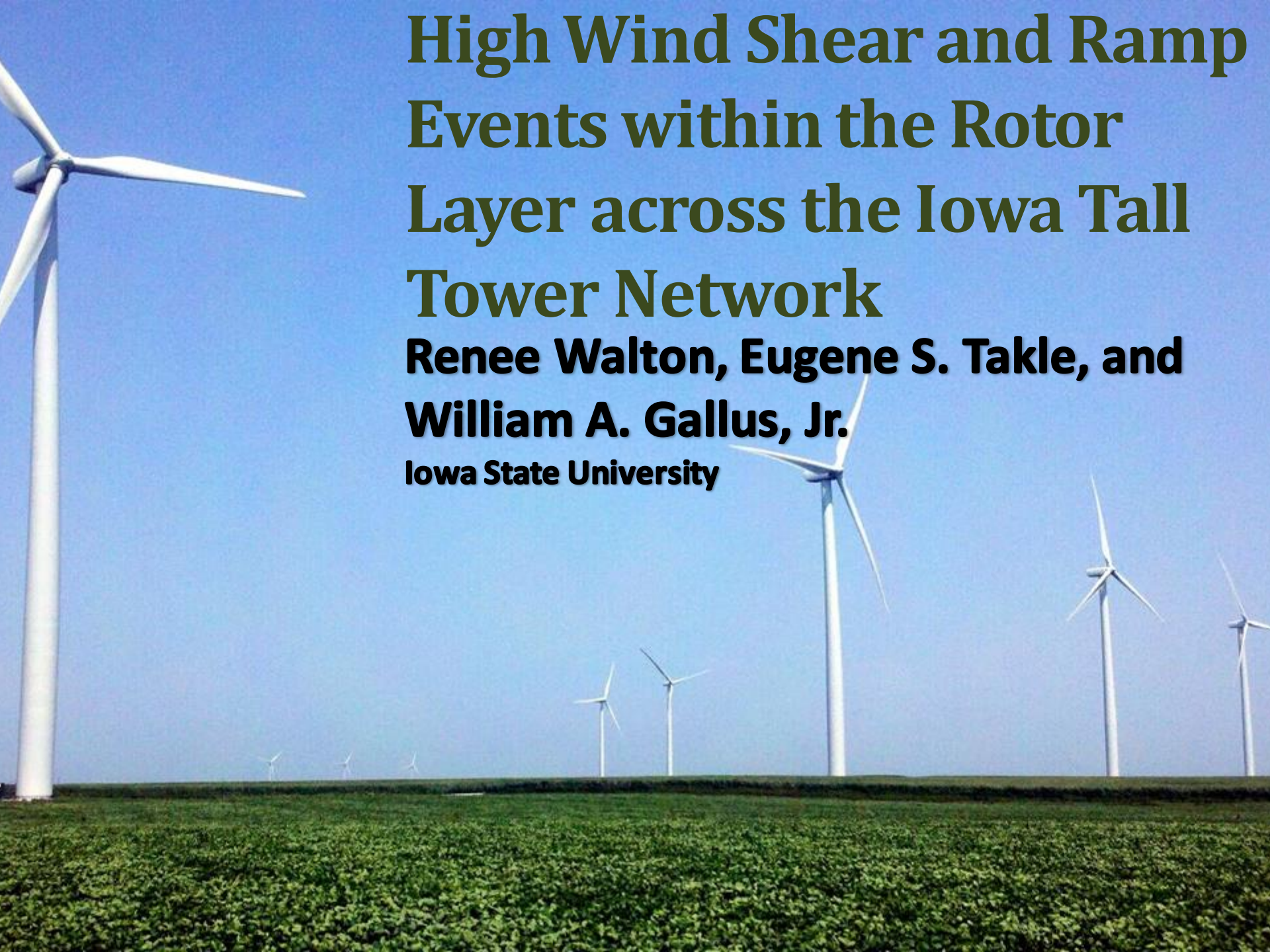


High Wind Shear and Ramp Events within the Rotor Layer across the Iowa Tall Tower Network

Renee Walton, Eugene S. Takle, and William A. Gallus, Jr.

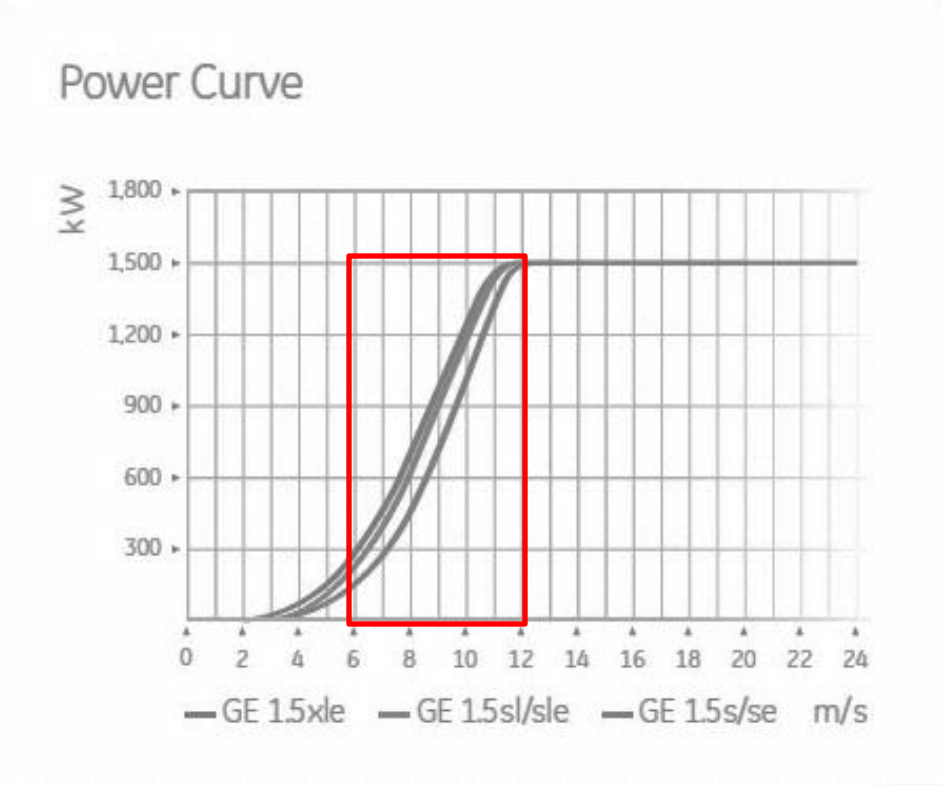
Iowa State University

Motivation

- Lack of observations through layer occupied by wind turbine blades
- Day-ahead forecast uncertainty - $1 million/month in Texas ISO (Ahlstrom et al 2013)
- Ramp events propagate across state creating widespread underperformance (Walton et al. 2013)

