



Measurements of the Wake Field of Hydrokinetic Devices

M. Cameron, M.L. Peterson
Mechanical Engineering
University of Maine

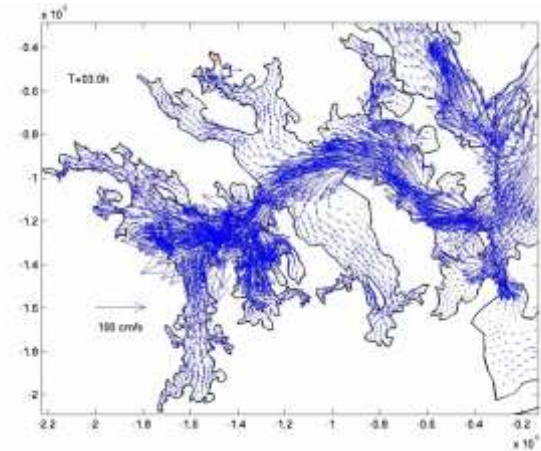
H. Xue
Marine Science
University of Maine

R.W. Kimball
Department of Engineering
Maine Maritime Academy

OVERVIEW

RESEARCH AREAS OF THE MAINE TIDAL POWER INITIATIVE

- TIDAL RESOURCE ASSESSMENT
 - Ocean Circulation Model
- TIDAL TURBINE DESIGN DEVELOPMENT
 - Numerical Model
 - Tow Tank Testing
- FOUNDATIONS TESTING
- ENVIRONMENTAL ASSESSMENT
 - Impact on Marine Animals
- Industrial Developers
 - Ocean Renewable Power Company (ORPC)
 - Blue Stream



Ocean Circulation Model of the Coast of Maine

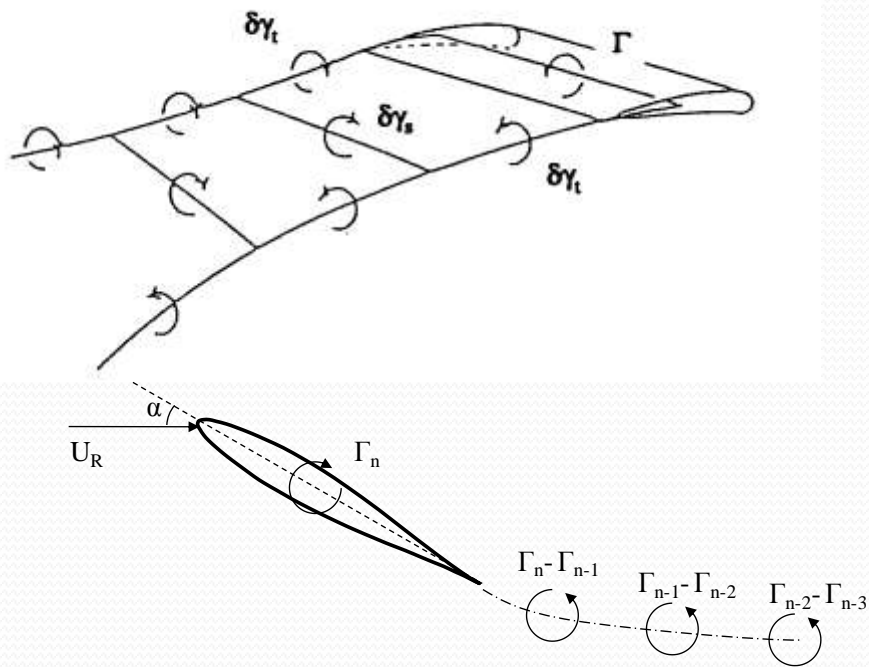


ORPC's Cross Flow Tidal Turbine to be Tested in Eastport Maine.

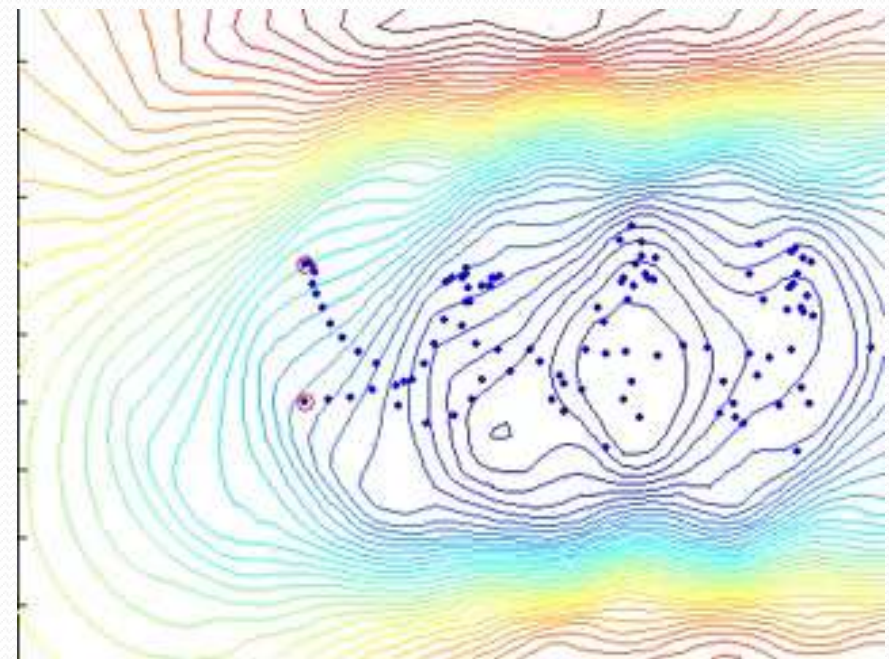
Motivations:

- Validate Vortex model
 - Compare measured wake field to model predictions
 - Accurate wake modeling is key for blade fluid interactions

