

Physical and Computational Modeling for Advancing Marine and Hydrokinetic Technology Development

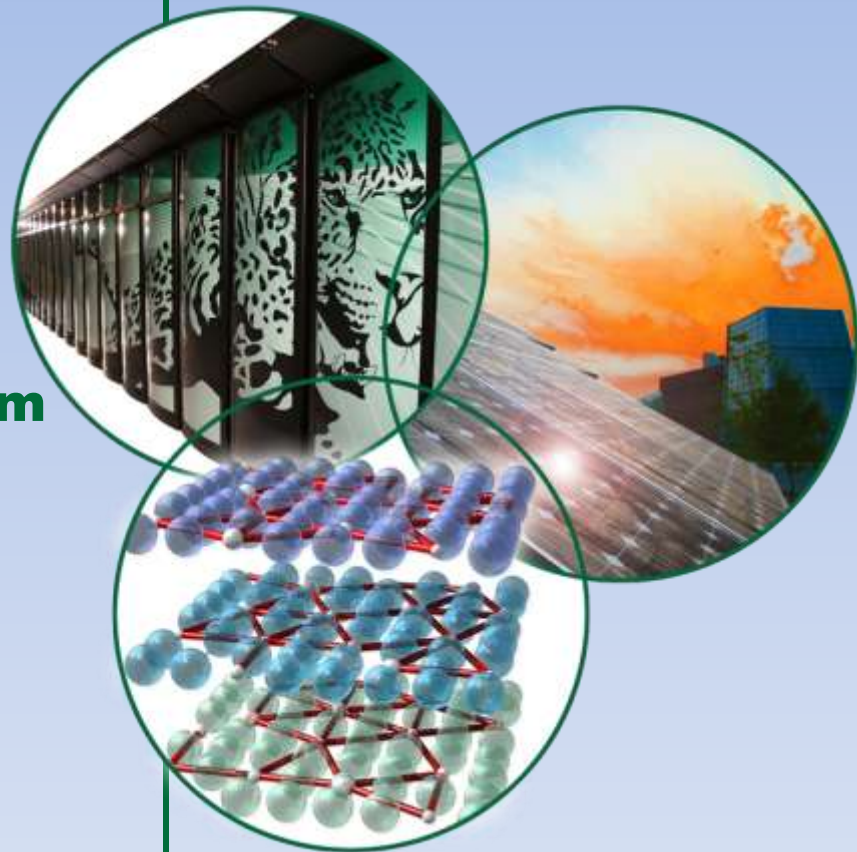
**Nortek USA Technical Symposium
Newport, RI
16-18 March 2011**

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In coordination with:

Fotis Sotiropoulos (SAFL)

Leonardo Chamorro (SAFL)



Oak Ridge National Laboratory

Tasks:

- Field Protocols Manual for MHK Site Flow Characterization (ORNL-PNNL)
- Acoustic Profiler Post-Processing Methods and MATLAB Code (ORNL-PNNL-SAFL)
- Acoustic Doppler Velocimeter (ADV) Post-Processing Methods and MATLAB Code (ORNL-PNNL-SAFL)

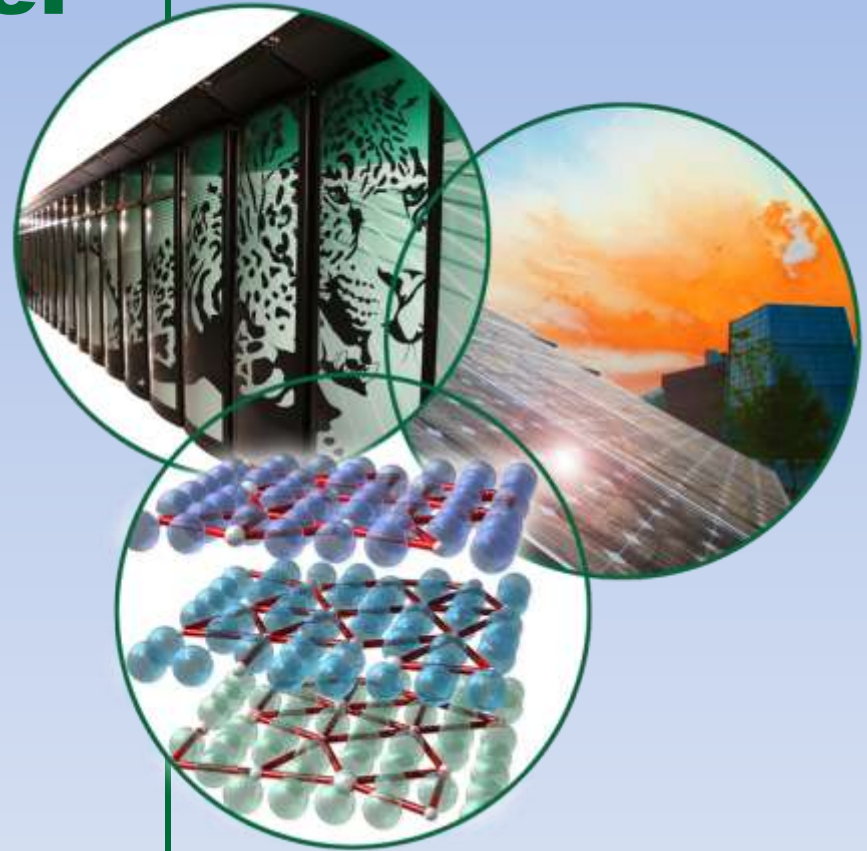
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Support for laboratory experiments:

