Fuelberg

Question about Senior Level Synoptic Meteorology---Prof. Fuelberg

The following questions were taken from a recent exam in Met 4500C. Therefore, Ph.D. candidates should be able to answer them with ease.

Answer **ALL** of the questions. It should take you about 1hour 15 minutes to complete them (less than the time it took the seniors). Show **ALL** of your work in the blue book.

1. (10) On Map 1 at point X (Omaha, NE) where the wind is from 240 deg at 25 kt, calculate horizontal temperature advection in units of deg C day^{-1}. Use any valid technique that you like. Show your coordinate axes on the chart. Let $\Delta x = \Delta y = \Delta s = \Delta n = 1$ cm = 200 km. (If you do not have a straight edge marked in cm, ask the proctor for one.)

$-V \cdot \nabla T = -\left(u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y}\right)$

2. Indicate the sign of **geostrophic temperature advection** in Map 1. At each intersection of an isotherm and a height contour, you should place a red "cherry" or a blue "berry", depending on whether there is warm or cold geostrophic temperature advection. The isotherms are at intervals of 3°C.

3. Give signs for the partial derivatives at the points indicated on the enclosed analysis. Determine these signs by inspection—no calculations are needed. "Z" represents height at 500 mb

Is $\partial Z/\partial y$ positive, negative or zero at Point A? —

Is $\partial Z/\partial x$ positive, negative, or zero at Point B? +

Is $\partial Z^2/\partial x^2$ positive, negative, or zero at Point C? ∅

Is $\partial Z/\partial y$ positive, negative, or zero at Point D? barely +, almost ∅

$\zeta = \frac{\partial V}{\partial x} - \frac{\partial u}{\partial y} = \frac{V}{r} - \frac{\partial V}{\partial n}$ in natural coord. $\frac{V}{r}$ = curvature $-\frac{\partial V}{\partial n}$ = (lateral/normal) Shear

4. Answer the following questions by inspection—not by calculations.

Does lateral (i.e., normal) shear lead to positive or negative vorticity at Point B? +

Does curvature lead to positive or negative vorticity at Point F? −

Does diffluence lead to positive or negative divergence at Point A? ? more info.
upper air sfc.

Does curvature lead to positive or negative vorticity at Point C? +

Indicate in red pencil the height gradient vector at Point B. ✓

5. (6) Write the partial derivative expression for relative vorticity that involves the u and v wind components. Then, write the corresponding u, v vorticity expression that employs centered finite differences. Indicate your subscripts carefully. $\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

6. Give typical **units** (not values) for the terms blow. The units will involve combinations of any of the following:

$\frac{km}{sec.} \times \frac{1}{km} = \frac{1}{sec} = sec^{-1}$

deg C, deg C^{-1}, sec, sec^{-1}, km, km^{-1}, day, day^{-1},

a. vorticity sec^{-1}

b. temperature advection $^oC * day^{-1}$ or $\frac{^oC}{day}$

c. radius of curvature km^{-1}

d. temperature gradient $^oC * km^{-1}$ or $\frac{^oC}{km}$

e. shearing deformation sec^{-1}

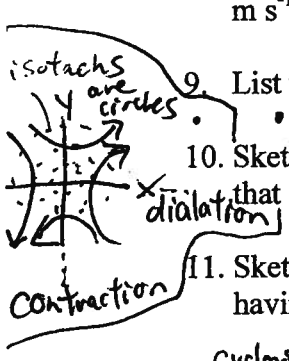
7. a. What is meant by a **conformal** map projection? - preserves wind fields - areas NOT preserved, smaller shapes preserved better than larger ones.

b. How can one determine at a glance whether a projection is conformal? (1) lat/lon lines are ⊥ (2) - Longitude lines are straight

c. What is meant by the term **standard parallel** of a conformal conic map projection? ? - parallel at which the image intersects the sphere

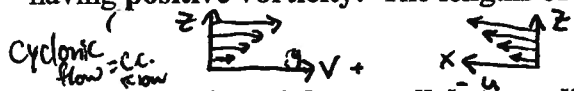
8. The wind is blowing from 30 deg at 10 knots. Calculate the u and v wind components, with units of m s^{-1}. Show all of you work in the blue book. $u = -spd \times \sin\alpha$ (wind dir.)
$v = -spd \times \cos\alpha$

9. List the five fundamental types of flow into which the actual flow can be de-composed.
• Translation • Vorticity • Divergence • Stretching Deformation • Shearing Deform •



10. Sketch streamlines for a case of pure **positive shearing deformation**. Superimpose several isotachs that are labeled in m s^{-1}. Label the axes of contraction and dilatation.

11. Sketch several **straight** streamlines (no curvature should be indicated) showing the straight flow having **positive vorticity**. The lengths of your streamlines will indicate the wind speed.



$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

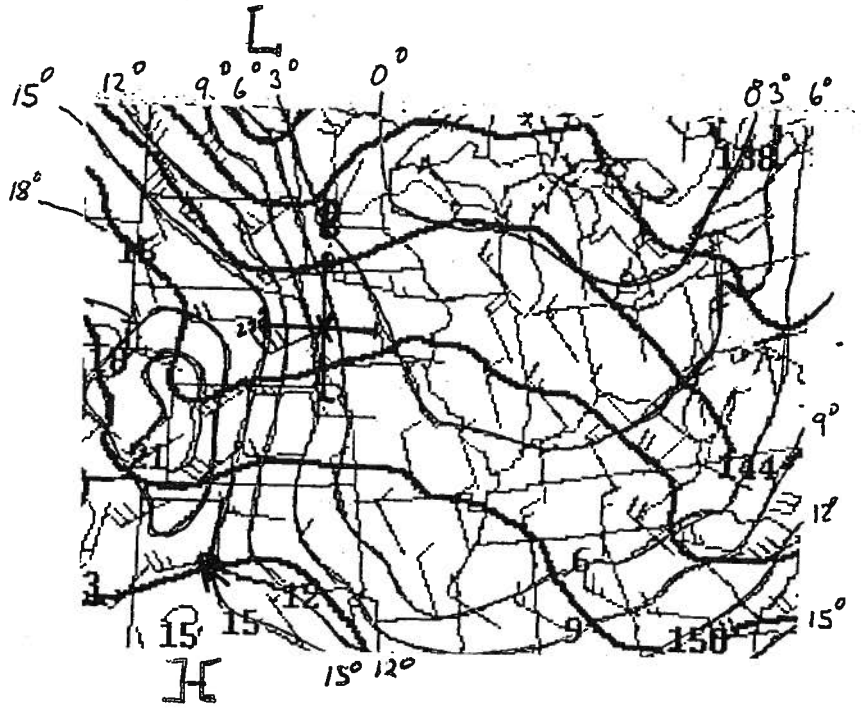
12. Sketch several **straight, parallel streamlines** showing **horizontal positive divergence**. The lengths of your streamlines will indicate the wind speed.

sfc.

13. Is the following rule for streamlines TRUE or FALSE (circle one answer)?

Only if the wind speed is calm at a point can streamlines approach each other at a finite (i.e., large) angle.

