

ATSC 5010 – Physical Meteorology Lab
Lab 5 – Thermodynamic diagrams, moisture

Today we are going to build on the lab from a few weeks ago when we produced an *emagram*. Recall that potential temperature is a function of both temperature and pressure, and by knowing the relationship between the three we can predict how the temperature, pressure, and/or potential temperature of a parcel changes for certain atmospheric processes.

Consider a parcel that contains moisture. Lab 3's emagram does not provide any information to predict at what point a parcel may reach saturation. From intuition and basic observations, we all know that for a closed parcel, as that parcel cools it gets closer to saturation. But how do we know when this will occur? Last week's emagram did not provide any information about the amount of vapor in the parcel!

To do this, we will add contours of mixing ratio to our emagram. From that and from knowing our starting point (dewpoint or mixing ratio or wetbulb within a parcel) we can determine at what temperature and/or pressure condensation will occur.

We learned in lecture that saturation vapor pressure is a function of temperature only. Thus if one knows the temperature of a parcel, one can determine the saturation vapor pressure. The saturation vapor pressure, e_s , is defined as:

e_s is the partial pressure of H_2O at which, for a given temperature, the rate of evaporation of water is exactly equal to the rate of condensation (over a flat surface of pure water).

Another -more pragmatic- way to think about this:

e_s defines the 'e' of a vapor/liquid mixture at equilibrium.

OR put another way:

Saturation vapor pressure is the vapor pressure necessary for a liquid/vapor system to persist at equilibrium.

When the vapor pressure, e , is less than the saturation vapor pressure, the parcel is sub-saturated with respect to water resulting in net evaporation of liquid (if liquid exists in the parcel). When the vapor pressure exceeds the saturation vapor pressure the parcel is super-saturated resulting in net condensation.

For our purposes, it is often useful to use another quantity to describe the amount of water and the point of saturation. This quantity is called *water vapor mixing ratio* (or just mixing ratio). The mixing ratio is the ratio of the mass of water vapor in a given volume to the mass of dry air (in that same volume: m_v/m_d , often expressed as the grams of water vapor in a kilogram of dry air [g/kg]). When that volume of air is saturated, then the mixing ratio is said to be at saturation (ie saturation mixing ratio). Unlike saturation vapor pressure, saturation mixing ratio depends on temperature and pressure of the parcel.

We begin with vapor pressure. We make the assumption that we can represent saturation vapor pressure in the atmosphere, ignoring temperature dependence of Latent heat, by integrating C-C (Clausius-Clapeyron Equation) such that saturation vapor pressure can be written as the following (we will do this in class in the coming days):

$$e_s = e_{s0} \cdot \exp \left\{ \left(\frac{L_{v0}}{R_v} \right) \left(\frac{1}{T_0} - \frac{1}{T} \right) \right\}$$

Where e_{s0} represents the saturation vapor pressure at some temperature, T_0 (our reference state). For this we will use 0 C. We have defined (in phycon) the saturation vapor pressure at 0 C.

Saturation mixing ratio can be related to pressure and saturation vapor pressure (and therefore, T) by through the following:

$$w_s = \frac{R_D}{R_v} \frac{e_s}{p - e_s}$$

In today's lab, you will build an emagram similar to the one from Lab 3. You will also build a two-dimensional array of saturation mixing ratio (similar to your array of potential temperature in Lab 3), and use that to add an additional set of contours to your thermodynamic diagram.

Exercise:

The procedure you build today will be very similar the emagram from Lab 3. I recommend you use Lab 3 as a starting point, note however that the limits for temperature and pressure have changed.

1. This week's procedure will have the name "at5c5010_yourname_lab3"
2. Build a chart, similar to last week with the following characteristics:
 - Your chart background should be white, your axes and gridlines should be black solid lines, and the chart size 500 pixels (in x) and 600 pixels (in y)
 - Temperature range from -30 to +40 C (label every 10 degrees, 0.1 C resolution)
 - Pressure range from 1050 mb to 250 mb (label every 100 mb, 1000 to 300, 1 mb resolution)
 - Potential Temperature lines 250 to 460, label every other line, lines **thick**, solid "Green"
 - Mixing Ratio lines (in g/kg): 0.5, 1, 2, 3, 4, 6, 8, 11, 15, 20, 30, 50, 75, 125, label every line, solid "red"
 - Chart Title should read: "ATSC5010, Lab 5: ThermoDynamic Chart"

QUESTIONS:

First go through an answer the following questions by hand using your thermodynamic diagram. Then check your answers by programming searches into your procedure (Use the *WHERE* function and the *MIN* function, similar to lab 3)

1. Consider a parcel at 15 C and 800 mb. What is the parcel's potential temperature? What is the parcel's saturation mixing ratio? From this information, can you determine the parcel's mixing ratio? Can you determine its dewpoint?
2. If the parcel in (1) is saturated, what is the parcel's mixing ratio? What is its dewpoint?
3. Consider a parcel with a dewpoint of 10 C at 700 mb. What is the parcels mixing ratio?
4. Now lift the parcel in (3) to 400 mb (assuming it doesn't saturate). What is the parcel's mixing ratio? What is the parcel's dewpoint?
5. Now allow the parcel to descend to 1000 mb, what is the parcel's mixing ratio? Dewpoint?
6. Consider a parcel at 900 mb, with a temperature of 20 C and a dewpoint of 0 C. Raise the parcel to the level of saturation (this is called the *lifting condensation level, LCL*). What is the pressure at the LCL? What is the temperature of the parcel at the LCL? What is the dewpoint? Is the mixing ratio at the LCL greater than, less than, or the same, as it was at 900 mb (our starting point?).

Computing saturation mixing ratio array:

YOU CAN DO THIS using a FOR loop (easiest):

First, you will need to define saturation vapor pressure as a function of temperature...

Second, you need to define the size of the saturation mixing ratio array.

Lastly, loop over Pressure and compute saturation MR for all values of temperature at that pressure:

```
Ws = DBLARR[number_of_pts_temperature, number_of_pts_pressure]
FOR i=0,number_of_pts_pressure
    Ws[* ,i] = yourfunction_satmixingratio( press[i],temperature[*] )
ENDFOR
```

OR you can do all of this with matrix_multiply and no loops (more tricky):

First, setup saturation vapor pressure array as above....

Then, you can create a 2D array for saturation vapor pressure using a matrix multiply by the value 1. that has:

```
es[number-pts_temperature, number-pts_pressure]
(in this case es[i,*] all have the same value)
```

Finally, you can calculate directly with vector math the saturation mixing ratio array

Note: similar to over-plotting with the plot function; to draw additional contour lines, one must use the *overplot* keyword in the CONTOUR function.

Problem 6:

You will likely need to utilize a DO loop. Best way to attack this problem: determine the MR and SatMR, raise the parcel one pressure level, compare the MR to SatMR. If saturation is reached, determine what your pressure and temperature is at that point, if saturation is not reached raise the parcel another level and repeat....