ATMO 352
Severe Weather and Mesoscale Forecasting
Spring 2007

Laboratory #2: Skew T, Log P Diagram and CAPE

Section 501, Thursday
1-25-07
Due: By beginning of next lab session (2-1-07)

Purpose:

The purpose of this laboratory assignment is to review the Skew T, Log P diagram and its use in convective and severe weather forecasting. In this lab, we will review the depiction of temperature (T) and dew point temperature (Td) on a Skew T, Log P diagram and the graphical estimation of the lifting condensation level (LCL), level of free convection (LFC), equilibrium level (EL), environmental lapse rate ($\Gamma = - dT/dz$), convective available potential energy (CAPE), and the convection condensation level (CCL).

Introduction:

The Skew T, Log P diagram is the standard thermodynamic chart for use in severe storm forecasting. The diagram is a graphic representation of pressure, density, temperature, and moisture. The diagram is constructed such that fundamental atmospheric energy transformations are visually depicted. A unit of area on the diagram represents a specific quantity of energy. When plotted with various meteorological parameters received from an upper air sounding, the Skew T, Log P represents a vertical picture of the atmospheric conditions present at the time of the observation and allows for computations of various parameters required by severe storm forecasters. Upper air soundings are taken at each station with radiosondes (weather balloon with package of meteorological instruments and sensors) at least twice every day (00 UTC and 12 UTC). If requested by a NWS forecaster, a special sounding can be taken at other times, during a developing convective weather situation.

As discussed in lecture, parcel theory is used in determination of unmeasured parameters and analysis of the characteristics of convection that develop nearby an upper-air station. In parcel theory, a small quantity of air (i.e., "air parcel") is moved upward or downward in the atmosphere. Changes to the air parcel's characteristics are determined and compared with the surrounding, unchanged air. Note that data from the upper air sounding represents the environmental or surrounding air. One can imagine that the parcel behaves approximately like a balloon, which expands or contracts as the parcel moves upward or downward, respectively, but which does not allow mixing with the surrounding air. The Skew-T, Log-P diagram is considered a "pseudo-adiabatic diagram" in that it is derived from the assumption that the latent heat of condensation is used to heat the air parcel only and that condensed moisture falls out of the parcel immediately. The simplifying assumption of "pseudo-adiabatic" ascent is not technically correct but is sufficiently accurate to provide reasonable estimates of atmospheric parameters in most meteorological situations.

Reading: On the ATMO 352 class web page, there is a digital copy of the Air Weather Service (AWS) Technical Report TR-79/006, "The Use of the Skew T, Log P Diagram in Analysis and Forecasting." (http://www.met.tamu.edu/class/atmo352/aws-tr79-006.pdf; Note: it is a large document). Each procedure required in the lab below is explained in detail within the manual. So, before proceeding with the analysis please complete the assigned reading (Sections 2.1, 2.2, 4.12, 4.13, 4.14, 4.15, 4.16, 4.19, 5.1, 5.2, 5.5, which are located on pages 2.1-2.2, 4.12-4.19, and 5.1-5.6). Feel free to read other sections to expand your knowledge of Skew-T, Log P diagrams and their application to severe storm forecasting.

Data: Table 1 below contains measured upper-air sounding data, including pressure (P, millibar, mb or equivalently hectopascal, hPa), height (z, meters), temperature (T, °C), and dewpoint (T_d, °C) from Shreveport, LA (SHV) at 0000 UTC (or 1800 CST, CST = UTC – 6 hours) on 11 November 2006 (or 10 November 2006 CST).

Exercises (70 points)

1. *(12 points) Plot the sounding data* on the Skew T, Log P diagram provided. Plot each (T, P) and (T_d, P) data pair on the diagram with pencil. Use a straight edge to "connect the dots" for both temperature and dewpoint. When complete, use distinct colors (e.g., red [blue]) pencil/pen to indicate the temperature [dew point] profile.

2. *(6 points) Lifting Condensation Level (LCL)*
   a. (2 points) In your own words, define the lifting condensation level (LCL).
   b. (4 points) Find the LCL by lifting a parcel from the surface and label it on your diagram. Describe your procedure in words. What is the pressure (mb) and temperature (°C) of the LCL?

3. *(6 points) Level of Free Convection (LFC)*
   a. (2 points) In your own words, define the level of free convection (LFC).
   b. (4 points) Find the LFC using a lifted surface parcel and label it on your diagram. Describe your procedure in words. What is the pressure (mb) and temperature (°C) of the LFC?

4. *(6 points) Equilibrium Level (EL)*
   a. (2 points) In your own words, define the equilibrium level (EL).
   b. (4 points) Find the EL and label it on your diagram. Describe your procedure in words. What is the pressure (mb) and temperature (°C) of the EL?

