Comparison of Observed Conditions with Stability Indices

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1. Introduction

While underway on the second leg of the winter 2001 Operational Oceanography cruise, the RV POINT SUR encountered a thunderstorm. To investigate this event and other phenomena, I chose to explore the stability of the atmosphere using the rawinsonde data that was collected. In addition to focusing on the thunderstorm event, the stability of the atmosphere during all rawinsonde flights was calculated and compared to the observed conditions.

The forecasting of thunderstorms is based primarily on the concepts of conditional instability, convective instability, and forced lifting of air near the surface. For the purposes of this study, I chose to look into conditional and convective instability.

Conditional instability can be defined in two ways. Using the lapse rate definition, conditional instability is when the environmental lapse rate of a parcel lies between the dry and the moist adiabatic lapse rates. If the parcel is saturated instability results, but if the parcel is unsaturated the available energy definition must be used to evaluate if the parcel possesses positive buoyant energy.

The available energy definition is sometimes referred to as latent instability. Consider the sounding in figure (1). A parcel of air at the surface is lifted dry adiabatically until it reaches saturation at the lifting condensation level (LCL). From that point it is lifted moist adiabatically. When it intersects the environmental sounding, this is called the level of free convection (LFC). In general the LCL is considered the base of stratus type clouds and the LFC is considered the base of convective clouds (cumulus). The two areas between the environmental sounding and the lifted parcel can be used to evaluate latent instability. In the negative area sometimes called Convective Inhibition

(CIN), there is forced lifting. The CIN is representative of the amount of energy required to initiate convection. The positive area represents a gain in kinetic energy and is referred to as Convective Available Potential Energy (CAPE). If the positive area is greater than the negative area, there is real latent instability. If the positive area is less than the negative area, there is pseudo latent instability and if there is only a negative area there is latent stability. Latent instability gives an indication of whether there is energy in a layer for sustained convection. This leads to the concept of using stability and instability indices to estimate the potential for convective activity.

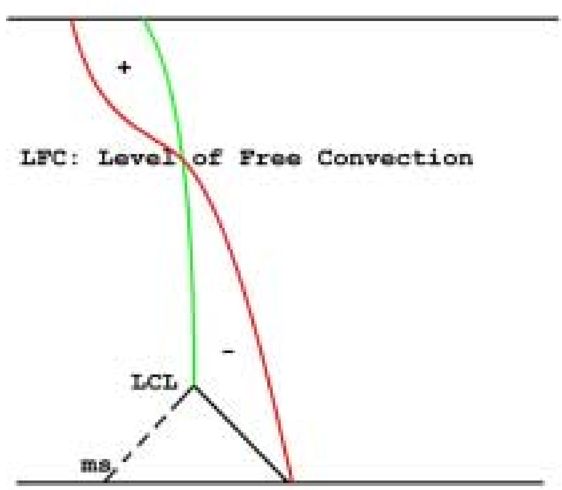

Figure (1)

Rossby defined convective instability to be when the lapse rate of wet-bulb temperature (Tw) exceeds the moist-adiabatic lapse rate (Γs), the equivalent potential temperature (θe) decreases with height, or the wet-bulb potential temperature (θw) decreases with height. The convectively unstable atmosphere is characterized by a fall with height of θe and most thunderstorm environments show this characteristic through most of the lower and middle troposphere. Typically, this produces a minimum of θe in the middle troposphere. This minimum in θe represents the potentially coldest air in the vertical air column described by the profile. It is thought to be rain-saturated air from the layers near the minimum of θe which forms the organized downdraft of severe thunderstorms.

2. Data Processing

During the cruise data, 20 rawinsondes were launched. Some were dedicated to an evaporative duct study while others collected no data. For the purposes of this study, I used data collected from 12 rawinsondes. For comparison purposes, I had 00Z and 12Z soundings from Oakland, California.

