Cloud Physics Lab

LAB 2: Thermodynamics Properties of Air

Introduction:

You will be required to calculate saturated water vapor over water and ice and determine Lifted Condensation Level (LCL) using Clausius-Clapeyron equation.

Objective:

a) Calculate and plot saturated water vapor over water and ice using Clausius-Clapeyron Equation
b) Calculate the LCL using Clausius-Clapeyron Equation for different temperatures and mixing ratios.

Theory:

The Clausius-Clapeyron equation gives the saturation vapor pressure over a plane surface of water as a function of temperature:

$$e_s = e_{so} \exp\left[\frac{L_v}{R_v}\left(\frac{1}{T_o} - \frac{1}{T}\right)\right] \tag{1}$$

where:
e_s: is saturation water vapor pressure over water,
e_{so}: 6.11 hPa
T_o = 273.15 K
T : is a temperature,
L_v: is latent heat of vaporization (2.501×10^6 J/kg),
R_v : is water vapor gas constant (461.5 J kg^{-1} K^{-1}).

The Clausius-Clapeyron equation also gives the saturation vapor pressure over ice as a function of temperature:

$$e_{s_i} = e_{so} \exp\left[\frac{L_s}{R_v}\left(\frac{1}{T_o} - \frac{1}{T}\right)\right] \tag{2}$$

where:
e_{si}: is saturation water vapor pressure over ice,
e_{so}: 6.11 hPa
T_o = 273.15 K
T : is a temperature,
L_s: is the specific latent heat of sublimation (2.834×10^6 J/kg),

R_v : is water vapor gas constant (461.5 J kg^{-1} K^{-1}).

LCL

The LCL is the pressure level a parcel of air reaches saturation by lifting the parcel from a particular pressure level. A rising parcel of air cools, thus the Relative Humidity (RH) increases inside a rising unsaturated parcel. Once the RH first reaches 100% in the parcel, the LCL occurs there.

Materials and Procedures:

1. Run the Matlab script **Lab2a.m** to calculate and plot the saturation water vapor over water as a function of temperature.
2. Run the Matlab script **Lab2b.m** to calculate and plot the saturation water vapor over water and ice as a function of temperature.
3. Run the Matlab script **Lab2c.m** to determine the LCL for the following conditions. Assume surface pressure is 1000 hPa:

Surface air temperature (oC)	Surface mixing ratio (kg/kg)	LCL (m)
20	0.005	
	0.007	
	0.010	
25	0.005	
	0.007	
	0.010	

Note: The mixing ratio is defined as the ratio of the mass of water vapor to the mass of dry air.

Analysis and Conclusions:

1. Explain the profile of the saturated water vapor over water for temperature ranges of -30 to +40 ^{o}C (fig 1).
2. Explain the profile of the saturated water vapor over water and ice for temperature ranges of -30 to 0 ^{o}C (fig 2).
3. Explain how LCL varies with surface air temperature and surface mixing ratio.

Questions:

1. What did you learn about saturation vapor pressure by completing the activity?
2. Why saturated vapor pressure over water is higher than saturated vapor pressure over ice at the same temperature.
3. Why LCL is important?