Where can theory contribute to practical concerns about rogue waves?

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What is needed?

What circumstances give rogue waves?

How much do we know of their properties and effects?

Where do we go from here?

What is needed - practical concerns

Probability of occurrence at a given location

e.g for oil rig design

or forecasting e.g. to make defensive preparations

or can a location be chosen to avoid rogue waves?

e.g. for ship routing

Properties of the waves

Effects of the waves

Any others?

Location

Ocean deeps
Continental shelf — all have different features
Coastal waters

even when they have similar wind/wave climates

We have plenty in this meeting on the deeper waters so a few comments about the coast.

Rogue waves are notorious for sweeping people into the sea.

Wave kills two in Southern Oregon

The Associated Press on The Seattle Times web site 11/11/05

PORT ORFORD, Ore. □□ A wave swept three people into the Pacific Ocean on Thursday, killing two and injuring one, the authorities said.

Pamela Flynn, 72, and Thomas Flynn, 44, were pronounced dead on Agate Beach, and Brian Flynn, 42, was treated for hypothermia at a local hospital, said Lt. Dennis Dinsmore of the Curry County Sheriff's Office. They were all from Slagle, Idaho.

Deputies said the Flynns were walking on Agate Beach in Port Orford just after 2 p.m. when the wave swept them into the surf.

Rescue crews, responding to a 9-1-1 call, pulled Pamela and Brian Flynn from the ocean. A fishing boat in the area spotted Thomas Flynn about a half-mile offshore. A U.S. Coast Guard helicopter dropped a rescue swimmer into the ocean to retrieve him.

The helicopter airlifted Flynn to the beach, but medics couldn't revive him, the Coast Guard said.

At Sydney there are numerous notices about the danger of waves on the ledges below its cliffs.

BWIMCOST project

Breaking Wave IMpact on COastal STructures.

Project funded from EPSRC, and E.U.

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Civil Engineering , Queen's University, Belfast

both now at Southampton University

Field measurements at Alderney

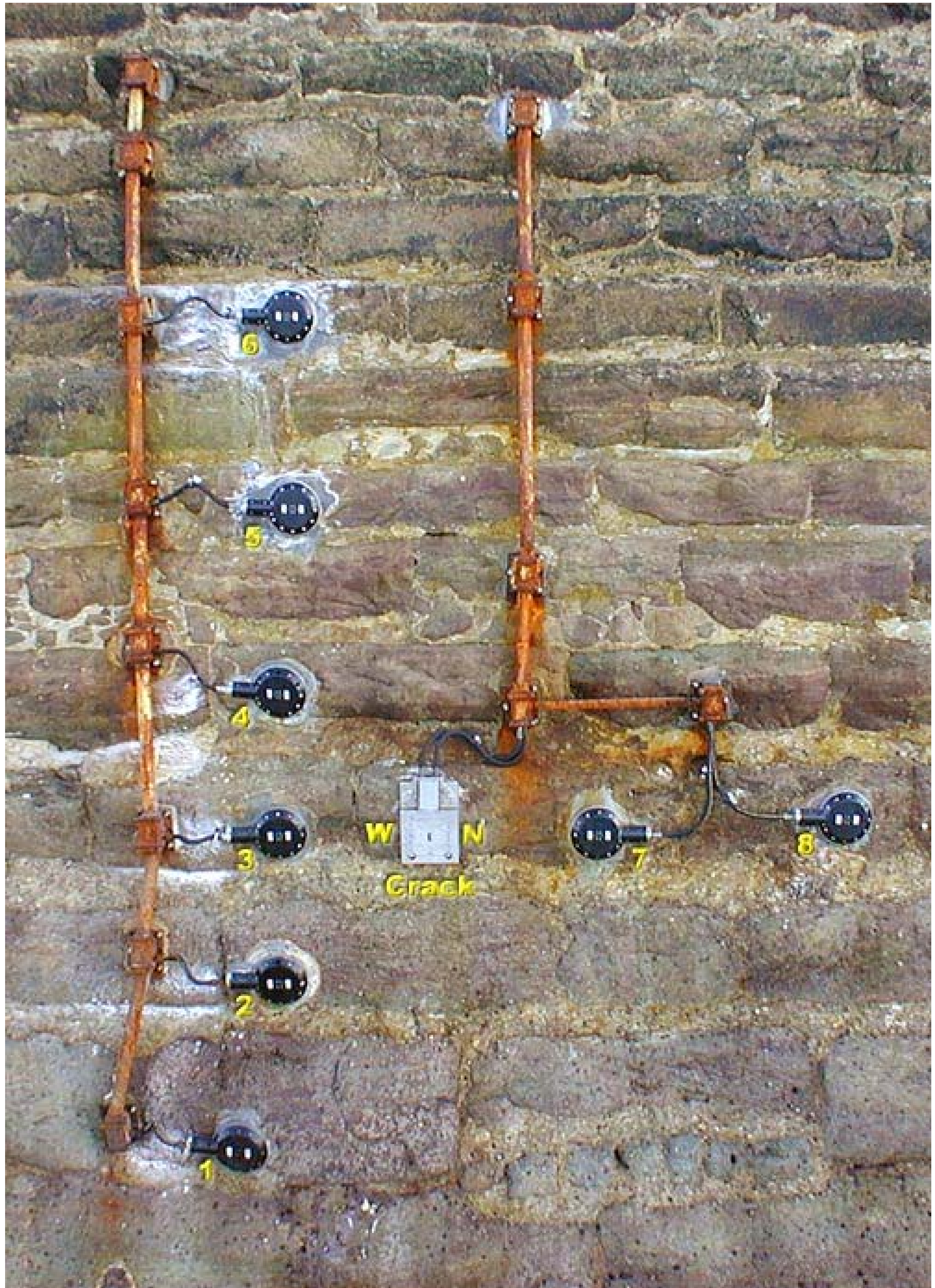
Laboratory experiments at Grosser Wellen Kanal, Hanover, and Plymouth

