Place an X here to count exam double!

Name: _____

Final Examination, MEA 443 Fall 2010
13 December 2010

If you wish to have the final exam count double and replace your midterm score, place an "X" in the box above. As always, you are allowed to ask me questions during the exam if you require clarification on a given problem. Good luck, and have a great Christmas break!

1.) On Saturday 4 December, temperatures climbed to or above 40°F at RDU airport in central NC. Precipitation was falling to the west of Raleigh, moving eastward. The precipitation began as snow immediately, as evident from the RDU METAR observations shown below:

KRDU 041751Z 27004KT 10SM SCT090 BKN110 BKN150 BKN250 04/M07 A2997 RMK AO2 SLP152 T00441067 10050 21017 58041
KRDU 041851Z VRB05KT 10SM BKN024 OVC031 04/M06 A2995 RMK AO2 SLP143 T00391061
KRDU 041859Z 23005KT 1 3/4SM -SN BR FEW008 OVC015 02/M03 A2995 RMK AO2 TWR VIS 2 SNB56 P0000
KRDU 041906Z 00000KT 2SM -SN BR BKN009 OVC013 02/M03 A2995 RMK AO2 SNB1856 P0000
KRDU 041946Z 00000KT 1/4SM SN FG OVC007 01/M02 A2994 RMK AO2 SFC VIS 1/2 SNB1856 P0001
KRDU 041951Z 29003KT 1/4SM SN FG OVC007 01/M02 A2994 RMK AO2 SFC VIS 1/2 SNB1856 SLP142 P0002 T00061017
KRDU 042051Z 00000KT 1/4SM SN FG OVC009 01/M01 A2992 RMK AO2 SLP135 P0011 60013 T00061011 58009

a.) Briefly explain why the precipitation began as snow, despite temperatures above freezing, and cite any evidence you can from the METAR data to support your answer.

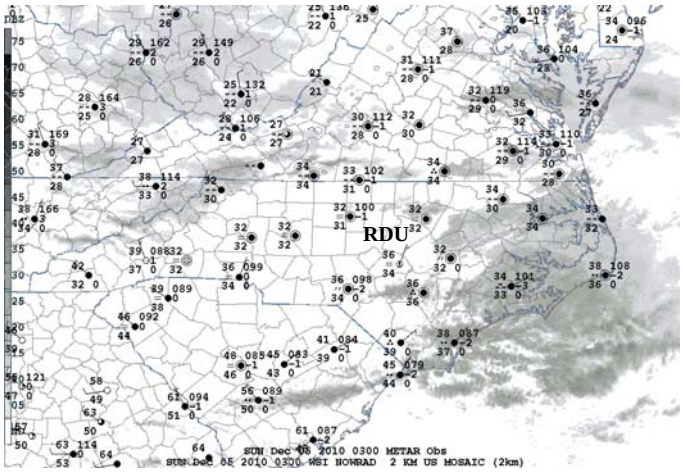
b.) Use these same RDU METAR observations to answer the following:

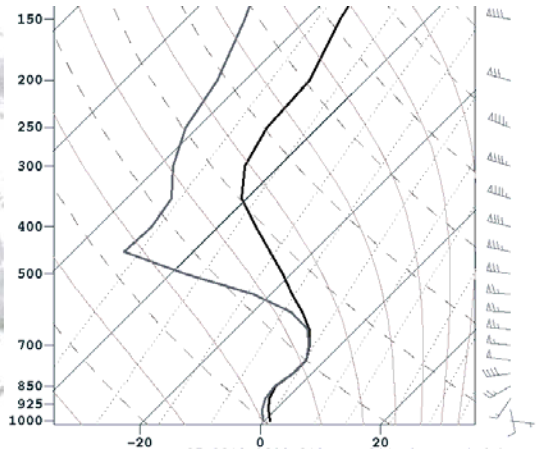
i.) What was the air temperature at 2:51 p.m. EST? _____ °C

ii.) What was the sea level pressure at 1751 UTC? _____ mb

iii.) How much precipitation fell in the 9 h ending 2051 UTC? _____ in

2.) The continuity equation in isobaric vertical coordinates is expressed $\nabla \cdot \vec{V} + \frac{\partial \omega}{\partial p} = 0$, neglecting sources and sinks of water vapor. For a synoptic-scale weather system, what is the typical order-of-magnitude value of ω in the mid-troposphere? Use scale analysis of this equation to determine your answer, and show your work below. Of course, be sure to include units.





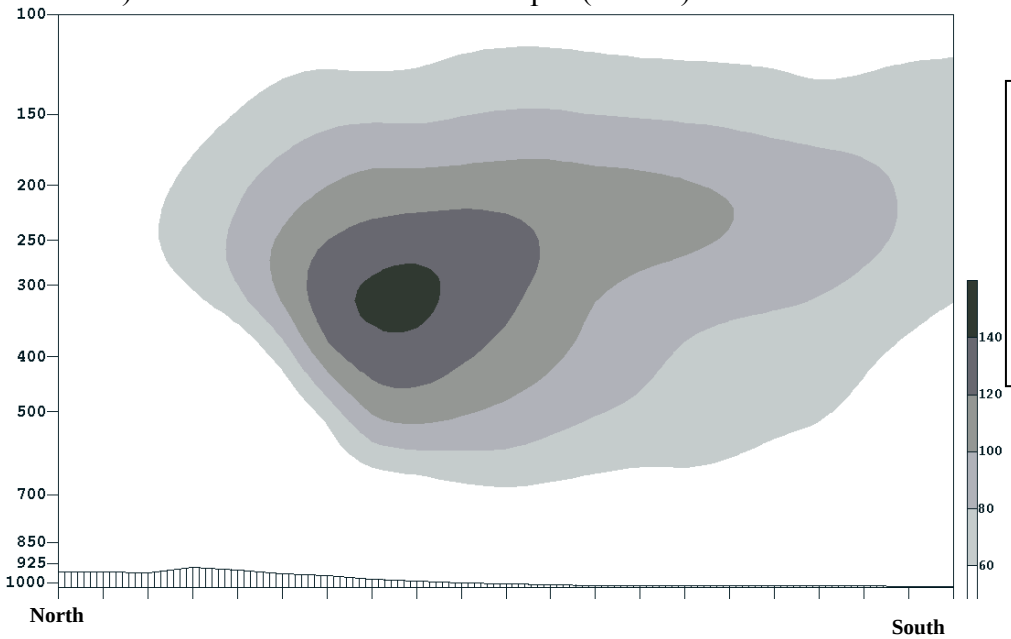
3.) On Saturday 4 December, a mix of snow and wintry precipitation fell across central NC. The data above show surface METAR observations with the mosaic composite radar reflectivity (left) and a NAM forecast sounding for RDU (right) at the end of the event. Precipitation had diminished in central NC during by this time (~03 UTC Sunday 5 December).

