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# Reflections on Lake Michigan Wind: A Study of Motion Compensated Laser Pulse Technology Using a Mobile Buoy Platform

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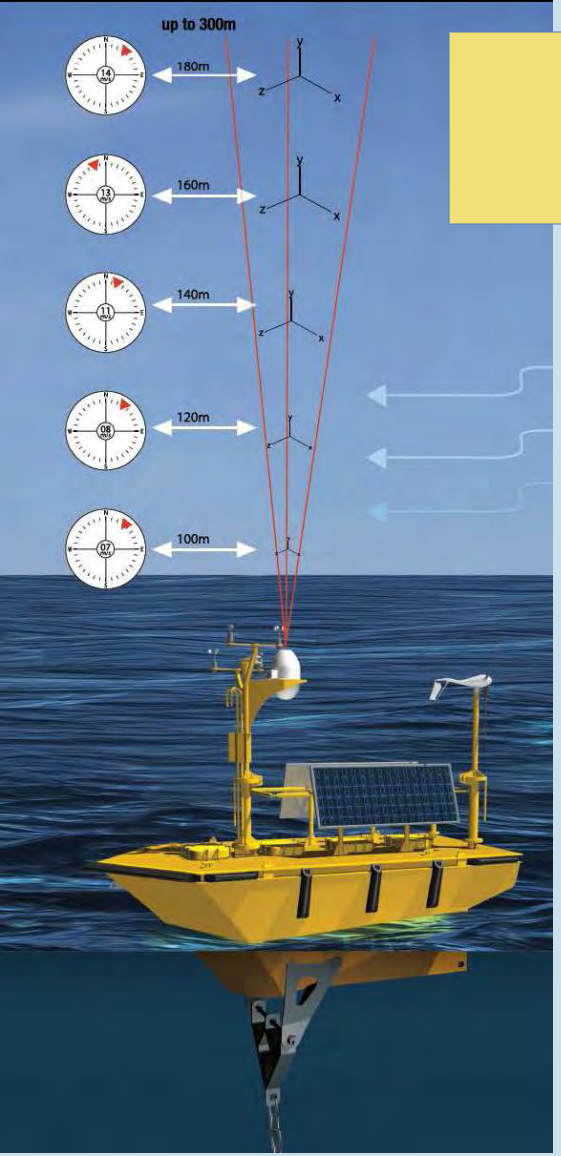
# Reflections on Lake Michigan Wind :

## A Study of Motion Compensated Laser Pulse Technology Using a Mobile Buoy Platform

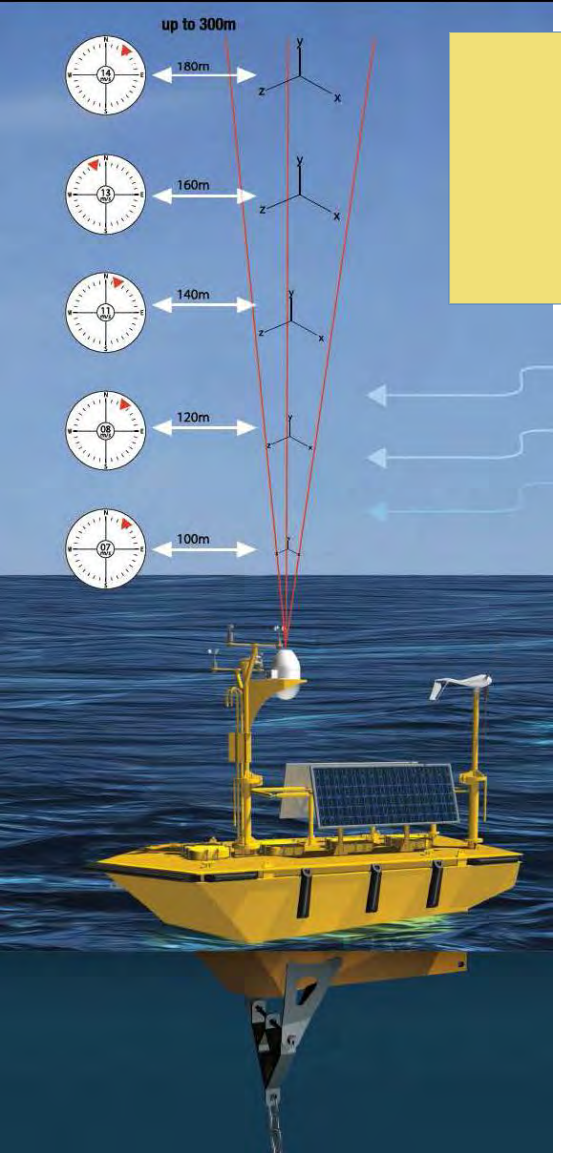
*Dave Zeitler*
*Mehmet Sozen*
*Charlie Standridge*

**GVSU Big Data Conference**
**April 26, 2013**



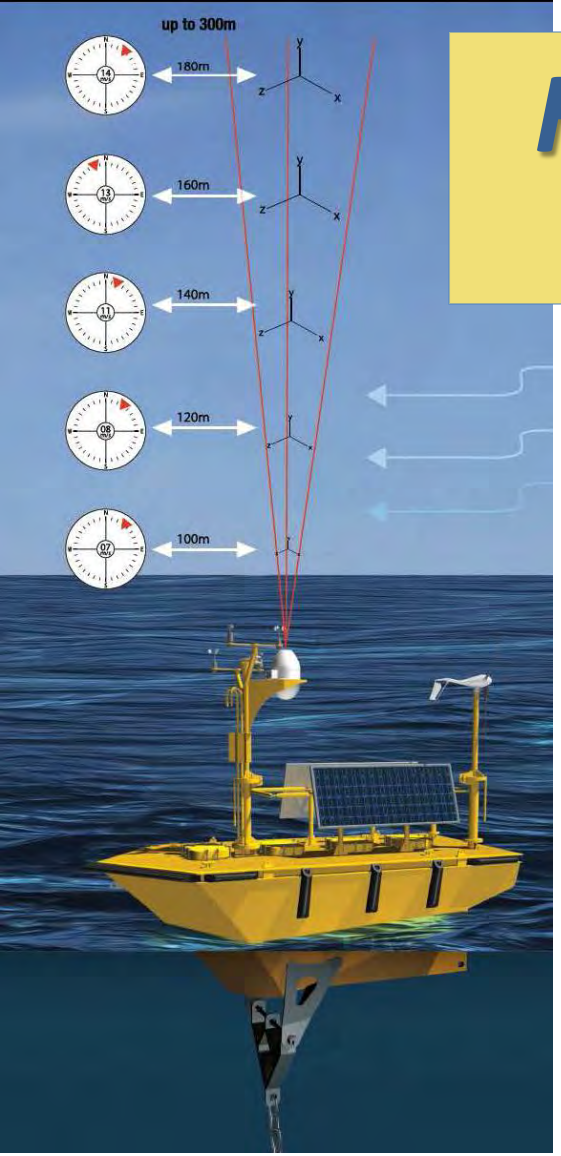

# Project Goals

- To collect and analyze wind data essential to the consideration of future wind industry development on the Great Lakes
- To develop real-time / hub-height offshore wind data collection capabilities called for by prior Great Lakes wind assessment studies
- To validate the use of laser pulse technology on a mobile platform as a viable wind assessment technology



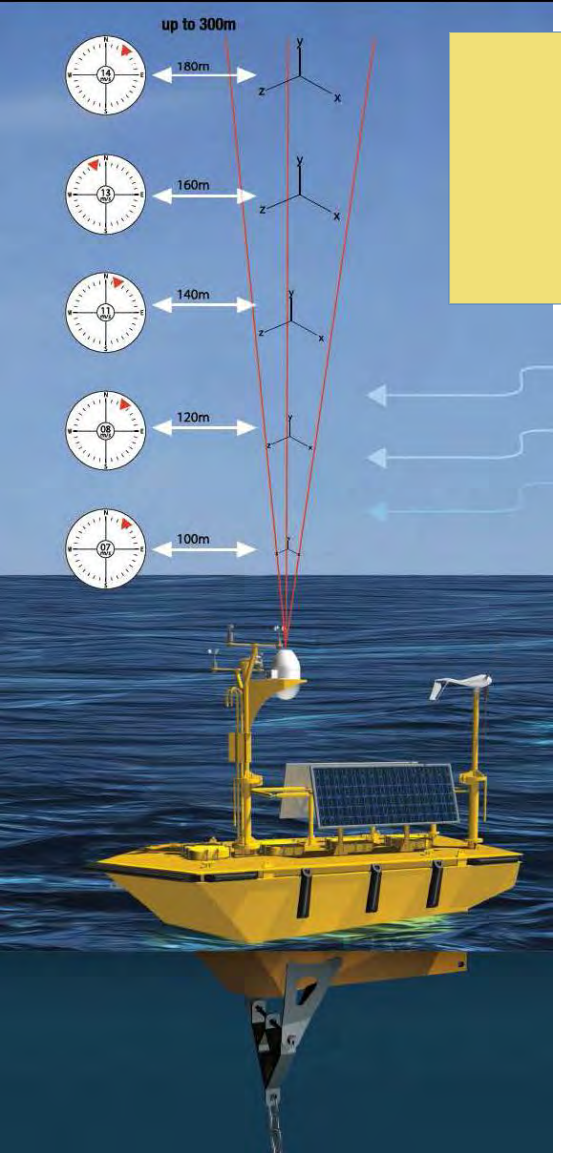

# Summer 2012: Mid-Lake Plateau

- May 8 through December 17 – 224 Days
- Measurements once per second
  - Wind speed and direction
  - 6 range gates and on deck
- 19,353,600 seconds
- 135,475,200 wind speeds observations



