Skew-T, ln p basics

Partly adapted from a ppt file put together by Dr. Ken Crawford
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The Skew-T, ln p diagram

- Our primary thermodynamic diagram
- Satisfies almost every desired feature of thermodynamic diagrams (see notes)
- Coordinates are ln p (proportion to height, horizontal lines) and T (skewed at about a 45° angle from the p lines.

Uses of thermodynamic diagrams

- Depiction of soundings (temperature and dewpoint temperature profiles)
- Nomogram* (http://en.wikipedia.org/wiki/Nomogram)
  - Equation of state (but density cannot be determined directly from the skew-T)
  - 1st Law of thermodynamics
  - Clausius-Clapeyron Equation
  - Determination of advanced atmospheric variables
    - θ, θ_e, θ_w, T_{sp}, T_{aw}, T_{ie}, r_v, r_{vs}
  - Other thermodyamic quantities can be calculated:
    - ρ, e, e_s, RH,
  - Determination of atmospheric processes, such as adiabatic mixing
- Evaluation of atmospheric stability

* A **nomogram** or **nomograph** is a graphical calculating device, a two-dimensional diagram designed to allow the approximate graphical computation of a function.

Atmospheric Stability

- Stable versus unstable
- Dry and saturated adiabatic processes
- Skew-T ln-p diagrams

Radiosondes

- http://www.aos.wisc.edu/~hopkins/wx-inst/wxi-raob.htm
- http://www.ua.nws.noaa.gov/factsheet.htm
- http://www.wmo.int/web/www/IMOP/meetings/Upper-Air/Systems-Intercomp/Doc3-4(1)Vaisala.pdf

Coded sounding:

TTAA 72121 72694 99012 11611 18010 00162 11211 18515 92812 0960923021 85511 06210 25025 70079 02911 26026 50566 19373 29036 4072830569 29538 30926 47164 30535 25044 56162 28047 20186 54364 2755115370 56164 29034 10625 57963 29045 88232 57362 27053 77999 5151510164 00003 10194 22521 26027=

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Decoded sounding:

DATE: 12Z 22 OCT 96

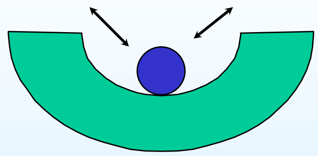
	p (mb)	H (m)	T (C)	TD (C)	DIR	SPD knt)	θ (K)	θ_e (K)	r_v (g/kg)
Sfc	1012.0	61	11.6	10.5	180	10	283.78	305.55	7.89
1	1000.0	162	11.2	10.1	185	15	284.35	305.85	7.78
2	966.0		10.6	9.7			286.57	308.45	7.84
3	920.0	812	9.6	8.7	230	21	289.57	311.33	7.69
4	850.0	1511	6.2	5.2	250	25	292.64	311.45	6.53
5	700.0	3079	-2.9	-4.0	260	26	299.27	311.49	4.06
6	641.0		-8.1	-10.3			301.00	309.39	2.72
7	638.0		-8.7	-11.1			300.72	308.64	2.57
8	630.0		-10.7	-36.7			299.53	300.42	0.26
9	615.0		-9.7	-36.7			302.75	303.68	0.27
10	601.0		-10.1	-29.1			304.28	306.21	0.57
11	581.0		-10.5	-36.5			306.78	307.79	0.29
12	500.0	5660	-19.3	-42.3	290	36	309.51	310.18	0.18
13	400.0	7280	-30.5	-49.5	295	38	315.35	315.74	0.10
14	300.0	9260	-47.1	-61.1	305	35	318.97	319.10	0.03
15	262.0		-55.1	-67.1			319.83	319.90	0.02
16	250.0	10440	-56.1	-68.1	280	47	322.66	322.73	0.02
17	232.0		-57.3	-69.3			327.81	327.87	0.01
18	215.0		-52.7	-65.7			342.16	342.27	0.03
19	200.0	11860	-54.3	-68.3	275	51	346.78	346.86	0.02
20	150.0	13700	-56.1	-70.1	290	34	373.42	373.51	0.02
21	118.0		-59.9	-72.9			392.94	393.03	0.02
22	100.0	16250	-57.9	-70.9	290	45	415.86	416.00	0.03
23	96.9		-56.9	-70.9			421.57	421.71	0.03
24	76.1		-57.1	-71.1			451.31	451.51	0.03
25	70.0	18500	-60.1	-73.1	310	28	455.81	455.97	0.03
26	60.0		-64.7	-76.7					

