begin{align*}
\frac{d\theta}{dt} &= \frac{L}{c_p \bar{\pi}} (C - E_r) + D_\theta \\
\frac{dw}{dt} &= -(C - E_r) + D_w \\
\frac{dl}{dt} &= C - A_r + D_l \\
\frac{dr}{dt} &= P_r + A_r - E_r + D_r
\end{align*} \]

\[ \begin{align*}
\bar{\pi} &= (\bar{p}/p_0)^{R/c_p}, \ C \text{ is the net condensation rate, } E_r \text{ is the rain evaporation rate, } A_r \text{ is the cloud-to-rain water conversion rate, } P_r \text{ is the convergence of rain water flux, and } D_l \text{ represents the effects of entrainment and mixing.} \]

**Microphysics**

- Water vapor
- Condensation
- Evaporation
- Cloud droplets
- Rain drops
- Condensation collection
- Evaporation
- Fall out (precipitation)

**Simplified Microphysics**

- Water vapor
- Condensation
- Evaporation
- Cloud droplets
- Rain drops
- Condensation collection
- Evaporation
- Fall out (precipitation)

\[ \begin{align*}
\text{Condensation} &= 0 \quad \text{(reversible)} \\
\text{Evaporation} &= \infty \quad \text{(irreversible)}
\end{align*} \]
Simplified Microphysics

\[
\frac{d\theta}{dt} = \frac{L}{c_p \bar{\pi}} C
\]
\[
\frac{dw}{dt} = -C + E_r
\]
\[
\frac{dl}{dt} = C - A_r
\]
\[
\frac{dr}{dt} = P_r + A_r - E_r
\]

\[
P_r = 0 \text{ (reversible)}
\]

\[
P_r = \infty \text{ (irreversible)}
\]

More Simplified Microphysics

\[
\frac{d\theta}{dt} = \frac{L}{c_p \bar{\pi}} C
\]
\[
\frac{dw}{dt} = -C
\]
\[
\frac{dl}{dt} = C - A_r
\]

\[
A_r = 0 \text{ (reversible)}
\]

\[
A_r = \infty \text{ (irreversible)}
\]

Parcel Model