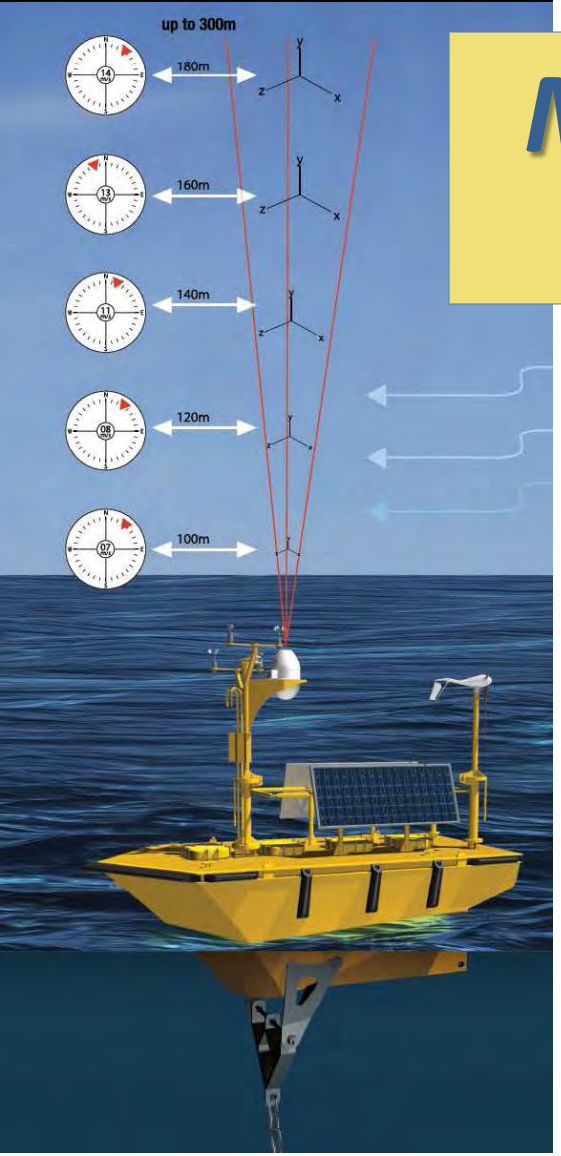

# How Effective is the Laser Wind Sensor?

- Noise at one-second requires aggregation of data
  - 10 minutes (traditional)
  - 30 seconds to 10 minutes depending on application
- Is data valid at all heights (75, 90, 105, 125, 150, 175 m)?




# Explaining Variation

- Does wind speed vary by:
  - Height (marine boundary layer)
  - Time of year
  - Location in lake
    - November-December 2011 deployment
    - Summer 2013 deployment



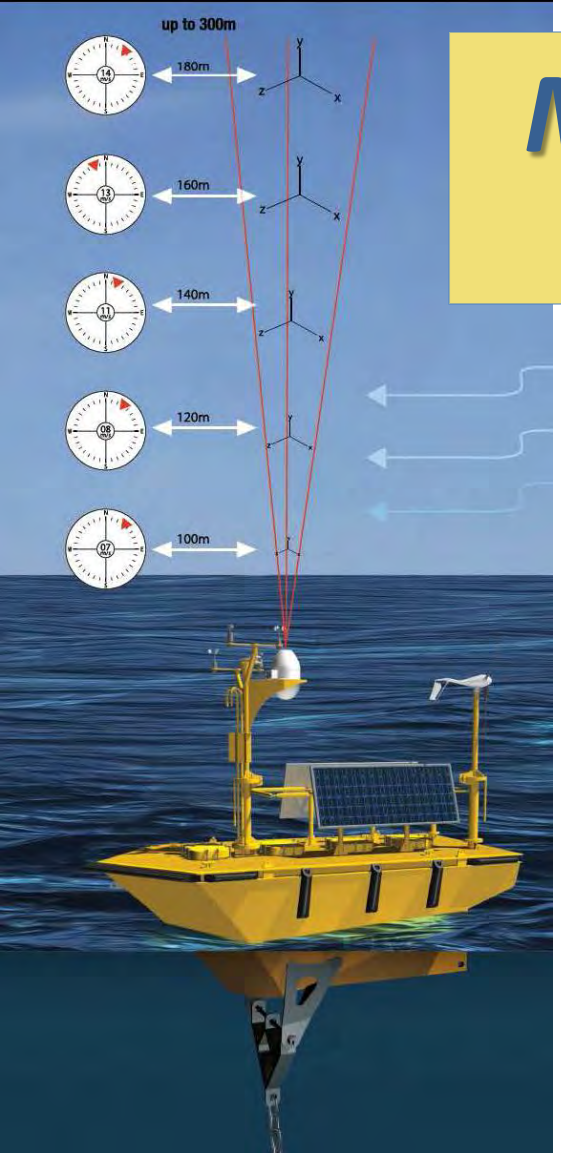

# Modeling the One-Second Data

David Zeitler

2011/2012
Yeni Nieves, Biostatistics PSM

2012/2013
Daniel Hodges, Biostatistics PSM
Andrew Borgman, Biostatistics PSM

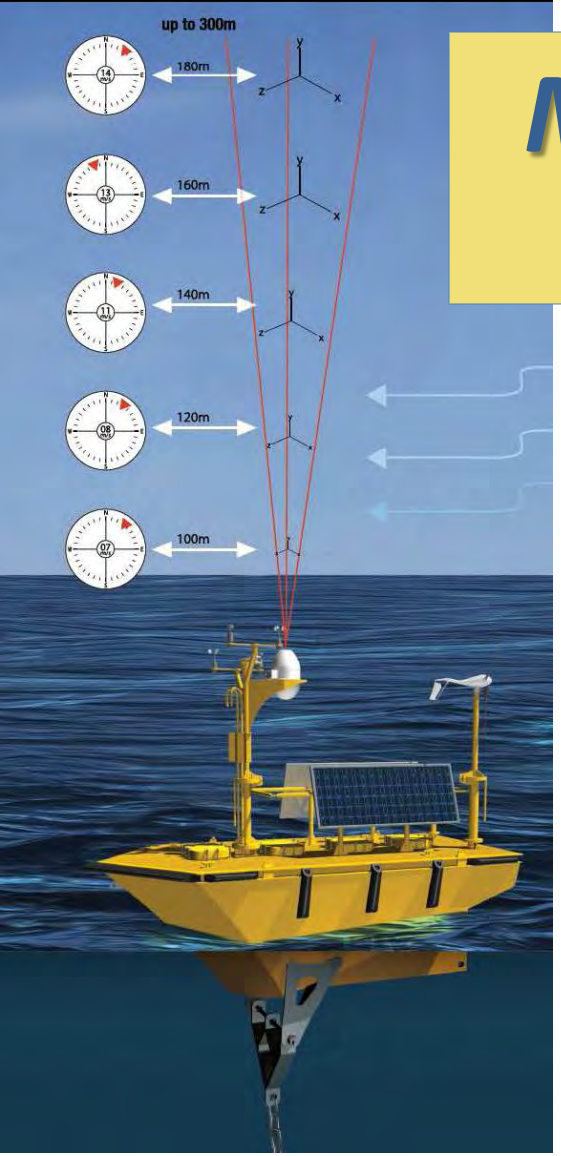
2013/2014
Tyson Spoelma, Statistics Major
Aaron Clark, Biostatistics PSM




# Modeling the One-Second Data

## Challenges

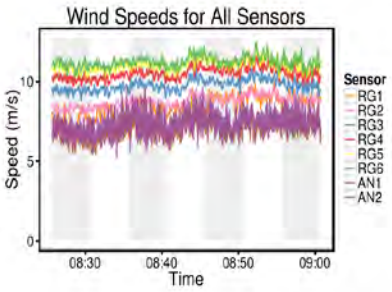
- We currently have about 55Gb of data, more coming.
- Data comes from multiple sources (Laser Wind Sensor, Meteorological Package, Water Quality Sensor, NOAA bouy).
- Data rates and recording times vary across sources from 1 second to 1 hour.
- Data has highly variable quality.