Trailing Vortex Sheets



Vortex Modal Wake



Motivations: Resource Assessment

Experimentally
measure flow field



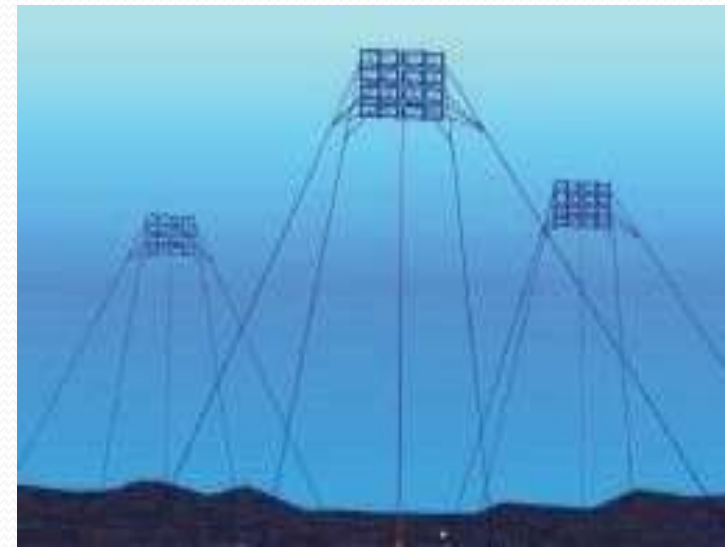
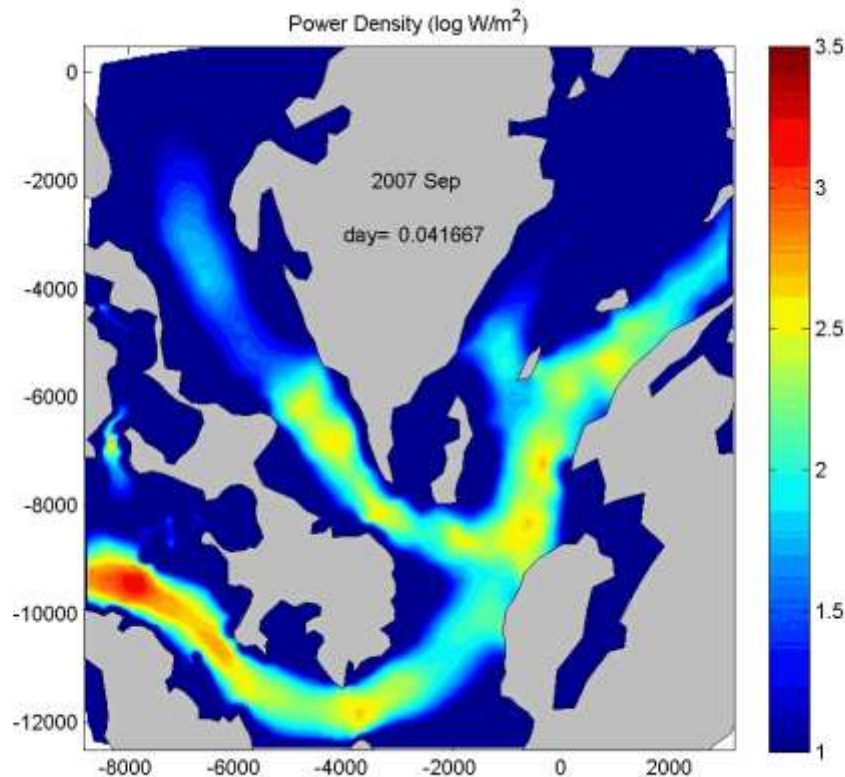
Parameterize the
down stream effect
and nest into the
circulation model



Predict interactions
between multiple
turbine

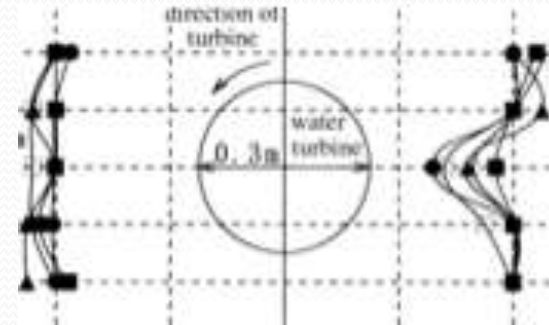


Optimization of
Array of Turbine



Objectives: Measurement

1. Mean two dimensional Velocity field



2. Turbulent kinetic Energy

$$TKE = \frac{1}{2}(u'^2 + v'^2 + w'^2)$$

3. Reynolds Shear

$$\tau_{turb} = \begin{pmatrix} u'v' \\ v'w' \\ w'u' \end{pmatrix}$$

4. Surface Elevation

Reynold's Time-Averaging Concept

$$u = \bar{u} + u'$$

$$\bar{u} = \text{Mean}$$

$$u' = \text{Fluctuation}$$

$$u = \text{Instantaneous}$$

University of Maine Tow Tank Device Testing Capabilities

- Cross-Flow Turbine
- Axial Flow Turbine
- Savonius Rotor Turbine



Cross-Flow Turbine Test Bed in University of Maine
Tow Tank

Maine Maritime Academy Collaboration

- i) Maritime facilities has provided the capability to test in the field
- ii) Providing the means for an infinite fluid test



