Ocean Engineering Group (OEG)/EWRE

(August 24, 2017)

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(Offshore Technology Research Center)

(Google: Kinnas Home Page – check courses and OE Theses/Dissertations)

***Research* in the area of *computational hydrodynamics* with applications on the prediction of performance and design of high-speed marine *propulsors* or *turbines*, modeling of *cavitating* or *separated flows*, and *wave/body interaction*.**

Teaching:

- ***CE358: Introductory Ocean Engineering (Fall '17 - 11-12:30, Tu & Th)***
- ***CE319F: Elementary Fluid Mechanics***
- ***CE380P.4: Boundary Element Methods (Fall '17 - 12:30-2:00, Wed & Fri)***
- ***CE380T: Computational Environmental Fluid Mechanics (Spring'18 – tent.)***
- ***CE397-32: Theory of Propellers and Turbines (Fall '18 – tent.)***

Facilities:

- ***CHL (Computational Hydrodynamics Laboratory) in ECJ 8.502***

Fuel-Efficient marine propulsors …

Must comply with new EEDI (Energy Efficiency Design Index) regulations on CO_2 emissions from newly built ships

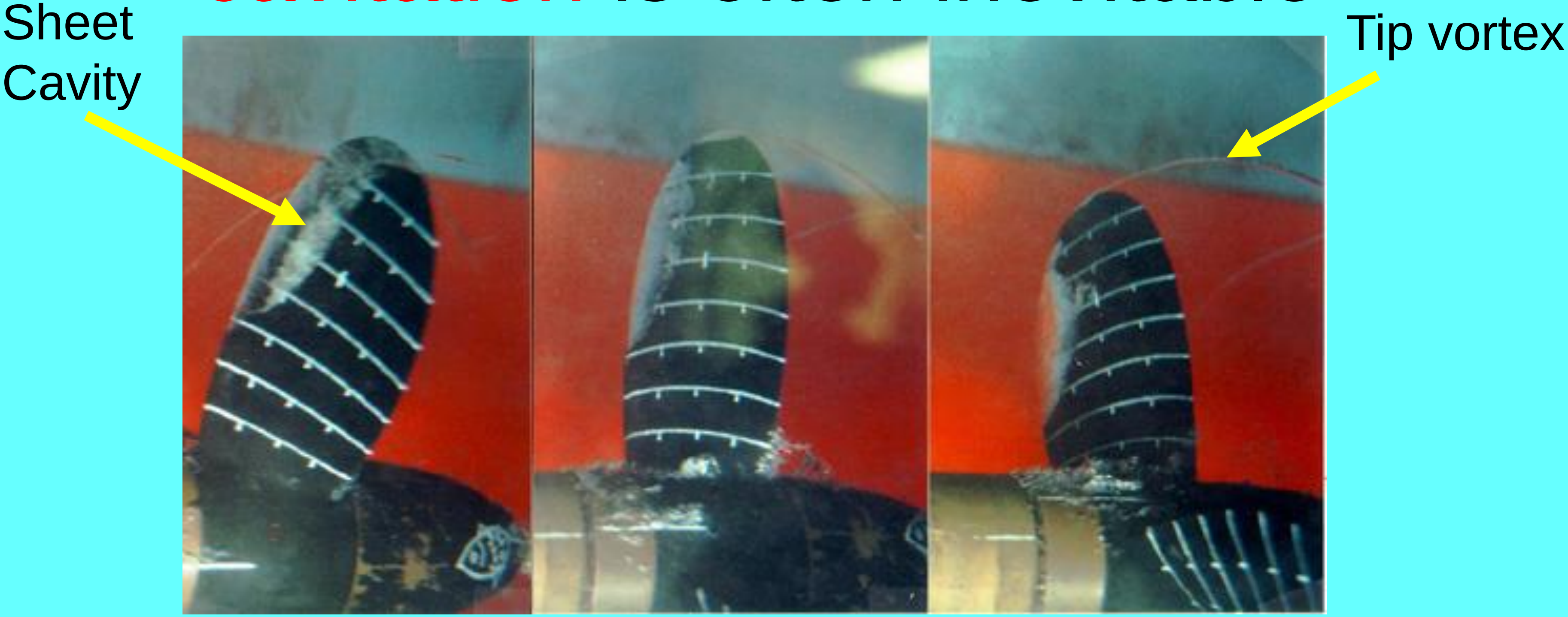
Contra-rotating props

Ducted prop

…and some water-turbines (used to generate energy from ocean currents)

Twin turbines (each 0.6 MW) pulled out of the sea for maintenance

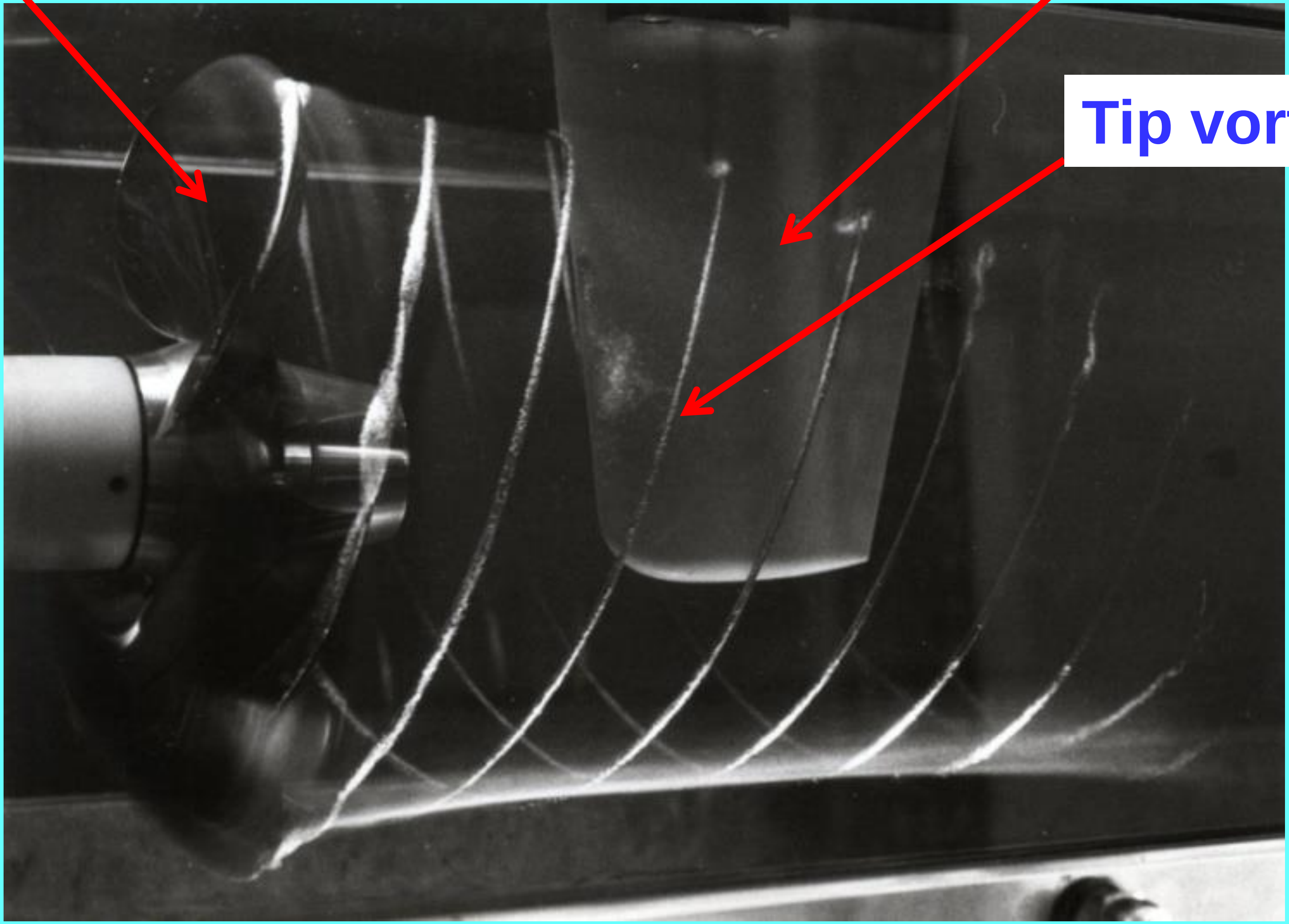
For high-speed propellers cavitation is often inevitable



- **Cavitation can accelerate erosion of blades, produce noise, or result in sudden loss of thrust**
- **However, allowing for some cavitation can increase efficiency**

