Identification of Tower Wake Distortions in Sonic Anemometer Measurements during XPIA

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Session 16, Contribution 16A.6, 24 June 2016, 4:45 PM

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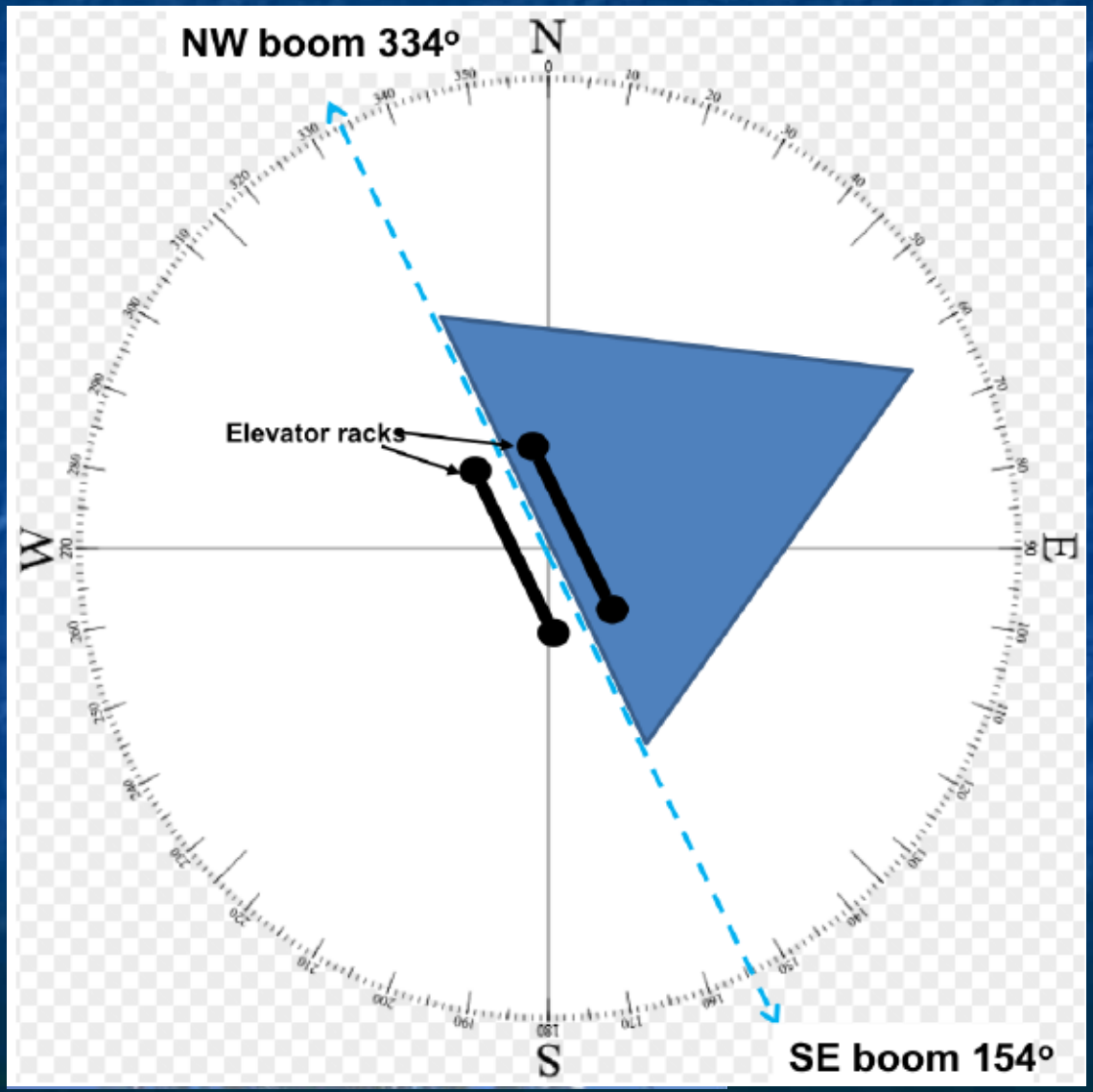
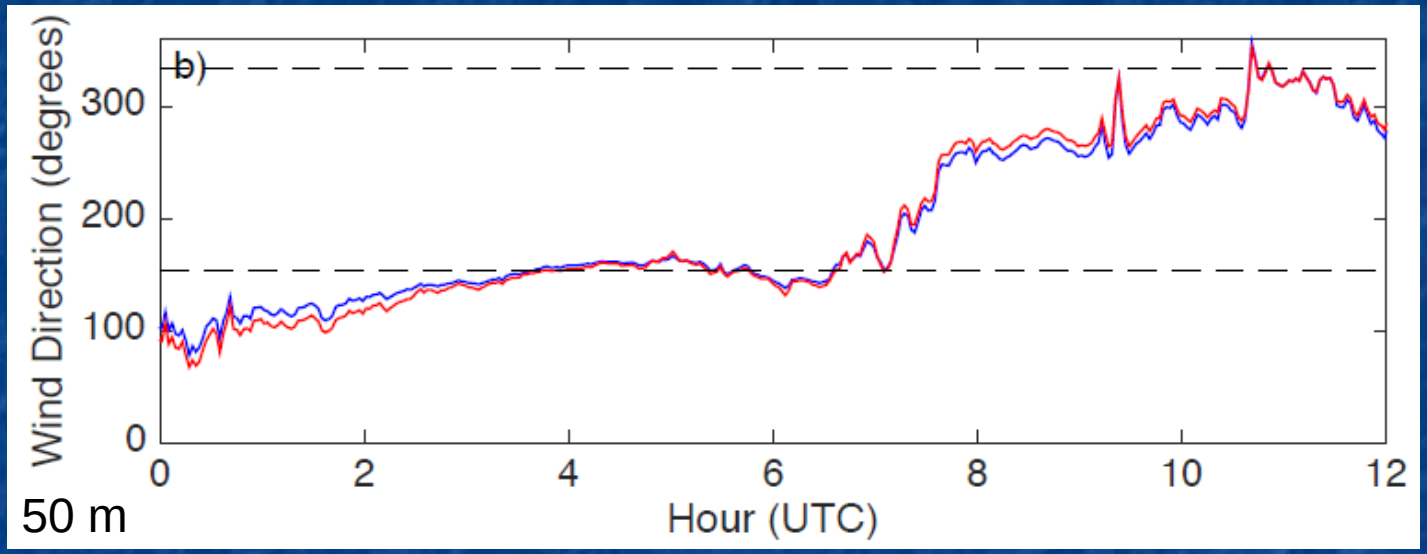
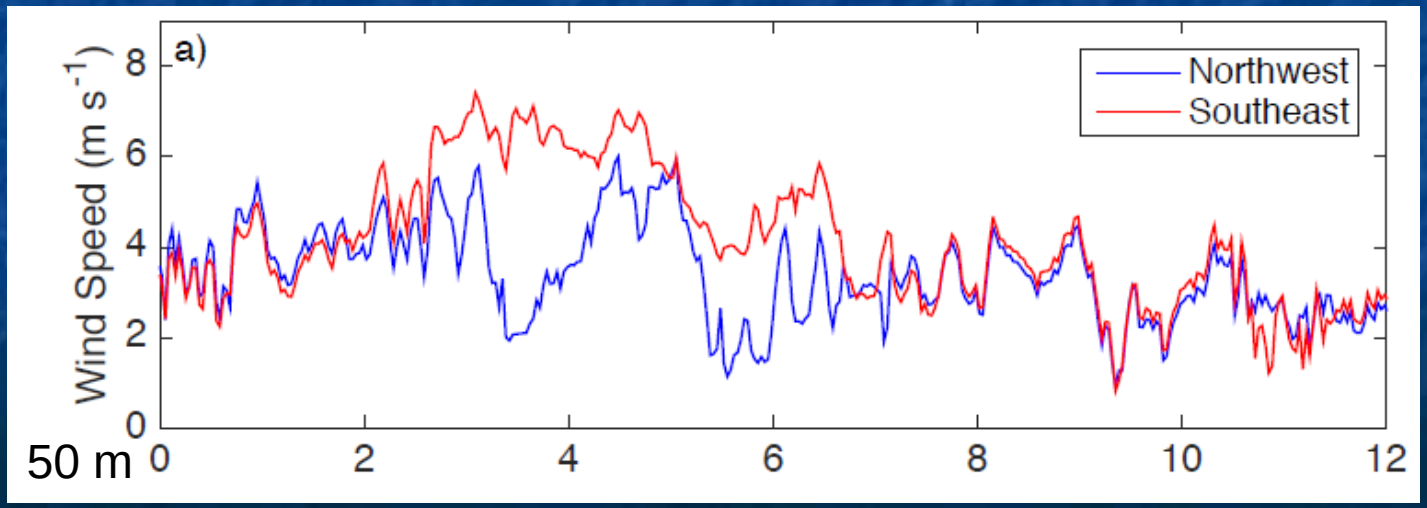
Opposing direction booms enable characterization of BAO tower wake