**MAINE MARITIME ACADEMY WATERFRONT
CASTINE, ME**



**Blue Stream's
Savonius turbine**

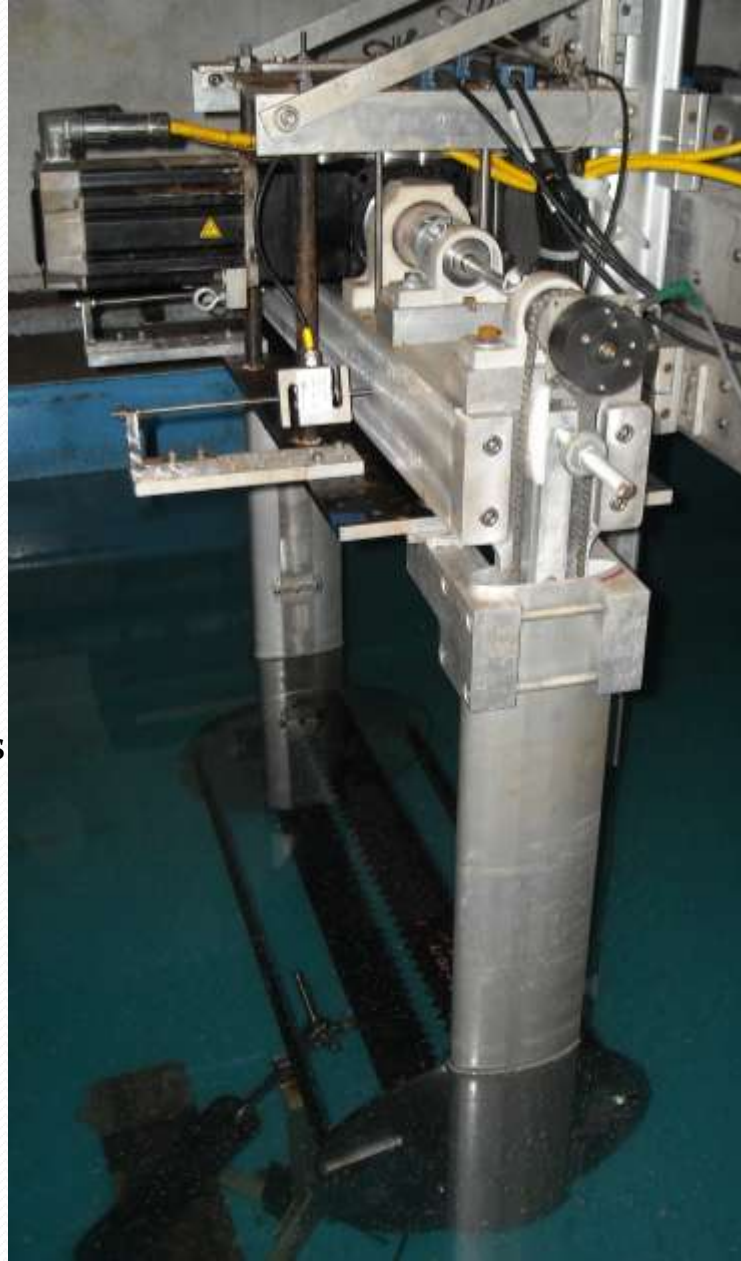
Cross Flow Turbine

Measured Quantities

1. Turbine Frontal Force
2. Turbine Position
3. Turbine Torque
4. Carriage Speed
5. Time Between Samples

Controlled Quantities

1. Carriage Speed
2. Turbine Rotational
4. Distance Carriage Travels

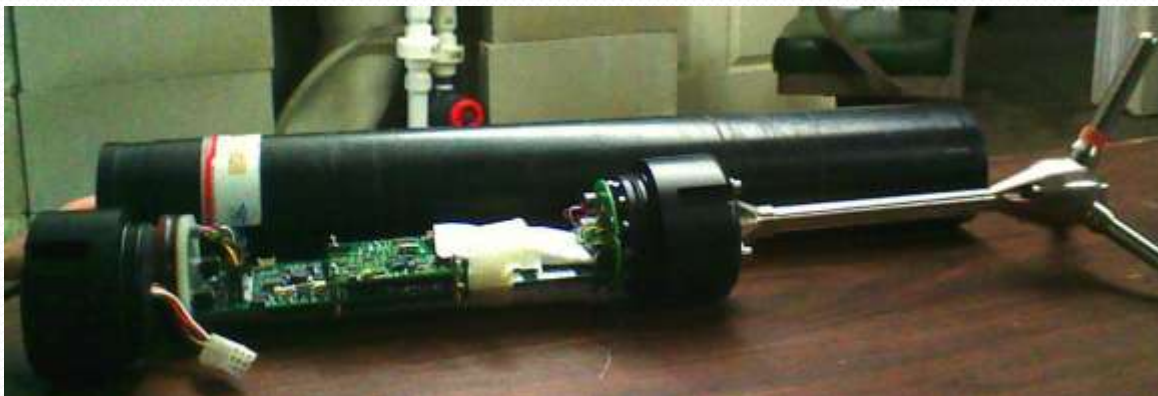


Results

1. Coefficient of performance
2. Coefficient of Thrust

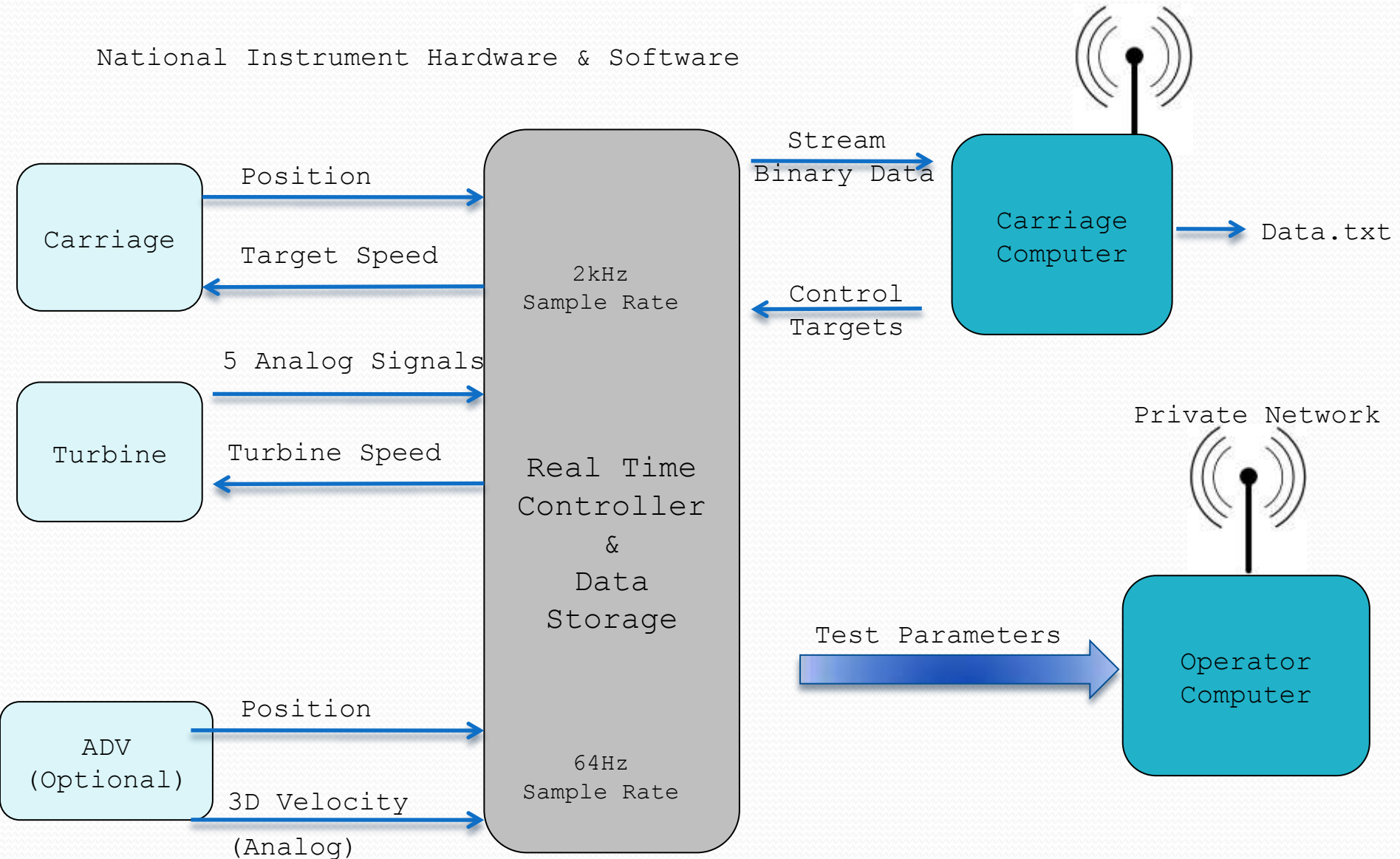
Velocity Equipment

- Acoustic Doppler Velocimeter (ADV)
- Limiting Factors
 - Velocity Window
 - Sampling rate 64 Hz
 - Synchronization



