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

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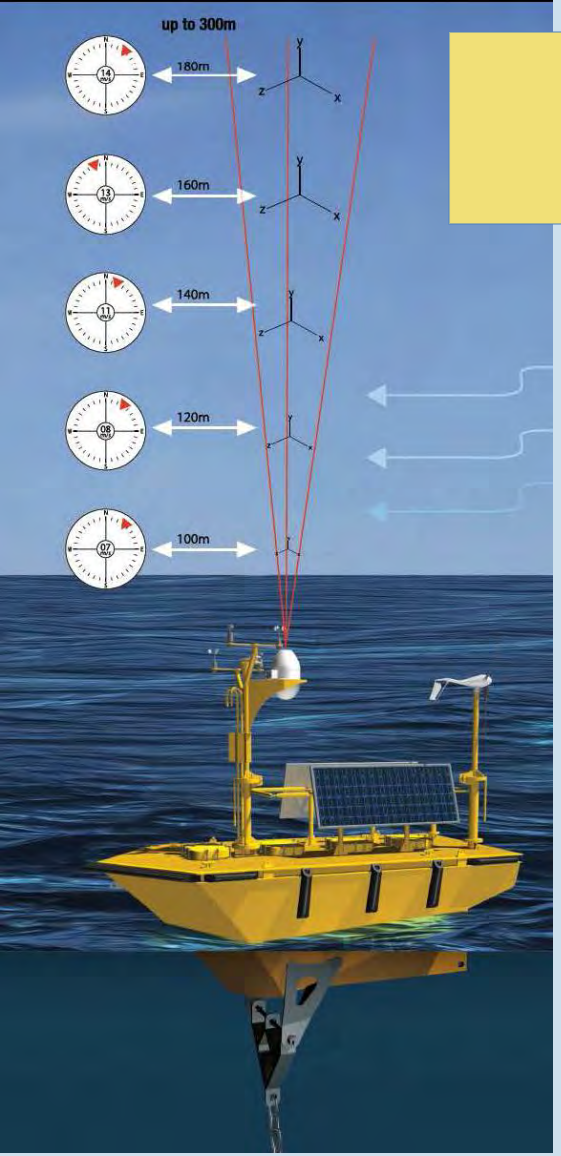
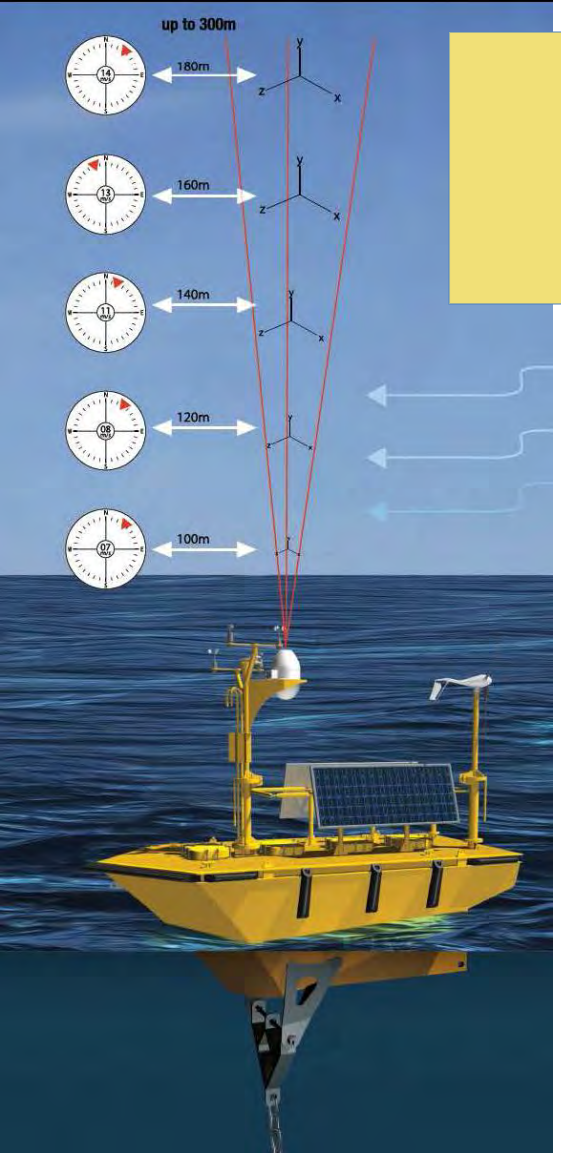
GVSU Big Data Conference
April 26, 2013