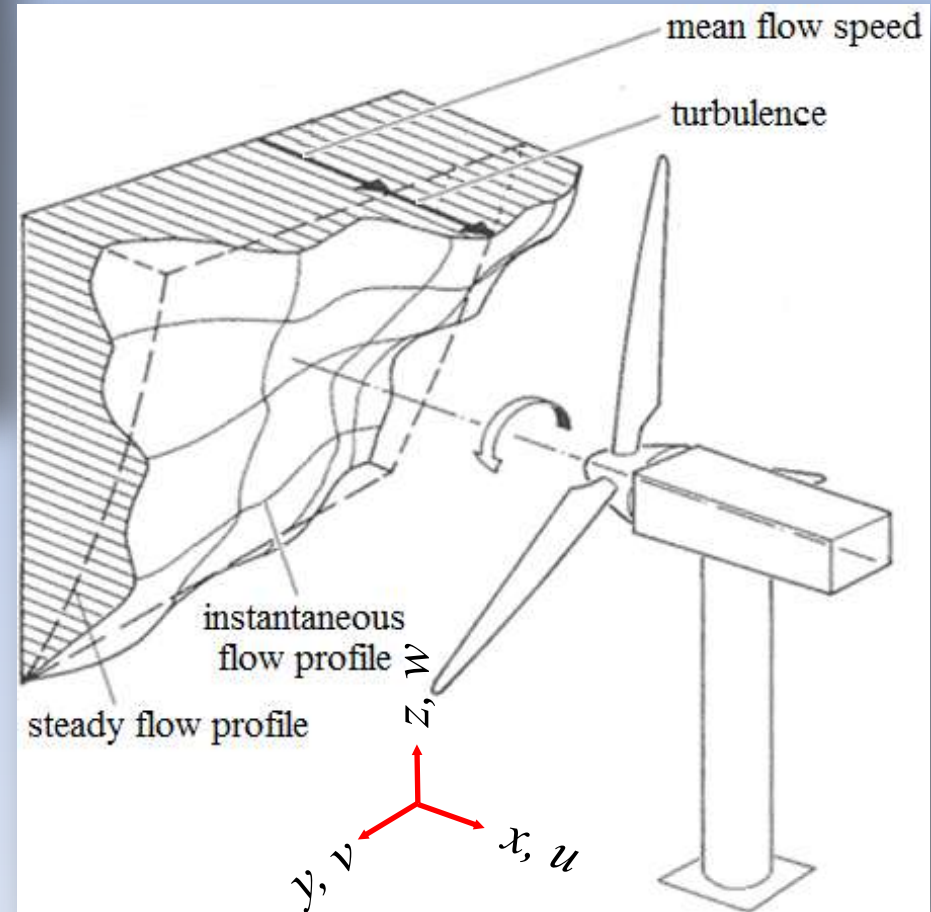
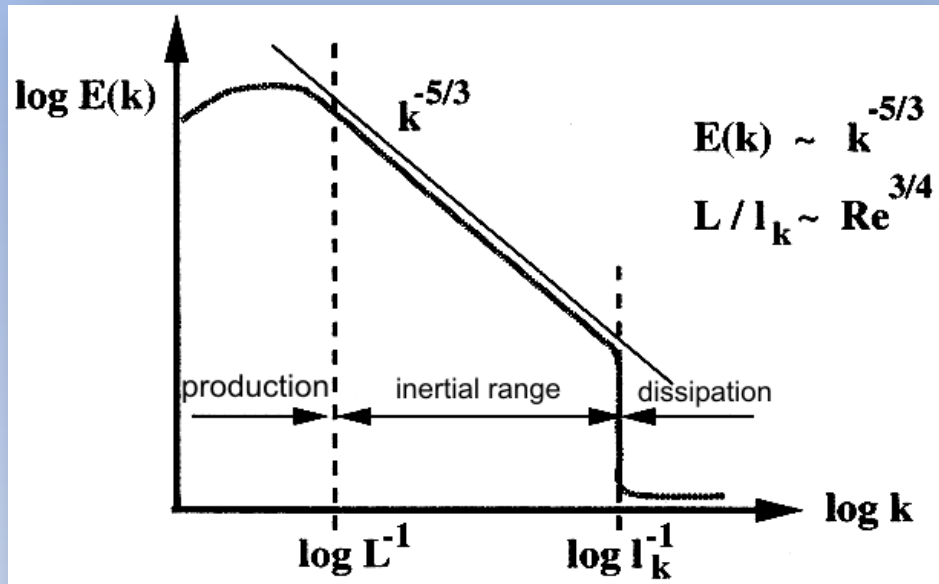
- Flow measurements (profilers, ADVs, ... PIV)
 - Numerical model validation
 - Unperturbed flows
 - Perturbed flows (wakes of instream structures, shipping vessels, waves)
 - Inflow and wake characterization
 - Power density, static and dynamic (unsteady) loads
 - Unperturbed flows
 - Perturbed flows (wakes of instream structures, shipping vessels, waves)
 - Lab and field protocols for acoustic measurements
 - For model development support (where, what, how, why?)
 - For resource characterization
 - Post-processing measurements

Resolving turbulence:

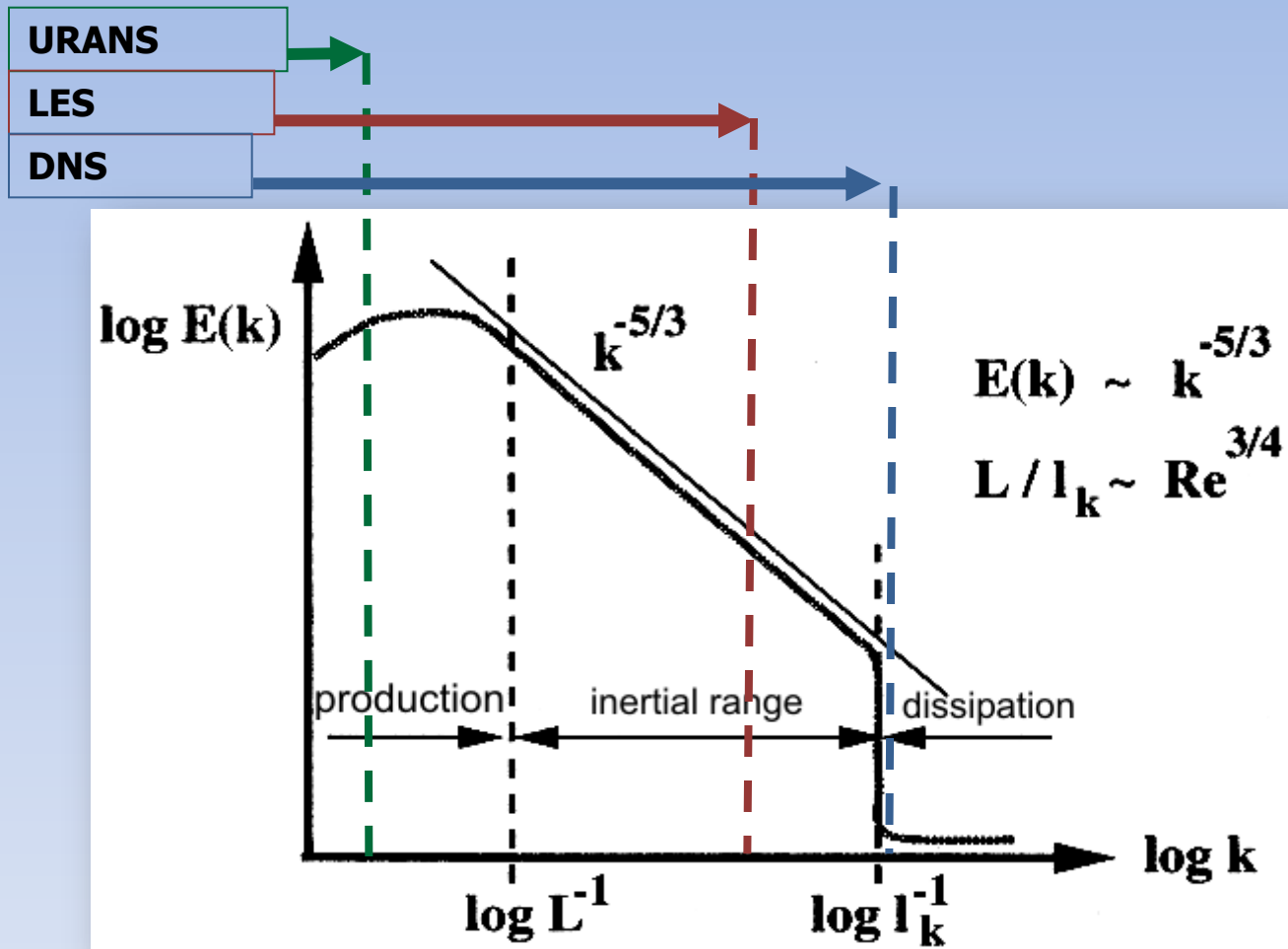
physical measurements
VS.
numerical simulations



What scales of turbulence matter?