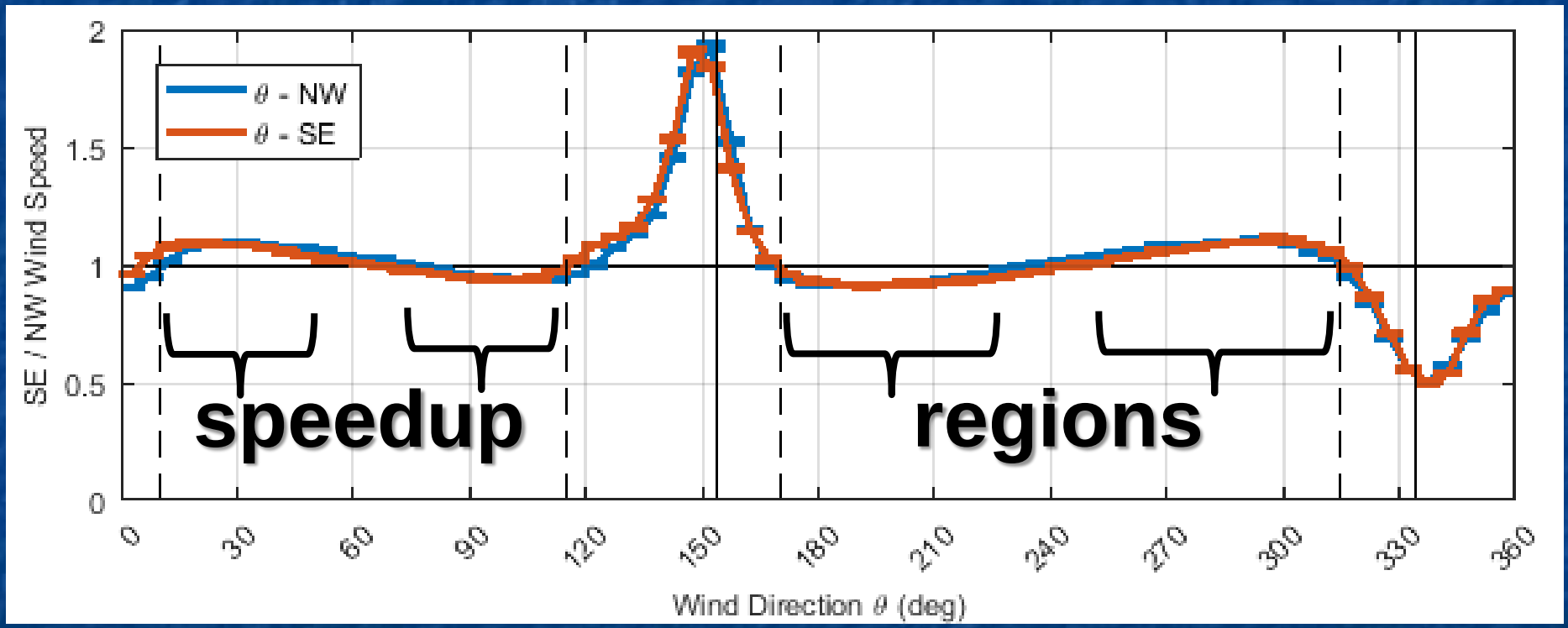
- Campbell Scientific CSAT3 sonic anemometers
- Tilt correction (Wilczak et al. 2001)
- 20 Hz data, 2-min WS & 20-min TKE averaging period

Sonic anemometer observations are affected by upstream tower wakes





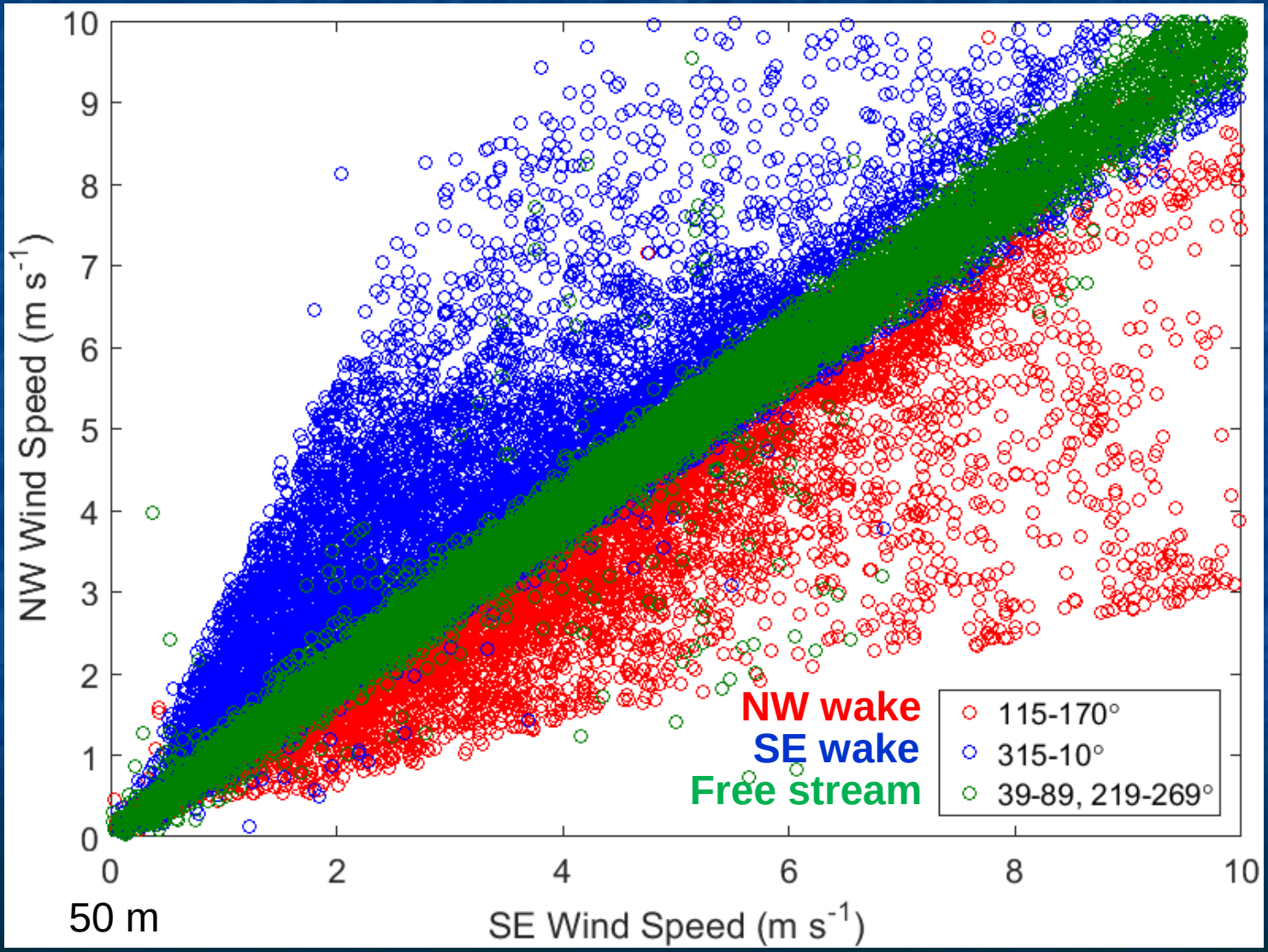
2-min SE/NW mean wind speed ratios reveal distinct wakes from BAO tower, along with speed-up regions



