Workshop on Very Large Floating Structures for the Future

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Efficient Hydrodynamic Analysis of VLFS

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Theoretical formulation and restrictions

- Linear (and 2nd order) potential theory (small amplitude waves and motions)
- Frequency-domain analysis (can be transformed to time domain if necessary)
- No considerations of current, slamming, viscous loads

Computational approach

- Boundary Integral Equation Method (BIEM) a.k.a. `Panel Method’ with free-surface Green function (source potential)
- General-purpose codes are applicable to a wide variety of structures and applications (different configurations, air-cushions, hydroelastic effects, multiple bodies)
- All relevant hydrodynamic parameters can be computed (loads, RAO’s, pressures, drift forces, free-surface elevations, etc.)

Computational tasks and restrictions

- Geometric representation of structure
- Structural representation (if hydroelastic)
- Confirmation of results requires convergence tests
- Computing time (and memory) increase rapidly with number of unknowns
- Short wavelengths aggravate everything!

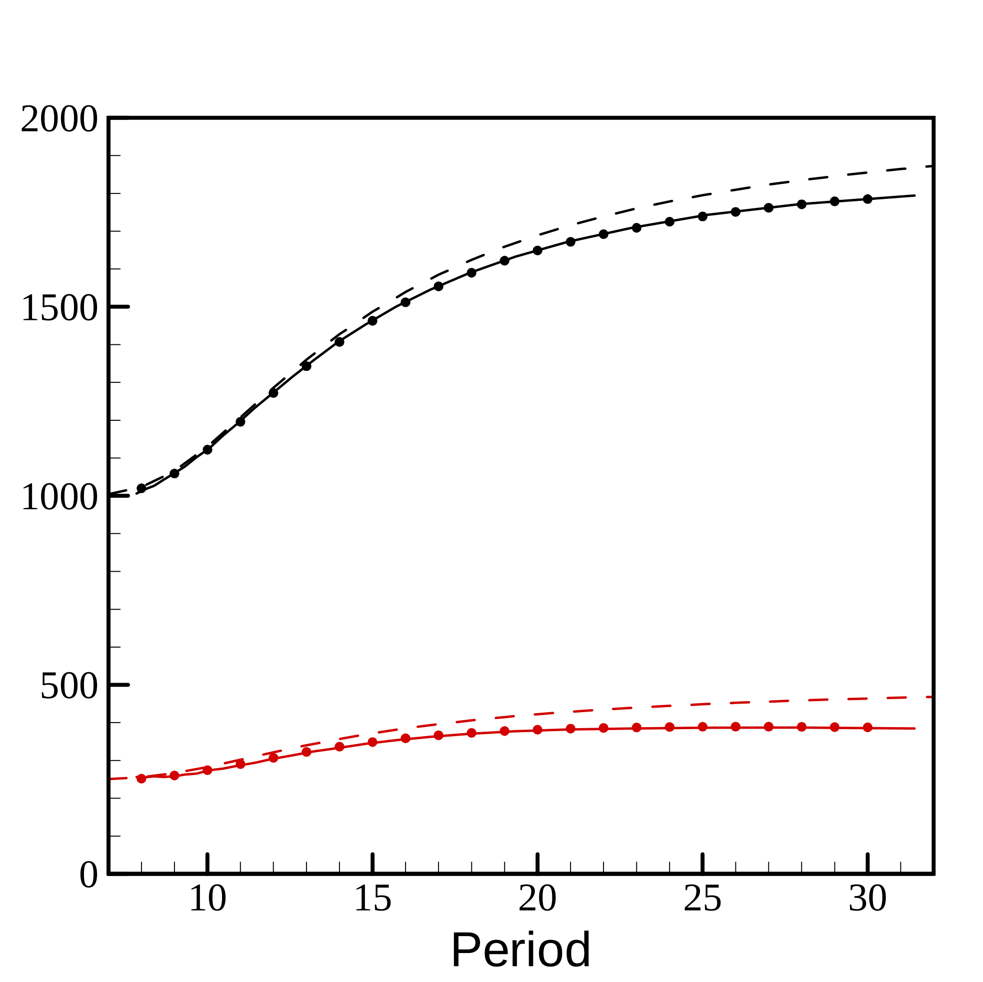
recent developments

- Higher-order panel method with B-spline basis functions for the solution
- pFFT Accelerated solver O(N log N)
- Exact geometry
- CAD coupling

Examples of Applications and Results

- Rigid barge 4km x 1km x 5m
- Hinged barges with hydroelasticity
- Hinged semi-subs with hydroelasticity
- Large arrays of cylinders

Drift forces on 4km x 1km x 5m rigid barge
Wave incidence angle 45^o -- Water depth = 50m



Red: Surge drift force
Black: Sway drift force
- higher-order method (727 unknowns)

Solid lines: Accelerated pFFT (`precorrected Fast Fourier Transform') method with 43,000 low-order panels (Order N log N)