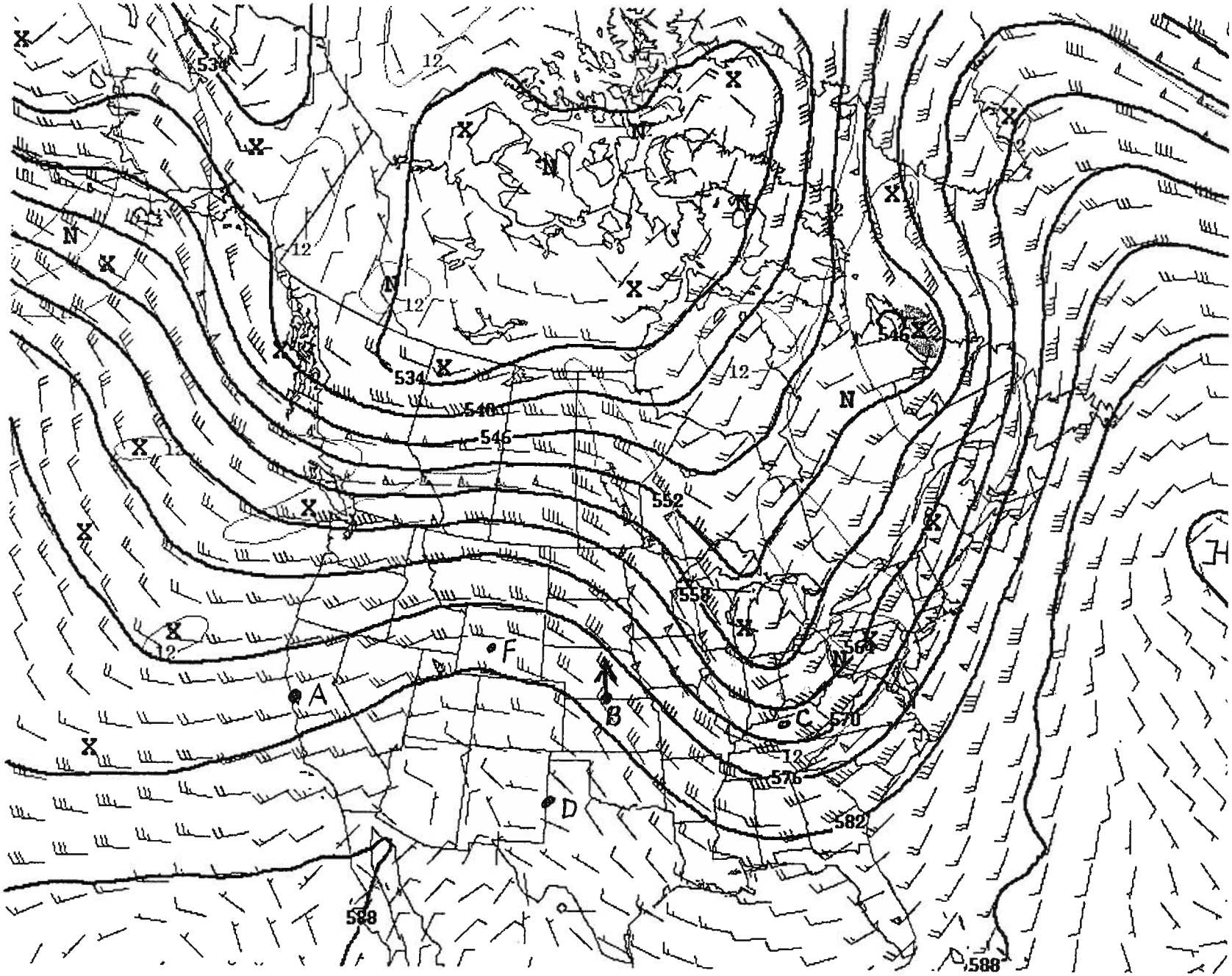
-1 CP



Map 1

Bold lines are height contours

Thin lines are isotherms


061001/0000V048 NGM 500 MB HGT, GEO ABS VORTICITY
534
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582
588
A
B
C
D
F
H

Fuelberg

Over the past years, we have calculated trajectories as part of our research. This question is designed to test your knowledge of those trajectories.

What is a trajectory? How does it differ from a streamline? an instant in time.
- future or past + good for computers analysis.

What are the underlying assumptions behind isobaric trajectories, isentropic trajectories, and kinematic trajectories? You will want to compare and contrast these three types.
pressure
variation w/dist. regardless of direction - good in nat. coord.

What are the advantages and disadvantages of the above three types of trajectories?

We are often asked how reliable trajectories are? How do you answer—a long answer is best.

Provide any additional information that shows your knowledge of trajectories.

Prof. Fuelberg--The following are questions from recent exams in **MET 2700**. Everyone should be able to answer them. Answer all five of the questions. You will probably need about 45 min. to complete the questions. You will need a calculator

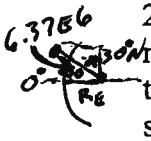
1. A classroom's dimensions are 10 m x 8 m x 4 m. The air inside is totally dry (no vapor). The air temperature is 24°C, and the pressure is 1000 hPa. The gas constant for dry air is 287 J K^{-1} kg^{-1}. What is the density of this air in SI units? Show all of your work, including all of your units and unit conversions.

$p = \rho R T$

$1000\ hPa = \rho \cdot (287\ J\ kg^{-1}\ K^{-1}) \cdot (273\ K$

$10 \times 8 \times 4$ Vol. $= l \cdot w \cdot h$

Vol. $= 320\ m^3$

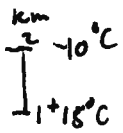


2. How many days would it take a hot air balloon traveling eastward along 30°N at a mean speed of 15 m s^{-1} to circumnavigate the Earth? The radius from the center of the Earth to the altitude of the balloon is 6.37 x 10^6 m. Include a sketch of the situation and show all of your work, including all units and unit conversions. Your answer should be in days.

$15 \frac{m}{s} * \frac{3600 \times 24\ s}{1\ day} = 1.296E6 \frac{m}{day}$ $V = \frac{d}{t}$ $1.296E6 \frac{m}{day} = \frac{2.0E7\ m}{x\ day}$

$C = 2\pi \sin(30) * r = 2.0E7\ m$

$x = 15.44$ days



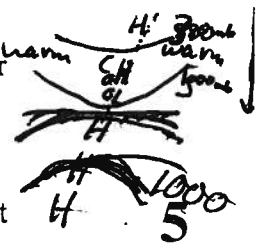
3. The temperature at a height of 2 km is -10°C, and the temperature at a height of 1 km is 15°C. Calculate the lapse rate for this layer in SI units.

$-25\ ^{\circ}C/km = -25\ ^{\circ}K/km$

4. How does the intensity of a cold core anticyclone vary with increasing height? First, state your answer. Then prove your answer by drawing a cross section and explaining that sketch along with any necessary concepts—especially thickness. Your sketch must contain both isotherms and isobars that are labeled with example values.

intensity dec. w/ height

Isobars space out more w/ height



$\theta = T\left(\frac{P_s}{P}\right)^{R/c_p}$

5. Calculate the potential temperature of a parcel having a temperature of 10 deg C at a pressure of 850 mb. Show all of your work. $\theta = 283\ K \left(\frac{1000\ hPa}{850\ hPa}\right)^{287\ J\ kg^{-1}\ K^{-1}/c_p}$

Prof. Fuelberg—Questions from **Mesometeorology.** Pick **any five** of the six questions. I am looking for full complete answers.

1. Compare and contrast conditional symmetric instability (CSI) with a) hydrostatic instability and b) inertial instability. No equations are necessary, but you should give full word explanations that are worthy of a doctoral candidate.

2. Sketch a cross section through a series of horizontal convective rolls. Indicate regions where rising and sinking air and clouds are expected. Explain how HCRs influence convection along the sea breeze front in Florida (and elsewhere).

3. Explain how the shape of a coastline (bays or capes) affects the sea breeze and resulting deep convection. Why does this effect occur?

4. List and briefly describe the major factors that adversely affect precipitation estimation from radar.

5. Interactions between a gust front and the vertical wind shear of its environment can lead to new cell development (RKW Theory). **Discuss** how the optimum combination of these two sources of horizontal vorticity can lead to new cell development. Also, mention some non-optimum scenarios.

6. What is meant by "baroclinic generation" of horizontal vorticity? Explain the role that it appears to play in the formation of a mesocyclone. Put that discussion in the context of all the processes leading to mesocyclone formation.

Describe the following types of deep convection:

Non severe storm
Multicell severe storm complex
Supercell storm

For each of these storm types, be sure to discuss the following items:

Stability and wind shear environments in which each storm occurs
Life cycle of each storm type
Major structural characteristics of each storm type
Appropriate sketches showing features of each storm type

Prof. Fuelberg—Questions from **Synoptic Meteorology**. Answer all five of the questions. This will require approximately 45 min. to complete.

1. A layer of air is very humid at its bottom and very dry at its top. The layer originally contains a very weak temperature inversion.

What is the likely sign (+, -, or 0) of $\partial\theta e/\partial z$? Explain your reasoning. θe dec w/altitude

If this layer is lifted until all parts are saturated, how will its ending lapse rate compare to the saturated adiabatic lapse rate?

Explain thoroughly why the lapse rate changed as you described above.

2. Explain how one graphically determines the Lifting Condensation Level (LCL) on a thermodynamic diagram (the various lines that one follows, etc.) THEN, explain **why** one follows this procedure, i.e., what is the physical basis for the procedure, what parameters do parcels conserve, etc.

3. Answer the following questions by inspection—not by calculations. The various locations are given on the enclosed 850 hPa analysis.