Rotating components interacting with stationary ones

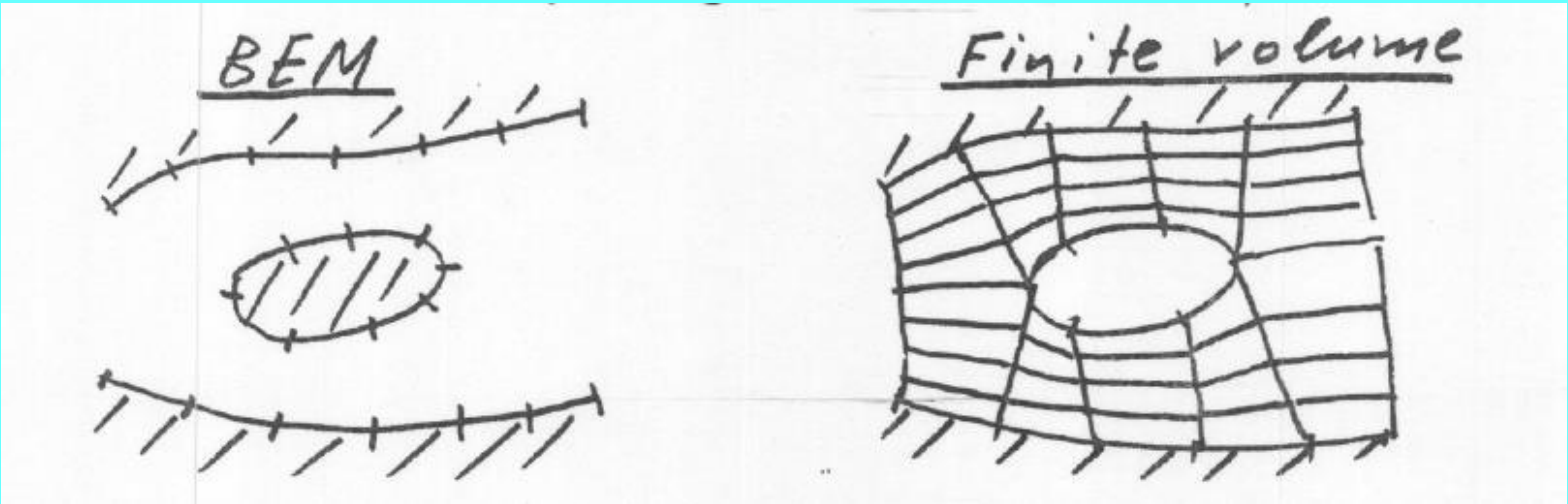
(propeller) (rudder)



Two methods to model flow

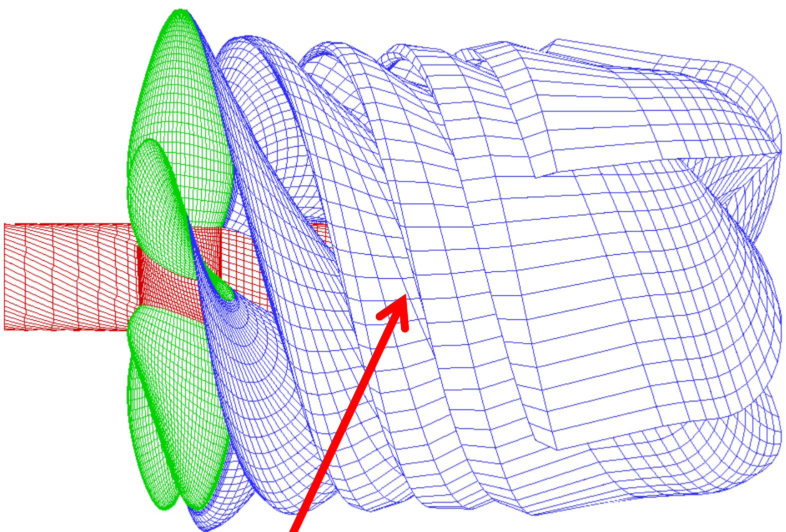
Boundary Element (or Panel) Method (addressed in CE380P.4)

Finite Volume Method (addressed in CE380T)

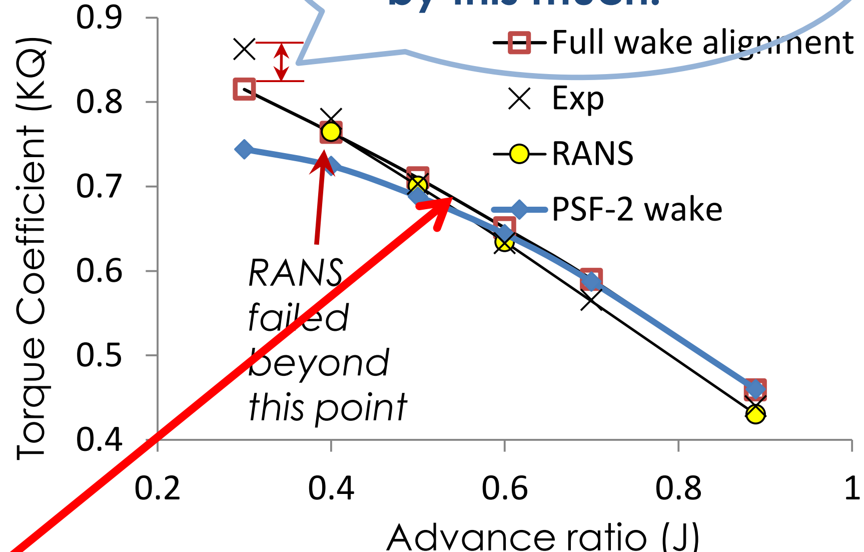


- **BEM can only handle the inviscid part of the flow (i.e. NOT very close to boundaries). The effects of viscosity are included via coupling with integral boundary layer methods**
- **FVM needs a very large number of cells to resolve the whole domain (especially the boundary layer) within acceptable accuracy**

Prediction of Propeller Performance at High Loading (Tian & Kinnas, Int. Journal of Rotating Machinery, 2012)



We want a model which can improve our existing method by this much!

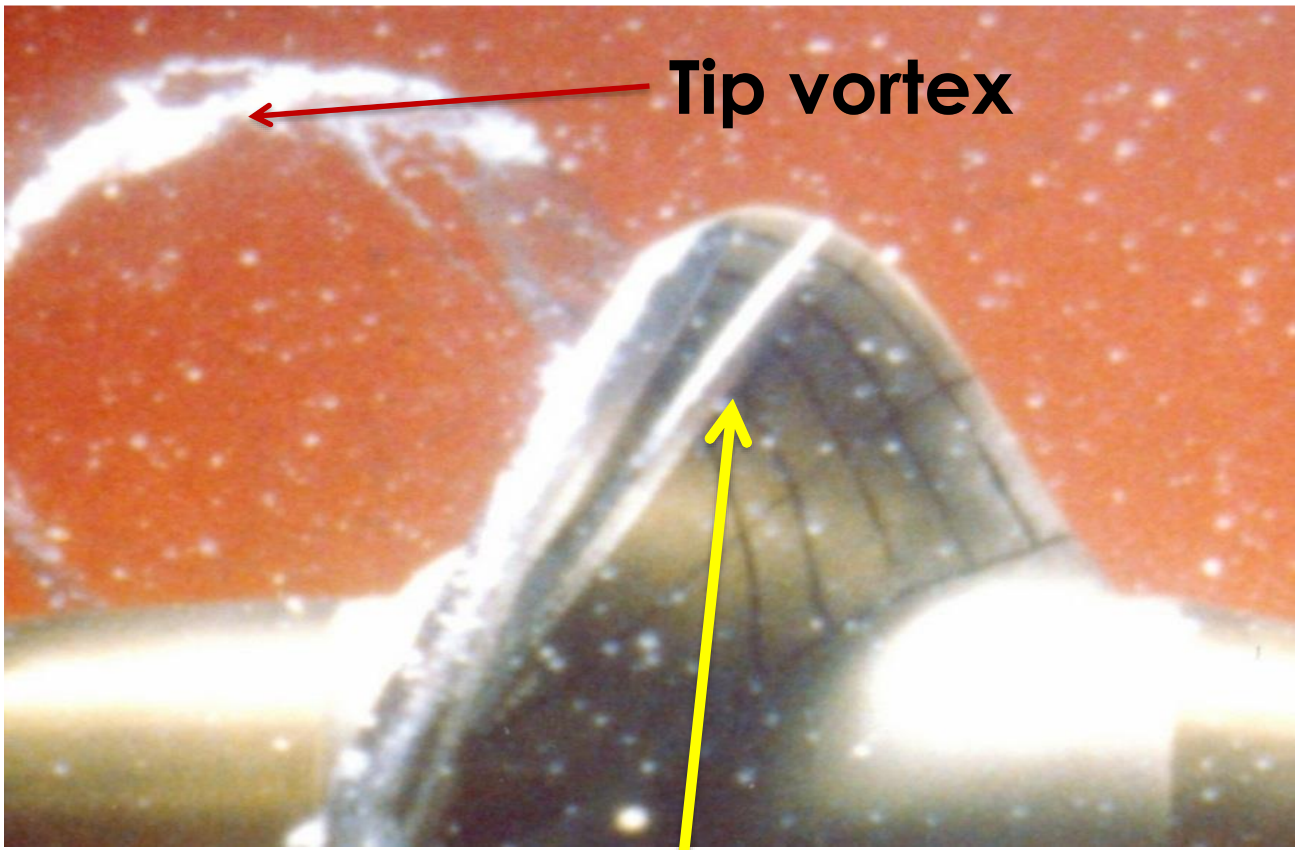


Correct position of "force-free" trailing wake improves prediction of performance

Panel method : 5 mins on a Laptop

RANS: 8 hrs on 24 CPUs.