To evaluate conditional instability, I used MATLAB to calculate the environmental lapse rate (dT/dz) from the ascending sounding data going up to maximum height. I did not use the descending data. Sometimes the recorded data had two consecutive points at the same level. To avoid dividing by zero (dz), I had to average these points into one point. If the lapse rate was greater than 9.8/km this was absolute instability. If it lied between the moist and dry lapse rate it was conditionally unstable and if it was less than the moist lapse rate it was absolutely stable. The moist adiabatic lapse rate varies because when a parcel becomes saturated, the latent heat released by condensing water vapor will make the parcel cool at a different less rate, generally 7 +/- 3°/km. Doing this calculation through the entire sounding was not very useful in determining conditional instability because the soundings jumped all over. Absolute instability seldom occurs except in desert regions and the way doing this calculation in this manner resulted in absolute instability regions.

Except for the few occasions there was fog, the atmosphere was not saturated. To continue with a conditional instability evaluation latent instability had to be investigated. It would have been nice to calculate CAPE and CIN. Unfortunately I was unable to do this because the moist adiabatic lapse rate varies and I could not find an expression to calculate this. In the lower atmosphere, it is close to -4. Higher in the atmosphere it becomes parallel with the dry adiabatic lapse rate. I could not visualize the positive and negative areas as presented in Figure (1) because MATLAB did not give me a true SKEW T plot. The plot was log Pressure, but with limited MATLAB programming skills, I could not figure out a way to skew the temperature. I believe the temperature could be skewed by gridding the data. So instead of evaluating CAPE and CIN, stability and instability indices were calculated. I chose to calculate the Showalter stability (positive indicates stability) index and the following instability (positive indicates instability) indices: K index, Modified K index, Totals Total Index, and SWEAT index. I did not calculate the Lifted index, CAPE, CIN, Precipitable Water, or Bulk Richardson Number because vertical integration would have been necessary. Below is a brief description of the indices I calculated.

The Showalter index assumes latent instability of the 850-500 mb layer estimates the possibility for convective rainfall. To get the index lift a parcel dry adiabatically from 850 mb to its condensation level and moist adiabatically to 500mb (**$SI = T_{500} - T_{p500}$**).

Showalter Index ($SI= T_{500} - T_{p500}$)	
SI >= 3	No convective rain
1 to 3	Showers likely
-2 to 1	Thunderstorms probable
-3 to -2	Severe thunderstorms
<= -3	Tornadoes probable

I calculated this value in three different ways using different moist adiabatic lapse rates to raise the parcel from the 850 mb LCL to 500 mb. I used -4°/km, -7°/km and the adiabatic lapse rate calculated by manually determining the T_{p500} from a Skew T plot.

The next index calculated was the K index. The larger K is the greater the probability of thunderstorms. The first three terms measure the conditional instability of the 850-500 mb level and the last two terms the saturation deficit of the middle level. The dryer that level is the more it hurts the conditional instability of the rising saturated parcel. It is best suited for forecasting air mass convection rather than severe weather. In addition the modified K index was calculated. It is similar to that of the K index except that instead of the T and Td at 850 mb, the average temperature and dew point between 850 and the surface are used.

$$\mathbf{K = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700})}$$
$$\mathbf{Mod\ K = (aveT_{sfc-850} - T_{500}) + aveT_{dsfc-850} - (T_{700} - T_{d700})}$$

K < 15	0 % Air mass thunderstorm probability
15-20	< 20% Air mass thunderstorm probability
21-25	20-40% Air mass thunderstorm probability
26-30	40-60% Air mass thunderstorm probability
31-35	60-80% Air mass thunderstorm probability
36-40	80-90% Air mass thunderstorm probability
K > 40	>90% Air mass thunderstorm probability

The Total Totals Index is similar to the K index, except that it does not depend on 700 mb moisture. As with the K index, larger numbers correspond to a greater likelihood of thunderstorms. Threshold values vary from place to place. The Total Totals Index combines the effect of the atmospheric lapse rate, and low level moisture. It is computed by using the Cross Totals Index (the 850mb dewpoint minus the temperature at 500mb), and the Vertical Totals Index (the 850mb temperature minus the 500mb temperature).

