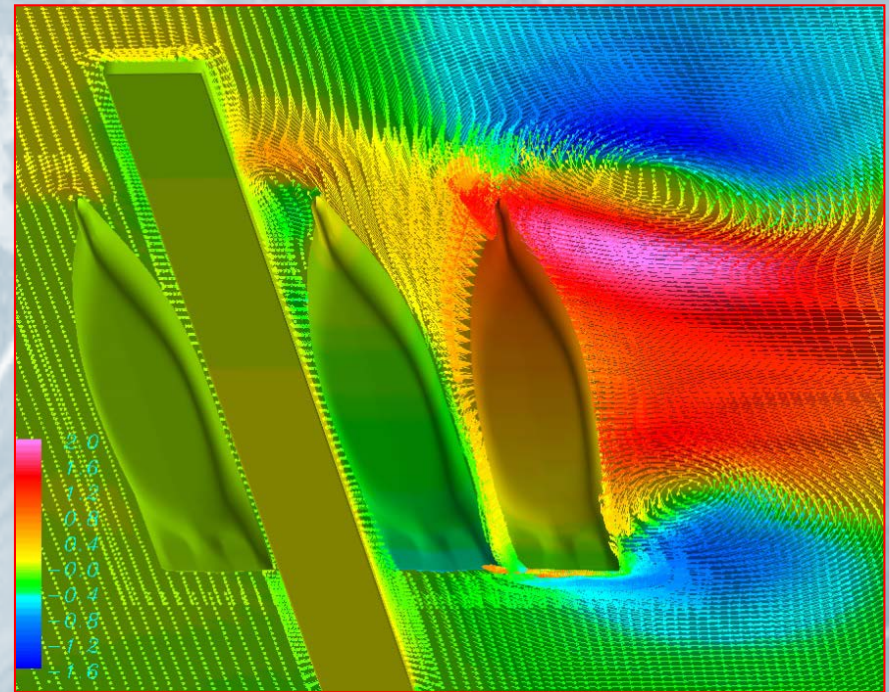
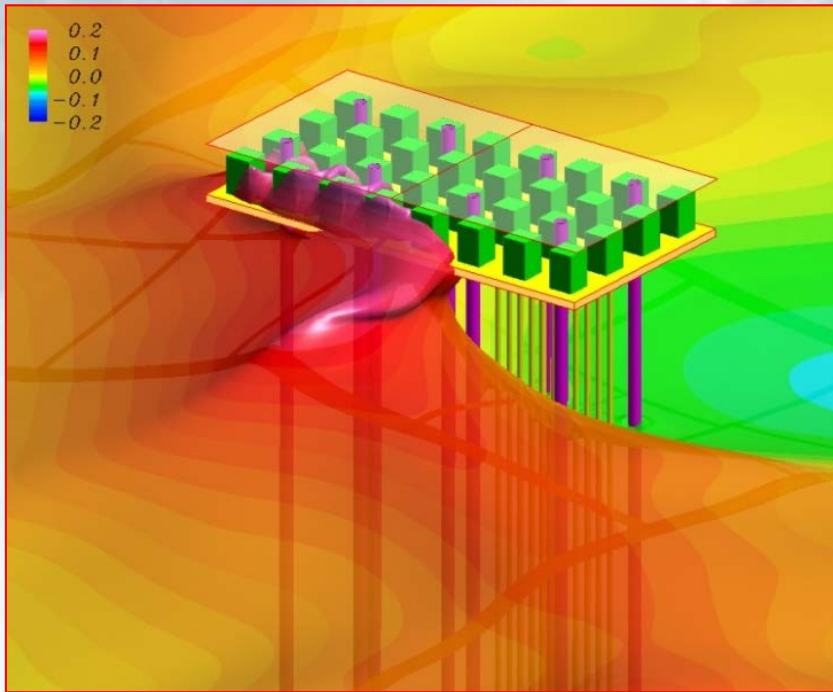


CFD Simulation of Fluid-Structure Interactions Including Violent Free Surface Flows

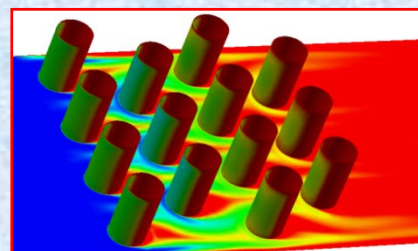
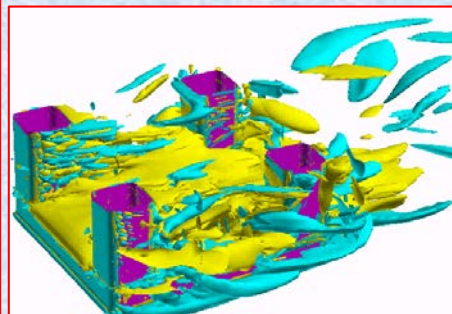
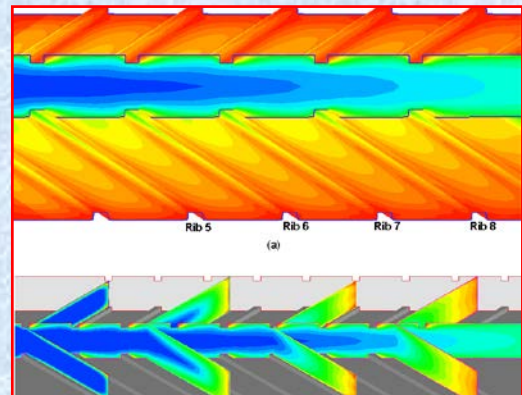
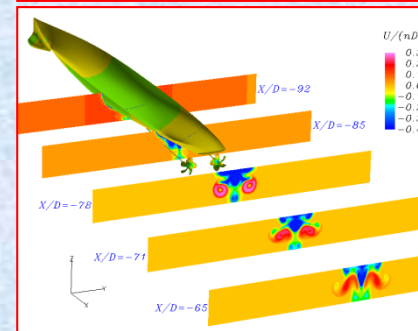
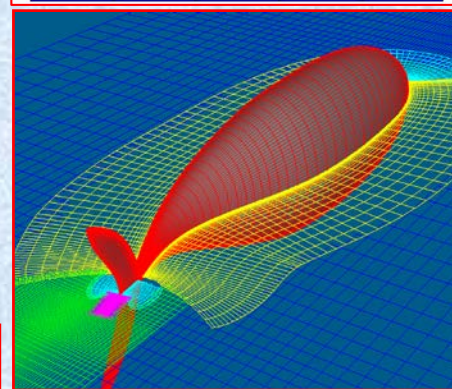
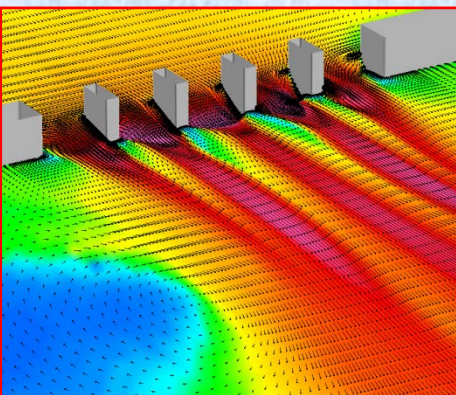
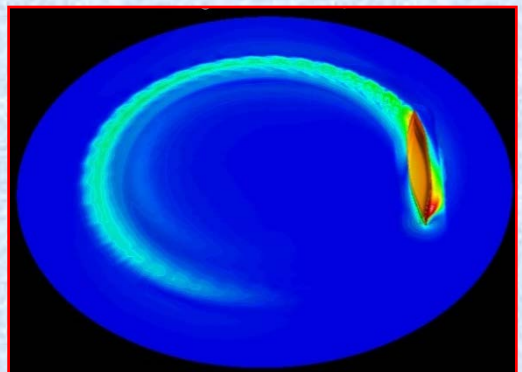
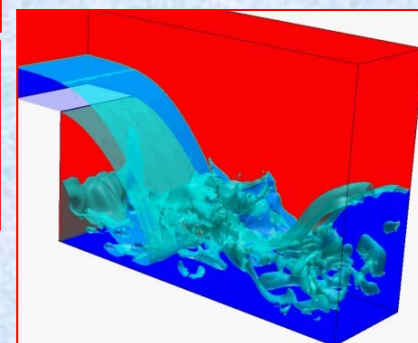
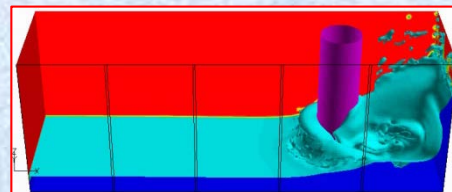
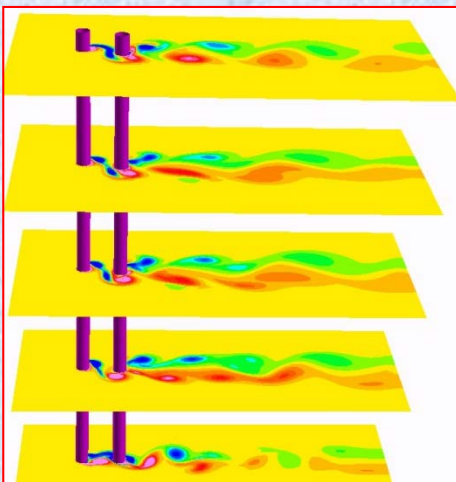
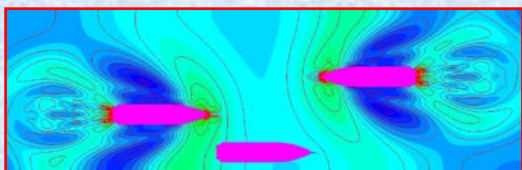
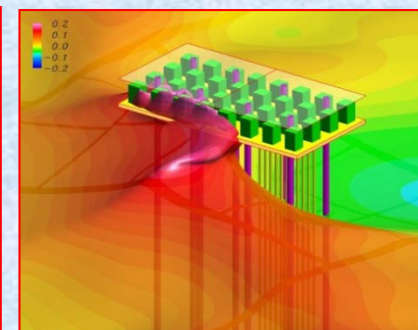
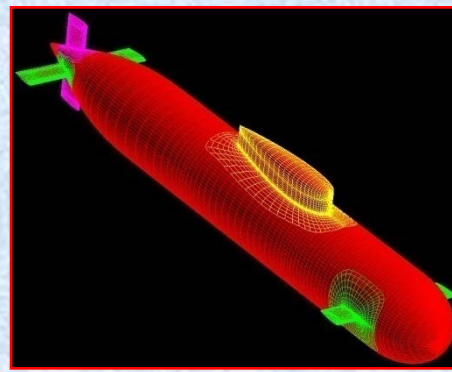
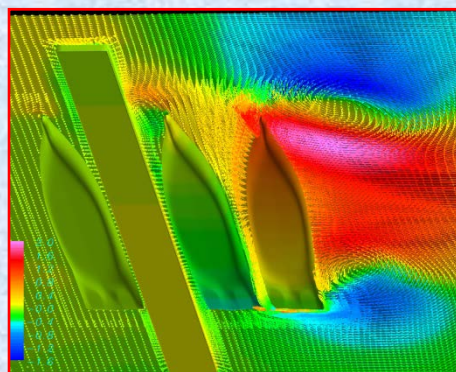
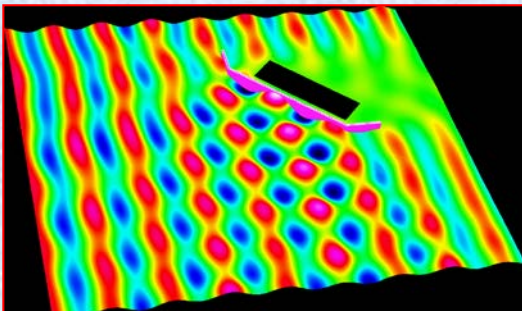