a.) What evidence, if any, do you see in the NAM sounding for ***ascent*** at this time?

b.) Given the sounding and a.), explain why precipitation was ***not*** falling at this time.

4.) The cross section below was taken in a Northern Hemisphere location, and shows isotachs. The wind was blowing ***into*** this north-south oriented cross section.

a.) Sketch a set of ~5 or 6 isentropes (dashed) that are consistent with *thermal wind balance*.



Thermal wind relations:

$$\frac{\partial u_g}{\partial z} \propto -\frac{\partial \theta}{\partial y}$$

$$\frac{\partial v_g}{\partial z} \propto \frac{\partial \theta}{\partial x}$$

5.) Suppose that after graduation, you are hired by NASA to study the atmospheres of other planets. You are assigned to a team that is designing instruments to sample the atmosphere of Jupiter, which rotates very rapidly about its axis. In particular, you are tasked with studying the midlatitude atmosphere of Jupiter, and the large storms that are observed there.

a.) Do you expect the large mid-latitude storms on Jupiter to be *quasi-geostrophic*? ____ (y or n)

b.) Why or why not? Briefly justify your answer below, explaining how you could check this.

c.) Do you think that these storms could be *Rossby waves*? How could you find out? Explain.

6.) Quasigeostrophic (QG) **True/False** and **multiple choice**.

a.) Which of the following two equations were combined in forming the *QG omega equation*?

___ i.) The vorticity equation
___ ii.) The Ideal Gas Law
___ iii.) The thermodynamic energy equation
___ iv.) The continuity equation
___ v.) The frontogenesis equation
___ vi.) The u and v momentum equations

____ b.) In class, we found that the QG equations were *not* suitable for the study of frontal circulations. Which of the following best explains why was this was the case?

i.) The cross-front length scale is small, yielding a *large Rossby number* in the cross-front direction.
ii.) Fronts are often associated with cyclones; the strongly curved flow in a cyclone violates QG assumptions.
iii.) Fronts cause lift by "plowing" warm air aloft, which is a process more similar to orographic lift, and not accounted for by the QG equations.
iv.) all of the above.

___ c.) For very strong, straight flows, such as the jet stream, the QG approximation is not valid.

___ d.) One of the fundamental QG assumptions is that the *wind speed is weak*, on the order of 10 m/s.

___ e.) The QG potential vorticity (QGPV) was obtained by rearranging the *QG omega equation*.

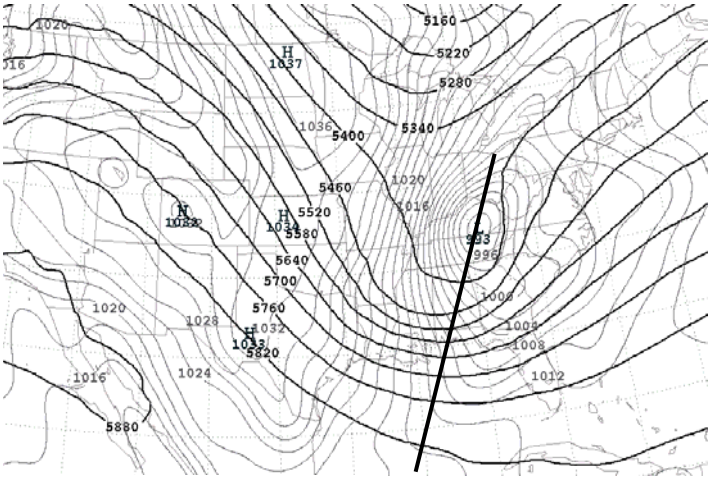
7.) Consider the plots shown below. The top panel shows 500-mb height and sea level pressure, with the location of a cross section line included. The two plots beneath show cross sections of *temperature advection* (left) and *vorticity advection* (right). Use these plots to answer the following.

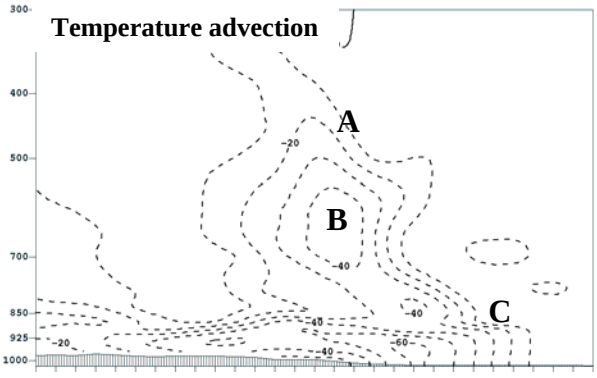
a.) Estimate the sign of the *QG height tendency* at points A, B, and C in this cross section (positive, negative, or weak)?

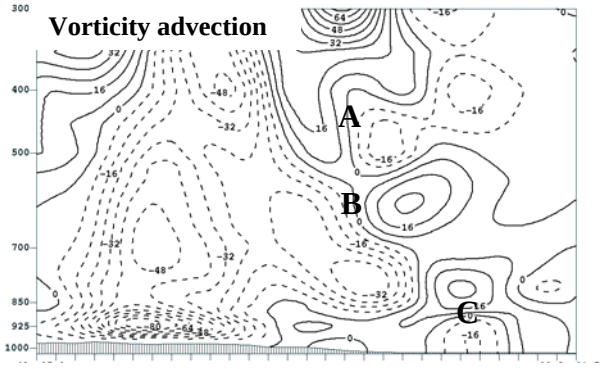
A: _____ B: _____ C: _____

b.) What is the expected *QG omega* at these same locations (ascent, descent, or weak)?