Approximate tide levels:

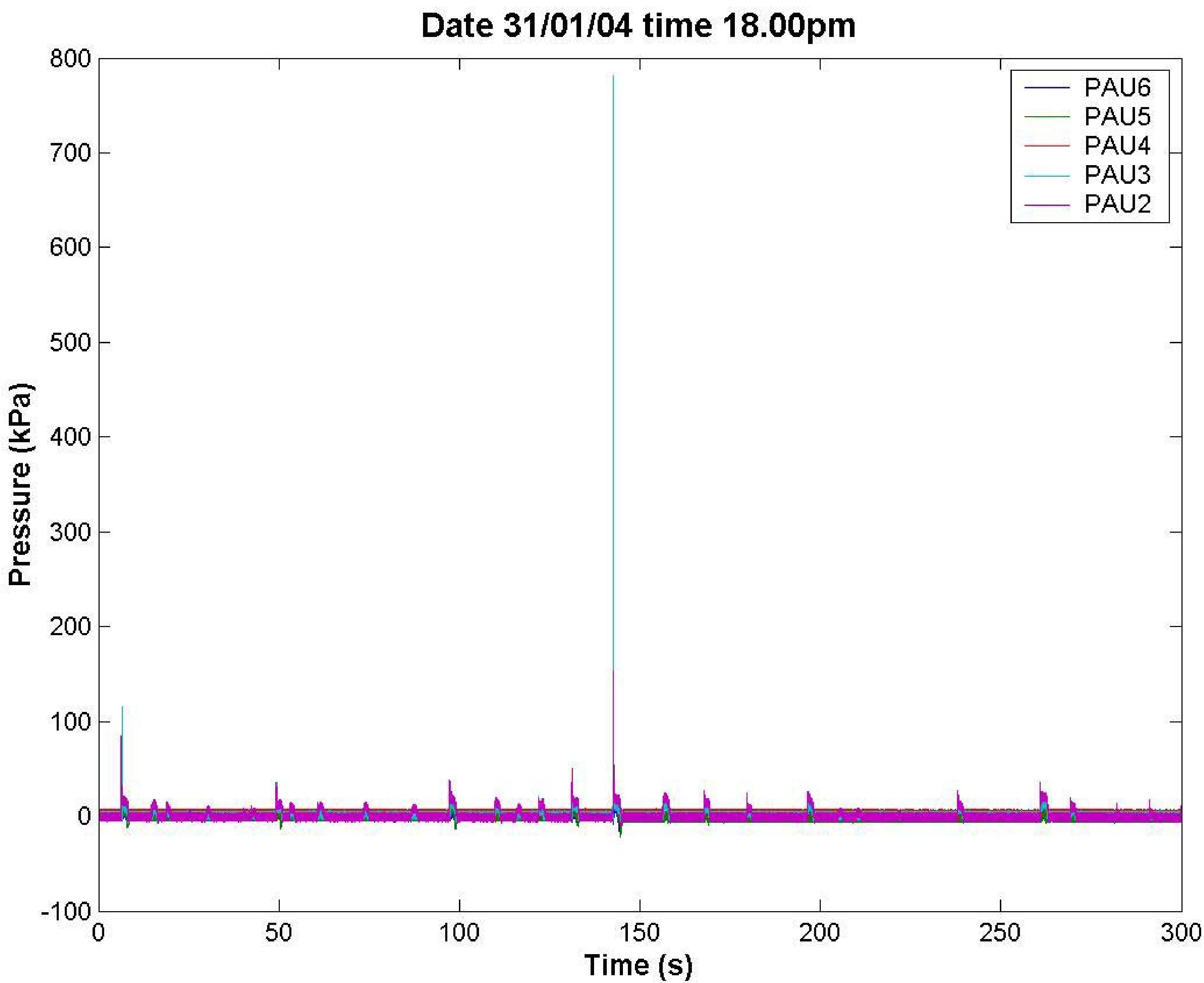
MHWS -

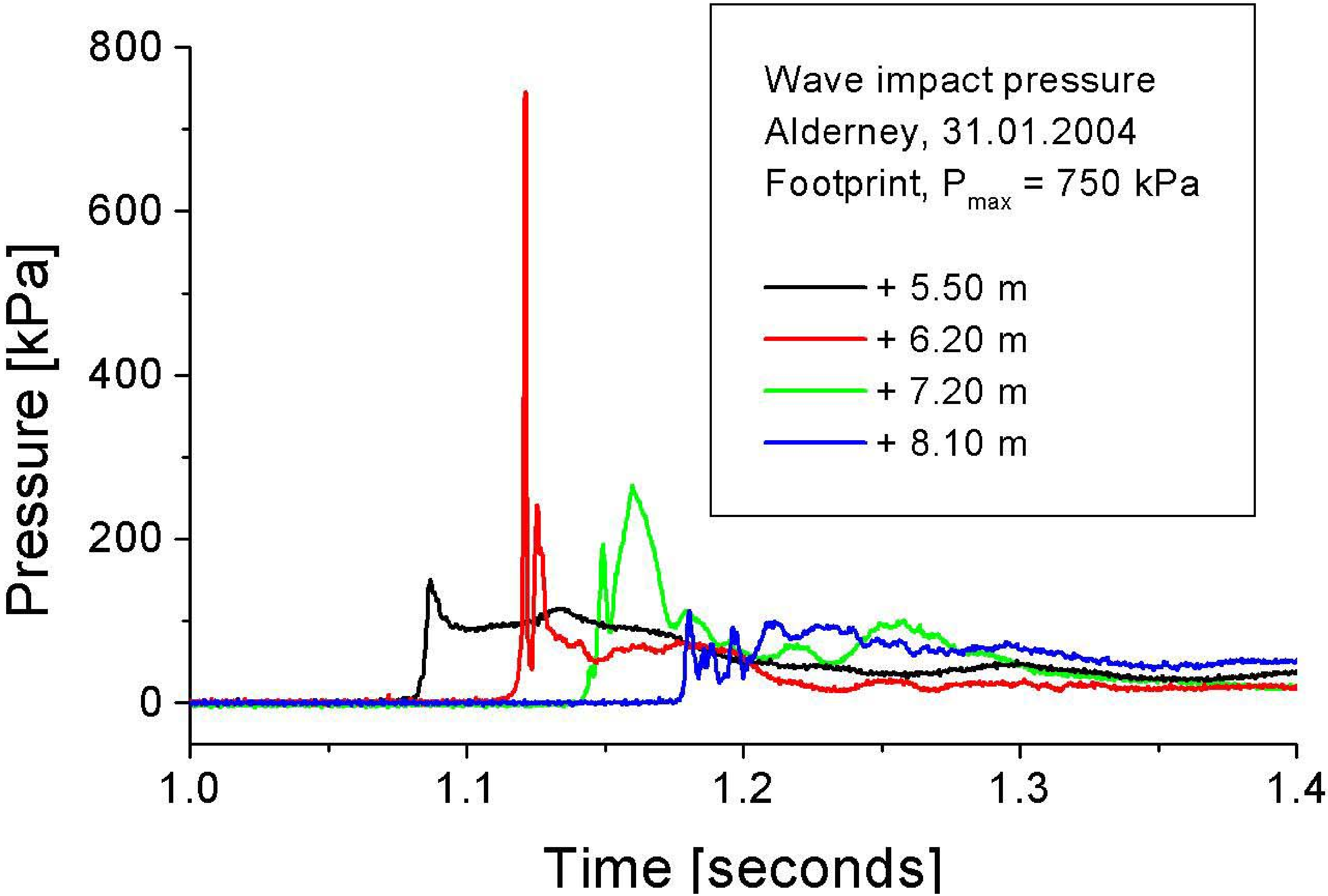
MHWN -

ML -



Array of 8 Pressure Aeration Units (PAUs) and a Crack Unit (CU) on the seaward face of the Breakwater


Date 31/01/04 time 18.00pm
Pressure (kPa)
Time (s)
PAU6
PAU5
PAU4
PAU3
PAU2
800
700
600
500
400
300
200
100
0
-100
0
50
100
150
200
250
300



Wave impact pressure
Alderney, 31.01.2004
Footprint, P_{max} = 750 kPa
+ 5.50 m
+ 6.20 m
+ 7.20 m
+ 8.10 m
Pressure [kPa]
800
600
400
200
0
1.0
1.1
1.2
1.3
1.4
Time [seconds]

Probability of occurrence at a given location

e.g. for oil rig design

or forecasting e.g. to make defensive preparations

or can a location be chosen to avoid rogue waves?

e.g. for ship routing

To assist in these areas we need to be aware of why rogue waves develop. There seem to be a number of possible reasons.