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October 26, 2017



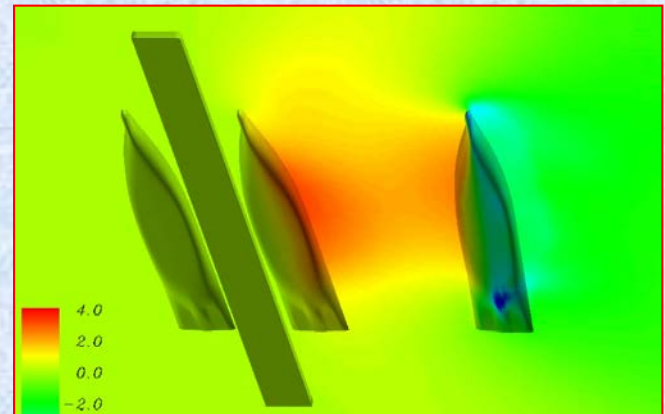
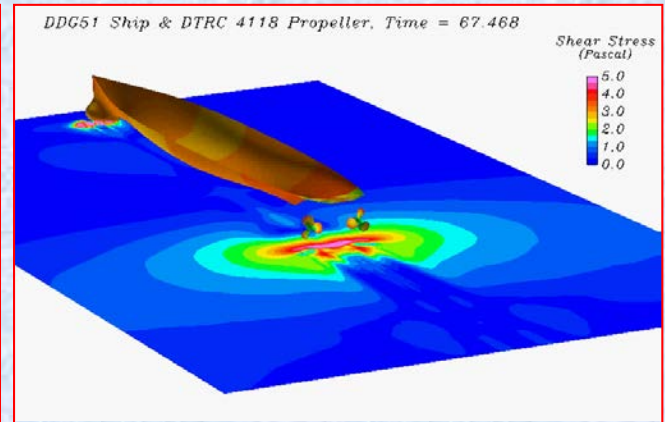
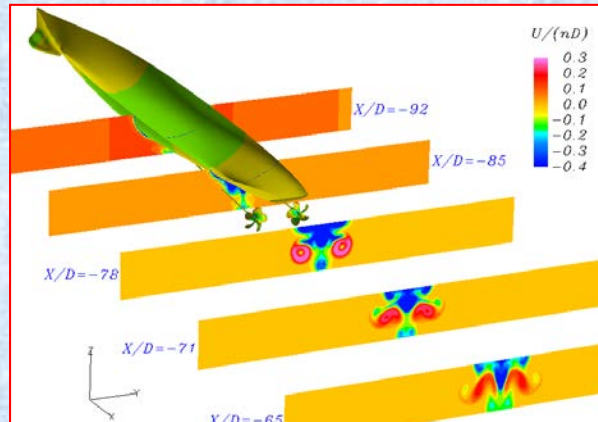
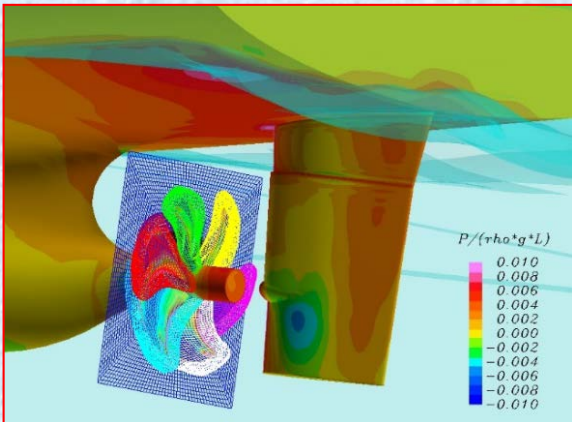
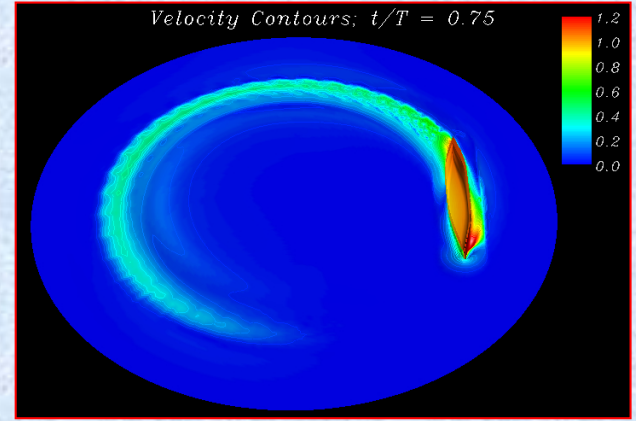
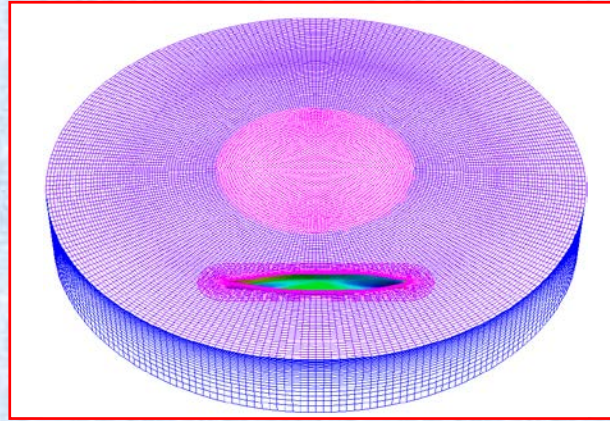
Finite-Analytic Navier-Stokes (FANS) Method



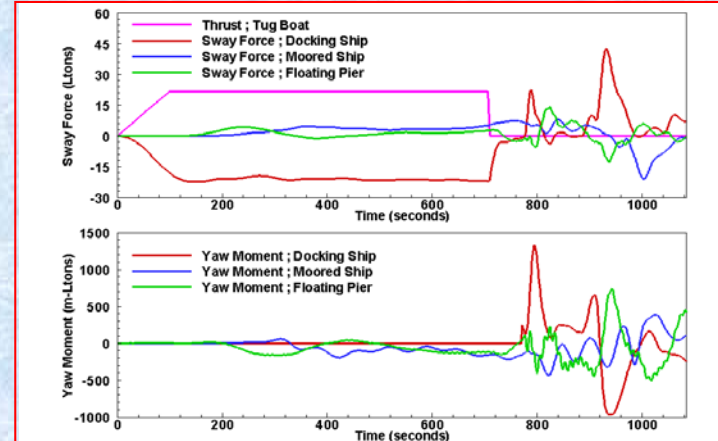
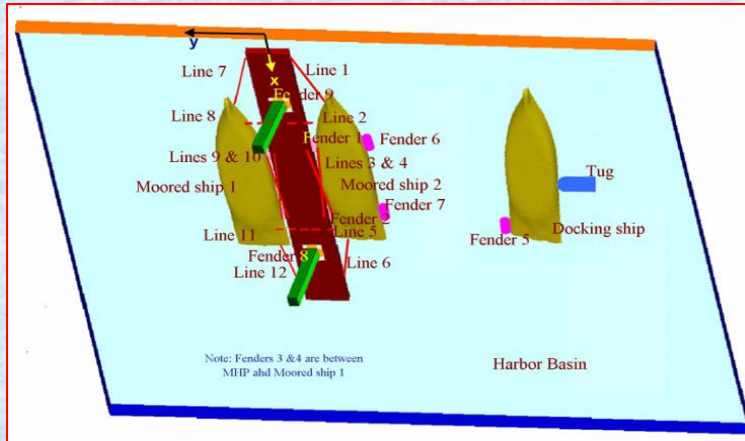
FANS Code Applications

- **Submarine and ship hydrodynamics**
- **Ship berthing operations and interaction with modular hybrid piers**
- **Passing ship effects on moored vessels and waterfront facilities**
- **Propeller wash and sediment re-suspension**
- **Liquefied natural gas (LNG) tank sloshing**
- **Green water and extreme slamming impact on ships in random waves**
- **Vortex-induced and wake-induced vibrations of top-tensioned and steel catenary risers , flexible jumpers, and free span pipelines**
- **VIV suppression by fairing and helical strakes**
- **Vortex-induced motions of deep-draft semi-submersible platforms**
- **Green water and hurricane wave impact load on offshore structures**
- **Dam breaking, levee overtopping and levee erosion**
- **Bridge scour, abutment scour, channel migration, and sediment transport**
- **Internal cooling and film cooling of turbine blades**
- **Heat transfer enhancement by ribbed turbulators, pin fin and dimples**