Started at: 7 SEP 06 11:12 UTC

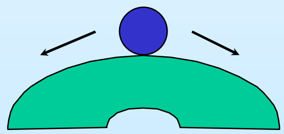
Time min/s	H m MSL	p hPa	T °C	RH %	T_d °C	RI	MRI	H ft MSL	Dir deg	Speed kts
0 0	174	996.1	14.5	97	14.0	340	367	571	360	1.0
0 5	202	992.8	15.7	93	14.6	340	372	663	360	1.0
0 10	230	989.5	16.9	88	14.9	339	375	755	28	4.7
0 15	258	986.3	18.1	84	15.4	339	379	846	28	4.7
0 20	287	983.0	19.2	80	15.7	338	383	942	46	6.2
0 25	314	979.9	19.4	76	15.1	334	383	1030	46	6.2
0 30	341	976.8	19.6	72	14.4	330	383	1119	65	8.0
0 35	368	973.7	19.8	70	14.2	327	385	1207	65	8.0
0 40	396	970.6	19.9	68	13.8	325	387	1299	83	9.3
0 45	424	967.4	20.1	66	13.6	323	389	1391	83	9.3
0 50	453	964.2	20.2	64	13.2	320	391	1486	101	10.9
0 55	480	961.2	20.3	63	13.1	318	394	1575	101	10.9
1 0	508	958.1	20.3	61	12.6	316	395	1667	118	12.1
1 5	534	955.2	20.4	60	12.4	314	398	1752	118	12.1
1 10	561	952.3	20.5	59	12.2	312	401	1841	135	13.0
1 15	588	949.3	20.7	57	11.9	310	402	1929	135	13.0
1 20	616	946.3	20.9	54	11.3	307	403	2021	151	13.8
1 25	642	943.4	21.1	52	10.9	304	405	2106	151	13.8

Atmospheric Stability

- Stable versus Unstable



Stable equilibrium



Unstable equilibrium

Atmospheric Stability (cont.)

- Adiabatic Processes
  - Parcel of air expands and cools, or compresses and warms, *with no interchange of heat with the surrounding environment*
  - An adiabatic process is reversible
- If the parcel doesn't saturate, then cooling or warming occurs at the ***dry adiabatic lapse rate***
  - Constant in our atmosphere **10 °C / km**

Atmospheric Stability (cont.)

- If the parcel does saturate and ascent is occurring...
  - Condensation (RH = 100%), latent heat is released
  - Latent heating offsets some of the cooling
  - Cooling at slower rate: ***saturated adiabatic lapse rate***
  - Not constant, varies with temperature and moisture

Average value **~ 6 ^{o}C / km**

  - Not reversible (heat added, moisture probably removed)
    - *Pseudo-adiabatic process*

Skew-T ln-p Diagram

- Convenient way to look at the vertical structure of the atmosphere
- Determine unreported meteorological quantities
- Assess parcel stability
- Used to display observations or model output
- Developed by the U.S. Air Force

Skew-T Log-P Diagram (cont.)

- Basic Definitions
  - ***mixing ratio*** (r_v)
    - mass of vapor to mass of dry air
  - ***saturation mixing ratio*** (r_{vs})
    - maximum for a given T and p
  - ***wet-bulb temperature*** (T_w)
    - equilibrium T when water evaporates from a wetted-bulb thermometer at a rate where latent heat lost is balanced by flow of heat from surrounding warmer air
  - ***potential temperature*** (θ)
    - temperature of air if brought dry-adiabatically to 1000 mb
  - ***vapor pressure*** (e)
    - partial pressure of water vapor

Skew-T Log-P Diagram (cont.)

