Evaluating offshore wind resources and ecological conditions in Lake Michigan with a NOMAD buoy and laser sensor

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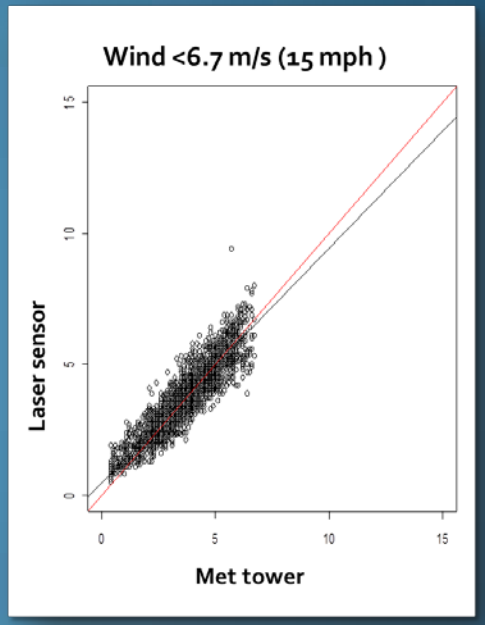
Are floating, laser-pulse sensors an effective alternative to offshore, tower-mounted anemometers?

The need for new measurement tools

Deployment and analysis



Validation of floating sensor

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Offshore tower-mounted anemometers are costly to construct. Alternative systems are needed.

Source: Noordzeewind

Offshore met tower costs range from $2.5 million to $10 million

Deep water particularly expensive

DOE: Need on-site measurements

- Validate models
- Support projects
- Existing buoys ill-suited
- *New technologies must be verified*

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Floating, laser pulse sensors have the potential to resolve some of the DOE's challenges, but must be validated.

The Vindicator

- Laser pulse
- 6 range gates
- Motion compensation
- 1 second data
- Gauge precision =0.1 m/s

We tested the WindSentinel buoy from AXYS Technologies

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The validation protocol consisted of two comparisons.

Previous studies have validated the operation of laser (LiDAR) sensors using co-located tower anemometers.

1. Compare laser sensors
   - Buoy-mounted
   - Land-based

2. Compare:
   - Buoy-mounted laser sensor
   - Land-based anemometer

Validation criteria

Mean differences are…

- not operationally significant (<0.1 m/s)
- not statistically significant ($p > 0.05$)

A comparison of fixed and buoy-mounted laser units found no operationally significant differences.

Race Rocks, BC
Two Vindicator units

- 3 range gates
- 700 m apart
- Data collected by buoy manufacturer, analyzed by GVSU

Paired *t*-tests, $n = 3022$

Height	Mean difference	SD
100 m	0.13* m/s	0.48
150 m	0.08* m/s	0.48
200 m	0.07* m/s	0.48