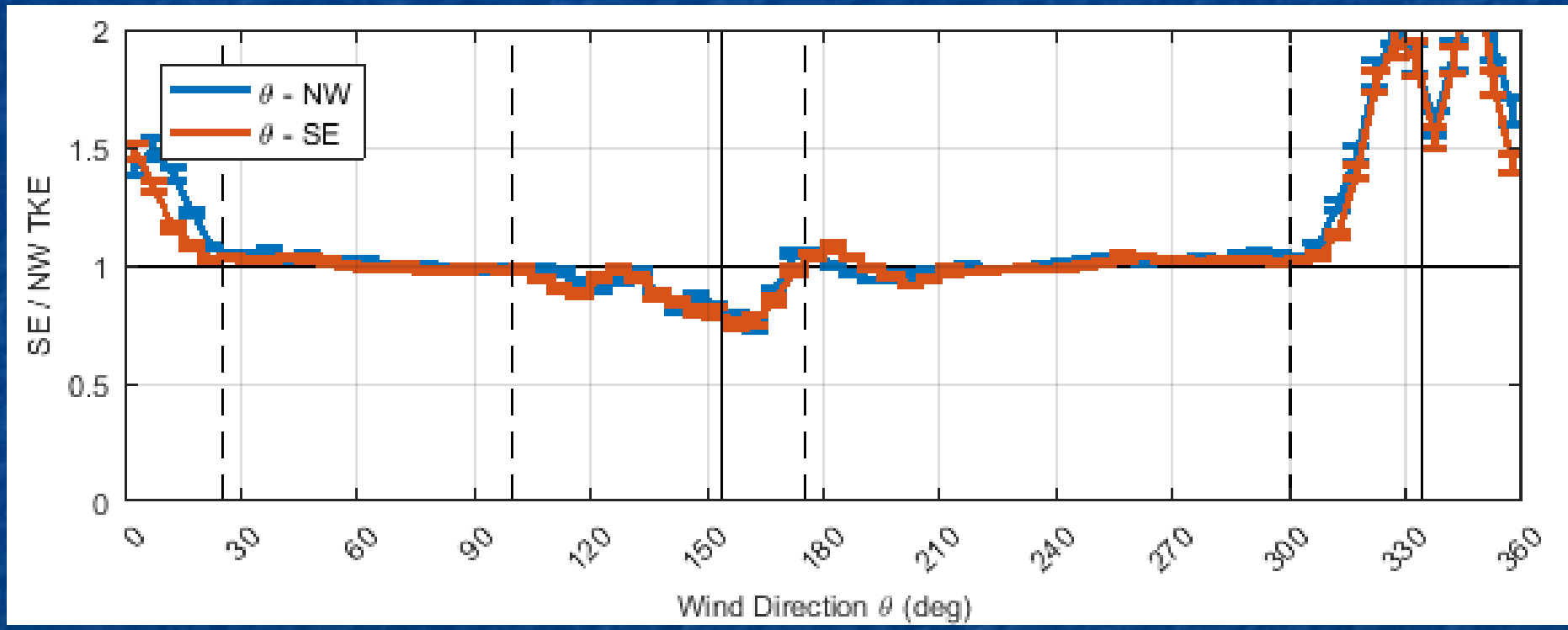
NW wake

SE wake

Sonics' 2-min mean wind speed show agreement in free stream regions



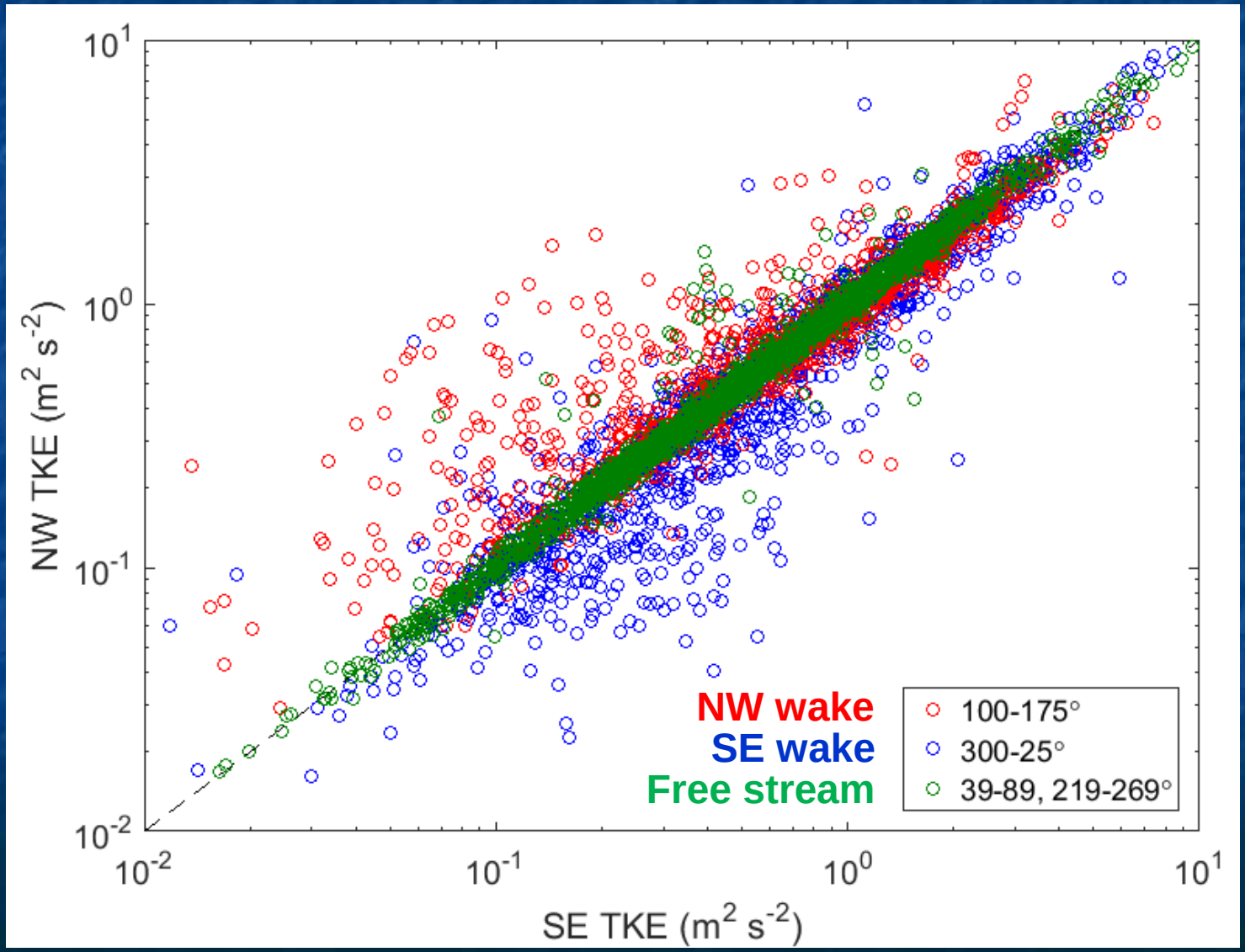
20-min SE/NW turbulent kinetic energy (TKE) reveal wider angular swaths of BAO tower wake



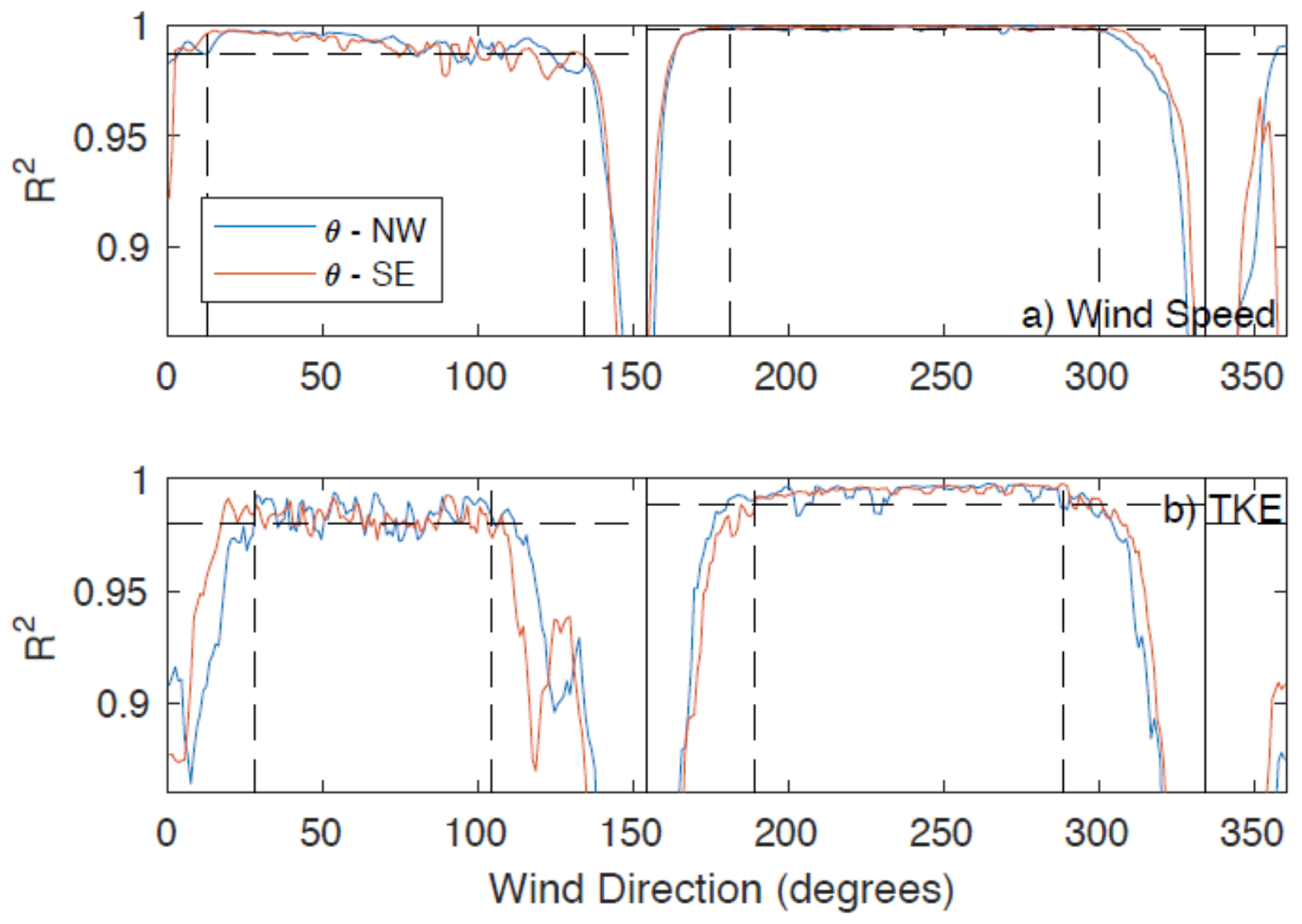
NW wake

SE wake

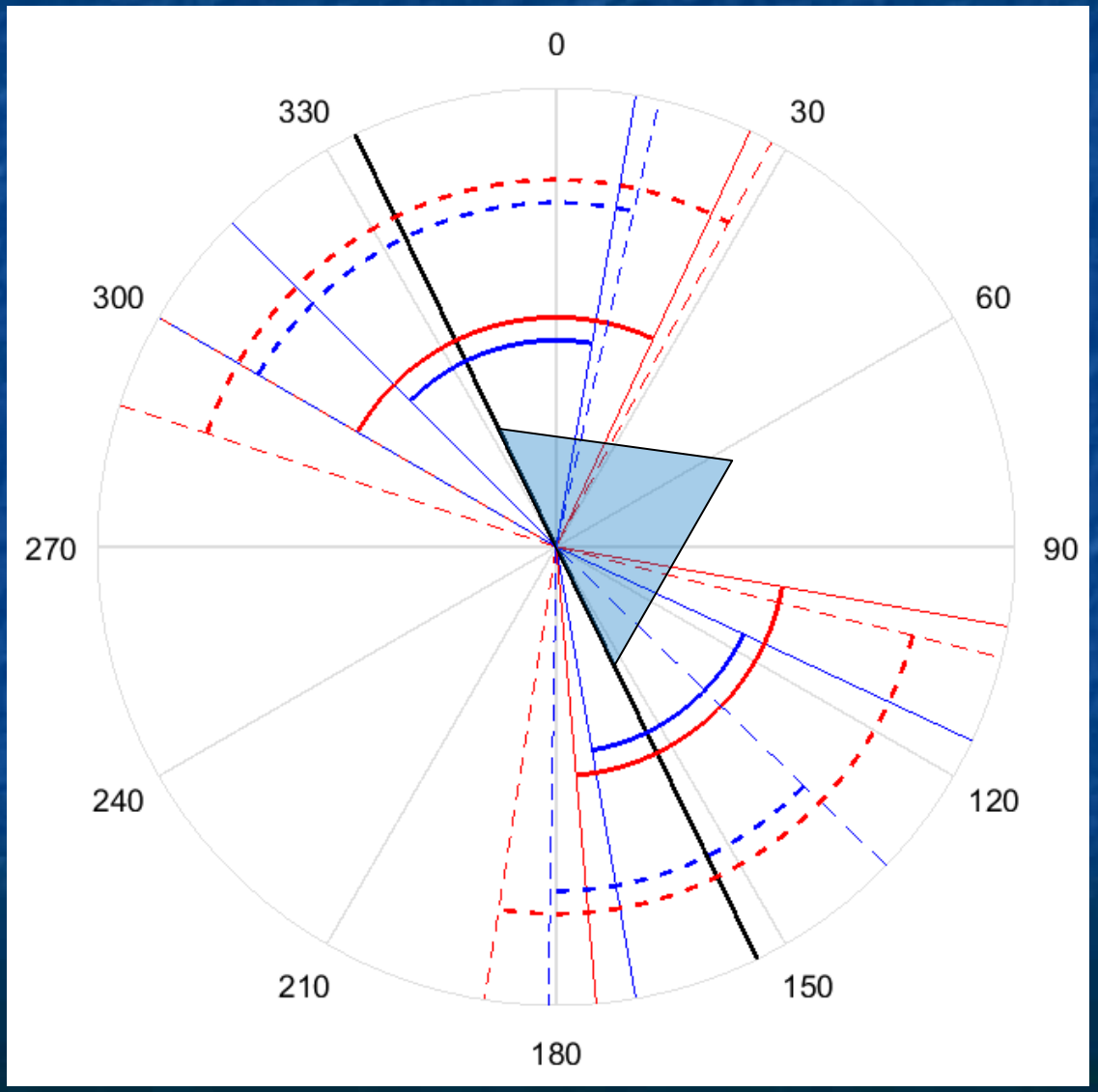
50 m sonics' 20-min TKE shows (log) agreement in free stream regions



