Wind Issues Affecting Wind Projects from Mega Wind Farms to Instrumentation

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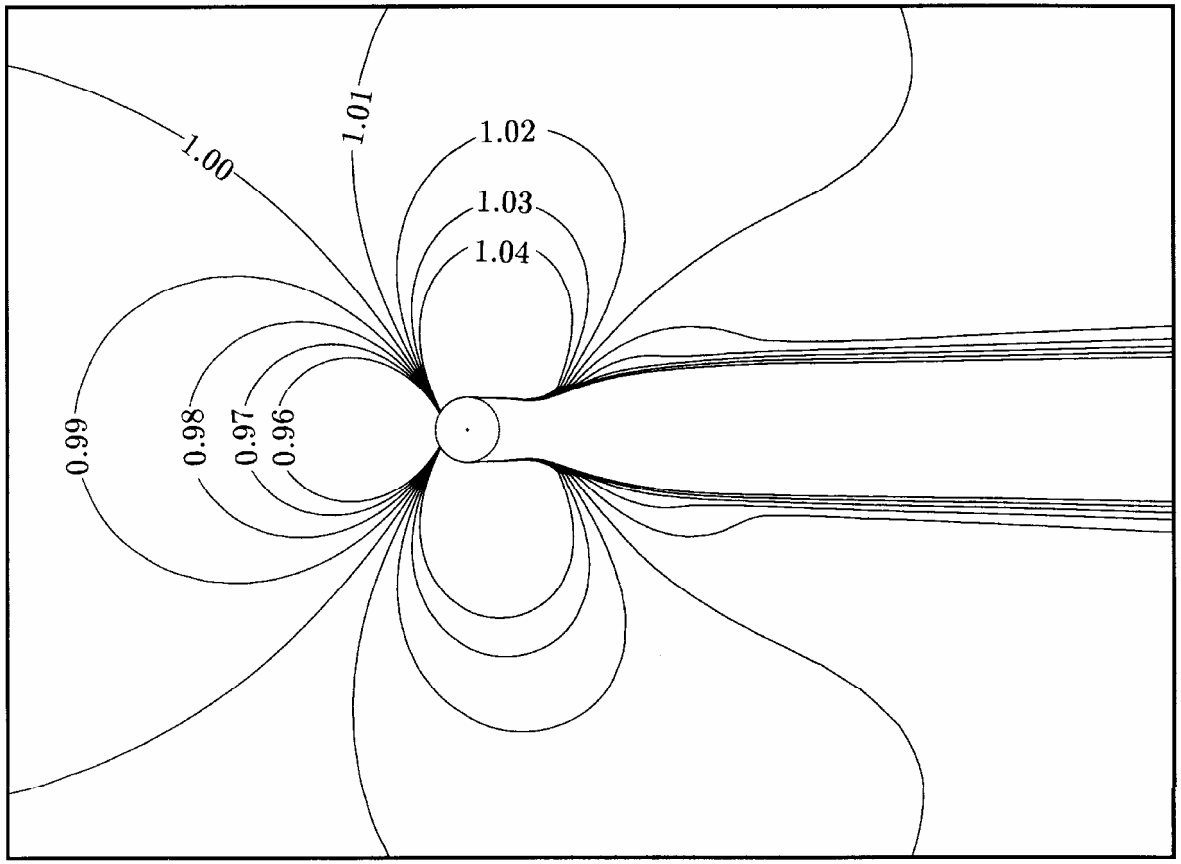
Topics of Discussion

- Instability in Performance of NRG Max40
- Mega Wind Farms & Mega Array Effects
- Bias in Long-term WS Estimates (Climatic Adjustment)

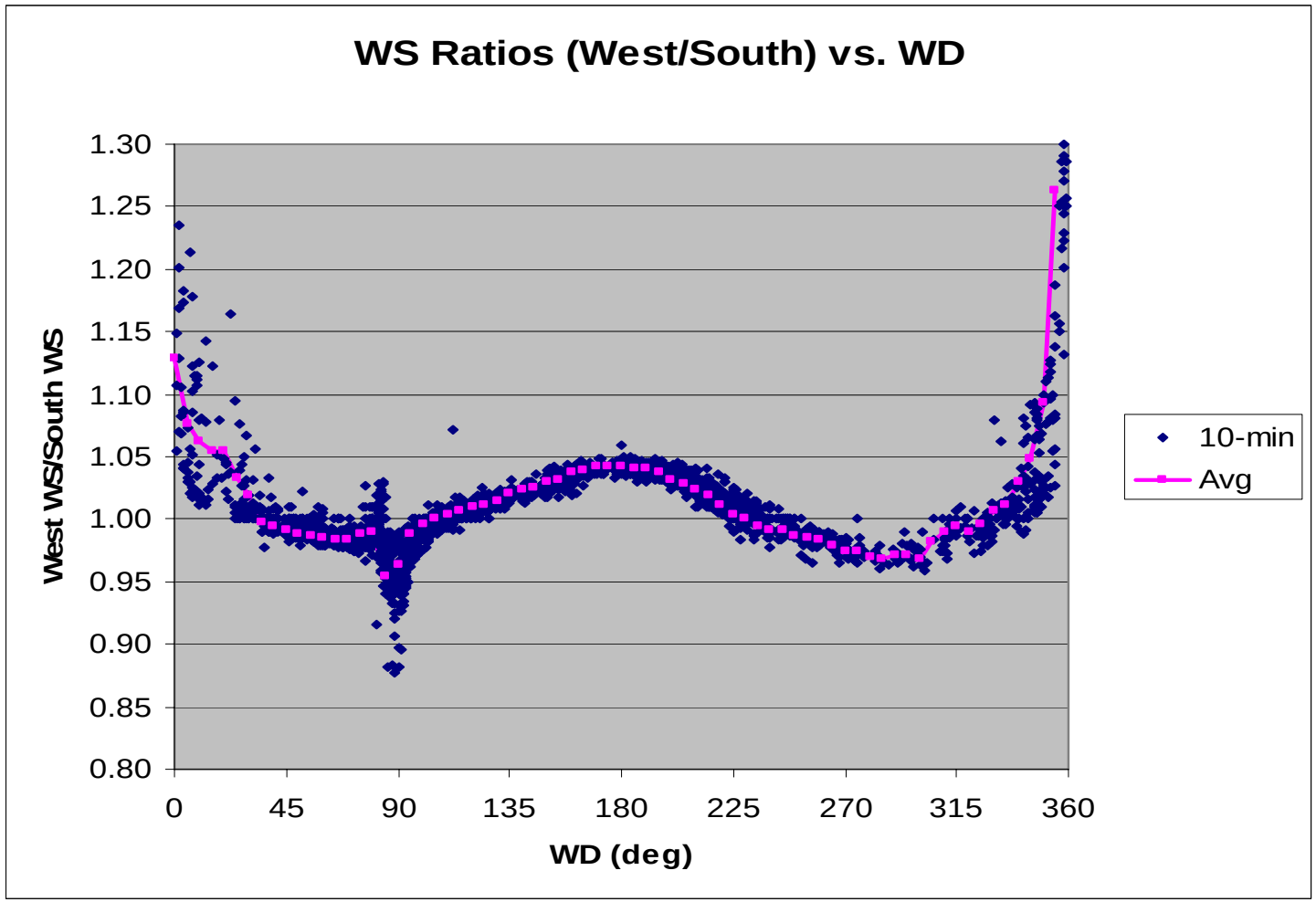
Background: Flow FX around a cylindrical tower.