System Automation

National Instrument Hardware & Software

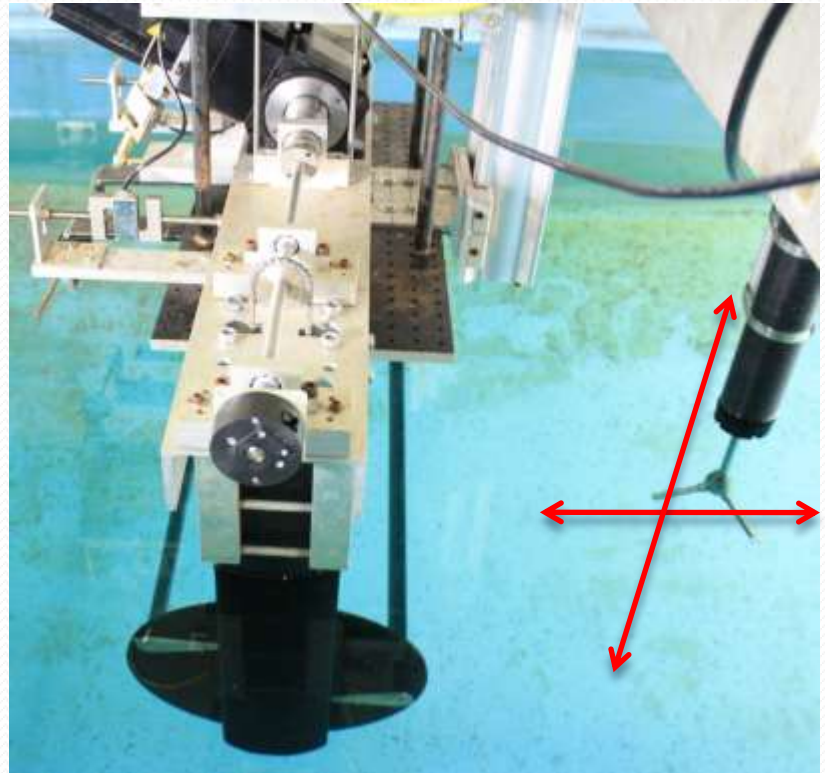


Velocity Data

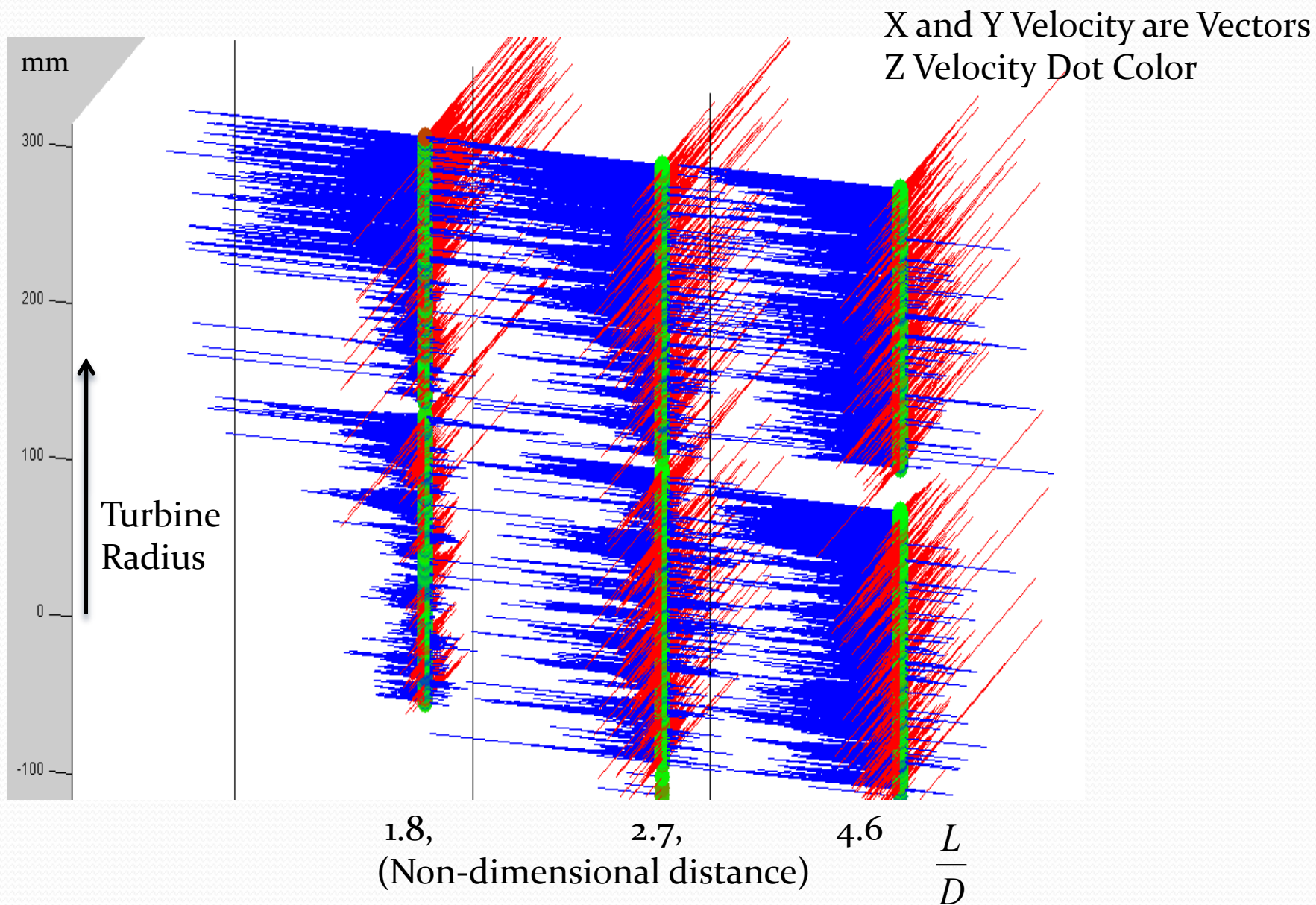
- Two methods of measuring wake

