

MEA 444, Spring 2009

Lab 1: Radar and satellite observations; review of basic equations [Out of 100 pts]

1/20/09

**[20 pts] 1. Study the following visible satellite image and discuss the following (referring to specific locations in the image to support your decision, and explaining your answers):**

**a) what is the likely synoptic setting?**

- There is a mid-latitude cyclone centered over South Dakota as shown by the classic “comma” shape seen in the visible satellite image.
- A boundary (either a cold front or dry line) associated with this low pressure extends southward through central South Dakota and through eastern Nebraska. The presence of this front can be inferred by a somewhat distinct boundary between the region of little/no cloudiness over most of western Nebraska, Wyoming and Colorado.
- There is another frontal boundary over northeast South Dakota that seems to extend eastward into Minnesota. This is evidenced by the convection in that area which may indicate a narrow region of enhanced lifting, possibly due to an occluded or warm front.

**b) what mesoscale phenomena are visible?**

- There is a line of convection, probably due to a cold front, just to the west of the eastern borders of South Dakota and Nebraska, as indicated by the line of high-topped convective cells observed over that area.
- There may be a “triple point” over eastern South Dakota, as surmised by the junction of two observed lines in cloud formations with taller clouds forming another line connecting the center of the low.
- A line of cumulonimbus clouds can be seen over the southwestern tip of Minnesota. Note the associated anvil tops.
- What looks to be snow cover over central South Dakota, Montana, and Wyoming, is most likely just low cloud cover. According to an archived IR loop, low clouds seem to dissipate rather quickly over the aforementioned regions in the next few hours.

**c) which areas of cloudiness are stratiform?**

- Western South Dakota, eastern North Dakota, most parts of Minnesota, eastern Iowa are areas where the clouds are mostly stratiform. The “texture” of the cloud tops are smooth with little to no signs of convective “mounds” of clouds

**d) which areas of cloudiness are cumuloform?**

- For the most part, the clouds in the southeast quadrant of the figure are cumuloform. The low sun angle clearly shows shadows cast by the tall CBs.

**[20 pts] 2. Study the following infrared satellite image and discuss the following (referring to specific locations in the image to support your decision, and explaining your answers):**

**a) the temperature at the surface is approximately?**

- $\sim 20^{\circ}\text{C}$
- Surface temperature can be inferred via IR satellite imagery only when there are no clouds to absorb the outgoing longwave terrestrial radiation originating from the surface. Western Pennsylvania seems to be cloud free and thus was used to determine the temperature at the surface.

**b) the temperature at the tropopause is approximately?**

- ~ -60°C
- Vertical velocity within CBs are strong enough to reach, and even penetrate, the tropopause. The tropopause, being an absolutely stable capping inversion, is the level at which the tops of CBs spread out laterally. Thus, the broad area of the cloud top temperatures (indicated by dark blue shading) over Iowa well represents the temperature of the tropopause.

**c) assume a reasonable depth for the troposphere and compute the lapse rate**

- $(T_{\text{trop}} - T_{\text{sfc}}) / (\text{depth of troposphere}) = (-60^{\circ}\text{C} - 20^{\circ}\text{C}) / (12 \text{ km}) = -6.7^{\circ}\text{C}/\text{km}$

**d) how would you characterize the stability of this lapse rate?**

- The lapse rate is between moist and dry adiabatic, so the atmosphere is conditionally unstable. Note that there are most likely high CAPE values over much of this region, as seen by the presence of intense convection and the fact that the lapse rate is approaching dry adiabatic.