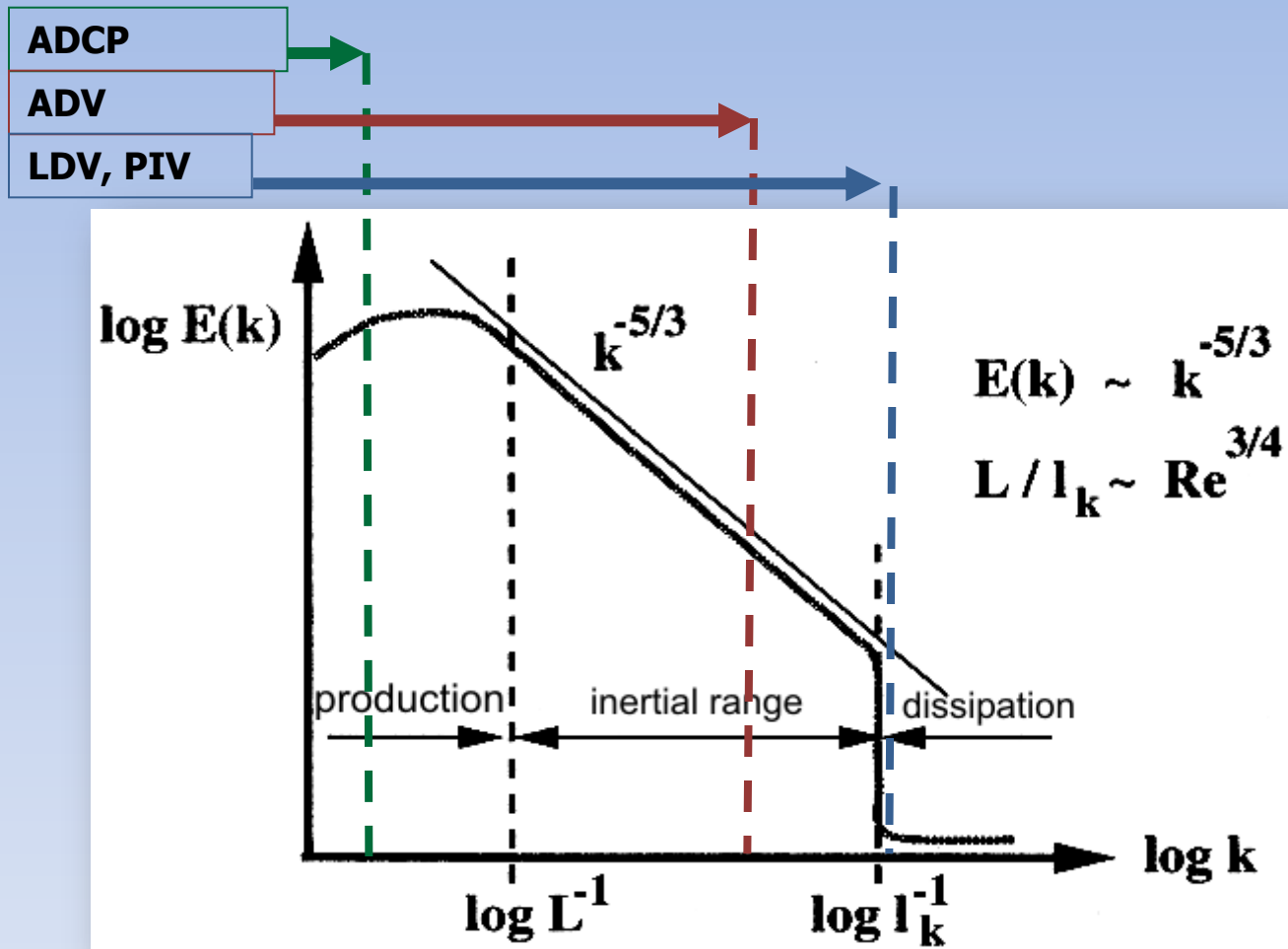


What scales can CFD models resolve?



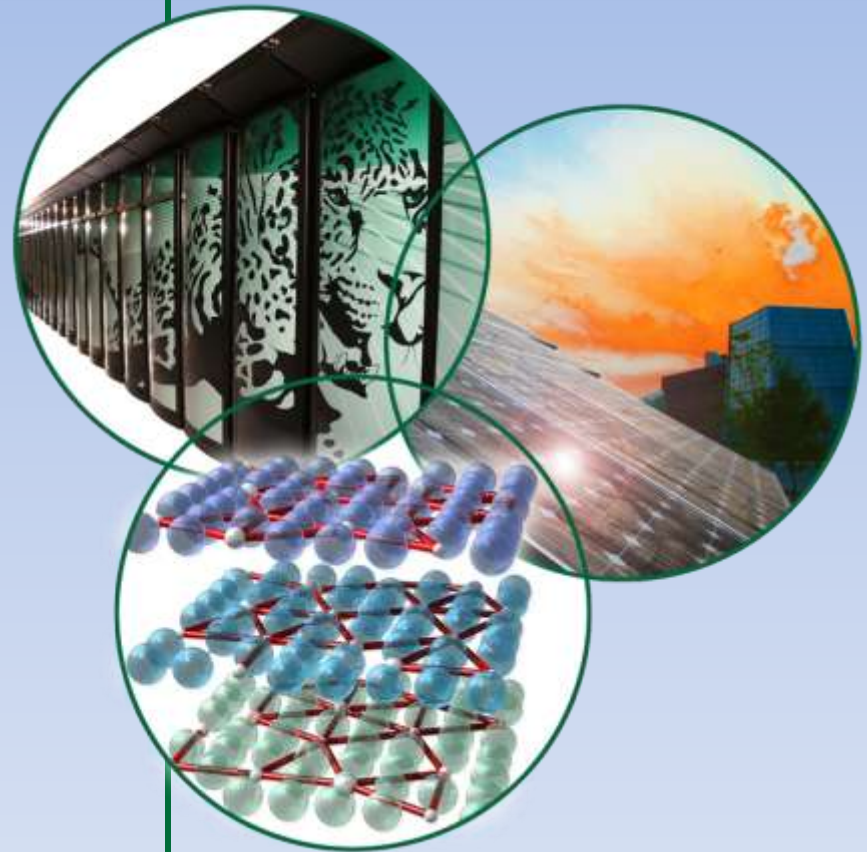
(by Thorsten Stoesser, Georgia Tech)

What scales can we measure?



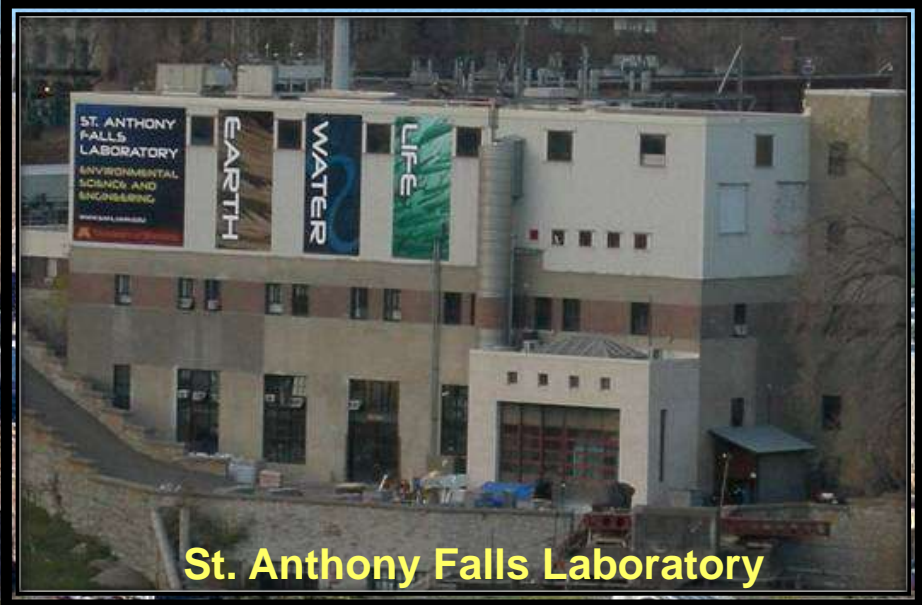
St. Anthony Falls Lab: Main Channel Flume Experiments

Developing an experimental test facility for Marine and Hydrokinetic machine and environmental impact research.