A: _____ B: _____ C: _____





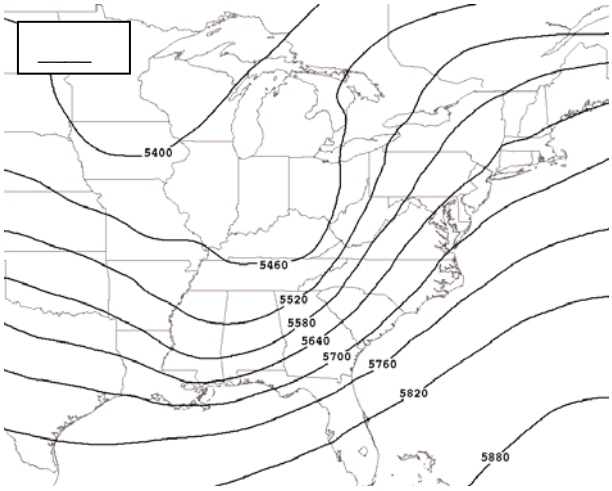


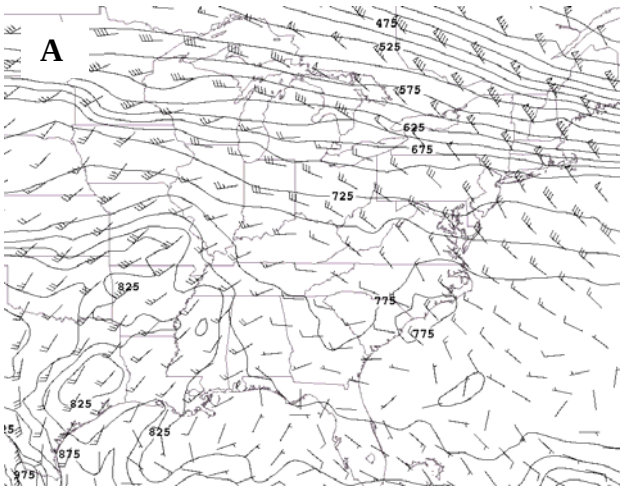
For reference, the QG height-tendency and QG omega equations are provided below:

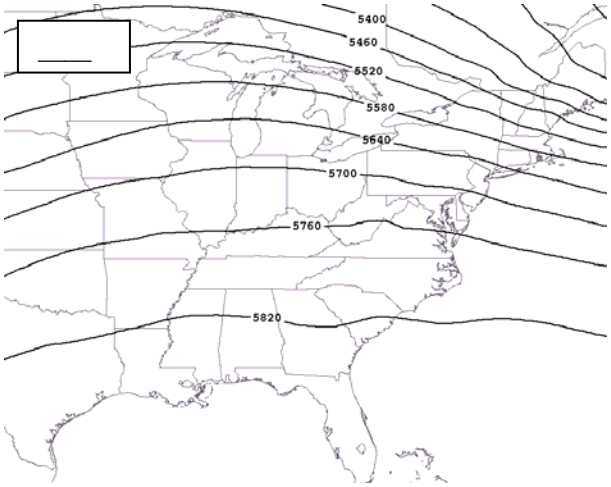
$$\left(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega=\frac{f_0^2}{\sigma}\frac{\partial}{\partial p}\left[\vec{V}_g\cdot\nabla\left(\frac{1}{f_0}\nabla^2\Phi+f\right)\right]+\frac{1}{\sigma}\nabla^2\left[\vec{V}_g\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$ QG omega eq.

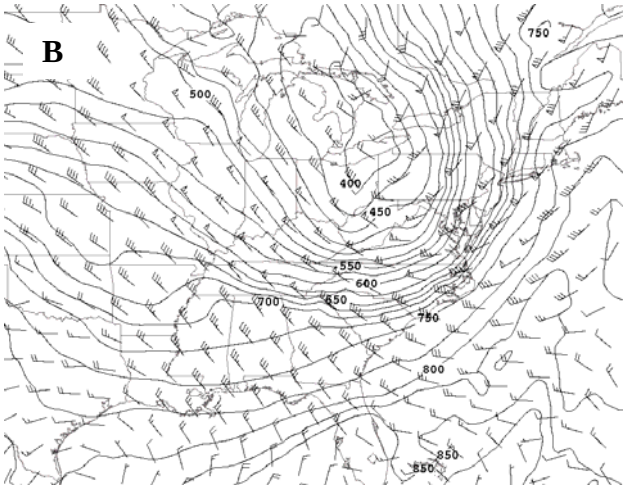
$$\left[\nabla^2+\frac{\partial}{\partial p}\left(\frac{f_0^2}{\sigma}\frac{\partial}{\partial p}\right)\right]\chi=-f_0\vec{V}_g\cdot\nabla\left(\frac{1}{f_0}\nabla^2\Phi+f\right)-\frac{\partial}{\partial p}\left[-\frac{f_0^2}{\sigma}\vec{V}_g\cdot\nabla\left(-\frac{\partial\Phi}{\partial p}\right)\right]$$ QG height-tendency eq.

