EXPERIMENTAL MEASUREMENT OF THE WASH CHARACTERISTICS OF A FAST DISPLACEMENT CATAMARAN IN DEEP WATER

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CONTENTS

NOMENCLATURE

Fn_L	Froude Number, $\left[U / \sqrt{gL} \right]$
Fn_H	Froude Depth Number, $\left[U / \sqrt{gH} \right]$
Rn	Reynolds Number, $\left[UL / \nu \right]$
U	Velocity [m s^{-1}]
W	Tank width [m]
H	Water depth [m]
L	Length on waterline [m]
A	Static wetted surface area [m^2]
B	Demihull maximum beam [m]
T	Demihull draught [m]
S	Separation between catamaran demihull centrelines [m]
∇	Volume of displacement [m^3]
Δ	Mass displacement in freshwater [kg]
C_B	Block coefficient
C_P	Prismatic coefficient
$L/\nabla^{1/3}$	Length : displacement ratio
R_T	Total resistance [N]
C_T	Coefficient of total resistance, $\left[R_T / \tfrac{1}{2}\rho A U^2 \right]$
R_W	Wave resistance [N]
C_W	Coefficient of wave resistance, $\left[R_W / \tfrac{1}{2}\rho A U^2 \right]$
R_{WP}	Wave pattern resistance [N]
C_{WP}	Coefficient of wave pattern resistance, $\left[R_{WP} / \tfrac{1}{2}\rho A U^2 \right]$
C_F	Coefficient of frictional resistance, [ITTC-57 Correlation line]
R	Resistance in general [N]
g	Acceleration due to gravity [9.80665 m s^{-1}]
ρ	Density of freshwater [1000 kg m^{-3}]
ν	Kinematic viscosity of freshwater [1.141×10^{-6} m^2 s^{-1} at 15^{o}C]

1 INTRODUCTION

Work on the resistance of high speed displacement catamarans has been ongoing over a number of years at the University of Southampton [1-3] in an effort to improve the understanding of their resistance components, seakeeping performance and to provide design and validation data.

This report describes a series of wash wave measurements for catamaran models travelling in deep water. The models were chosen from the series used in [4, 5], for which extensive resistance and seakeeping characteristics in deep water are available.

The tests covered two catamaran separation: length ratios [S/L]. The experiments entailed the measurement of wave profiles at seven transverse positions. The wave pattern measurements would also enable estimates of the wave pattern resistance to be made.

The work described forms part of a wider research programme, funded by EPSRC and industry and managed by Marinetech South Ltd over a two year period, which includes the development of theoretical methods for the prediction of the wash and wave resistance of catamarans. The theoretical work is the subject of a separate report [6].

2 DESCRIPTION OF MODELS

Two different scale models of the same hullform, designated Model 5s, were tested. Details of the principal particulars of the models are given in Table 1 and the body plan is given in Figure 1. Model 5s is of round bilge/ transom stern form and is based on the Series 64 form [7].

The larger of the two models tested has a waterline length of 4.5m, a test displacement (FW) of 324kg and is constructed in GRP. It is free running, propelled by gas fuelled internal combustion engines and radio controlled more information on the 4.5m model is given in [5]. The smaller model tested, (provided by Seaspeed Technology Ltd), has a waterline length of 1.6m, a test displacement of 13.4kg, is propelled by electric motors and is radio controlled.

3 FACILITIES AND TESTS

3.1 General

The model tests were carried out in the Ocean Basin at QinetiQ Haslar, formerly DERA. The basin has a length of 120m, breadth of 60m and water depth of 5.5m. The basin is equipped with a rotating arm 30m from one end. This was positioned across the tank, allowing seven wave probes to be attached to it. Another array of five wave probes was positioned further up the tank. Two wave buoys were situated at the second array of probes, but a significant distance off the model track. A schematic view of the tank, model track and wave probe positions is shown in Figure 2.

For each test run, the wave buoy acquisition was started, then the model engines were started and the model released once it was straight. A straight course was maintained by the radio control operator. The acquisition for the first array of probes was started when the model was 10m away. The acquisition for the second array was started 10m before the model reached this array. The acquisition of both arrays ran until the model turned out of the run.

3.2 Test conditions

The track of the models was selected to be 10m from the wall of the tank. This was partly due to the position of the rotating arm, which would interfere with the model and wave pattern and partly to position the probes as a function of tank width in order to calculate the wave resistance of the model.

The model speed was determined by measuring the time taken between the two probe arrays. The mean time was taken from at least two independent timekeepers to increase the accuracy.

3.3 Wave pattern measurements

Extensive wave profile measurements were carried out in order to establish a wide database of wash wave characteristics in deep water, which would be suitable for design and validation purposes. Such an extensive set of wave data would also facilitate the description of the near field wave pattern in three dimensions from the experimental results and facilitate the interpolation of the experimental data at various transverse positions. The width of the Ocean Basin allowed wave cuts at up to 10 ship lengths from the 4.5m model.

During each test run, seven longitudinal wave profiles were measured, with transverse positions (Y) relating to the centreline of the tank as shown in Figure 2. Relative to model length, these positions have values of Y/L =1.41, 3.75, 4.19, 5.0, 5.56, 5.63, and 8.44 for the 1.6m model and Y/L=0.5, 1.33, 1.49, 1.78, 1.98, 2.0 and 3.0 for the 4.5m model. Wave buoys were also deployed some distance from the model in an attempt to monitor wave decay. The longitudinal and lateral wave probe positions are given in
Figure 2 and Table 2.

The waves were measured using resistance type wave probes, constructed from 500mm lengths of stainless steel rod. The probes were energised with 5 volts from a Churchill box. The output signal was acquired using an analogue to digital converter and a PC. The signals were acquired at a sampling frequency of 100Hz. The acquisition program allowed a run time up to 40 seconds to be used.

The wave buoys had their own PC based calibration and acquisition system, which had a maximum sampling frequency of 10Hz. This allowed a maximum run time of 20 minutes to be acquired.

3.4 Trim changes

A limited series of tests were carried out on both models with significant stern trim. These would provide information on the influence of trim changes on the model resistance and the measured wash waves. It was decided not to test with a bow down trim as this would have made the models difficult to control in a safe manner.

4 DATA REDUCTION AND PRESENTATION

The measured wave profiles are presented in terms of wave height (mm) to a base of distance (m) in Figures 3 to 45. The influence of steering errors and comparison between various wave profiles are given in Figure 46 to 51.

5 DISCUSSION OF RESULTS

5.1 Measured wave profiles

The measured wave profiles are presented in Figures 3 to 45. These figures show the wave cuts for each wave probe. Figures 3 to 27 are the wave cuts for the first array of wave probes and Figures 28 to 45 are the wave cuts for the second array of wave probes.

Figure 46 shows the effect on the wave pattern of running the model off the intended track. In order to determine how close to the intended track the model ran, it is possible to compare the first few waves in the cuts from the fifth and sixth probes in the first array. Figure 47 compares the wave cuts for the 1.6m catamaran at a separation to length ratio of 0.2. It is evident that the five waves are in phase and of the same period but of different amplitude. This would indicate that the model was on track. Figure 48 shows the two wave cuts when the model was off the intended track. Although the period and amplitude of the waves are similar the phasing is different.

Figures 49 and 50 compare the wave cuts from the first and second arrays. Figure 49 has good agreement between all five of the wave cuts indicating that the model ran on a straight course past both arrays. Figure 50 shows phase differences between the fifth and sixth wave cuts, indicating that the model deviated off of its course between the two arrays.

It was intended to use the wave buoys to measure waves at a significant distance from the track of the model and to determine some indication of wave decay. Figure 52 presents the wave trace from the wave buoy for the 4.5m model at a separation to length ratio of 0.2 and a speed of 3.22 m s^{-1}, (the actual results are found from 250 to 450 seconds). Unfortunately the position of the rotating arm prevented waves from propagating out to the wave buoys before reflected waves from the sides of the tank reached it. The wave buoy measurements are therefore not presented.

5.2 Influence of model scale

Scale effects have been investigated by scaling the waves produced by the 4.5m model to that of the 1.6m model. Figure 51 compares the wave cuts at similar Y/L positions and similar speeds. The scaled waves have a similar wave period and amplitude. The slightly larger wave height for the 4.5m model may be due to its larger (geometric) displacement (smaller length: displacement ratio) than the 1.6m model, and the small differences in Fn and Y/L of the probes. The comparison starts to break down after six wave periods because of the reflection of the waves from the 4.5m model. The agreement between the two different size models is an important result as it indicates that there is little scale effect between the small and big models, and that the small model can provide reliable results.

5.3 Influence of hull separation

It was not possible to directly compare the wave traces of the models in the two spacing configurations as the wider separation S/L=0.4 achieved a higher speed than the smaller separation S/L=0.2.

5.4 Influence of static trim angles

Figure 53 presents the wave cuts for two runs, one with static trim and one without. The trim appears to increase the amplitude of the waves by a small amount and to cause a small phase shift.

5.5 Wave resistance

Considerable effort was made to position the wave probes to enable the wave pattern resistance to be estimated. However, the asymmetry of the setup (with a wall adjacent to the starboard side of the model track) and small deviations in the position of the model relative to the probes, resulted in unreliable estimates of the wave pattern resistance.

6 CONCLUSIONS

6.1 A database of experimental wash wave measurements for a ship model travelling in deep water has been established. The experiments covered one hull form in catamaran mode at two model scales.

6.2 The results at the two model scales were geometrically similar, indicating that there was little scale effect between the small and big models, and that models built to the scale of the smaller model should provide reliable results.

ACKNOWLEDGEMENTS

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TABLES

L [m]	1.6	4.5
Δ [Kg]	13.4	324
L/B	12.8	12.8
B/T	2.0	1.9
$L/\nabla^{1/3}$	8.5	8.3
C_B	0.537	0.540
C_P	0.633	0.637
C_M	0.848	0.848
A/L^2	0.102	0.115
LCB %	-6.4	-6.4

Table 1: Principal particulars of Models (demihulls).

Longitunal Position [m]		Lateral Position from model track [m] (tank side [m])						
	30	2.25 (7.75)	6 (4)	6.7 (3.3)	8 (2)	8.9 (1.1)	-9 (19)	-13.5 (23.5)
	70.5	2.25 (7.75)	6 (4)	6.7 (3.3)	8 (2)	8.9 (1.1)	-22.5 (32.5)	-45 (55)

Table 2:Position of wave probes and wave buoys

Model Length [m]	S/L	Trim	V [m/s]
1.6	0.2	Level	1.8, 1.9, 2.2, 3.2, 3.9
		Stern down	1.78
	0.4	Level	1.9, 2
		Stern down	1.8
4.5	0.2	Level	3.2, 2.9
		Stern down	3.6
	0.4	Level	4.0, 4.1, 3.9
		Stern down	3.8, 4.1

Table 3: Test matrix for Haslar Ocean Basin. Tests over 2 days, in deep water (5.5m).

FIGURES

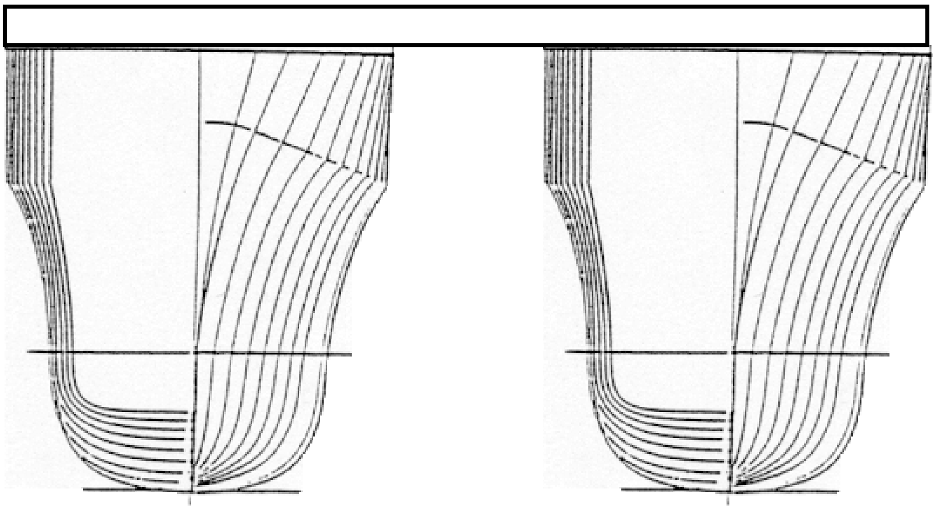


Figure 1: Bodyplan Model 5s

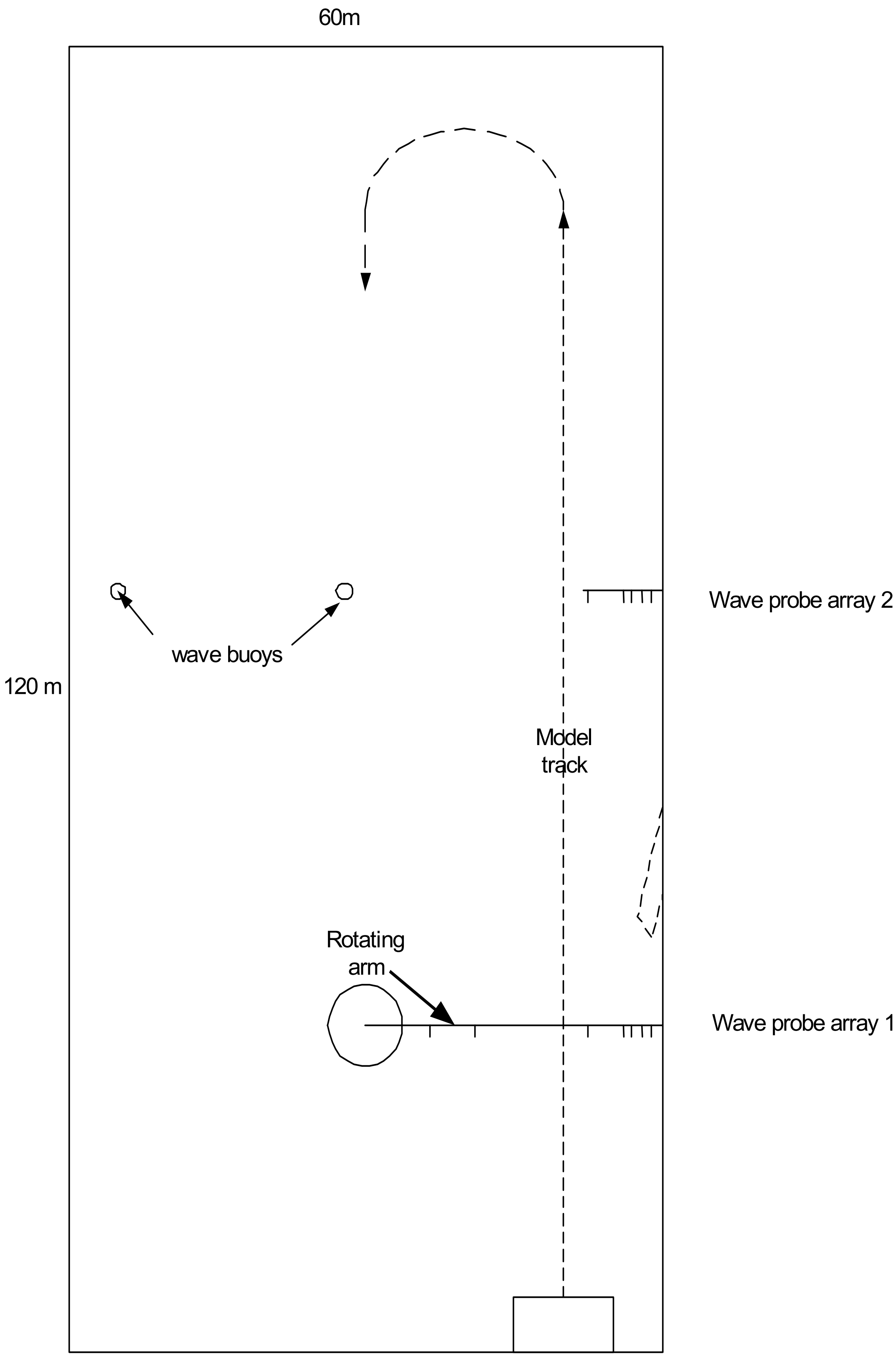
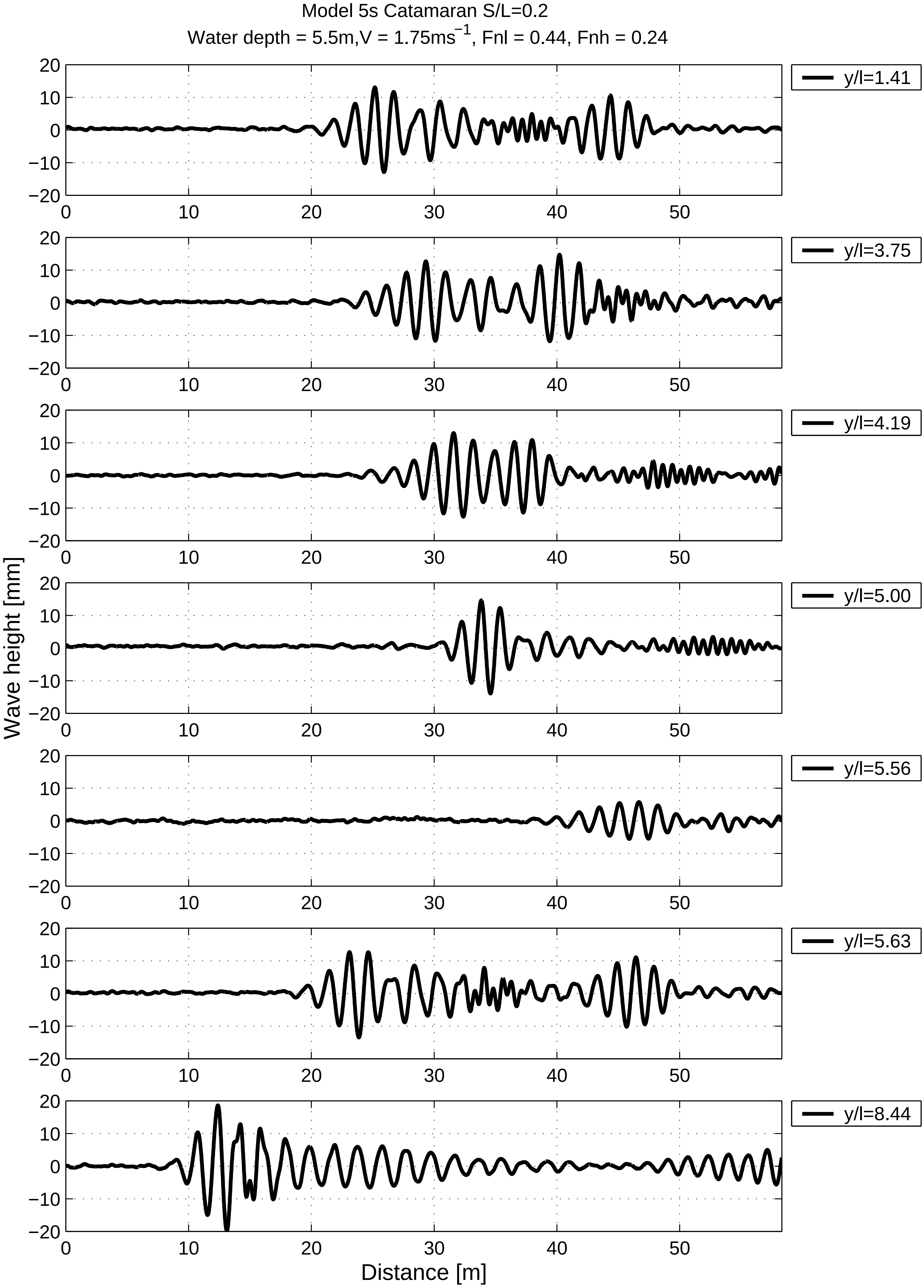
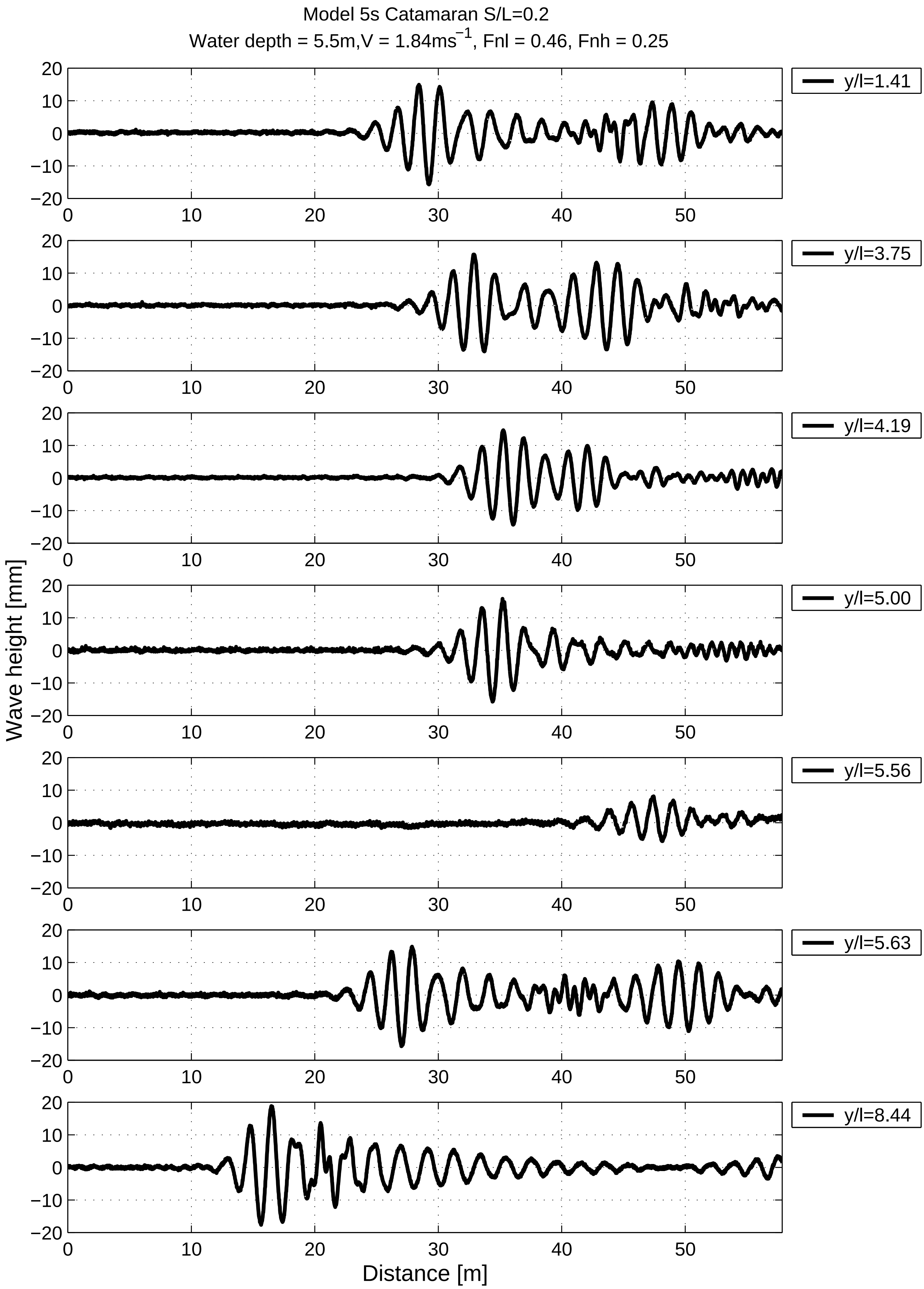


Figure 2: Schematic of Haslar Ocean Basin



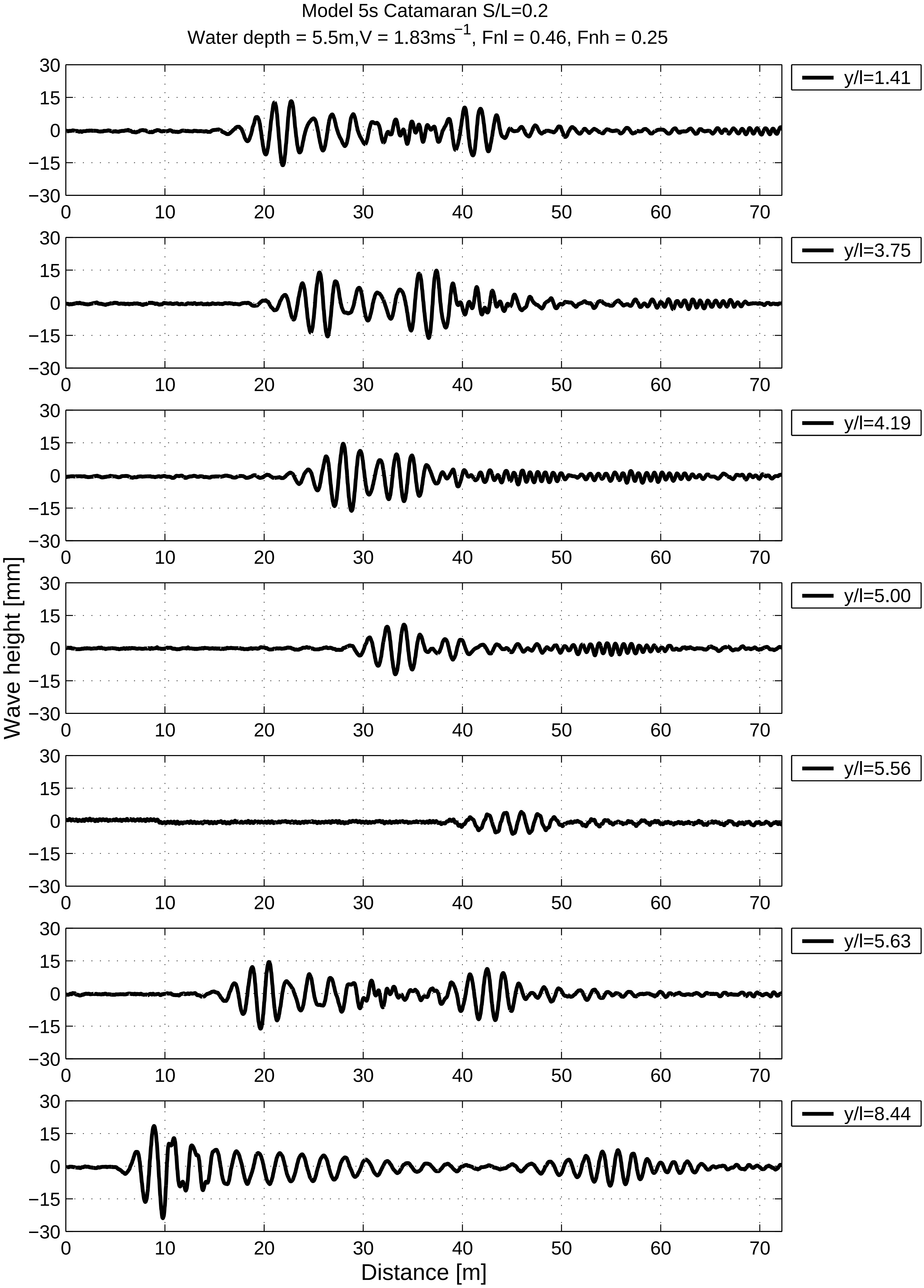
Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.75ms^{-1}, Fnl = 0.44, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 3



Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.84ms−1, Fnl = 0.46, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 4


Model 5s Catamaran S/L=0.2
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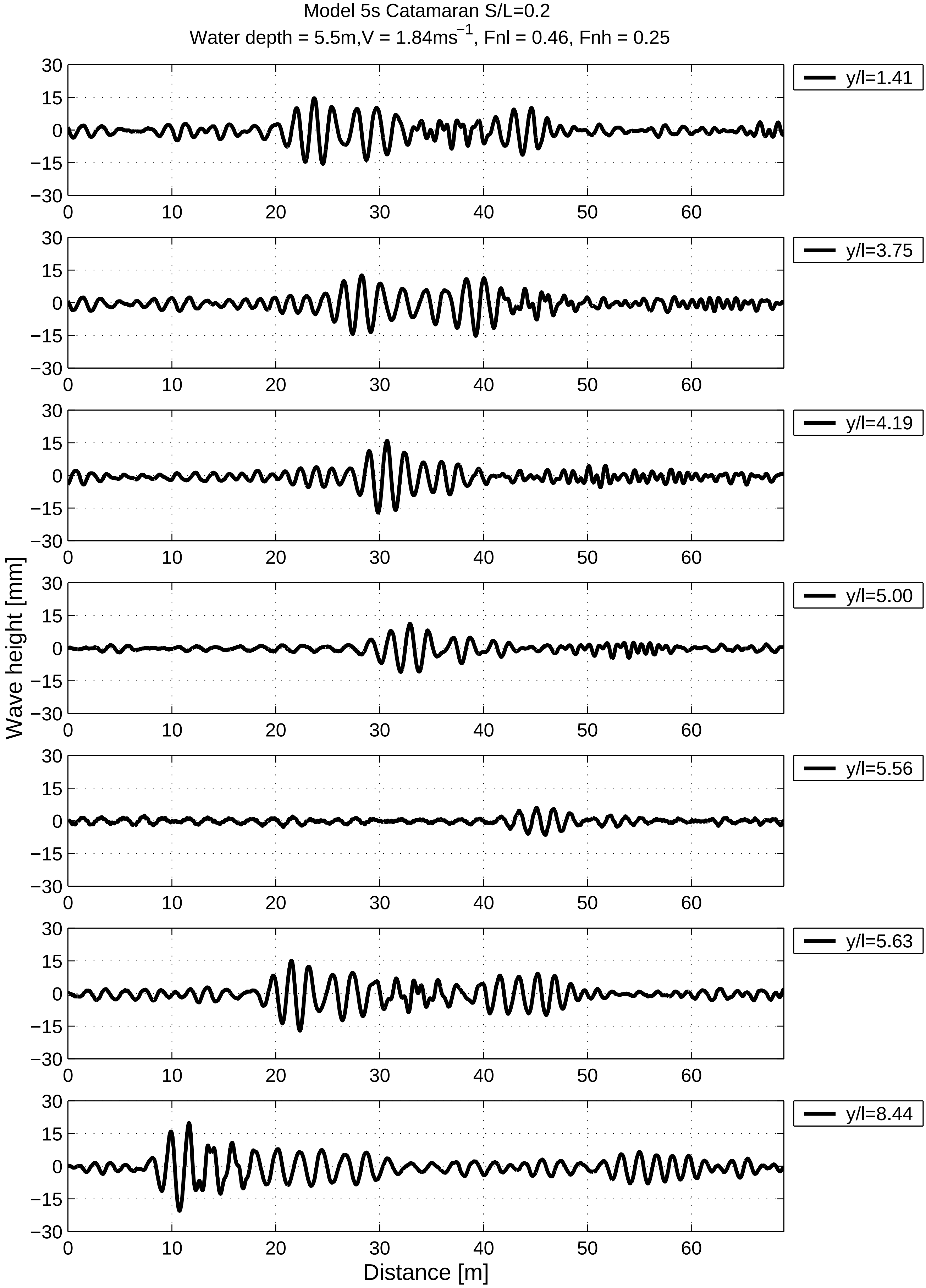
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 5



Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.84ms^{-1}, Fnl = 0.46, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 6

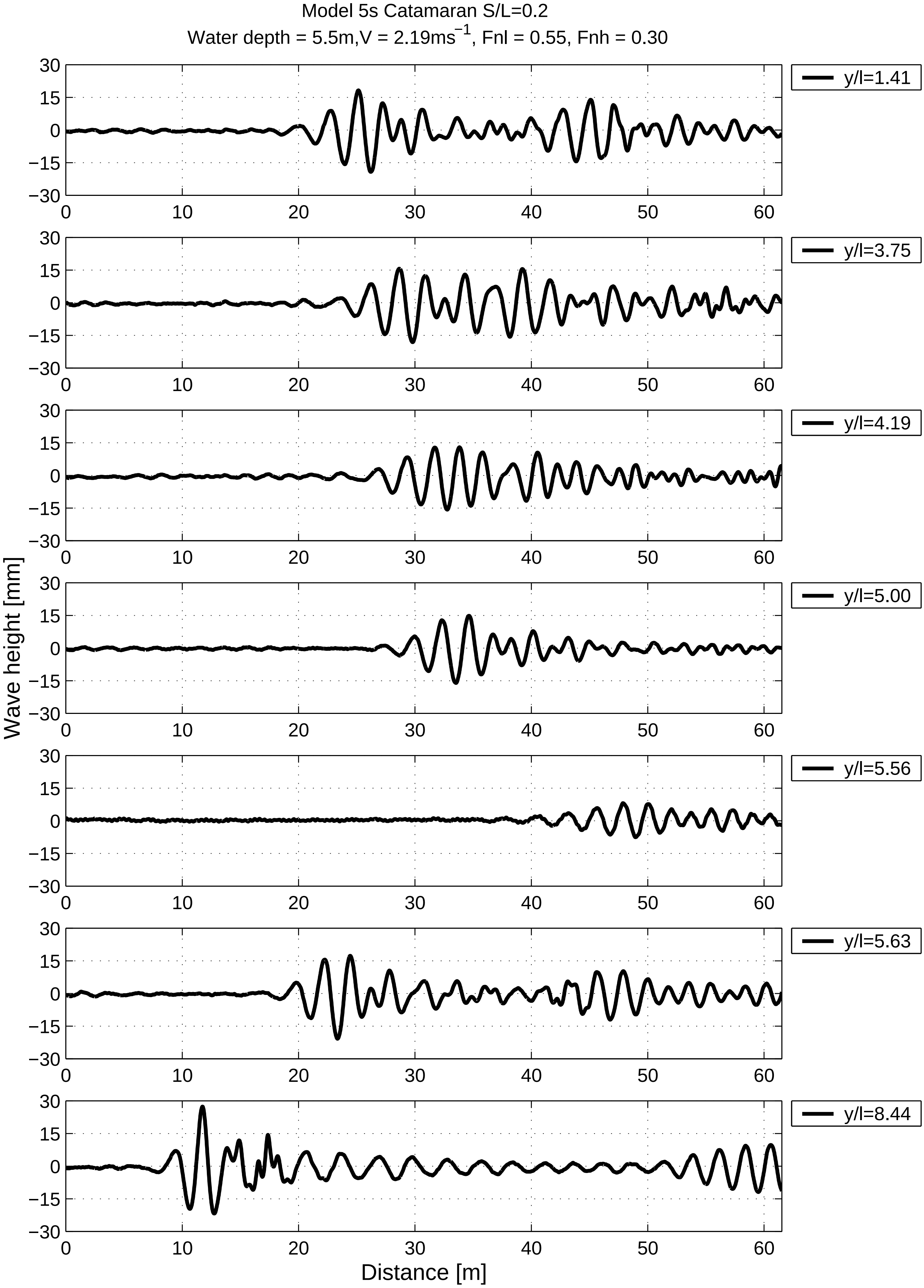

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 2.19ms^{-1}, Fnl = 0.55, Fnh = 0.30
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
30
15
0
−15
−30
0
10
20
30
40
50
60

Figure 7

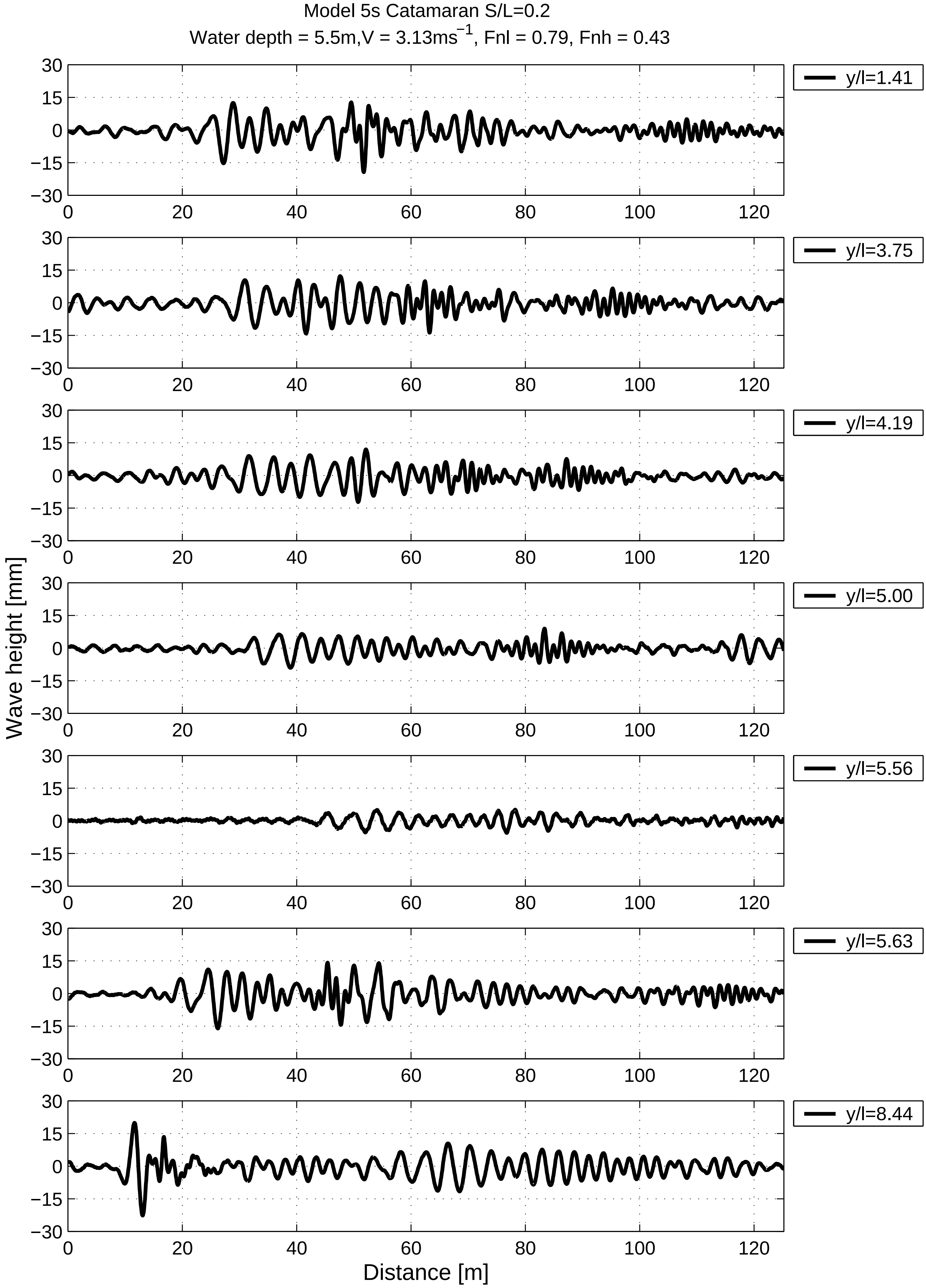
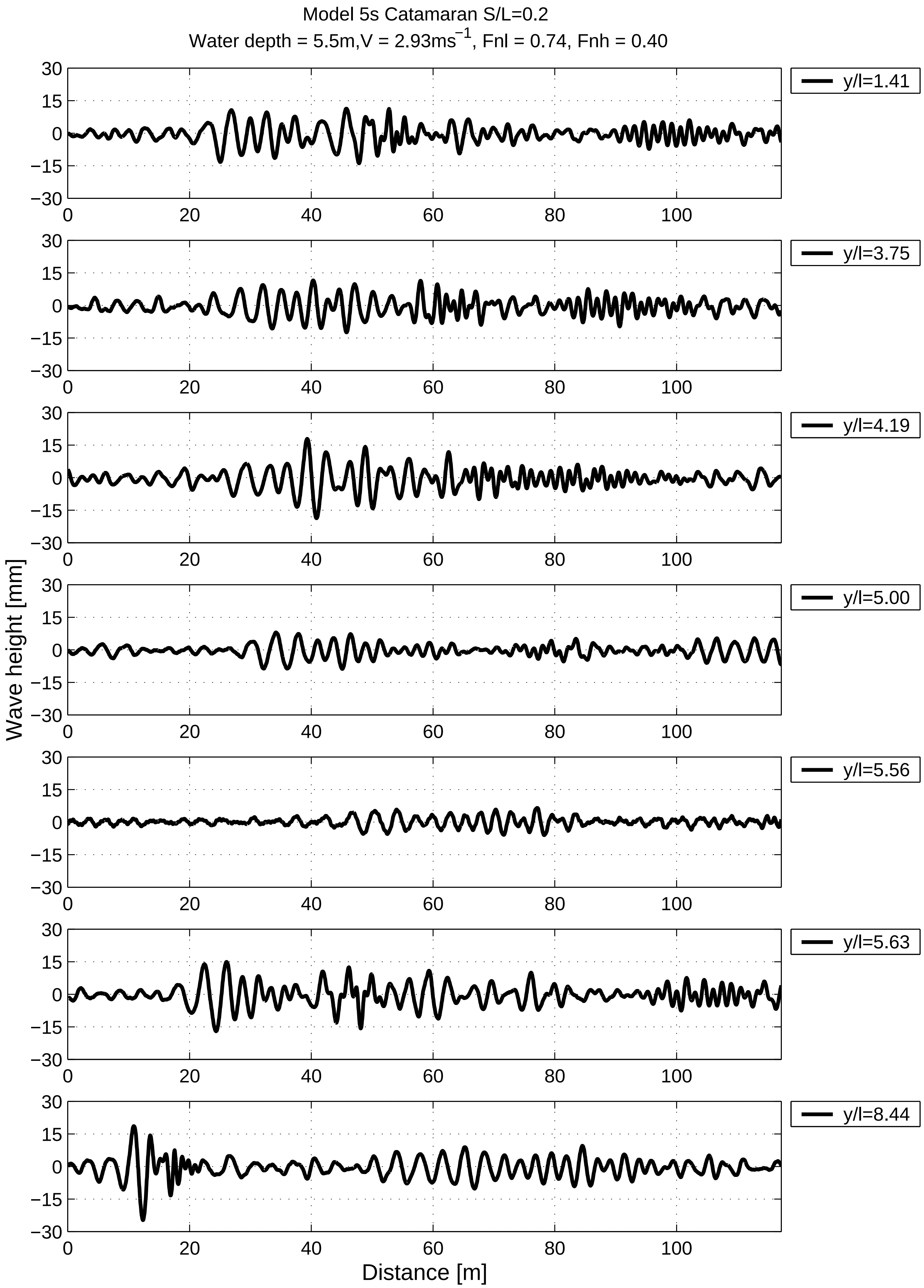
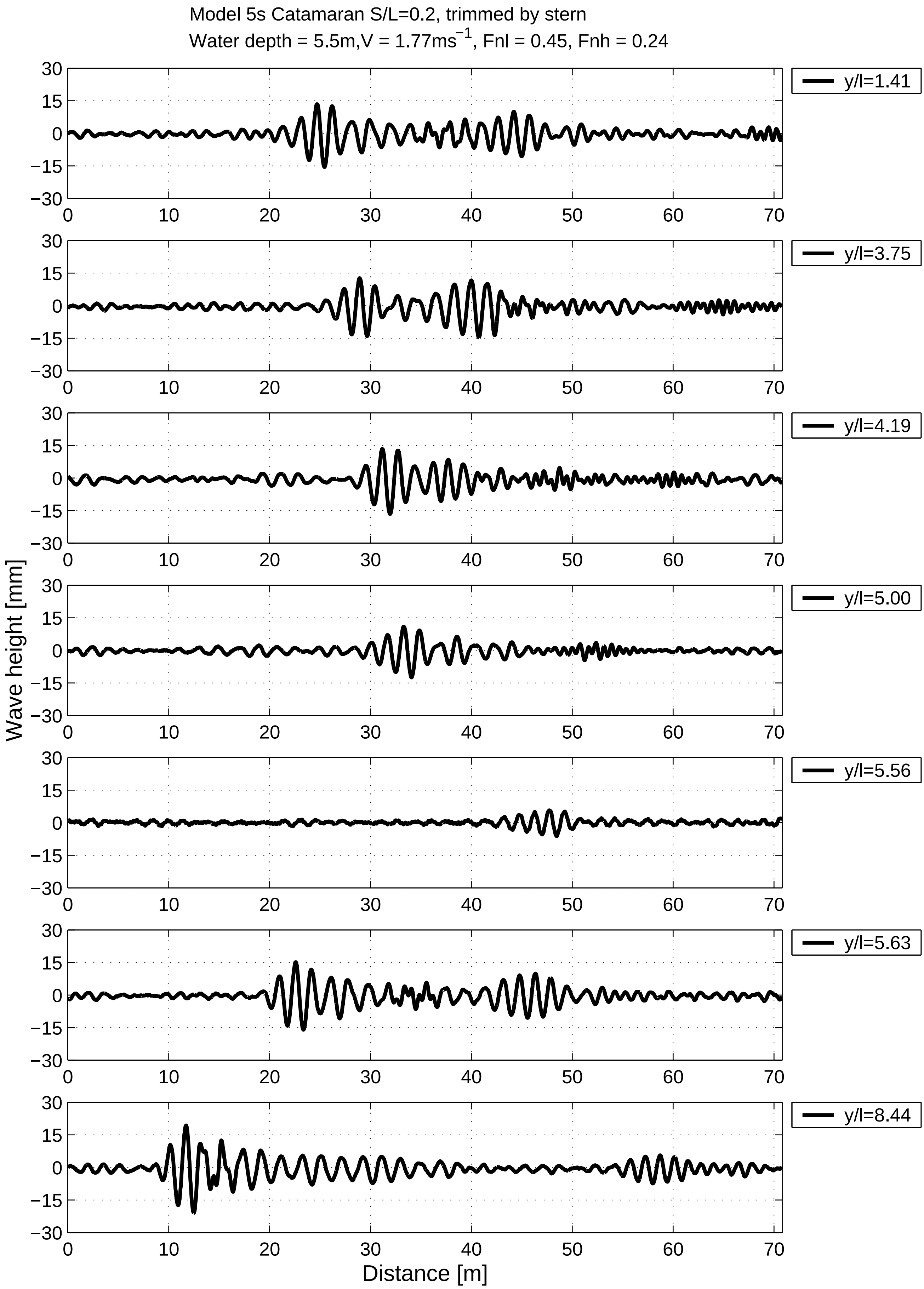

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 3.13ms^{-1}, Fnl = 0.79, Fnh = 0.43
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
30
15
0
−15
−30
0
20
40
60
80
100
120

Figure 8



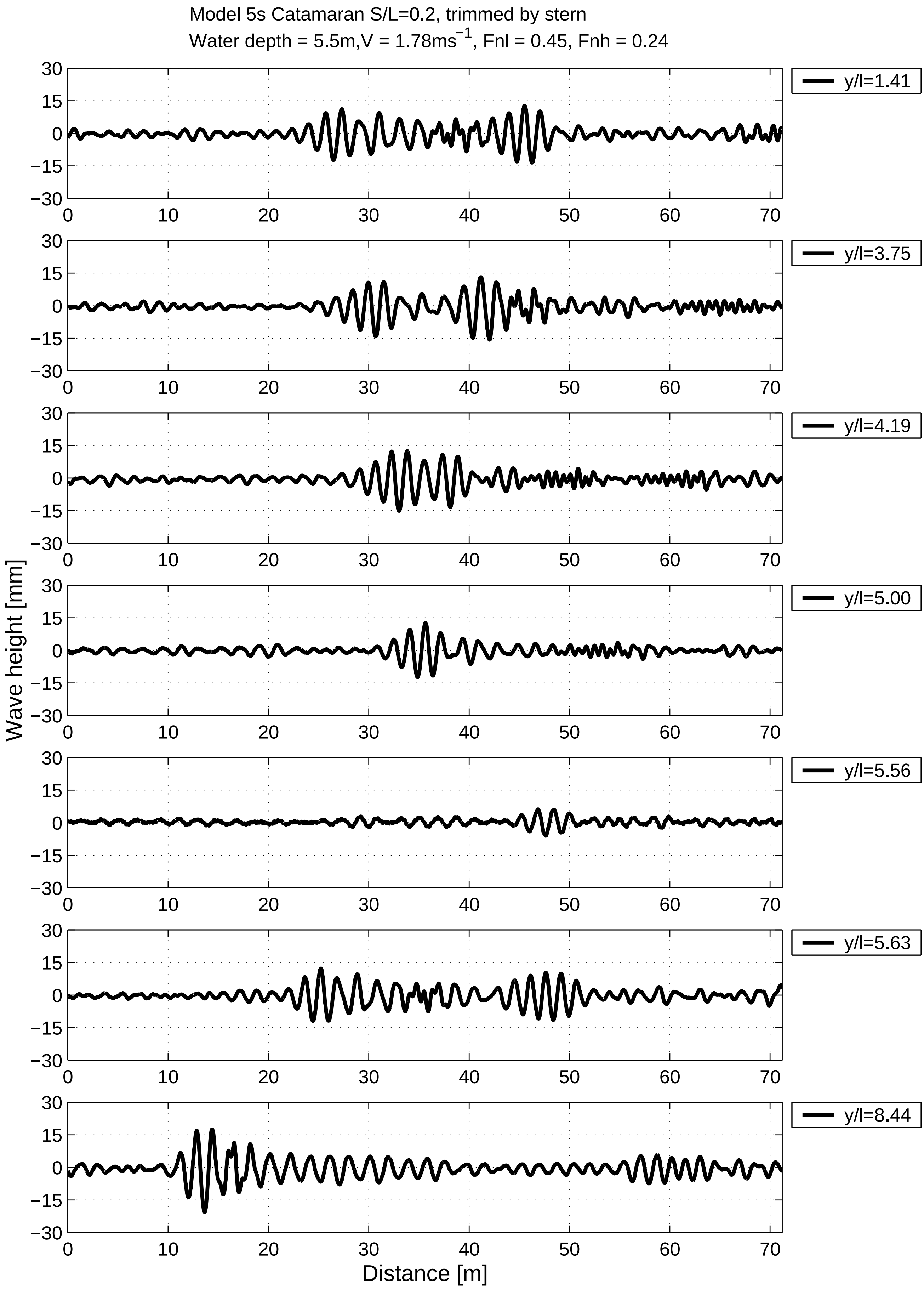
Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 2.93ms^{-1}, Fnl = 0.74, Fnh = 0.40
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
30
15
0
−15
−30
0
20
40
60
80
100

Figure 9



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 1.77ms^{-1}, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 10



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 1.78ms−1, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
30
15
0
−15
−30
0
10
20
30
40
50
60
70

