

# Finding the Planetary Boundary Layer

## Teacher's Notes

**Objective:** Students will learn about the presence of the planetary boundary layer within the troposphere. Then using real life data, observe the changing levels of the boundary layer.

### National Science Education Standards:

- Standard A: Science as Inquiry
- Standard B: Teacher will guide and facilitate a learning environment
- Standard D: Students will be provided with time, space and resources to conduct their research.
- Standard E: Science and Technology

### Materials:

#### For each group of 2 students:

- Access to computer with spreadsheet software.
- <http://weather.uwyo.edu/upperair/sounding.html> or other similar website

**Class time:** approximately two 40 minute class periods.

### Teacher notes:

#### Engage:

1. Ask students to name the different layers of the atmosphere, helping out when needed.
2. Inform students that while they have done wonderful identifying the layers of the atmosphere they have left off a very important layer that they will be exploring today, and it is their job to quickly find some information on the missing layer.
3. Ask students if they have ever been in an airplane when it experienced turbulence. Ask students for ideas about what possibly might have caused that turbulence.
4. After students have shared their ideas about turbulence, inform them that while they may not discover the exact cause of turbulence, they will learn how to locate where most turbulence occurs.

#### Explore:

1. Inform students that they will work with a partner to find some basic information about boundary layers, in general, and the planetary boundary layer specifically. Then the students report back to class what they have learned. (allow 10-15 minutes for this)
2. Once students have returned with their information have each group share with the class what they have learned. Be sure to keep a running list of student findings either on the board or on a projector screen.
3. When the students finish sharing their information, inform them that they will now be finding the location of the boundary level for each day in the last two weeks. Explain to the students how looking at virtual potential temperature (calling it an adjusted temperature will work for now) will allow us to see the boundary layer. Be sure to inform them that because the boundary layer is well mixed the virtual potential temperature (or adjusted temperature) should also be well mixed and thus have little variance through out the boundary layer. You can pick any number of days that would work well for your class size. Be sure to assign each student or each group a different date, but all groups should use the 00 Z data.
4. Have students work through the instructions to find the height of the boundary level for their specific day. Be sure to check on students as they work through the handout as some students may need help interpreting the graph.

5. Once students have found the height of the boundary levels for their specific day, have them draw on their printed graph the location of the boundary layer. As students finish, have them put their graphs around the classroom in order of days so that they can see the changing height of the boundary layer.

### Explain:

1. Once all students have graphed their boundary layers ask students to make observations of the different graphs. Hopefully students will realize that the boundary layer is not always the same but varies on a day to day basis.
2. Have students work in their groups to come up with reasons as to why the boundary layer changes. Encourage students to compare the weather of the past two weeks with the boundary layer's height above ground level. Students will create PowerPoint presentations to show any relationship between past boundary layer heights and past weather conditions.

### Extend:

1. This activity could be extended with students, specifically with a meteorology class, by looking at the interaction between the boundary layer and the surface layer
2. Students could plot data from 12 Z to study the nocturnal boundary layer.

### Evaluate:

1. Students will complete each part of the lab showing, showing their finished graphs for grading.
2. Part 4 will be evaluated using the rubric. The rubric should be given to the students in advance so that expectations are clear.
3. If the extension activity is not done as a class extra credit could be awarded to those students who wish to complete the extension.

## Teacher Notes

### Part 1:

You have been asked to research a few quick facts on the boundary layer and report back to class. In the space provided below please include any interesting facts you find about the boundary layer, be sure to leave room for your classmates findings as well. **Here are some things students should find:**

*Boundary Layer = extends from the surface to between 500 and 3,000 m altitude. Located within troposphere*

*Surface Layer = comprises the bottom 10% of the Boundary Layer.*

*Mixed Layer = area of upward and downward motion of air resulting in a very well mixed layer of air. Very unstable*

*Entrainment Zone = area between the boundary layer and the free atmosphere.*

*Free Atmosphere = area above the boundary layer.*

*Cloud Layer = region within the boundary layer where clouds appear.*

*Subcloud Layer = region underneath the cloud layer*

*Nocturnal Boundary layer = portion of mixed layer that loses its buoyancy at night. Very stable*