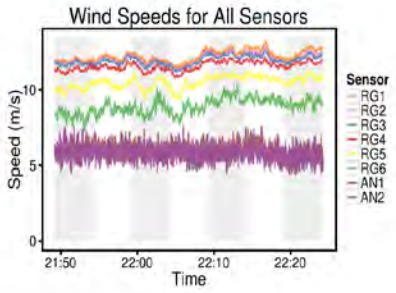



# Modeling the One-Second Data

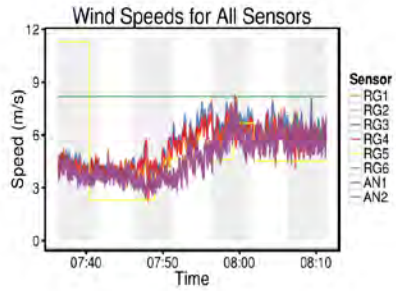
Data Quality Issues

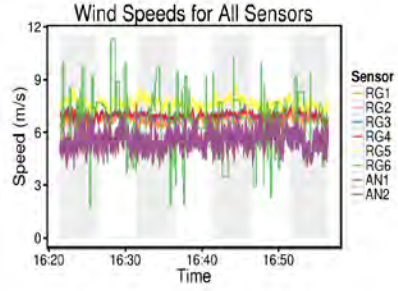
## Good Quality Data

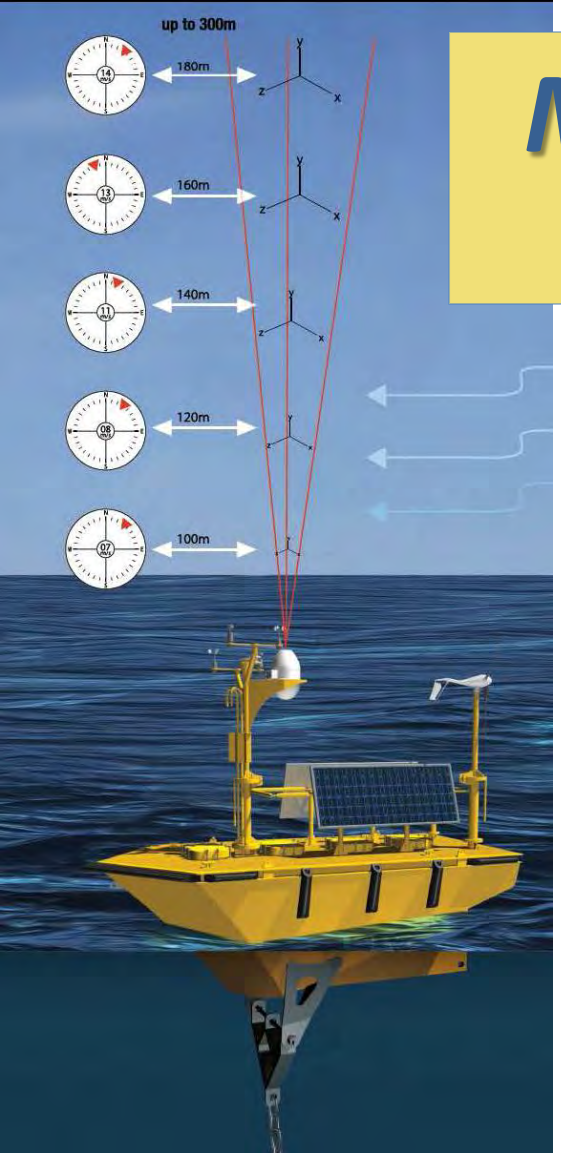



## Problematic Data

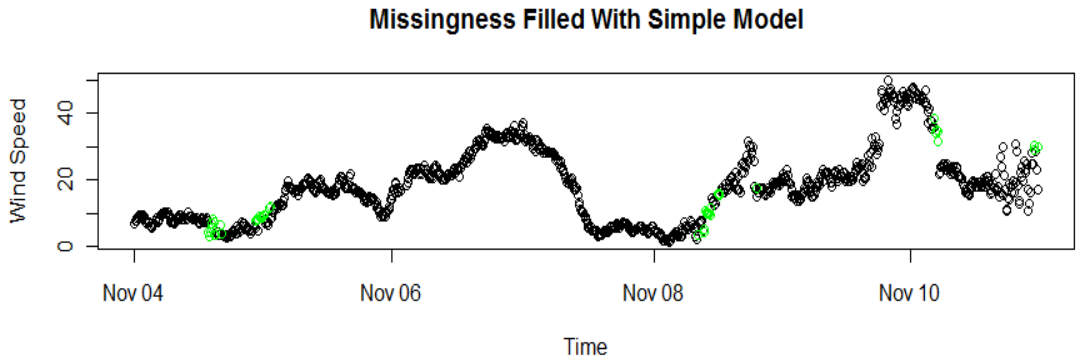


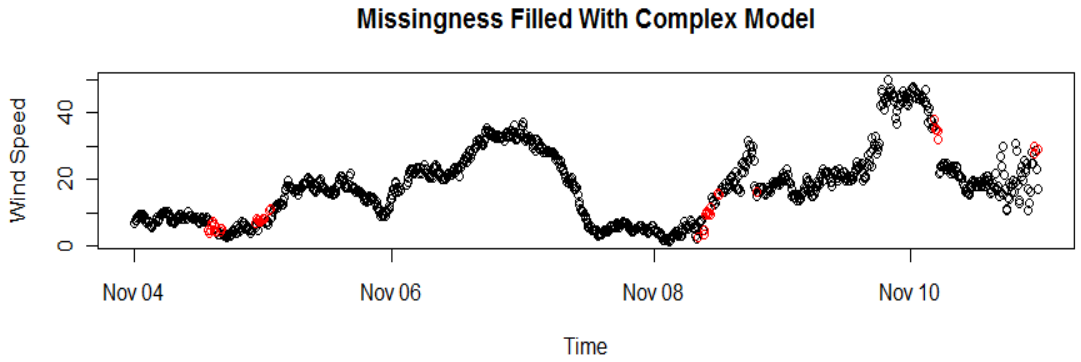



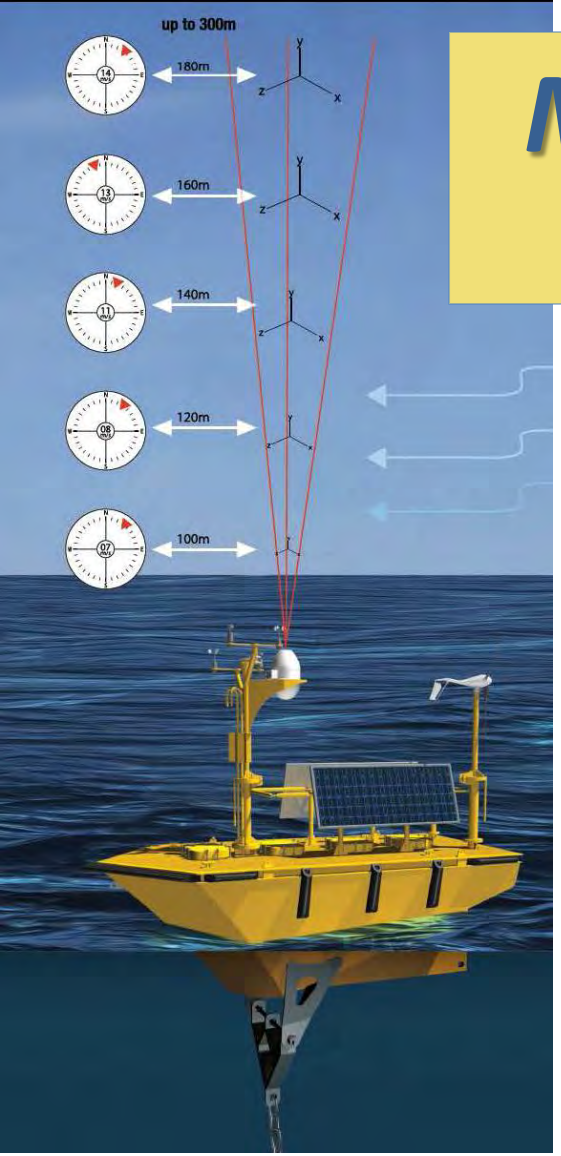



# Modeling the One-Second Data

Missing data imputation