Figure 11

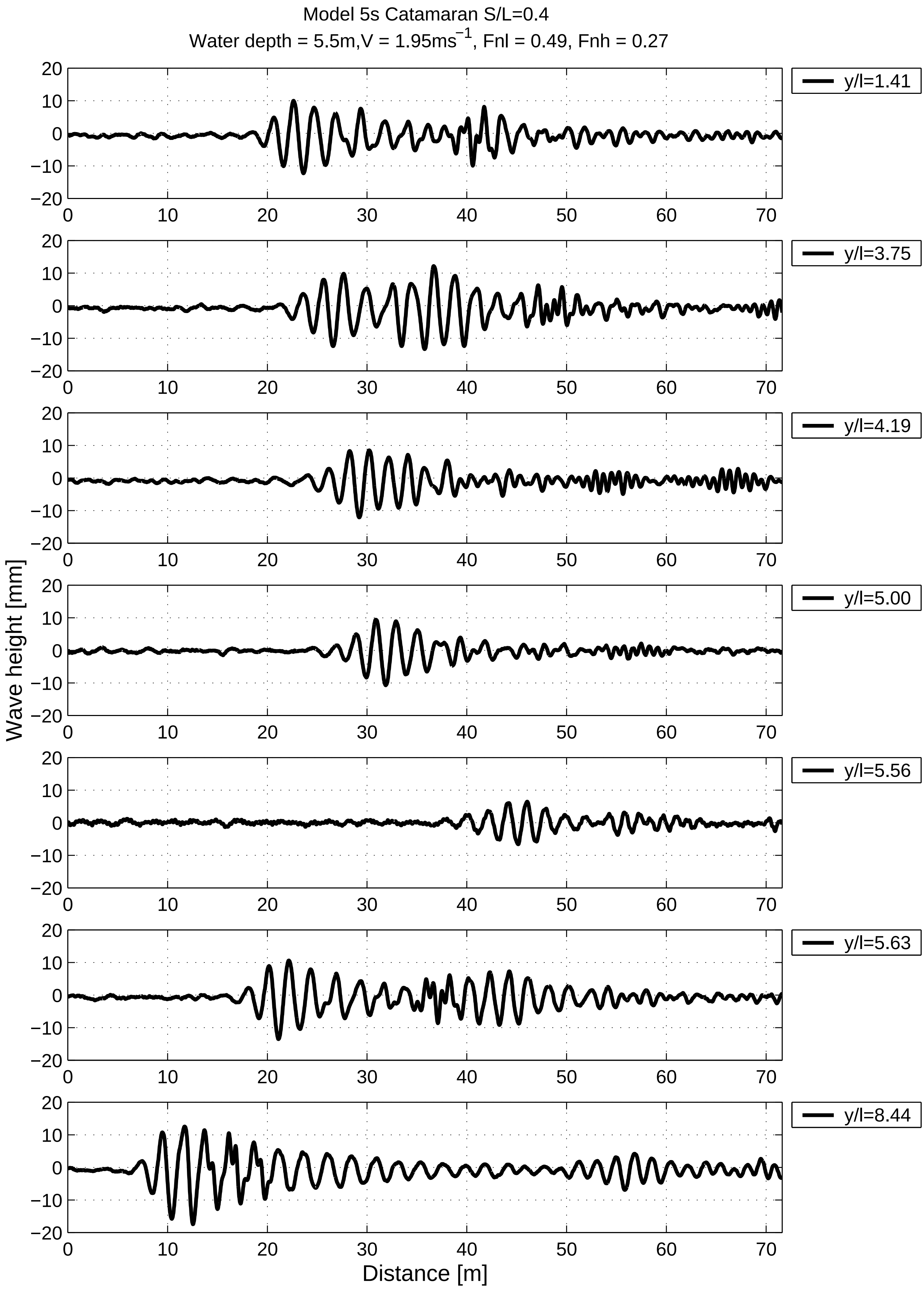
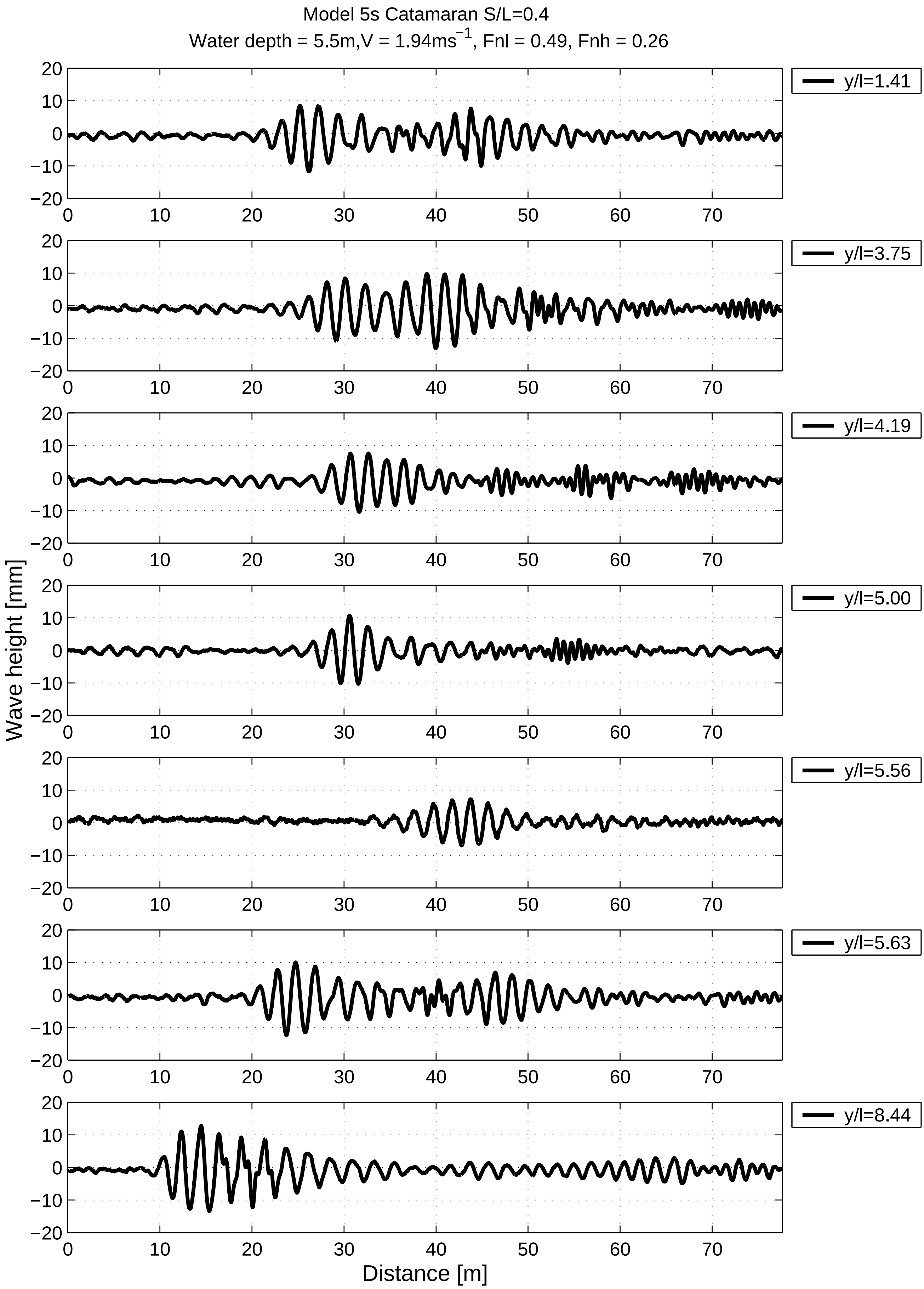

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.95ms−1, Fnl = 0.49, Fnh = 0.27
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
20
10
0
−10
−20
0
10
20
30
40
50
60
70

Figure 12



Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.94ms^{-1}, Fnl = 0.49, Fnh = 0.26
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
20
10
0
−10
−20
0
10
20
30
40
50
60
70

Figure 13

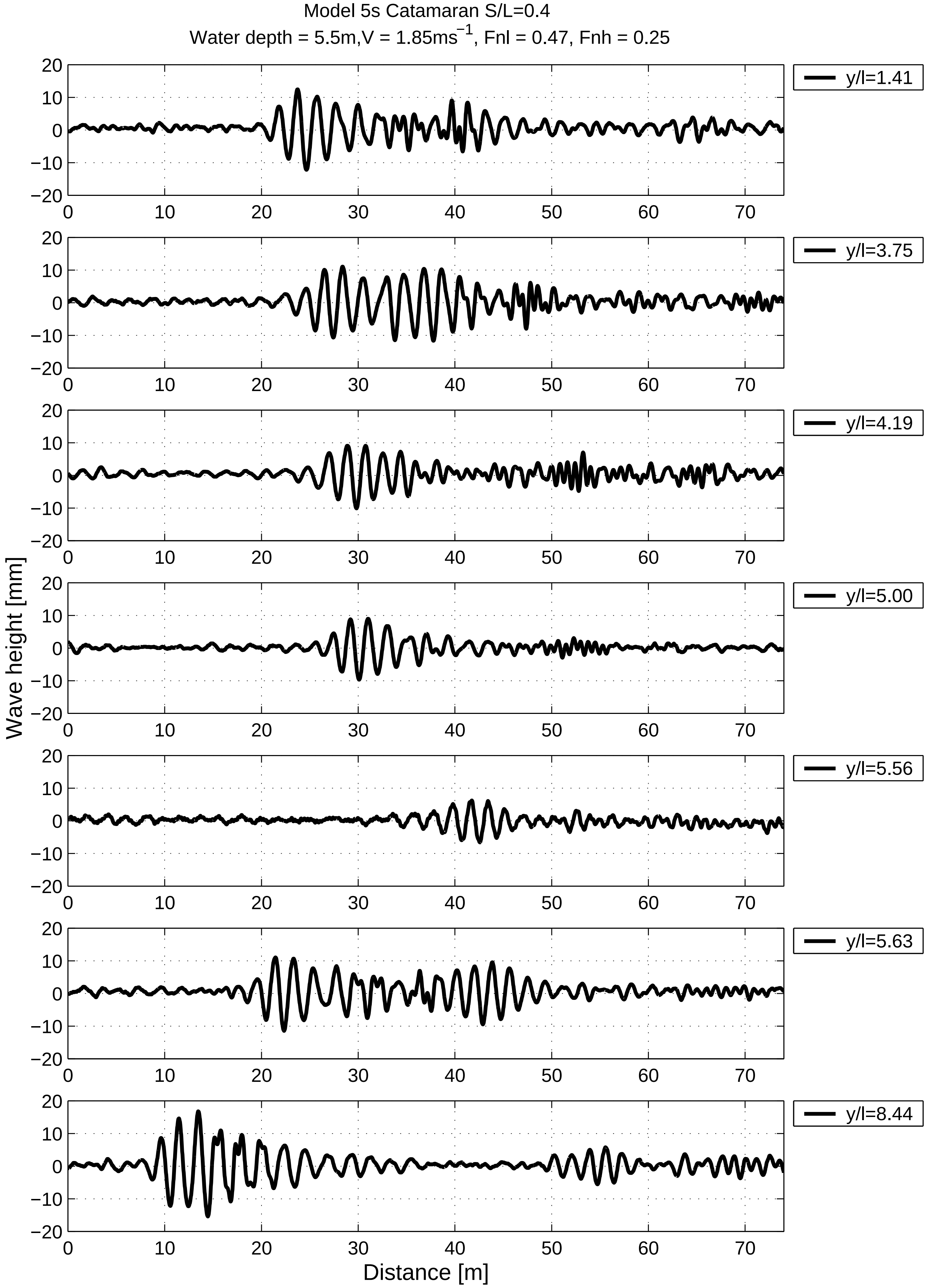
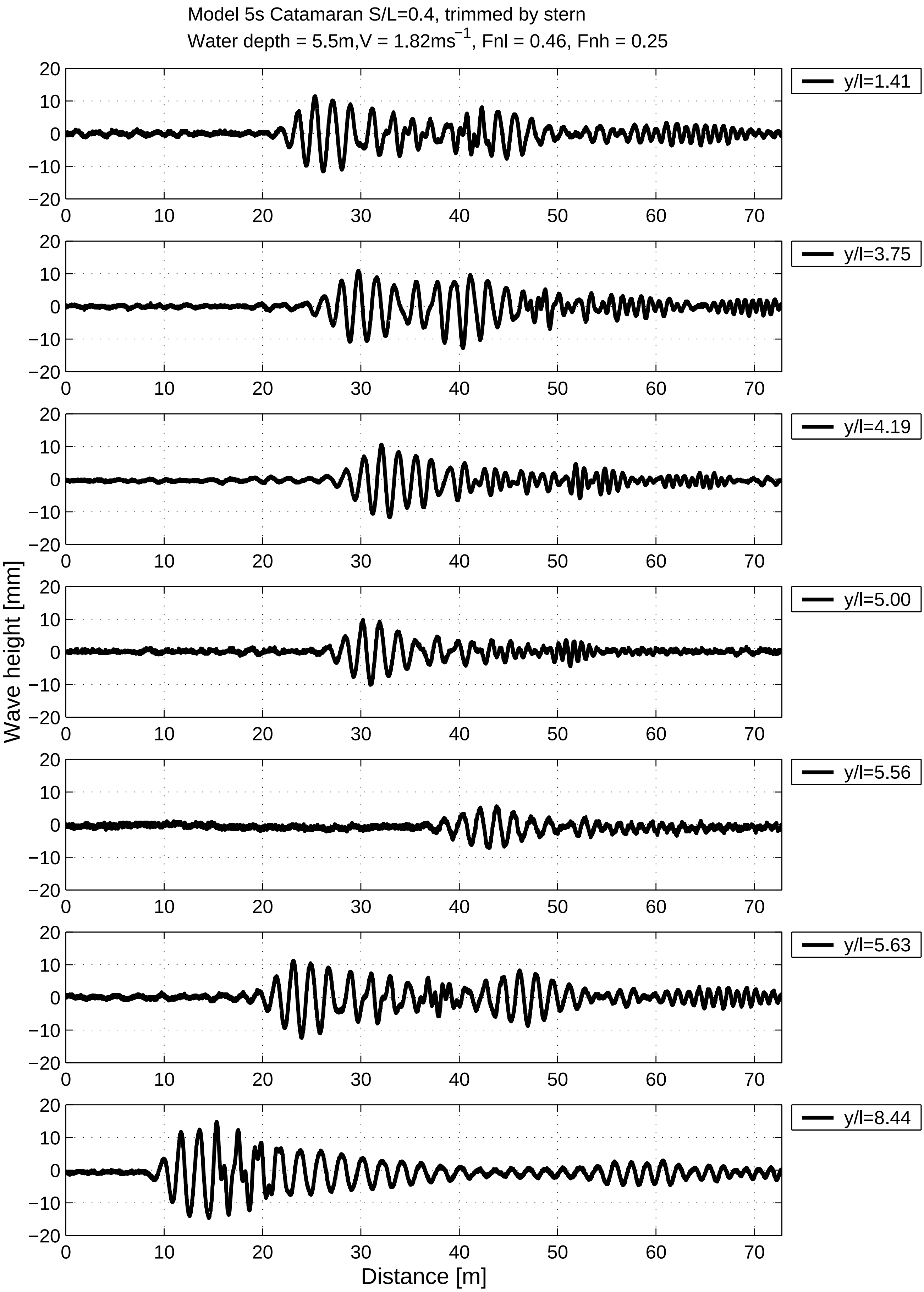
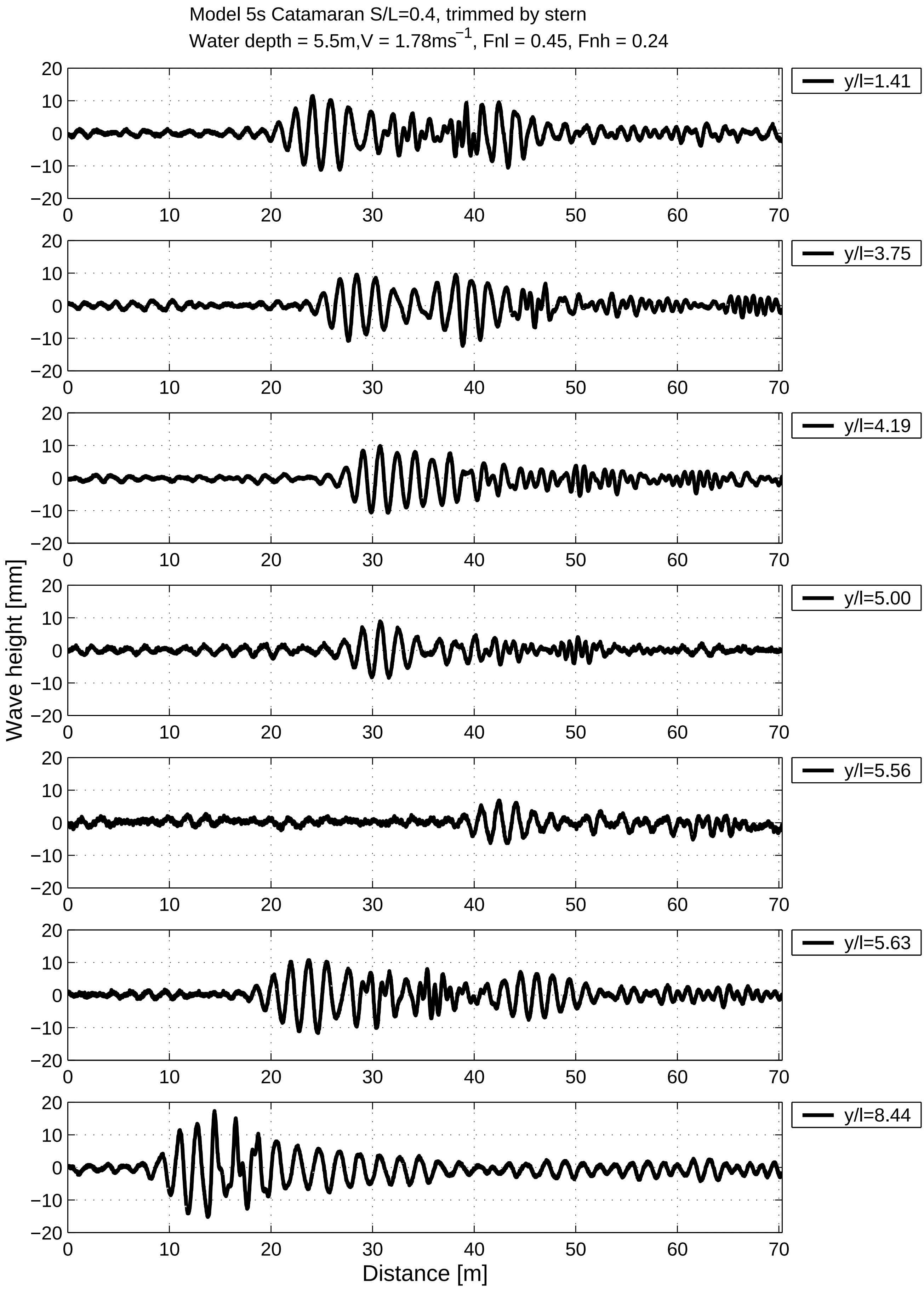

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.85ms^{-1}, Fnl = 0.47, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]
20
10
0
−10
−20
0
10
20
30
40
50
60
70

Figure 14



Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 1.82ms^{-1}, Fnl = 0.46, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 15



Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 1.78ms^{-1}, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 16

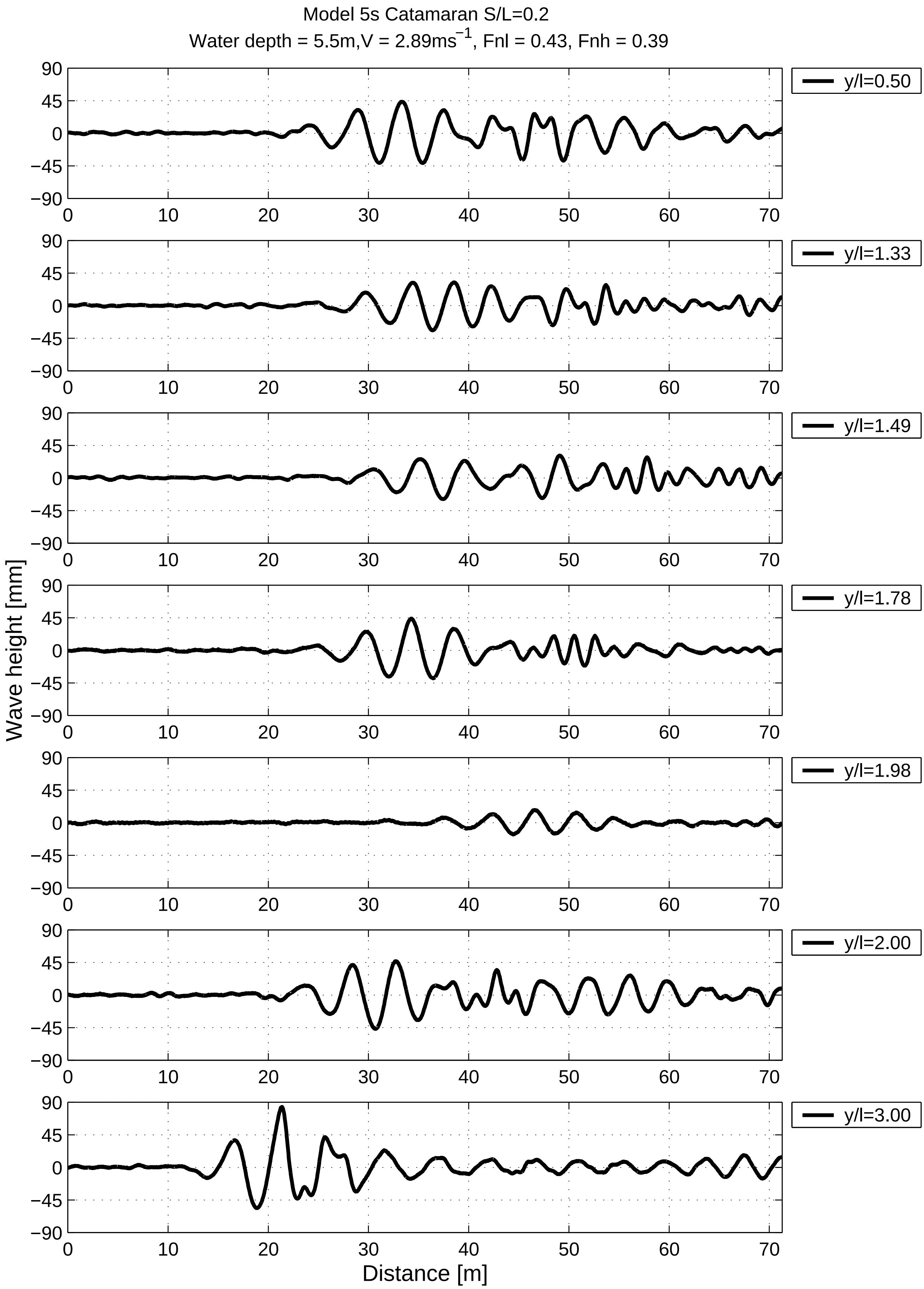

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 2.89ms^{-1}, Fnl = 0.43, Fnh = 0.39
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]

Figure 17

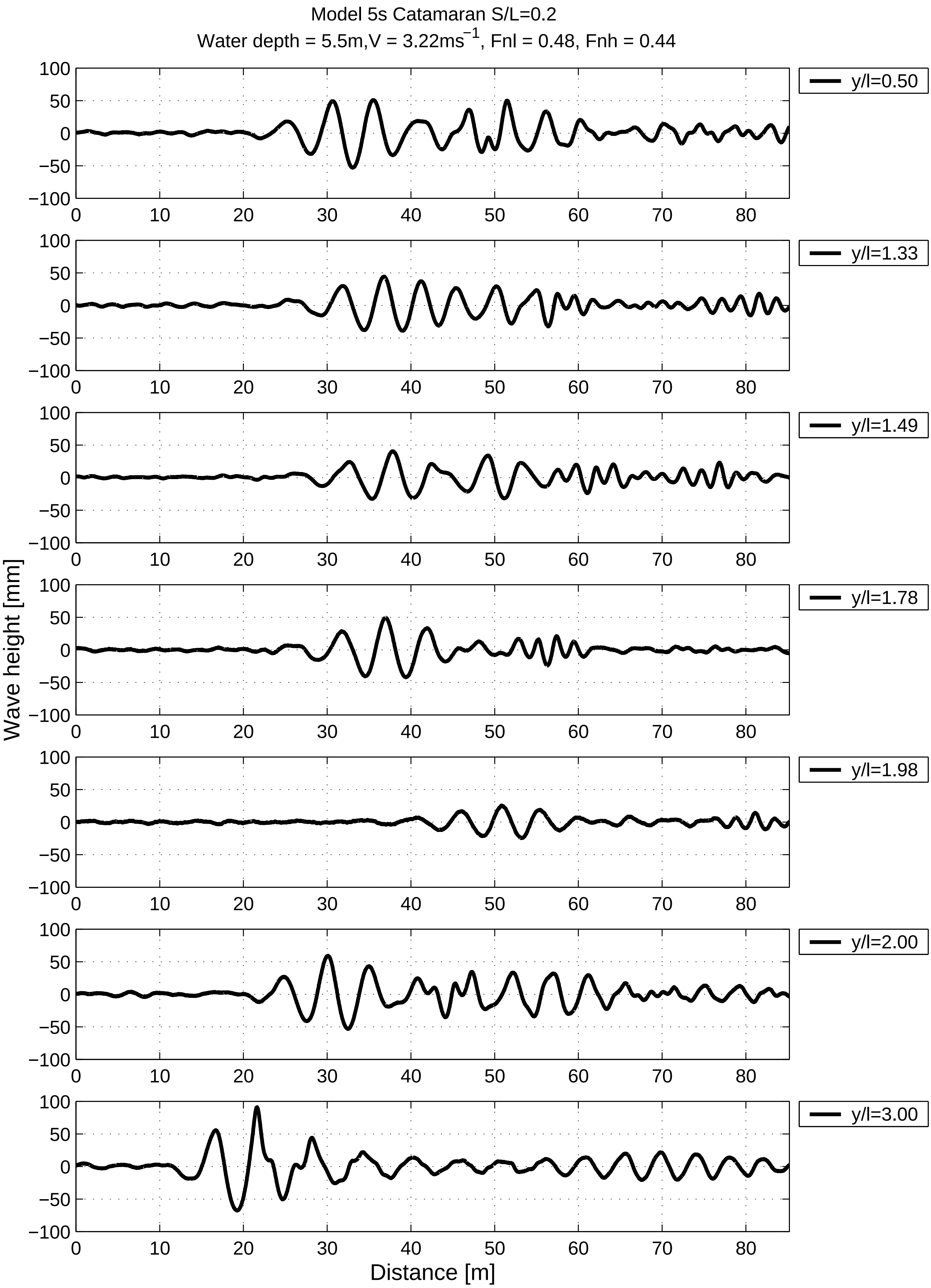

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 3.22ms^{-1}, Fnl = 0.48, Fnh = 0.44
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]