5. *(8 points) Environmental Lapse Rate (Γ).* The environmental or temperature (T) lapse rate (Γ) is the decrease of temperature with height (z) where T is measured from a radiosonde and plotted as above. Mathematically, $\Gamma = -dT/dz$. The dry adiabatic lapse rate (Γ_d) is 9.8°C km^{-1} and is indicated by dry adiabats on the skew T. The moist adiabatic lapse rate (Γ_m) depends on the amount of moisture present and typically varies from 3-7°C km^{-1} in the lower troposphere and is shown by moist adiabats on the Skew T, Log P diagram.

a. (3 points) From the given data in Table 1, calculate the environmental lapse rate (Γ, °C km^{-1}) in the 700 mb to 500 mb layer.

b. (5 points) What is the stability condition of the parcel in the 700 to 500 mb layer? Explain.

6. *(22 points) "Positive Area" and CAPE (Convective Available Potential Energy)*
   a. (3 points) Identify, highlight (with hatching), and label the positive area on the diagram for a lifted surface-parcel. Describe your procedure.
   b. (3 points) Using the mathematical definition of CAPE provided in class, describe how the "positive area" highlighted above is related to CAPE. Describe what CAPE physically represents.
   c. (9 points) As discussed in class, area on the skew-T chart is proportional to energy. On your version of the skew-T log-P chart (DOD WPS 9-16-1), 1 cm^2 = 84 J kg^{-1}. Using this conversion, *estimate* CAPE from your chart.
   d. (3 points) Describe in your own words how CAPE is related to kinetic energy of a positively buoyant parcel. Using the class notes, provide a mathematical justification for this description.
   e. (4 points) Calculate the maximum updraft speed (w_{max}, m s^{-1}) according to parcel theory. Why does parcel theory usually overestimate updraft strength? Using the rule of thumb discussed in class, provide a more realistic estimate of the likely maximum updraft speed. Based on our discussions in lecture and the above values, how would you characterize the intensity of this convection? Explain.

7. *(10 points) Convection Condensation Level (CCL)*
   a. (2 points) In your own words, define the convection condensation level (CCL).
   b. (3 points) Find the CCL and label it on your diagram. Describe your procedure in words. What is the pressure (mb) of the CCL?
   c. (2 points) Under what conditions would you use the CCL versus LCL?
   d. (3 points) Describe the convection temperature and estimate it (°C) from your diagram.

Table 1. Shreveport, LA (SHV) sounding from 11 November 2006 at 00 UTC.

PRES (P)	HGHT (z)	TEMP (T)	DWPT(Td)
hPa or mb	Meter (m)	°C	°C
1000	84	26.6	19.6
993	146	26.8	20.8
979	271	26.2	21.2
975.2	305	25.9	21.1
941.9	610	23.2	19.8
925	768	21.8	19.2
909.5	914	20.4	18.6
887	1132	18.4	17.8
878	1219	17.7	17.1
850	1497	15.6	15.1
829	1709	14	13.6
817.3	1829	13.3	12.3
788.3	2134	11.6	8.8
788	2137	11.6	8.8
783	2190	11.6	6.6
768	2352	10.6	5.6
764	2395	10.6	3.6
760.1	2438	10.4	3.4
759	2450	10.4	3.4
746	2594	10	-2
739	2672	9.2	-0.8
732.7	2743	8.8	-4.8
732	2751	8.8	-5.2
702	3096	6.2	-4.8
700	3119	6	-6
671	3465	4.4	-10.6
655.1	3658	2.8	-11.5
628	4000	-0.1	-13.1
607.4	4267	-1.2	-14.2
598	4391	-1.7	-14.7
574	4716	-3.9	-16.9

P (mb)	z (m)	T (°C)	Td (°C)
562.4	4877	-5.1	-16.9
555	4981	-5.9	-16.9
541	5181	-7.1	-26.1
533	5297	-7.9	-26.9
520.1	5486	-9.5	-28
504	5729	-11.5	-29.5
500	5790	-12.1	-29.1
480.2	6096	-15.2	-27.9
477	6146	-15.7	-27.7
446	6648	-19.1	-43.1
442.5	6706	-18.9	-45.9
438	6782	-18.7	-49.7
429	6936	-19.5	-57.5
400	7450	-23.9	-63.9
390.7	7620	-25.4	-65.4
367	8071	-29.5	-69.5
314.8	9144	-36.8	-74.4
304	9389	-38.5	-75.5
300	9480	-39.3	-76.3
251.2	10668	-50	-73.4
250	10700	-50.3	-73.3
249	10726	-50.5	-73.5
234	11130	-52.9	-72.9
229	11270	-52.3	-72.3
218.2	11582	-54.6	-73
216	11647	-55.1	-73.1
214	11706	-54.3	-72.3
208	11889	-55.3	-73.3
202	12076	-55.1	-73.1
200	12140	-53.9	-72.9
198.4	12192	-54	-72.8
197	12237	-54	-72.8
188	12536	-54.5	-72.5