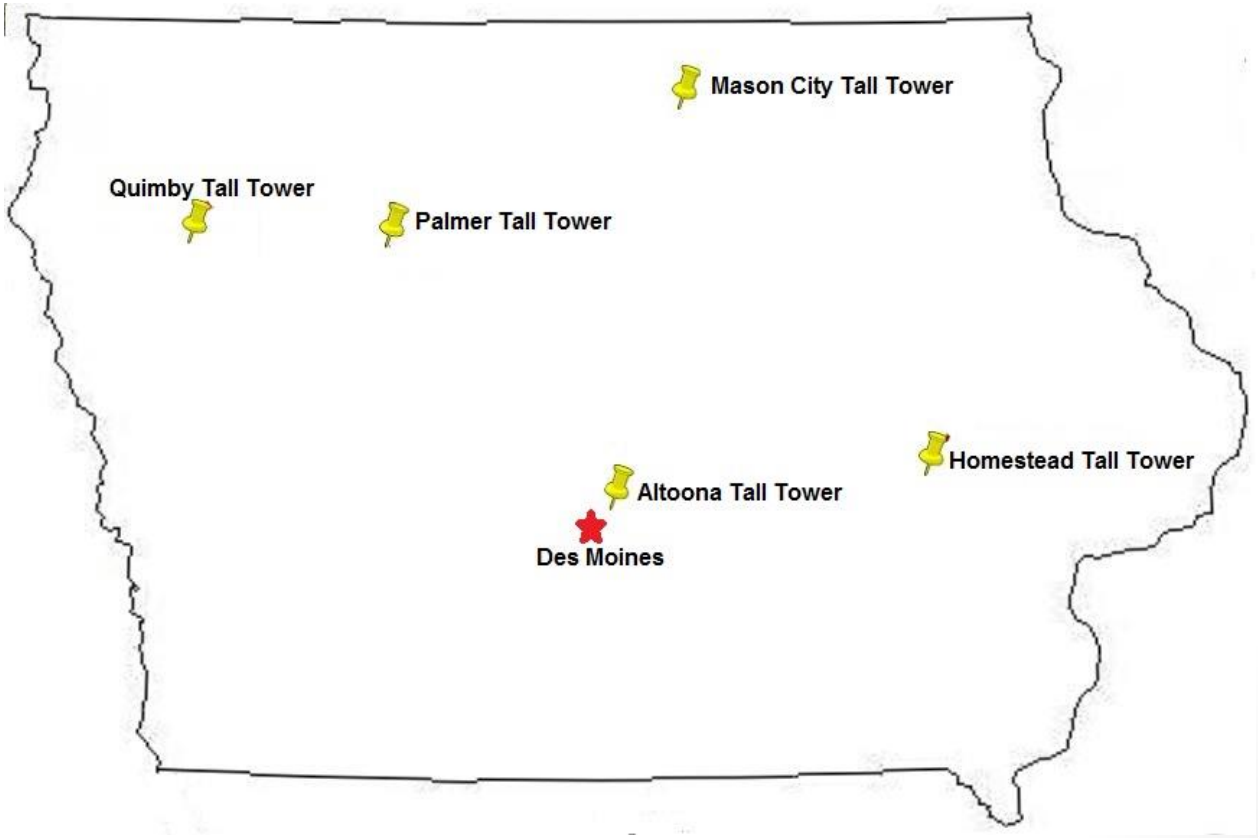
Background information

- Ramp event defined as 50% change in power in 4 hours or less
- High shear events upwards of 15 ms^{-1} from 50 – 200 m or 0.50 s^{-1} shear exponent



Data

- Five tall towers across Iowa
- Two years of 10 min wind speed and direction and temperature data at 50 m, 100 m, 150 m, and 200 m

