User Relevant Verification for Wind Forecasts

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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

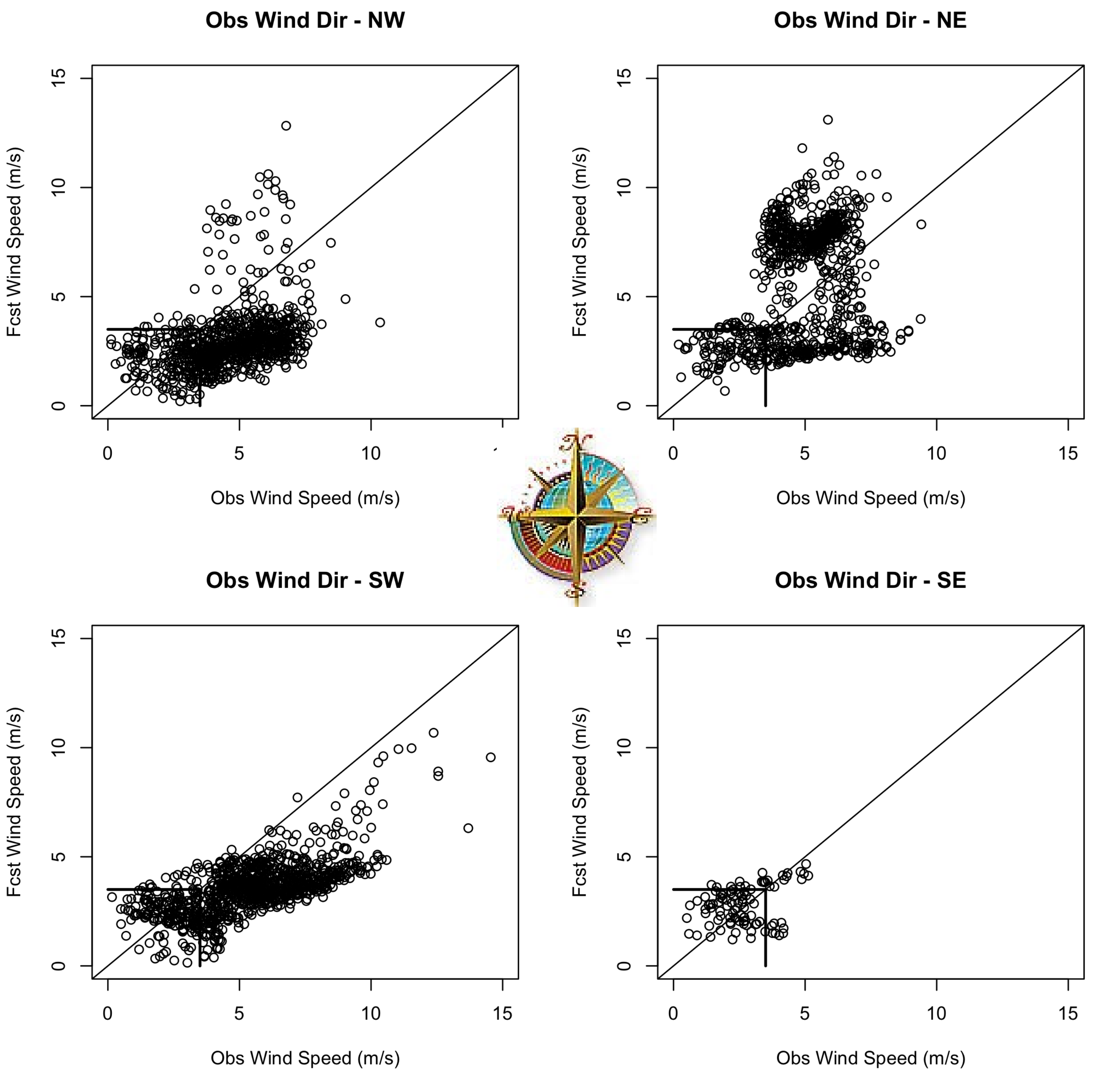
Example user relevant methods

- 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

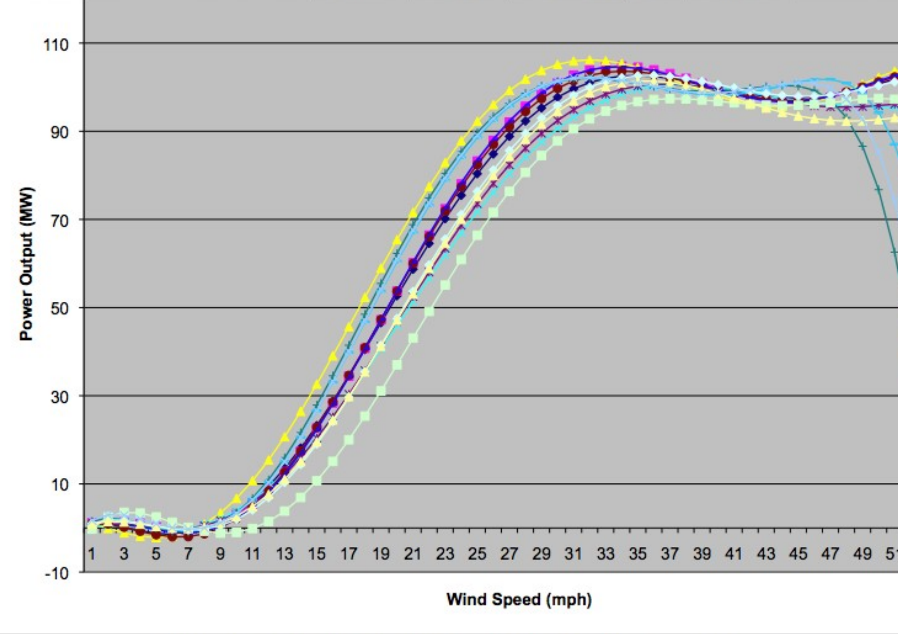
Wind Direction from -180 to 180 degrees, 0 = North

