Review of the Thermal Wind

Note: The total points on this lab are 50 points, but it will be divided by 2 to keep it consistent with the contribution from the other labs.

Question 1

1.1) Starting with the horizontal momentum equations and using pressure as a vertical coordinate, derive the thermal wind equations. Show all your working and assumptions (7 points)

1.2) Write the thermal wind equation in terms of the thickness gradient. Show all your assumptions and working (3 points)

[10 points]

Question 2

The following questions are based on the geostrophic wind changes shown below. These constants may be useful in your calculations: \( f = 10^{-4} \) s\(^{-1}\), \( g = 10 \) m.s\(^{-2}\), \( R_d = 287 \) J K\(^{-1}\) kg\(^{-1}\)

The magnitude of the longer and shorter wind vectors may be taken to be 50 m.s\(^{-1}\) and 30 m.s\(^{-1}\), respectively, and the angle between the vectors in (a) and (b) is 60\(^\circ\).

6.1 Calculate the thermal wind at (A), (B) and (C). (3 points)

6.2 Draw a vector indicating the thermal wind on each figure. (3 points)

6.3 Calculate the thickness gradient for each case. (3 points)

6.4 Calculate the 500-1000 mb mean temperature gradient for each case. (3 points)

6.5 Draw in lines of constant thickness on each figure. Label the lines \( Z_1, Z_2 \ldots Z_n \) where \( Z_1 > Z_2 > \ldots > Z_n \) (3 points)

6.6 Give a mathematical expression for positive, negative and neutral temperature advection. (3 points)

6.7 Show the direction of the horizontal temperature gradient on each figure. (3 points)

6.8 Discuss whether warm advection, cold advection or neutral advection is occurring in each case (3)

6.9 Should the gradient of the temperature field in figure (c) be reversed discuss how the geostrophic winds at the 1000 and 500 mb levels would change, if they do change. (3 points)

[27 points]
a)

\[ V_{g1000} \]

B

A

\[ V_{g500} \]

b)

\[ V_{g1000} \]

B

A

\[ V_{g500} \]

\[ V_{g500} \]

c)

\[ V_{g1000} \]

C

\[ V_{g500} \]
Question 3

3.1) Indicate on the 700 mb map the regions where warm air advection is occurring (3 points)
3.2) Using the 850 and 500 mb maps, determine whether the geostrophic winds are backing or veering with height at these locations. Do your answers agree with thermal wind theory? (3 points)

3.3) On the 500 mb map, roughly sketch the thermal wind vectors in the region of warm air advection (3 points)
3.4) Look at the 700 mb map. The thermal wind vector should roughly be aligned like the temperature contours. Are they? If not discuss why. (2 points)

3.5) Remember that warm advection favors upward motion, and is therefore a region more favorable for cloud formation. Using an appropriate satellite image, comment on whether or not cloud cover does occur in this region. Please attach a copy of the satellite image (2 points)