Does lateral (i.e., normal) shear lead to positive or negative vorticity at Point E in New York? _____

Does curvature lead to positive or negative vorticity at Point A (northeast of Maine)? _____

Does diffluence lead to positive or negative divergence at Point F in southwest Canada? _____

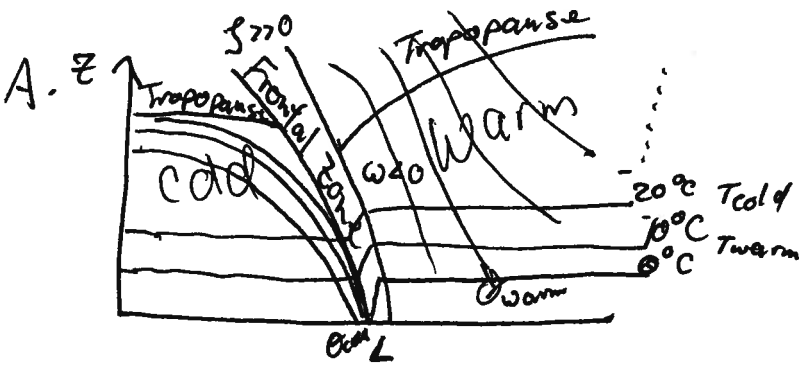
Does curvature lead to positive or negative vorticity at Point G over the North Pacific Ocean? _____

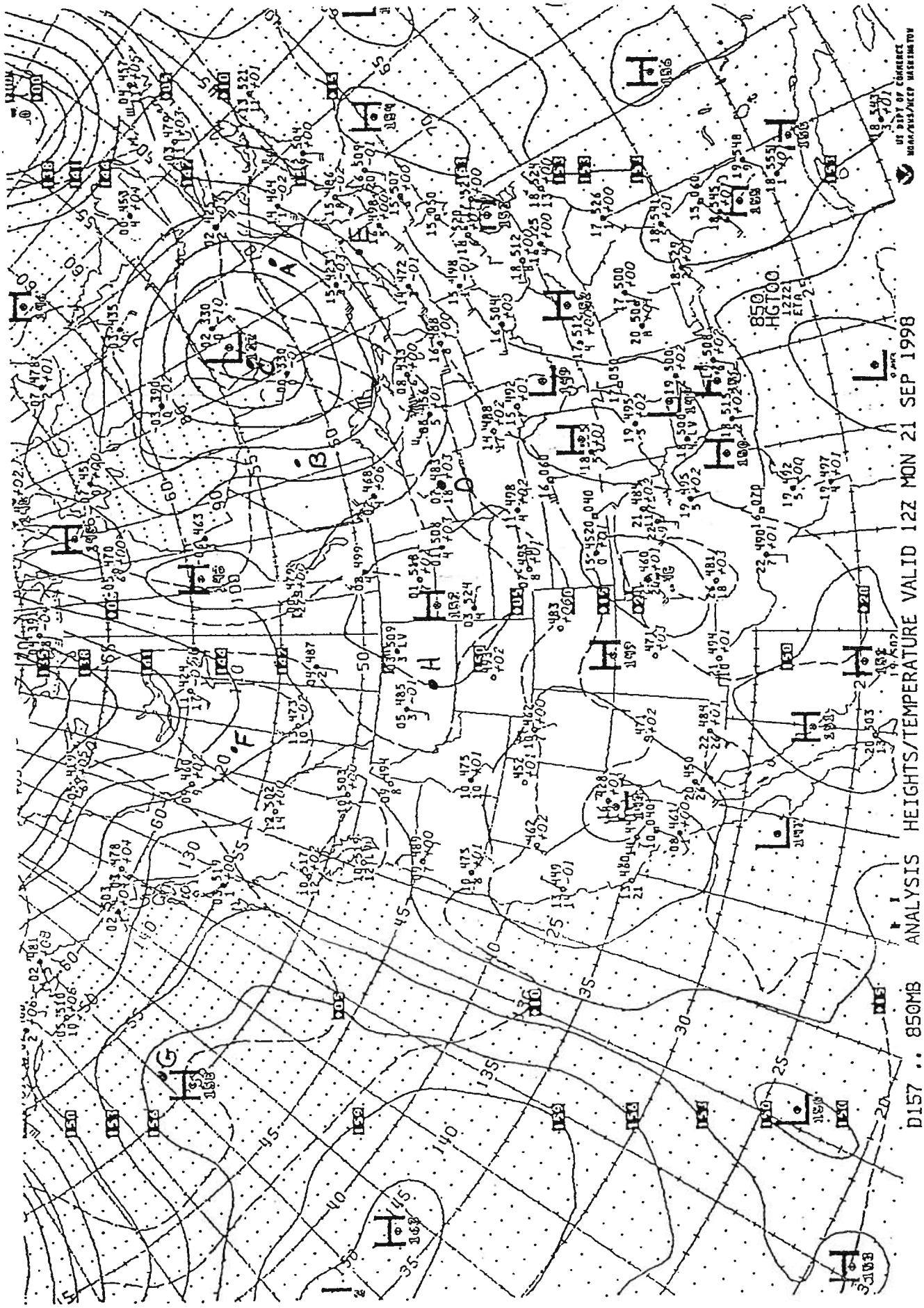
Indicate in red pencil the height gradient vector at Point H over Montana.

4. Draw an x-y (Cartesian) coordinate system and then superimpose streamlines for a case of pure positive shearing deformation. Also, superimpose several isotachs that are labeled in m/s. Label the axes of contraction and dilatation.

5. a. Draw a cross section through a cold front. Label the cold side and the warm side of the front. Then superimpose two isotherms (label them T_{cold} and T_{warm}) that begin in the warm air, pass through the front, and then pass into the cold air. Also, superimpose two isentropes (label them θ_{warm} and θ_{cold}) that pass through the front as done above.

5. b. Explain how isentropic upglide produces precipitation around warm fronts. As part of your answer, you will need to refer to your cross section through a warm front from question 5a. Explain the upglide process based on this sketch and thermodynamic principles.




D157 .. 850MB ANALYSIS HEIGHTS/TEMPERATURE VALID 12Z MON 21 SEP 1998
850 HGT00
A
B
C
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E
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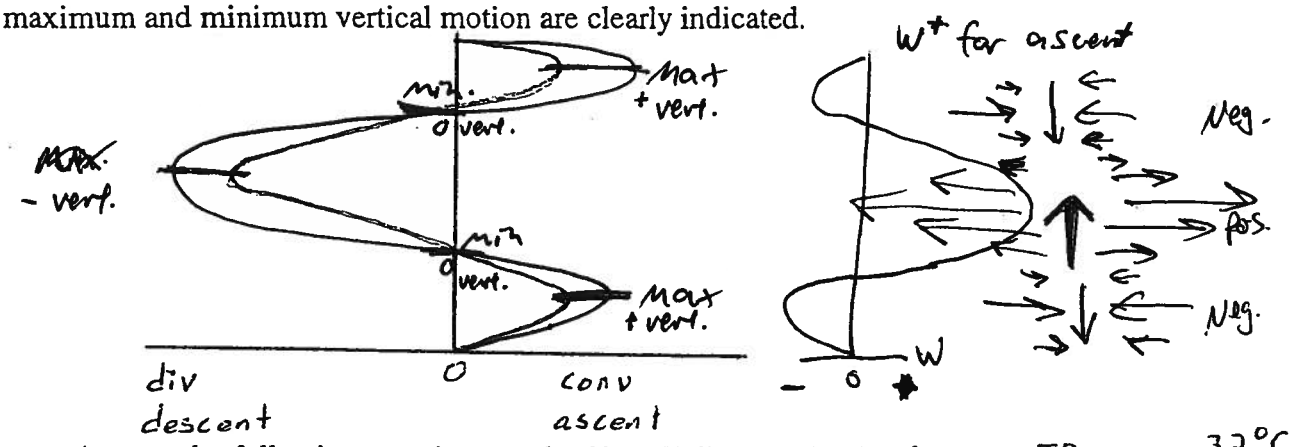
H

Basic Synoptic Meteorology

Dr. Fuelberg

Answer all three of the questions below.

The graph below is a plot of horizontal divergence as a function of height. Superimpose the profile of **vertical motion** (w). Make sure that the altitudes of maximum and minimum vertical motion are clearly indicated.