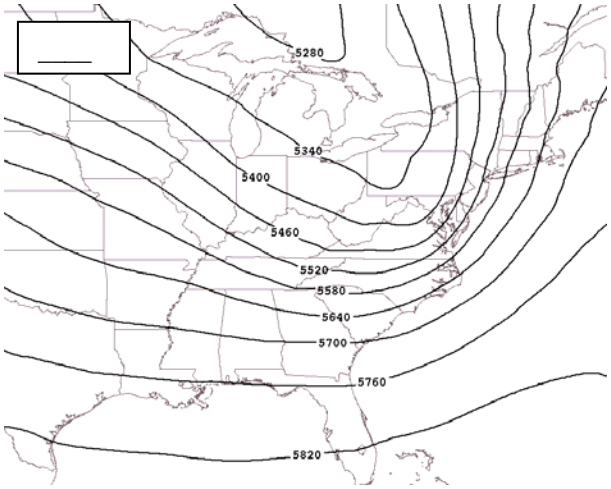
8.) Isentropic analysis matching: Based on the patterns and your knowledge of the structure of synoptic-scale weather systems, match the three *isentropic analyses* at right (for the 300K isentropic surface) to the corresponding *500-mb height analyses* at left.

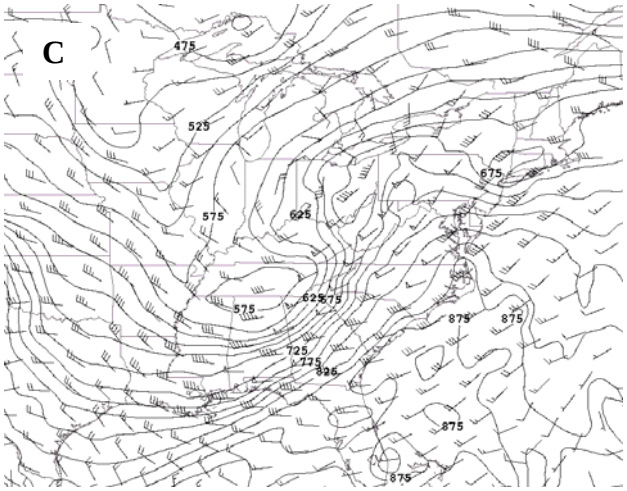








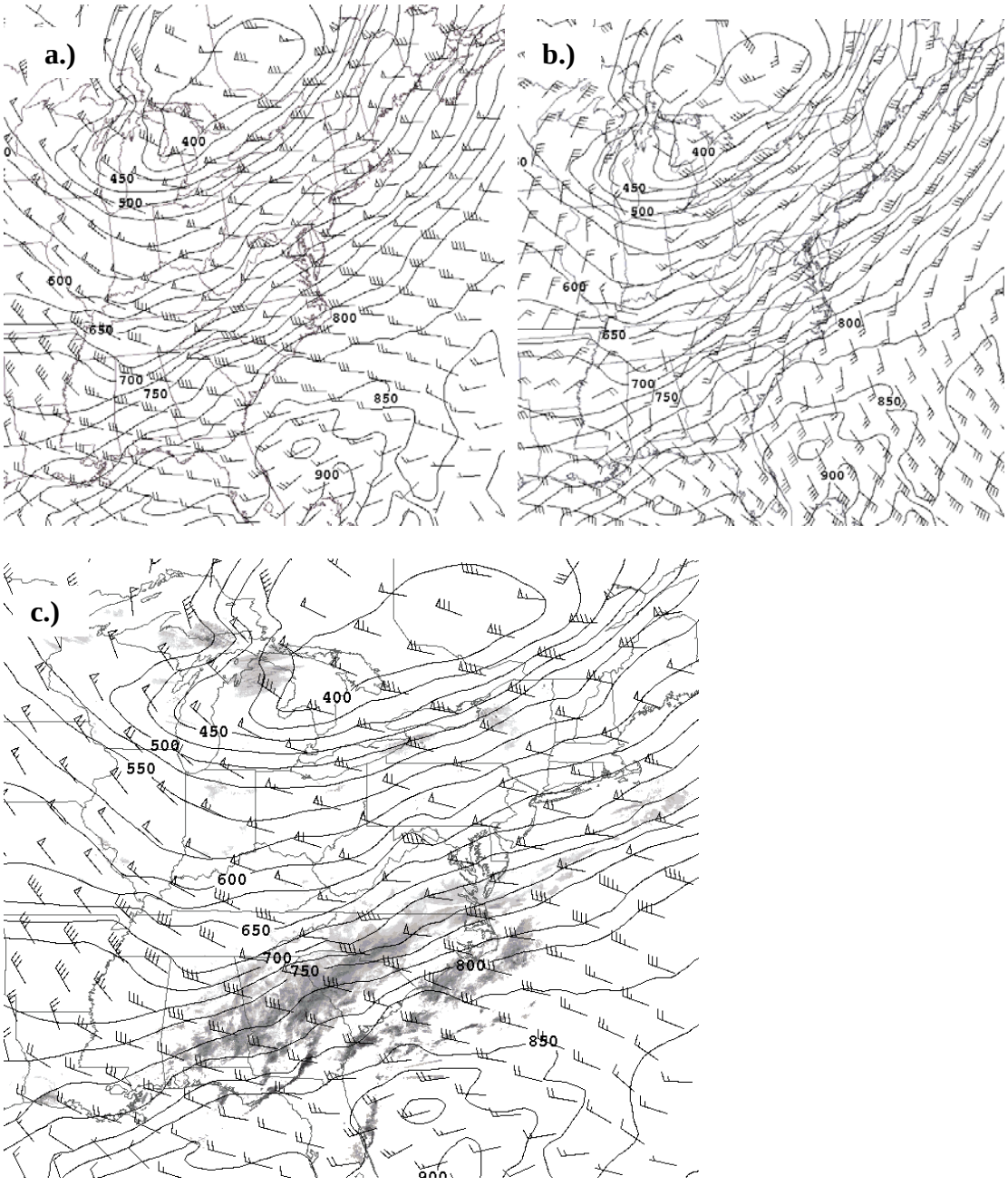




9.) Three isentropic analyses (showing winds and pressure on the 300K isentrope) are shown below, valid at the same time. The lower image includes radar, the top two do not. One of the top two analyses shows *storm-relative winds*, the other shows the *full observed wind*. [Panel c.) shows either storm-relative or full wind.]

a.) Which of the top two images shows the storm-relative wind? ____ (a. or b.)

b.) Briefly justify your answer to a.) in the space below.