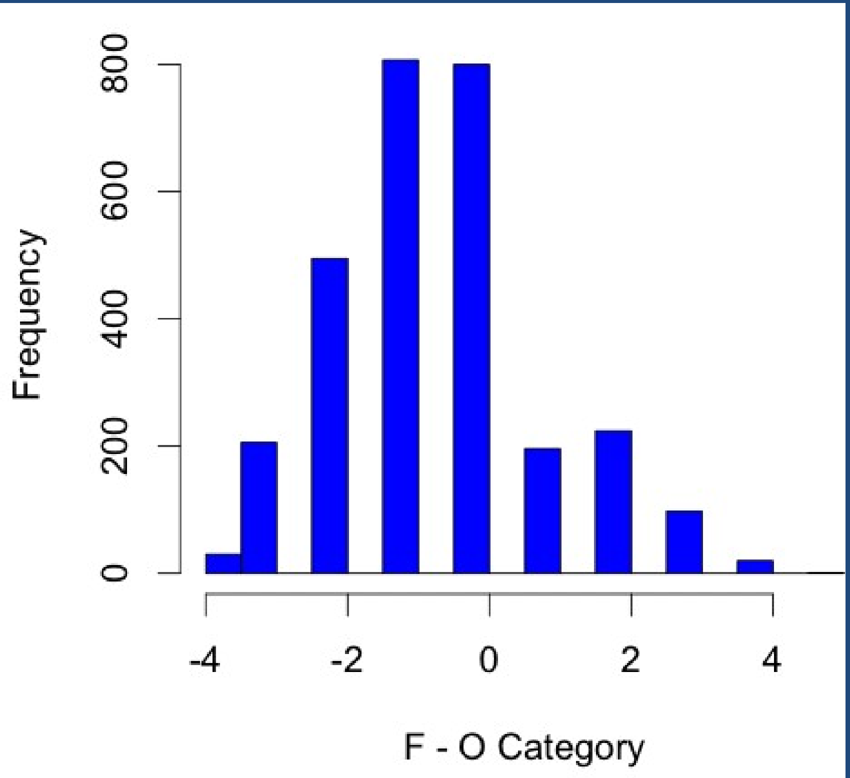

Obs Wind Dir - NW
Obs Wind Dir - NE
Obs Wind Dir - SW
Obs Wind Dir - SE
Fcst Wind Speed (m/s)
Obs Wind Speed (m/s)
0
5
10
15

Categorical Wind Vx

% Correct - 28
HSS – 0.06
GSS – 0.09

Wind Speed	Bias	Threat
<3.6	2.52	0.33
3.6-5.3	0.73	0.13
5.3-6.7	0.13	0.04
6.7-8	0.77	0.02
8-9.4	1.74	0
9.4-11.	1.36	0.04
11.2+	0.60	0





