Robust and Low Cost Drag Anemometer

Lawrence Tsai, Christopher D. Wallis, Anthony S. Wexler

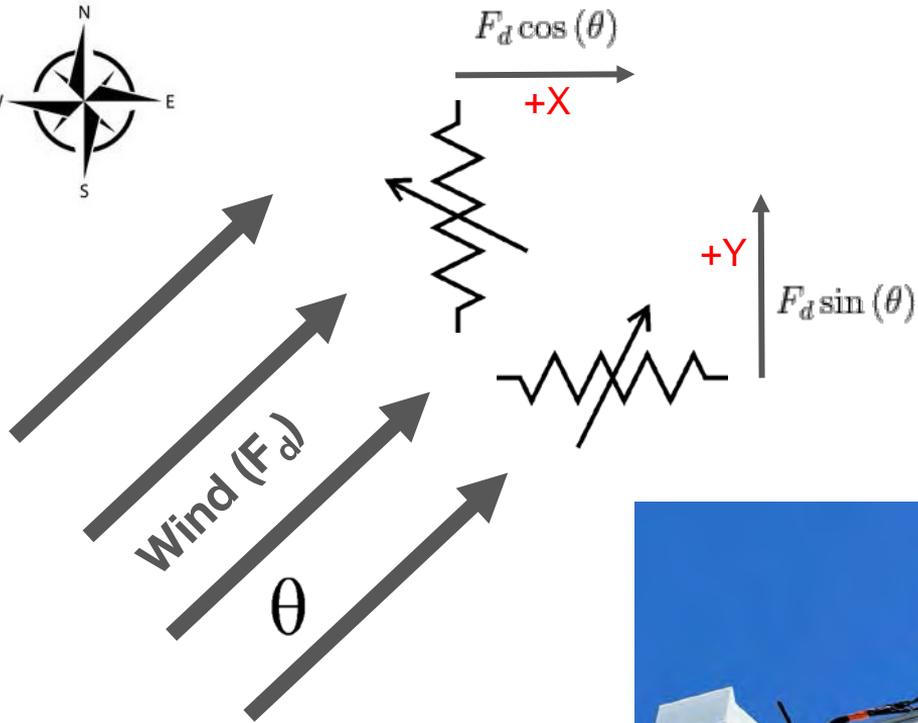**Air Quality Research Center, University of California Davis**
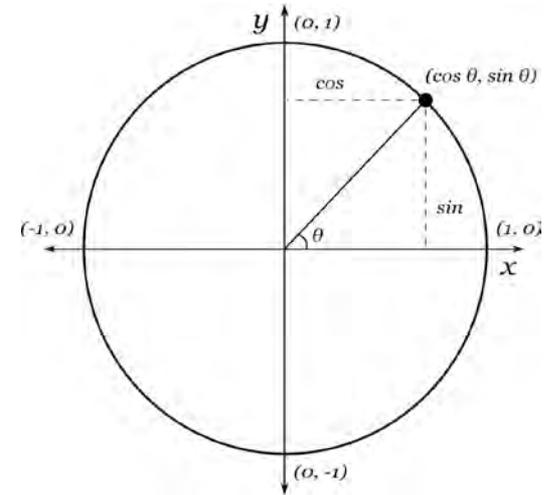

October 4, 2022

Introduction - Motivations

- Currently, no meteorology data at IMPROVE sites (except for a few)

- Bosch BME280 chip can give us temperature, RH and barometric pressure – cheap

  - RH dependence is in the regional haze rule

  - Temperature and pressure can also help unravel mysteries

- Need wind speed and direction to complete the set

  - Wind direction key to source apportionment

- IMPROVE currently uses off-site wind data

- Developed an anemometer with no moving parts that costs <$100
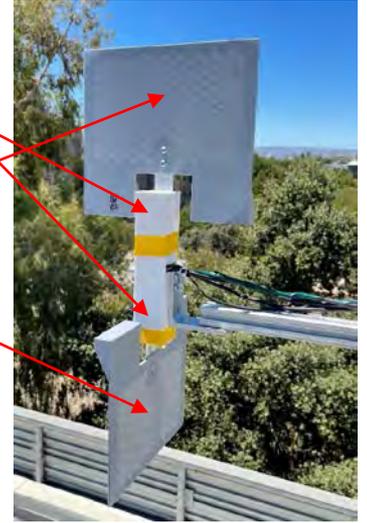
Drag Anemometer Concept

$$F_d = C_d A \frac{1}{2} \rho u^2 => \sqrt{F_d} \propto u$$

$F_d \cos(\theta)$

+X

+Y

$F_d \sin(\theta)$

Wind (F_d)

θ

+X

+Y

y $(0, 1)$

$\cos$

$(\cos \theta, \sin \theta)$

$\sin$

$(-1, 0)$

$(1, 0)$

θ

x

$(0, -1)$

Drag Anemometer Concept (cont.)

