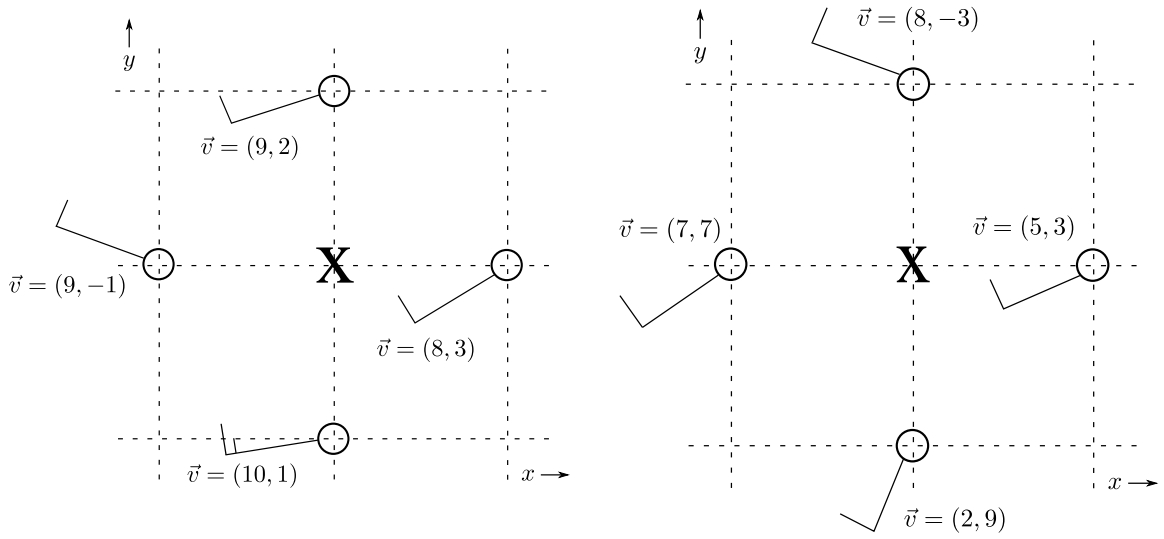
Name _____

SCI-123 Spring 2020

Introduction to Meteorology
Vorticity, Divergence, and Thermal Advection Exercises

Directions: Work the following assigned exercises on separate paper. Be sure to show intermediate, necessary steps. You may work cooperatively, but each student must turn in their own work.

1. Figure 1(a) shows station locations on a spatial grid. The distance between grid lines is a uniform 100 km in both the x (horizontal) and y (vertical) directions. The velocity vector $\vec{v}$ at each station is shown with its component magnitudes (units are m·sec^{-1}) as the ordered pair (u, v). Calculate the (a) divergence and, (b) vorticity for the location at the center (marked by "X") of the four stations. **Report your answer in units of 10^{-5} sec^{-1}.**



(a) Case 1.

(b) Case 2.

Figure 1: Velocity vectors for station 1 and 2.

2. Figure 1(b) shows station locations on a spatial grid. The distance between grid lines is a uniform 100 km in both the x (horizontal) and y (vertical) directions. The velocity vector $\vec{v}$ at each station is shown with its component magnitudes (units are m·sec^{-1}) as the ordered pair (u, v). Calculate the (a) divergence and, (b) vorticity for the location at the center (marked by "X") of the four stations. **Report your answer in units of 10^{-5} sec^{-1}.**

3. Calculate the speed of a Rossby wave if the wind speed is 55 m·sec^{-1}, the wavelength $\lambda = 6000$ km and the latitude is 45°N.

4. Calculate the speed of a Rossby wave if the wind speed is 60 m·sec^{-1}, the wavelength $\lambda = 3000$ km and the latitude is 45°N.

5. Suppose the 300 mb jet stream has a wave number of 4. Calculate the average wavelength if the latitude is 45°N.

6. Suppose the 500 mb jet stream has a wave number of 5. Calculate the average wavelength if the latitude is 45°N.

7. The length of one 500 mb wave is 6000 km, and a short wave has a wavelength of 200 km. If the short wave trough is 400 km behind the long wave trough, how long will it be before their trough axes are aligned if the 500 mb wind speed is 55 m·sec^{-1}? Assume angle $\phi = 45°$.