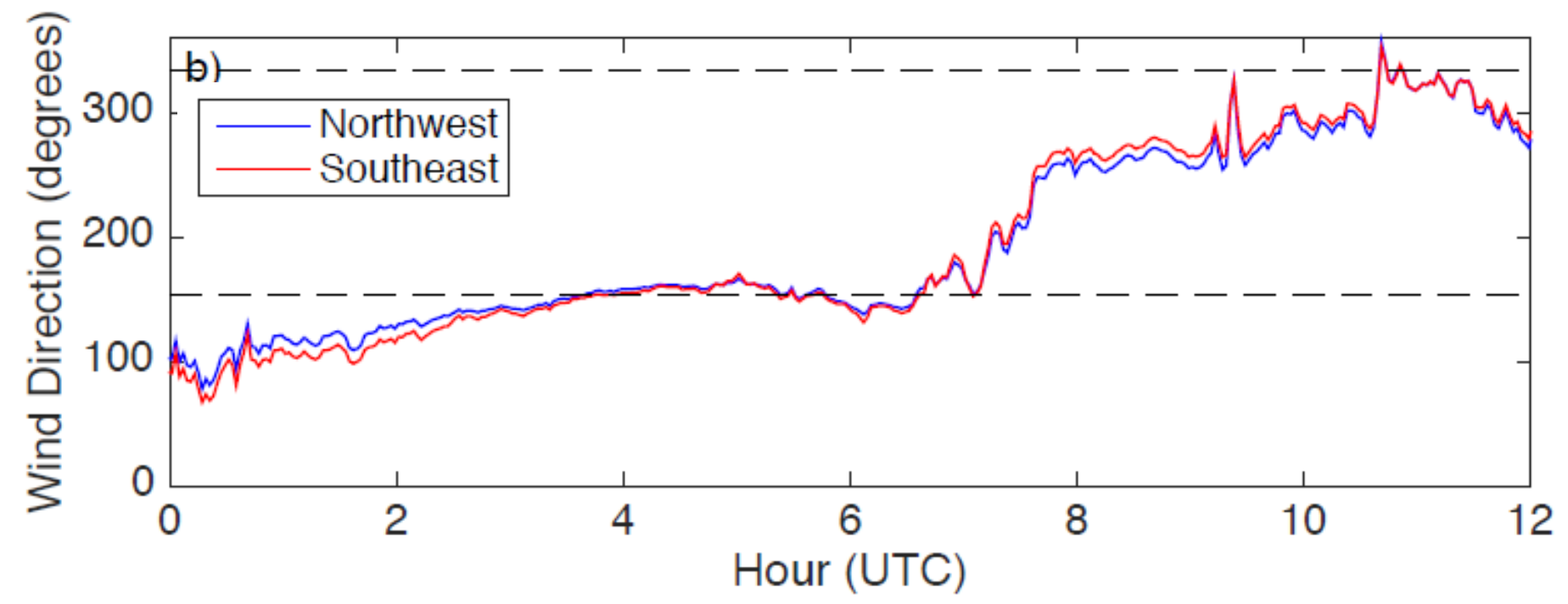
R^2 between sonics for wind speed & TKE vs. wind dir. precisely defines wake edges



Compass summary of wake boundaries shows BAO tower asymmetry

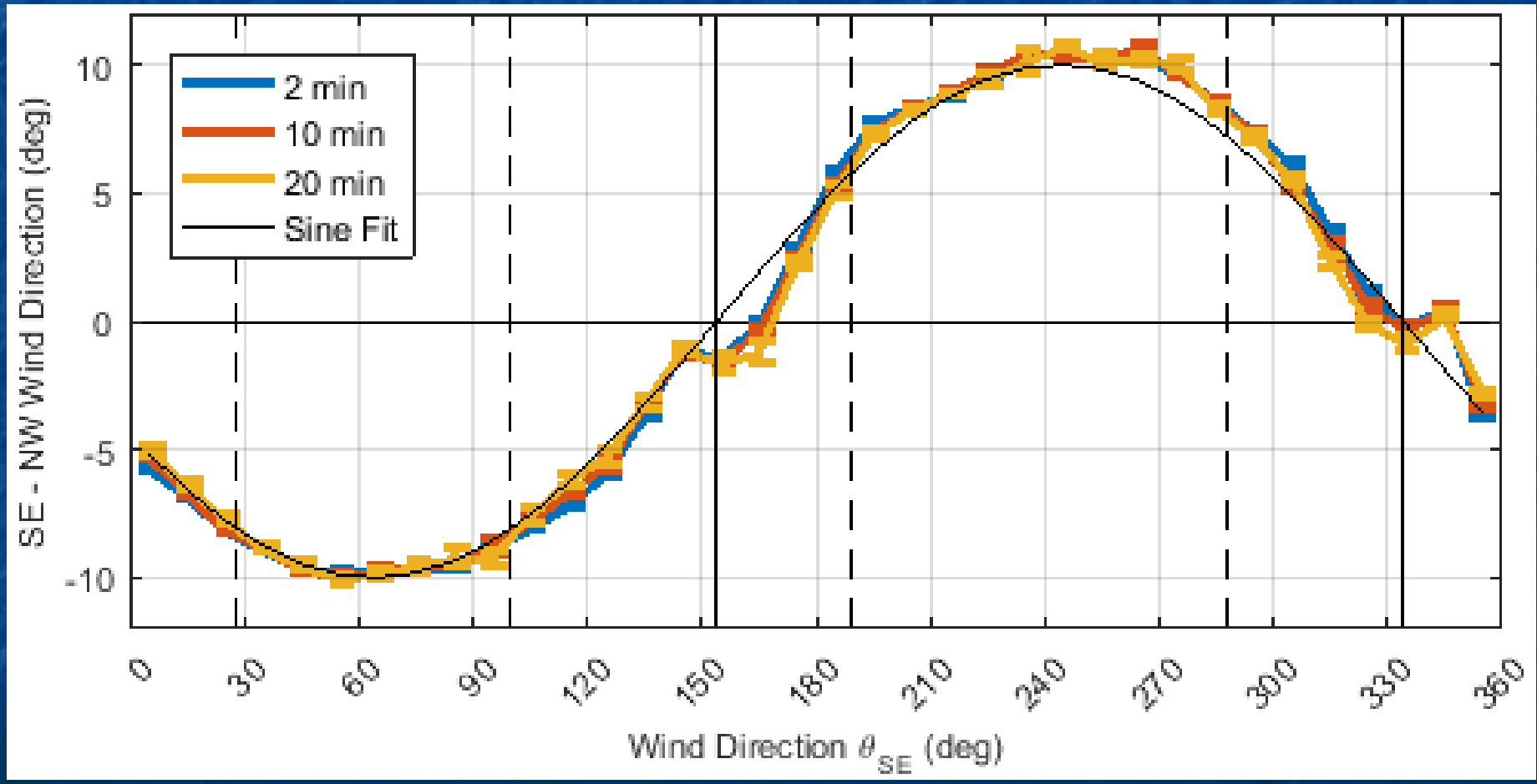


Recall the example wind direction time series

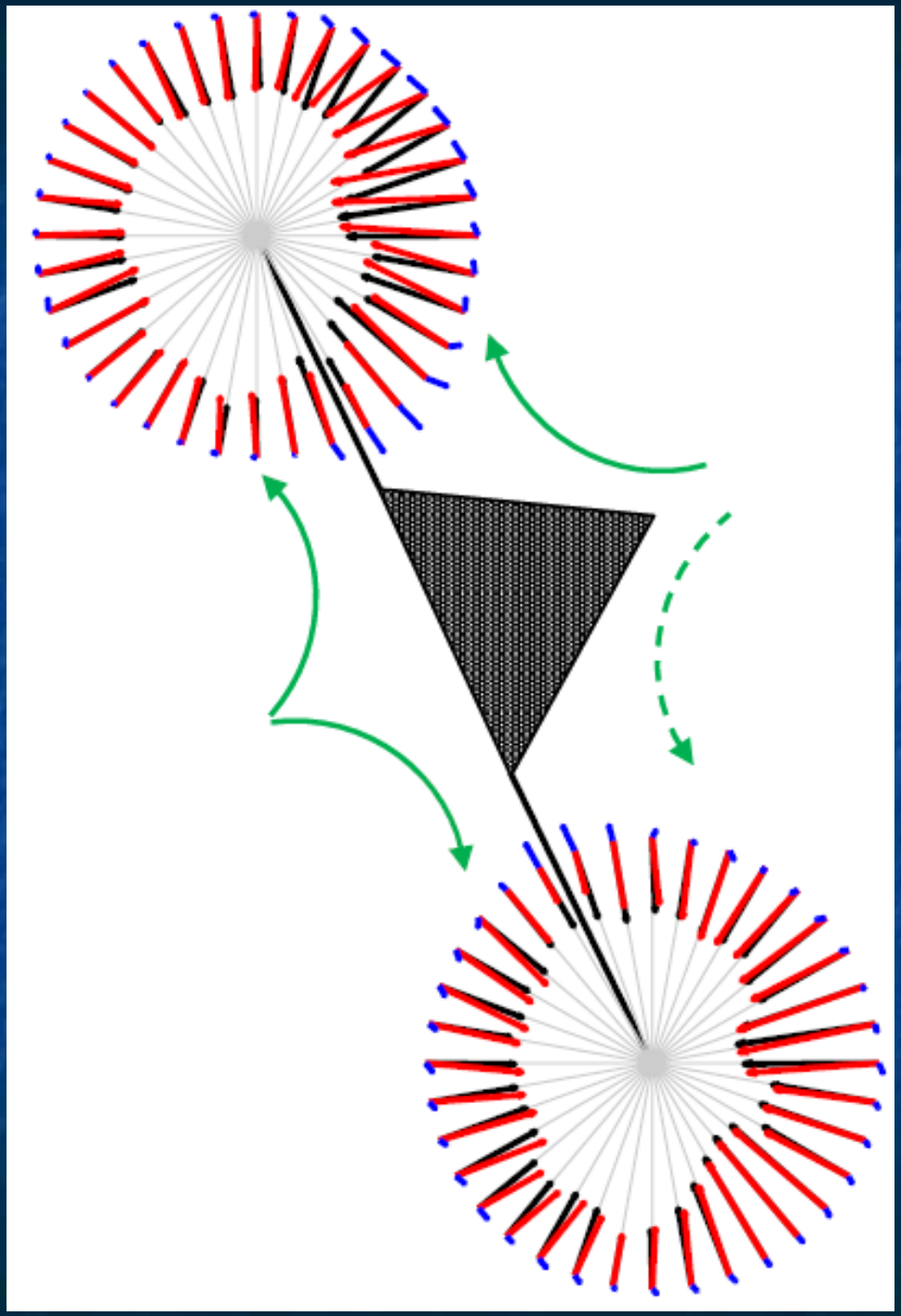


The free stream zones show a consistent sign of difference in wind direction measured from the two sonics

