Climate & Sustainability

PHYS 189 Fall 2017

Matlab Exercise for Balloon Launch

1 Purpose

This project aims to analyze the data taken during the October 23 balloon launch. The objectives of this assignment are to:

1. Gain experience in using Matlab as a software data analysis platform.
2. Analyze the balloon data and compare with our observations.
3. Use the raw data to calculate:
   - altitude
   - dew point temperature
   - relative humidity
   - dry static energy
   - moist static energy
   - environmental lapse rate
4. Answer some questions based on these calculations and plots

2 Getting started with Matlab

Open a command line window. It will likely have a "$" as a prompt. To start Matlab, type "matlab" at the prompt. The matlab prompt is a "»". To exit Matlab, type "exit".

Code that runs matlab commands typically end in a ".m". To run these, type the filename without the ".m" extension. For example, to run "`Phys189L_humidity_Solution.m`", type:

```
» Phys189L_humidity_Solution
```

3 Sounding data

We have two data sets, one taken directly from the balloon launch (Airsonde_sounding_23_Oct_2017.txt), the other from Albuquerque's sounding on the same day (KABQ_12Z_23_Oct_2017.txt).

There are several different ways to read data into Matlab (and thus a lot of ways in which it can go wrong). Note that in both of these files, there are headers identifying what each column of data looks like. While we can tell Matlab to skip that first line, we have to be very careful with how it interprets the rest of the data. You can read about it at `https://www.mathworks.com/help/matlab/ref/dlmread.html`.

To keep things simple, one option is to remove the headers (and the information at the bottom of the file included in the Albuquerque sounding). This leaves us with columns of numbers separated by white space which it consistently interprets as a single delimiter (characters or strings of characters separating data values). I've also included the modified files with all text removed:

- Airsonde_sounding_23_Oct_2017-noheader.txt
- KABQ_12Z_23_Oct_2017_noheaderfooter.txt

4 Plotting Relative Humidity

The first thing we'll do is go through the same matlab script, which I've modified from Dr. Minschwaner. This is `Phys189L_humidity_Solution.m`.

If you open the script in a text editor, you'll note that several lines begin with a "%". This is a *comment* symbol, which means Matlab ignores everything on the line following the %. It is a good way to document your code, or to make it easier to debug, troubleshoot, or change what you want a program to do.

Also note that most lines end in a ";" (semi-colon). This tells Matlab you want it to do something, but you don't want it to show you what it is doing. Removing this when you read a data file will print the entire data file (which is likely undesireable, unless you want to make sure you are interpretting the file the same way Matlab is).

Here is a rough step-by-step explanation of what is happening in the file. Each step refers to a single or several uncommented lines which represent the specific commands. These are also documented in the code.

1. The program first identifies the filename (denoted as `fname`), then reads it into an array nameed `a` using `dlmread`. There are no optional arguments used in `dlmread` since we stripped out the extra information in the data files.

2. The number of rows and columns are counted. If you'd like to see how many of either, simply remove the ";" at the end of the line before you run the program and it will show you. This is useful if you use options in the `dlmread` command (in which case it counts white spaces as columns, so it is useful to remove the ";" to realize that while you may think there are only 4 columns of data, Matlab might think there are 16).

3. Assign data columns to a vector. The syntax `wb = a(:,3)` means take all rows in the third column of data array `a` and assign it to a vector named `wb` (for wet-bulb).

4. Convert pressure, p, to altitude, z, using

   $$p = p_{surface} e^{-(z - z_{surface})/h}$$

   where h is the scale height (we assume to be 7.5 km), $p_{surface}$ and $z_{surface}$ are the surface values (assuming $z = 0$ is sea level, $z_{surface} = 1.42$ km). Solving this for z gives

   $$z = z_{surface} + h \log(p_{surface}/p)$$

   $p_{surface}$ is given by the first element of the vector $p1$.

5. Calculate relative humidity using the following steps:

   (a) Calculate **saturation water vapor pressure**, p_{sat} (`ps` in the script) from the temperature, T (`t1` in the script).

   (b) Calculate saturation water vapor at the web bulb (T_{wet} or `wb`).

   (c) Calculate the **environmental** water vapor pressure (`pse` in the script).

   (d) The **relative humidity** is the ratio of environmental to saturation vapor pressure:

   $$RH = p_{env}/p_{sat}$$

   `RH=pse./ps` (in matlab code; the period in front of the division sign, "./", is important.

(e) Multiply by 100 to give the percent.

6. Identify and read ABQ sounding data.
7. Count rows and columns.
8. Identify vectors for the data we need from this array (altitude, tempreature, and relative humidity).
9. Since data is given in meters and we are plotting in km, convert.
10. Plot the relative humidity data
    (a) plotting command, identifying the $x-$ and $y-$ variables and line style (`'b-'` is a blue dashed line, `'r:'` is a red dotted line) for each data set.
    (b) Set the x and y axis ranges
    (c) Label axes, title, and create a legend (in the same order as what is plotted).
11. Save the image so you can print and turn it in.

5 Dry, moist, and saturated moist static energies

A good strategy to learn coding is to take a working program and modify it to do a new task. That is the strategy we'll use for this task. First, copy the file `Phys189L_humidity_Solution.m` to a new file with a `.m` filename extension. For example, you could name it `dryNmoistStaticEnergy.m`.