10.) Isentropic analysis short answer, true/false:

a.) During winter, a _____ (warmer or colder) isentrope is typically needed relative to summer.

b.) For the forecasting of lake-effect snow, isentropic analysis _____ (would or would not) allow a complete representation of the ascent associated with the precipitation.

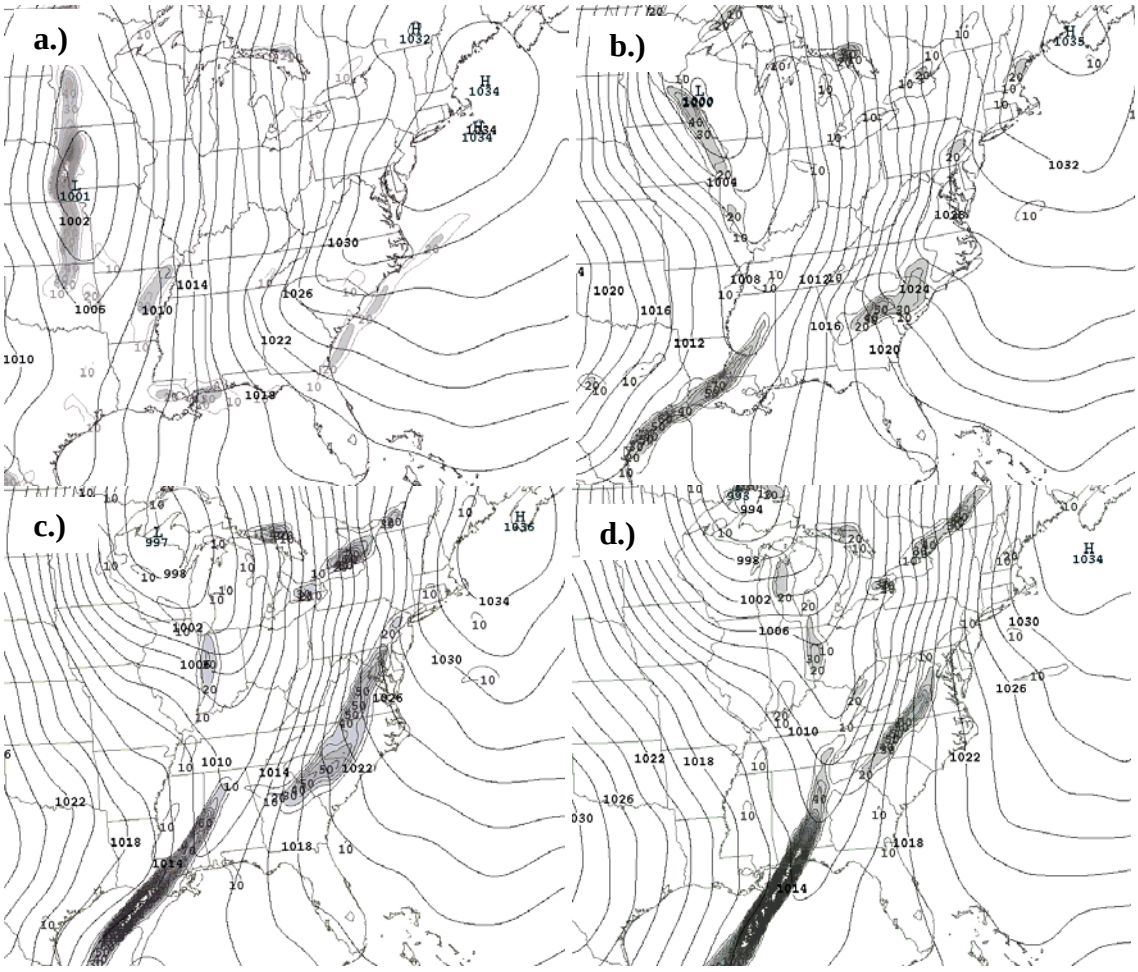
c.) Isentropic analysis often produces different results from the QG omega equation for predicting ascent; this is because much of the ascent observed in the atmosphere is due to non-QG effects. _____ (True or False)

11.) Below are 4 RUC SLP and 1000-mb frontogenesis analyses, approximately 6 hours apart. A CAD event is underway at the initial time (panel a.), but is largely over by the time of panel d.)

___ a.) Which *synoptic CAD erosion pattern* is evident in this sequence?

i.) coastal low ii.) northwest low iii.) cold-frontal passage iv.) residual cold pool

b.) What *physical processes* do you expect to be at work in eroding the CAD in this case? List the process(es), and briefly describe any evidence you see for their presence here.



___ 12.) Which of the following are reasons why is it necessary for models to *parameterize* processes such as turbulence and cumulus convection?

a.) Because there are not enough detailed observations of these quantities to provide initial conditions for them.

b.) Because they are too small to be resolved by models, but are sufficiently important that they must be accounted for anyway.

c.) Because if terms were included in the model equations to account for these processes, then the system of equations would no longer be closed.

d.) All of the above.

___ 13.) The "CFL" condition describes a relation between which of the following aspects of a numerical model?

a.) The PBL and convective parameterization schemes.

b.) The microphysics and the convective parameterization schemes

c.) The grid spacing, the time step, and the speed of waves in the model equations.

d.) The grid spacing and whether it is necessary to run with a convective parameterization scheme.

14.) List and describe one useful type of information that is available from an ensemble forecasting system that is not available from a single deterministic model run.

___ 15.) Suppose that you are analyzing a model precipitation forecast, and you note that a given region is forecast to have a large amount of "convective" precipitation from the model (as seen by examining the precipitation generated by the model convective parameterization (CP) scheme). Which of the following is the best forecast interpretation?

a.) The CP precipitation is not meant to be used in forecasting, and should be disregarded completely.

b.) The CP precipitation amount tends to be far too large and too localized, and should not be considered in the forecast.

c.) The CP precipitation is generally less reliable than grid-scale precipitation, but can still be useful in prediction of showery conditions.

d.) The CP precipitation tends to be less uniform in coverage than grid scale precipitation, so the coverage from the CP precipitation should be expanded to provide a more realistic forecast.