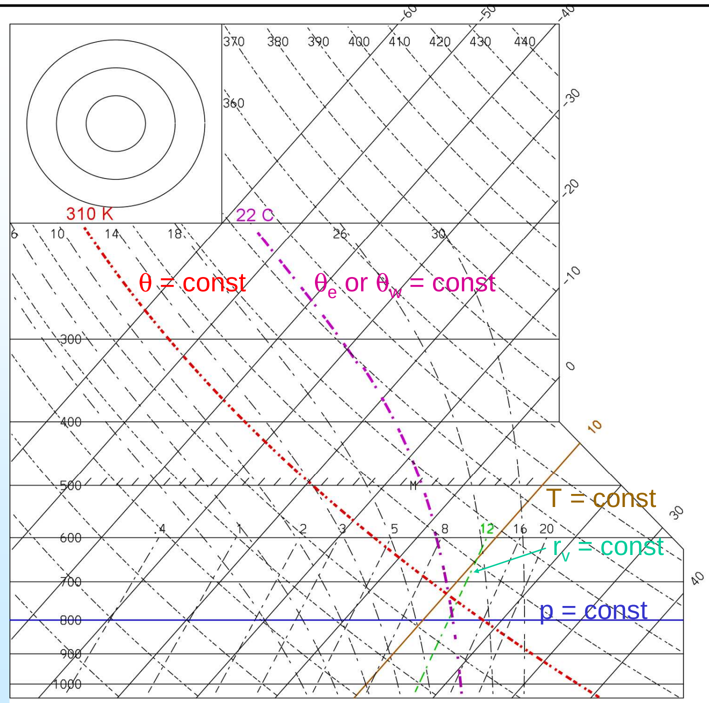
- Basic Definitions (cont.)
  - ***virtual temperature*** (T_v)
    - temperature dry air at pressure P would have so its density equals that of a moist parcel at T and P
  - ***dew point temperature*** (T_d)
    - temperature of a parcel cooled to saturation at constant P
  - ***relative humidity***
    - 100 x (mixing ratio / saturation mixing ratio)
  - ***specific humidity*** (q)
    - mass of vapor to mass of moist air (nearly the same as mixing ratio)
  - ***equivalent temperature*** (T_e)
    - temperature air would have if all of its latent heat were released

Skew-T Log-P Diagram (cont.)

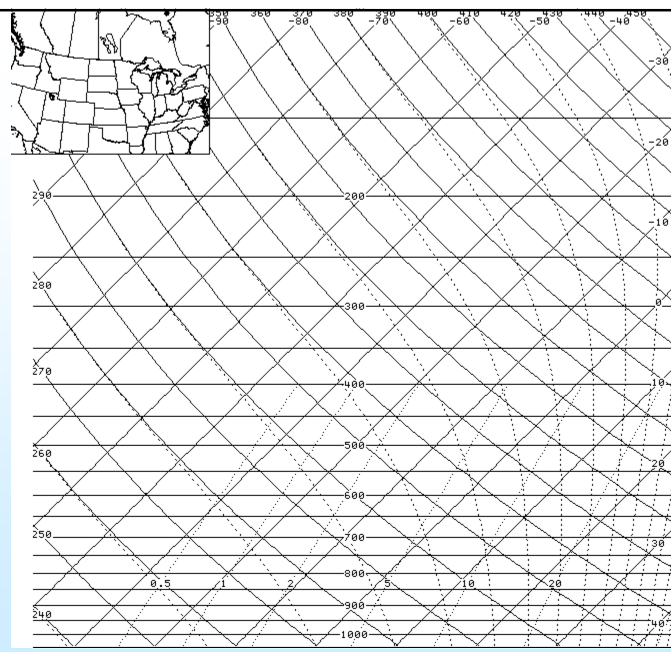
- Basic Definitions (cont.)
  - ***equivalent potential temperature*** (θ_e)
    - temperature of a parcel if all moisture condensed out (latent heat released) then the parcel brought dry-adiabatically to 1000 mb
  - ***Convective condensation level*** (CCL)
    - Height where rising parcel just becomes saturated (condensation starts)
  - ***Convective temperature*** (T_c)
    - T that must be reached for a surface parcel to rise to CCL
  - ***Lifting condensation level*** (LCL) (or saturation point)
    - Height where parcel becomes saturated by lifting dry-adiabatically
  - ***Level of free convection*** (LFC)
    - Height where parcel lifted dry-adiabatically until saturated, then moist-adiabatically, first becomes warmer than the surrounding air

Skew-T Log-P Diagram (cont.)