$$\mathbf{TT = T_{850} + T_{d850} - 2T_{500}}$$

Total Totals Index (TT)

44-45	Isolated moderate thunderstorms
46-47	Scattered moderate / few heavy thunderstorms
48-49	Scattered moderate / few heavy / isolated severe thunderstorms
50-51	Scattered heavy / few severe thunderstorms and isolated tornadoes
52-55	Scattered to numerous heavy/few to scattered severe thunderstorm/few tornadoes
> 55	Numerous heavy / scattered severe thunderstorms and scattered tornadoes

There is a false sense of security when using this index. It is not meant to be used for the sole purpose of severe thunderstorm forecasting. High lapse rates and cold mid level temperatures will yield a high Total Totals number, but it does not take into consideration the low-level moisture that is needed for deep convection.

The SWEAT index stands for the severe weather threat index. This index evaluates severe weather potential by combining the effects of low level moisture at the 850mb level, convective instability from the TT Index, jet maxima from the 850mb and 500mb wind speed, and warm air advection noted by using the veering directional shear between 850mb and the 500mb levels. This will tell the forecaster if ordinary or severe convection can be expected.

SWEAT Index = $12D + 20(TT-49) + 2v_8 + v_5 + 125(S+0.2)$

S = sin(500mb wind direction - 850 mb wind direction)

$D = T_{d850}$

No terms can be negative. If a term is negative replace with zero. The following four criterion must be met or 125(S+0.2) = 0:

Both the 850mb and 500mb wind is greater than 15 knots.

(500 mb wind direction - 850 mb wind direction) must be positive (winds veering).

850 mb wind direction must be between 130 and 250.

500 mb wind direction must be between 210 and 310.

< 272: unlikely

273 to 299: general storms; slight risk of severe storms

300 to 400: storms approaching severe limits; moderate risk of severe storms

401 to 600: few severe storms with isolated tornadoes; strong risk

601 to 800: scattered tornadoes; high risk

To evaluate convective stability, I did several calculations. The first of which was calculating θe. I used the following formulas to calculate θe:

$\theta e = T_e \times (p_0/p)^{R/Cp}$
T_e = Equivalent Temperature (K) = $T(1 + (Lw/c_pT))$
T = temperature (K)
w = mixing ratio (unit less) = q/(1-(e/p))
q = specific humidity = 0.622*e/p
e = partial pressure of water vapor (mb)(vapor pressure) = rhxe_s
rh = relative humidity in %
e_s = saturation vapor pressure (mb) = 6.1078x exp(19.8x(T-273)/T)
L = 2.54×10^6 J/Kg = latent heat of vaporization
p_0 = 1000 mb = standard reference pressure
p = pressure at a point (mb)
R = 287 J/deg K g = universal gas constant
c_p = 1004 J/deg K g = specific heat of dry air at constant pressure

In addition to using lapse rate differences as a stability parameter, I used the vertical gradient of potential temperature as an indication of stability. I calculate θ, dθ/dz, and dθe/dz.

$\theta = T \times (p_0/p)^{R/Cp}$

For unsaturated air:	dθ/dz > 0 stable	For saturated air:	dθe/dz > 0 stable
	dθ/dz = 0 neutral		dθe/dz = 0 neutral
	dθ/dz < 0 instability		dθe/dz < 0 instability

The Matlab program used to calculate and plot results is in appendix A.

3. Program Verification

To verify my Matlab program was calculating values correctly, I obtained the raw data from the Oakland sounding at 11/00Z and 11/12Z from Mr. Thompson at NCAR. I compared the values my program produced with those that were printed on the SKEW T for the OAKLAND soundings that I printed from GARP. Below are the results. My program is function correctly. See appendix A for soundings and program output.