16.) Matching problem for the NCEP Short-Range Ensemble Forecast System (SREF) and the GFS Ensemble Forecast System (GEFS). For each characteristic, label SREF, GEFS, both, or neither.

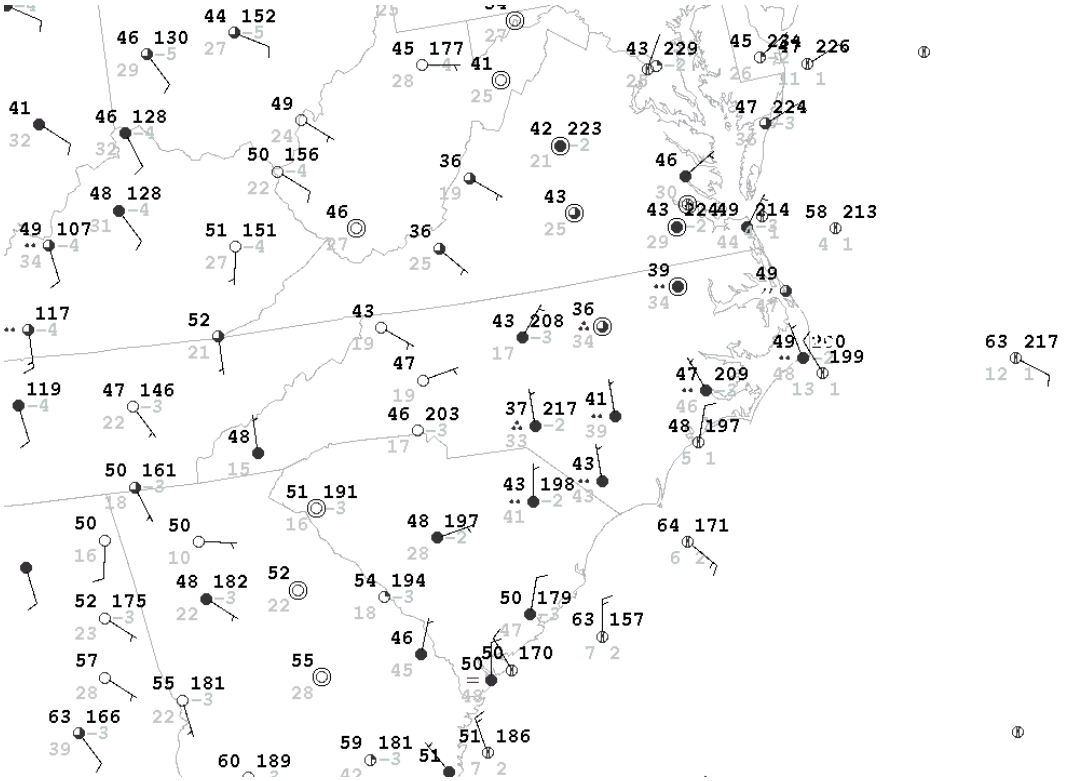
_____ a.) An "initial condition" ensemble with the same physics between members.

_____ b.) A "physics ensemble" with different models and physics between members.

_____ c.) Emphasis on high-impact weather, including severe weather

_____ d.) Useful in quantifying uncertainty in the planetary-scale weather pattern.

17.) Consider the surface observations shown below, from 18 UTC Saturday, 11 December. Sketch a quick analysis of sea level pressure with a 2 mb contour interval, and isotherms in dashed lines with a 10°F interval. Also locate any frontal boundaries using the correct symbols.



18.) The GFS MOS forecast based on the model run of 00 UTC 10 December is shown below at right. The predicted daytime maximum for Saturday the 11th was 52°F. From the surface map above, valid 18 UTC Saturday, we can see it is colder than this across central NC. The observed maximum was only 41°F at RDU on Saturday.

___ a.) At the time of the analysis above, it is colder in central NC than elsewhere in the state. Which of the following processes was most likely responsible for these cold surface temperatures?

i.) Cold advection
ii.) Adiabatic cooling due to ascent
iii.) Evaporation of falling rain
iv.) Melting of falling snow