A VIScous Vorticity Equation (VISVE) Model for Propeller at Off-Design with Leading Edge Vortex (LEV)



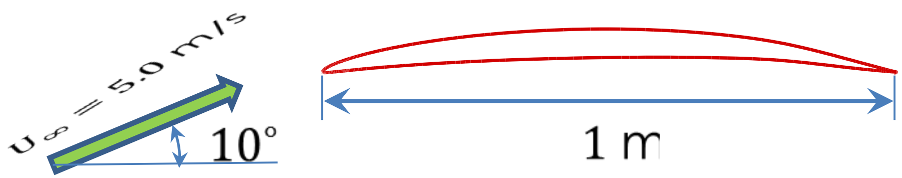
Tian, PhD
OEG/UT 2014

Tian & Kinnas;
SMP'15

Leading edge vortex (LEV)

NEW METHOD FOR EVALUATION OF LE SEPARATION

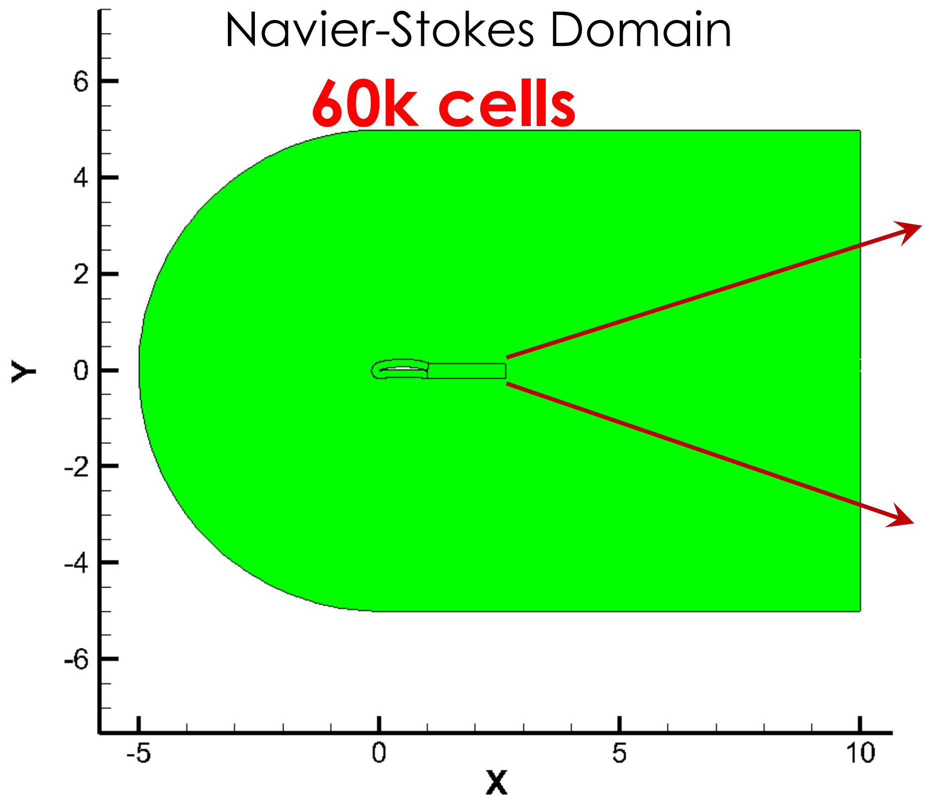
- **2D hydrofoil at high angle of attack**



$Re = 5 \times 10^4$

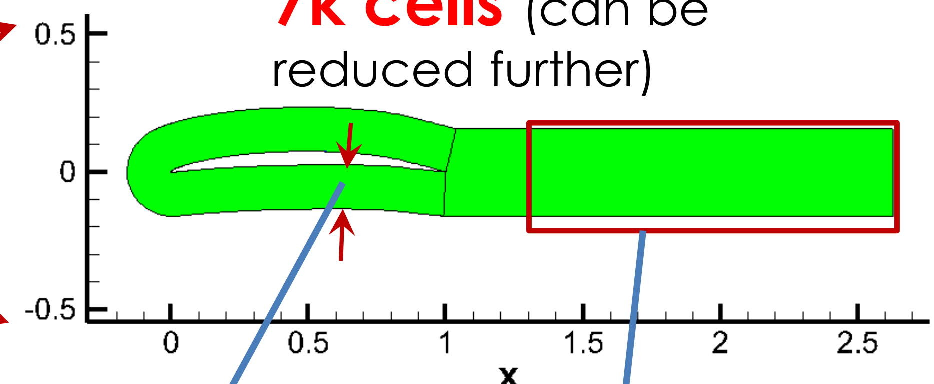
Navier-Stokes Domain

60k cells



VISVE Domain

7k cells (can be reduced further)



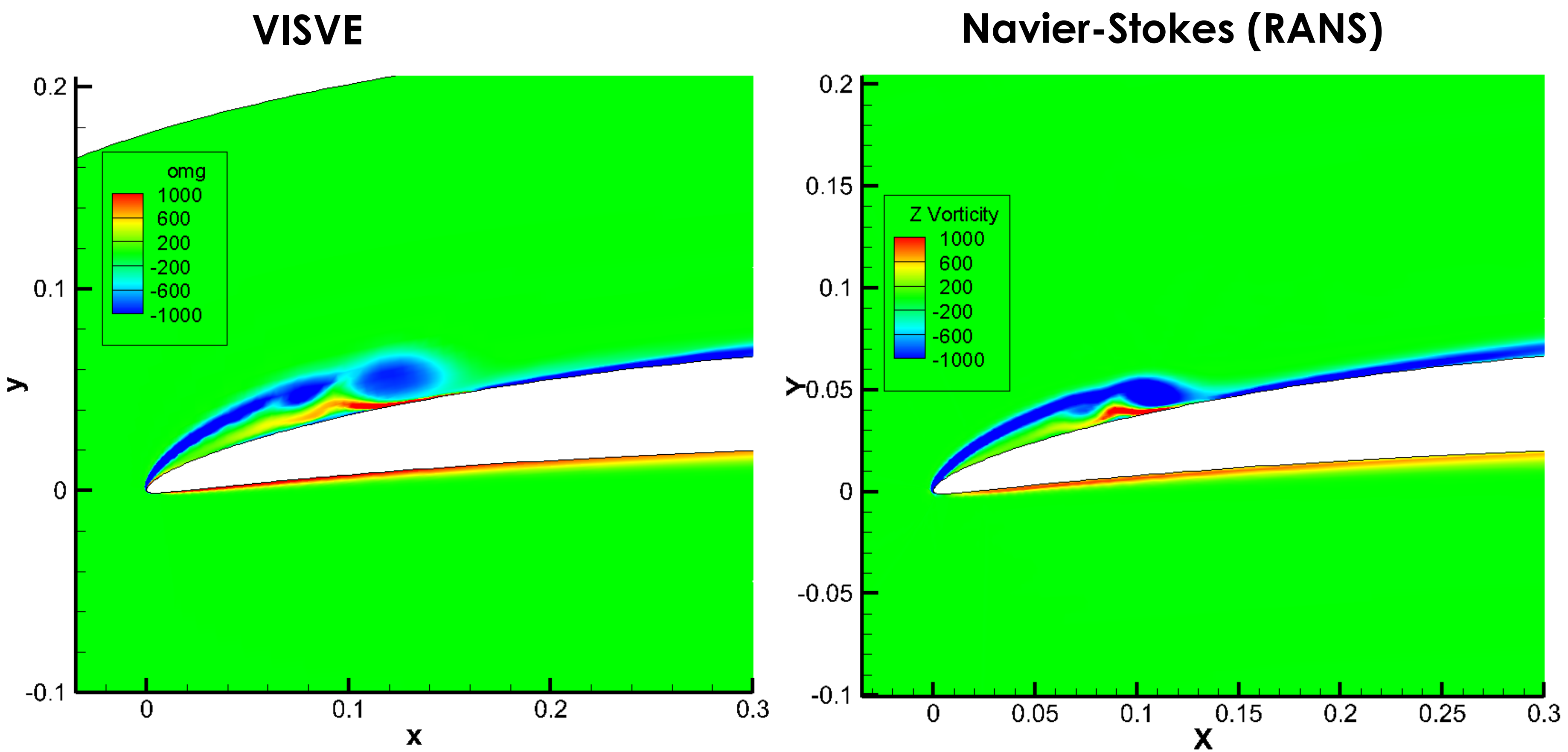
# of layers of cells can also be reduced.

This region is NOT necessary and will be replaced.