When, or why, do rogue waves occur?

Normal wave spectrum: maximum from superposition of modes.
from Dysthe's talk we see it gives Tayfun/ Piterbarg results
give agreement with some measurements.

Superposition of waves from more than one source, or
a complex source, e.g. moving hurricane.

Nonlinear self focussing
(often misleadingly called Benjamin-Feir instability)
should appear in Dysthe et al.'s computations?

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Refraction by variations in currents and/or bed topography

When, or why, do rogue waves occur?

Normal wave spectrum: maximum from superposition of modes.
from Dysthe's talk we see it gives Tayfun/ Piterbarg results
give agreement with some measurements.
much discussed already

Superposition of waves from more than one source, or
a complex source, e.g. moving hurricane.
perhaps important at times

Nonlinear self focussing
(often misleadingly called Benjamin-Feir instability)
should appear in Dysthe et al.'s computations?

Refraction by variations in currents and/or bed topography

Other causes?
I have in mind here massive waves that appear to
come from an odd direction with long crests.

For weakly nonlinear waves we have the nonlinear Schrödinger equation (NLS) as a good first approximation. Even though the highest waves may be rather too steep and their propagation rather too long for accurate results, their evolution for a number of periods as they near their peak is adequately modelled by it.

The NLS gives us two contrasting views:

1. for a steady wave field we have the defocussing NLS– equation, so that at a focus for linear waves, the weakly nonlinear waves are lower and have almost uniform amplitude as they focus.

2. for 1D propagation, in deep enough water with the NLS+ equation, the waves self focus and give peak waves roughly three times as big as those corresponding to the mean energy density.

Wave solutions of either NLS equation have their amplitude coupled to their length and time scales in much the same way, whether they are solitons, multisolitons, Ma solitons, dark solitons or numerical solutions.

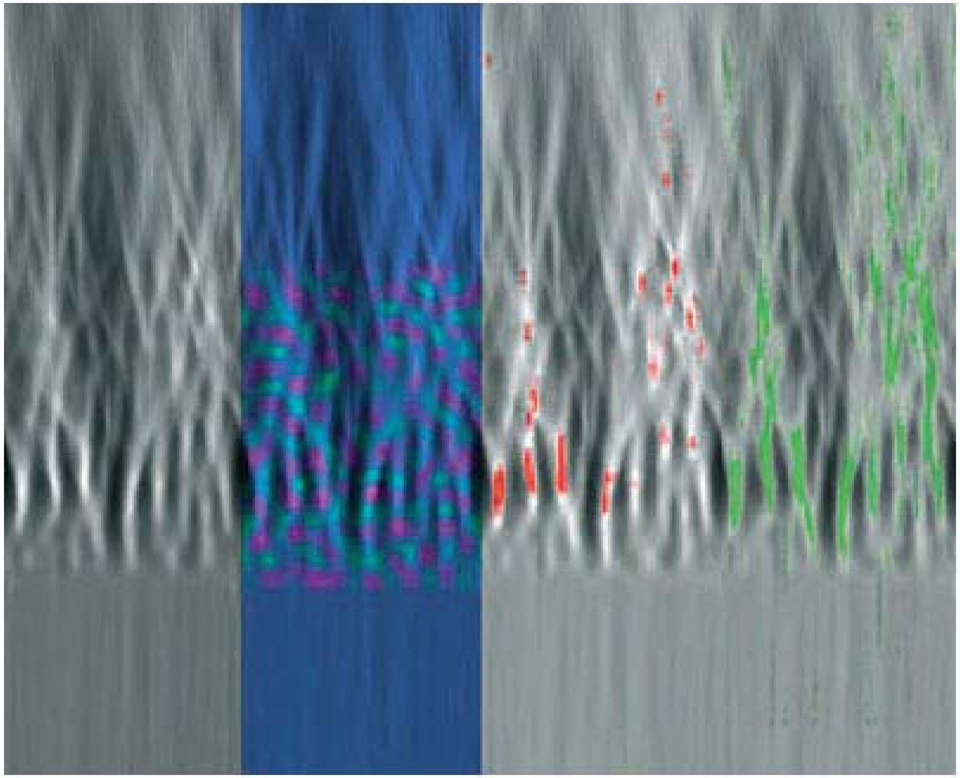
This means that for the steepest waves the length/time scales are relatively short and give an isolated high crest or deep trough depending on the phase of the underlying 'carrier' wave.