Answer the following questions on the Skew T diagram that is attached. $TD_{700} = -32°C$

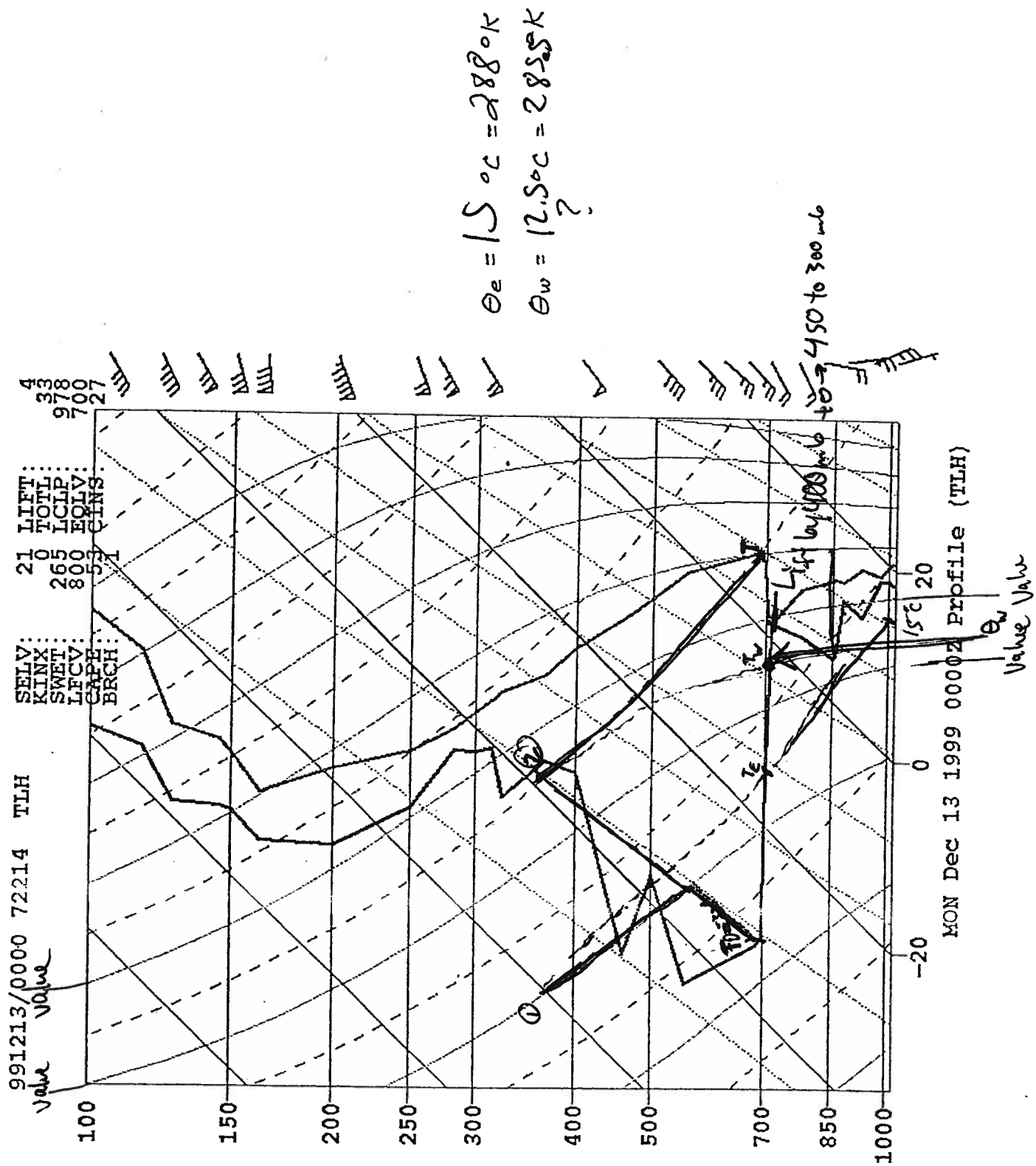
a) Darken the process lines showing how to find θe at 700 mb. Write the answer at the right of the diagram. ✓

b) Darken the process lines showing lifting of the 850-700 mb layer by 400 mb. Draw a red line showing the temperature lapse rate after this lifting (as done in lab).

c) Darken the lines showing how to find θw at 700 mb. Write the answer at the right of the diagram. ✓

inc. in intensity

How does the intensity of a **warm core anticyclone** vary with height? Draw a diagram showing isobars, two isotherms (labeled cold and warm), and thicknesses that depicts this situation. Now, **explain** this situation **thoroughly**, referring to your diagram.


$\theta_e = 15^{\circ}C = 288^{\circ}K$
$\theta_w = 12.5^{\circ}C = 285.5^{\circ}K$
?
450 to 300 mb
Lift by 400 mb
991213/0000 72214 TLH
Value Value
SELV: 21
KINX: 0
SWET: 265
LFCV: 800
CAPE: 53
BRCH: .1
LIFT: 4
TOTL: 33
LCLP: 978
EQLV: 700
CINS: 27
100
150
200
250
300
400
500
700
850
1000
20
0
-20
15°C
MON Dec 13 1999 00002 Profile (TLH)
θ_w
Value Value

Basic Synoptic Meteorology Dr. Fuelberg

Answer each of the three parts below. Be sure to **DISCUSS** the physical reasoning for your answers.

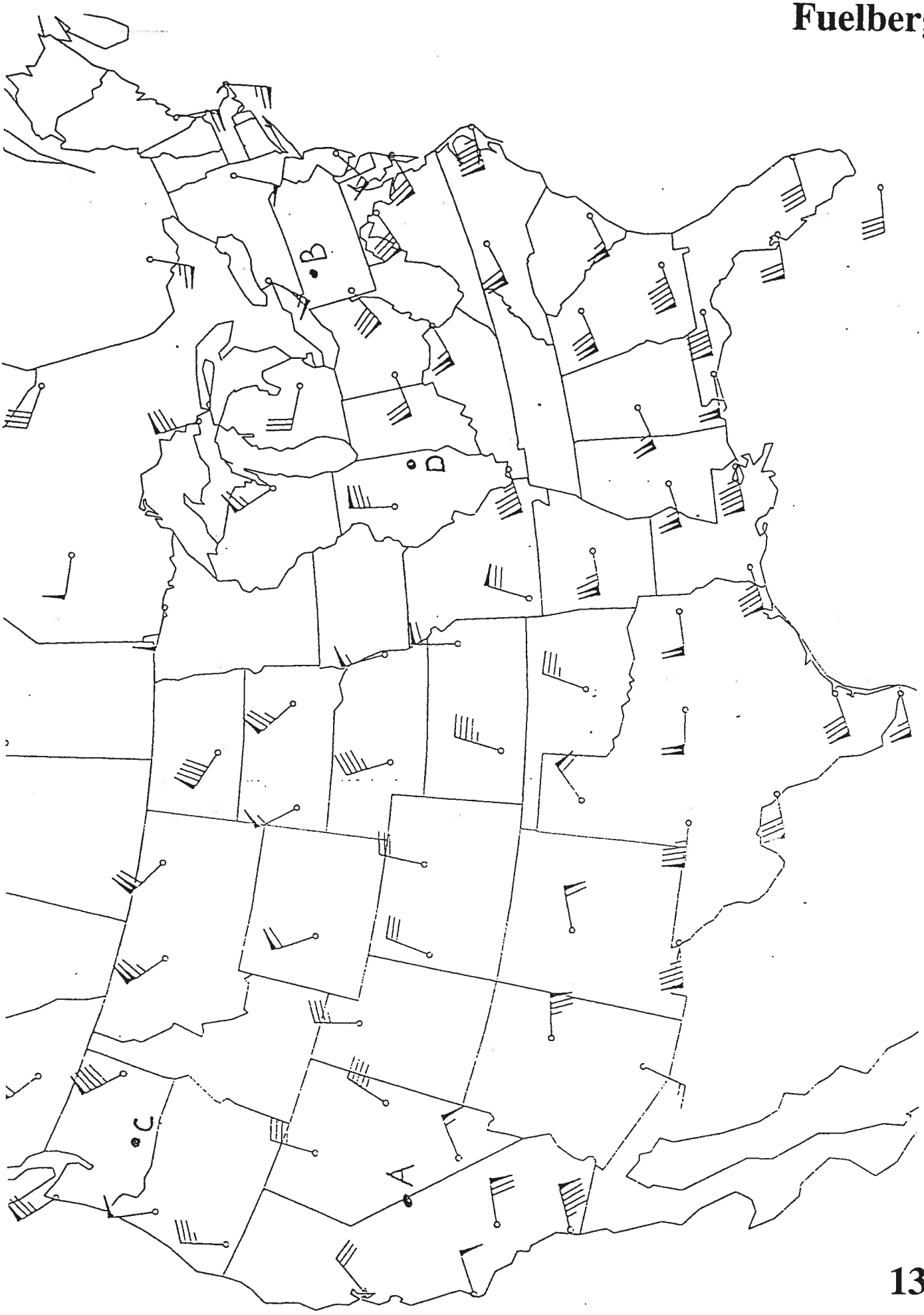
A. Use the enclosed 300 mb data plot to answer part A.