Method 1: Fixed distance from turbine

- ADV is mounted to a two dimensional traverse that is attached to the Carriage

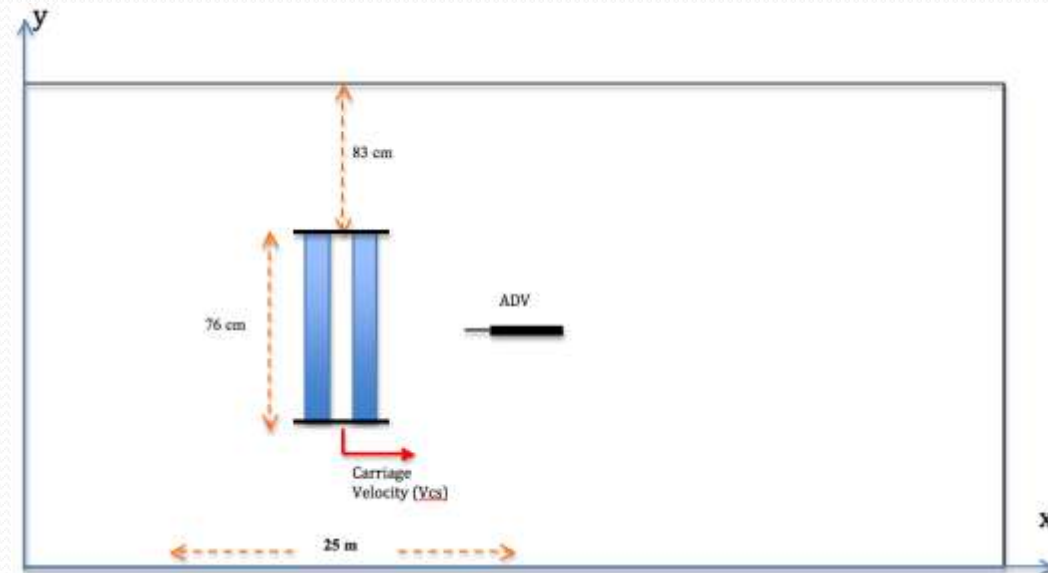
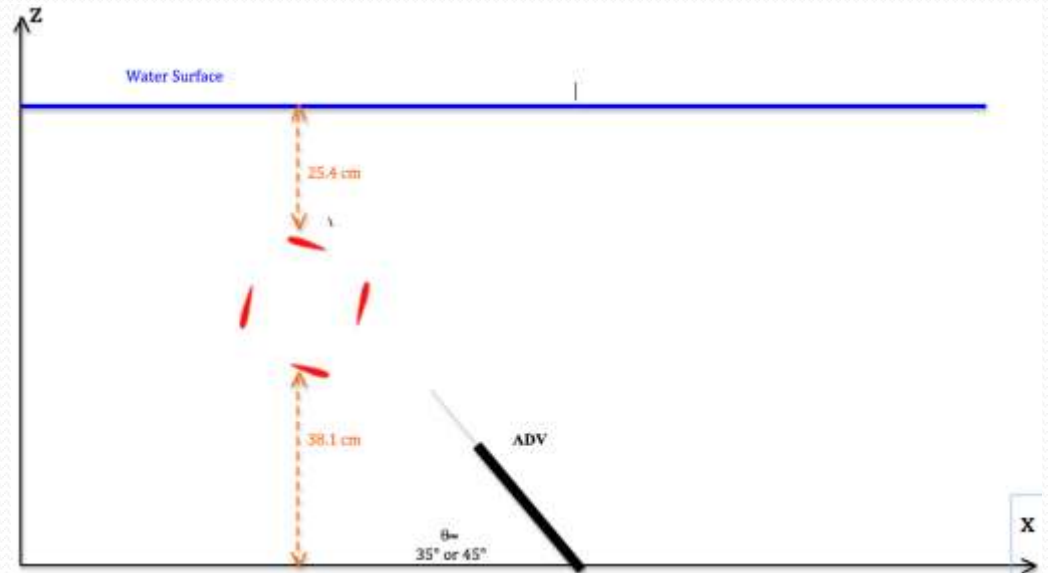