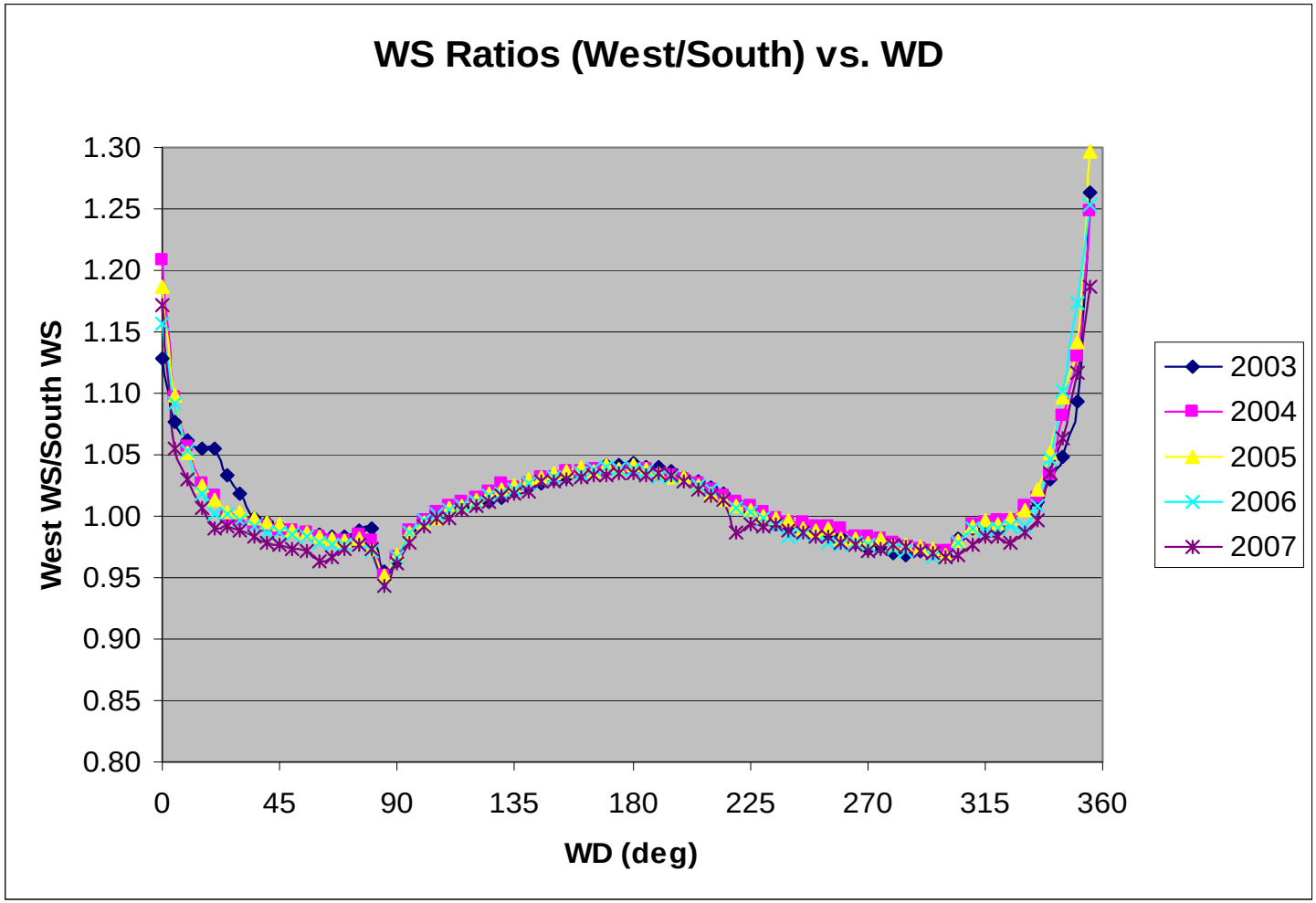
Analysis and Observed Effects

- Redundant WS from side-mount anemometers at the same level.
- Typical orientations are orthogonal or opposite sides.
- Calculate mean 10-minute WS ratios vs. WD.
- Threshold of 4.0 m/s.
- Rotation rate of anemometer is slowed.
- Effects are chaotic – not constant.