RESULTS

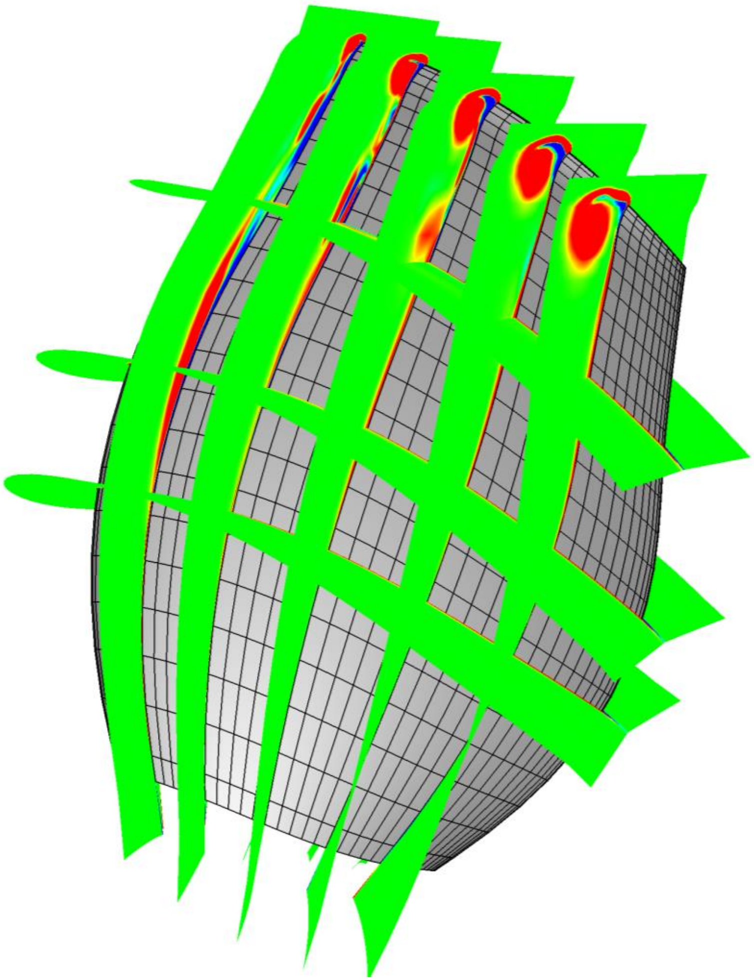
- **2D hydrofoil at high angle of attack**

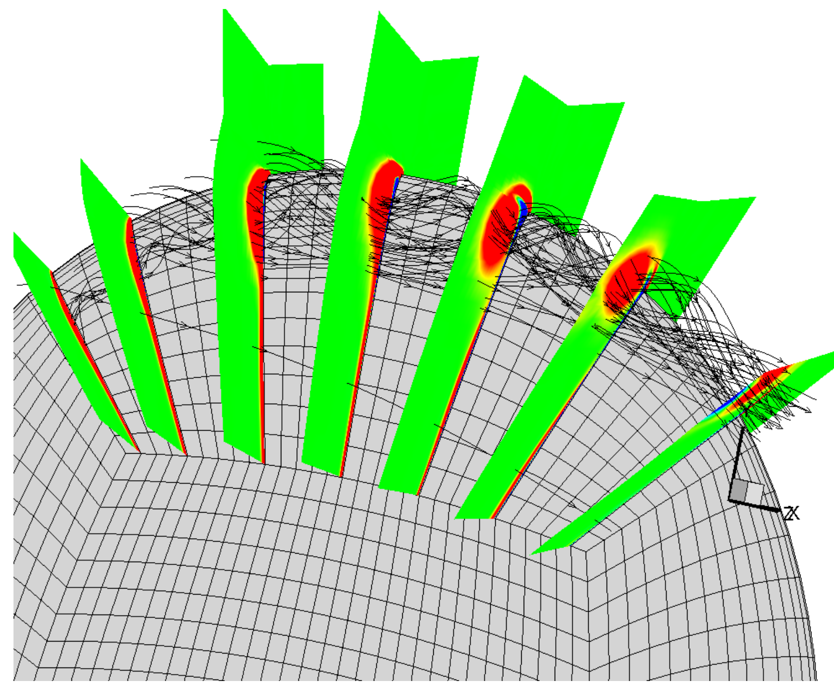
t=0.3s



RESULTS (VORTICITY STRENGTH IS SHOWN IN COLOR)

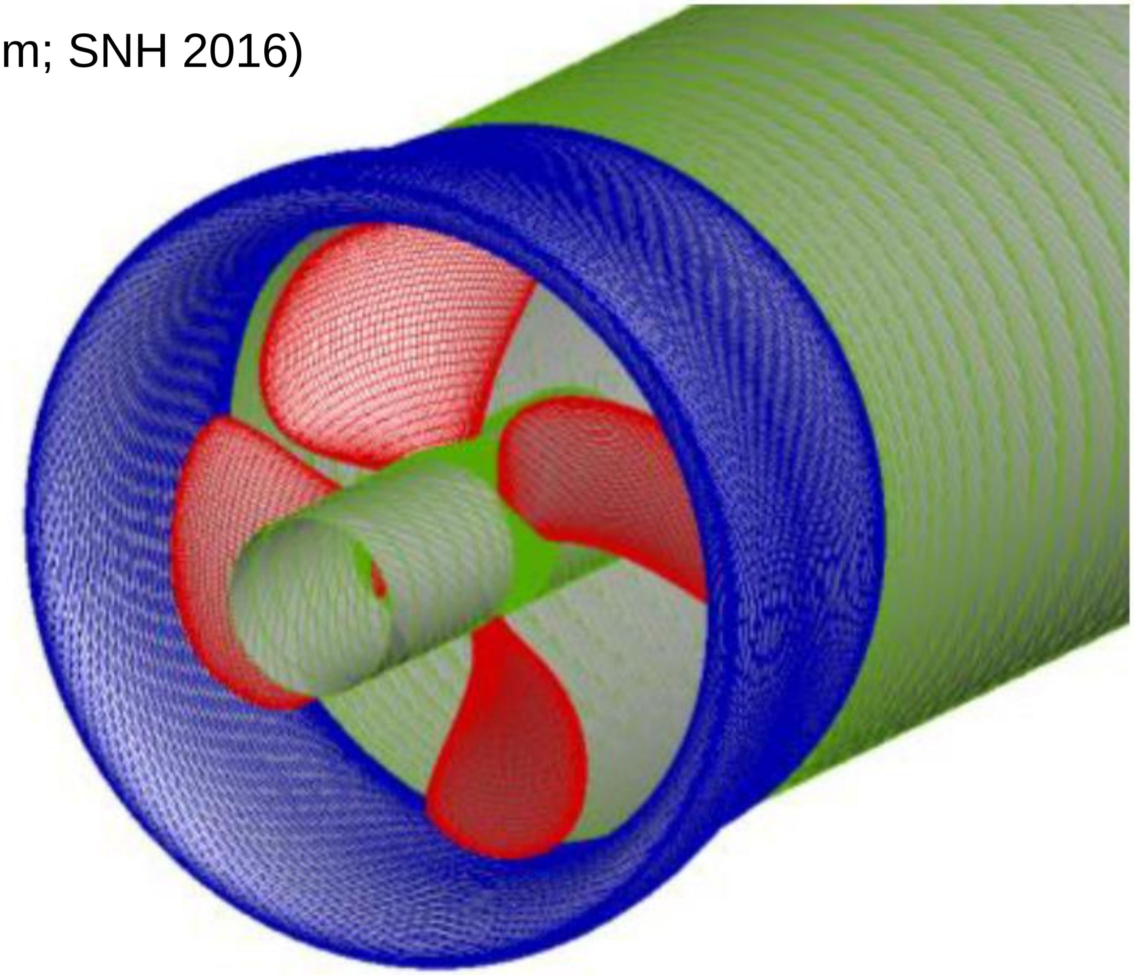
A Square Tip Propeller (left) and a Round Tip Propeller (right)



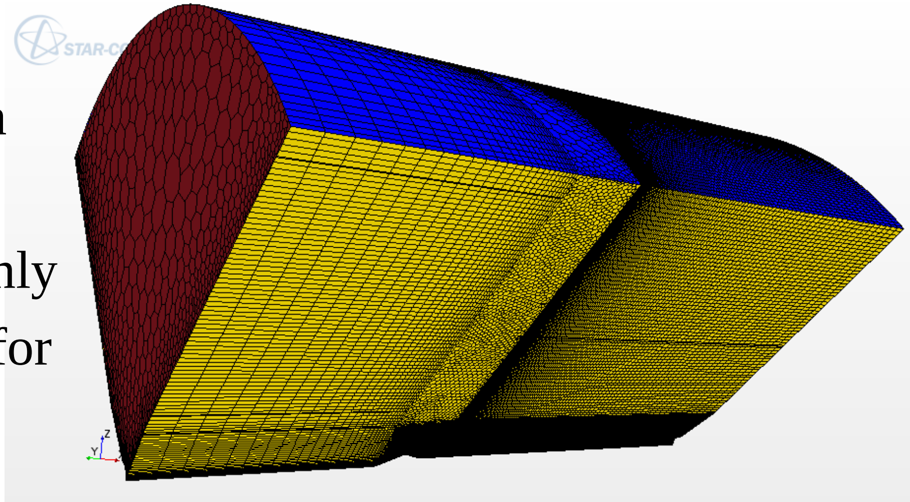


Application on Ducted Propellers
Correlation of our Methods with RANS solvers
(Star-ccm+ & Fluent)