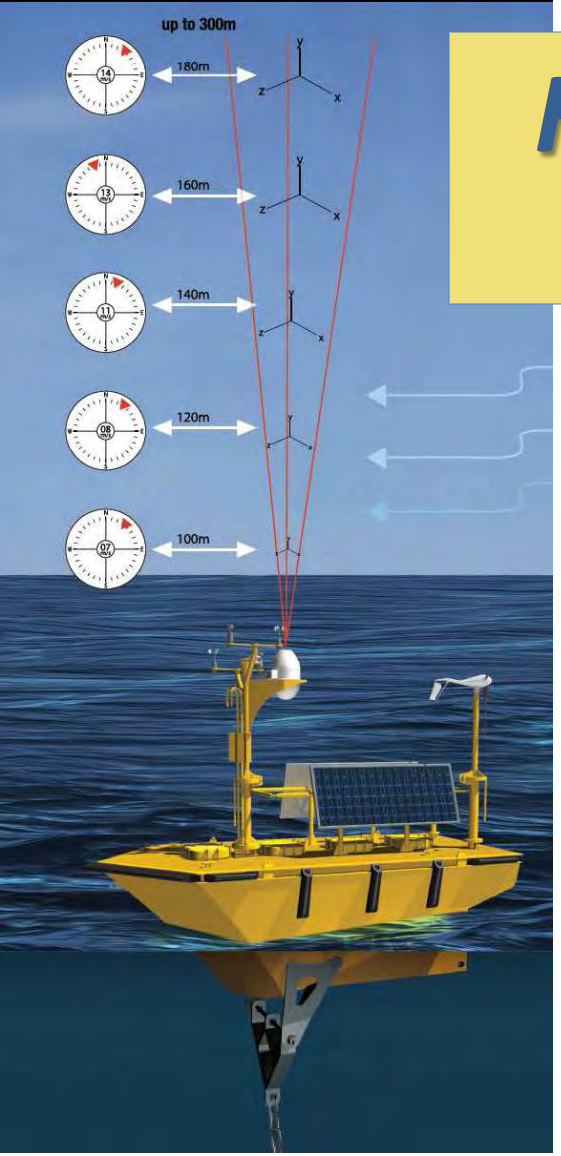
Project Goals

- 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



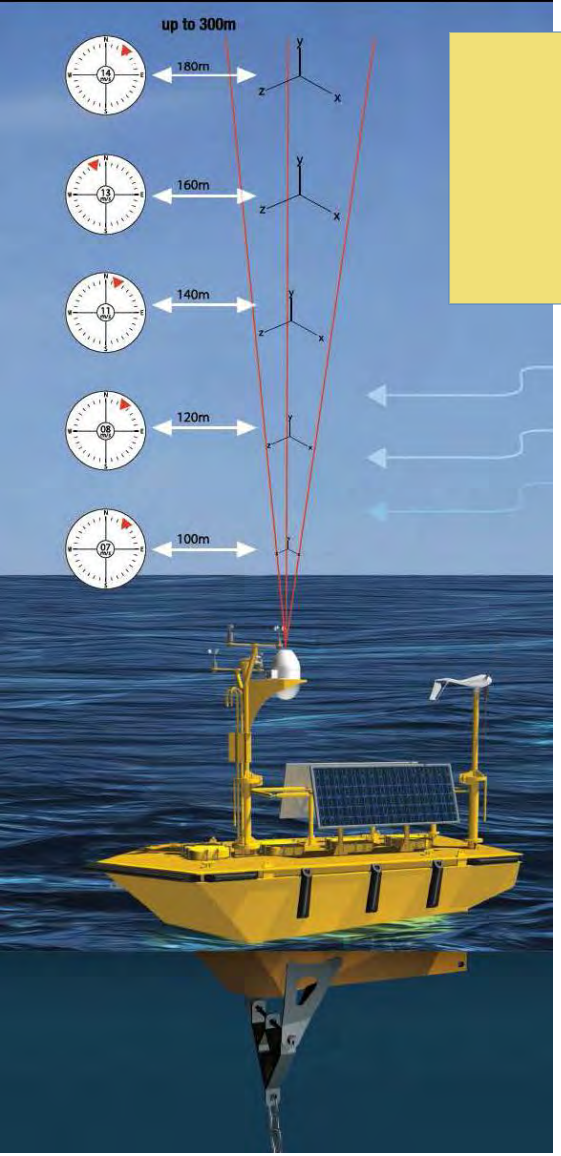
Summer 2012: Mid-Lake Plateau

- 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



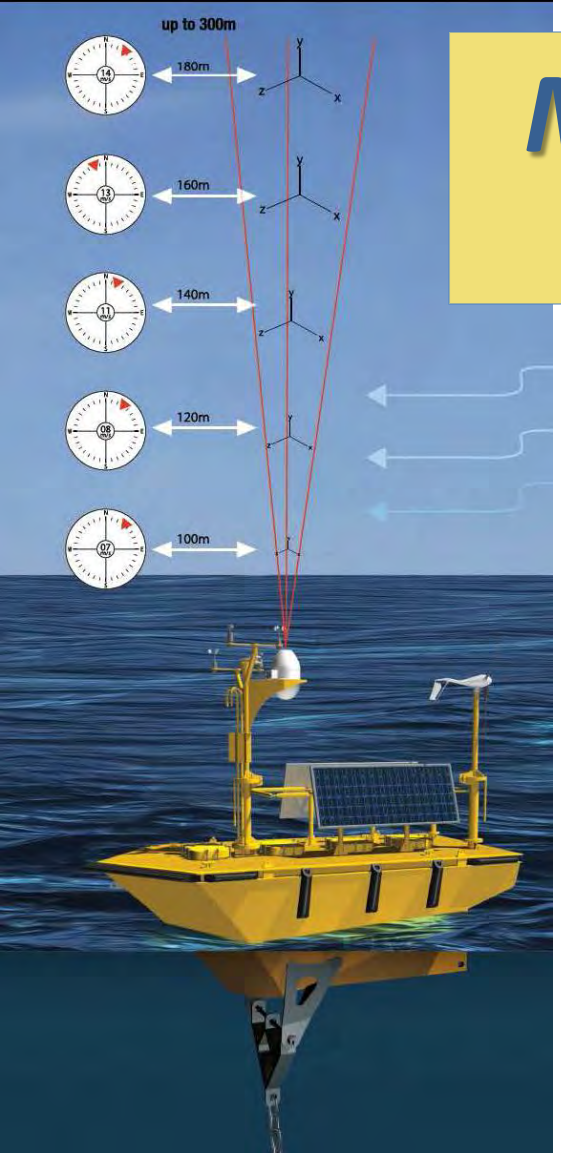
How Effective is the Laser Wind Sensor?

- 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



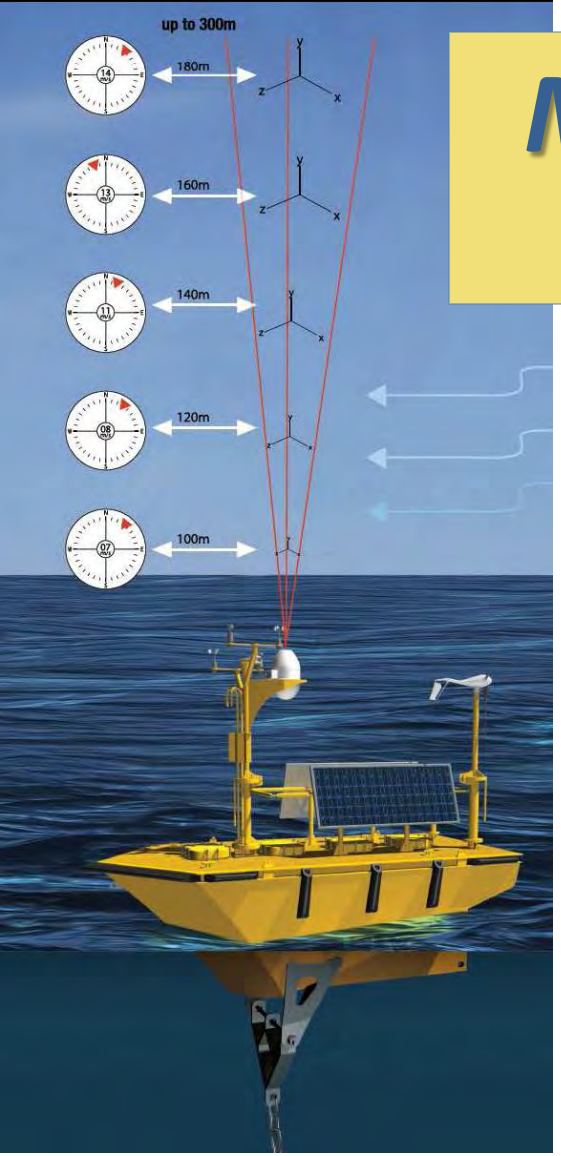
Modeling the One-Second Data

David Zeitler

2011/2012
Yeni Nieves, Biostatistics PSM

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

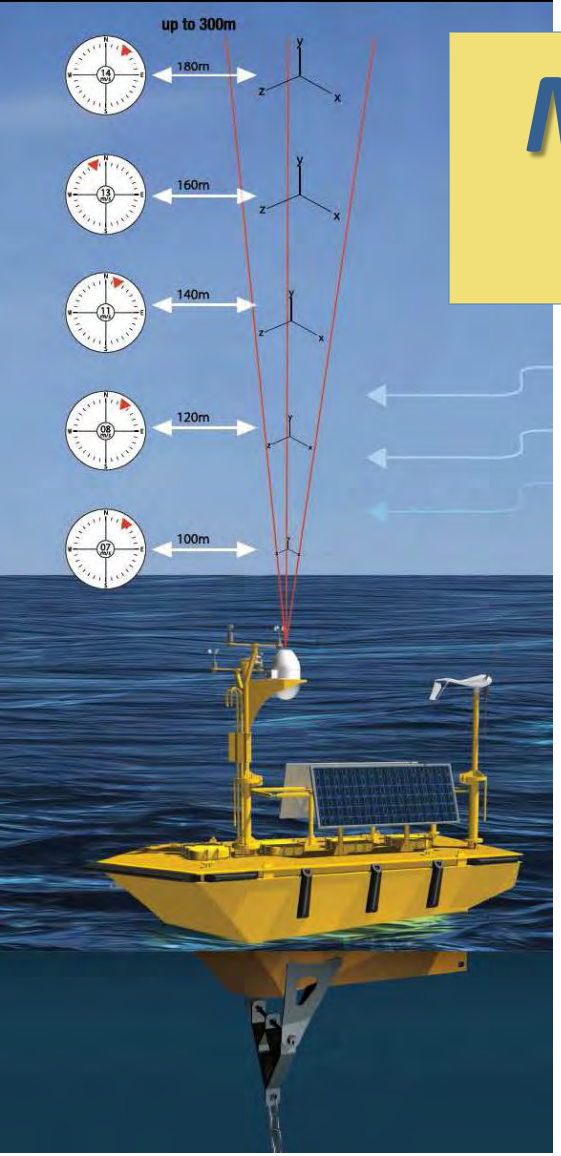
2013/2014
Tyson Spoelma, Statistics Major
Aaron Clark, Biostatistics PSM



Modeling the One-Second Data

Challenges

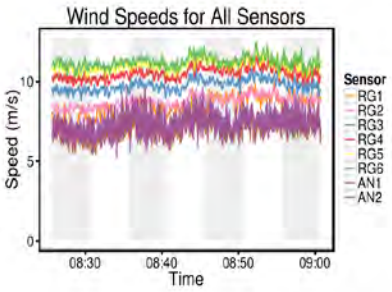
- We currently have about 55Gb of data, more coming.
- Data comes from multiple sources (Laser Wind Sensor, Meteorological Package, Water Quality Sensor, NOAA bouy).
- Data rates and recording times vary across sources from 1 second to 1 hour.
- Data has highly variable quality.