Value Calculated	MATLAB produced value	Value off sounding from GARP
11/00Z LCLP	978.2252mb	978 mb
11/00Z K index	11.1	11
11/00Z SWET index	176.2289	178
11/00Z TOTL index	54.4	54
11/12Z LCLP	978.5574mb	979 mb
11/12Z K index	24.5	25
11/12Z SWET index	344.6974	345
11/12Z TOTL index	58	58

4. Results

Appendix B contains program output and plots for each sounding analyzed.

Below are tables summarizing the results:

05/1800 Z Sounding **Observed conditions were FOG**

Sounding Gamma s	-9.2137 deg C
Showalter Index using Sounding Gamma s	10.9778 **No Convective Rain**
Showalter Index using -4 deg/km	16.8038 **No Convective Rain**
Showalter Index using -7 deg/km	13.4514 **No Convective Rain**
K index	-52.3478 **0 % Air mass thunderstorm probability**
Modified K index	-32.0259 **0 % Air mass thunderstorm probability**
TT index	15.3744 Severe weather not indicated
SWEAT index	66.5227 **Severe weather unlikely**
% height absolutely unstable	31.79%
% height conditionally unstable	33.57%
% height absolutely stable	34.62%
% height unstable for saturated air $d\theta e/dz < 0$	35.05%
% height stable for saturated air $d\theta e/dz > 0$	64.92%
% height unstable for unsaturated air $d\theta/dz < 0$	30.61%
% height stable for unsaturated air $d\theta/dz > 0$	69.36%

Discussion: There is fog during the first two soundings(05/18Z and 06/14Z). These environments are very stable. There are local θe maximums in the lower levels. The stability and instability indices all indicate stable conditions. By the third sounding (06/18Z), the fog has lifted and there are now stratocumulus clouds. This is also a pretty stable atmosphere. Once again the stability indices do well. For the next two soundings the skies have cleared up (07/21Z and 07/23Z). The indices are still indicating stable conditions. Surprisingly, the stable percentages of height have all increased by almost 10%. The next sounding at 08/17Z is very similar to the last two. Present conditions were not recorded for comparison.

06/1400 Z Sounding Observed conditions were FOG (margin of log)

Sounding Gamma s	-8.8173 deg C
Showalter Index using Sounding Gamma s	15 **No Convective Rain**
Showalter Index using -4 deg/km	19.8328 **No Convective Rain**
Showalter Index using -7 deg/km	16.8232 **No Convective Rain**
K index	-34.35 **0 % Air mass thunderstorm probability**
Modified K index	-4.7207 **0 % Air mass thunderstorm probability**
TT Index	7.1500 Severe weather not indicated
SWEAT index	No wind data available.
% height absolutely unstable	31.91%
% height conditionally unstable	21.07%
% height absolutely stable	46.99%
% height unstable for saturated air $d\theta e/dz < 0$	36.17%
% height stable for saturated air $d\theta e/dz > 0$	63.79%
% height unstable for unsaturated air $d\theta/dz < 0$	31.33%
% height stable for unsaturated air $d\theta/dz > 0$	68.64%

06/1800 Z Sounding Observed conditions were Stratocumulus clouds

Sounding Gamma s	-8.3005 deg C
Showalter Index using Sounding Gamma s	14.6 **No Convective Rain**
Showalter Index using -4 deg/km	11.6223 **No Convective Rain**
Showalter Index using -7 deg/km	13.6995 **No Convective Rain**
K index	-43.7333 **0 % Air mass thunderstorm probability**
Modified K index	-22.8808 **0 % Air mass thunderstorm probability**
TT index	19.7667 Severe weather not indicated
SWEAT index	No wind data available.
% height absolutely unstable	33.64%
% height conditionally unstable	26.53%
% height absolutely stable	39.79%
% height unstable for saturated air $d\theta e/dz < 0$	32.87%
% height stable for saturated air $d\theta e/dz > 0$	67.10%
% height unstable for unsaturated air $d\theta/dz < 0$	33.08%
% height stable for unsaturated air $d\theta/dz > 0$	66.88%