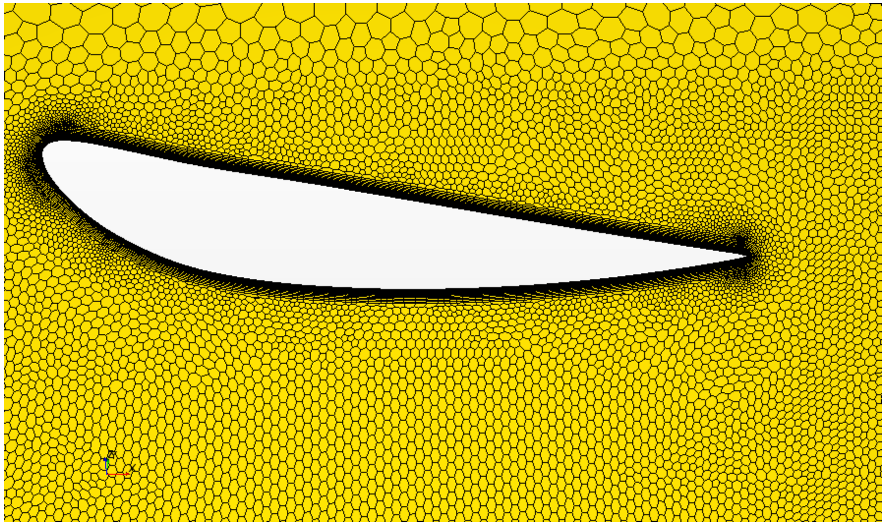
(Kinnas, Su, Du, Kim; SNH 2016)



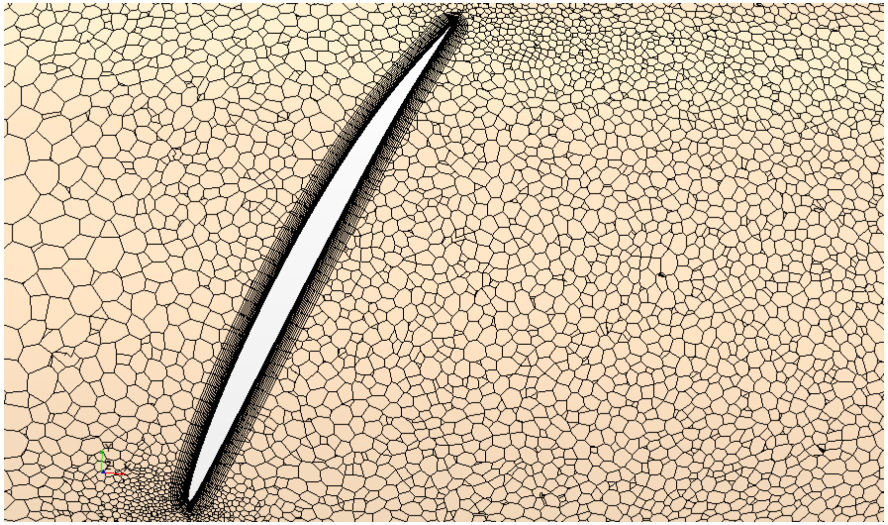
- Mesh conditions in fully 3-D viscous simulation
  - Polyhedral cells and hexahedral cells are respectively utilized in the rotating region and static region.
  - Periodic interfaces are applied, making only a quarter of the whole domain necessary for the simulation.



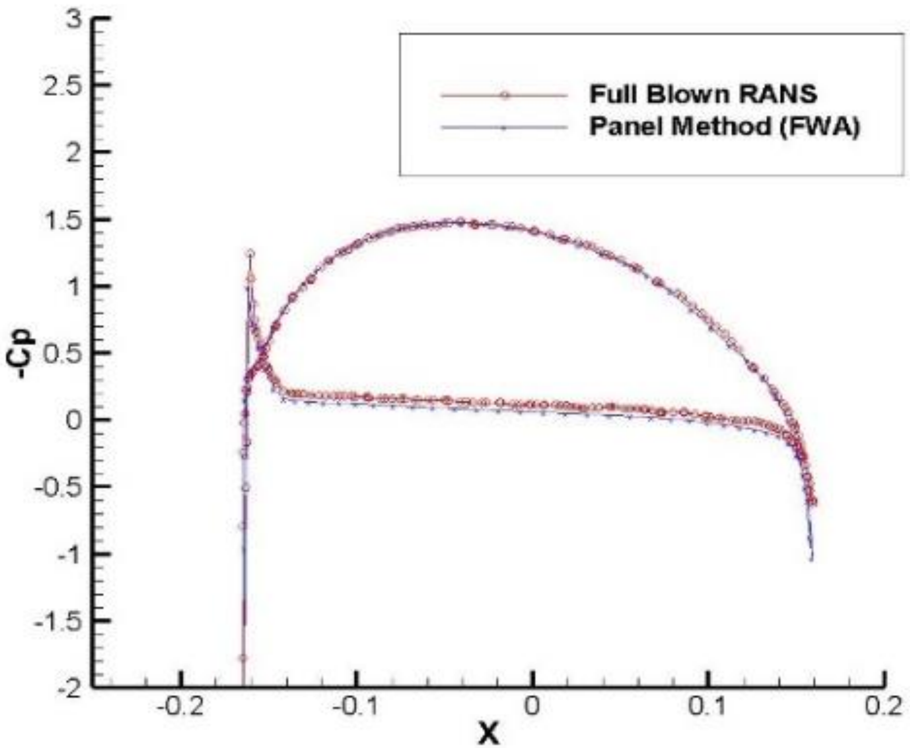
mesh of periodic domain

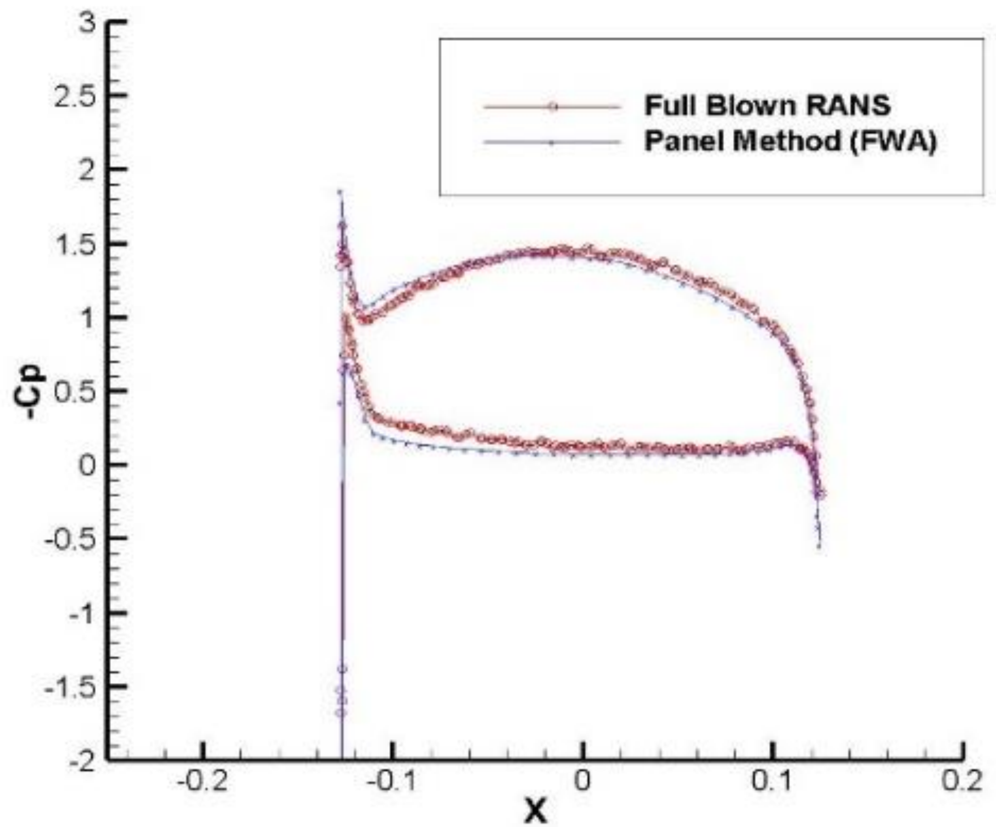


mesh around duct



mesh around blade station r/R=0.60





Correlation of pressure distribution (J_s=0.5) at different radial sections r/R=0.5927 (left), and r/R=0.9305 (right

