Prepared for:

Rijkswaterstaat/RIKZ

Hindcast Petten and Westerschelde with SWAN 40.20

Period correction SWAN 40.20

A1200

March 2004

Client	**Rijkswaterstaat/RIKZ**
Title	**Hindcast Petten and Westerschelde with SWAN 40.20**
	Period Correction SWAN 40.20

Abstract

The SWAN model version 40.20 has been used to hindcast 5 storms near the Petten Sea Defence and 3 storms in the Westerschelde. Two hindcast methods have been used; a relatively simple standard method and an advanced method in which a better description of boundary conditions has been used. The standard method uses the default settings of SWAN 40.20 and the advanced method uses those of the calibrated SWAN 40.20. The results indicate that for both areas the initial under-prediction of the significant wave height is changed into an over-prediction of equal magnitude in the advanced method. For the mean wave period the initial under-prediction is reduced. The scatter in the results remains large. Since the prediction errors are still rather erratic, generic correction factors need to be derived based on an error analysis of the responsible physical conditions and processes at various locations. These factors should be derived for both the peak periods T_p and T_{pm}, the mean wave period $T_{m-1,0}$ and the significant wave height H_{m0}.

References: Offer A1200LE02, date 29 September 2003.
Contract RKZ-1340, date 2 October 2003

Rev.	Originator	Date	Remarks	Checked by	Approved by
0	G.Ph. van Vledder	18 Nov. 2003		H.J. Steetzel	G.Ph. van Vledder
2	G.Ph. van Vledder	23 Jan. 2004	Revised draft	H.J. Steetzel	G.Ph. van Vledder
3	G.Ph. van Vledder	4 Feb. 2004	Revised draft	H.J. Steetzel	G.Ph. van Vledder
4	G.Ph. van Vledder	31 March 2004	Final	H.J. Steetzel	G.Ph. van Vledder

Document Control		Contents		Status
Report number:	A1200R1r4	text pages :	59	☐ preliminary
Keywords:	SWAN, Petten, Westerschelde	tables :	42	☐ draft
Project number:	A1200	figures :	47	☒ final
File location:	A1200R1R4	appendices :	8	

Alkyon
Hydraulic Consultancy & Research

postal address
PO Box 248
8300 AE, Emmeloord
The Netherlands

visiting address
Voorsterweg 28, Marknesse
tel : 0527 24 81 00
fax: 0527 24 81 11

e-mail
info@alkyon.nl
internet
http://www.alkyon.nl

Executive's summary

The SWAN model version 40.20 has been used to hindcast 5 storms near the Petten Sea Defence and 3 storms in the Westerschelde. Two hindcast methods have been used; a relatively simple standard method and an advanced method in which a better description of boundary conditions has been used. In the standard hindcast method the default settings of SWAN 40.20 have been used and in the advanced hindcast method those of the calibrated SWAN 40.20 model.

The results indicate that for both areas the advanced hindcast methods yields higher but not better significant wave heights H_{m0} and also higher and better wave periods compared to the standard hindcast. The initial under-prediction of the significant wave height is changed into an over-prediction of equal magnitude for both areas. For Petten the relative bias in the predicted values of the mean period $T_{m-1,0}$ remains very small, whereas for the Westerschelde the initial under-prediction is reduced. The scatter in the results remains more or less the same indicating that no fundamental improvements in the wave model and its behaviour were obtained in the advanced hindcast.

A detailed analysis of the results shows that the changes in model performance are quite similar for the various Westerschelde cases, but rather erratic for the Petten cases. Since the scatter in the results is still large and in view of the erratic behaviour in the predicted values, accurate predictions of the peak periods T_p and T_{pm}, the mean wave period $T_{m-1,0}$, and to a lesser degree also for the significant wave height H_{m0}, can only be obtained by deriving generic correction factors for these parameters. In the determination of these correction factors the sources of the deviations need to be identified by considering the responsible physical conditions and processes, and locations where they occur.

Contents

List of tables

List of figures

Appendix F contains the following Figures:

1 Introduction

1.1 Background of the study

For the design and safety assessment of the Dutch Sea dikes Hydraulic Boundary Conditions (HBC) are needed. These HBC are determined by the Dutch Ministry of Transport and Public Works on the basis of statistical analyses of wind, wave and water level conditions, and on the results of extensive wave model computations. By Dutch law these HBC need to be determined every 5 years. RIKZ is now considering the use of SWAN model version 40.20 for the execution of these wave model computations for the determination of the HBC for 2006.

Various studies with the SWAN model (e.g. Andorka Gál, 1997; Jacobse et al., 2002; Gautier, 2003 and WL|Delft Hydraulics & Alkyon, 2003; and Alkyon 2003) indicate that SWAN consistently under-predicts wave period measures. This under-prediction is a severe problem for the determination of the HBC for 2006. These HBC will be determined on the basis of extensive series of SWAN 40.20 computations for the Dutch coast. It is therefore important that SWAN 40.20 produces reliable results. To remedy the under-prediction of period measures by SWAN, a short-term approach and a long-term approach are followed by RIKZ. The long-term approach aims at fundamental improvements in the numerics and the parameterisation of physical processes in SWAN. The short-term approach aims at determining correction factors for SWAN applicable for a sufficiently wide range of conditions. As part of that strategy a calibration of SWAN 40.20 has been performed (Alkyon, 2003).

In this study the calibrated SWAN 40.20 model has been used to hindcast a number of historical storms that occurred near the Petten Sea Defence and in the Westerschelde. The wave conditions near Petten are considered to be representative for those along the closed Dutch coast, and the wave conditions in the Westerschelde are considered to be representative for estuaries.

The results of these hindcasts will be used to determine if the calibrated SWAN 40.20 performs better with respect to the period measures and to decide if the determination of correction factors is required.

This study is a sequel to two earlier hindcast studies that have recently been performed for these areas. For the Westerschelde a hindcast was carried out by Royal Haskoning (Gautier, 2003) and for the Petten Sea Defence a hindcast study was carried out by a joint venture of WL|Delft Hydraulics and Alkyon Hydraulics Consultancy & Research (WL|Delft Hydraulics & Alkyon, 2003). These hindcast studies have both been carried out with the SWAN model versions 30.62 and 40.16.

In 1999 wave conditions have been determined for large parts of the Dutch coast with SWAN version 30.62 using a relatively simple standard hindcast method. The results of these wave computations have been assimilated in the RAND2001 database. In Alkyon & WL|Delft Hydraulics (2002) a new and generic method has been proposed for hindcasting measured storm events with the SWAN model. In the following this generic method is referred to as advanced hindcast method.

The standard and the advanced hindcast method have been used in the previously mentioned hindcast studies for the Petten Sea Defence and the Westerschelde. In these studies comparisons have been made between results obtained with both model versions and with both hindcast methods.

The characteristics of the standard hindcast method are the use of parametric wave boundary spectra, constant water level, no currents, a uniform and constant wind field and the bottom topography used in the 1999 SWAN computations.

The characteristics of the advanced hindcast method comprise wave boundary spectra that are based on measured wave spectra, astronomical and wind-driven spatially varying water levels and currents obtained from computations with the WAQUA model, a spatially varying wind field based on measured winds at various stations, and an updated bottom topography in the vicinity of the measurement locations. In addition the advanced hindcast method comprises the use of stricter convergence criteria. Details can be found in WL|Delft Hydraulics & Alkyon (2003) and Gautier (2003).

The SWAN model is being developed at Delft University of Technology. A detailed description of this model can be found in Booij et al. (1999). This paper contains detailed information about the SWAN model and it's state of approximately six years ago. Since then, the SWAN model has developed significantly. Since the execution of the above mentioned hindcast studies SWAN version 40.20 has been released and results of a calibration of SWAN 40.20 (Alkyon, 2003) have become available. The present standard version 40.20 (status May 2003, including some recent bug-fixes) contains improved numerics and various other improvements such as a frequency-dependent under-relaxation technique with respect to the previous SWAN release, viz. model version 40.11.

The calibration study led to numerical and physical settings for SWAN 40.20. A limitation of the calibration study of SWAN 40.20 (Alkyon, 2003) is its restriction to the storm of 26-27 October 2002. No other storm data have been used for a verification of the new settings. Therefore, this study provides additional validation data of the calibrated SWAN 40.20.

In this study SWAN version 40.20 has been applied for the Petten Sea Defence and the Westerschelde using the standard and the advanced hindcasting method. In the standard hindcast method SWAN 40.20 has been applied with its default numerical and physical settings. In the advanced hindcast the calibrated SWAN 40.20 has been applied. Computational results are compared with measurements and with results of the previous hindcast studies in the form of scatter plots of measured and computed wave parameters and tables of statistical parameters.

The present hindcast study with SWAN 40.20 uses the same measurements, the same time instants, locations and boundary conditions as the previous hindcast studies with SWAN 30.26 and SWAN 40.16. These similarities are also reflected in the choice of tables and figures.

This study has been carried out by G.Ph. van Vledder, F.J.H. Olijslagers and D.P. Hurdle. Quality assurance was carried out by H.J. Steetzel.

Project co-ordination and guidance at RIKZ was performed by A.T.M.M. Kieftenburg, M. Zijlema and J.W. Seijffert.

1.2 Objective

The objective of this study is to perform hindcast studies with SWAN 40.20 for the Westerschelde and the Petten Sea Defence and to compare the results with measurements and with the results of hindcast studies performed with SWAN 30.62 and SWAN 40.16.

The following questions need to be answered:

Q1 Does SWAN 40.20 produce more reliable results than previous SWAN versions in the standard hindcast method?

Q2 Does a better description of input boundary conditions by means of a more advanced hindcast method lead to better results?

Q3 Does the calibrated SWAN 40.20 lead to improved period predictions?

Q4 Are there differences in performance of SWAN 40.20 for the Petten Sea Defence and the Westerschelde?

In view of the overall scope of the project "Period correction SWAN 40.20" the following question is also important:

Q5 Is there still a need to determine correction factors for period measures?

The above questions will be answered in chapter 6 on the basis of the results presented in the Chapters 3, 4 and 5.

1.3 Approach of the study

For the Petten Sea Defence and for the Westerschelde hindcast studies have been performed with SWAN 40.20 using a standard and an advanced hindcast method. The selected time instants and the conditions driving the wave model are the same as those in the previous hindcast studies for the Petten Sea Defence (WL|Delft Hydraulics & Alkyon, 2003) and for the Westerschelde (Gautier, 2003). All data for wind fields, water levels, current fields, bottom topography and wave boundary conditions have been taken from these previous hindcast studies. No changes were made to these data. These data were originally provided by RIKZ.

For the Petten area the following 5 storms are considered:

- January 1st, 1995
- January 2nd, 1995
- January 10th, 1995
- February 23rd, 2002
- October 26-27th, 2002

For the Westerschelde the following 3 storms are considered:

- May 28th, 2000
- December 28th, 2000
- October 26-27th, 2002

It is noted that measured wave data of two of the five time instants of the October 2002 storm have also been for the calibration of SWAN 40.20 (Alkyon, 2003).

In the previous hindcast studies four different types of SWAN computations have been performed. These types are indicated as case 1 through case 4. Case 1 comprised applying SWAN 30.62 with the standard hindcasting method. Case 2 comprised applying

SWAN 30.62 with the advanced approach. The cases 3 and 4 comprised applying SWAN 40.16 with the standard and advanced approach, respectively.

The characteristics of the various cases are summarised as follows:

case	Standard	Advanced
30.62	1	2
40.16	3	4
40.20	5	6

Results of case 1 have been be used to check the reliability of the contents of the database RAND2001. Results of case 2 have been used to determine if a better description of the conditions driving the wave model lead to a better performance of SWAN 30.62. Results of the cases 3 and 4 have been used to determine if SWAN 40.16 gives better results than SWAN 30.62. One of the main differences between these model versions is the option in SWAN 40.16 to compute the source terms for triad and quadruplet interactions simultaneously. It is noted that this option (could only and) was only used in the case 4 computations.

In this study two additional cases are used: case 5 and case 6 corresponding to applying SWAN 40.20 in the standard and advanced hindcast method, respectively. The details of these cases are:

Case 5: SWAN 40.20

This case comprises the use SWAN 40.20 with default numerical and physical settings as specified by the SWAN development team at Delft University of Technology. Similar to the cases 1 and 3, triads and quadruplets are not allowed to be active computed simultaneously. Which of these source terms is active for a certain grid point is determined by the value of the Ursell number. If the Ursell number is lower than 0.1 only the quadruplets are active. If the Ursell number exceeds 0.1, the triads source term is activated and the quadruplet source term is turned off. In case 5 the default convergence criteria of SWAN 30.62 have been used. In addition, the same boundary conditions for winds, water levels, currents and wave boundary conditions are used as for case 3.

Case 6: SWAN 40.20+

This case comprises the use of the calibrated SWAN 40.20, strict convergence criteria and the advanced hindcast method. The calibrated SWAN 40.20 contains different numerical and physical settings than the SWAN 40.20 version used in the case 5 computations. The source terms for triads and quadruplets can be active simultaneously depending on the value of the Ursell number. Apart from differences in SWAN version and the numerical and physical settings from the calibration, case 6 is similar to the cases 2 and 4. In addition, the same boundary conditions for winds, water levels, currents, bottom and wave boundary conditions are used as in case 4.

For the cases 5 and 6 a comparison will be made with measurements, in the form of scatter plots and statistical parameters of integral parameters. The statistical results will also be compared with those obtained in the previous hindcast studies for the Petten Sea Defence and the Westerschelde.

- Results of case 5 are used to draw conclusions whether SWAN 40.20 produces improved results compared to the SWAN versions 30.62 and 40.16 using the same boundary conditions.
- Results of case 6 will lead to conclusions if a calibrated SWAN 40.20 using the advanced hindcast method produces improved results, and to decide if a period correction is needed for this version and hindcast method. It will also give additional validation data for the new numerical and physical settings of the calibrated SWAN 40.20.

1.4 Restrictions to the study

To be able to compare the results to preceding hindcast studies, the graphs and tables in this report will be in the same format as the graphs in WL | Delft Hydraulics & Alkyon (2003) and Gautier (2003) for the Petten Sea Defence and the Westerschelde respectively. Therefore the graphs and tables in this report do not satisfy uniformity standards.

Since this the report is a sequel to the previous reports, it was decided not to repeat the reasoning behind the choice of grids, schematisations, time instants, storms and their conditions. The definition of spectral period measures and statistical parameters is repeated.

1.5 Outline of the report

The structure of this report is as follows. Chapter 2 describes preparatory activities, such as the adaptation of SWAN input files for the hindcast using SWAN 40.20. The chapters 3 and 4 contain results of the hindcasts with SWAN 40.20 for the Petten Sea Defence and the Westerschelde, respectively. Chapter 5 contains a comparison between results obtained with this hindcast study and result obtained with the previous hindcast studies. Conclusions and recommendations are given in chapter 6. In this chapter an answer will be given to the question if period corrections are required.

Figures and Tables appear at three places in this report. Some of them are included in the main body of text. Some are included in an appendix and the remaining ones are given at the end of the references.

2 Set-up of hindcast studies

2.1 Introduction

This chapter gives an overview of the activities carried out to perform the hindcast with SWAN 40.20 for the Petten Sea Defence and the Westerschelde. Since this study is a sequel to the previous hindcast studies, the reasoning behind the choice of grids, treatment of boundary conditions, construction of current fields and water level, and selection of moments in time is not repeated. Only the main aspects are summarised. Detailed information can be found in WL|Delft Hydraulics & Alkyon (2003) and Gautier (2003).

2.2 Description of the Petten hindcasts

2.2.1 Measurement locations

The locations of the measurement stations are shown in the Figures 2.1 and 2.2 (after references). The co-ordinates of these locations, as well as their abbreviations and type of instrument are given in Table 2.1. This table also gives the storms for which these instruments provided data. All measurement sites, except ELD and YMW, are located on a hypothetical line, perpendicular to the coast line near Petten. In the following this line is referred to as the Petten ray.

Name location	code	co-ordinate (x, y in RDM)	Used in	Instrument
Eierlandse Gat	ELD	106514, 587986	Jan 1995, Feb 2002	Wavec buoy
IJmuiden	YMW	65344, 507662	Jan1995, Feb/Oct 2002	Wavec buoy
Meas. Point 1	MP1	98981, 536444	Jan 1995	Dir. Waverider
	011	99003, 535832	Oct 2002	Dir. Waverider
Meas. Point 2	MP2	103000, 533800	Jan 1995	Waverider
	021	102890, 533728	Feb/Oct 2002	Dir. Waverider
Meas. Point 3	MP3	105230, 531990	Jan 1995	Staff gauge
	033	105234, 531985	Feb/Oct 2002	Radar level meter
Meas. Point 5	MP5	105520, 531830	Jan 1995	Dir. Waverider
Meas. Point 6	MP6	105650, 531746	Jan 1995	Capacity wire
	062	105661, 531752	Feb/Oct 2002	Pressure sensor
	063	105661, 531752	Feb/Oct 2002	Radar level meter
Meas. Point 16	161	105377, 531886	Feb 2002	Pressure sensor
	162	105377, 531886	Oct 2002	Pressure Sensor
Meas. Point 17	171	105522, 531817	Feb/Oct 2002	Pressure sensor
	175	105522, 531817	Oct 2002	Pressure sensor
Meas. Point 18	181	105617, 531771	Oct 2002	Pressure sensor

Table 2.1: Characteristics of measurement locations near the Petten Sea Defence.

2.2.2 Boundary conditions

The boundary conditions for driving the SWAN 40.20 model have all been obtained from the previous hindcast study for the Petten Sea Defence (WL|Delft Hydraulics & Alkyon, 2003). No modifications were made to these boundary conditions.

Tidal current and water level data, were initially provided by RIKZ and were obtained by applying the flow model WAQUA. These data were subsequently interpolated to the SWAN computational grids. The wind fields were generated from KNMI measurements at three stations in the vicinity of the Petten ray (viz. the stations YMS, TXH, 064 and MPN). Furthermore, for the computations of case 5 wave spectra that were measured at the stations IJmuiden (YMW) and Eierlandse Gat (ELD) were converted to parametric JONSWAP wave spectra. Finally, the bottom files were updated with recent bottom measurements. All of these modifications were performed in the previous hindcast studies.

2.2.3 Choice of instants of selected storm days

One of the aims of the present hindcast study is to see how the SWAN 40.20 performs under different conditions. Therefore, five different situations have been considered:

1. a situation in which the current direction is opposite to the wind direction;
2. a situation in which the current direction is parallel to the wind direction;
3. a situation in which the wave height is limited by the water depth;
4. a situation in which the wave height is not limited by the water depth;
5. a situation where the spectrum contains a significant amount of low frequency energy.

In WL|Delft Hydraulics & Alkyon (2003) these criteria were used to select the following 21 moments of time:

	instants	wind vs current	Depth-limited	not depth-limited	low-freq. energy
1 January 1995	1:00	135°	MP6	MP1, MP5	MP5, MP6
	2:00	135°	MP6	MP1, MP2, MP5	MP6
	6:40	-45°	MP3, MP6	MP1, MP5	MP5, MP6
	10:00	-45°	MP2, MP3, MP6	MP1, MP5	MP5, MP6
2 January 1995	4:20	135°	MP2, MP3, MP6	MP1, MP5	MP3, MP6
	14:40	135°	MP6	MP1, MP5	MP3, MP5, MP6
	16:40	180°	MP6	MP1, MP5	MP3, MP5, MP6
	21:20	0°	MP6	MP1, MP5	MP5, MP6
10 January 1995	9:20	110°	MP2, MP3, MP6	MP1	MP2, MP3, MP5, MP6
	11:20	110°	MP3, MP6	MP1	MP3, MP5, MP6
	16:20	-90°	MP6	MP1, MP5	MP3, MP5, MP6
	20:20	-90°	MP6	MP1, MP2, MP3, MP5	MP5, MP6
23 February 2002	7:20	-90°	MP2, MP3, MP16, MP6	MP17	MP6
	10:20	90°	MP2, MP3, MP16, MP6	MP17	MP6
	13:20	90°	MP3, MP16, MP6	MP17	MP6
	19:20	-90°	MP2, MP3, MP16, MP6	MP17	MP6
26 October 2002	7:00	90°	MP16, MP6	MP1, MP17	MP18, MP6
27 October 2002	6:00	0°	MP6	MP1, MP2, MP3, MP17	
	11:00	45°	MP16, MP6	MP1, MP17	
	14:20	60°	MP2, MP3, MP16, MP6	MP17	MP18, MP6
	17:00	90°	MP2, MP3, MP16, MP6	MP17	MP18, MP6

Table 2.2: Conditions and active stations at selected instants in 5 storms.

2.2.4 Computational grids and output points

In the present study two sets of computational grids have been used. In the first set the computational grids (N02, K12, and D33) have been used. In this set the outer grid N02 has a resolution of 500 m, the intermediate K-grid a resolution of 100 m and the detailed D grid a resolution of 20 m (see Figure 2.3, after references). In the second set, the detailed 20 m D33 grid was replaced by the detailed 20 m grid E24 (see Figure 2.4, after references). This grid is better centred on the Petten ray. The grids N02, K12 and D33 have been used in the case 5 computations and the grids N02, K12 and E24 have been used in the case 6 computations. Numerical characteristics of the computational grids are given in Table 2.3.

Grid	X_0 (m)	Y_0 (m)	X_{len} (m)	Y_{len} (m)	α (°)	M_x	M_y	Δx (m)	Δy (m)
N02	81,500	450,000	155,000	40,000	66	310	80	500	500
K12	105,521	511,382	40,000	22,000	70	400	220	100	100
D33	105,500	525,000	9,000	4,000	82	450	200	20	20
E24	105,500	529,000	7,000	4,500	74	350	225	20	20

Table 2.3: Names and numerical characteristics of computational grids.

The SWAN output points are identical to the locations of all measurement sites. This includes the locations were the boundary conditions are specified (ELD and YMW) and the measurement locations in the Petten ray. Their co-ordinates are given in Table 2.1.

2.3 Description of the Westerschelde hindcasts

2.3.1 Measurement locations

In this study the same measurement locations have been used as in the previous hindcast for the Westerschelde (Gautier, 2003). The locations of these measurement locations are shown in the Figures 2.5 and 2.6. The co-ordinates of these locations, as well as their codes and type of measurement instrument are given in Table 2.4. The locations are shown in the Figures 2.5 and 2.6 (given in the text).

Nr.	Code	Name	X [m]	Y [m]	Instrument
1	EUW	Europlatform	9963	447601	Dir wave rider
2	LEG	Lichteiland Goeree	36779	438793	Radar
3	SWB	Schouwenbank	11244	419519	wave rider
4	DRL	Deurloo	6071	392601	wave rider
5	SCW	Scheur West	-7797	380645	wave rider
6	SCO	Scheur Oost	9915	381366	Wave rider
7	WIE	Wielingen	17667	383867	Wave rider
8	CDD	Cadzand diep	14426	379500	Dir wave rider
9	CDZ	Cadzand ondiep	15210	378670	Stappenbaak
10	HFP	Hoofdplaat diep	35636	377877	Stappenbaak
11	HF1	Hoofdplaat ondiep	35641	377534	Stappenbaak
12	HSR/W	Hansweert diep	58395	384989	Radar/stappenbaak
13	HS1	Hansweert ondiep	58659	384982	Stappenbaak
14	BA1	Bath ondiep	73084	379591	Stappenbaak
15	BAT	Bath diep	73098	379510	Stappenbaak
16	PVT	Pas van Terneuzen	45040	374771	Wave rider
17	WCT	WS Container Terminal	38268	383383	Wave rider

Table 2.4: Characteristics of measurement locations in the Westerschelde.

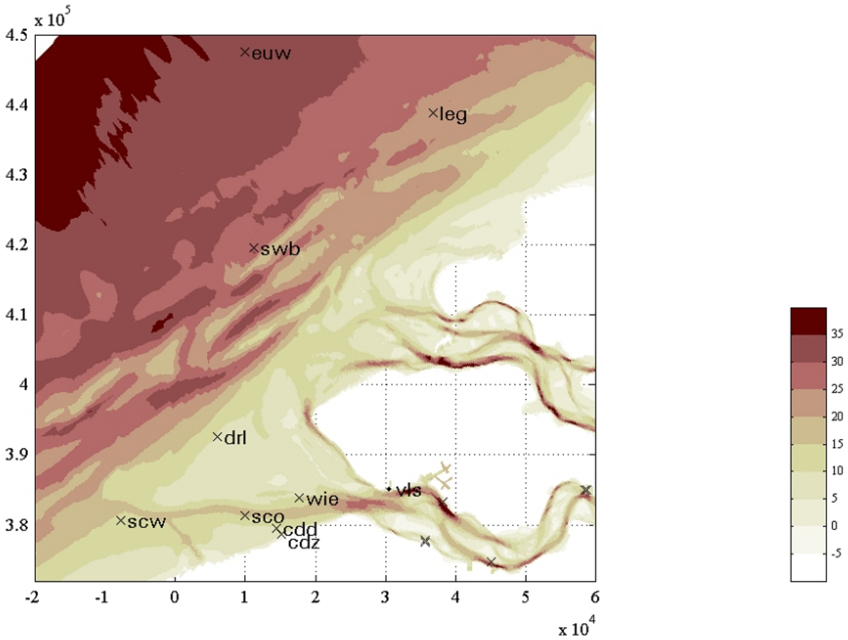


Figure 2.5: Locations of measurement stations in the North Sea and mouth of the Westerschelde (source: Gautier 2003).

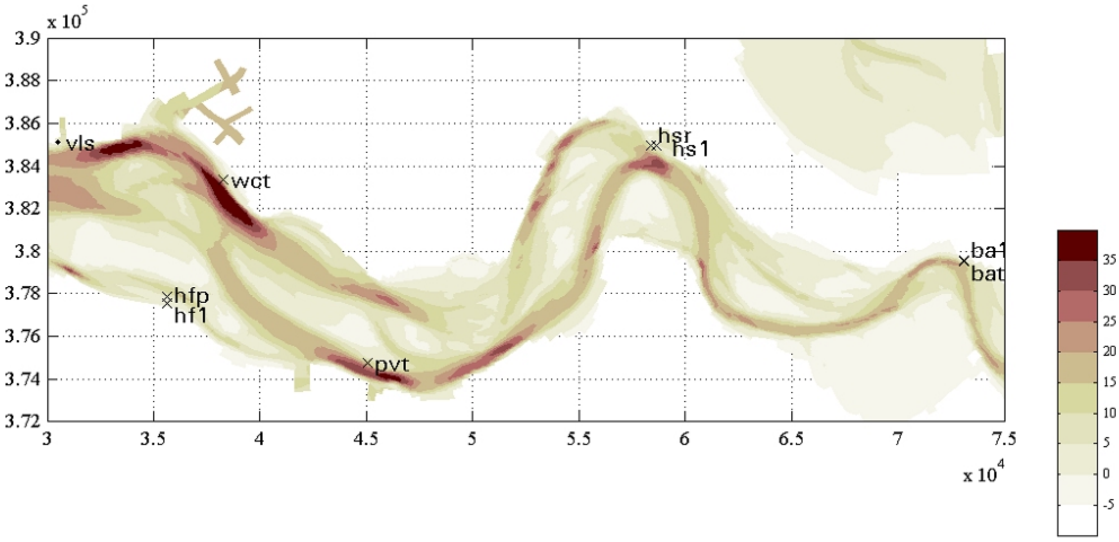


Figure 2.6: Locations of measurement stations in the Westerschelde (source: Gautier 2003).

2.3.2 Boundary conditions

The boundary conditions for driving the SWAN 40.20 model have all been obtained from the previous hindcast study for the Westerschelde (Gautier, 2003). No modifications were made to these boundary conditions. The wave boundary conditions are based on the measured spectra at station ELD.

Tidal current and water level data, were initially provided by RIKZ who applied the flow model WAQUA. These results were provided on curvi-linear grids and were interpolated to the rectangular computational grids of SWAN. The wind fields were generated from KNMI measurements at station Vlissingen located at the entrance of the Westerschelde.

Furthermore, for the computations of case 5 wave spectra that were measured at stations Euro platform (EUW) were converted to parametric JONSWAP wave spectra Finally, the bottom files were updated with more recent measurements in the vicinity of the measurement locations.

The SWAN computations for case 5 have been carried out with a constant water level. This is a crude assumption since in reality water level differences can be significant (up to 2 m) in the Westerschelde for a given instant in time. Therefore two computations have been carried out for each selected condition. The first set "a" uses the lowest water level measured in either one of the stations Bath, Cadzand, Hansweert and Vlissingen. The second set "b" uses the highest measured water level in either one of these stations.

The actual wave parameters have been computed by linear interpolation (or extrapolation, when necessary) for the actual water level in the point considered and based on the wave parameters as computed in the "a" and "b" computations. In Gautier (2003) it is noted that the actual measured water level may deviate from the water level computed by the WAQUA model.

2.3.3 Computational grids and output points

The SWAN 40.20 computations have been performed with a series of nested rectangular grids. For the North Sea grid N01 with a spatial resolution of 500 m has been used. In the Westerschelde three nested grids (W01, W02 and W03) with a spatial resolution of 100 m have been used. Around the measurement locations, detailed grids with a spatial resolution of 20 m have been used (D01 through D09, and R02). The detailed grids contain one or more measurement locations.

An overview of these computational grids together with the bottom topography is given in Figure 2.7 (given in the text).