SE-NW wind direction bias varies sinusoidally with wind direction

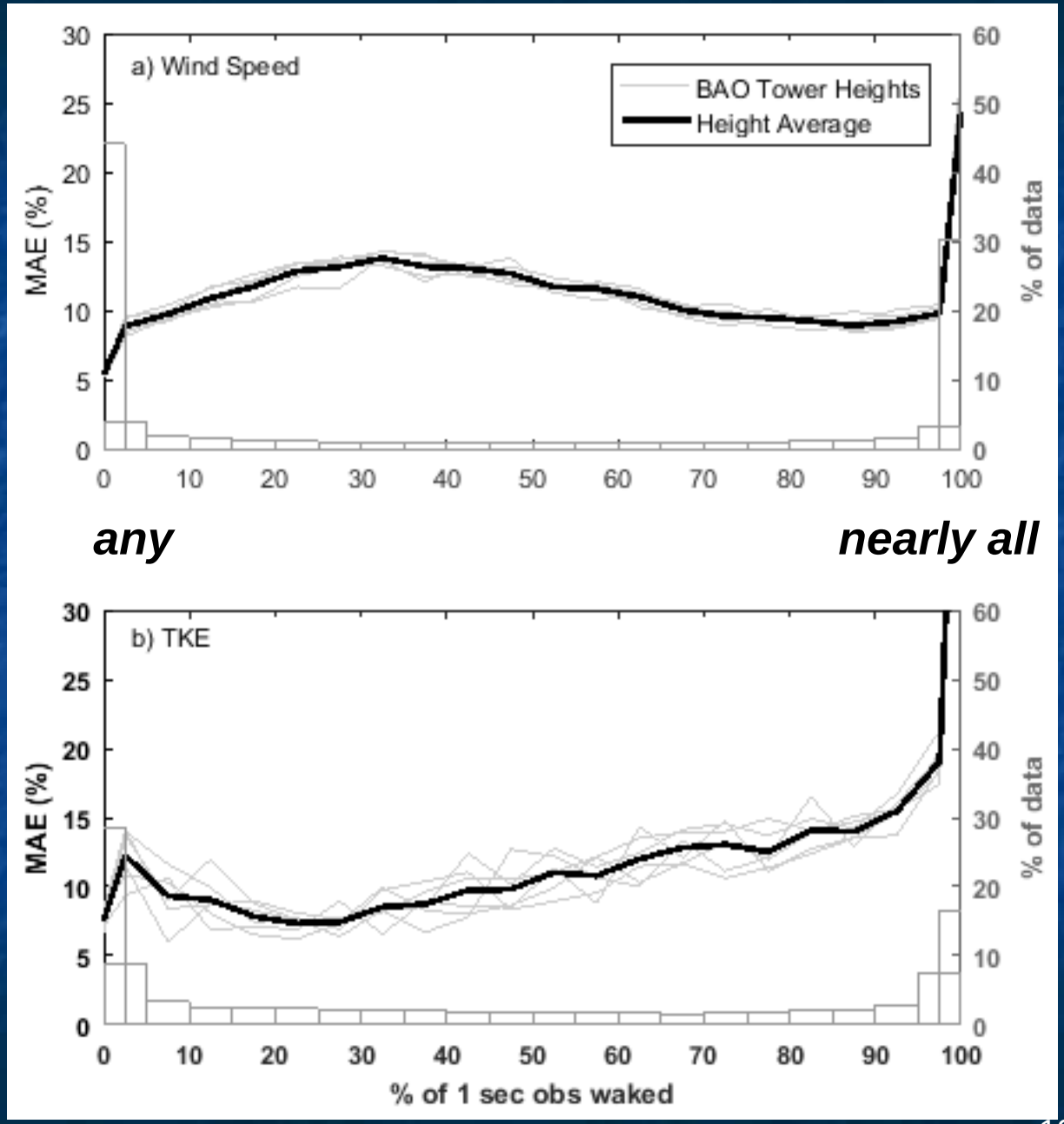


$$\Delta\theta_{SE\ to\ NW} = 10\sin(\theta_{SE} - 154)\ \ (\text{deg})$$



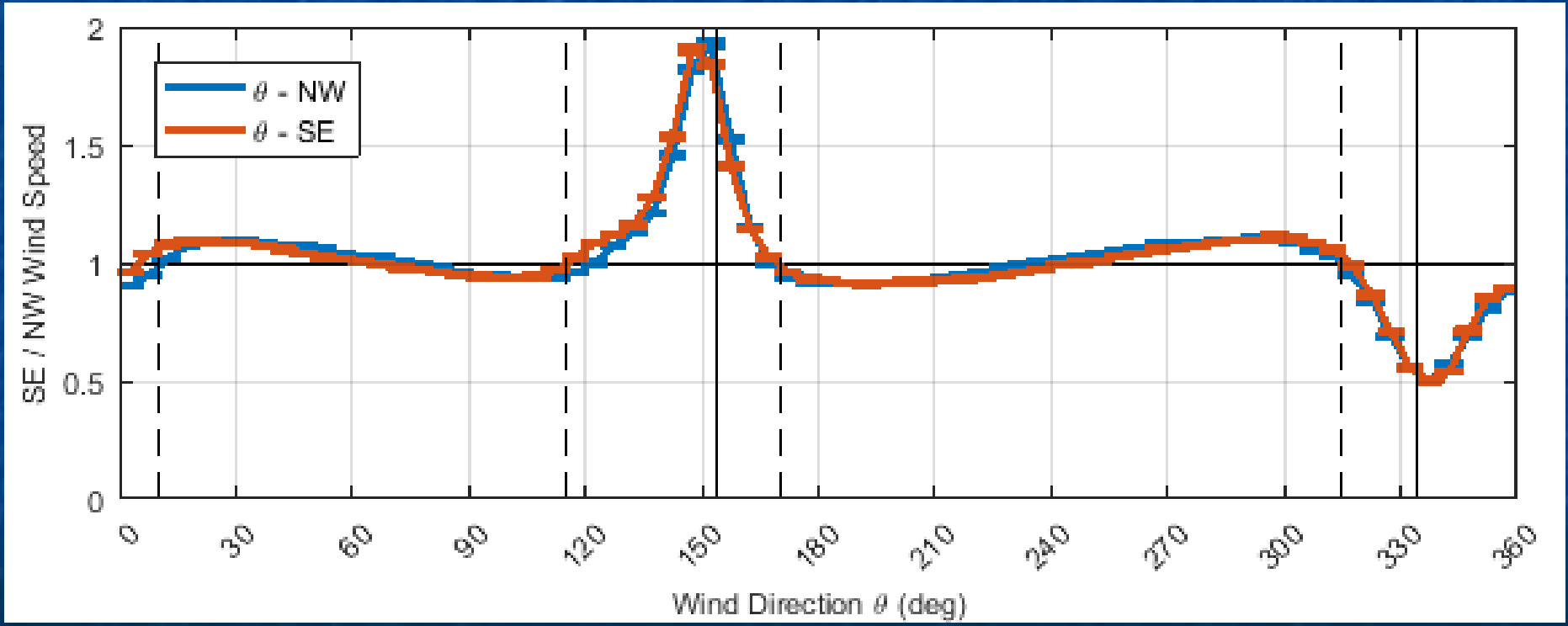
Vector representation of tower winds vs. free stream winds shows greatest differences near the perpendicular direction

Sonics MAE % comparison of 2-min WS or 20-min TKE increases rapidly if *any* or *nearly all* data points are waked



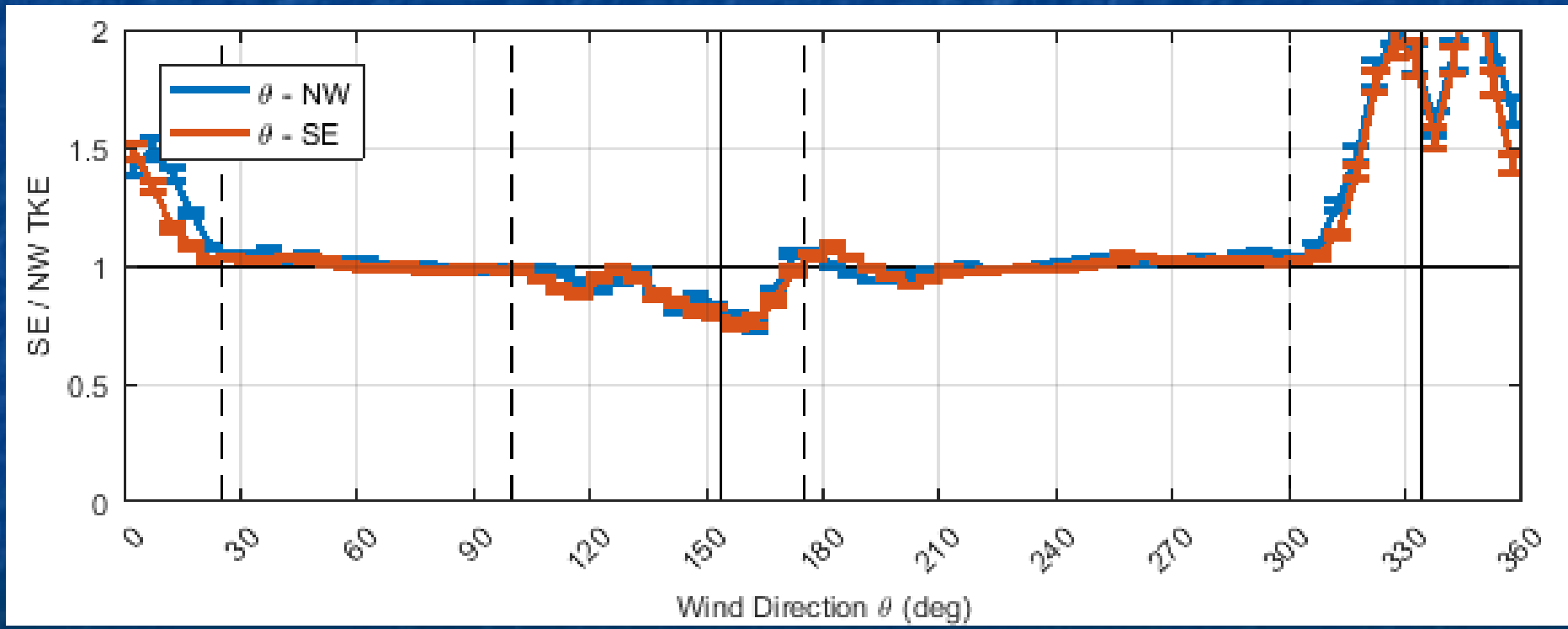
BAO tower wake characterization is vital for successful XPIA data usage

- Wake effect up to 50% wind speed reduction, with adjacent speedup regions up to 5%