1. Does shear lead to positive or negative vorticity at point A? Explain.
2. Does curvature lead to positive or negative vorticity at point A? Explain
3. Repeat questions 1 and 2, but for point B. Explain
4. Does stretching lead to positive or negative divergence at point C? Explain
5. Does spreading lead to positive or negative divergence at point C? Explain
6. How will geostrophic wind speeds compare to gradient wind speeds at point D? Explain

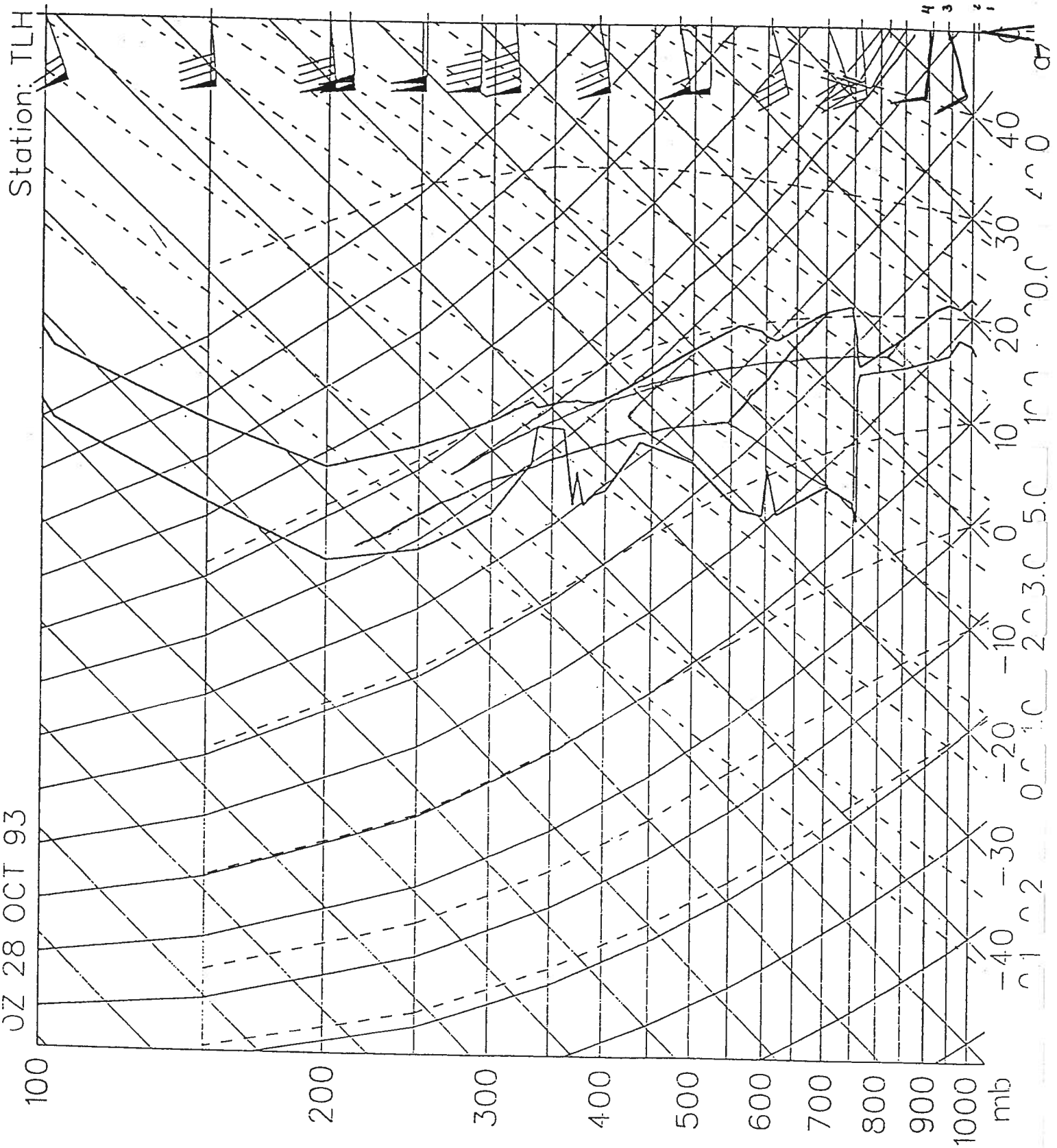
B. Answer the following questions based on the enclosed thermodynamic diagram.

7. Is cold or warm temperature advection occurring between the surface and 850 mb? Describe/explain the theory that allows you to infer temperature advection from this wind profile.
8. What is equivalent potential temperature? How does equivalent potential temperature vary with height between 850 and 700 mb? What is the convective (potential) stability category of this layer? Explain your answer thoroughly.
9. How does potential temperature vary with height between 500 and 400 mb? Explain

C. 10. How does the intensity of a WARM core surface CYCLONE vary with height? Explain your answer thoroughly using hydrostatic concepts.



Plot of 300 mb Wind barbs for 0Z 28 OCT 93


Station: TLH
00Z 28 OCT 93
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-20
-10
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40

Answer all of the questions below. It should take you approximately 1 hour to complete the six questions.

1. How will the **geostrophic** wind speed compare to the wind that is plotted on the enclosed analysis at the three locations A, B, and C? (Circle one answer for each location.)

Point A:	Geostrophic wind is:	greater	less than	equal
Point B:	Geostrophic wind is:	greater	less than	equal
Point C:	Geostrophic wind is:	greater	less than	equal

Now **explain** why the geostrophic and observed winds differ at locations A and C. You will need to discuss the concept of the gradient wind.

2. A parcel of unsaturated air is forced to rise until it reaches its Lifting Condensation Level (LCL). **Describe** the lines on a thermodynamic diagram (e.g. a Skew T diagram) that you would go up (or down) to simulate this process. Then, **explain** why these are the lines that must be used—and not some other.

3. A layer of air is dry at the top and humid at the bottom such that θe decreases with altitude. The layer is lifted until all portions are saturated.

How will the lapse rate of the layer change during the ascent?
Lr becomes moist adiabatic

Explain in detail why the lapse rate changed during the lifting process.

4. How does the intensity of a **cold core cyclone** vary with height? Draw a cross section showing isobars, two isotherms (labeled cold and warm), and several thickness lines that depict this situation. Now, **explain** your findings **thoroughly**, referring to your diagram.
pt. inc w/ height

5. Winds are veering with height in a layer (rotating clockwise with altitude). Is cold or warm temperature advection occurring in the layer?