Moving Overset (Chimera) Grids

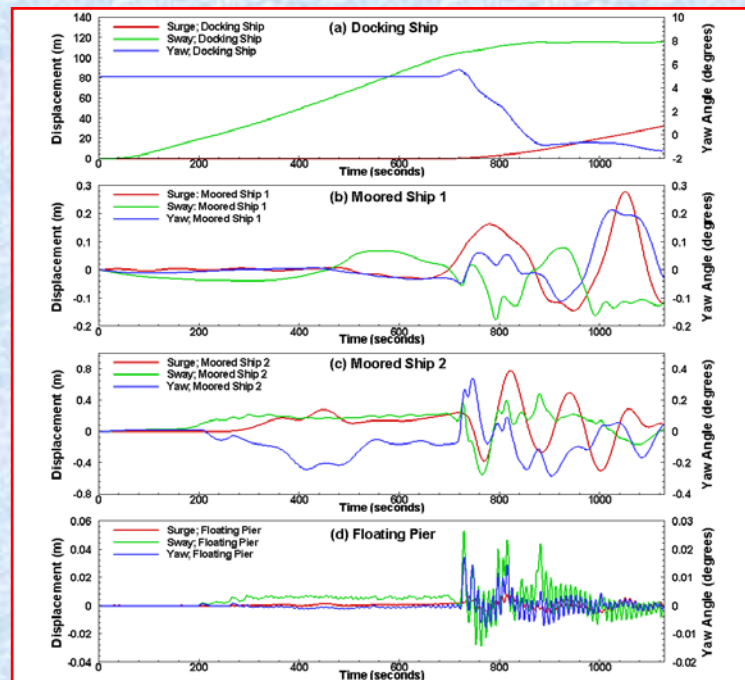


Multiple ships and MHP Interactions

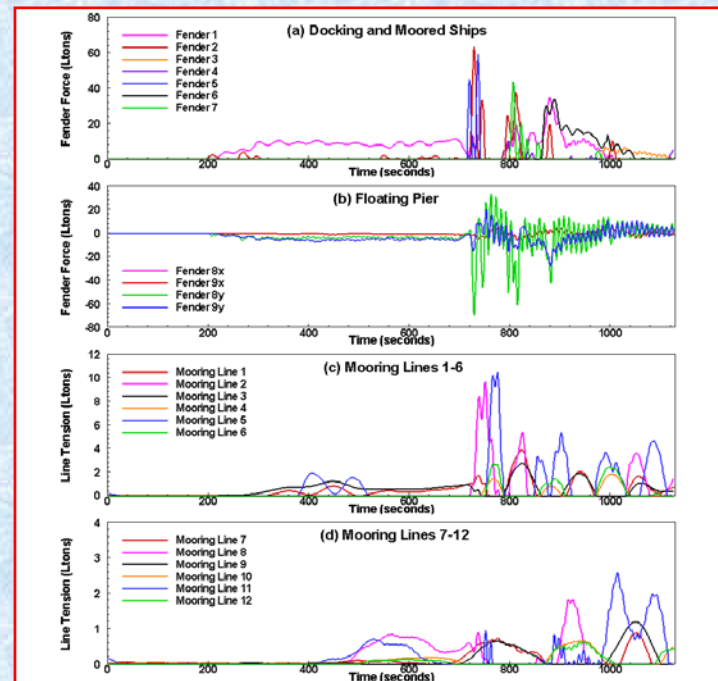


Sway Forces

Yaw Moments



Sway,
Heave,
Yaw
Motions



Fender Reaction Forces

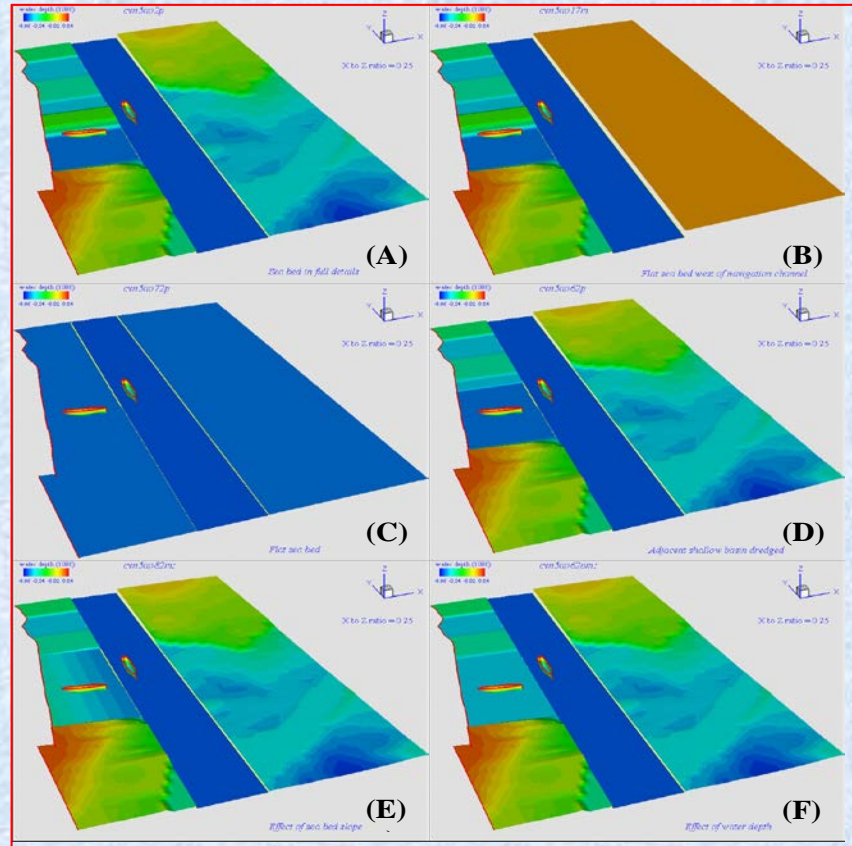
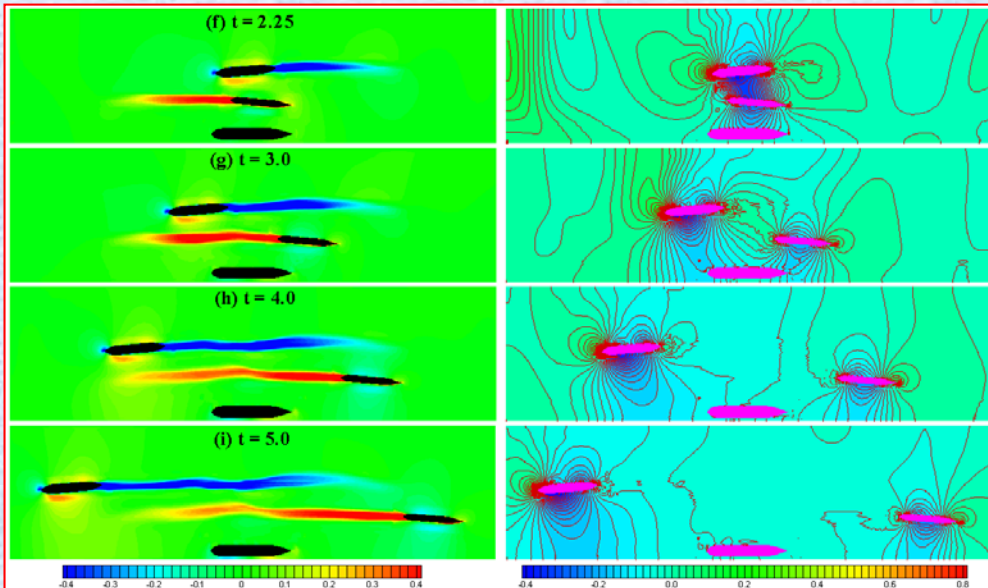
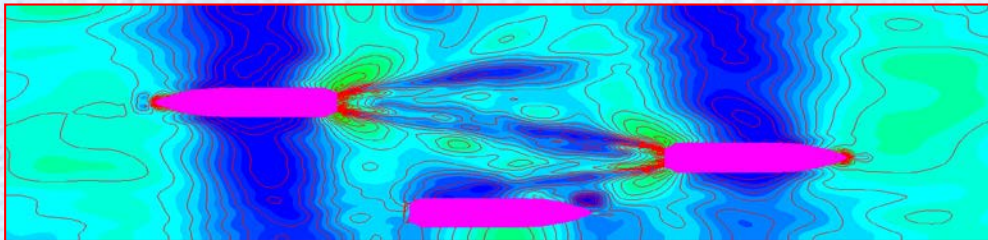
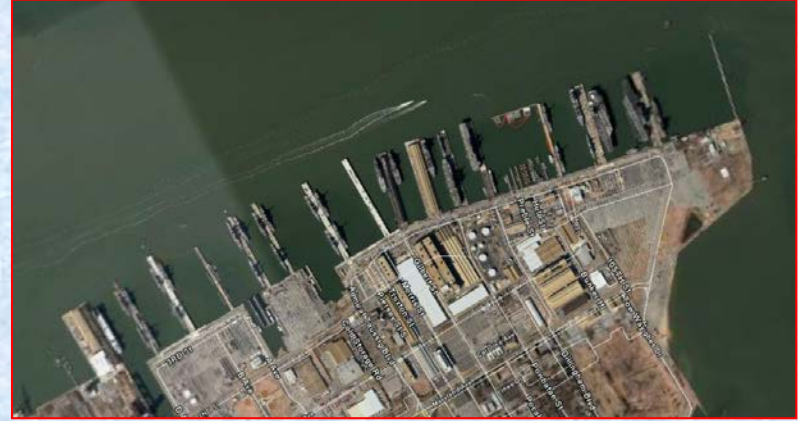
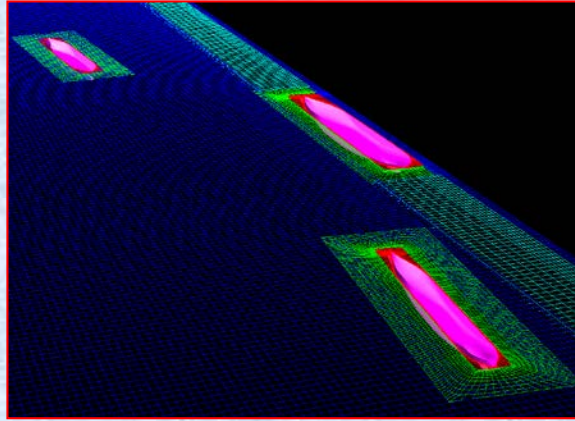
Mooring Line Tensions

- Tug boat, docking ship, two moored ships and MHP
- 7 form fenders, 12 mooring lines, 2 mooring dolphins & 2 fenders for MHP

