Report

2009 Annual WAMIT Consortium Meeting

September 29-30, 2009

Woods Hole, Massachusetts

Agenda for 2009 Annual WAMIT Meeting
Room 310, Marine Resource Center, Swope Center, Woods Hole, MA

September 29, 2009:

9:00AM: Welcome

9:30AM: “Status of WAMIT V6.4, V6.4S and V6.5”
C.-H. Lee, WAMIT

10:00AM: “Diffraction effects and ship motions on an artificial seabed”
M.D. Ferreira, Petrobras and J. N. Newman WAMIT

10:40AM: Break

11:10PM: "MultiSurf Components are Company Assets"
R. Page, AeroHydro

11:40AM: "Use of Control Surface in Shallow Water"
C.-H. Lee, WAMIT

12:20PM: Lunch, Swope Center Dining Hall

1:40PM: "Detecting Sensor Failure in an Array of Measured Data"
J. Niedzwecki, OTRC

2:10PM: “Second order forces on deep columns”
C.-H. Lee, WAMIT

3:00 PM: Break

3:30 PM: “Technical discussion”

5:30PM: Mixer and Dinner, Swope Center Dining Hall

September 30, 2009

9:00AM: “Parallel Programming in OpenMP for WAMIT?”
X. Zhu, WAMIT

9:30PM: “WAMIT V65 and beyond”
C-H Lee WAMIT , Inc

10:30AM: Break

11:00AM: Business meeting

12:00AM: Lunch, Swope Center Dining Hall

Contents

Status of WAMIT V6.4, V6.4S and V6.5

V6.4 Updates

- An option is added to read user specified RAO. User may

  i) evaluate hydrodynamic coefficients and wave exciting forces from WAMIT ii) take into account of viscous damping, mooring line or other external forces through other specialized software for RAO and iii) the RAO, in turn, can be used in WAMIT to evaluate body/field pressure, mean drift forces and second order forces (in V6.4S for the latter).
- Updates made to account for dipole elements inside tanks to simulate potential flow effect of plates in tanks
- Update made in F2T to correctly accept WAMIT output for multibody interaction
- Extensive tests has been made and numerous corrections/updates made in particular in surface trimming and automatic generation of control surfaces

Status of V6.4S

- New programming was initiated to implement the second order extensions to V6.4. Parts of the previous codes experimented with V6.2 and V6.3 were carried over.
- Original motivation to extend beyond V6.1S was to improve the integration of RHS forcing for the higher-order method. Despite this deficiency the solution from higher-order method of V6.1S is significantly more accurate and is efficiently evaluated than the low order method especially for the diffraction problem where the error is confined to close vicinity of waterline.
- New motivations to extend V6.4 includes internal tanks, control surface approach, trimming and other new features in V6.4 such as automatic generation of free surface/control surface in conjunction with higher-order option.

- All capabilities in V6.4 are effective in V6.4S.

  Exceptions: generalized modes, dipole elements, thin bodies on the free surface, walls, wavemakers, free/fixed modes, second order effect of the external constrains is not calculated internally.

- Evaluation of the influence coefficient on the exact surfaces and waterlines (the quality of the integration is also dependent of the approximation of the forcings but this issue is not addressed in V6.4S).

- Control surface approach for quadratic forces

- Complete second-order solution in the tanks available (to be tested)

- Various input formats of free surface geometry (to be tested)

- Automatic free surface generation for ILOWHI=1 (not yet implemented)

- V6.414 is available immediately

  Further work in V6.4

  1. Update the definitions and normalizations of output from F2T

- V6.4S -alpha – quadratic forces and second-order potential forces by direct method will be made available by the end of current consortium year (10/31).

  Remaining works in V6.4S

  1. Field quantities including 2nd-order free surface elevation
  2. 2nd -order body pressure
  3. 2nd -order forces by indirect method.
  4. Update User Manual
  5. Automatic free surface generation for ILOWHI=1

V6.5 & beyond

- Option to exploit geometric symmetry when NBODY>1 (This extension is available on request.)
- Output patch data in header of .out file if NPER=0
- Improved error messages for bad input files
- Option to interrupt/restart run and save Rankine data
- Option to run new frequencies with saved Rankine data
- Extension for Grue & Palm small velocity/current interaction

Diffraction effects and ship motions on an artificial seabed

by M.D. Ferreira & J. N. Newman

(extended version from 24th IWWWFB)

Background and motivation

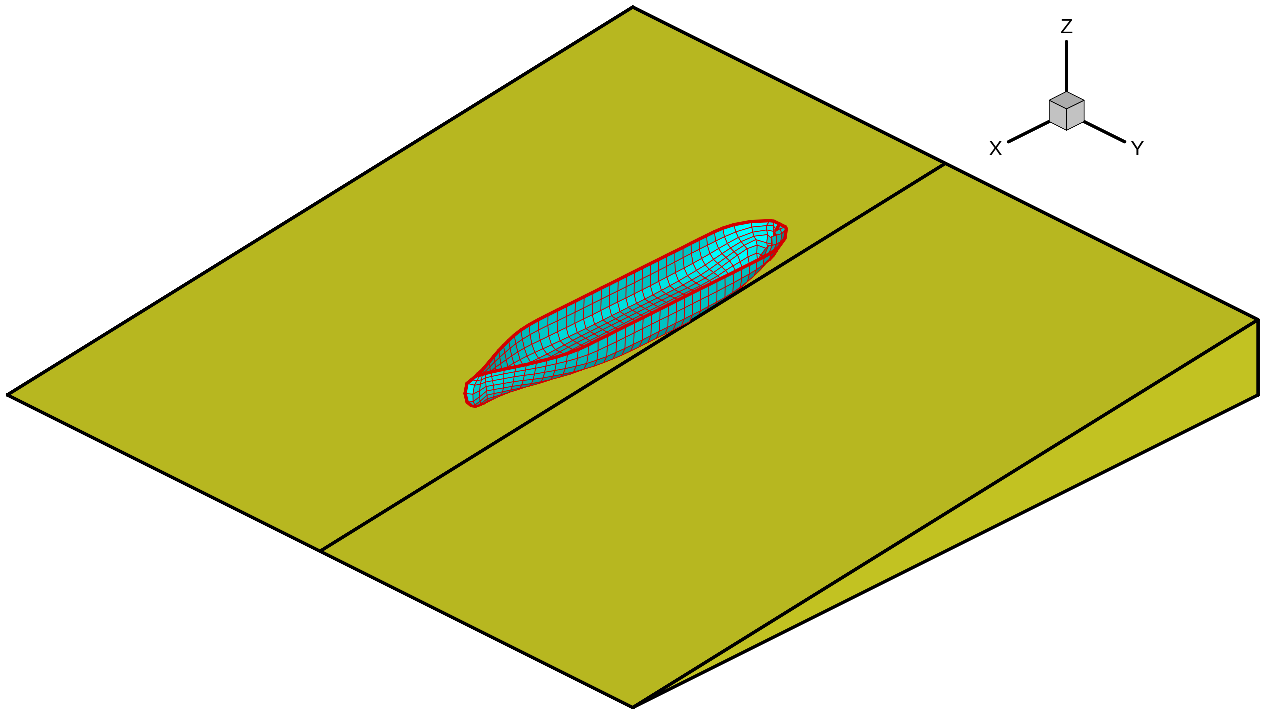
- Recent interest in effects of bathymetry (nonuniform depth) on moored ships, e.g. LNG offshore terminals near a coastline with sloping bottom

Paper by Bas Buchner (MARIN) OMAE 2006

LNG Ship on sloping bottom

ship length 274m, bottom 550m by 550m

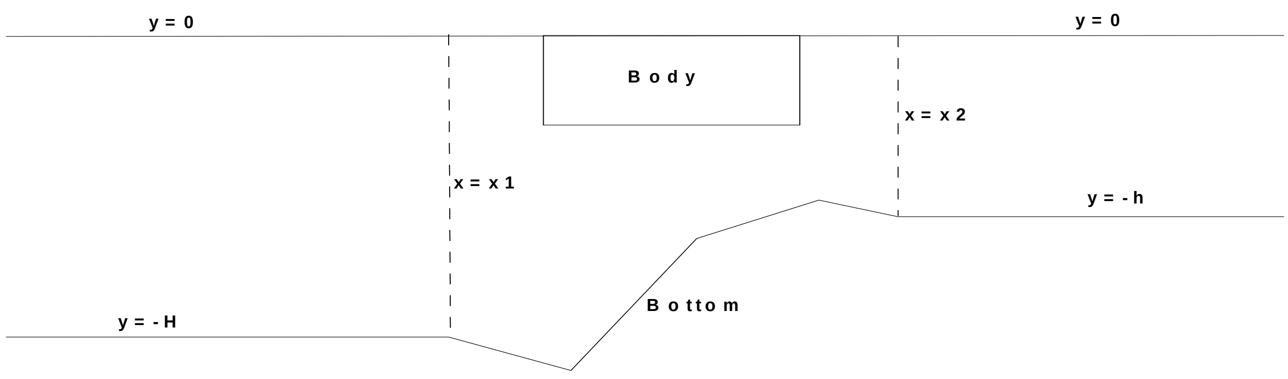
wave frequencies 0.1 – 0.6 rad/sec



Outline

- 2D computations, special code, no ship
  (`benchmark' for waves without ship)
- 3D computations, WAMIT, no ship
  (diffraction effects of artificial bottom)
- 3D computations, WAMIT, with ship
  (force coefficients and heave/pitch RAOs of ship – also mean drift force)

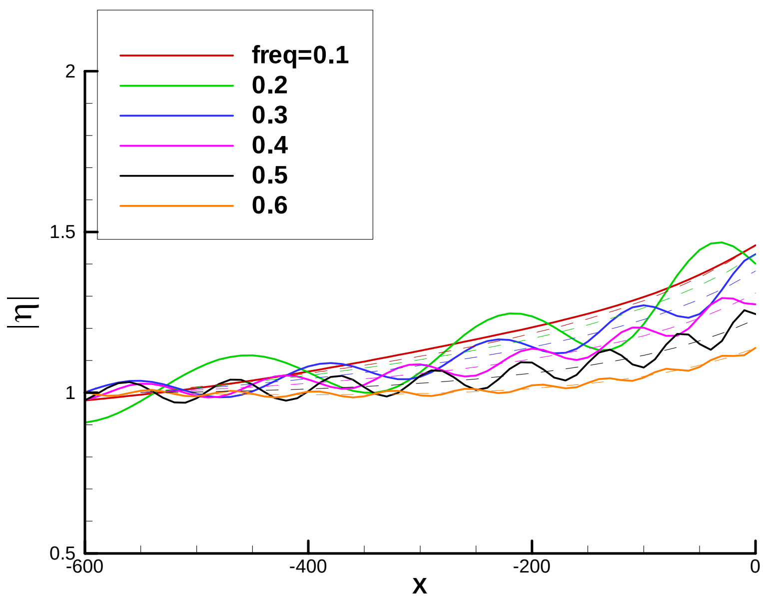
2D computational method

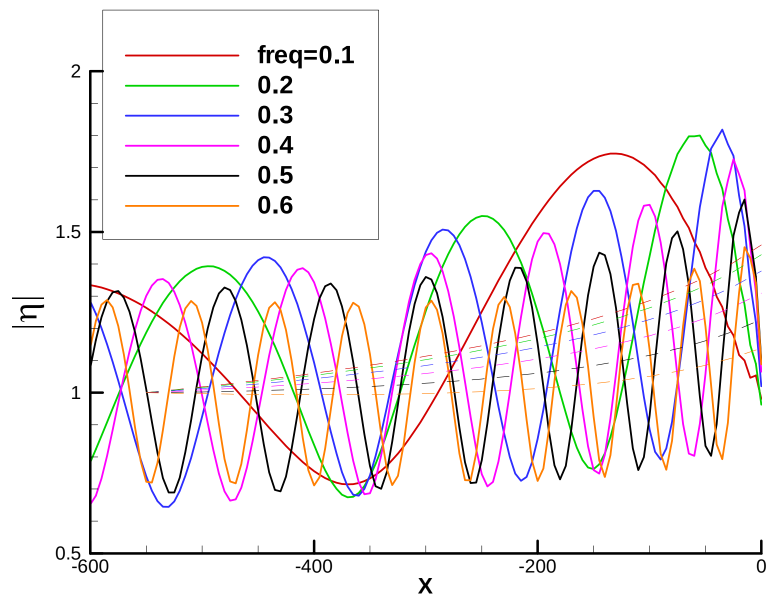


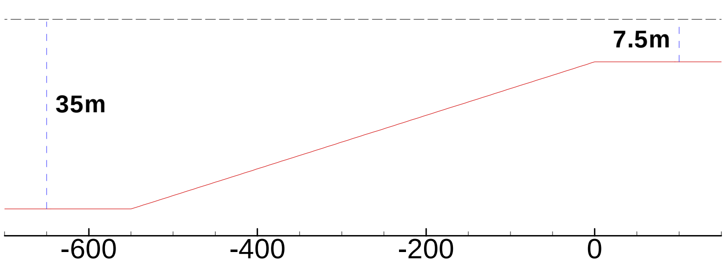
- Outer regions: Eigenfunction expansions
- Inner region: 2D Panel method
  (based on Green's Theorem, solved for potential)
- Uses infinite-depth free-surface Green function!
- Body is optional in inner region, not used here

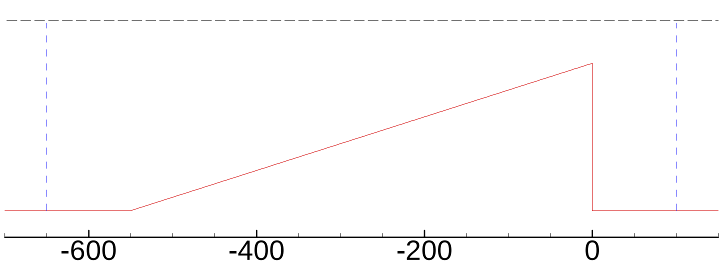
Amplitude of 2D free-surface elevation on the slope

(dashed lines: Green's approximation)