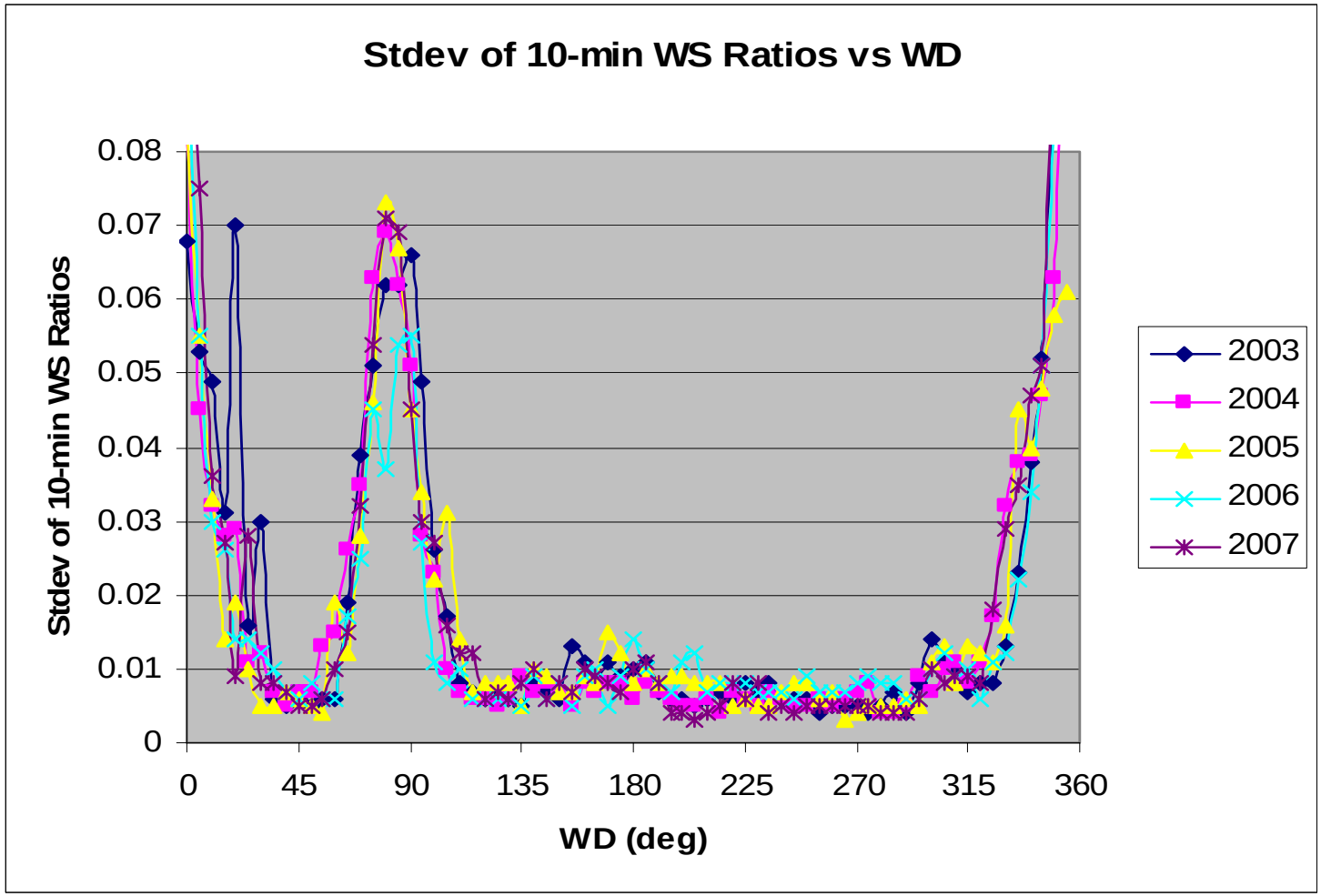
Typical Orthogonal Ratios vs. WD



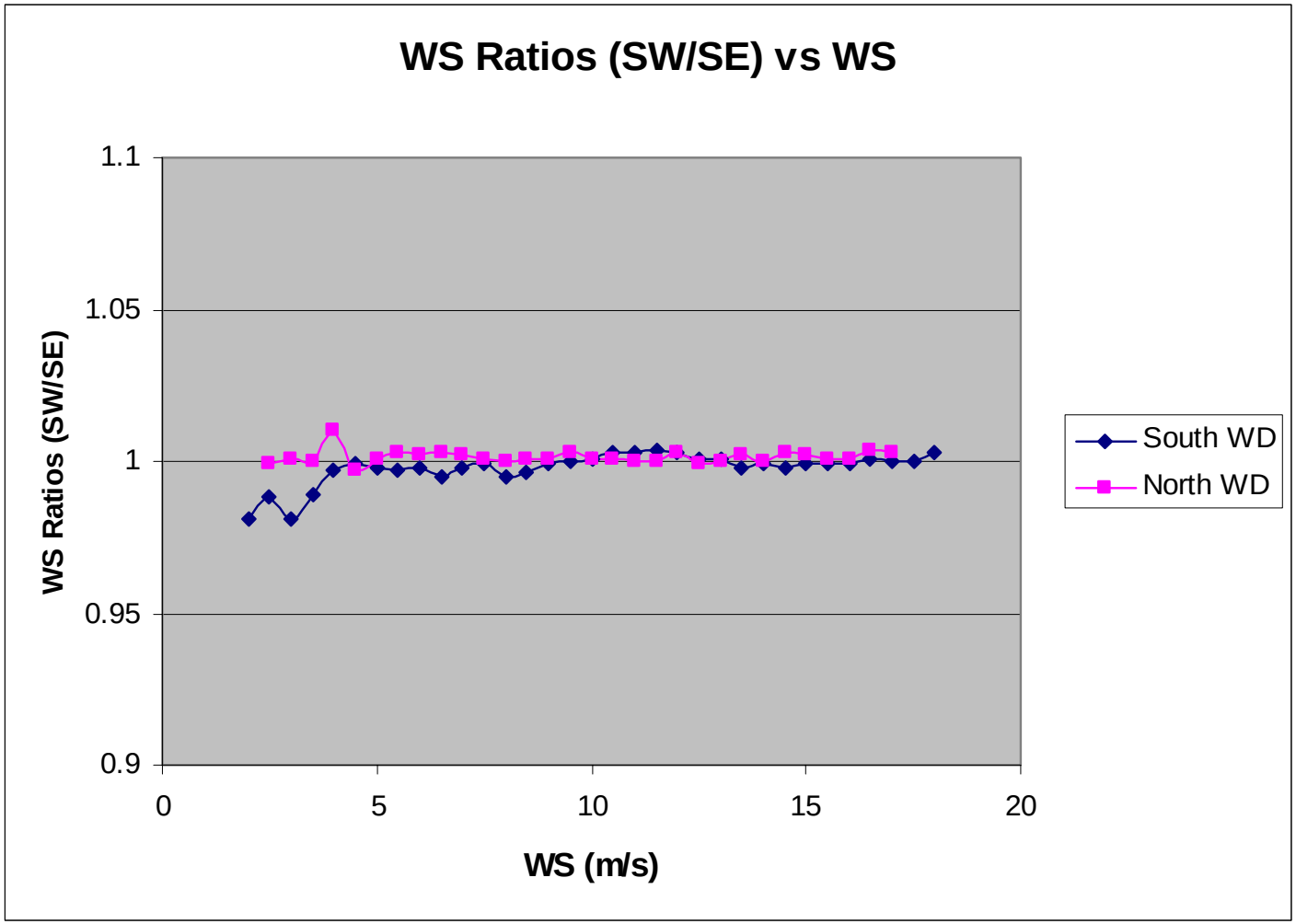