07/2100 Z Sounding Observed conditions were clear

Sounding Gamma s	-8.4932 deg C
Showalter Index using Sounding Gamma s	12.4 **No Convective Rain**
Showalter Index using -4 deg/km	3.0160 **No Convective Rain**
Showalter Index using -7 deg/km	9.2814 **No Convective Rain**
K index	-10.1 **0 % Air mass thunderstorm probability**
Modified K index	3.3289 **0 % Air mass thunderstorm probability**
TT index	32.4 Severe weather not indicated
SWEAT index	No wind data available.
% height absolutely unstable	22.63%
% height conditionally unstable	29.82%
% height absolutely stable	47.53%
% height unstable for saturated air $d\theta e/dz < 0$	25.55%
% height stable for saturated air $d\theta e/dz > 0$	74.43%
% height unstable for unsaturated air $d\theta/dz < 0$	23.19%
% height stable for unsaturated air $d\theta/dz > 0$	76.79%

07/2300 Z Sounding Observed conditions were clear with cumulus clouds in distance

Sounding Gamma s	-8.5195 deg C
Showalter Index using Sounding Gamma s	11.8867 **No Convective Rain**
Showalter Index using -4 deg/km	2.8726 **No Convective Rain**
Showalter Index using -7 deg/km	8.8561 **No Convective Rain**
K index	-16.7467 **0 % Air mass thunderstorm probability**
Modified K index	-2.1082 **0 % Air mass thunderstorm probability**
TT index	32.9667 Severe weather not indicated
SWEAT index	No wind data available.
% height absolutely unstable	28.11%
% height conditionally unstable	35.07%
% height absolutely stable	36.79%
% height unstable for saturated air $d\theta e/dz < 0$	30.59%
% height stable for saturated air $d\theta e/dz > 0$	69.38%
% height unstable for unsaturated air $d\theta/dz < 0$	27.46%
% height stable for unsaturated air $d\theta/dz > 0$	72.51%

08/1700 Z Sounding Observed conditions not listed

Sounding Gamma s	-7.9469 deg C
Showalter Index using Sounding Gamma s	14.3167 **No Convective Rain**
Showalter Index using -4 deg/km	11.1773 **No Convective Rain**
Showalter Index using -7 deg/km	13.5635 **No Convective Rain**
K index	-16.3881 **0 % Air mass thunderstorm probability**
Modified K index	-9.1512 **0 % Air mass thunderstorm probability**
TT index	20.4667 Severe weather not indicated
SWEAT index	No wind data available.
% height absolutely unstable	28.17%
% height conditionally unstable	25.98%
% height absolutely stable	45.83%
% height unstable for saturated air $d\theta e/dz < 0$	30.27%
% height stable for saturated air $d\theta e/dz > 0$	69.70%
% height unstable for unsaturated air $d\theta/dz < 0$	27.54%
% height stable for unsaturated air $d\theta/dz > 0$	72.44%

09/1800 Z Sounding Observed conditions were moderate intermittent rain

Sounding Gamma s	-7.7012 deg C
Showalter Index using Sounding Gamma s	5.9 **No Convective Rain**
Showalter Index using -4 deg/km	8.7346 **No Convective Rain**
Showalter Index using -7 deg/km	3.1273 **No Convective Rain**
K index	22.3 **20-40% Air mass thunderstorm probability**
Modified K index	30.1386 **60-80% Air mass thunderstorm probability**
TT index	50.1 **Scattered heavy / few severe thunderstorms and isolated tornadoes**
SWEAT index	278.7463 **general storms; slight risk of severe storms**
% height absolutely unstable	28.48%
% height conditionally unstable	17.68%
% height absolutely stable	53.82%
% height unstable for saturated air $d\theta e/dz < 0$	33.05%
% height stable for saturated air $d\theta e/dz > 0$	66.93%
% height unstable for unsaturated air $d\theta/dz < 0$	27.79%
% height stable for unsaturated air $d\theta/dz > 0$	72.19%