- Calculate mean resultant vector and its angle:

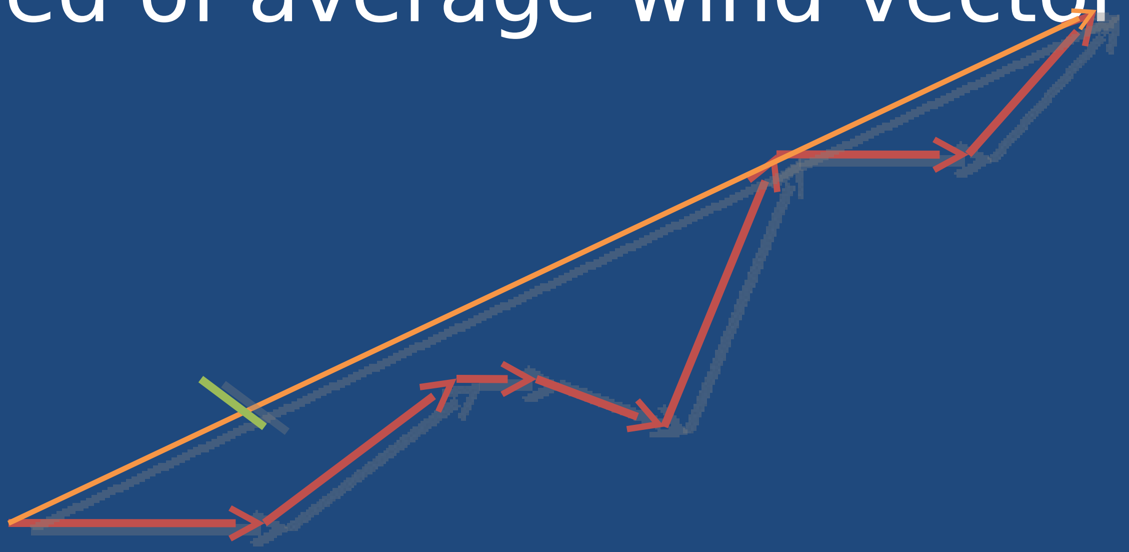
$$\overline{R} = \frac{1}{n}\left[\left(\sum_i x_i \cos\theta_i\right)^2 + \left(\sum_i x_i \sin\theta_i\right)^2\right]^{1/2}$$

$$\overline{\theta} = \texttt{atan2}\left(\sum_i x_i \sin\theta_i, \sum_i x_i \cos\theta_i\right)$$