Preliminary Data Set:



Setup 2: Floor Mount

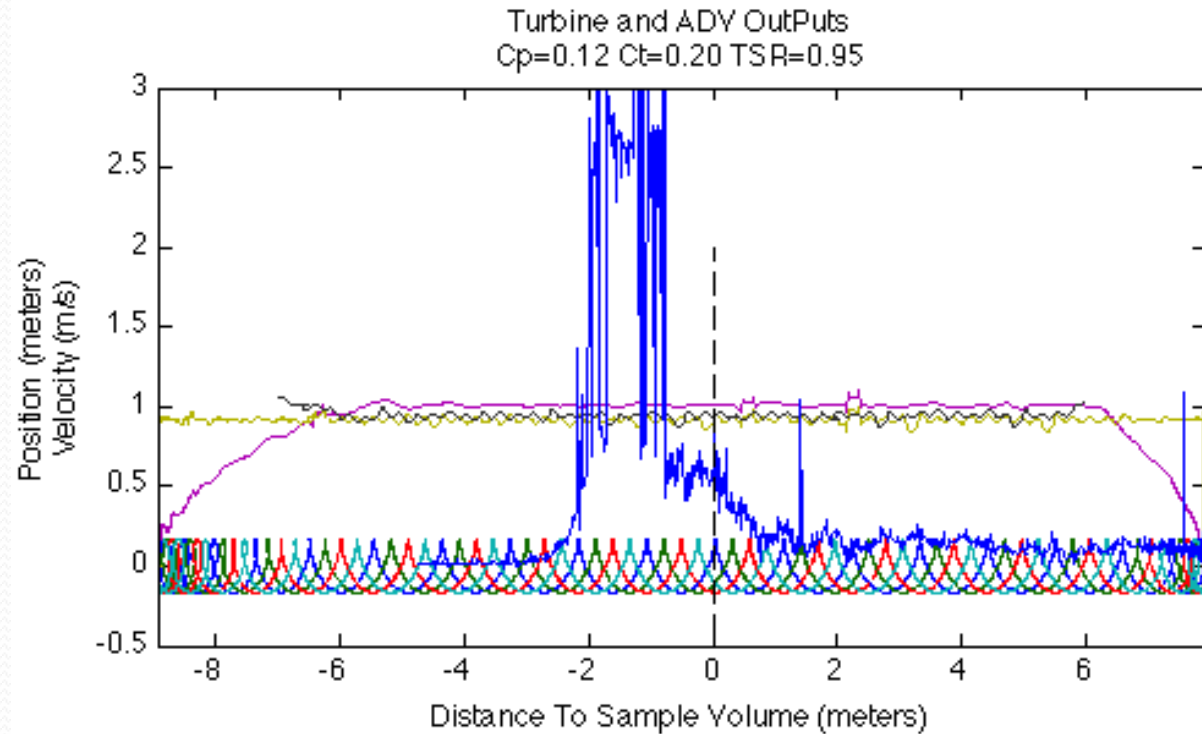
- ADV fixed to the tank floor while turbine passes over
- Pressure Transducer records Surface elevation
- Advantages
 - Able to measure the approach and departure of the turbine
 - Able to measure the far field
- Disadvantages
 - Measurement limited to the lower edge of the turbine
 - ~2 cm into active area



Synced System

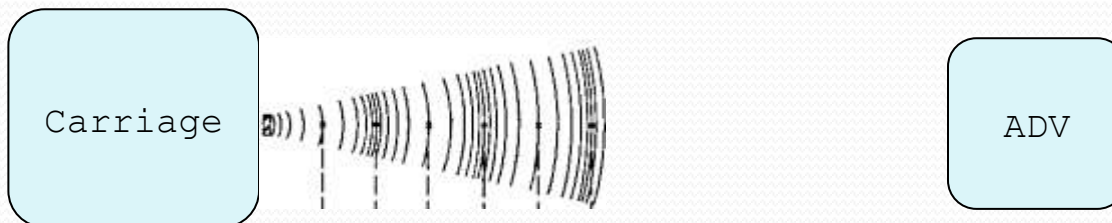
Syncing three independent Data Acquisition methods