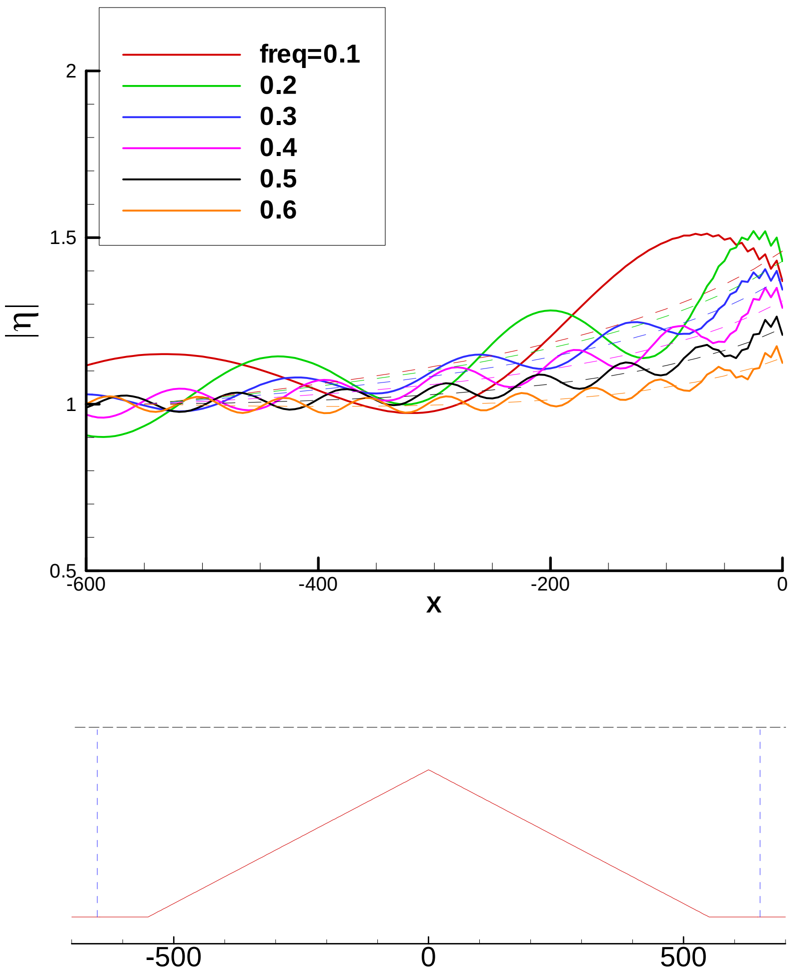


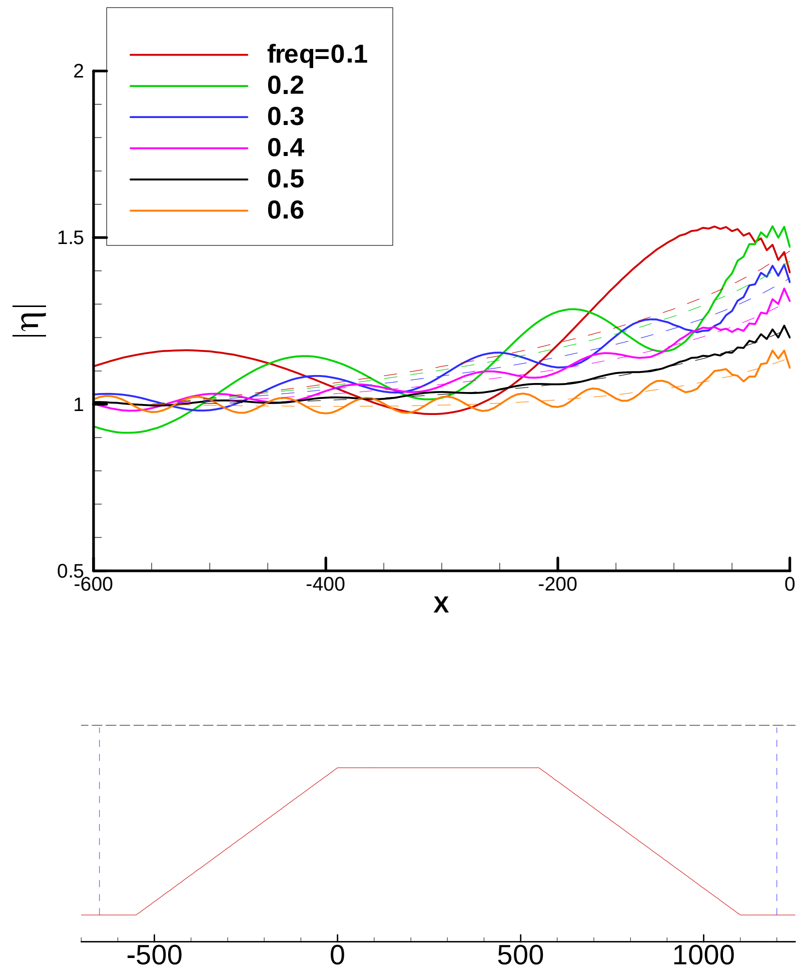




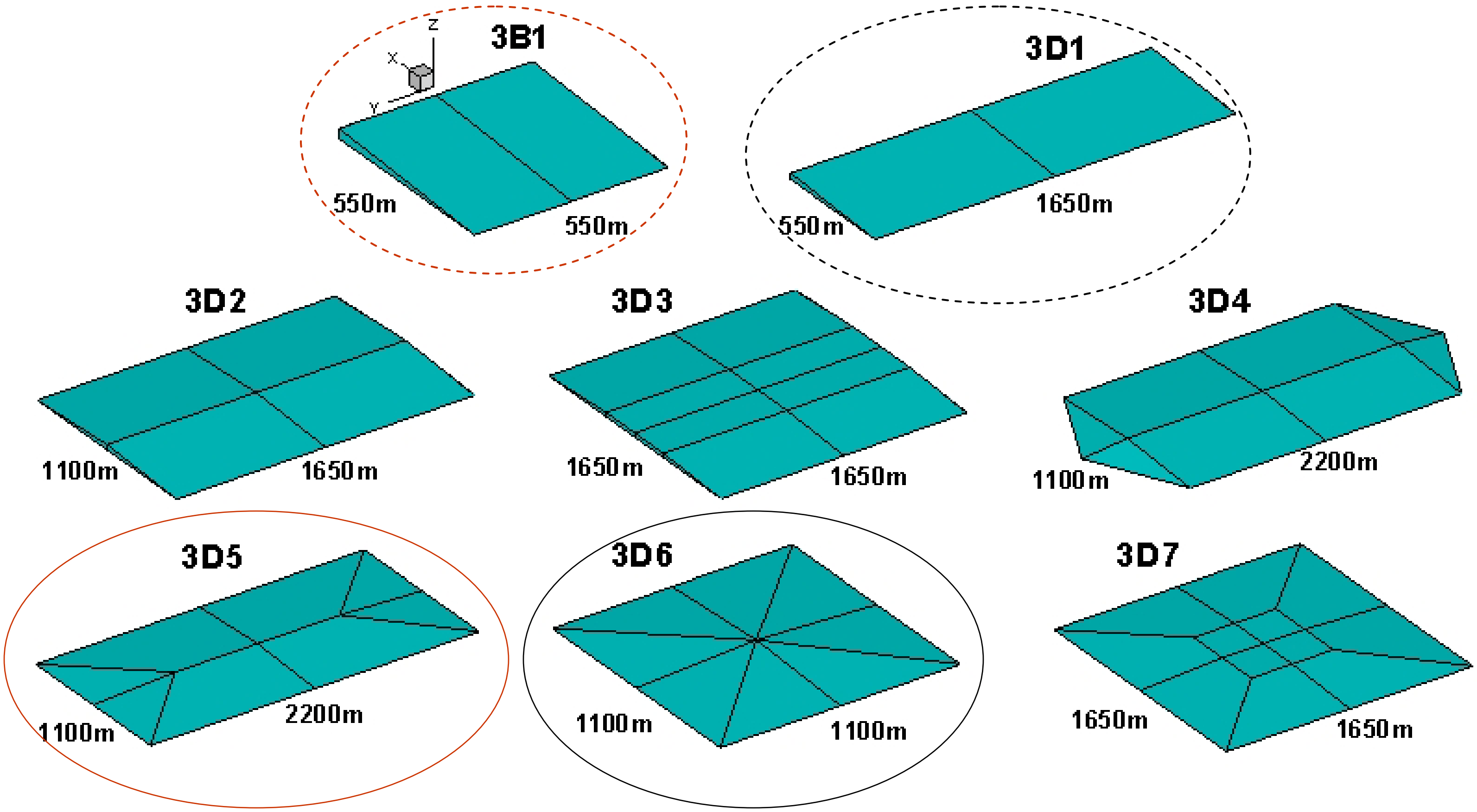


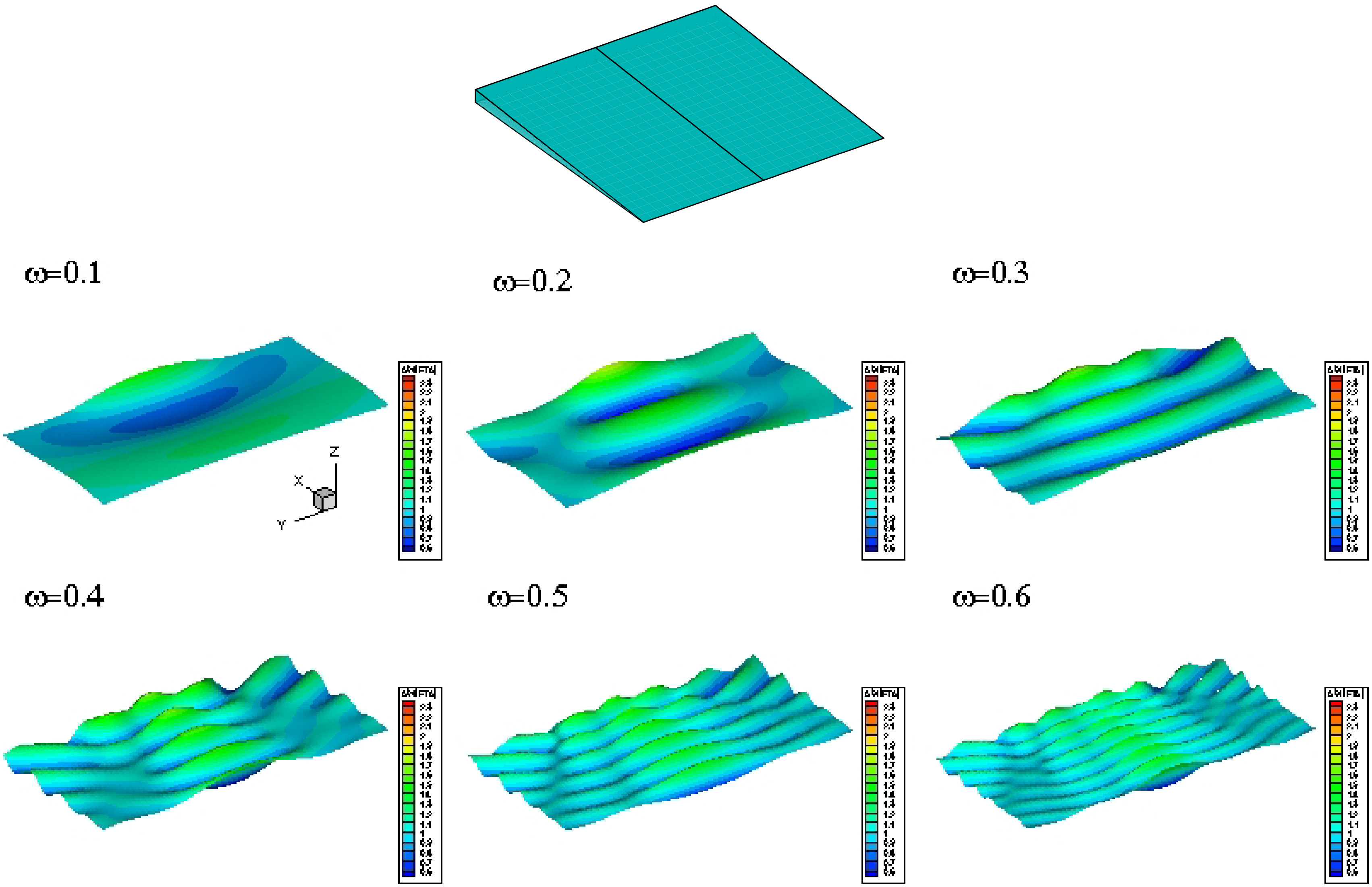
Improved finite-length bottom profiles (2D)





3D bottom configurations

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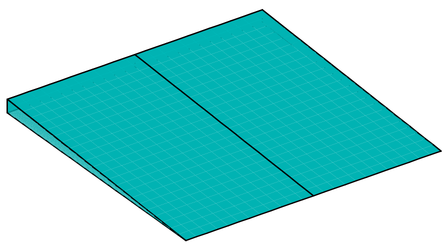
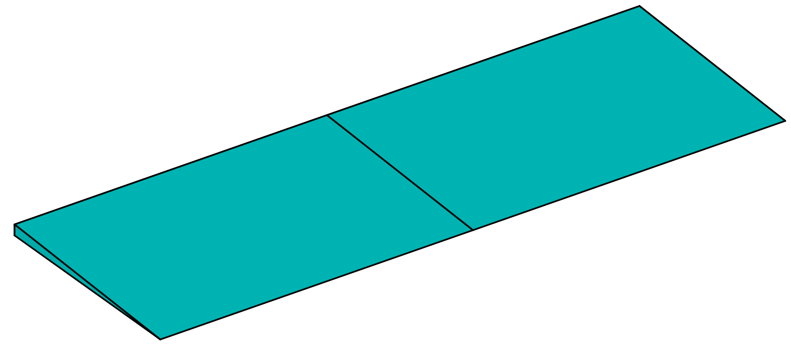
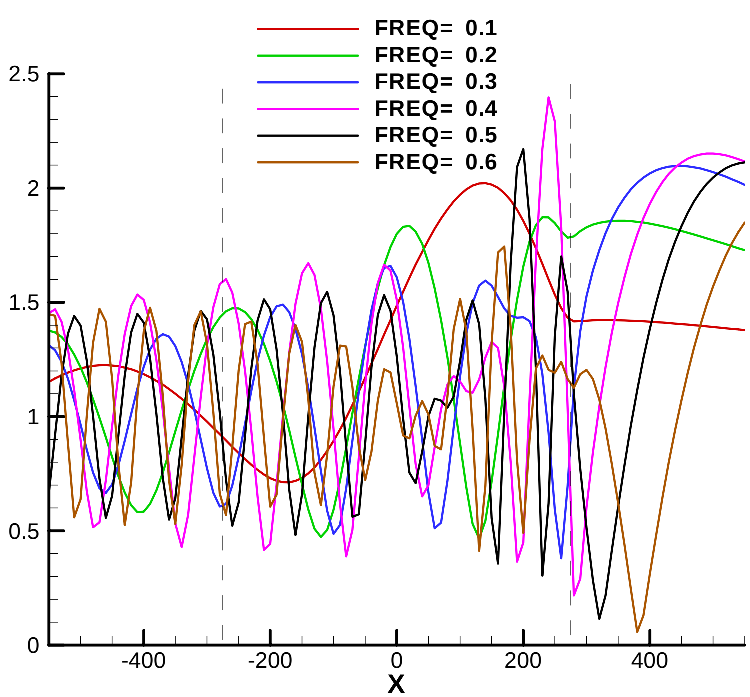
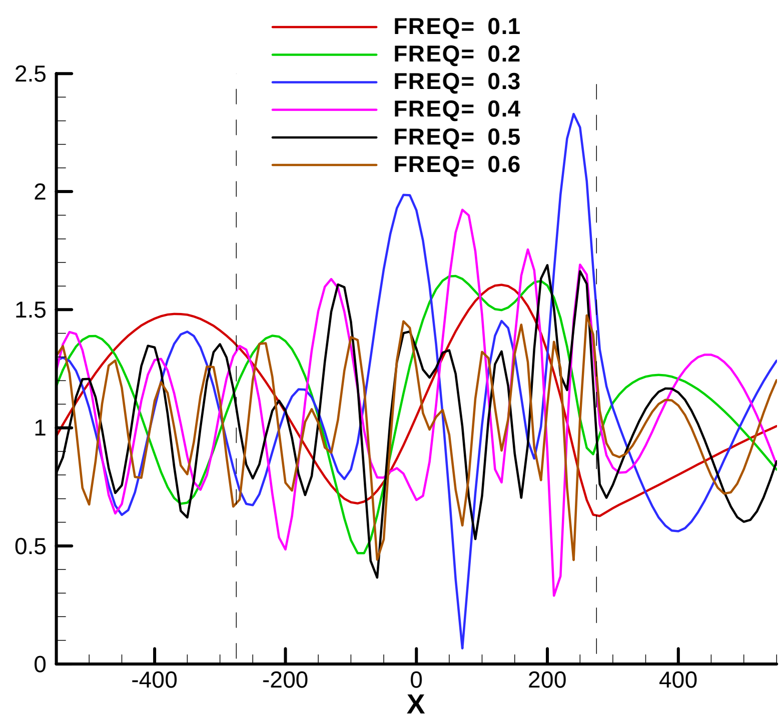
ω=0.2
ω=0.3
ω=0.4
ω=0.5
ω=0.6
X
Y
Z



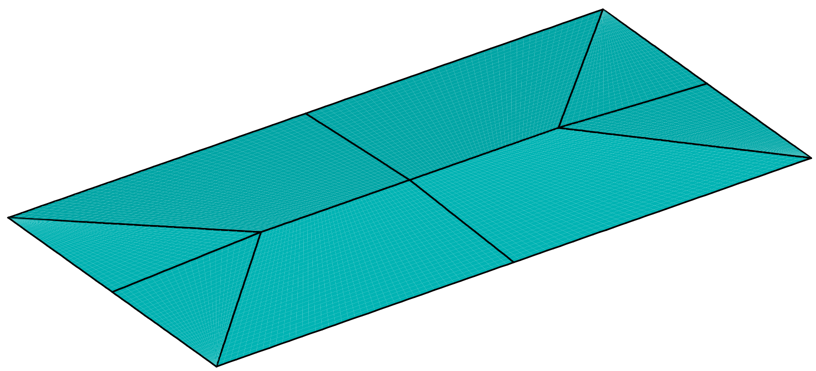


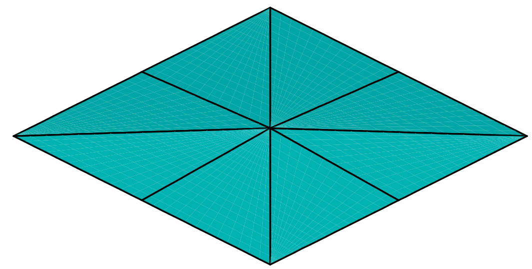


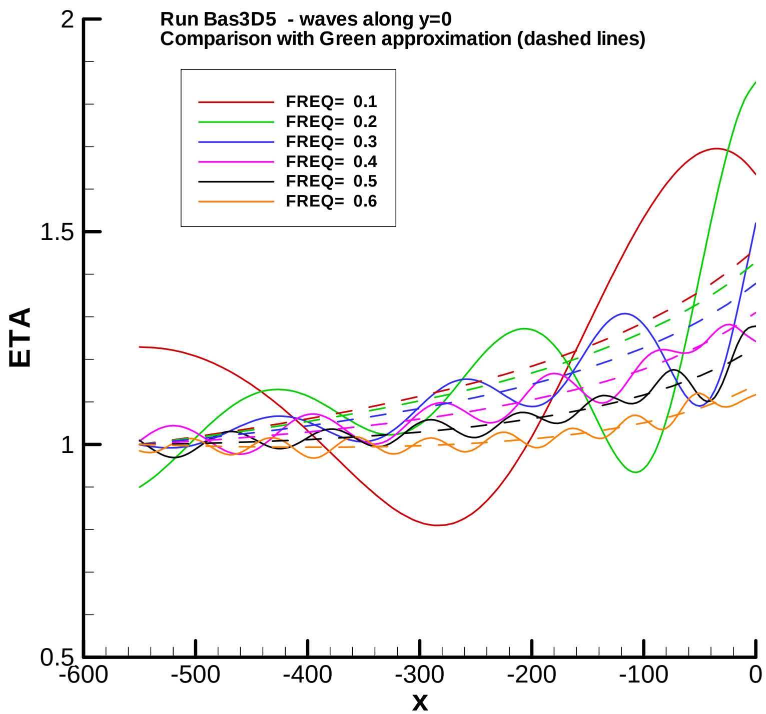
FREQ= 0.1
FREQ= 0.2
FREQ= 0.3
FREQ= 0.4
FREQ= 0.5
FREQ= 0.6
2.5
2
1.5
1
0.5
0
-400
-200
0
200
400
X



