Atmospheric Sciences 5300

Exercise #5

This exercise deals with the saturation adiabatic lapse rate, stability, buoyancy oscillations, CAPE, and maximum updraft speeds.

1. Write (and hand in a listing of) a program to calculate the saturation-adiabatic lapse rate Γ_s (in K km^{-1}) for the following pressures and temperatures: 1000, 850, 700, 500, 300, 100 mb; +40, +30, +20, +10, 0, -10, -20, -30, -40 °C. Present your results in a table similar to the one in the text, or as a contour plot, *clearly labeled*.

2. In a stable unsaturated atmospheric layer, a parcel displaced vertically from its equilibrium level will oscillate with a frequency

   $$N = [\frac{g}{T}(\Gamma_d - \gamma)]^{1/2}$$

   called the *Brunt-Väisälä frequency.* The corresponding period of oscillation is $\tau = 2\pi/N$. Calculate N and τ for the following values of γ using $T = 288$ K:
   (a) $\gamma = 6.5$ K/km (standard atmosphere value),
   (b) $\gamma = 3$ K/km (stable layer),
   (c) $\gamma = 0$ K/km (isothermal, very stable layer),
   (d) $\gamma = 9$ K/km (weakly stable layer).

3. Plot the Tropical Atmosphere temperature sounding (from the accompanying table) on a skew T-log p diagram with 10-mb and 1-°C intervals, such as this diagram: `http://www.inscc.utah.edu/~krueger/5130/skewt_part_8x11.pdf`. Plot the temperature of a parcel that is displaced (adiabatically) upwards from the surface. Assume that the parcel properties at the surface are the same as those of the sounding at the surface. Determine the LCL, LFC, and LNB for the parcel.

   You may plot the Tropical Atmosphere sounding temperatures at 1-km intervals, except plot at 0.25-km intervals when necessary in order to determine the parcel's LCL, LFC, and LNB to the nearest 10 mb.

   If you use your large laminated skew T-log p diagram, please copy or scan or photograph the diagram with the sounding and the parcel properties plotted on it, and the LCL, LFC, and LNB indicated.

4. Calculate the maximum parcel vertical velocity for the following values of PA: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000 J/kg.

5. Calculate the initial parcel updraft speed required for a parcel to just reach its LFC if the NA is: 50, 100, 150, 200, 300, 400, 500 J/kg.

6. (Extra Credit) In a well-mixed (that is, constant potential temperature) boundary layer that is 2 km deep, a parcel rises from the surface with a potential temperature that is 1 K greater than that of the boundary layer. The boundary layer is capped by a thick isothermal (constant *temperature*) layer that is 1 K warmer than the boundary layer temperature at 2 km.

   (a) At the top of the boundary layer, what is the upward speed of the parcel due to its CAPE?
   (b) How far does the parcel penetrate (overshoot) into the overlaying isothermal layer?

   Hint: The parcel buoyancy can be expressed using potential temperature as

   $$g\frac{\theta - \bar{\theta}}{\theta_0},$$

   where no subscript indicates parcel properties, an overbar indicates environment properties, and subscript 0 indicates the reference profile, equal to a constant (288 K) in this case.

Tropical Atmosphere

z(km)	P(mb)	T(K)	w(g/kg)	O3(kg/kg)
16.500	102.00	196.00	0.0032500	3.2500e-07
16.250	106.40	196.50	0.0032250	2.8250e-07
16.000	111.00	197.00	0.0032000	2.4000e-07
15.750	115.90	198.80	0.0032490	2.3250e-07
15.500	121.00	200.50	0.0032980	2.2500e-07
15.250	126.40	202.30	0.0033490	2.1750e-07
15.000	132.00	204.00	0.0034000	2.1000e-07
14.750	137.60	205.50	0.0035180	2.0000e-07
14.500	143.50	207.00	0.0036410	1.9000e-07
14.250	149.60	208.50	0.0037680	1.8000e-07
14.000	156.00	210.00	0.0039000	1.7000e-07
13.750	162.10	211.80	0.0043610	1.6500e-07
13.500	168.50	213.50	0.0048770	1.6000e-07
13.250	175.10	215.30	0.0054540	1.5500e-07
13.000	182.00	217.00	0.0061000	1.5000e-07
12.750	189.30	218.80	0.0079960	1.4500e-07
12.500	196.90	220.50	0.010480	1.4000e-07
12.250	204.80	222.30	0.013730	1.3500e-07
12.000	213.00	224.00	0.018000	1.3000e-07
11.750	221.00	225.50	0.022630	1.2500e-07
11.500	229.40	227.00	0.028460	1.2000e-07
11.250	238.00	228.50	0.035790	1.1500e-07
11.000	247.00	230.00	0.045000	1.1000e-07
10.750	256.20	231.80	0.057500	1.0580e-07
10.500	265.80	233.50	0.073480	1.0150e-07
10.250	275.70	235.30	0.093900	9.7250e-08
10.000	286.00	237.00	0.12000	9.3000e-08
9.7500	296.20	238.80	0.14420	9.0500e-08
9.5000	306.70	240.50	0.17320	8.8000e-08
9.2500	317.70	242.30	0.20810	8.5500e-08
9.0000	329.00	244.00	0.25000	8.3000e-08
8.7500	339.50	245.50	0.29430	8.0750e-08
8.5000	350.30	247.00	0.34640	7.8500e-08
8.2500	361.50	248.50	0.40780	7.6250e-08
8.0000	373.00	250.00	0.48000	7.4000e-08
7.7500	386.90	251.80	0.54540	7.3000e-08
7.5000	401.40	253.50	0.61970	7.2000e-08
7.2500	416.40	255.30	0.70410	7.1000e-08
7.0000	432.00	257.00	0.80000	7.0000e-08
6.7500	446.30	258.80	0.90330	6.9000e-08
6.5000	461.00	260.50	1.0200	6.8000e-08
6.2500	476.20	262.30	1.1520	6.7000e-08
6.0000	492.00	264.00	1.3000	6.6000e-08
5.7500	507.90	265.50	1.4650	6.5250e-08
5.5000	524.40	267.00	1.6520	6.4500e-08
5.2500	541.40	268.50	1.8630	6.3750e-08
5.0000	559.00	270.00	2.1000	6.3000e-08
4.7500	576.70	271.80	2.2570	6.2000e-08
4.5000	594.90	273.50	2.4250	6.1000e-08

4.2500	613.70	275.30	2.6060	6.0000e-08
4.0000	633.00	277.00	2.8000	5.9000e-08
3.7500	652.60	278.80	3.2990	5.8750e-08
3.5000	672.80	280.50	3.8880	5.8500e-08
3.2500	693.60	282.30	4.5820	5.8250e-08
3.0000	715.00	284.00	5.4000	5.8000e-08
2.7500	736.50	285.00	6.2350	5.7500e-08
2.5000	758.70	286.00	7.2000	5.7000e-08
2.2500	781.50	287.00	8.3140	5.6500e-08
2.0000	805.00	288.00	9.6000	5.6000e-08
1.7500	828.70	289.50	10.150	5.5250e-08
1.5000	853.10	291.00	10.730	5.4500e-08
1.2500	878.20	292.50	11.350	5.3750e-08
1.0000	904.00	294.00	12.000	5.3000e-08
0.75000	930.10	295.50	12.900	5.1750e-08
0.50000	956.90	297.00	13.860	5.0500e-08
0.25000	984.60	298.50	14.890	4.9250e-08
0.0000	1013.0	300.00	16.000	4.8000e-08