Both methods take about 0.4 hour/period on a 2GHz PC

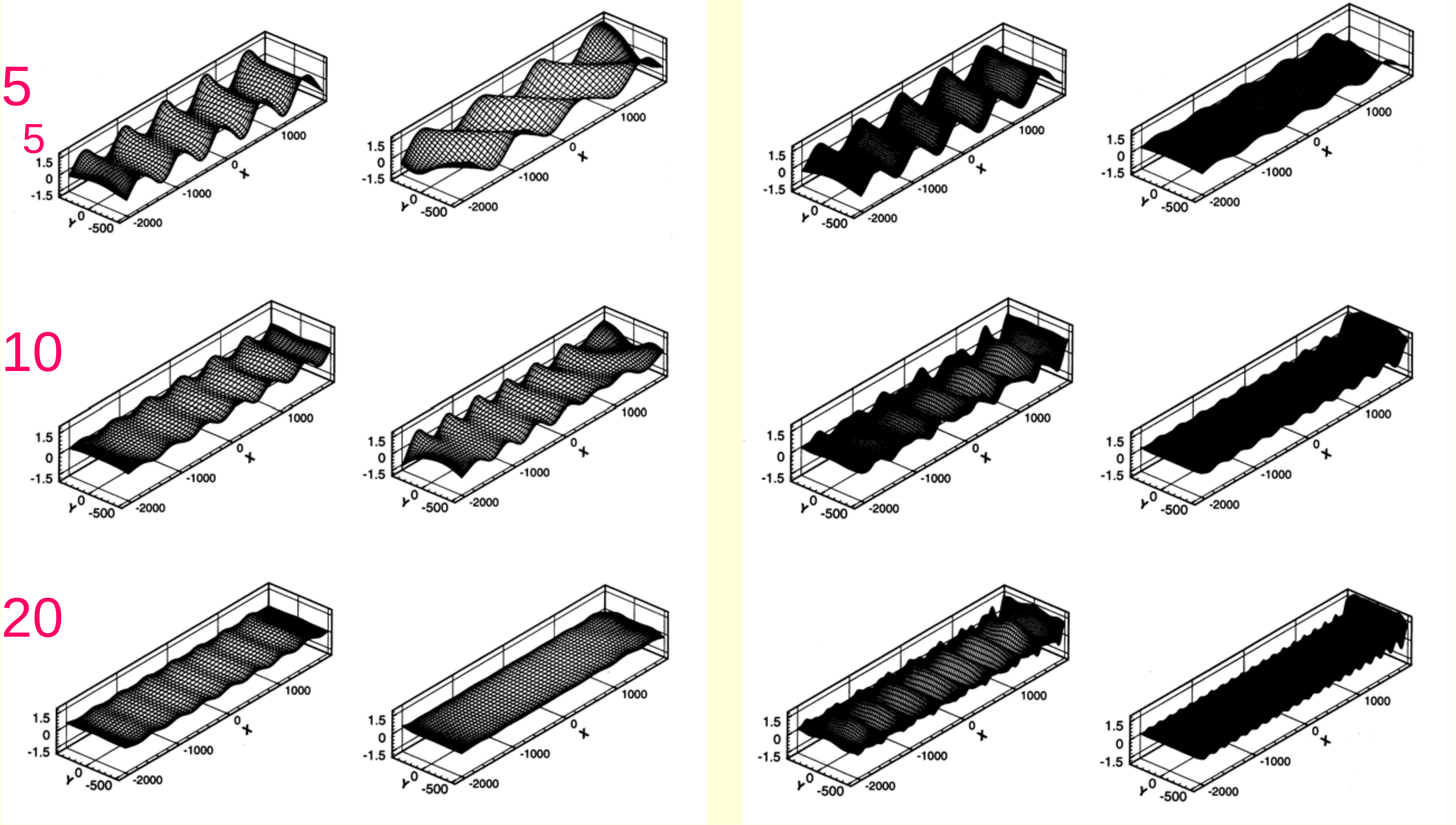
Dashed lines: Asymptotic approximation for short wavelengths