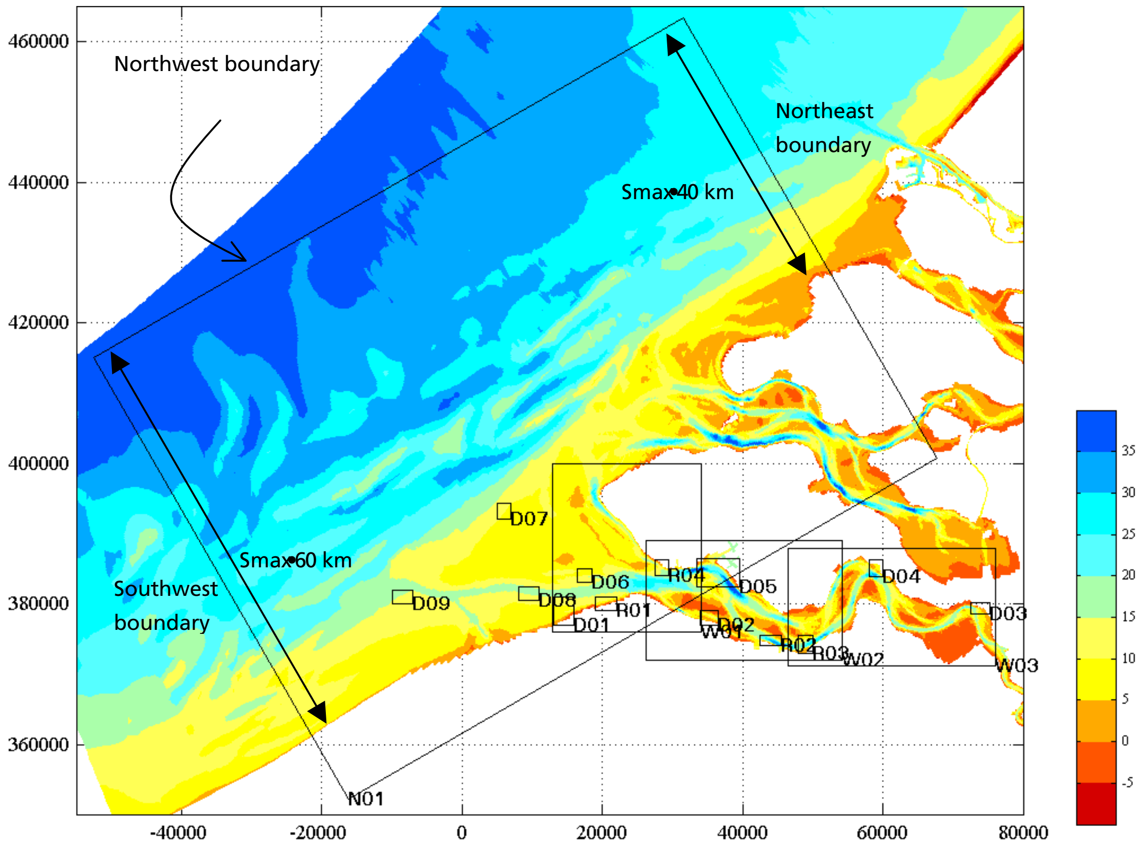


Figure 2.7: Computational grids in the Westerschelde and bottom topography (depth in meter w.r.t. NAP). (source: Gautier 2003).

The numerical characteristics of these grids are given in Table 2.5.

Grid	X0 [m]	Y0 [m]	Lx [m]	Ly [m]	α[°]	dx [m]	dy [m]
N01	-52,500	415,000	72,500	97,000	300	500	500
W01	12,900	376,000	21,200	24,000	0	100	100
W02	26,200	372,000	28,000	17,000	0	100	100
W03	46,500	371,200	29,500	16,700	0	100	100
D01	13,000	377,000	30,00	4,000	0	20	20
D02	34,000	377,000	2,500	2,000	0	20	20
D03	72,500	378,500	2,700	1,700	0	20	20
D04	58,000	383,800	2,000	2,500	0	20	20
D05	33,500	382,500	6,000	4,000	0	20	20
D06	16,500	383,000	2,000	2,000	0	20	20
D07	5,000	392,000	2,000	2,300	0	20	20
D08	8,000	380,000	3,000	2,000	0	20	20
D09	-10,000	380,000	3,000	2,000	0	20	20
R02	42,500	374,000	3,000	1,500	0	20	20

Table 2.5: Numerical characteristics of SWAN computational grids in the Westerschelde.

2.3.4 Choice of instants of selected storm days

One of the aims of the present hindcast study is to see how the SWAN 40.20 model performs under different conditions. To do so, the same five different situations as in Gautier (2003) are considered:

A. a situation in which the wave field is strongly affected by an ebb current, often the current direction is opposite to the wind direction;
B. a situation in which the wave field is strongly affected by a flood current, often the current direction is parallel to the wind direction;
C. a situation in which the wave height is limited by the water depth, using the criterion $H_{m0}/d>0.3$;
D. a situation in which the wave height is not limited by the water depth, using the criterion $H_{m0}/d<0.3$;
E. a situation where the spectrum is clearly bi-modal with a swell dominated peak and a local wind sea peak.

Gautier (2003) applied these criteria to select time instants in the storms of May 28th, 2000, December 28th, 2001 and October 27th, 2002. For each storm 5 instants in time were selected which were satisfied above criteria and for which sufficient measurement are available. Gautier (2003) noted that situation E did rarely happen. The selected moment in time for the Westerschelde hindcast are given in Table 2.6.

Storm	Time	Date	Time [CET]	H_{m0} [m] EUW	Tp [s] EUW	dir [naut] EUW	wind [m/s] Vlis. +0.5m/s	wind [naut] Vlis.	min. water-level [m NAP]	max. water-level [m NAP]
A	t1	28 May 2000	8:00	2.33	5.60	145	14.70	200	0.24	1.35
A	t2	28 May 2000	10:00	3.08	7.10	188	18.90	220	1.91	2.44
A	t3	28 May 2000	12:30	4.29	7.70	231	19.75	245	1.01	2.54
A	t4	28 May 2000	14:00	4.52	8.30	258	20.60	270	0.23	1.48
A	t5	28 May 2000	16:40	4.23	8.30	282	13.57	253	-0.67	-0.46
B	t1	28 Dec 2001	10:00	3.14	7.70	245	16.40	250	-0.42	0.37
B	t2	28 Dec 2001	13:00	4.17	7.70	271	12.70	280	2.07	3.21
B	t3	28 Dec 2001	15:00	4.40	8.10	276	15.30	270	1.07	2.78
B	t4	28 Dec 2001	17:00	4.45	8.30	283	13.60	270	-0.25	1.03
B	t5	28 dec 2001	19:00	4.33	8.30	292	11.20	290	-0.62	-0.36
C	t1	27 Oct 2002	8:20	3.72	7.70	234	14.40	233	0.08	1.35
C	t2	27 Oct 2002	12:00	5.13	9.10	236	21.40	240	-0.64	-0.56
C	t3	27 Oct 2002	14:40	6.33	9.10	241	22.77	256	0.83	1.25
C	t4	27 Oct 2002	17:20	5.67	8.30	258	19.10	273	2.39	3.30
C	t5	27 Oct 2002	19:40	5.87	9.10	295	16.50	290	1.78	3.47

Table 2.6: Summary of selected moments in time and measured wave height, wave period, wind and water levels in the Westerschelde.

2.4 Numerical and physical settings

The numerical and physical settings of SWAN 40.20 for case 5 are the same as for the cases 1 and 3 in the previous hindcast studies. The corresponding SWAN commands are given by:

```
GEN3 KOMEN
BREAK 1 0.73
FRIC JONSWAP
TRIAD
NUM ACCUR 0.03 0.03 0.3 97 30
```

The physical settings corresponds to the following SWAN commands for the parameter values of whitecapping dissipation, quadruplet interactions and surf breaking:

```
GEN3 KOMEN CDS2=2.36E-5
QUAD LAMBDA=0.25 CNL4=3E7
BREAK CON ALPHA=1.0 GAMMA=0.73
TRIAD URSLIM=0.1
LIM URSELL=0.1   QB=1.E-5
```

Based on the results of the calibration of SWAN 40.20 (Alkyon, 2003) the following SWAN commands for the physical and numerical settings have been applied in the case 6 computations:

```
GEN3 KOMEN CDS2=1.36E-5
QUAD LAMBDA=0.28 CNL4=4E7
BREAK CON ALPHA=1.0 GAMMA=0.9
TRIAD URSLIM=0.01
LIM URSELL=10   QB=1.0
NUM ACCUR 0.01 0.01 0.01 99 STAT MXITSTS=[mxitst]
```

The maximum number of iterations was set to [mxitst]=25 for the Petten hindcast and [mxitst]=35 for the Westerschelde hindcast. These numbers are based on the results of the sensitivity studies performed in the SWAN calibration project (Alkyon, 2003).

A summary of the SWAN settings for the cases 5 and 6 is given in Table 2.7.

Parameter	SWAN 40.20	SWAN 40.20+
CDS2	2.36E-5	1.36E-5
LAMBDA	0.25	0.28
CNL4	3E7	4E7
ALPHA	1.0	1.0
GAMMA	0.73	0.90
URSLIM	0.1	0.01
URSELL	0.1	10
QB	1E-5	1
DREL	0.03	0.01
DHABS, DHOVAL	0.03	0.01
DTABS, DTOVAL	0.3	0.01
NPNTS	97	99
MXITST (Petten)	15	25
MXITST (Westerschelde)	30	35

Table 2.7: Summary of numerical and physical settings for the SWAN 40.20 computations.

2.5 Modifications to SWAN 40.20 input files

The SWAN 40.20 input and output files are based on the SWAN 40.16 input files. Due to small differences in the treatment of the input files, SWAN 40.20 could not directly use them. For case 5 a few changes were needed whereas for case 6 in addition to case 5 different physical and numerical settings needed to be specified.

The following modifications were made to the input files:

1. All strings “case3” were replaced by the string “case5”
2. All strings “case4” were replaced by the string “case6”
3. For case 6 the command “GEN3 KOMEN” was replaced by the following two commands:
   GEN3 KOMEN CDS2=1.36E-5
   QUAD LAMBDA=0.28 CNL4=4E7
4. The command “TRIAD URSELL=0.01” was replaced with the command:
   “TRIAD URSLIM=[urslim]”. For case 5 [urslim]= 0.1 and for case 6 [urslim]=0.01.
5. The command “LIM URSELL=10 Qb=1 iter=100” was replaced by the command:
   “LIM URSELL=[ursell] qb=[qb]. For case 5 [ursell]=0.1 and [qb]=0.00001, and for case 6 [ursell]=10 and [qb]=1.0.
6. For case 6 the command “BREAK 1 0.73” was replaced by the command:
   “BREAK CON ALPHA=1.0 GAMMA=0.9”
7. The command “NUM SIGIMPL EPS1=0.” was added to avoid problems in computations with currents in the Westerschelde runs. The need for adding this command arose during the test phase of the calibration of SWAN 40.20 (Alkyon, 2003). It is probably related to subtle changes in numerics in SWAN 40.20 with respect to SWAN 40.16.
8. To generate block output in rectangular format, and to increase the number decimals in table and spectral output, the following command was added:
   OUTPUT OPTIONS ''!'' TABLE 16 BLOCK 6 1000 SPEC 4
   The “!” symbols is the comment symbol in the header lines of tables. The number 16 is the maximum number of columns in the tables. The number 6 is the number of

decimals in the block files and the number 1000 is the maximum number of data values on a row in the block files.
9. For case 6 the command "NUM ACCUR 0.03 0.03 0.3 97 30…" was replaced by: "NUM ACCUR 0.01 0.01 0.01 99 STAT MXITSTS=[mxitst]" with [mxitst]=25 for the Petten computations and [mxitst]=35 for the Westerschelde.
10. For the Westerschelde computations, the path to various files was simplified.

No modifications were made in the boundary files for bottom, wind, currents, water levels and wave boundary conditions because SWAN 40.20 could directly use them.

2.6 Output parameters

Output of the SWAN 40.20 computations consists of block files of integral wave parameters, 1D and 2D wave spectra and integral wave parameters. The following integral wave parameters have been computed on the basis of the 1D frequency spectra:

- the significant wave height H_{m0},
- the mean wave periods $T_{m0,1}$, $T_{m0,2}$ and $T_{m-1,0}$,
- the peak period T_p,
- the block peak period T_{pb},
- the equivalent block peak period T_{pbeq}, and
- the mean peak period T_{pm}.

The definition of these parameters is given in Appendix A of this report. The spectral moments that are required to determine the significant wave height and the mean wave periods are determined by integrating over the finite frequency domain with f_{low}=0.03 Hz and f_{high} =0.5 Hz. This range was applied to both the measured and computed wave spectra.

This range was also applied in the previous hindcast studies, and therefore no changes were made to these limits. The lower limit corresponds to the lowest model frequency in the SWAN computations. The upper limit was chosen in view of the fact that the spectra contain only a small amount of energy above this frequency. Therefore it hardly affects the estimates of the mean wave period $T_{m-1,0}$. It also leads to more stable parameter estimates for the mean wave periods $T_{m0,1}$ and $T_{m0,2}$.

2.7 Statistical parameters

The following statistical parameters have been used to quantify the performance of SWAN 40.20 near the Petten Sea Defence and in the Westerschelde:

BIAS bias.
MAE mean absolute error.
RMSE root mean square error.
SCI scatter index (-).
MPI model performance index (-).
OPI operational performance index (-).
STD standard deviation.
The definitions of these statistical parameters are given in Appendix B of this report.

For assessing the performance of SWAN the measures for the bias and standard deviation are transformed into relative measures. This is achieved by dividing them by the mean of the measured value. The tables in Appendix D for Petten contain absolute values. All other tables of statistical parameters in the text of this report and in Appendix G contain relative values.

An important aspect in the statistical analysis is the interpretation of the differences in bias and standard deviation between various model applications (viz. the cases 1 through 6). Prediction errors by SWAN are the result of an incomplete modelling of the (real) physics. Such errors can be distinguished in systematic and non-systematic errors. In general systematic errors can be quantified in terms of the bias, whereas non-systematic errors can be quantified in terms of the standard deviation. Systematic errors can relatively easy be remedied by calibration. Reducing non-systematic errors requires fundamental improvements in the conditions driving the wave model and/or the parameterisations of the physics, viz. the source terms.

2.8 Scatter diagrams

The scatter diagrams show a direct comparison of measured and computed wave parameters. For both areas the computed values are given along the x-axis, whereas the measured values are given along the y-axis. For both areas best-fit lines have been computed and shown in the scatter diagrams together with their numerical values.

For the Petten Sea Defence best fit lines of the model $y=bx$ have been computed using a least square analysis of available data. In applying this model, the x-data correspond to the computed values and the y-data correspond to the measured data. A value of $b=1$ refers to a zero bias. A value of $b>1$ corresponds to an under-prediction, whereas a value of $b<1$ corresponds to an over-prediction of parameter values.

For the Westerschelde best-fit lines have been computed for the models $y=bx+a$ and $y=bx$. In line with Gautier (2003), but in contrast to WL|Delft Hydraulics & Alkyon (2003), the x-values correspond to the measured data values which are given along the y-axis, and the y-values correspond to the computed data values which are given along the x-axis. This implies that a value of $b>1$ corresponds to an over-prediction, whereas a value of $b<1$ corresponds to an under-prediction.

3 Results of the Petten hindcast

3.1 Introduction

This Chapter describes the results of the hindcast of 5 storms for the Petten Sea Defence with SWAN 40.20. The results of the SWAN 40.20 computations are compared with measurements in the form of scatter diagrams and tables with scores of statistical parameters of integral wave parameters.

Scores are given for:
1. Each individual instant.
2. Each storm (i.e., averaged over all selected time instants within one storm).
3. Each physical condition (i.e., ebb current, flood current, wave height limited by the depth, wave height not limited by the depth and spectra with a significant amount of energy in the lower frequencies).
4. Each location (i.e., MP1, MP2, MP3, MP5, MP6, MP16 and MP17).
5. All cases together (i.e. at all locations and at all instants).

In conformity with WL|Delft Hydraulics & Alkyon (2003) location MP18 is not used in the analysis. During the execution of this study doubts were raised about the quality of the results for measurement location MP17. Therefore, results of this station are not included in the tables in which results of various stations are combined, but they are shown in the tables showing the scores per station. It is noted here that instrument 175 at location MP17 was included in the calibration of SWAN 40.20 (Alkyon, 2003).

3.2 Selected data for statistical analysis

The various cases for which a statistical analysis has been made are coded by means of case names.

Case names corresponding to individual instants have the format: F**de**pet**nm**. The character F has no meaning. The two characters **de** are either ‘1a’, ‘1b’, ‘2a’, ‘2b’ or ‘3a’. They indicate a specific storm day (1a: 1 January 1995; 1b: 2 January 1995; 2a: 10 January 1995; 2b: 23 February 2002; 3a: 26/27 October 2002). The last two digits **nm** in the case names denote the sequence number of the selected time instant in that storm day. The cases are described in Table 3.1.

Case names corresponding to a certain storm or physical condition have the format S**nmpqr**01. The characters **nm** run from 01 to 17. The characters **pqr** refer to the type of condition: storm days (‘str’), locations (‘loc’) or physical processes (‘opp’, ’par’, ‘dep’, ‘nde’ and ‘dbl’). The characters “S” and “01” have no meaning. The cases for individual time instants are not mentioned in Table 3.1, but they are given in the tables in Appendix D.

Casename	Simulation date and time	Locations
S01opp01	1995/01/01 01:00, 02:00	MP1, MP2, MP3, MP5, MP6
(opposing cur)	1995/01/02 04:20, 16:40	MP1, MP2, MP3, MP5, MP6
S02par01	1995/01/01 06:40	MP1, MP2, MP3, MP5, MP6
(following	1995/01/01 10:00	MP1, MP3, MP5, MP6
current)	1995/01/02 21:20	MP1, MP2, MP3, MP5, MP6
	2002/10/27 06:00	MP1, MP2, MP3, MP17, MP6
	2002/10/27 11:00	MP1, MP2, MP3, MP16, MP17
S03dep01	1995/01/01 01:00, 02:00	MP6
(depth limited)	1995/01/01 06:40	MP3, MP6
	1995/01/01 10:00	MP2, MP3, MP6
	1995/01/02 04:20	MP2, MP3, MP6
	1995/01/02 14:40, 16:40, 21:20	MP6
	1995/01/10 09:20	MP2, MP3, MP6
	1995/01/10 11:20	MP3, MP6
	1995/01/10 16:20, 20:20	MP6
	2002/02/23 07:20, 10:20, 19:20	MP2, MP3, MP16, MP6
	2002/02/23 13:20	MP3, MP16, MP6
	2002/10/26 07:00	MP16, MP6
	2002/10/27 06:00	MP6
	2002/10/27 11:00	MP16, MP6
	2002/10/27 14:20	MP2, MP3, MP16, MP6
	2002/10/27 17:00	MP2, MP3, MP16, MP6
S04nde01	1995/01/01 01:00, 06:40, 10:00	MP1, MP5
(not depth	1995/01/01 02:00	MP1, MP2, MP5
limited)	1995/01/02 04:20, 14:40, 16:40, 21:20	MP1, MP5
	1995/01/10 09:20, 11:20	MP1
	1995/01/10 16:20	MP1, MP5
	1995/01/10 20:20	MP1, MP2, MP3, MP5
	2002/02/23 07:20, 10:20, 13:20, 19:20	MP17
	2002/10/26 07:00	MP1, MP17
	2002/10/27 06:00	MP1, MP2, MP3, MP17
	2002/10/27 11:00	MP1, MP17
	2002/10/27 14:20, 17:00	MP17
S05dbl01	1995/01/01 01:00, 06:40, 10:00	MP5, MP6
(low freq.	1995/01/01 02:00	MP6
energy)	1995/01/02 04:20	MP3, MP6
	1995/01/02 14:40, 16:40	MP3, MP5, MP6
	1995/01/02 21:20	MP5, MP6
	1995/01/10 09:20	MP2, MP3, MP5, MP6
	1995/01/10 11:20, 16:20	MP3, MP5, MP6
	1995/01/10 20:20	MP5, MP6
	2002/02/23 07:20, 10:20, 13:20, 19:20	MP6
	2002/10/26 07:00	MP6
	2002/10/27 14:20, 17:00	MP6
S06loc01	All 12 instants in 1995	MP1
(MP1)	2002/10/26 07:00	011
	2002/10/27 06:00, 11:00	011
S07loc01	11 instants in 1995 (excl. 1995/01/01	MP2
(MP2)	10:00)	
	All 9 instants in 2002	021
S08loc01	All 12 instants in 1995	MP3
(MP3)	2002/02/23 07:20, 10:20, 13:20, 19:20	031
	2002/10/26 07:00	033

	2002/10/27 06:00,11:00, 14:20, 17:00	033
S09loc01 (MP16)	2002/02/23 07:20, 10:20, 13:20, 19:20 2002/10/26 07:00 2002/10/27 11:00, 14:20, 17:00	161 162 162
S10loc01 (MP17)	2002/02/23 10:20, 13:20, 19:20 2002/10/26 07:00 2002/10/27 06:00, 11:00, 14:20, 17:00	171 175 175
S11loc01 (MP5)	All 12 instants in 1995	MP5
S12loc01 (MP6)	All 12 instants in 1995 2002/02/23 07:20, 10:20, 13:20, 19:20 2002/10/26 07:00 2002/10/27 06:00, 14:20, 17:00	MP6 062 062 062
S13str01	1995/01/01 01:00, 02:00, 06:40 1995/01/01 10:00	MP1, MP2, MP3, MP5, MP6 MP1, MP3, MP5, MP6
S14str01	1995/01/02 04:20, 14:40, 16:40, 21:20	MP1, MP2, MP3, MP5, MP6
S15str01	1995/01/10 09:20, 11:20, 16:20, 20:20	MP1, MP2, MP3, MP5, MP6
S16str01	2002/02/23 07:20 2002/02/23 10:20, 13:20, 19:20	MP2, MP3, MP16, MP6 MP2, MP3, MP16, MP17, MP6
S17str01	2002/10/26 07:00 2002/10/27 06:00 2002/10/27 11:00 2002/10/27 14:20, 17:00	MP1, MP2, MP3, MP16, MP17, MP6 MP1, MP2, MP3, MP17, MP6 MP1, MP2, MP3, MP16, MP17 MP2, MP3, MP16, MP17, MP6

Table 3.1a: Summary of cases considered in the analysis for the Petten hindcast (source: WL|Delft Hydraulics & Alkyon, 2003).

E.g., for case S14str01 the measured and computed wave conditions are compared at four instants in the storm of January 2nd, 1995 at five locations, resulting in 20 comparisons. For case S05dbl01 we end up with 36 comparisons. Case S11loc01 denotes measuring point 16 (MP16).

In this study doubts have been raised about the usability of station 175. As a consequence results of this station have been omitted from the analysis of the different situations considered in section 3.1, but also for the comparison with the results for the cases 1 through 4 of the previous hindcast in chapter 5. Still, statistics of station 175 for all available instants of time are included in the tables showing the performance of SWAN 40.20 per measurement location.

3.3 Scatter plots and statistical information

Scatter plots showing a comparison of the SWAN 40.20 computations for the cases 5 and 6 with measurements are presented in Appendix C. The scatter diagrams can be used to assess the performance of SWAN 40.20 in a glance.

Plots are given for the following cases: S01opp01, S02par01, S03dep01, S04nde01, S05dbl01 (distinction per physical process) and S06loc01, S07loc01, S08loc01, S09loc01, S11loc01, S12loc01 (distinction per location) and S13str01, S14str01, S15str01, S16str01, S17str01 (distinction per storm period). Note that case S10loc01 (MP17) has been left out.

For each case a figure is presented consisting of four subplots. Each subplot contains results of the computations for the cases 5 and 6 (SWAN 40.20 and 40.20+). The results for the cases 5 and 6 are indicated with red and blue markers, respectively. Scatter diagrams are given for the parameters H_{m0}, $T_{m0,1}$, $T_{m0,2}$ and $T_{m-1,0}$. Each scatter diagram contains 3 lines. The black line indicates a perfect agreement and can be used as a reference. The red and the blue line are the best-fit lines of the statistical model *y=bx* for the cases 5 and 6, respectively. The coefficient *b* of this model has been obtained by a least square regression analysis. The resulting coefficients are shown in the upper left corner of the scatter plots.

The statistical parameters for all cases mentioned in Table 3.1 are given in Appendix D. Results are presented for spectral wave parameters H_{m0}, $T_{m0,1}$, $T_{m0,2}$, $T_{m-1,0}$, T_p, T_{pb}, T_{pbeq}, and the mean peak period T_{pm} . For each parameter 2 columns are given with results for the two cases 40.20 and 40.20+. It is noted that the peak period measure T_p is very sensitive to fluctuations in the (measured) spectra. Therefore, in the analysis the emphasis is on the spectral mean wave period measures.

The scatter plots and statistical parameters provide useful information about the performance of SWAN 40.20 and the performance of the calibrated SWAN 40.20 using the advanced wave hindcast. The performance of the two cases will be discussed for each spectral wave parameter H_{m0}, $T_{m0,1}$, $T_{m0,2}$,$T_{m-1,0}$, and T_{pm}. A comparison of the results of the cases 5 and 6 with those of the cases 1 to 4 will be presented in Chapter 5.

3.4 Tables with statistical information

The scores presented in Appendix D are given in terms of absolute values. To better judge the performance of SWAN 40.20 tables are presented of the relative bias and standard deviation of the parameters H_{m0}, $T_{m0,1}$, $T_{m0,2}$, $T_{m-1,0}$ and T_{pm}, See the Tables 3.2a through 3.4e.

The Tables 3.2a through 3.2e contain the scores per measurement location and include results for all time instants and all conditions. The Tables 3.3a through 3.3e contain the scores per storm and include the results for all conditions and all measurement locations, except MP17. The Tables 3.4a through 3.4e contain the scores per condition and include the results for all time instants and all measurement locations, except MP17.

The tables 'a' contain results for the parameter H_{m0}, 'b' for $T_{m0,1}$, 'c' for $T_{m0,2}$, 'd' for $T_{m-1,0}$ and 'e' for T_{pm}.

The number of data points per storm, location and condition is summarised in Table 3.1b.

Storm	#points	Location	#points	Condition	#points
1 Jan. 1995	20	MP1	15	Opposing	20
2 Jan. 1995	20	MP2	20	Following	23
10 Jan, 1995	20	MP3	21	Depth-lim.	46
23 Feb. 2002	16	MP16	8	No depth-lim.	30
27 Oct. 2002	21	MP5	12	Low freq.	35
		MP6	20		

Table 3.1b: Number of data points per storm, location and condition for the Petten measurements. Total number of points is 97.

The "total" scores are obtained by considering all available data points for all selected moments in time and all selected locations. These data points are considered once even if belong to various overlapping subgroups. The total scores are given as a reference. In this study some 'total' relative standard deviations are larger than maximum individual relative standard deviations. At first sight this may seem strange, but a simple explanation of this behaviour is given in Appendix H of this report.

In the discussion of differences of the performance of SWAN 40.20 for case 6 with respect to case 5 an improvement in the (relative) bias refers to a decrease of the absolute value of this difference. For example, a change in the relative bias from –10% to +9% is considered as an improvement. Similarly, an improvement in the relative standard deviation refers to a decrease. Moreover, an increase in the relative bias simply refers to a higher mean of the predicted values of a parameter compared to the mean of the measured values.

H_{m0}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
MP1	-2.9	0.2	23.4	17.3
MP2	-4.5	3.2	16.5	18.9
MP3	-6.0	0.0	17.1	10.5
MP16	-8.8	13.3	4.8	7.7
MP17	*20.2*	*50.0*	*19.9*	*14.5*
MP5	-7.9	14.0	12.8	11.8
MP6	-25.1	15.3	9.0	12.3
Total	-8.5	4.8	17.9	16.1

Table 3.2a: Relative bias and standard deviation of the significant wave height H_{m0} at all locations and all time instants. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m0,1}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
MP1	-0.5	-6.2	15.4	7.1
MP2	-13.8	-8.6	12.9	7.8
MP3	2.2	8.3	10.6	7.7
MP16	2.8	10.0	5.3	7.3
MP17	*-19.2*	*-9.4*	*9.4*	*5.6*
MP5	4.4	1.6	18.1	6.1
MP6	11.1	18.8	14.4	11.8
Total	0.0	3.0	15.7	13.0

Table 3.2b: Relative bias and standard deviation of the mean wave period $T_{m0,1}$ at all locations and for all time instants. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m0,2}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
MP1	-0.9	-8.3	13.5	8.9
MP2	-24.2	-12.4	16.1	9.0
MP3	-1.0	11.2	12.6	8.6
MP16	4.9	12.2	7.3	10.7
MP17	*-32.6*	*-17.5*	*12.1*	*5.4*
MP5	-0.8	1.1	25.7	6.4
MP6	23.2	30.3	19.0	16.8
Total	-1.5	4.4	22.5	18.0

Table 3.2c: Relative bias and standard deviation of the mean wave period $T_{m0,2}$ at all locations and for all time instants. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m-1,0}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
MP1	0.1	-2.3	13.9	5.8
MP2	-6.7	-4.7	11.7	6.9
MP3	0.2	3.9	8.8	5.7
MP16	-1.9	6.1	4.1	4.9
MP17	*-11.5*	*-2.9*	*6.5*	*6.0*
MP5	1.6	0.5	11.9	5.6
MP6	-7.7	0.2	9.2	8.6
Total	-3.3	-0.4	11.3	8.3

Table 3.2d: Relative bias and standard deviation of mean wave period $T_{m-1,0}$ at all locations and for all time instants. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

T_{pm}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
MP1	4.5	-0.4	11.0	6.3
MP2	0.4	-3.6	12.5	11.2
MP3	3.0	-3.6	7.5	7.4
MP16	-0.5	-0.2	6.9	5.4
MP17	*4.3*	*2.6*	*11.5*	*9.8*
MP5	5.9	-5.4	8.1	8.9
MP6	-18.7	-21.0	19.1	18.3
Total	-3.6	-8.4	18.7	17.9

Table 3.2e: Relative bias and standard deviation of mean peak period T_{pm} at all locations and for all time instants. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

H_{m0}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
1995/01/01	-4.0	7.1	20.2	14.4
1995/01/02	-23.0	-4.5	20.0	17.5
1995/01/10	0.6	-0.6	15.4	12.9
2002/02/23	-7.0	2.5	10.9	10.6
2002/10/27	-7.3	17.9	12.8	13.4
Total	-8.5	4.8	17.9	16.1

Table 3.3a: Relative bias and standard deviation of the significant wave height H_{m0} for all storm days. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m0,1}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
1995/01/01	2.4	-0.6	9.7	8.9
1995/01/02	-11.1	-0.7	17.3	14.7
1995/01/10	12.4	4.4	18.0	13.3
2002/02/23	-0.1	5.6	10.4	15.4
2002/10/27	-2.5	7.0	7.3	10.0
Total	0.0	3.0	15.7	13.0

Table 3.3b: Relative bias and standard deviation of mean wave period $T_{m0,1}$ for all storm days. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m0,2}$	relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
1995/01/01	2.4	-0.7	15.0	11.8
1995/01/02	-15.4	-0.4	24.5	17.9
1995/01/10	8.6	5.5	29.4	18.3
2002/02/23	0.7	8.4	19.4	23.6
2002/10/27	-1.8	9.8	11.5	15.7
Total	-1.5	4.4	22.5	18.0

Table 3.3c: Relative bias and standard deviation of the mean wave period $T_{m0,2}$ for all storm days. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

$T_{m-1,0}$	relative bias		relative standard deviation	
	40.20	40.20+	40.20	40.20+
1995/01/01	-3.0	-3.7	10.6	10.7
1995/01/02	-10.9	-2.9	8.9	8.4
1995/01/10	7.7	0.3	11.9	7.0
2002/02/23	-4.5	2.2	6.8	7.5
2002/10/27	-5.7	2.8	6.3	5.8
Total	-3.3	-0.4	11.4	8.3

Table 3.3d: Relative bias and standard deviation of the mean wave period $T_{m-1,0}$ for all storm days. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

T_{pm}	Relative bias		relative standard deviation	
	40.20	40.20+	40.20	40.20+
1995/01/01	-6.8	-12.0	26.6	28.1
1995/01/02	-8.2	-11.6	17.9	16.2
1995/01/10	5.1	-9.8	17.4	15.1
2002/02/23	-2.6	-4.4	15.0	13.5
2002/10/27	-5.7	-2.4	9.8	10.2
Total	-3.6	-8.4	18.7	17.9

Table 3.3e: Relative bias and standard deviation of the mean peak period T_{pm} for all storm days. (Results of MP17 are not used for the computation of the total scores, and total scores are included as a reference.)

