

Low-Cost Anemometer (2023 Update)

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Prototype from 2022 update



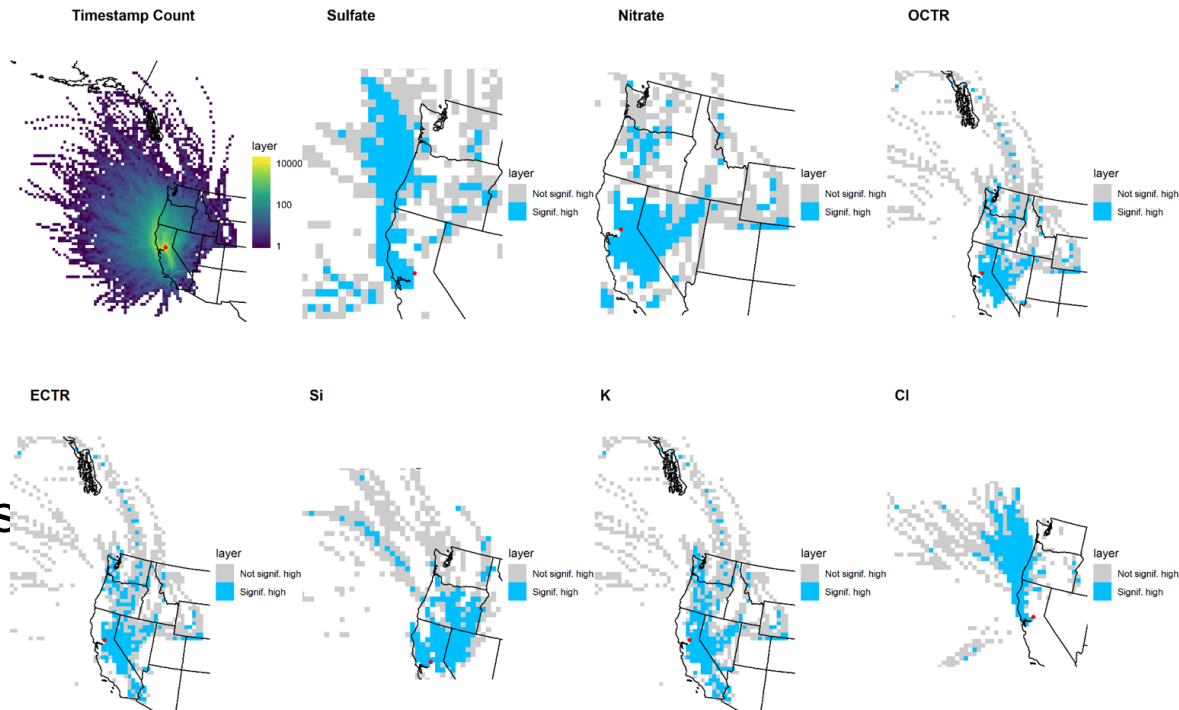
2023 prototype at SULA1

October 17, 2023

Introduction - Motivations

06-067-0006

- Wind would improve pollutant source apportionment



- IMPROVE currently uses off-site wind data

HYSPLIT trajectories generated from IMPROVE samples

Introduction - Motivations

- High cost of existing technologies
- Harsh weather conditions demand robustness
- Biannual maintenance schedule considerations