- Basic Definitions (cont.)
  - ***Positive area*** (or CAPE)
    - Area between the sounding and the moist adiabat that intersects the CCL, above the CCL. Proportional to the amount of energy the parcel gains from the environment.
  - ***Negative area*** (or CIN)
    - Area between the sounding and the dry adiabat that intersects the CCL, below the CCL. Proportional to the energy needed to move the parcel.
  - ***Equilibrium level*** (EL)
    - Height where the temperature of a buoyant parcel again becomes equal to the temperature of the environment.
  - ***Wet bulb zero***
    - Height above ground where the wet bulb first reaches zero degrees Celsius. This is the level where hail will begin to melt.

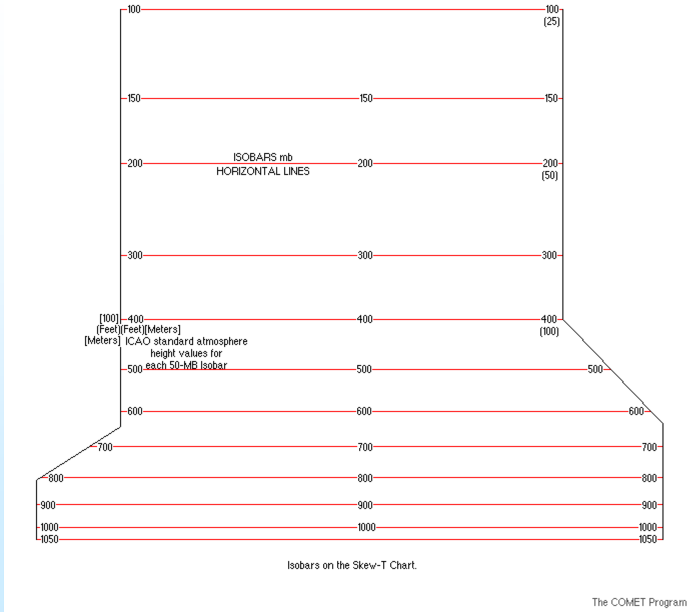


Skew-T Diagram



Skew-T Diagram

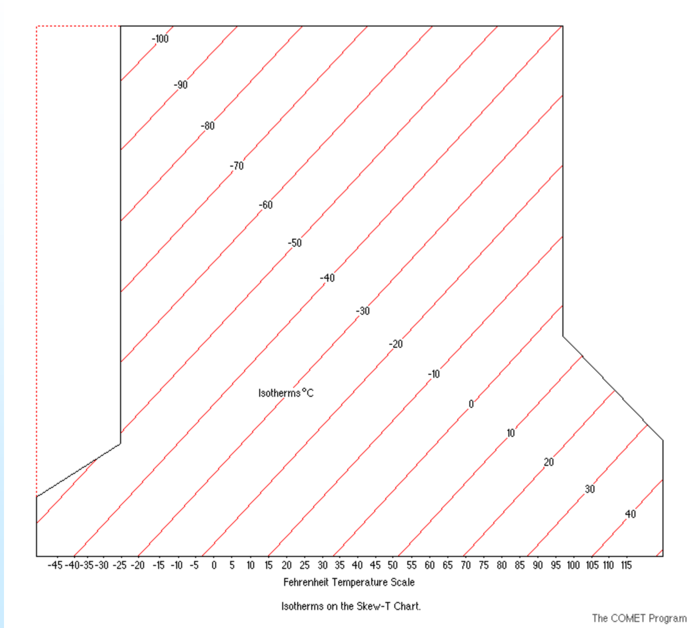
Isobars



Isobars on the Skew-T Chart.