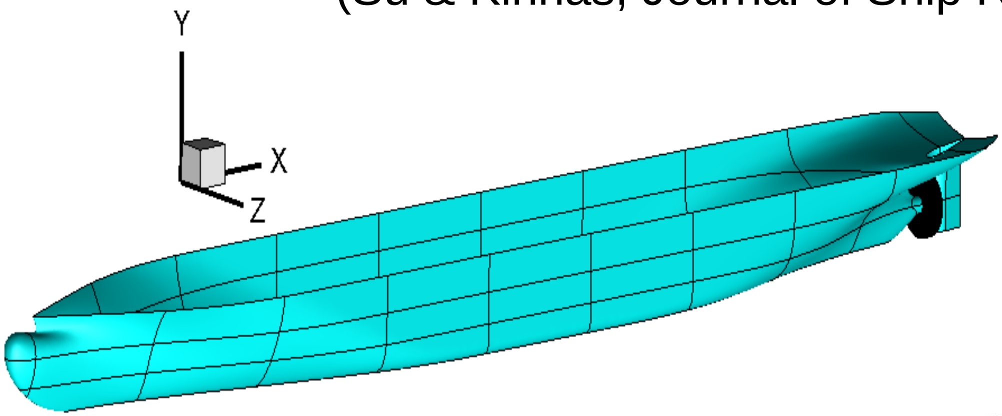
Comparison of running times

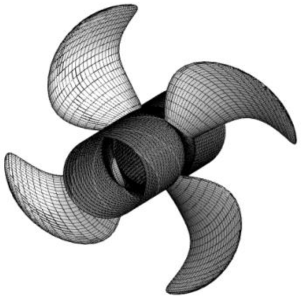
Method	Full blown RANS	PANEL METHOD
Cell No.	Over 5 million cells	Less than 12K panels (10 iterations for wake)
Total running time	Over 30 hours (32 CPUs)	30 minutes (1 CPU)

Table 4-2 Computation efficiency comparison between the panel method and the full blow RANS simulation

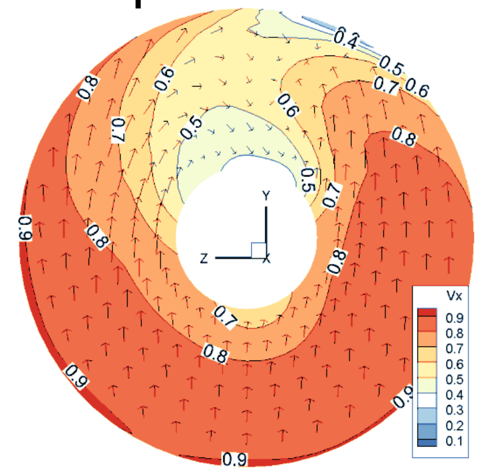
Ship Hull – Propeller – Rudder Interaction

(Su & Kinnas, Journal of Ship Research, 2017 – in press)

