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Improved Wind and Turbulence Measurements Using a Low-Cost 3-D Sonic Anemometer at a Low-Wind Site

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Disclaimer

IMPROVED WIND AND TURBULENCE MEASUREMENTS USING A LOW-COST 3-D SONIC ANEMOMETER AT A LOW-WIND SITE

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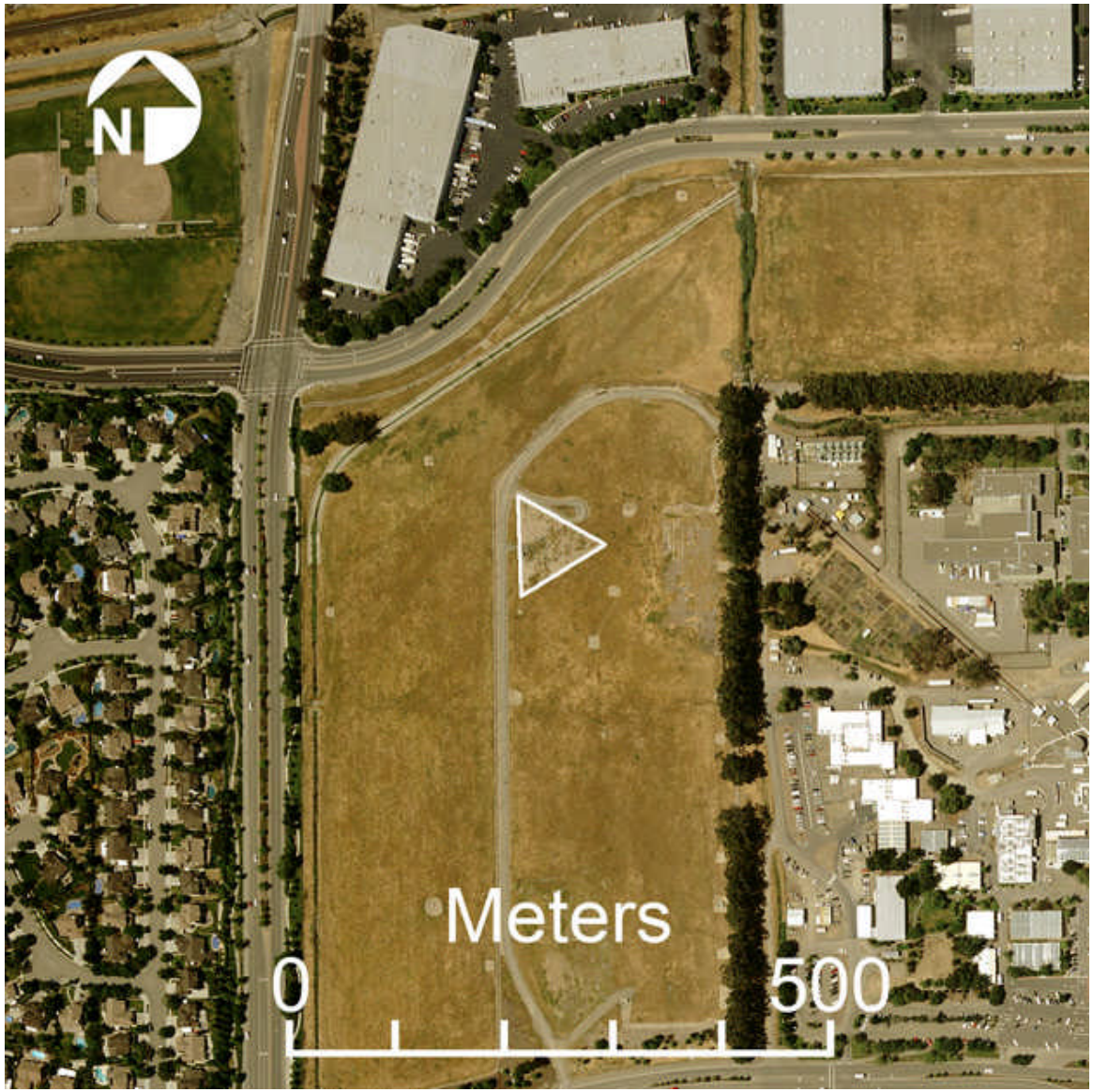
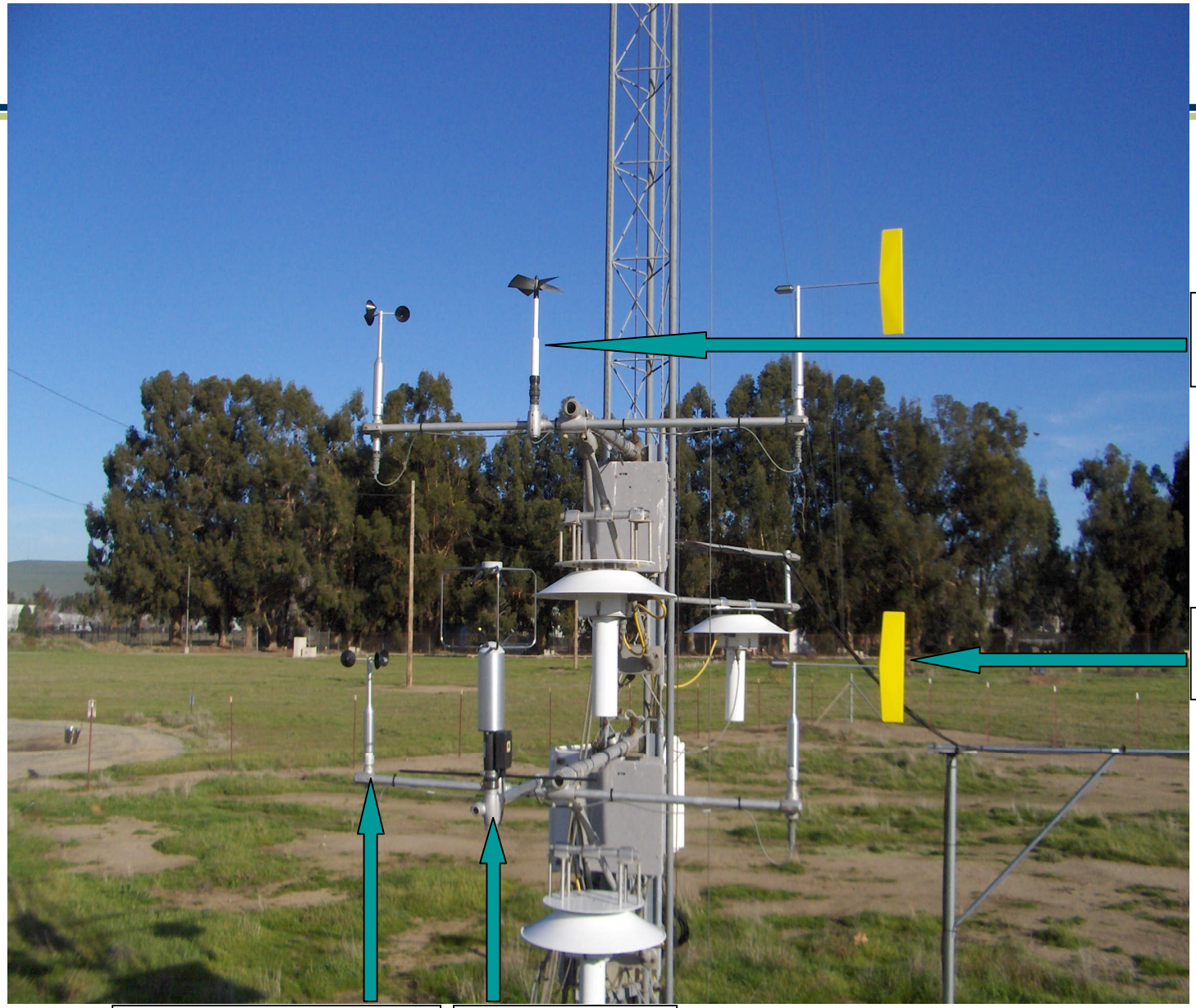
Sonic Anemometer Use Increasing