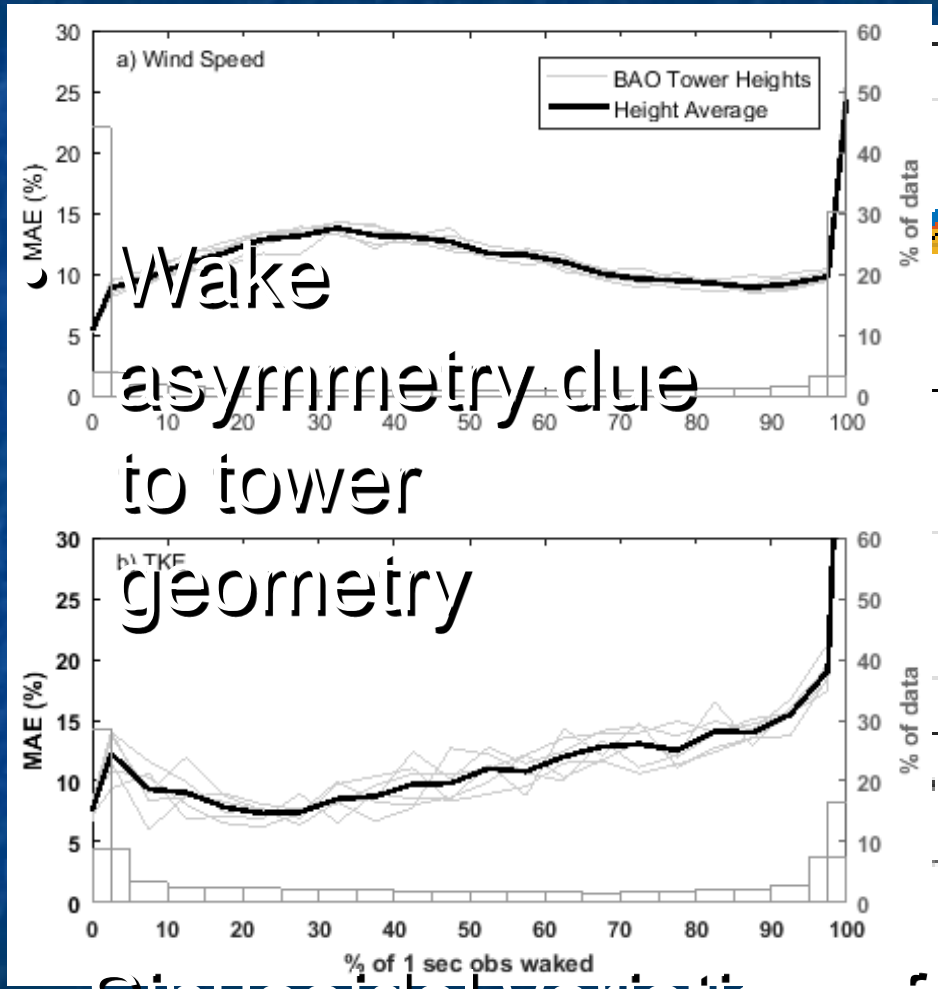


BAO tower wake characterization is vital for successful XPIA data usage

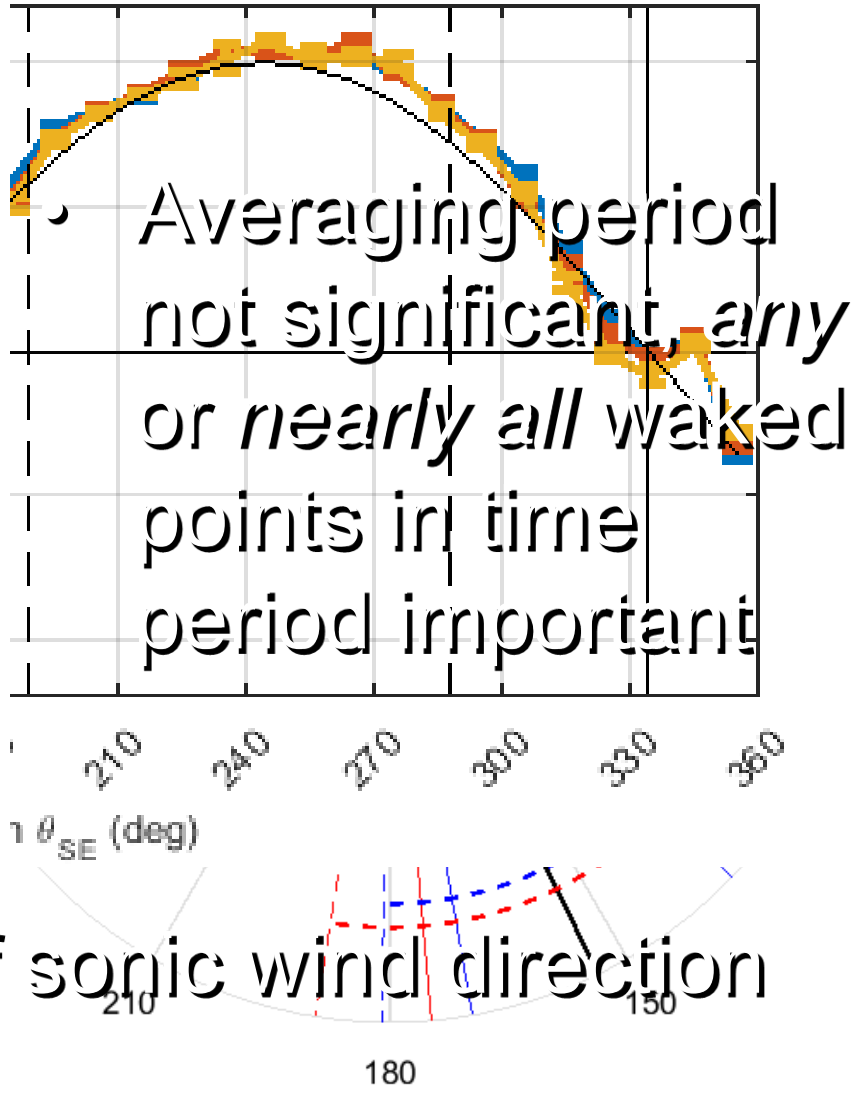
- Wake angular swath wider in TKE than WS



BAO tower wake characterization is vital for successful XPIA data usage



- Wake asymmetry due to tower geometry



- Averaging period not significant, *any* or *nearly all* waked points in time period important

- Sinusoidal variation of sonic wind direction differences

Time for Questions…

McCaffrey K., P.T. Quelet, A. Choukulkar, J. Wilczak, D.E. Wolfe, A. Brewer, S. Oncley, J.K. Lundquist, 2016: Identification of Tower Wake Distortions in Sonic Anemometer Measurements. Atmospheric Measurement Techniques. *Submitted*.

Watershed School (Boulder, CO) 6th & 7th grade MGAUS Radiosonde Launch, BAO Tower During, XPIA 17 Mar 2015 Bill Brown