*Residual layer = the remaining portion of the mixed layer at night*

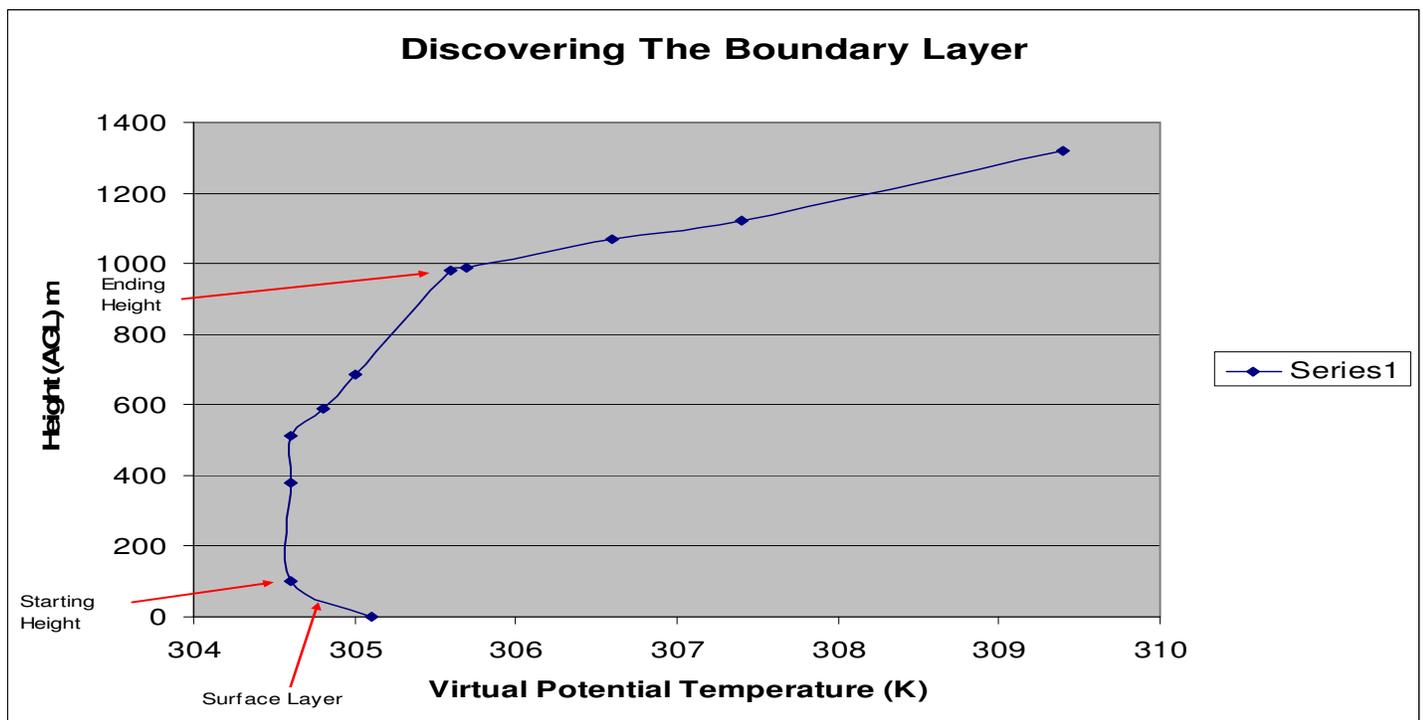
Part 2:

The written instructions for Part 2 are for a WINDOWS® -based computer. You will have to prepare instructions if you are using a different type of computer.