4km x 1km x 5m barge, 27*16 generalized modes

L/wavelength = 5,10,20 – depth = 20m – Period = 57,28,15 seconds

DEFLECTION | PRESSURE

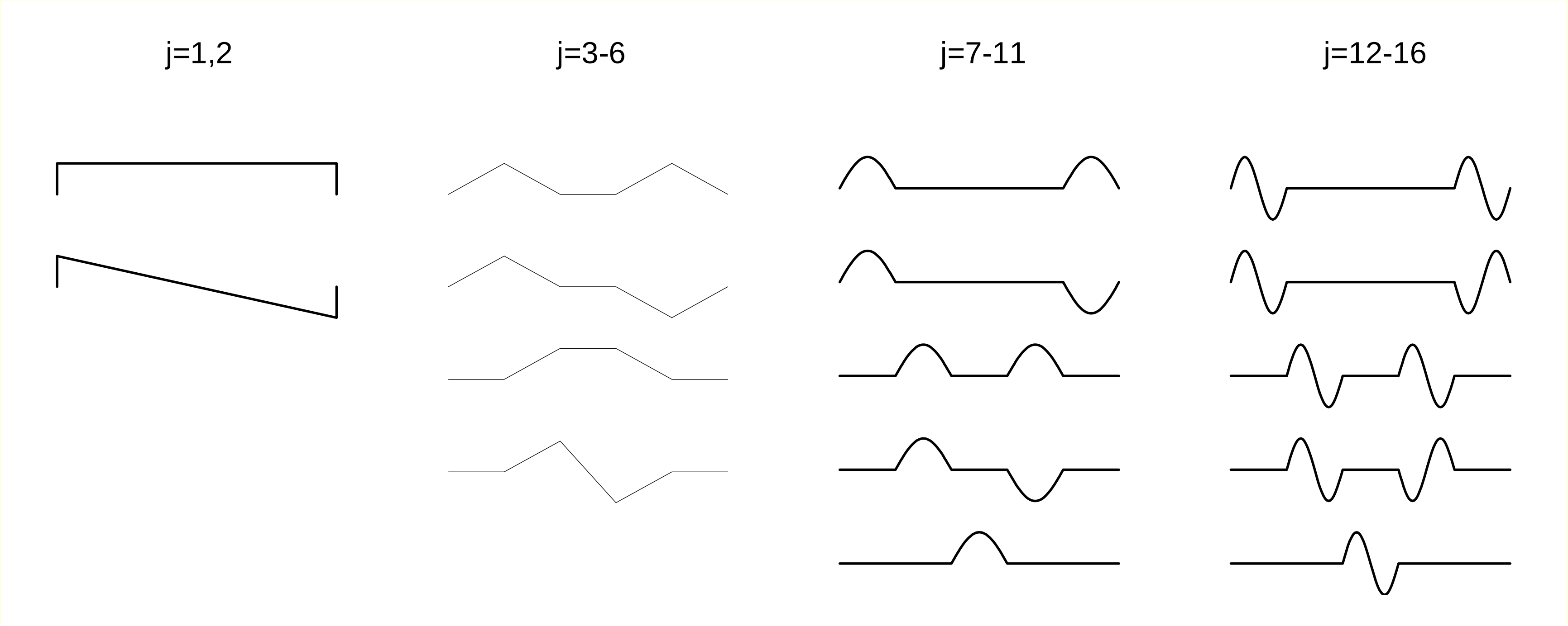
Head seas | 45 degrees | Head seas | 45 degrees



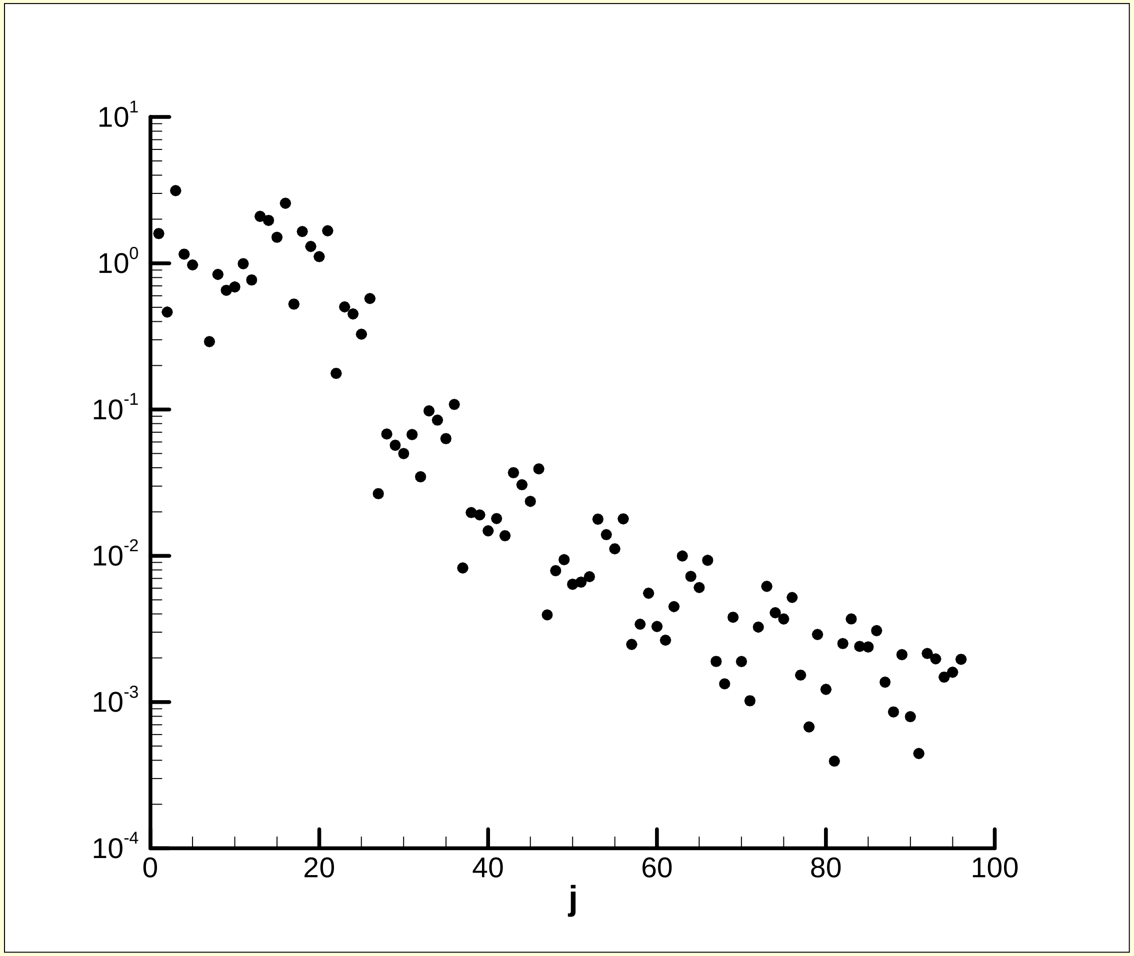
From C.-H. Lee, `Wave interactions with huge floating structure’, BOSS `97