~\$3000



~\$1500

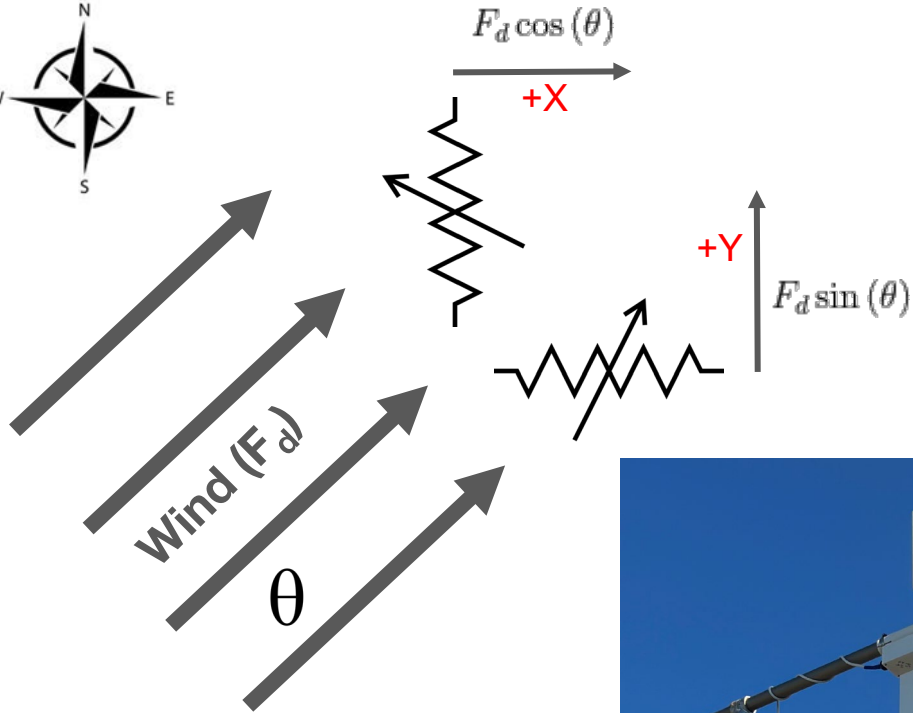


FRES1



GRR11

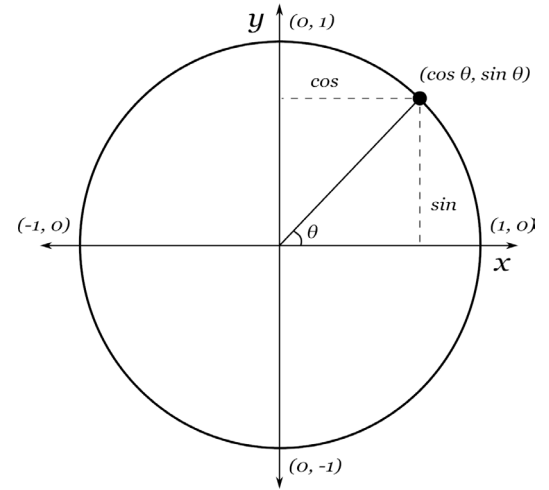
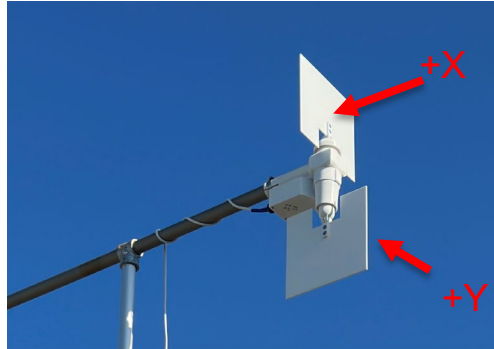
Drag Anemometer Concept



Air velocity

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

Drag force



Drag Anemometer Concept (cont.)

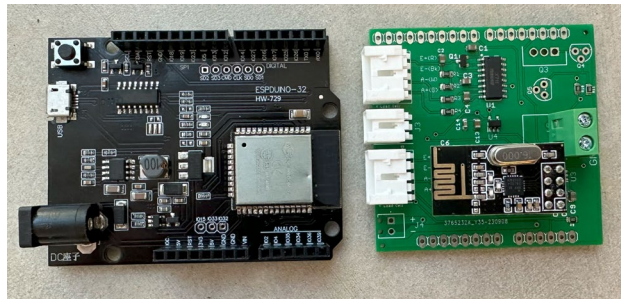


Features:

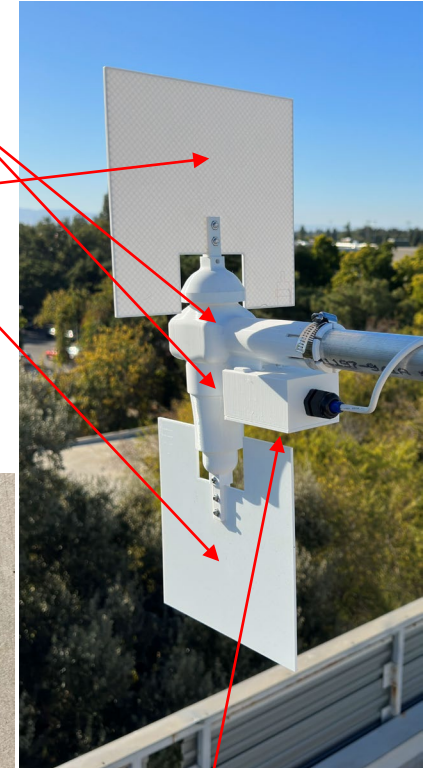
- Simple & robust design
- Easy to assemble
- Low cost ~\$50-60
- Weatherproof

Load Cells (underneath)

Drag Bodies



Microcontroller & Custom PCB



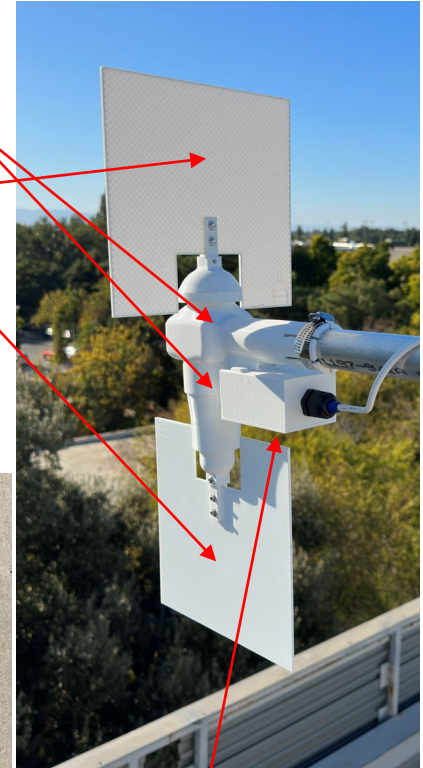
Electronics Enclosure

Drag Anemometer Concept (cont.)

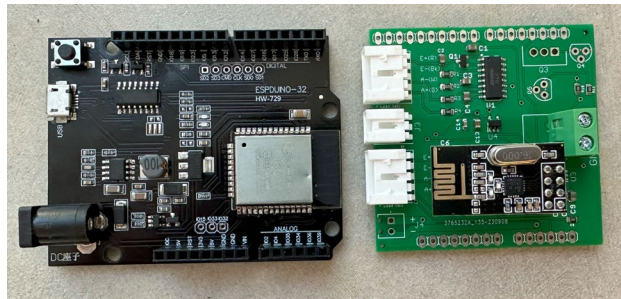


Load Cells (underneath)

Drag Bodies



Part	Material Cost
ESP32 Microcontroller	\$5
Custom PCB	\$10
Load cells	\$3
Long USB cable/Power Supply	\$7
3D Printing Material	\$15
Other	\$10
TOTAL (wired/wireless):	\$50/60