Photo Courtesy: Bill Brown, NCAR

Extra Slides

Presentation Outline

I. Sonic Anemometers (“Sonics”) Comparisons and Correlations

II. Independent Identification: Sonic Anemometer vs. Lidar Observations

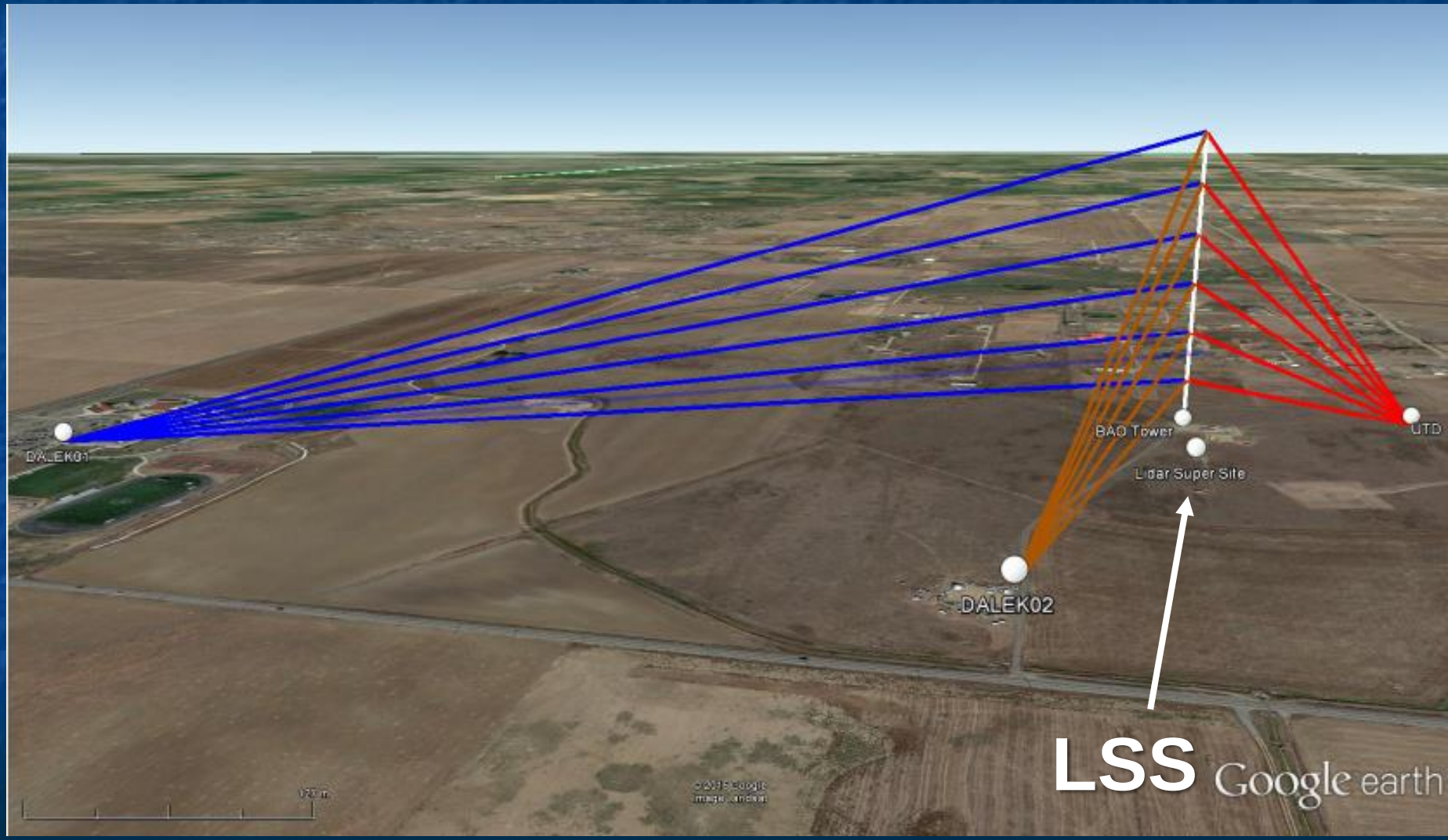
III. Flow Deflection around Tower

IV. Time Averaging and Temporal Extent of Wake Impacts

V. Conclusions

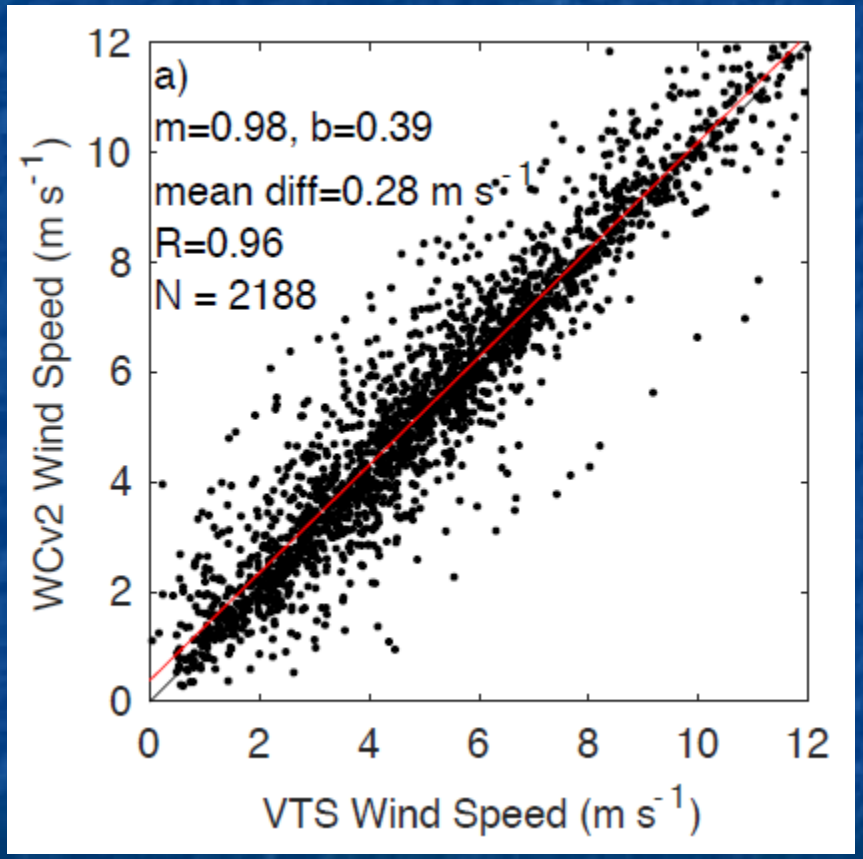
XPIA Lidar Super Site (LSS): WCv2 Vert. Prof. Horiz. Wind

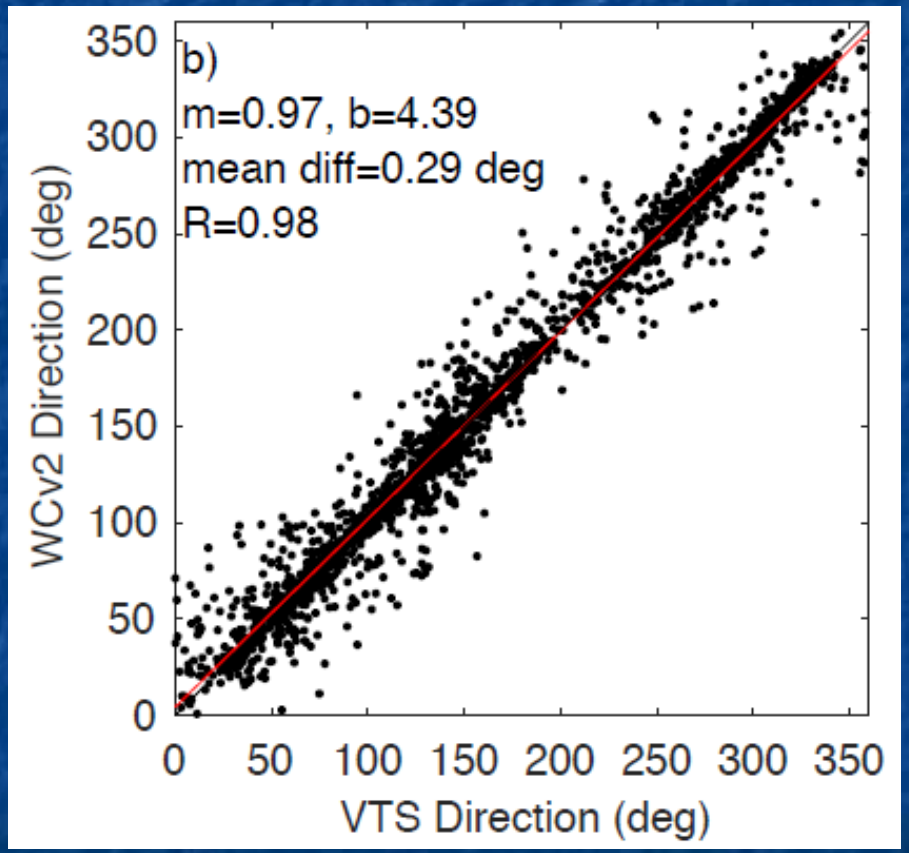
Scanning lidars: VTS ≈ 10m, LSS 130m, south of BAO Tower



Lundquist et al. (2016), BAMS, accepted.