Symmetric/antisymmetric modes for a hinged structure with five elements

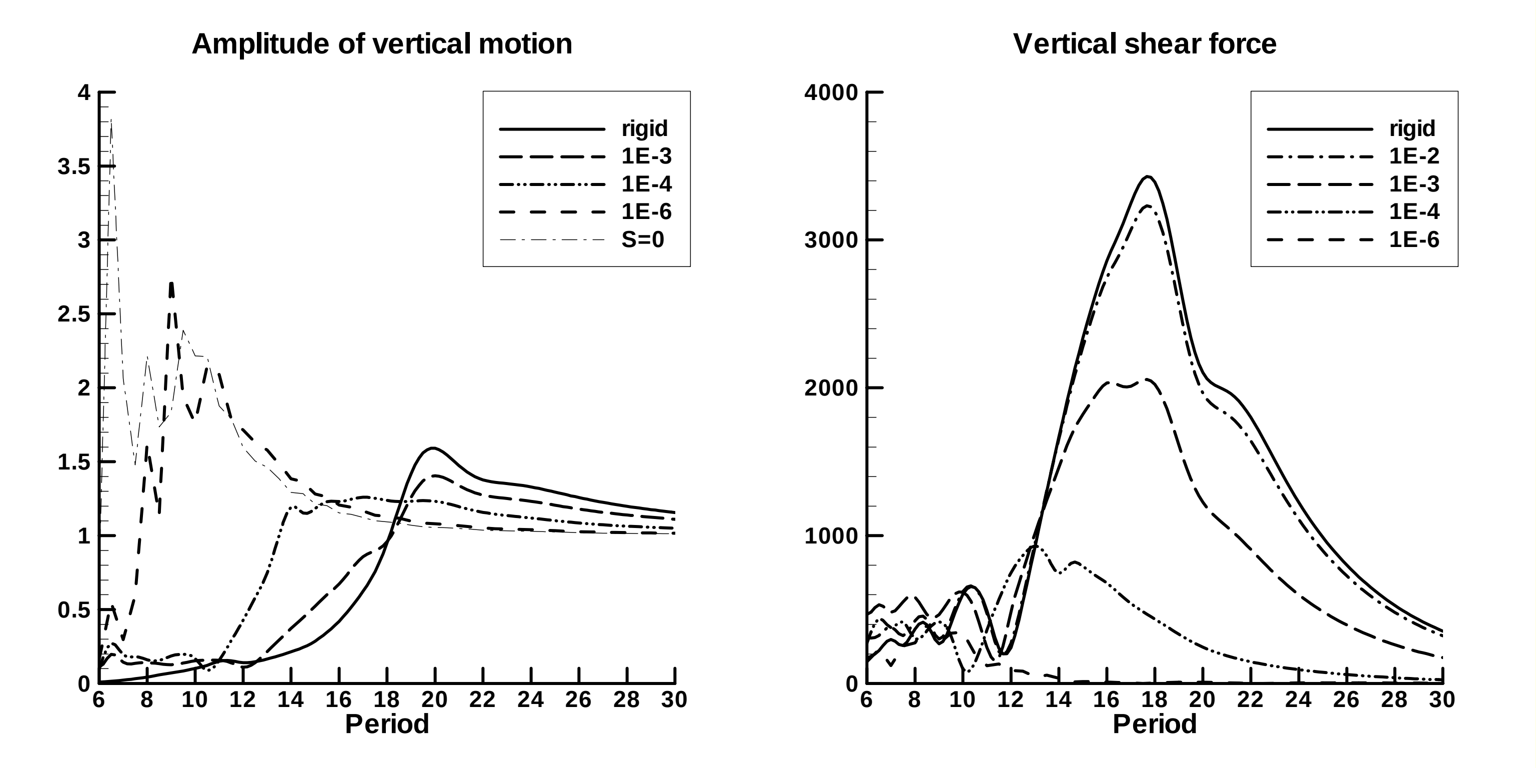
Modes 7-11 and 12-16 are Fourier bending modes for hydroelastic analysis