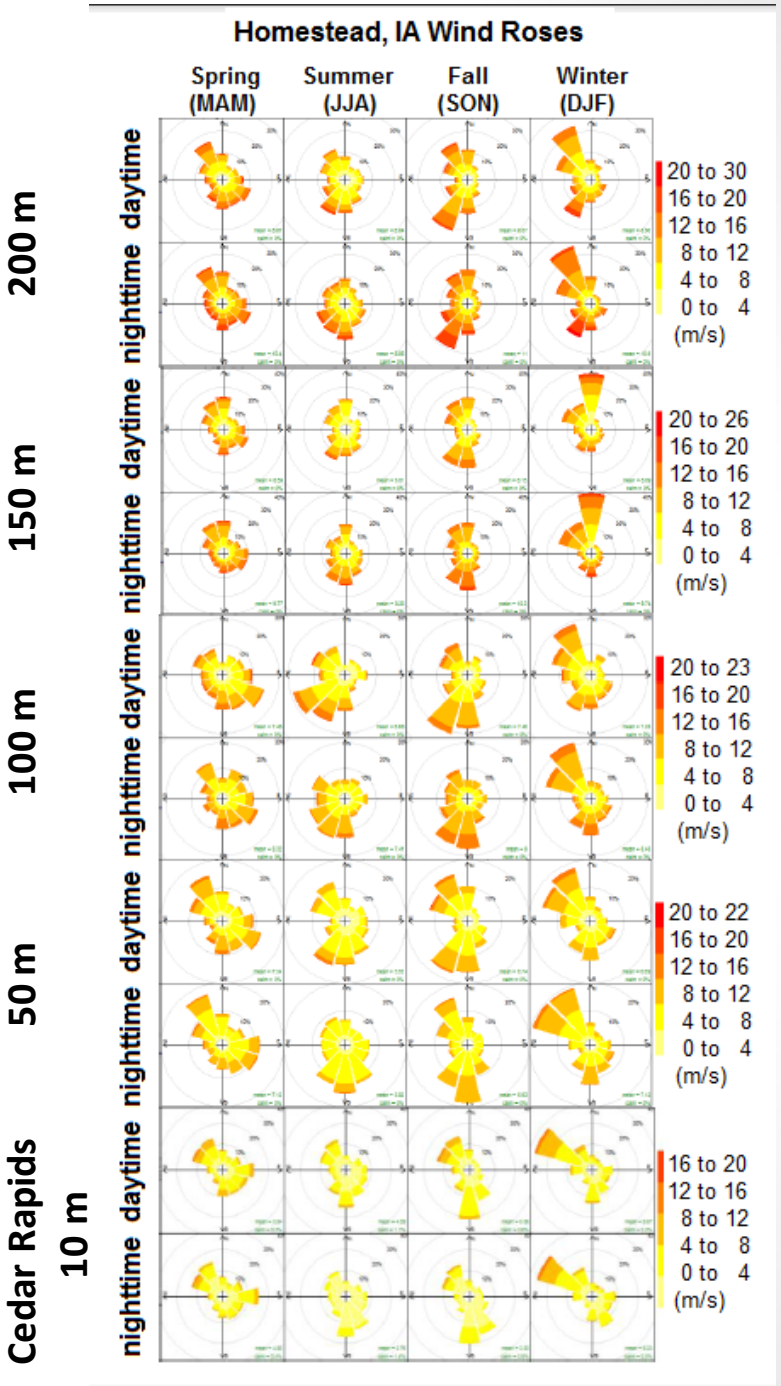


Methods

- Created climatology of diurnal and seasonal behavior
- Determined existence of ramp and high shear events
- Tracked propagation of ramp events in vertical and horizontal

Seasonality

- Stronger nighttime winds except at 50 m and 10 m
- Winds veer with height
- Highest shear fall and winter at night
- Southerly component in winter related to western system creating southerly low level jet in Plains



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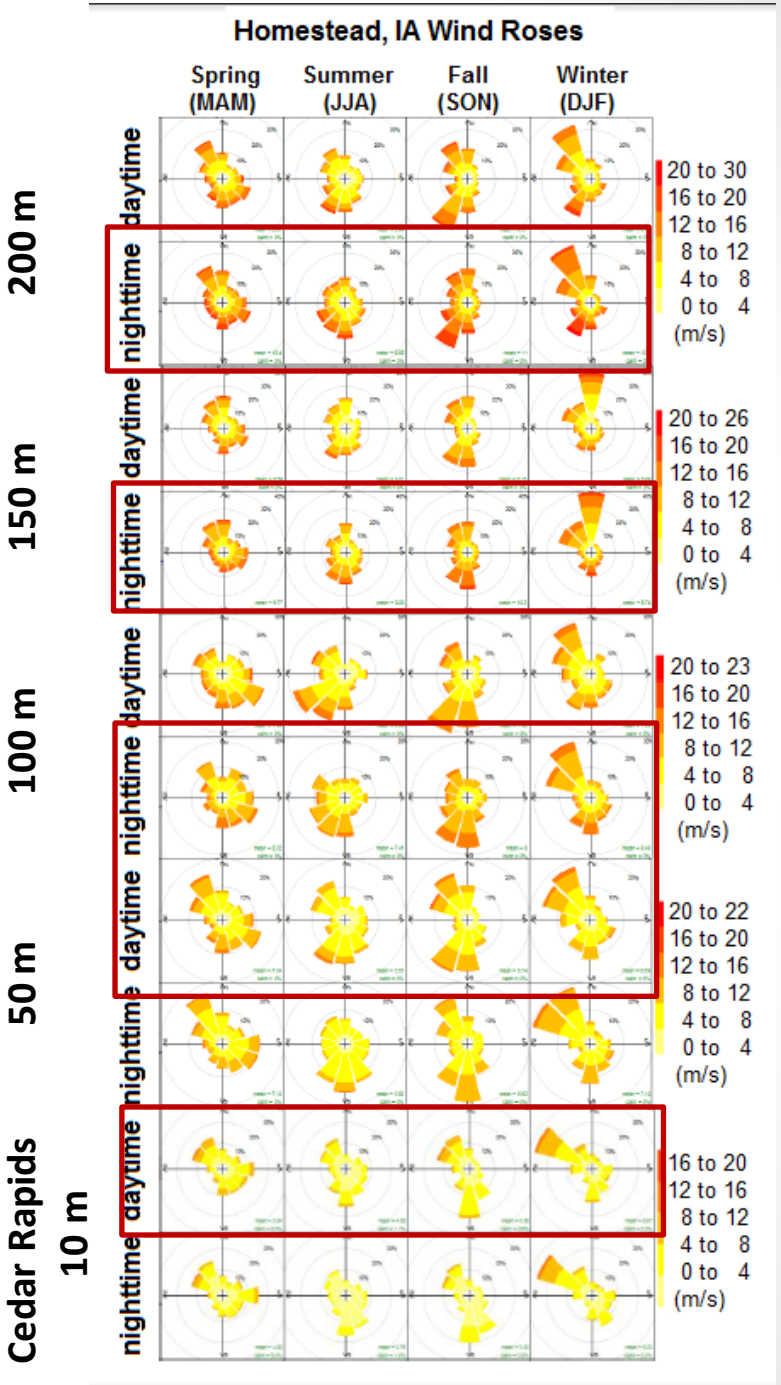

