San Francisco State University
Department of Earth & Climate Sciences

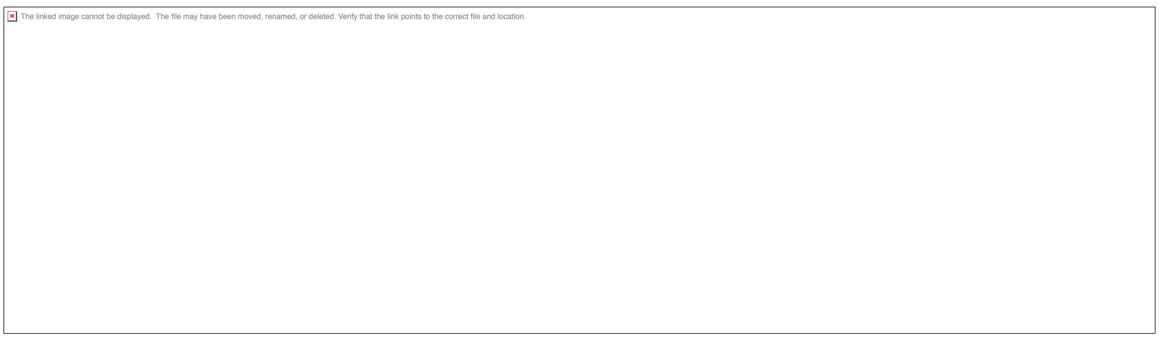
Name ___________________________________

ERTH 465: Synoptic and Mesoscale Meteorology of the Middle Latitudes

Laboratory Exercise 1:
Temperature Tendency Equation and Temperature Advection (100 pts)

A. Background

Advection is one way in which temperatures at a stationary observation site may be changed. Temperature advection is one term in a concept equation that will help you understand how temperatures at a location change. We derived this equation in ERTH 260.



In algebraic form, the Temperature Tendency Equation can be written:

Term A = Term B + Term C

Using algebraic symbols

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} + (-V\ \Delta T/\Delta s - w\ \Delta T/\Delta z) \quad (1)$$

where $(-V\ \Delta T/\Delta s)$ is the temperature change to horizontal advection and s $(-\ w\ \Delta T/\Delta z)$ is the temperature change due to vertical advection.

At the very bottom of the atmosphere, vertical motions are zero. Hence, if the weather station is at the ground equation (1) becomes simplified.

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} + (-V\ \Delta T/\Delta s) \quad (2a)$$

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} - V\ \Delta T/\Delta s \quad (2b)$$

Equation 2b is known as the Simplified Temperature Tendency equation in natural coordinates.

where T= temperature, t= time, V= mean wind speed along the portion of a streamline, s, along which the advection is to be evaluated and the subscript air parcel means with respect to the air parcel.

Questions

1. What are the SI (mks) units of each of the terms in equation (2b)? (15 pts)

   Term A ___**[Temp] [time]$^{-1}$ in MKS: $K^o\ s^{-1}$ or $C^o\ s^{-1}$**

   Term B _______**[Temp] [time]$^{-1}$ in MKS: $K^o\ s^{-1}$ or $C^o\ s^{-1}$**

   Term C ____[dist] [time]$^{-1}$ [Temp] [dist]$^{-1}$_**[Temp] [time]$^{-1}$ in MKS: $K^o\ s^{-1}$ or $C^o\ s^{-1}$**

2. Which term in (2b) estimates the temperature changes at the local station caused by horizontal motion (advection) of colder or warmer air to the station (thus, replacing the air there formerly and causing a temperature change). (5 pts)

   Term C estimates the temperature changes at the local station caused by horizontal motion (advection) of colder or warmer air to the station (thus, replacing the air there formerly and causing a temperature change).

3. Which term in (2b) estimates the temperature changes experienced by a thermometer at a station at a fixed location (sometimes called the "temperature tendency.") Explain. (5 pts)

   Term A estimates the temperature changes experienced by a thermometer at a station at a fixed location (sometimes called the "temperature tendency.")

4. Which term in (2b) estimates the temperature changes experienced by air parcels themselves, whether they are moving or not (for example, due to conductional heating or cooling, latent heat release, compressional warming due to sinking etc.). Explain. (5 pts)

   Term B estimates the temperature changes experienced by air parcels as they move along (for example, due to conductional heating or cooling, latent heat release, compressional warming due to sinking etc.)