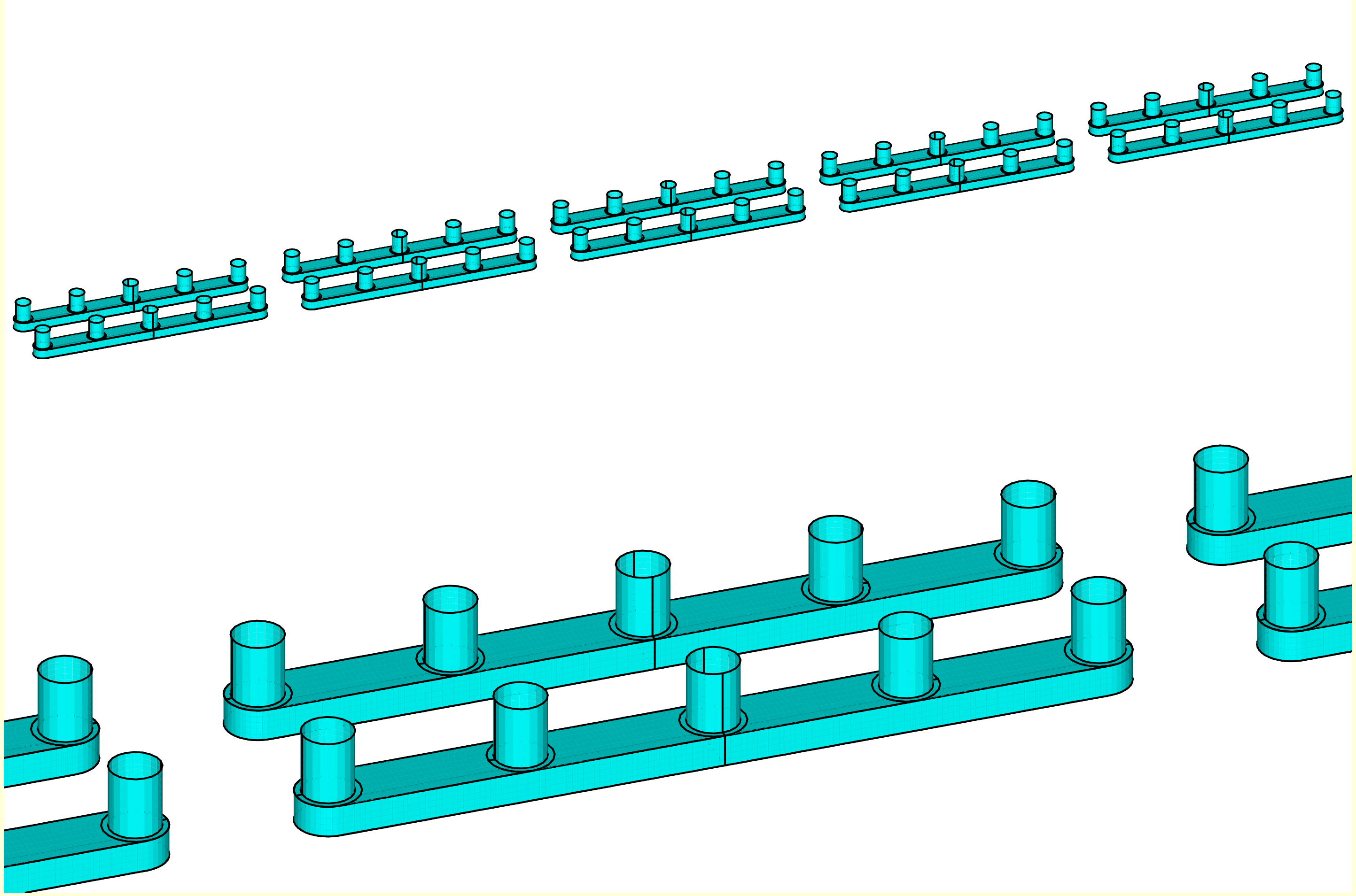
Array of five 300x80x6m barges with zero stiffness
RAO of each mode, period 12 seconds



Array of five 300x80x6m barges with stiffness S
(Stiffness is normalized by L=300m)
Motion and shear force at the upwave hinge



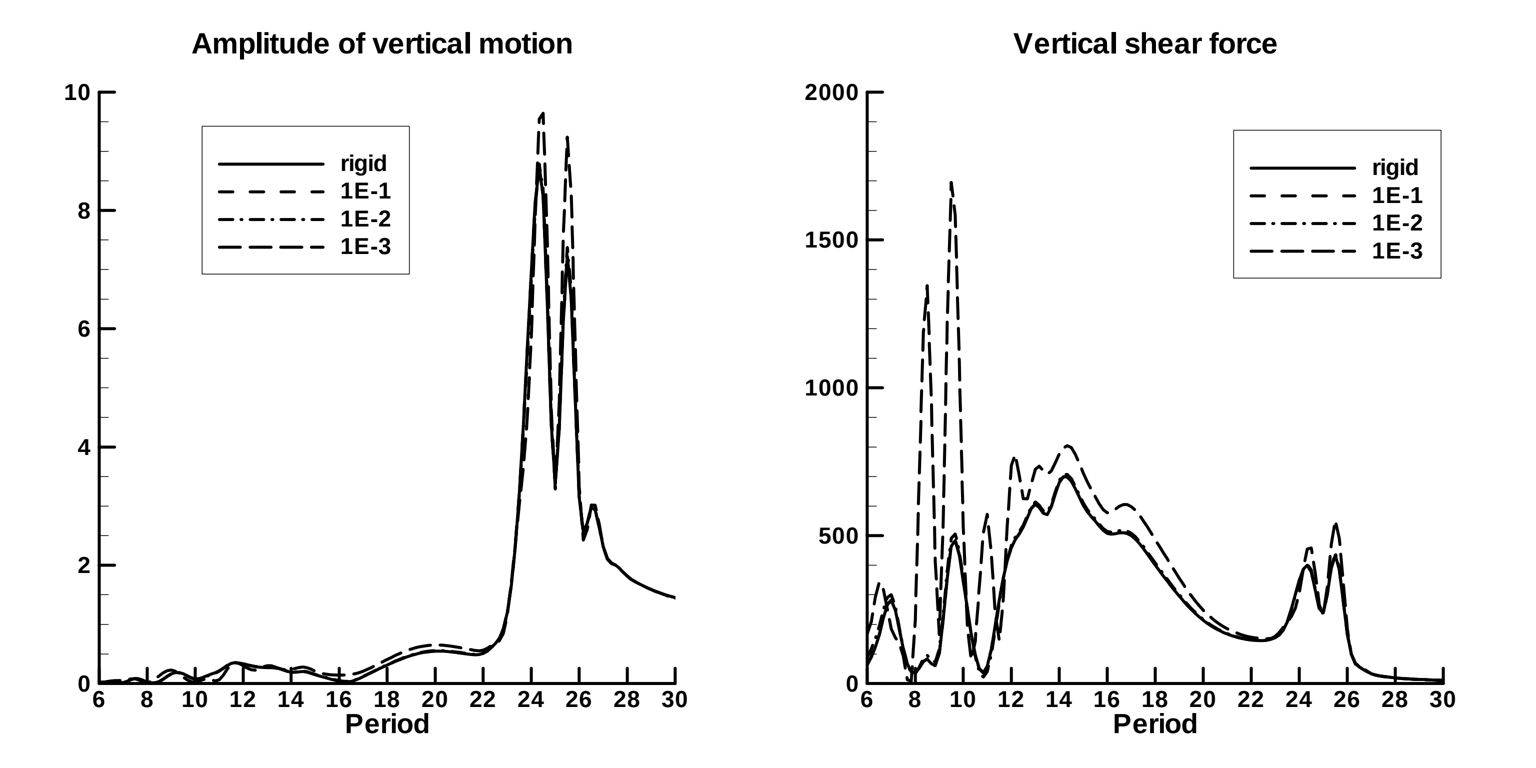
Array of 5 hinged semi-subs, each 300m long (lower figure shows zoom of one element)