$*p < 0.05$

Validation criteria
Mean differences are…

- Not operationally significant
- Not statistically significant

Conclusion: motion compensation works

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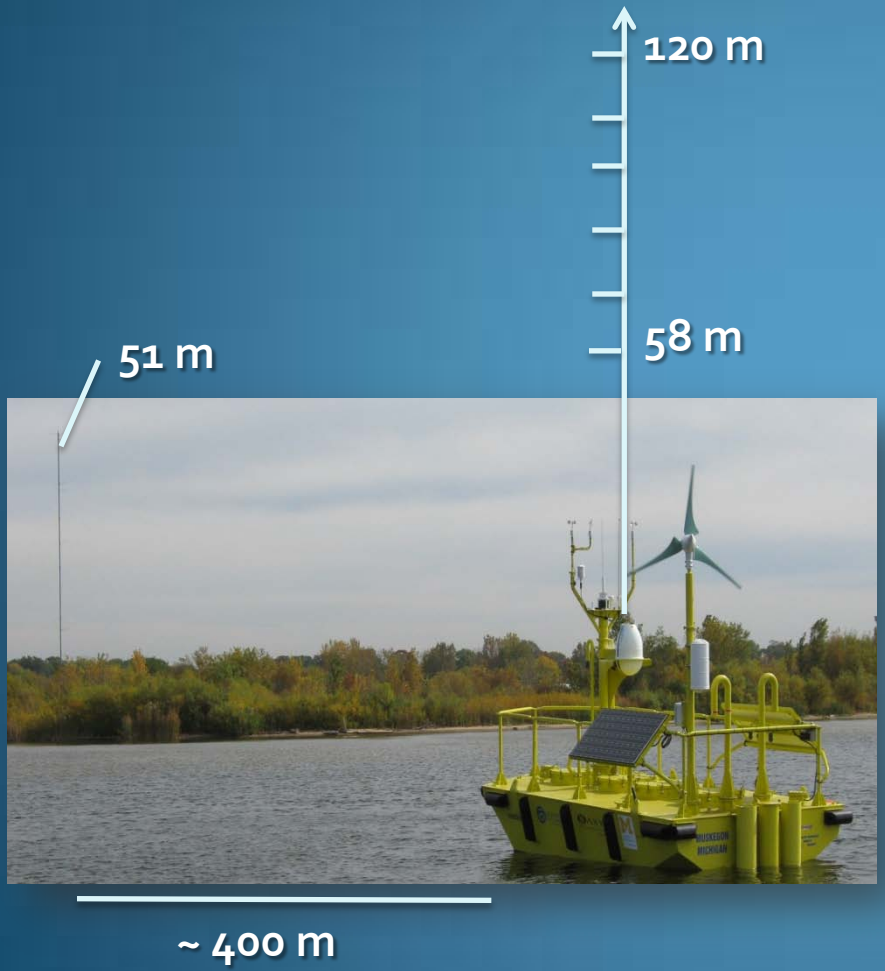
The research team validated buoy measurements using an onshore anemometer.



Field trial

Muskegon Lake, Michigan
October 7 – November 3, 2011
10 minute average data
Gauge precision = 0.1 m/s

2 wind regimes

Calm
<6.7 m/s

Windy
>6.7 m/s

3 storm events were removed from the dataset.

Wind images source: Corbis Images

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The buoy was placed about 400 m offshore from the met tower at the east end of Muskegon Lake.

Image: USGS

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On calm days, the measurement differences were not operationally significant.