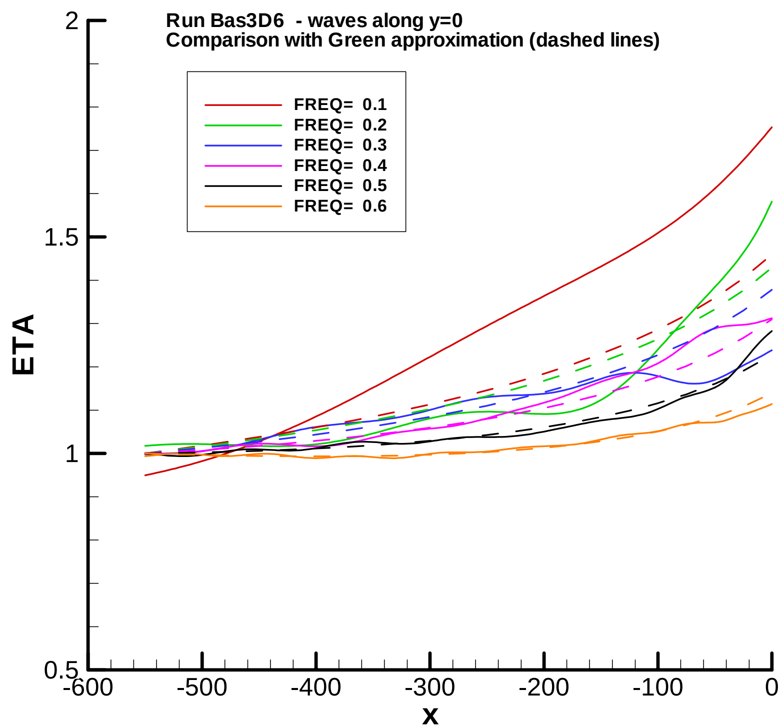
FREQ= 0.1
FREQ= 0.2
FREQ= 0.3
FREQ= 0.4
FREQ= 0.5
FREQ= 0.6
2.5
2
1.5
1
0.5
0
-400
-200
0
200
400
X







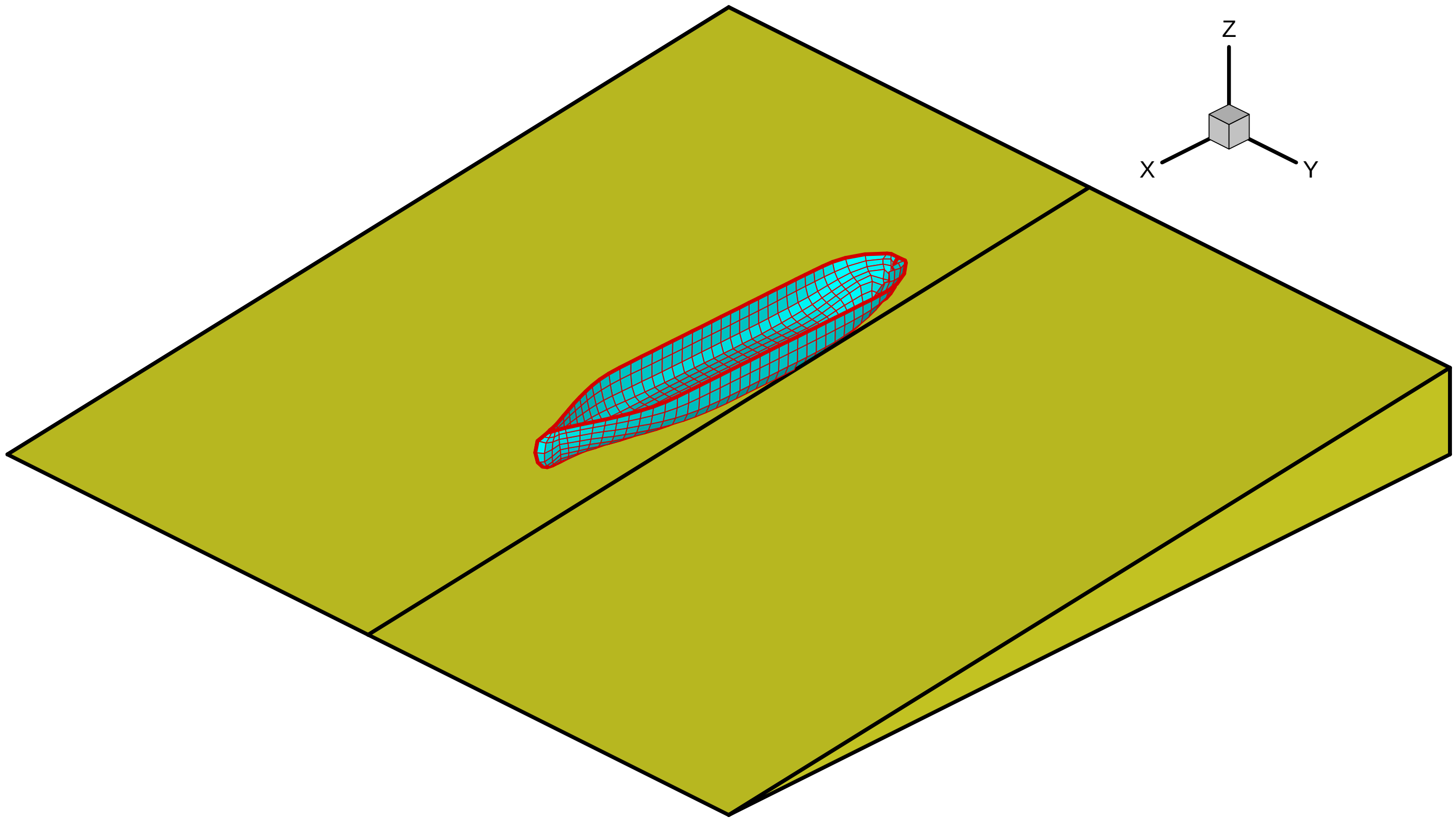
Run Bas3D5 - waves along y=0
Comparison with Green approximation (dashed lines)
FREQ= 0.1
FREQ= 0.2
FREQ= 0.3
FREQ= 0.4
FREQ= 0.5
FREQ= 0.6
ETA
2
1.5
1
0.5
-600
-500
-400
-300
-200
-100
0
X



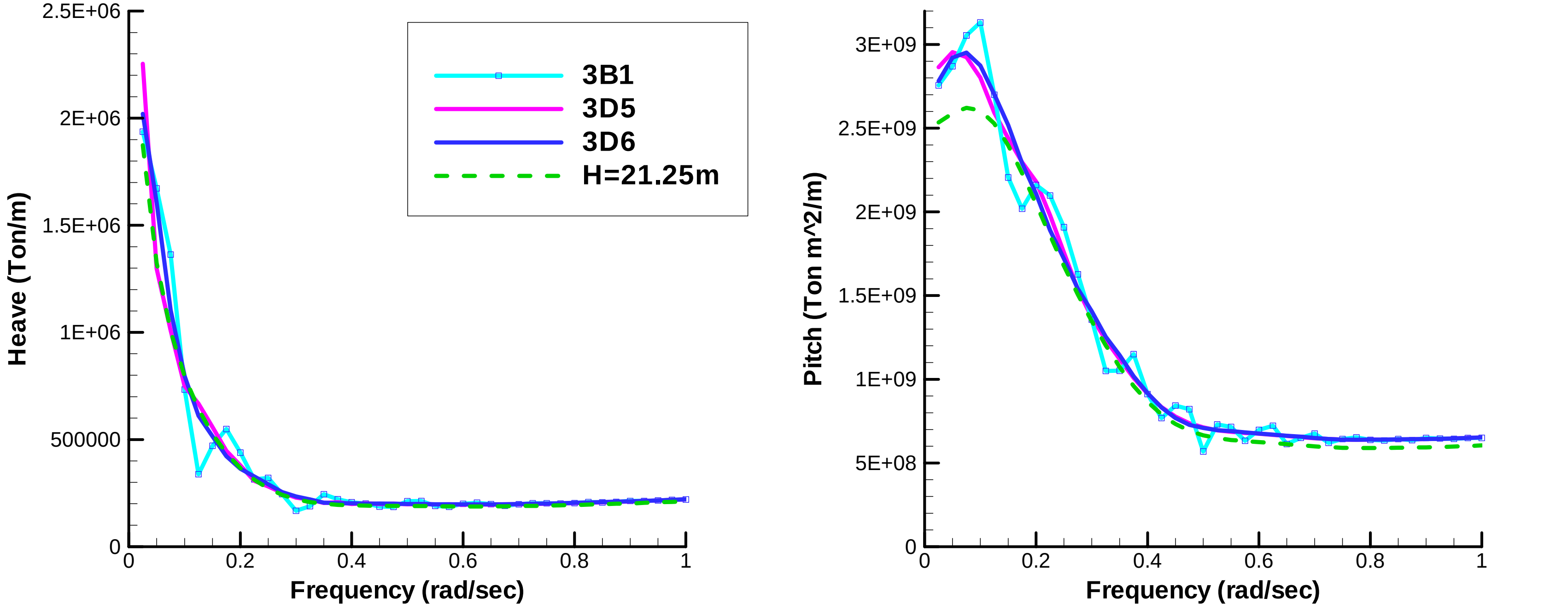
Run Bas3D6 - waves along y=0
Comparison with Green approximation (dashed lines)
FREQ= 0.1
FREQ= 0.2
FREQ= 0.3
FREQ= 0.4
FREQ= 0.5
FREQ= 0.6
ETA
2
1.5
1
0.5
-600
-500
-400
-300
-200
-100
0
X

LNG Ship on sloping bottom

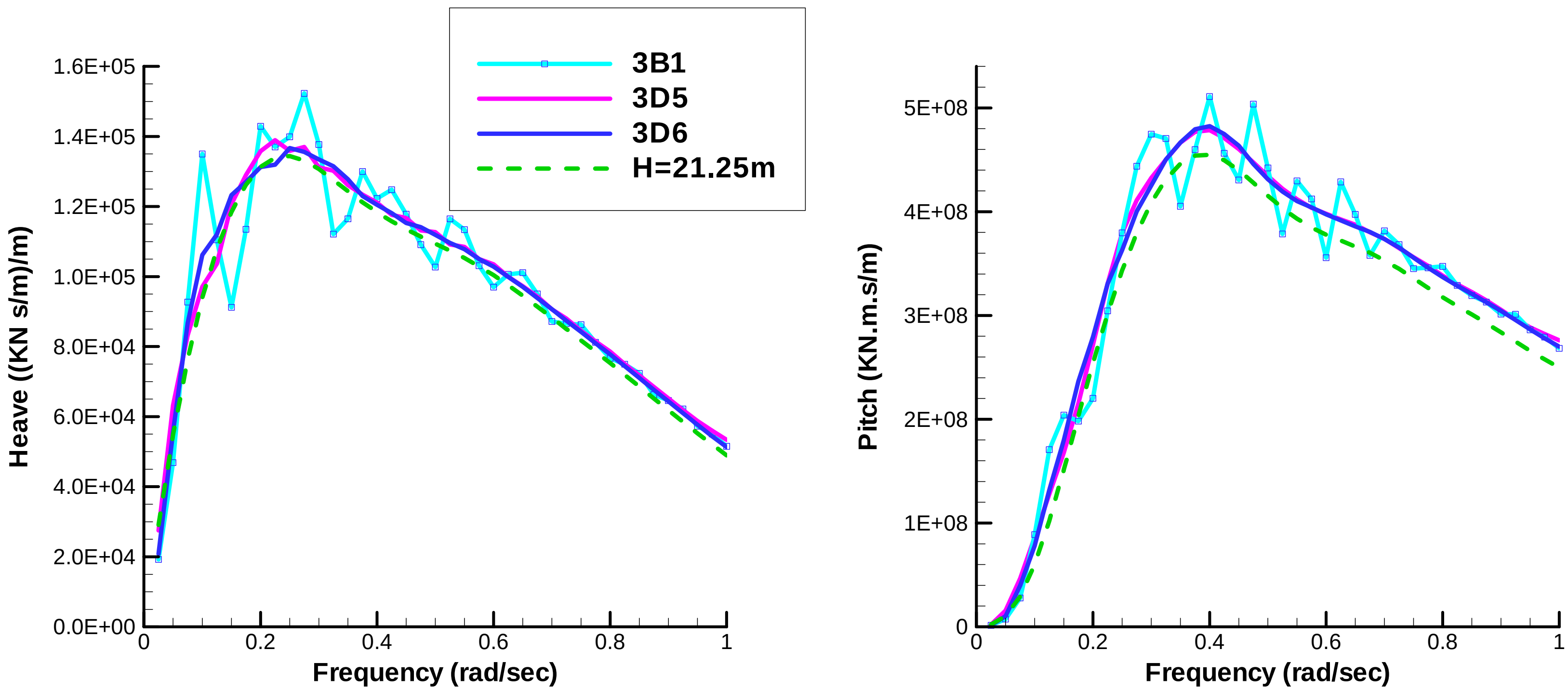
(Heave/Pitch in head seas)