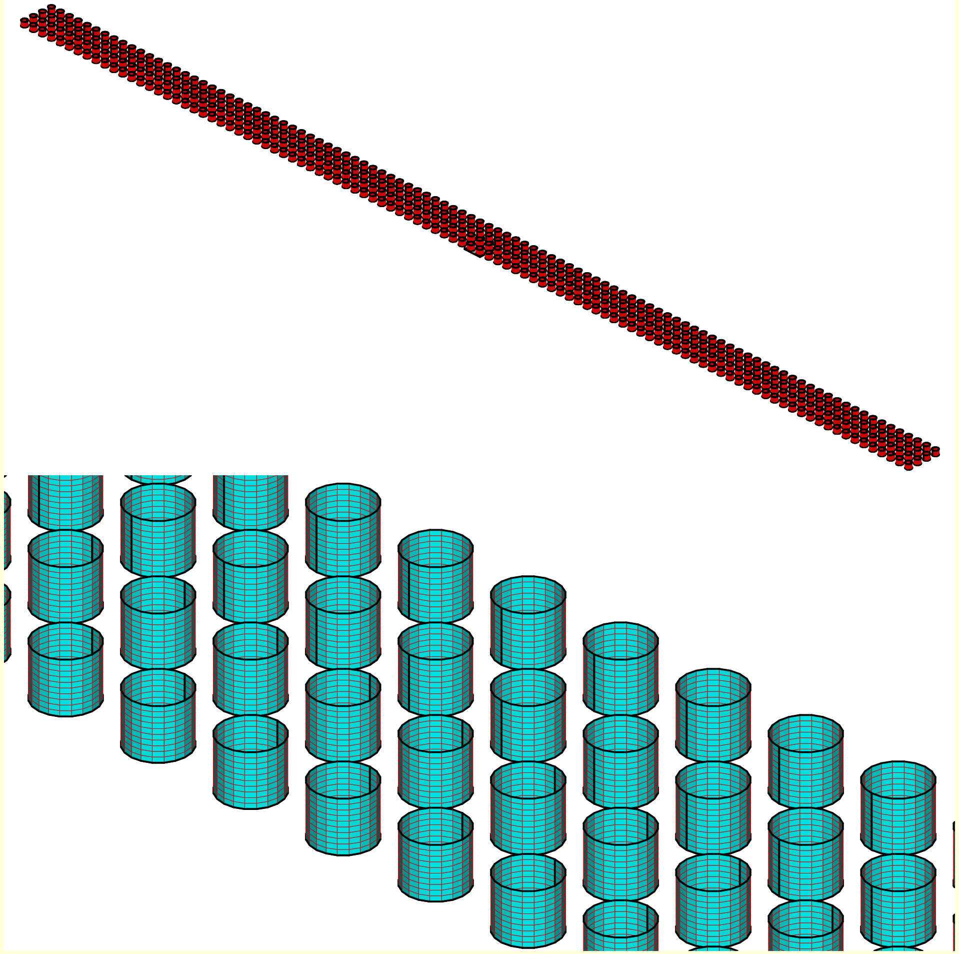
Array of five semi-subs with stiffness S

(Stiffness is normalized by L=300m)