H_{m0}	relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
Opposing current	-13.2	2.1	22.8	15.5
Following current	-13.3	6.2	20.6	17.9
Depth-limitation	-10.8	5.8	11.7	13.7
No depth-limitation	-3.2	5.4	25.0	17.6
low-freq. energy	-15.3	8.9	14.1	13.3
Total	-8.5	4.8	17.9	16.1

Table 3.4a: Relative bias and standard deviation of the significant wave height H_{m0} for all types of conditions (total scores are included as a reference).

$T_{m0,1}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
opposing current	-8.0	-1.1	18.5	13.0
following current	-0.4	3.3	10.5	9.3
depth-limitation	2.7	8.9	13.7	13.1
no depth-limitation	1.2	-1.8	16.2	9.7
low-freq. energy	7.0	11.1	15.7	12.8
Total	0.0	3.0	15.7	13.0

Table 3.4b: Relative bias and standard deviation of the mean wave period $T_{m0,1}$ all types of conditions (total scores are included as a reference).

$T_{m0,2}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
opposing current	-10.1	0.5	26.2	14.8
following current	-2.2	-2.6	15.8	13.0
depth-limitation	5.3	13.9	22.7	18.6
no depth-limitation	-3.1	-3.6	18.3	11.6
low-freq. energy	11.0	17.4	24.2	18.7
Total	-1.5	4.4	22.5	18.0

Table 3.4c: Relative bias and standard deviation of the mean wave period $T_{m0,2}$ for all types of conditions (total scores are included as a reference).

$T_{m-1,0}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
opposing current	-9.0	-3.5	9.2	8.0
following current	-3.4	0.5	9.5	10.2
depth-limitation	-5.5	0.4	8.6	9.2
no depth-limitation	1.6	-0.3	14.2	6.4
low-freq. energy	-4.4	0.1	10.4	7.6
Total	-3.3	-0.4	11.3	8.3

Table 3.4d Relative bias and standard deviation of mean wave period $T_{m-1,0}$ for all types of conditions (total scores are included as a reference).

T_{pm}	relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
opposing current	-5.0	-9.5	13.1	13.0
following current	-7.4	-8.5	25.5	27.0
depth-limitation	-9.7	-13.4	21.5	21.0
no depth-limitation	5.0	-2.1	10.9	8.9
Low-freq. energy	-7.9	-14.4	20.4	17.8
Total	-3.6	-8.4	18.7	17.9

Table 3.4e: Relative bias and standard deviation of the mean peak period T_{pm} for all types of conditions (total scores are included as a reference).

3.5 Performance of SWAN 40.20

The performance of SWAN 40.20 using the standard and the advanced hindcast technique has been visualised in the form of scatter diagrams and tables with statistical parameters. In this section attention is given to the differences between the cases 5 and 6. In the description of the results, case 5 is considered as the base case and case 6 as the new case. A comparison with results of the previous hindcasts (viz. the cases 1 to 4), is given in Chapter 5.

3.5.1 Prediction of significant wave height per location

In the standard hindcast method the significant wave height is under-predicted by 8.5%. Using the calibrated SWAN in the advanced hindcast an over-estimation of 4.8% is found. The results in Table 3.2a show a general trend of a higher relative bias for all locations, but that the magnitude of this increase is different for each location. In general the relative bias improves. The best results are found for location MP3, whereas they worsen for the locations MP5, MP16 and MP17. Table 3.2a also shows that the values for measurement point MP17 deviate considerably from the other values. This supports the assumption that this measurement point is unreliable. The overall standard deviation reduces slightly from 17.9% to 16.1%.

3.5.2 Prediction of wave period measures per location

The prediction of the mean wave period $T_{m-1,0}$ improves considerably. The overall under-prediction of 3.3% improves to a small under-prediction of 0.4%. The relative standard deviation reduces slightly from 11.3% to 8.3%. The best results are found for location MP6.

The mean peak period T_{pm} shows different behaviour as the mean wave periods. The under-prediction of 3.6% increases to an under-prediction of 8.4% and the relative standard deviation changes by less than a percent.

The overall behaviour of the statistics of the mean periods $T_{m0,1}$ and $T_{m0,2}$ is rather similar. The bias worsens with 3% for $T_{m0,1}$ and with 5.9% for $T_{m0,2}$. The results in the Tables 3.2b and 3.2c also show a decrease of about 4% in the relative standard deviations. The relative standard deviation is larger for $T_{m0,2}$ than for $T_{m0,1}$.

3.5.3 Prediction of significant wave height per storm

The bias improves for three of the five storms, but not for the first and last storm. For all storms, except the storm of January 10th 1995, the bias increases. The best improvement is found for the storm of January 2nd 1995 (from –23.0% to –4.5%). The worst bias is found for the storm of October 27th 2002 (17.9%).

The standard deviations reduce by a few percent, except for the October 27th 2002 storm. The standard deviation for the 1995 storms is generally higher than those of the 2002 storms.

3.5.4 Prediction of wave period measures per storm

The relative bias of the mean wave period $T_{m-1,0}$ improves for most storms, except the first storm of 1995 where it remains more or less the same. In general the bias increases. The changes in standard deviation are different per storm. A clear trend is not visible.

The relative bias of the mean peak period T_{pm} worsens for most storms, except for the storm of October 27th 2002. The standard deviations change by a few percent, but no uniform trend exists for all storms.

The behaviour of the relative bias for the mean wave periods $T_{m0,1}$ and $T_{m0,2}$ is similar per storm. They improve for the 1995 storms and they worsen for the 2002 storms. For the first and third storm of 1995 the bias decreases, whereas the relative bias increases for the other storms. There is no clear trend in the behaviour of the standard deviation. For the storms of 1995 the standard deviation decreases, whereas it increases for the storms of 2002.

3.5.5 Prediction of significant wave height per condition

For most conditions the bias of the significant wave height H_{m0} improves, except for the no-depth limitation condition. The best results are found for the opposing current situation. The standard deviations decrease by a few percent except for depth-limited case.

3.5.6 Prediction of wave period measures per condition

The bias of the mean wave period $T_{m-1,0}$ improves for all conditions. The bias increases for all conditions, except for the no-depth limitation case. The behaviour for the standard deviation differs per condition. It improves for the following current, depth-limitation and low freq. energy conditions, whereas it worsens for the other cases.

The under-prediction of the mean peak period T_{pm} gets stronger for all conditions. Only small differences are found in the standard deviation.

The relative bias of the mean wave periods $T_{m0,1}$ and $T_{m0,2}$ only improves for the opposing current conditions. This is also the situation with the best result for the relative bias. The standard deviation decreases for all cases.

3.6 Summary of results

In this Chapter results have been presented of the hindcast of 5 historical storms with SWAN 40.20 at the Petten Sea Defence. Two hindcast methods have been used, a standard method and an advanced method. The standard method has also been used in the extensive SWAN computations in 1999 and results thereof have been assimilated in the RAND2001 database. In the advanced hindcast method a better description of boundary conditions is included. The standard method uses SWAN 40.20 with its default settings. The advanced hindcast method uses the calibrated version of SWAN 40.20 including stricter convergence criteria. In both SWAN versions, triads and quadruplets can be active simultaneously.

The main findings of the hindcast with SWAN 40.20 for the Petten Sea Defence are:

- The biases of the significant wave height H_{m0} and mean wave periods improve, whereas the under-prediction of the mean peak period T_{pm} gets worse.
- The initial under-prediction of the significant wave height of –8.5% is replaced by an over-prediction of 4.8%.
- The initial under-prediction of the mean wave period $T_{m-1,0}$ of 3.3% improves to a small under-prediction of 0.4%.
- The under-prediction of the mean peak period T_{pm} worsens from from 3.6% to 8.4%.
- The mean wave periods $T_{m0,1}$ and $T_{m0,2}$ are rather well predicted for case 5, but in case 6 they are both over-predicted by about 4%.
- The relative standard deviations of the significant wave height and the wave periods measures reduce by a few percent, but still remain rather high.
- The changes in performance of all parameters are similar if we consider the various locations, but they are not rather erratic if we consider the various storms or conditions. This implies that the various conditions and characteristics of each storm have a large effects on the results.

The best results per location in the advanced hindcast for the significant wave height H_{m0} are found for the stations MP1, MP2 and MP3. For the mean wave period $T_{m-1,0}$ the best results are found for station MP6.

The best results per storm for the significant wave height H_{m0} and the mean wave period $T_{m-1,0}$ in the advanced hindcast are found for the storm of January 10th 1995 and **not** for the storm of October 27th 2002. This is surprising since data from the latter storm were used in the calibration of SWAN 40.20. A possible explanation for this behaviour is related to the fact that the calibration was not only performed for two coastal locations near the Petten Sea Defence but also for two coastal locations in the Westerschelde. This implies that effects of the Westerschelde 'pollute' the performance of SWAN near the Petten Sea Defence. In view of the results of the sensitivity study performed in the SWAN 40.20 calibration project (Alkyon, 2003), it is suggested that the over-prediction of the significant wave heights is mainly due to the use of the relative high value of .90 for the gamma parameter in the source term for depth-limited wave breaking.

The rather high bias (order 20%) for the significant wave height H_{m0} in the October 2002 storm is consistent with the bias found for the locations MP2 and MP6 in the calibration of SWAN (Alkyon, 2003) using the SWAN 40.20+ settings, see Table 2.7.

In addition, the calibration was performed for only two moments of time in the October 27th 2002 storm. It may well be that these conditions are not representative for all moments of time during this storm, or that the results for the two selected locations is not representative for all locations.

4 Results of the Westerschelde hindcast

4.1 Introduction

This chapter presents the results of the hindcast of 3 storms in the Westerschelde with SWAN 40.20. The results of the SWAN 40.20 computations are compared with measurements in the form of scatter diagrams and tables with scores of statistical parameters of integral wave parameters.

Scores are given for 5 different physical conditions (the number of data entries are given between square brackets):

A	ebb current (velocity ≥ 0.5 m/s en u-component < 0)	[28]
B	flood current (velocity ≥ 0.5 m/s en u-component > 0)	[68]
C	breaking situation ($H_{m0}/d \geq 0.3$)	[17]
D	no breaking ($H_{m0}/d < 0.3$)	[198]
E	double peaked conditions	[12]

Scores are also given for the areas:

NZ	North Sea	[75]
MON	Mouth of the Westerschelde estuary	[68]
WS	Middle and eastern part of the Westerschelde	[72]

The total number of data points is 215.

Scatter plots containing observed and computed wave conditions are given in Appendix E. Statistical information is given in the Tables 4.1 through 4.3. The Tables 4.1a through 4.1d are given Appendix F.

Following Gautier (2003), the tables with statistical parameters are grouped per case. The first block of results contains the results for all moments of time (ts=0), followed by blocks of results for typical conditions A, B, C, D and E (see section 2.3). In addition a distinction is made between various computational areas (North Sea, the mouth of the Westerschelde and the remainder of the Westerschelde). The measurement locations are shown in the Figure 2.5 and 2.6.

The North Sea area contains the following 5 measurement locations: Europlatform (EUW), Lichteiland Goeree (LEG), Schouwenbank (SWB), Deurloo (DRL), Scheur West (SCW).

The mouth of the Westerschelde contains the stations Wielingen (WIE), Cadzand (CDD, CDZ), Scheur Oost (SCO) and the Westerschelde Container Terminal (WCT).

The inner area of the Westerschelde contains the following 7 measurement stations: Pas van Terneuzen (PVT), Hoofdplaat (HF1, HFP), Hansweert (HSR, HS1) and Bath (BAT, BA1).

4.2 Tables with statistical information

The performance of SWAN 40.20 is expressed in terms of a number of statistical parameters. These tables are given in Appendix F. In this section a selection of these tables is presented. Tables of the relative bias and relative standard deviation are presented for the integral wave parameters H_{m0}, $T_{m0,1}$, $T_{m0,2}$, $T_{m-1,0}$ and T_{pm},

The scores for these parameters for each condition are given in the Tables 4.2a through 4.2e.

H_{m0}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
A (ebb)	-11.8	7.2	15.6	21.8
B (flood)	-7.9	10.7	17.6	23.9
C (breaking)	-9.5	10.5	19.1	11.6
D (no breaking)	-8.4	9.1	20.6	24.8
E (double peak)	-11.9	3.9	18.3	20.4
Total	-8.5	9.3	20.5	24.0

Table 4.2a: Relative bias and relative standard deviation of the significant wave height H_{m0} for all cases and per condition (total scores are included as a reference).

$T_{m0,1}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
A (ebb)	-22.8	-9.5	10.4	11.8
B (flood)	-5.9	-6.5	11.5	12.8
C (breaking)	-9.1	-4.8	8.8	13.8
D (no breaking)	-12.1	-7.6	12.7	12.3
E (double peak)	-20.6	-11.9	6.9	9.5
Total	-11.8	-7.4	12.5	12.5

Table 4.2b: Relative bias and relative standard deviation of the mean wave period $T_{m0,1}$ for all cases and per condition (total scores are included as a reference).

$T_{m0,2}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
A (ebb)	-27.7	-15.2	11.2	16.7
B (flood)	-10.8	-14.7	12.0	13.0
C (breaking)	-11.4	-9.7	12.1	18.1
D (no breaking)	-16.2	-14.2	13.5	14.6
E (double peak)	-25.2	-17.7	9.6	14.1
Total	-15.8	-13.8	13.6	15.0

Table 4.2c: Relative bias and relative standard deviation of the mean wave period $T_{m0,2}$ for all cases and per condition (total scores are included as a reference).

$T_{m-1,0}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
A (ebb)	-19.5	-5.6	10.2	8.8
B (flood)	-3.4	-0.7	11.5	12.8
C (breaking)	-8.9	-1.9	8.9	10.9
D (no breaking)	-10.2	-3.5	12.9	11.8
E (double peak)	-18.6	-8.8	5.9	6.4
Total	-10.0	-3.3	12.6	11.7

Table 4.2d: Relative bias and relative standard deviation of the mean wave period $T_{m-1,0}$ for all cases and per condition (total scores are included as a reference).

T_{pm}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
A (ebb)	-18.4	-7.4	10.2	11.7
B (flood)	-2.2	0.8	11.5	12.8
C (breaking)	-10.3	-3.4	8.9	13.4
D (no breaking)	-10.5	-4.6	12.9	13.8
E (double peak)	-20.1	-15.4	5.9	7.2
Total	-10.5	-4.5	12.6	13.7

Table 4.2e: Relative bias and relative standard deviation of the mean peak period T_{pm} for all cases and per condition (total scores are included as a reference).

The performance of SWAN 40.20 for the cases 5 and 6 for each area is presented in the Tables 3.4a though 4.3e.

H_{m0}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
NZ	-5.7	12.6	15.6	17.2
MON	-11.0	9.2	11.0	19.0
WS	-17.2	-7.8	29.5	30.5
Total	-8.5	9.3	20.5	24.0

Table 4.3a: Relative bias and relative standard deviation of the significant wave height H_{m0} for all cases and per area (total scores are included as a reference).

$T_{m0,1}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
NZ	-6.2	-6.4	8.0	7.6
MON	-17.4	-9.8	12.0	11.5
WS	-16.4	-5.1	14.5	19.4
Total	-11.8	-7.4	12.5	15.0

Table 4.3b: Relative bias and relative standard deviation of the mean wave period $T_{m0,1}$ for all cases and per area (total scores are included as a reference).

$T_{m0,2}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
NZ	-11.5	-15.2	7.7	7.7
MON	-22.0	-16.4	12.6	11.5
WS	-16.2	-5.1	17.2	19.4
Total	-15.8	-13.8	13.6	15.0

Table 4.3c: Relative bias and relative standard deviation of the mean wave period $T_{m0,2}$ for all cases and per area (total scores are included as a reference).

$T_{m-1,0}$	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
NZ	-2.8	0.0	8.2	7.7
MON	-15.1	-5.4	11.7	12.0
WS	-18.3	-7.6	12.8	13.9
Total	-10.0	-3.4	12.6	11.7

Table 4.3d: Relative bias and relative standard deviation of the mean wave period $T_{m-1,0}$ for all cases and per area (total scores are included as a reference).

T_{pm}	Relative bias		Relative standard deviation	
	40.20	40.20+	40.20	40.20+
NZ	0.1	3.6	9.1	8.8
MON	-17.0	-10.1	12.1	13.3
WS	-22.7	-12.7	14.2	13.7
Total	-10.5	-4.5	15.0	13.7

Table 4.3e: Relative bias and relative standard deviation of the mean peak period T_{pm} for all cases and per area (total scores are included as a reference).

4.3 Scatter diagrams

The scatter plots are given in Appendix E as Figure 4.1 through Figure 4.15. These figures show the scatter plots of H_{m0}, T_{pm} and $T_{m-1,0}$ for specific situations, i.e. ebb, flood, depth-limited and non depth-limited situations. Colours are used to distinguish the various cases. There are insufficient situations with double peaked spectra to make relevant scatter diagrams.

Following Gautier (2003), situations with small wave height (H_{m0} < 0.3 m) have been omitted from the scatter diagrams. Such conditions occur in shallow points or in situations with offshore winds where waves start to grow. As such they are not relevant for this study, which concentrates on storm waves. In addition entries with suspicious high values of T_{pm} or T_{pbeq} (> 3.5 $T_{m0,,2}$) have been omitted from the analysis.

4.4 Performance of SWAN 40.20

The performance of SWAN 40.20 is discussed on the basis of the Tables 4.2 and 4.3 with statistical parameters and on the basis of the scatter diagrams in Appendix E.

4.4.1 Significant wave height

The prediction of the relative bias for the significant wave height gets a little worse. It changes from an under-prediction by 8.5% to an over-prediction by 9.3%. The bias increases for all situations. In both cases the relative scatter is relatively high (about 20%). Closer inspection of the results indicates that the over-prediction is the strongest for the entries corresponding to flood and breaking situations.

Current situations

The results for the ebb and flood situations indicate that SWAN performs better in the flood situation for case 5, and the ebb situation for case 6. In both cases the bias increases with about 18%. The corresponding standard deviations worsen for both cases by about 7%. Closer inspection reveals that the storm of December 2000 gives the largest over-prediction for the flood situation in case 6.

Breaking or non-breaking situations

The results for the breaking or non-breaking situation show that there are more situations without breaking (17 points) than with wave breaking (198 points). For case 5 SWAN under-predicts the significant wave heights by about 10%, whereas for case 6 they are over-predicted by about 9%. The scatter for the breaking cases improves from (19.1% to 11.6%) whereas is worsens for the non-breaking cases (20.6% to 24.8%).

Computational area

The bias improves for the mouth and the other parts of the Westerschelde, whereas it worsens for the North Sea area. For all areas the bias increases. For case 5 the significant wave height is under-predicted in all areas, whereas for case 6 it is over-predicted for all areas except for area WS (the middle and eastern part of the Westerschelde). The standard deviation worsens for all areas.

4.4.2 Wave period measures

The prediction of the mean wave period $T_{m-1,0}$ improves for all conditions and areas. The overall bias improves from –10.0% to –3.4%. The overall standard deviation improves slightly from 12.6% to 11.7%. In general the biases of T_{pm} are similar to those of $T_{m-1,0}$, but the standard deviation worsens slightly from 15.0% to 13.7%.

The overall biases of the mean wave period $T_{m0,1}$ and $T_{m0,2}$ improve. They are both under-estimated in the cases 5 and 6. The standard deviations worsen a few percent, but they both remain rather high at 15%.

Current situations

The relative bias of the mean period $T_{m-1,0}$ and the mean peak period T_{pm} improve for all current conditions, whereas their standard deviations change only a few percent.

Results for the different current situations indicate that the biases of $T_{m0,1}$ and $T_{m0,2}$ improve for the ebb conditions, whereas they worsen for the flood conditions. In both cases the standard deviation increases for both parameters.

Breaking or non-breaking situations

The results of the biases of all period measures of the breaking and non-breaking cases indicate that in general SWAN 40.20 performs a better for the breaking cases than for the non-breaking cases. It is also found that for all cases and all period measures the biases for case 6 are better than those of case 5. This is in contrast with the behaviour of the standard deviations of the period measures, which in general worsen for all conditions. The best result is found for the mean wave period $T_{m-1,0}$ for case 6 and the no breaking condition with a relative bias of –1.9% and a standard deviation of 10.9%.

Computational area

The results for the biases of the period measures $T_{m-1,0}$ and T_{pm} per area indicate that in general SWAN performs better in North Sea area, and the worst in the “Westerschelde” part. It is also found that the bias of the period measures increase for all areas.

For the mean wave period $T_{m-1,0}$, excellent results are obtained for the North Sea area and case 6. For the other areas the prediction of this parameter improves considerably, but they are still under-predicted. The best results for the mean peak period T_{pm} where found for the North Sea area in case 5 (0.1%). The corresponding standard deviations change only a few percent and remain greater than 10%.

The biases of the mean wave periods $T_{m0,1}$ and $T_{m0,2}$ improve, but are still under-predicted in case 6. Their standard deviations worsen by a few percent.

4.5 1D wave spectra

The Figures 4.16a through 4.20b show the measured and calculated 1D-spectra for unique instants and for all locations. To reduce the number of figures, only the spectra of storm of December 2000 are given.

The comparison of the computed spectra with measurement reveals striking difference between the cases 5 and case 6. As is evident from the previous section, cases 6 give higher significant wave heights and period measures than case 5. This can clearly be seen in the spectra.

For the station EUW, LEG and SWB the computed spectra correspond rather well with the measured spectra. But this is not surprising because these measurement points are close to the boundary of the computational grid where the wave boundary conditions were imposed.

4.6 Summary of results

In this Chapter results have been presented of the hindcast of 3 historical storms with SWAN 40.20 in the Westerschelde. The SWAN 40.20 version has been applied in two hindcast methods, a standard and an advanced approach. Details of these methods have been given in chapter 1.

The main findings of the SWAN 40.20 computations for the Westerschelde for the cases 5 and 6 are:

- The bias of the significant wave height and all period measures worsens slightly. The corresponding standard deviations change marginally.

- The changes in performance of SWAN are very similar for the different conditions and areas.
- The initial under-prediction of the significant wave height of about 9% changes to an over-prediction of about 9% in case 6. The corresponding standard deviation worsen slightly from 21% to 24%.
- The initial under-prediction of the mean wave period $T_{m-1,0}$ of 10% changes to a small under-prediction of 3.4%, and the standard deviation improve from 13% to 12%.
- The biases of the other period measures improve but remain negative.
- The best results for $T_{m-1,0}$ are found for case 6 in the North Sea area and for the cases with an flood current.

5 Comparison with previous hindcasts

5.1 Introduction

This Chapter presents the performance of SWAN 40.20 compared with those of SWAN 30.62 and SWAN 40.16 using the standard and advanced hindcast methods for the Petten Sea Defence (WL|Delft Hydraulics & Alkyon, 2003) and the Westerschelde (Gautier, 2003).

The various sets of SWAN computation are referred to as the cases 1 through 6 and they correspond to the SWAN versions 30.62, 30.62+, 40.16, 40.16+, 40.20 and 40.20+. The + refers to the advanced hindcast approach. Case 6 differs from the other cases because it uses different settings for some physical and numerical parameters. These different settings have been obtained in the SWAN 40.20 calibration project (Alkyon 2003).

Detailed inter-comparisons between the cases 1 through 4 have been described in the reports of the hindcast studies for the Petten Sea Defence (WL|Delft Hydraulics & Alkyon, 2003) and the Westerschelde (Gautier 2003).

The comparison is based on the tables of the relative bias and the relative standard deviation for the integral wave parameters H_{m0}, $T_{m0,1}$, $T_{m0,2}$, $T_{m-1,0}$ and T_{pm}. Results are shown for the SWAN 40.20 computations in the Westerschelde and the Petten Sea Defence.

The inter-comparison of the results for the cases 1, 3 and 5 and the inter-comparison of the results for the cases 2 and 4 gives information about the performance of the SWAN versions 30.62, 40.16 and 40.20. This is possible since the computations have been applied under the same conditions. Case 6 can best be compared with the results of case 4. Since SWAN 40.20 is very similar to SWAN 40.16 an inter-comparison between the results for the cases 4 and 6 will highlight the differences in performance due to the calibration of SWAN 40.20 with stricter convergence criteria.

This chapter only presents the results of a comparison of SWAN results for the cases 1 through 6 for the parameter H_{m0}, $T_{m-1,0}$ and T_{pm}. A comparison of SWAN results for the mean period measures $T_{m0,1}$ and $T_{m0,2}$ was deemed less important. Conclusions about the need for period corrections are described in chapter 6.

It is noted that some statistical parameters from the Petten hindcast deviate slightly from results presented in WL|Delft Hydraulics (2003). This is due to some improvements in the programs used for the statistical analysis of the SWAN computations for Petten. Such differences do not occur in the statistical parameters for the Westerschelde hindcasts.

5.2 Petten

For Petten tables of the relative bias and relative standard deviation have been taken from the two hindcast studies for Petten. The cases 1 through 4 were taken from WL|Delft Hydraulics &Alkyon (2003).

In line with WL|Delft Hydraulics & Alkyon (2003) results are shown for all storms and locations combined, and for a distinction per location. In view of the page layout the tables for the relative bias and relative standard deviation are given in separate tables (relative bias in the "a"-tables and the relative standard deviation in the "b"-tables).

Due to doubts about the validity of the measured wave conditions at location MP17, the measured data from the instruments 171 and 175 are omitted from the statistical analysis of the cases 1 to 6. According to Table 4.2 of WL|Delft Hydraulics & Alkyon (2003) this affect the results for the storms of February and October 2002, the results for the “following current”, the “no depth-limitation” and the “totals”. As noted in section 3.1, instrument 175 was used in the calibration of SWAN 40.20 (Alkyon, 2003).

The tables 5.1a through 5.3b present the statistics for H_{m0}, $T_{m-1,0}$, and T_{pm0} clustered per location. The tables 5.4a through 5.6b present the statistics per storm and the tables 5.7a through 5.9b present the results per conditions.

H_{m0}	relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	-1.7	-1.7	-2.3	-3.8	-2.9	0.2
MP2	-4.3	-5.3	-4.5	-6.8	-4.5	3.2
MP3	-8.2	-8.3	-5.5	-7.7	-6.0	4.0
MP16	-10.1	-9.9	-8.6	-2.5	-8.8	13.3
MP5	-3.1	-0.2	-6.7	-0.8	-7.9	14.0
MP6	-30.0	-7.7	-25.8	0.3	-25.1	15.3
Total	-9.0	-6.0	-8.1	-5.1	-8.5	4.8

Table 5.1a: Relative bias [%] of significant wave height H_{m0} at all locations.

H_{m0}	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	21.8	15.3	22.8	14.8	23.4	17.3
MP2	15.7	13.2	16.4	14.8	16.5	18.9
MP3	16.1	10.8	17.9	11.0	17.1	10.5
MP16	4.9	6.2	5.1	7.8	4.8	7.7
MP5	13.3	5.1	13.1	6.0	12.8	11.8
MP6	9.2	9.7	9.0	10.1	9.0	12.3
Total	17.7	13.3	18.1	14.2	17.9	16.1

Table 5.1b: Relative standard deviation [%] of significant wave height H_{m0} at all locations.

$T_{m-1,0}$	Relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	-1.1	-3.3	0.5	-2.6	0.1	-2.3
MP2	-8.1	-5.6	-6.7	-5.1	-6.7	-4.7
MP3	-0.9	2.2	0.1	3.4	0.2	3.9
MP16	-6.6	5.6	-2.0	6.7	-1.9	6.1
MP5	-9.0	1.1	1.5	3.9	1.6	0.5
MP6	-16.1	1.5	-7.9	1.8	-7.7	0.2
Total	-7.5	-0.7	-3.3	0.2	-3.3	-0.4

Table 5.2a: Relative bias [%] of mean wave period $T_{m-1,0}$ at all locations.