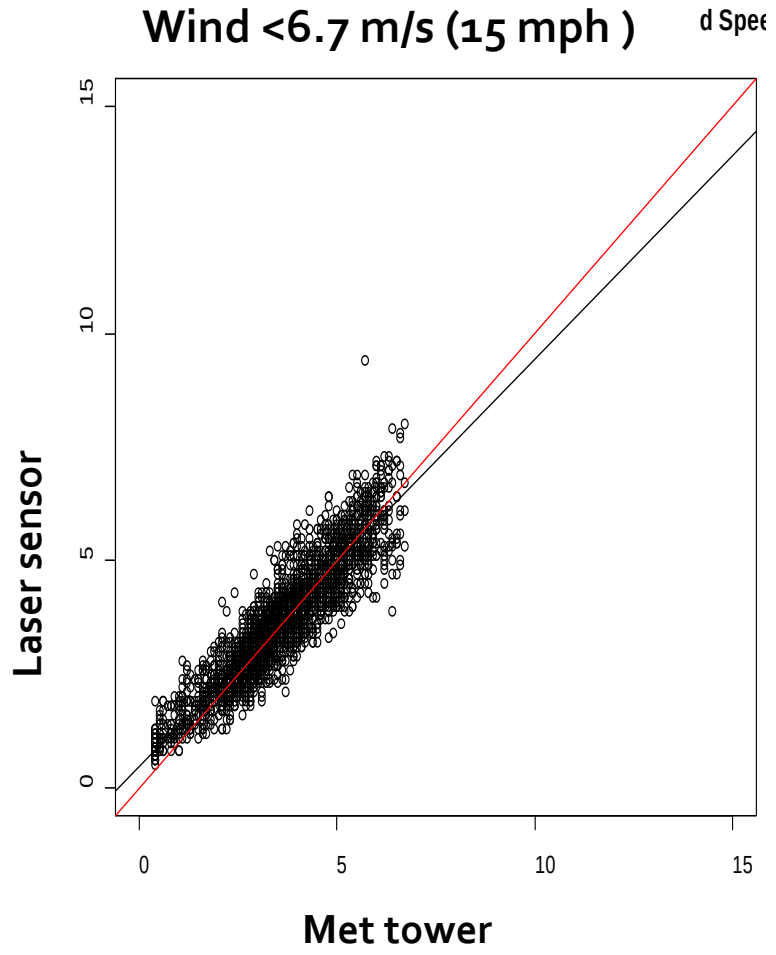
Calm days <6.7 m/s

Paired *t*-test, *n* = 2149
Mean difference = -0.10* (0.58)
**p* < 0.05

Validation criteria
Mean differences are…

- Not operationally significant
- Not statistically significant

Conclusion: On calm days, laser as accurate as anemometer.



Wind images source: Corbis Images

On windy days, the measurement differences were not statistically or operationally significant.

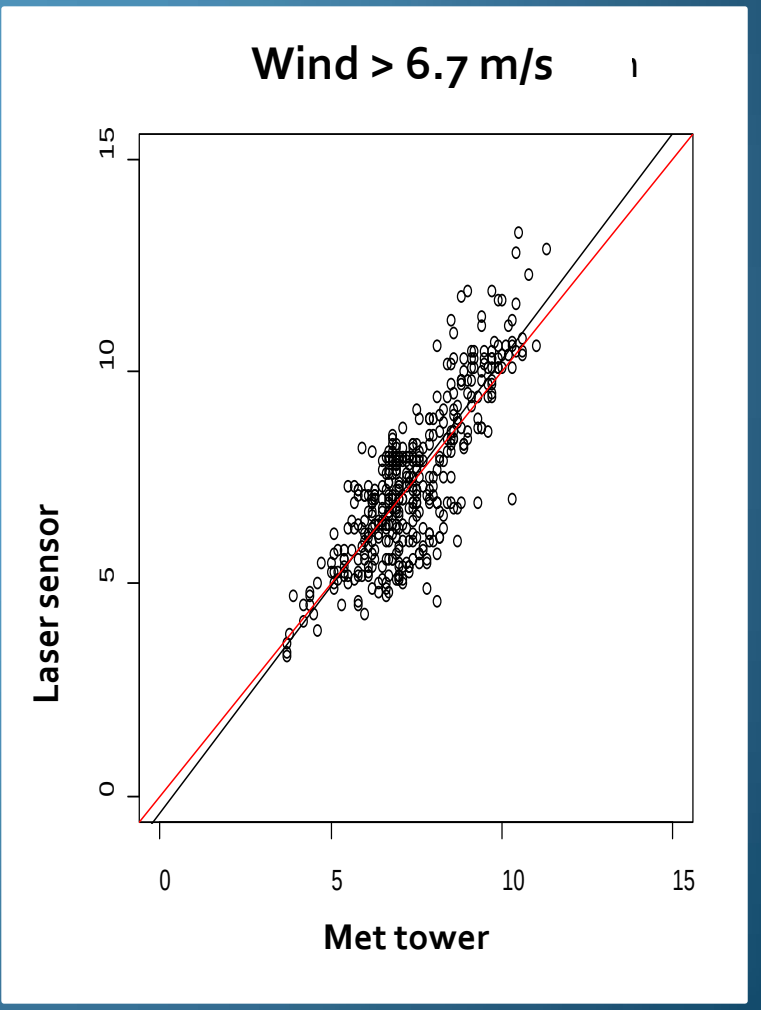
Windy days >6.7 m/s, no storms

Paired *t*-test, *n* = 416
Mean difference = -0.03 m/s (1.09)
p >0.05

Validation criteria
Mean differences are…

- Not operationally significant
- Not statistically significant

Conclusion: On windy days, laser as accurate as anemometer.