Electronics Enclosure

Load Cells

3D-printed
Drag Bodies

Features:

- Simple & robust design
- Easy to assemble & repair
- Low cost ~$70
- Weatherproof

Microcontroller & Custom PCB

Drag Anemometer Concept (cont.)

Electronics Enclosure

Load Cells (underneath)

Drag Bodies

Part	Est. Cost
Arduino Microcontroller	$15
Custom PCB	$15
Load cells	$3
Power Supply	$15
3D Printing Material	$5
Misc. Parts	$20
TOTAL:	**$70**

Microcontroller & Custom PCB

Assembly time: < 2 hours

Testing Method

Testing location at UC Davis, Davis Campus

On-campus experimental IMPROVE site

Testing Method

Young 81000 3-Axis Ultrasonic Anemometer
- Reference wind speed/direction

Prototype
- Connected to IMPROVE Sampler via wired USB

IMPROVE Sampler
- Automatically logs and uploads data

Wireless serial communication via Zigbee
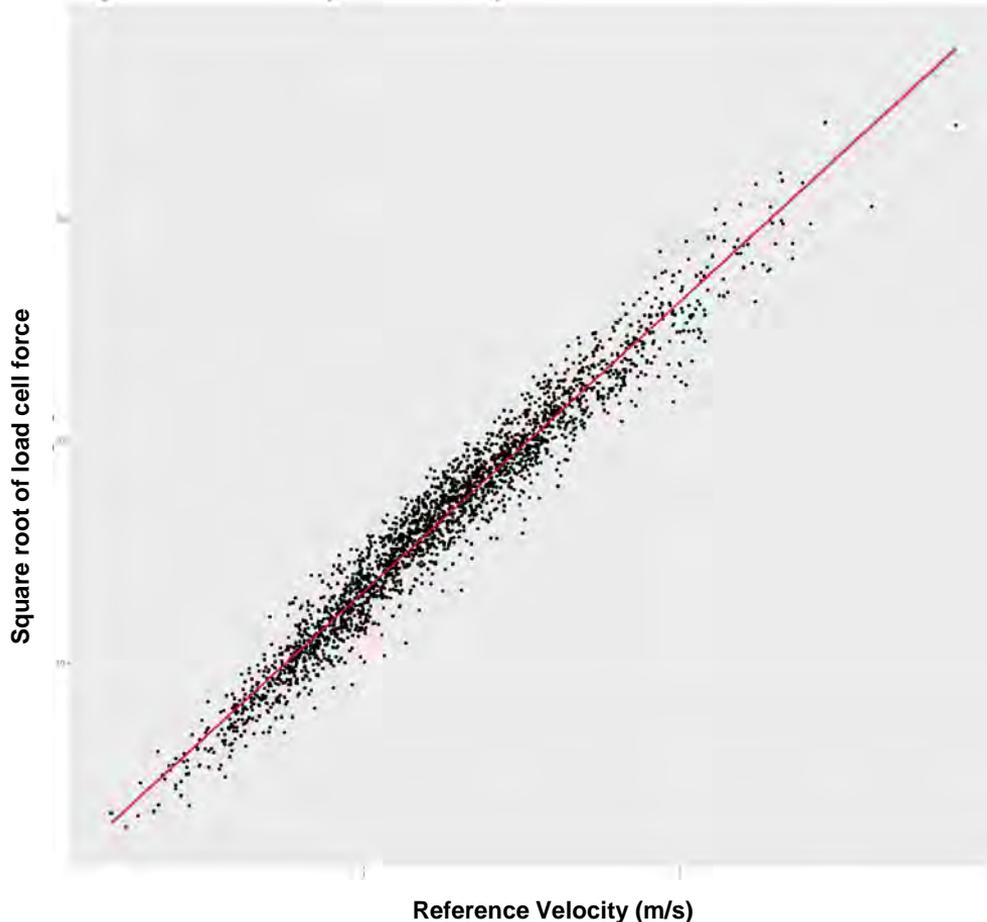
Field laptop
- Reference wind data parsing and logging