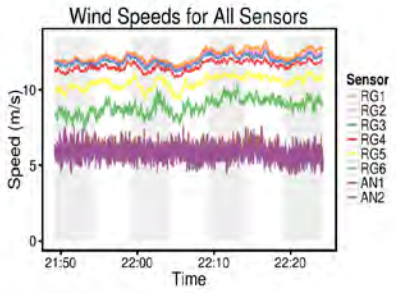


Modeling the One-Second Data

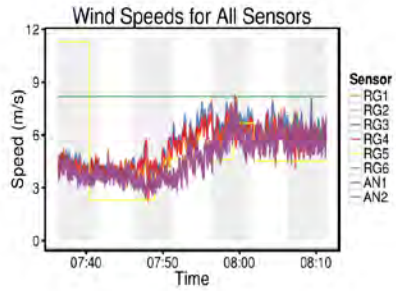
Data Quality Issues

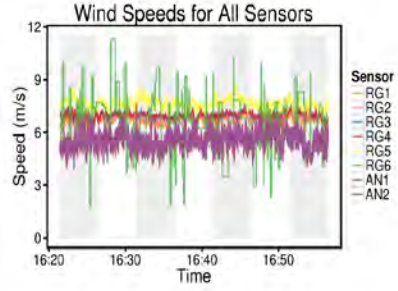
Good Quality Data

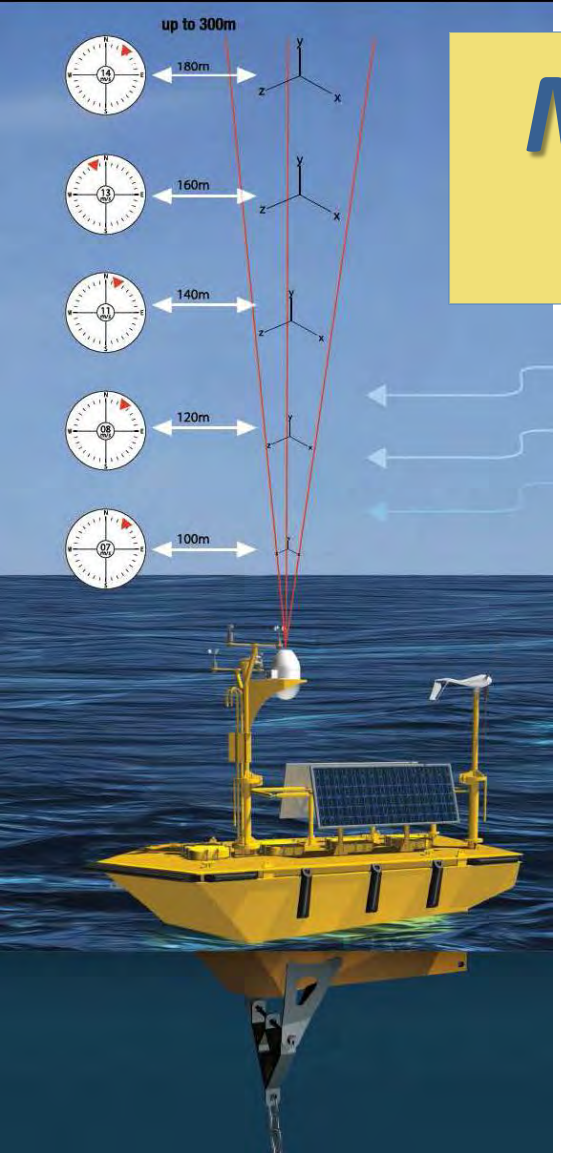




Problematic Data

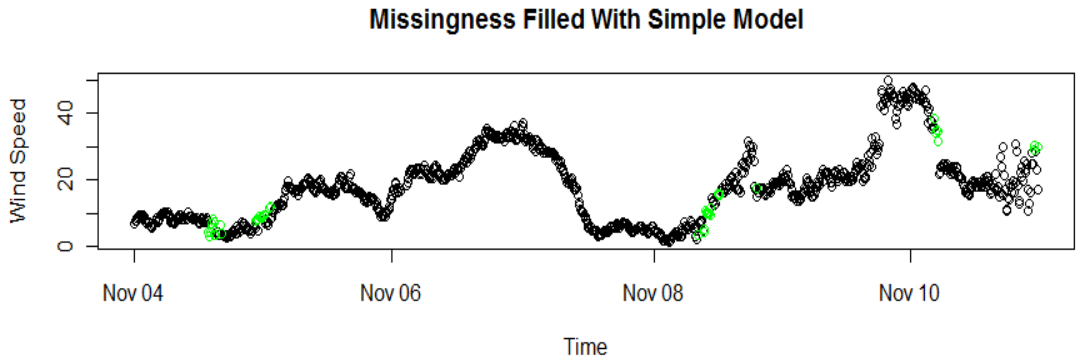


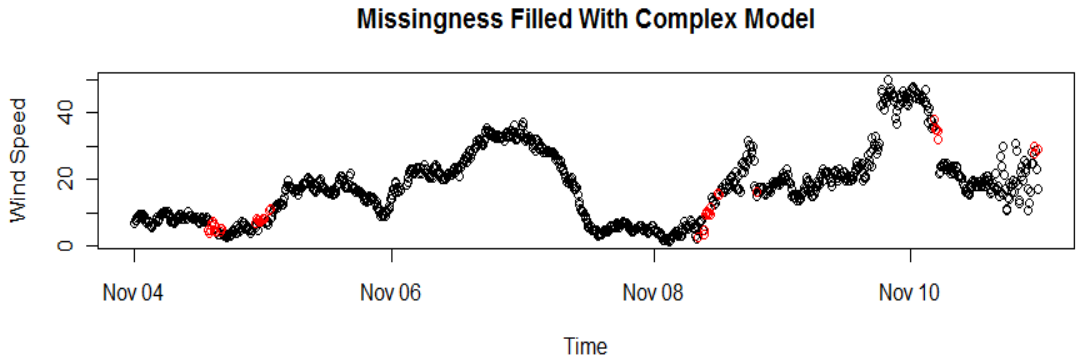