09/2100 Z Sounding **Observed conditions were clear after rain shower**

Sounding Gamma s	-7.7003 deg C
Showalter Index using Sounding Gamma s	9.7222 **No Convective Rain**
Showalter Index using -4 deg/km	-2.9391 **Thunderstorms Probable**
Showalter Index using -7 deg/km	7.3261 **No Convective Rain**
K index	7.4542 **0% Air mass thunderstorm probability**
Modified K index	18.0372 **<20% Air mass thunderstorm probability**
TT index	40.2034 **Severe weather unlikely**
SWEAT index	118.6102 **Severe weather unlikely**
% height absolutely unstable	24.07%
% height conditionally unstable	28.74%
% height absolutely stable	47.17%
% height unstable for saturated air $d\theta e/dz < 0$	26.61%
% height stable for saturated air $d\theta e/dz > 0$	73.38%
% height unstable for unsaturated air $d\theta/dz < 0$	23.39%
% height stable for unsaturated air $d\theta/dz > 0$	76.59%

09/2300 Z Sounding **Observed conditions were no rain**

Sounding Gamma s	-7.7750 deg C
Showalter Index using Sounding Gamma s	5.8385 **No Convective Rain**
Showalter Index using -4 deg/km	-7.1519 **Severe thunderstorms**
Showalter Index using -7 deg/km	3.1701 **No Convective Rain**
K index	19.0050 **<20% Air mass thunderstorm probability**
Modified K index	28.6141 **40-60% Air mass thunderstorm probability**
TT index	48.3667 **Storms approaching severe limits; moderate risk of severe storms altered moderate / few heavy / isolated severe thunderstorms**
SWEAT index	352.4315 : **storms approaching severe limits; moderate risk of severe storms**
% height absolutely unstable	29.05%
% height conditionally unstable	27.33%
% height absolutely stable	43.61%
% height unstable for saturated air $d\theta e/dz < 0$	32.37%
% height stable for saturated air $d\theta e/dz > 0$	67.61%
% height unstable for unsaturated air $d\theta/dz < 0$	28.32%
% height stable for unsaturated air $d\theta/dz > 0$	71.66%

11/0700 Z Sounding Observed conditions none recorded low cumulus and mid cumulonimbus

Sounding Gamma s	-7.9073 deg C
Showalter Index using Sounding Gamma s	3.9286 **No Convective Rain**
Showalter Index using -4 deg/km	-10.4328 **Severe thunderstorms**
Showalter Index using -7 deg/km	.5938 **No Convective Rain**
K index	21.2823 **<20% Air mass thunderstorm probability**
Modified K index	30.9939 **40-60% Air mass thunderstorm probability**
TT index	54.0143 **Scattered to numerous heavy/few to scattered severe thunderstorm/few tornadoes**
SWEAT index	117.8568 **Severe Weather unlikely.**
% height absolutely unstable	19.27%
% height conditionally unstable	34.21%
% height absolutely stable	46.5%
% height unstable for saturated air $d\theta e/dz < 0$	22.18%
% height stable for saturated air $d\theta e/dz > 0$	77.80%
% height unstable for unsaturated air $d\theta/dz < 0$	18.57%
% height stable for unsaturated air $d\theta/dz > 0$	81.41%

The next three soundings (09/18Z, 09/21Z and 09/23Z) all have drops in stability indicated by the calculated indices. This make sense because the observed conditions ranged from intermittent rain to rain. The Showalter index is not doing very well. It has been replaced by the integrated index, the Lifting Index. The Total Totals and SWEAT indices are both indicating more severe weather in the 09/18Z and 09/23Z soundings than in the 09/21Z. As the thunderstorm event approached (12/04Z), one might think that the instability indices would get larger. This did happen until 11/10Z. This could have to do with the fact that a trough passed over the ship around 11/07Z. As far as convective instability, it becomes more apparent after 11/10Z with the lowest θ_e occuring just prior to the thunderstorm event.