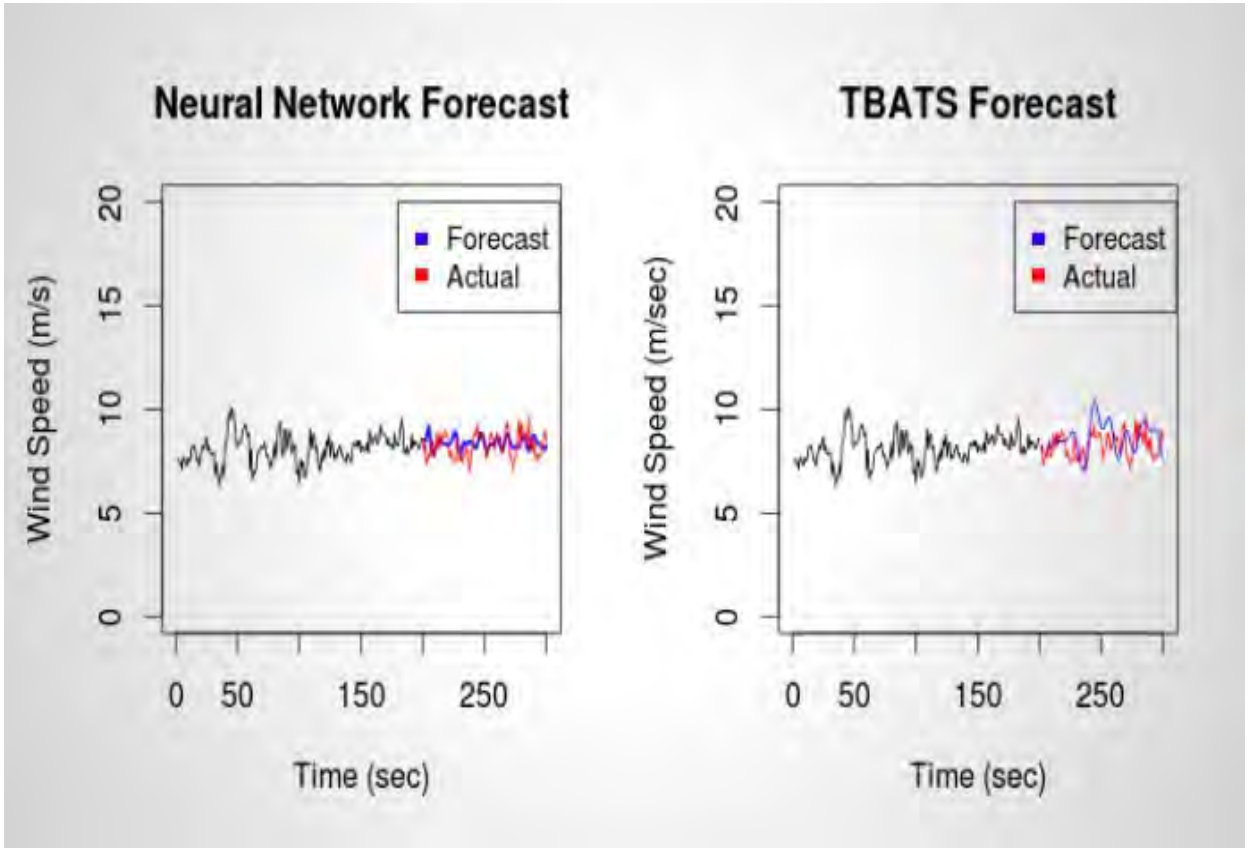


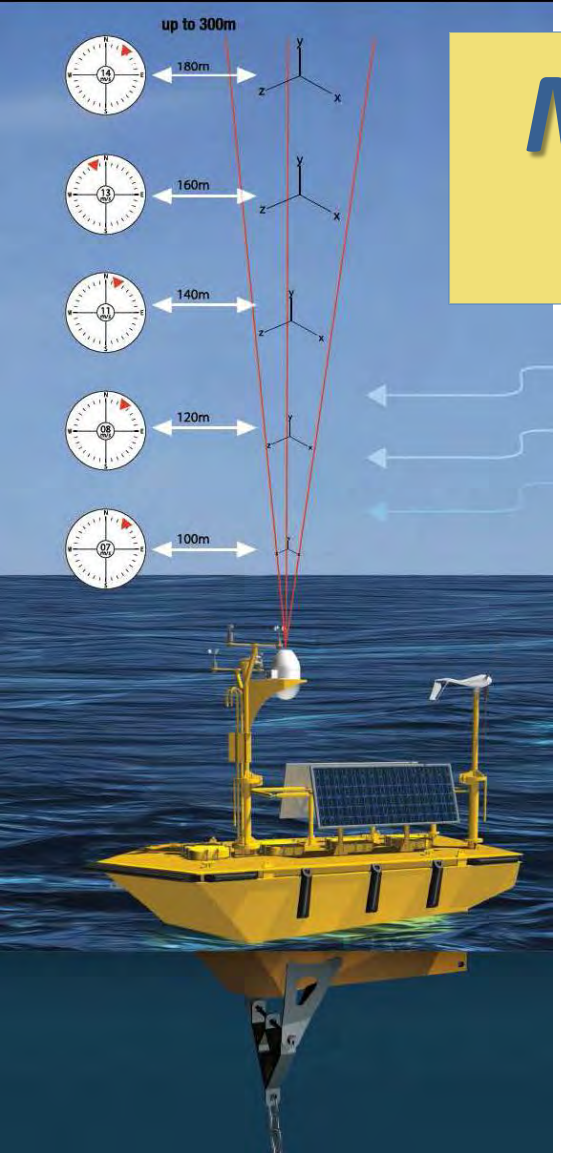






# Modeling the One-Second Data

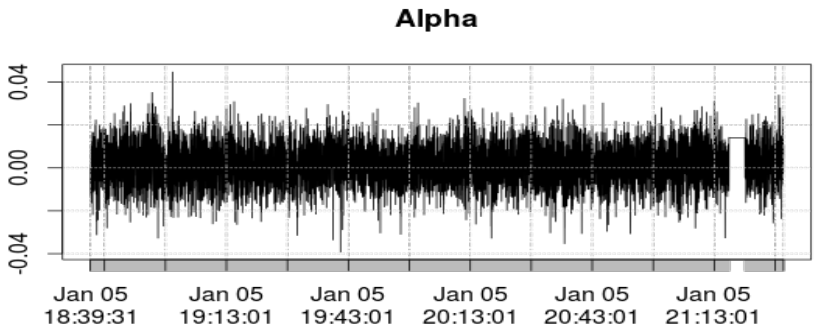
Forecasting






# Modeling the One-Second Data

## Wind profiling




*Generalization:*

$u/u_r = (z/z_r)^{\alpha}$

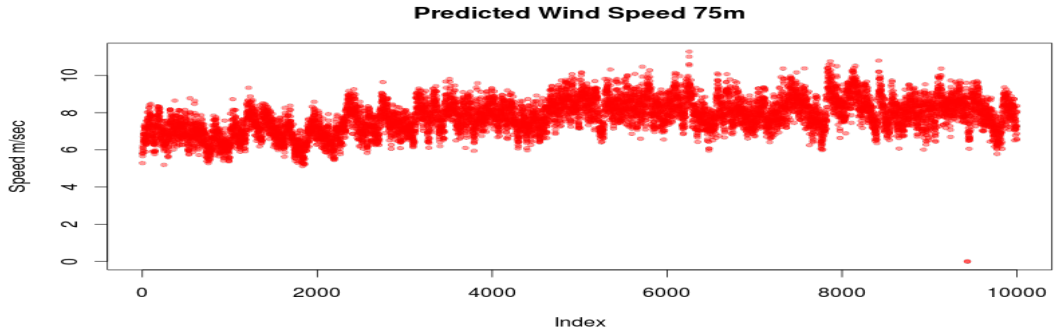
*u -> wind speed @ z*

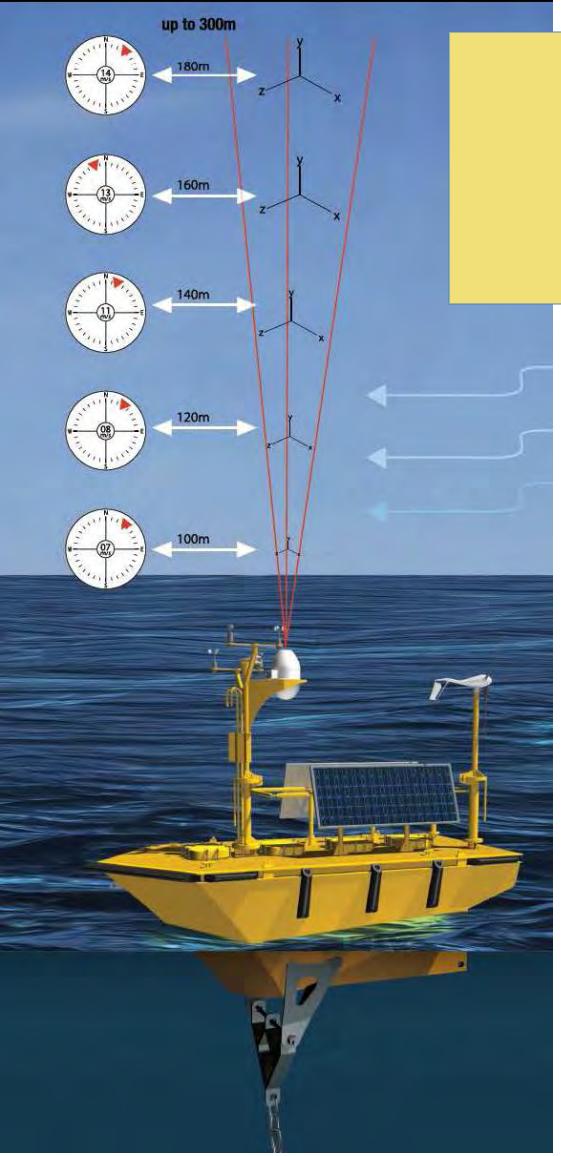
$u_r$ -> wind speed @ $z_r$

z -> height one

$z_r$ -> height two

α -> exponent





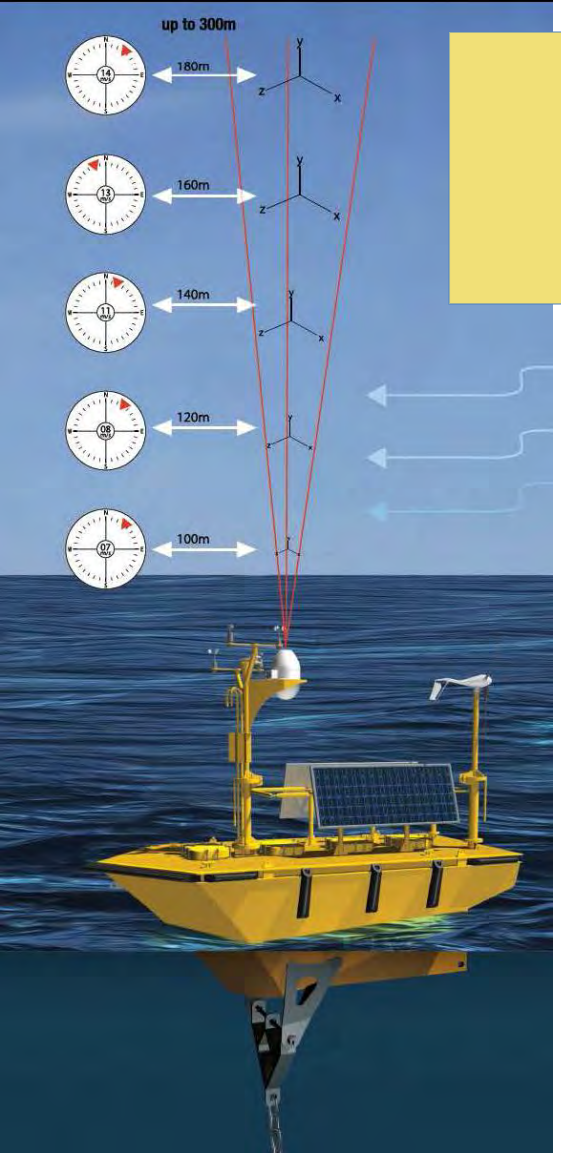