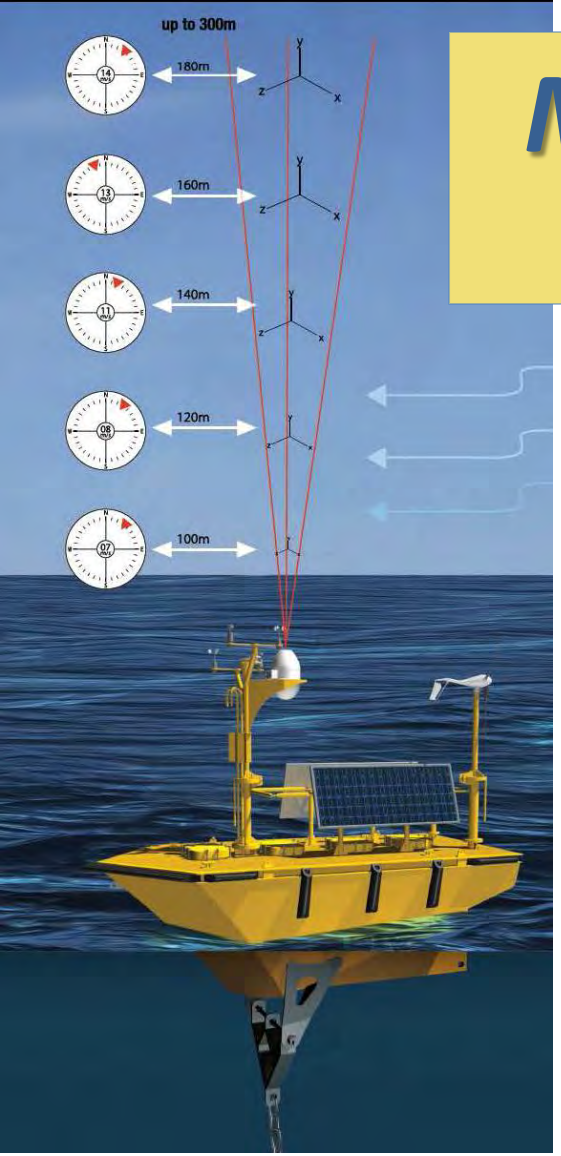


Modeling the One-Second Data

Missing data imputation

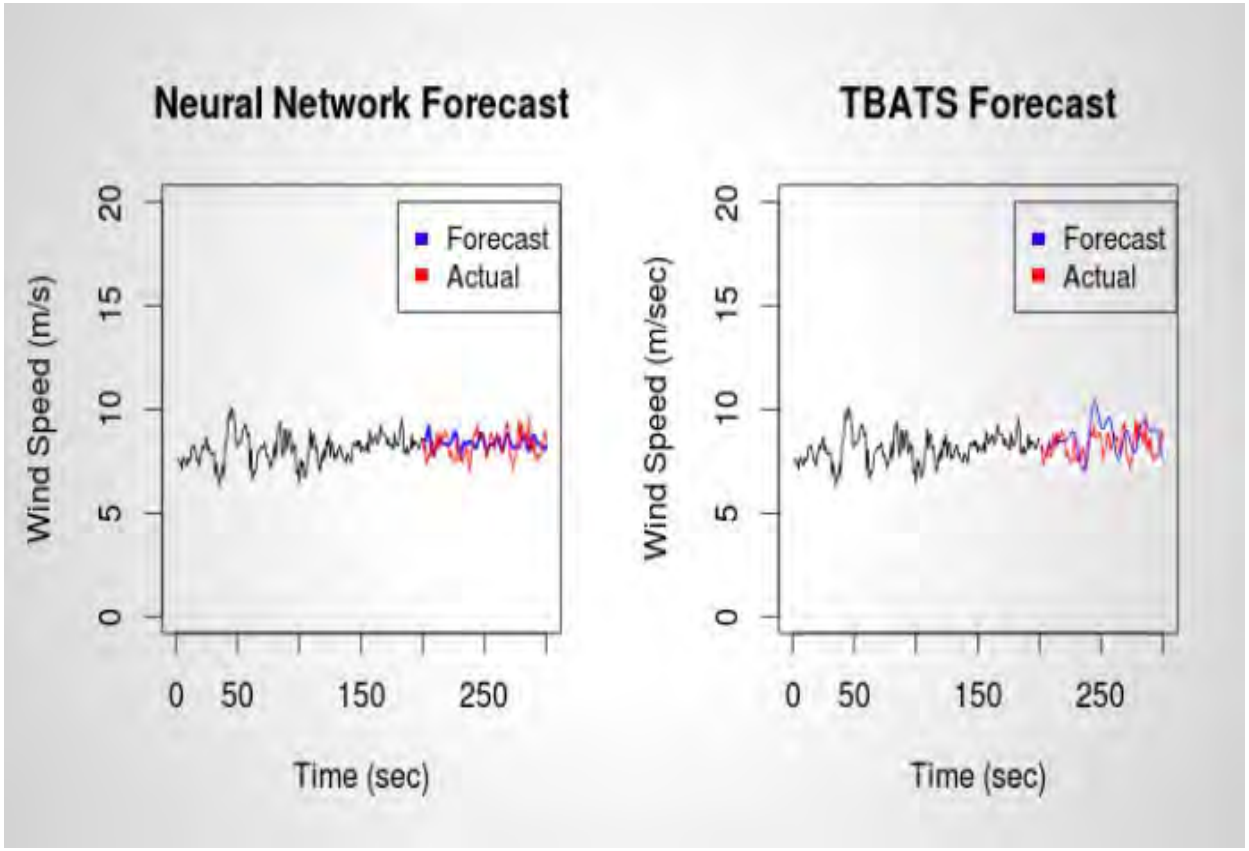


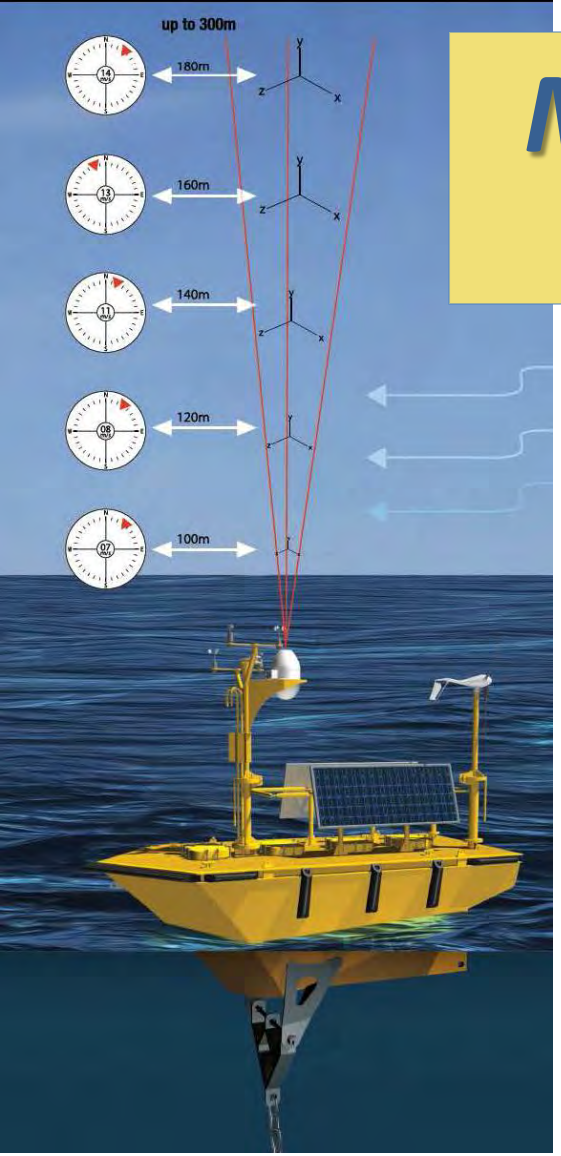




Modeling the One-Second Data

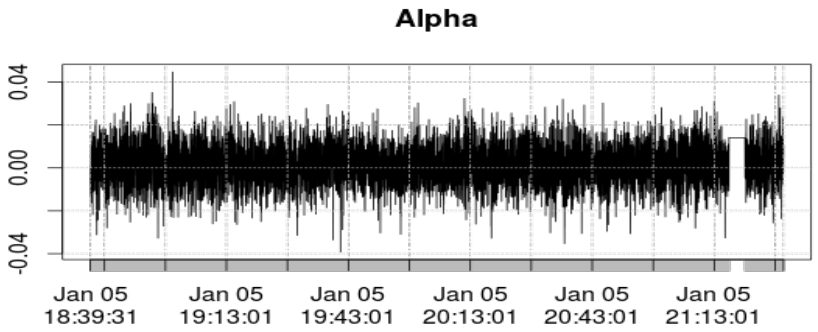
Forecasting





Modeling the One-Second Data

Wind profiling



Generalization:

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

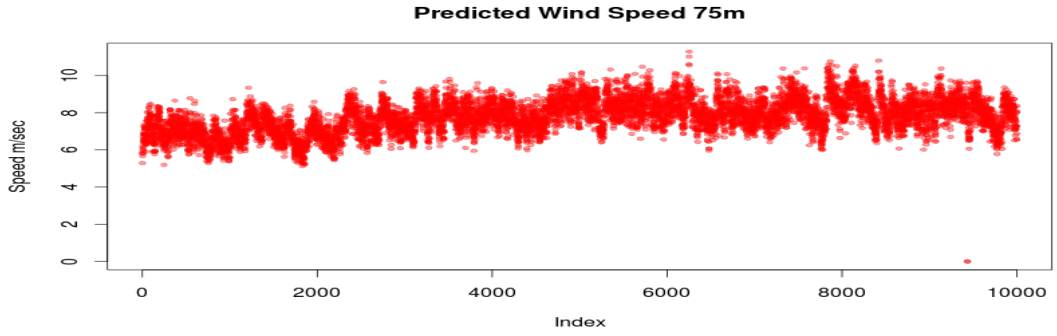
u -> wind speed @ z

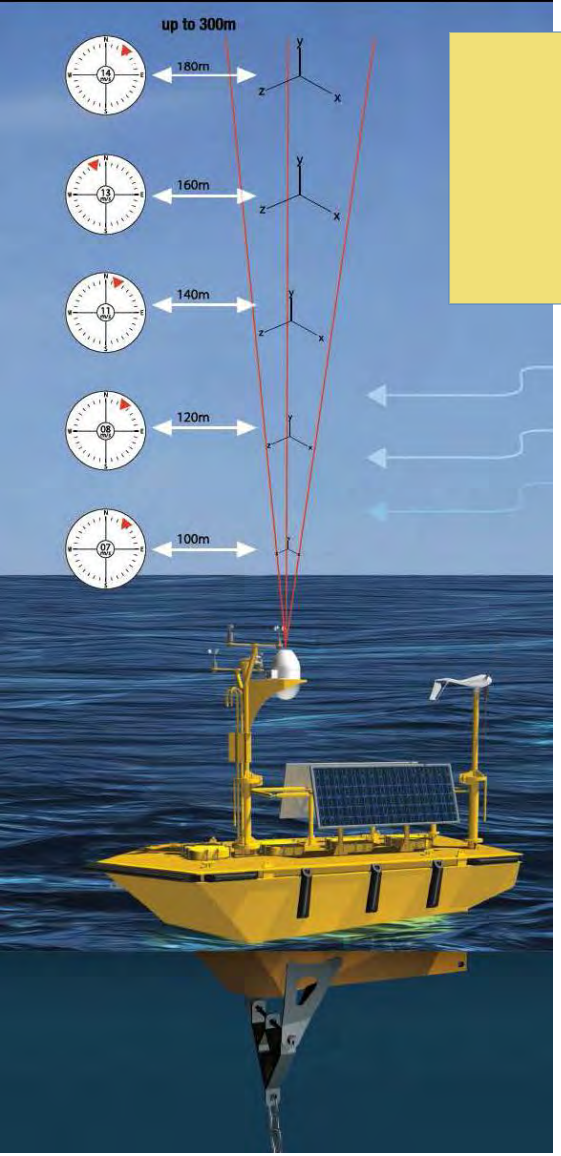
u_r -> wind speed @ z_r

z -> height one

z_r -> height two

α -> exponent





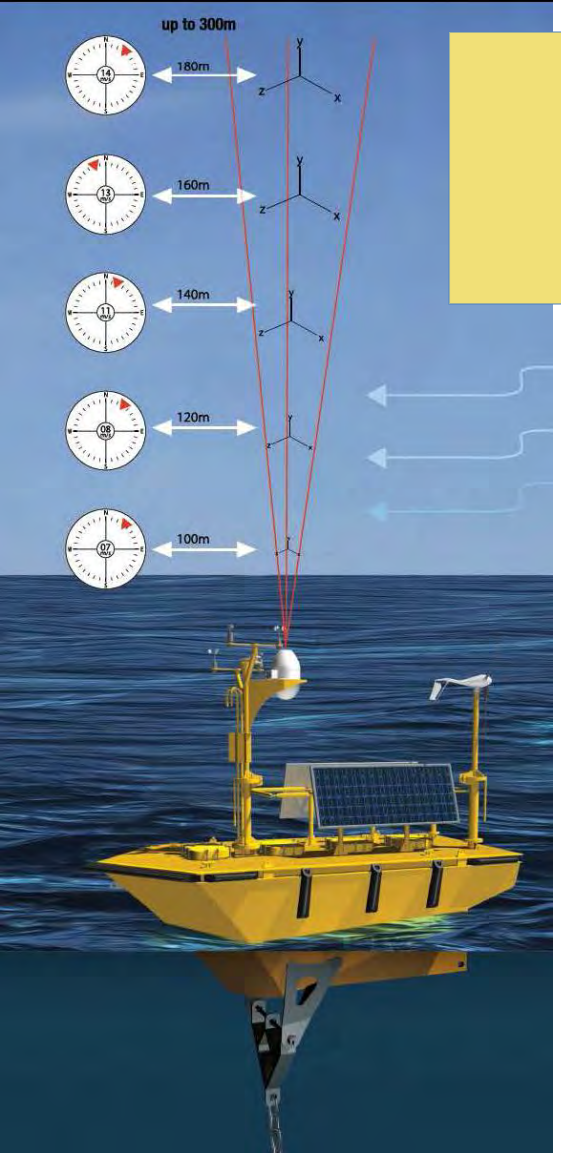
Modeling for Power Estimation

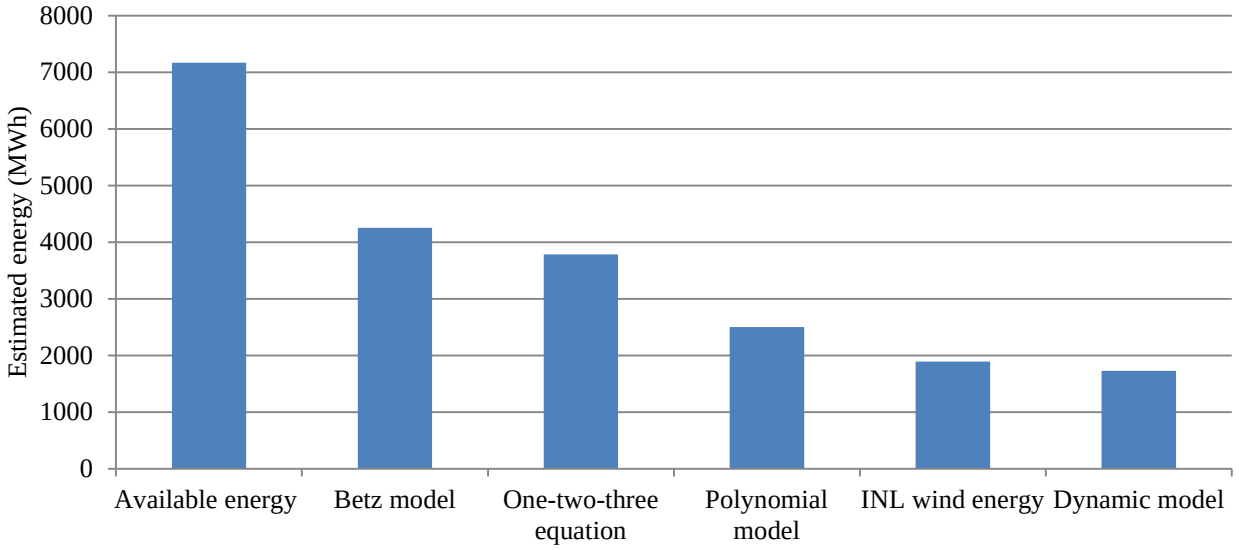
Faculty members: Mehmet Sözen and Azizur Rahman
Graduate Assistant: Md Nahid Pervez