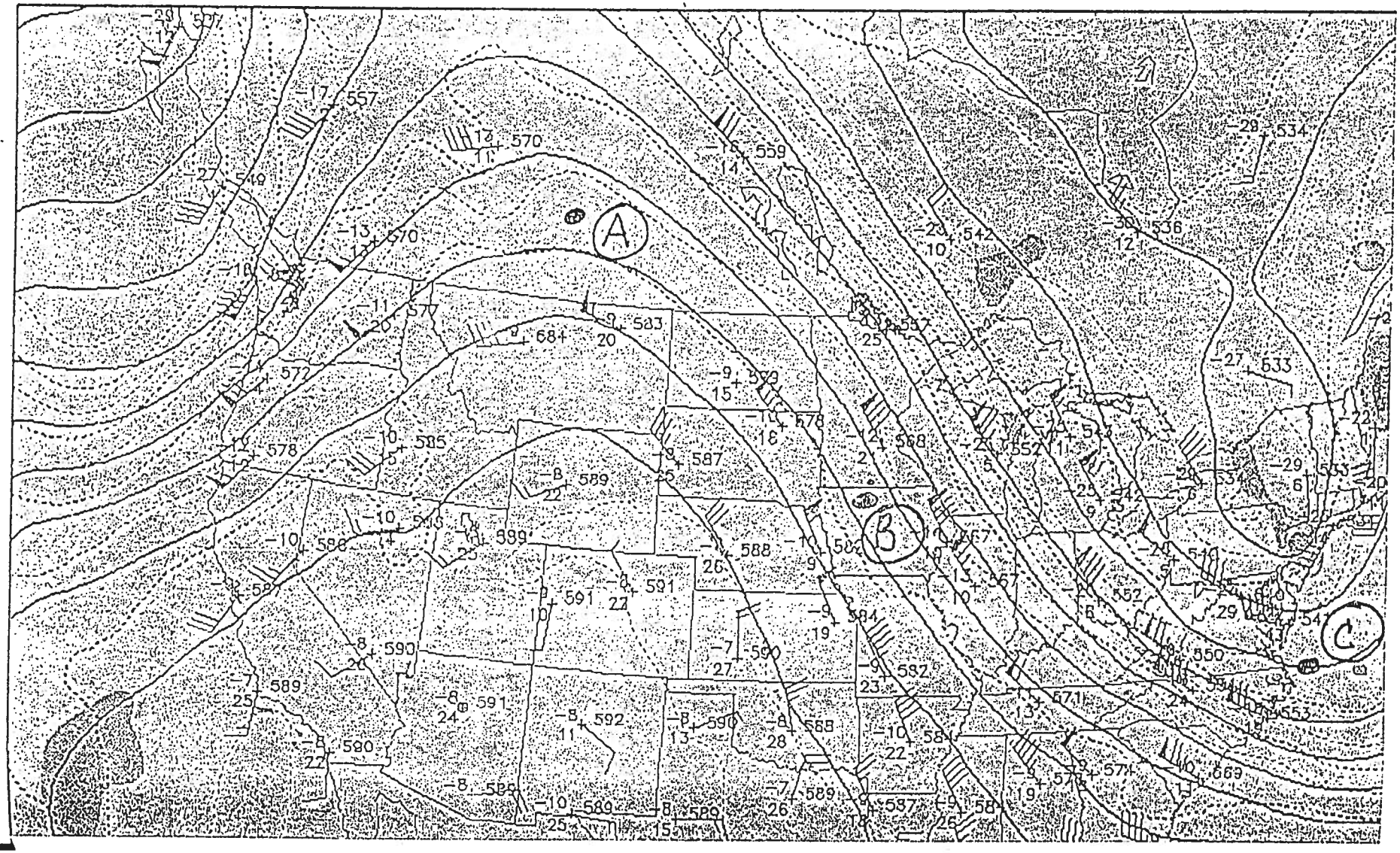
Draw a vector diagram showing the actual winds and the thermal wind in this layer. Then, **explain thoroughly** how you determined the advection described above.

6. I have a 1000-500 mb thickness analysis, but no surface data. How would I determine the surface locations of fronts? **Explain this carefully.**

500 mb Heights (dm) / Temperature (°C) / Humidity (%)

0-hour analysis valid 0000 UTC Thu 23 Oct 2003

RUC



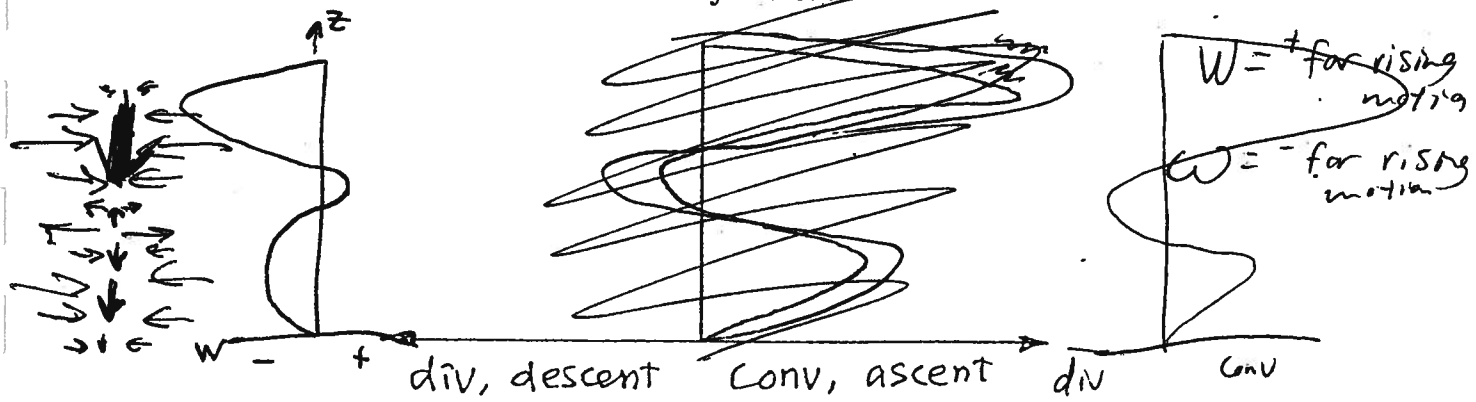
Fuelberg

Professor Henry E. Fuelberg
Answer both questions.
approximate time required: 1 hr 30 min

1. (Basic Synoptic Meteorology)

The following questions require only brief answers. Pick any four of the five questions.

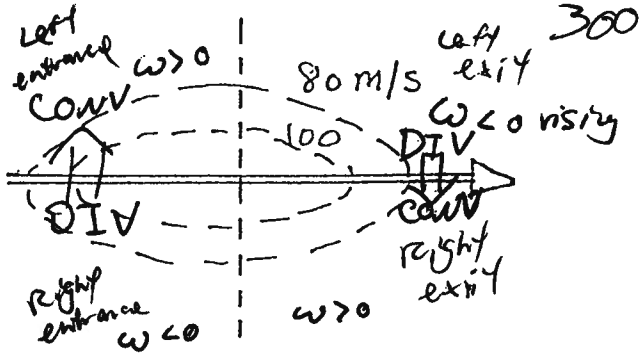
(a) The graph below is a plot of horizontal divergence as a function of height. Superimpose the profile of vertical motion (w). Make sure that the altitudes of maximum and minimum vertical motion are clearly indicated. Assume $w = 0$ at surface.



(b) How does the intensity of a cold core anticyclone vary with altitude? Thoroughly explain your answer.

(c) Is cold or warm temperature advection occurring when winds back with increasing altitude? Sketch a vector diagram showing this situation. Explain your answer thoroughly, making use of the thermal wind concept.

(d) The diagram below shows a typical jet streak at 300 hPa. In each of the four quadrants, indicate whether there is horizontal divergence of convergence at 300 hPa. Also indicate in each quadrant whether rising or sinking air is occurring in the middle troposphere.



(e) A layer of air is very dry at the top and very moist at the bottom. If the entire layer is lifted to saturation, what will happen to the lapse rate of the layer? Explain your answer in terms of the relative amounts of cooling occurring at the top and bottom of the layer.
How would equivalent potential temperature vary with height in the layer?

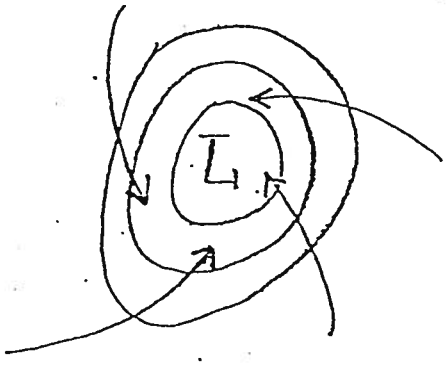
del · w | height

You and a friend are watching The Weather Channel. He asks you, "Why are the winds blowing this way on the surface chart that they are showing (see part of that chart below)".

Your preliminary exam question is to provide a suitable explanation for his question.

Your friend has a degree in engineering; so, he has had mathematics through differential equations plus several courses in physics. You should answer his question with that background in mind—don't just give him a freshman type answer that will insult him.

The question is open ended. Therefore, you should provide as much pertinent information as you know (your friend might get tired of your long answer, but Fuelberg will not).



Mesometeorology (MET 5511 C) Fuelberg 45 minutes

The following question relates to thermally-induced mesoscale circulations. Answer each part of the question.

A. Describe the mechanism by which sea breezes form during the day and land breezes form at night. As part of your answer, you should describe the vertical structure of the circulations and how they change during a typical 24 hour period.

B. What is the sea breeze front? Describe it and mention how typical surface meteorological parameters vary as the front passes.

C. How does the large-scale flow affect the sea breeze circulation? For example, contrast situations with onshore and offshore flow.