On the other hand the recently computed 'crescent' waves may be a more relevant model in a short-crested sea. e.g.Fuhrman, et al., (2004) *J. Fluid Mech*. **513**.

This photo is only illustrative. Note the current refraction outweighs the countervailing effect of depth variation here. I know there are antidunes in the bed too.

The simplest case of refraction enhancement is where waves are trapped, between two caustics on a line of maximum adverse current.

This has long been known to be relevant for the Agulhas current and other strong ocean boundary currents.



▲ Fig. 4: This figure collects data from a long run with "Longuett-Higgins" Gaussian seas impinging from below on an eddy field, here represented as a potential force field. In the left panel, the average energy density of the waves is plotted in grayscale, with lighter regions having higher energy density. The potential field (deflecting the rays) is shown as hills (green) and valleys (purple) in the next panel. Severe freak wave events (waves six or more standard deviations computed from the mean Gaussian) were recorded as red in the next panel; note that there are no events before the refraction starts and some after it has ended. Finally the 4.4 σ events are shown in green in the right panel; there are a few of these before the refraction but many more after it starts and beyond.

Eric Heller, following White & Fornberg 1998 has computed refraction in a random medium over length scales that may interest us.

The figure, from Europhysics News Sept/Oct 2005 shows an example shaded in differing ways.

A problem with this is that only a uniform incident wave is considered.

Contrary to our understanding, this is a steep wave group propagating *with* the maximum current for several kilometres.

With regard to Properties of the waves

For 2D waves efficient boundary-integral programs have been available for some years.

For waves with moderately long crests this should suffice.

[For 3D waves, it seems we shall hear more in this workshop.]

In practice . . . .

often no more than second-order theory is used with regard to the Effects of the waves

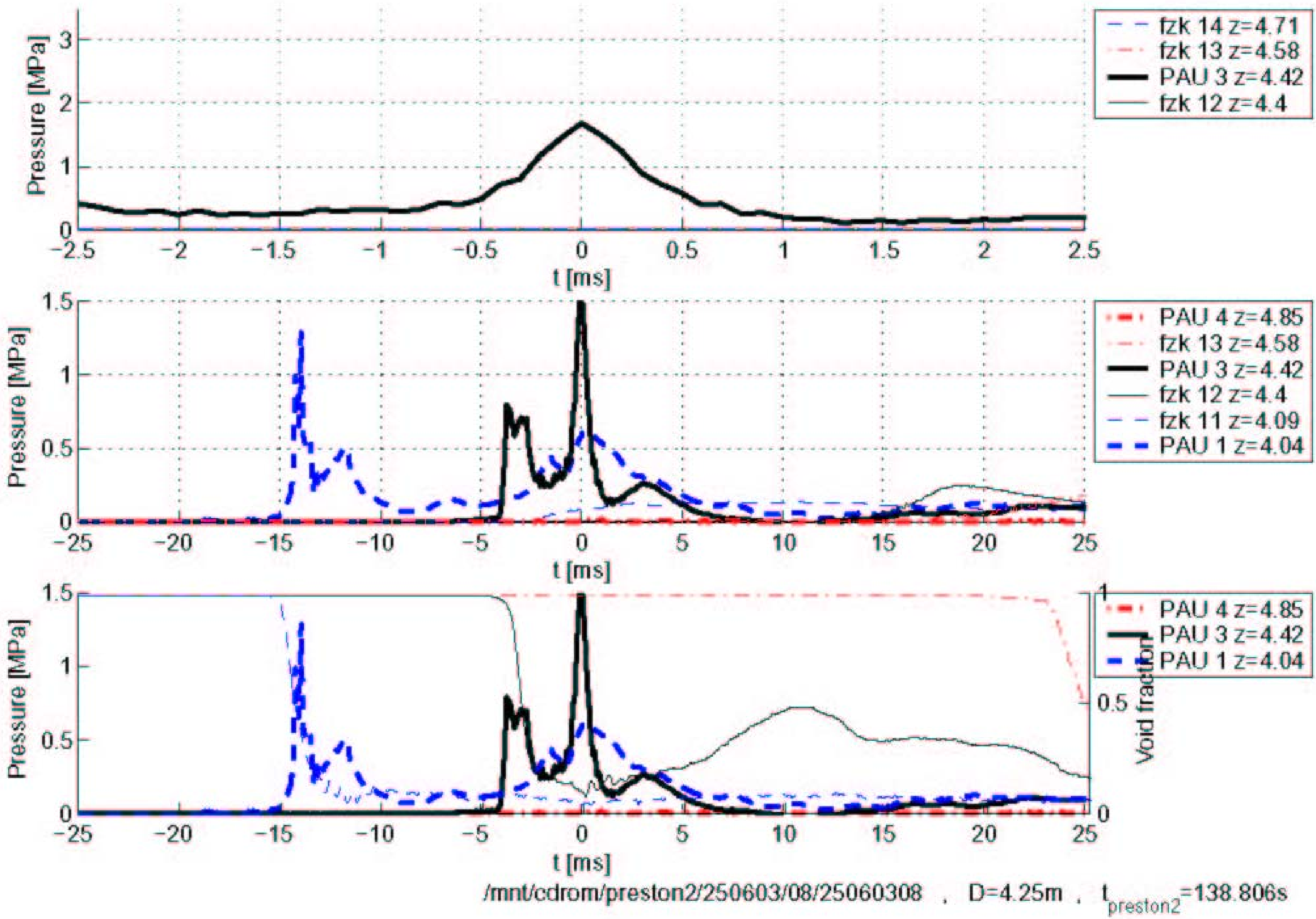
In most cases the major requirement is to estimate the effect on structures, especially forces.