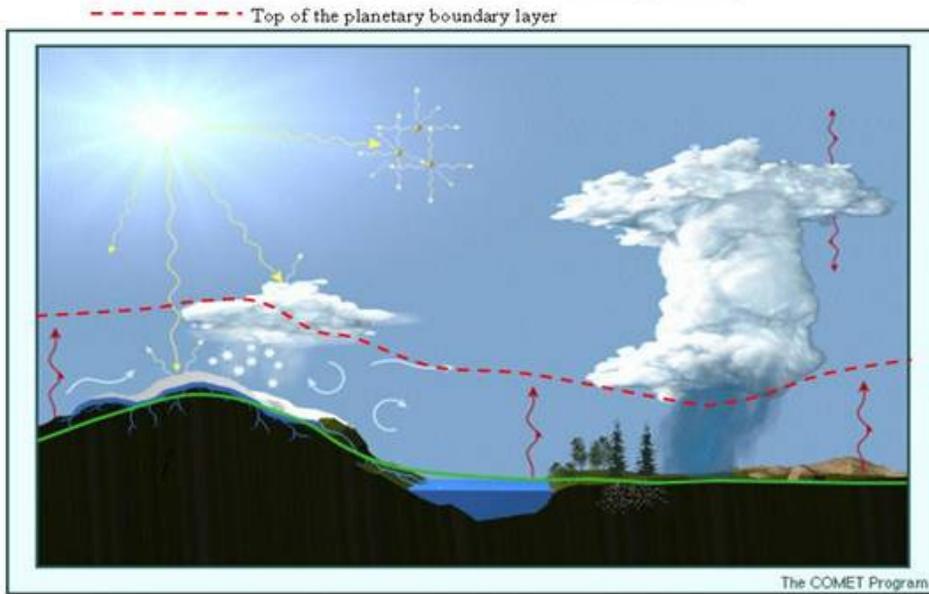
***There are a lot of steps to this process; depending on your class you can also model this activity for your students once and then help individual students if problems arise.***

1. Record your specific day and time here: Have students choose 00 Z as the time.
2. Go to the website <http://weather.uwyo.edu/upperair/sounding.html>
3. You may choose to use another website to obtain the soundings text data.
4. Make sure students use the data starting with the station elevation, which is usually the second row. You should be able to scroll to the bottom of the sounding data and find station elevation, just to verify the starting row.

***Student graph should look similar to the following graph. Arrows point to the surface layer, starting and ending height of the boundary layer.***



**Depiction of various surfaces and PBL processes**



<http://www.esrl.noaa.gov/research/themes/pbl/img/fig1.jpg>

This picture shows the top of the boundary layer and its changing height.

Parts 3 and 4:

**Have students place their graphs side by side somewhere in the room so that the days are in order. Hopefully students see the variable height of the boundary layer and begin asking questions as to why this might be the case. Discuss the grading rubric with the class.**

**Grading Rubric**

Category	4	3	2	1
Participation	Used time extremely well in lab and was focused throughout the activity	Used time well in lab and was focused for most of the activity.	Did not use time in class efficiently and was occasionally focused during the activity.	Student participation was minimal and their focus was lacking throughout the activity.

Category	4	3	2	1
Presentation	Student slides are exceptionally well designed, neat, and attractive. There is clear evidence that students made connections between boundary layer height and weather conditions.	Student slides are well designed, and relatively attractive. There is evidence that students are beginning to make connections between the boundary layer and weather conditions.	Student slides are completed but not very neat nor attractive. Students made little effort to find a relationship between the boundary layer and weather conditions.	Student slides are not complete. Students have made no effort to find a relationship between boundary layer and weather conditions.

Category	4	3	2	1
Research	Student utilized all time given to them to research the boundary layer	Student utilized most of the time given to them to research the boundary layer	Student utilized only a small portion of the time given to them to research the boundary layer	Student chose not to research the boundary layer during the time given to them.

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Period: \_\_\_\_\_

## Finding the Planetary Boundary Layer

### Part 1:

You have been asked to research a few quick facts on the meaning of “boundary layer”, especially the planetary boundary layer, and report back to the class. In the space provided below please include any interesting facts you find about the planetary boundary layer, be sure to leave room for your classmates findings as well.

### Part 2:

From now on, it will be alright to refer to the planetary boundary layer as just the “boundary layer”. Now that you have a basic understanding of what the boundary layer is, it is time to use graphing techniques to locate it. You will be using past weather data to locate the boundary layer. The directions below will lead you through the data collection and the creation of a graph.