Figure 18

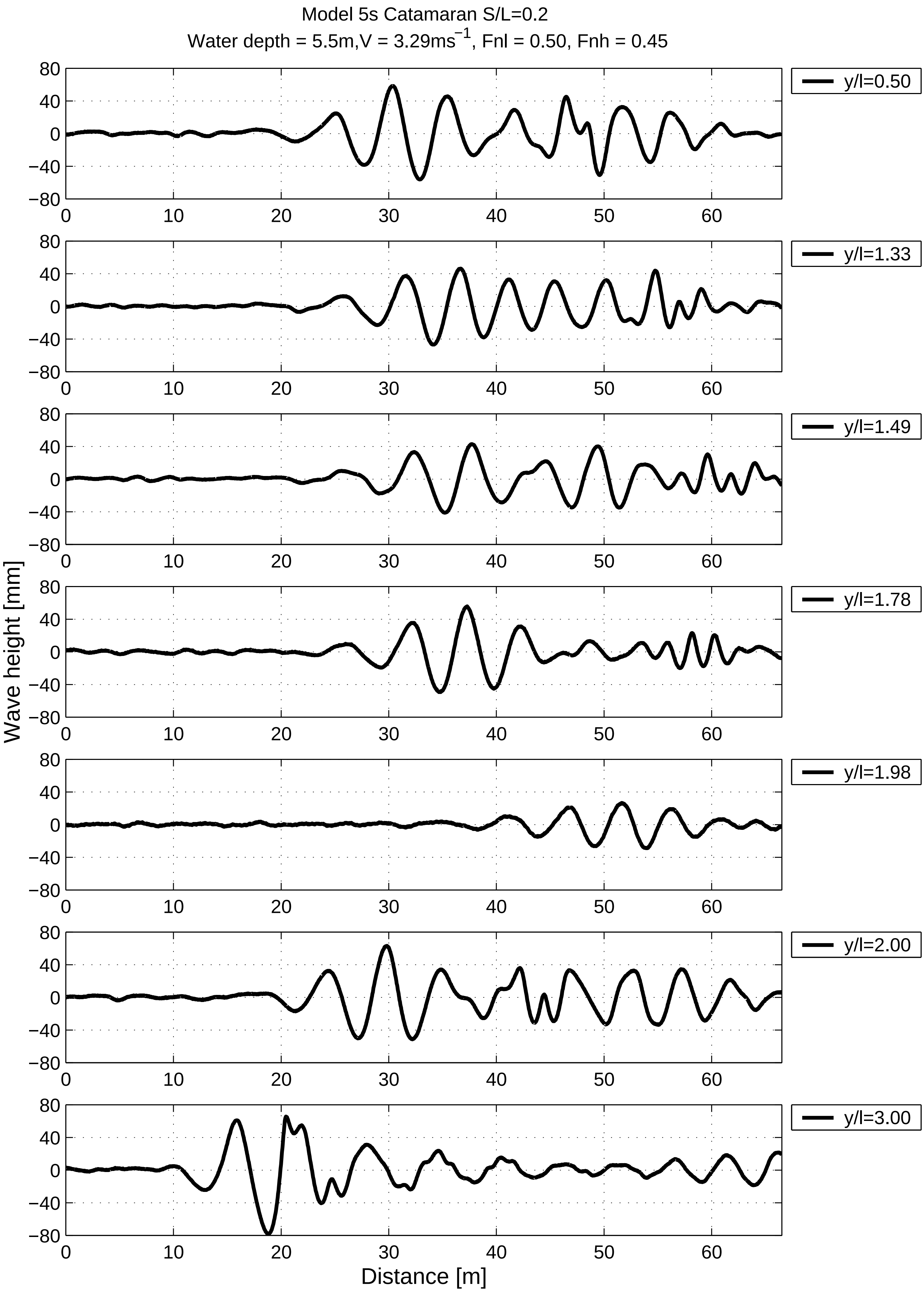
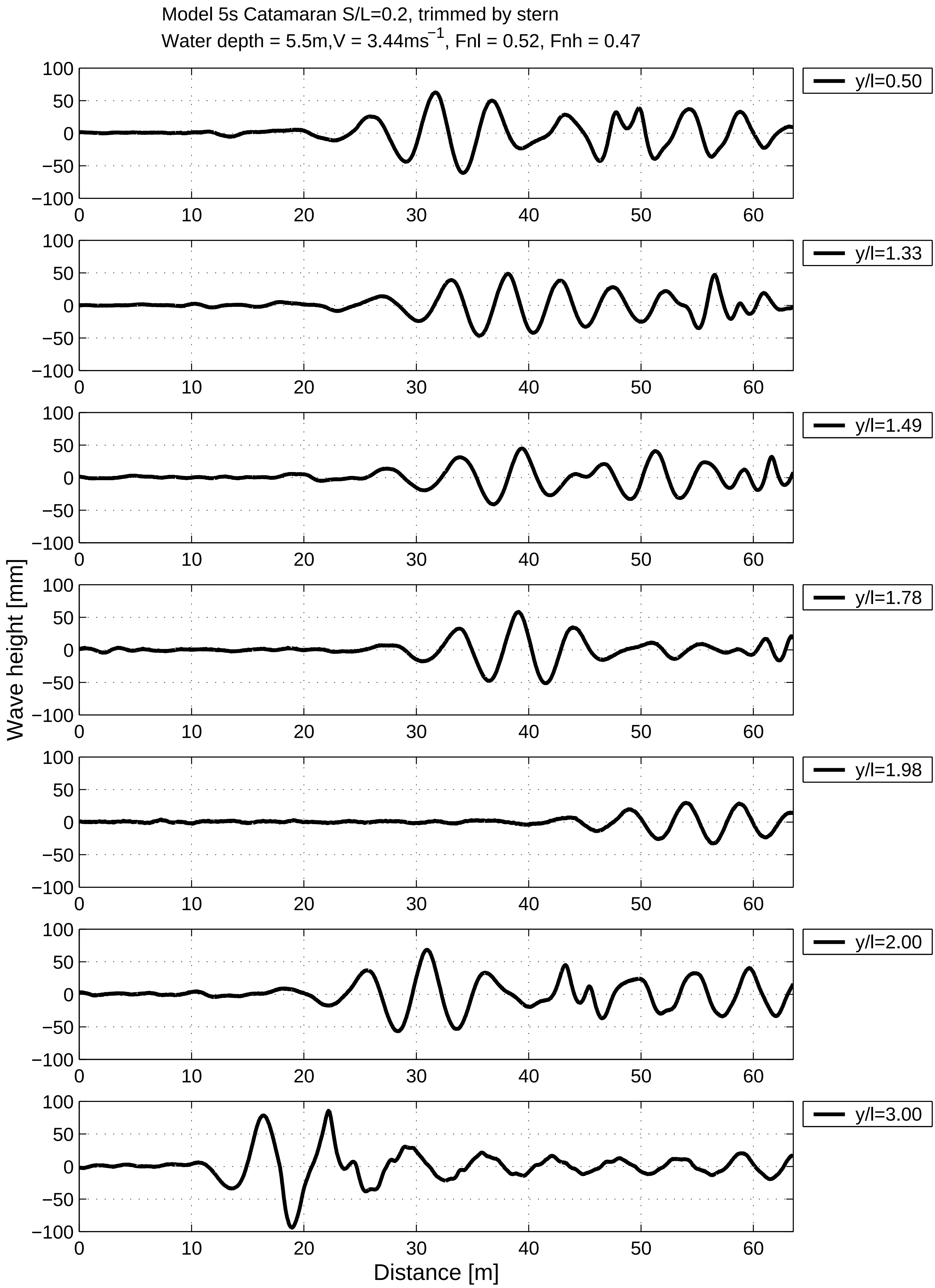
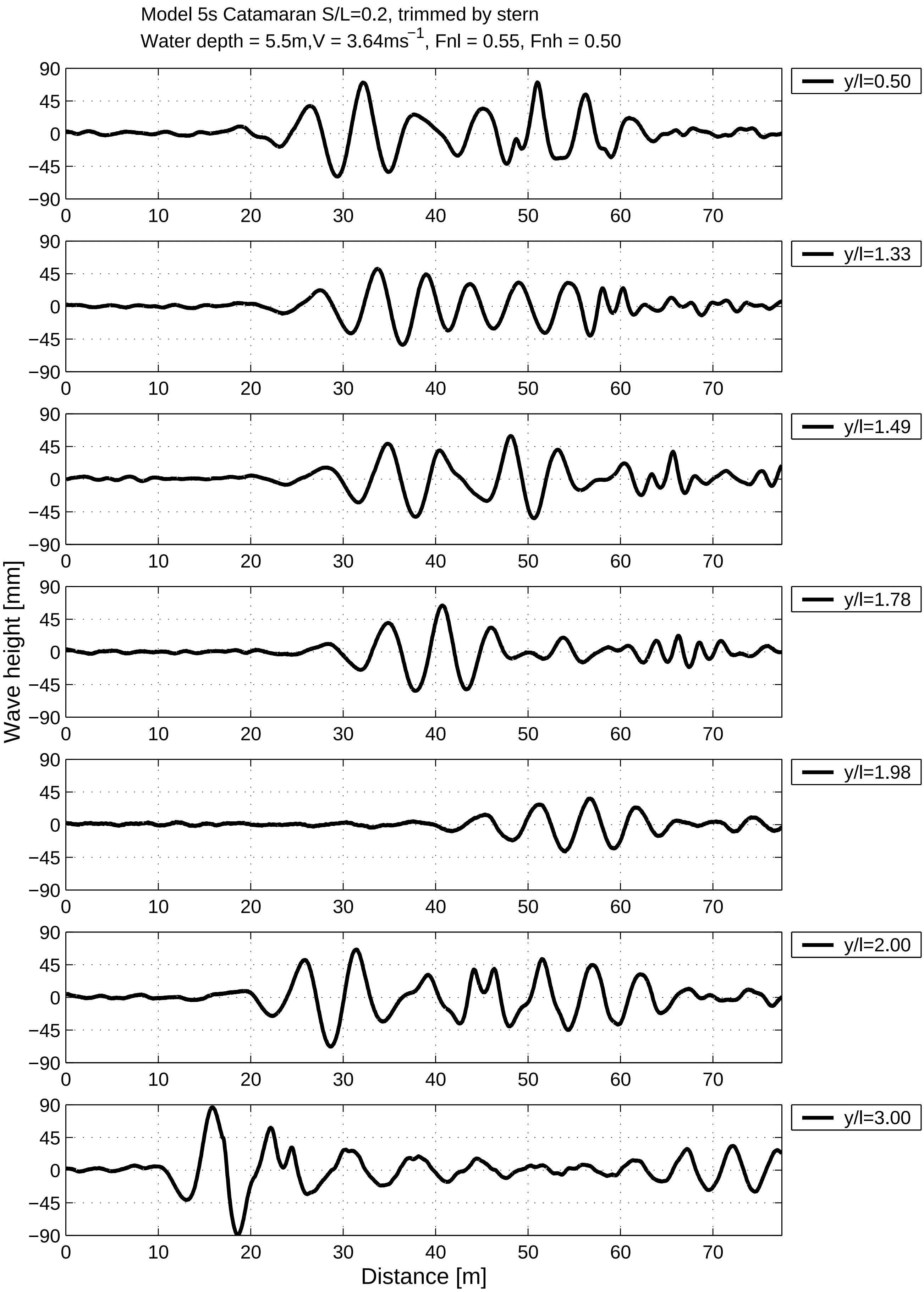

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 3.29ms^{-1}, Fnl = 0.50, Fnh = 0.45
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
80
40
0
−40
−80
0
10
20
30
40
50
60

Figure 19



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 3.44ms^{-1}, Fnl = 0.52, Fnh = 0.47
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]

Figure 20


Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 3.64ms^{-1}, Fnl = 0.55, Fnh = 0.50
Wave height [mm]
Distance [m]
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Figure 21

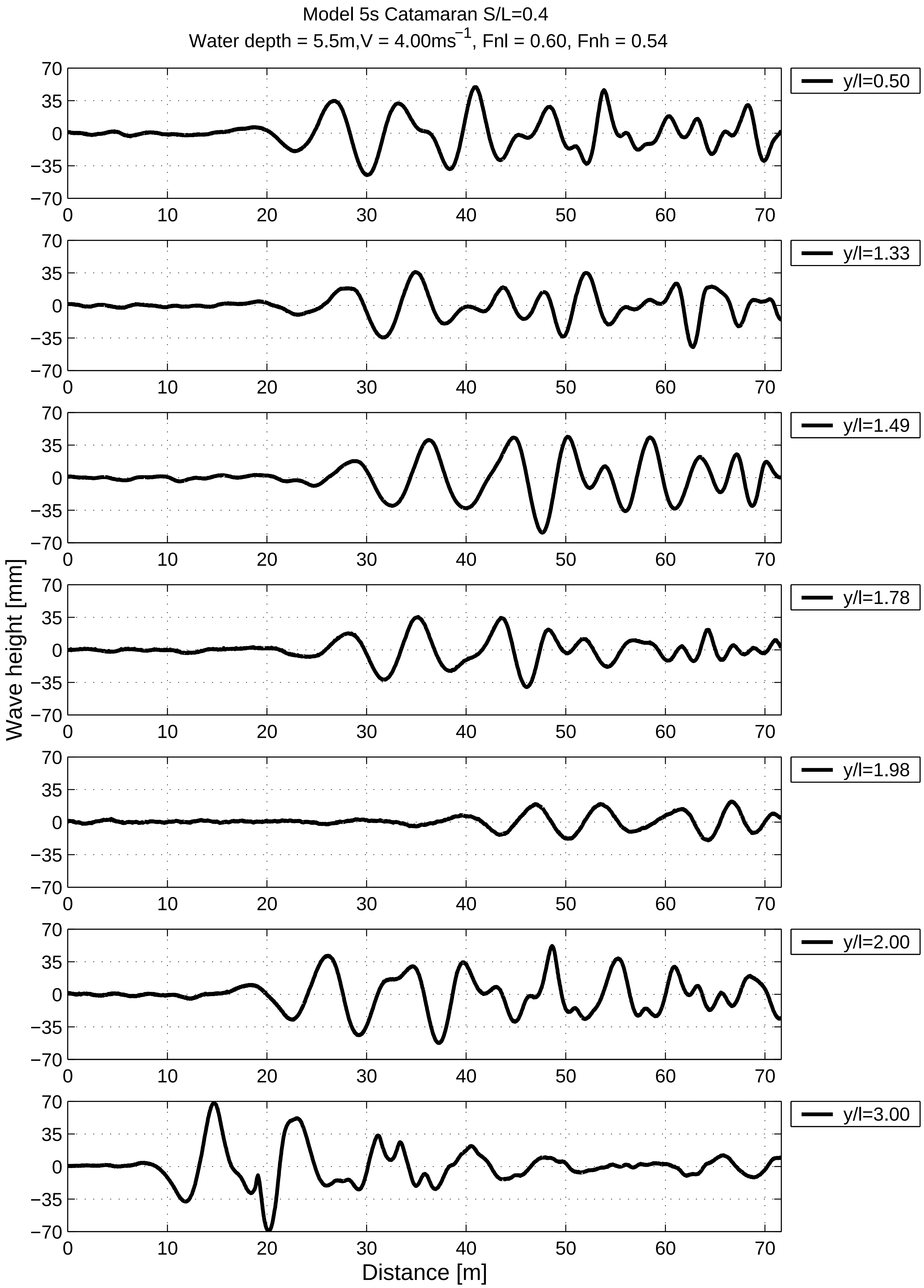

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 4.00ms^{-1}, Fnl = 0.60, Fnh = 0.54
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
70
35
0
−35
−70
0
10
20
30
40
50
60
70

Figure 22

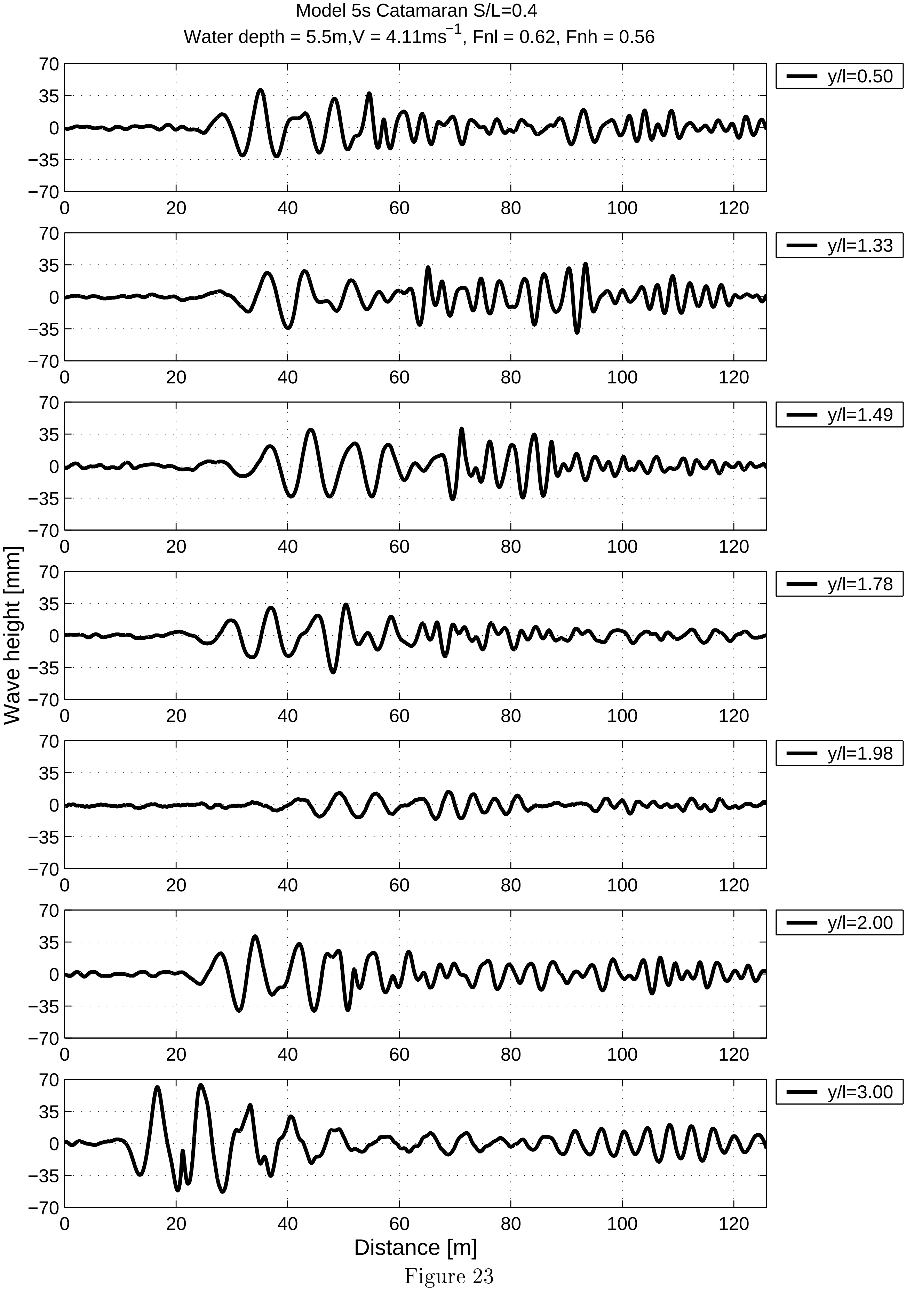

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 4.11ms^{-1}, Fnl = 0.62, Fnh = 0.56
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
70
35
0
−35
−70
0
20
40
60
80
100
120

Figure 23

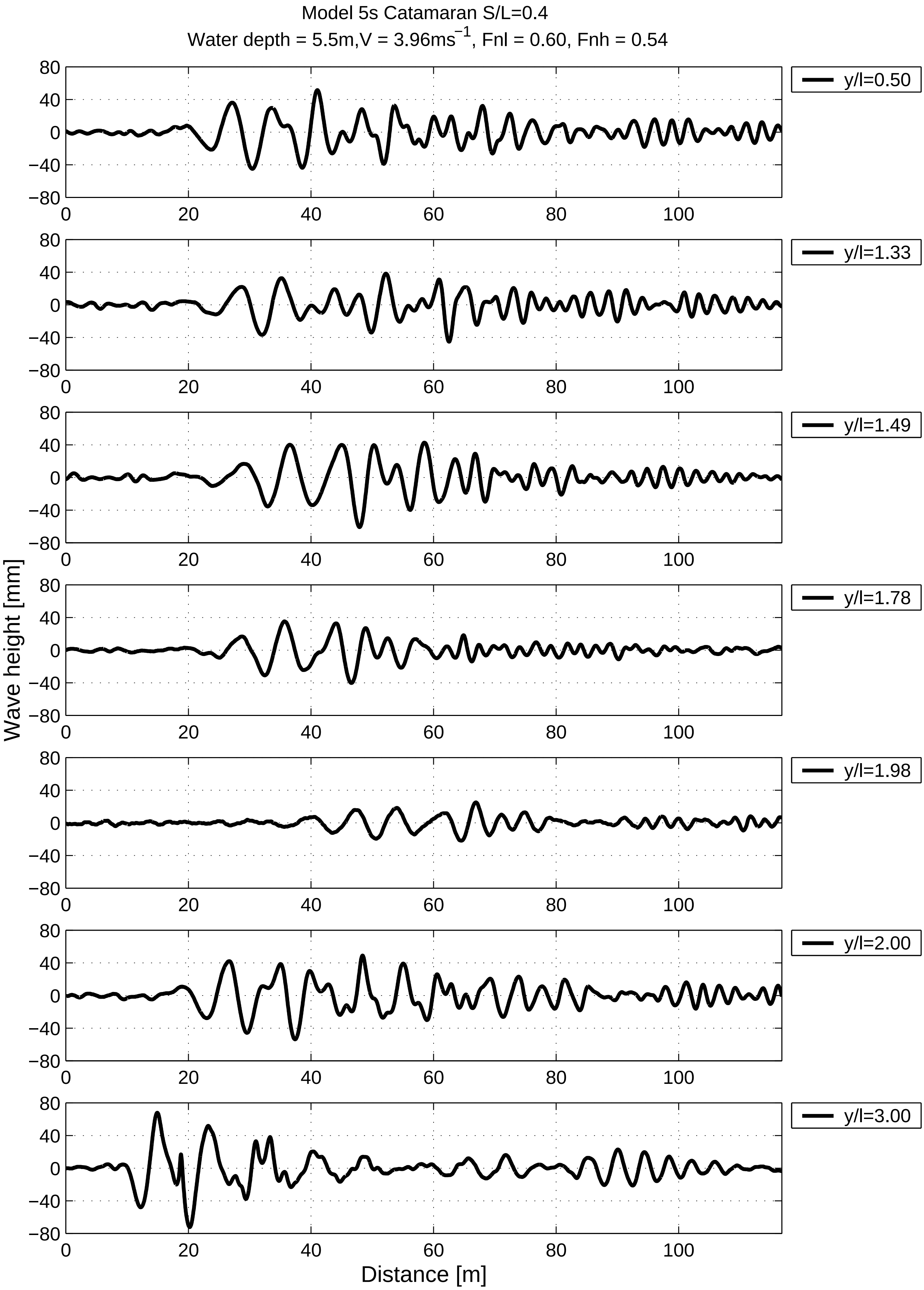
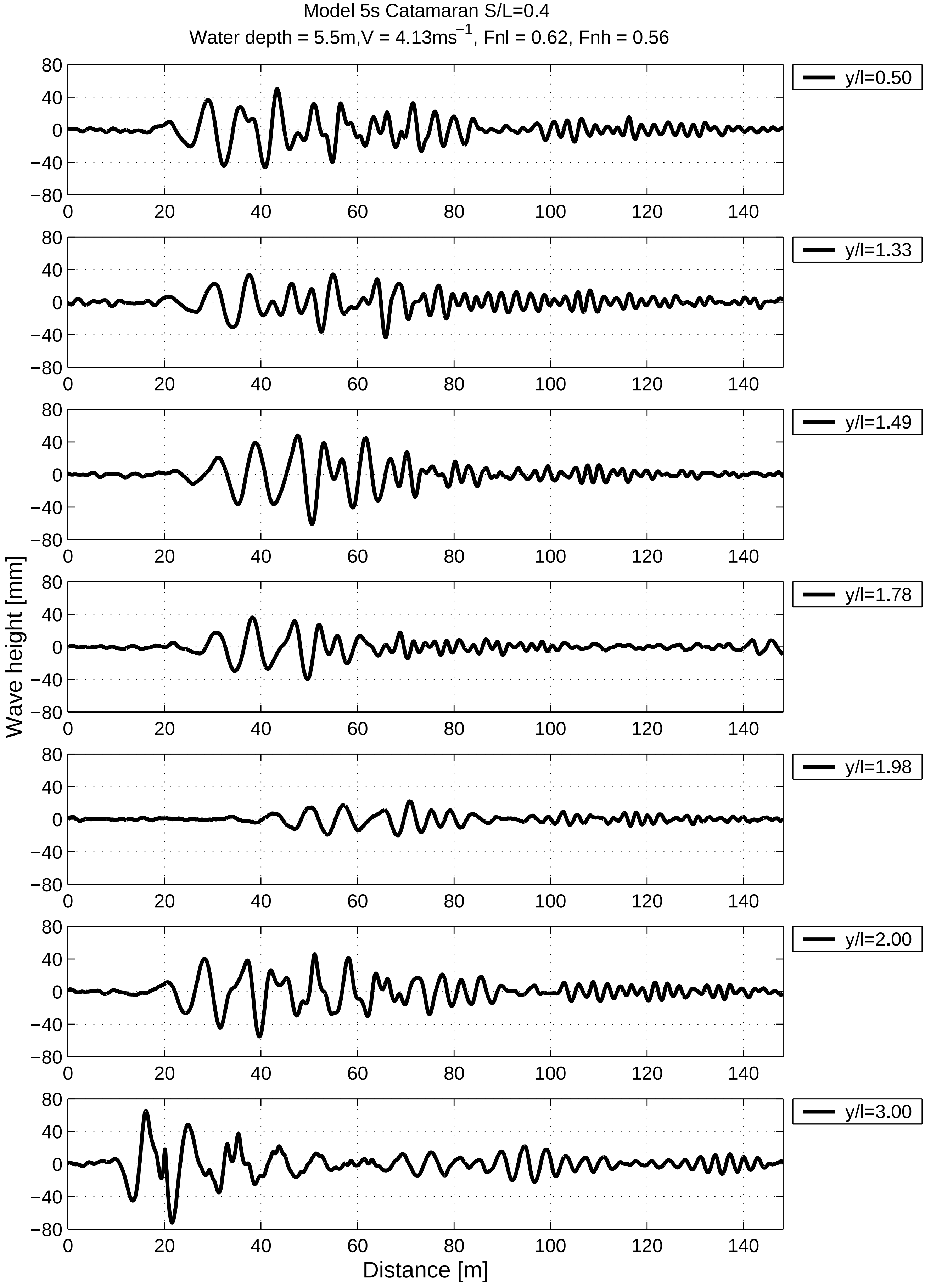
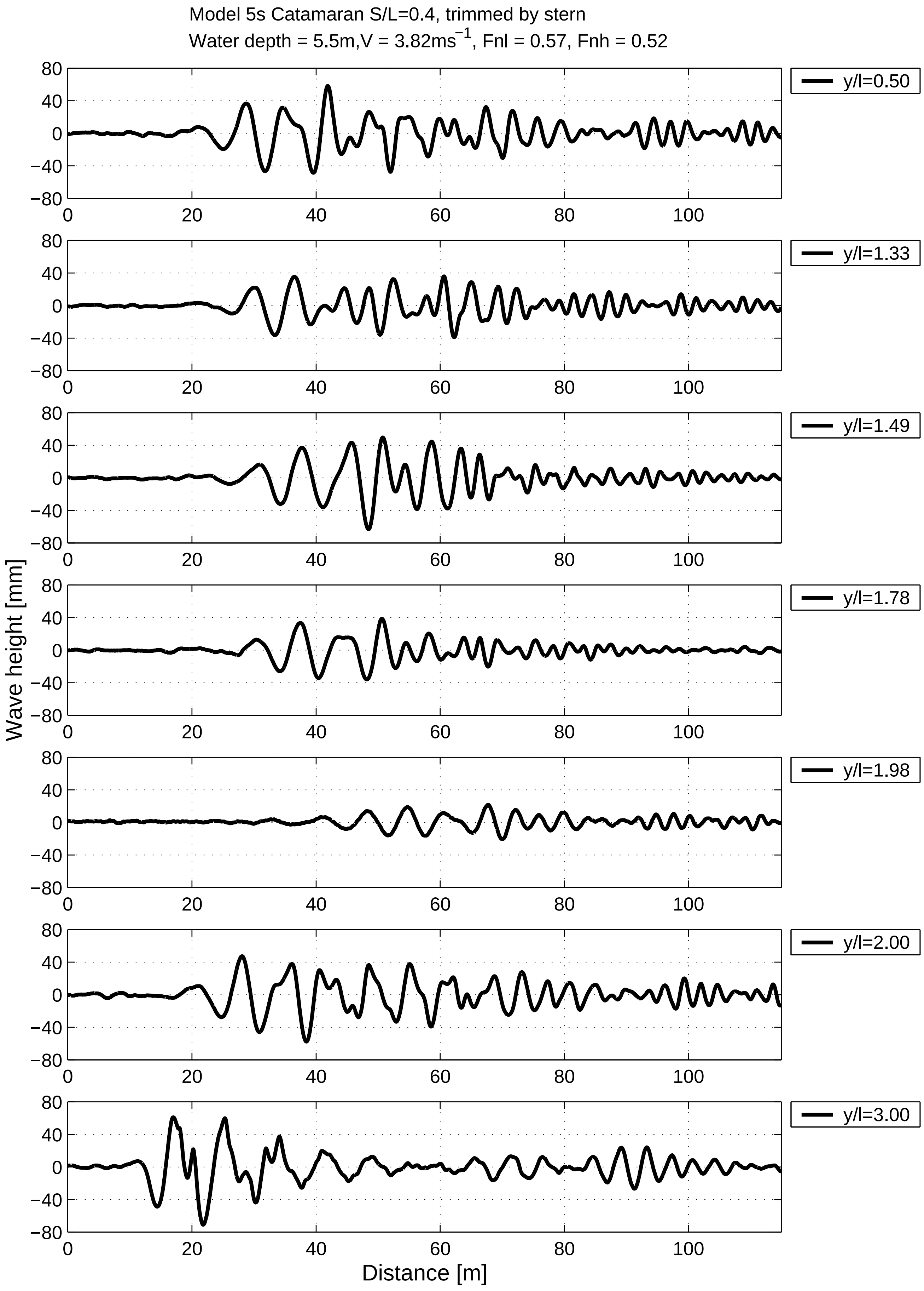