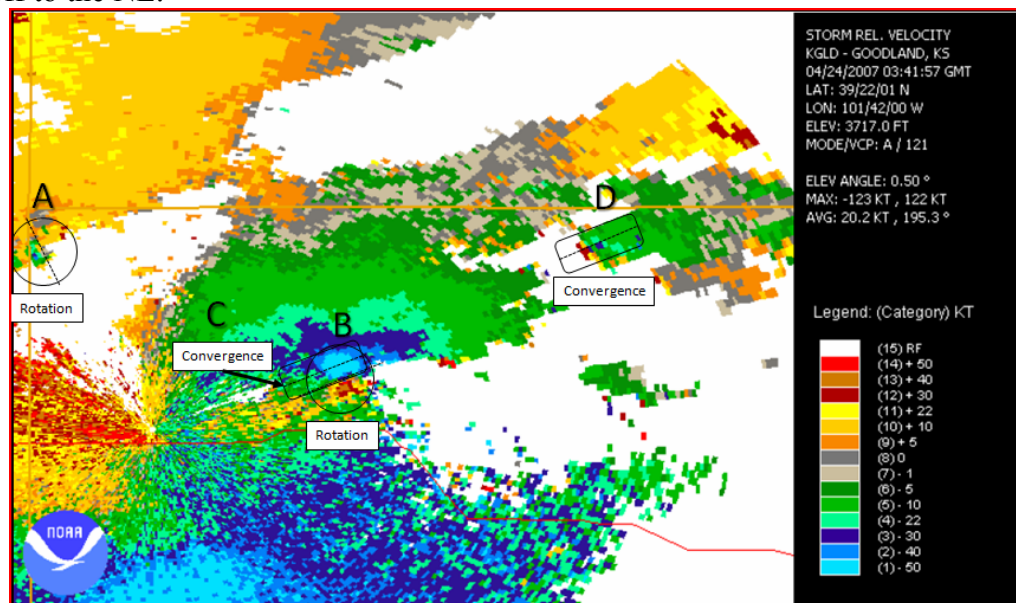
**[10 pts] 3. Study the following radar images and discuss the following (referring to specific locations in the image to support your decision, and explaining your answers):**

**a) what are locations of local rotation (in/near the storm cells)?**

- The westernmost cell in the radar reflectivity image features a hook echo. The associated rotation can be seen in the storm-relative velocity image via the couplet (labeled “A” in the figure) of inbound and outbound velocities straddling the radar beam. Another couplet, “B”, is associated with the intense cell located near the center of the image.

**b) what are locations of local convergence (in/near the storm cells)?**

- Convergence “C” is indicated by the couplet oriented in line with the radar beam and perhaps represents an outflow boundary propagating away from the parent storm; Convergence “D” can be seen just off to the NE.



**[20 pts] 4. Study the following radar radial velocity image; using the height-range plot, determine the approximate wind direction and speed at the following heights:**

**Range rings are every 20 km**

- a) **1.5 km above ground level:** From the ESE at  $30 \text{ ms}^{-1}$
- b) **3 km AGL:** From the E at  $30 \text{ ms}^{-1}$
- c) **4.5 km AGL:** From the ENE at  $30 \text{ ms}^{-1}$
- d) **6 km AGL:** From the ENE (more easterly than at 4.5 km AGL) at  $30 \text{ ms}^{-1}$

**[10 pts] 5. Beginning with equations (2.32) and (2.33) in the text, explain the meaning of the geostrophic approximation. In other words, what is assumed to be negligible?**

- In geostrophic flow, friction is considered negligible and it is assumed that there are no accelerations.
- The meaning of the geostrophic approximation is that the horizontal wind is not accelerated. Thus, the Coriolis force is left to balance the horizontal pressure gradient force.

**[10 pts] 6. Beginning with equations (2.34) in the text, explain the meaning of the hydrostatic approximation. In other words, what is assumed to be negligible?**

- The effects of friction and accelerations acting in the vertical direction are assumed to be negligible in an atmosphere that is in hydrostatic balance.
- The meaning of the hydrostatic approximation is that vertical accelerations are negligible. Thus, the vertical pressure gradient force is left to balance gravity.

**[10 pts] 7. Compare equations (2.17-2.20) with equation (2.34). Explain how horizontal convergence/divergence is related to vertical motions. What actually *causes* vertical motions?**

- The continuity equation is diagnostic and simply shows that vertical motions are associated with convergence or divergence. There is no cause and effect evident in this equation.
- Equation 2.34 is a prognostic equation and therefore can be used to predict changes in vertical motion over time. Vertical motion occurs when the vertical pressure gradient force, friction, and/or the gravitational force change disproportionately so that  $[dw/dt \neq 0]$ . Since gravity is considered a constant and friction negligible, vertical motions occur as a result the vertical pressure gradient force becoming out of balance with gravity.
- Vertical motions are actually caused by the vertical perturbation pressure gradient force.