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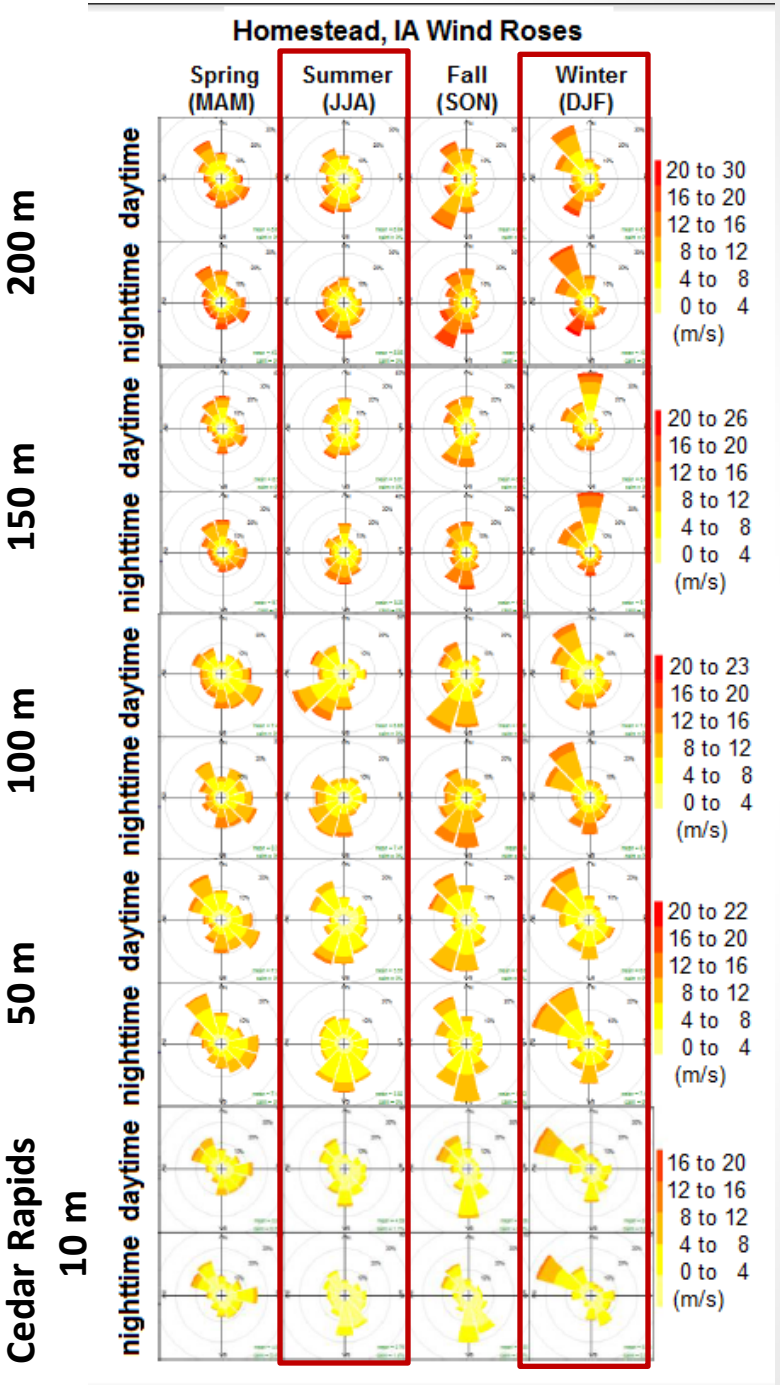

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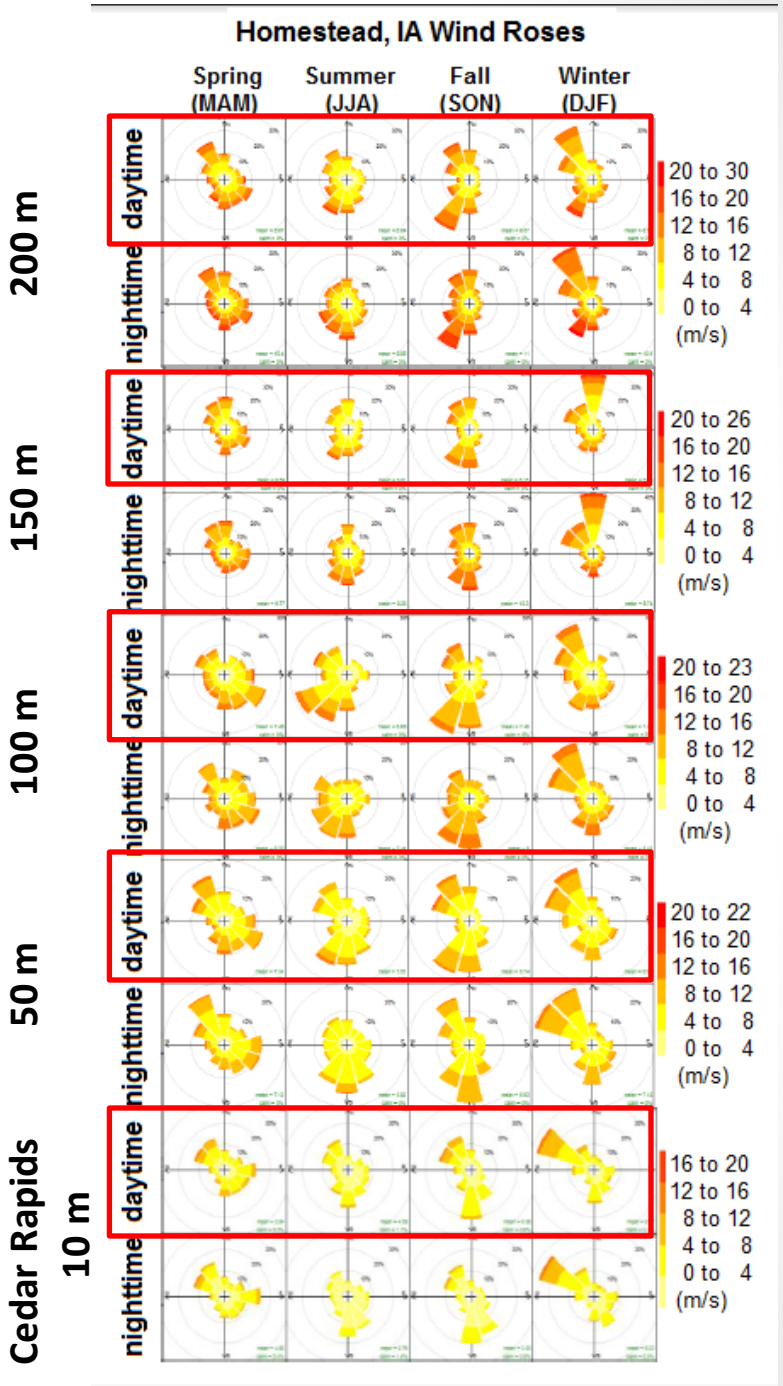
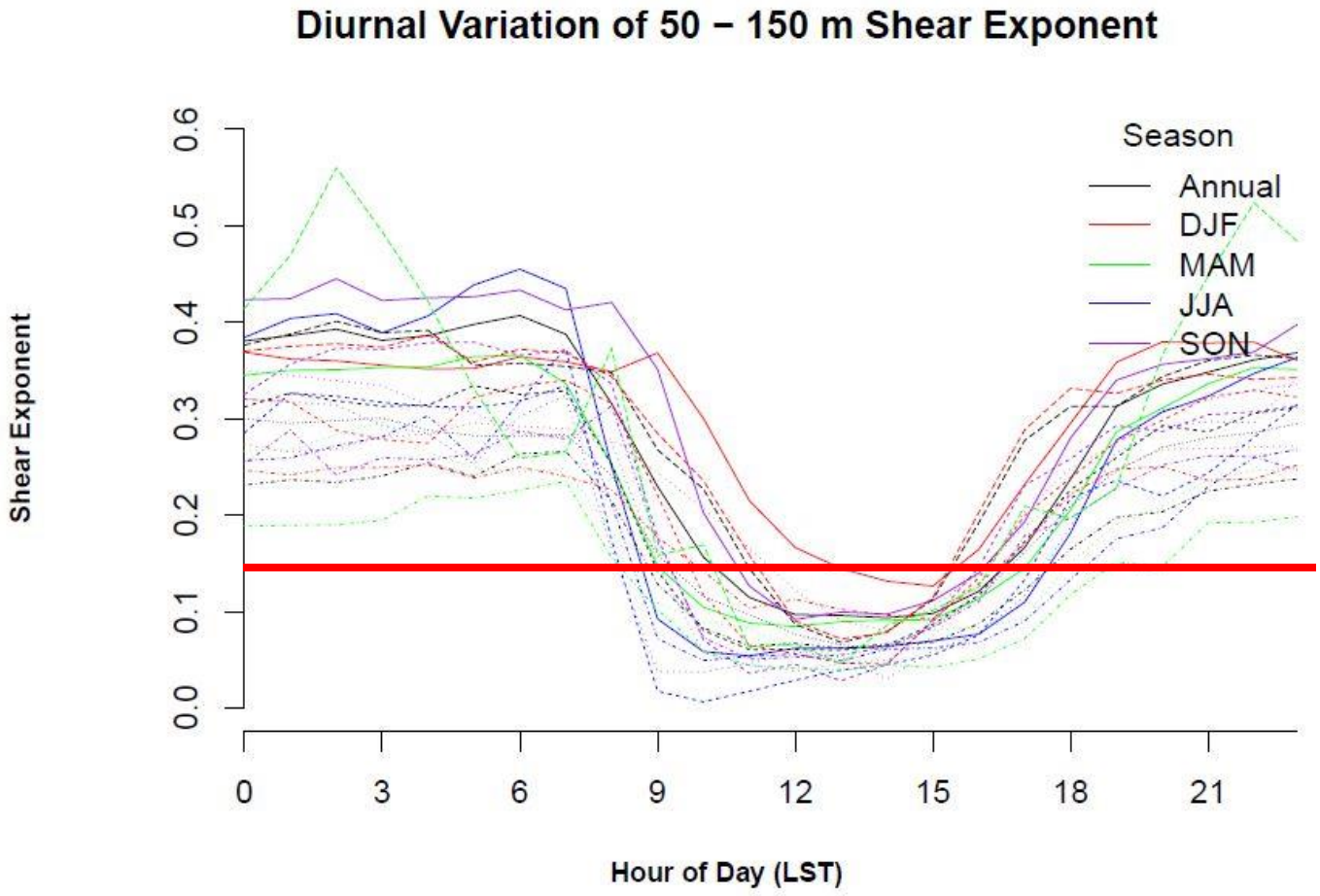