Same site: 2003 - 2007



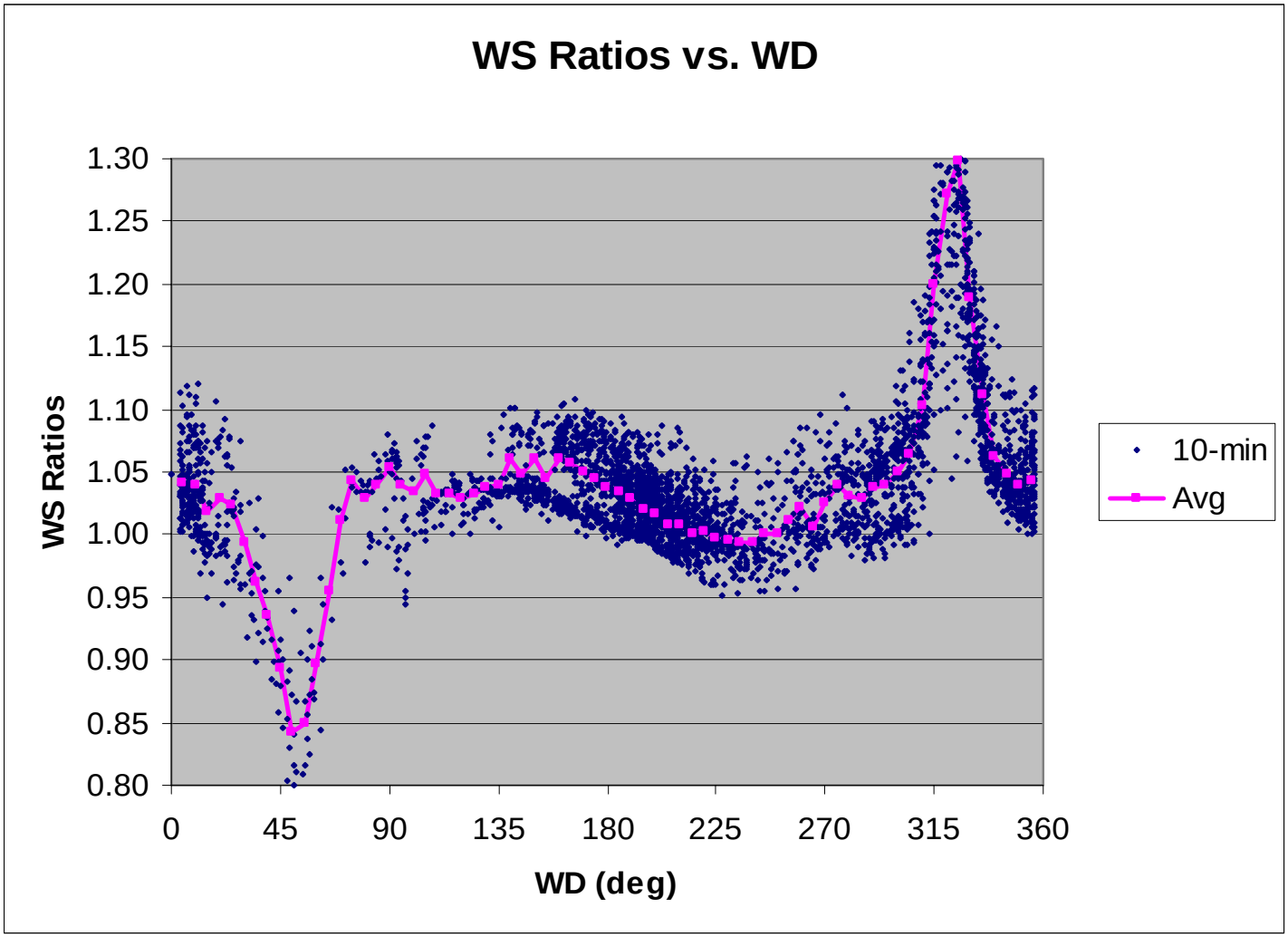
Scatter in WS Ratios – Stdev.