D. What is an "inland sea breeze"? Describe several causes for the temperature gradients that can produce these circulations.

E. What is a katabatic circulation?

Professor Henry E. Fuelberg
Answer all the questions on this page.
approximate time required: 45 min

Use the enclosed 300 mb data plot to answer the following questions.

1. Does shear lead to positive or negative vorticity at point A? Discuss this.
2. Does curvature lead to positive or negative vorticity at point A? Discuss this.
3. Repeat questions 1 and 2 for point B.
4. Does stretching lead to positive or negative divergence at point C? Discuss this.
5. Does spreading lead to positive or negative divergence at point C? Discuss this.
6. How will geostrophic wind speeds compare to gradient wind speeds at point A? How will they compare at point B? Explain.

Answer the following questions based on the enclosed thermodynamic diagram.

7. Is cold or warm temperature advection occurring between the surface and 850 mb? Explain this.
8. How does equivalent potential temperature vary with height between 850 and 700 mb (pos. or neg.)? What is the convective stability category of this layer? Explain.
9. How does the potential temperature vary with height between 500 and 400 mb? Explain.

10. In what direction do cold core surface low pressure centers tilt with height? Explain your answer using the concept of thickness.

Synoptic Meteorology Fuelberg 45 minutes

This question consists of several parts. It will test your knowledge about several aspects of synoptic meteorology. Answer each part of the question.

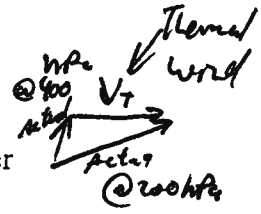
A. An anticyclone at the surface has comparatively cold temperatures near its center. Will the anticyclone be stronger or weaker at higher altitudes? Explain your answer thoroughly using the concept of thickness. Diagrams also would be useful.

cold core anticyclones intensity ↓ dec. w/ height due to thickness.

$$\Delta z = \frac{R}{g}\bar{T} * \ln\left(\frac{P_1}{P_2}\right)$$

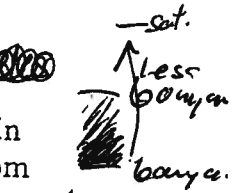
B. Winds are changing direction in a clockwise manner with increasing height. What type of temperature advection is occurring? Fully explain your answer with diagrams and a discussion.

veering → WAAV



Lifting stable layers makes them less stable

A layer of air is very dry at the top and very humid at the bottom. If the entire layer is lifted to saturation, what will happen to the stability of the layer? Explain your answer by discussing the amounts of cooling that occur at the top and bottom of the layer.



more cooling at top, less cooling at bottom b/c sat. b/c unsat.

parcels follow θ_e lines upward if saturated

What is equivalent potential temperature? How might it be useful in assessing the stability of this layer.

θ_e is the temp. a parcel would have if all its moisture condensed out pseudo-adiabatically & then brought dry-adiab. back to 1000 mb

D. There is strong cyclonic curvature in a given region at 500 mb. Compare actual wind speed and direction in the region to the geostrophic values. Explain the causes for the differences that you mention.

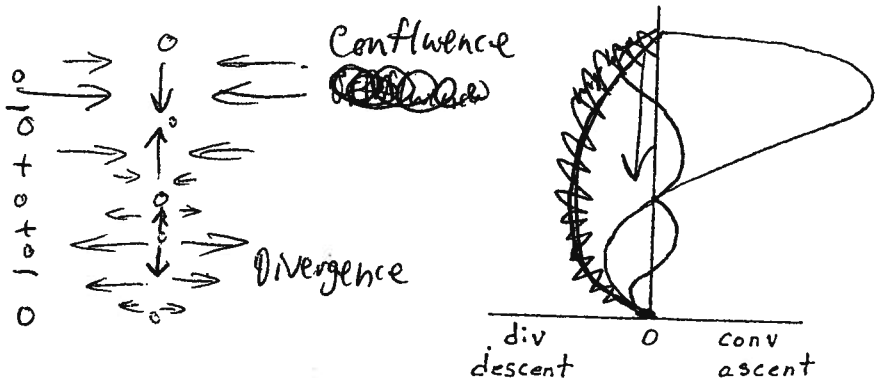
$$fV_g = -\frac{\partial \phi}{\partial n}$$

$$\frac{V^2}{R} + fV = -\frac{\partial \phi}{\partial n}$$

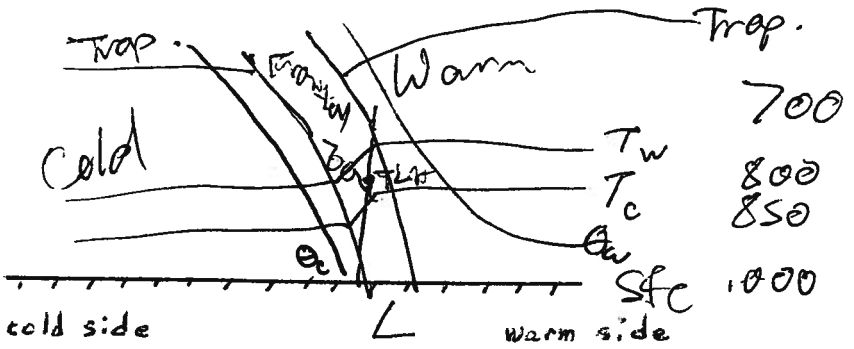
Curvature will slow down the V_g

Actual > Geostr. Values

E. The diagram below is a vertical profile of horizontal divergence. Explain how to obtain a corresponding vertical profile of vertical motion. Then, transfer the diagram to your blue book and superimpose the vertical motion profile on top of the divergence profile. Note that I have indicated "ascent and descent" on the diagram.



1. Draw a cross section through a cold front. The front should have the proper shape and contain two isotherms (labeled Tw and Tc) and two isentropes labeled θw and θc.



2. A cold front is located on the TLH sounding at 800 mb.

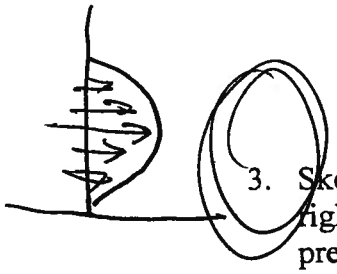
Has the front passed TLH at 850 mb?

Possibly, prob. not yet

Has the front passed TLH at 700 mb?

NO

Sketch a cross section of this scenario and **EXPLAIN** your answers thoroughly.



3. Sketch a vertical cross section through a gravity wave that is propagating to the right. Show a representative isentropic surface (labeling the high and low pressure areas at the surface), areas of convergence and divergence, as well as areas of ascent and descent

4. What is an "inland sea breeze"? List four to five ways by which they can be formed, i.e., the ways by which horizontal temperature gradients are produced.

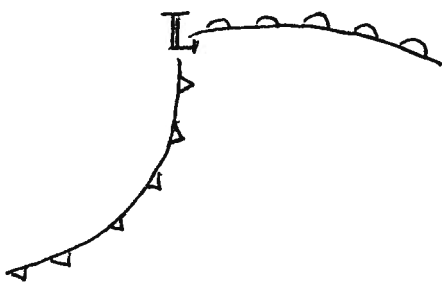
5. A layer of air originally is humid at its base but very dry at its top. The entire layer then is lifted until all portions become saturated. How will the ending temperature lapse rate compare to the original lapse rate? Explain in detail why this change occurs. What does this have to do with the convective stability criteria?

1. **Define** and **distinguish** between (i.e., intercompare) the following terms:

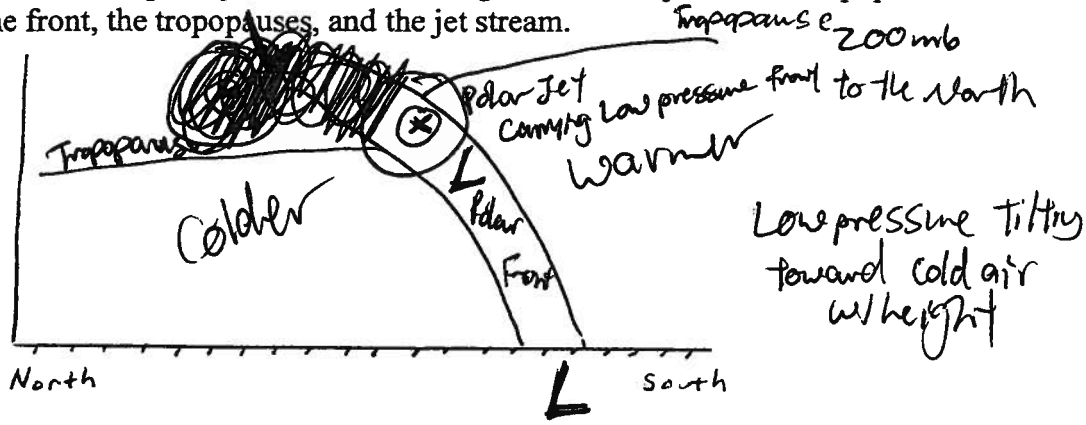
   Conditional instability, potential instability, convective instability, CAPE, and CIN.