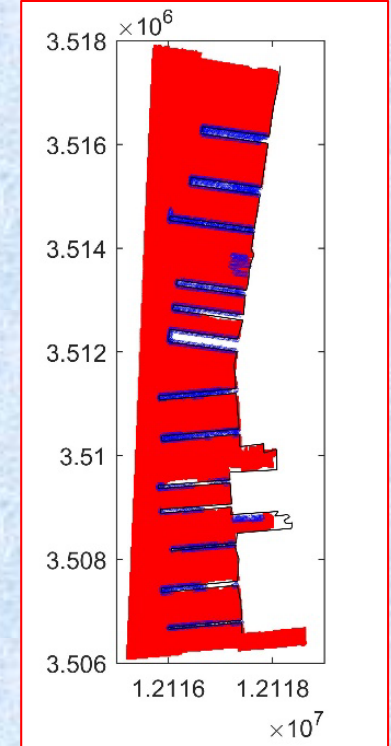
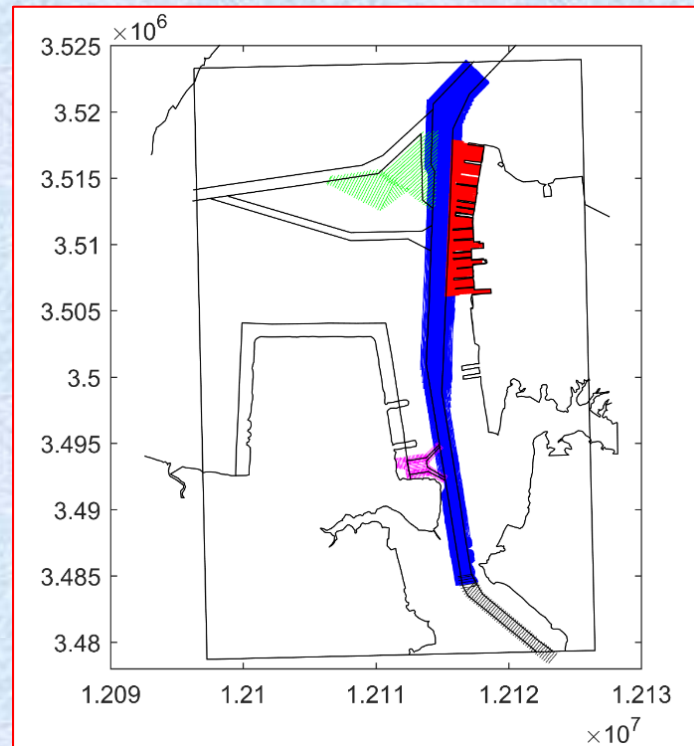
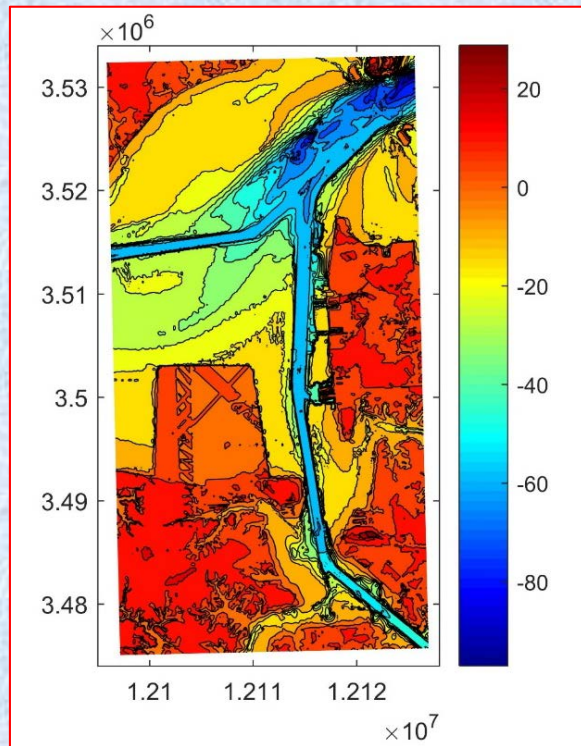
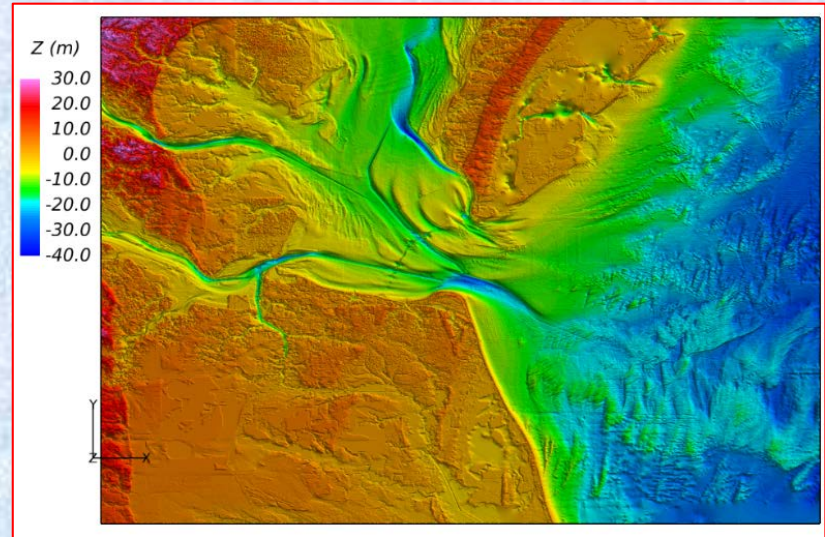
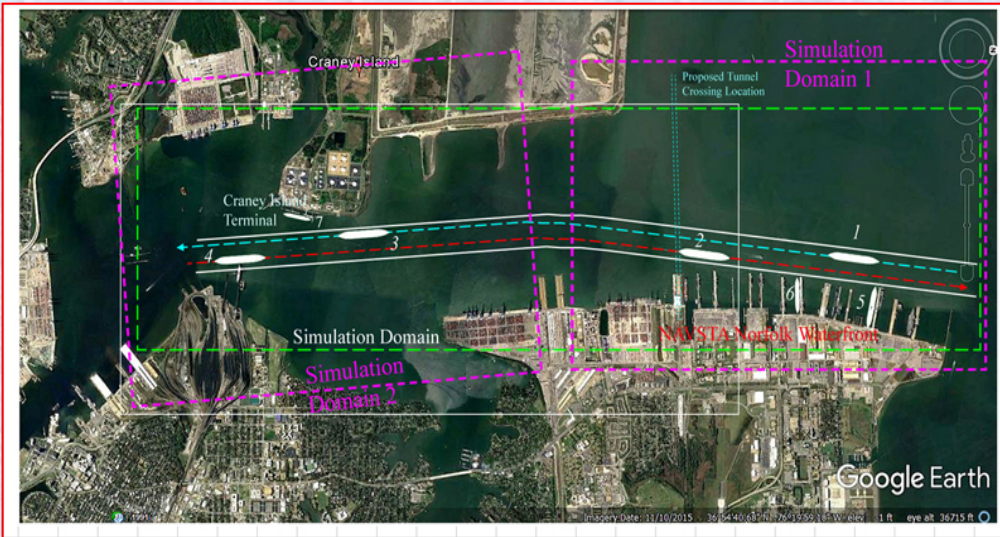
Moving Overset (Chimera) Grid Approach

- Chimera is a monster with a lion's head, goat's body and serpent's tail - an amalgamation of various animals
- Just like the chimera in Greek mythology, the chimera grid embedding scheme used in CFD is a combination of many different numerical grids
- **Composite, structured boundary-fitted grids**
- **Embedding, overlapping, or matching grids**
- **Select the most suitable grid structure for each block**
- **Local grid refinement to improve accuracy and efficiency**
- **Relative grid motions can be easily accommodated**
- **Interpolation of flow variables across grid blocks**
- **Conservation of mass and momentum at grid interface for incompressible flows**
- **Parallelization for arbitrarily large groups of consecutive or non-consecutive blocks on different processors**

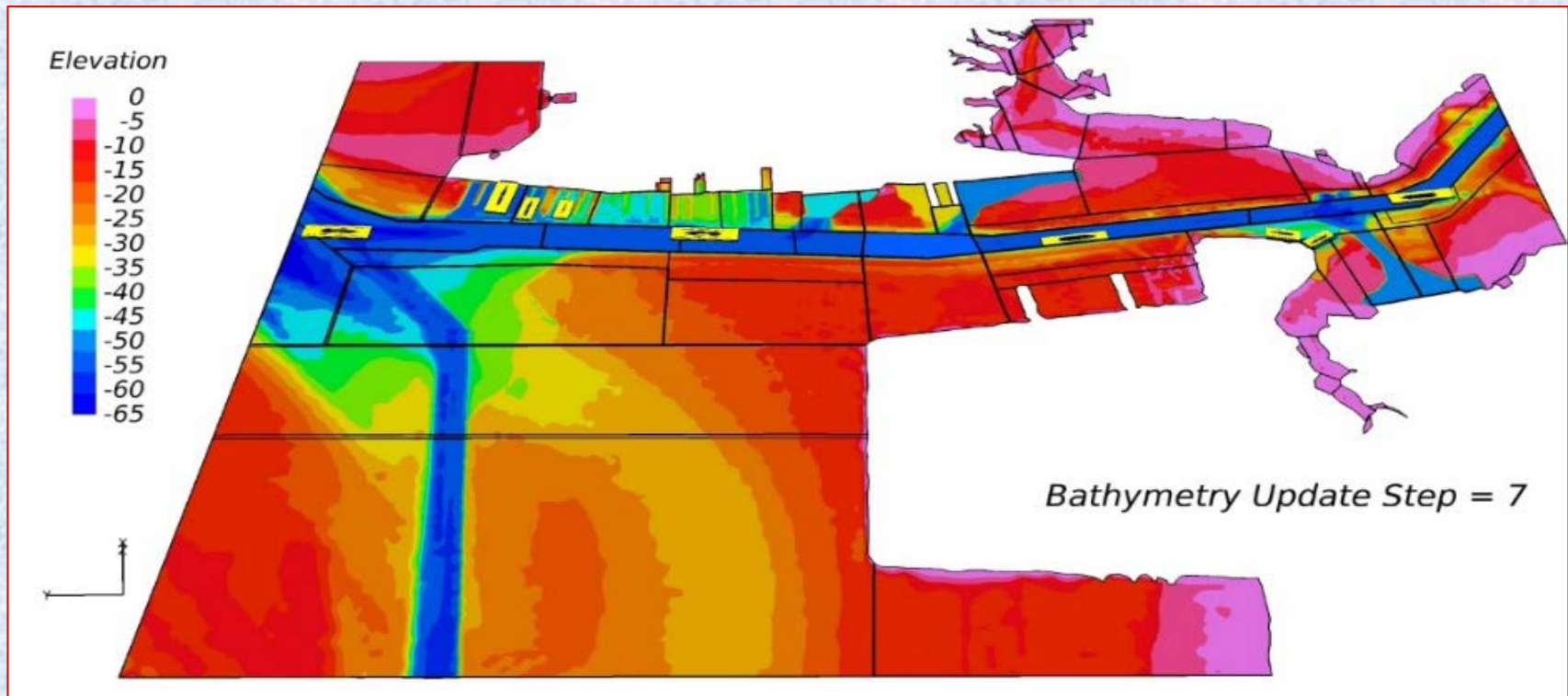
Passing Ship Effects: Craney Island and Norfolk Harbor



Site-Specific Simulation of Passing Ship Effects

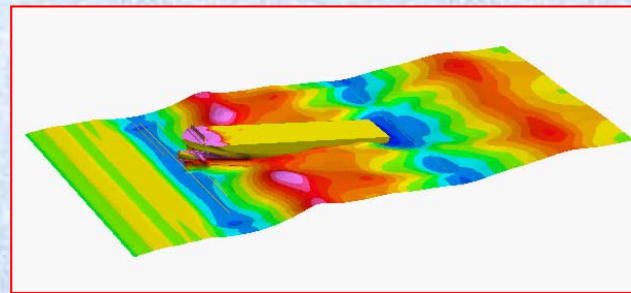
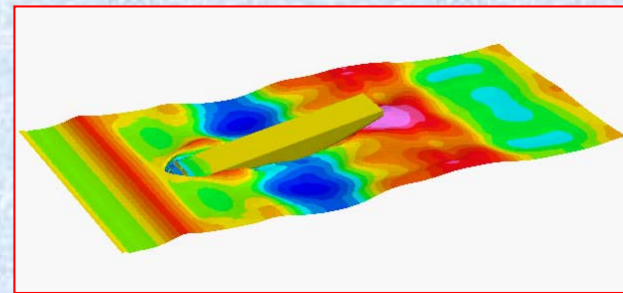
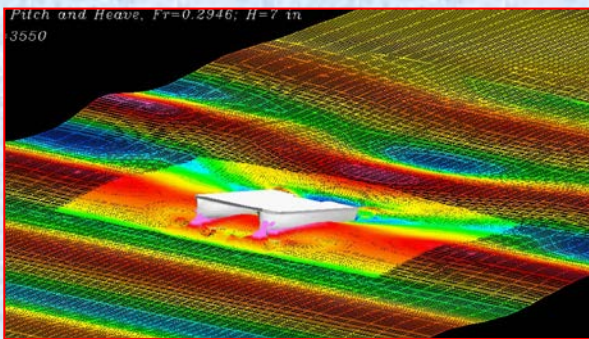
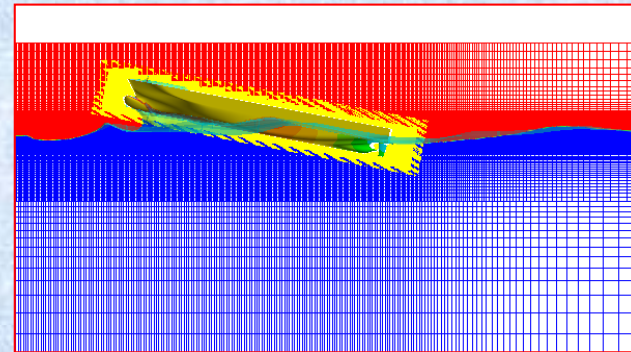
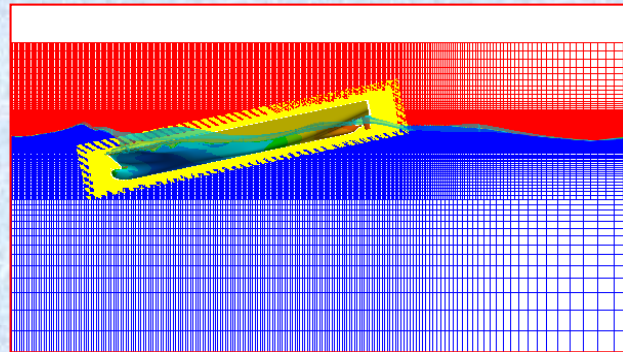


