Table 1: 00Z 9 September 2016 sounding - OKX

<table>
<thead>
<tr>
<th>p (mb)</th>
<th>wind speed (kts)</th>
<th>wind direction (degrees)</th>
<th>u (m/s)</th>
<th>v (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1008</td>
<td>2</td>
<td>215</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>1000</td>
<td>8</td>
<td>190</td>
<td>0.7</td>
<td>4.0</td>
</tr>
<tr>
<td>975</td>
<td>17</td>
<td>200</td>
<td>3.0</td>
<td>8.2</td>
</tr>
<tr>
<td>925</td>
<td>18</td>
<td>260</td>
<td>9.1</td>
<td>1.6</td>
</tr>
<tr>
<td>870</td>
<td>24</td>
<td>285</td>
<td>11.9</td>
<td>-3.2</td>
</tr>
<tr>
<td>850</td>
<td>27</td>
<td>295</td>
<td>12.6</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

The sounding above was launched at 00Z September 9, 2016, from OKX (Upton, NY), as a squall line was passing Albany. Keep in mind that wind is defined by the direction the air is coming from. A wind direction of 0° is northerly, 90° is easterly, 180° is southerly, and 270° is westerly.

(1) From the wind direction and speed information, which is given in degrees and knots, respectively, compute the $u$ and $v$ components in m/s at each level. 1 kt = 0.514 m/s. Fill values in the table. One decimal place suffices.

**Ans:** See table above. Remember you needed to convert from knots to m/s.

(2) Plot the resulting $u$ vs. $v$ components as a hodograph, like the Bluestein and Jain example seen in class. (Visit the class web page if you need another copy.) You can use graph paper, Excel, or another strategy. Label your plot fully, and attach it to this paper.

![Figure 1: Hodograph for OKX sounding 00Z 9 Sept. 2016.](image)
(3) Compute the magnitude and direction of the vertical shear between the 1000 and 975 mb levels, and between the 975 and 925 mb levels. Express the magnitude in m/s and direction in degrees, using meteorological conventions. (Keep in mind that you can check your answers by using the hodograph. The shear vectors will be parallel to the line segments connecting the points.)

**Ans:** For the 1000-975 mb wind shear, note \( u_{1000} = 0.7 \) and \( v_{1000} = 4.0 \), and \( u_{975} = 3.0 \) and \( v_{975} = 8.2 \), all in m/s. So \( \vec{V}_{975} - \vec{V}_{1000} = [u_{975} - u_{1000}] \hat{i} + [v_{975} - v_{1000}] \hat{j} = (3.0 - 0.7) \hat{i} + (8.2 - 4.0) \hat{j} = 2.3 \hat{i} + 4.2 \hat{j} \). This is a magnitude of

\[
\sqrt{2.3^2 + 4.2^2} = 4.8 \text{ m/s.}
\]

and makes an angle of

\[
\tan \theta = \frac{\text{opp}}{\text{adj}} = \frac{4.2}{2.3} \rightarrow \theta = \arctan(1.83) = 61.3^\circ.
\]

This direction of 61.3° is the geometric direction (CCW from East), but not the meteorological wind direction. That is from 209° as illustrated in the top panel of the figure below.

For the 975 to 925 mb shear (see bottom panel of figure below), the same strategy results in a vector that points from 317° with a magnitude of 9.0 m/s.

![Figure 2: Figure for #3.](image-url)
(4) Suppose the forecast wind for the 925 mb level at this time was from the southwest at 15 m/s. Defining error as the forecast wind minus the observed wind, draw the forecast and observed wind vectors, and the vector representing forecast error. What is the magnitude of the forecast error, in m/s, and direction, in degrees?

As the forecast wind is from the SW at 15 m/s, its $u$ and $v$ components are

$$u_f = 15 \cos(45) = 10.6 \text{ m/s},$$

and

$$v_f = 15 \sin(45) = 10.6 \text{ m/s}.$$ 

The vector error, drawn from the head of the observed wind vector to the head of the forecast wind vector, is $(10.6 - 9.1)i + (10.6 - 1.6)j$, for a magnitude of 9.1 m/s, geometric direction (see figure) of 81° CCW from East, and a meteorological direction of 189°.

![Figure 3: Figure for #4.](image)

(5) Refer to Fig. 4. What is the divergence at points $P$, $Q$, and $R$? Answer with one of the following for each point: divergent, convergent, or nondivergent. Explain your answer.

**Ans:** The flow is nondivergent at all three points. At the very least, divergence requires the $u$ wind to change in the $x$ direction and/or the $v$ wind to change in the $y$ direction. In this case, there is no $v$ component, and the $u$ component is not varying in the $x$ direction.

(6) Again referring to Fig. 1. What is the vertical vorticity at points $P$, $Q$, and $R$? Answer with one of the following for each point: positive, negative, or irrotational. Explain your answer.

**Ans:** The flow has CW spin in the horizontal plane, and thus represents negative vertical vorticity by the definition of the curl and the right-hand rule. For flow to be rotational, at the very least you need the $v$ component to vary in the $x$ direction and/or the $u$ component to vary in the $y$ direction. The latter condition is satisfied here.
(7) A horizontal flow field is described by $\vec{V} = y\hat{i} + x\hat{j}$. Sketch this flow field. Compute its horizontal divergence and vertical vorticity. Show your work.

**Ans:** The flow field is sketched below. Note $u = y$ and $v = x$. For divergence

$$\nabla \cdot \vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$
$$= \frac{\partial}{\partial x}(y) + \frac{\partial}{\partial y}(x)$$
$$= 0 \text{ nondivergent.}$$

For vorticity

$$\vec{k} \cdot (\nabla \times \vec{V}) = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$
$$= \frac{\partial}{\partial x}(x) - \frac{\partial}{\partial y}(y)$$
$$= 1 - 1$$
$$= 0 \text{ irrotational.}$$
Figure 5: Figure for #7.