3. **Explain** why we pack isotherms behind a front (on the cold side).

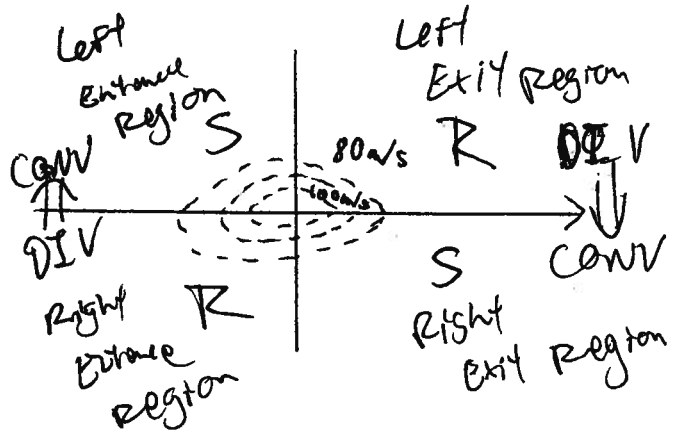
4. The surface analysis below contains a cyclone, a cold front, and a warm front. Superimpose the warm and cold conveyor belts as well as the dry intrusion. Then, **write** a few sentences explaining whether each of these features is ascending or descending.

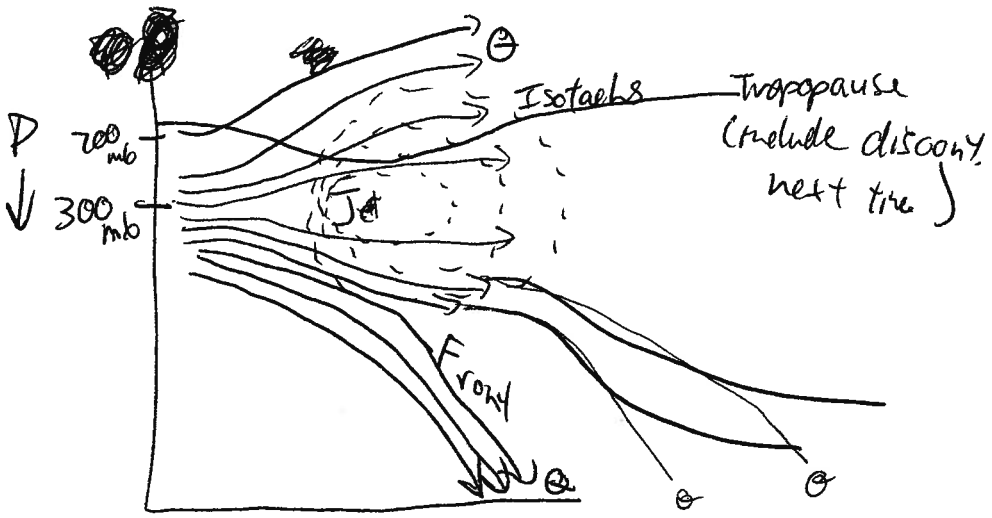


1. Sketch a vertical cross section showing either conceptual model describing how the polar front and polar jet stream are configured with respect to the tropopause. Show the front, the tropopauses, and the jet stream.

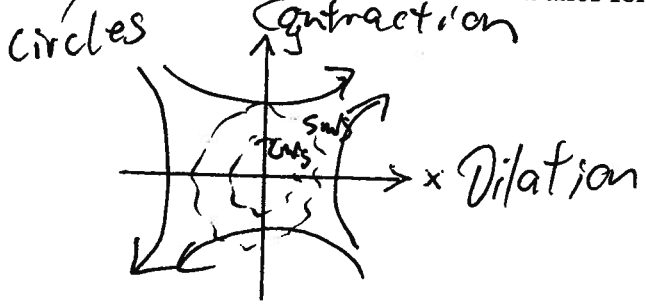


2. The analysis below is at 300 mb. A straight streamline and several isotachs are shown to depict a jet streak. In each of the four quadrants, indicate whether the air is rising (by an "R") or sinking (S). Then, label two quadrants as the "entrance region" and the other two quadrants as the "exit region" of the jet streak.

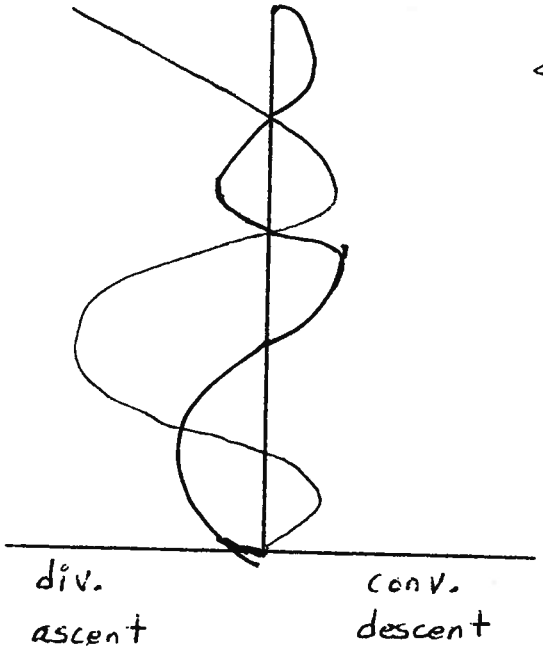


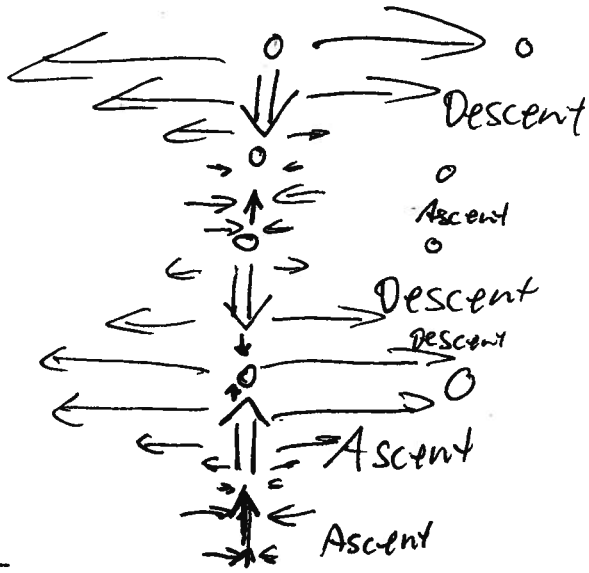


4. (5) Sketch streamlines for a case of pure **positive <u>shearing</u> deformation.** Superimpose several isotachs that are labeled in m s^{-1}. Label the axes of contraction and dilatation. I have sketched the Cartesian axes for you.



5. The graph below is a plot of horizontal divergence as a function of height. Superimpose the profile of vertical motion (w). Be sure to consider the relative magnitudes of w at the various heights.





Prelim. Questions in Mesometeorology
Dr. Fuelberg

***Answer the questions in the spaces provided.**
***Answer all of the questions.**
You should complete the exam in about 60 minutes.

1. Draw a west to east cross section through a dry line in Oklahoma. **Label** the moist and dry sides, show the correct slope of the dry line, and show a **Skew T** of temperature and dew point on the dry side and on the humid side of the surface position.

2. List the four physical processes that determine **buoyancy** at the convective scale.
   1.
   2.
   3.
   4

3. What is meant by "**baroclinic generation**" of horizontal vorticity?

13. Draw a cross section through a gravity wave that is occurring during calm large scale winds. Using wind arrows and word labels, indicate areas of horizontal convergence, divergence, ascent and descent.

13. Draw a cross section through a gravity wave that is occurring during calm large scale winds. Using wind arrows and word labels, indicate areas of horizontal convergence, divergence, ascent and descent.