Skew-T Diagram

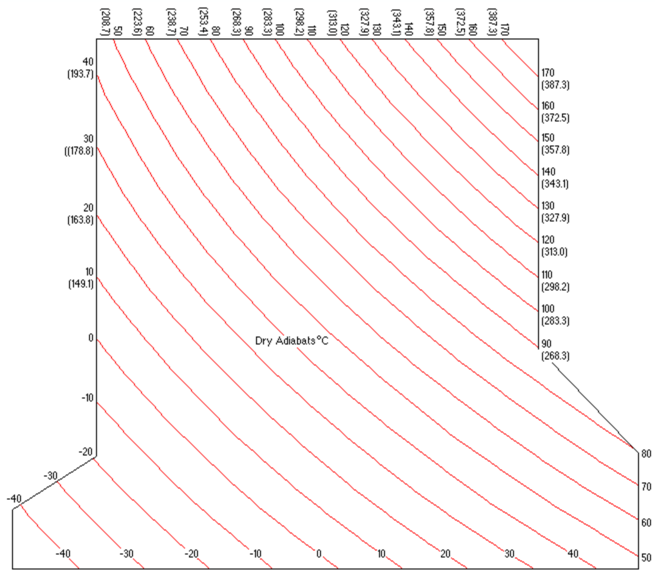
Isotherms



Isotherms on the Skew-T Chart.

Skew-T Diagram

Dry Adiabats

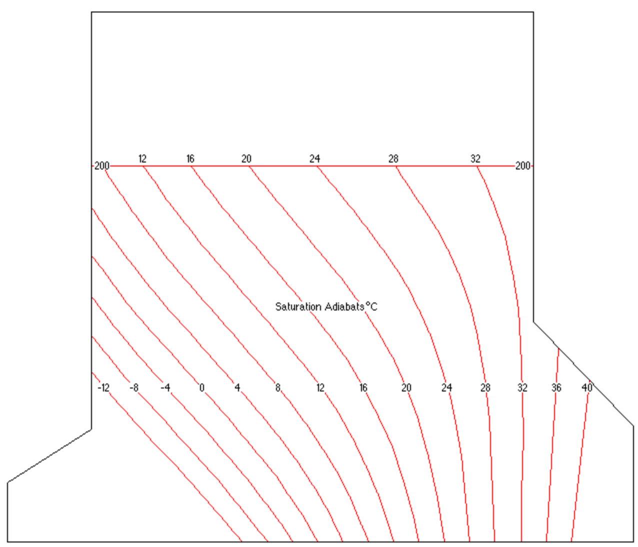


Dry Adiabats on the Skew-T Chart.

