Weather Analysis and Forecasting
ATMO 574
Homework #2: Synoptic Analysis of a Significant Weather Event
Analysis of upper-air data

Part 1: Standard upper air plots

You are provided GEMPAK files with model zero hour analysis fields at standard pressure levels for the same significant weather event in Homework #1. Plot the following on a white background:

250-mb: Map
Geopotential heights at 60 m intervals (black)
Isotachs at 25 knot intervals (dashed blue or shaded)

500-mb: Map #1
Geopotential heights at 60 m intervals (black)
Isotachs at 25 knot intervals (dashed blue or shaded)

500-mb: Map #2
Geopotential heights at 60 m intervals (black)
1000 to 500-mb thickness at 60m intervals (dashed red)

700-mb
Geopoential heights at 30 m intervals (black)
Isotherms at 5 degree Celsius intervals (dashed red)

Given the surface analysis you performed in the previous assignment:

- Discuss how the upper-air analysis bears on determining the stage of development within the Norwegian cyclone model. Does this additional information modify your initial conclusions in the first assignment? Why or why not?
- Does the upper-air trough have a positive, negative, or neutral tilt? Is there any evidence of jet streaks? Why are these features important to diagnose?

Part 2: Hand calculations from upper-air maps

Do the following calculations for Topeka, Kansas (TOP). Make sure all variables in calculations and final answers have the appropriate SI units.

Balanced wind solutions:

Using your isotach maps at 500-mb, calculate geostrophic, gradient, and cyclostrophic wind solutions. Consider a natural coordinate system with a directional vector **n** normal to geopotential height lines and **s** parallel to geopotential height lines. Use a reasonable synoptic-scale distance about the station to calculate spatial derivative quantities (~1000 km) with a finite differencing approach, as demonstrated in lecture.

How does your calculated winds compare to the actual observed winds at these locations? Which value is closest to observed and why? How do your results bear on upper-level vertical motion in relation to this cyclone?

Thermal wind diagnosis:

Using your 1000-mb and 500-mb geopotential height maps, calculate the thermal wind in the 1000-mb to 500-mb layer using vector subtraction. Express your answer in two ways: 1) with zonal (u_T) and meridional (v_T) components and 2) the thermal wind speed and direction.

Next, use the thermal wind information to calculate the horizontal temperature gradient in the 1000-mb to 500-mb layer at Topeka using the thermal wind equation. You may assume R is equal to the dry gas constant for the atmosphere in these calculations. Express your answer in two ways: 1) Vector components in x and y directions and 2) magnitude and direction. How does you answer compare to actual measured temperature gradient at 700-mb?

Based on your analysis, are the winds backing or veering at this location? How does this relate to temperature advection relative to where Topeka is located within this mid-latitude cyclone?

Vorticity and divergence:

Calculate relative vorticity and divergence, again considering a natural coordinate system as shown in class. What are the most predominant kinematic flow properties at these geographic locations, based on your results?

Part 3: Diagnosis of terms in the QG-omega equation

Vorticity and vorticity advection: Plot an additional 500-mb map with geopotential height (black lines) and relative vorticity (shaded). Indicate positive (negative) vorticity maxima with X (N). Superimpose on your map (with dashed lines) the vorticity advection. Use the example class templates provided to suggest reasonable contouring intervals.

Temperature advection: Plot an additional 700-mb map temperature identical to Part 1, superimposing temperature advection (with colored dashed lines).

QG-Vertical motion diagnosis: Considering vorticity advection and temperature advection, identify and discuss 1) the specific geographic regions on your map where both factors are synergistically contributing to either rising or sinking motion and 2) where that is occurring within the idealized structure of mid-latitude cyclone, and 3) the type(s) of surface weather observed at these places. Do you think diabatic heating may be substantially affecting the vertical motion in this case? Why or why not?

Part 4: Q-vector analysis in the vicinity of the front

Using the information from your 700-mb analysis, compute the Q-vector at Topeka, Kansas. Use the following equations to compute the Q-vector in the x and y components and the magnitude and direction (show your work):

$$-\frac{\Delta u_g}{\Delta x}\frac{\Delta \theta}{\Delta x}-\frac{\Delta v_g}{\Delta x}\frac{\Delta \theta}{\Delta y}=Q_x$$

$$-\frac{\Delta u_g}{\Delta y}\frac{\Delta \theta}{\Delta x}-\frac{\Delta v_g}{\Delta y}\frac{\Delta \theta}{\Delta y}=Q_y$$

Hints

- You will need to calculate geostrophic winds first in x and y directions
- Use a reasonable synoptic-scale distance to compute spatial derivatives
- Express the Q-vector units as K m s^{-1}.

What is the orientation of the vector relative to the front? Does the Q-vector indicate a frontogenetic or frontolytic ageostrophic circulation? Why is this important?

Extra credit: Plot the map of 700-mb Q-vectors, following the template provided on the class website. Discuss how the patterns of Q-vectors and Q-vector convergence bear on synoptic-scale vertical motion. Discuss the relative strengths and weaknesses of using Q-vectors as compared to the approach of analyzing the individual component terms of the QG omega equation as in Part 3.

Due October 24