# Modeling for Power Estimation

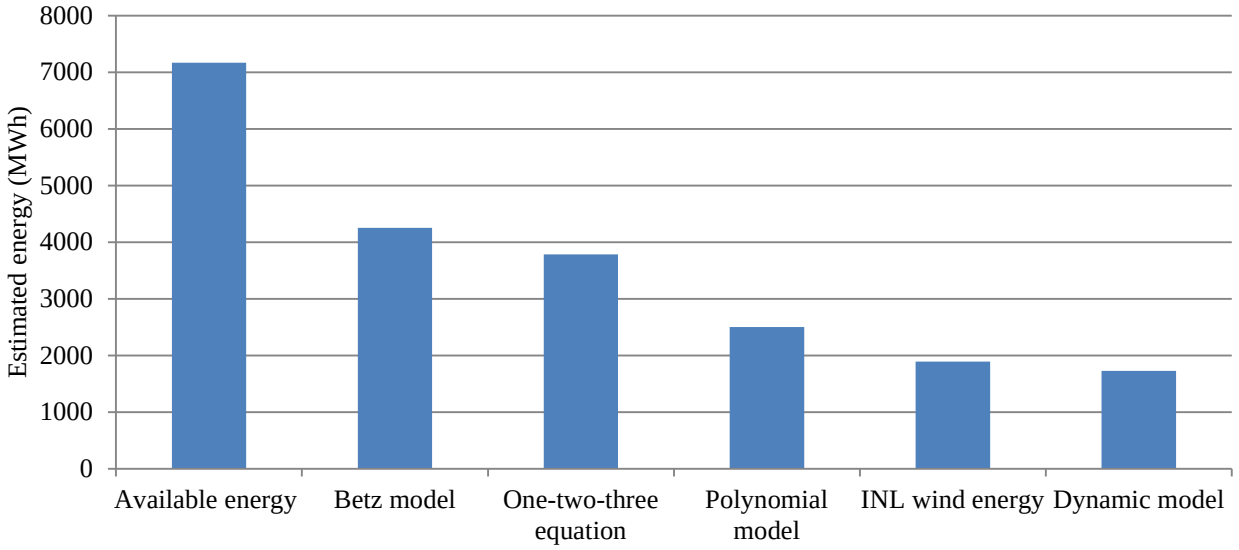
Faculty members: Mehmet Sözen and Azizur Rahman
Graduate Assistant: Md Nahid Pervez

**Objectives**

- **Accurate power estimation from wind speed and wind direction data**
- **Integration for estimating total energy generation**
- **Developing a model for a wind turbine with dynamic yaw control for more accurate energy estimation than traditional models with no yaw control**