The COMET Program

Skew-T Diagram

Moist Adiabats

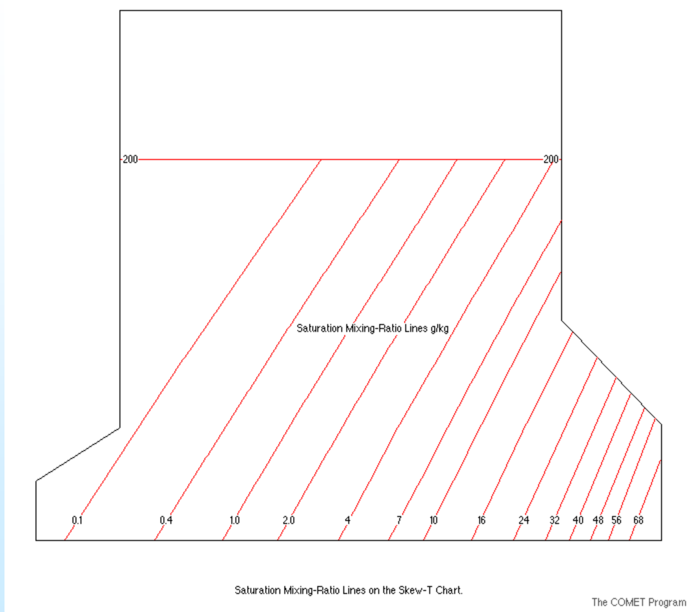


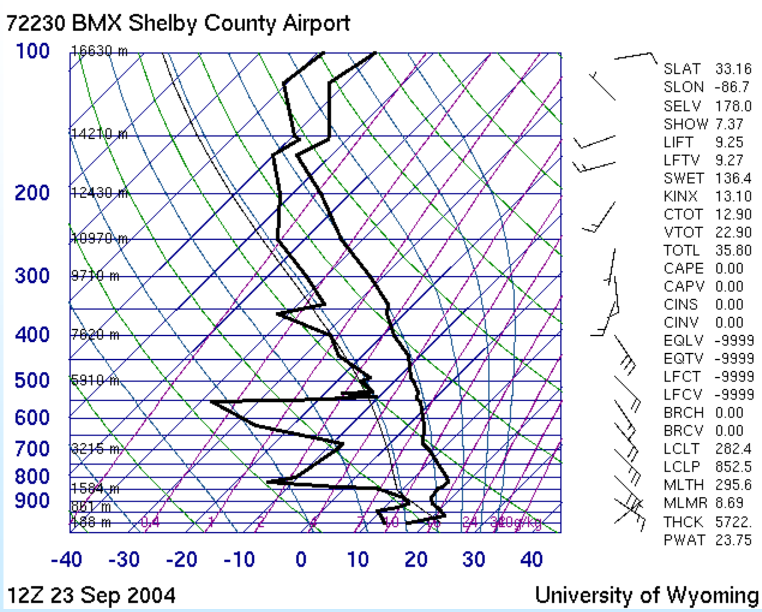
Saturation Adiabats on the Skew-T Chart.

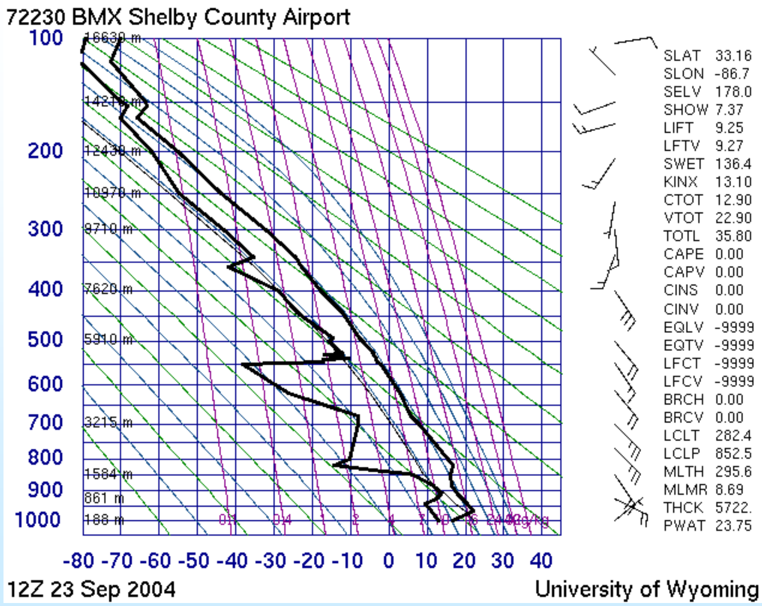
The COMET Program

Skew-T Diagram

Saturation Mixing Ratio



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200
300
400
500
600
700
800
900
1000
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12430 m
10970 m
9710 m
7620 m
5910 m
3215 m
1584 m
861 m
188 m
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40
SLAT 33.16
SLON -86.7
SELV 178.0
SHOW 7.37
LIFT 9.25
LFTV 9.27
SWET 136.4
KINX 13.10
CTOT 12.90
VTOT 22.90
TOTL 35.80
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
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BRCV 0.00
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LCLP 852.5
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MLMR 8.69
THCK 5722.
PWAT 23.75
12Z 23 Sep 2004
University of Wyoming