1. Record your specific day and time here: \_\_\_\_\_
2. Go to the website <http://weather.uwyo.edu/upperair/sounding.html> or other website as directed by your teacher.
3. In the upper left hand corner set the Year, Month, Date and Time to match what you recorded earlier.
4. The stations on the map of the United States are abbreviated using three letters. There are many stations across the United States; you should pick the station with the closest distance to your school. If you have more than one station as an option your teacher will provide the three letter abbreviation for the station they would like you to use.
5. Once you have identified which station you will be using simply move the cursor so that it is located over the station, the station name should appear at the far bottom of the screen, and click on the station to retrieve the data for your day. A new window should appear with all the information you will need to locate the boundary layer.
6. When the new window appears you are ready to start collecting the data from which your graph will be made. Start with the first full row of data (usually the second row). Use the cursor to highlight the far left column of data and drag the cursor over to the far right column of the data, making sure to keep the mouse button held down.
7. Once you have the first row of information highlighted from left to right drag your cursor down until the first 14 lines of information are highlighted. The information that is now highlighted is what you want to copy. Right click your mouse and select “copy”.

8. You have one more step until we can start graphing. Click your start menu, go to “all programs,” select “accessories,” and then select “notepad.”
9. Once notepad is open simply right click in the box and select “paste.” Your copied information should appear.
10. Now that your data has been entered to notepad you will want to save. Click on the “file” tab and then “save as.” Be sure to save your data in either your personal folder or in the class folder.
11. Once your data is saved you can now open excel. Click your start menu; go to “all programs’ then open the spreadsheet software you will use to plot the data. Once the spreadsheet software is opened you can import your weather data. Your teacher can provide assistance, if necessary, to import the data into the spreadsheet.
12. After selecting “import data” you may have to import the data from the folder where you saved your weather data. Make sure to direct the spreadsheet to the correct folder!
13. Once you have found your information and opened it you will see a box titled “Import text wizard’ appear in Excel. Simply select “next’, then “next” again, then “finish’ and finally “OK” Your data should now appear in excel!!!
14. Because we are only interested in viewing the relationship between height and virtual potential temperature (adjusted temperature) we only need columns B and K. Simply highlight the entire column B, right click, and select “copy.” Once you have finished with that scroll over to column L and left click on the first row, then right click and select “paste.” Be sure that Column K and L both start in the same row number.
15. Because the height readings that we are interested in are height above ground level and not heights above sea level we need to adjust the height readings. Click on the first cell in column L and type the following: =B2-(enter value from B2 here) enter. Be sure to drag this information down to all cells in column L so that the adjusted is made for each cell.
16. Highlight column K and L and then from the top menu select the chart wizard, there should be a picture that looks like a graph in the menu.
17. A new window should now appear and you are almost finished. Under chart type select XY (scatter), under chart sub type select the second chart on the left hand side and then click “next.” The next box that appears should read “Data Range” simply click “next” to proceed to the next box. The final box should allow you to label your graph. The X axis is where we have plotted virtual potential temperature (adjusted temperature) and the Y axis is where we have graphed height above sea ground level. Be sure to give your graph a title and to include the correct units.
18. You now have your graph!!!!!!!!!!!! Look at the graph and see if you can identify the location of the boundary layer, remember to look for a well mixed area where our adjusted temperature would change only slightly with height. This should be just above the surface layer, where virtual temperature drops slightly with height. Be sure to record starting height and ending height of the boundary layer:

Starting height:\_\_\_\_\_

Ending height:\_\_\_\_\_

Part 3:

Now that you have identified the location of the boundary layer you are ready to create a graph to share with the class. Print your graph and mark the location of the boundary layer starting and ending height. You will be sharing this data with your classmates and recording your observations below:

*Observations:*

Part 4:

Your final task is to develop a PowerPoint presentation with a maximum of 10 slides that addresses possible reasons that the boundary layer's starting and ending height have changed over the past two weeks. (Hint: think of air moving and interacting with the boundary layer) Please take note of the grading rubric that will be used to score your presentation.

