A Maximum Vertical Velocity Comparison for Idealized Parcel CAPE from ARM RWP and Sonde at SGP

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Abstract

Events with well-defined CAPE (Convective Available Potential Energy) values allow one to infer the maximum possible vertical wind speed for an ideal air parcel under specific conditions. Monitoring of CAPE occurs at reasonable resolution from the ARM SGPSonde data and the near real time ARIE/GOES data. These data allow for comparisons of CAPE values for any given event when the data sets are sufficiently robust and consistent with SMOS (Surface Meteorological Observation System) data. From these values it is possible to estimate the maximum possible vertical updraft or to index the relative severity of the resulting system. Since this type of index is not static, and is based upon a vertical integration, it contains more atmospheric information than a single static index for a fixed spatial location can contain. Operation of the RASS/RWP (Radar Wind Profiler) also has allowed for direct measurements of vertical wind speeds. When these are correlated with ideal CAPE readings a direct comparison of wind speeds is possible. Here we carry out a simple comparison of these speeds by statistically testing for a direct correlation and for any possible skewness in the comparison indicating a systematic error in analysis. We then search for a method for a better match by using a one-parameter regression and investigate the nature of the ideal conditions required for the comparison.

CAPE
Convective Available Potential Energy

$$E_p = \int \frac{\vec{F}}{m} \bullet d\vec{r}$$

$$E_p = \int_{z_o}^{z_f} \left(\frac{T_{parcel}(z) - T_{env}(z)}{T_{env}(z)} \right) dz \; \frac{J}{kg}$$

Specific Available Energy from Vertical Lifted Parcel

$$v_{\max} \approx \frac{1}{2}\sqrt{2E_p} \quad \frac{m}{s}$$

Maximum possible vertical velocity
From buoyant forces: all KE.

NII: Buoyancy of Ideal Parcel Dynamics of Vertical Lift

$$m\frac{dv_z}{dt} = (r_{env}\ Vg) - mg$$

$$\frac{dv_z}{dt} = g\frac{(r_{env}\ V) - m}{m} = g\frac{(r_{env} - r_{parcel})}{r_{parcel}}$$

by equation of state

$$\frac{dv_z}{dt} = g\frac{(T_{parcel}(z) - T_{env}(z))}{T_{env}(z)}$$

General Parcel Dynamic Equations of Motion

Definition of Parcel: A volume of air large enough to ignore ... macroscopic state variables as constants

$$NII: \frac{d\vec{v}}{dt} = -\frac{1}{r}\hat{\nabla}P - g\ldots$$

$$Th1\&2: \quad c_v \frac{dT}{dt} + p\frac{d\alpha}{dt} = \ldots + r\nabla \bullet v = 0$$

$$Eq.of\ State: F(r, P, \ldots) = 0$$

where

$$\frac{dv_i}{dt} = \frac{\partial v_i}{\partial t} + \frac{\partial v_i}{\partial x_1}\frac{dx_1}{dt} + \frac{\partial v_i}{\partial x_2}\frac{dx_2}{dt} + \frac{\partial v_i}{\partial x_3}\frac{dx_3}{dt}$$

$$F = p - rRT$$

tatistical Tests of Idealized Model

Data: 7-18-00 to 7-31-00, N=32 Sonde points

. Deviations should average to zero:

. Linear Correlation of V-CAPE to V-RWP: low and high

. Probability for Correlation, r:

. Chi Squared- test of distribution

. Probability for Chi Squared

$$1: a.d = \frac{\sum_{i=1}^{N}(v_i - \bar{v})}{N} \approx 0 \quad N = 32, \quad a.d. = 3.2\ m/s \quad compare \ \frac{a.d.}{\bar{v}} \approx 0.26$$

$$2: r_j = \frac{\sum (v_{iCAPE} - \bar{v}_{CAPE})(v_{iRWPhi\text{-}low} - \bar{v}_{RWP})}{\left[\sum (v_{iCAPE} - \bar{v}_{CAPE})^2 (v_{iRWPhi\text{-}low} - \bar{v}_{RWP})^2\right]^{1/2}}$$

$a) CAPE - RWPlow: r = 0.38$

$b) CAPE - RWPhi: r = 0.31$

$$3: P_N(|r| \geq |r_o|) = \frac{2\Gamma[(N-1)/2]}{\sqrt{p}\,\Gamma[(N-2)/2]}\int_{|r_o|}^{1}(1-r^2)^{(N-4)/4}dr$$

$N = 38 \quad r_o = 0.35$

$a) CAPE - RWPlow: P \approx 7.2\%$

$b) CAPE - RWPhi: P \approx 5.4\%$

$$4: \tilde{c}^2 = \frac{1}{d}\sum_{k=1}^{n}\frac{(O_k - E_k)}{E_k}$$

$a) CAPE - RWPlow: \tilde{c}^2 = 3.8$

$b) CAPE - RWPhi: \tilde{c}^2 = 4.7$

$$5: P_d(\tilde{c}^2 \geq \tilde{c}_o^2) = \frac{2}{2^{d/2}\Gamma(d/2)}\int_{\tilde{c}_o}^{\infty} x^{d-1}e^{-x^2/2}dx$$

$n = 38, d - degrees\ of\ freedom = n - c, c = 3: N, s_v, \bar{v}: d \approx n$

$\tilde{c}_o^2 = 0.973$

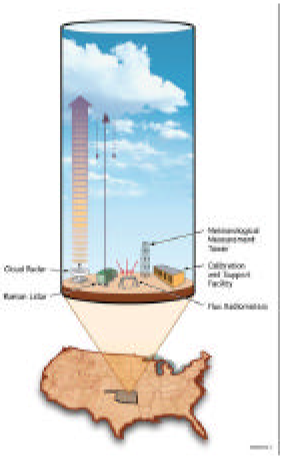
$a) P = 63\%$

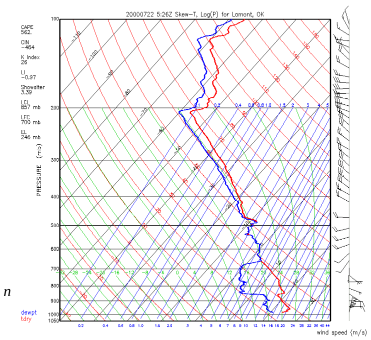
$b) P = 29\%$

Vertical Parcel Column Above SGP

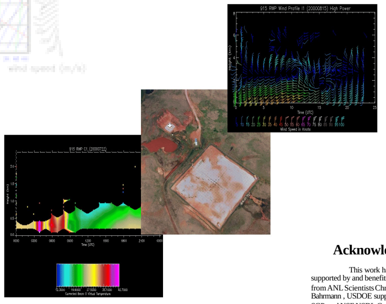
Parcel Theory Column

ANL: ARM Research





RWP Ariel Photo and sample data.



onclusions

. 1. Low Altitude and High Altitude RWP Values are equally correlated on all CAPE measurements, correlations are strongest for the high altitude RWP and relatively low CAPE values - no severe weather present.

2. CHI Square test suggests the deviations are Gaussian and a larger survey, N>80, would indicate if this is significant.

. 3. Dry parcel ideal CAPE theory is a weak indicator of maximum vertical velocity from RWP, corrections for moist adiabatic energy transfer must be made giving a leading order correction, in dimensionless terms, as high as 1.21 to kinetic energy in some cases.

. 4.Multi-platform cross-correlations support the general principles of the equations of motion but strong nonlinearities and potential chaotic behavior has not been investigated,in addition phase change effects which appear in the dynamical equations have been ignored.

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