This is an area which is essentially difficult: even for a simple circular cylinder, where there is thin runup, flow around the cylinder may separate, and the surface can break due to various causes.

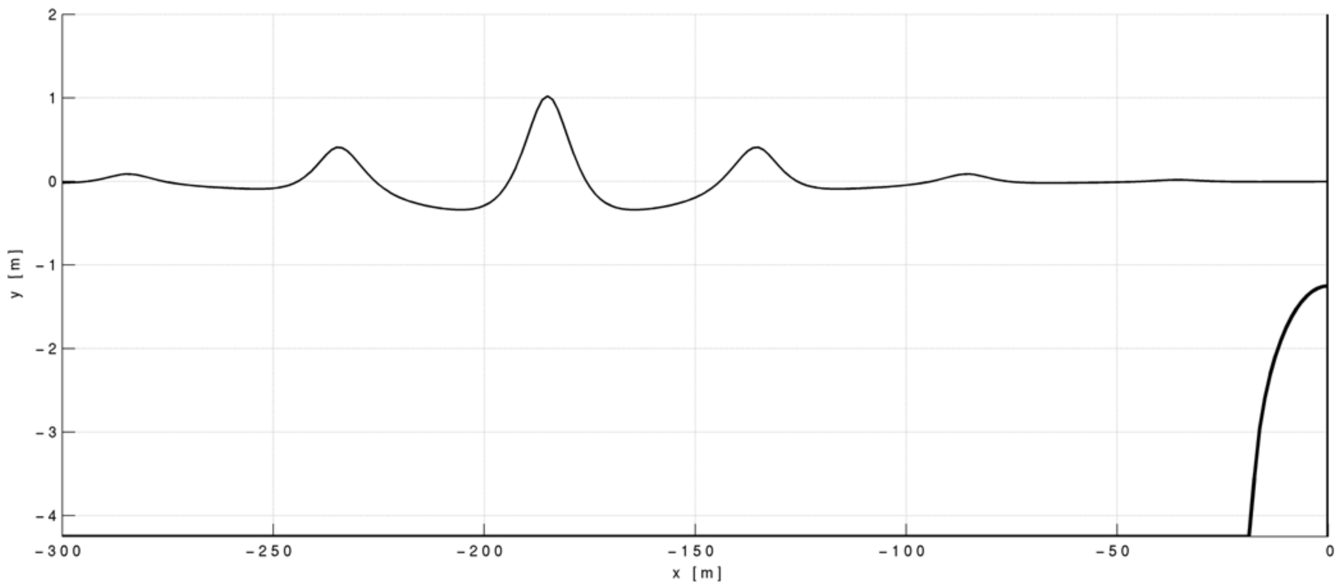
It is worse for the more violent wave impacts, or the effects on complex structures, especially when there is a current or the structure is moving.

I'll give a brief account of what we have achieved in the BWIMCOST project.