Added mass and moment of inertia

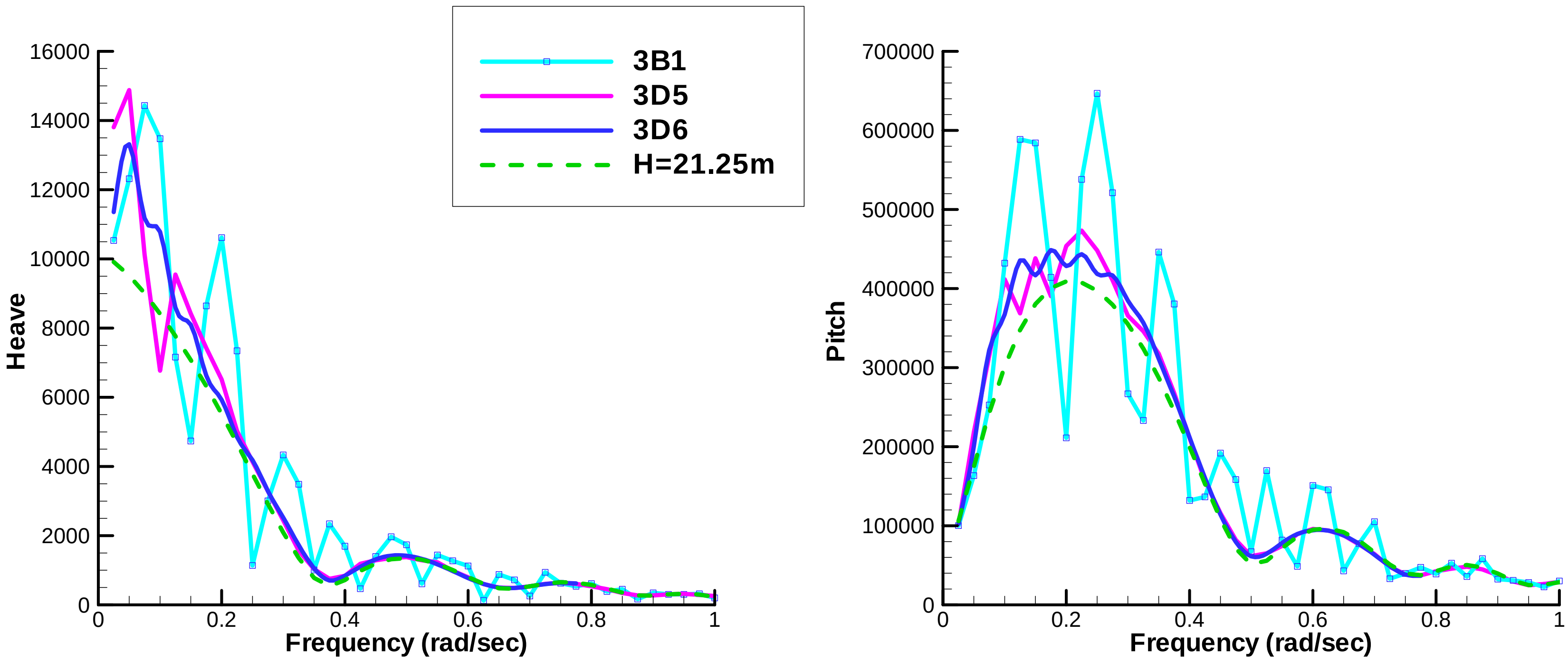


Damping

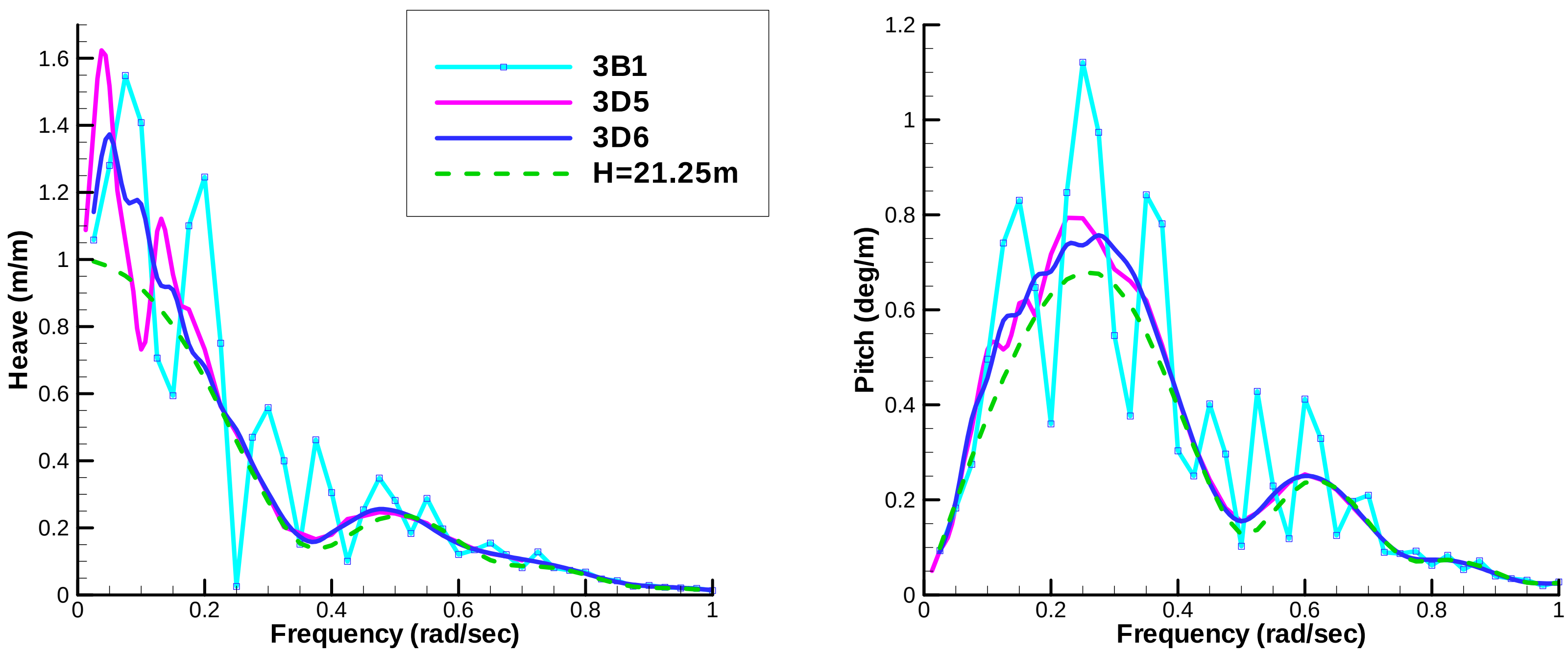


3B1
3D5
3D6
H=21.25m
Heave ((KN s/m)/m)
1.6E+05
1.4E+05
1.2E+05
1.0E+05
8.0E+04
6.0E+04
4.0E+04
2.0E+04
0.0E+00
0
0.2
0.4
0.6
0.8
1
Frequency (rad/sec)
Pitch (KN.m.s/m)
5E+08
4E+08
3E+08
2E+08
1E+08
0
0
0.2
0.4
0.6
0.8
1
Frequency (rad/sec)

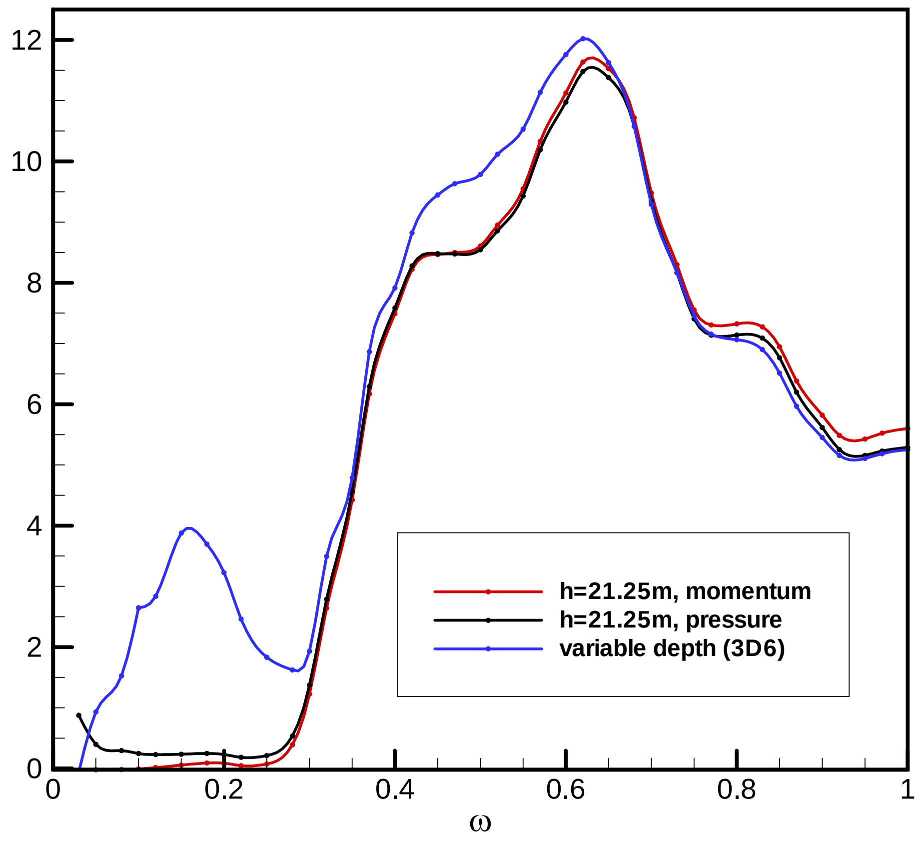
Exciting force and moment



Heave/Pitch RAO'S



Drift force Fx



CONCLUSIONS

- Abrupt depth changes are bad!
- Both reflection from end (as in 2D) and refraction from sides (3D) are important
- In both experiments and computations careful attention should be given to the design of a localized artificial bottom
- With proper attention, most (not all) results are similar comparing variable depth with constant average of depth
- Interesting implications for slowly-varying 2^{nd} order loads!

Use of Control Surface in Shallow Water

Summary

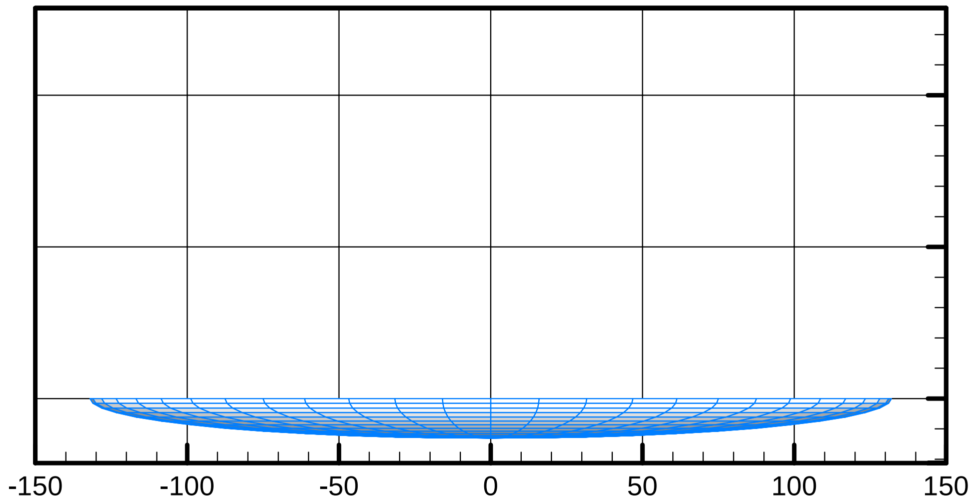
- Control surface can be used for the computation of mean drift forces, when far-field momentum is not applicable (for examples, for multiple bodies, or forces/moments in vertical modes) and pressure integral is not accurate.

- Ferreira and Newman studies wave effect on a vessel over artificial seabed using WAMIT. Due to uneven bottom, the far-field momentum is not available directly even for the horizontal mean drift forces and control surface may be useful.

- It is observed the control surface is not accurate in the shallow water for long waves which may be due to small gap between the body and the sea bottom.

- However the accuracy can be improved by using elaborate control surfaces.
  An ellipsoid and a box are used to illustrate the use of control surfaces in the shallow water. (Note: it is not necessary to rely on control surface for the ellipsoid or other bodies with smooth surfaces. Accurate pressure mean drift forces/moments can be computed using higher-order method. In the following, these results, however, are used to show the relative accuracy of control surface.)

Ellipsoid in shallow water



Length=260m, Beam=40m, Draft=11m

(Rxx=10m, Ryy=Rzz=65m, VCG=0.)

Water Depth = 21.25m (Gap=10.25m)

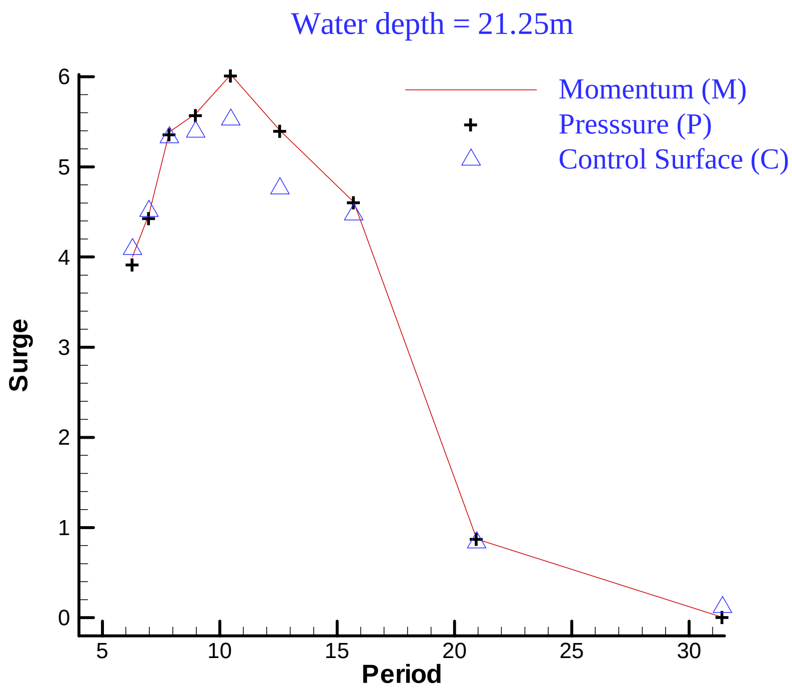
Computational results using ellipsoidal control surface enclosing the ellipsoid are shown first. (Comparisons are made between momentum, pressure and control surface.) This control surface is not suitable for the bodies in the shallow water.

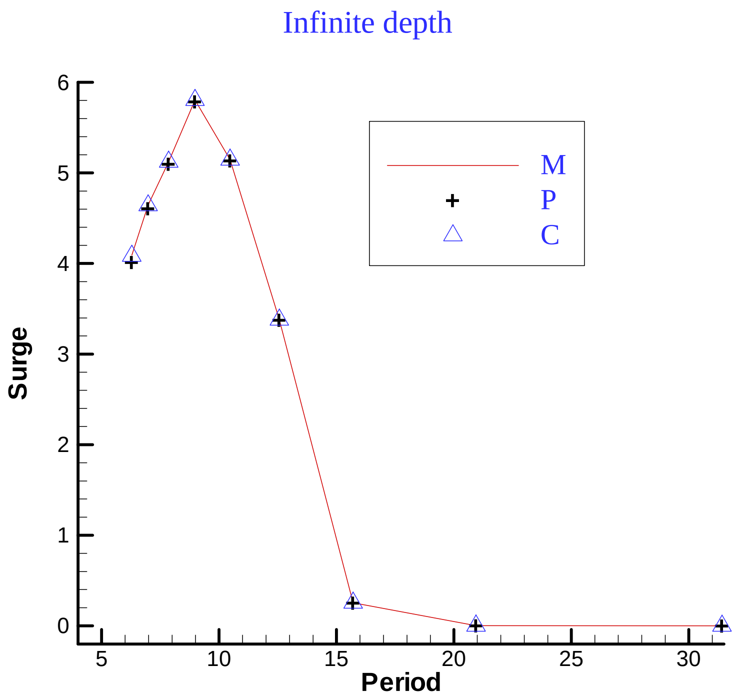
The ellipsoidal control surface is 2m away from the body surface.
Length= 264m, Beam=44m and Draft=13m. (Results using other dimensions, between 1m to 5m, are similar.)

PANEL_SIZE on the body and the control surfaces are 15m and 10m, respectively.

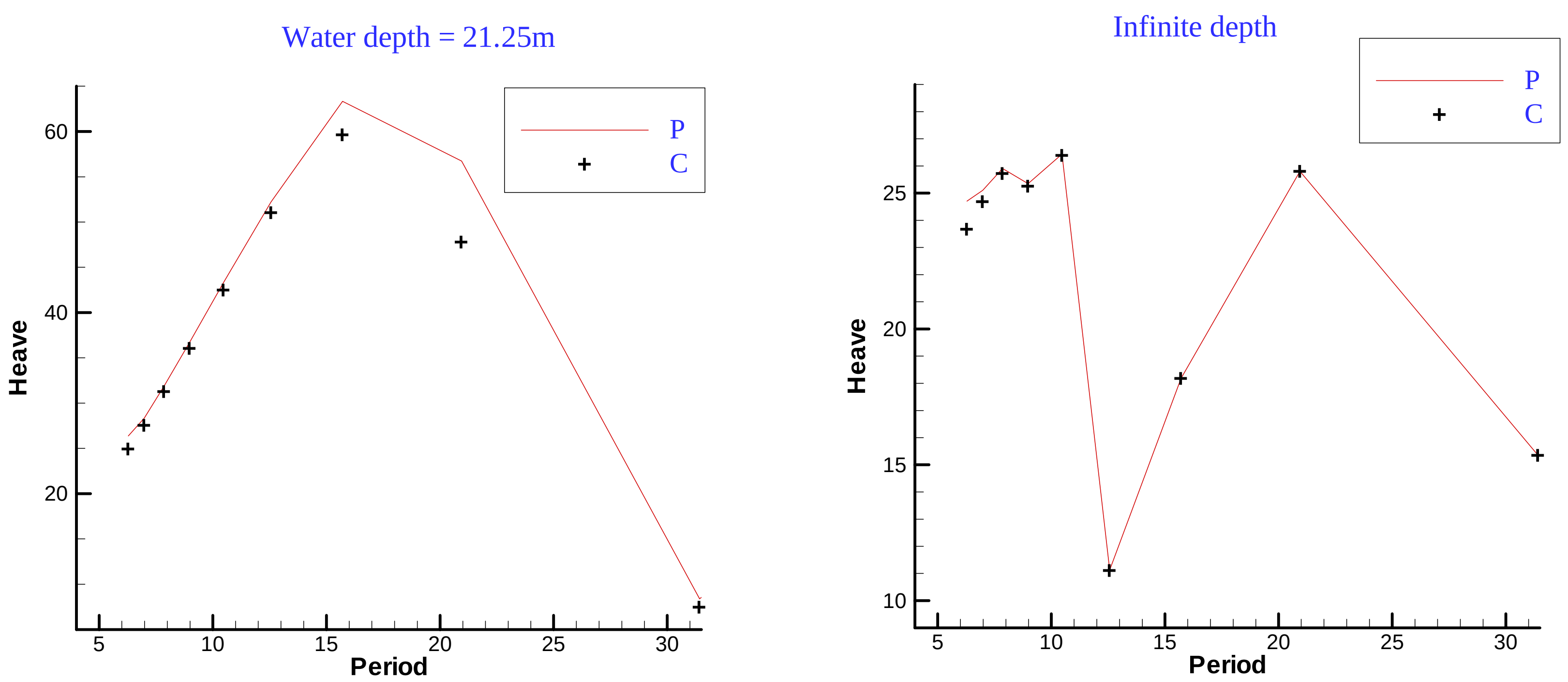
Surge mean force on freely floating ellipsoid

(The results are converged and further appreciable refinement is not possible.)