- 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

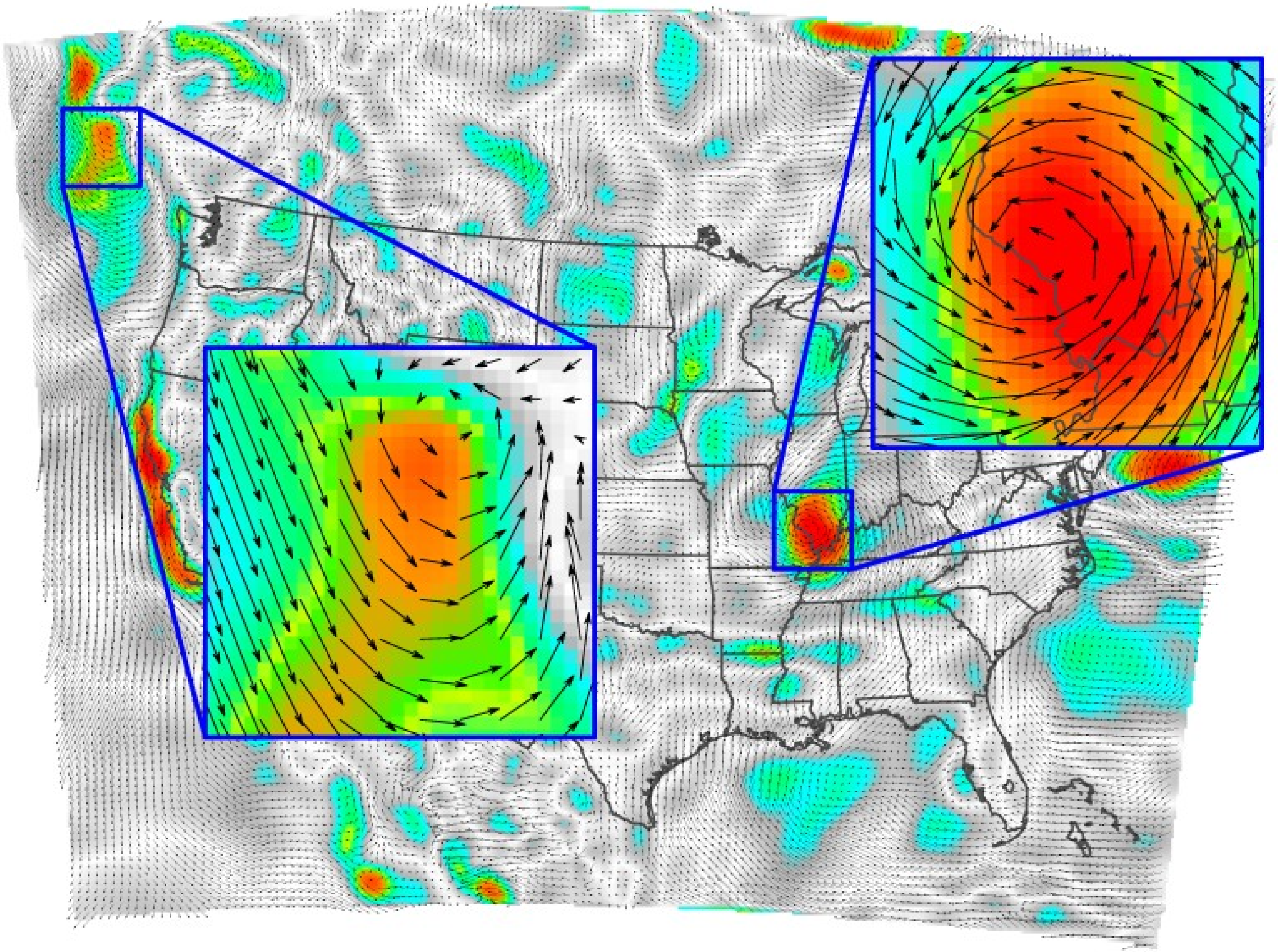
Wind vectors	Mean orientation		Mean resultant length	
	Forecast	Obs	Forecast	Obs
20050712	6	93	1.8	0.2
20050817	-144	-69	2.0	3.0
20051021	-22	42	3.4	4.2
20051108	-134	-98	3.2	5.1
20060111	-115	-100	3.6	6.9
20060216	-8	29	7.7	4.8
20060508	-108	-92	3.4	4.5

We used MODE with three derived scalar fields:

Divergence	$\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y}$
Curl	$\dfrac{\partial u}{\partial y} - \dfrac{\partial v}{\partial x}$
Speed	$\sqrt{u^2 + v^2}$