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**

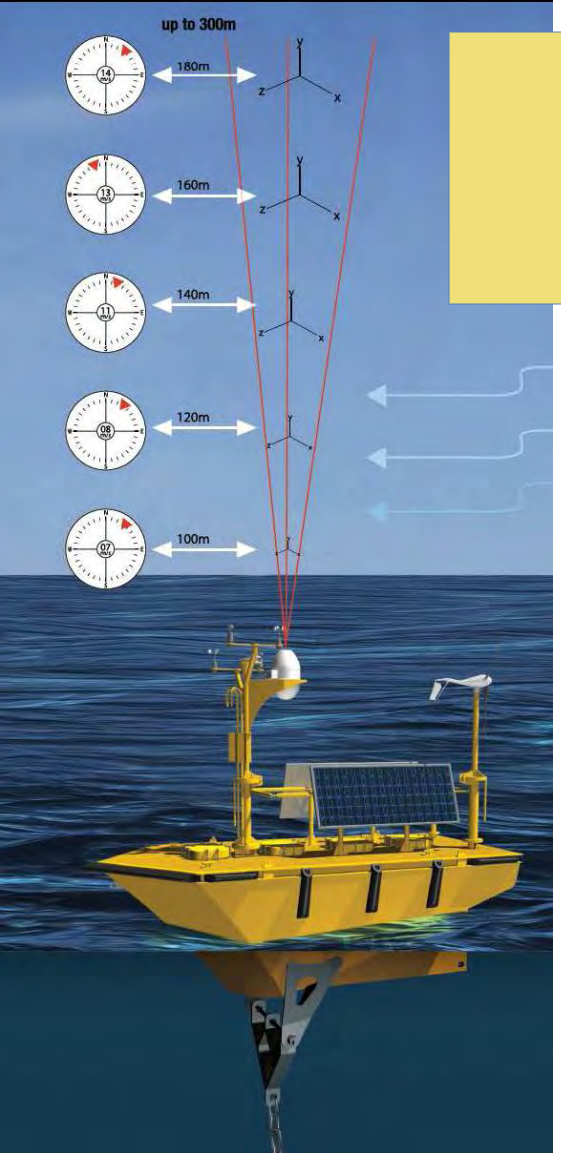
Modeling for Power Estimation

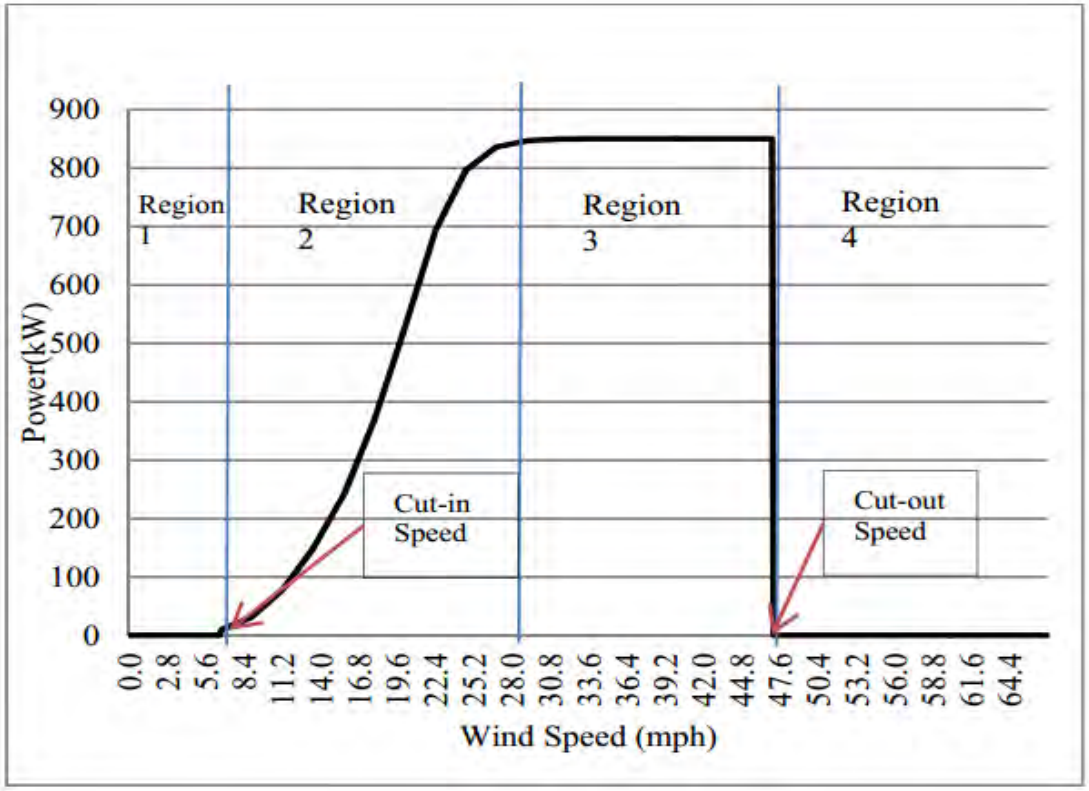




Estimated energy by different models

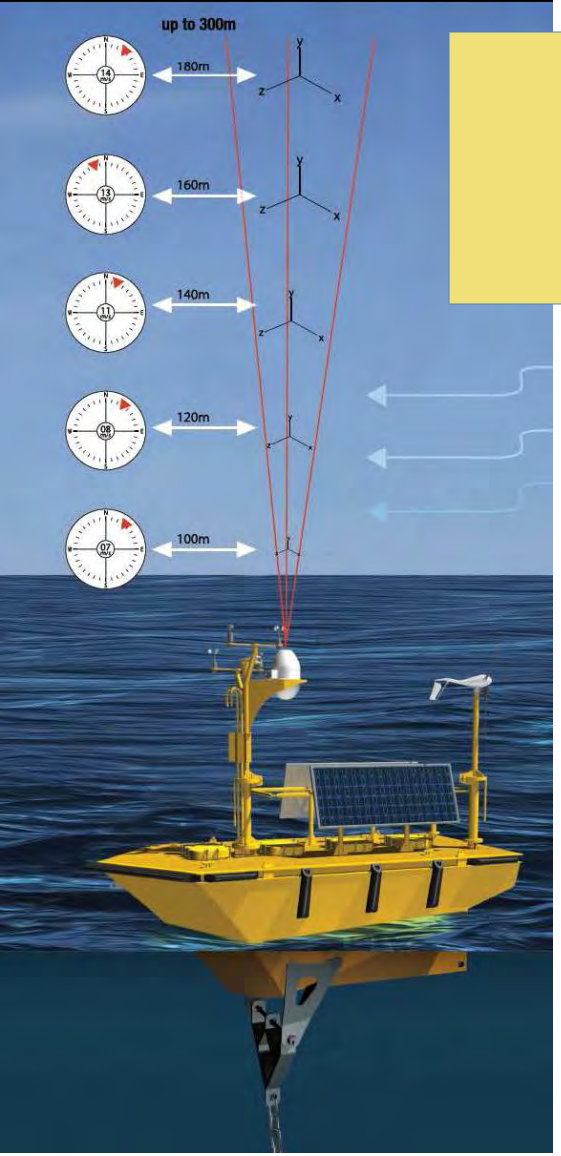
Modeling for Power Estimation

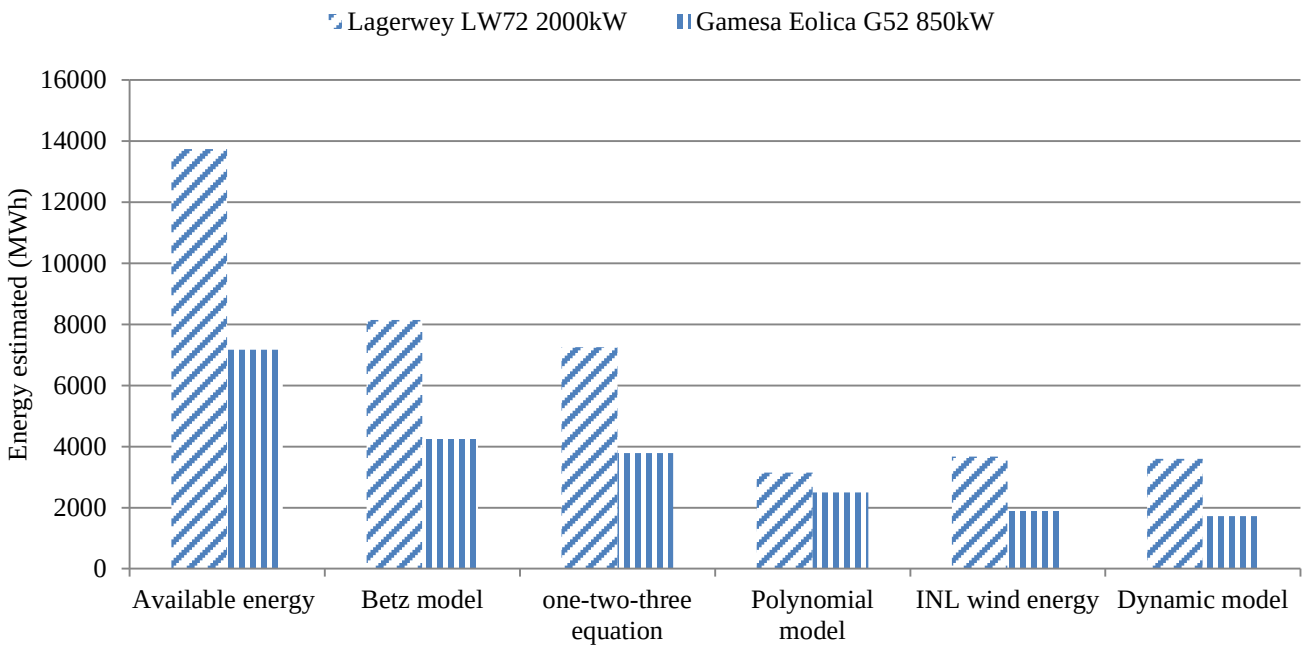




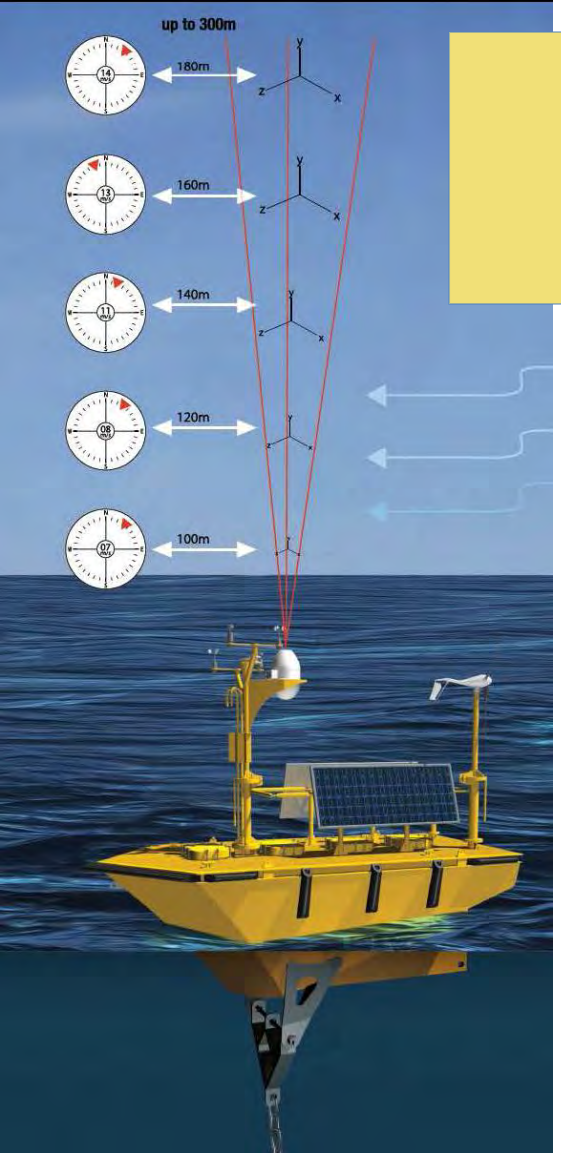
Power curve for Gamesa Eolica G58-850 kW wind turbine