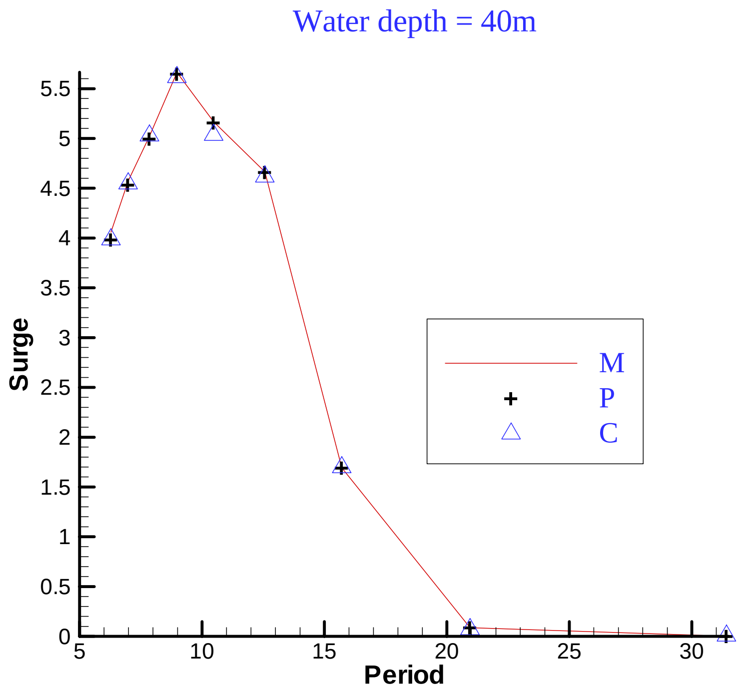


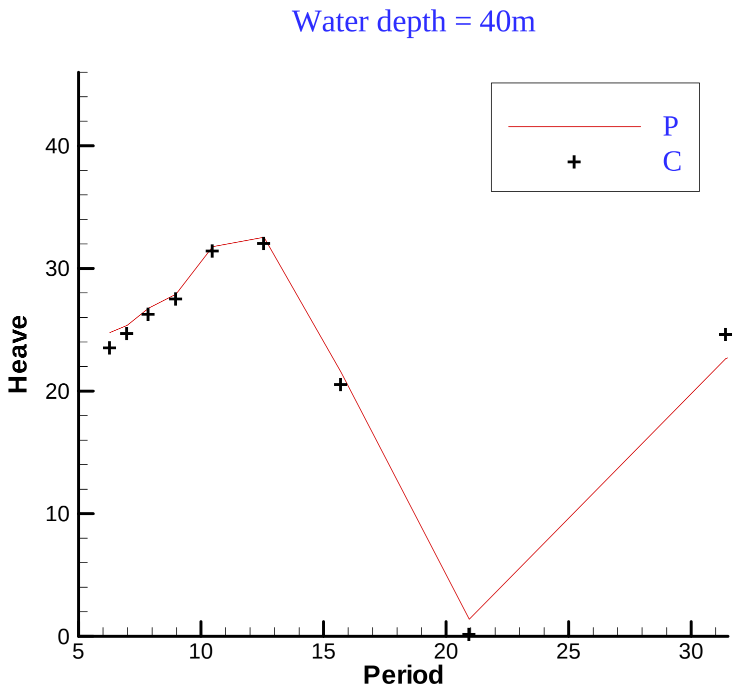


Heave mean force on freely floating ellipsoid

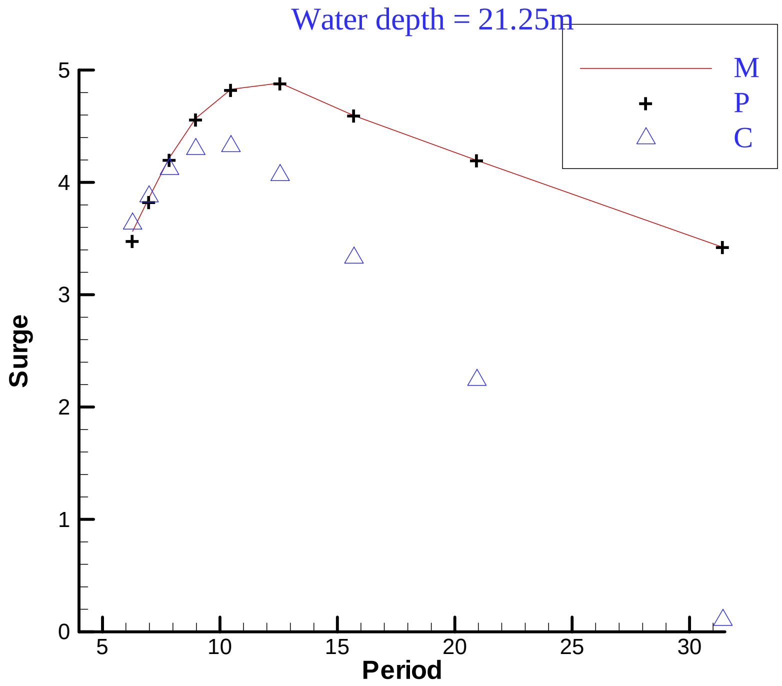


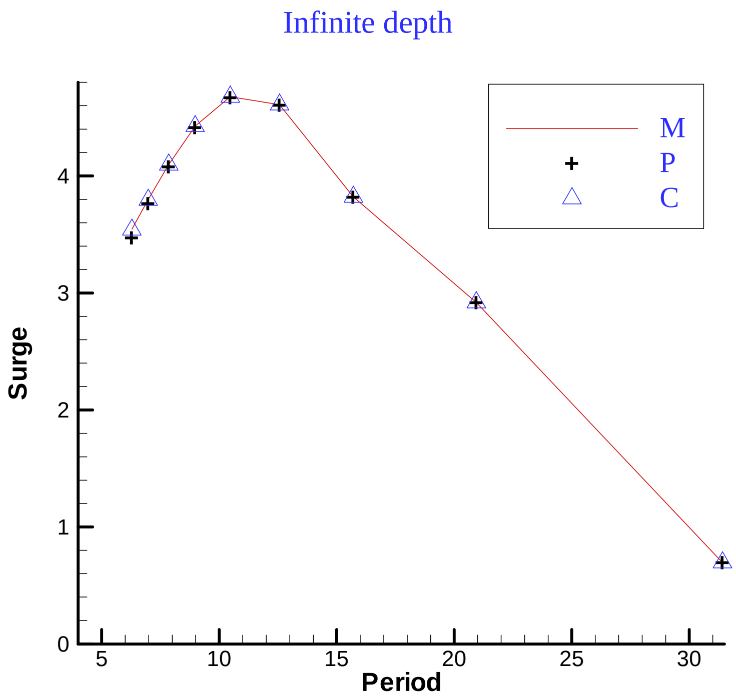
Mean force on freely floating ellipsoid (water depth 40m).



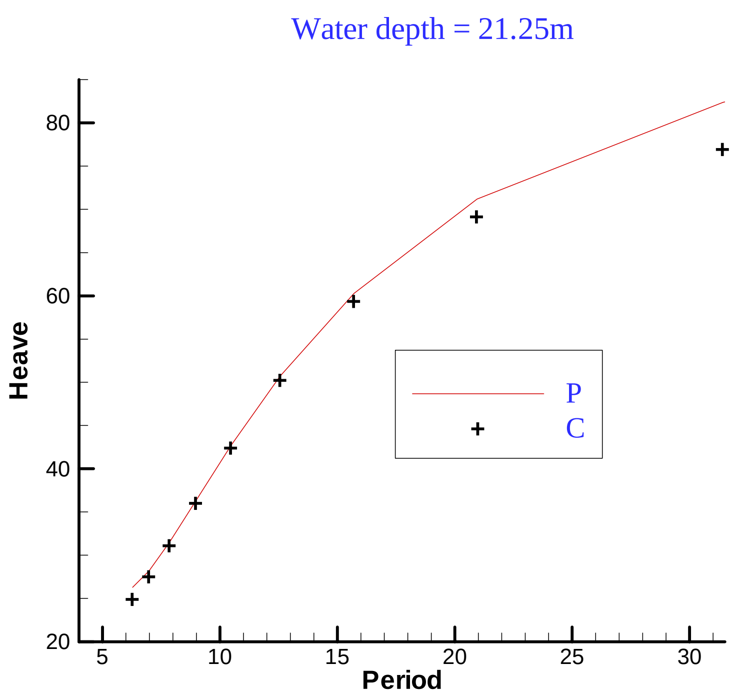


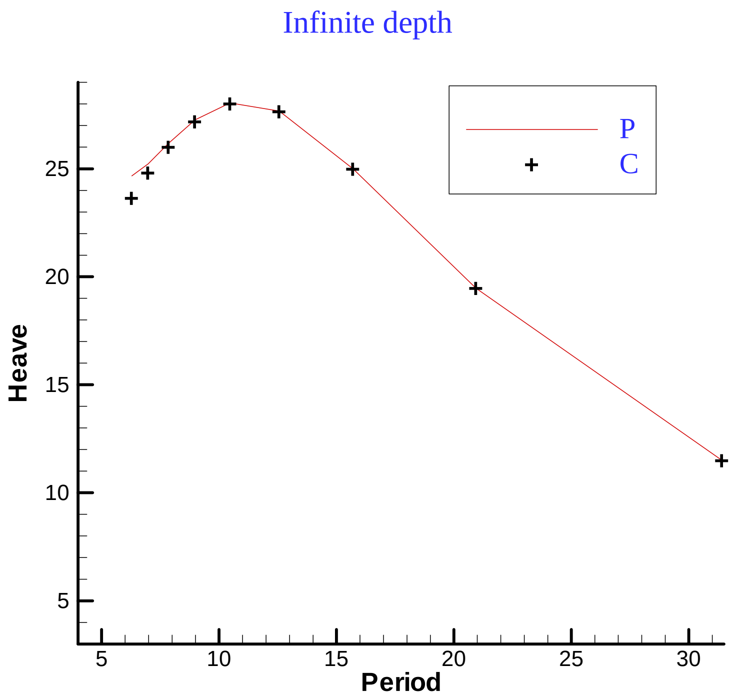
Surge mean force on fixed ellipsoid



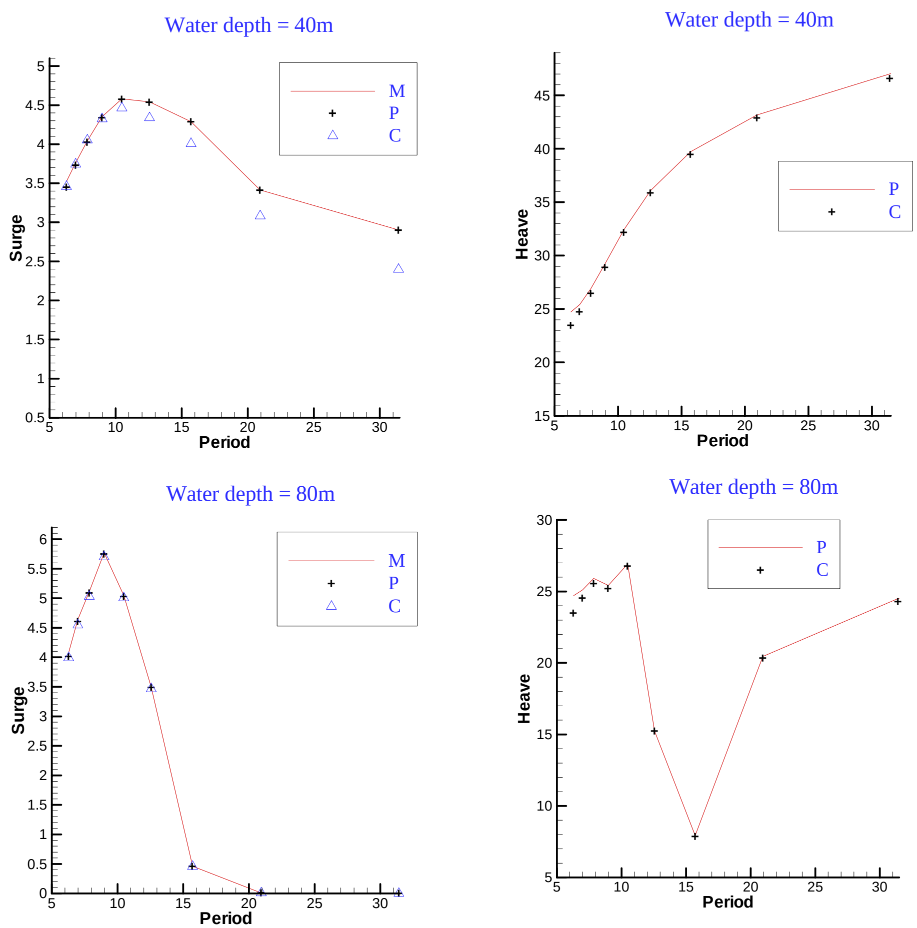


Heave mean force on fixed ellipsoid





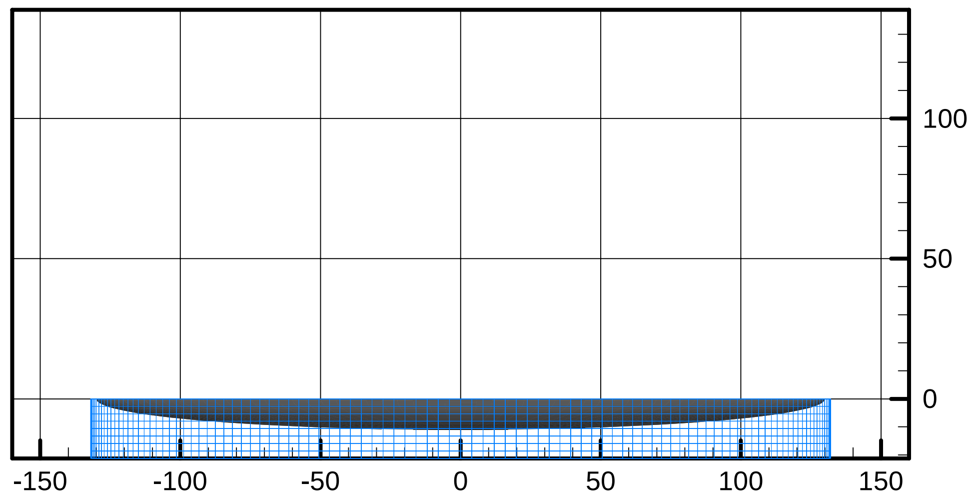
Mean force on fixed ellipsoid (water depth 40m and 80m).



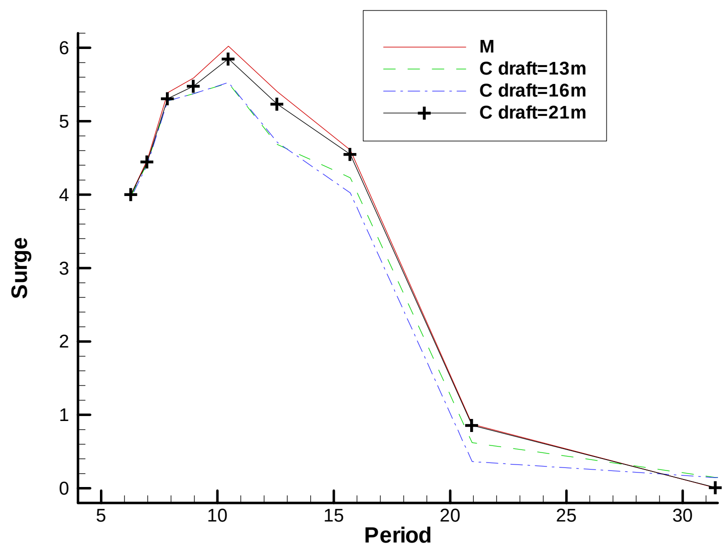
Computational results using elliptic cylinder with 3 different drafts are shown next.