The Helmholtz theorem

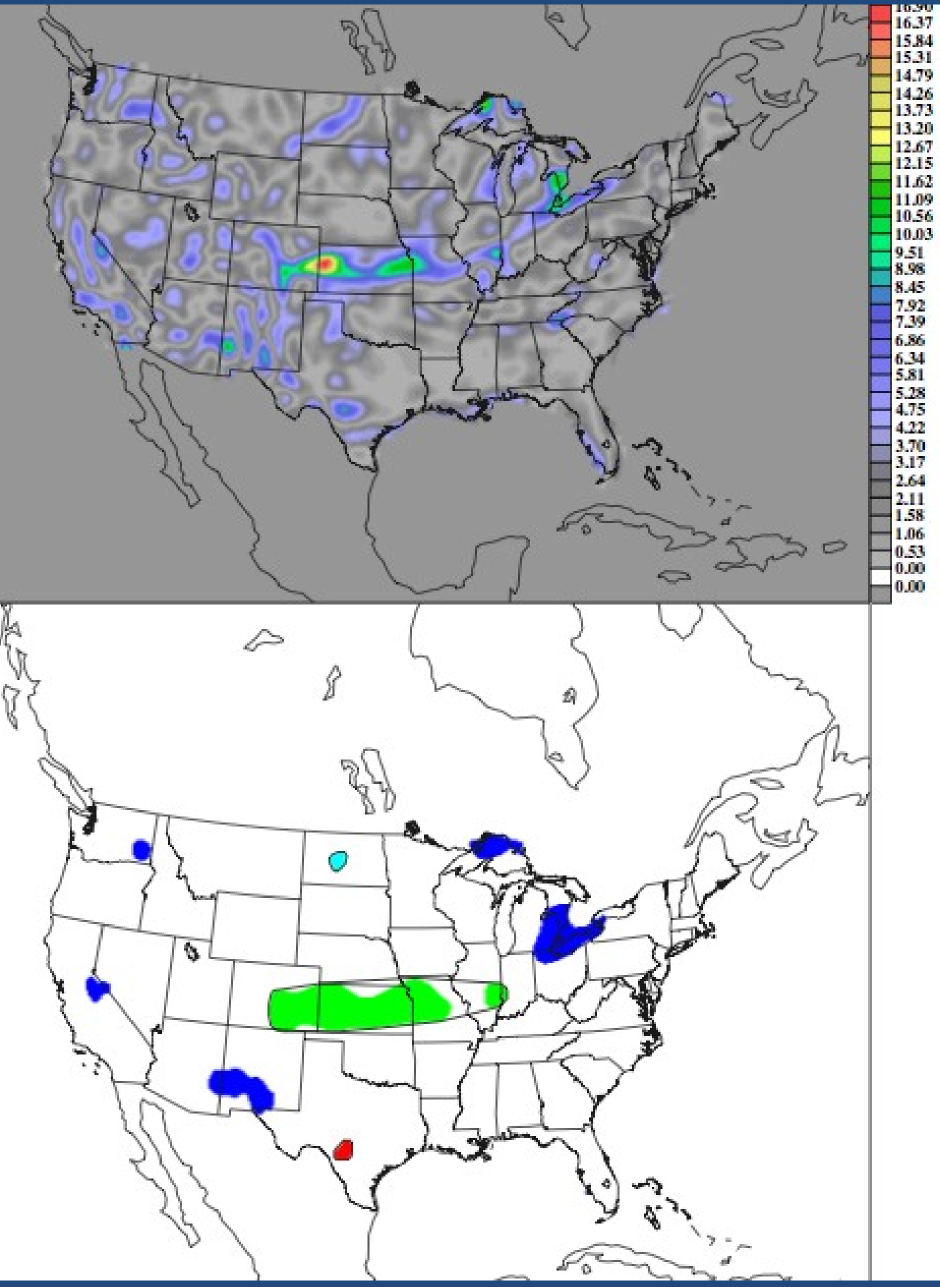
- Given the divergence and curl of a vector field in some bounded region, then the original vector field can be reconstructed from these using explicit formulas.
- => no loss of information from the wind field in calculating the divergence and curl.
- However, our calculation of divergence and curl is an