Microcontroller & Custom PCB

Electronics Enclosure

Assembly time: 1-2 hours

Prototype Testing



**Young 81000 3 -
Axis Ultrasonic
Anemometer**

- Reference wind speed/direction



Prototype Unit

- Connected to IMPROVE Sampler



IMPROVE Sampler

- Automatically logs and uploads data



BeagleBone Black SBC

- Reference wind data parsing and logging

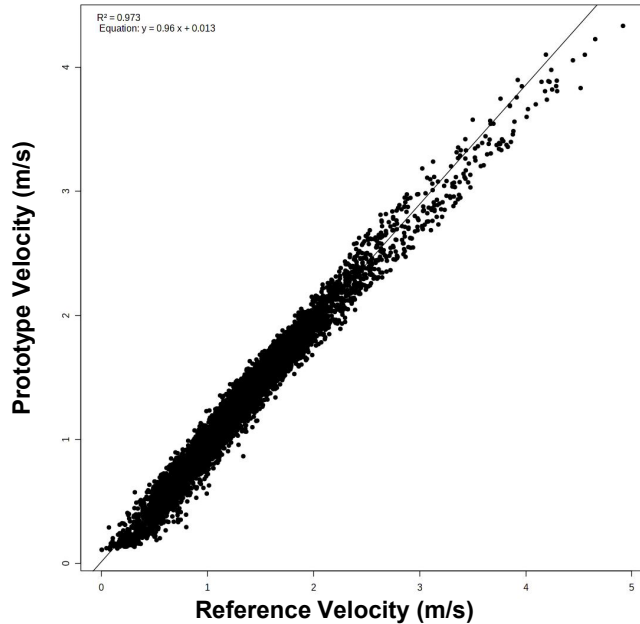
Remote Server

- Processes and stores prototype and reference wind data in MySQL database
- Runs R Shiny Web App for data visualization

Wind Speed & Direction Results

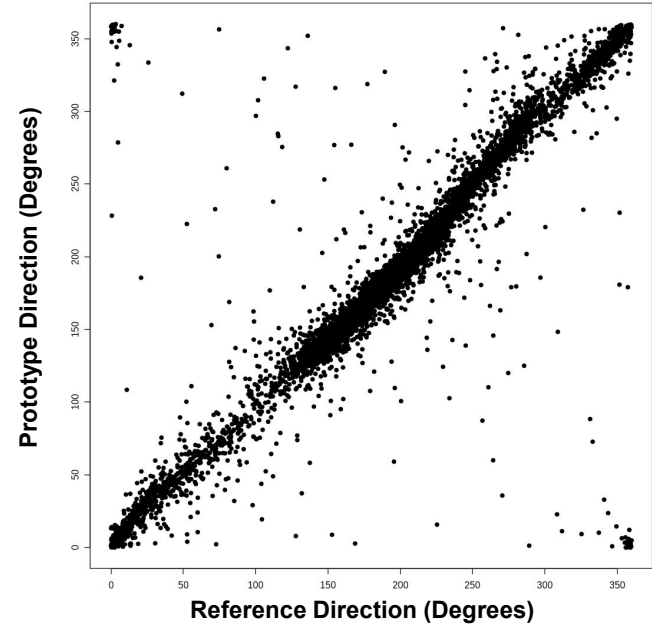
Data from 7/22/23 – 9/14/23

Prototype vs reference velocity
(10-min avg)



95% of velocity values fall within ± 0.2 m/s of reference

Prototype vs reference direction
(10-min avg, all wind speeds)



95% of direction values fall within ± 15 degrees of reference
(only at > 1 m/s wind speed)

Live IMPROVE Site Deployments



HOOV1 (April 2023)



PINN1 (October 2023)

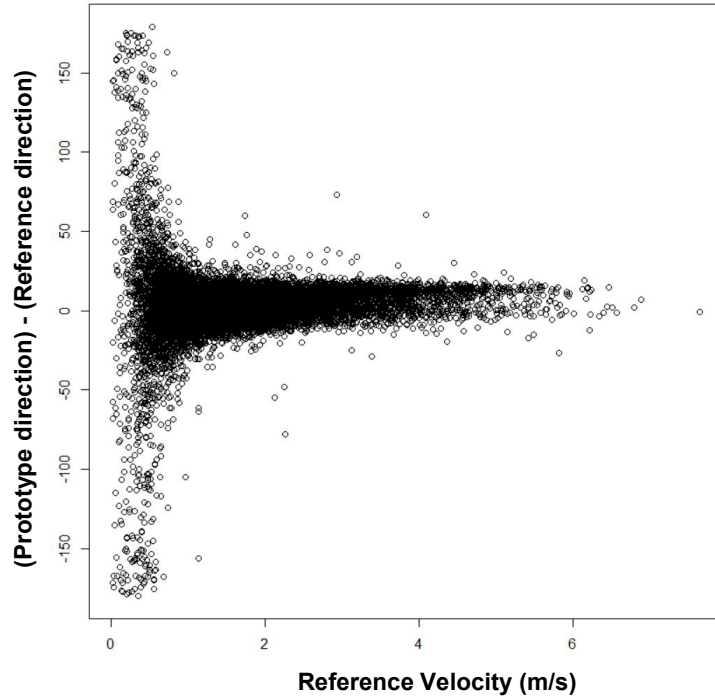


SULA1 (July 2023)