100 to 200 m lidar comparisons agree as independent measurements

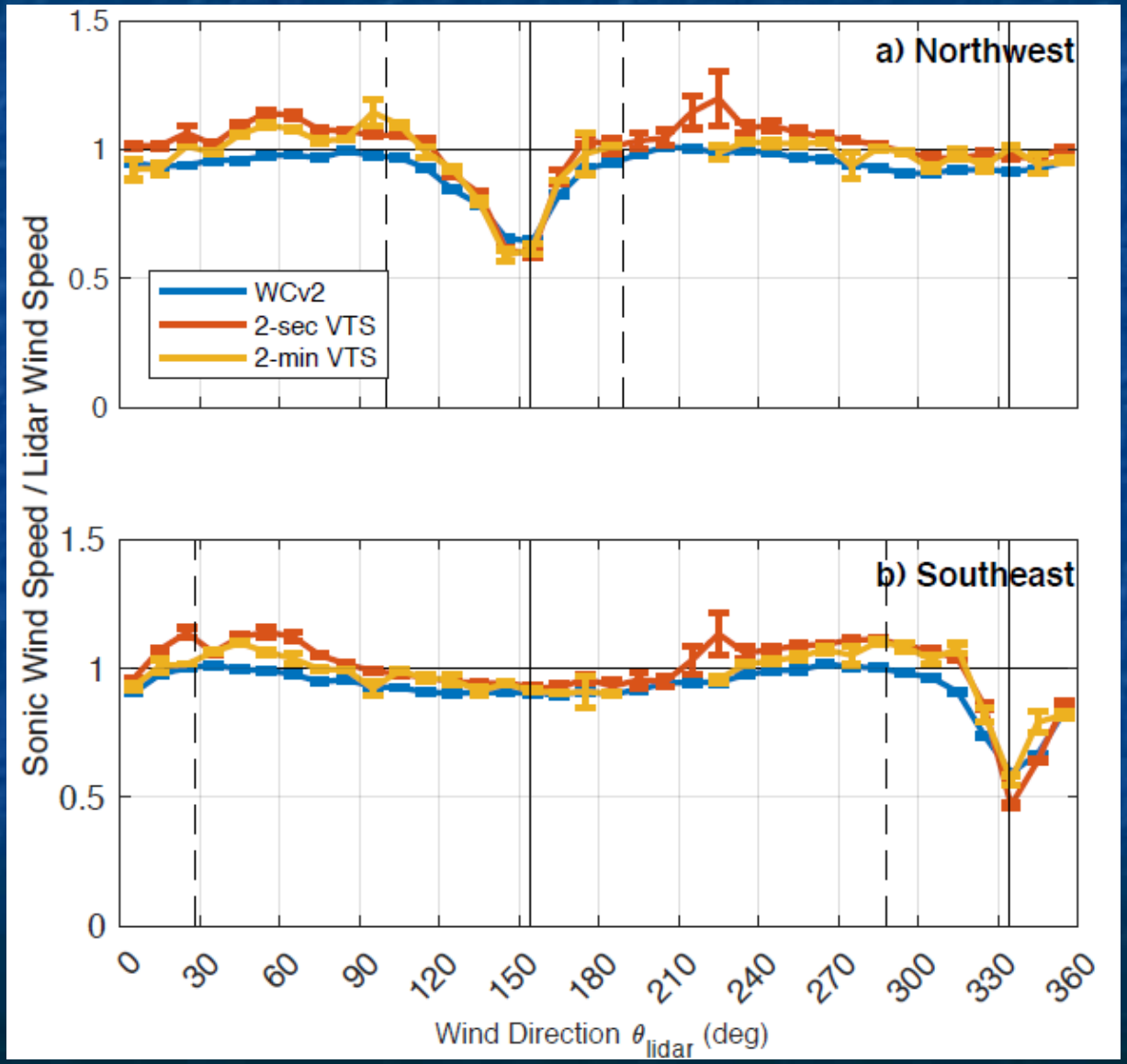




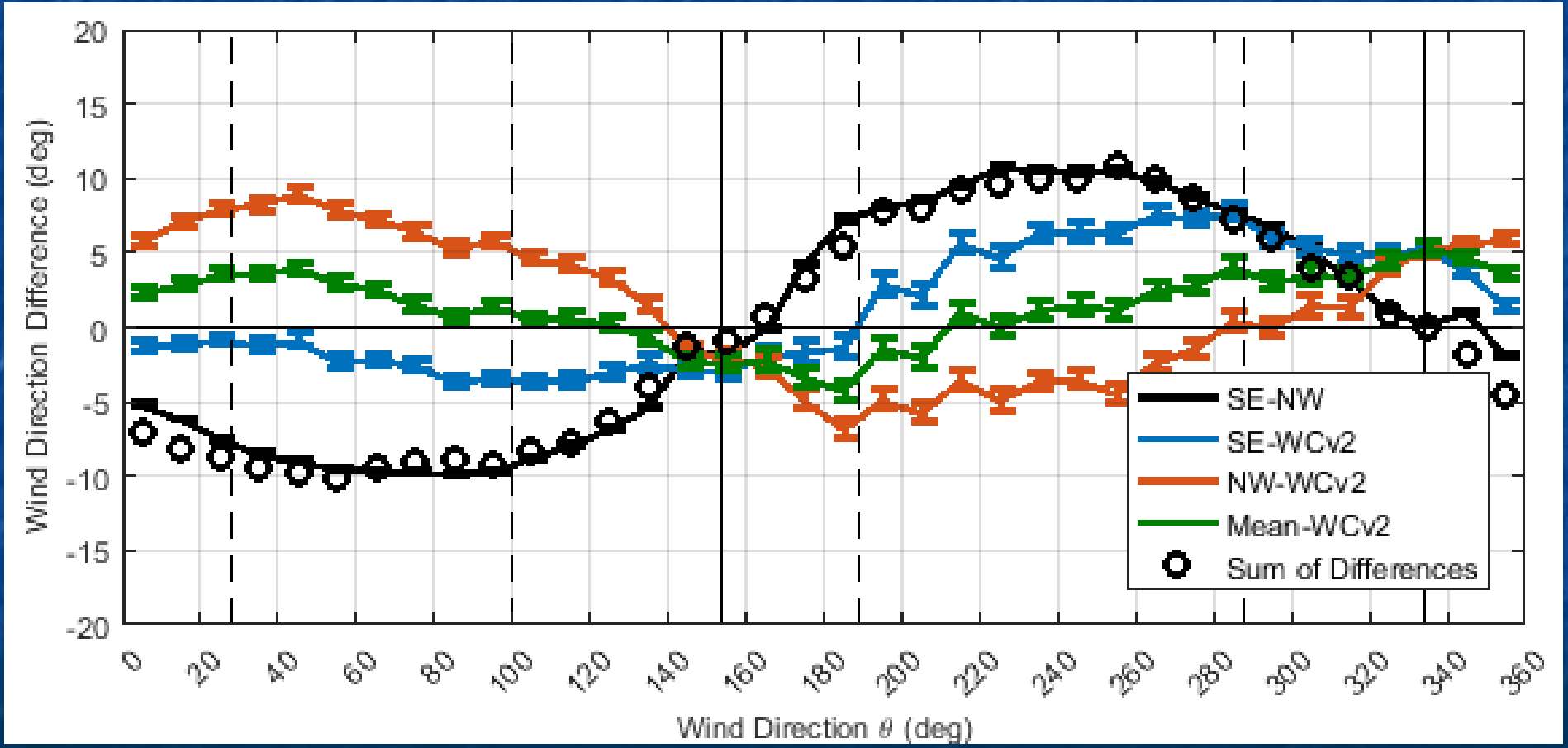
Wind Speed

Wind Direction

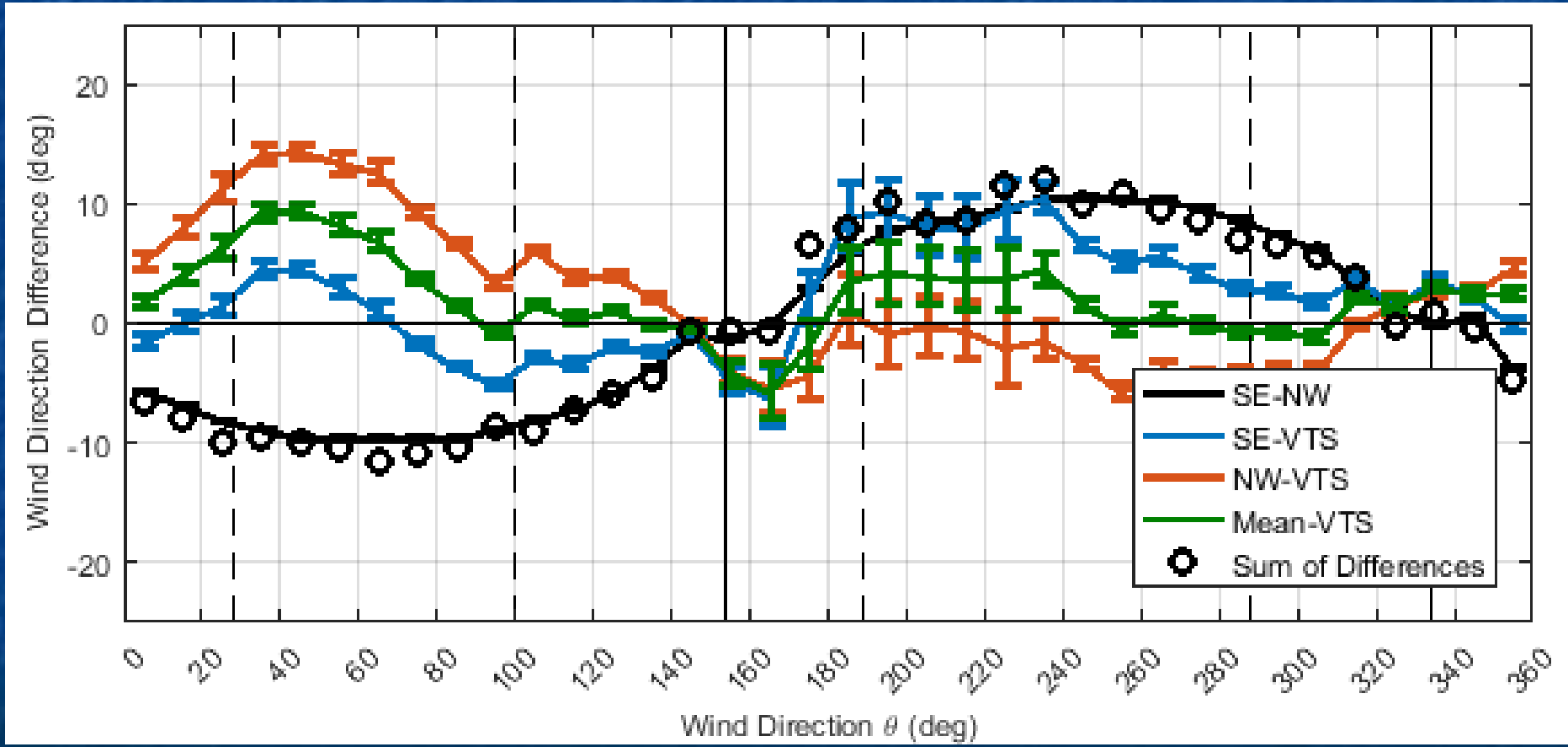
Ratio of a) NW and b) SE compared to WCv2 and VTS also shows tower wakes



Sonic wind direction differences are asymmetric compared to independent WCv2 measurements



Sonic wind direction differences are asymmetric compared to independent VTS measurements

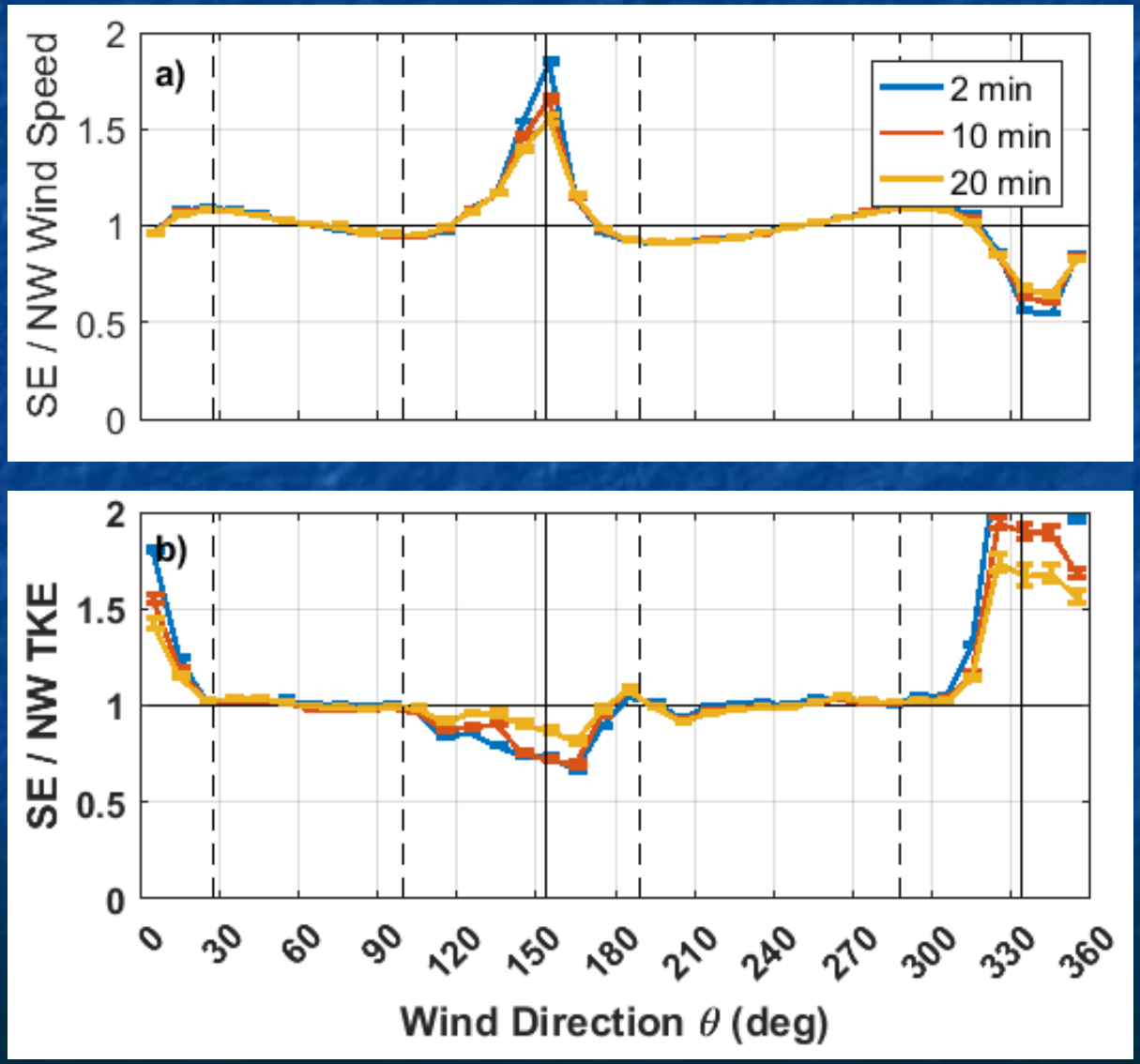


Mean of sonic wind dir. reduces differences.

Increasing averaging interval length decreases prominence of tower wake

Wind Speed

TKE



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