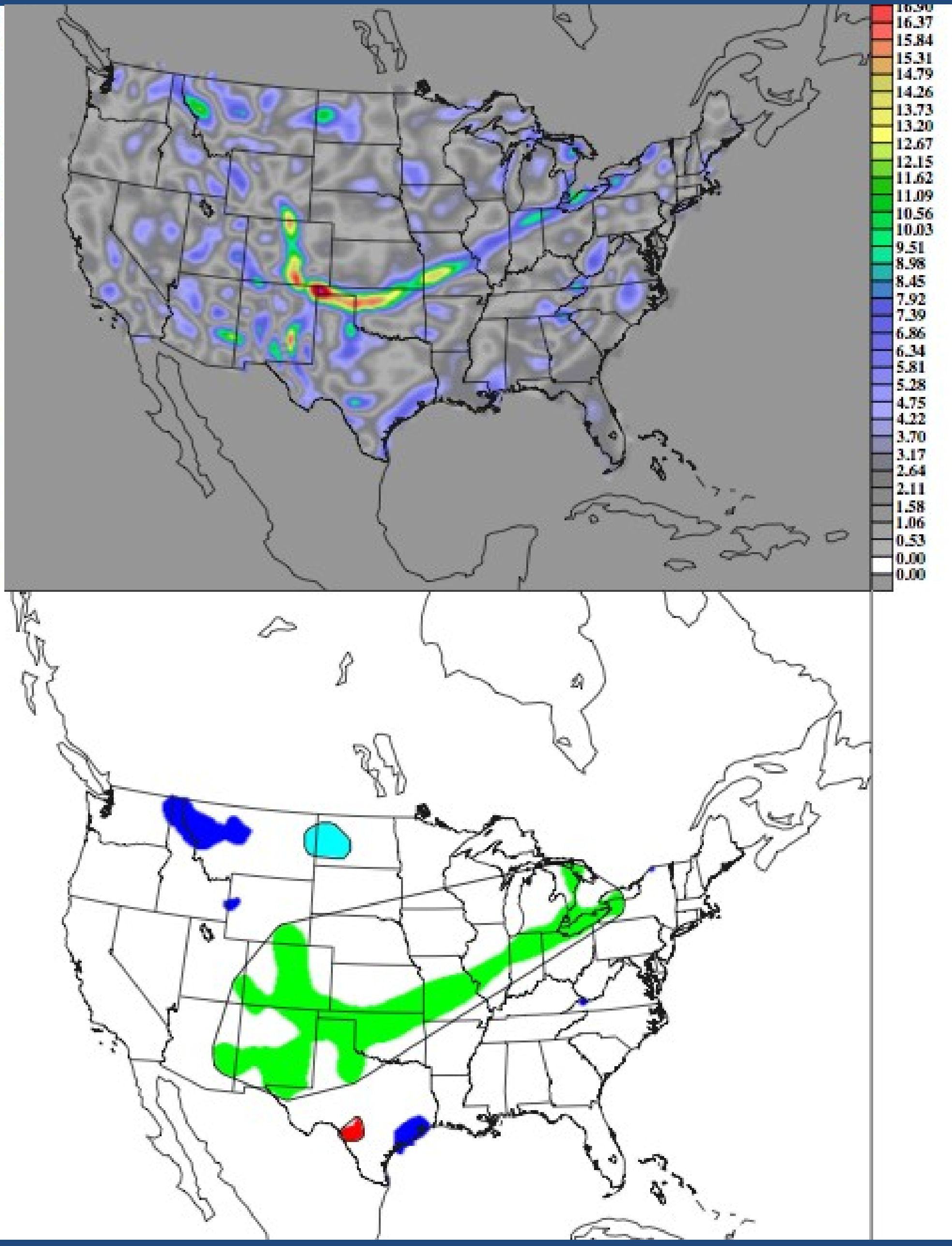
Curl

Valid Jul 12, 2005 12h   Lead 00h

Forecast Divergence

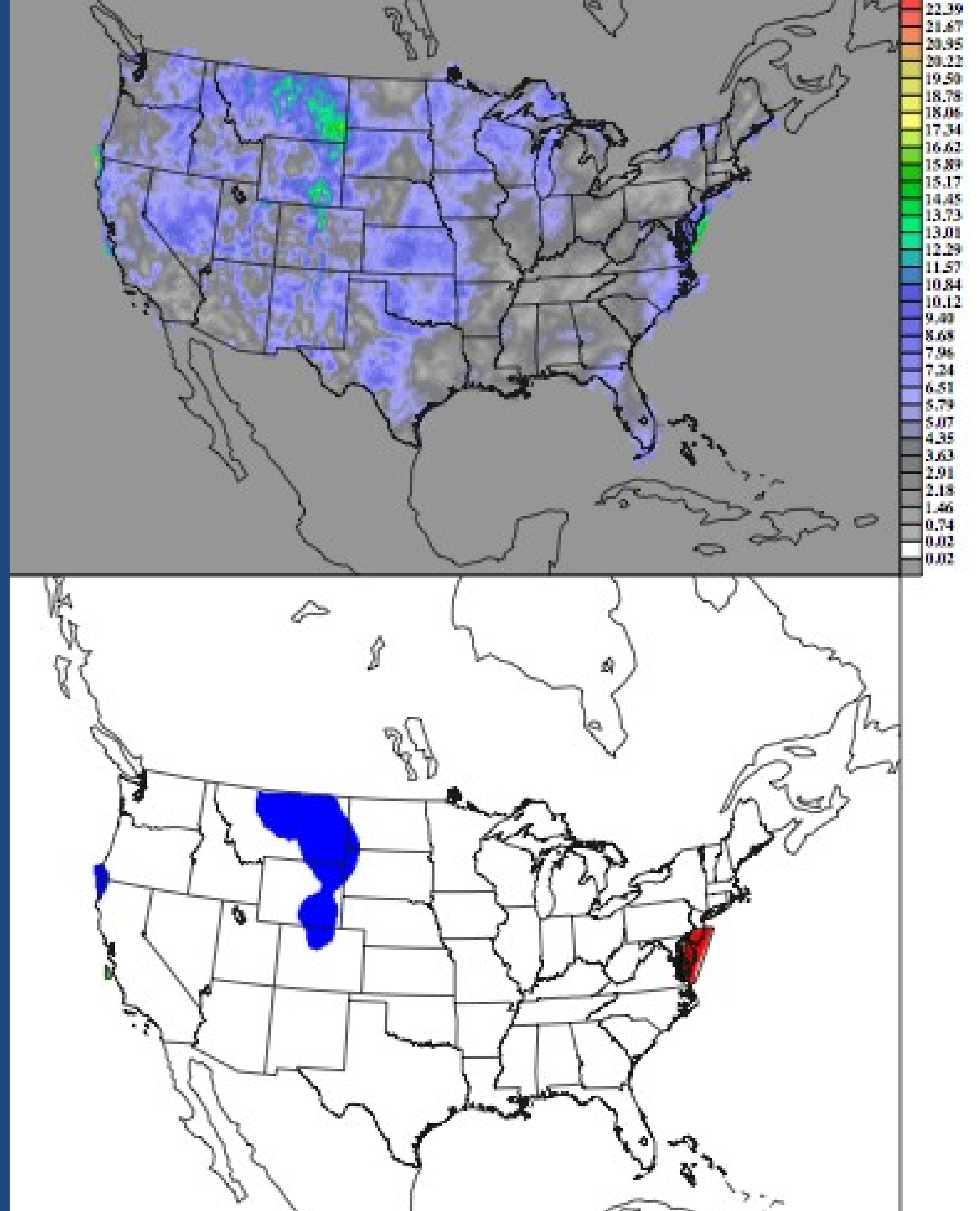


Observed Divergence



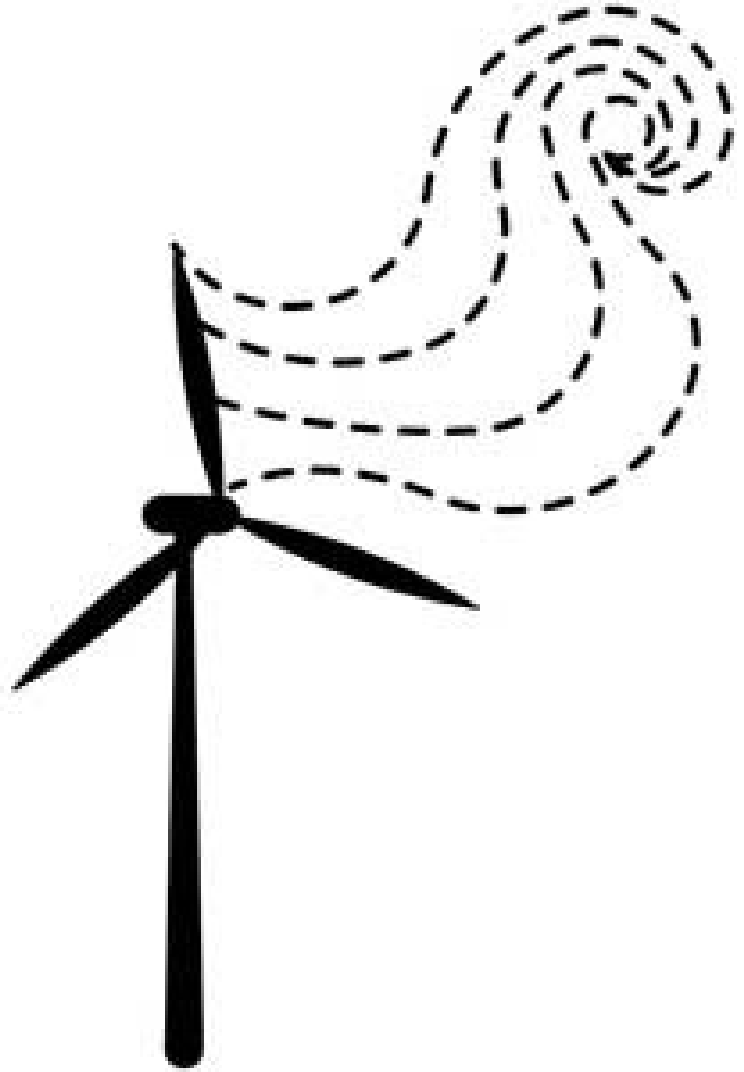
Wind Speed Field

- High Winds
    - E Montana
    - East Coast
- MODE identifies



Types of Features Detectable in Derived Wind Fields

- Vortices – curl and diverg
- Boundaries - divergence
- Troughs – curl
- Shear – curl
- High wind events – wind s



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