Site-Specific Passing Ship Effects



- 4 passing ships and 5 moored ships (coupled with fenders and mooring lines)
- Grid A: 53 blocks with 10,124,676 grid points
- Grid B: 100 blocks with 7,372,131 grid points
- Nearly 200 simulations of passing ship effects with various combinations of ship lanes, ship speeds, drift angles, dredged channel depths, and passing ship coupling effects (head-on or overtaking encounters)
- Using 14-20 processors on TAMU Ada cluster with 16-22 CPU hours per case
- 1 TB data for 10 cases, took 20 hours to download to external hard drives

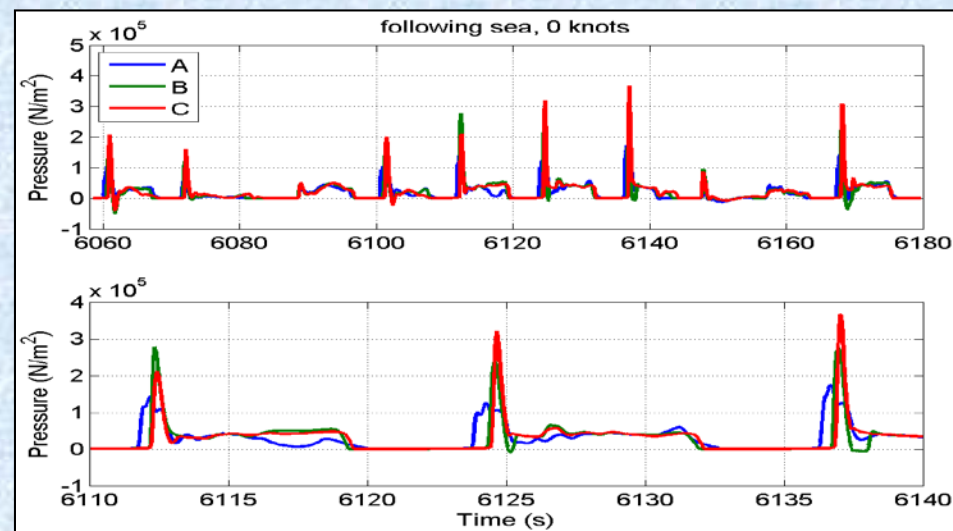
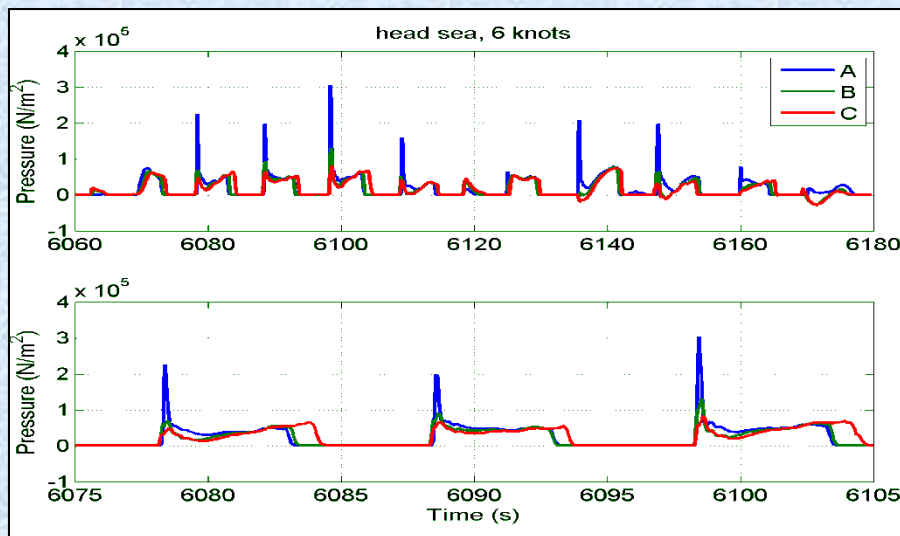
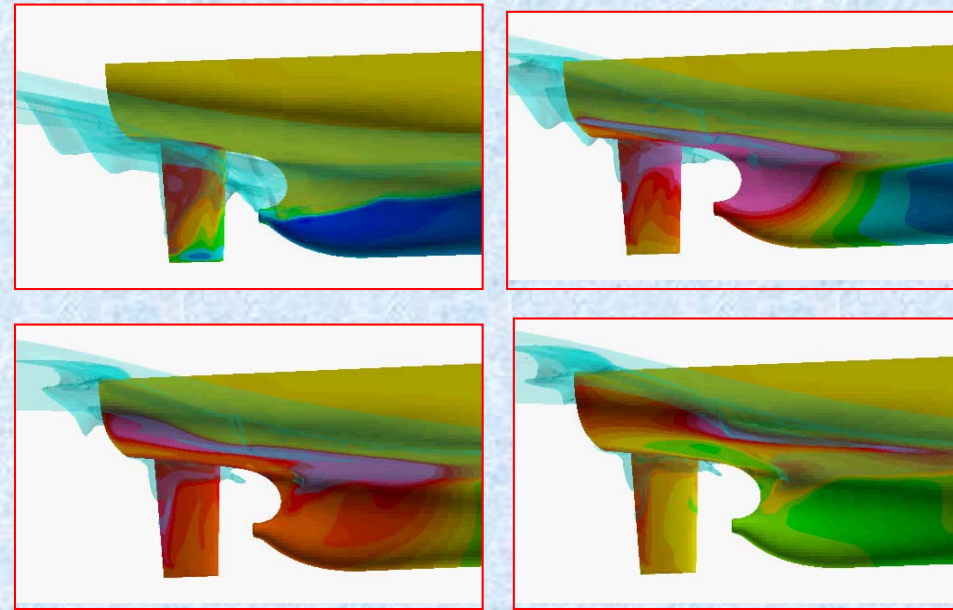
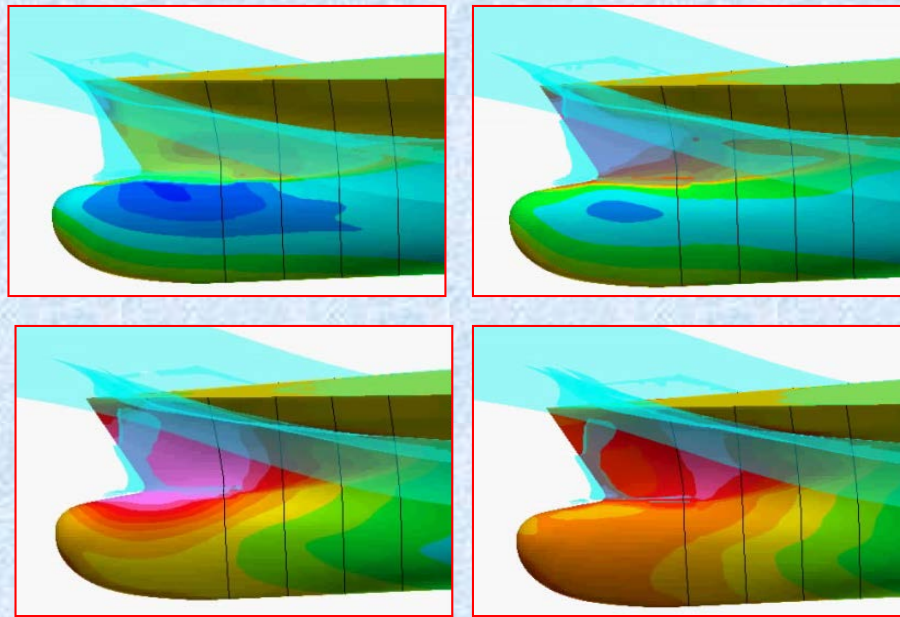
Ship Motion and Slamming Load in Random Waves