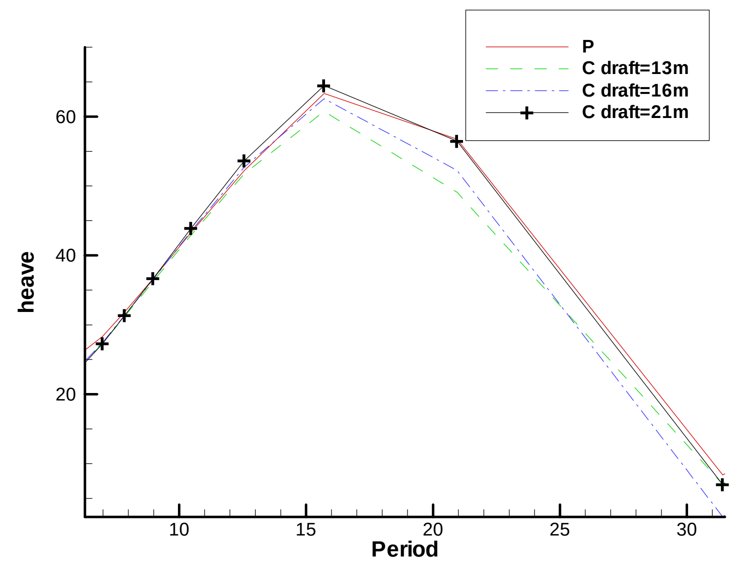
Control Surface Length= 264m, Beam=44m and Draft=13m, 18m and 21.24m.

PANEL_SIZE on the body and the control surfaces are 15m and 10m, respectively.

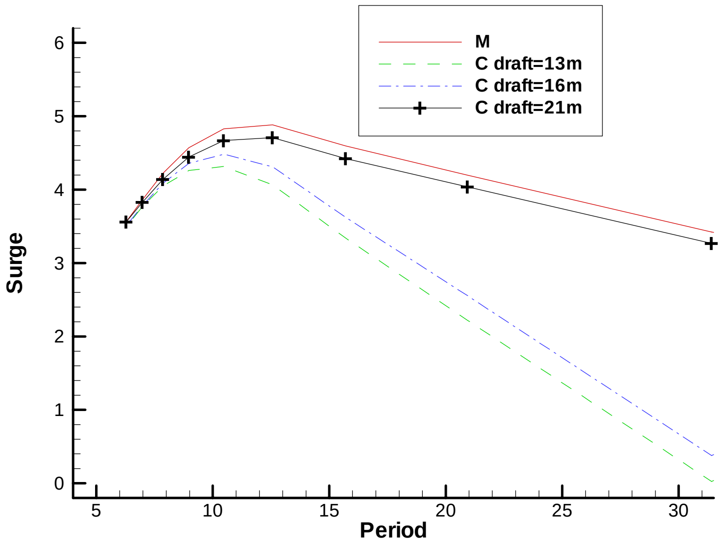


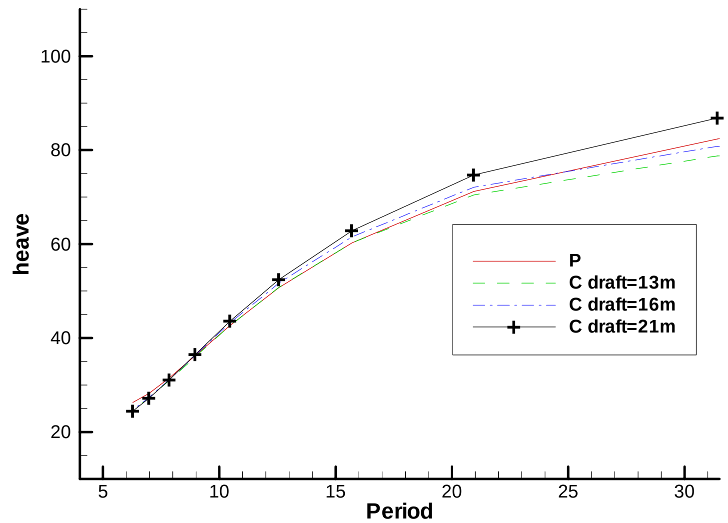
Mean force on freely floating ellipsoid



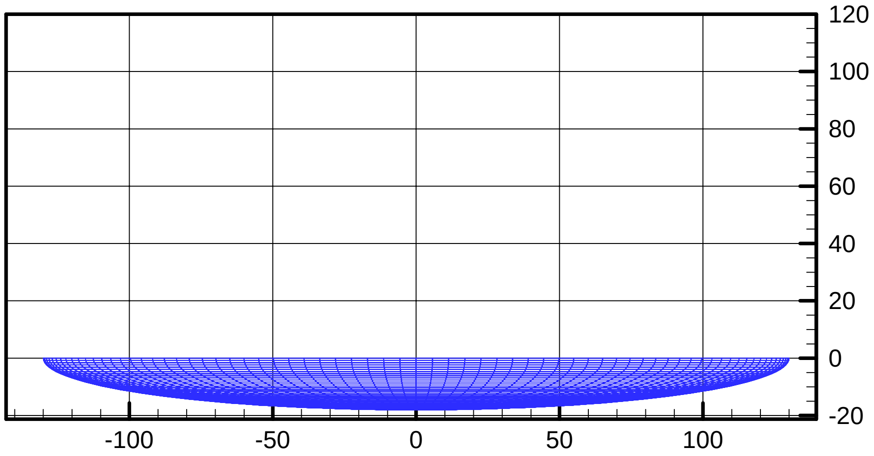


Mean force on fixed ellipsoid

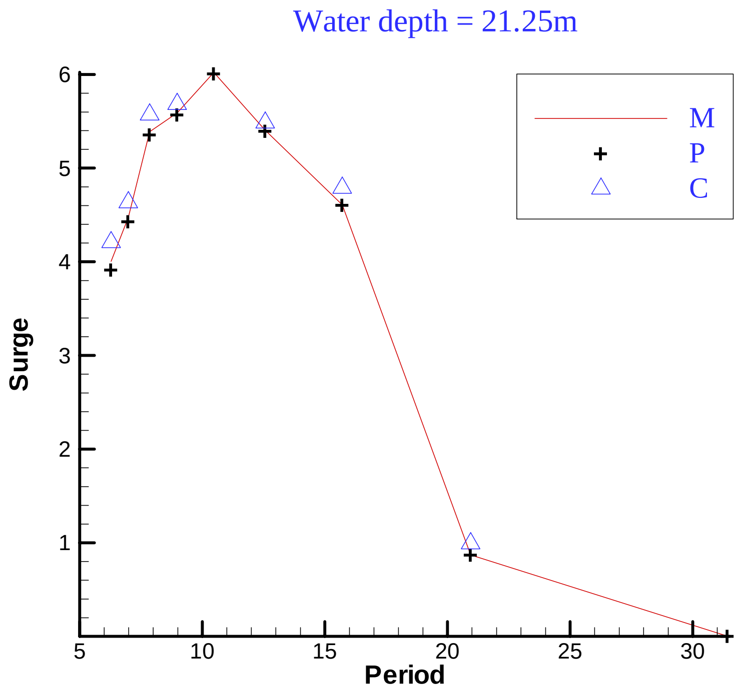


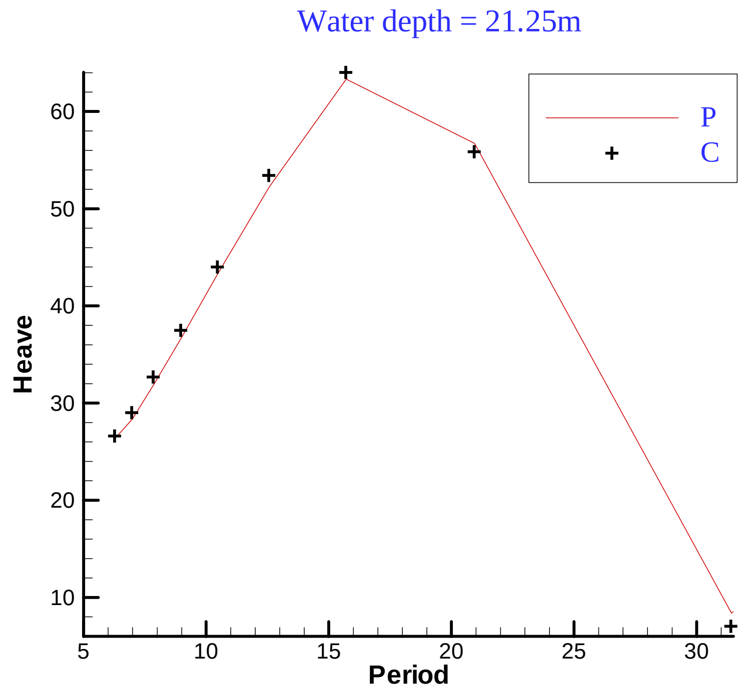


- Draft of the ellipsoid is increased from 11m to 18m. The gap between the body and the bottom is 3.25m.

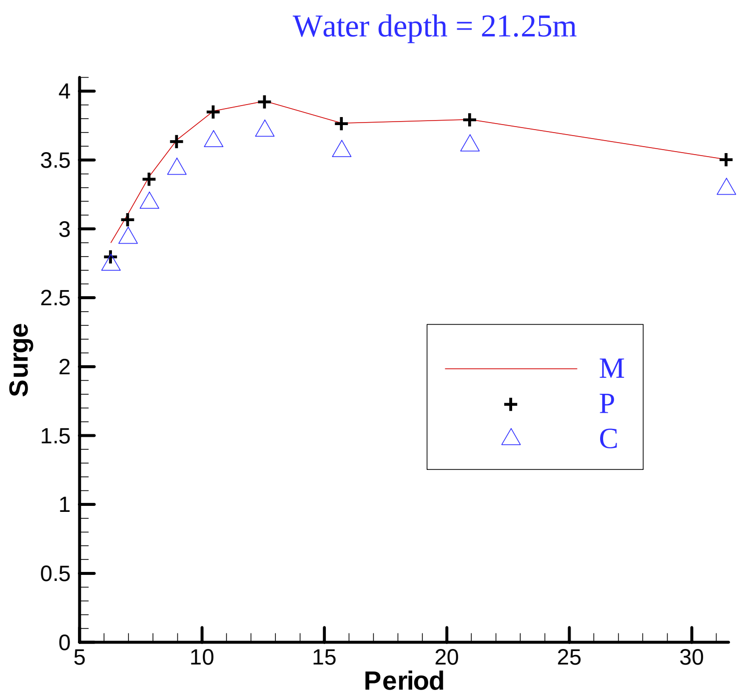


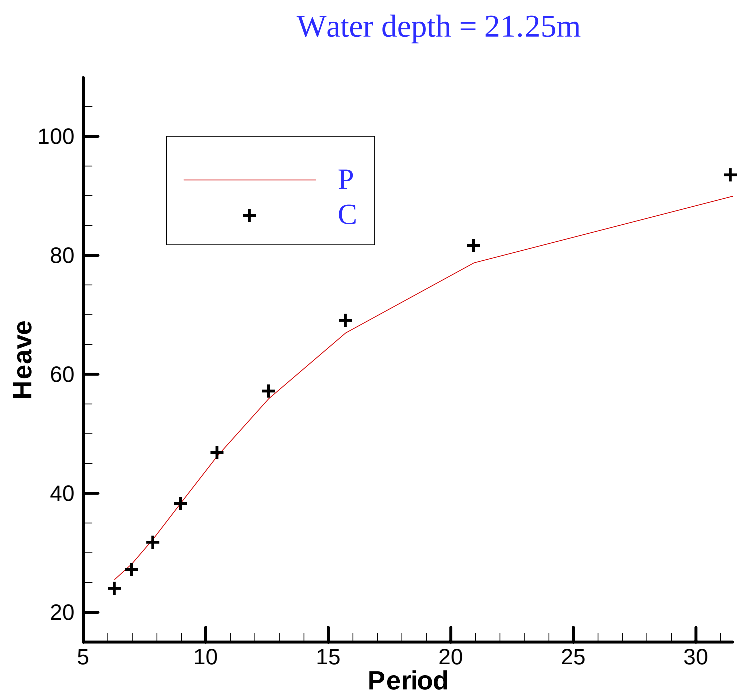
Mean force on the freely floating ellipsoid of 18m draft





Mean force on fixed ellipsoid of 18m draft.



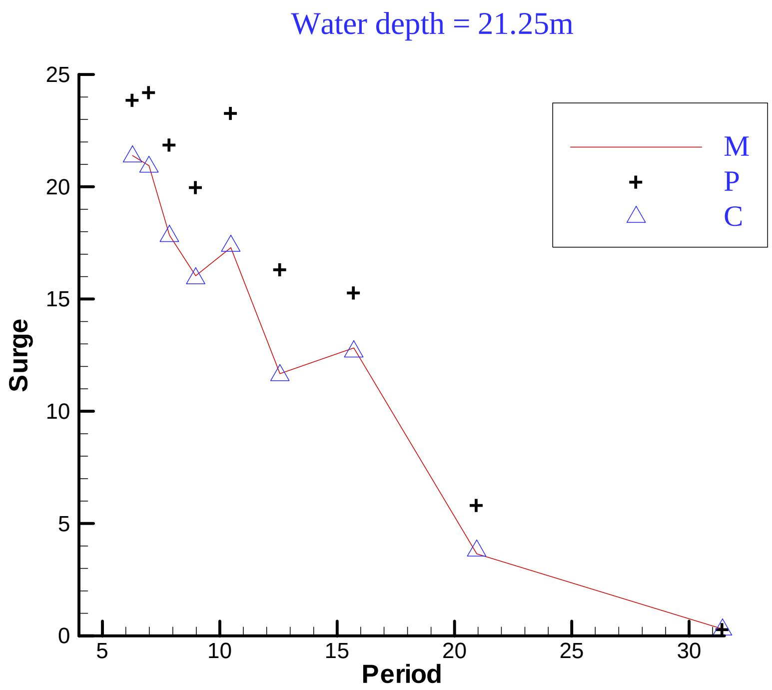


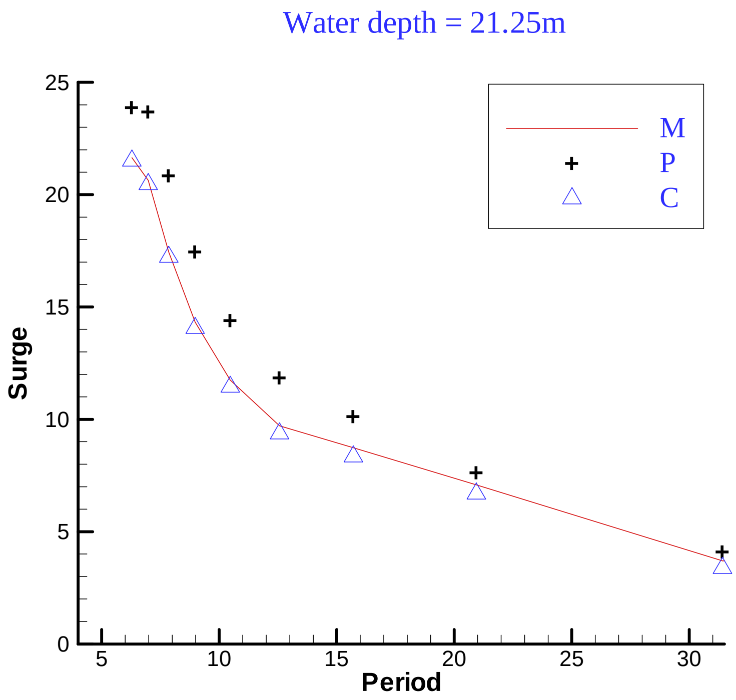
Next two slides show the forces on a box in the same shallow water of depth 21.25m. The results illustrate the advantage of control surface over pressure integration when body surfaces are not smooth.