St. Anthony Falls Laboratory

Minneapolis, Minnesota, USA



St. Anthony Falls Laboratory

St. Anthony Falls

Mississippi River

St. Anthony Falls Laboratory

Experimental Research Opportunities

- Companies testing, planning testing or considering testing at SAFL;
 - Verdant Gen 5 turbine (TRL 7-9)
 - Marine Renewable Tech (TRL 5-6)
 - VIVACE (TRL 5-6)
 - ORPC (TRL 7-9)
 - DoE Reference Turbines (No IP concerns!!)
- Performance testing;
- Dynamic loadings from perturbed inflows;
- Environmental effects on hydrodynamics, bed morphology, fish passage.

SAFL Main Channel Specifications

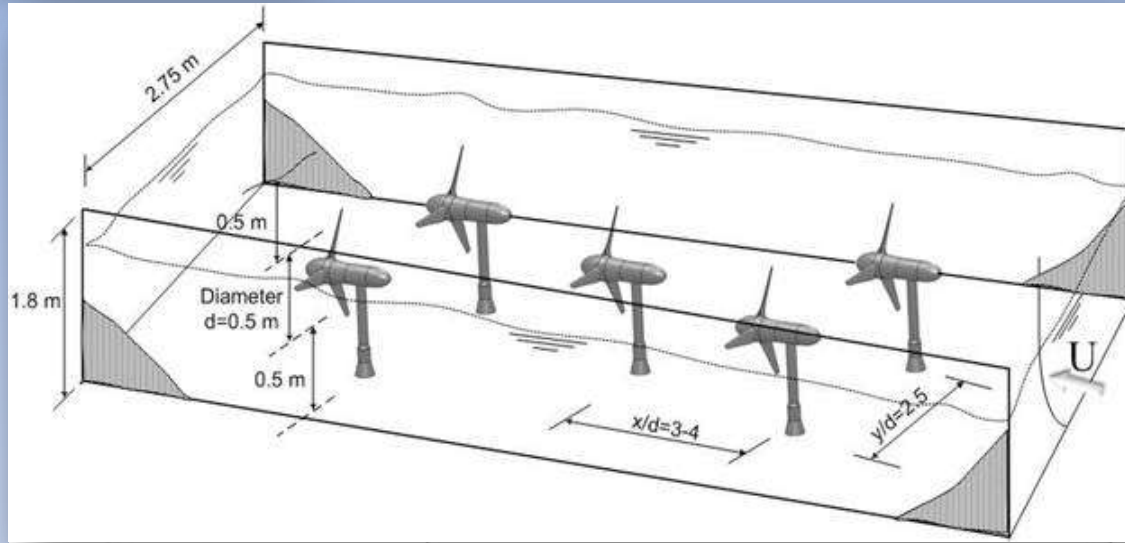


Channel	Value	Unit
Width	2.75	m
Length	85	m
Depth	1.8	m
Slope	Variable	

Hydraulics	Value	Unit
Flow Range	0-8.5	m ³ /s
Wave height	0.05-0.6	m
Velocity	3.5	m/s
Wave length	0.6-12	m
Available ponded depth	1.4	m

Sediment Transport	Value	Unit
Transport size range	1-40	mm
Sediment recirculation	0-3	kg-dry/sec
Flux monitoring drums	5	
Flux monitoring rate	1	Hz

Verdant: Experimental Setup

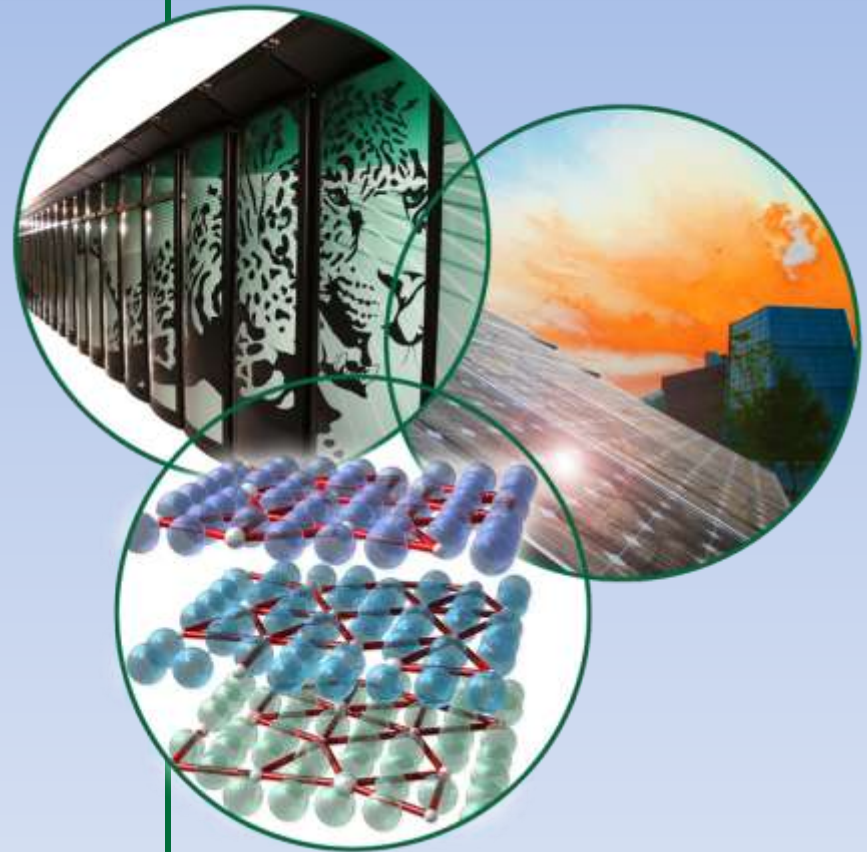


- Flow depth = 1.15 m
- $H_{\text{hub}} = 0.425 \text{ m}$
- $U_{\text{hub}} = 0.5 \text{ m/s}$
- Tip speed ratio $\lambda \approx 4.5 \pm 0.2$