$T_{m-1,0}$	Relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	14.7	7.7	13.9	6.9	13.9	5.8
MP2	11.6	8.8	11.9	8.7	11.7	6.9
MP3	8.8	7.7	8.5	8.0	8.8	5.7
MP16	4.1	4.7	4.1	5.7	4.1	4.9
MP5	8.2	8.8	12.0	10.0	11.9	5.6
MP6	8.8	7.2	9.2	8.1	9.2	8.6
Total	12.0	9.0	11.4	9.4	11.4	8.3

Table 5.2b: Relative standard deviation [%] of mean wave period $T_{m-1,0}$ at all locations.

T_{pm}	Relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	3.9	-0.7	4.4	-2.1	4.5	-0.4
MP2	-0.1	-5.0	0.3	-5.2	0.4	-3.6
MP3	0.4	-4.6	3.0	-5.0	3.0	-3.6
MP16	-0.4	-1.9	-0.4	-2.3	-0.5	-0.2
MP5	5.8	-4.8	5.9	-5.0	5.9	-5.4
MP6	-18.4	-18.4	-18.7	-23.3	-18.7	-21.0
Total	-4.2	-8.3	-3.6	-9.9	-3.6	-8.4

Table 5.3a: Relative bias [%] of mean peak period T_{pm} at all locations.

T_{pm}	Relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
MP1	11.5	7.9	11.2	7.6	11.0	6.3
MP2	13.2	12.7	12.6	12.5	12.5	11.2
MP3	8.3	7.8	7.6	10.3	7.5	7.4
MP16	6.8	6.6	6.8	9.0	6.9	5.4
MP5	8.4	11.9	8.1	13.2	8.1	8.9
MP6	19.6	17.1	19.2	17.1	19.1	18.3
Total	18.9	17.0	18.7	18.3	18.7	17.8

Table 5.3b: Relative standard deviation [%] of mean peak period T_{pm} at all locations.

Statistical parameters per storm

H_{m0}	relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	-3.0	-3.3	-3.2	-3.9	-4.0	7.1
1995/01/02	-22.0	-9.1	-22.0	-9.6	-23.0	-4.5
1995/01/10	-0.1	-5.9	1.2	-7.3	0.6	-0.6
2002/02/23	-9.7	-10.6	-7.3	-8.4	-7.0	2.5
2002/10/27	-8.9	-2.1	-8.0	2.4	-7.3	17.9

Table 5.4a: Relative bias [%] of significant wave height H_{m0} for all storm days.

H_{m0}	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	20.9	18.3	20.0	18.3	20.2	14.4
1995/01/02	18.2	12.3	20.4	13.6	20.0	17.5
1995/01/10	15.6	10.9	16.2	11.9	15.4	12.9
2002/02/23	10.5	10.4	11.0	12.8	10.9	10.6
2002/10/27	14.0	12.9	13.1	12.0	12.8	13.4

Table 5.4b: Relative standard deviation [%] of significant wave height H_{m0} for all storm days.

$T_{m-1.0}$	Relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	-8.3	-1.0	-2.6	0.1	-3.0	-3.7
1995/01/02	-15.7	-5.7	-10.9	-4.8	-10.9	-2.9
1995/01/10	2.5	0.3	7.6	1.7	7.7	0.3
2002/02/23	-8.3	2.9	-4.6	4.5	-4.5	2.2
2002/10/27	-7.3	1.4	-5.9	1.2	-5.7	2.8

Table 5.5a: Relative bias [%] of mean wave period $T_{m-1,0}$ for all storm days.

$T_{m-1,0}$	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	11.8	9.9	10.9	10.7	10.6	10.7
1995/01/02	9.1	10.9	9.1	10.8	8.9	8.4
1995/01/10	12.1	7.1	11.8	7.7	11.9	7.0
2002/02/23	8.5	7.1	6.8	7.9	6.8	7.5
2002/10/27	8.4	5.3	6.4	6.0	6.3	5.8

Table 5.5b: Relative standard deviation [%] of mean wave period $T_{m-1,0}$ for all storm days.

T_{pm}	Relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	-8.0	-10.0	-6.5	-9.7	-6.8	-12.0
1995/01/02	-8.8	-12.3	-8.4	-15.3	-8.2	-11.6
1995/01/10	5.4	-8.1	5.1	-11.4	5.1	-9.8
2002/02/23	-3.9	-4.5	-2.6	-4.6	-2.6	-4.4
2002/10/27	-6.4	-4.9	-5.8	-5.6	-5.7	-2.4

Table 5.6a: Relative bias [%] of mean peak period T_{pm} for all storm days.

T_{pm}	Relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
1995/01/01	26.5	27.0	26.6	27.7	26.6	28.1
1995/01/02	18.3	16.0	18.0	17.4	17.9	16.2
1995/01/10	17.3	15.0	17.4	15.1	17.4	15.1
2002/02/23	14.7	11.5	15.5	13.4	15.0	13.5
2002/10/27	9.8	9.9	9.6	11.8	9.8	10.2

Table 5.6b: Relative standard deviation [%] of mean peak period T_{pm} for all storm days.

H_{m0}	relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	-11.8	-1.9	-12.2	-2.6	-13.2	2.1
Following current	-12.9	-7.6	-13.4	-7.6	-13.3	6.2
depth-limitation	-14.0	-10.0	-10.8	-6.4	-10.8	5.8
no depth-limitation	-0.8	0.0	-2.5	-1.7	-3.2	5.4
Low-freq. energy	-16.5	-5.6	-15.0	-2.2	-15.3	8.9

Table 5.7a: Relative bias [%] of significant wave height H_{m0} for all types of conditions.

H_{m0}	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	22.3	11.9	23.3	12.0	22.8	15.5
Following current	19.9	16.4	20.5	17.4	20.6	17.9
depth-limitation	12.1	11.9	12.2	14.4	11.7	13.7
no depth-limitation	23.1	14.9	24.9	14.6	25.0	17.6
Low-freq. energy	15.5	8.5	14.8	9.3	14.4	13.3

Table 5.7b: Relative standard deviation [%] of significant wave height H_{m0} for all types of conditions.

$T_{m-1,0}$	relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	-12.7	-7.6	-8.7	-7.3	-9.0	-3.5
Following current	-8.3	2.6	-3.4	3.9	-3.4	0.5
depth-limitation	-10.2	0.4	-5.7	1.0	-5.5	0.4
no depth-limitation	-3.2	-0.7	1.7	0.7	1.6	-0.3
low-freq. energy	-12.2	0.4	-4.1	1.7	-4.4	0.1

Table 5.8a: Relative bias [%] of mean wave period $T_{m-1,0}$ for all types of conditions.

$T_{m-1,0}$	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	9.7	10.1	9.3	9.5	9.2	8.0
Following current	10.7	8.8	9.8	9.3	9.5	10.2
depth-limitation	10.1	8.3	8.6	8.9	8.6	9.2
no depth-limitation	14.1	8.5	14.1	8.9	14.2	6.4
low-freq. energy	9.6	8.4	10.4	9.3	10.4	7.6

Table 5.8b: Relative standard deviation [%] of mean wave period $T_{m-1,0}$ for all types of conditions.

T_{pm}	Relative bias					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	-4.8	-12.4	-4.9	-16.0	-5.0	-9.5
Following current	-8.7	-5.6	-7.3	-5.6	-7.4	-8.5
depth-limitation	-10.5	-12.6	-9.6	-15.1	-9.7	-13.4
no depth-limitation	4.6	-2.7	5.0	-3.0	5.0	-2.1
low-freq. energy	-7.8	-12.6	-7.9	-16.5	-7.9	-14.8

Table 5.9a: Relative bias [%] of mean peak period T_{pm} for all types of conditions

T_{pm}	relative standard deviation					
	30.62	30.62+	40.16	40.16+	40.20	40.20+
Opposing current	13.0	12.7	13.1	15.1	13.1	13.0
Following current	25.4	25.8	25.5	26.4	25.5	27.0
depth-limitation	21.3	19.3	21.5	20.6	21.5	21.0
no depth-limitation	11.3	10.1	11.0	11.3	10.9	8.9
low-freq. energy	20.6	16.7	20.4	18.2	20.4	17.8

Table 5.9b: Relative standard deviation [%] of mean peak period T_{pm} for all types of conditions

Inspection of the results of the cases 5 show and 6 with respect to the cases 1 to 4 reveals the following:

Case 5 all parameters

The results for the relative bias and relative standard deviation of case 5 are very similar to the corresponding results of the cases 1 and 3. This holds for all parameters, areas and conditions. This implies that SWAN 40.20 behaves more or less similar to the SWAN versions 30.62 and 40.16. This holds for each area as well as each condition.

Case 6, the significant wave height H_{m0}

Comparison of the results for the significant wave height of case 6 with those of case 4 shows that the overall relative bias changes from an under-prediction of 5% to an over-prediction of +5% and that the relative standard deviation slightly increases from 14% to 16%. For case 4 the best results are found a the location MP6 whereas for case 6 the best results are found at location MP1.

Case 6, the mean wave period $T_{m-1,0}$.

Comparison of the results for the mean wave period $T_{m-1,0}$ of case 6 with those of case 4 shows that the small over-prediction of 0.2% changes to a small under-prediction of 0.4% in case 6. This is surprising since the change in the results between the cases 3 and 4 (-3.3% to 0.2%) is similar to the change in the results between the cases 5 and 6 (-3.3% to –0.4%) This indicates that the improved performance of SWAN in case 6, is mainly due to using a better hindcasting method.

The best results are found at location MP6. This is not surprising since this point was used in the calibration of SWAN 40.20. At deeper water, i.e. the stations MP1 and MP2, SWAN

40.20 still under-predict the mean wave period $T_{m-1,0}$. In general the standard deviation decreases for all storms and physical conditions, except for the storm of January 1st 1995.

Case 6, the mean peak period T_{pm}.
Comparison of the results for the mean peak period T_{pm} of case 6 with those of case 4 shows that in general the relative under-prediction of –9.9% in case 4 changes to a slightly smaller under-prediction of –8.4%. The relative standard deviations for case 6 are equal or slightly better than those of case 4. The trend of the changes of the bias and standard deviation does not show a uniform trend per location, storm or conditions. For some cases the bias improves, whereas for other cases it gets worse.

5.3 Westerschelde

For the Westerschelde tables of the relative bias and relative standard deviation have been taken from the two hindcast studies for the Westerschelde. For the cases 1 through 4 results and post-processing software originate from Gautier (2002). They where provided by RIKZ for the purposes of this study. In the present study a check was performed to ensure that the software produced the same results as reported in Gautier (2003).

In line with Gautier (2002) results are shown for all storms and locations combined, and for a distinction between the difference areas: the North Sea, the mouth of the Westerschelde estuary and the remainder of the Westerschelde. Tables 5.10 through 5.12 present the statistics for H_{m0}, $T_{m-1,0}$, and T_{pm}.

	H_{m0} all		H_{m0} North Sea		H_{m0} mouth		H_{m0} Westerschelde	
Case	Rel. bias	Rel. std	Rel. bias	Rel. Stdev	Rel. bias	Rel. std	Rel. bias	Rel. std
1	-6	18	-5	15	-6	12	-10	25
2	-1	23	3	15	-1	19	-18	30
3	-10	18	-8	14	-11	11	-17	25
4	-6	21	-2	16	-7	19	-24	24
5	-9	20	-6	17	-11	11	-17	30
6	9	24	13	17	9	19	-8	30

Table 5.10: Relative statistical parameters [%] per case and per area for the significant wave height $H_{m0.}$

	$T_{m-1,0}$ all		$T_{m-1,0}$ North Sea		$T_{m-1,0}$ mouth		$T_{m-1,0}$ Westerschelde	
Case	Rel. Bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. tdev
1	-8	12	-2	7	-13	13	-13	13
2	-7	11	-3	7	-10	12	-12	12
3	-9	12	-3	8	-14	12	-16	13
4	-8	11	-4	8	-11	9	-14	13
5	-10	13	-3	8	-15	12	-18	13
6	-4	12	0	8	-5	12	-18	14

Table 5.11: Relative statistical parameters [%] per case and per area for the mean wave period $T_{m-1,0}$.

	T_{pm} all		T_{pm} North Sea		T_{pm} mouth		T_{pm} Westerschelde	
Case	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std
1	-8	14	1	9	-15	12	-18	14
2	-9	14	0	8	-15	13	-19	13
3	-9	14	0	9	-15	13	-20	14
4	-10	13	-2	9	-16	11	-21	13
5	-10	15	0	9	-17	12	-23	14
6	-4	14	4	9	-10	13	-13	14

Table 5.12: Relative statistical parameters [%] per case and per area for the mean peak period T_{pm}.

In addition to Gautier (2003), the statistics for the different conditions are presented in the Tables 5.13 through 5.15 for the parameters H_{m0}, $T_{m-1,0}$ and T_{pm}. The number of data entries per situation are: ebb (N=17), flood (N=28), wave breaking (N=66), non-breaking situations (N=193) and situations with double peaked spectra (N=12).

	H_{m0} (A, ebb)		H_{m0} (B, flood)		H_{m0} (C, breaking)		H_{m0} (D, no brk)		H_{m0} (E double p)	
Case	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std
1	-11	14	-6	17	-11	9	-5	19	-8	15
2	0	20	-1	25	-7	10	0	24	-6	14
3	-13	15	-10	17	-12	10	-10	18	-12	15
4	-4	17	-6	23	-8	11	-6	22	-10	13
5	-12	16	-8	17	-9	19	-8	21	-11	18
6	7	22	11	24	11	12	9	25	4	20

Table 5.13: Relative statistical parameters [%] per case and per condition for the significant wave height H_{m0}.

	$T_{m-1,0}$ (A, ebb)		$T_{m-1,0}$ (B, flood)		$T_{m-1,0}$ (C, breaking)		$T_{m-1,0}$ (D, no brk)		$T_{m-1,0}$ (E double p)	
Case	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std
1	-19	8	-1	11	-7	6	-8	13	-18	6
2	-9	10	-4	13	-5	9	-7	11	-13	6
3	-19	9	-3	12	-8	7	-9	13	-18	24
4	-10	8	-7	13	-6	11	-9	11	-13	7
5	-19	10	-3	11	-9	9	-10	13	-19	24
6	-6	9	-1	13	-2	11	-4	12	-9	15

Table 5.14: Relative statistical parameters [%] per case and per condition for the mean wave period $T_{m-1,0}$.

	T_{pm} (A, ebb)		T_{pm} (B, flood)		T_{pm} (C, breaking)		T_{pm} (D, no break)		T_{pm} (E double p)	
Case	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std	Rel. bias	Rel. std
1	-18	10	0	11	-9	13	-8	14	-20	6
2	-12	13	-4	13	-9	13	-9	14	-20	7
3	-18	10	-1	12	-9	14	-9	14	-20	7
4	-13	11	-6	14	-9	14	-11	13	-21	7
5	-19	11	-2	13	-10	15	-10	15	-20	7
6	-7	12	1	13	-3	13	-5	14	-15	7

Table 5.15: Relative statistical parameters [%] per case and per condition for the mean peak period T_{pm}.

Inspection of the results of the cases 5 show and 6 with respect to the cases 1 to 4 reveals the following:

Case 5 all parameters
The results for the relative bias and relative standard deviation of case 5 are very similar to the corresponding results of the cases 1 and 3. This holds for all parameters, areas and conditions. This implies that SWAN 40.20 behaves more or less similar to the SWAN versions 30.62 and 40.16.

Case 6, the significant wave height H_{m0}
Comparison of the overall results for the significant wave height of case 6 with those of case 4 shows that the relative bias changes from –6% to +9% and that the relative standard deviation slightly worsens from 21% to 24%. For the "Westerschelde" part the relative bias remains negative. For the North Sea area the relative over-prediction is the strongest, whereas for the mouth of the Westerschelde, the results are similar to the overall results.

Case 6, the mean wave period $T_{m-1,0}$.
Comparison of the results for the mean wave period $T_{m-1,0}$ of case 6 with those of case 4 shows that in general the relative under-prediction of 8% in case 4 changes into an smaller under-prediction of 4%. This trend also occurs for the other areas and conditions except for the "Westerschelde" part. In this area this mean wave period is still strongly

under-predicted. The relative standard deviations for case 6 are equal to or slightly higher than those of case 4, except for the situations with double peaked spectra where the standard deviation more than doubles from 7% to 15%.

Case 6, the mean peak period T_{pm}.
Comparison of the results for the mean peak period T_{pm} of case 6 with those of case 4 shows that in general the relative under-prediction of 10% in case 4 improves to a smaller under-prediction of 4%. The strongest under-predictions of T_{pm} occur for the “Westerschelde” part and for the condition with double peaked spectra. The relative standard deviations for case 6 are more or less equal to those of case 4.

6 Conclusions and recommendations

6.1 Introduction

In this study the SWAN 40.20 model was used to hindcast historical storms near the Petten Sea Defence and in the Westerschelde. Two versions of the SWAN 40.20 have been used. The standard version with default settings and the calibrated SWAN 40.20 model (Alkyon, 2003). The calibration of SWAN was performed for two moments of time in the October 2002 storm, and for two coastal locations in the mouth of the Westerschelde estuary and two near-shore locations near the Petten Sea Defence.

The results of the wave model computations were also compared to the results of previous hindcast studies for the Petten Sea Defence (WL|Delft Hydraulics & Alkyon, 2003) and for the Westerschelde (Gautier, 2003). Of special interest is to determine whether the calibrated SWAN 40.20 model leads to better predictions of wave period measures.

As stated in Chapter 1, the following questions needed to be answered:

Q1 Does SWAN 40.20 produce more reliable results than previous SWAN versions in the standard hindcast method?

Q2 Does a better description of input boundary conditions by means of a more advanced hindcast method lead to better results?

Q3 Does a calibrated SWAN 40.20 (denoted as 40.20+) lead to improved period predictions?

Q4 Are there differences in performance of SWAN 40.20 for the Petten Sea Defence and the Westerschelde?

In addition to the previous questions, the following question needs to be answered also:

Q5 Is there still a need to determine correction factors for period measures?

The overall performance of SWAN with respect to the significant wave height H_{m0} and mean wave period $T_{m-1,0}$, per case and per area is summarised in Tables 6.1.

PT refers to Petten and WS refers to the Westerschelde.

H_{m0}	30.62	30.62+	40.16	40.16+	40.20	40.20+
R. bias PT	-9	-6	-8	-5	-9	5
R. bias WS	-6	-1	-10	-6	-9	9
R. std PT	18	13	18	14	18	16
R. std WS	18	23	18	21	20	24
$T_{m-1,0}$						
R. bias PT	-8	-1	-3	0	-3	0
R. bias WS	-8	-7	-9	-8	-10	-4
R. std PT	12	9	11	9	11	8
R. std WS	12	11	12	11	13	12

Table 6.1: Summary of performance of SWAN for the significant wave height H_{m0} and mean wave period $T_{m-1,0}$ per case for Westerschelde and Petten.

6.2 Conclusions

Based on the results of this study the following answers can be given to the questions. These answers are also considered as conclusions:

A1 As indicated in Chapter 5, the results of the cases 1, 3 and 5 indicate that SWAN 40.20 produces similar results as SWAN 40.16 and slightly better results than SWAN 30.62.

A2 As indicated in Chapter 5 the results of case 2 and 4 show that a better description of the boundary conditions improves the performance of SWAN. This conclusion cannot be supported by the results of case 6 compared to those of case 5, since for case 6 also a SWAN version has been used with different numerical and physical settings. Therefore the effects of a better description of boundary conditions cannot be isolated.

A3 The results of the cases 4 and 6 indicate that the calibrated SWAN 40.20 produces much better period measures than the other SWAN versions (default SWAN 30.62 SWAN 40.16 and SWAN 40.20). For Petten both cases produce on average a good agreement. For the Westerschelde the bias improves considerably. These results also indicate that for both areas the initial under-prediction of the significant wave height is replaced by an over-estimation of the significant wave height.

A4 For Petten, the overall magnitude of the over-estimation of the significant wave height is smaller than the over-estimation in the Westerschelde. Also, the overall prediction of the mean wave period $T_{m-1,0}$ is rather good at Petten, whereas for the Westerschelde the mean wave period $T_{m-1,0}$ is still under-predicted, although the under-prediction was reduced by a factor 2 (case 6 compared to case 4). The changes in performance for the various parameters show a uniform trend in the North Sea part and mouth of the Westerschelde, i.e. they all change in the same direction for the various areas and physical conditions. This cannot be said for the SWAN 40.20 results for the Petten Sea Defence, where the direction of changes is different for the various locations, storms and conditions.

A5 The results of the SWAN computations for Petten for the conditions and areas for which the calibration of SWAN 40.20 was performed (viz. 2 coastal locations and 2 moments of time in the October 2002 storm), are not as good as those obtained in the calibration of SWAN 40.20 based on Petten data only. This is partly due to the fact that the settings of the calibrated SWAN 40.20 are based on a combination of data from the Petten Sea Defence and the Westerschelde, implying that the settings are a kind of average of optimal settings for either the Petten Sea Defence of the Westerschelde.

Another reason for this mismatch is the fact that the calibration of SWAN 40.20 was only performed for four moments in time of the October 2002 storm and four near-shore location (two moments and two locations for each area). It is therefore likely that the chosen calibration points are not representative for all conditions occurring in the other storms, viz. wave boundary, wind, water level, and flow conditions. This suggestion is supported by the fact that for the Petten area the changes in the results are different for the 1995 and 2002 storms.

The over-prediction of wave heights for Petten and for case 6 (SWAN 40.20+) is probably due to the use of a rather high value of 0.9 for the GAMMA parameter in the source term for depth-limited wave breaking. In Alkyon (2003) also a calibration was performed using only locations near Petten (viz. 062 and 175). This calibration resulted in a lower GAMMA value, viz. 0.70. Since predicted wave heights are more or less proportional to GAMMA, as shown by the sensitivity study of physical parameters in the calibration study (Alkyon, 2003), using a GAMMA of 0.90 leads to too high predicted values for the significant wave heights.

It is also noted that the scatter in the results, as expressed by the standard deviations, only slightly improves in the case 6 computations. This is an indication that no fundamental improvements in wave model performance occurred.

A detailed analysis of the results shows that the changes in model performance are quite similar for the various Westerschelde cases, but rather non-systematic for the Petten cases. Since the scatter in the results is still large and in view of the erratic behaviour in the predicted values, proper predictions of the peak periods T_p and T_{pm}, the mean wave period $T_{m-1,0}$, and to a lesser degree also for the significant wave height H_{m0}, can only be obtained by deriving generic correction factors. In the determination of these correction factors the sources of the deviations need to be identified by considering the responsible physical conditions and processes and the locations where they occur.

Above considerations lead to the answer of question Q5 that a derivation of correction factors is required. Not only for the wave periods but also for the significant wave heights. Moreover, correction factors are needed both for Petten and the Westerschelde. In the derivation of the correction factors attention should to be given to the sources of error in the prediction of wave parameter per condition and per location.

6.3 Recommendations

Based on the results of and experience in this study the following recommendations are made:

1. Derive correction factors for the mean wave period $T_{m-1,0}$,the significant wave height H_{m0}, the peak periods T_p and T_{pm}. In the determination of these correction factors, the sources of deviations need to be identified by considering the locations and the various physical conditions and processes responsible for deviations in the prediction of these parameters. This analysis will probably lead to suggestions for fundamental changes and improvements in the wave model and its behaviour.
2. A re-calibration of SWAN 40.20 should be considered, and should include a wider range of storm conditions and measurement locations than used in the present calibration of SWAN 40.20. This re-calibration should lead to lower wave heights compared to the present settings of SWAN 40.20+.
3. The software used in this study is partly based on the SWAN ‘testbank’ software and software developed by WL|Delft Hydraulics and Royal Haskoning. The software for the statistical analysis of SWAN computations should be simplified considerably because it is rather inflexible and in-transparant to modify.

References

Alkyon, 1999: Wave computations for the coast of the Netherlands. Alkyon report A480, November 1999.

Alkyon and WL | Delft Hydraulics, 2002: Generieke methode voor het hindcasten van gemeten stormen (Generic method for hindcasting measured storms). Alkyon - WL | Delft Hydraulics report A1002/H4149 (in Dutch), September 2002.

WL | Delft Hydraulics and Alkyon, 2003: Reliability of SWAN at the Petten Sea Defence. WL | Delft Hydraulics and Alkyon report H4197/A1044, June 2003.

Alkyon, 2003: Calibration SWAN for Slotermeer, Petten and the Westerschelde, report A1168, November 2003.

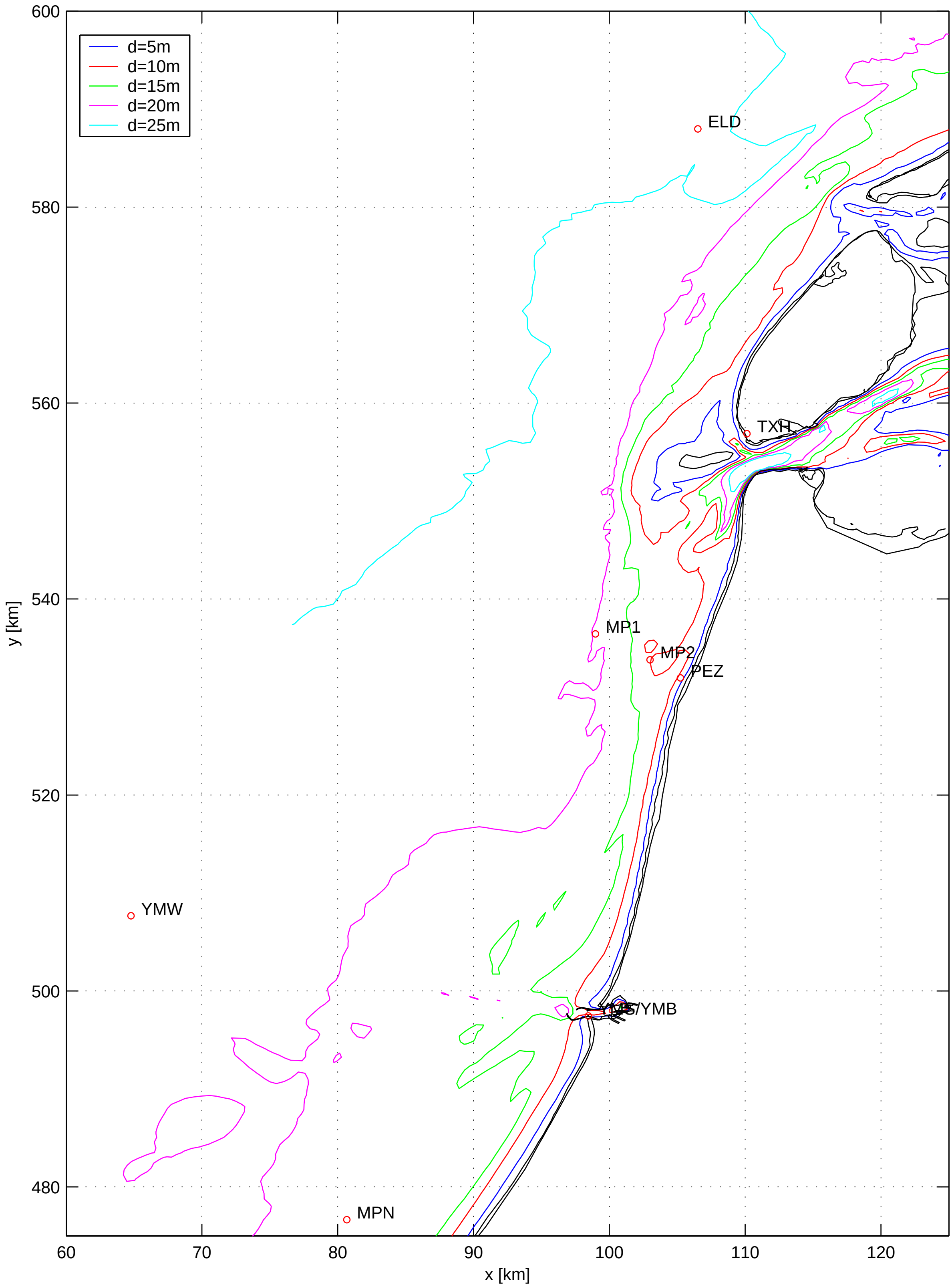
Andorka Gál. J.H., J.C.M. de Jong, A. T. Kamsteeg, J.G. de Ronde, 1997: Golfrandvoorwaarden op de Westerschelde, Gegeven een 1/4000 windsnelheid (deel 2). RIKZ/98.018.

Booij, N., R.C. Ris, and L.H. Holthuijsen, 1999. A third-generation wave model for coastal regions. Part I: Model description and validation. J. Geoph. Research, 104 (C4) 7649-7666.

Gautier, C., 2003: Betrouwbaarheid SWAN in de Westerschelde (in Dutch), Reliability of SWAN in the Westerschelde, June 2003.

Jacobse, J.J., A.T.M.M. Kieftenburg, and F. den Heijer, 2002: Betrouwbaarheid golfcondities met SWAN. Een verkenning naar de betrouwbaarhied van golfcondities uit RAND2001, berekend met SWAN. RIKZ/OS-2002.116x.