Modeling for Power Estimation



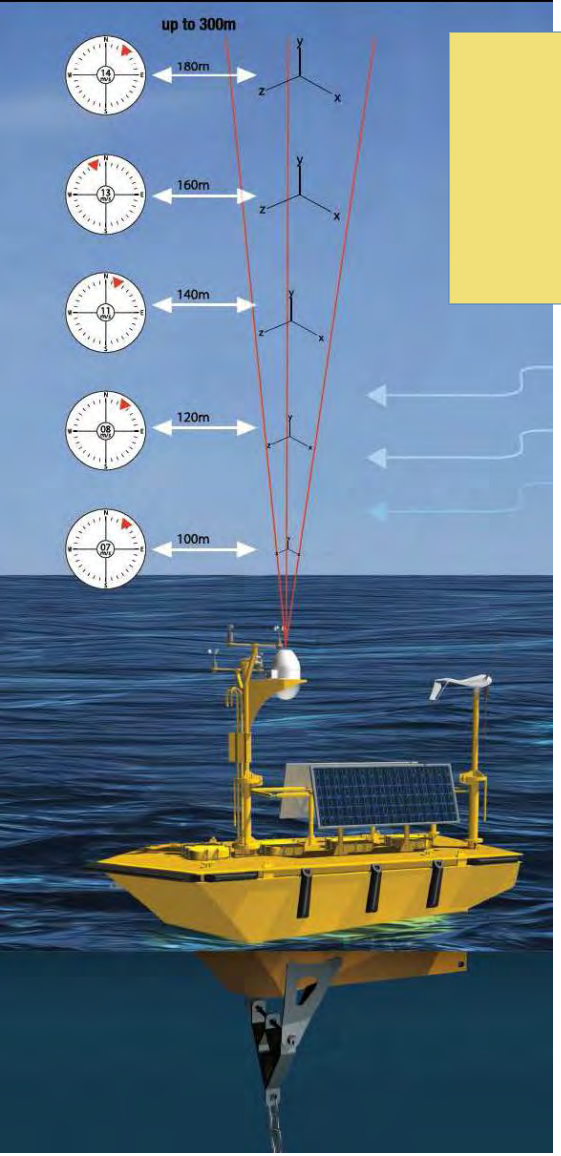


Energy estimated by different wind turbine models

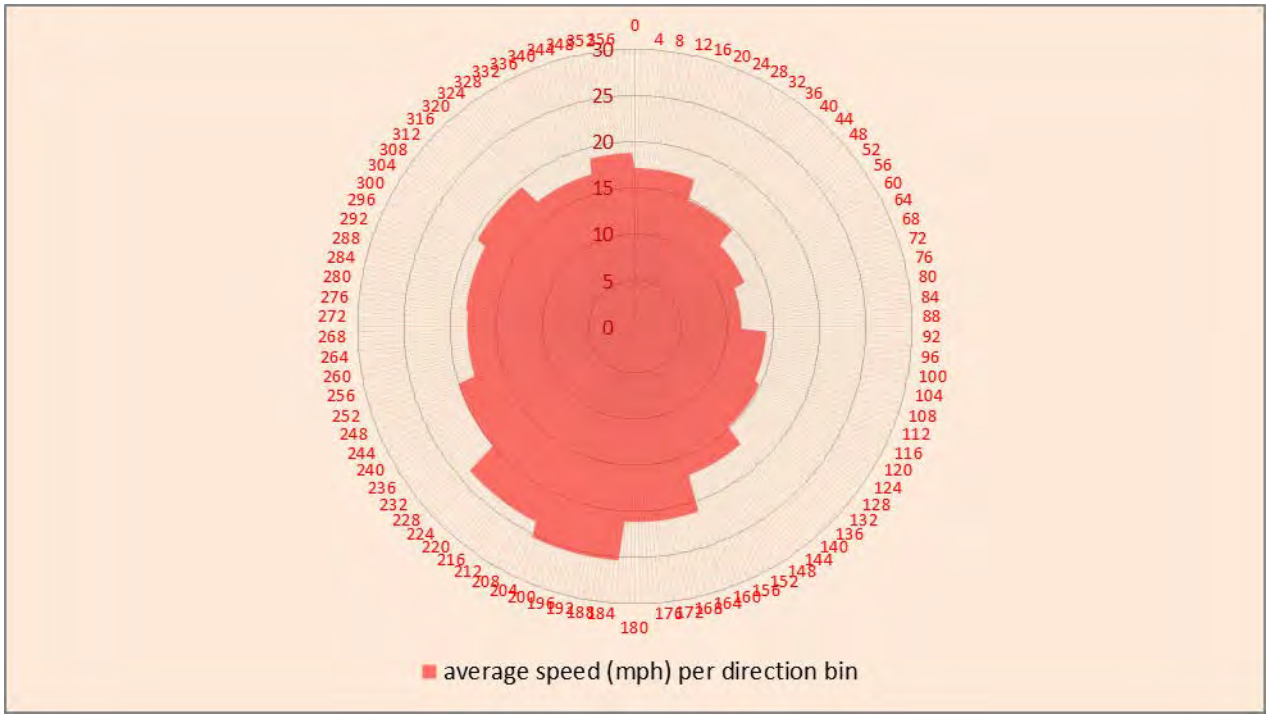


Modeling for Power Estimation

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%

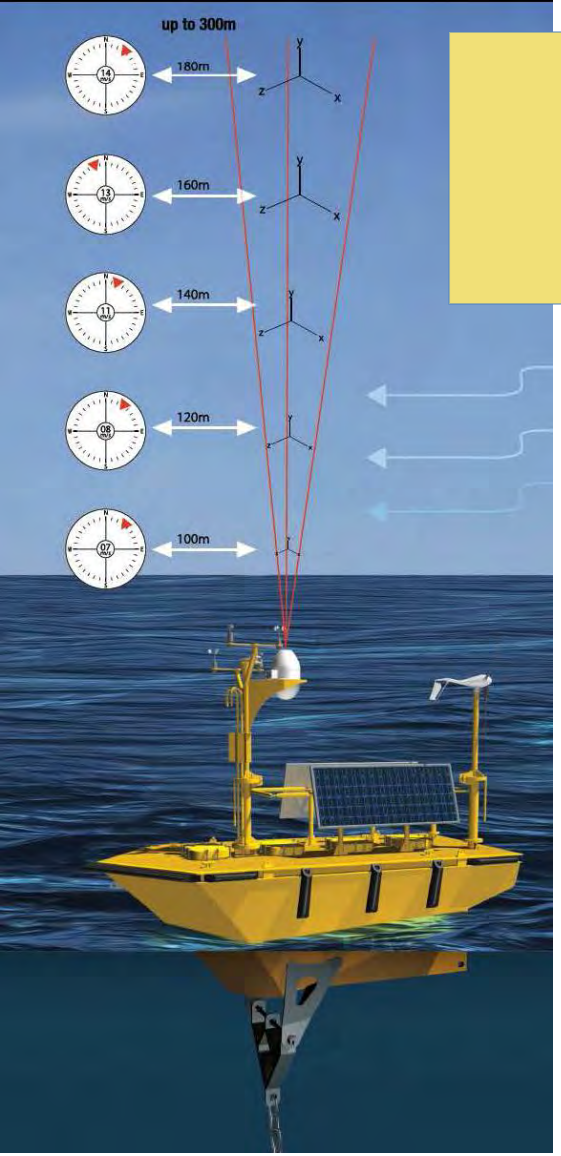


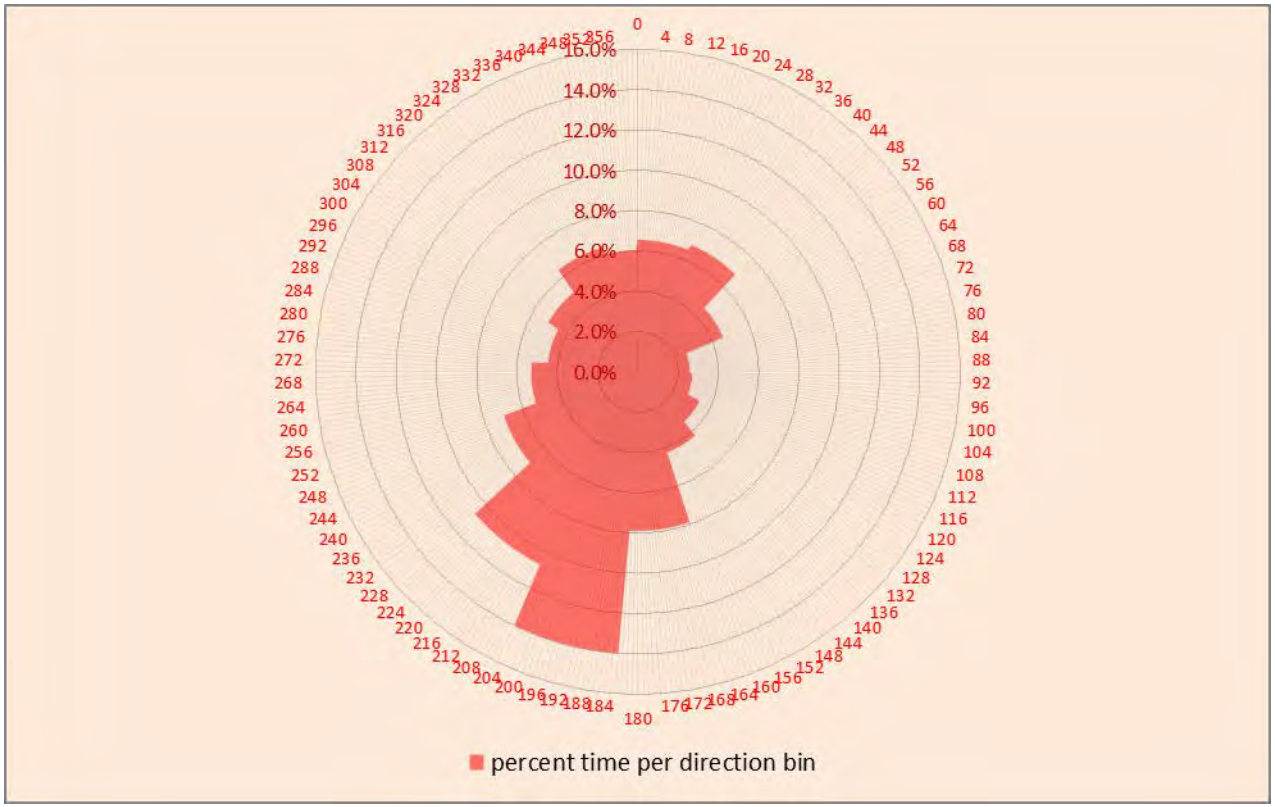