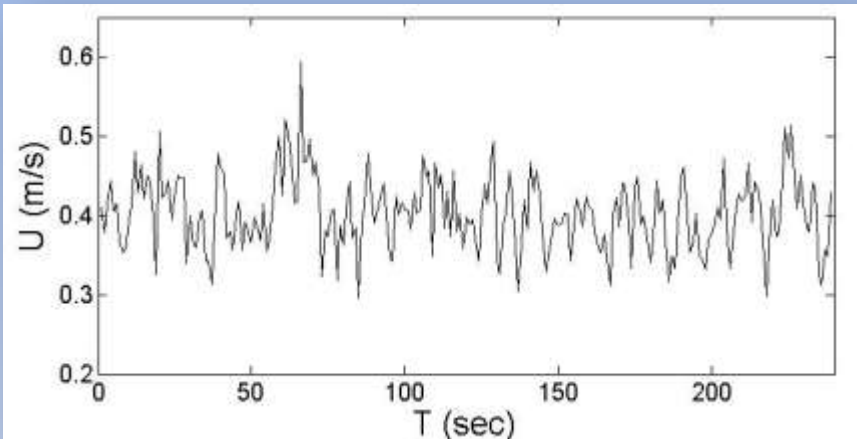


Preliminary Measurements: December 2010

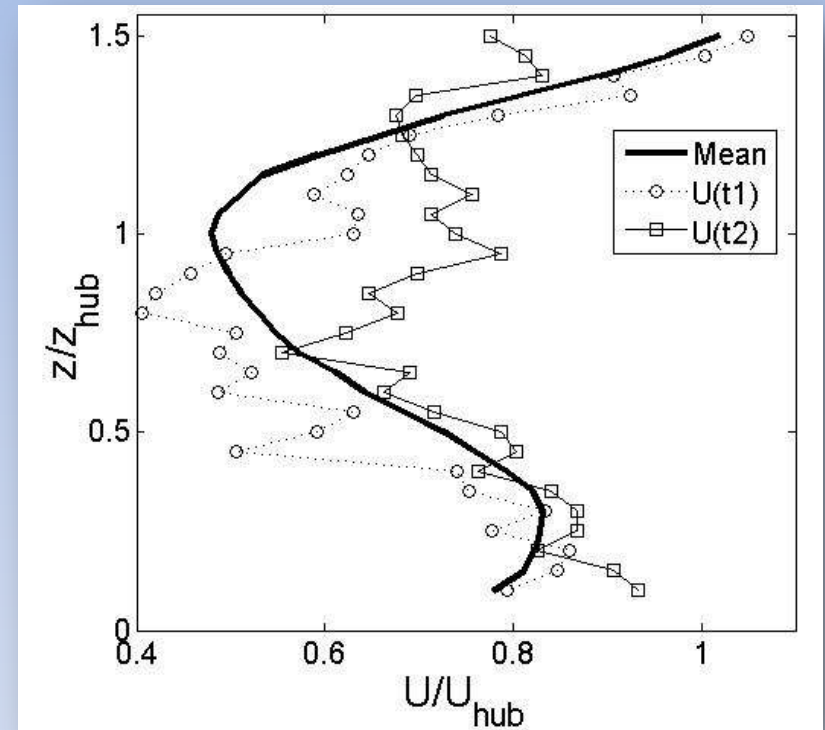
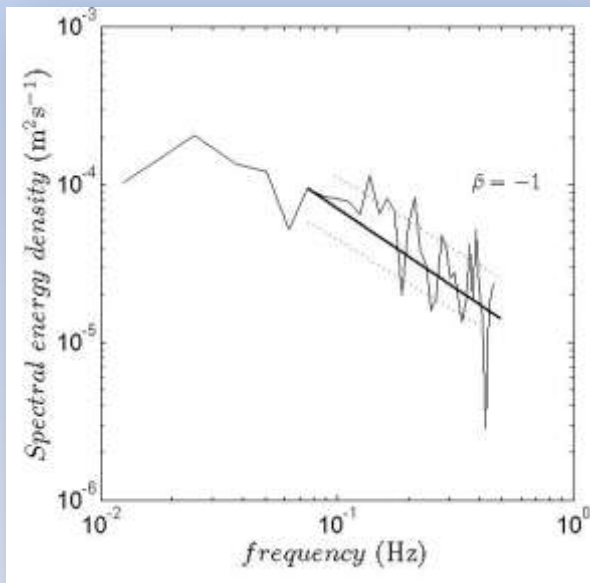
Inflow and wake measurements.



Velocity measurements: AquaDopp profiler

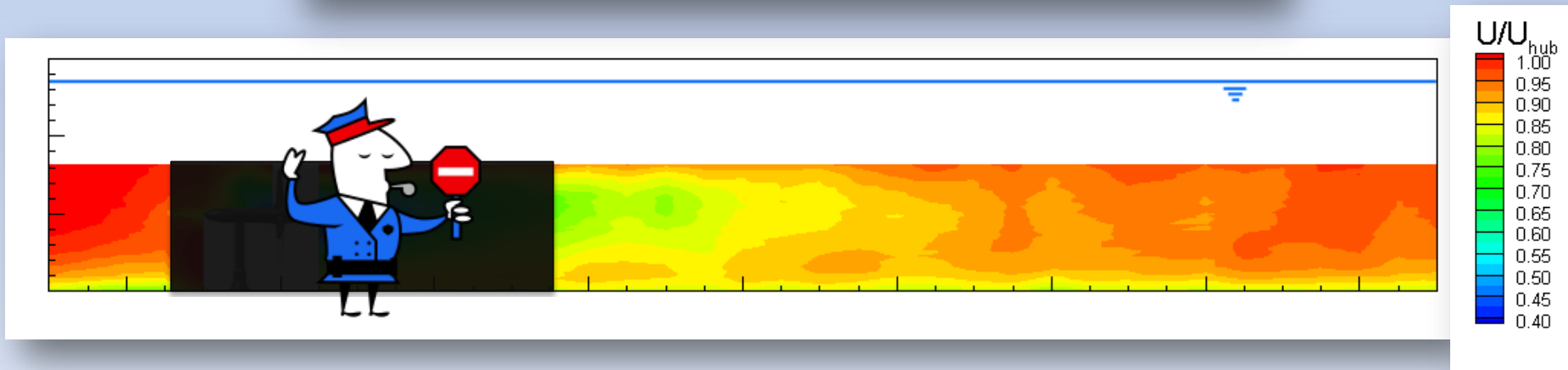
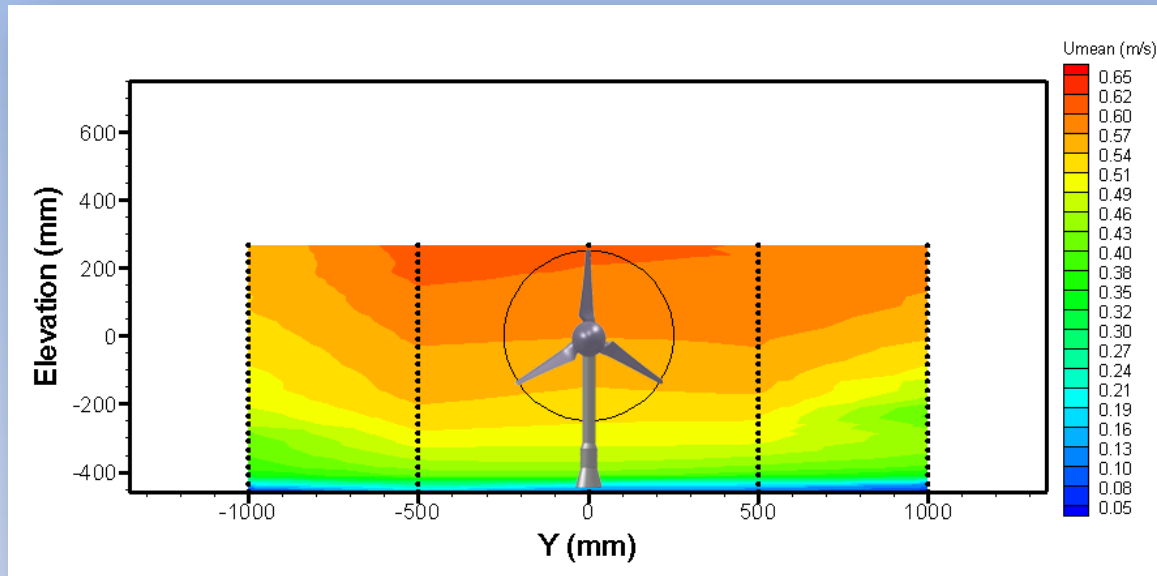