- **Advantages**
  - Low/No Maintenance Requirements
  - Measurements at very low wind speeds
  - Improved technology ⇒ lower cost
- **Recent Conversions to 2-D Sonics**
  - NWS/FAA (ASOS)
  - Tennessee Valley Authority
- **Recent Conversions to 3-D Sonics**
  - South Coast Air Quality Management District (CA)
  - Army Research Laboratory

Regional Area (Toward South)

Local Area Around Tower





Sensor Orientation

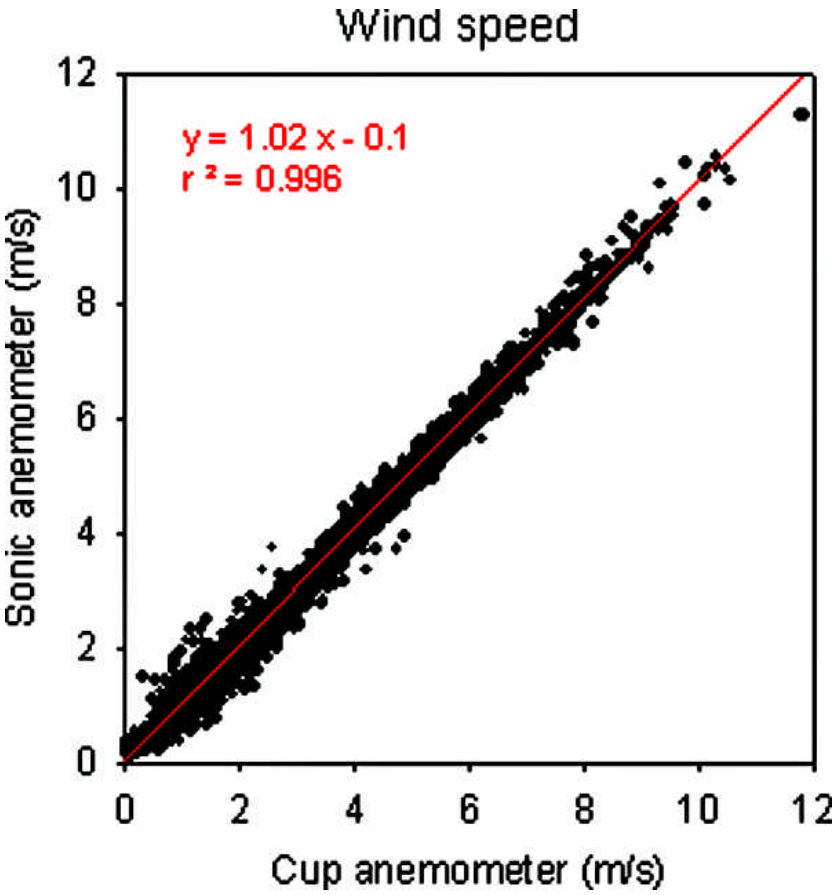
Sensor Characteristics

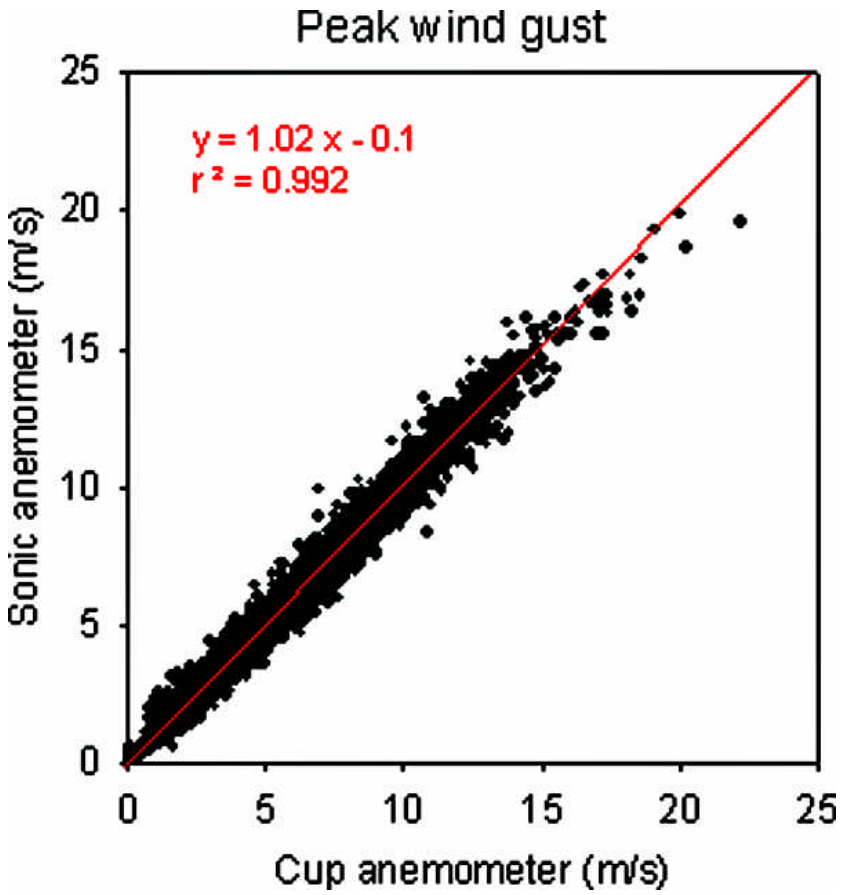
- **R.M. Young 81000 Sonic:**
  - 3 pairs of opposing ultrasonic transducers
  - 0.01-0.2 m/s starting threshold
  - 160 Hz internal, 4-32 Hz external sampling rate
- **Met One Sensors:**
  - 010C wind vane: +/- 3º, D.C. < 0.9 m
  - 020C anem: +/-1%(<30 m/s), D.C.<1.5 m
  - starting thresholds = 0.22 m/s
- **R.M. Young 27106F propeller:**
  - +/-1%(+/-20 m/s), D.C. = 2.1 m
  - 1.25 factor for non-cosine response
  - starting threshold = 0.22 m/s

Data Analyses

- **Year of 15-min. data (2004) from sonic & mechanical sensors analyzed/compared:**
  - 15-min. avg. & peak (1-sec.) scalar wind speed (u)
  - standard deviation of along-wind fluctuations (σ_u)
  - wind direction (θ) and its standard deviation (σ_θ)
  - standard deviation of vertical wind (σ_w) and angle fluctuations (σ_ϕ) [note: $\sigma_\phi \cong \sigma_w/u$]
  - vertical momentum flux ($-\overline{u'w'}$)
- **Suspicious data deleted**
- **All data measured at 1 Hz rate**