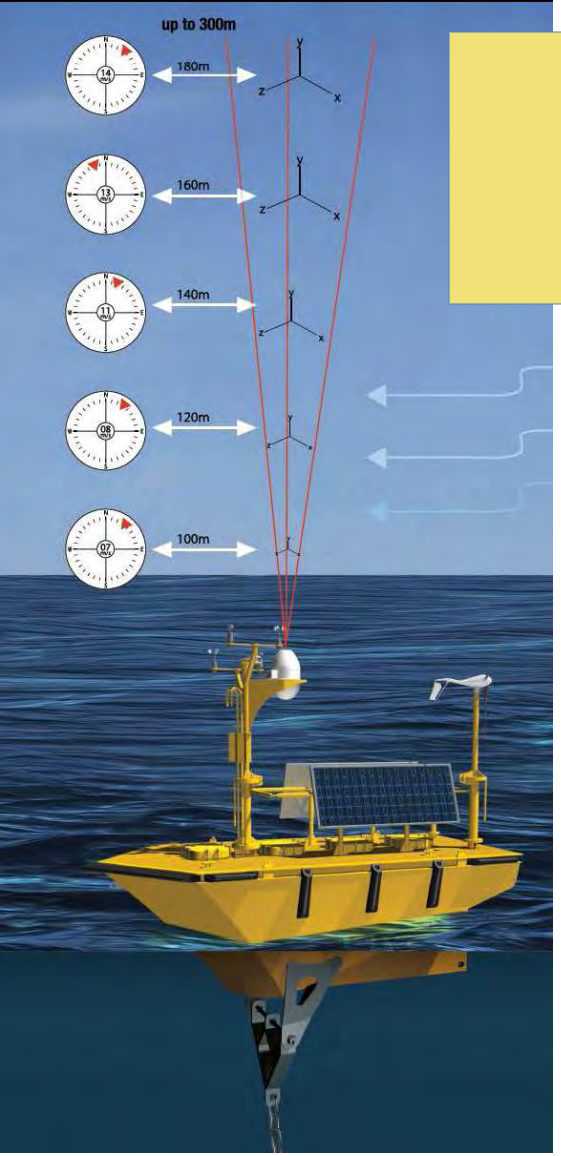
# Modeling for Power Estimation

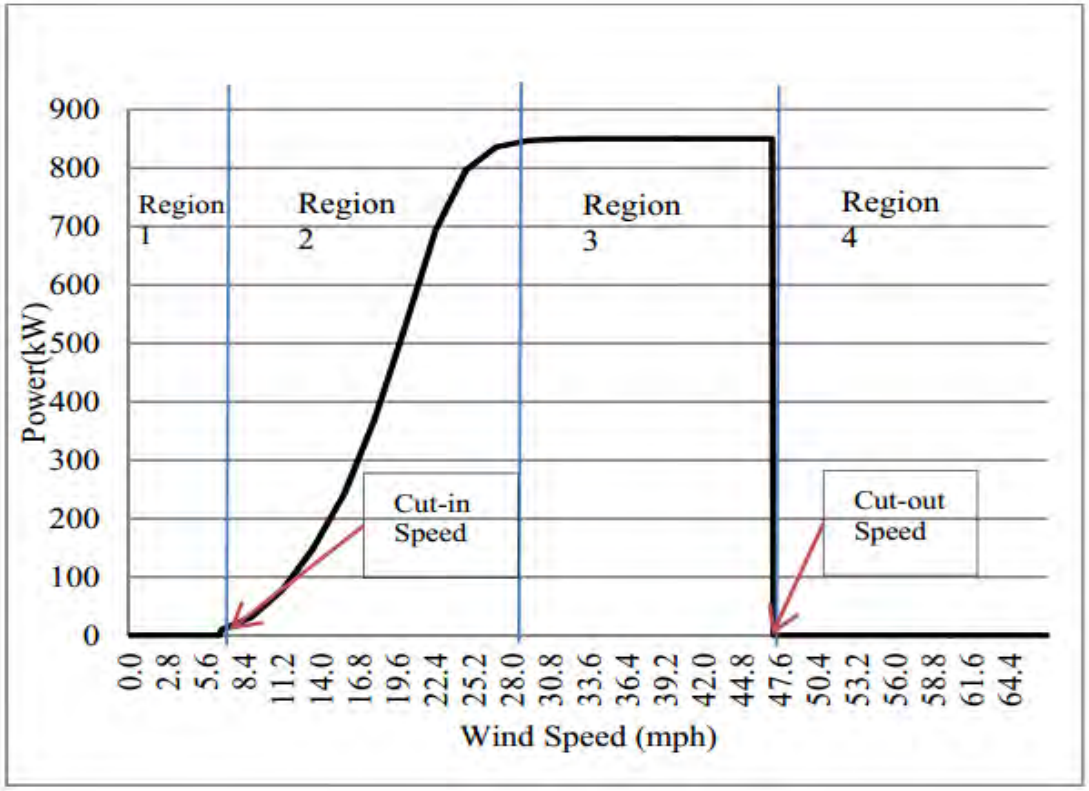



Estimated energy by different models

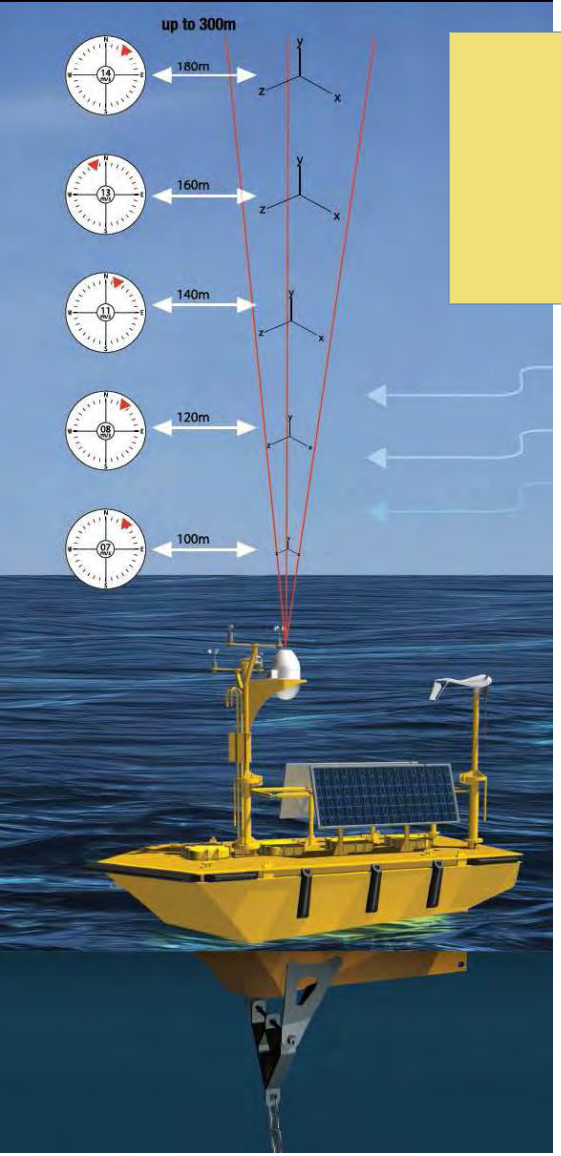
# Modeling for Power Estimation

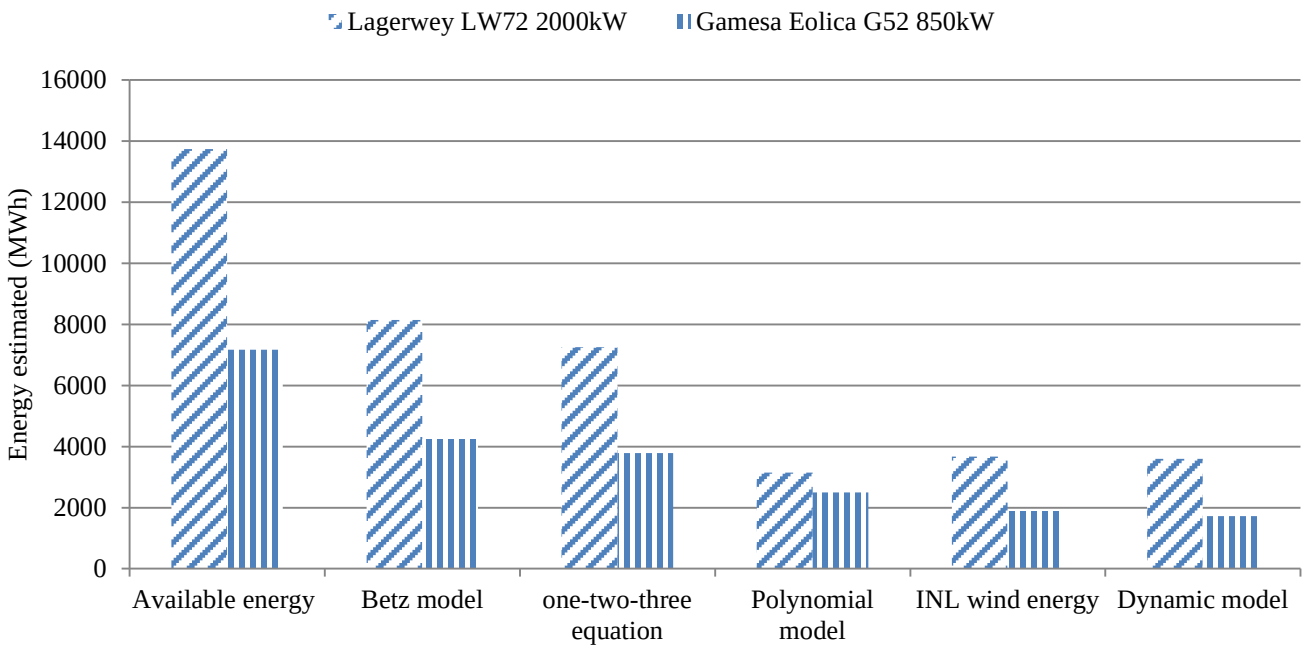


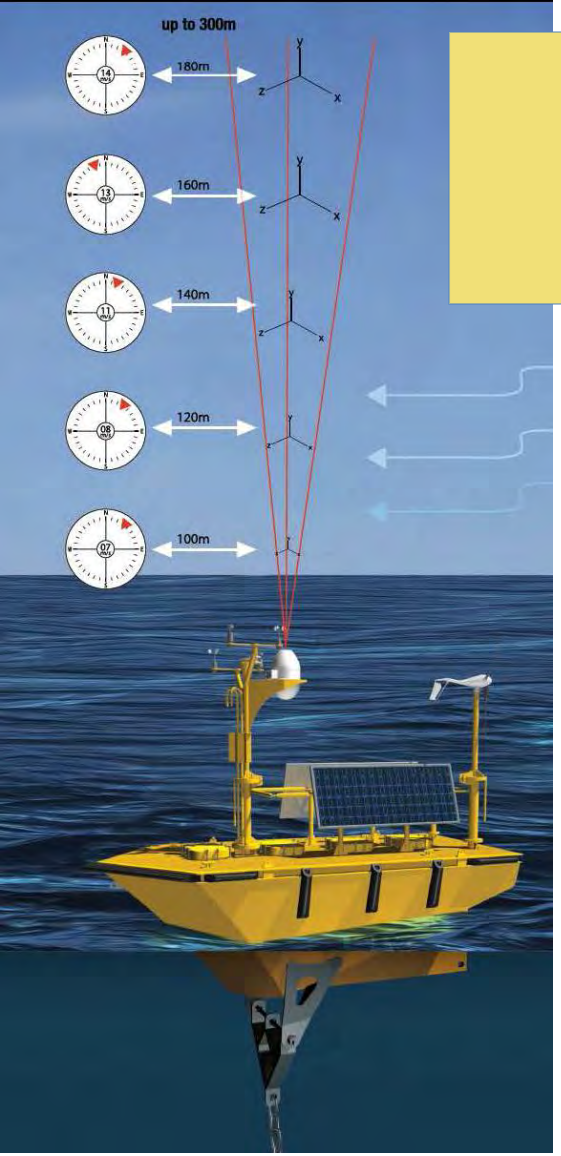

Power curve for Gamesa Eolica G58-850 kW wind turbine

# Modeling for Power Estimation



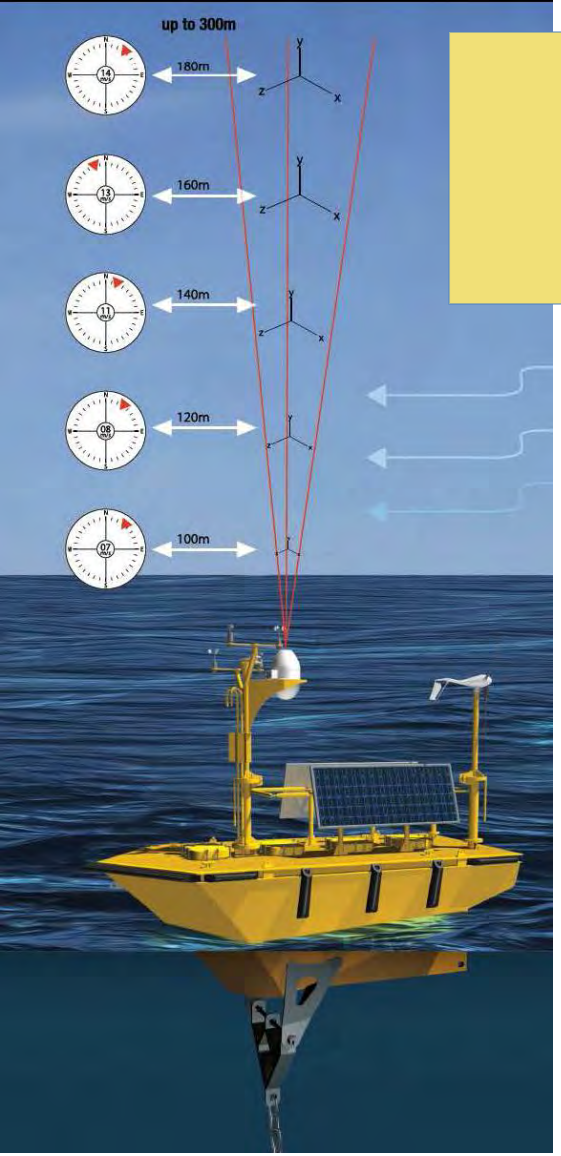