Shear exponent



Shear exponent

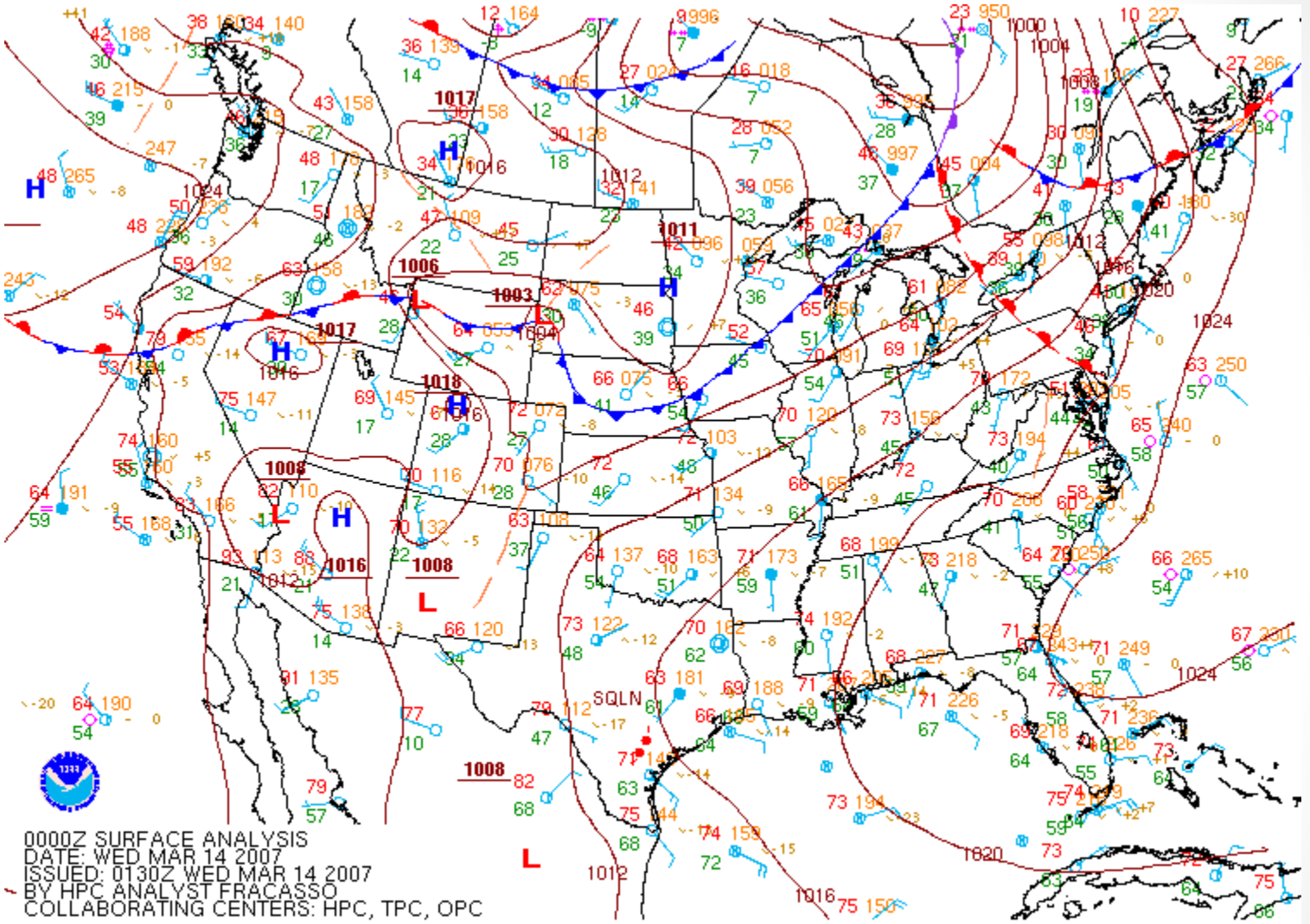
- Kelley et al. (2004) outlines conditions for “challenging flow”
  - Hub height wind speed between 8 and 13 ms^{-1}
  - Critically stable layer ($0 < Ri < 0.25$)
  - Shear exponent larger than 0.2 s^{-1}
- All towers experienced these conditions around 25% of the time