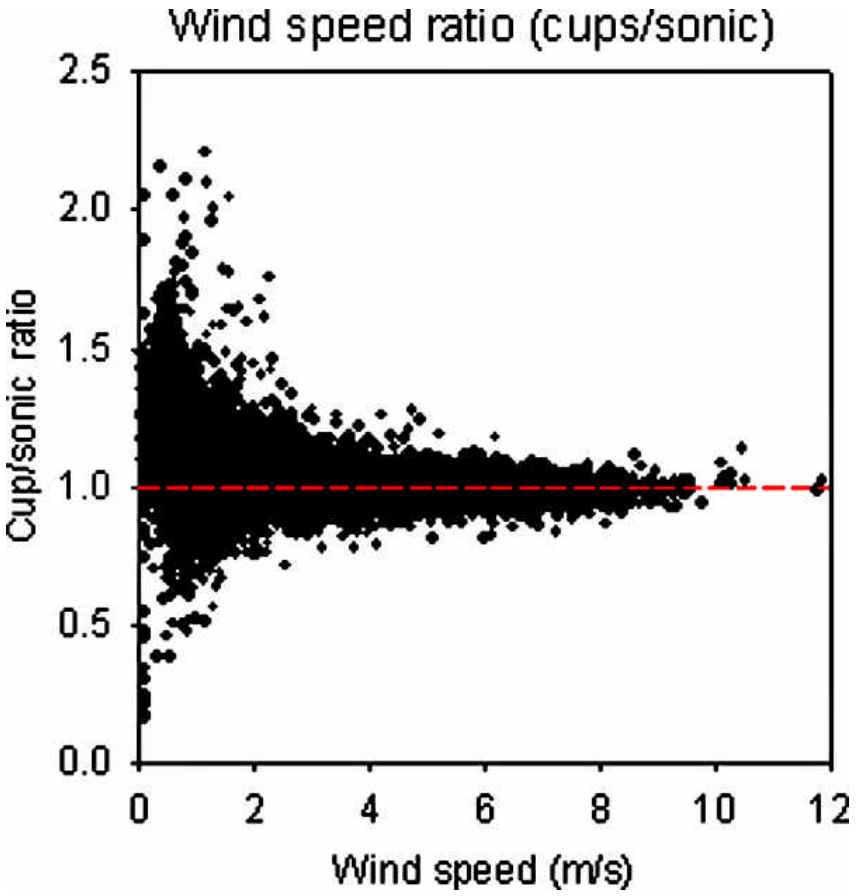
Wind Speed & Gust Correlations

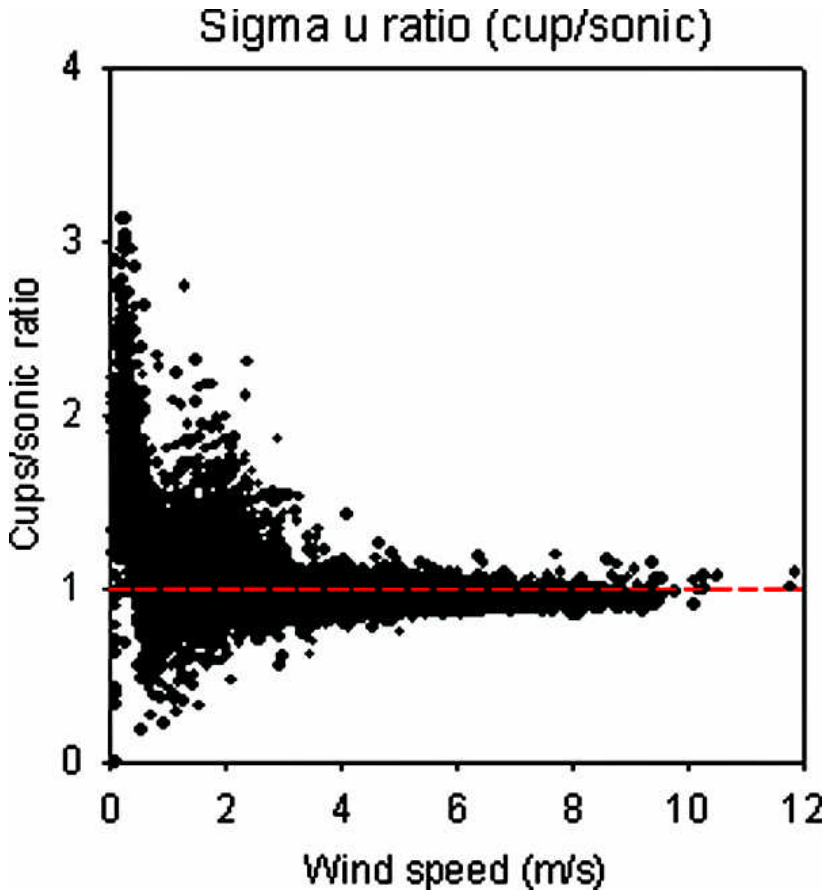




Very good over-all correlation…

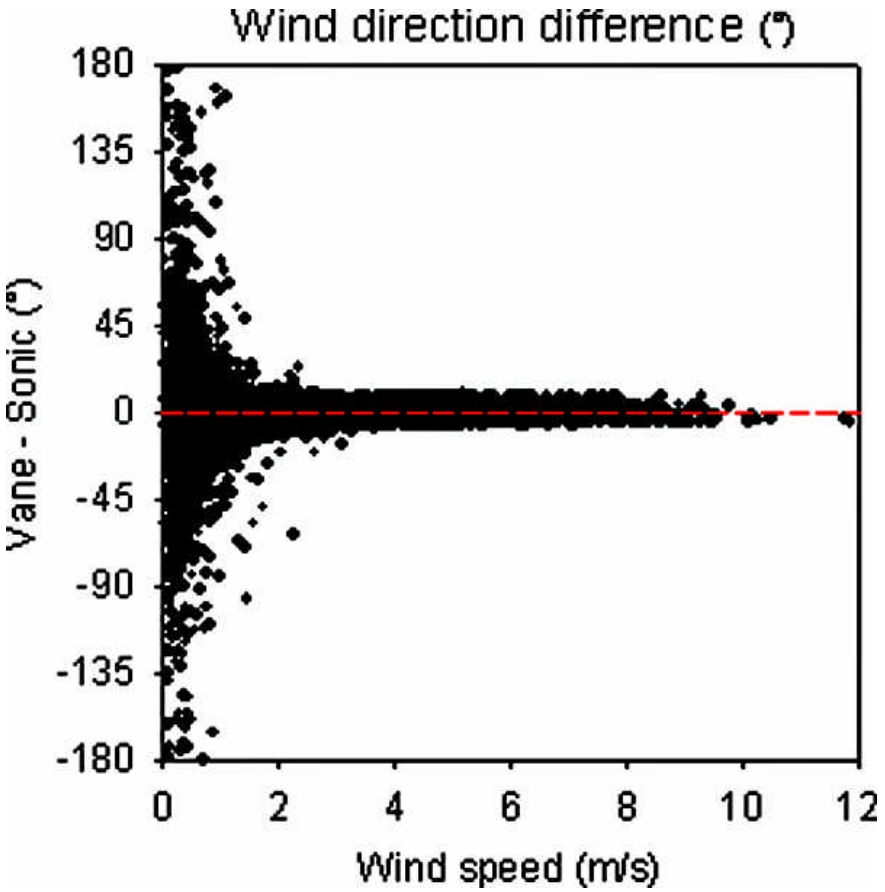
Wind Speed & σ_u Ratios

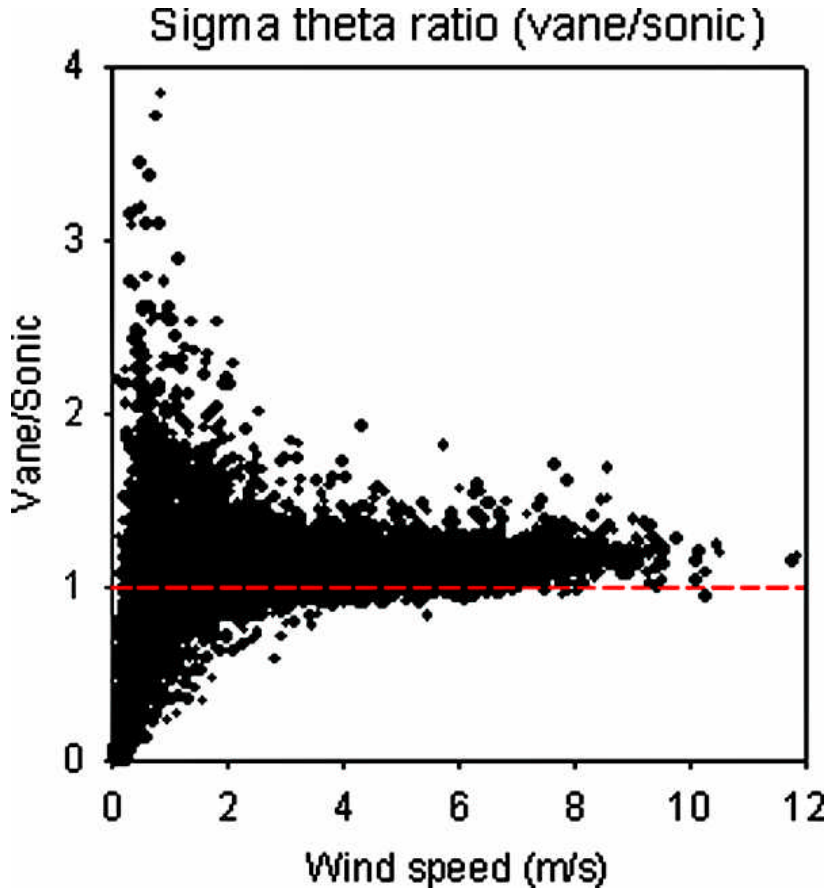




But large bias at low speeds

Wind Direction & σ_θ Comparison

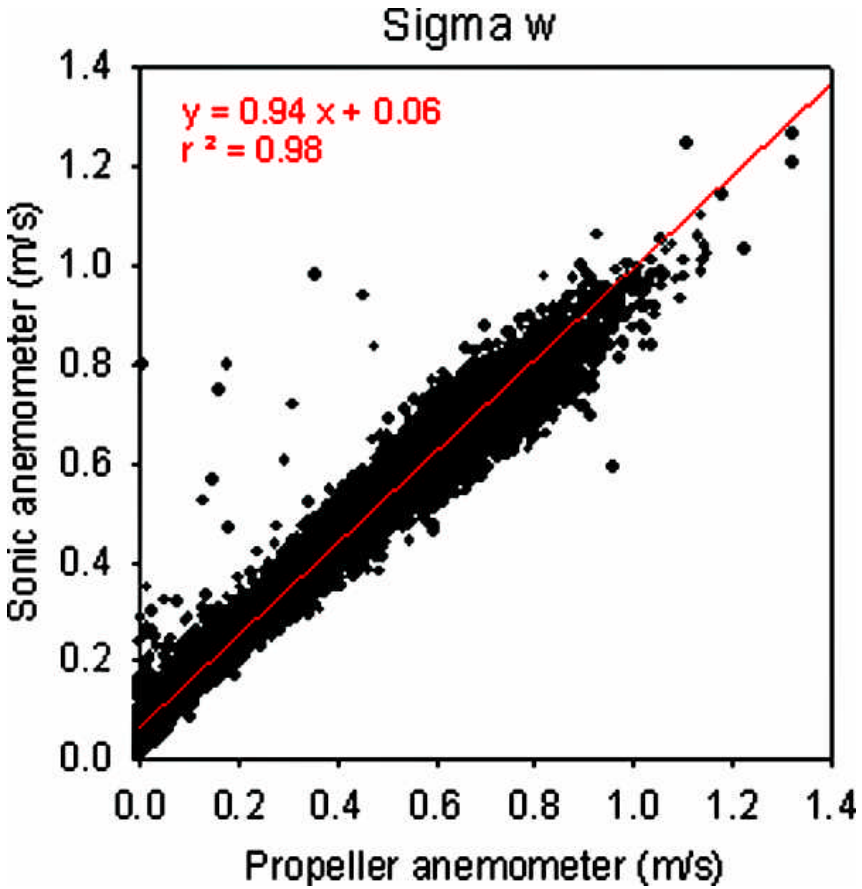


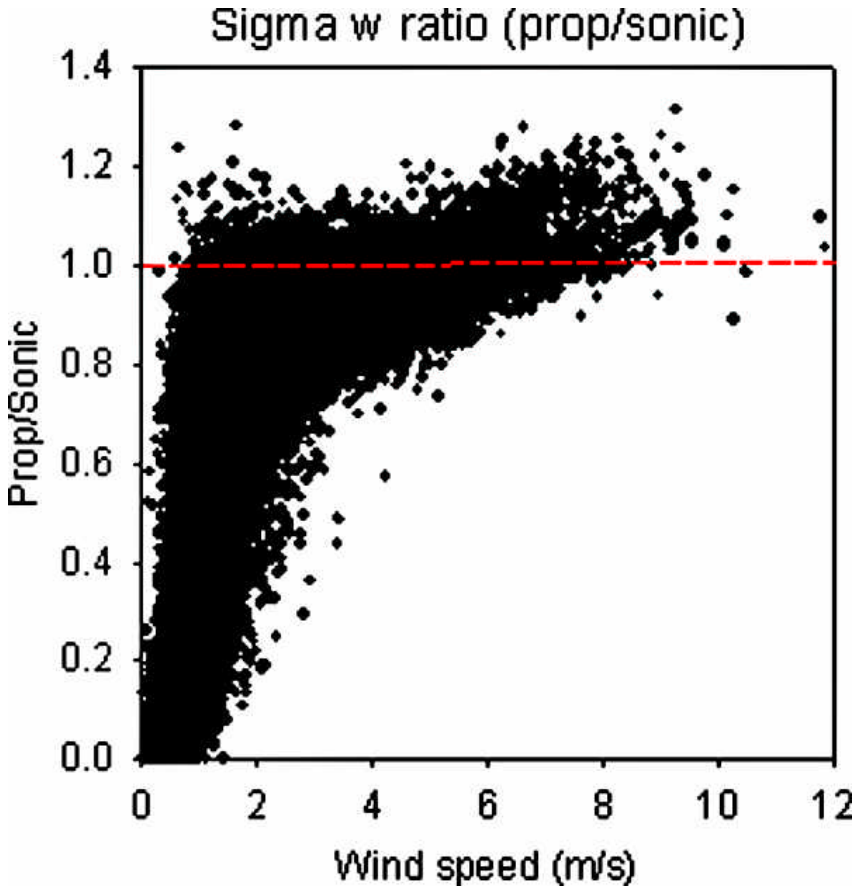