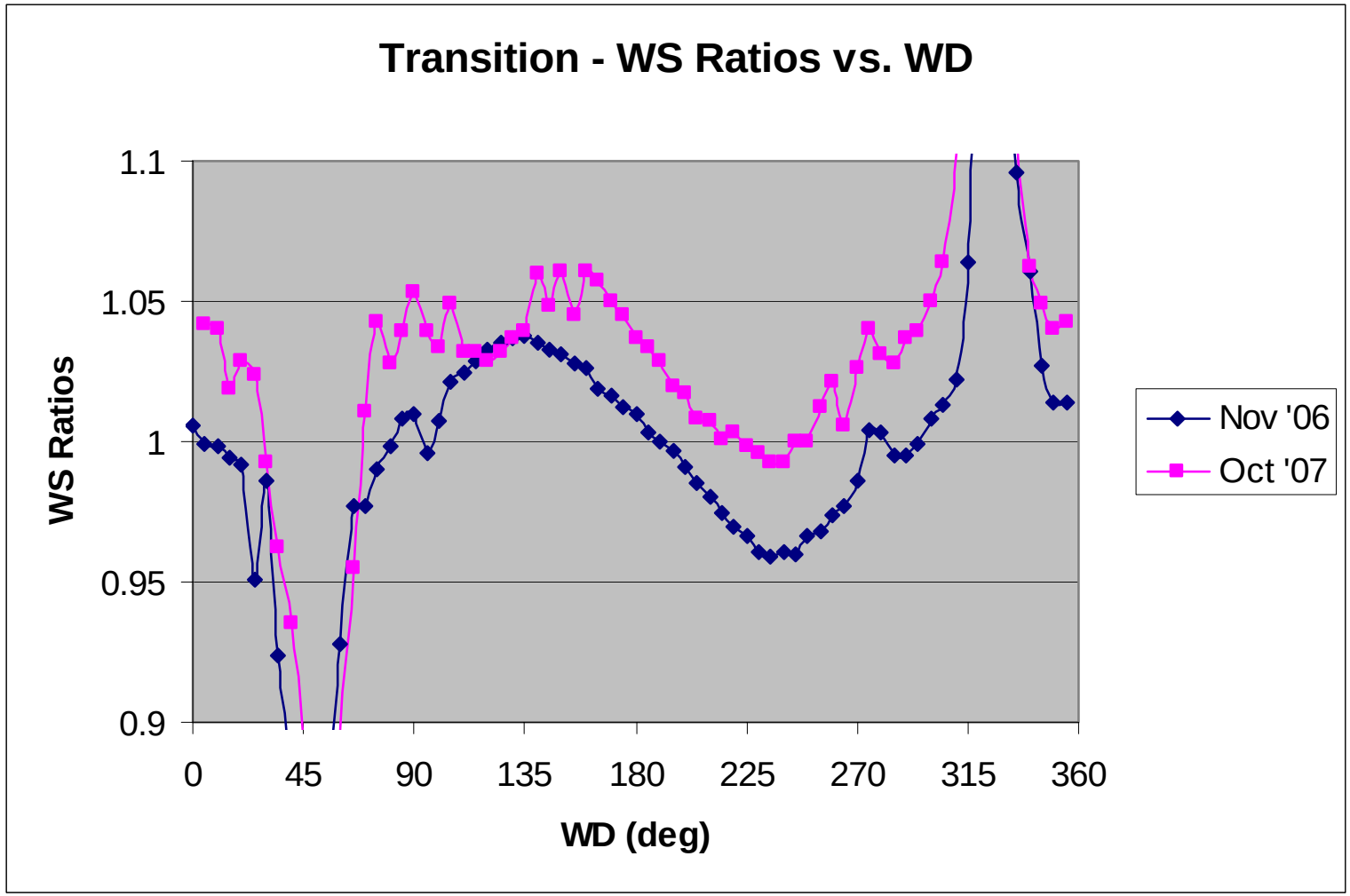
Mean WS Ratios vs. WS



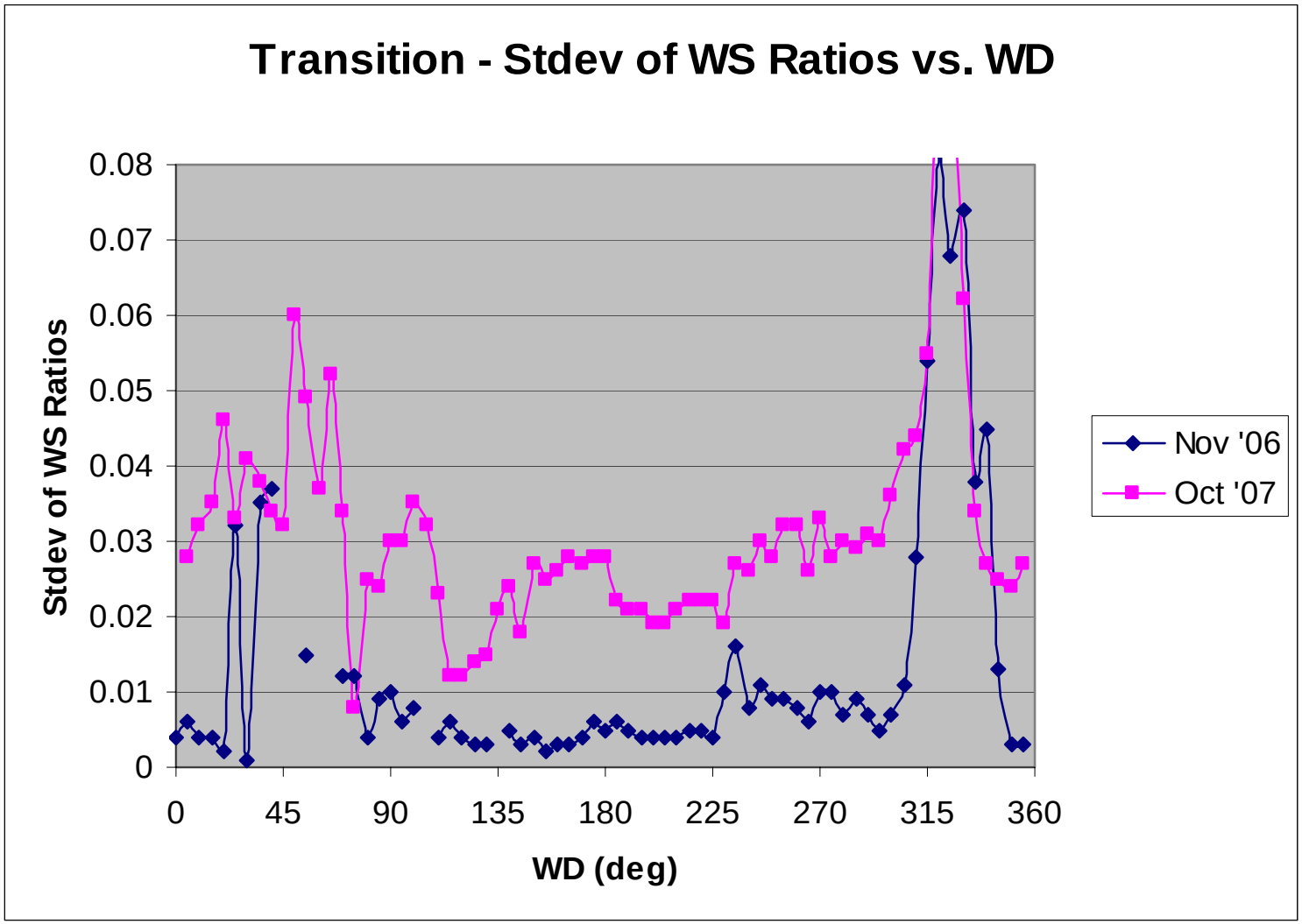
Problems Observed



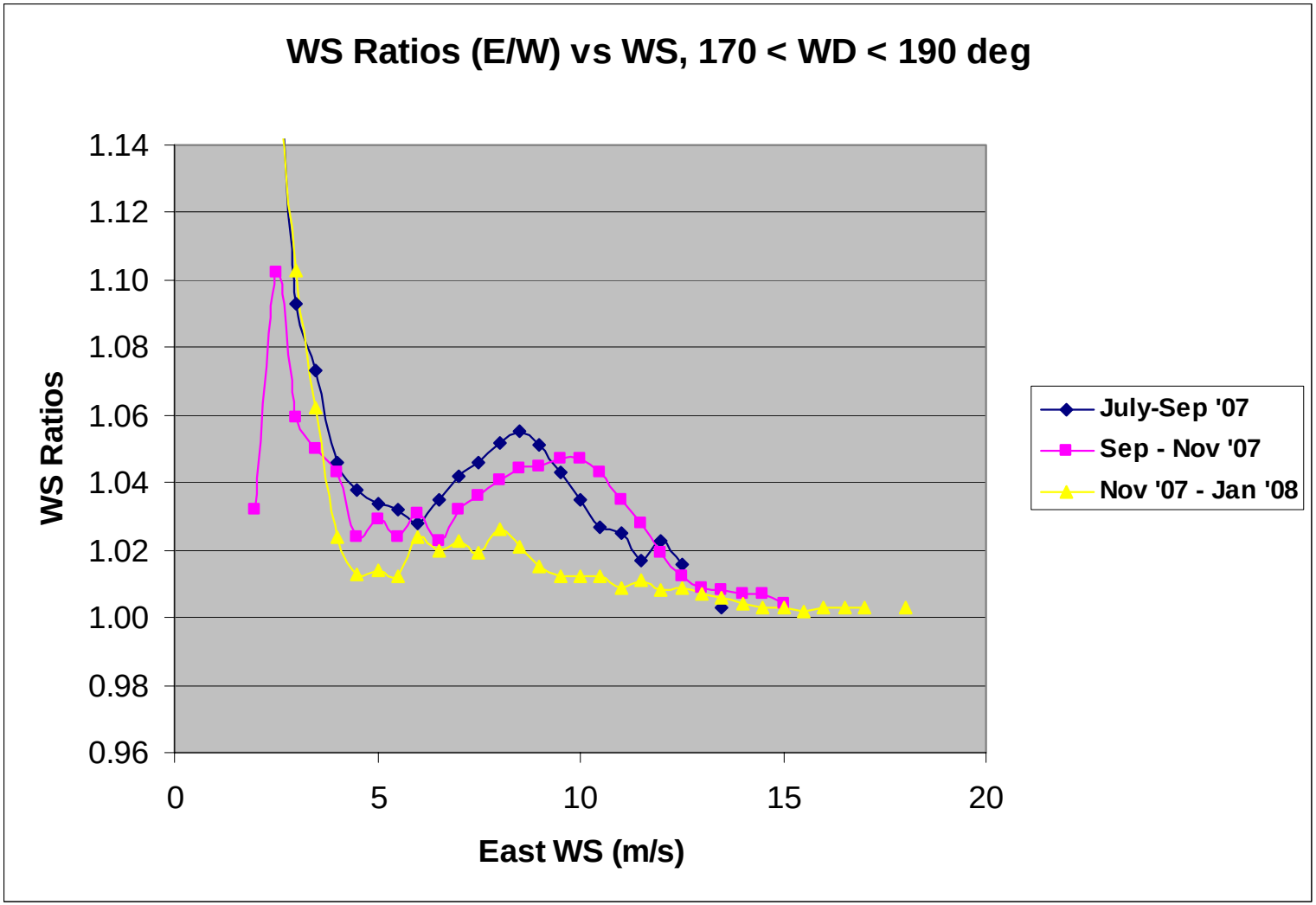
Transition in Mean WS Ratios



Transition in Stdev. of Ratios



Chaotic Variation in Performance



Max40 Conclusions

- Affected sensors spin slower – lower WS.
- Affects sensors since late 2005.
- Probably half or more of all units affected.
- Magnitude of effect up to ~5% (10-min) but chaotic in time and magnitude. Overall effect from < 1% to ~3% on affected sensor.
- Most likely result is reduction in estimates of HH WS, but over estimation possible.
- Requires careful analysis of redundant pairs to determine effects.

Mega Wakes from Mega Arrays