5. Suppose winds were calm. Explain which term in (2b) would be zero. Rewrite Equation (2b) for this case. (5 pts)

   Term C would be zero because advection is the product of a wind speed with a gradient. If the wind is calm, this term is zero. Hence, the local change would entirely be due to the temperature changes experienced by the air parcels themselves.

   $$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels}$$

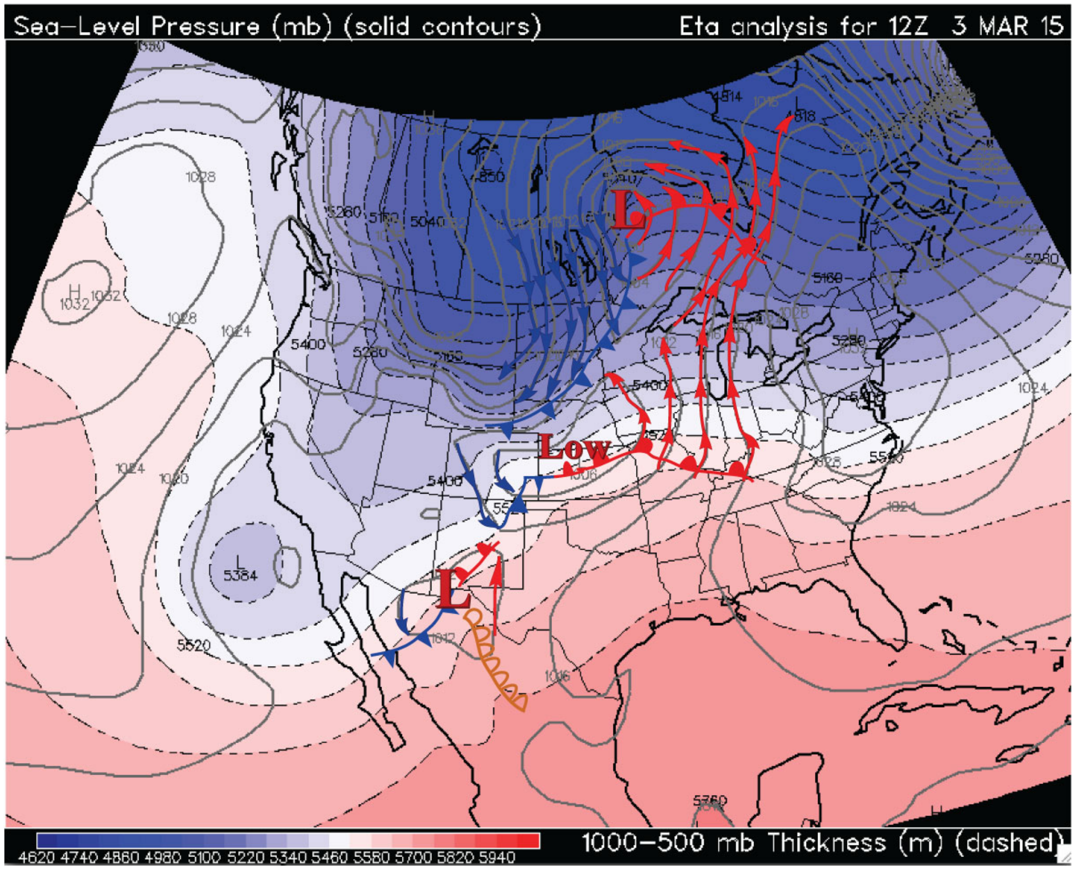
6. Suppose the changes in temperature experienced by air parcels themselves are very small on a given day in which a wave cyclone with substantial warm advection ahead of the warm front is affecting a weather station. Simplify Equation (2b) for this case. (5 pts)

   In this case, the total change would neglected on an order of magnitude basis. Hence, the local tendency or local changes would be entirely due to horizontal advection.

   $\mathbf{(\Delta T/\Delta t)_{local} = -V\ \Delta T/\Delta s}$

7. In ERTH 260, you learned that surface temperature advection can be visualized conceptually by drawing "advection arrows" on plots showing isobars with 1000-500 mb thickness (or isotherms) superimposed. The technique involves assuming the surface wind is geostrophic and drawing an arrow tangent to the isobars at each intersection with a thickness contour, colored red for warm and blue for cold advection.

   On the distributed copy of the graphic shown here,surface isobars with overlain 1000-500 mb thickness contours, to the best of your ability draw temperature advection arrows at each intersection of thickness contours with isobars, as explained above and in class. Complete your analysis in the boxed domain only. (35 pts)



8. A first pass position of surface warm fronts can be estimated on the warm air side of the greatest packing of warm advection arrows. Draw a warm front (using correct symbols, symbol orientation, and color convention) on the advection arrow analysis you completed above. (10 pts)

9. Given our discussions in class, rewrite equation (1) above, using correct calculus symbols. (15 pts)

$$\frac{\partial T}{\partial t} = \frac{DT}{Dt} - \vec{V} \bullet \nabla T$$

where the term on the far right is the three dimensional temperature advection.

$$-\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right):$$