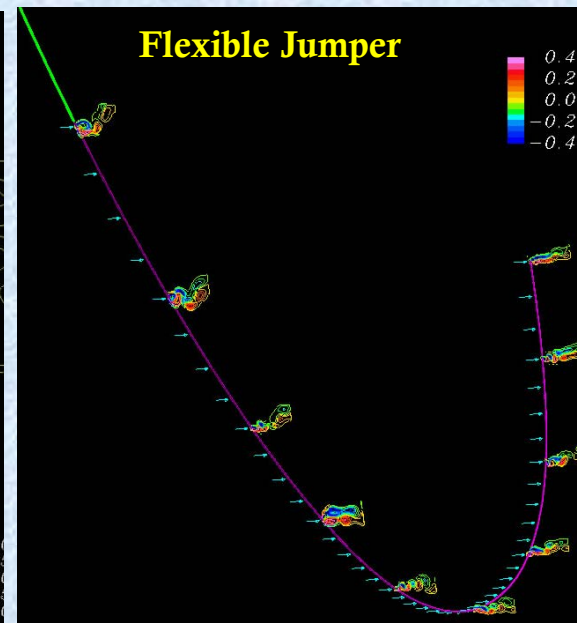
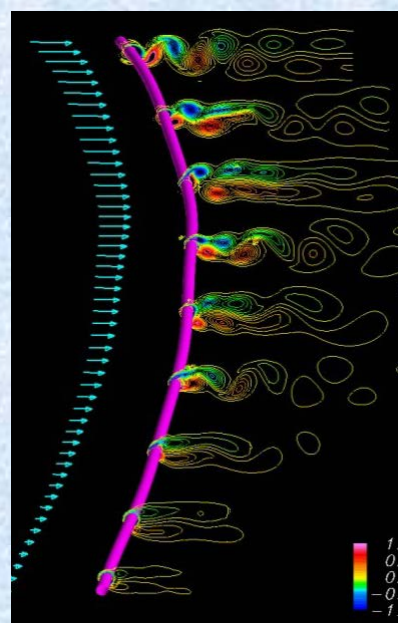
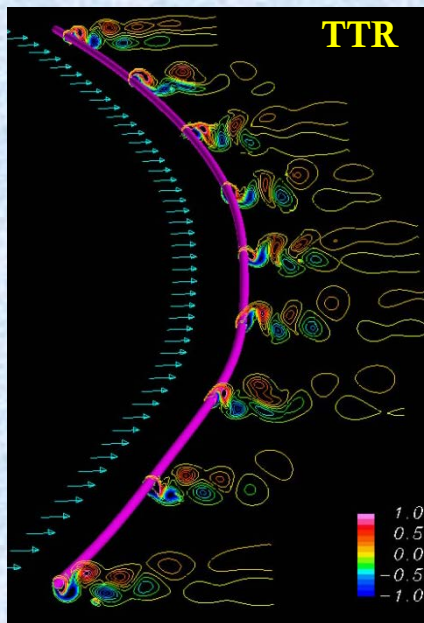
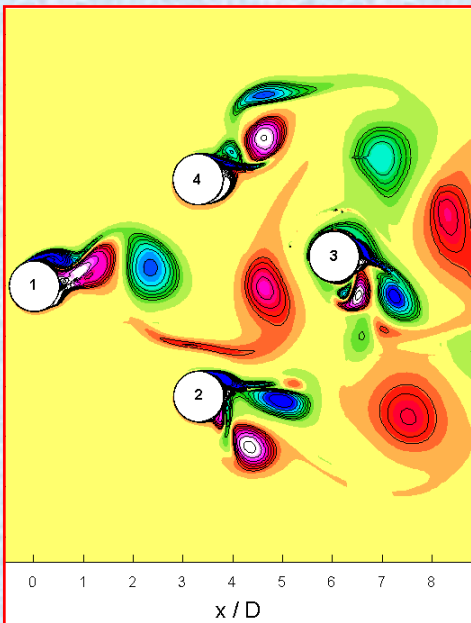
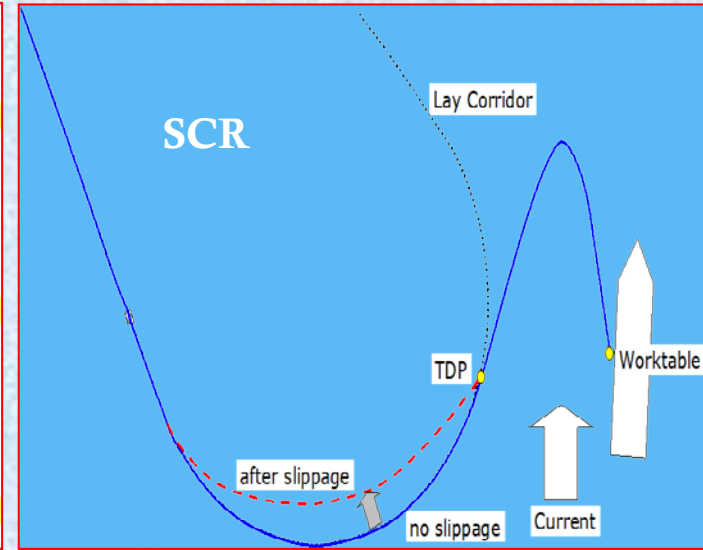
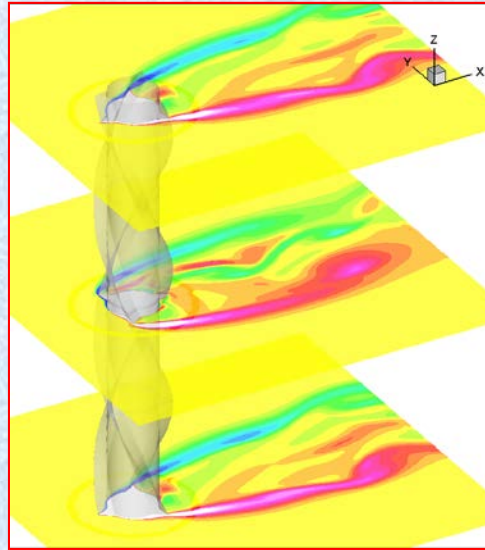
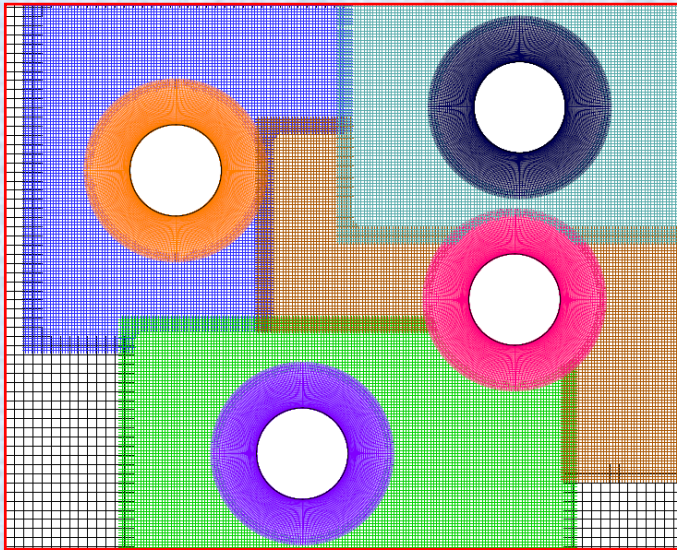
Extreme Wave Slamming Impact in Random Seaways

(a) Head Sea, 6 kts, $H_s=13.4$ m

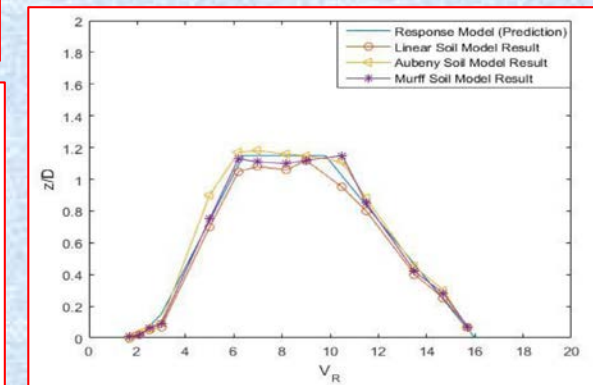
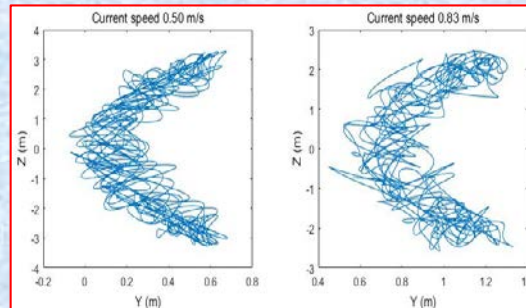
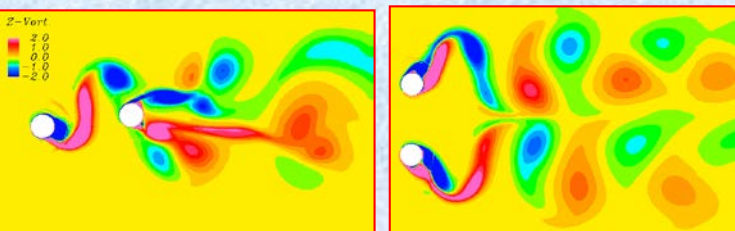
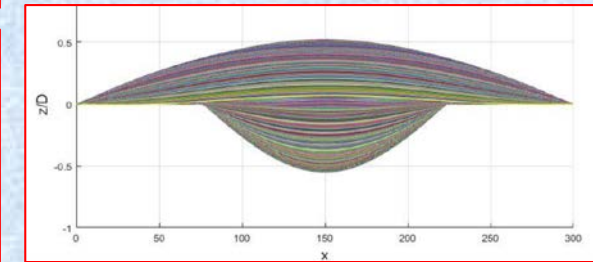
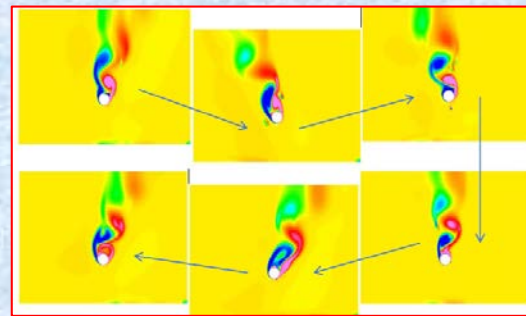
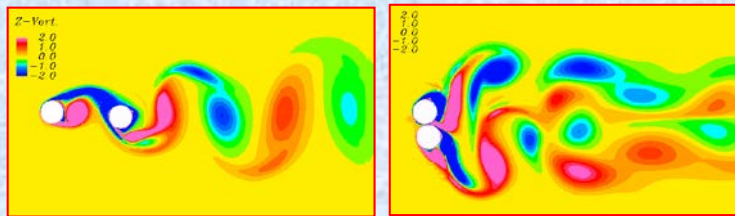
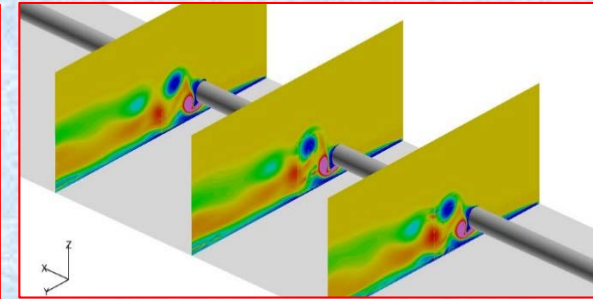
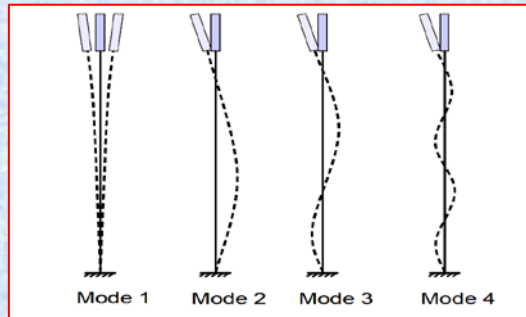
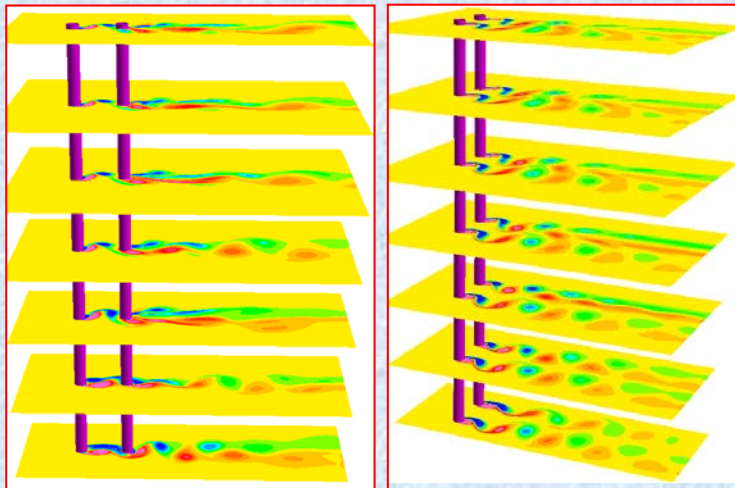
(b) Following Sea, 5 kts, $H_s=13.4$ m



Riser VIV, Riser Interference and VIV Suppression

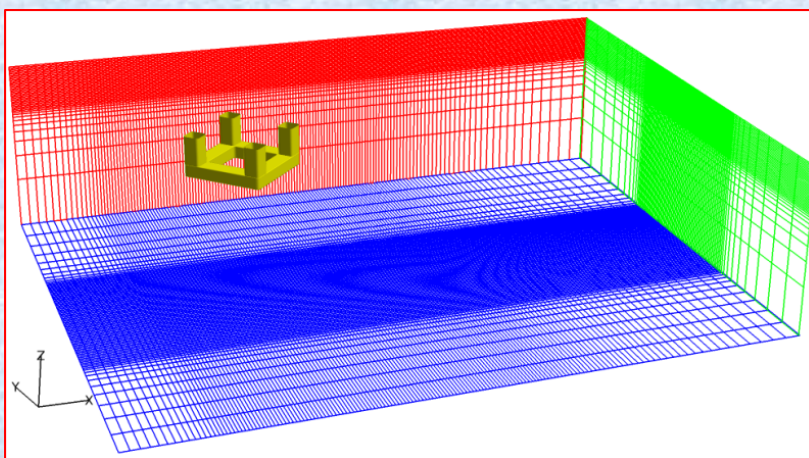
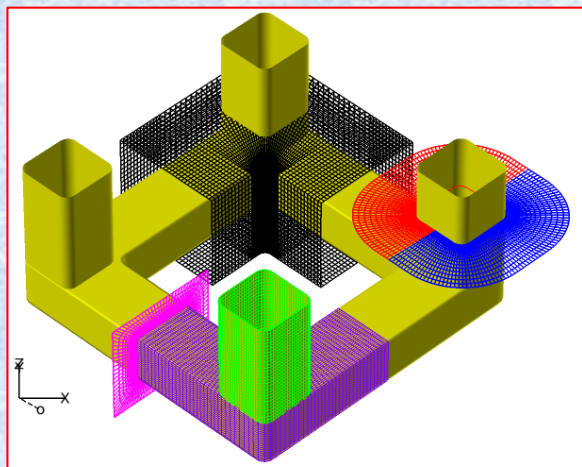