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 3.96ms^{-1}, Fnl = 0.60, Fnh = 0.54
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]

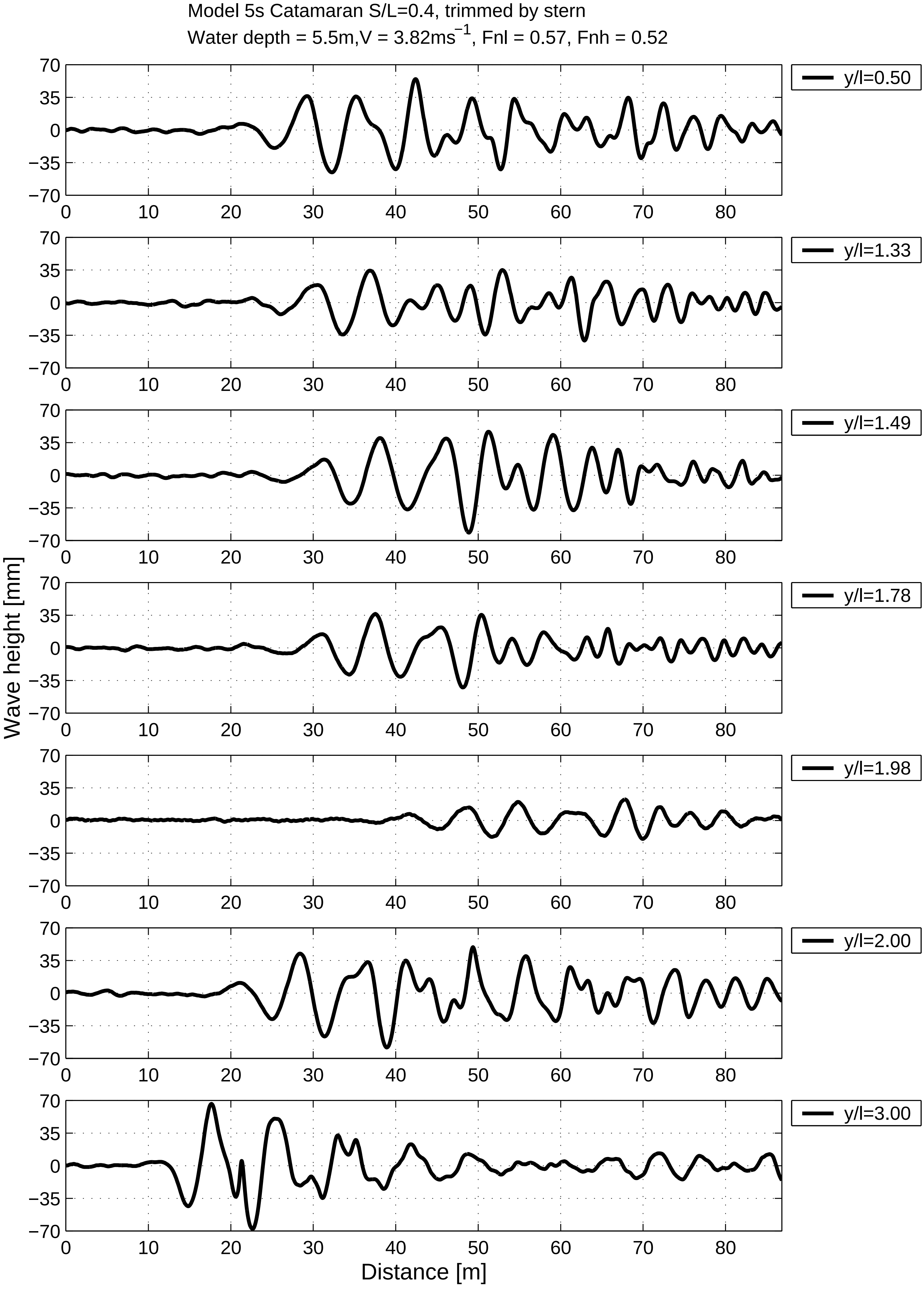
Figure 24

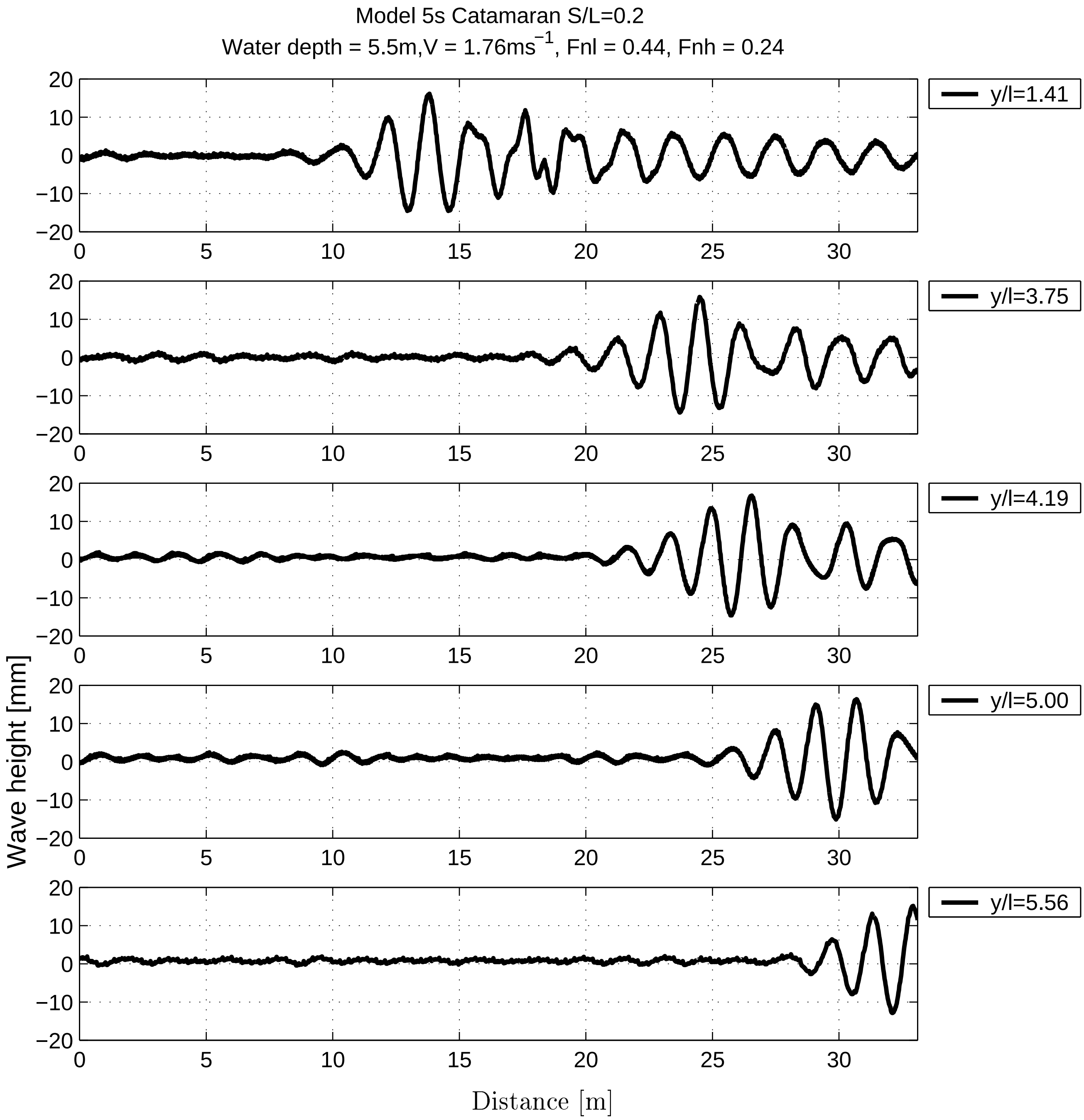


Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 4.13ms^{-1}, Fnl = 0.62, Fnh = 0.56
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
80
40
0
−40
−80
0
20
40
60
80
100
120
140

Figure 25

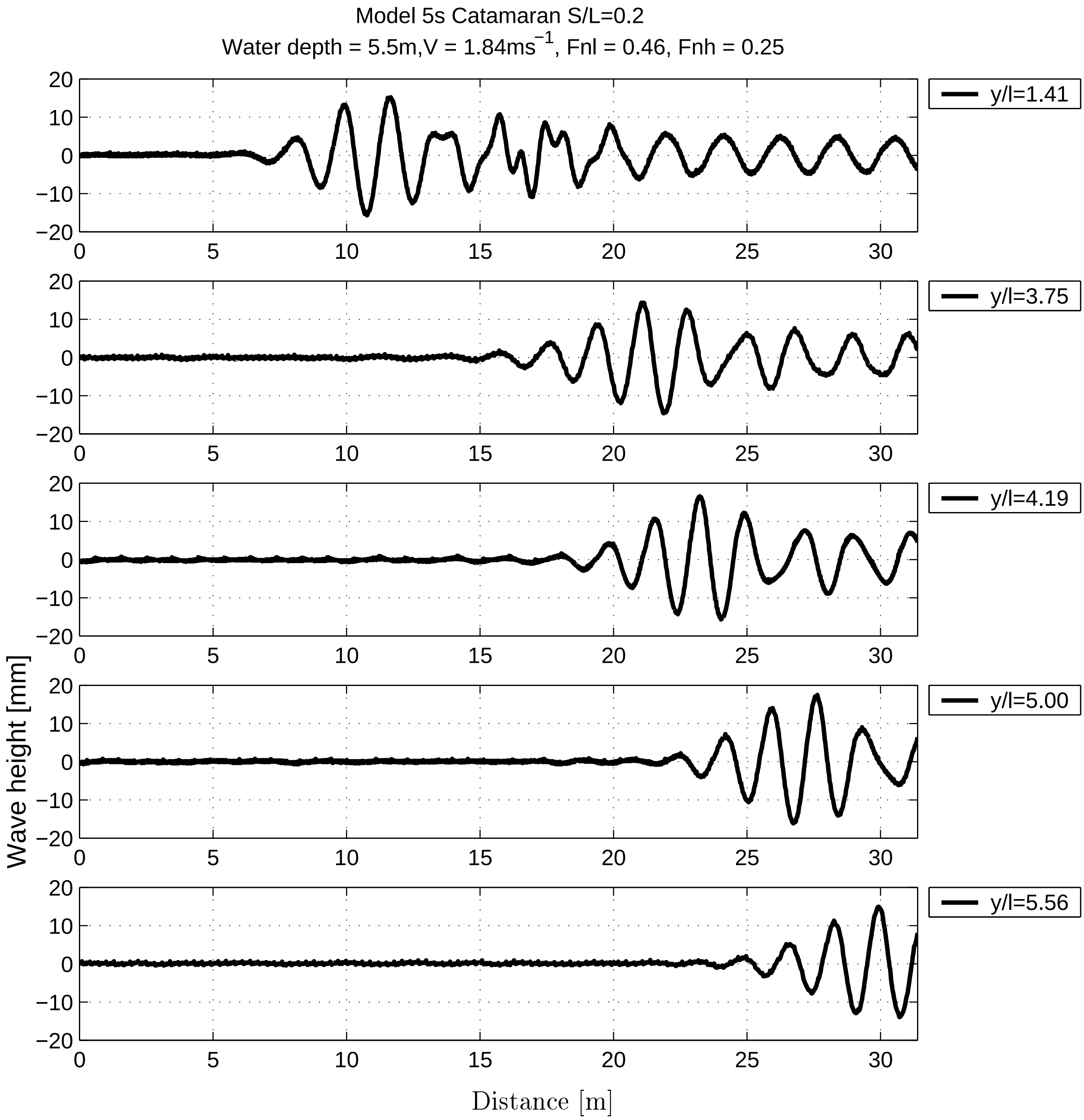

Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 3.82ms^{-1}, Fnl = 0.57, Fnh = 0.52
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
80
40
0
−40
−80
0
20
40
60
80
100
Figure 26


Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 3.82ms^{-1}, Fnl = 0.57, Fnh = 0.52
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
y/l=2.00
y/l=3.00
Wave height [mm]
Distance [m]
70
35
0
−35
−70
0
10
20
30
40
50
60
70
80
Figure 27



Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.76ms^{-1}, Fnl = 0.44, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 28



Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.84ms^{-1}, Fnl = 0.46, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]
20
10
0
−10
−20
0
5
10
15
20
25
30

Figure 29

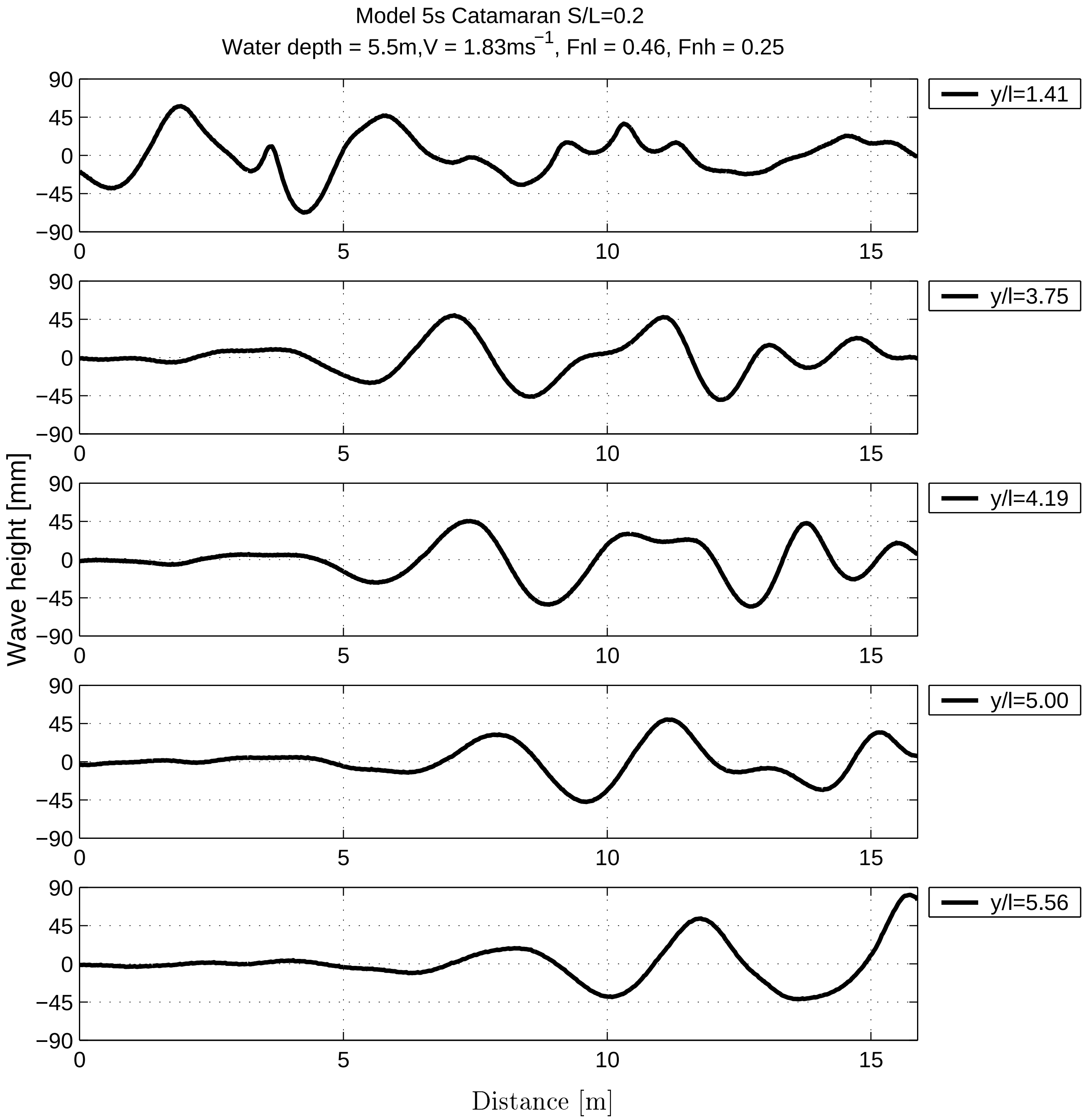
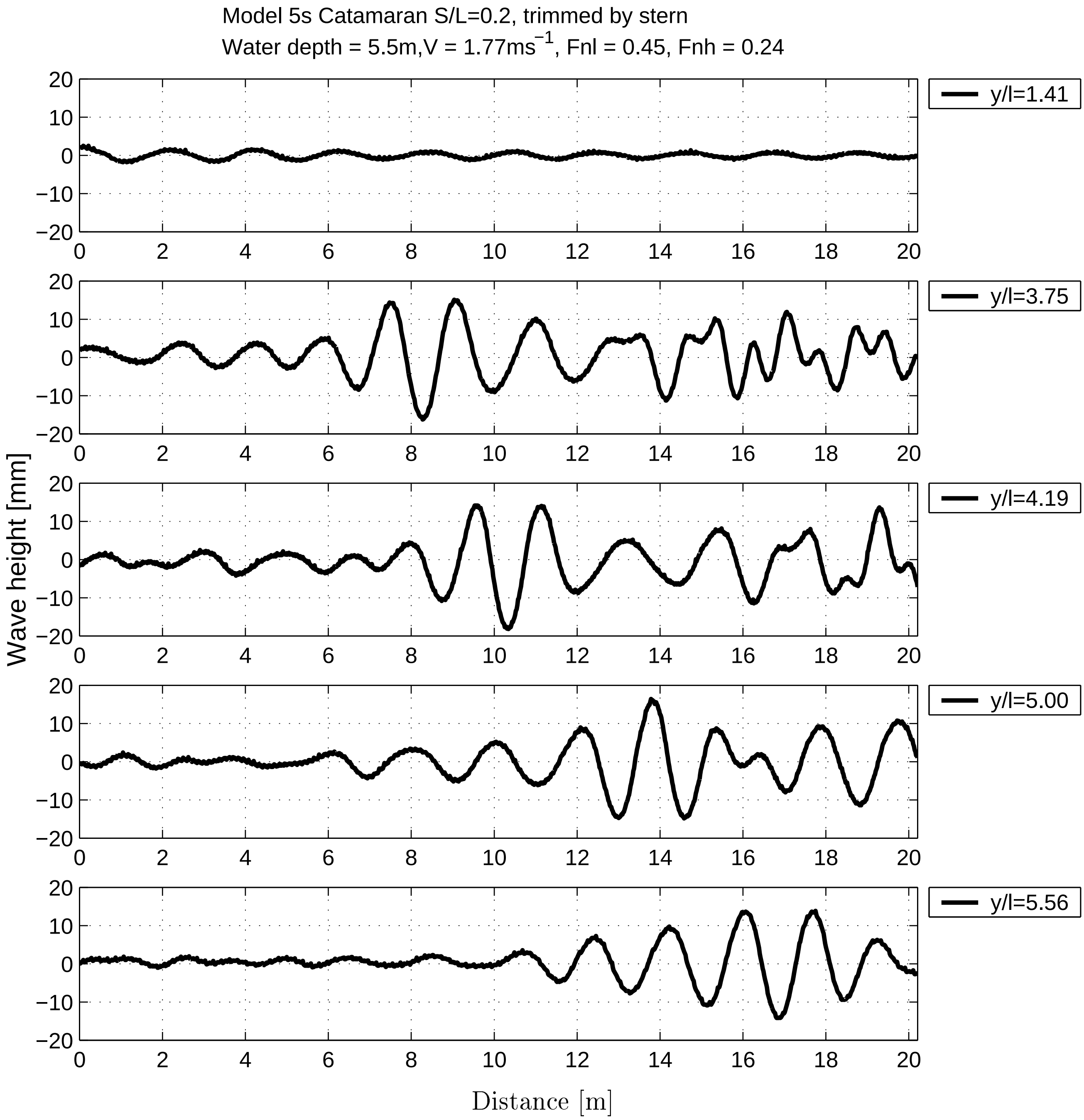

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 1.83ms^{-1}, Fnl = 0.46, Fnh = 0.25
90
45
0
−45
−90
0
5
10
15
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 30



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 1.77ms^{-1}, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 31

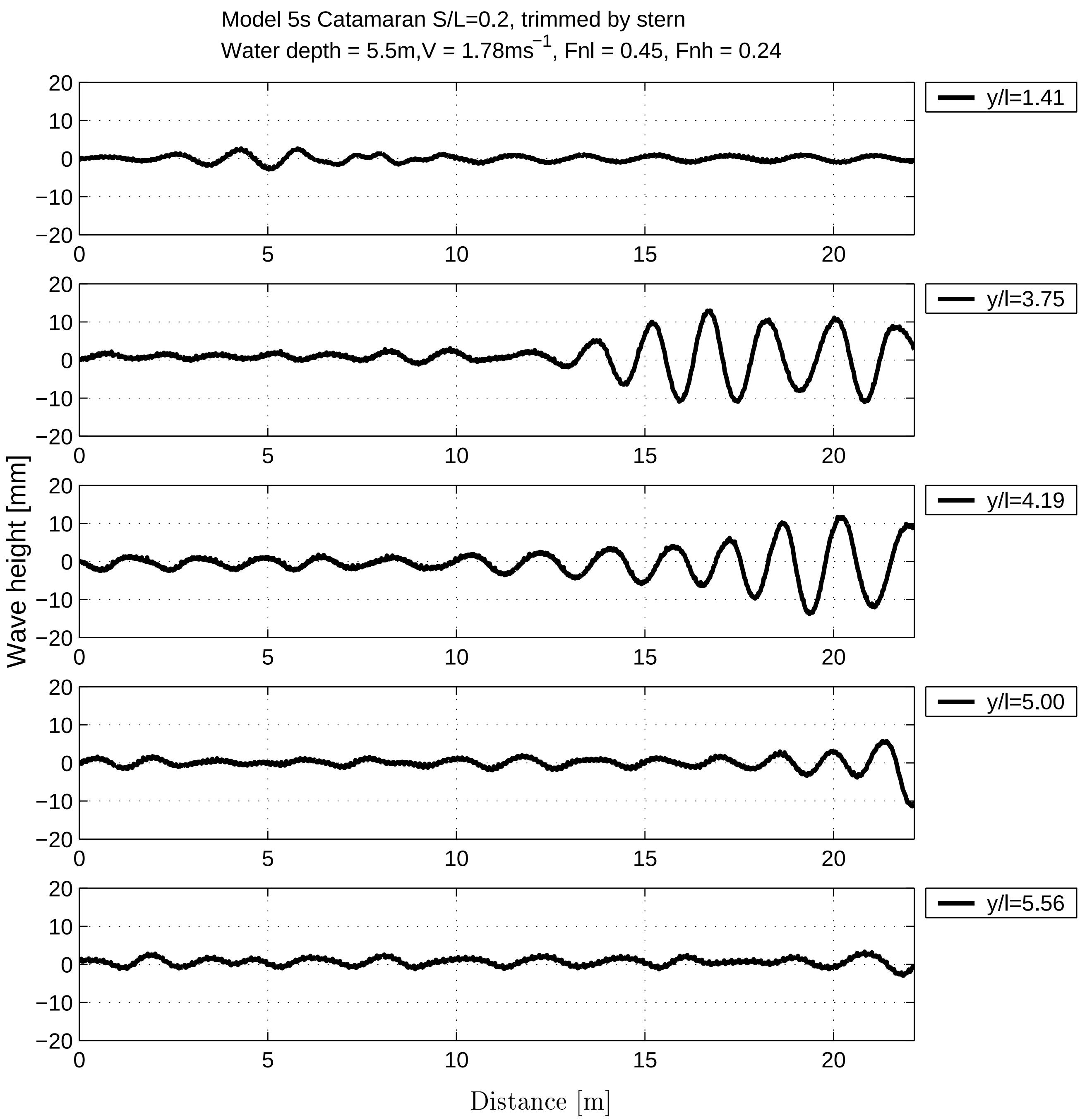
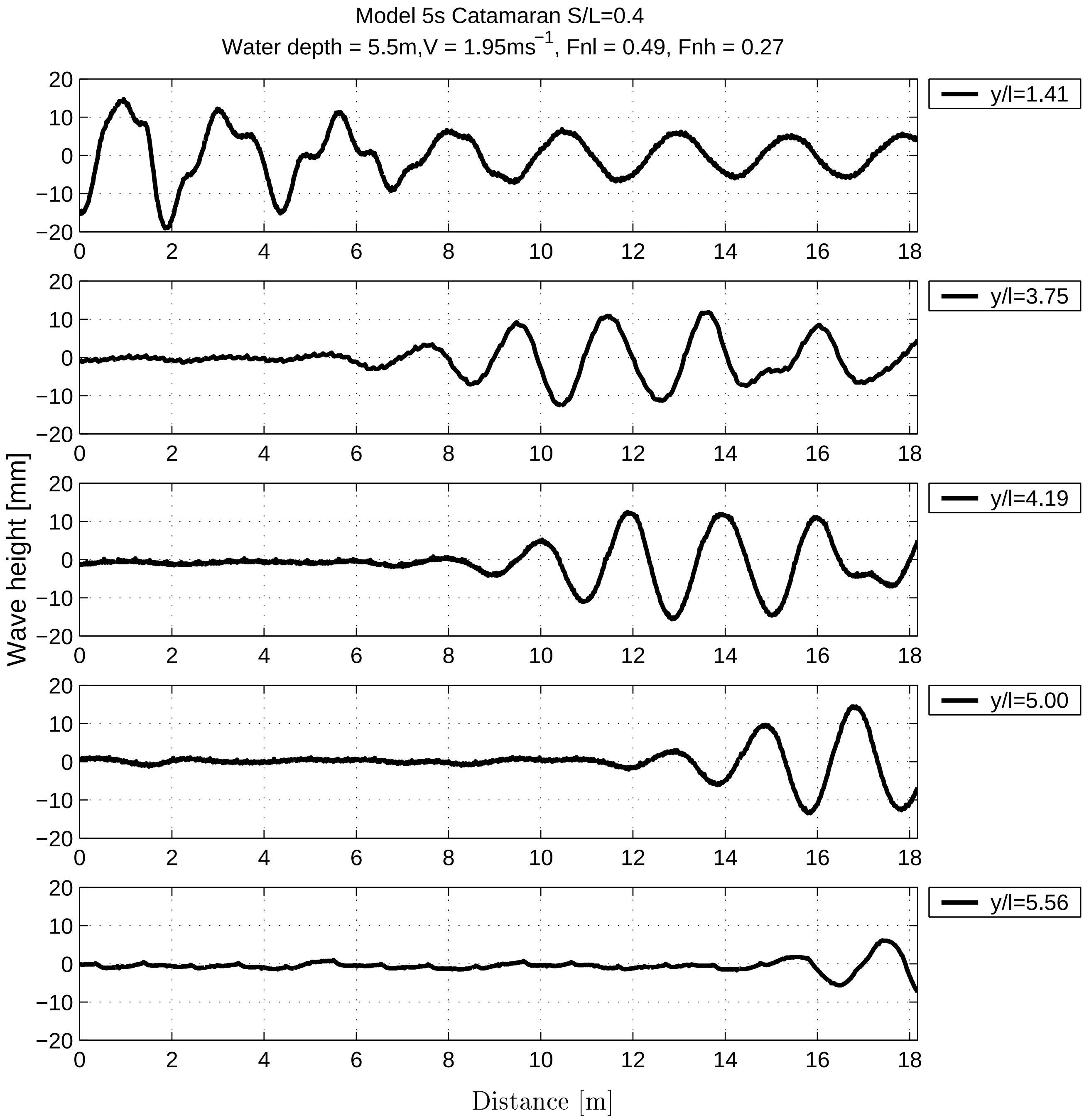

Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 1.78ms^{-1}, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 32



Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.95ms^{-1}, Fnl = 0.49, Fnh = 0.27
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 33

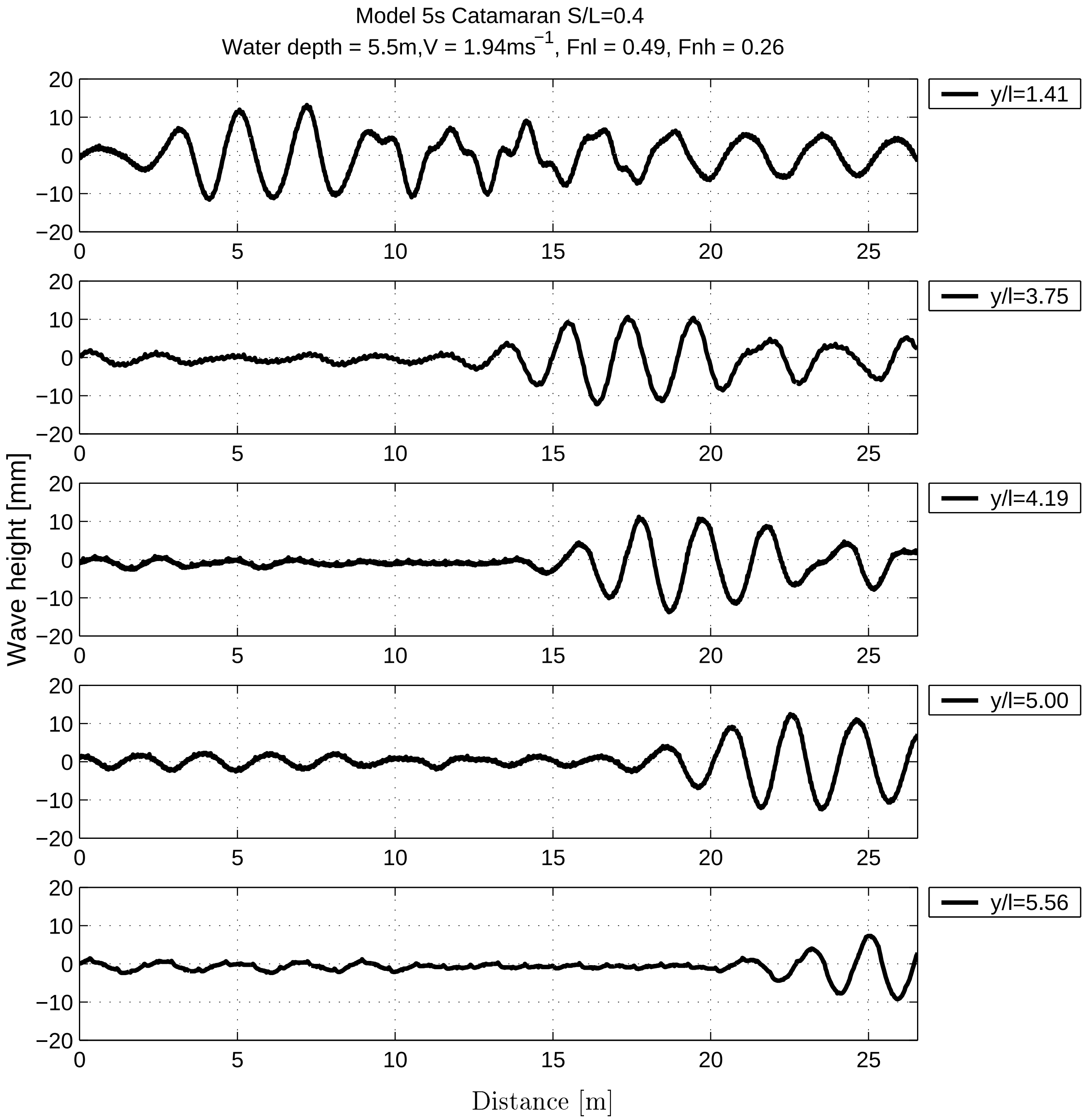

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.94ms^{-1}, Fnl = 0.49, Fnh = 0.26
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 34

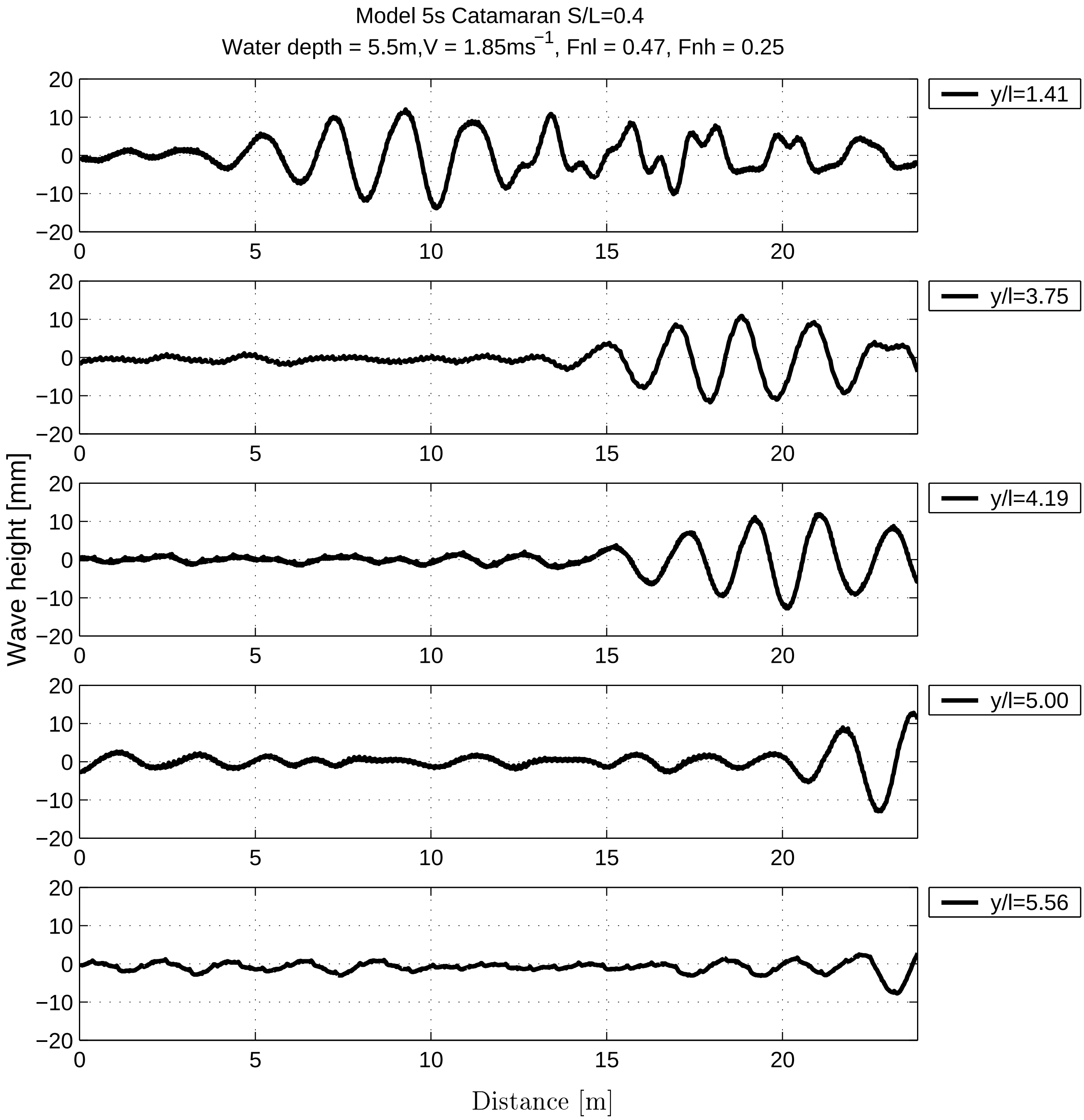
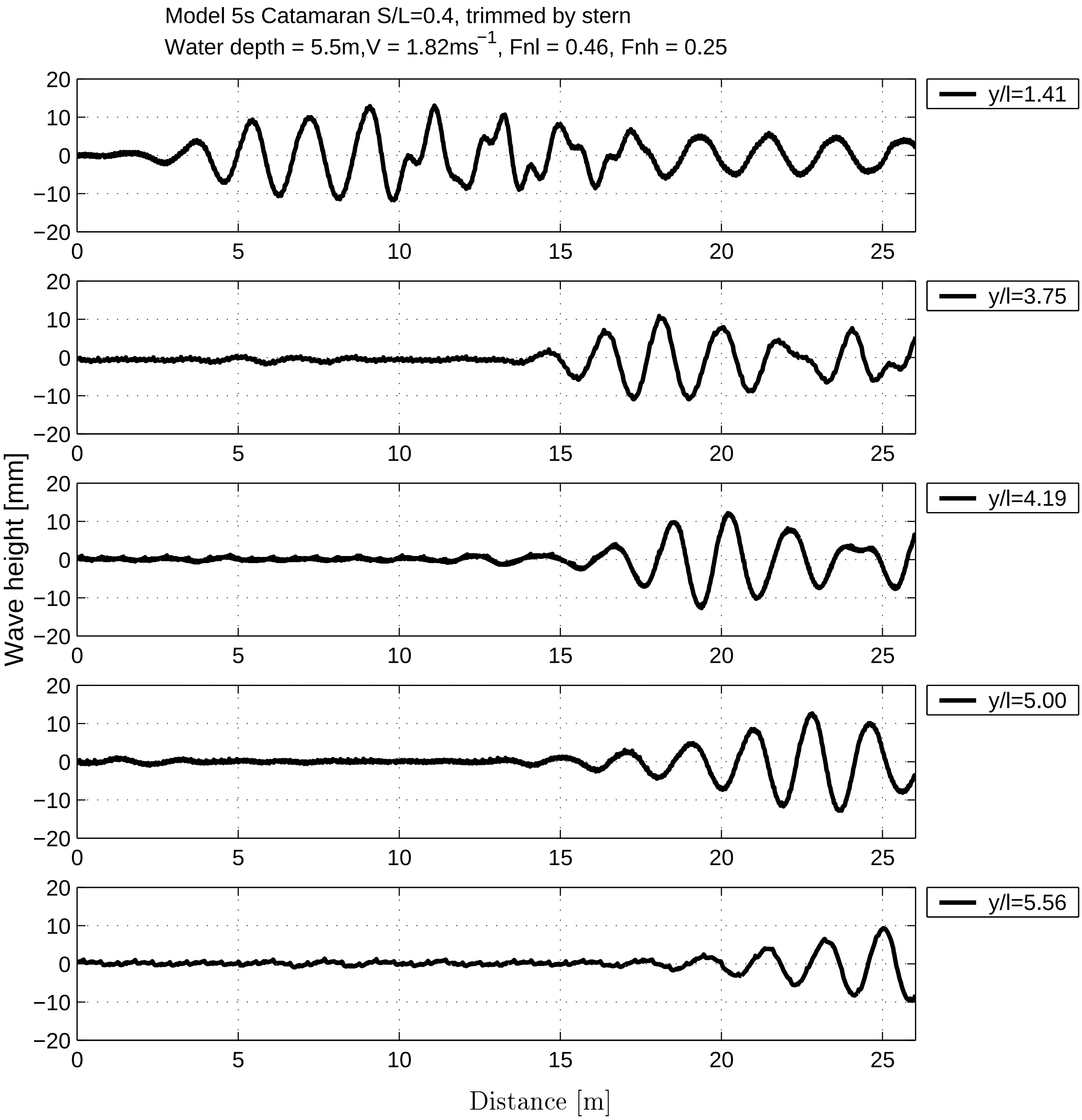

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 1.85ms^{-1}, Fnl = 0.47, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]
20
10
0
−10
−20
0
5
10
15
20

Figure 35



Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 1.82ms^{-1}, Fnl = 0.46, Fnh = 0.25
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 36

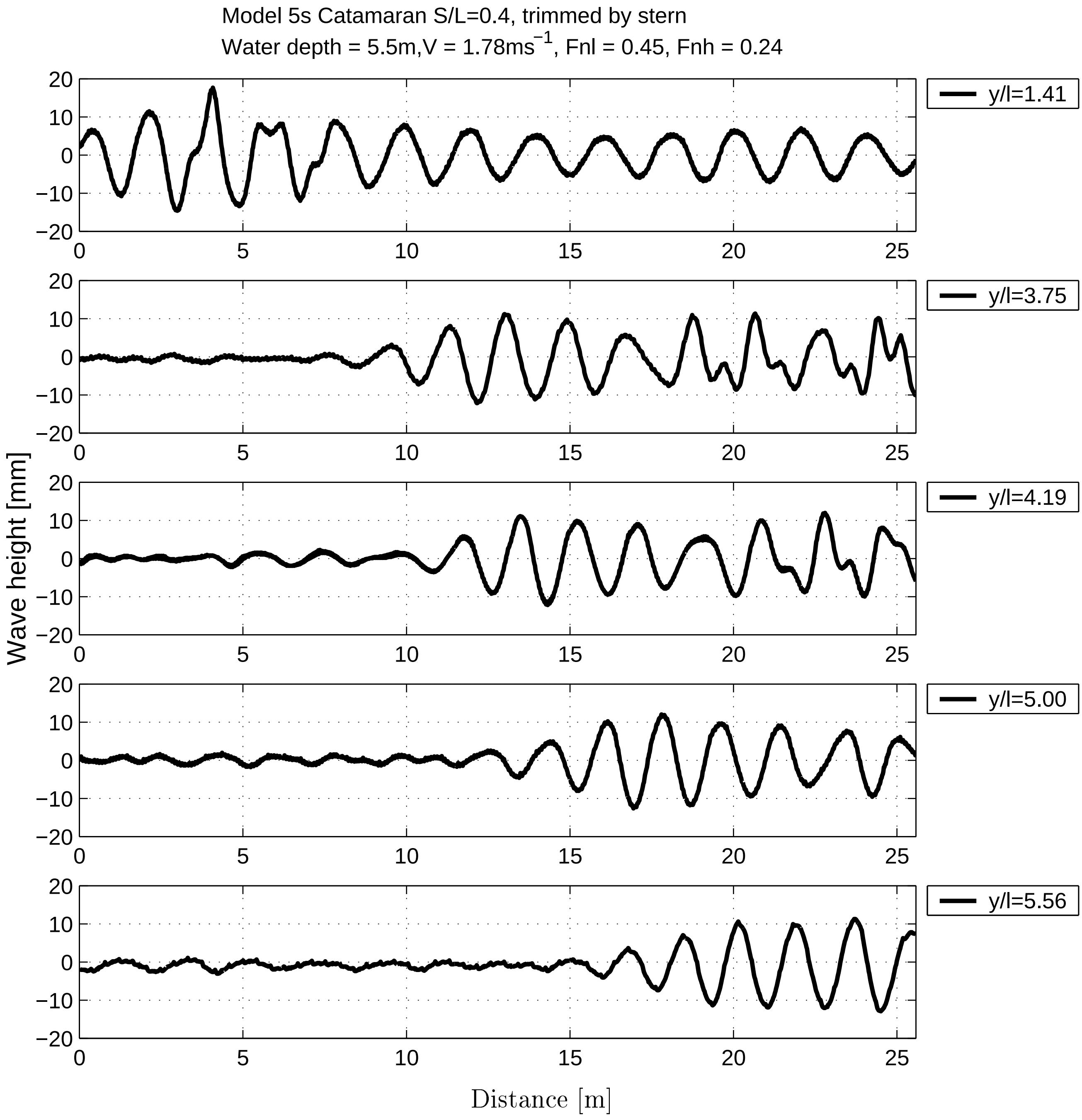

Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 1.78ms^{-1}, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
Wave height [mm]
Distance [m]

Figure 37

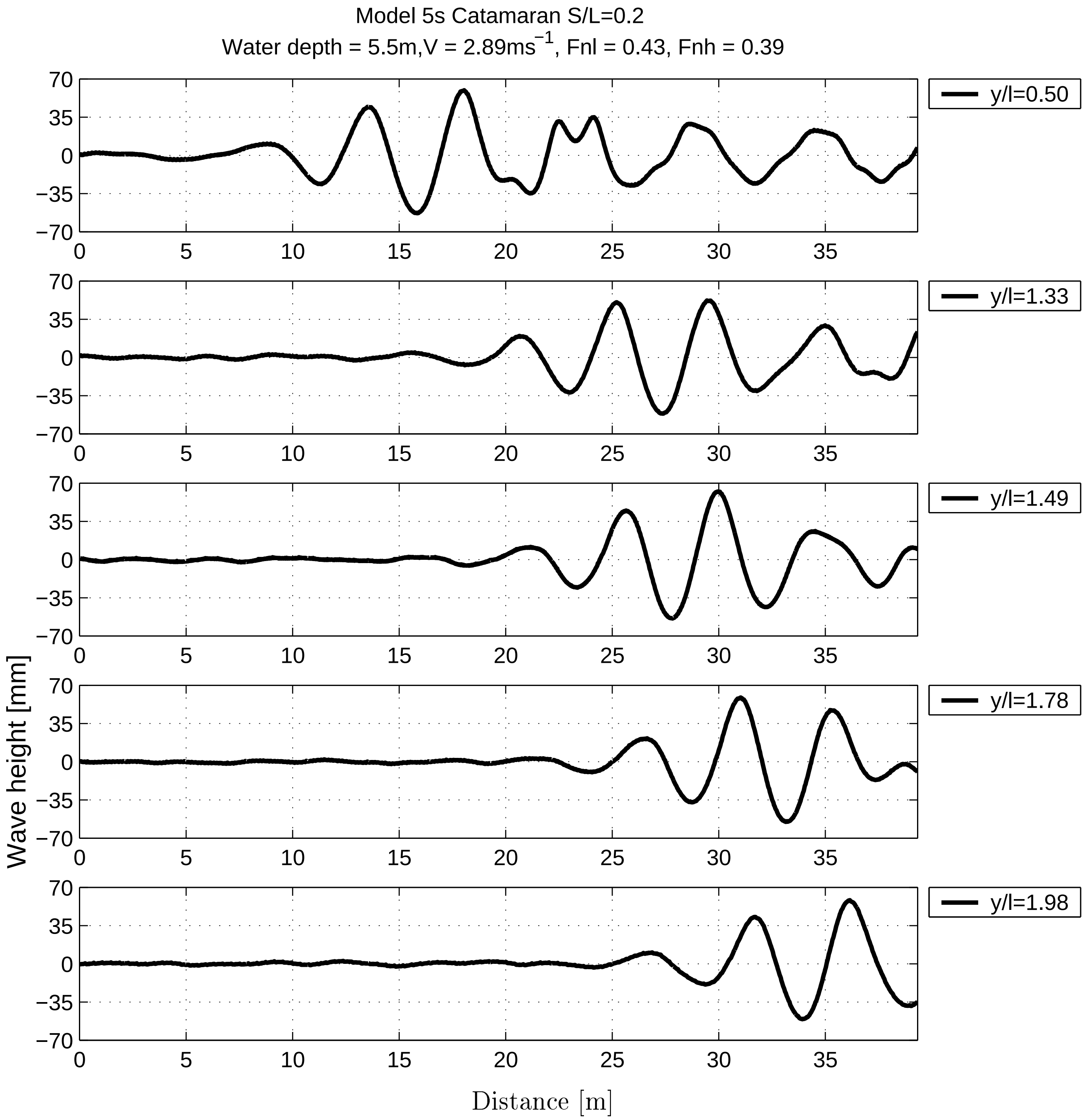
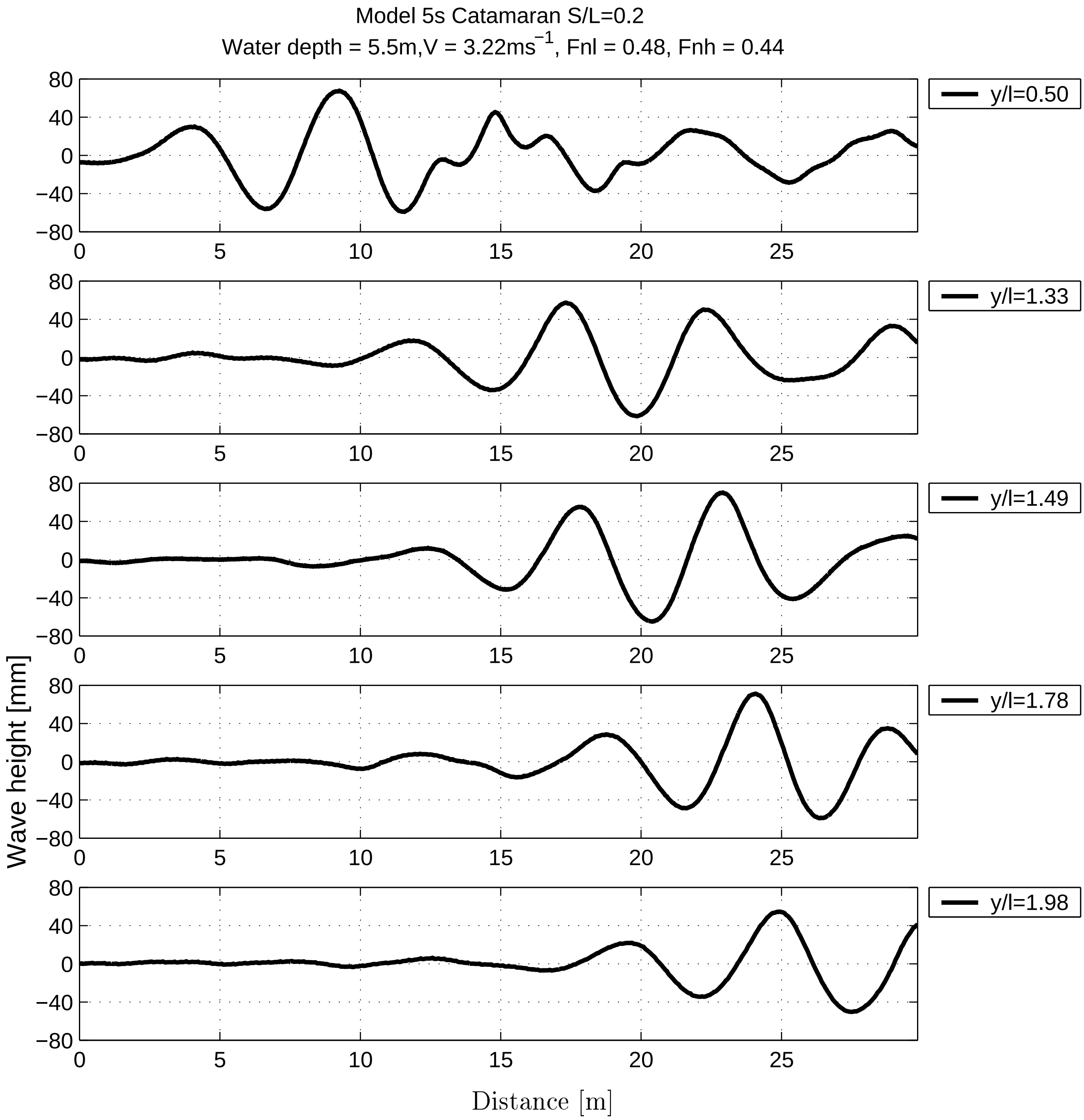
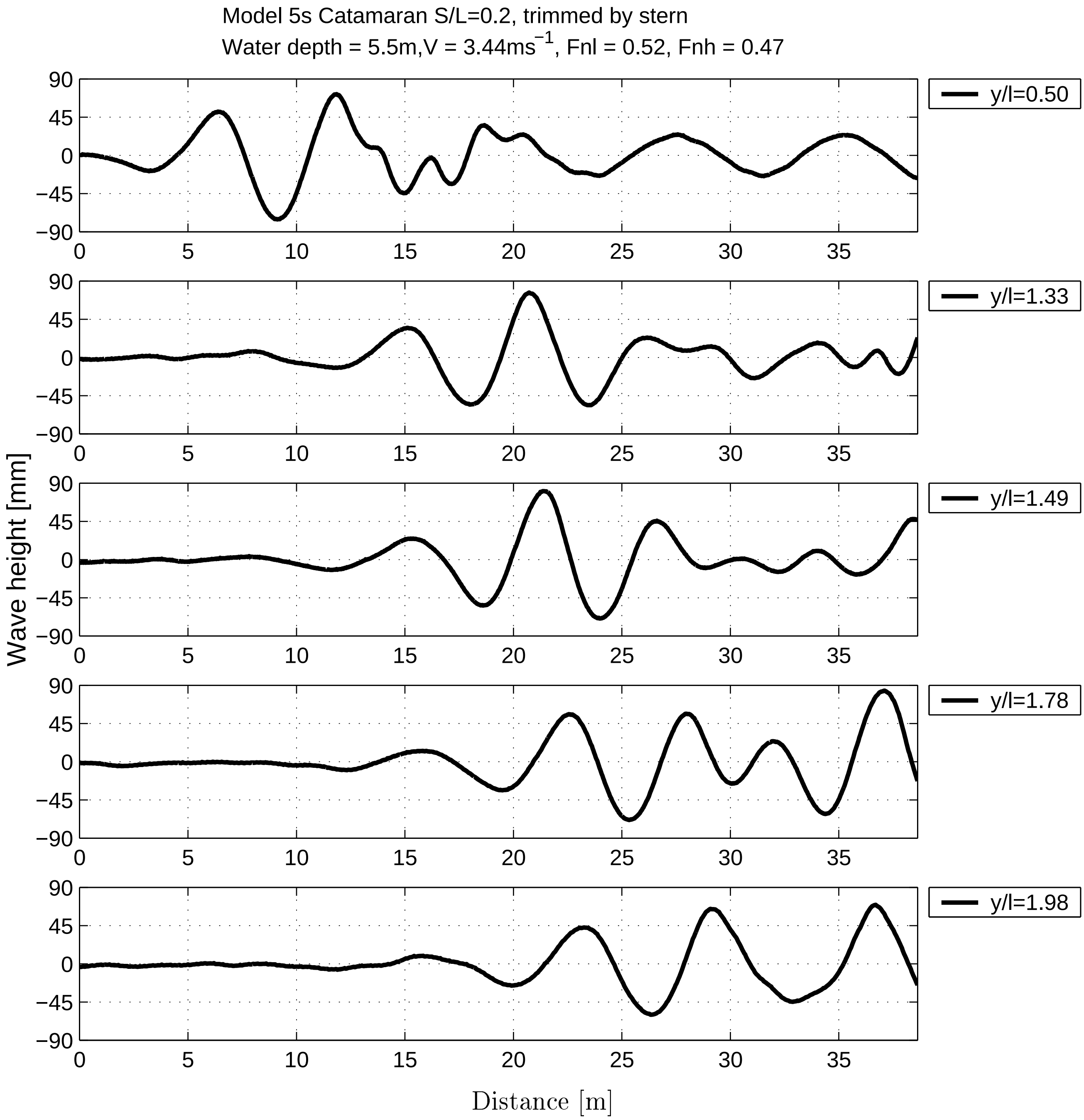

Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 2.89ms^{-1}, Fnl = 0.43, Fnh = 0.39
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]

Figure 38



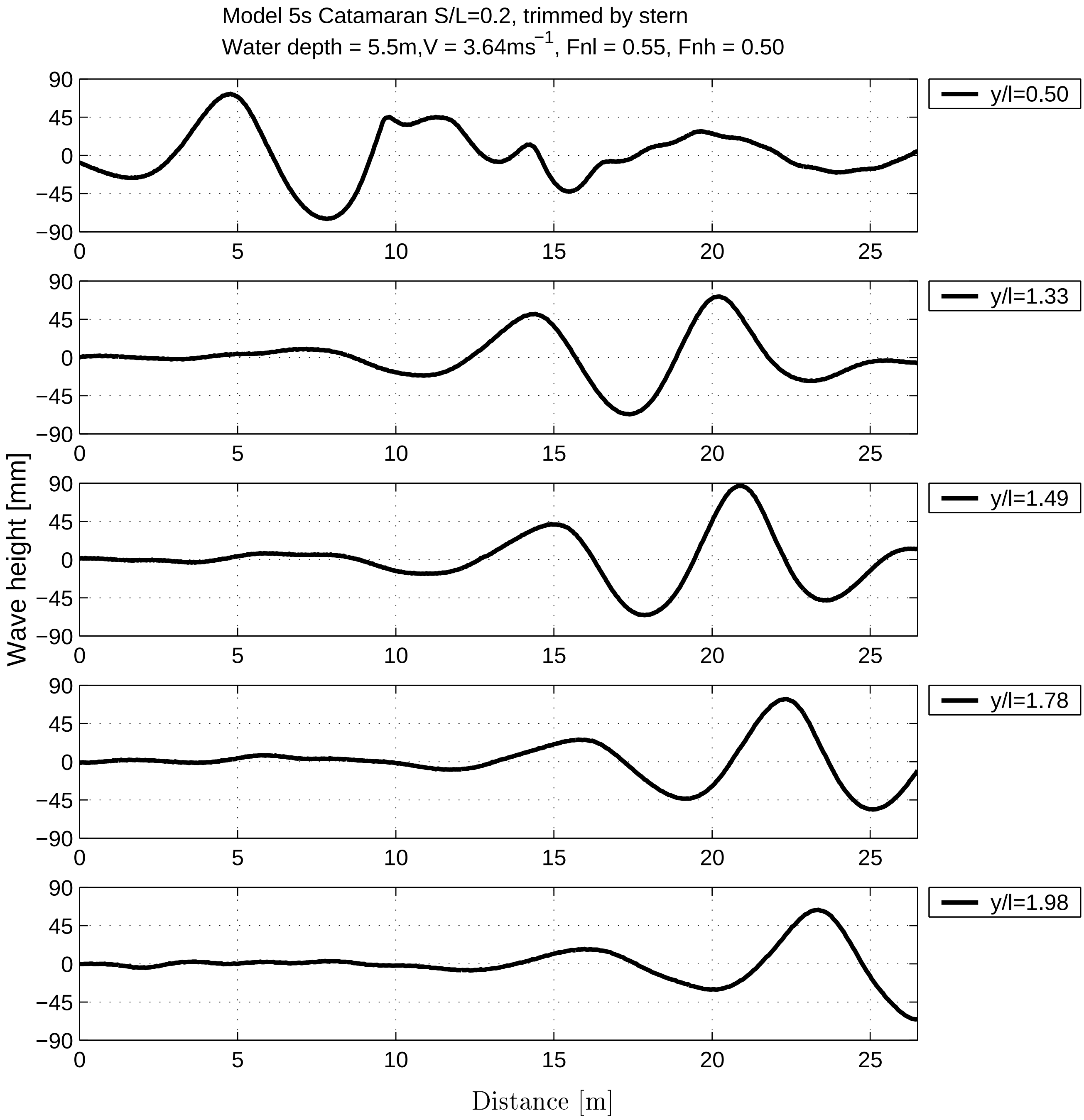
Model 5s Catamaran S/L=0.2
Water depth = 5.5m,V = 3.22ms^{-1}, Fnl = 0.48, Fnh = 0.44
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]
80
40
0
−40
−80
0
5
10
15
20
25

Figure 39



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 3.44ms^{-1}, Fnl = 0.52, Fnh = 0.47
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]
90
45
0
−45
−90
0
5
10
15
20
25
30
35

Figure 40



Model 5s Catamaran S/L=0.2, trimmed by stern
Water depth = 5.5m,V = 3.64ms^{-1}, Fnl = 0.55, Fnh = 0.50
Wave height [mm]
Distance [m]
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
90
45
0
−45
−90
0
5
10
15
20
25

Figure 41

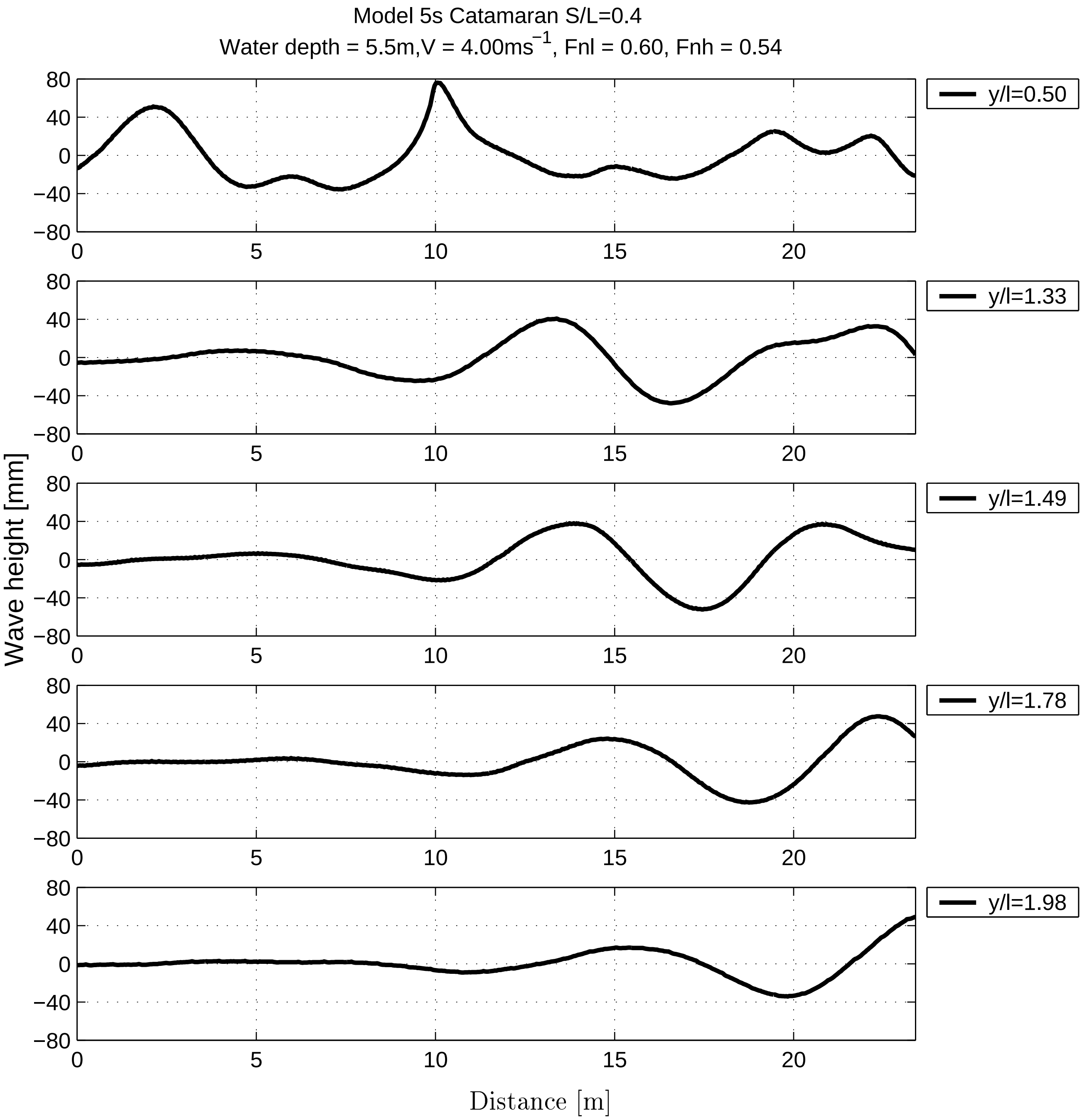
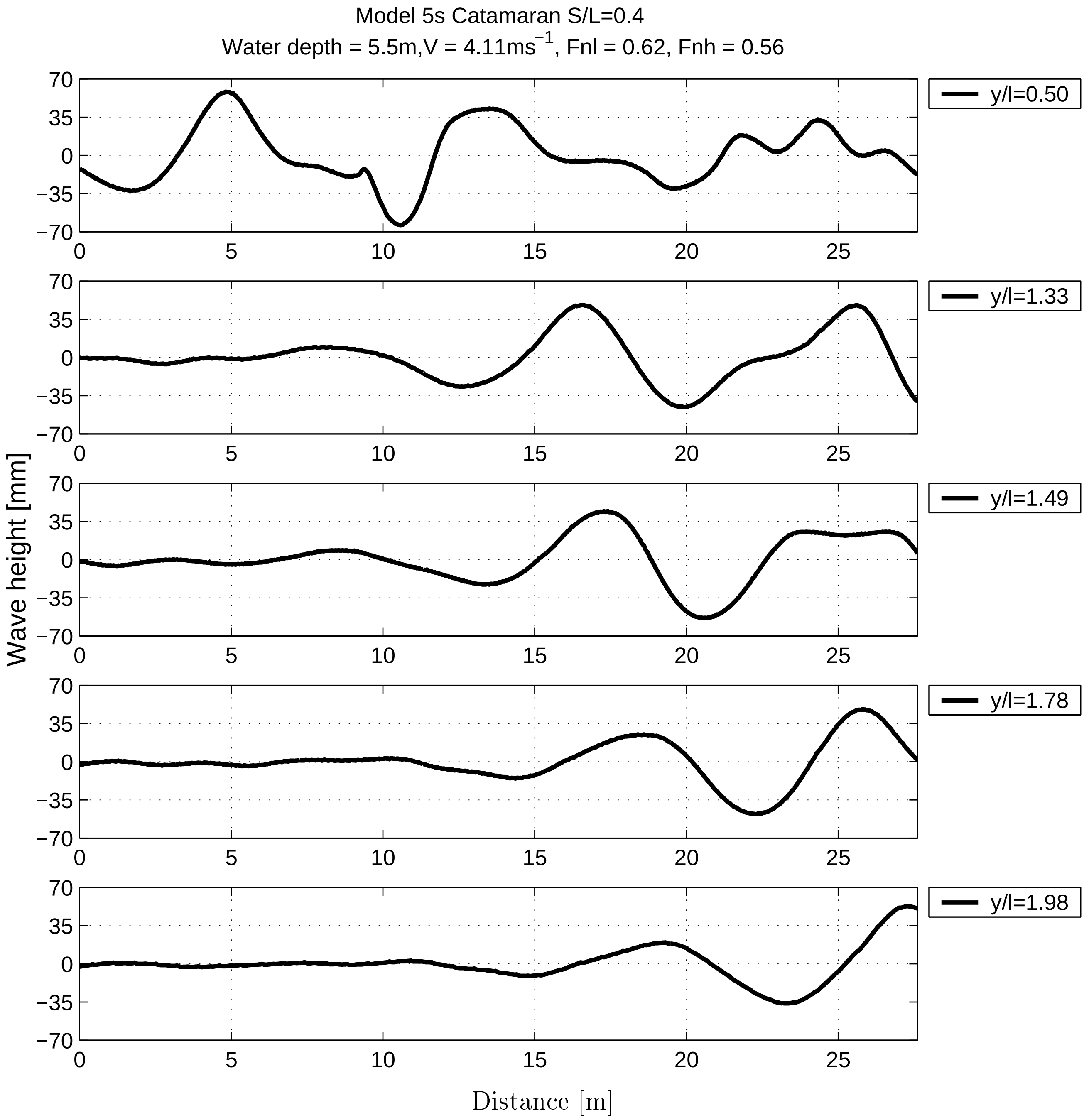
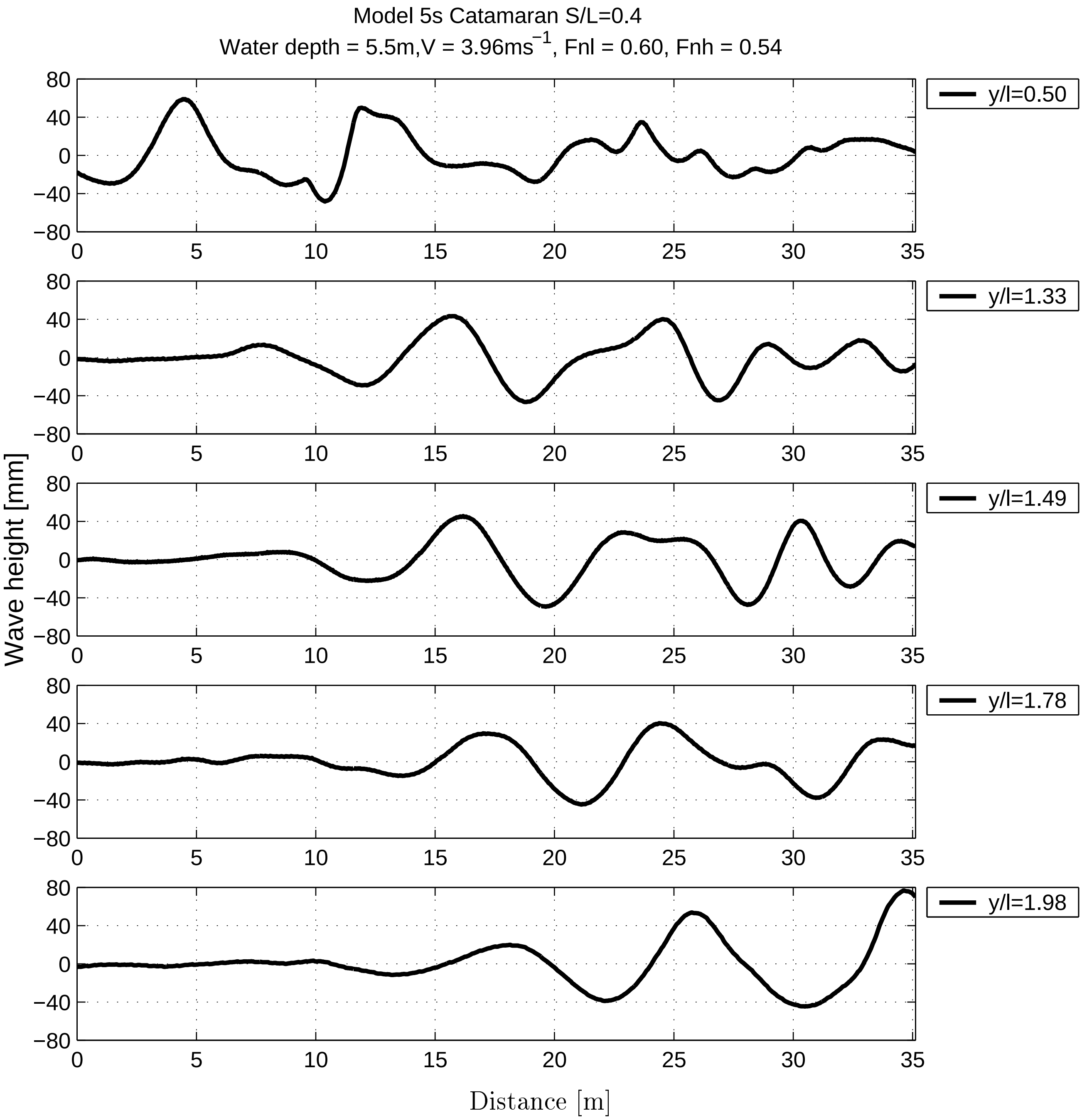

Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 4.00ms^{-1}, Fnl = 0.60, Fnh = 0.54
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]

Figure 42



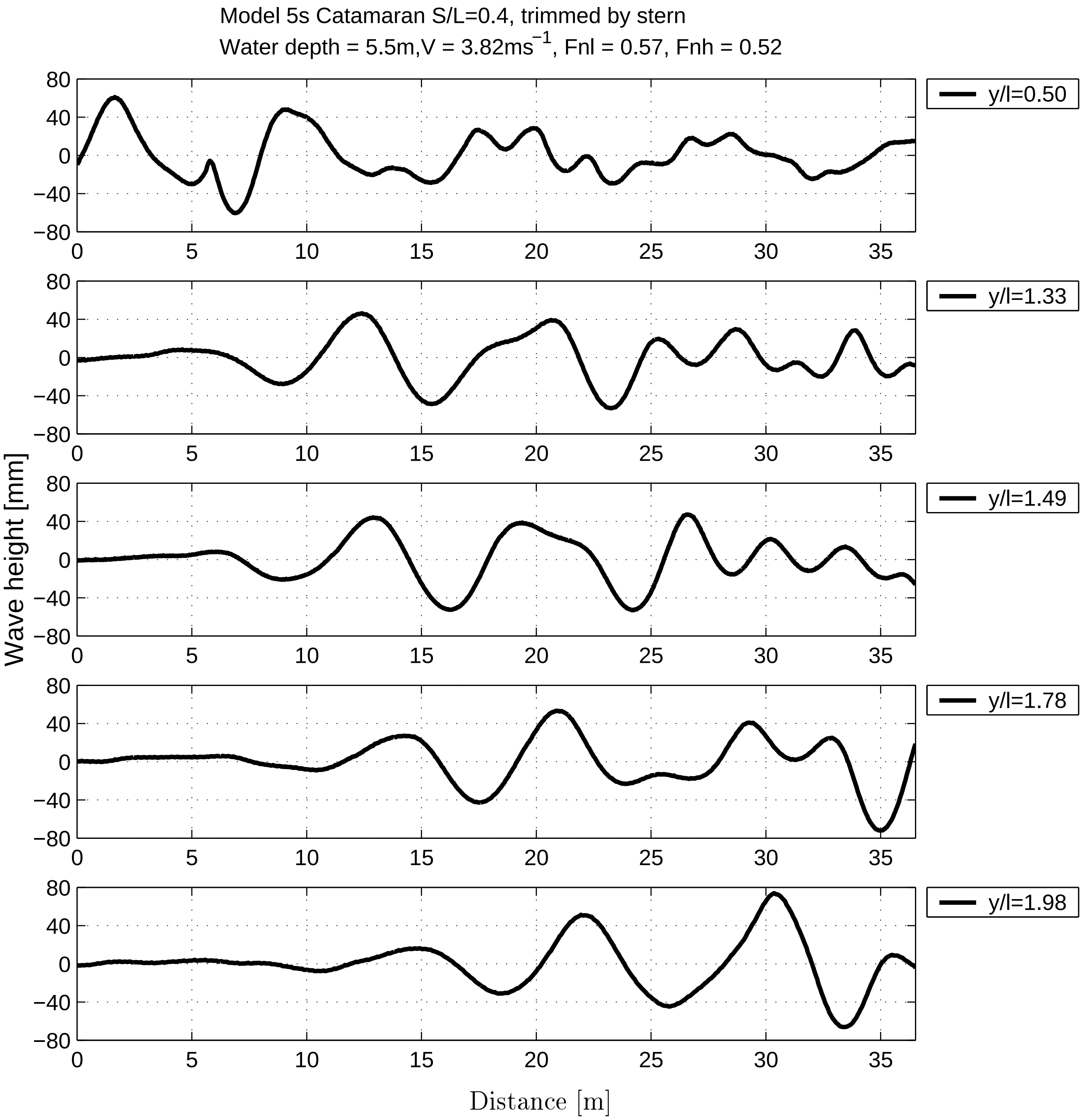
Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 4.11ms−1, Fnl = 0.62, Fnh = 0.56
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]
70
35
0
−35
−70
0
5
10
15
20
25

Figure 43



Model 5s Catamaran S/L=0.4
Water depth = 5.5m,V = 3.96ms−1, Fnl = 0.60, Fnh = 0.54
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]

Figure 44



Model 5s Catamaran S/L=0.4, trimmed by stern
Water depth = 5.5m,V = 3.82ms^{-1}, Fnl = 0.57, Fnh = 0.52
y/l=0.50
y/l=1.33
y/l=1.49
y/l=1.78
y/l=1.98
Wave height [mm]
Distance [m]
80
40
0
−40
−80
0
5
10
15
20
25
30
35