8. The length of one 500 mb wave is 3000 km, and a short wave has a wavelength of 200 km. If the short wave trough is 300 km behind the long wave trough, how long will it be before their trough axes are aligned if the 500 mb wind speed is 60 m·sec^{-1}? Assume angle $\phi = 45°$.

Figure 2 shows surface temperature contours (solid lines, in degrees F) on a spatial grid. The distance between grid lines (dotted) is a uniform 100 km in both the x (horizontal) and y (vertical) directions. Station locations, numbered 1 - 4, are shown.

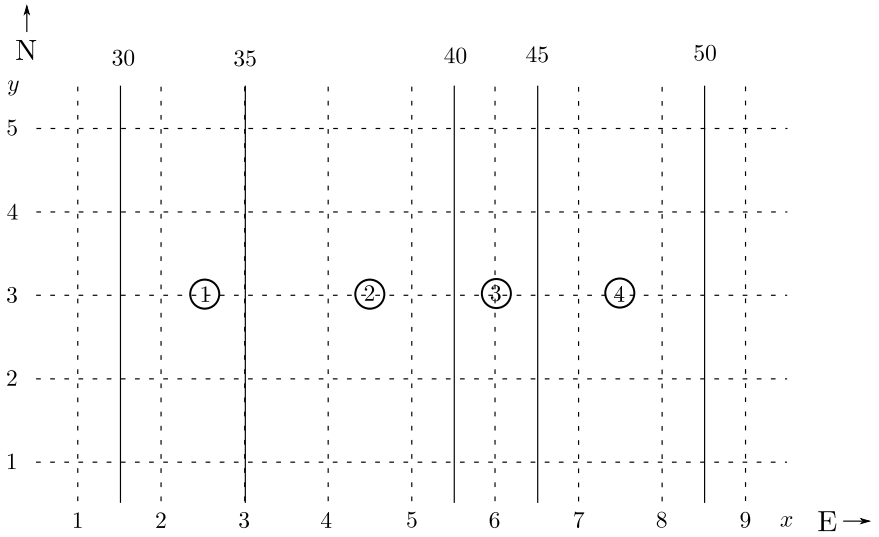


Figure 2: Spatial grid with temperature contours (in degrees Fahrenheit).

9. Calculate the temperature gradient $\dfrac{\Delta T}{\Delta x}$ (in 10^{-5} °F/meter) for station 1.
10. Calculate the temperature gradient $\dfrac{\Delta T}{\Delta x}$ (in 10^{-5} °F/meter) for station 2.
11. Calculate the temperature gradient $\dfrac{\Delta T}{\Delta x}$ (in 10^{-5} °F/meter) for station 3.
12. Calculate the temperature gradient $\dfrac{\Delta T}{\Delta x}$ (in 10^{-5} °F/meter) for station 4.
13. Station 1 has a westerly wind with a speed of 10 m·sec^{-1}(the wind vector is $\vec{v} = (10, 0)$). Calculate the magnitude of the thermal advection at station 1 in °F/hour.
14. Station 2 has a westerly wind vector $\vec{v} = (15, 0)$. Calculate the magnitude of the thermal advection in °F/hour.
15. Station 3 has a westerly wind vector $\vec{v} = (10, 10)$. Calculate the magnitude of the thermal advection in °F/hour.
16. Station 4 has a westerly wind vector $\vec{v} = (-10, 10)$. Calculate the magnitude of the thermal advection in °F/hour.
17. Answer each of the following on your separate sheet of paper.
    (a) If the wind speed doubles, then the magnitude of the temperature advection will _____. Explain.
    (b) If the magnitude of the temperature gradient doubles, then the magnitude of the temperature advection will _____. Explain.
    (c) Explain why the magnitude of thermal advection is zero if the wind blows parallel to the isotherms.