- Array sizes greater than ~300 MW of concern. Mega array of 4000 MW in Texas .
- Wake dissipation/wind regeneration. Stable nocturnal boundary layer & jets. Limited or inhibited wind regeneration.
- Macro wakes in Altamont Pass to Mega Wakes in the Great Plains?
- How to model energy generation in future as other large arrays developed nearby?

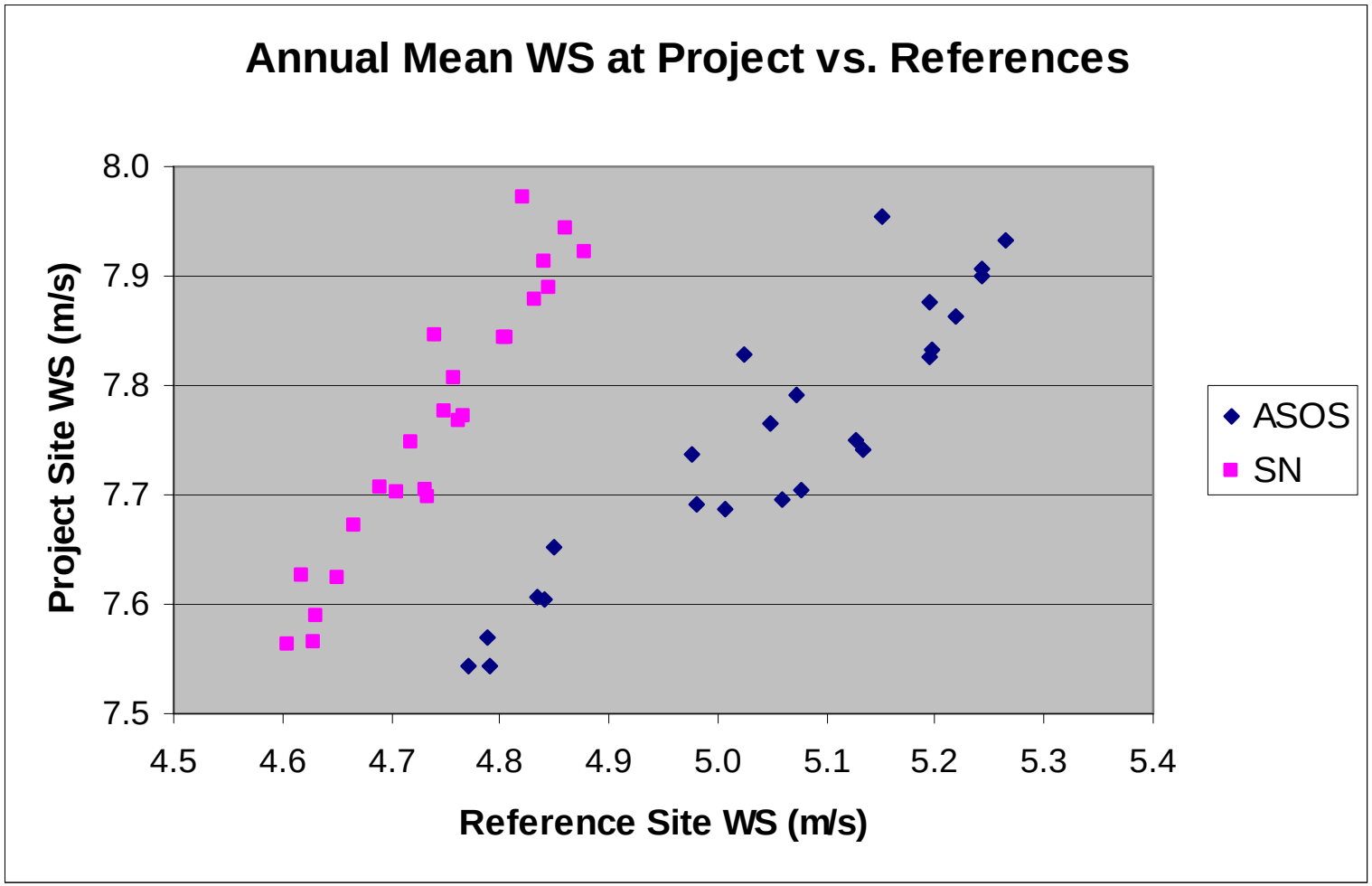
Bias in Long-term WS Estimates

- Upward bias in LT WS estimates in below-average periods at reference station.
- Not all reference sites created equal, some produce significant bias, some don't.
- Related to sensitivity to wind forcing – reference stations in low-lying areas more susceptible to producing bias.
- Ratio methods of all kinds, linear regressions all produce bias.