Instantaneous velocity signal



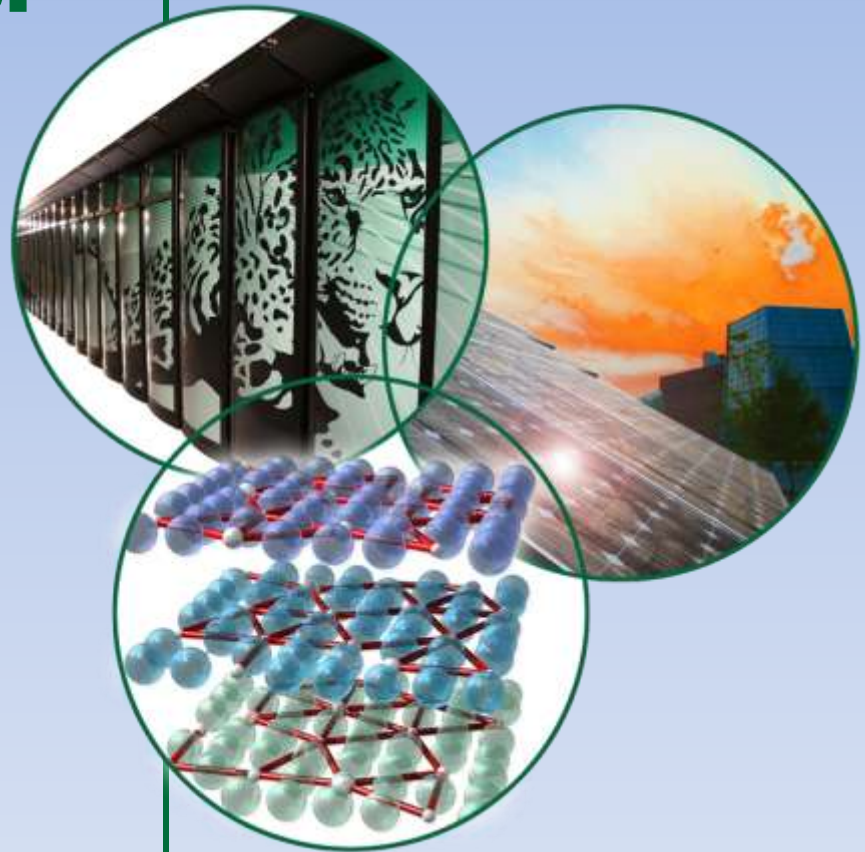
Instantaneous and mean velocity

Inflow and Wake measurements

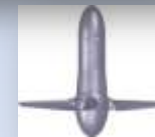
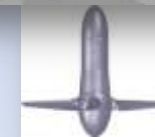
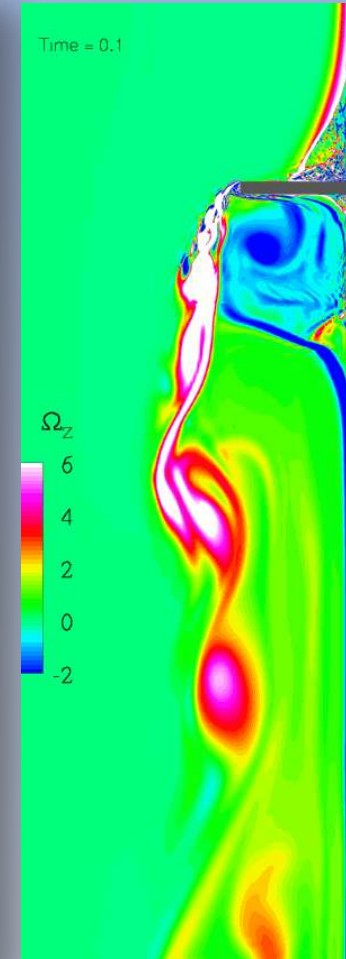
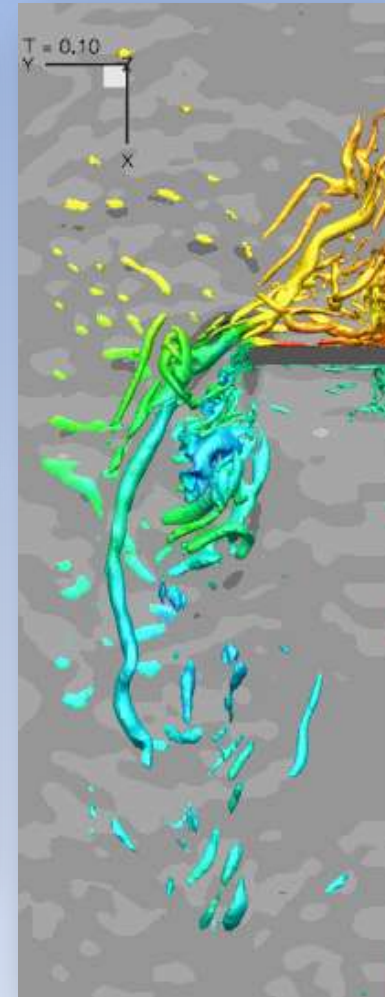
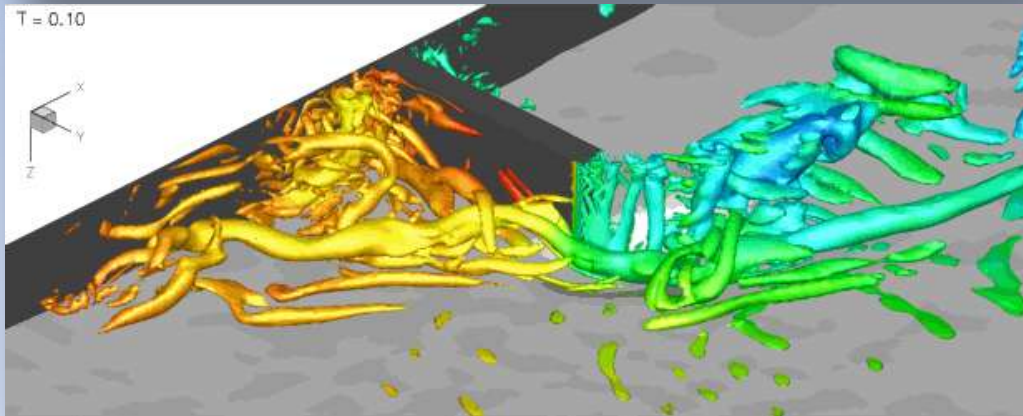
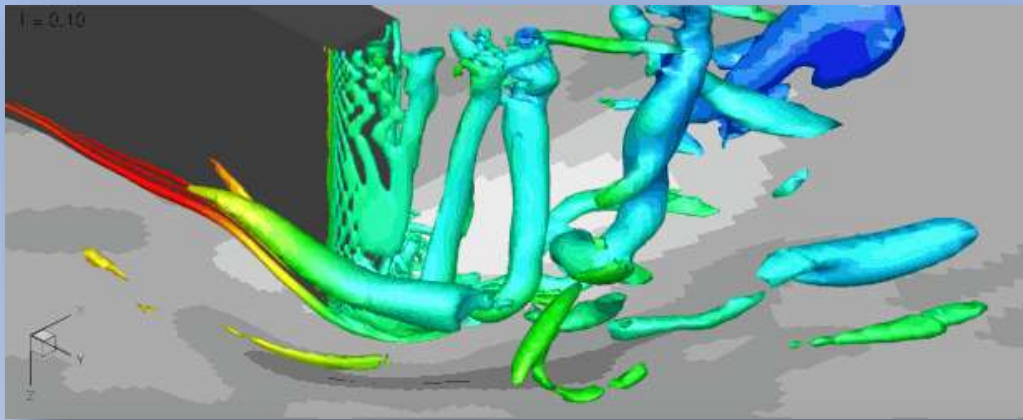