Improved Direction Calibration

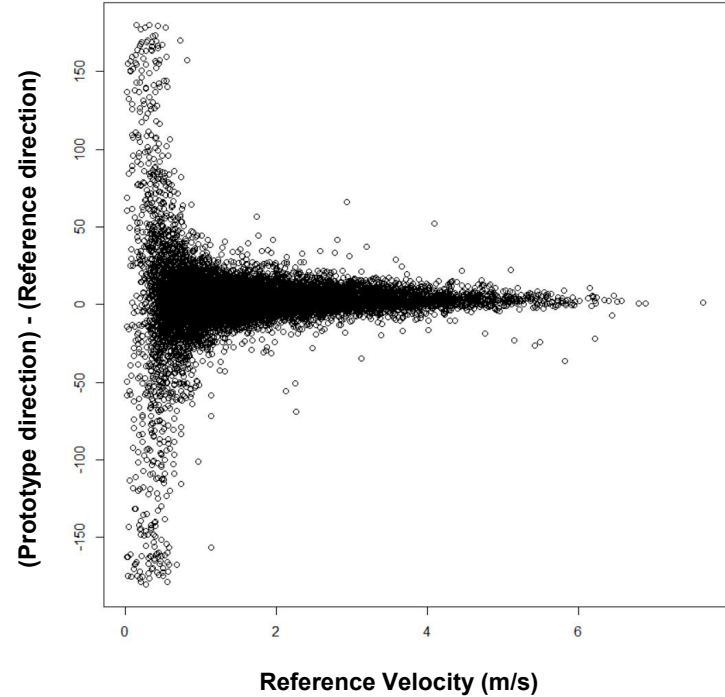
Before:

Direction Error vs Velocity



After:

Direction Error vs Velocity



Improved Direction Calibration



Mid-2022
Model

Data from
8/14/22 – 9/19/22

Cardinal_Direction	Direction_Min	Direction_Max	Sample_Count	Direction_Error_SD
N	0.01	359.90	212	7.68
NE	22.54	60.10	34	6.14
E	70.38	106.71	12	13.41
SE	114.27	157.46	221	7.47
S	157.54	202.33	747	10.20
SW	202.62	247.50	720	10.20
W	247.53	291.60	200	6.11
NW	292.88	337.02	61	11.50

80% of direction values fall within ± 15 degrees of reference
($> 1\text{m/s}$ wind speed)