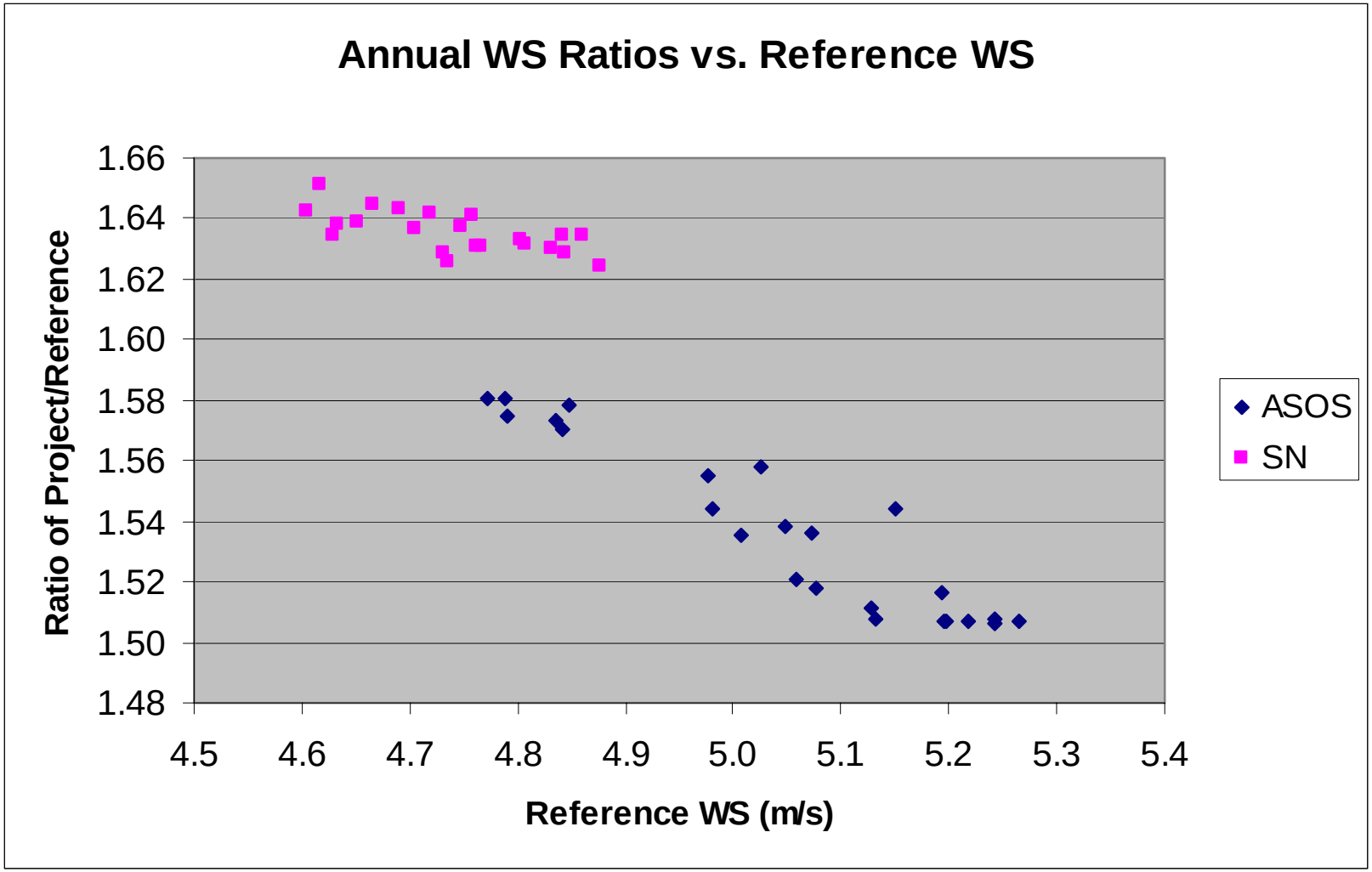
Example Project & References

- Three years of data at Project Site.
- Two reference stations; ASOS & State network; 13 years of reference data.
- Correlation of daily average WS, r^2 = 0.86 (ASOS); r^2 = 0.88 (State network).
- Examine relationship in WS in moving 12-month periods. Emulate situation of having only one year of data.