1. Synchronize clocks over network

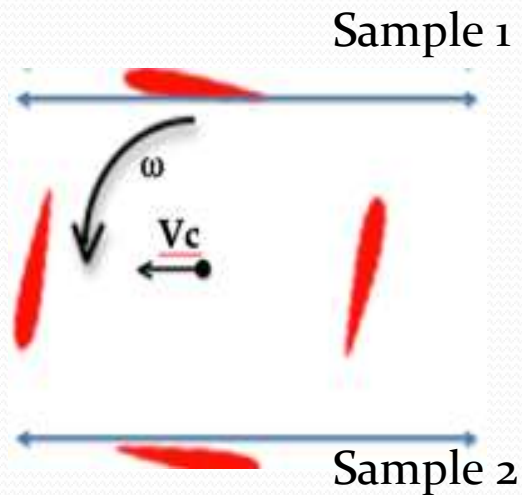


2. Synchronize clocks through acoustics

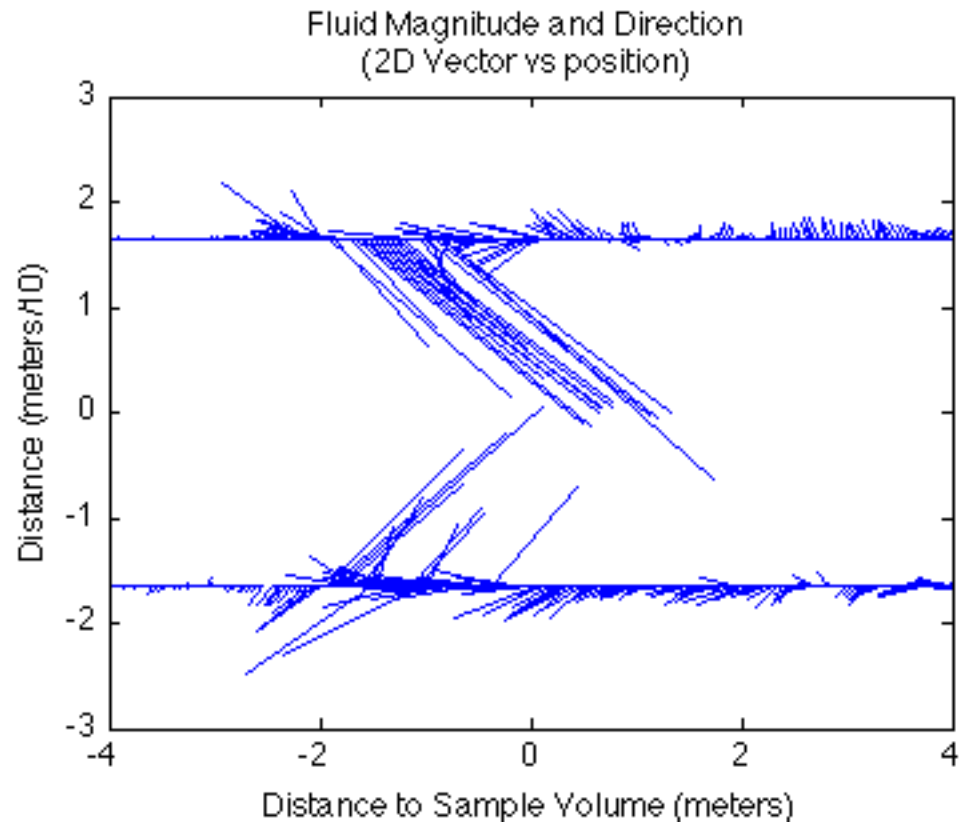
At time = 0



Method 2: Sample Data



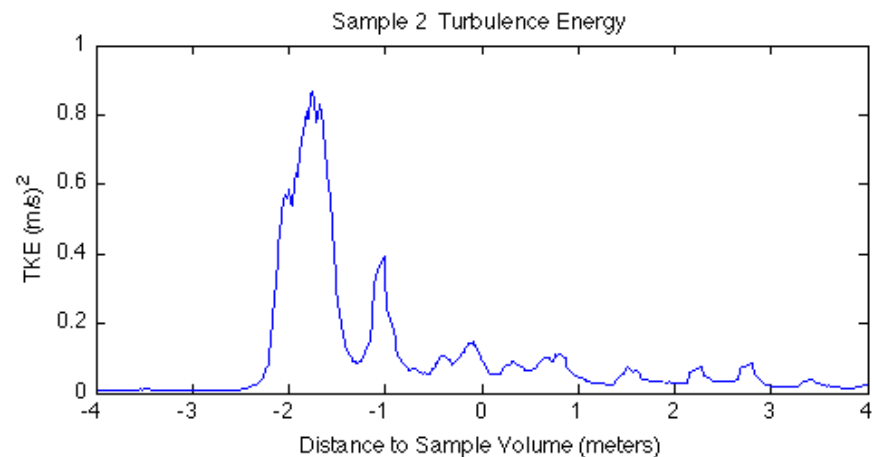
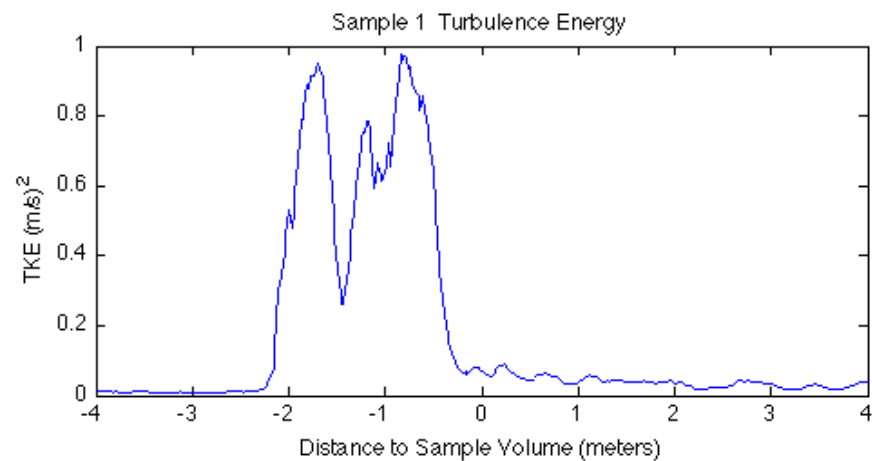
$V_c = 1 \text{ m/s}$
 $w \sim 1 \text{ rev/sec}$