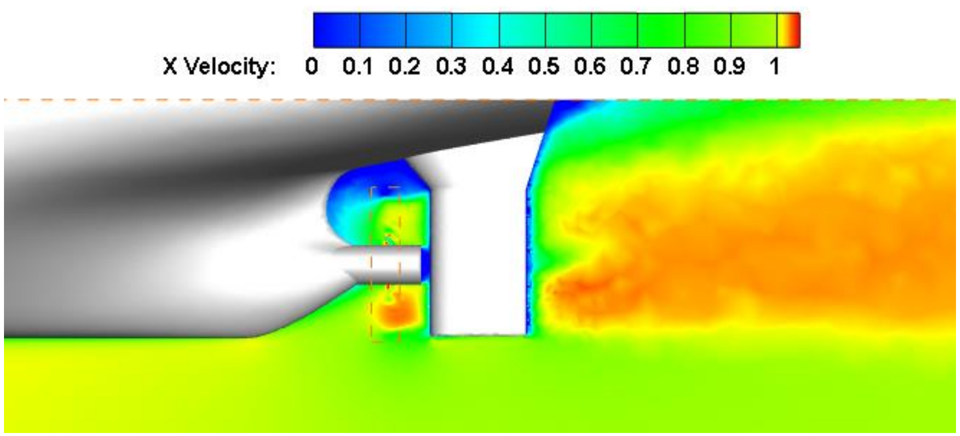


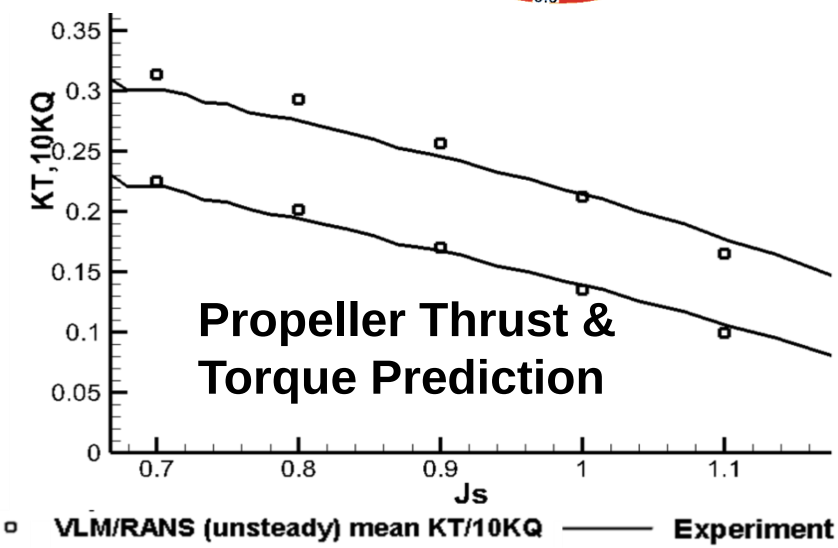


Propeller Inflow

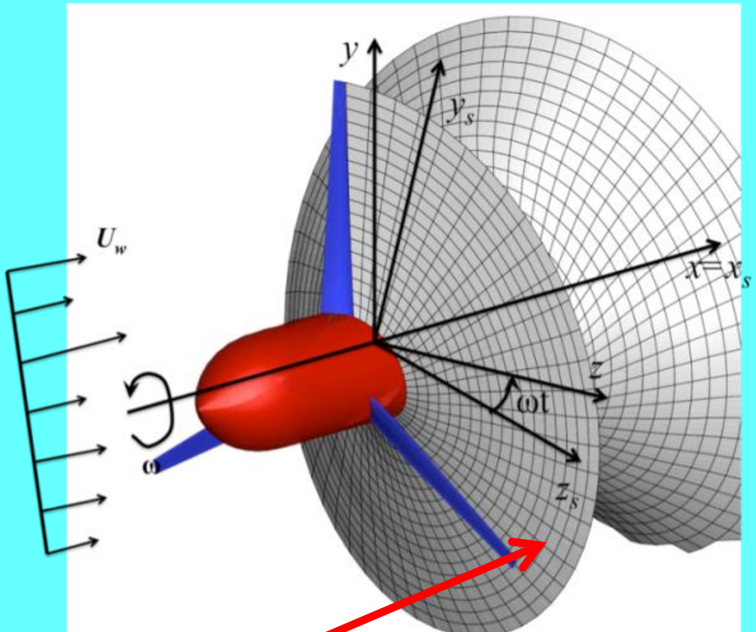


Axial Velocity/Ship Speed

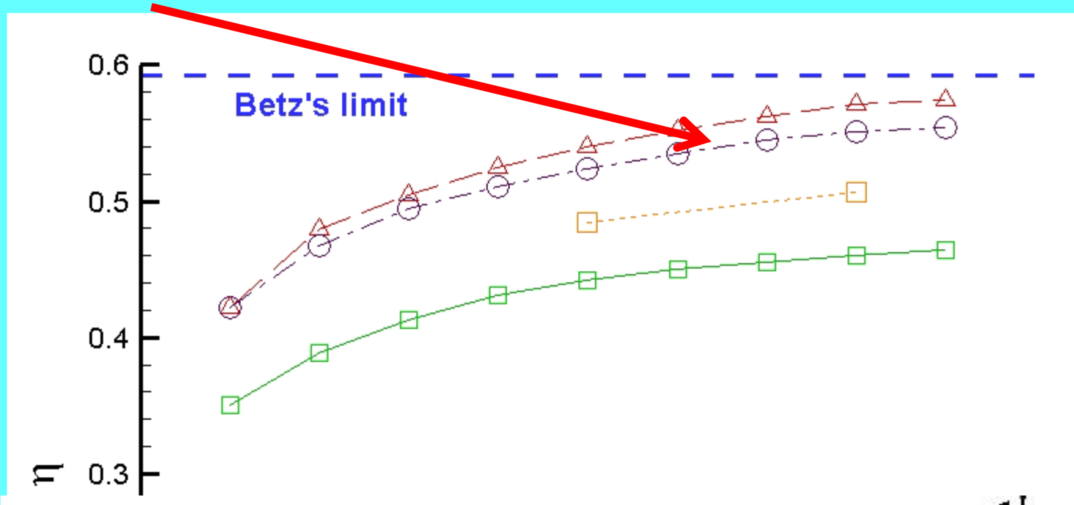


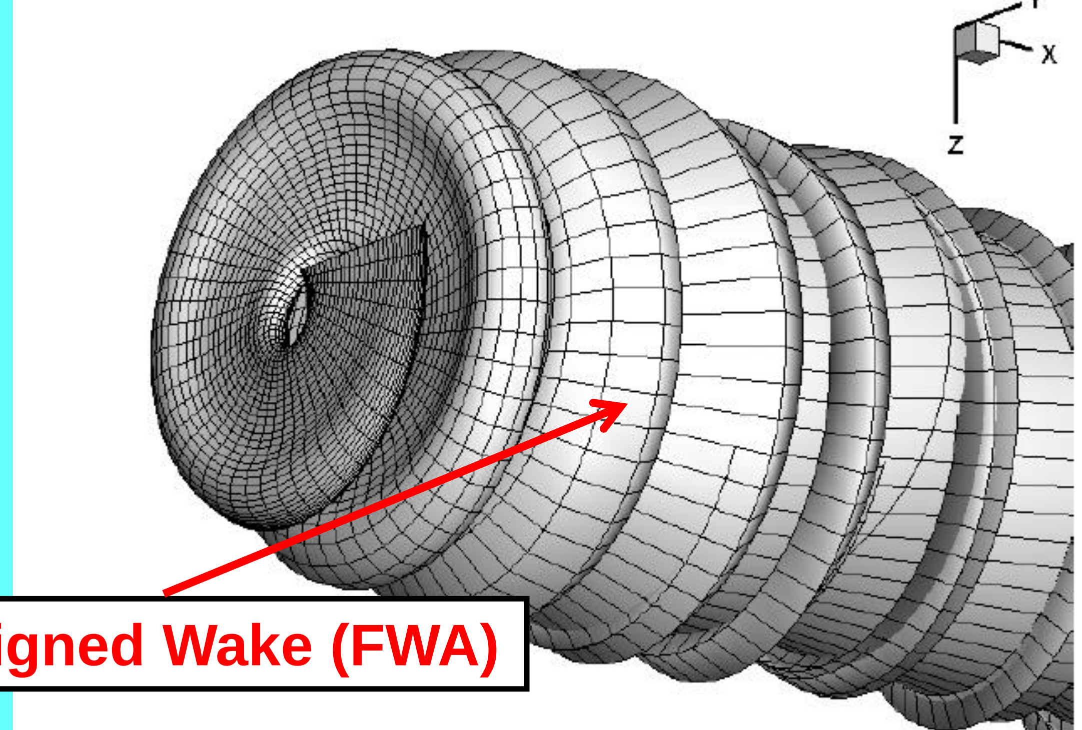


New design method produces more efficient turbines
(Menendez, MS, OEG 13, Menendez & Kinnas JSR'14)



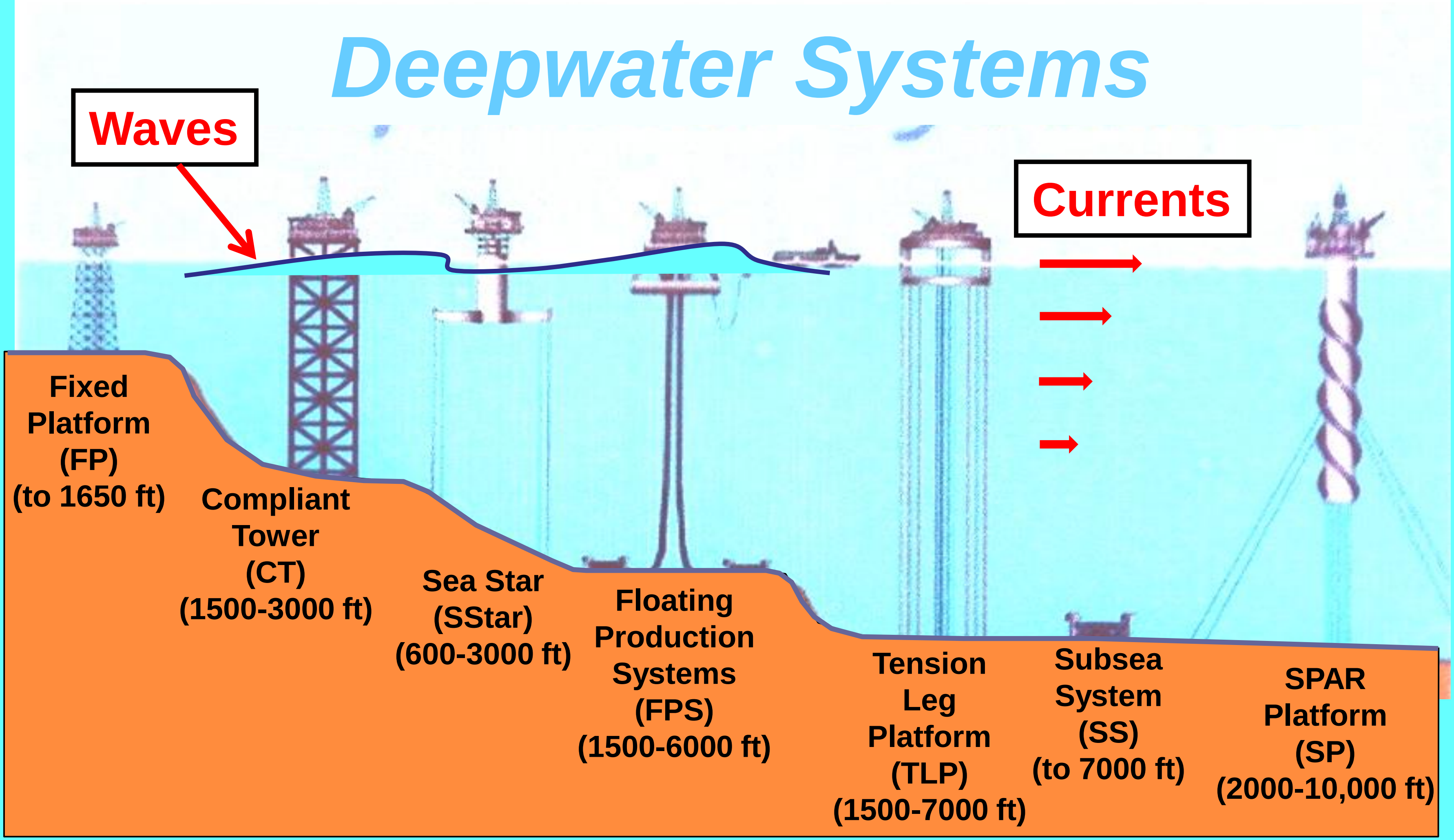
Non- or partially aligned wake





Fully Aligned Wake (FWA)

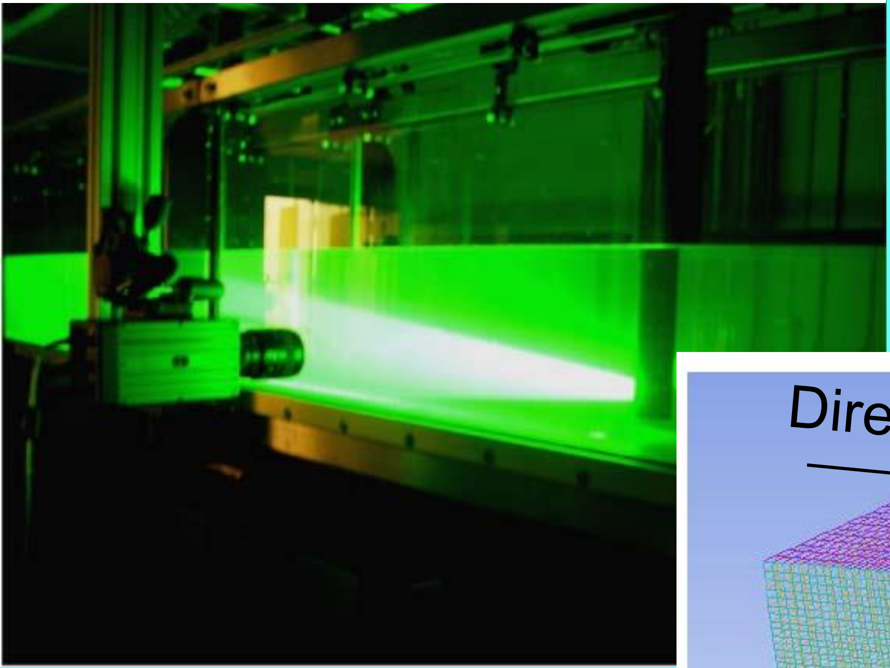
OFFSHORE PLATFORMS



Source: Bureau of Ocean Energy Management

Experiment and simulation of flow around cylinder subject to wave (G. Wang; MS, OEG, 2015)

UT's flume and Particle Image Velocimetry (PIV) system



Simulation of viscous flow inside flume (using ANSYS/Fluent)

- Reynolds-Averaged Navier-Stokes (RANS)
- Large Eddy Simulation (LES)