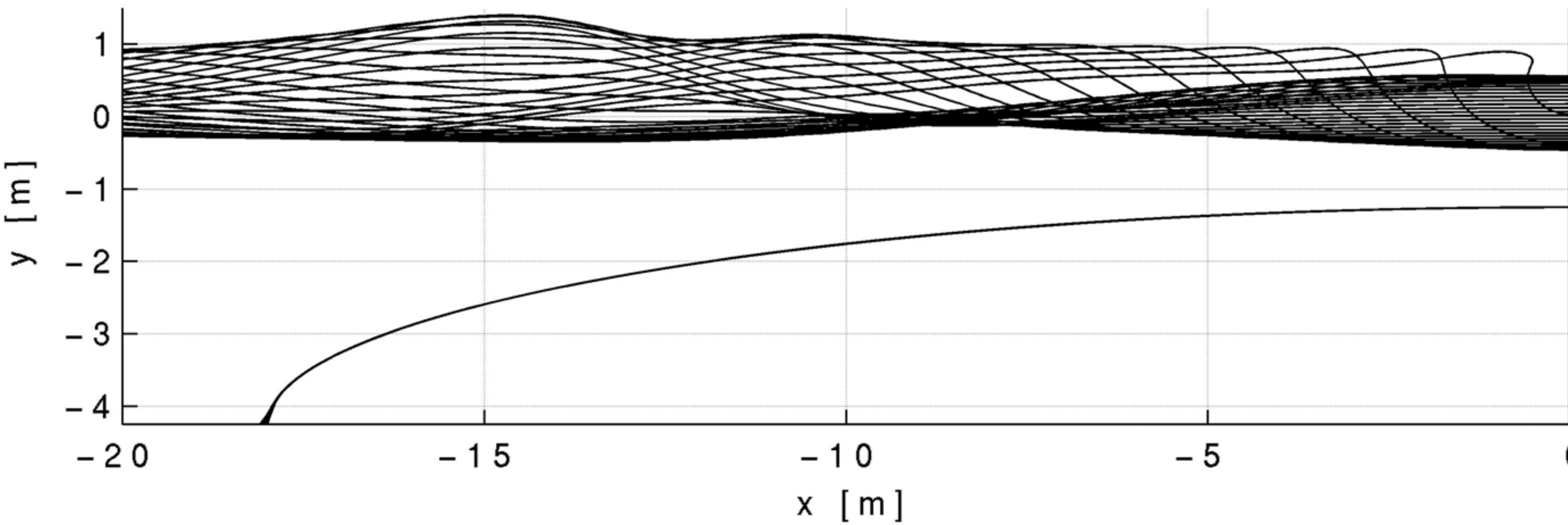

Vertical wall - Regular wave
H=1.35m T=8s d=4.25m



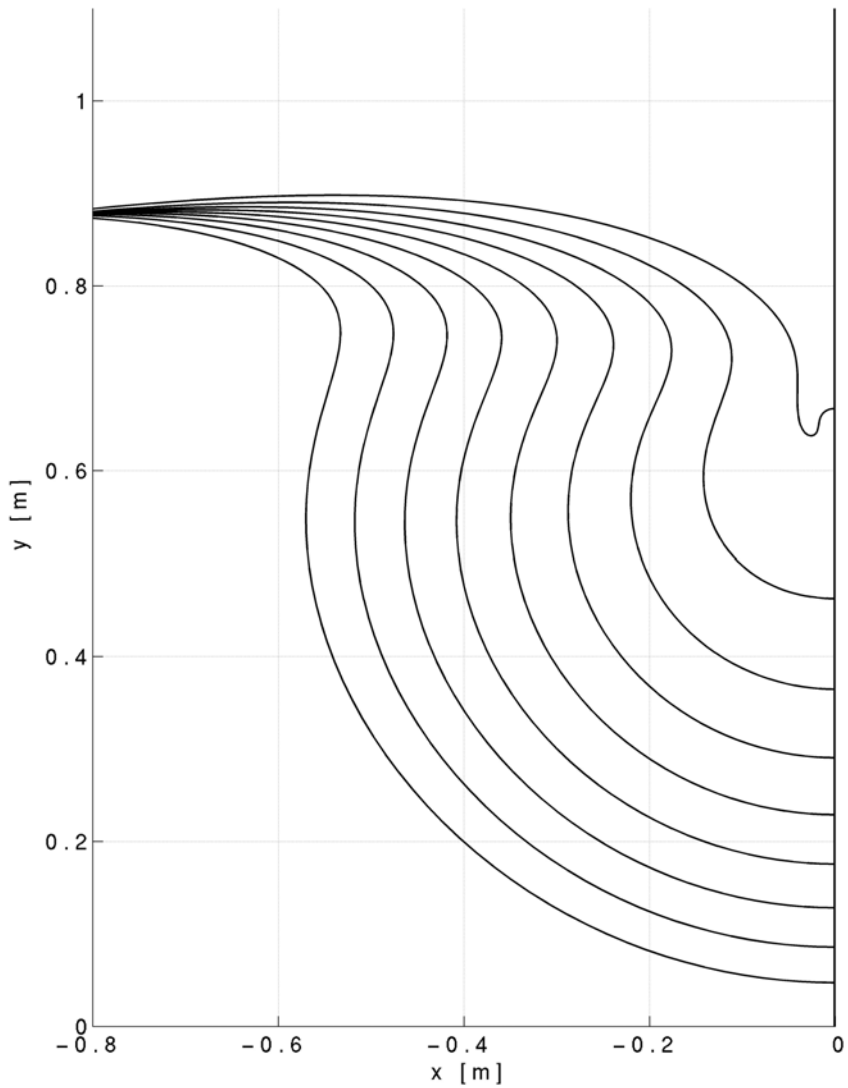
Pressure [MPa]
t [ms]
fzk 14 z=4.71
fzk 13 z=4.58
PAU 3 z=4.42
fzk 12 z=4.4
PAU 4 z=4.85
fzk 11 z=4.09
PAU 1 z=4.04
Void fraction
/mnt/cdrom/preston2/250603/08/25060308 , D=4.25m , $t_{preston2}$=138.806s



Outline of the geometry and initial surface profile for waves propagating toward impact.
Vertical exaggeration approximately 7:1.