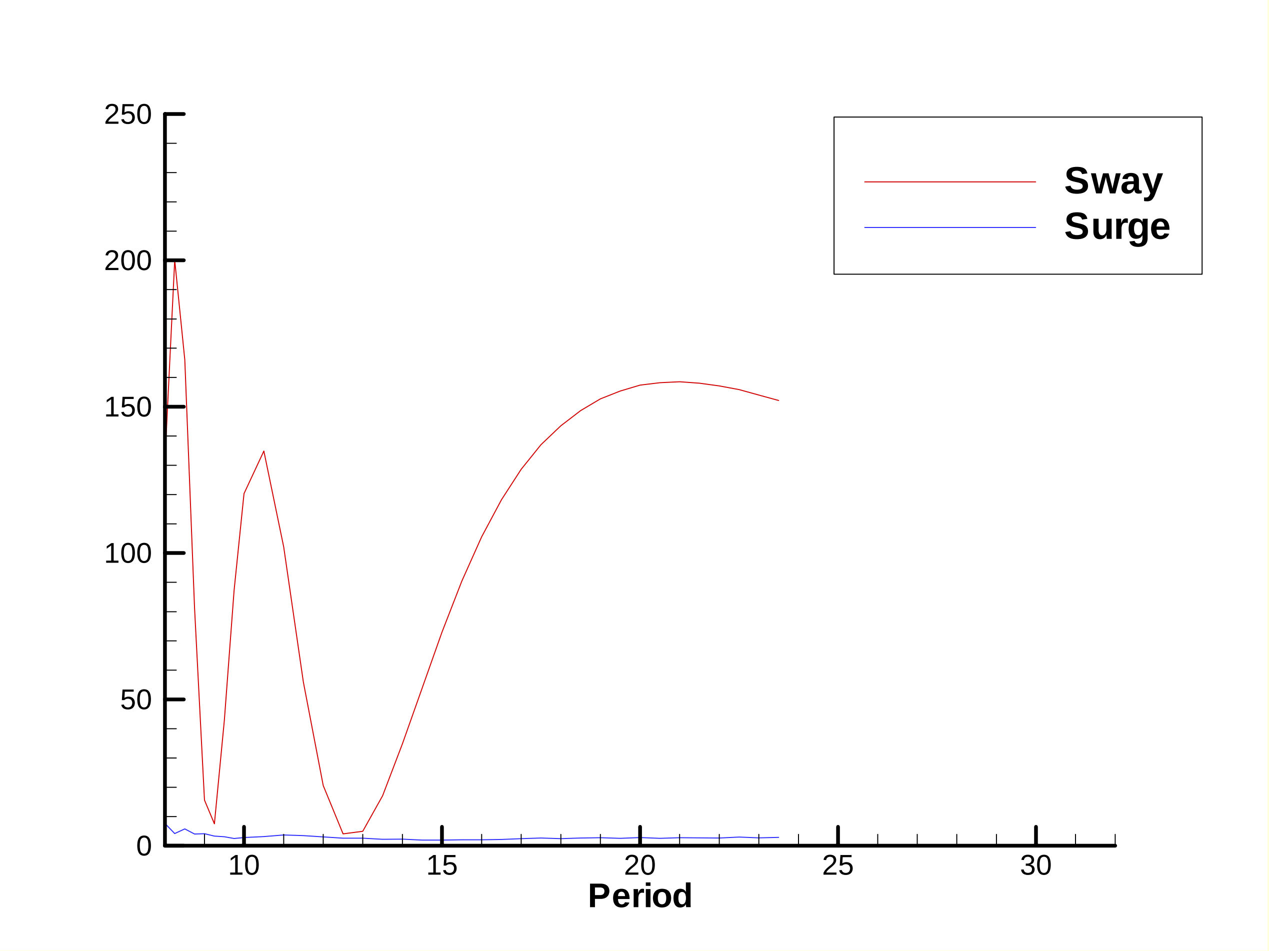
Motion and shear force at the upwave hinge