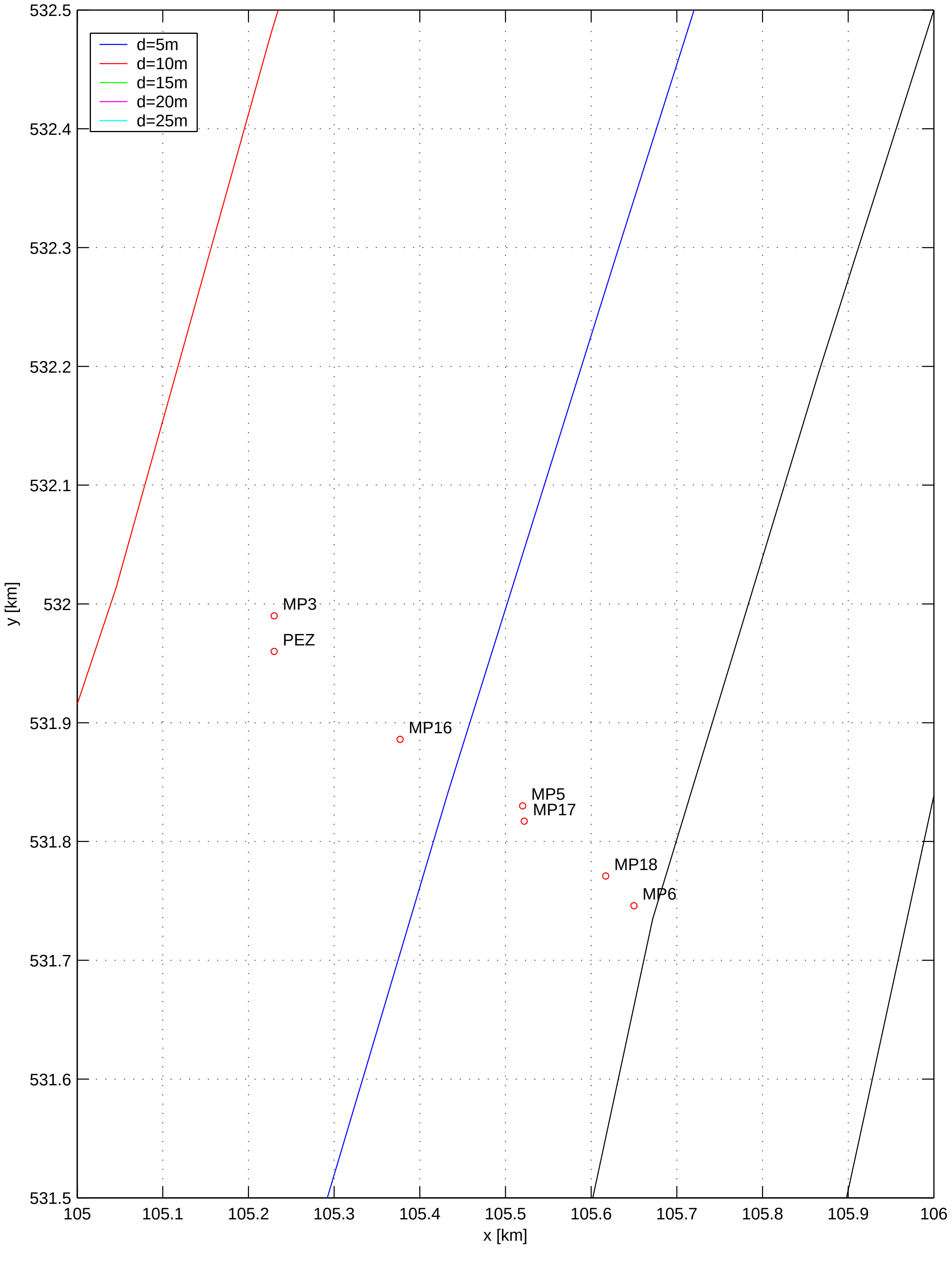
Ris, R.C., N. Booij, and L.H. Holthuijsen, 1998: A third-generation wave model for coastal regions, Part II: Verification. J. Geoph. Res. Vol. 104, C4, 7649-7666.



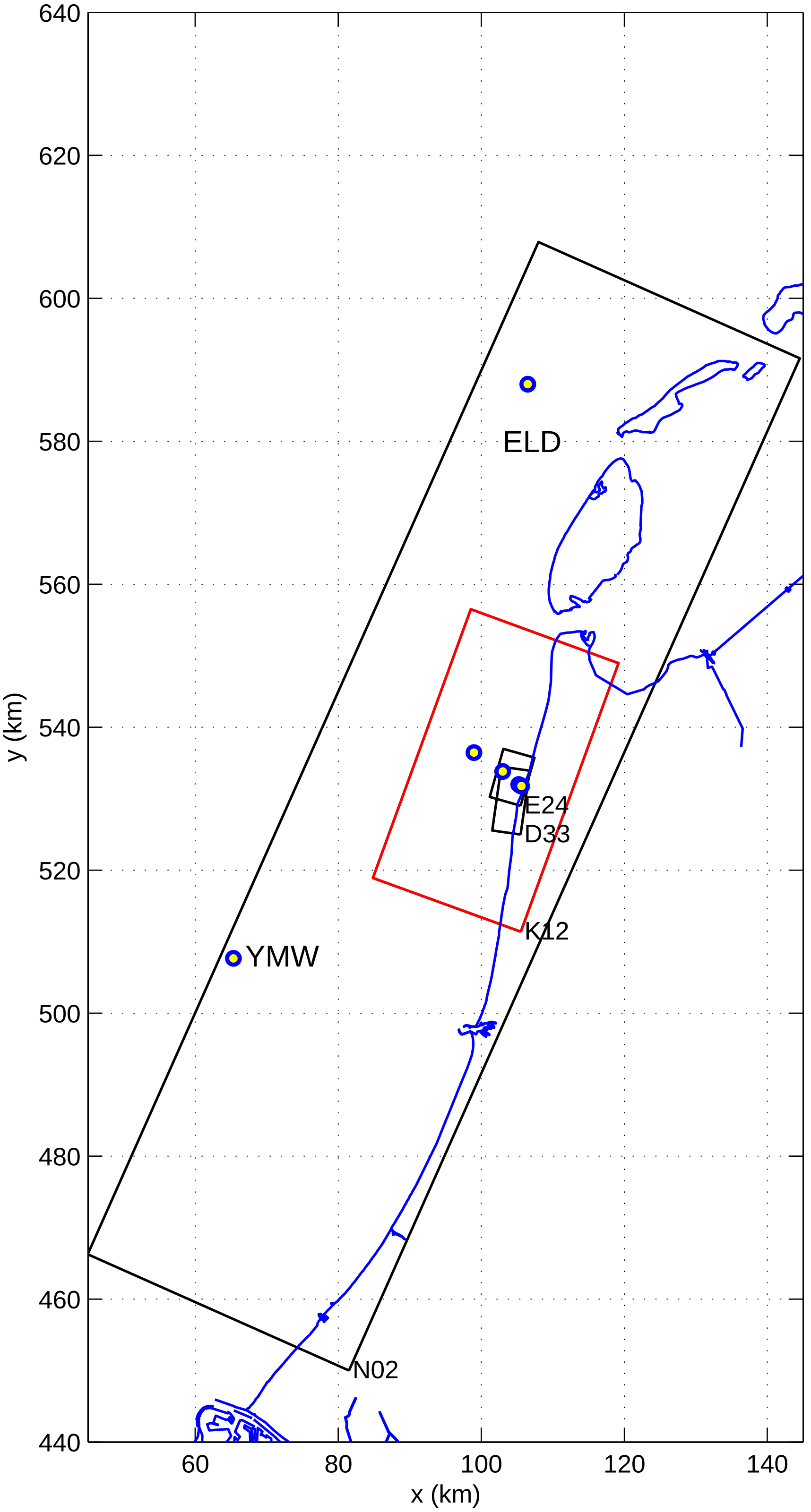
Location of measurement stations (water level, wind and waves)

Period correction SWAN 40.20

ALKYON HYDRAULIC CONSULTANCY & RESEARCH | A1200 | Fig. 2.1



Location of measurement stations (water level, wind and waves) near Petten	Period correction SWAN 40.20	
ALKYON HYDRAULIC CONSULTANCY & RESEARCH	A1200	Fig. 2.2

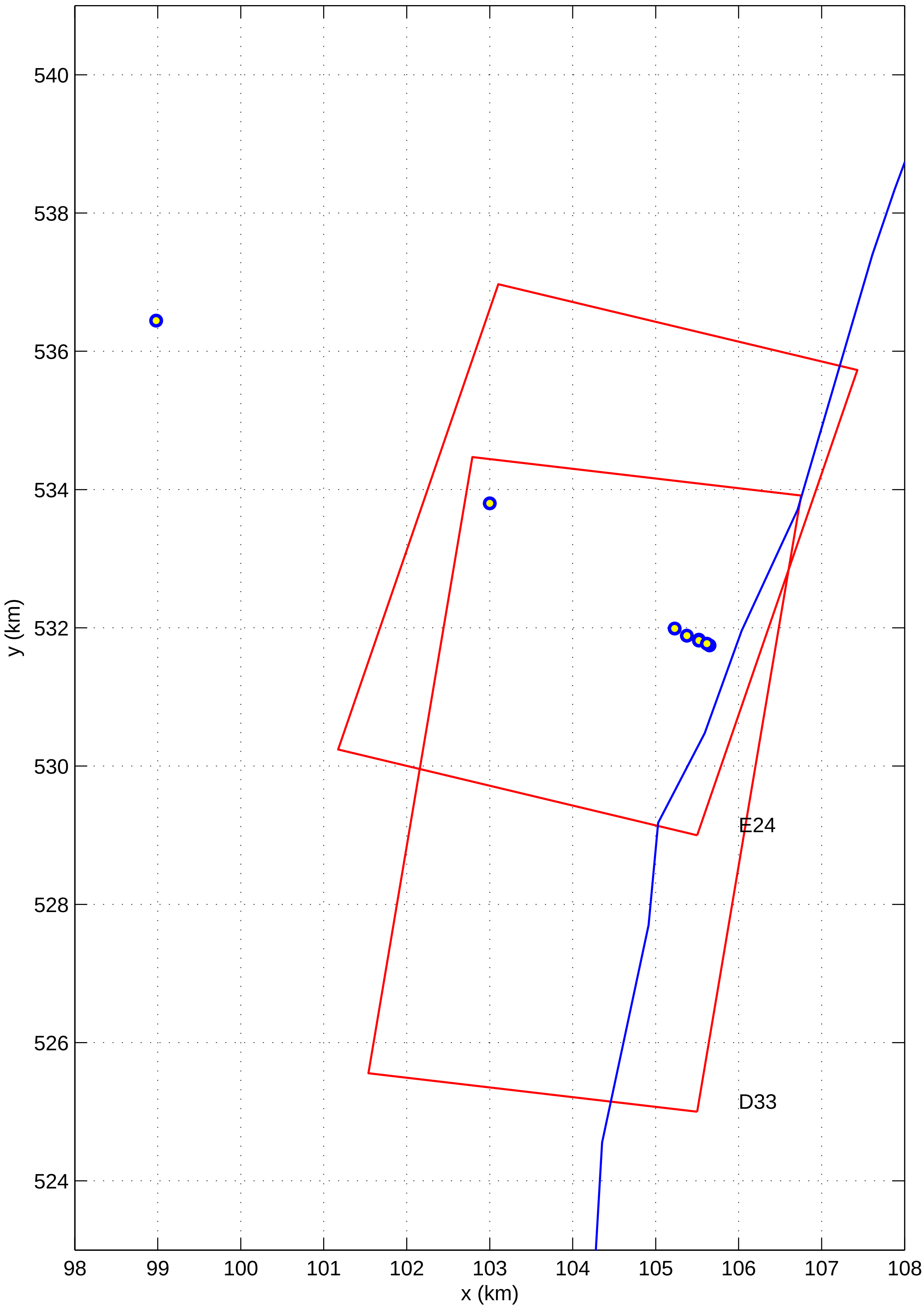


Computational grids and output locations in the North Sea
and near the Petten Sea Defence

Period correction SWAN 40.20

Hindcast Petten and Westerschelde with SWAN 40.20 A1200 Alkyon Fig. 2.3

fig_grids02.m Date:23/01/2004 Time:13:40:16



Detailed computational grids and output locations in the Petten ray

Period correction SWAN 40.20

Hindcast Petten and Westerschelde with SWAN 40.20 A1200 Alkyon Fig. 2.4

A Definition of spectral period measures

A number of additional spectral parameters are computed, such as extra mean period measures, peak period measures and equivalent period measures. To increase the robustness of the computation of some of these parameters for measured spectra a smoothing technique is used. This appendix contains the definitions of these parameters and the smoothing algorithm that is applied. Background information about these parameters and the smoothing algorithm are given in Alkyon (1999.

Mean period measures

The mean period measures $T_{m0,1,}$ $T_{m0,2}$ and $T_{m-1,0}$ are computed on the basis of the frequency moments m_i of a wave spectrum:

$$m_i = \int_{f_{low}}^{f_{high}} f^i E(f)\, df \tag{A.1}$$

in which f_{low} and f_{high} are the integration limits. The mean period measures are defined as:

$$T_{m0,1} = \frac{m_0}{m_1} \tag{A.2}$$

$$T_{m0,2} = \sqrt{\frac{m_0}{m_2}} \tag{A.3}$$

and

$$T_{m-1,0} = \frac{m_{-1}}{m_0} \tag{A.4}$$

Since the SWAN computations are carried on a finite frequency domain, both measured and computed mean wave periods are determined by integrating the moments in (A.1) over a finite integration domain with f_{low}=0.3 Hz and f_{high} =0.5 Hz .

The peak period T_p

The peak period T_p is defined as the frequency at which the frequency spectrum has its maximum value.

The block peak period T_{pb}

The block peak period T_{pb} is defined as the mean period $T_{m-1,0}$ in an interval around the peak period T_p. The limits of the frequency interval are determined as the frequencies where on the lower and higher frequency (f_1 and f_2) flank around the spectral peak the energy density has a downward crossing with the level of 40% of the energy density level at the spectral peak. The equation for the computation of the block peak period is:

$$T_{pb} = \frac{\int_{f_1}^{f_2} f^{-1} E(f)\, df}{\int_{f_1}^{f_2} E(f)\, df} \qquad \text{(A.5)}$$

Equivalent period measures for double peaked spectra

In the case of a double peaked spectrum the peak periods T_{p1} and T_{p2} and the block peak periods T_{pb1} and T_{pb2} are computed for each sub-spectrum. Based on these peak period measures an equivalent peak period T_{peq} and an equivalent block peak period T_{pbeq} are computed by a weighting with the total amount of energy per sub spectrum and the fourth power of the (block) peak in each sub-spectrum:

$$T_{peq} = \sqrt[4]{T_{p1}^4 \frac{m_0^{(1)}}{m_0} + T_{p2}^4 \frac{m_0^{(2)}}{m_0}} \qquad \text{(A.6)}$$

and

$$T_{pbeq} = \sqrt[4]{T_{pb1}^4 \frac{m_0^{(1)}}{m_0} + T_{pb2}^4 \frac{m_0^{(2)}}{m_0}} \qquad \text{(A.7)}$$

in which m_0 is the total variances of the double peaked spectrum, and $m_0^{(1)}$ and $m_0^{(2)}$ are total wave variance in each sub-spectrum.

Peak period T_{pm}

For double peaked spectra, both the block peak period T_{pb} (based on the highest peak) and the equivalent block peak period T_{pbeq} are computed. Based on these two estimates the characteristic peak period T_{pm} is computed as:

$$T_{pm} = \max\left(T_{pb}, T_{pbeq}\right) \qquad \text{(A.8)}$$

B Definition of statistical parameters

The statistical analysis determines the model performance of the different SWAN versions with a number of statistical parameters. In this appendix these parameters will be discussed briefly. The statistical parameters are subdivided into three types of error measures. These are prediction errors, average errors and the relative error. For detailed information regarding these statistical parameters reference is made to for instance Ris et al. (1998).

Prediction error

The prediction error can be characterised with the first and second moment, similar to the moments of a time series. These moments are known as *BIAS* and the standard deviation *STD*, in formula:

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}(y_i - x_i) = \overline{y} - \overline{x} \tag{B.1}$$

$$STD^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - x_i - BIAS)^2 \tag{B.2}$$

in which N is the number of the observed (and computed) values (not including the imposed values at the up-wave boundaries), x_i is the observed value at location *i* and y_i is the value computed by the SWAN model at location i.

$\overline{x}$ and $\overline{y}$ are the mean values of the observations and predictions, respectively:

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N}x_i \quad \text{and} \quad \overline{y} = \frac{1}{N}\sum_{i=1}^{N}y_i \tag{B.3}$$

Average error

Two measures for the average error are considered important. These are the mean absolute error (*MAE*) and the root mean square error (*RMSE*). The mean absolute error is given by:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|y_i - x_i| \tag{B.4}$$

and the root mean square error is defined as:

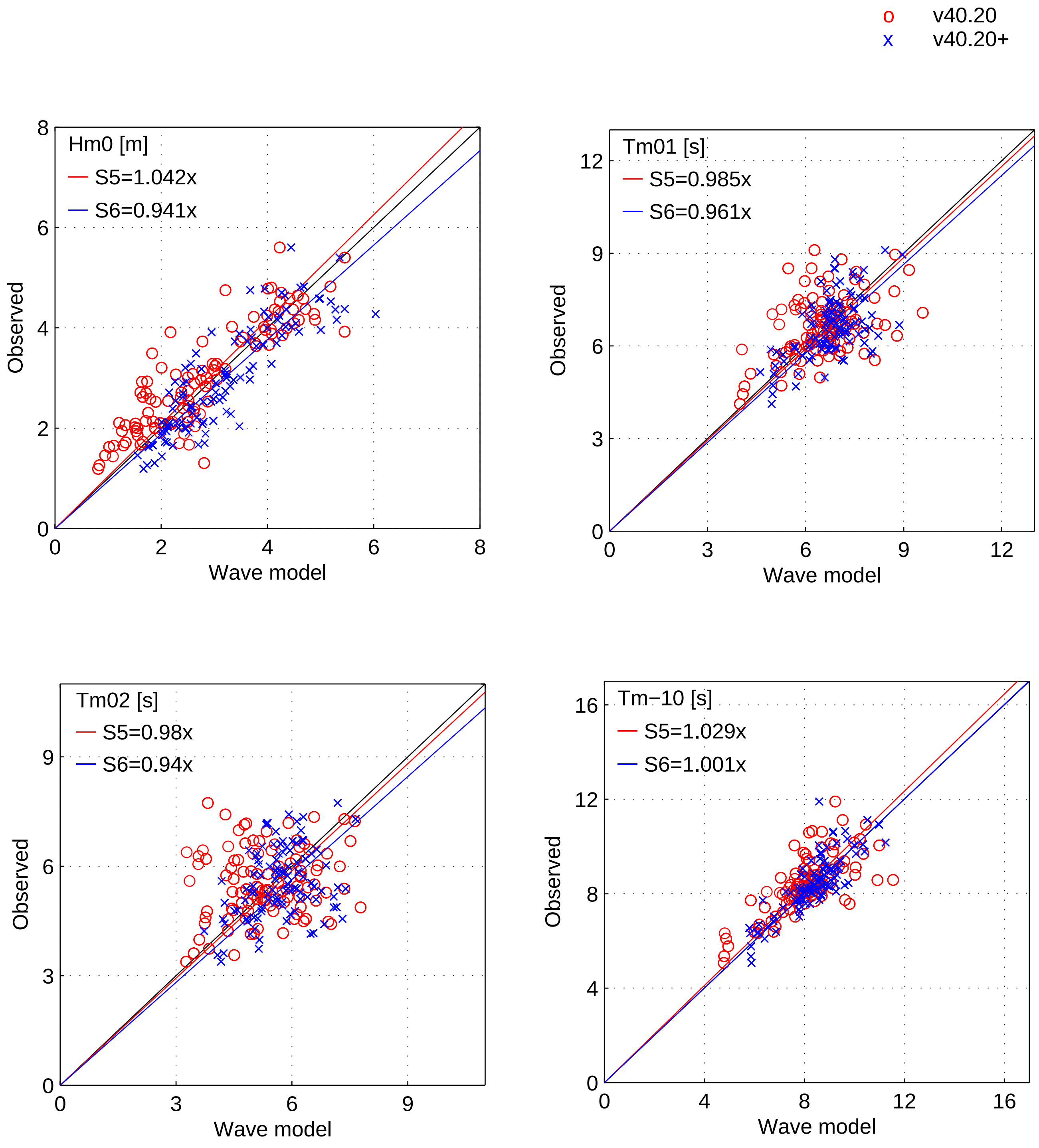
$$RMSE = \left\{ \frac{1}{N} \sum_{i=1}^{N} \left(x_i - y_i \right)^2 \right\}^{1/2} \quad \text{(B.5)}$$

Relative error

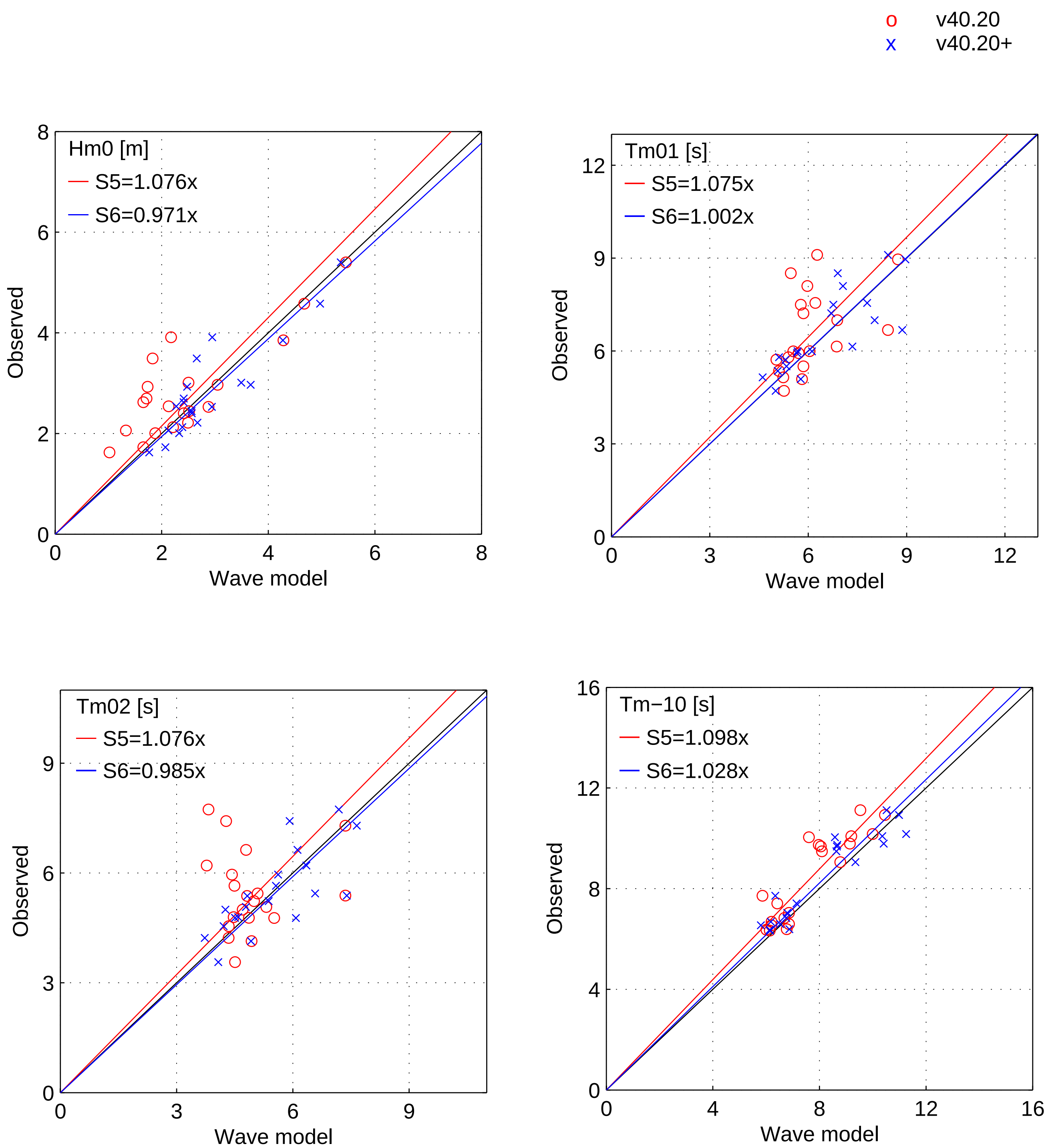
For many applications absolute measures of errors are less relevant than relative measures. In the statistical post processing program one straightforward relative measure of errors is used, i.e. the Scatter Index. The Scatter Index *SCI* is defined as the root mean square error normalised with the mean of the observed wave parameters and is given by:

$$SCI = \frac{RMSE}{\left| \bar{x} \right|} \quad \text{(B.6)}$$

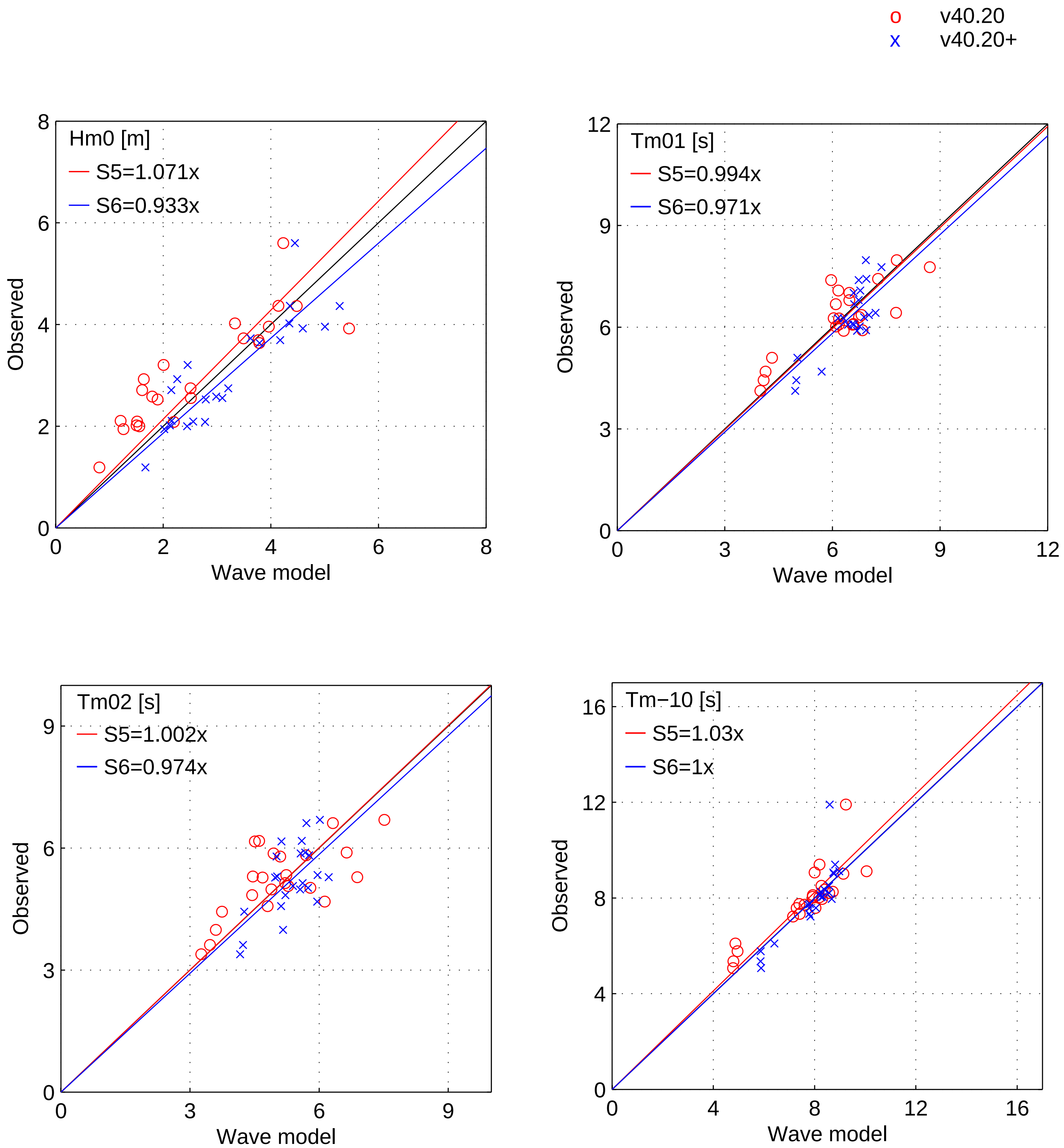
C Scatter plots Petten Hindcast



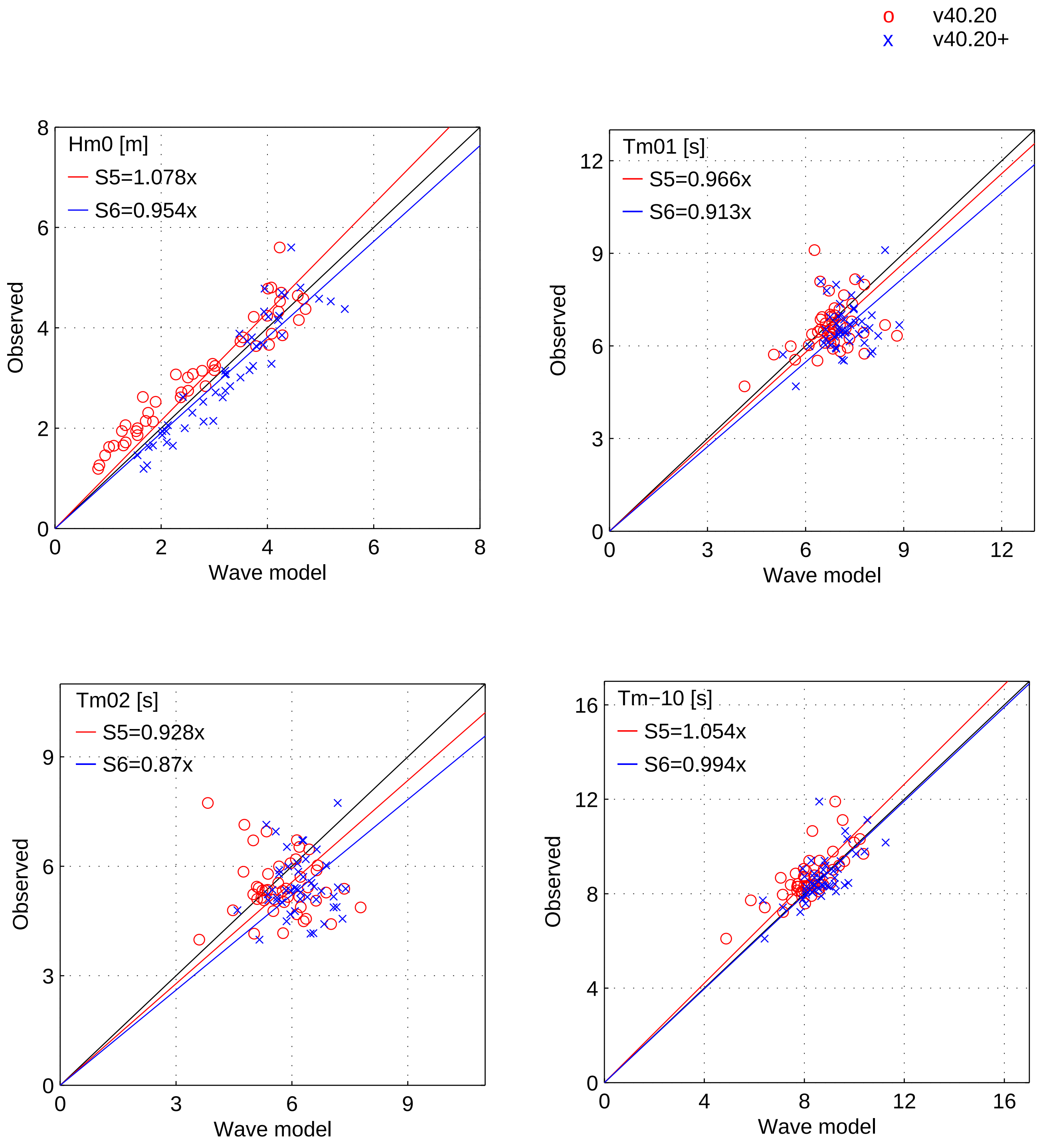
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s00all01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **all cases** Fig. : **3.1**