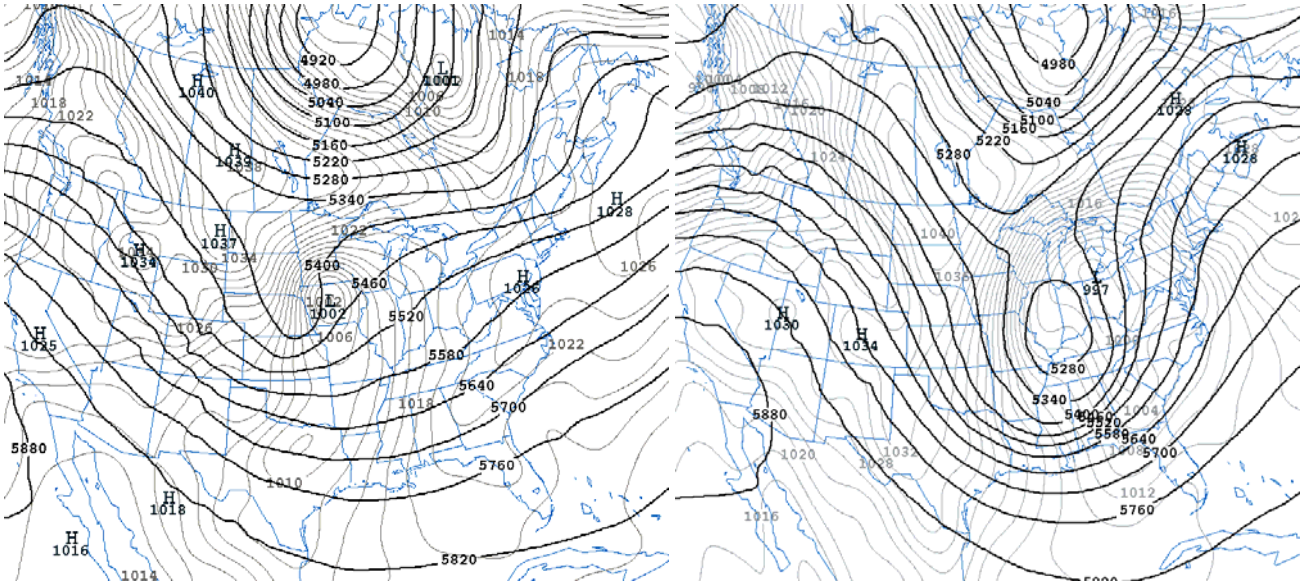
b.) Based on the evidence, why was the GFS MOS forecast so far off? In other words, what was happening, meteorologically? Provide a concise explanation in the space provided below at left.

```
KRDU   GFS MOS GUIDANCE   12/10/2010  0000 UTC
DT /DEC  10           /DEC  11           /DEC  12           /
HR   06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 18 00
X/N                    45          27          52          39    47
TMP  24 22 21 36 42 44 35 31 29 29 29 42 49 50 44 42 41 41 41 44 36
DPT  12 11 11 15 17 21 27 26 23 24 24 30 32 35 38 38 39 40 40 35 23
CLD  OV BK OV OV BK SC FW CL BK OV OV OV OV BK OV OV OV OV OV OV CL
WDR  11 09 09 10 22 23 09 00 00 06 06 08 12 13 10 11 13 18 21 27 27
WSP  03 02 02 03 03 03 01 00 00 01 01 04 06 06 03 04 03 04 07 13 10
P06         2     2     0     1    15    21     9    19    52 75 21
P12                     2          15          29          52    75
Q06         0     0     0     0     0     0     0     0     1  2  0
Q12                     0          0           0           1     2
T06      0/ 6  0/ 8  0/ 0  0/ 5  0/ 5  0/ 4  0/ 0  0/ 5  1/ 2  0/11
T12            0/ 8        0/10        1/ 6        0/ 5        1/18
POZ   2  4  3  9  5  1  2  8  8  8  6  6  1  1  2  3  2  3  2  0  1
POS  95 96 85 89  6 34 43 39 37 36 20 16  0  0  0  0  0  0  0 11 76
TYP   S  S  S  S  R  R  R  S  R  R  R  R  R  R  R  R  R  R  R  R  S
```

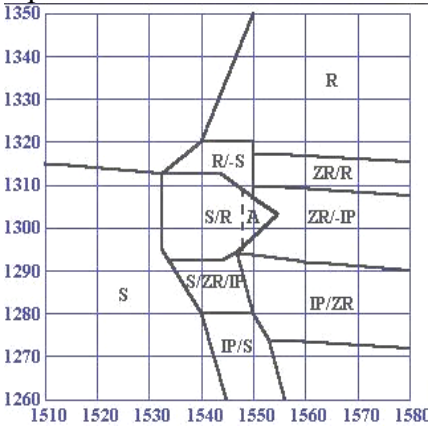
19.) Two GFS analyses are shown below, featuring 500-mb height (darker solid contours) and sea level pressure (lighter solid contours) for times 24-h apart.

a.) The upper-level (500-mb) trough shown in the left panel has amplified by the time of the right panel, 24-h later. Based on what you see here, what process(es) led to this amplification?

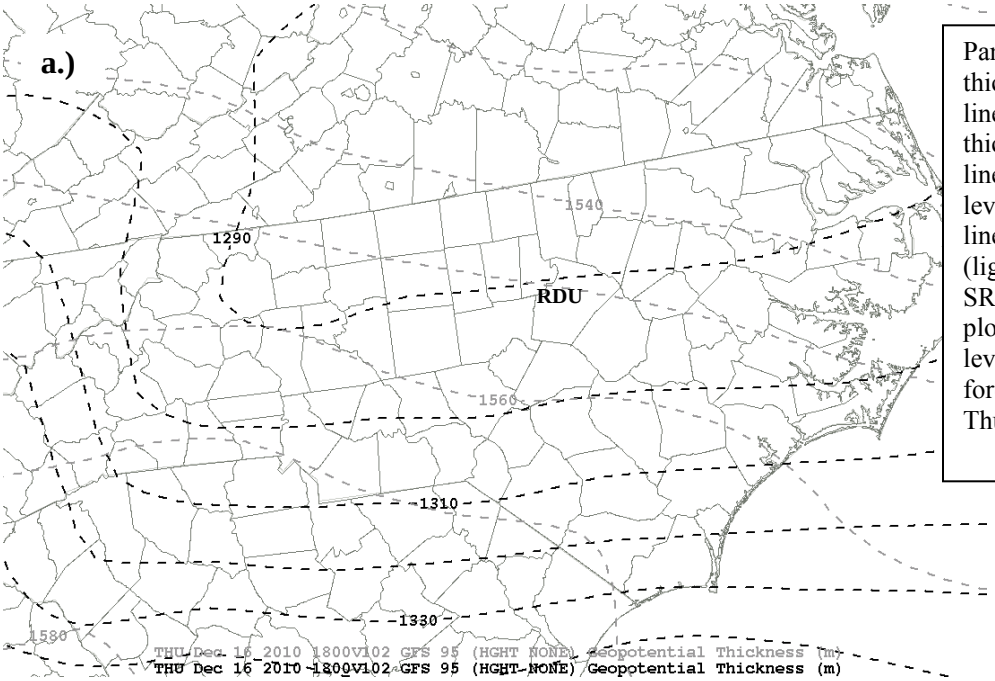
b.) Consider the surface cyclone over Iowa in the left panel, and over northern Ohio in the right panel. Based on what you see here, is Sutcliffe-Petterssen self development evident for this storm? Explain what you looked for, and whether you saw it.