Energy estimated by different wind turbine models

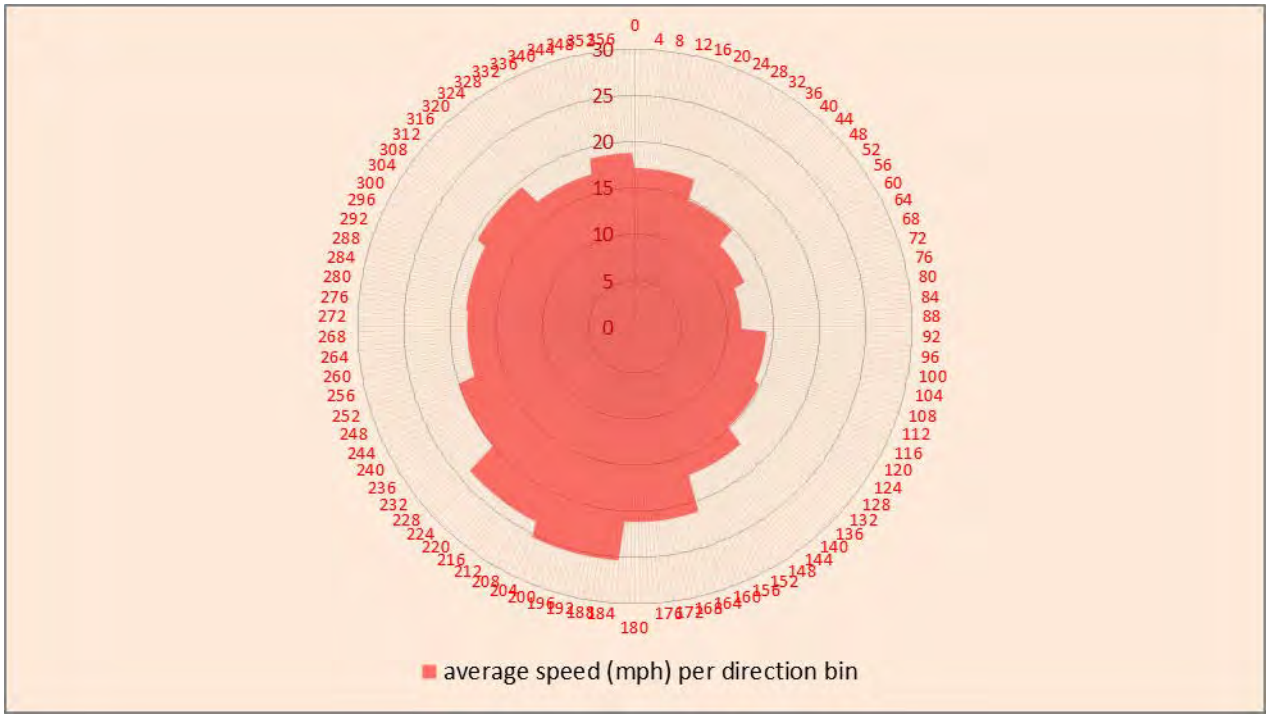



# Modeling for Power Estimation

| Range Gate | Altitude (m) | Energy output (MWh) | Nameplate capacity (kW) | Capacity factor |
|---|---|---|---|---|
| RG1 | 75 | 1707.732224 | 850 | 37.9% |
| RG2 | 90 | 1786.540252 | 850 | 39.3% |
| RG3 | 105 | 1805.26632 | 850 | 39.7% |
| RG4 | 125 | 1754.083151 | 850 | 38.5% |