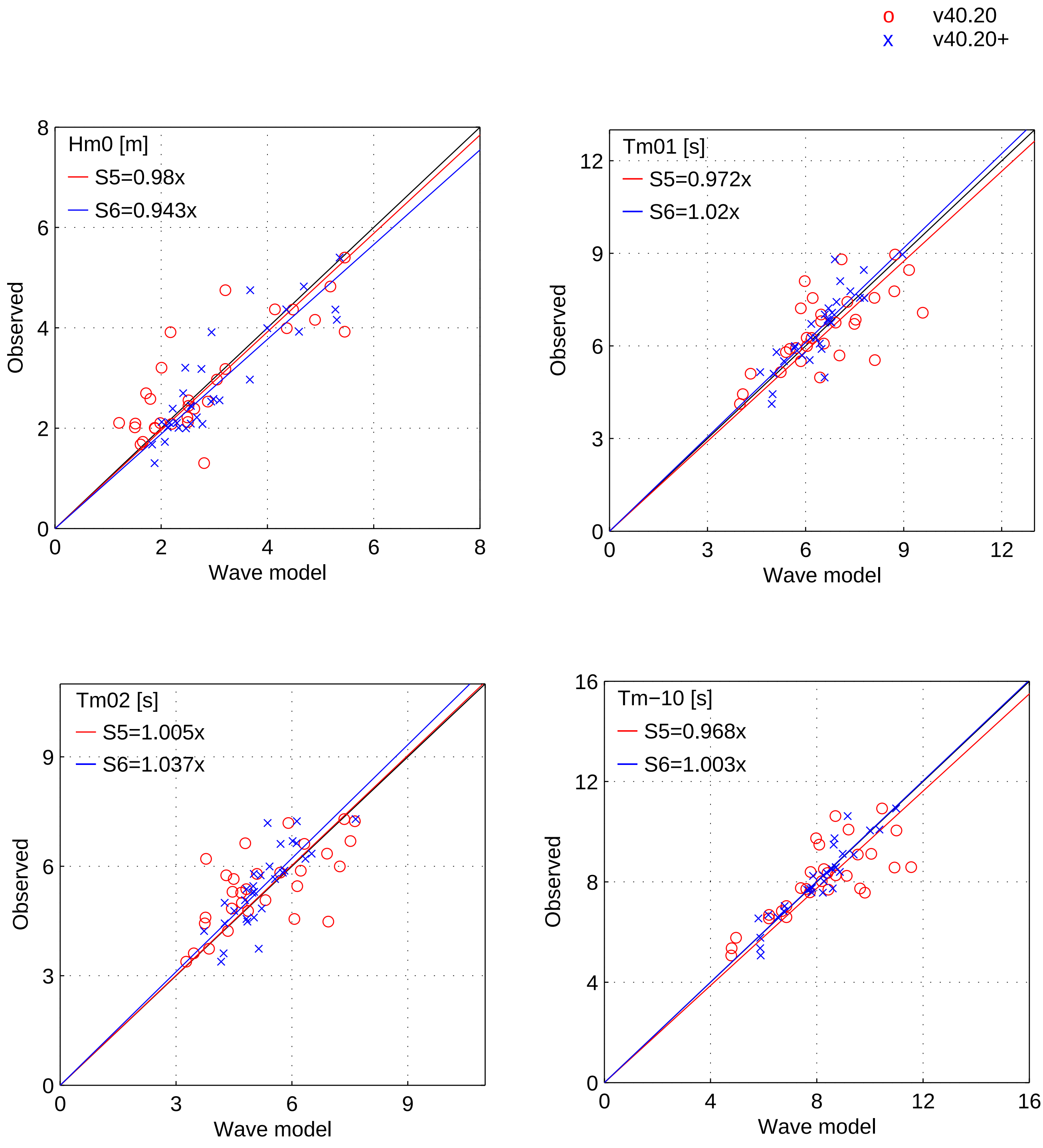
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s01opp01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **opposing current** Fig. : **3.2**



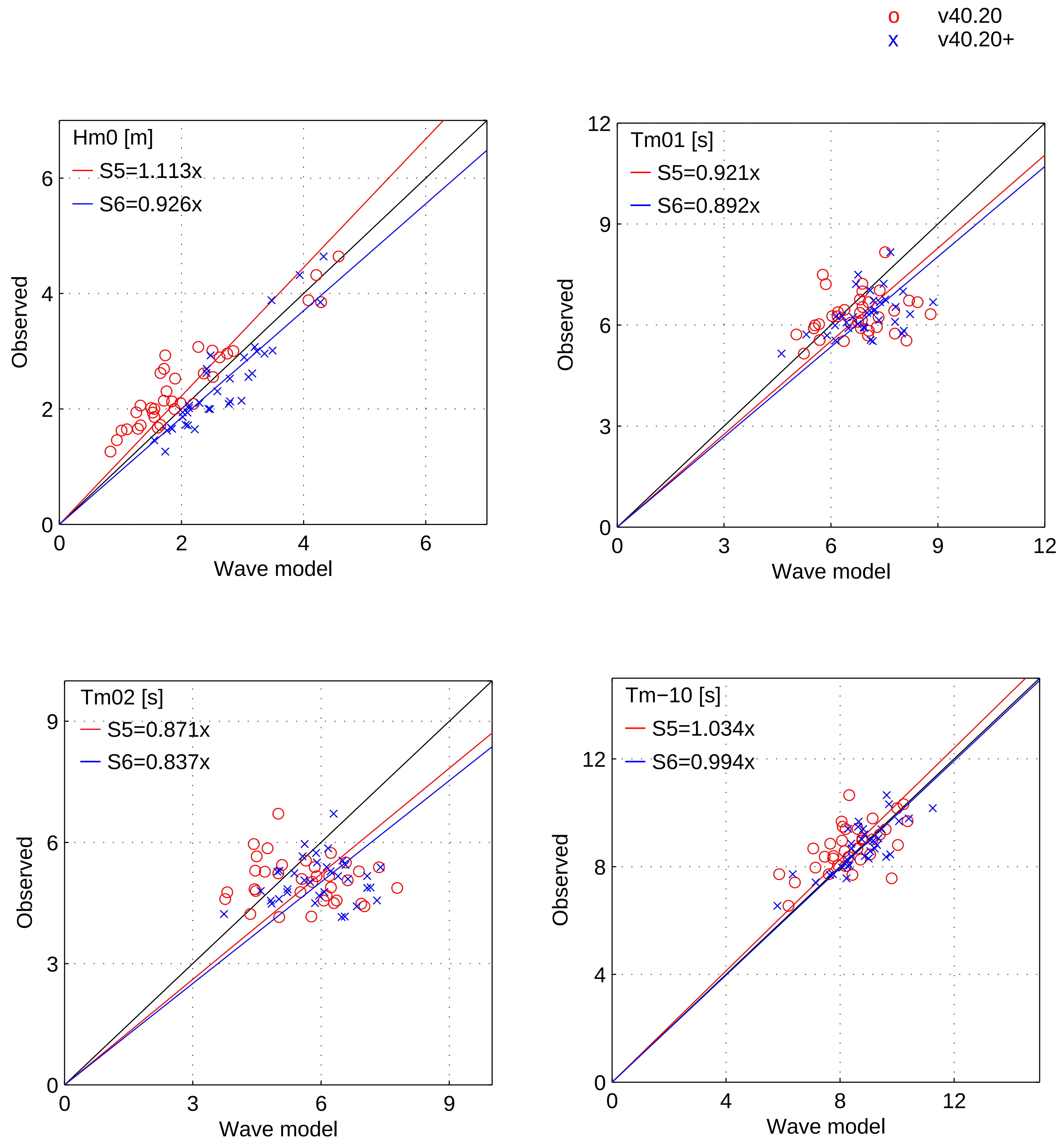
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s02par01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **following current** Fig. : **3.3**



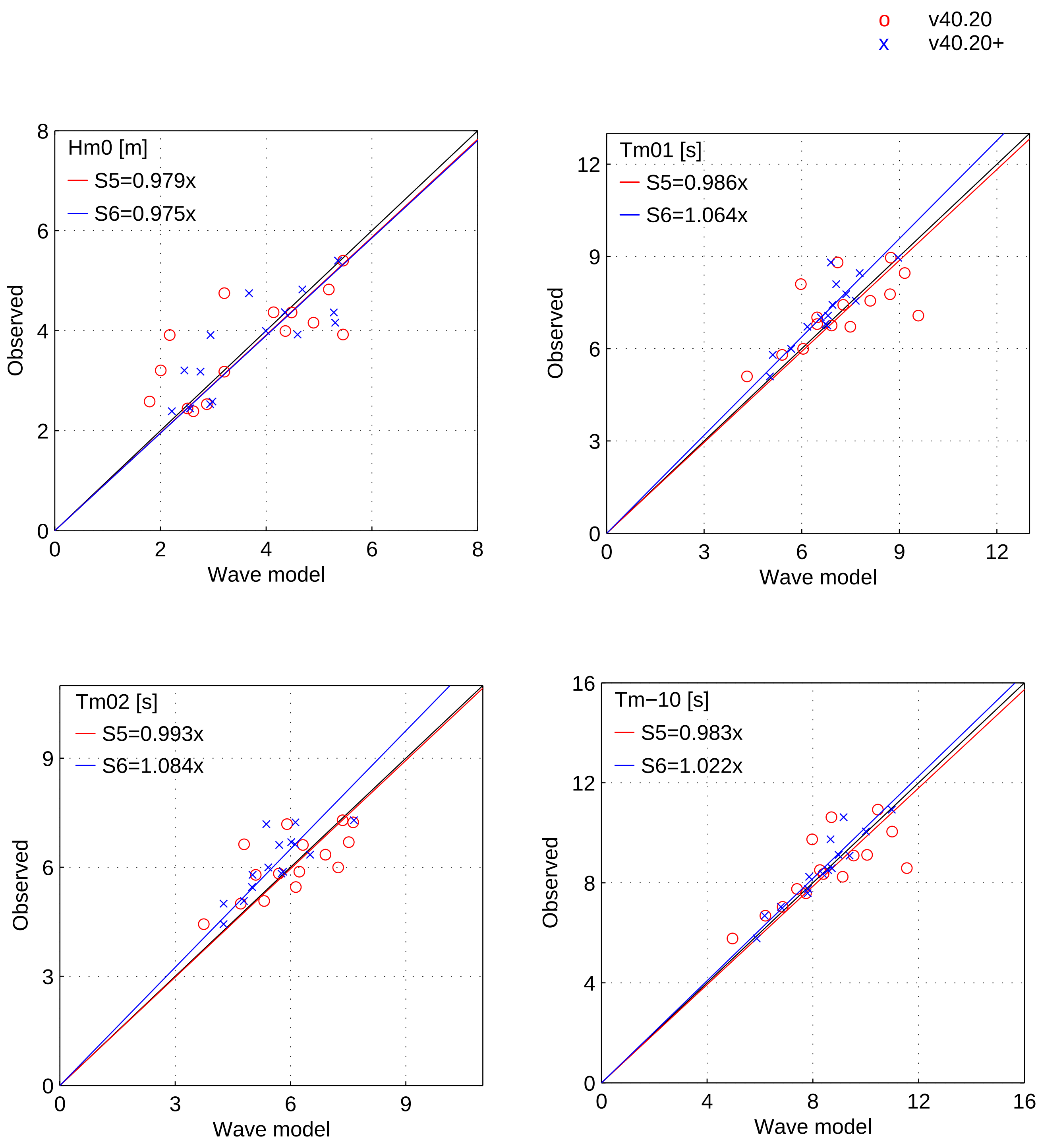
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s03dep01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **depth limited** Fig. : **3.4**



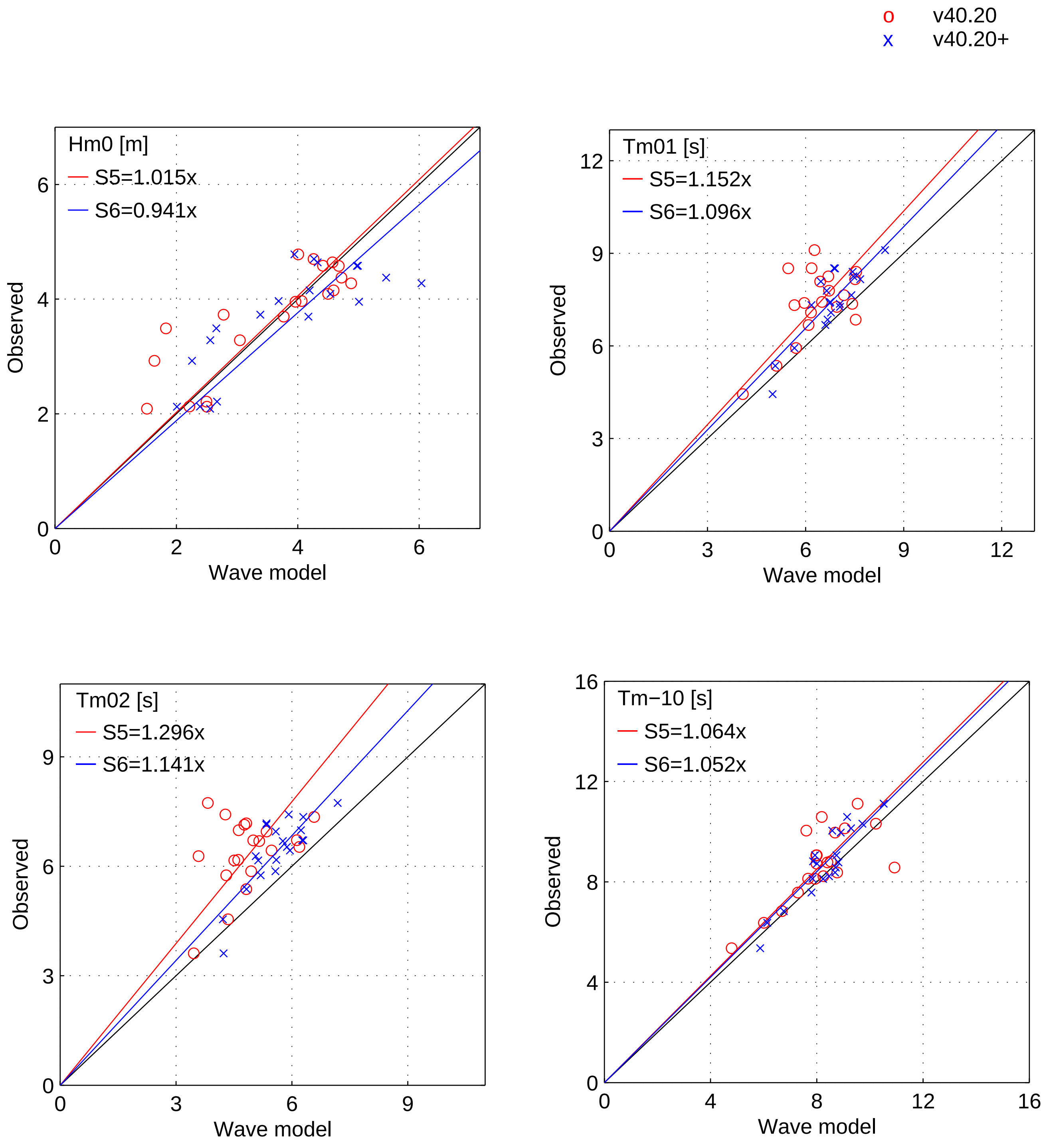
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s04nde01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **not depth limited** Fig. : **3.5**



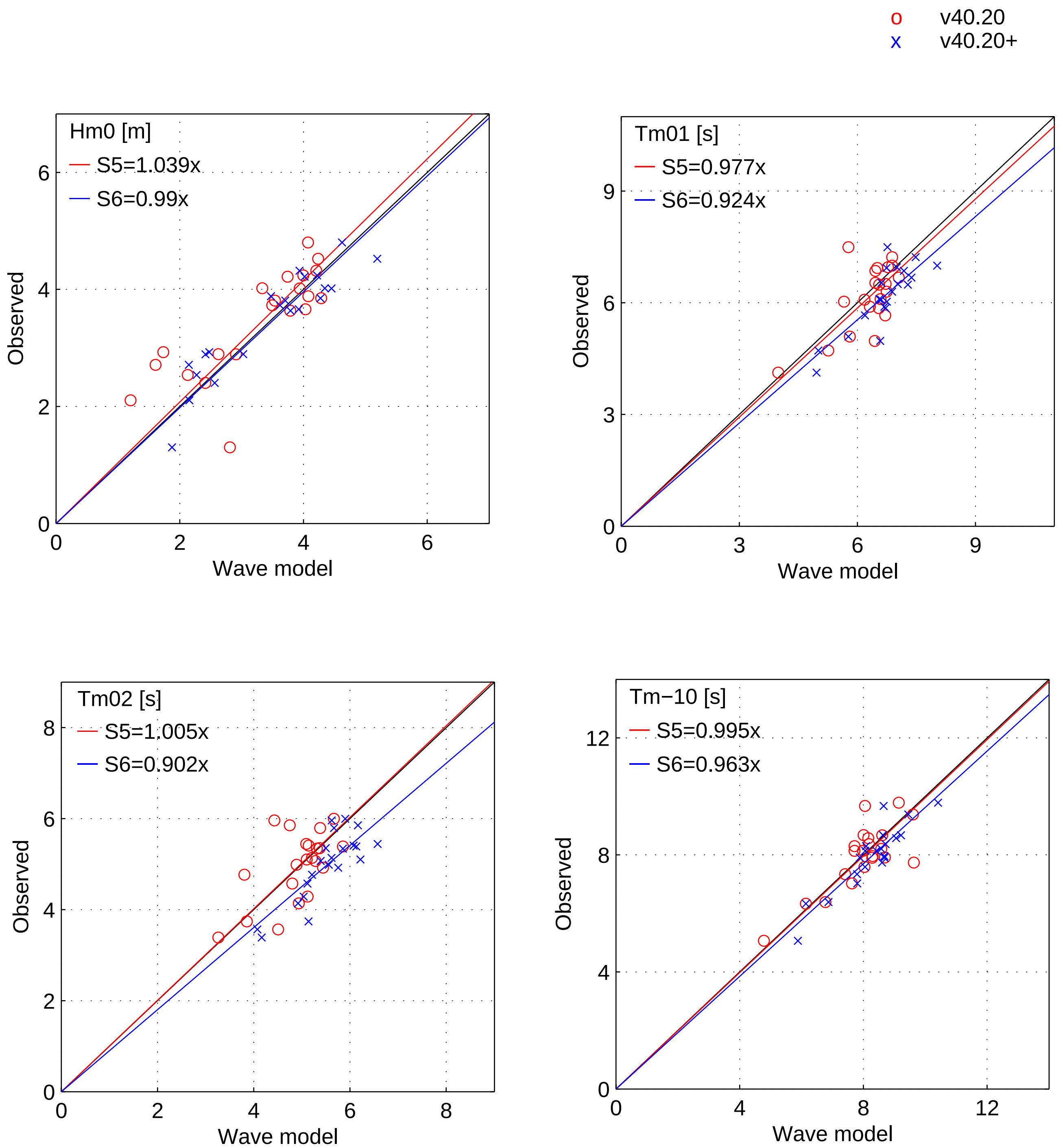
Alkyon Hydraulic Consultancy & Research	A1200
	Filename: s05dbl01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case : **low frequency** Fig. : **3.6**



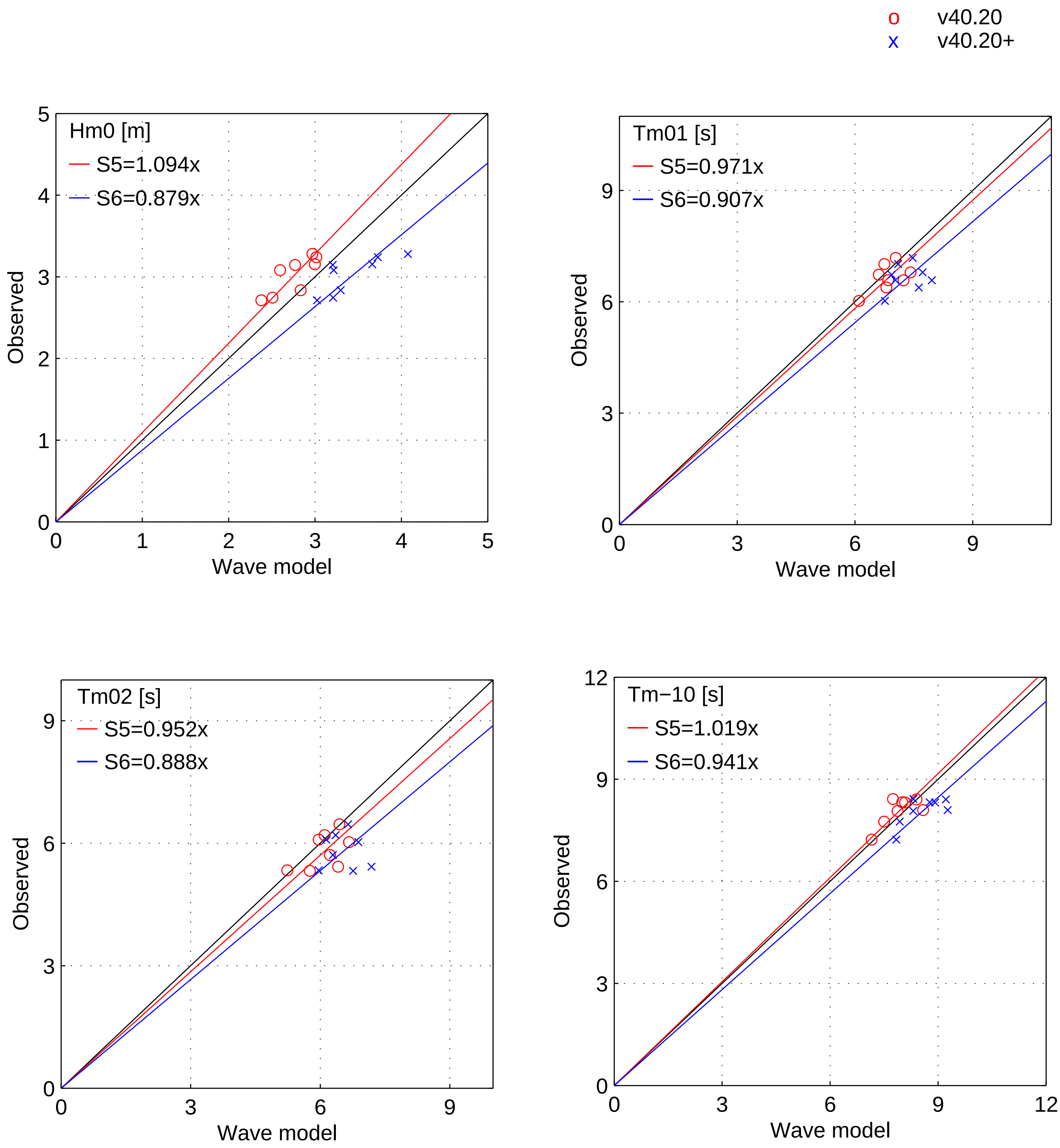
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s06loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **mp1/011** Fig. : **3.7**



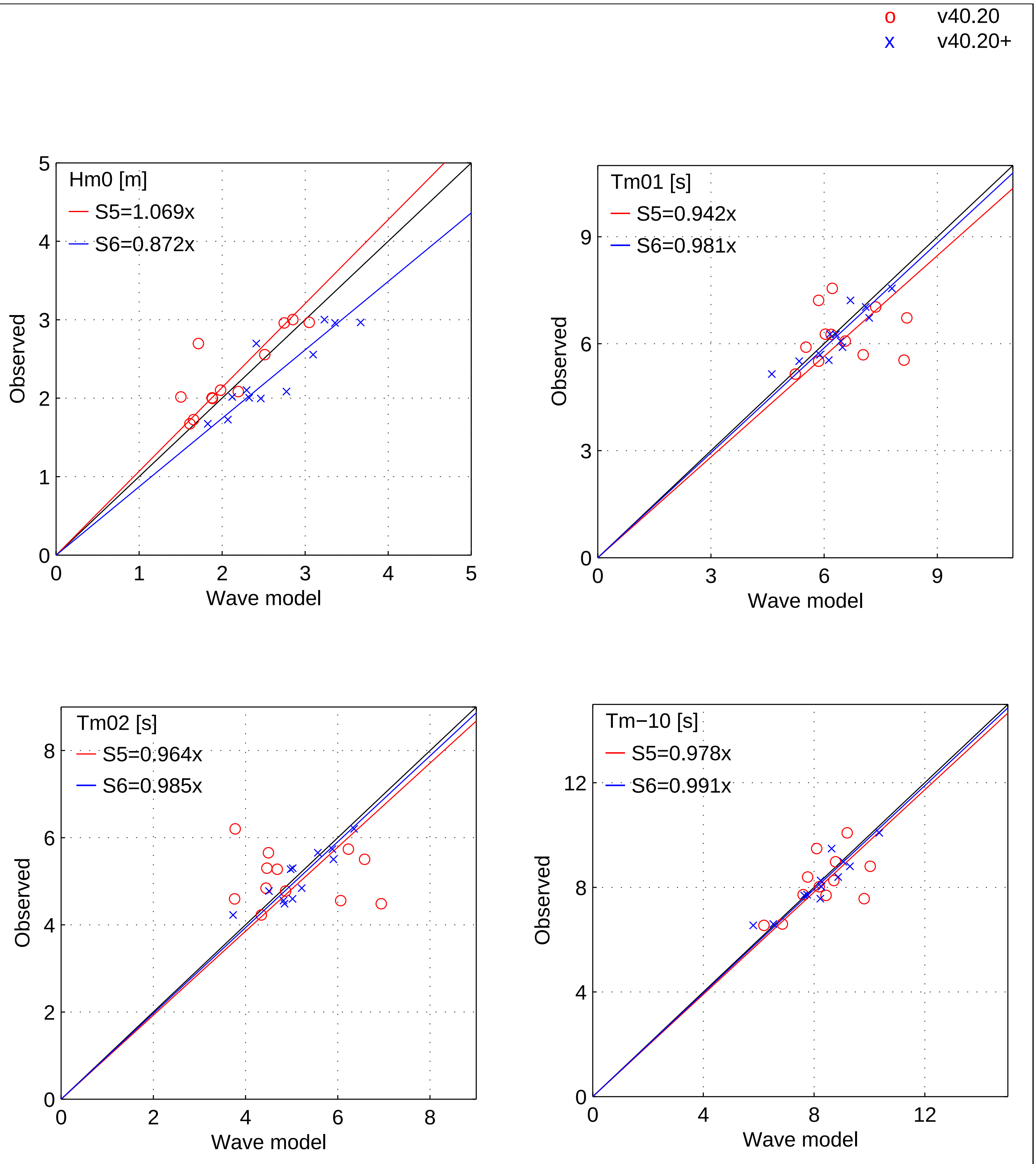
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s07loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **mp2/021** Fig. : **3.8**