Large bias if u<1.5 m/s

Variable bias if u<1.5 m/s

σ_w Correlation and Ratios

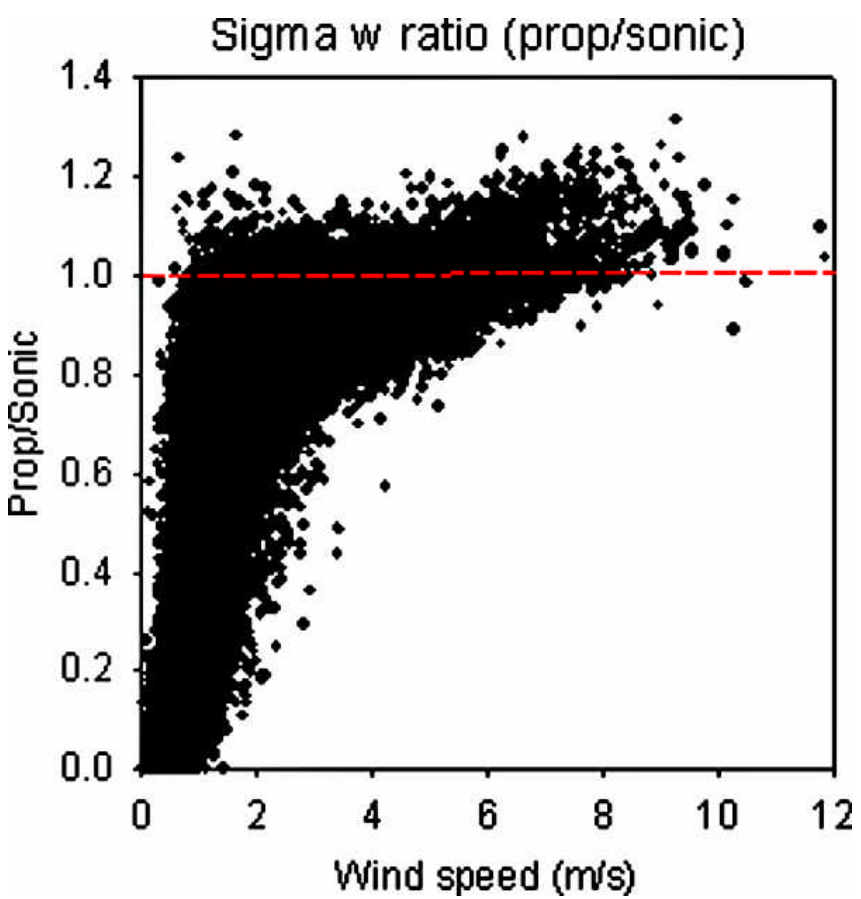


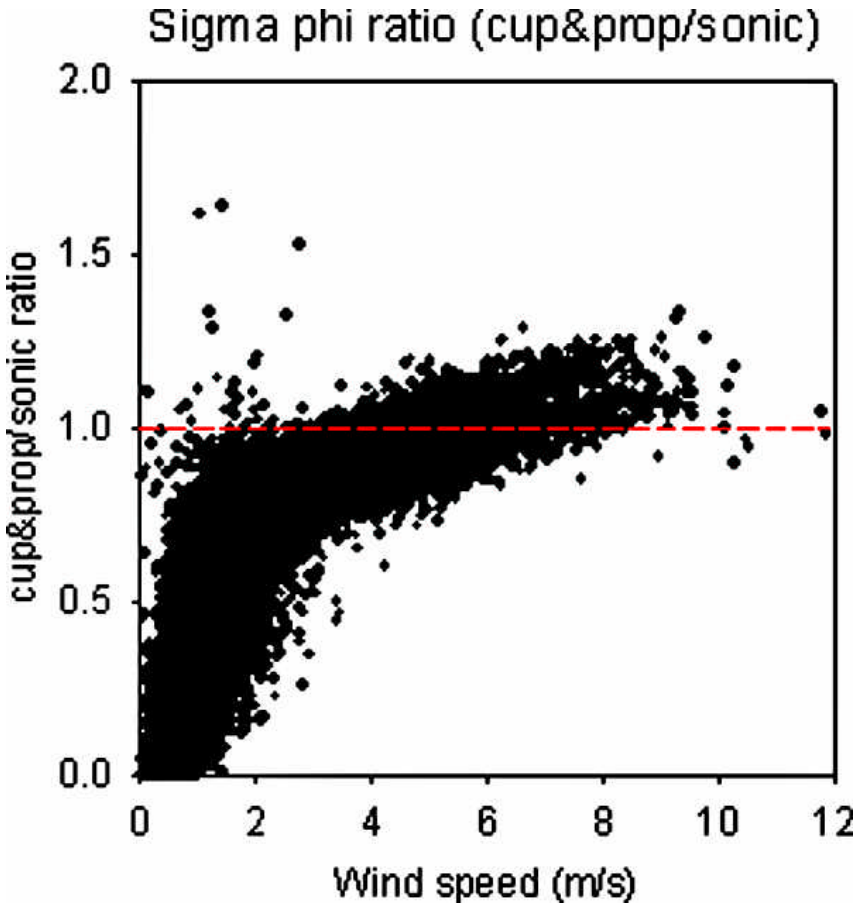


Good over-all correlation…

But large bias at low speeds

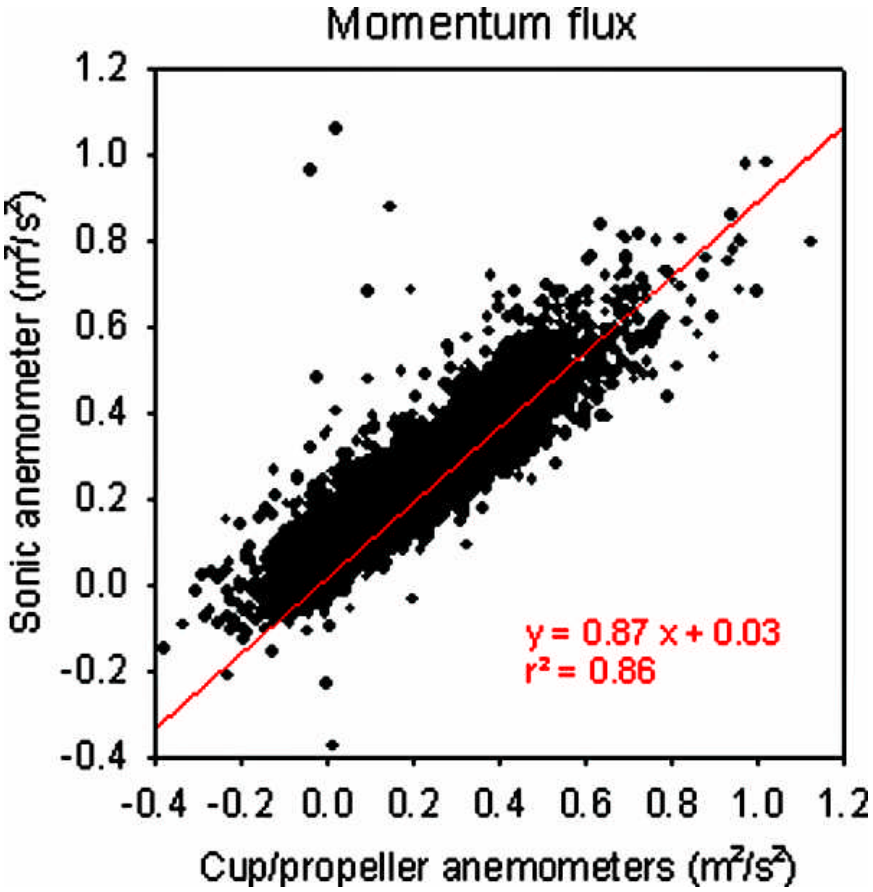
σ_w and σ_ϕ Ratios





Mechanical sensors < responsive at low speeds⇒large bias

Fluxes



- **Now estimating (using eddy correlation):**