Ramp events

- Occur multiple times per day
- More ramps at upper levels
- Not much difference between seasons

Spatial consistency

- Multiple instances of spatially consistent ramps in vertical and across state
- Example: 14 March 2007
  - Ramp in western Iowa at 0200 LST – cold front present
  - Ramp in central Iowa at 0500 LST – cold front moves east
  - Ramp in eastern Iowa at 0800 LST – cold front continues east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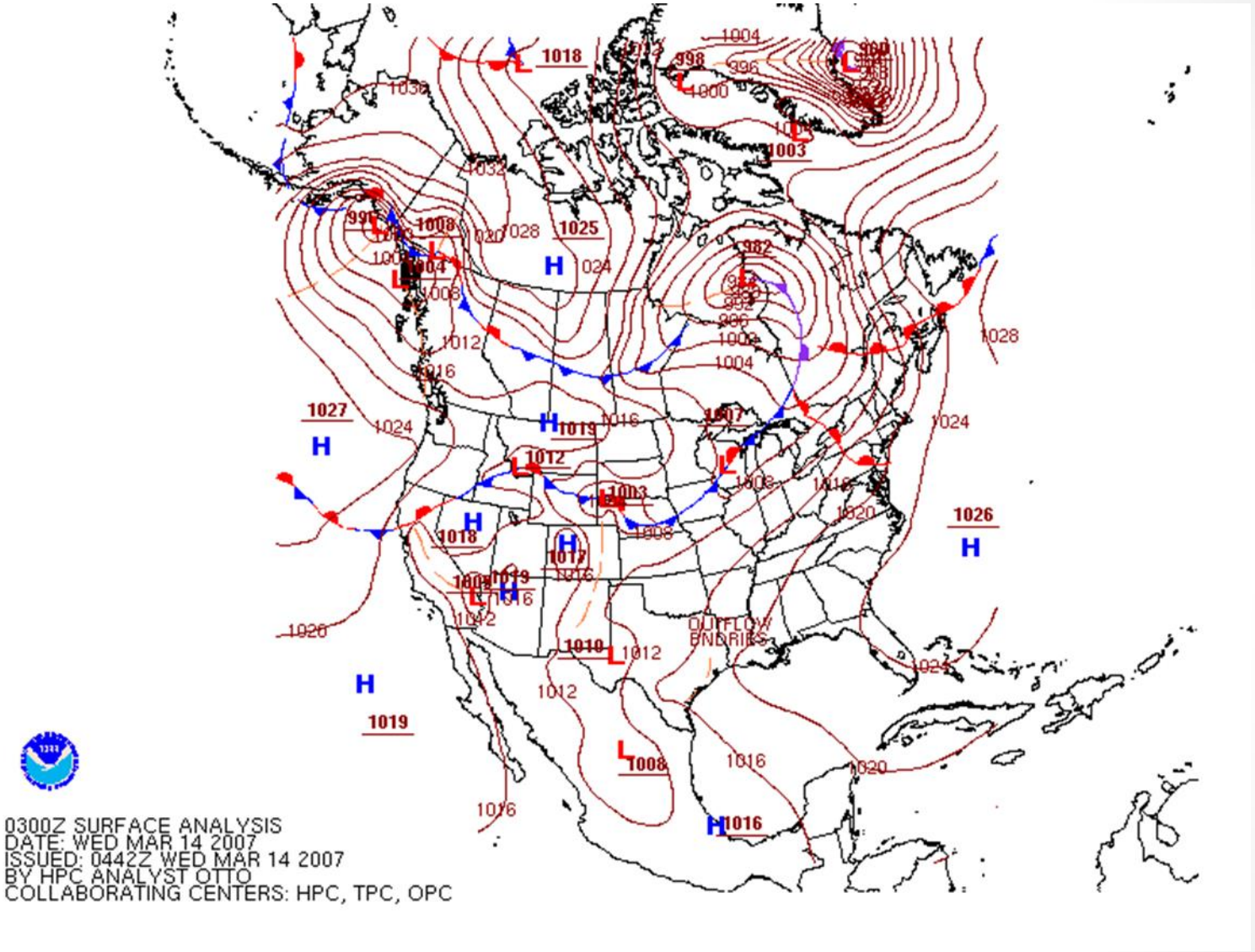