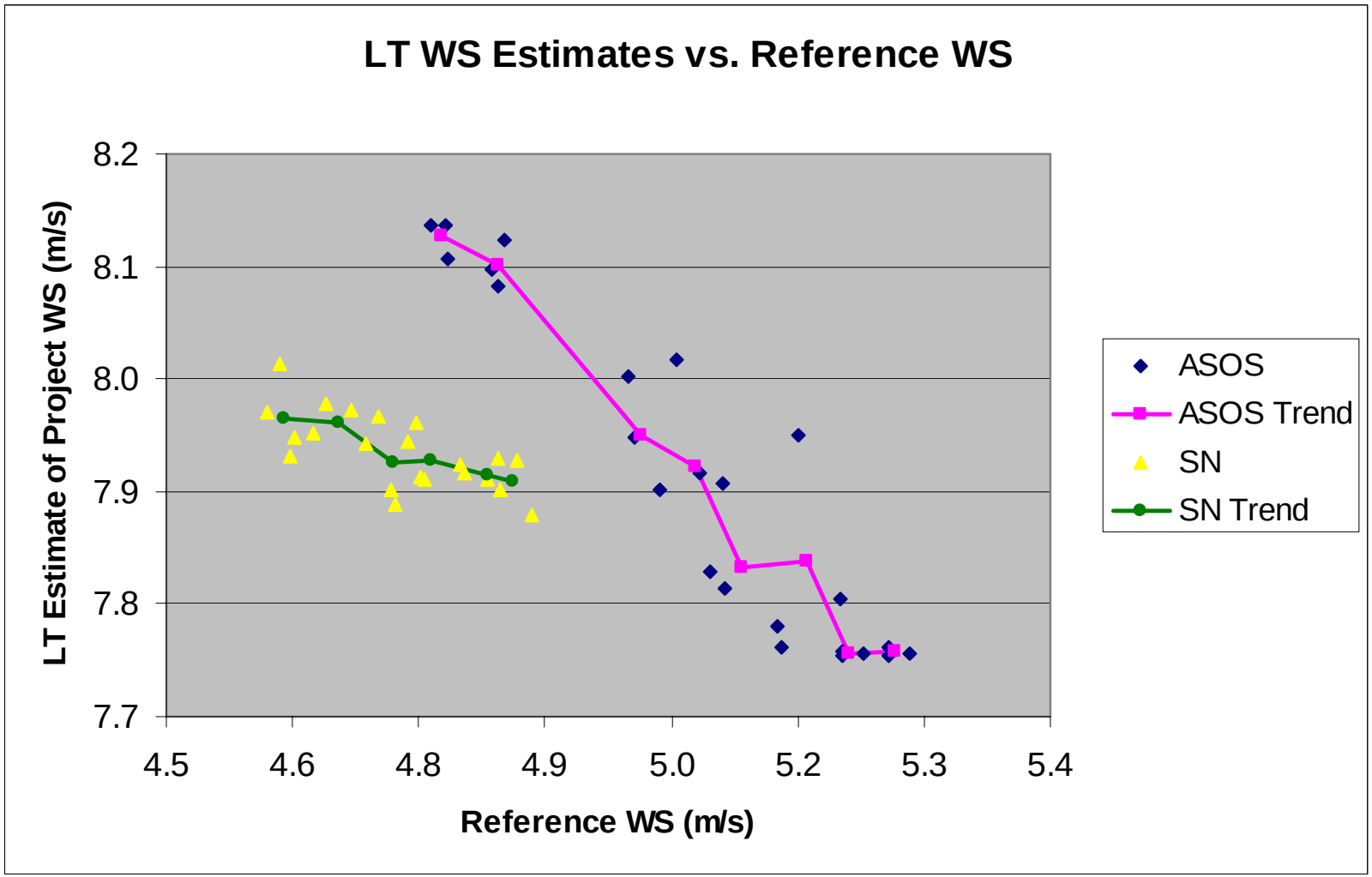
Annual Mean WS Analysis



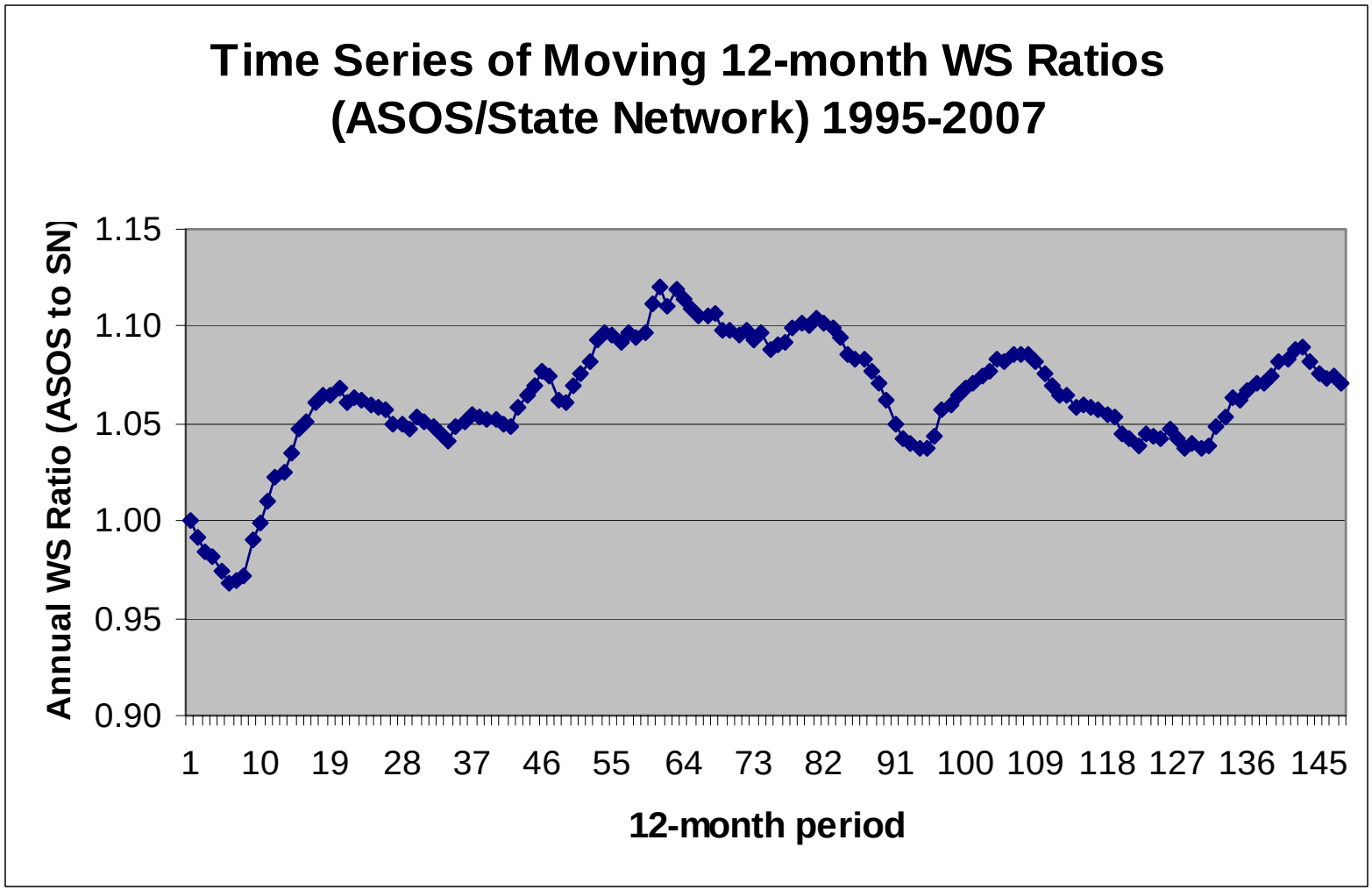
Ratios of Annual WS vs. Reference



LT Estimates vs. Reference WS



Variability in Reference WS



Conclusions: Climatic Adjustment

- Bias in long-term WS estimates observed using 12 months of data.
- Bias results from variance in response to wind forcing between project site and reference site.
- Sheltered, poorly exposed, reference sites more likely to produce strong bias.
- Considerable amount of variance in estimates possible, even from "windy" references.
- Collect as much on-site data as possible!