Array of 100 x 4 = 400 cylinders
Radius=11.5m, Draft=20m, Axial spacing=40m

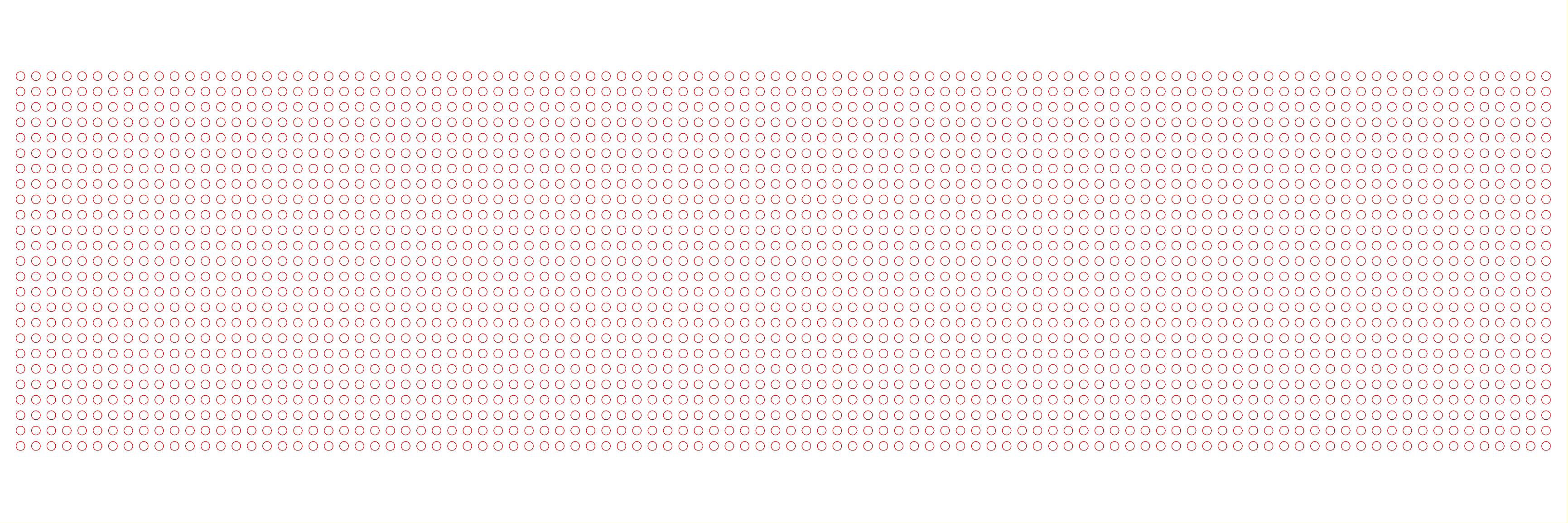


Mean drift forces on Array of 100 x 4 cylinders
Wave incidence angle 45^{o} -- Water depth = 50m



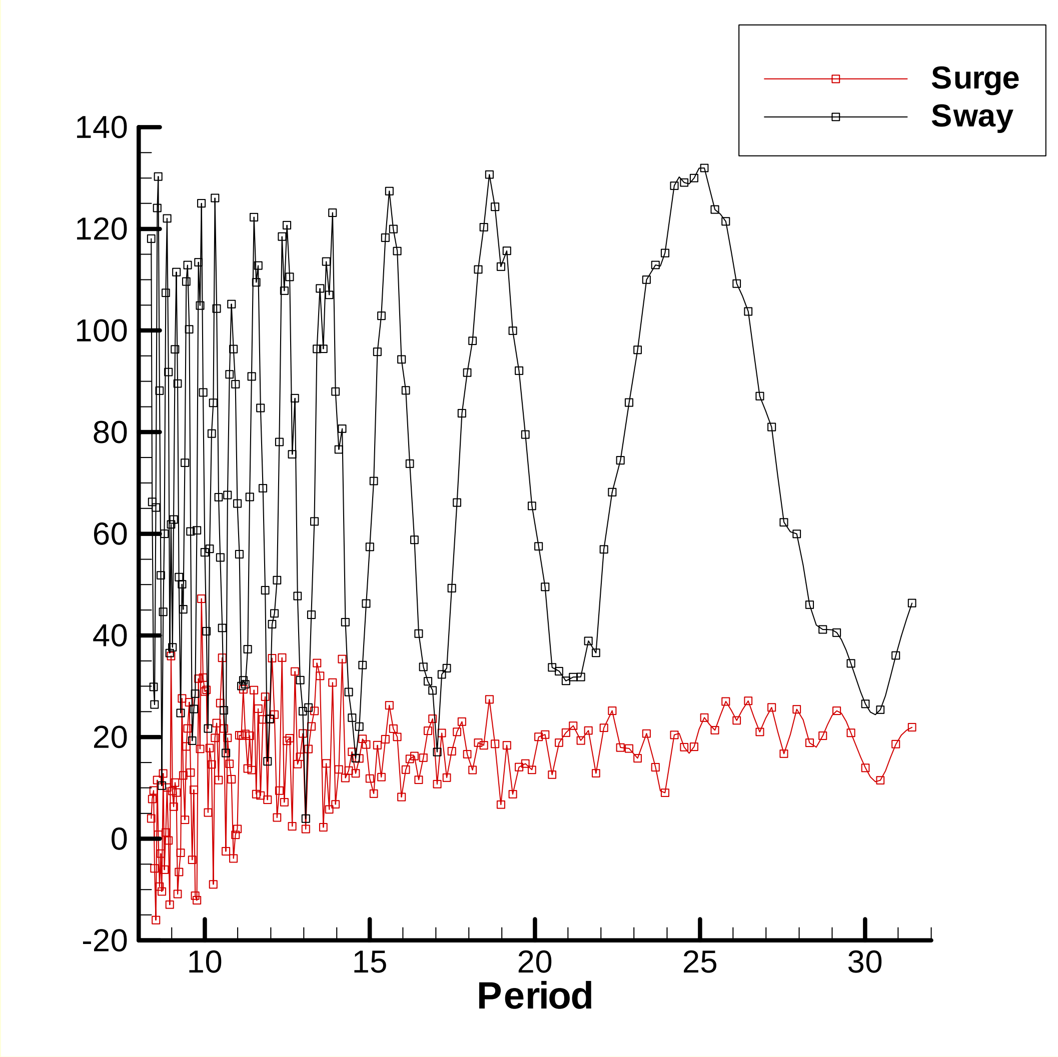
Array of 100 x 25 = 2500 cylinders

Radius=11.5m, Draft=20m, Axial spacing=40m



Drift forces on the 100x25 Cylinder Array

Wave incidence angle 45^o -- Water depth = 50m



240,000 low-order panels were used here (96 on each cylinder).

These computations were performed on a 2.6GHz PC using the accelerated pFFT method. The CPU time averaged about one hour per period.

The peak magnitudes are much larger below 8 seconds, where near-trapping occurs between adjacent cylinders.

Conclusions

- Contemporary hardware/software can be used to analyze wave effects for many VLFS configurations with length scales of order 1-4 km
- These capabilities will increase in the future
- Short wavelengths, bottom topography, breakwaters, etc, present special challenges
- Analytic/asymptotic theories are still required for >>1km length scales, e.g. ice fields, and to validate computations in the short-wavelength regime

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Further information:

www.wamit.com/Publications