VIV and WIV of Risers and Pipelines

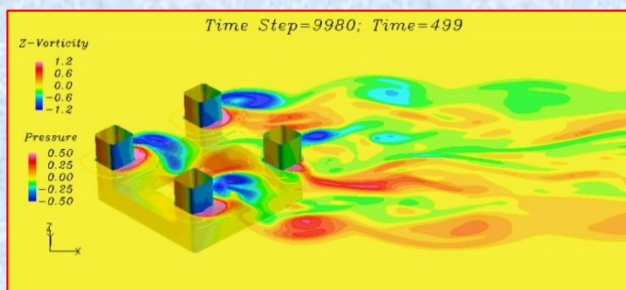


- Vortex-induced vibrations (VIV) and wake-induced vibrations (WIV)
- VIV of free-standing hybrid risers
- Free-span pipeline VIV and nonlinear pipe-soil interactions

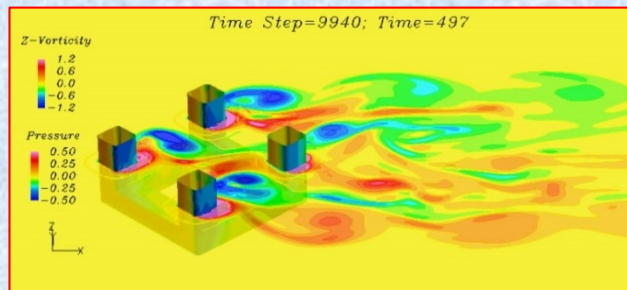
Vortex-Induced Motion of Deep-Draft Semi-Submersibles



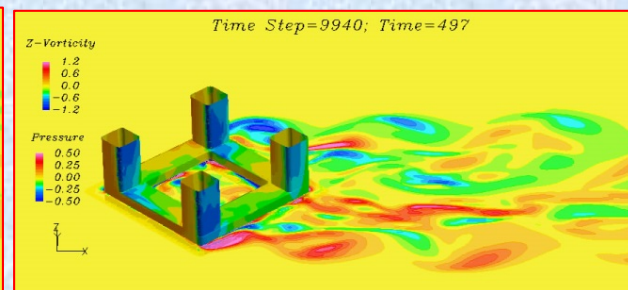
- Propotype: $L = 14$ m
 $U_o = 1.0$ m/s
- 1:70 Model: $L = 0.2$ m
 $U_o = 1/\sqrt{70}$ m/s
- 5.74M ~ 13.6M grid points



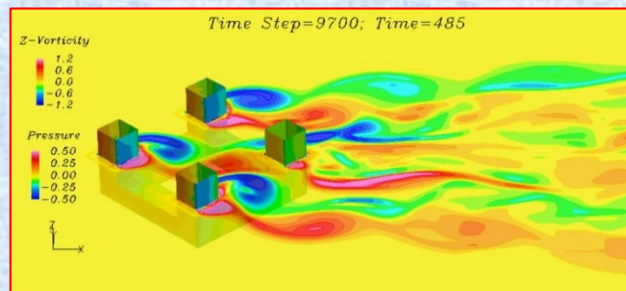
(a) Model, $D = 1.283 L$, $z = -L$



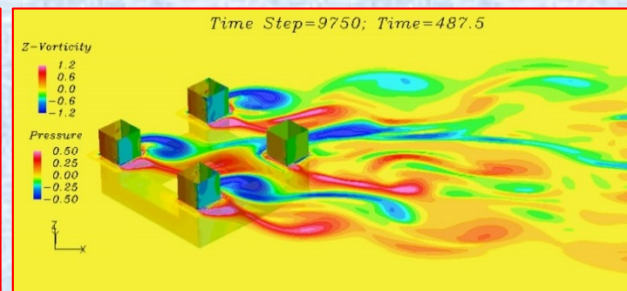
(b) Prototype, $D = 1.283 L$, $z = -L$



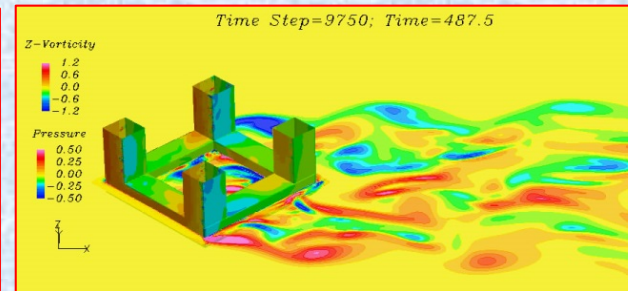
(c) Prototype, $D = 1.283 L$, $z = -2.1L$



(d) Prototype, $D = 1.385 L$, $z = -L$

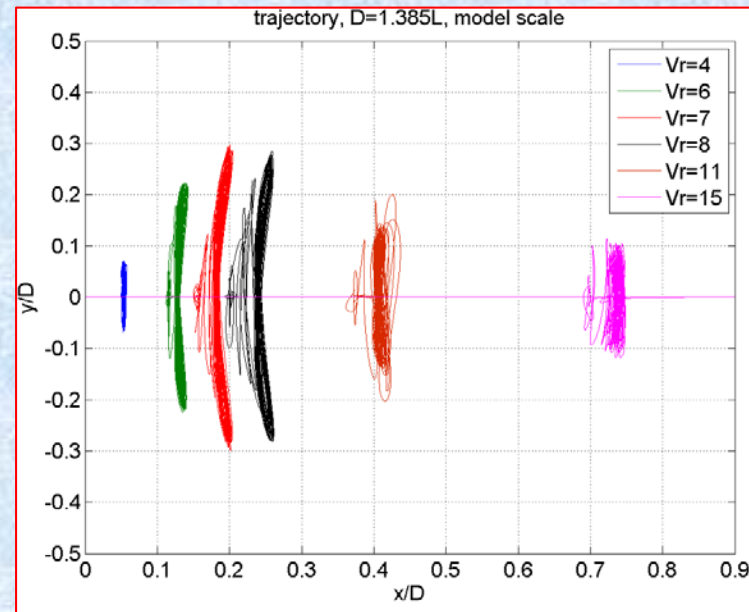
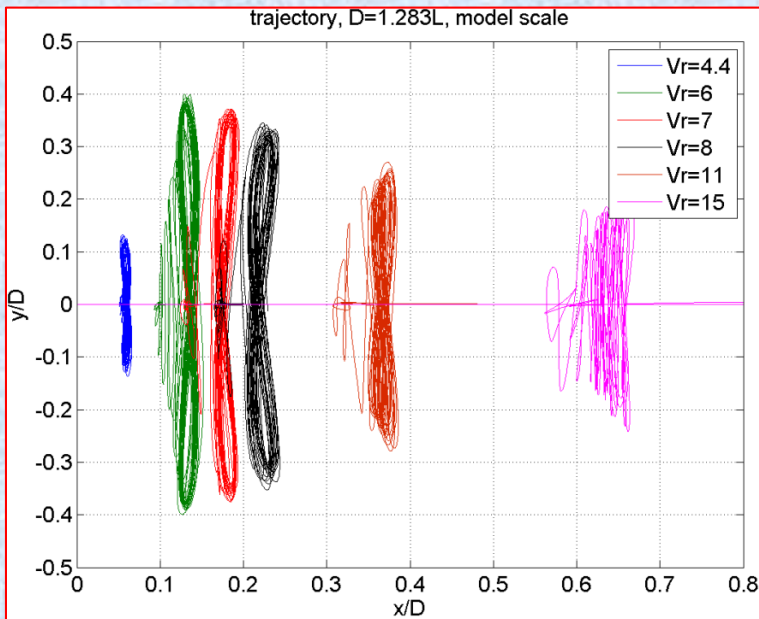
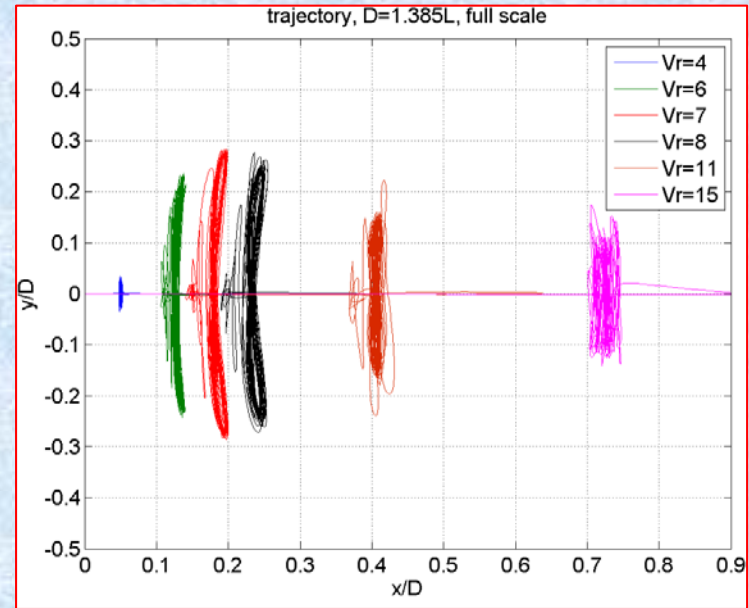
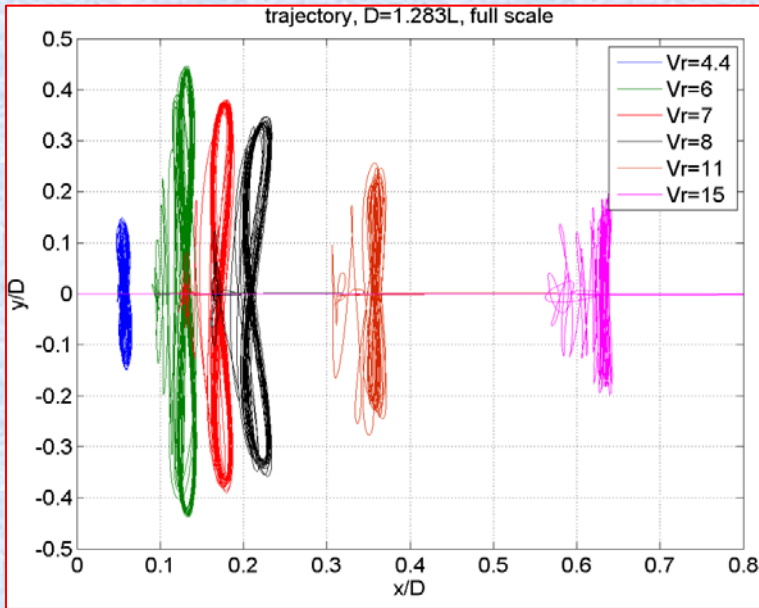