11/1000 Z Sounding Observed conditions were clearing no rain

Sounding Gamma s	-7.6289 deg C
Showalter Index using Sounding Gamma s	1.2286 **No Convective Rain**
Showalter Index using -4 deg/km	-13.2694 **Tornadoes Probable**
Showalter Index using -7 deg/km	7.3261 **Thunderstorms Probable**
K index	26.5714 **40-60% Air mass thunderstorm probability**
Modified K index	34.1484 **60-80% Air mass thunderstorm probability**
TT index	58.6429 **Severe weather unlikely**
SWEAT index	352.4315 **storms approaching severe limits; moderate risk of severe storms**
% height absolutely unstable	19.95%
% height conditionally unstable	23.57%
% height absolutely stable	56.47%
% height unstable for saturated air $d\theta e/dz < 0$	25.27%
% height stable for saturated air $d\theta e/dz > 0$	25.27%
% height unstable for unsaturated air $d\theta/dz < 0$	19.36%
% height stable for unsaturated air $d\theta/dz > 0$	80.62%

11/1300 Z Sounding Observed conditions were no rain

Sounding Gamma s	-8.0847 deg C
Showalter Index using Sounding Gamma s	6.6818 **No Convective Rain**
Showalter Index using -4 deg/km	-6.9410 **Tornados Proplems**
Showalter Index using -7 deg/km	3.0642 **No Convective Rain**
K index	16.6678 **<20% Air mass thunderstorm probability**
Modified K index	29.5174 **40-60% Air mass thunderstorm probability**
TT index	48.0246 **Scattered moderate / few heavy / isolated severe thunderstorms**
SWEAT index	102.4635 **Severe Weather unlikely.**
% height absolutely unstable	17.11%
% height conditionally unstable	32.18%
% height absolutely stable	50.69%
% height unstable for saturated air $d\theta e/dz < 0$	21.85%
% height stable for saturated air $d\theta e/dz > 0$	78.13%
% height unstable for unsaturated air $d\theta/dz < 0$	17.11%
% height stable for unsaturated air $d\theta/dz > 0$	50.69%

12/00 Z Sounding Observed conditions fair weather

Sounding Gamma s	-8.1925 deg C
Showalter Index using Sounding Gamma s	3.2 **No Convective Rain**
Showalter Index using -4 deg/km	-10.7823 **Severe thunderstorms**
Showalter Index using -7 deg/km	-.7772 **No Convective Rain**
K index	13.3167 **0% Air mass thunderstorm probability**
Modified K index	24.4125 **40-60% Air mass thunderstorm probability**
TT index	55.4 **Scattered to numerous heavy/few to scattered severe thunderstorm/few tornadoes**
SWEAT index	267.2797 **Severe Weather unlikely.**
% height absolutely unstable	17.52%
% height conditionally unstable	24.88%
% height absolutely stable	57.58
% height unstable for saturated air $d\theta e/dz < 0$	19.58%
% height stable for saturated air $d\theta e/dz > 0$	80.41%
% height unstable for unsaturated air $d\theta/dz < 0$	16.57%
% height stable for unsaturated air $d\theta/dz > 0$	83.42%

5. Conclusions

Instability is a critical factor in severe weather development. Severe weather stability indices can be a useful tool when applied correctly to a given convective weather situation. However, great care should be used when applying these empirical indices because they simply cannot be applied to every weather situation and must always be applied in conjunction with other parameters.

Soundings must be looked at as a whole. The calculation in which I attempted to solve for conditional instability is flawed. A more correct approach might be to visually divide the sounding into layers and then calculate environmental lapse rates by layer.

The stability and instability indices, I used for my study were not designed for California. Some of them performed quite well, but the good performance was not consistent. Local adaptations must be made to make these indices truly useful for this area. One must also consider the fact that sometimes the upper air sounding itself may not even be representative of the overall synoptic situation. Stability indices are only a forecasting tool. One should never depend on a single index.

The determination of the convective instability using θ_e seemed to be a better indicator in our region. The soundings during the cruise were seldom saturated therefore it would have been really interesting to be able to calculate CAPE and CIN.

Appendix A

Appendix B