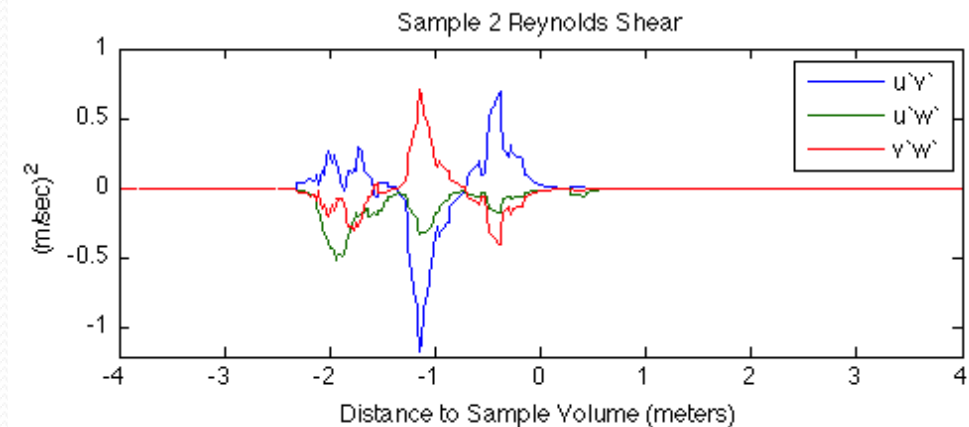
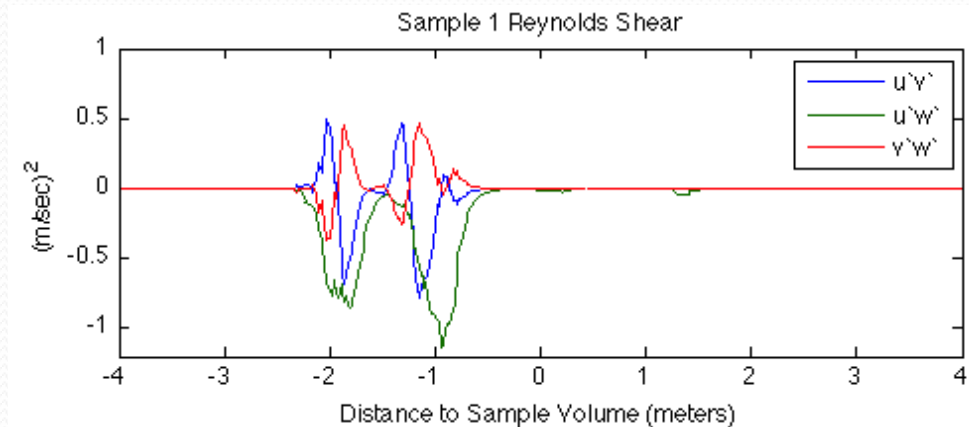
Note:
To obtain samples 1-2 blade are rotated 180° and turbine rotates clockwise direction

Derived Measurements

Turbulent Kinetic Energy



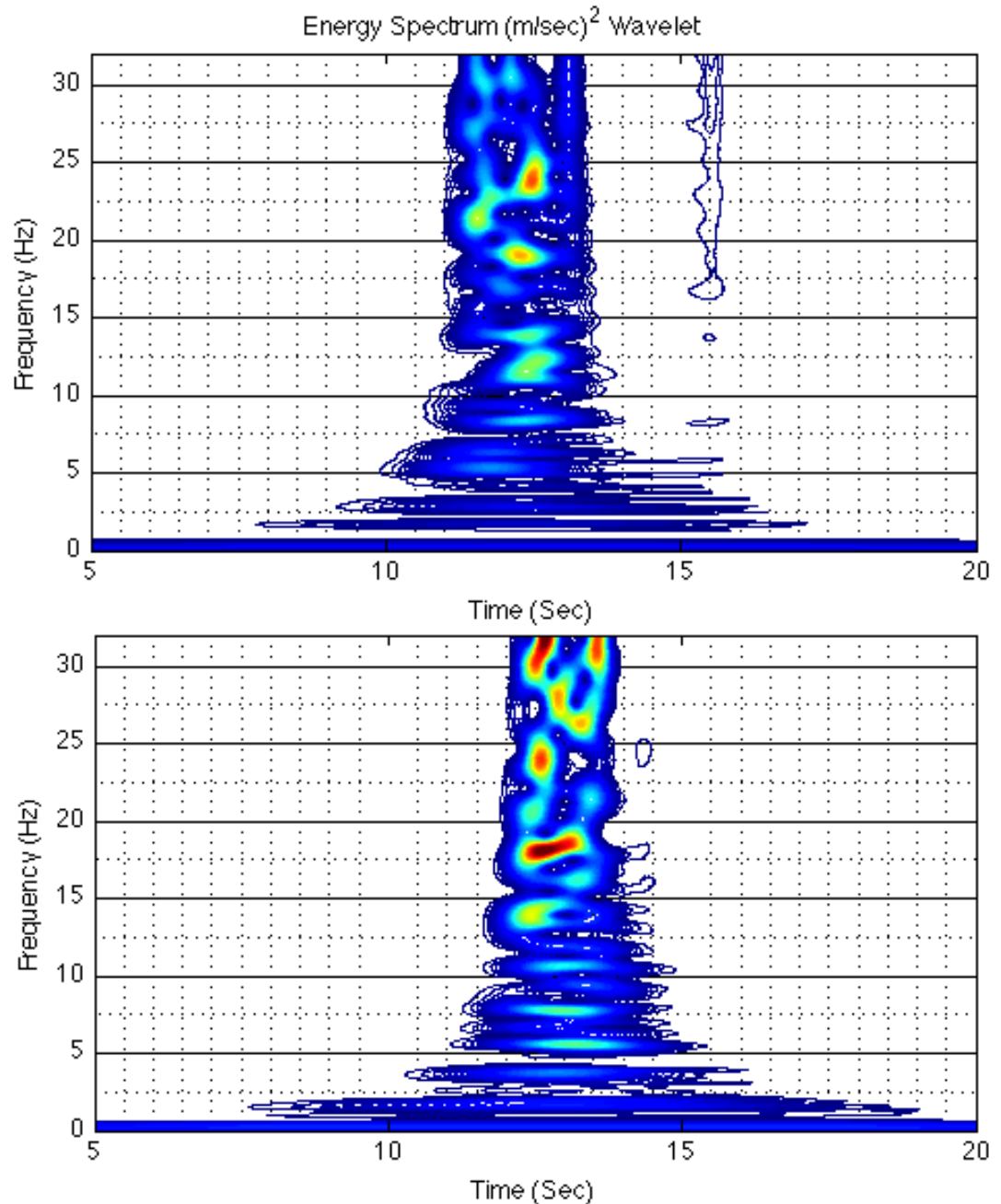
Low Frequency Reynolds Shear



Energy Spectrum

Wavelet

Energy represented
in time and
frequency Demand



Ongoing & Future Work

- Continue testing
 - Improve Synchronization
 - Obtain a complete data set
- Develop analysis
 - Compare model to measurements
- Measure the effect of blockage and free surface
- Utilize the water frontage at Maine Maritime Academy



Questions?