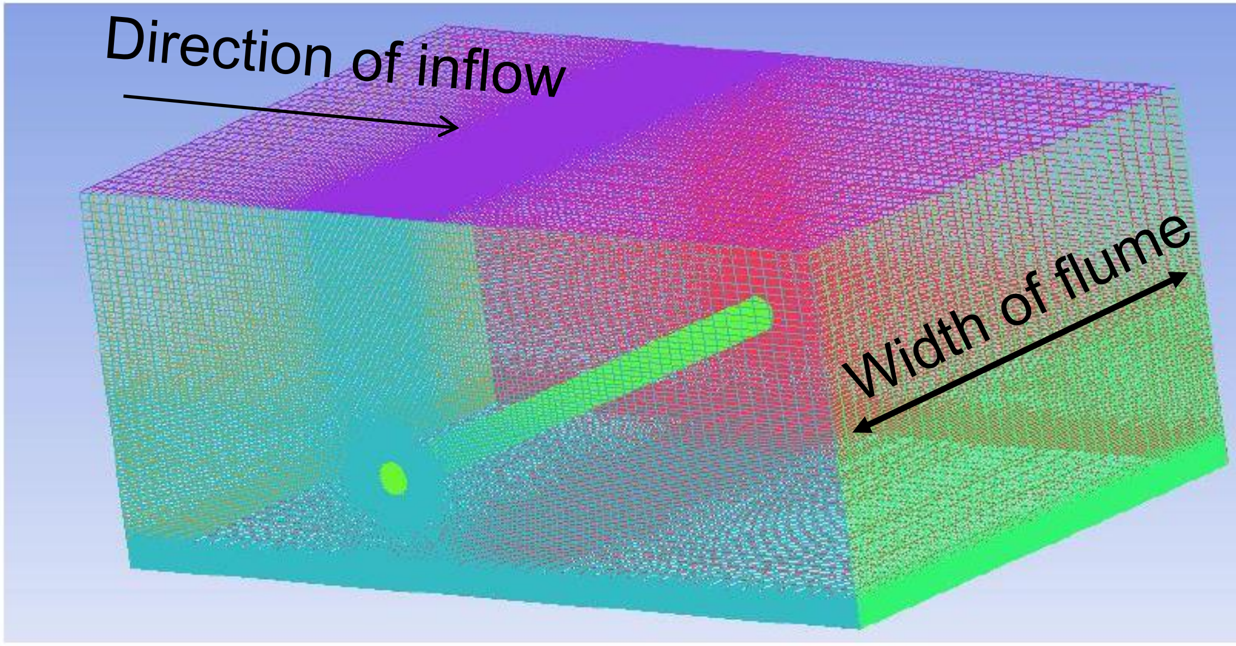


Figure 4.37 3D mesh including free surface

Measured vs. predicted velocity over time

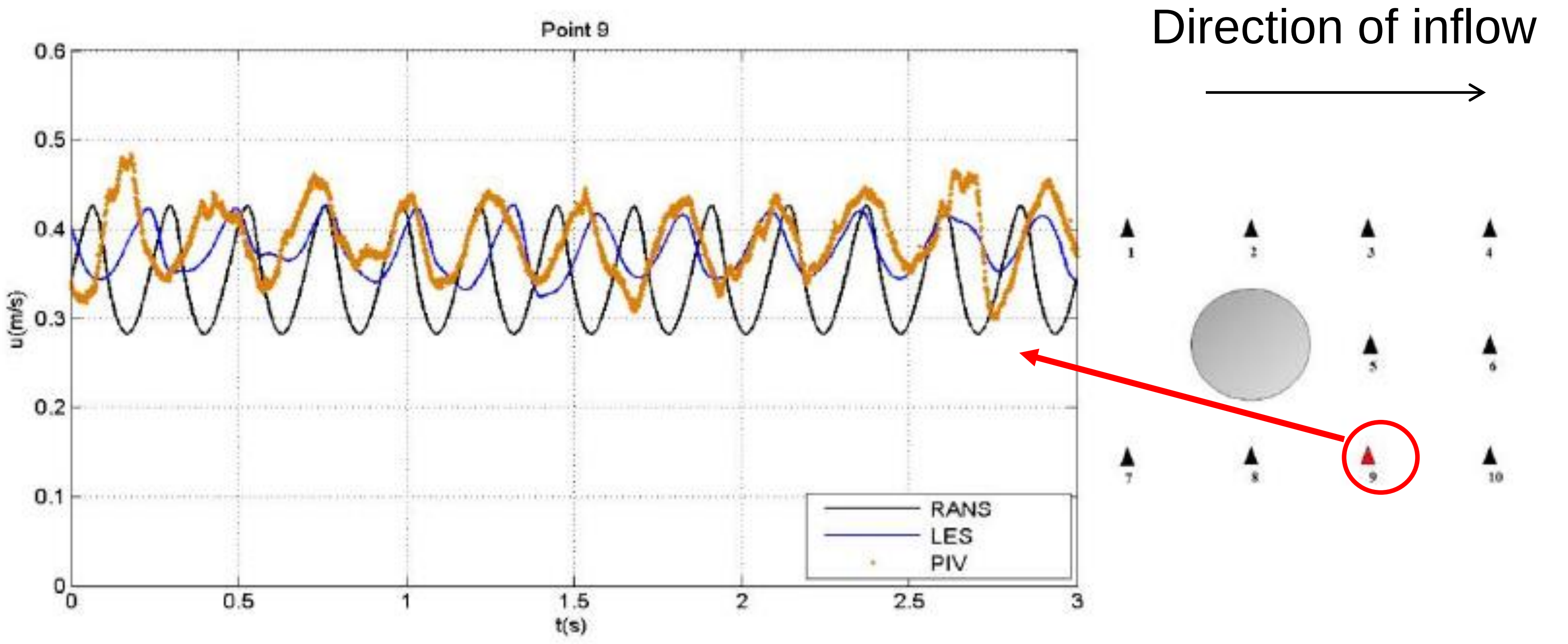


Figure 4.13 Time history of horizontal velocity of point 9

Measured vs. computed time averaged velocities (Reynolds stresses)

LES appears to do a much better job than RANS in simulating the viscous flow

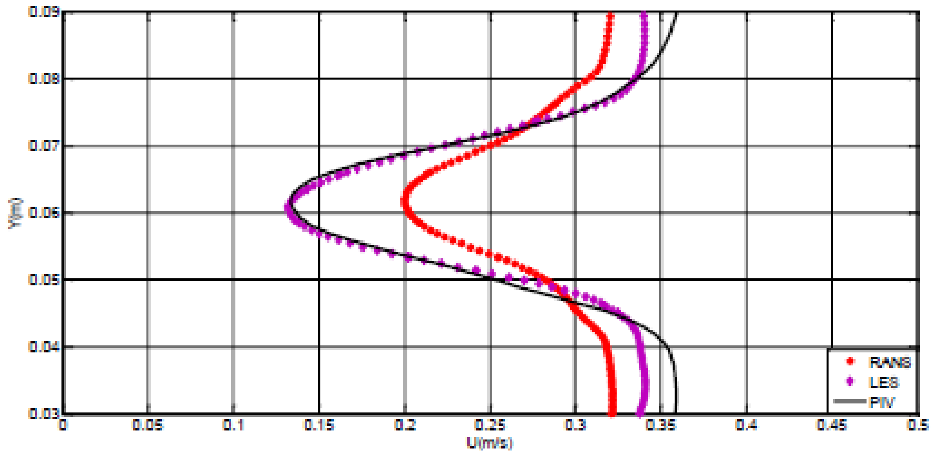


Figure 4.16 Time-averaged horizontal velocity at section 1

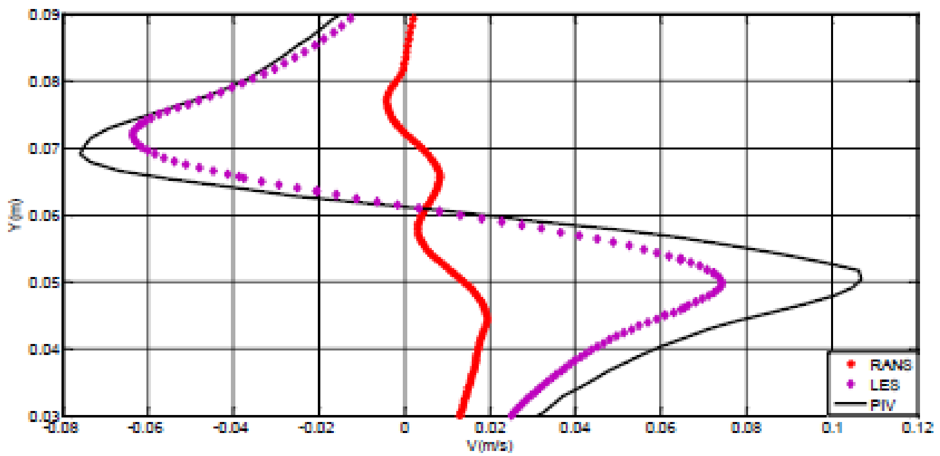


Figure 4.17 Time-averaged vertical velocity at section 1

2017-18 Opportunities in OEG:

- **10 hour grader (for CE358 class - committed)**
- **MS Thesis in OE on the topics listed (unfunded) – Requires strong background in Fluid Mechanics, Advanced Calculus, and Computational Methods**