(e) Prototype, $D = \sqrt{2} L$, $z = -L$



(f) Prototype, $D = \sqrt{2} L$, $z = -2.1L$

Prototype vs Model: Trajectories



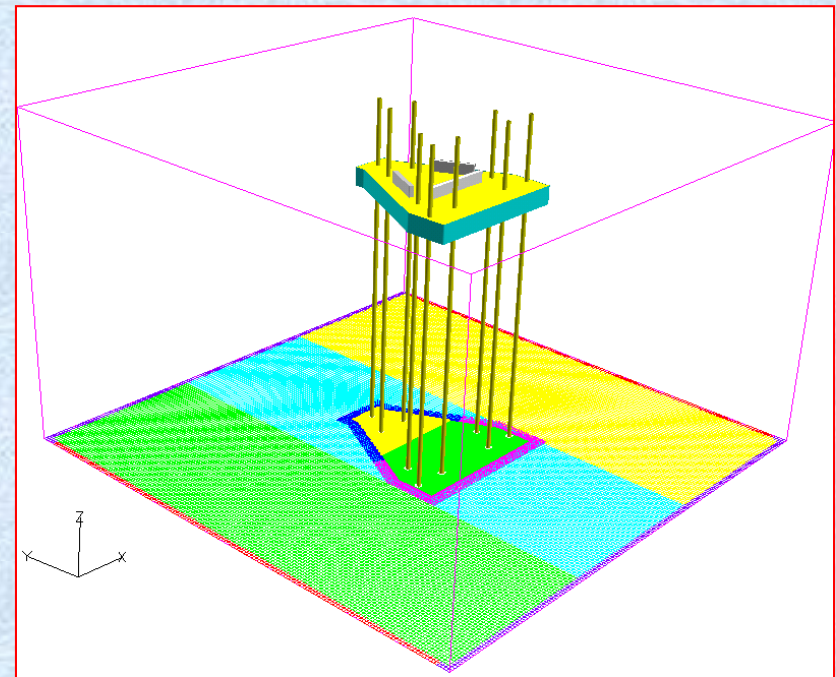
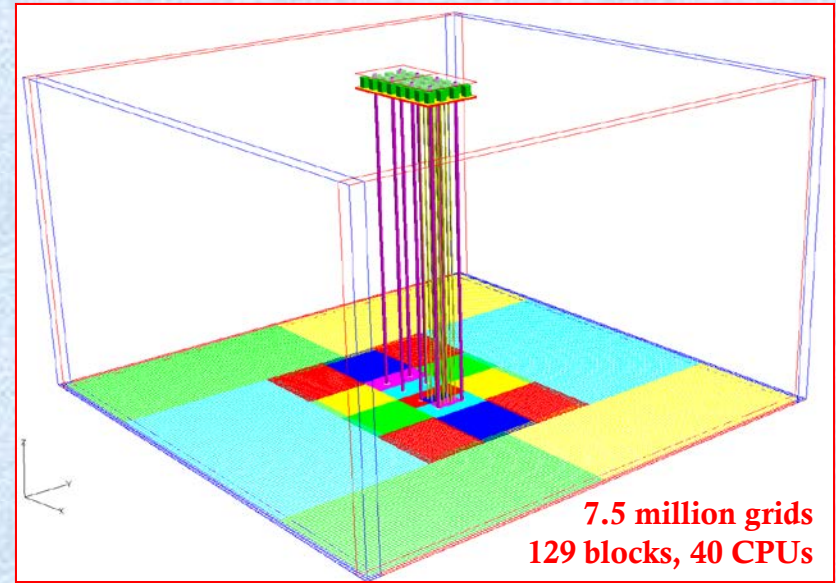
Hurricane Wave Loads on Offshore Structures

Wave-In-Deck

Provided by Skip Ward

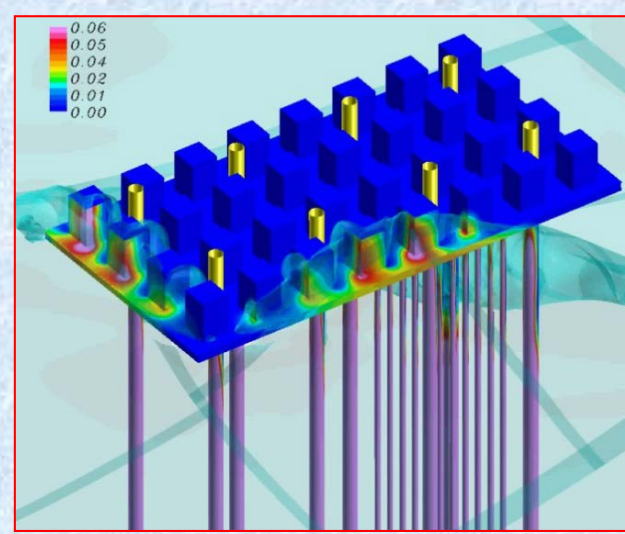
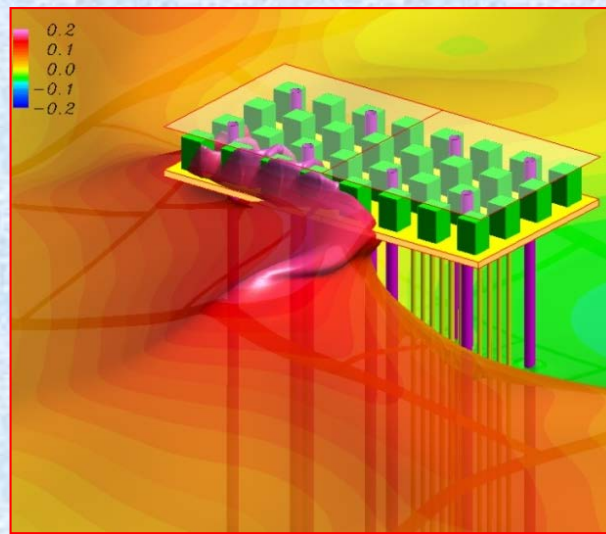
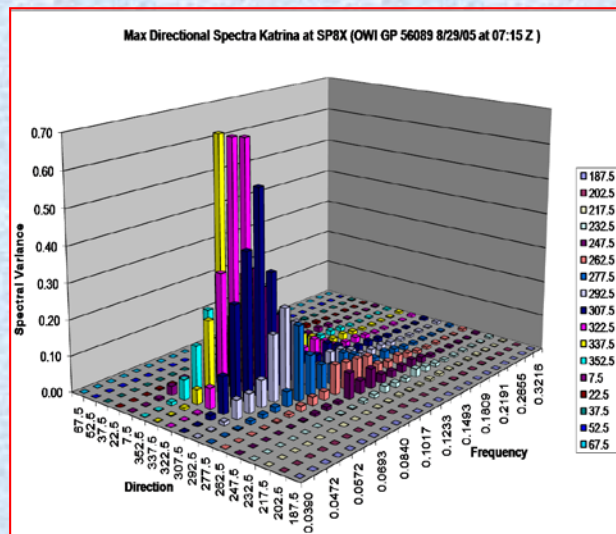
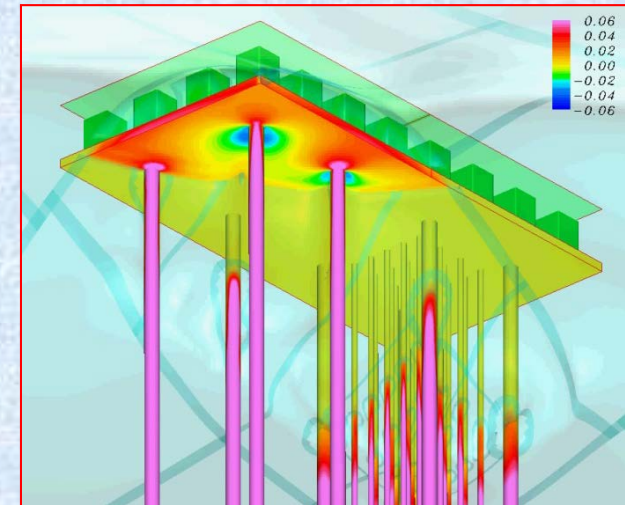
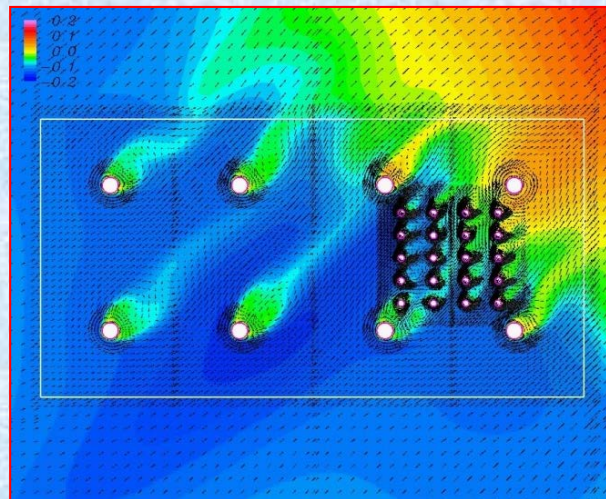
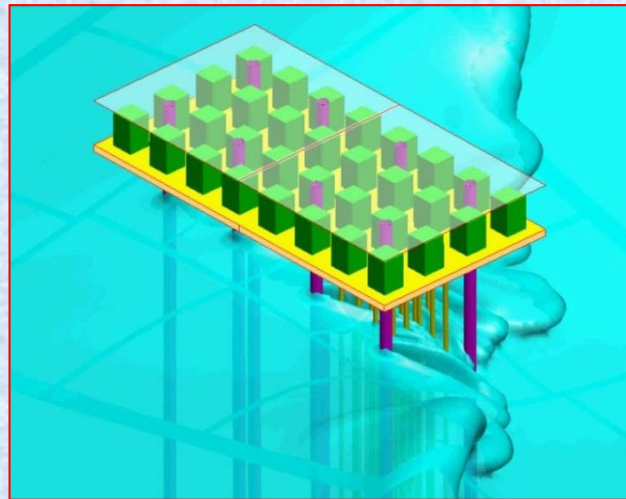


2005/10/12



Hurricane Katrina Wave Load on Offshore Structure

- Monochromatic wave, $H = 108$ ft, $T = 14.067$ sec, **peak impact pressure ~ 2600 psf (18 psi)**
- Directional short-crested wave, $H_{\max} = 18.048$ m for $0 < t < 30,000$ sec (occurred at $t = 16,387$ s), **peak impact pressure ~ 5200 psf (36 psi)**



Prospective Proposals

1. VIV Assessment of Subsea Rigid Jumper Systems

- Develop a CFD-based fluid-structure coupling program to predict the vortex-induced vibrations (VIV) and fatigue life of rigid jumper systems including 6-DOF motion of the jumpers under subsea currents.

2. VIM of Deep-Draft Semisubmersibles in Currents and Waves

- Generalize the FANS code for time-domain simulation of vortex-induced motions (VIM) of deep-draft column stabilized floaters in combined currents and waves. Perform parametric study to investigate the effects of floater geometries, column shapes, and structure damping for various combinations of reduced velocities and wave conditions.

Prospective Proposals

3. Extreme Wave Loads on Offshore Platforms, FPSOs, and Offshore Wind Farms

- Develop a coupled level-set and volume-of-fluid (CLSVOF) method for CFD simulation of fluid-structure interactions of offshore structures, FPSOs, and offshore wind farms in extreme storm waves.
- Assessment of peak impact pressure caused by directional short-crested waves as well as greenwater loads on offshore structures

4. Multiple-Vessel Interactions Under Site-Specific Conditions

- The FANS code can be readily generalized for site-specific CFD simulation of multiple-vessel interactions including the docking and moored vessels, offshore platforms, floating piers and/or waterfront facilities.