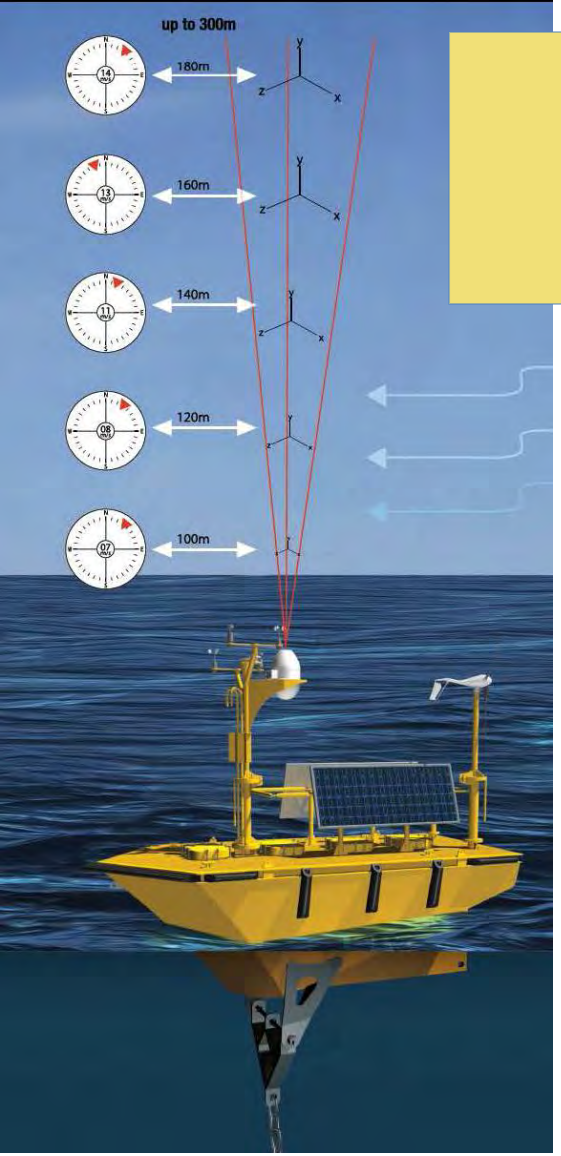


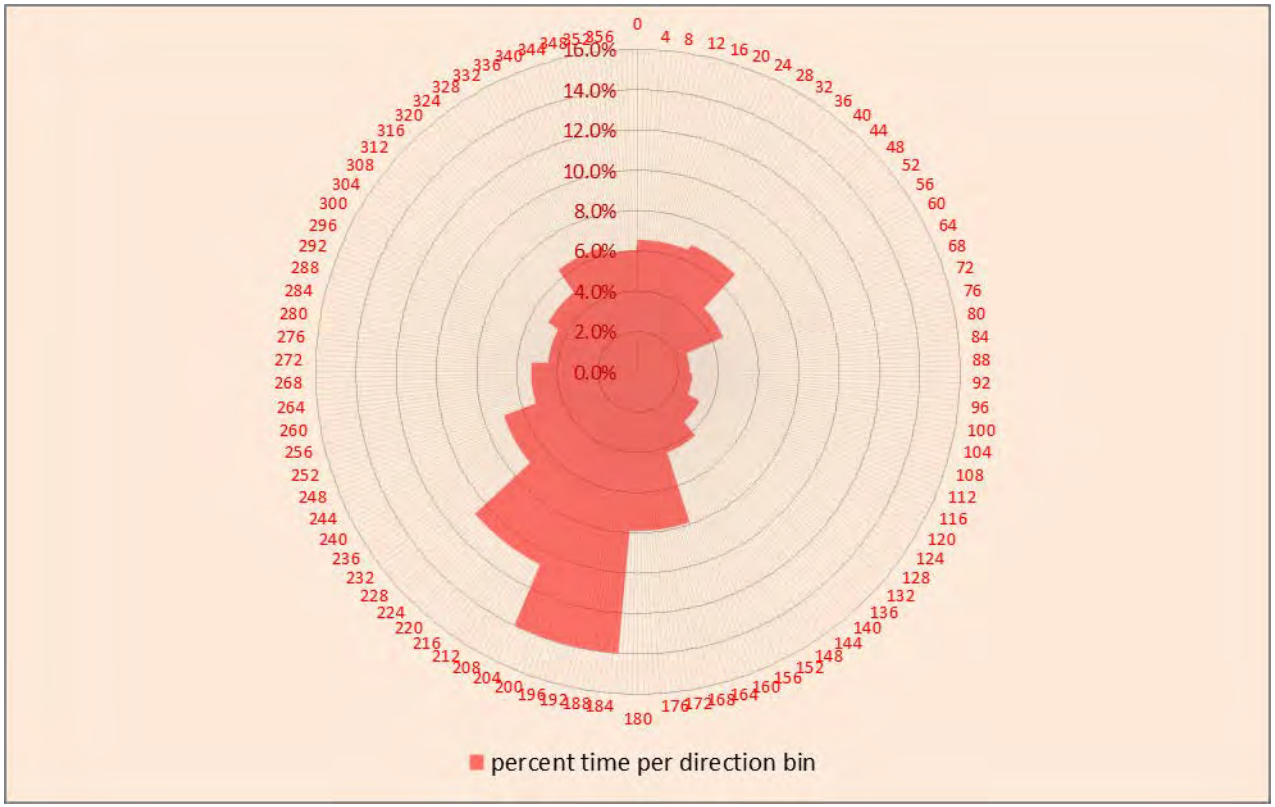

# Modeling for Power Estimation




Wind rose of averaged speed per direction bin

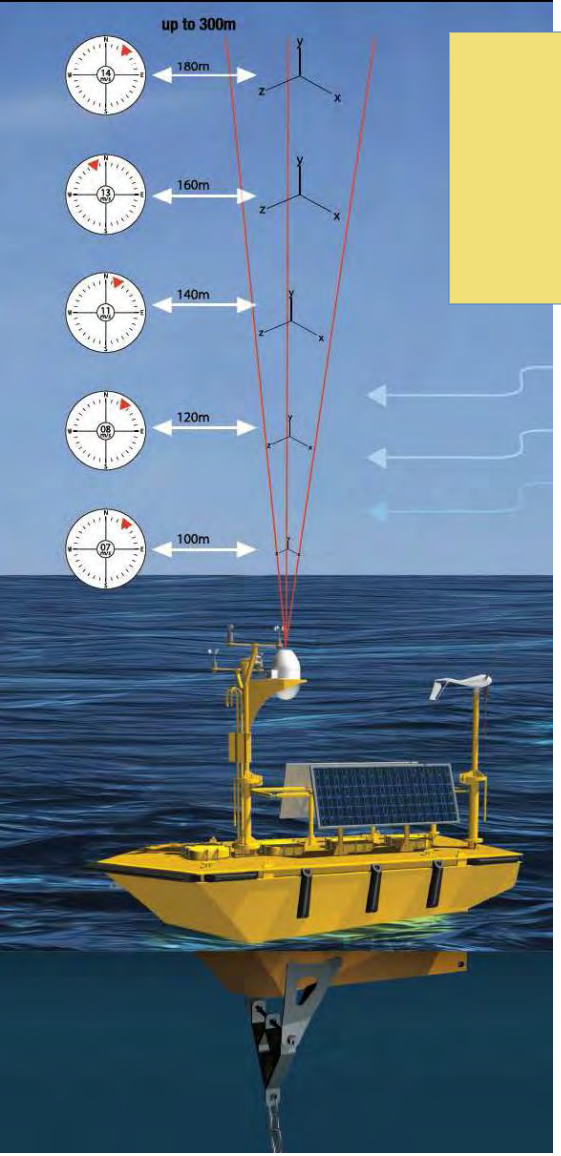
# Modeling for Power Estimation

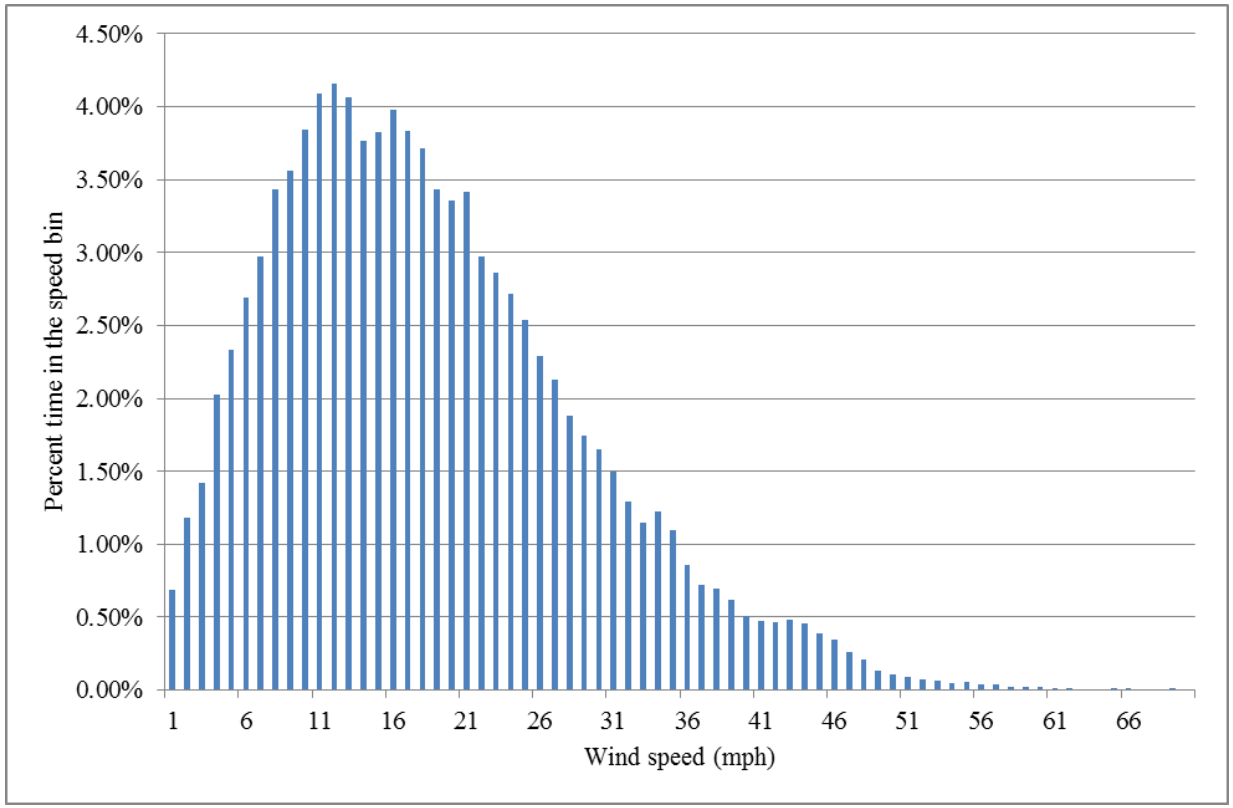



Wind rose of fraction time per direction bin

# Modeling for Power Estimation




Frequency distribution of RG 1