Thermodynamic Applications

Outline:
• classical stability analysis, using recent soundings
• Bjerknes “slice” approach
• conserved variable diagrams
Skew T - log-p diagram. Miami, 7 am local, Tuesday
Surface parcel properties matter. Denver, 6 am LT & 6 pm
Miami eve, CAPE=942 J/kg

AM CAPE=235 J/kg
Oklahoma City

Cape = 1495 J/kg
The Dependence of Numerically Simulated Convective Storms on Vertical Wind Shear and Buoyancy

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ABSTRACT

The effects of vertical wind shear and buoyancy on convective storm structure and evolution are investigated with the use of a three-dimensional numerical cloud model. By varying the magnitude of buoyant energy and one-directional vertical shear over a wide range of environmental conditions associated with severe storms, the model is able to produce a spectrum of storm types qualitatively similar to those observed in nature. These include short-lived single cells, certain types of multicells and rotating supercells. The relationship between wind shear and buoyancy is expressed in terms of a nondimensional convective parameter which delineates various regimes of storm structure and, in particular, suggests optimal conditions for the development of supercell type storms. Applications of this parameter to well-documented severe storm cases agree favorably with the model results, suggesting both the value of the model in studying these modes of convection as well as the value of this representation in identifying the proper environment for the development of various storm types.

- defines CAPE
- Belief that storms are particularly sensitive to parcel buoyancy and wind shear
Parcel method does not account for reaction of Environmental air to the intrusion of a cloud(s).


Helps explain the spacing in between clouds

APE = energy available for conversion into kinetic Energy (sum of potential, internal, and latent energies).

Assumes a closed system.

APE turns out to be
True enthalphy = enthalpy of a reference state

Reference state is one with no conditional instability;
All boundary layer air brought to its LNB
Actual state vs. reference state

Lorenz
Successes of the parcel method:

• provides insight into conditions necessary for convection, or lack thereof

• helps explain some general features of the atmosphere (inter-cloud spacing; general circulation)
Drawbacks of parcel method stability analysis:

- ice not represented well
- mixing not represented
- sondes don’t measure liquid
- environmental response not considered

Conserved variable diagrams examine mixing and air mass history.

Liquid is included

have mainly been applied to non-precipitating convection
Adiabatic quantities form each coordinate axis;

- Plotted data can only change values through irreversible or diabatic processes
- (linear) mixing shows up as a straight line

=> Useful for examining mixing processes in clouds

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The Entrainment Mechanism in Colorado Cumuli

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ABSTRACT

Cloud air and clear air properties are analyzed to determine the altitude from where the entrained air originates. This is done using two parameters that are conserved with adiabatic altitude changes and that mix in a nearly linear manner. The method employed is only applicable to cloud regions that do not contain significant amounts of ice or precipitation size drops. The analysis shows that most of the entrained air originates several kilometers above the observation level. The mixed regions are typically found in downdrafts and the weaker updraft regions. The present results are inconsistent with the laterally entraining plume model. The results indicate that mixing of dry environmental air with cloud air produces sufficient evaporative cooling to create downdrafts that penetrate several kilometers into the cloud. The updraft air is diluted primarily through mixing with nearby downdraft air.

JAS, 1979
“Paluch diagrams”: total water mixing ratio $r_t$ vs equivalent potential temperature

\[ r_t = \text{water vapor} + \text{liquid water m.r.} \]
Study concludes most cloud air has mixed with environmental air Several km above cloud top.

Common in cumuli developing in dry environments (downdrafts develop sufficient neg. buoyancy)
Similarly for stratocumulus breakup:

“jump” criterion in both $\theta_e$ and m.r.

Randall, 1980 & Deardorff, 1980
Took Paluch’s analysis one step further: A *Saturation Point* is defined for each data
Cloud water is a parcel property

⇒ Liquid water potential temperature $\Theta_{ll} = \theta \exp(-Lll/c_p T)$

The lowest $\theta$ attainable through evaporating all water

Saturation point: LCL if unsaturated
    “sinking evaporation level” if saturated

Air parcel specified solely by its $T_{sl}$, $p_{sl}$, and $p_{sl} - p$

Allows for a treatment of negatively buoyant parcels
Particularly elegant analysis of the impact of Cooling through evaporation of rain, and liquid Water loading of an air parcel

(Evaporation both cools and moistens; whether a Mixture becomes positively or negatively buoyant Depends on \( \theta_i \))
If upper air is dry enough, becomes strongly cooled by Evaporation => downdraft.