Harsh Environments: Dynamic loading from perturbed inflows

Spring 2011



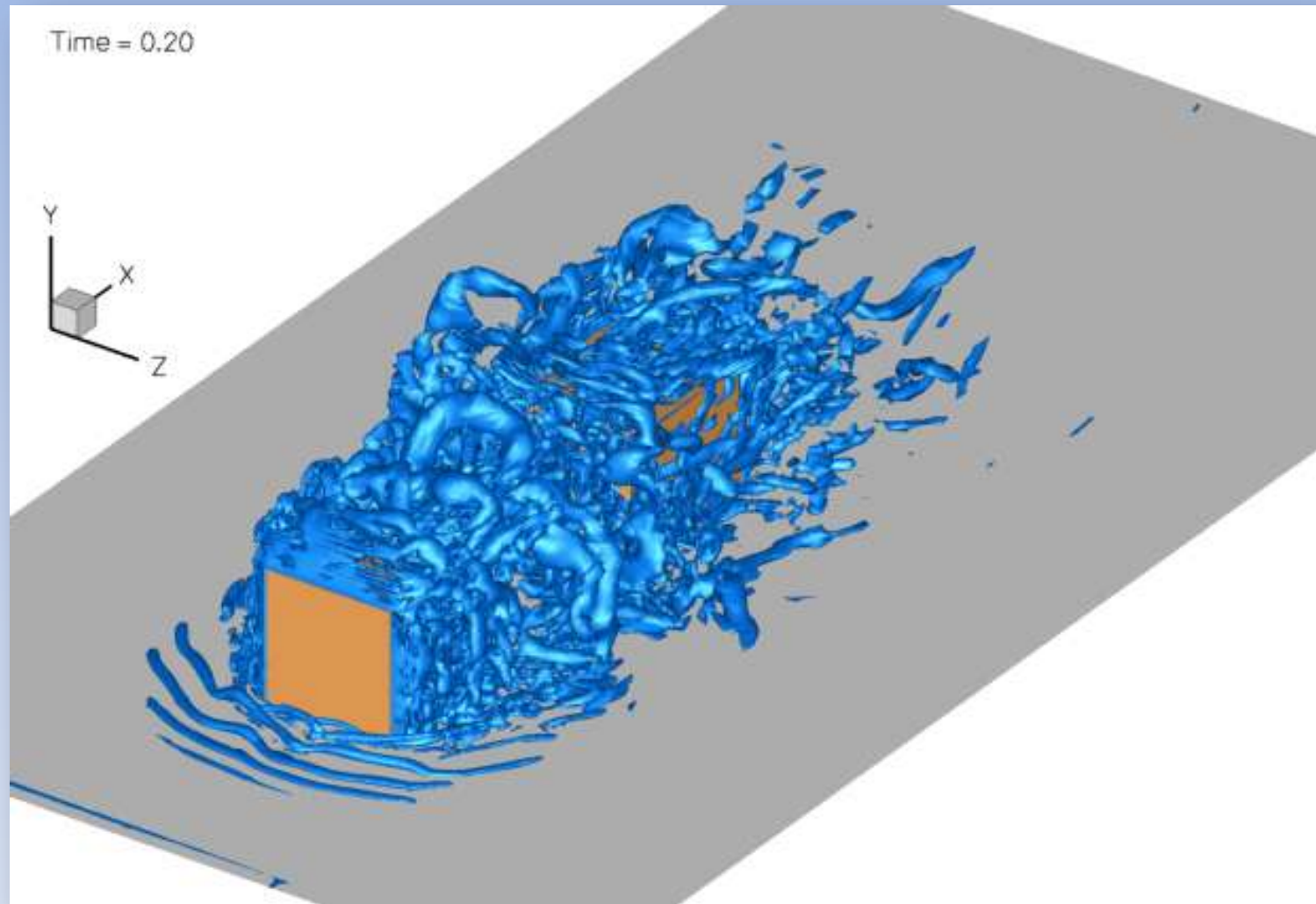
Bridge Abutments



Paik, Escauriaza & Sotiropoulos, ASCE JHE 2010

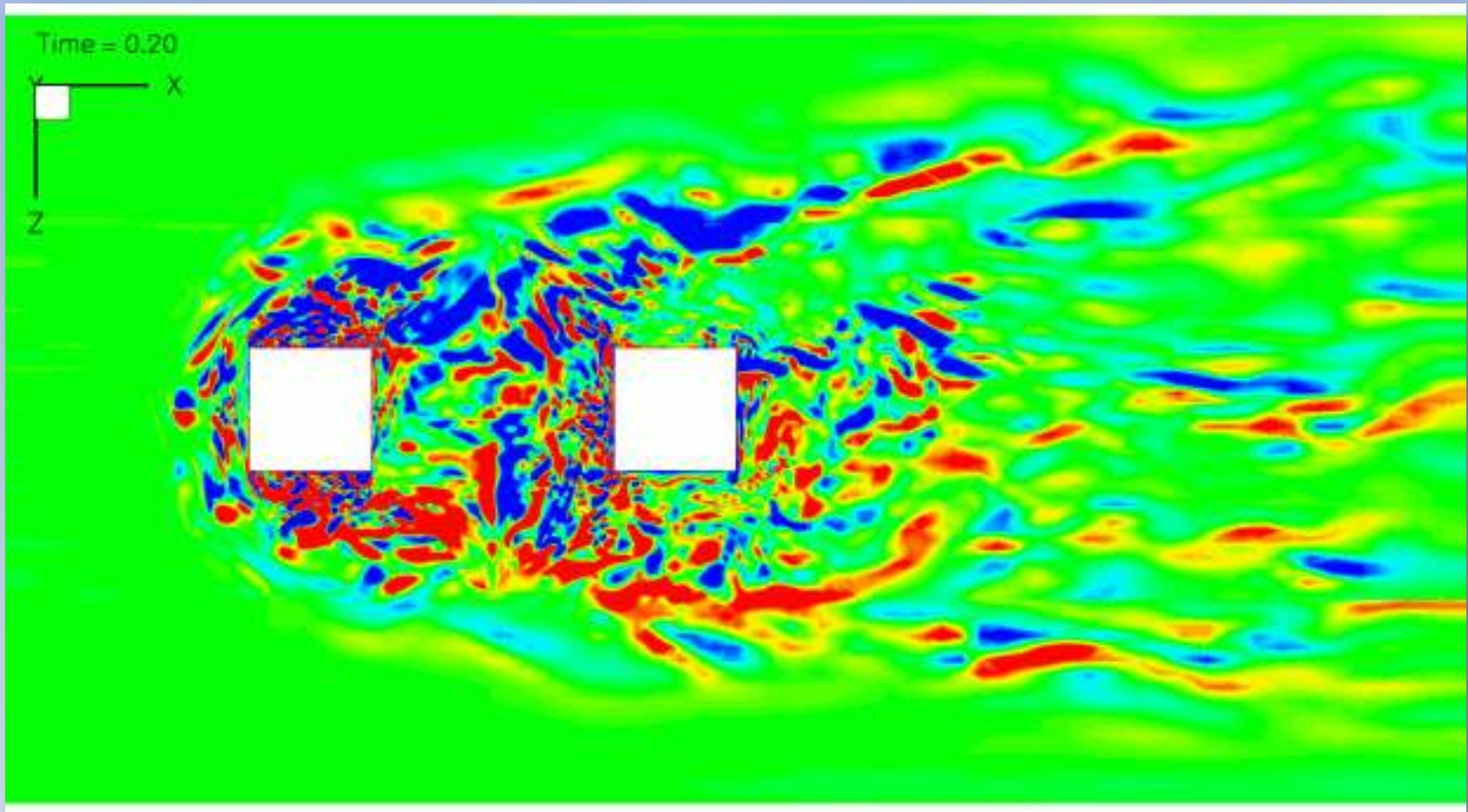
Paik & Sotiropoulos, Ph. Of Fluids, 2006