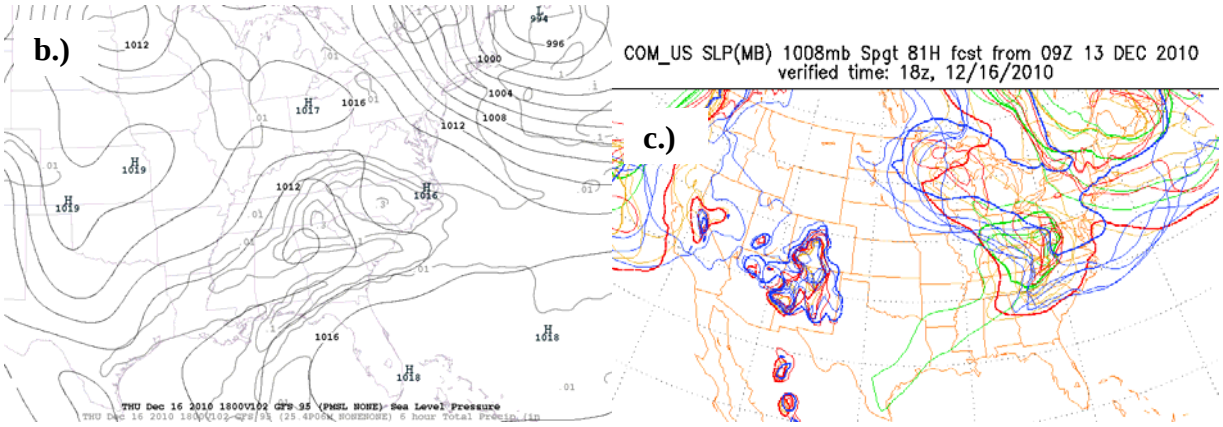
20.) Some models are indicating that a cyclone will move east, spreading precipitation over the southeast on Thursday. Based on the 102-h forecasts provided on the following page, and the thickness nomogram below, *make* and *justify* a precipitation-type forecast for Raleigh valid at the time of the forecast images shown (18 UTC Thursday). Note that an ensemble "spaghetti" sea-level pressure forecast from the SREF is also provided to allow assessment of forecast confidence as well.



Forecast and justification, valid 12-18 UTC Thursday:



Panel a.) 1000-850 mb thickness (dark dashed lines) and 850-700 mb thickness (gray dashed lines); b.) GFS 102-h sea level pressure (darker solid lines) and 6-h precipitation (lighter gray lines); c.) SREF ensemble spaghetti plot showing 1008 mb sea level pressure contour. All forecasts valid 18 UTC Thursday 16 December.



21.) Based on panel b.) above, assuming that this forecast would verify exactly,

a.) What is the most likely *wind direction* over central NC at this time? _____ (answer with a one- or two-letter combination in standard convention, e.g., NW = "northwest")

b.) Is CAD evident at this time? _____ (Y or N). If so, what *type* of CAD?

True/False:

____ **22.)** In order to produce significant lake-effect snow, the lapse rate from the lake surface to the 850-mb level should be nearly equal to (or greater than) the dry adiabatic lapse rate.

____ **23.)** The GFS is the best choice from among the NCEP operational models for *resolving* lake-effect snowbands.

24.) Suppose that you are viewing a NAM 212 forecast for North Carolina in GEMPAK format, using GARP. A particular graphic you plot has the following date/time label: 101225/2100V039.

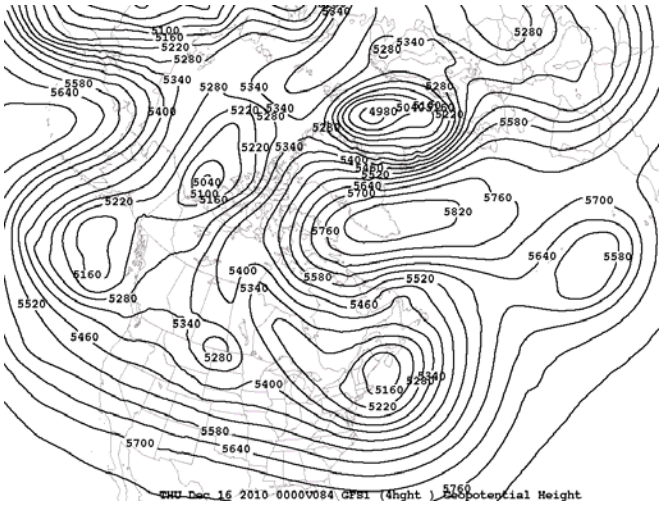
a.) At what date and time is the image valid? _____

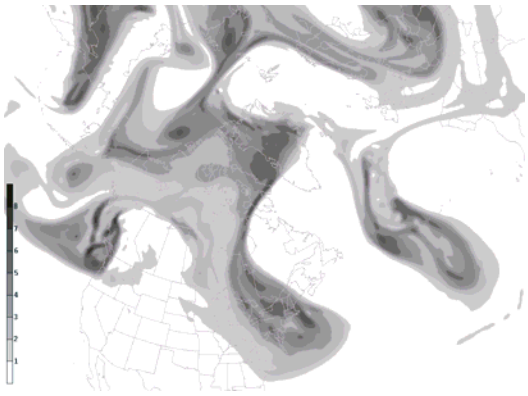
b.) What is the lead time of the forecast in hours? _____

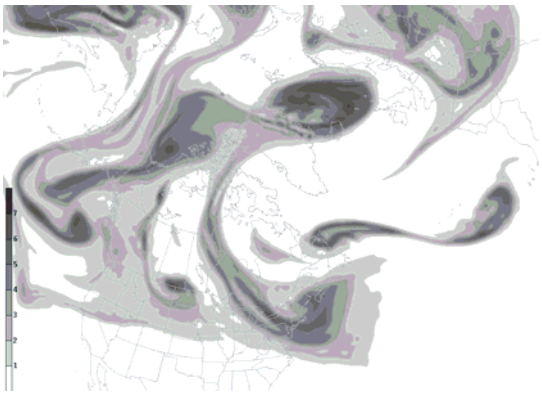
c.) What *time of day*, local time or EST, is the image valid? _____

25.) The 500-mb map below, valid 00 UTC Thursday the 16th, matches one of the plots of upper-level potential vorticity (PV) in the 400-250-mb layer shown below.

Which of the PV plots matches the 500-mb plot? ___







Happy Holidays!