Remote Server (Linode)
- Combines prototype and reference wind data
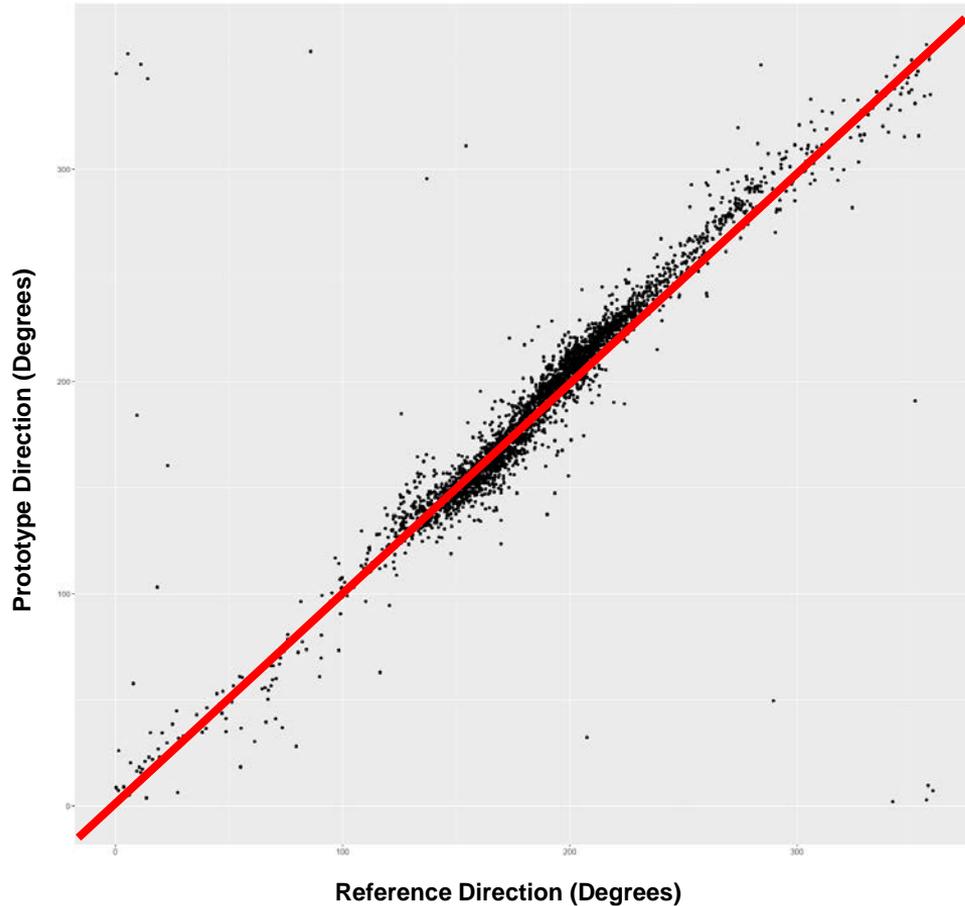- Runs R Shiny Web App for data visualization

Results - Wind Speed

- Strain gauge force vs Wind Speed
- 10-min average
- R2 = 0.95
- Intercept 0.19 m/s
- Slope = 13
- $F_d = C_d A \frac{1}{2} \rho u^2 => \sqrt{F_d} \sim 13u$

Square root of load cell force

Reference Velocity (m/s)
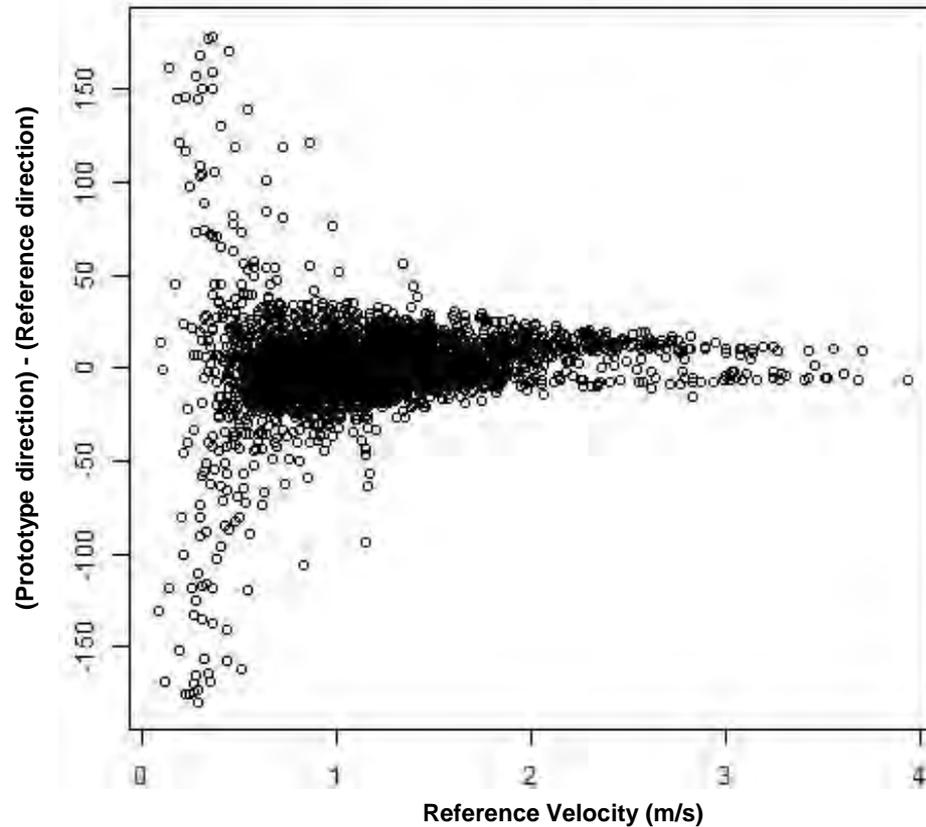
Results - Wind Direction