DATE: WED MAR 14 2007
ISSUED: 0130Z WED MAR 14 2007
BY HPC ANALYST FRACASSO
COLLABORATING CENTERS: HPC, TPC, OPC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DATE: WED MAR 14 2007
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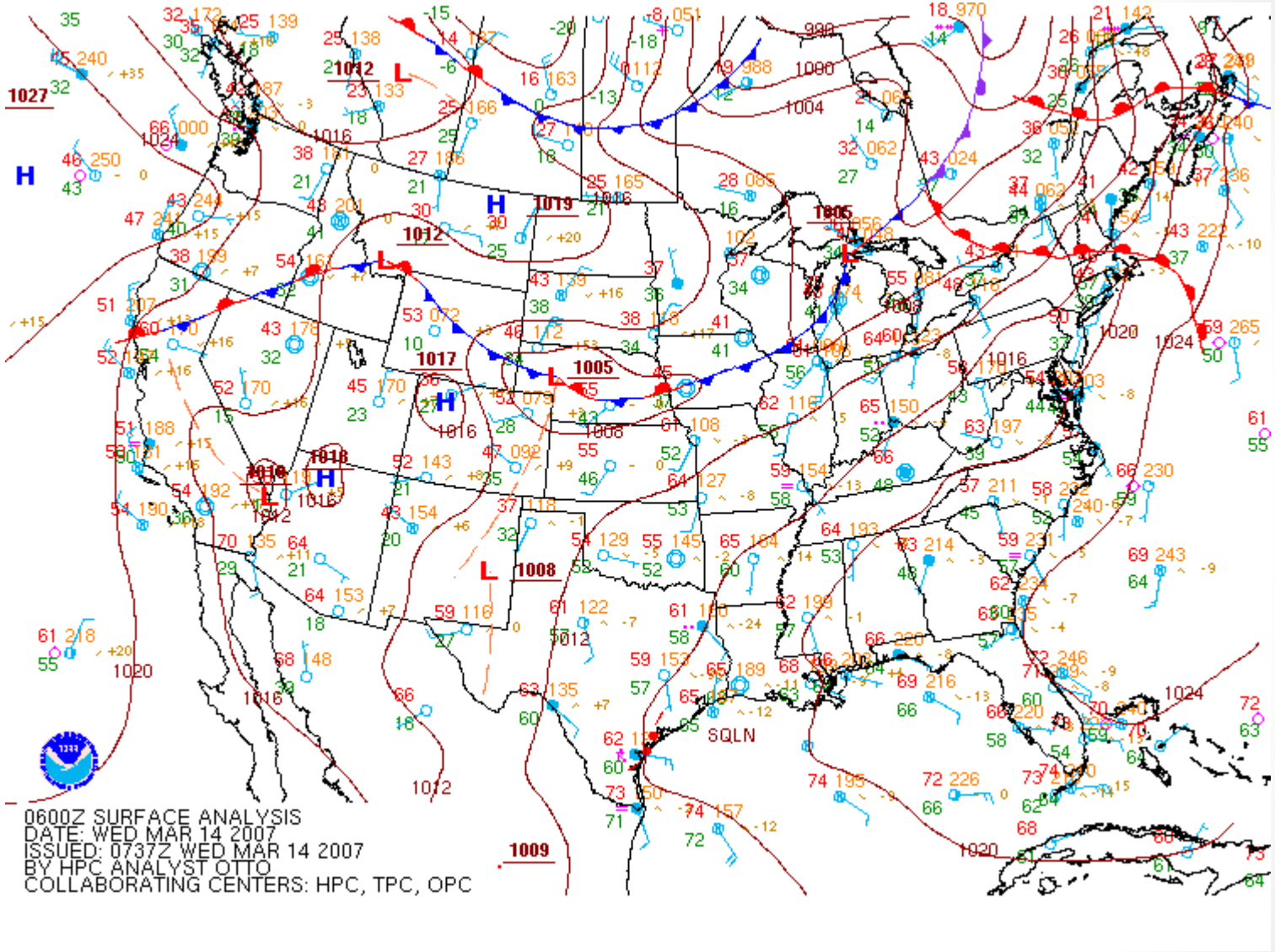
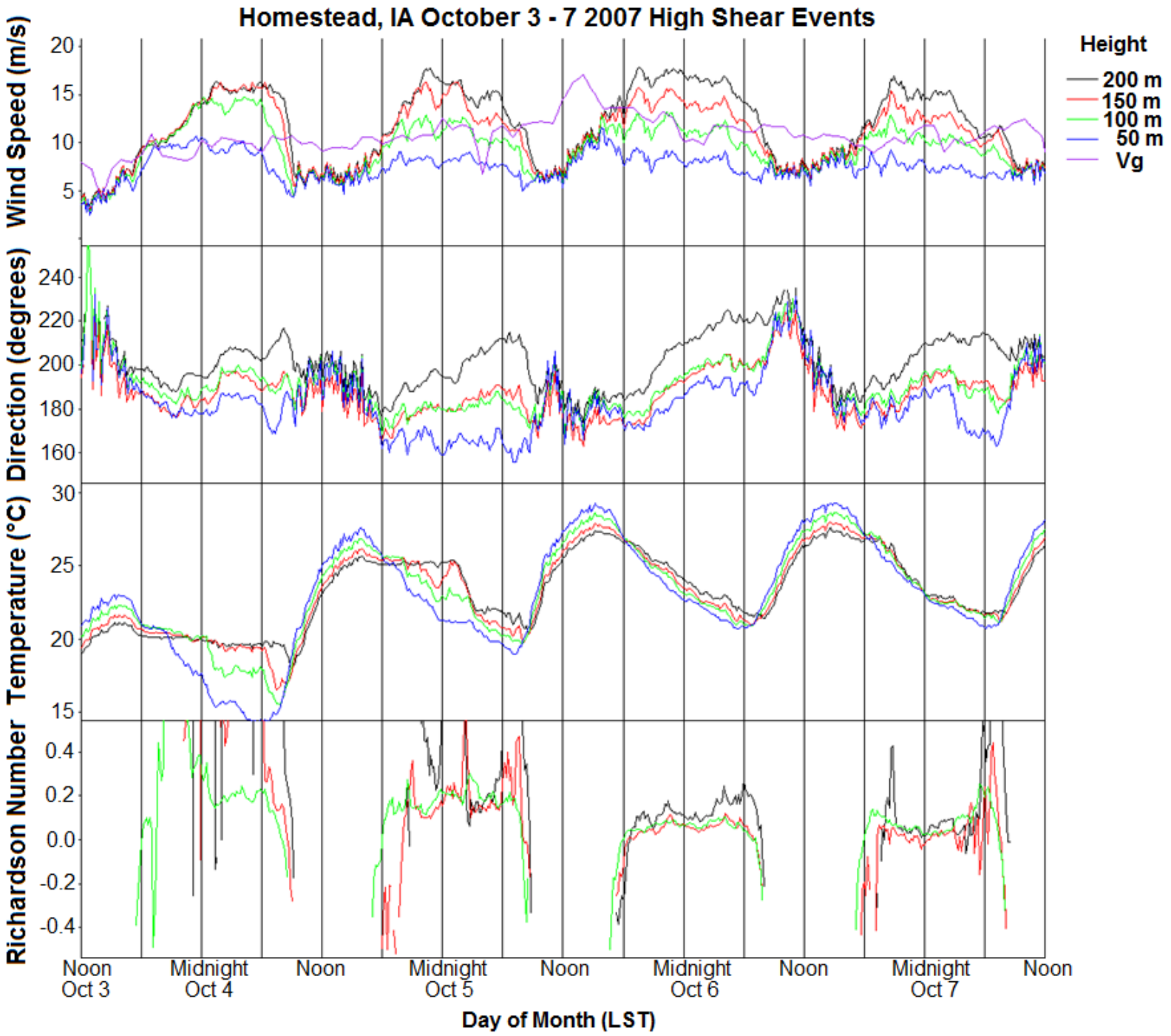
BY HPC ANALYST OTTO
COLLABORATING CENTERS: HPC, TPC, OPC
OUTFLOW BNDRIES