Instream structures (e.g. Boulders)



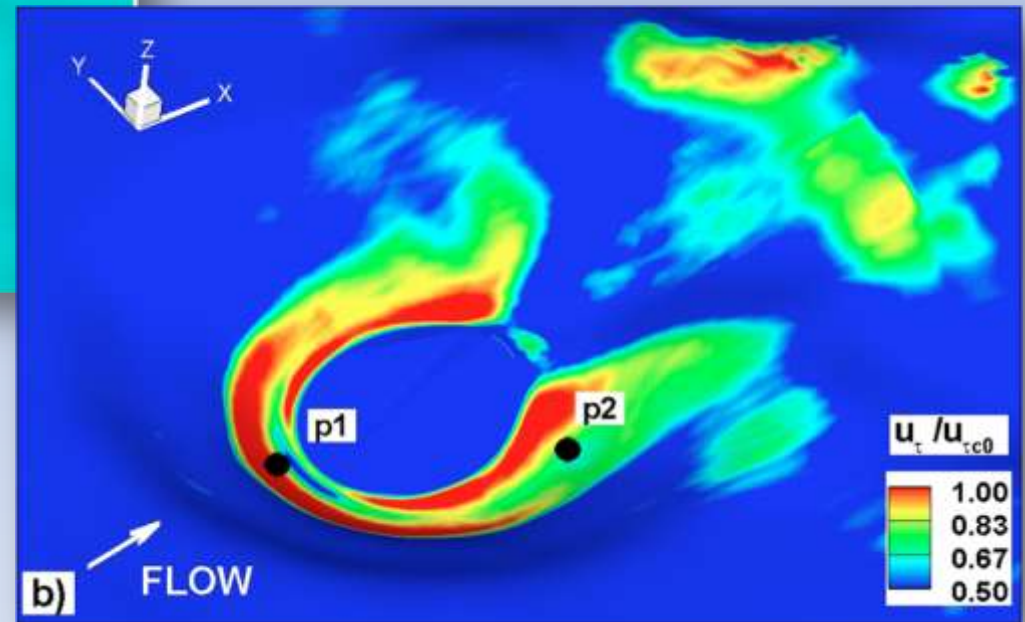
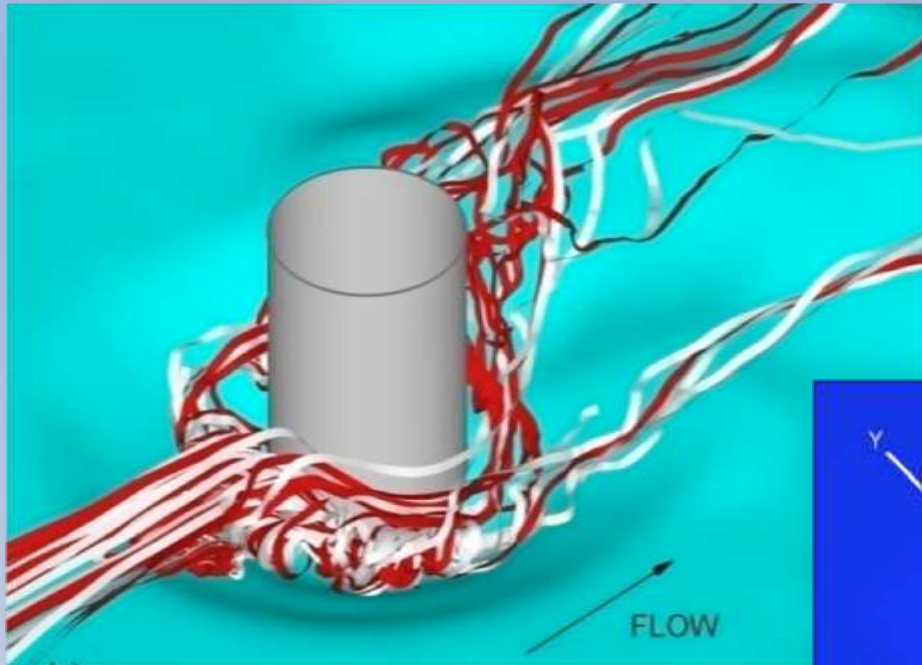
Paik et al., Int. J. Heat & Fluid Flow, 2009

Instream structures (e.g. Boulders)



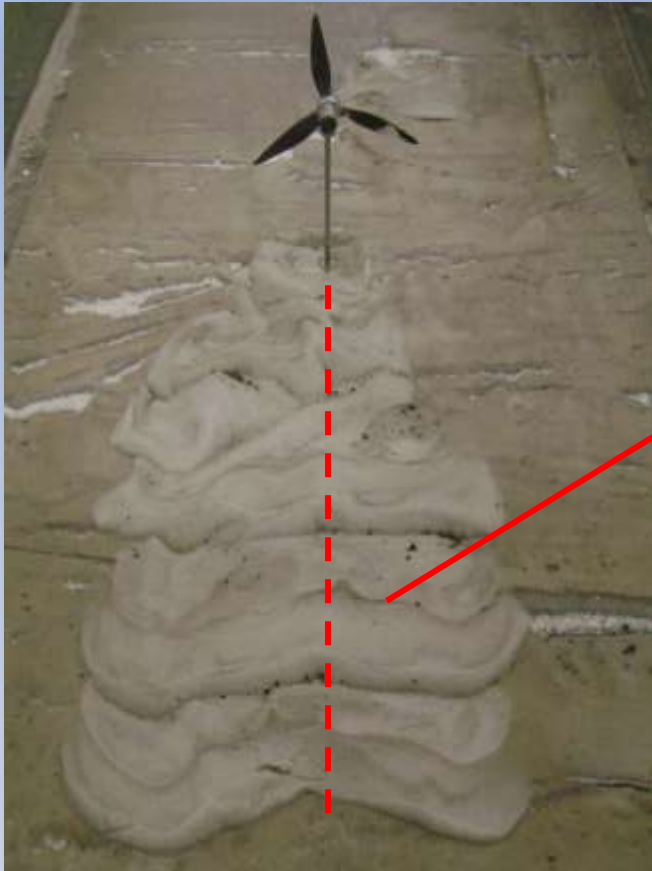
Paik et al., Int. J. Heat & Fluid Flow, 2009

Hydrodynamics and Morphodynamics around MHK towers



Neary et al., J. Hydraulic Engineering., *In Review*

Hydrodynamics and Morphodynamics downstream of MHK devices:



(Chamorro, 2011)



- Sediment resuspension and transport in the wake of hydrokinetic turbines.
- Effects on downstream turbines?

Vortex shedding from MHK devices



(S. Kang & F. Sotiropoulos, SAFL)

Leveraging other DoE Lab Expertise and Resources for SAFL Experiments

- Instrumenting machines to measure dynamic loadings, stresses and strains on machine;
- DoE Reference turbine testing;
- EFDC far field model validation;
- LES turbine array;
- PSU wake field modeling;
- PNNL sensor fish testing;
- Real fish (larvae)-machine interaction testing.



Thank You!
Questions?