- Prototype vs reference direction
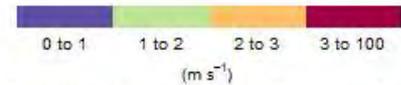- 10-min avg
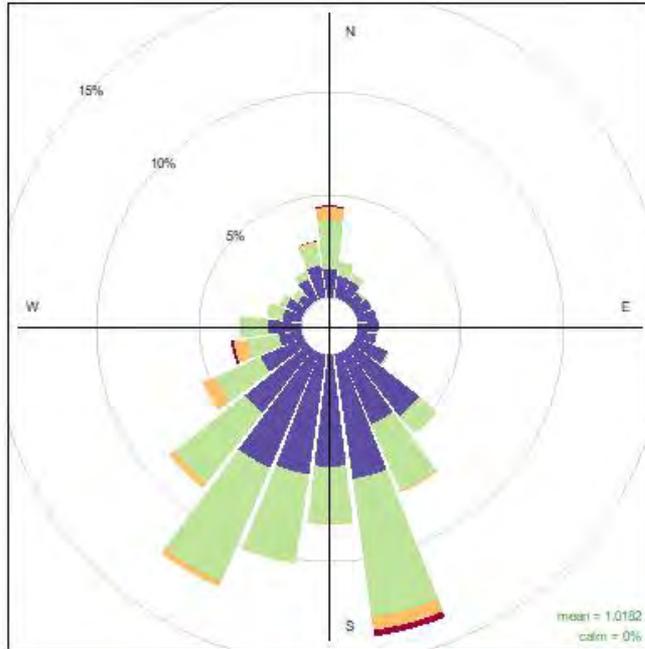- Direction averaging with cosines

Results - Wind Direction

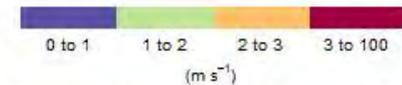*Data from 8/14 – 9/19*

P2: Direction error vs Velocity
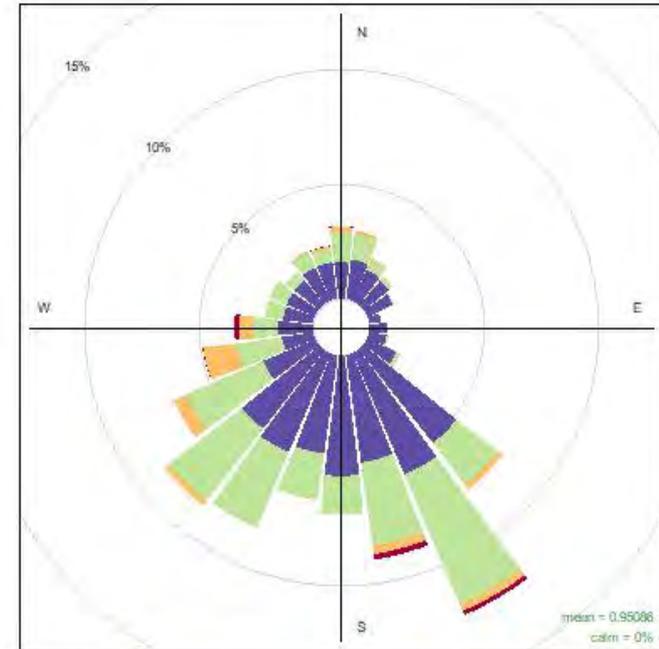
Results: Wind Speed + Direction

Young 81000 Ultrasonic Anemometer

Prototype

Conclusion

- Good velocity and direction measurements

- Especially compared to nothing!

- Low cost, no moving parts

- Works with IMPROVE controller

- Patent in progress

- Needs real-world test (PORE1?)

Point Reyes

Questions?