Box Length=260m Beam=40 and Draft=11m & 18m

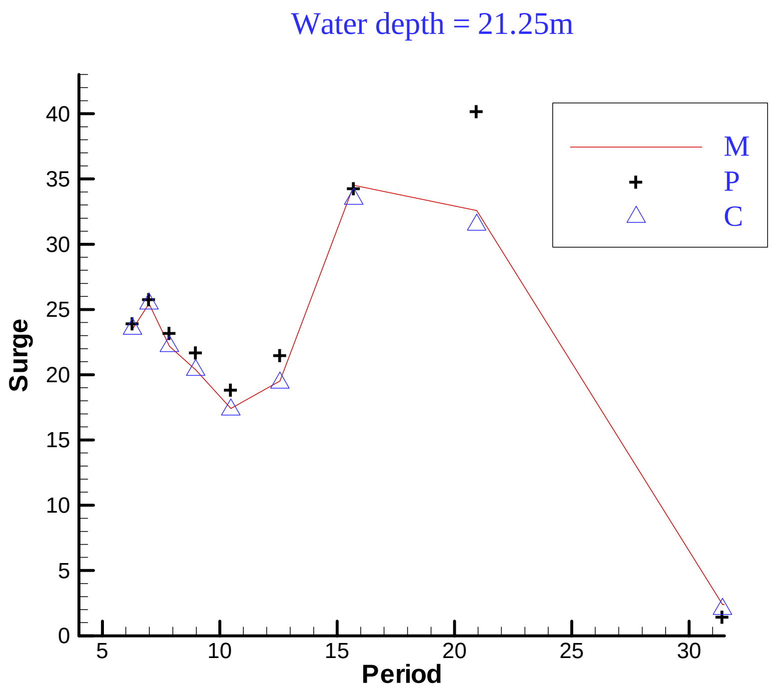
Control Surface Length=264m Beam=44m and Draft=21.24m

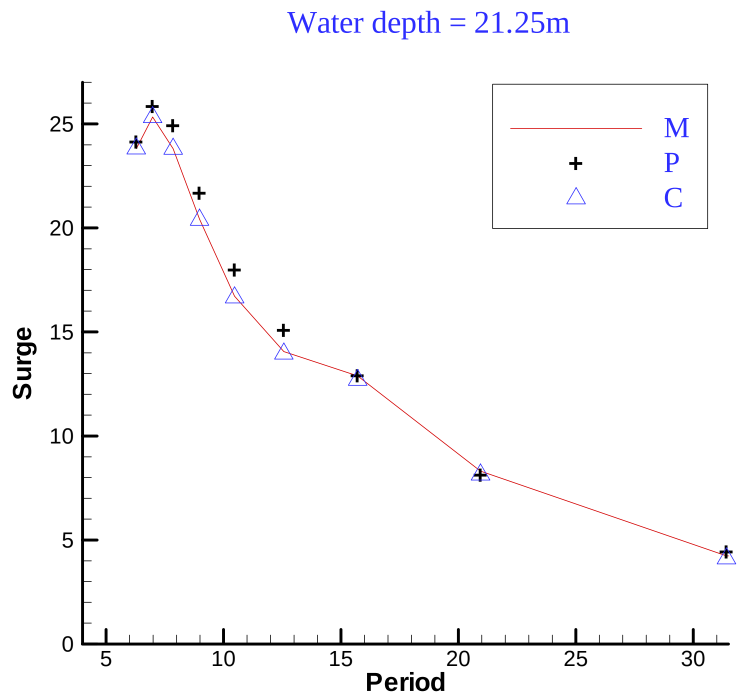
Mean force on a box of draft 11m. Left-floating. Right fixed.





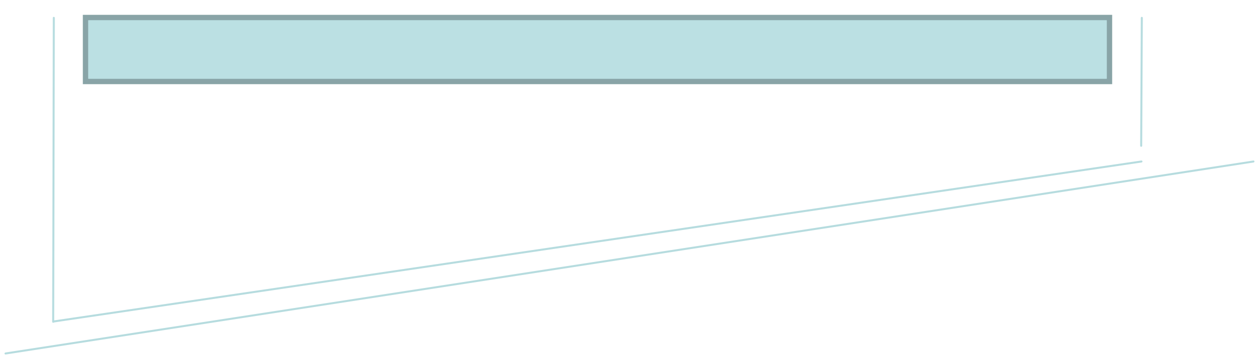
Mean force on a box of draft 18m. Floatingleft and fixed right.





The submerged part of the control surface contains two terms $V * V_n - N (V*V)$ of momenturm flux where V and N denote the fluid velocity and normal vectors and V_n is normal velocity on the control surface. For control surfaces close to the seabed, the contribution from the first term is small.

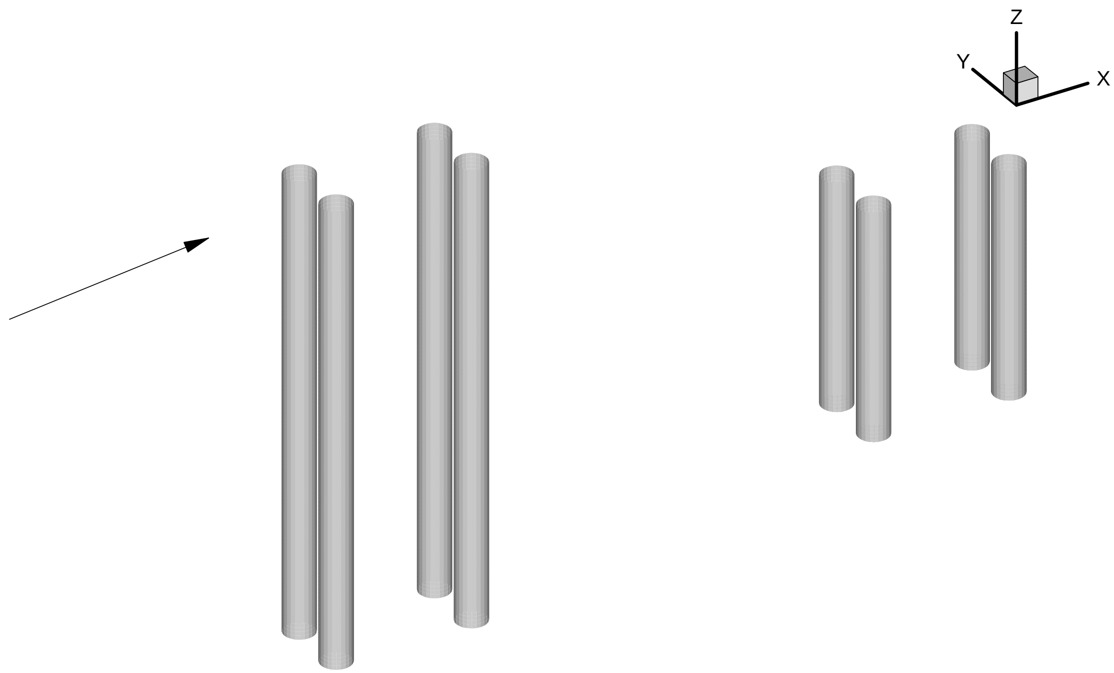
Computation with artificial seabed has not been done where more elaborate control surfaces are necessary. But it is expected the accuracy for both horizontal and vertical forces in that situation would be similar to the vertical forces on constant depth using the control surface close and parallel to the seabed.



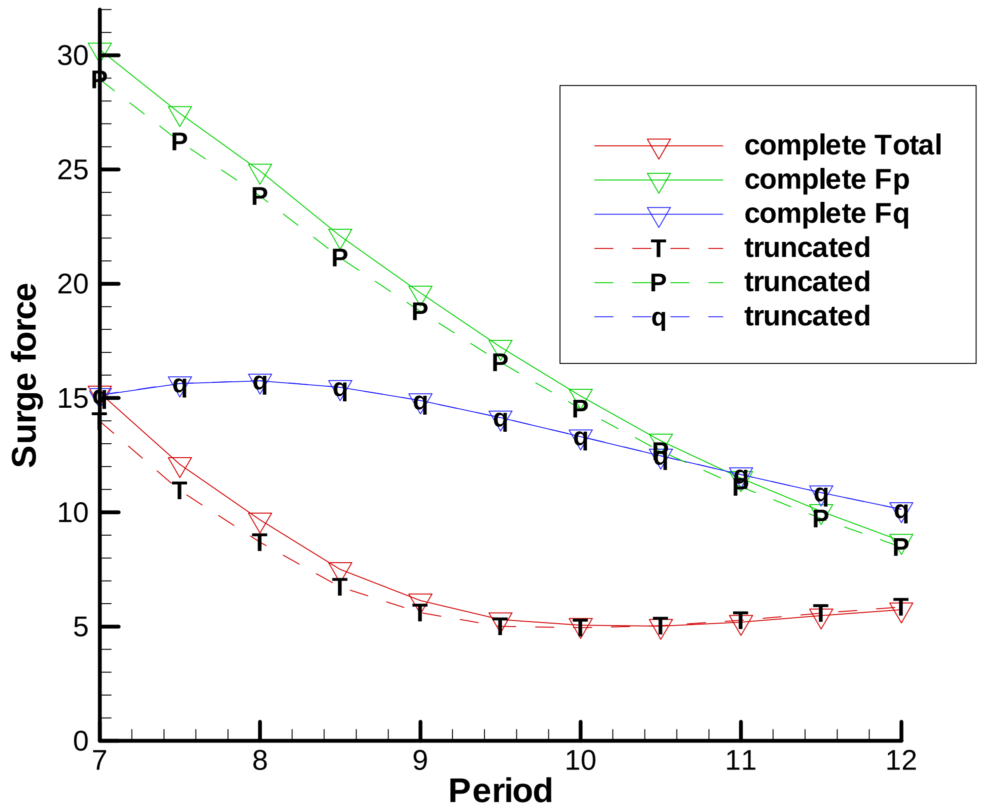
Second order forces on deep columns

In conjunction with second-order sum frequency analysis, comparisons are made between complete columns and truncated columns. Can the latter be an efficient computational model for the former?

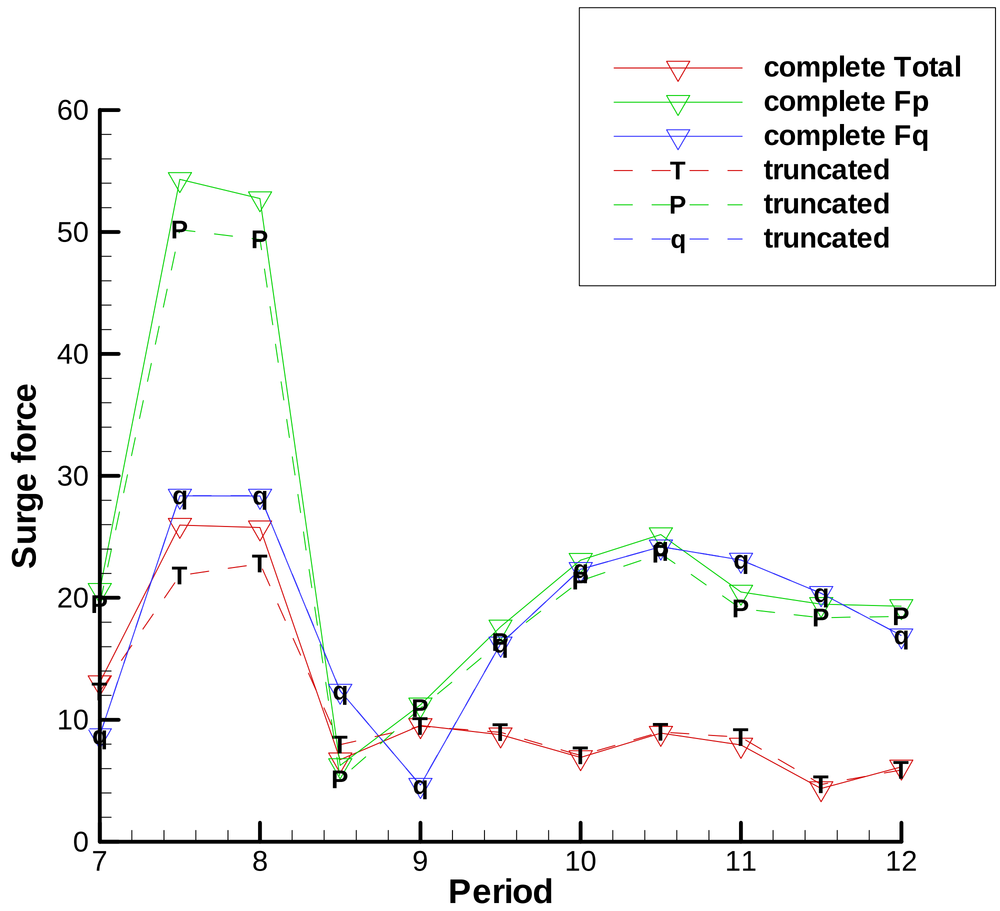
Radius=10m Draft=300m (complete) and 150m (truncated)



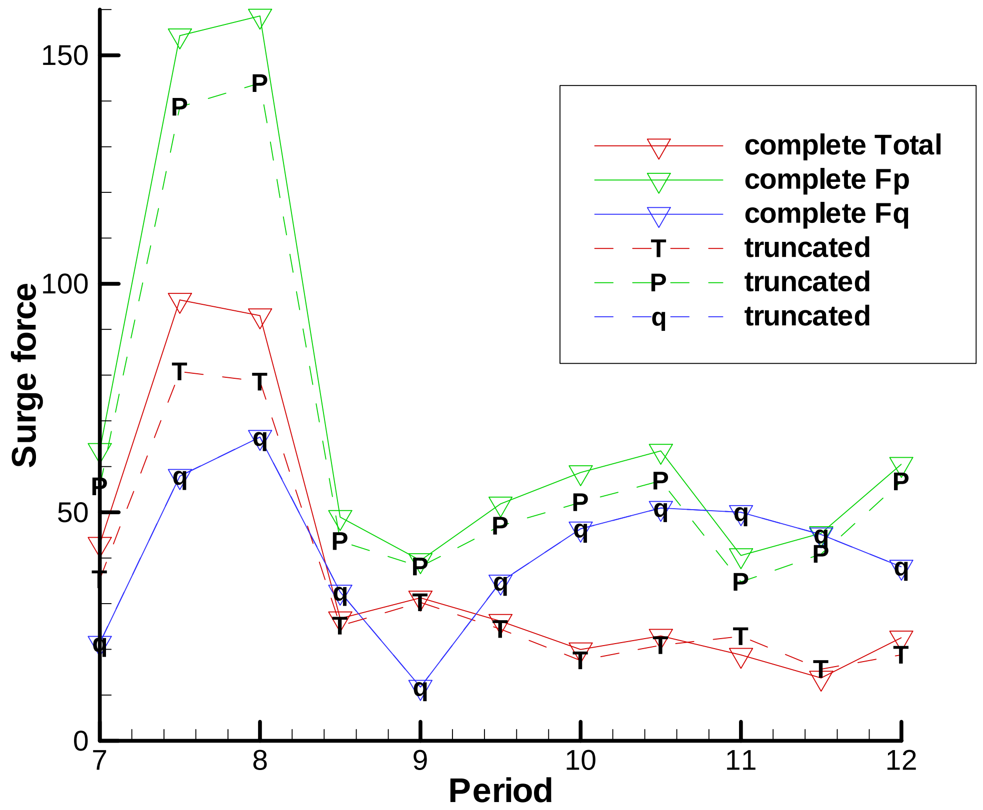
Comparison of total, second-order potential and quadratic forces on one column