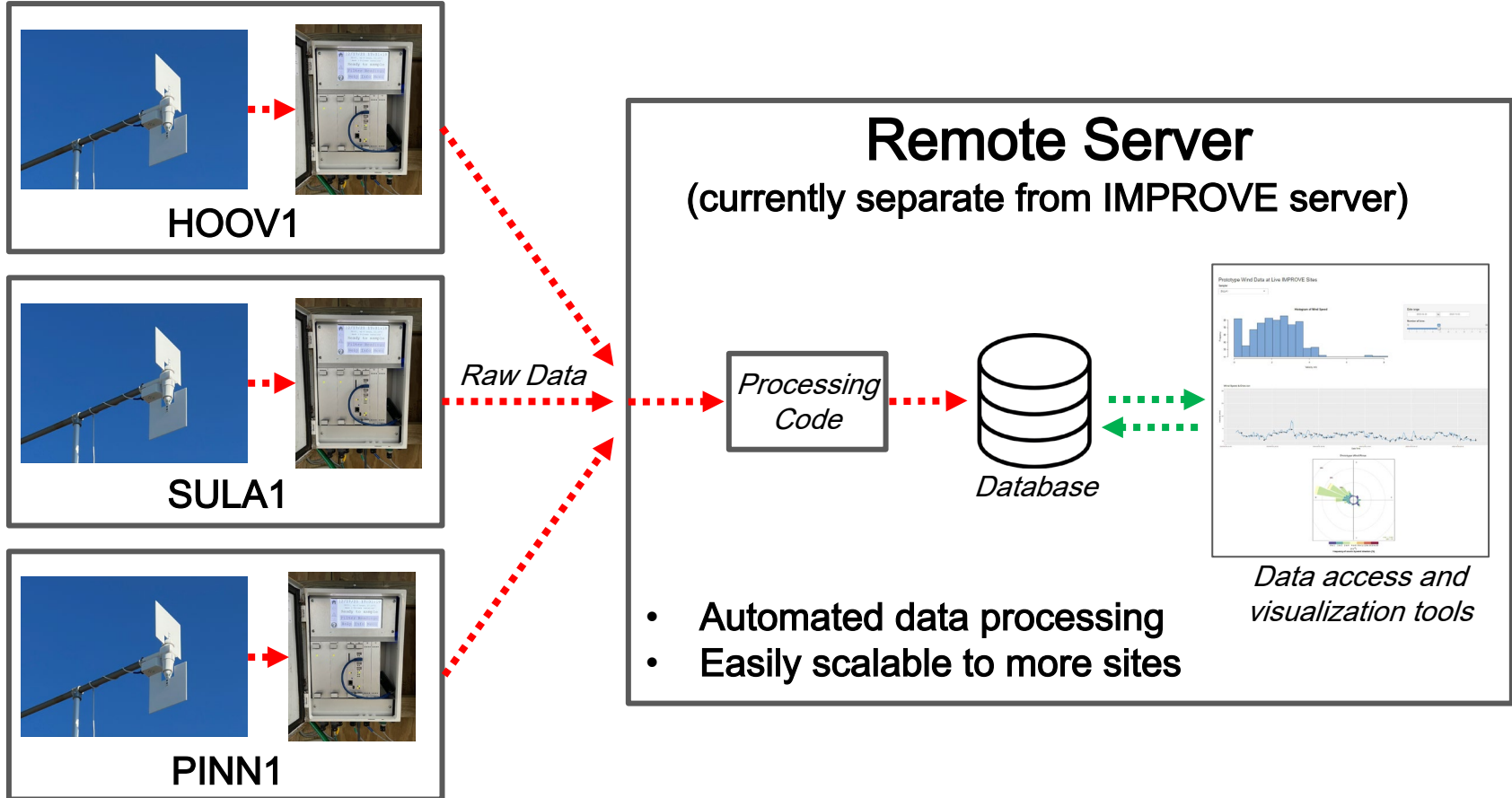
2023 Model

Data from
7/22/23 – 9/14/23

Cardinal_Direction	Direction_Min	Direction_Max	Sample_Count	Direction_Error_SD
N	0.05	359.96	474	4.16
NE	22.73	67.01	132	5.77
E	67.88	111.10	43	6.08
SE	114.40	157.46	585	5.34
S	157.52	202.49	2227	4.64
SW	202.56	247.27	1244	5.74
W	247.52	292.33	683	5.91
NW	292.65	337.36	168	6.79

95% of direction values fall within ± 15 degrees of reference
($> 1\text{m/s}$ wind speed)

Web App w/Database Integration



Outside Commercial Interest

- AirPhoton interested in integrating lowcost wind sensor into mobile air sampler
- Sample unit, followed by order for 4 units
- Pricing TBD, likely charge \$100200 per unit



AirPhoton filter station

Work In Progress

- Defining precise measurement specifications for wind speed and direction
- Electronics need more protection against corrosion
- Streamlining assembly process

Summary and Conclusion

- Much improved velocity and direction measurements for a low cost
- Deployed to 3 IMPROVE sites, more underway
- Built data processing/management system ready to be scaled to many sites
- Outside commercial interest may justify resuming pursuit of patent



Questions and Feedback Welcome!