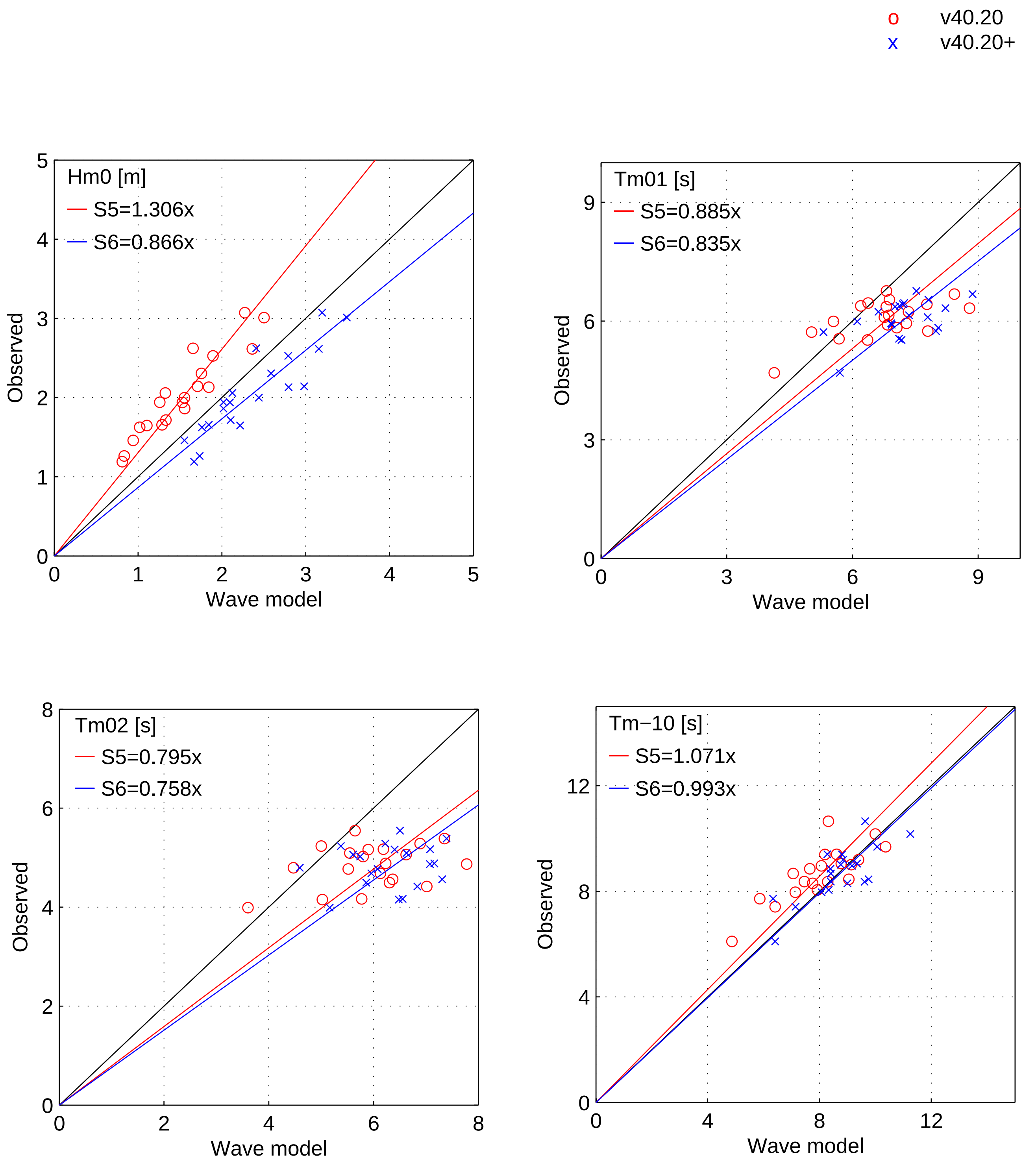
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s08loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **mp3/031/033** Fig. : **3.9**



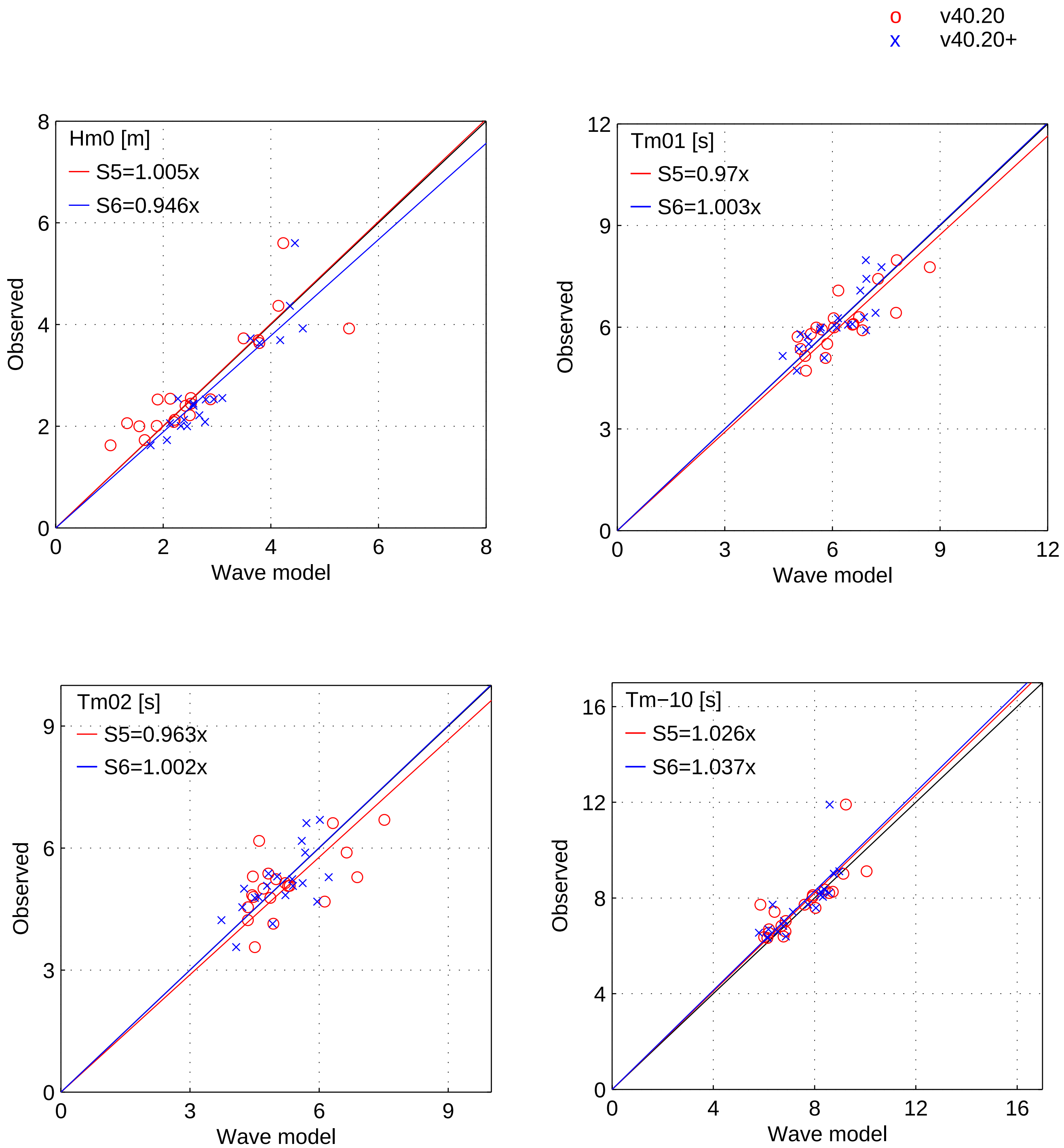
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s09loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **161/162** Fig. : **3.10**



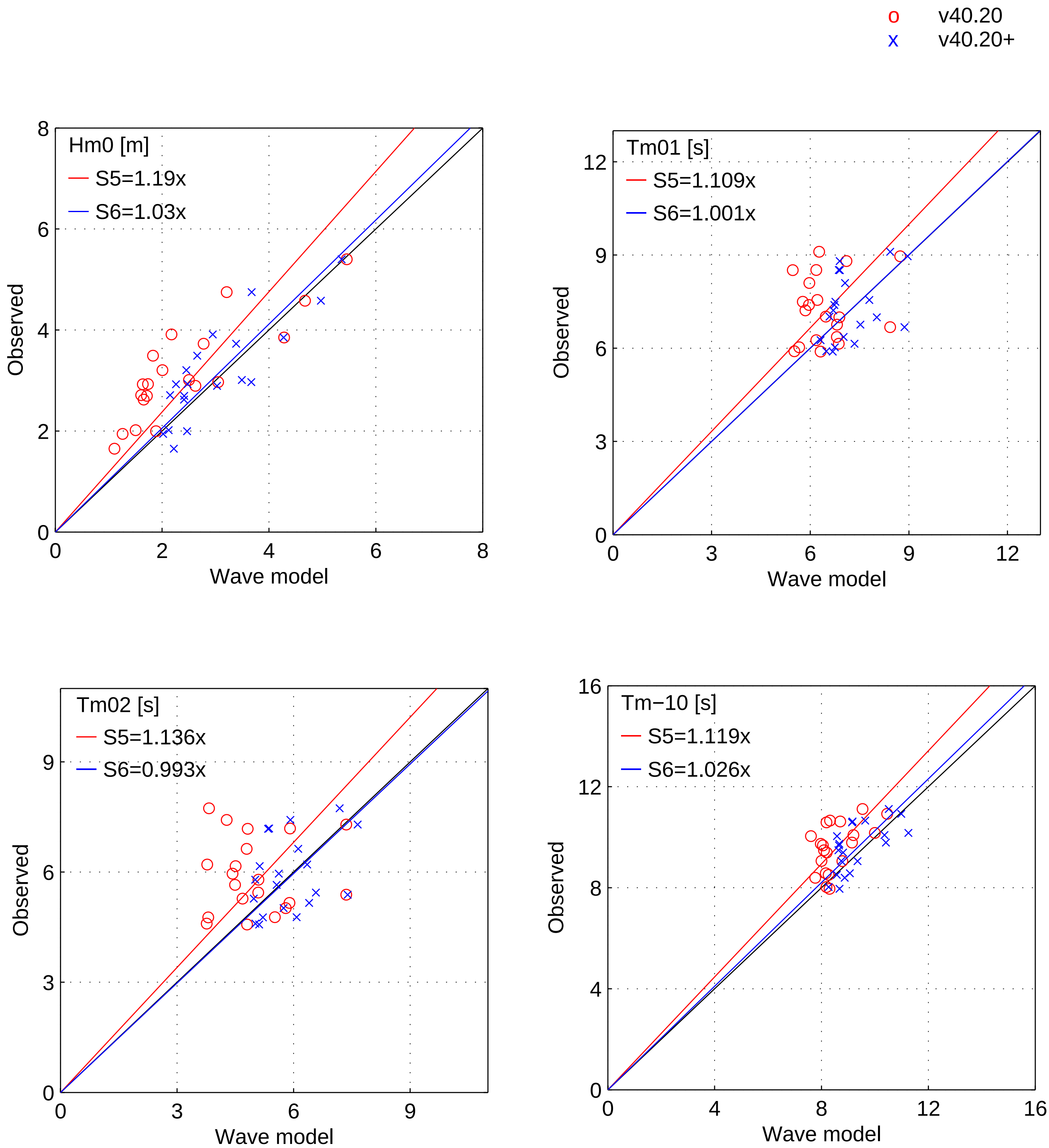
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s11loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **mp5** Fig. : **3.11**



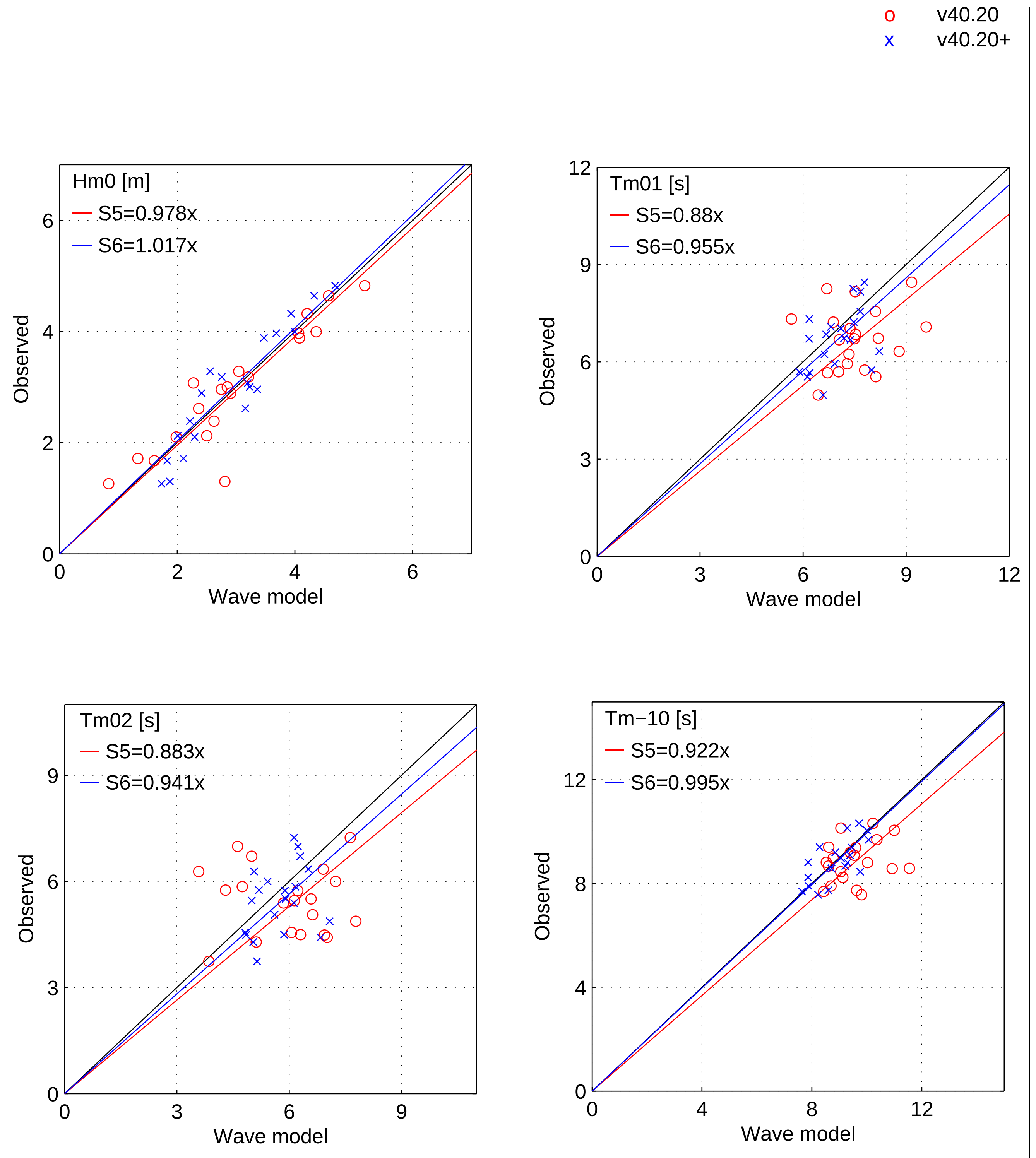
Alkyon Hydraulic Consultancy & Research	A1200
	filename: s12loc01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Loc. : **mp6/062** Fig. : **3.12**



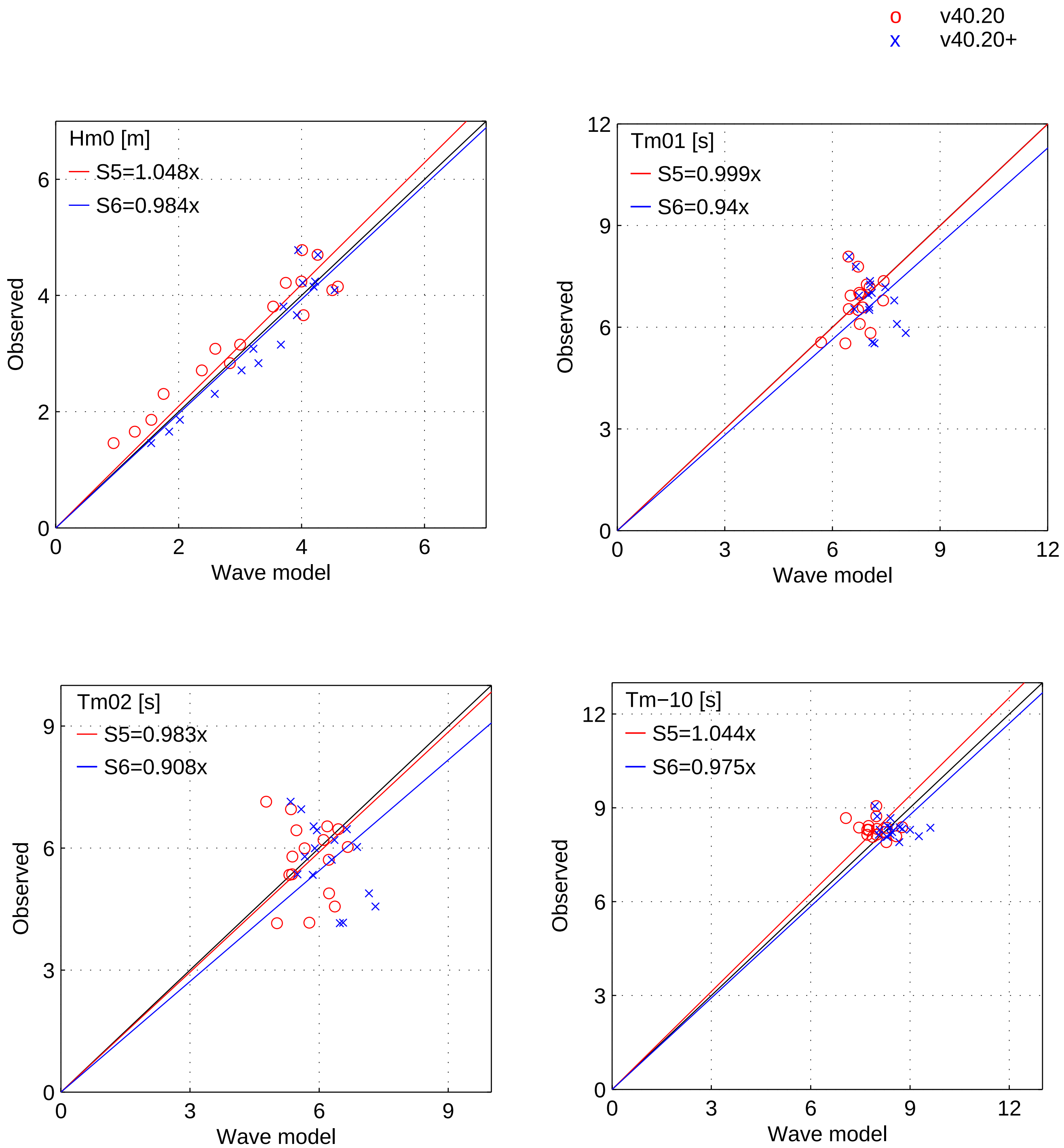
Alkyon Hydraulic Consultancy & Research	A1200
	Filename; s13str01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case. : **storm 1** Fig. : **3.13**



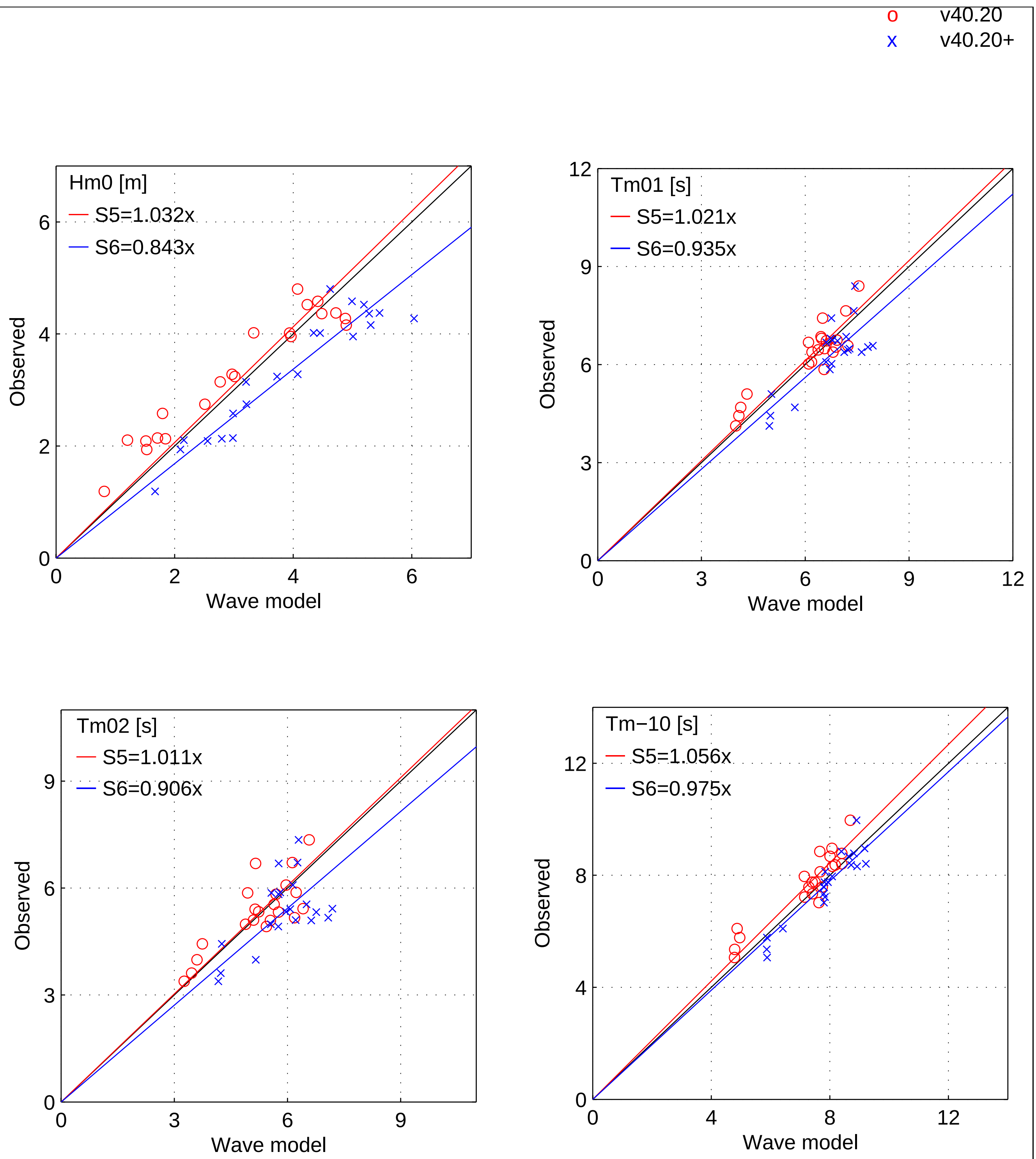
Alkyon Hydraulic Consultancy & Research	A1200
	Filename; s14str01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case. : **storm 2** Fig. : **3.14**



Alkyon Hydraulic Consultancy & Research	A1200
	Filename; s15str01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case. : **storm 3** Fig. : **3.15**



Alkyon Hydraulic Consultancy & Research	A1200
	Filename; s16str01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case. : **storm 4** Fig. : **3.16**



Alkyon Hydraulic Consultancy & Research	A1200
	Filename; s17str01a.a
Wave model: SWAN 40.20 Period Correction SWAN 40.20	Case. : **storm 5** Fig. : **3.17**

D Statistical parameters Petten Hindcast

Computed statistical parameters for case : f1apet01
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.093	2.093	5.348	5.348	4.427	4.427	6.729	6.729	7.243	7.243	7.627	7.627	8.658	8.658	8.712	8.712
bias	-0.187	0.118	-0.140	-0.327	0.049	-0.254	-0.649	-0.610	-0.044	-0.044	-0.355	-0.609	-1.513	-1.758	-1.440	-1.695
mae	0.248	0.225	0.395	0.444	0.375	0.457	0.649	0.610	0.804	0.804	0.590	0.688	1.513	1.758	1.440	1.695
rmse	0.332	0.241	0.449	0.470	0.476	0.492	0.890	0.748	0.845	0.845	0.687	0.851	2.798	2.788	2.524	2.647
sci	0.159	0.115	0.084	0.088	0.108	0.111	0.132	0.111	0.117	0.117	0.090	0.112	0.323	0.322	0.290	0.304
std	0.307	0.234	0.477	0.378	0.530	0.471	0.681	0.483	0.944	0.944	0.658	0.664	2.631	2.419	2.318	2.274

Computed statistical parameters for case : f1apet02
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.242	2.242	5.703	5.703	4.918	4.918	6.853	6.853	8.356	8.356	7.558	7.558	7.642	7.642	7.769	7.769
bias	-0.043	0.284	0.089	0.009	0.071	-0.034	-0.135	-0.034	-0.324	-0.324	0.349	0.293	0.122	0.209	0.139	0.083
mae	0.300	0.284	0.356	0.313	0.384	0.405	0.393	0.227	0.460	0.460	0.440	0.388	0.293	0.256	0.276	0.224
rmse	0.388	0.320	0.420	0.370	0.461	0.465	0.502	0.274	0.549	0.549	0.519	0.447	0.317	0.275	0.302	0.237
sci	0.173	0.143	0.074	0.065	0.094	0.095	0.073	0.040	0.066	0.066	0.069	0.059	0.041	0.036	0.039	0.030
std	0.431	0.165	0.459	0.414	0.509	0.519	0.541	0.304	0.496	0.496	0.430	0.377	0.327	0.200	0.300	0.248

Computed statistical parameters for case : f1apet03
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.374	3.374	6.556	6.556	5.567	5.567	7.965	7.965	9.455	9.455	9.251	9.251	8.996	8.996	9.333	9.333
bias	-0.212	0.233	0.023	0.119	-0.207	-0.032	0.015	0.187	0.545	0.545	0.658	0.323	0.437	0.577	0.576	0.241
mae	0.243	0.282	0.544	0.476	0.871	0.671	0.183	0.187	0.545	0.545	0.658	0.391	0.859	0.638	0.630	0.370
rmse	0.321	0.348	0.636	0.567	1.037	0.769	0.231	0.251	0.704	0.704	0.690	0.467	0.937	0.742	0.682	0.458
sci	0.095	0.103	0.097	0.086	0.186	0.138	0.029	0.031	0.074	0.074	0.075	0.050	0.104	0.082	0.073	0.049
std	0.269	0.290	0.710	0.619	1.136	0.859	0.258	0.187	0.498	0.498	0.231	0.378	0.927	0.521	0.407	0.435

Computed statistical parameters for case : f1apet04
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.448	3.448	6.909	6.909	5.568	5.568	9.300	9.300	15.611	15.611	10.849	10.849	13.057	13.057	13.666	13.666
bias	-0.004	0.161	0.609	0.056	0.572	0.182	-0.156	-0.669	-3.933	-4.192	0.861	-0.670	-2.309	-2.852	-1.956	-3.349
mae	0.721	0.622	0.683	0.635	0.731	0.536	0.912	0.818	4.954	5.213	0.861	0.817	3.715	3.447	3.195	3.496
rmse	0.944	0.703	0.799	0.683	0.893	0.592	1.293	1.494	9.947	9.965	0.964	0.975	5.189	5.324	4.590	5.247
sci	0.274	0.204	0.116	0.099	0.160	0.106	0.139	0.161	0.637	0.638	0.089	0.090	0.397	0.408	0.336	0.384
std	1.055	0.766	0.578	0.761	0.767	0.630	1.435	1.494	10.215	10.108	0.485	0.792	5.196	5.026	4.642	4.516

Computed statistical parameters for case : f1bpet01
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.961	3.961	7.859	7.859	6.412	6.412	10.417	10.417	13.524	13.524	12.390	12.390	13.523	13.523	13.523	13.523
bias	0.033	0.392	-0.550	0.558	-0.932	0.619	-0.749	0.290	-1.071	1.047	0.397	-0.312	-1.763	-1.445	-0.736	-1.445
mae	0.235	0.409	1.252	0.828	1.744	0.838	0.749	0.529	2.681	2.845	0.676	0.767	1.763	1.445	0.748	1.445
rmse	0.305	0.461	1.609	1.128	2.244	1.074	0.889	0.633	3.625	3.178	0.844	0.788	2.152	1.688	1.274	1.688
sci	0.077	0.116	0.205	0.143	0.350	0.167	0.085	0.061	0.268	0.235	0.068	0.064	0.159	0.125	0.094	0.125
std	0.339	0.271	1.690	1.096	2.282	0.981	0.534	0.630	3.873	3.355	0.832	0.809	1.380	0.976	1.163	0.976

Computed statistical parameters for case : f1bpet02
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.003	3.003	7.202	7.202	5.778	5.778	9.769	9.769	12.691	12.691	12.235	12.235	12.994	12.994	13.434	13.434
bias	-0.682	-0.048	-0.945	-0.297	-0.940	-0.310	-1.541	-0.594	-1.530	-1.013	-1.198	-1.569	-2.706	-2.058	-2.396	-2.497
mae	0.682	0.518	0.968	1.126	1.234	1.149	1.541	0.978	3.792	3.792	2.412	2.150	2.706	2.137	2.536	2.576
rmse	0.855	0.605	1.312	1.250	1.368	1.308	1.760	1.071	4.717	4.546	2.719	2.700	3.965	3.234	3.661	3.570
sci	0.285	0.202	0.182	0.174	0.237	0.226	0.180	0.110	0.372	0.358	0.222	0.221	0.305	0.249	0.272	0.266
std	0.576	0.675	1.018	1.357	1.111	1.421	0.951	0.997	4.988	4.955	2.729	2.456	3.241	2.789	3.094	2.852

"
Computed statistical parameters for case : f1bpet03
"
Number of stations at which computed data is available : 5
"

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.130	3.130	7.492	7.492	6.086	6.086	9.599	9.599	10.786	10.786	10.922	10.922	11.496	11.496	11.621	11.621
bias	-1.308	-0.549	-1.506	-0.538	-1.384	-0.226	-1.497	-0.822	0.375	0.769	0.640	-0.996	-1.316	-0.787	-0.059	-0.912
mae	1.308	0.549	1.795	1.020	1.683	0.749	1.497	0.941	1.625	1.372	0.909	0.996	1.316	0.787	0.218	0.912
rmse	1.349	0.625	1.956	1.088	1.870	0.932	1.656	1.015	2.100	1.595	0.945	1.068	1.333	0.797	0.340	0.965
sci	0.431	0.200	0.261	0.145	0.307	0.153	0.173	0.106	0.195	0.148	0.086	0.098	0.116	0.069	0.029	0.083
std	0.369	0.334	1.395	1.057	1.406	1.011	0.792	0.665	2.310	1.562	0.777	0.431	0.236	0.142	0.374	0.352

Computed statistical parameters for case : f1bpet04
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.559	2.559	6.584	6.584	5.364	5.364	8.590	8.590	11.444	11.444	10.085	10.085	11.263	11.263	11.263	11.263
bias	-0.956	-0.359	-0.234	0.083	-0.386	-0.169	-0.400	0.024	-1.444	0.233	0.284	0.241	-1.229	-0.936	-0.894	-0.936
mae	0.956	0.433	0.583	0.517	0.790	0.676	0.600	0.385	1.444	0.788	1.098	0.961	1.705	1.558	1.667	1.558
rmse	1.003	0.518	0.736	0.578	0.920	0.719	0.743	0.451	1.730	0.995	1.340	1.208	3.188	2.695	2.812	2.695
sci	0.392	0.202	0.112	0.088	0.172	0.134	0.087	0.052	0.151	0.087	0.133	0.120	0.283	0.239	0.250	0.239
std	0.340	0.418	0.781	0.640	0.934	0.782	0.701	0.503	1.065	1.081	1.464	1.323	3.288	2.826	2.980	2.826