0600Z SURFACE ANALYSIS
DATE: WED MAR 14 2007
ISSUED: 0737Z WED MAR 14 2007
BY HPC ANALYST OTTO
COLLABORATING CENTERS: HPC, TPC, OPC

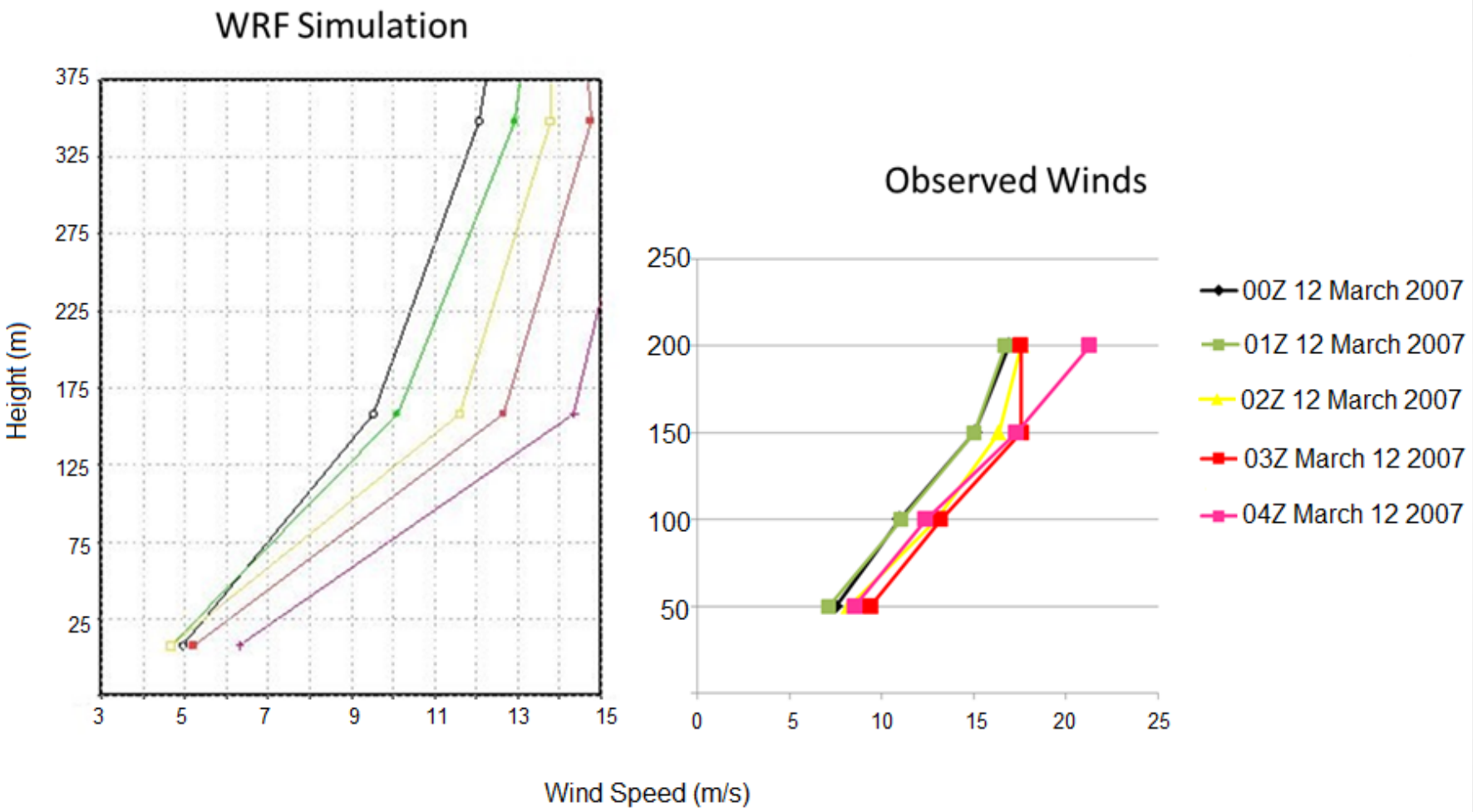
High shear events

- Several events through all seasons
- Example: Homestead, IA October 3 - 7 2007
  - Speed shear increases from 1800 LST – 0000 LST and collapses by 0900 LST
  - Directional shear near 30° coincides with speed shear
  - Temperature inversion and Richardson number greater than zero
- Timing of events suggest influence of inertial oscillation


Homestead, IA October 3 - 7 2007 High Shear Events
Wind Speed (m/s)
Direction (degrees)
Temperature (°C)
Richardson Number
Height
200 m
150 m
100 m
50 m
Vg
Noon Oct 3
Midnight Oct 4
Noon
Midnight Oct 5
Noon
Midnight Oct 6
Noon
Midnight Oct 7
Noon
Day of Month (LST)

WRF simulations

- Attempt to simulate high shear events and spatially consistent ramp events
- Preliminary results replicated high shear events at smaller magnitude
- Ramp events not recreated thus far


WRF Simulation
Height (m)
375
325
275
225
175
125
75
25
3
5
7
9
11
13
15
Observed Winds
250
200
150
100
50
0
5
10
15
20
25
00Z 12 March 2007
01Z 12 March 2007
02Z 12 March 2007
03Z March 12 2007
04Z March 12 2007
Wind Speed (m/s)

Thank you

Characteristics of 50 - 200 m Winds and Temperatures Derived From an Iowa Tall Tower Network submitted to JAMC

Contact Info: rshowers@iastate.edu

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- Deppe, Adam J., William A. Gallus, Jr., and Eugene S. Takle, 2013: A WRF ensemble for improved wind speed forecasts at turbine height. *Wea. Forecasting*, **28**, 212–228. doi: http://dx.doi.org/10.1175/WAF-D-11-0112.1.
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- Walton, R. A., E. S. Takle, and W. A. Gallus, Jr., 2014: Characteristics of 50 – 200 m Winds and Temperatures Derived From an Iowa Tall Tower Network. Submitted to J. Appl. Meteorol. Clim.
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