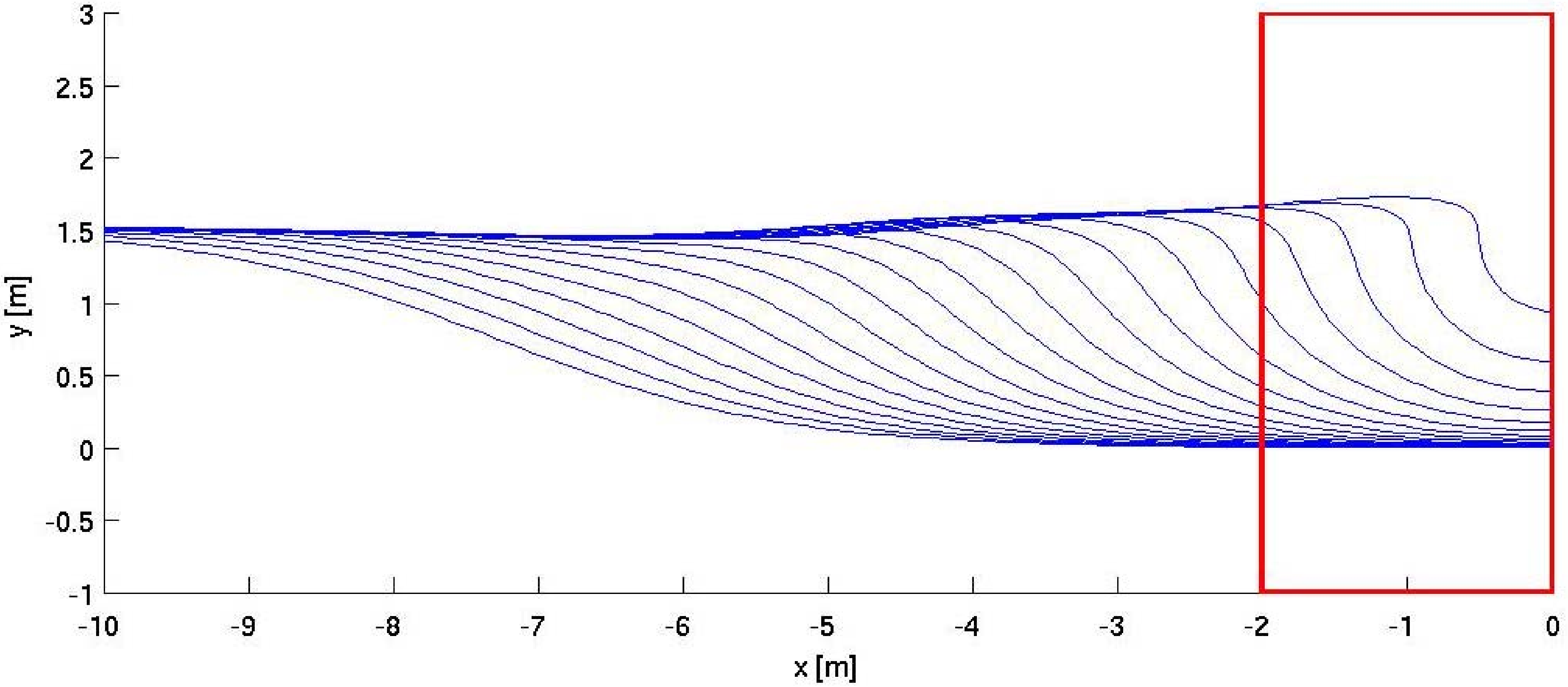


A set of profiles at time intervals of 0.5 sec for initial wave height 1.45m.
No vertical exaggeration.



black

Compressible flow modelled in region outlined



5% aeration of water assumed

Plus pure air

200x400 cells (1cm discretisation)

See

Peregrine, D.H., Bredmose, H., McCabe,A., Bullock,G., Obhrai,C., Müller,G. & Wolters,G. 2004 Violent water wave impact on walls and the role of air. *Proc. 29th Internat. Conf. Coastal Engng.,* Lisbon, Ed. J.McK. Smith, World Sci. **4**, 4005-4017.

for a brief account. Full papers are in preparation.

Conclusions?

Progress in developing useful results is being made and will clearly continue.

An area where more effort might be placed is in understanding the effects of current and depth refraction on realistic waves.