

Name \_\_\_\_\_

Date \_\_\_\_\_

ERTH 465  
Fall 2015

Lab 3

**Vertical Consistency  
and Analysis of Thickness**

1. All labs are to be kept in a three hole binder. Turn in the binder when you have finished the Lab.
2. Show all work in mathematical problems. No credit given if only answer is provided.

## A. The Hypsometric Equation

The hydrostatic equation states that, for the synoptic-scale atmosphere, the vertical pressure gradient force in a column of air is balanced by the weight of that air column; thus, the vertical acceleration is zero. Note that this does not mean that there is an ABSENCE of vertical motion, but just that such motion is in steady state (not changing in time).

The hydrostatic equation is

$$\frac{\partial p}{\partial z} = -\rho g \quad (1)$$

In finite difference form, equation (1) may be written

$$\Delta z = \frac{-\Delta p}{\rho g} \quad (2)$$

which relates the "thickness" (i.e., vertical extent) of an air column to the change in pressure per unit mass in that air column. Since density can not be measured directly, the equation of state

$$p = \rho R T \quad (3)$$

may be substituted into (1). If the air column is taken to be that which extends from 1000 mb to 500 mb, the following results in finite difference form

$$\Delta z = z_{500} - z_{1000} = \frac{R}{g} \ln 2 \bar{T} \quad (4)$$

where  $z_{500}$  is the 500 mb height and  $z_{1000}$  is the 1000 mb height. Equation (4) states the thickness of the 1000-500 mb layer is directly proportional to the mean (virtual) temperature of that layer. The general form of equation (4) is known as the HYPSONOMETRIC EQUATION.

## B. Questions and Exercises

Question 1: Explain by using the physical interpretation of the hypsometric relation why the mean height of the tropopause (at the 200 mb level) is 16 km at the equator, 12 km in the middle latitudes and 8 km at the poles. What assumptions did you have to make to answer the question (Hint: one assumption is that the tropopause is near the 200 mb level all the time.)

- Question 2:
- (a) Explain why cyclones with asymmetric temperature distributions are found progressively tilted towards cold air with increasing elevation. Illustrate with schematic cross-sections.
  - (b) Explain why surface cyclones with warm cores (thermal lows) weaken with height but are “vertically stacked”. Illustrate with schematic cross-sections.

### **Exercise 1:** Thickness Maps: Graphical Subtraction

Bluestein, pp. 186-187.

Djuric, Fig. 6-1, p. 89. Appendix 1.

Figure 1a is the 500 mb chart and Fig. 1b the 1000 mb chart (heights in m at 60 m interval) for a day in which a surface low with an asymmetric temperature distribution can be found in the Great Lakes area. Fig. 2a is the 500 mb chart and Fig. 2b the 1000 mb chart (heights in m at 30 m interval) for a day in which a warm core low, a hurricane, was present in the Atlantic.

Procedure discussed in class.

- (a) Prepare thickness charts for each of these models to show the horizontal distribution of 1000-500 mb thickness in decameters. (See Appendix 1)
- (b) Assuming the 1000 mb winds are geostrophic, show the type of advection through the 1000-500 mb layer. The color convection is red arrows indicate warm advection, blue arrows indicate cold advection. One arrow is placed at each intersection of the 1000 mb contours and the thickness lines. Motion is assumed parallel to the 1000 mb contours. Motion from high thickness is considered warm advection and vice versa.

- (c) Given your answer to Question 1 and your procedure/results from Homework 2, determine the mean temperature which corresponds to each thickness contour. Label each thickness contour with its value in decameters and in mean 1000-500 mb temperature.

## Exercise 2

Taking the derivative with respect to time of both sides of equation (4) yields:

(5)

(Fill in the resulting modified equation above.)

In the spot forecasting portion of the course, you will need to have a way to quickly obtain a temperature change on the basis of the ETA forecast thickness change. Design an Excel Spreadsheet that computes the thickness and modify it so that you may use it both to (a) compute thickness of a layer if you know the mean temperature of the layer and vice versa; and, (b) to compute the thickness change experienced by a layer if you know the temperature change experienced by the layer and vice versa (to be used in the spot forecasting contest).

**NO BORROWING ANYONE ELSE'S WORK FOR THIS.**

After making sure it works, put a copy in your subdirectory in the /courses/M430 folder.

## Appendix 1. Procedure: **Thickness Maps: Graphical Subtraction**

1. Obtain a hard copy (or construct one) of the 1000 mb heights contoured at 60 or 30 meter intervals. (Note: negative heights refer to the 1000 mb heights obtained hysometrically from surface temperatures and pressures, where the integration is from 1000 mb to the surface pressure). Enlarge the contour values in black, so that they will be clearly visible.
2. (a) Obtain a transparency overlay of the 500 mb heights analyzed at 60 meter intervals, standard contours, AND AT THE SAME SCALE as the 1000 mb height map.  
  
(b) Highlight the 500 mb contours in a color different than red or black, and make sure the contour values are clearly visible by enlarging them in the same color.
3. Place the 500 mb transparent overlay in register on top of the 1000 mb chart.
4. Obtain a clean acetate and red grease pencil.
5. (a) Overlay (4) on (3).  
  
(b) At each intersection of 1000 and 500 mb contours plot a small red "X".  
  
(c) Perform a subtraction of heights at a few locations (as shown in class) and plot the value of the difference (the 1000-500 mb thickness) in red to the upper right of the respective red "X".
6. Begin drawing a thickness contour (red dashed) as shown in class.  
  
(a) Thickness contours can cross 1000 or 500 mb contours only at intersections (as marked by your red "X"'s).  
  
(b) If you are drawing a thickness contour "down the gradient" (i.e., from higher values of heights to lower values of heights), remember that the next intersection to be crossed will be the one on the next lower 1000 and 500 mb height contours, as shown in class.  
  
(c) When you are satisfied with your analysis, transfer final copy to your hard copy 1000 mb height map.