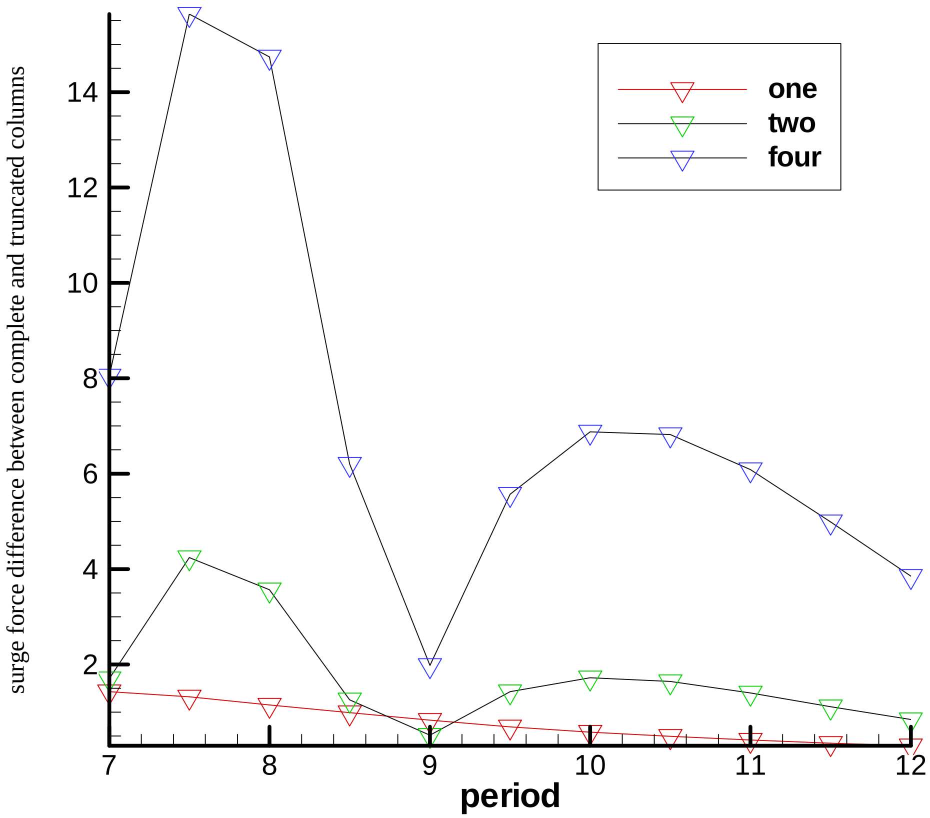
Comparison of total, second-order potential and quadratic forces on two columns



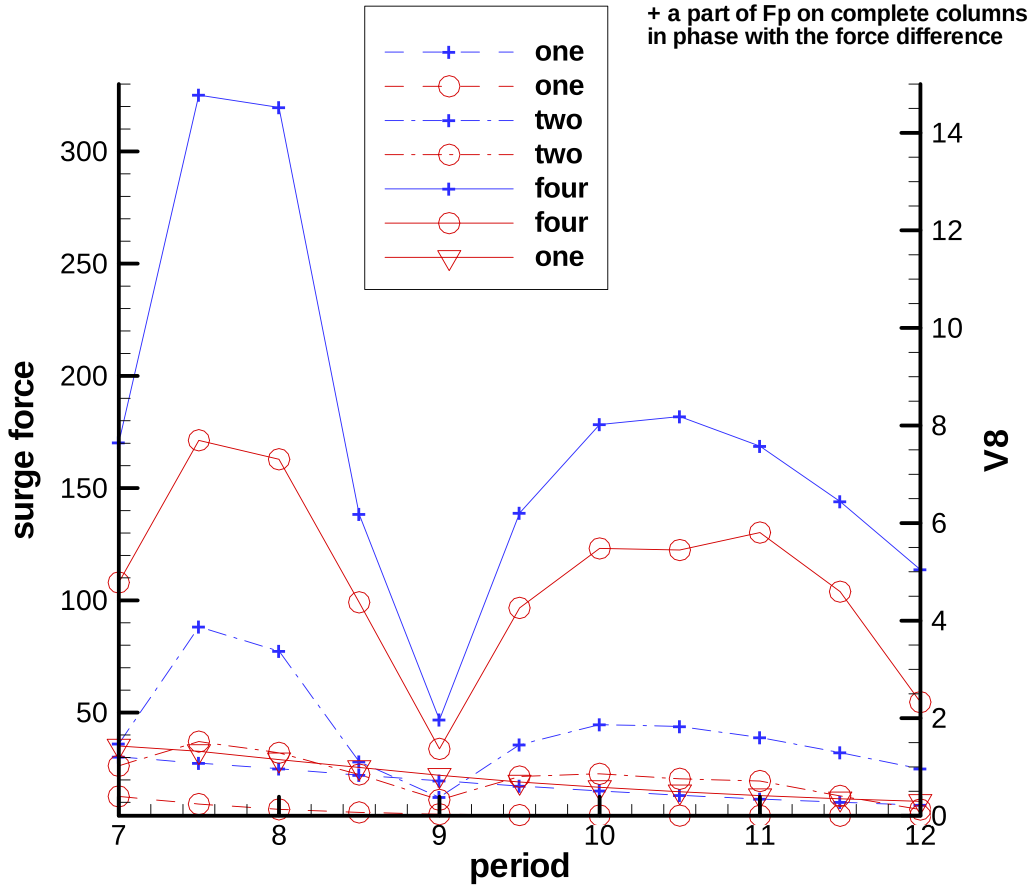
Comparison of total, second-order potential and quadratic forces on four columns



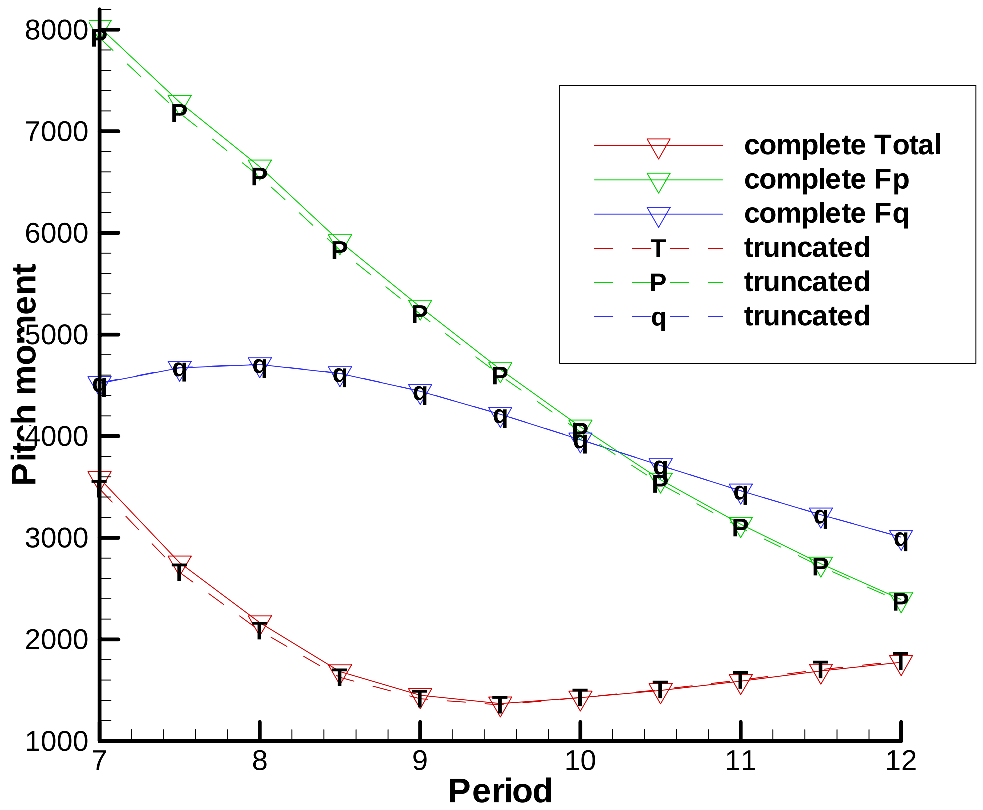
Surge force difference between complete and truncated columns for 3 different number of columns



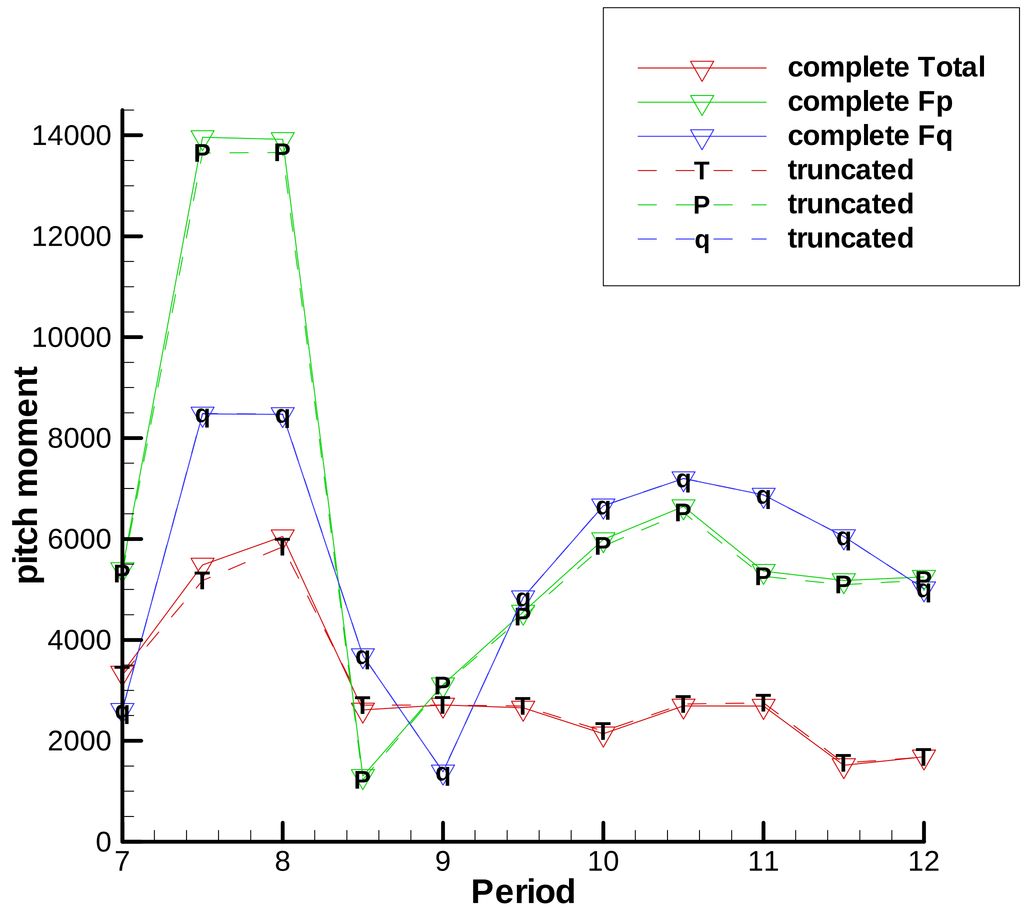
Two components of Fp



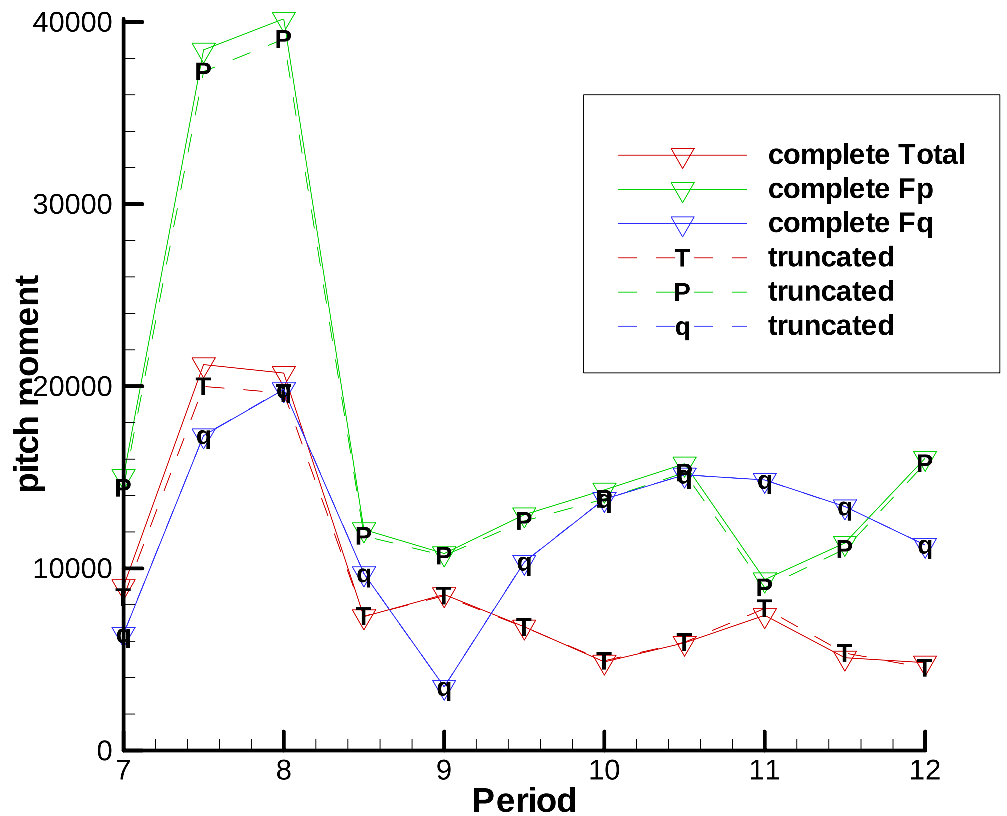
Single columns



Two columns


complete Total
complete Fp
complete Fq
truncated
truncated
truncated
pitch moment
Period
0
2000
4000
6000
8000
10000
12000
14000
7
8
9
10
11
12

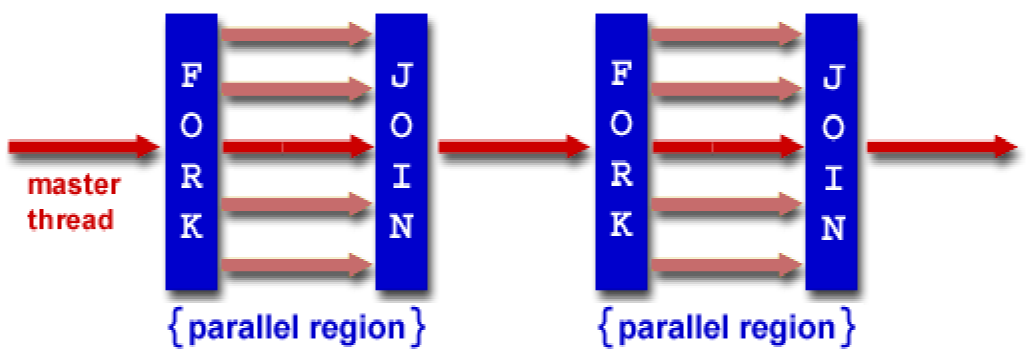
Four columns



Possibility of Parallel Programming in OpenMP for WAMIT?

What is OpenMP

- An Application Program Interface (API) that supports multi-threaded, shared memory parallelism
- Three components: compiler derivatives, runtime library routines, and environment variables
- OpenMP is independent of the underlying machine or operating system
- Folk/Joint Model



Source: https://computing.llnl.gov/tutorials/openMP/

Matrix Multiplication Code

……………………

* openMP run time library, control the parallel execution environment.

```
call omp_set_num_threads(num)
```

*openMP directives:

* specify the scope attributes of variable within a parallel construct

```
  !$omp parallel do private(I,J,K)
  !$omp+ reduction(+:SUM)
      DO 10  I=1,N
        DO 20 J= 1,N
           SUM= 0.0
           DO 30 K=1,N
              SUM = SUM + A(I,K)*B(K,J)
30         CONTINUE
            C(I,J) = SUM
20       CONTINUE
10   CONTINUE
```

………………………

OpenMP Benchmark

- My computer model
  - Lenovo, Microsoft Windows XP Professional
  - Intel® Core™ 2 Duo CPU T9300 @2.5GHz
  - 2.49GHz, 1.97 GB of RAM
- Runtime of a Matrix Multiplication

Matrix Size	600x600	1000x1000	2000x2000
Sequential CPU time (s)	1.156	5.499	52.734
2 threads CPU time (s)	0.749	3.093	29.015
4 threads CPU time (s)	0.718	3.071	29.031
2 threads; inner loop only CPU time (s)	0.905	4.239	34.032

WAMIT CPU Runtime

- Circular cylinder with one wave period
- CPU time breakdown from most time consuming subroutines
- CPU time increases linearly for WAVEGR, SOLVE, FLDCSF (CSF option only) with the number of wave periods

	ILOWHI=1; different panel sizes				
	0.08	*0.16*	*0.32*	*0.64*	*1.28*
RANKINE CPU time (s)	618.4	56.0	7.61	1.59	0.72
WAVEGR CPU time (s)	27.00	2.10	0.20	0.05	0.02
SOLVE CPU time (s)	0.65	0.11	0.02	0.00	0.00

	ILOWHI=0; different number of panels				
	6400	*1760*	*480*	*144*	*64*
RANKINE CPU time (s)	6.13	1.05	0.09	0.03	0.00
WAVEGR CPU time (s)	110.4	9.21	0.45	0.06	0.05
SOLVE CPU time (s)	389.5	11.73	0.63	0.13	0.02

Observation

- Loop-Level parallelism, easy to implement.
- Ideal number of threads maybe the number of processors
- Substantial efforts required to parallelize a large portion of a complicated application. Be careful in communication and synchronization between threads
- Understand factors that affect parallel performance. An application may run slower than the original serial code if not properly coded
- Speed up in WAMIT ? Need further investigation

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