Figure 45

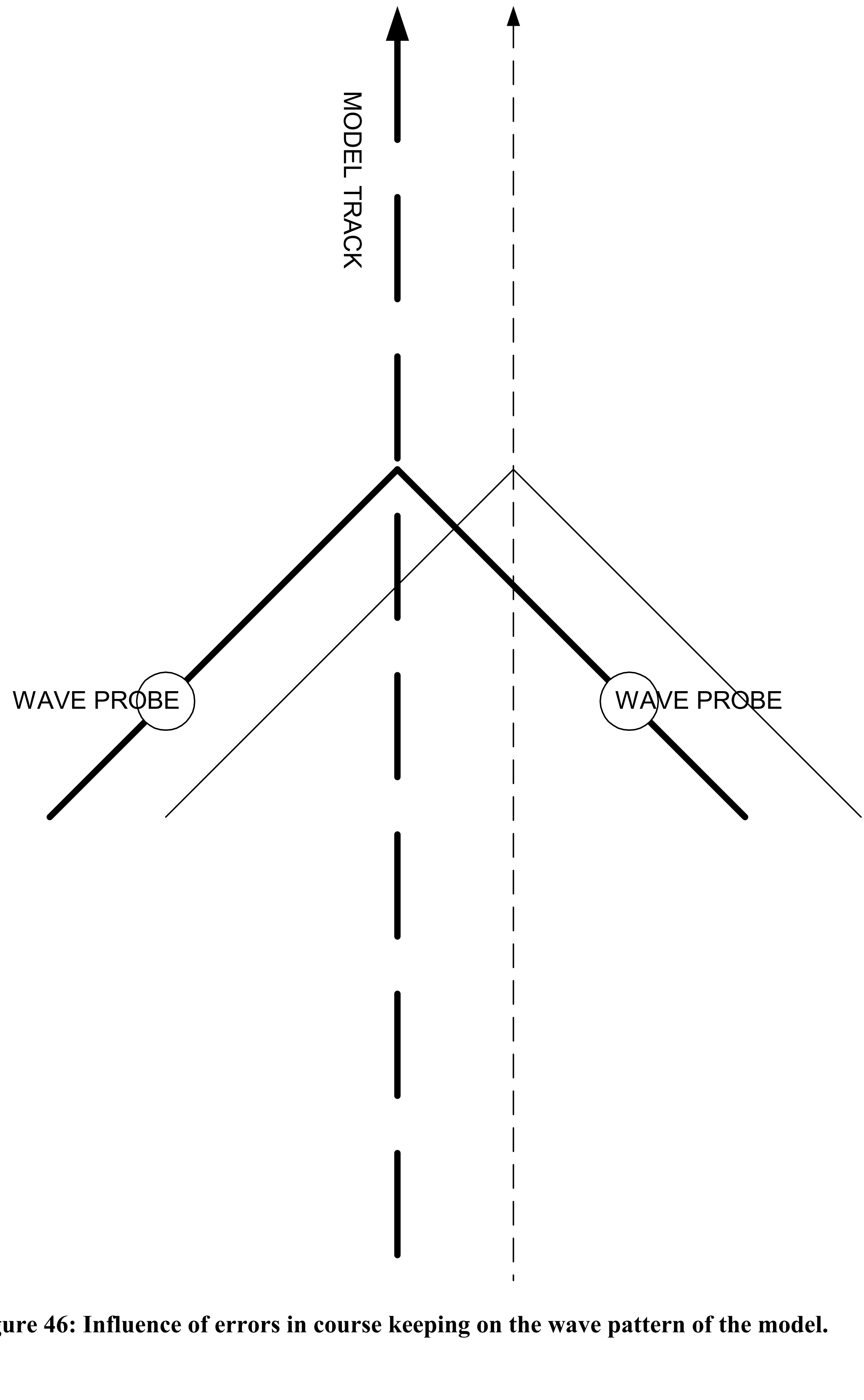
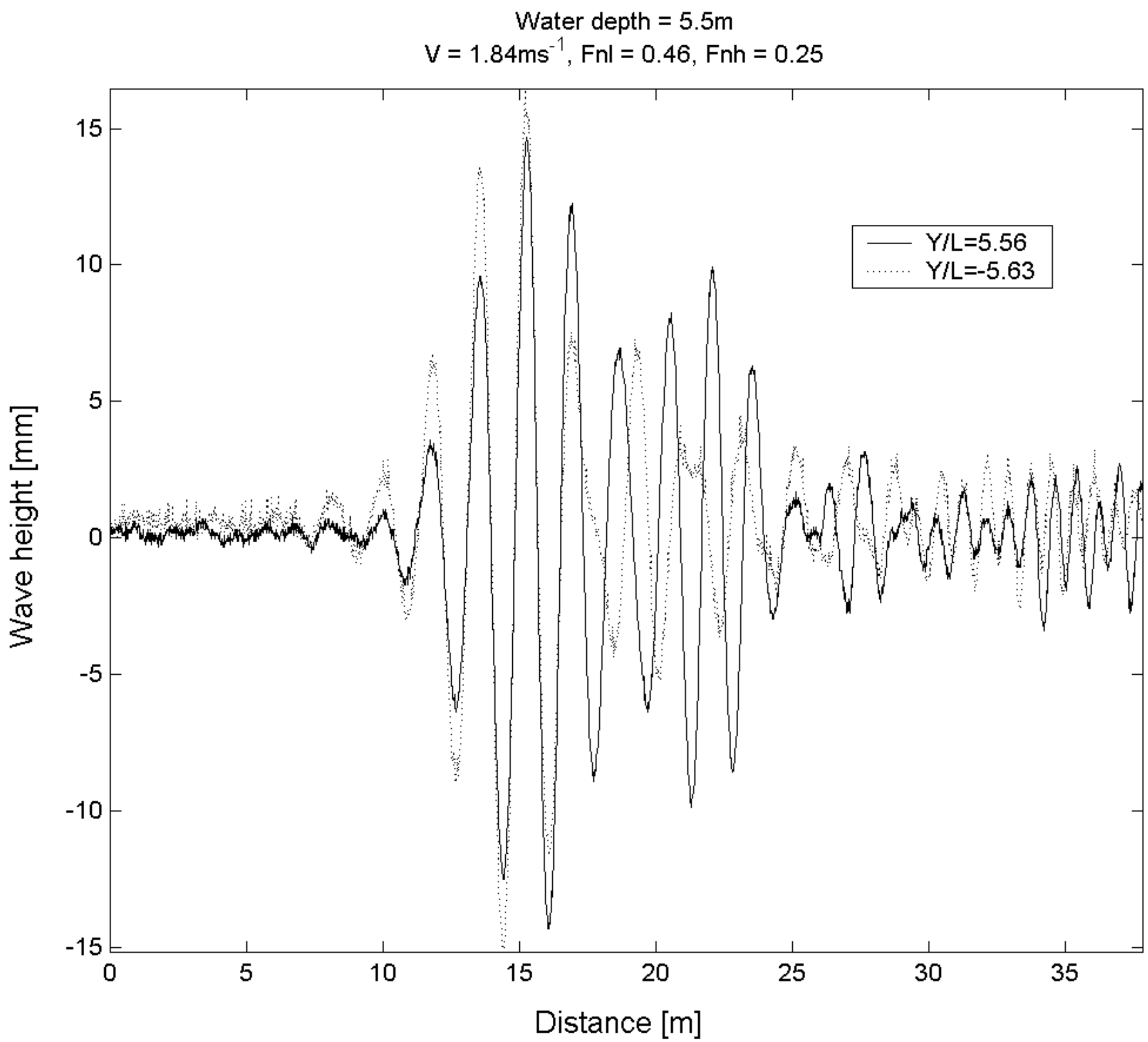


Figure 46: Influence of errors in course keeping on the wave pattern of the model.



Water depth = 5.5m
V = 1.84ms-1, Fnl = 0.46, Fnh = 0.25
Y/L=5.56
Y/L=-5.63
Wave height [mm]
Distance [m]
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35

Figure 47

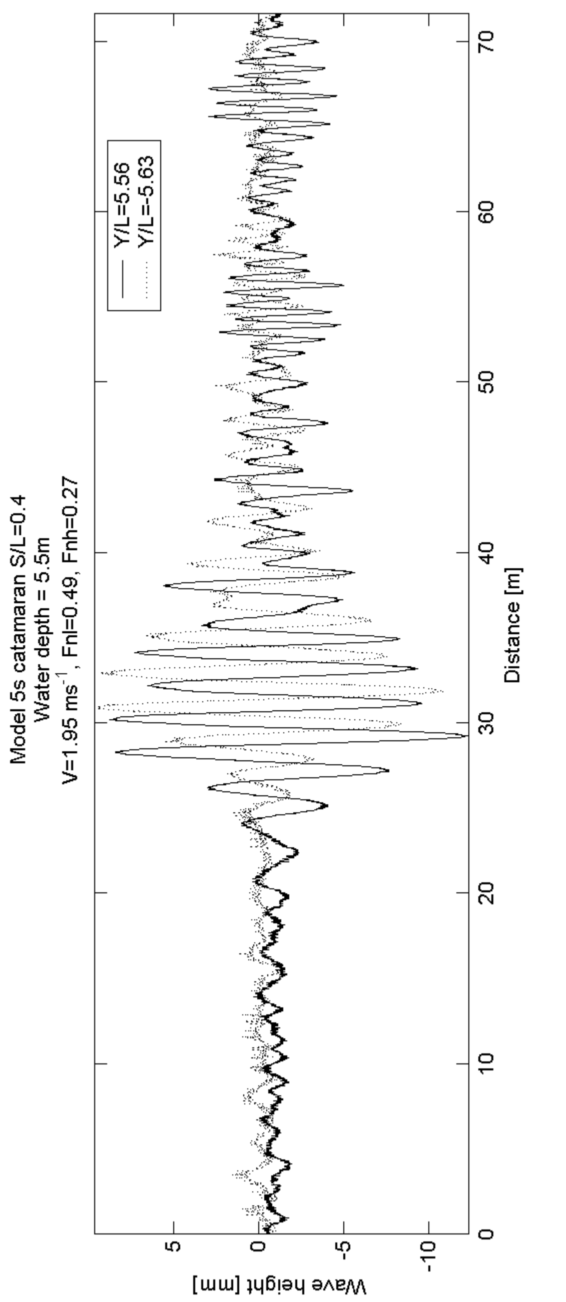
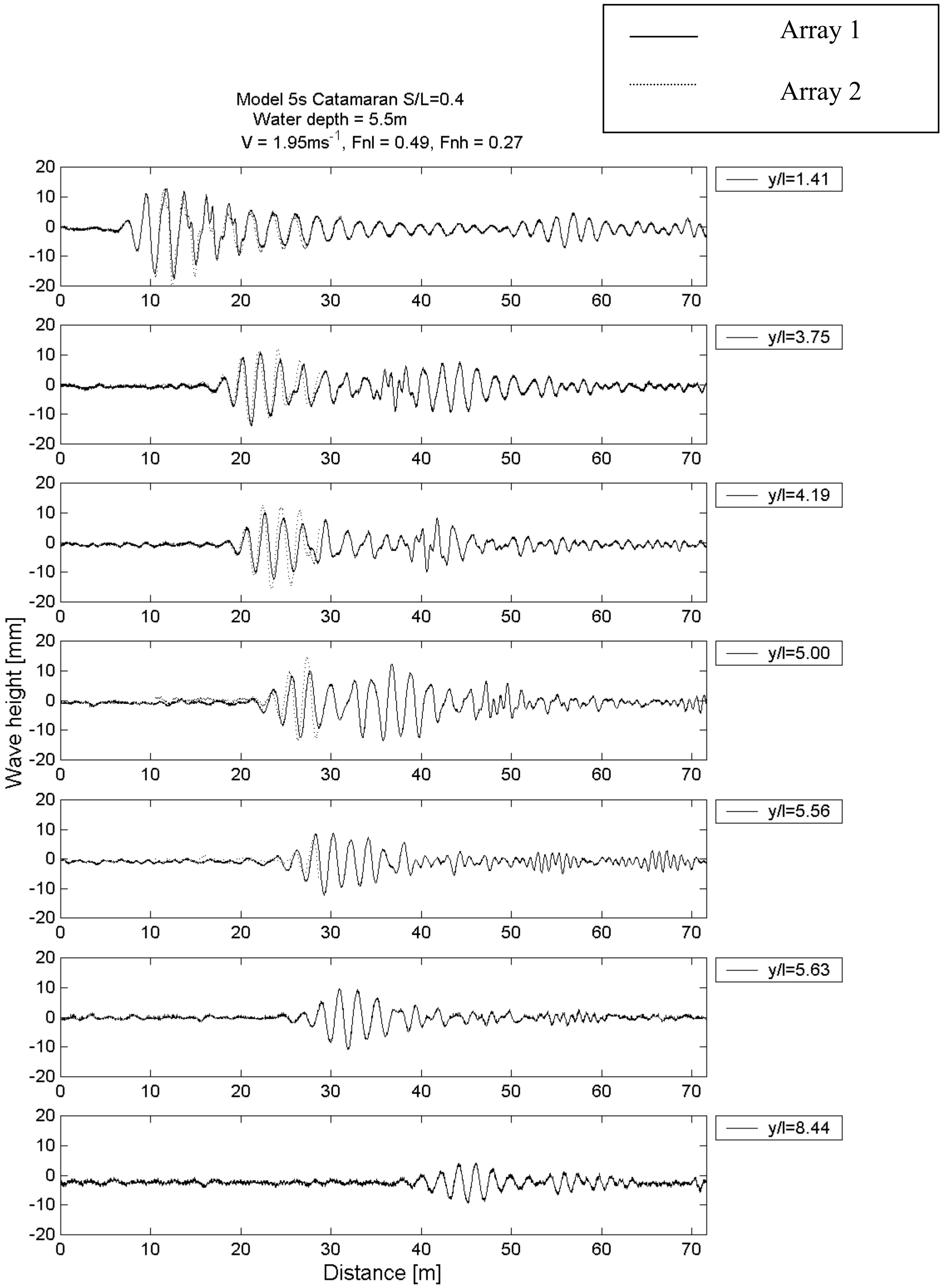

Model 5s catamaran S/L=0.4
Water depth = 5.5m
V=1.95 ms^{-1}, Fnl=0.49, Fnh=0.27
Y/L=5.56
Y/L=-5.63
Wave height [mm]
Distance [m]
5
0
-5
-10
0
10
20
30
40
50
60
70

Figure 48



Array 1
Array 2
Model 5s Catamaran S/L=0.4
Water depth = 5.5m
V = 1.95ms-1, Fnl = 0.49, Fnh = 0.27
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 49

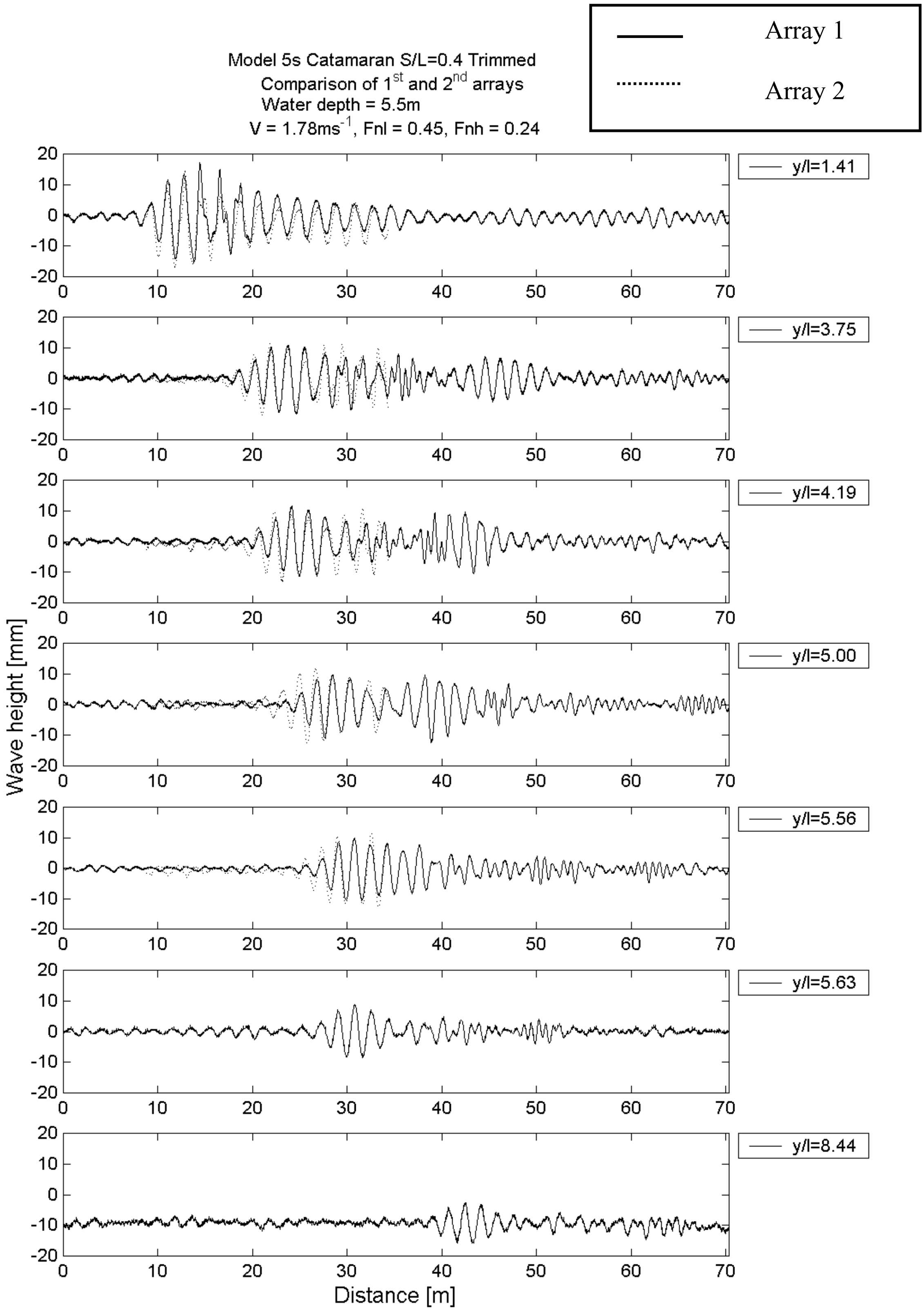

Array 1
Array 2
Model 5s Catamaran S/L=0.4 Trimmed
Comparison of 1st and 2nd arrays
Water depth = 5.5m
V = 1.78ms-1, Fnl = 0.45, Fnh = 0.24
y/l=1.41
y/l=3.75
y/l=4.19
y/l=5.00
y/l=5.56
y/l=5.63
y/l=8.44
Wave height [mm]
Distance [m]

Figure 50

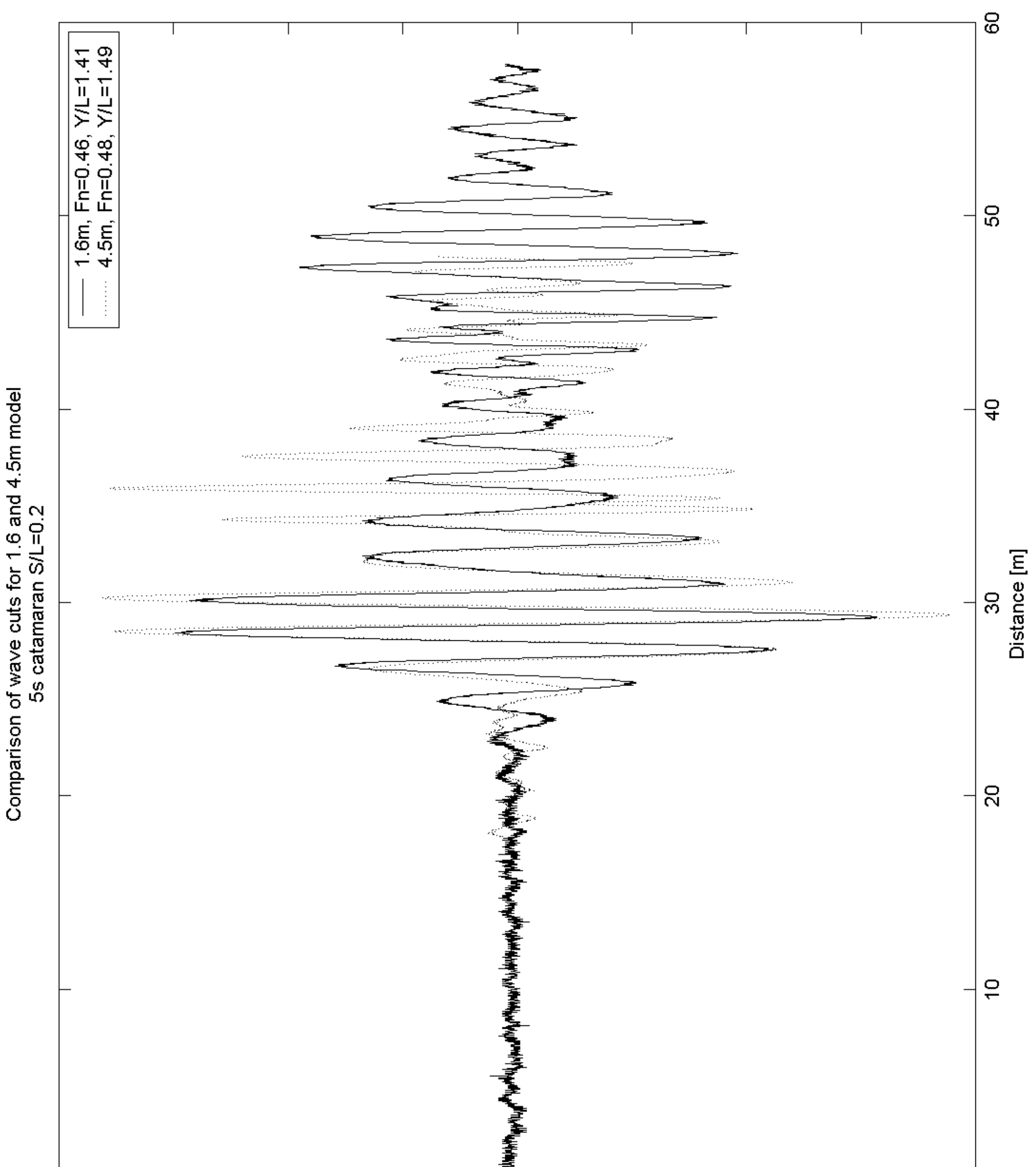

Comparison of wave cuts for 1.6 and 4.5m model
5s catamaran S/L=0.2
1.6m, Fn=0.46, Y/L=1.41
4.5m, Fn=0.48, Y/L=1.49
Wave height [mm]
Distance [m]
20
15
10
5
0
-5
-10
-15
-20
0
10
20
30
40
50
60

Figure 51

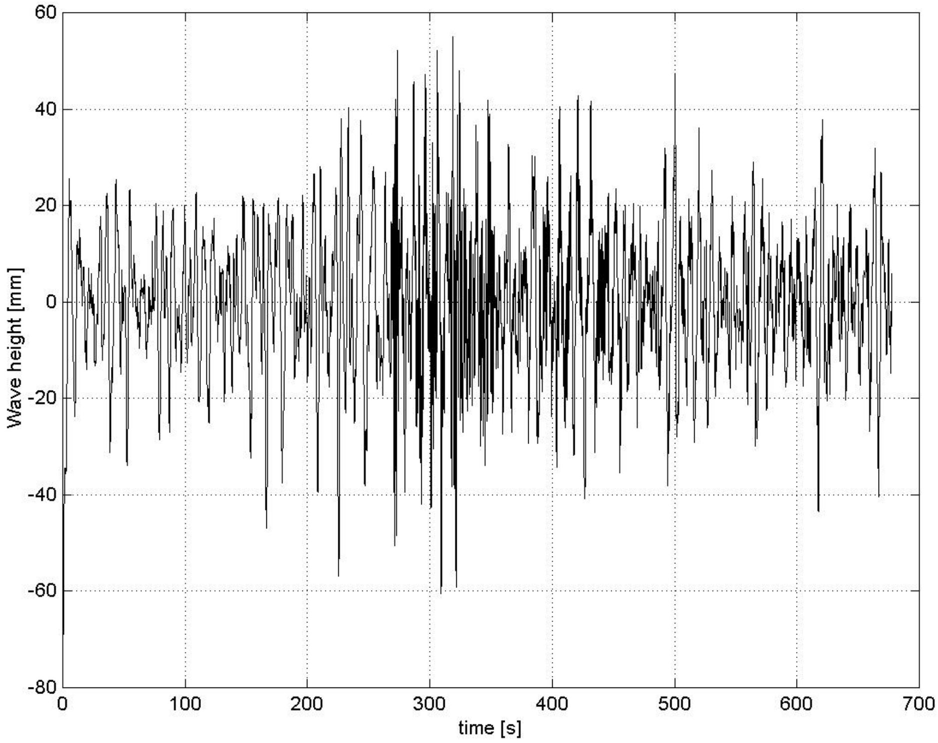


Figure 52: Wave trace from wave buoy for 4.5m model, S/L=0.2 at 3.22 m s^{-1}.

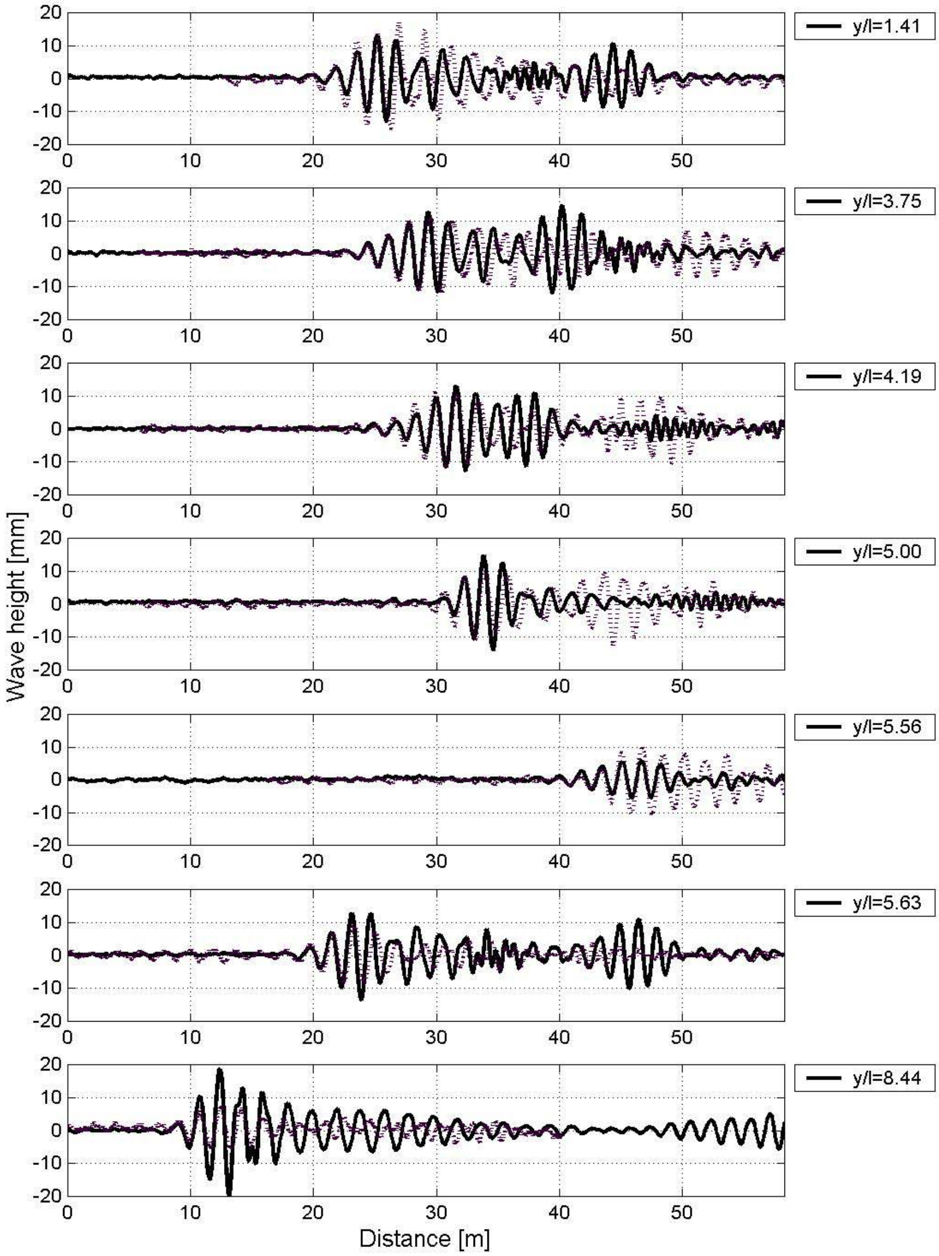


Figure 53: Comparison of level (-) and trimmed (:) model at a speed of 1.75m s^{-1}.