We'll only worry about the Socorro sounding data. Here are a few steps that may be useful to follow. You don't have to do them in this order, this is just what I did.

1. Remove all of the lines that refer to the ABQ data (optional–you'll need it for the next section so you can just keep it at this stage).
2. Calculate dry static energy. I'm going to use `dse` for the script to identify this variable. Recall $dse = c_pT + gz$.
    (a) define c_p: `cp=1006. ;` (with units of J kg^{-1} K^{-1})
    (b) define g: (9.8 m s^{-1})
    (c) define dse. Use calculations above for an example of how to write equations.
    Don't forget that the altitude is defined in km and temperature in Celcius! Convert!!
    Also, note that multiplying and dividing scalars and vectors in matlab require a period in front of the operator sign (".*" and "./"). It means something else if there is no period.
3. Now is a good time to see if your code makes sense by plotting dse as a function of altitude.
4. Calculate Moist static energy.
    (a) Define Latent heat of condensation ($L = 2.501 \times 10^6$ J/kg); or at the Matlab prompt: `Lv=2.501e6 ;`

(b) calculate the mixing ratio, mr, from the environmental water vapor pressure (in the previous script, this was the variable `pse`):

$$mr = \frac{pse * R_d}{R_v(p - pse)}$$

with $R_d = 287.0$ J/kg/K and $R_v = 461.5$ J/kg/K, the gas constants of dry air and water vapor, respectively.

(c) calculate the specific humidity from mixing ratio:

$$q = mr/(mr + 1)$$

(d) Calculate the MSE:

$$MSE = DSE + L_v q$$

5. Now calculate saturated MSE:

(a) Calculate saturated mixing ratio from saturated vapor pressure (`ps`):

$$satmr = \frac{ps * R_d}{R_v(p - ps)}$$

(b) Calculate saturation specific humidity:

$$satq = satmr/(satmr + 1)$$

(c) Caculate saturated MSE:

$$satmse = DSE + L_v * satq$$

6. Plot DSE, MSE, satMSE on the same graph. Save the image so you can print it and turn it in.

6 Plotting Temperature and Dew Point Temperature

An approximation of the Clausius-Clapeyron equation relates the vapor pressure and saturation vapor pressures to the temperature and dew point temperature. For e=vapor pressure and e_{sat} the saturation vapor pressure:

$$e = 6.11 \times e^{\left(\frac{Lv}{Rv}\right)\left(\frac{1}{T_0} - \frac{1}{T_{dew}}\right)} \quad (1)$$

$$e_{sat} = 6.11 \times e^{\left(\frac{Lv}{Rv}\right)\left(\frac{1}{T_0} - \frac{1}{T}\right)} \quad (2)$$

with vapor pressure measured in mb, and $T_0 = 273$ K. L_v and R_v are defined above.

The last Matlab exercise is to plot the temperature and dew point temperature as a function of altitude (or pressure if you'd like). We have all we need except an expression for T_{dew}. Taking the first of the equations and solving for T_{dew} gives:

$$T_{dew} = \left[\frac{1}{T_0} - \frac{R_v}{L_v}\ln\left(\frac{e}{6.11}\right)\right]^{-1}$$

You can either copy and modify the previous file or just continue to use the same file (if you removed the ABQ sounding data, you'll need to put it back in). The challenge is to correctly calculate T_{dew} and plot it along with T. Don't forget to pay attention to UNITS. In the equation above, T_{dew} is in K; T in the data is in Celcius. It doesn't matter what you choose to plot, just be consistent.

Include the ABQ Sounding data in your plot. You'll have to read in the data file, but you don't have to do any more calcuations (except for converting units).

7 Homework questions

Either print out or email your matlab files. Also, print all three plots and use them to answer the following questions.

1. Compare the Socorro and Albuqueque temperature soundings.
   (a) Why is the Socorro temperature sounding warmer near the surface?
   (b) Does either sounding show inversion layers? If so, what altitudes are they located?
   (c) The soundings should agree best away from the surface, above 3km altitude. How well do the temperatures agree between 3.5 and 4.5 km? How large are any temperature differences?
   (d) Calculate the average environmental lapse rate.
2. Compare the Socorro and Albuquerque humidity soundings:
   (a) Which humidity sounding has a lower relative humidity near the surface (the lowest 1km), and what is the main reason why?
   (b) Above about 4km, how well do the two humidity soundings agree?
   (c) Why does the Socorro humidity sounding have such a strange behavior above about 4.5 km?
3. Formulation of relative humidity from wet-bulb temperature. Look a the MATLAB script for computing relative humidity from the wet-bulb temperature. Write down the equations that are used to do this. Use the following definitions for the primary variables:
   - $T=$ air temperature
   - $p=$ pressure
   - $TWB=$ wet-bulb temperature
4. Examine the plot of dry static energy (DSE), moist static energy (MSE), and saturated moist static energy (satMSE).
   (a) Do the values of DSE, MSE, and satMSE roughly agree with the soundings? In other words, are there features that are in common with the temperature and humidity soundings? Explain.
   (b) Based on the energies, is the atmosphere dry?
   (c) Draw a line from a parcel at the surface that rises adiabatically. What is the lifting condensation level? Label CAPE and CIN. Do you expect convection, based on this sounding?
   (d) Is this consistent with your observations from the day?