  - Sensible heat flux (from sonic measurements)
  - Evaporative heat flux & evaporation (from sonic & H_2O gas analyzer)

Summary Table

Variable/ parameter	r^2	Median Mechanical Sensors/Sonic ratio			
		All winds	≥2 m/s	<2 m/s	<1 m/s
Wind speed (u)	0.966	1.06	1.03	1.16	1.24
Peak wind gust	0.922	1.02	1.00	1.07	1.12
Sigma u (σ_u)	0.98	0.95	0.94	0.98	1.08
Sigma theta (σ_θ)	0.84	1.05	1.07	1.00	0.94
Sigma w (σ_w)	0.98	0.83	0.91	0.47	0.10
Sigma phi (σ_ϕ)	0.56	0.78	0.88	0.42	0.08
Momentum flux $(-\overline{u'w'})$	0.86	0.74	0.89	0.02	0.00

Summary

- **Sonic vs. mechanical sensor measurements:**
  - Good agreement for stronger winds (σ_w bias: 1.25 factor)
  - Better measurements for light winds (large % differences)
  - Errors especially large for vertical turbulence $\Rightarrow$
    - sonic σ_ϕ: 5-10° greater when cup/prop $\sigma_\phi < 5°$
    - large (factors of 2-10+) errors in σ_z estimates
- **Sonic anemometer limitations:**
  - Data loss from wetting (rain/fog with light winds)
  - Needs more power (110 mA): 10X cup/vane; 20X vert. propeller
- **Ideal supplement & backup to routine measurements**

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