Wind images source: Corbis Images

Buoy-mounted laser sensors show promise as an alternative to offshore met towers.

Under most conditions, the measured wind speed differences were not operationally significant.

Race Rocks (two laser sensors)

- Differences not operationally significant

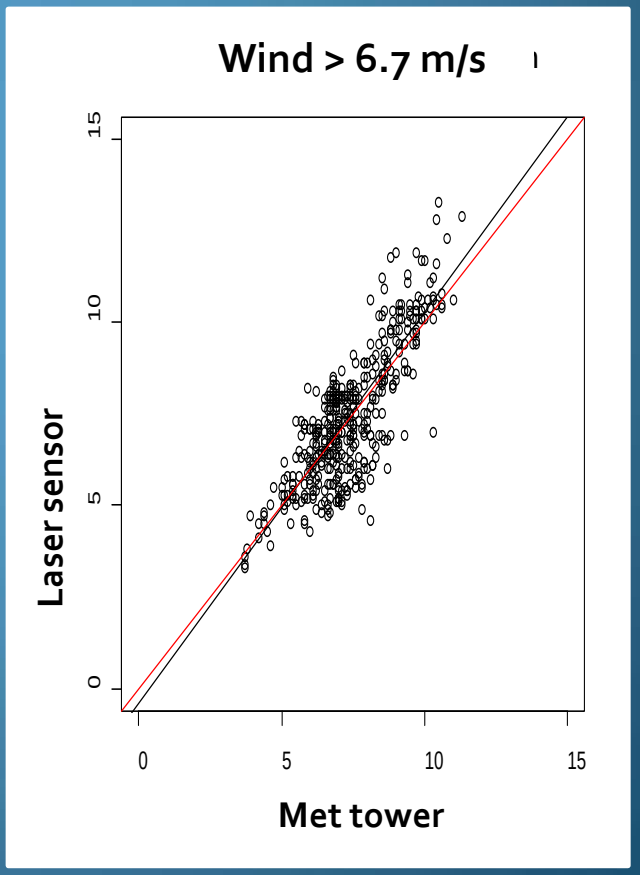
Muskegon Lake

Calm days

- Differences not operationally significant

Windy days

- Differences not operationally or statistically significant



The research buoy is now deployed at Lake Michigan's Mid-Lake Plateau.

Collecting data on:

Wind

Birds

Bats

Water (biological)

Water (physical)

Data images source: Corbis Images

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Thank you for this opportunity.

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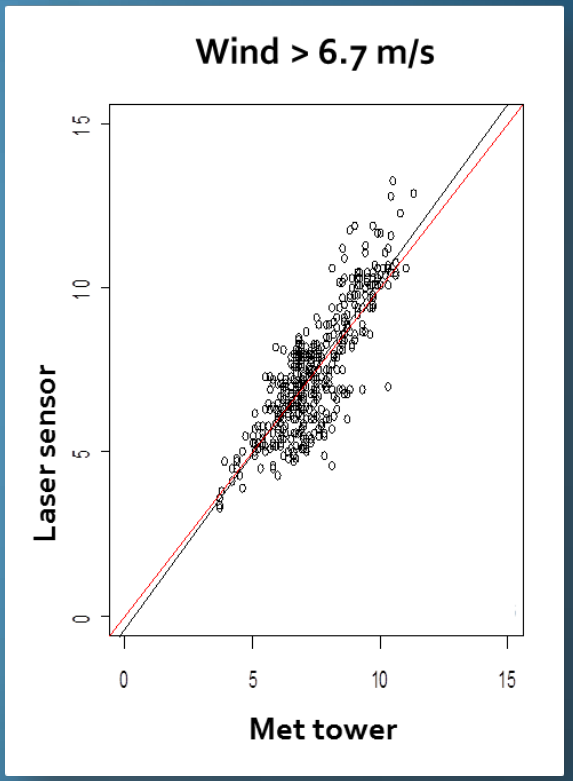

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