Modeling for Power Estimation



Wind rose of averaged speed per direction bin

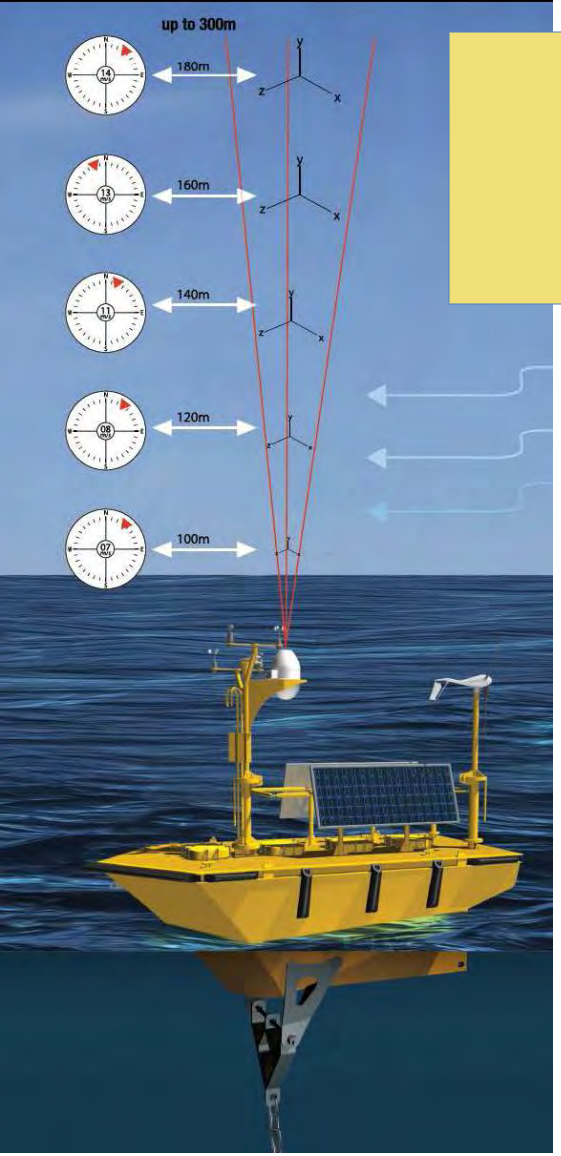
Modeling for Power Estimation

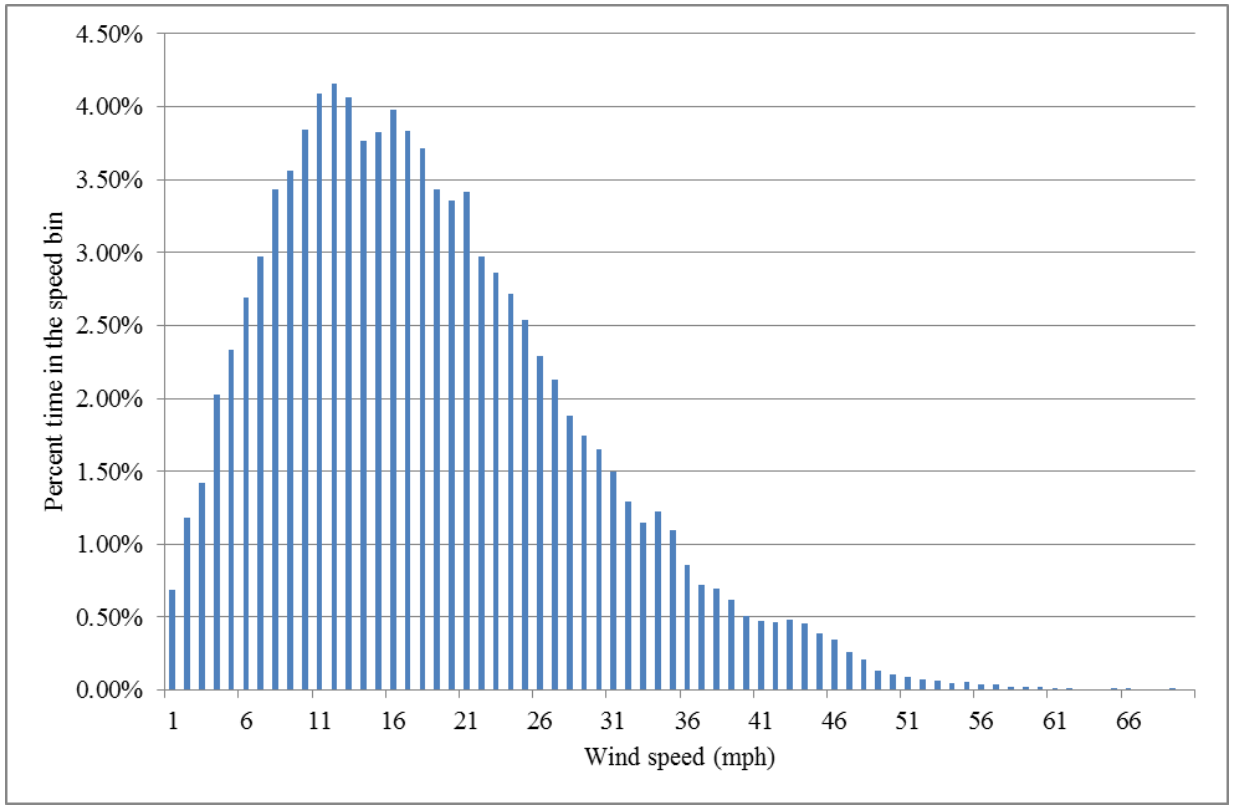




Wind rose of fraction time per direction bin

Modeling for Power Estimation





Frequency distribution of RG 1