User Relevant Verification for Wind Forecasts

Tressa L. Fowler
Randy Bullock, Barbara Brown, Matt Pocernich
Which Users?

• Some users most interested in time series of power output. Matt will tell you about that later this week.

• NWP and statistical models have more info in space and less in time.

• How to do diagnostic verification of these?

• Can we find verification metrics that do not treat the components of wind
Example user relevant methods

- Speed errors by direction
- Categorical stats
- Vector errors
- Finding features in derived wind fields
  - object based verification using MODE

7 WRF forecasts and analyses of surface winds
Wind Speed in meters / second
Wind Direction from -180 to 180 degrees, 0 = North
  - Northeastern Colorado, CONUS
# Categorical Wind

**Vx**

% Correct - 28  
HSS - 0.06  
GSS - 0.09

<table>
<thead>
<tr>
<th>Wind Speed</th>
<th>Bias</th>
<th>Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3.6</td>
<td>2.52</td>
<td>0.33</td>
</tr>
<tr>
<td>3.6-5.3</td>
<td>0.73</td>
<td>0.13</td>
</tr>
<tr>
<td>5.3-6.7</td>
<td>0.13</td>
<td>0.04</td>
</tr>
<tr>
<td>6.7-8</td>
<td>0.77</td>
<td>0.02</td>
</tr>
<tr>
<td>8-9.4</td>
<td>1.74</td>
<td>0</td>
</tr>
<tr>
<td>9.4-11.</td>
<td>1.36</td>
<td>0.04</td>
</tr>
<tr>
<td>11.2+</td>
<td>0.60</td>
<td>0</td>
</tr>
</tbody>
</table>
Calculate mean resultant vector and its angle:

\[
\overline{R} = \frac{1}{n} \left[ \left( \sum_i x_i \cos \theta_i \right)^2 + \left( \sum_i x_i \sin \theta_i \right)^2 \right]^{1/2}
\]

\[
\overline{\theta} = \text{atan2} \left( \sum_i x_i \sin \theta_i, \sum_i x_i \cos \theta_i \right)
\]

Only makes sense when the wind direction is unimodal, otherwise vectors cancel each other out.

Restriction to small spatial domain and time period is recommended.
Pictorial Example

- Angle of average wind vector.
- Speed of average wind vector.
## Example results

<table>
<thead>
<tr>
<th>Wind vectors</th>
<th>Mean orientation</th>
<th>Mean resultant length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecast</td>
<td>Obs</td>
</tr>
<tr>
<td>20050712</td>
<td>6</td>
<td>93</td>
</tr>
<tr>
<td>20050817</td>
<td>-144</td>
<td>-69</td>
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<tr>
<td>20051021</td>
<td>-22</td>
<td>42</td>
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<tr>
<td>20051108</td>
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<tr>
<td>20060111</td>
<td>-115</td>
<td>-100</td>
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<tr>
<td>20060216</td>
<td>-8</td>
<td>29</td>
</tr>
<tr>
<td>20060508</td>
<td>-108</td>
<td>-92</td>
</tr>
</tbody>
</table>
We used MODE with three derived scalar fields:

Divergence: \( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \)

Curl: \( \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} \)

Speed: \( \sqrt{u^2 + v^2} \)
The Helmholtz theorem

• Given the divergence and curl of a vector field in some bounded region, then the original vector field can be reconstructed from these using explicit formulas.

• => no loss of information from the wind field in calculating the divergence and curl.

• However, our calculation of divergence and curl is an approximation.
Curl

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Wind Speed Field

- High Winds
  - E Montana
  - East Coast
- MODE identifies
Types of Features Detectable in Derived Wind Fields

- Vortices - curl and divergence
- Boundaries - divergence
- Troughs - curl
- Shear - curl
- High wind events - wind speed
Conclusions

• Categorical and conditional statistics and graphics provide more detailed information than a single overall statistic.

• Mean resultant vectors keep the components of wind together. Only work for unimodal winds => small domain and short time period.

• Comparison of mean resultant vectors gives an overall sense of error, but ignores distribution of each error.

• Curl, divergence, and wind speed fields each contain wind features, verifiable as objects. In particular, they identify changes in the wind over space.
Future Work

• Identify uncertainty measures for mean resultant angle and length.
• Research use of axial (non-cancelling) mean resultant vector for multi-modal winds.
• Adjust MODE settings to handle wind objects and biases.
• Use time domain version of MODE to identify timing errors in the forecasts.