Computed statistical parameters for case : f2apet01
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.964	3.964	7.379	7.379	6.034	6.034	9.647	9.647	10.833	10.833	11.008	11.008	12.662	12.662	12.662	12.662
bias	-0.166	-0.063	0.731	0.290	0.313	0.280	0.597	0.060	3.056	0.328	2.440	0.150	-0.356	-1.043	0.786	-1.043
mae	0.310	0.274	1.127	0.757	1.439	0.890	0.633	0.319	3.056	0.863	2.440	0.958	1.298	1.321	1.563	1.321
rmse	0.407	0.298	1.363	0.956	1.669	1.143	0.765	0.390	3.345	1.400	2.745	1.097	1.748	1.668	1.655	1.668
sci	0.103	0.075	0.185	0.129	0.277	0.189	0.079	0.040	0.309	0.129	0.249	0.100	0.138	0.132	0.131	0.132
std	0.415	0.326	1.287	1.018	1.832	1.239	0.535	0.431	1.522	1.522	1.405	1.215	1.913	1.456	1.629	1.456

Computed statistical parameters for case : f2apet02
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.492	3.492	7.053	7.053	5.774	5.774	9.066	9.066	9.934	9.934	9.893	9.893	11.644	11.644	11.644	11.644
bias	0.053	0.017	0.350	0.467	0.352	0.545	-0.058	0.277	1.227	1.622	1.485	0.662	-1.020	-0.628	-0.267	-0.628
mae	0.213	0.294	0.974	0.782	1.297	0.846	0.479	0.617	2.477	3.336	1.501	0.984	1.330	1.013	1.410	1.013
rmse	0.232	0.345	1.199	1.111	1.621	1.186	0.596	0.752	2.703	3.930	1.674	1.001	2.135	1.559	1.781	1.559
sci	0.067	0.099	0.170	0.158	0.281	0.205	0.066	0.083	0.272	0.396	0.169	0.101	0.183	0.134	0.153	0.134
std	0.253	0.385	1.282	1.128	1.769	1.177	0.663	0.782	2.693	4.002	0.865	0.840	2.096	1.595	1.968	1.595

Computed statistical parameters for case : f2apet03
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.635	2.635	6.324	6.324	5.128	5.128	8.411	8.411	10.469	10.469	9.765	9.765	11.560	11.560	11.560	11.560
bias	-0.138	-0.208	0.523	-0.112	0.378	-0.020	0.268	-0.506	0.692	-0.005	1.385	-0.729	-1.037	-2.525	-0.411	-2.525
mae	0.158	0.441	1.190	0.559	1.457	0.648	0.700	0.506	1.763	1.511	1.878	0.959	1.925	2.525	1.526	2.525
rmse	0.209	0.473	1.226	0.642	1.621	0.725	0.731	0.681	2.192	1.662	1.983	1.429	2.828	3.292	2.268	3.292
sci	0.079	0.180	0.194	0.102	0.316	0.141	0.087	0.081	0.209	0.159	0.203	0.146	0.245	0.285	0.196	0.285
std	0.175	0.475	1.240	0.707	1.763	0.810	0.760	0.509	2.325	1.858	1.588	1.374	2.942	2.363	2.494	2.363

Computed statistical parameters for case : f2apet04
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	1.750	1.750	6.076	6.076	4.894	4.894	8.331	8.331	12.579	12.579	9.202	9.202	11.039	11.039	11.039	11.039
bias	0.327	0.183	1.717	0.546	0.835	0.398	1.932	0.290	1.310	1.310	4.137	0.926	1.175	-0.381	2.299	-0.381
mae	0.522	0.297	1.717	0.723	1.414	0.852	1.932	0.427	1.468	1.468	4.137	0.950	1.567	0.902	2.299	0.902
rmse	0.729	0.352	1.865	0.893	1.610	0.959	2.145	0.516	1.653	1.653	4.227	1.142	1.848	1.068	2.486	1.068
sci	0.417	0.201	0.307	0.147	0.329	0.196	0.257	0.062	0.131	0.131	0.459	0.124	0.167	0.097	0.225	0.097
std	0.729	0.336	0.814	0.790	1.539	0.975	1.042	0.477	1.128	1.128	0.970	0.747	1.594	1.116	1.059	1.116

Computed statistical parameters for case : f2bpet01

Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.414	3.414	6.814	6.814	5.777	5.777	8.455	8.455	9.545	9.545	9.991	9.991	10.057	10.057	10.403	10.403
bias	-0.442	-0.077	-0.231	0.101	-0.127	0.265	-0.728	-0.250	0.455	-0.584	-0.504	-0.544	-1.202	-0.751	-0.917	-0.957
mae	0.442	0.239	0.651	0.765	0.929	1.011	0.728	0.270	0.455	0.584	0.504	0.544	1.202	1.039	0.917	0.957
rmse	0.444	0.265	0.725	1.008	1.155	1.380	0.738	0.381	0.643	0.740	0.760	0.714	2.071	1.786	1.575	1.510
sci	0.130	0.078	0.106	0.148	0.200	0.239	0.087	0.045	0.067	0.078	0.076	0.071	0.206	0.178	0.151	0.145
std	0.052	0.293	0.794	1.158	1.326	1.564	0.136	0.331	0.525	0.525	0.657	0.534	1.948	1.871	1.478	1.349

Computed statistical parameters for case : f2bpet02
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.881	2.881	6.671	6.671	5.761	5.761	8.155	8.155	9.455	9.455	9.418	9.418	9.411	9.411	9.599	9.599
bias	0.207	0.374	0.358	0.664	0.146	0.555	0.248	0.844	1.706	1.500	1.348	0.643	0.434	0.854	1.167	0.667
mae	0.331	0.374	0.492	0.803	0.833	1.094	0.275	0.844	1.706	1.500	1.448	0.856	1.029	0.930	1.293	0.743
rmse	0.378	0.490	0.642	1.109	1.059	1.376	0.331	0.910	1.764	1.885	1.662	1.011	1.107	1.091	1.435	0.964
sci	0.131	0.170	0.096	0.166	0.184	0.239	0.041	0.112	0.187	0.199	0.176	0.107	0.118	0.116	0.149	0.100
std	0.353	0.354	0.597	0.994	1.173	1.407	0.244	0.382	0.498	1.275	1.086	0.872	1.139	0.758	0.932	0.778

Computed statistical parameters for case : f2bpet03
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.225	3.225	6.927	6.927	6.076	6.076	8.232	8.232	9.636	9.636	9.527	9.527	9.143	9.143	9.568	9.568
bias	-0.052	0.423	-0.122	0.263	-0.201	0.161	-0.313	0.346	0.364	0.364	0.257	0.363	-0.049	0.627	0.215	0.321
mae	0.327	0.431	0.388	0.553	0.741	0.823	0.323	0.346	0.364	0.364	0.375	0.372	0.581	0.869	0.417	0.333
rmse	0.355	0.519	0.450	0.810	0.888	1.150	0.388	0.406	0.575	0.575	0.439	0.471	0.750	0.897	0.475	0.462
sci	0.110	0.161	0.065	0.117	0.146	0.189	0.047	0.049	0.060	0.060	0.046	0.049	0.082	0.098	0.050	0.048
std	0.393	0.336	0.484	0.857	0.967	1.273	0.255	0.238	0.498	0.498	0.398	0.336	0.836	0.717	0.474	0.372

Computed statistical parameters for case : f2bpet04
Number of stations at which computed data is available : 5

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.934	2.934	6.740	6.740	5.741	5.741	8.437	8.437	10.444	10.444	9.877	9.877	10.228	10.228	10.605	10.605
bias	-0.365	0.015	-0.421	-0.070	-0.437	0.002	-0.833	-0.348	-0.444	-0.212	-0.131	-0.571	-1.291	-0.941	-0.859	-1.219
mae	0.392	0.391	0.578	0.902	0.999	1.221	0.833	0.444	0.444	0.677	0.624	0.645	1.291	1.247	1.208	1.310
rmse	0.458	0.487	0.823	1.087	1.274	1.455	0.970	0.576	0.703	0.874	0.794	0.747	2.583	2.203	2.040	2.036
sci	0.156	0.166	0.122	0.161	0.222	0.253	0.115	0.068	0.067	0.084	0.080	0.076	0.253	0.215	0.192	0.192
std	0.310	0.544	0.791	1.213	1.338	1.626	0.557	0.513	0.609	0.948	0.876	0.538	2.501	2.227	2.068	1.823

Computed statistical parameters for case : f3apet01
Number of stations at which computed data is available : 6

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.402	3.402	6.719	6.719	5.944	5.944	7.747	7.747	8.712	8.712	8.721	8.721	8.223	8.223	8.721	8.721
bias	0.071	0.696	-0.308	0.034	-0.480	-0.075	-0.294	0.071	0.249	0.249	0.194	0.325	0.421	0.823	0.194	0.325
mae	0.323	0.696	0.594	0.581	0.803	0.691	0.550	0.359	0.379	0.379	0.194	0.325	0.442	0.823	0.194	0.325
rmse	0.389	0.754	0.774	0.674	1.124	0.834	0.626	0.430	0.453	0.453	0.220	0.335	0.528	0.860	0.220	0.335
sci	0.114	0.222	0.115	0.100	0.189	0.140	0.081	0.056	0.052	0.052	0.025	0.038	0.064	0.105	0.025	0.038
std	0.419	0.318	0.778	0.738	1.113	0.910	0.605	0.465	0.415	0.415	0.114	0.089	0.349	0.272	0.114	0.089

Computed statistical parameters for case : f3apet02
Number of stations at which computed data is available : 6

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	1.881	1.881	4.847	4.847	4.205	4.205	5.723	5.723	6.500	6.500	6.213	6.213	6.853	6.853	6.955	6.955
bias	-0.597	0.395	-0.733	0.274	-0.720	0.195	-0.878	0.253	-0.713	0.104	-0.523	0.558	-1.239	-0.082	-1.265	-0.184
mae	0.597	0.395	0.733	0.688	0.720	0.831	0.878	0.449	0.713	0.273	0.523	0.558	1.239	1.017	1.265	0.915
rmse	0.635	0.435	0.942	0.770	1.069	0.937	0.983	0.508	0.742	0.302	0.549	0.607	1.901	1.358	1.768	1.314
sci	0.338	0.231	0.194	0.159	0.254	0.223	0.172	0.089	0.114	0.047	0.088	0.098	0.277	0.198	0.254	0.189
std	0.244	0.202	0.661	0.804	0.884	1.025	0.493	0.492	0.228	0.317	0.186	0.265	1.612	1.516	1.381	1.454

Computed statistical parameters for case : f3apet03

Number of stations at which computed data is available : 6

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.358	3.358	6.523	6.523	5.690	5.690	7.594	7.594	9.091	9.091	8.626	8.626	8.255	8.255	8.637	8.637
bias	-0.032	0.774	-0.556	-0.002	-0.796	-0.140	-0.443	0.108	-0.130	-0.130	0.017	0.369	0.115	0.735	0.006	0.357
mae	0.338	0.774	0.627	0.507	0.796	0.622	0.472	0.436	0.130	0.130	0.353	0.369	0.245	0.735	0.341	0.357
rmse	0.436	0.837	0.964	0.650	1.297	0.804	0.738	0.512	0.130	0.130	0.372	0.482	0.266	0.790	0.361	0.460
sci	0.130	0.249	0.148	0.100	0.228	0.141	0.097	0.067	0.014	0.014	0.043	0.056	0.032	0.096	0.042	0.053
std	0.487	0.358	0.881	0.726	1.145	0.886	0.660	0.559	0.000	0.000	0.416	0.347	0.268	0.324	0.403	0.323

Computed statistical parameters for case : f3apet04

Number of stations at which computed data is available : 6

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.186	3.186	6.807	6.807	5.720	5.720	8.541	8.541	10.139	10.139	10.171	10.171	9.754	9.754	10.436	10.436
bias	-0.064	0.429	-0.408	0.336	-0.490	0.456	-0.656	0.002	-0.139	-0.139	-0.190	-0.369	-0.291	0.047	-0.455	-0.635
mae	0.542	0.501	0.574	0.604	0.846	1.002	0.656	0.250	1.639	1.639	1.107	1.110	0.333	0.436	0.842	0.845
rmse	0.580	0.676	0.752	0.708	1.181	1.088	0.738	0.342	1.949	1.949	1.272	1.219	0.506	0.551	0.941	1.059
sci	0.182	0.212	0.111	0.104	0.207	0.190	0.086	0.040	0.192	0.192	0.125	0.120	0.052	0.057	0.090	0.102
std	0.645	0.584	0.706	0.696	1.202	1.104	0.377	0.382	2.174	2.174	1.406	1.298	0.462	0.614	0.921	0.948

Computed statistical parameters for case : f3apet05

Number of stations at which computed data is available : 6

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.253	3.253	7.038	7.038	5.887	5.887	8.867	8.867	11.389	11.389	11.156	11.156	10.165	10.165	11.156	11.156
bias	0.034	1.099	-0.342	0.434	-0.375	0.623	-0.675	0.035	-1.389	-0.460	-0.784	-0.902	-0.599	0.090	-0.784	-0.902
mae	0.447	1.099	0.770	0.946	1.179	1.293	0.675	0.510	1.389	0.520	0.784	0.902	0.599	0.364	0.784	0.902
rmse	0.467	1.178	0.998	1.019	1.567	1.379	0.833	0.626	1.496	0.779	0.881	0.968	0.750	0.453	0.881	0.968
sci	0.144	0.362	0.142	0.145	0.266	0.234	0.094	0.071	0.131	0.068	0.079	0.087	0.074	0.045	0.079	0.087
std	0.521	0.474	1.049	1.031	1.700	1.375	0.547	0.699	0.621	0.703	0.448	0.394	0.504	0.496	0.448	0.394

Computed statistical parameters for case : s01opp01

Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.856	2.856	6.601	6.601	5.461	5.461	8.399	8.399	9.977	9.977	9.624	9.624	10.330	10.330	10.406	10.406
bias	-0.376	0.061	-0.527	-0.074	-0.549	0.026	-0.758	-0.294	-0.266	0.362	0.258	-0.406	-1.118	-0.945	-0.524	-0.992
mae	0.523	0.367	0.950	0.651	1.046	0.612	0.822	0.577	1.392	1.370	0.654	0.710	1.221	1.061	0.671	1.069
rmse	0.737	0.437	1.303	0.839	1.497	0.787	1.070	0.719	2.155	1.848	0.766	0.819	1.893	1.683	1.432	1.647
sci	0.258	0.153	0.197	0.127	0.274	0.144	0.127	0.086	0.216	0.185	0.080	0.085	0.183	0.163	0.138	0.158
std	0.650	0.444	1.223	0.857	1.429	0.807	0.775	0.673	2.194	1.859	0.740	0.730	1.568	1.429	1.367	1.348

Computed statistical parameters for case : s02par01

Number of stations at which computed data is available : 23

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.042	3.042	6.269	6.269	5.214	5.214	7.889	7.889	10.659	10.659	9.175	9.175	9.888	9.888	10.198	10.198
bias	-0.404	0.188	-0.025	0.206	-0.117	0.137	-0.270	0.036	-1.208	-0.751	0.274	0.126	-0.866	-0.581	-0.750	-0.867
mae	0.578	0.471	0.520	0.523	0.633	0.596	0.528	0.438	1.667	1.496	0.721	0.621	1.635	1.582	1.478	1.430
rmse	0.736	0.563	0.641	0.607	0.812	0.676	0.785	0.785	4.731	4.683	0.880	0.818	3.002	2.896	2.656	2.832
sci	0.242	0.185	0.102	0.097	0.156	0.130	0.099	0.100	0.444	0.439	0.096	0.089	0.304	0.293	0.260	0.278
std	0.628	0.543	0.655	0.584	0.821	0.677	0.753	0.802	4.677	4.727	0.855	0.826	2.939	2.901	2.605	2.757

Computed statistical parameters for case : s03dep01

Number of stations at which computed data is available : 46

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.097	3.097	6.615	6.615	5.453	5.453	8.692	8.692	11.289	11.289	10.509	10.509	11.267	11.267	11.643	11.643
bias	-0.333	0.181	0.180	0.591	0.287	0.755	-0.481	0.030	-0.723	-0.650	0.010	-0.495	-1.602	-1.233	-1.124	-1.554
mae	0.421	0.371	0.652	0.857	0.908	1.011	0.651	0.573	1.833	1.573	0.908	0.836	1.937	1.814	1.706	1.758
rmse	0.488	0.456	0.915	1.041	1.255	1.257	0.880	0.794	3.924	3.793	1.255	1.156	3.173	2.938	2.717	2.878
sci	0.158	0.147	0.138	0.157	0.230	0.231	0.101	0.091	0.348	0.336	0.119	0.110	0.282	0.261	0.233	0.247
std	0.361	0.423	0.907	0.867	1.235	1.016	0.746	0.802	3.899	3.778	1.269	1.056	2.769	2.696	2.501	2.449

″
Computed statistical parameters for case : s04nde01
″
Number of stations at which computed data is available : 30
″

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.923	2.923	6.526	6.526	5.441	5.441	8.067	8.067	9.568	9.568	8.951	8.951	9.617	9.617	9.733	9.733
bias	-0.093	0.159	0.079	-0.116	-0.169	-0.193	0.131	-0.022	0.760	0.976	1.269	0.361	0.145	-0.101	0.487	-0.207
mae	0.507	0.424	0.769	0.461	0.746	0.519	0.836	0.355	1.285	1.184	1.529	0.722	0.900	0.734	0.823	0.686
rmse	0.725	0.531	1.045	0.630	0.990	0.648	1.132	0.508	1.761	1.681	2.038	0.868	1.127	0.905	1.147	0.874
sci	0.248	0.182	0.160	0.097	0.182	0.119	0.140	0.063	0.184	0.176	0.228	0.097	0.117	0.094	0.118	0.090
std	0.732	0.515	1.060	0.630	0.993	0.629	1.143	0.516	1.615	1.392	1.622	0.803	1.137	0.915	1.056	0.864

Computed statistical parameters for case : s05dbl01
Number of stations at which computed data is available : 35

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.426	2.426	6.315	6.315	5.058	5.058	8.730	8.730	11.131	11.131	10.542	10.542	11.894	11.894	12.063	12.063
bias	-0.371	0.217	0.442	0.698	0.556	0.880	-0.361	0.012	-0.032	0.256	0.571	-0.437	-1.908	-1.643	-0.951	-1.733
mae	0.414	0.335	0.822	0.858	1.129	1.001	0.741	0.524	1.859	1.686	1.511	1.120	2.142	1.917	1.788	1.884
rmse	0.501	0.386	1.071	1.058	1.328	1.283	0.966	0.654	2.721	2.524	1.959	1.418	3.112	2.802	2.604	2.731
sci	0.207	0.159	0.170	0.168	0.263	0.254	0.111	0.075	0.244	0.227	0.186	0.135	0.262	0.236	0.216	0.226
std	0.341	0.323	0.990	0.807	1.224	0.947	0.909	0.663	2.761	2.548	1.901	1.369	2.494	2.303	2.459	2.142

Computed statistical parameters for case : s06loc01
Number of stations at which computed data is available : 15

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.735	3.735	7.221	7.221	6.096	6.096	8.538	8.538	9.168	9.168	9.373	9.373	9.711	9.711	9.798	9.798
bias	-0.109	0.006	-0.036	-0.449	-0.056	-0.508	0.011	-0.192	1.163	0.871	0.861	0.234	0.431	0.047	0.437	-0.039
mae	0.623	0.483	0.798	0.468	0.638	0.577	0.841	0.322	1.356	0.974	1.171	0.507	0.912	0.582	0.856	0.495
rmse	0.850	0.623	1.074	0.669	0.796	0.731	1.147	0.514	1.855	1.280	1.526	0.600	1.187	0.661	1.132	0.595
sci	0.228	0.167	0.149	0.093	0.131	0.120	0.134	0.060	0.202	0.140	0.163	0.064	0.122	0.068	0.116	0.061
std	0.873	0.645	1.111	0.513	0.822	0.544	1.188	0.494	1.495	0.971	1.304	0.572	1.144	0.682	1.082	0.615

Computed statistical parameters for case : s07loc01
Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.689	3.689	7.378	7.378	6.381	6.381	8.708	8.708	10.256	10.256	9.735	9.735	9.819	9.819	10.064	10.064
bias	-0.167	0.115	-1.018	-0.637	-1.543	-0.788	-0.582	-0.408	-0.008	-0.207	0.369	-0.166	-0.152	-0.122	0.039	-0.366
mae	0.448	0.570	1.092	0.692	1.543	0.849	0.859	0.566	1.399	1.252	0.964	0.811	0.732	0.787	0.794	0.881
rmse	0.617	0.688	1.378	0.850	1.838	0.967	1.153	0.716	1.742	1.672	1.465	1.096	0.980	0.895	1.222	1.161
sci	0.167	0.187	0.187	0.115	0.288	0.152	0.132	0.082	0.170	0.163	0.151	0.113	0.100	0.091	0.121	0.115
std	0.610	0.696	0.953	0.577	1.024	0.576	1.021	0.604	1.787	1.702	1.455	1.111	0.994	0.910	1.253	1.130

Computed statistical parameters for case : s08loc01
Number of stations at which computed data is available : 21

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.452	3.452	6.166	6.166	4.962	4.962	7.959	7.959	9.986	9.986	9.490	9.490	9.543	9.543	9.909	9.909
bias	-0.205	0.001	0.135	0.510	-0.047	0.547	0.013	0.310	0.307	0.139	0.716	-0.067	0.081	0.007	0.297	-0.358
mae	0.461	0.303	0.492	0.598	0.448	0.600	0.512	0.460	0.985	0.765	0.989	0.615	0.671	0.671	0.588	0.682
rmse	0.612	0.353	0.655	0.691	0.610	0.686	0.681	0.543	1.227	1.226	1.431	0.699	0.822	0.805	0.788	0.801
sci	0.177	0.102	0.106	0.112	0.123	0.138	0.086	0.068	0.123	0.123	0.151	0.074	0.086	0.084	0.079	0.081
std	0.591	0.362	0.656	0.477	0.623	0.425	0.698	0.457	1.217	1.248	1.270	0.713	0.839	0.825	0.747	0.734

Computed statistical parameters for case : s09loc01
Number of stations at which computed data is available : 8

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.024	3.024	6.661	6.661	5.820	5.820	8.077	8.077	9.823	9.823	9.795	9.795	9.042	9.042	9.831	9.831
bias	-0.266	0.403	0.188	0.664	0.282	0.710	-0.157	0.494	0.062	0.077	-0.015	0.019	0.043	0.772	-0.051	-0.017
mae	0.266	0.403	0.320	0.664	0.364	0.710	0.280	0.520	0.683	0.453	0.490	0.459	0.206	0.772	0.454	0.424
rmse	0.299	0.458	0.382	0.805	0.485	0.917	0.344	0.618	0.976	0.835	0.707	0.553	0.222	0.810	0.637	0.499
sci	0.099	0.151	0.057	0.121	0.083	0.158	0.043	0.077	0.099	0.085	0.072	0.056	0.025	0.090	0.065	0.051
std	0.146	0.232	0.356	0.486	0.422	0.620	0.328	0.397	1.041	0.888	0.755	0.591	0.233	0.261	0.678	0.533

Computed statistical parameters for case : s10loc01
Number of stations at which computed data is available : 0

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999
bias	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999
mae	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999
rmse	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999
sci	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999
std	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999	-99.999

Computed statistical parameters for case : s11loc01
Number of stations at which computed data is available : 12

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.315	2.315	6.243	6.243	5.096	5.096	8.179	8.179	10.304	10.304	9.108	9.108	10.266	10.266	10.427	10.427
bias	-0.183	0.323	0.272	0.103	-0.042	0.058	0.127	0.044	0.743	1.537	1.933	0.471	-0.301	-0.424	0.615	-0.561
mae	0.215	0.370	0.837	0.326	0.999	0.295	0.722	0.331	1.589	1.892	2.051	1.030	0.811	0.832	0.767	0.840
rmse	0.337	0.416	1.116	0.381	1.254	0.318	0.944	0.440	2.289	2.474	2.505	1.176	0.921	1.049	1.013	1.047
sci	0.146	0.180	0.179	0.061	0.246	0.062	0.115	0.054	0.222	0.240	0.275	0.129	0.090	0.102	0.097	0.100
std	0.296	0.274	1.130	0.383	1.309	0.327	0.977	0.457	2.261	2.025	1.664	1.125	0.909	1.003	0.841	0.923

Computed statistical parameters for case : s12loc01
Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.039	2.039	6.065	6.065	4.837	4.837	8.689	8.689	11.516	11.516	11.020	11.020	12.692	12.692	12.892	12.892
bias	-0.511	0.312	0.675	1.139	1.121	1.465	-0.670	0.015	-1.093	-0.604	-0.540	-0.963	-3.247	-2.628	-2.412	-2.702
mae	0.511	0.333	0.870	1.180	1.215	1.485	0.831	0.584	1.876	1.580	1.105	1.209	3.329	2.812	2.665	2.749
rmse	0.541	0.396	1.088	1.335	1.435	1.665	1.026	0.724	2.965	2.544	1.482	1.600	4.138	3.648	3.404	3.552
sci	0.265	0.194	0.179	0.220	0.297	0.344	0.118	0.083	0.258	0.221	0.134	0.145	0.326	0.287	0.264	0.276
std	0.183	0.251	0.875	0.714	0.919	0.812	0.798	0.743	2.828	2.536	1.416	1.311	2.633	2.596	2.464	2.365

Computed statistical parameters for case : s13str01
Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.789	2.789	6.129	6.129	5.120	5.120	7.712	7.712	10.166	10.166	8.821	8.821	9.588	9.588	9.870	9.870
bias	-0.112	0.199	0.145	-0.036	0.121	-0.034	-0.231	-0.282	-0.939	-1.004	0.378	-0.166	-0.816	-0.956	-0.670	-1.180
mae	0.378	0.353	0.495	0.467	0.590	0.517	0.534	0.461	1.691	1.756	0.638	0.571	1.595	1.525	1.385	1.446
rmse	0.560	0.441	0.596	0.535	0.760	0.592	0.832	0.856	5.012	5.020	0.733	0.723	2.989	3.031	2.645	2.950
sci	0.201	0.158	0.097	0.087	0.149	0.116	0.108	0.111	0.493	0.494	0.083	0.082	0.312	0.316	0.268	0.299
std	0.563	0.403	0.593	0.548	0.770	0.606	0.820	0.829	5.051	5.047	0.644	0.722	2.950	2.951	2.626	2.774

Computed statistical parameters for case : s14str01
Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.163	3.163	7.284	7.284	5.910	5.910	9.594	9.594	12.111	12.111	11.408	11.408	12.319	12.319	12.460	12.460
bias	-0.728	-0.141	-0.809	-0.048	-0.911	-0.021	-1.047	-0.276	-0.918	0.259	0.031	-0.659	-1.753	-1.306	-1.021	-1.448
mae	0.795	0.477	1.149	0.872	1.362	0.853	1.097	0.708	2.385	2.199	1.274	1.219	1.873	1.482	1.292	1.623
rmse	0.955	0.556	1.473	1.043	1.677	1.031	1.340	0.834	3.271	2.928	1.643	1.621	2.841	2.303	2.400	2.439
sci	0.302	0.176	0.202	0.143	0.284	0.174	0.140	0.087	0.270	0.242	0.144	0.142	0.231	0.187	0.193	0.196
std	0.634	0.552	1.263	1.069	1.445	1.057	0.858	0.808	3.221	2.993	1.685	1.519	2.294	1.945	2.228	2.013

Computed statistical parameters for case : s15str01
Number of stations at which computed data is available : 20

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	2.960	2.960	6.708	6.708	5.458	5.458	8.864	8.864	10.954	10.954	9.967	9.967	11.726	11.726	11.726	11.726
bias	0.019	-0.018	0.830	0.298	0.470	0.301	0.685	0.030	1.571	0.814	2.362	0.252	-0.309	-1.144	0.602	-1.144
mae	0.301	0.326	1.252	0.705	1.402	0.809	0.936	0.467	2.191	1.795	2.489	0.963	1.530	1.440	1.700	1.440
rmse	0.446	0.373	1.438	0.916	1.630	1.019	1.232	0.602	2.551	2.393	2.834	1.178	2.181	2.073	2.076	2.073
sci	0.151	0.126	0.214	0.137	0.299	0.187	0.139	0.068	0.233	0.218	0.284	0.118	0.186	0.177	0.177	0.177
std	0.457	0.382	1.205	0.889	1.602	0.999	1.051	0.616	2.062	2.309	1.608	1.181	2.215	1.774	2.038	1.774

Computed statistical parameters for case : s16str01
Number of stations at which computed data is available : 16

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.295	3.295	6.750	6.750	5.731	5.731	8.342	8.342	9.798	9.798	9.865	9.865	9.859	9.859	10.208	10.208
bias	-0.231	0.081	-0.005	0.378	0.041	0.479	-0.376	0.184	0.492	0.087	0.077	-0.127	-0.636	-0.199	-0.266	-0.445
mae	0.383	0.280	0.508	0.812	0.810	1.045	0.537	0.498	0.770	0.657	0.633	0.592	1.120	1.032	0.941	0.848
rmse	0.419	0.348	0.681	1.075	1.078	1.394	0.667	0.635	1.032	0.893	0.821	0.686	1.907	1.634	1.505	1.409
sci	0.127	0.106	0.101	0.159	0.188	0.243	0.080	0.076	0.105	0.091	0.083	0.070	0.193	0.166	0.147	0.138
std	0.360	0.350	0.704	1.039	1.113	1.352	0.569	0.627	0.937	0.918	0.844	0.696	1.856	1.675	1.530	1.381

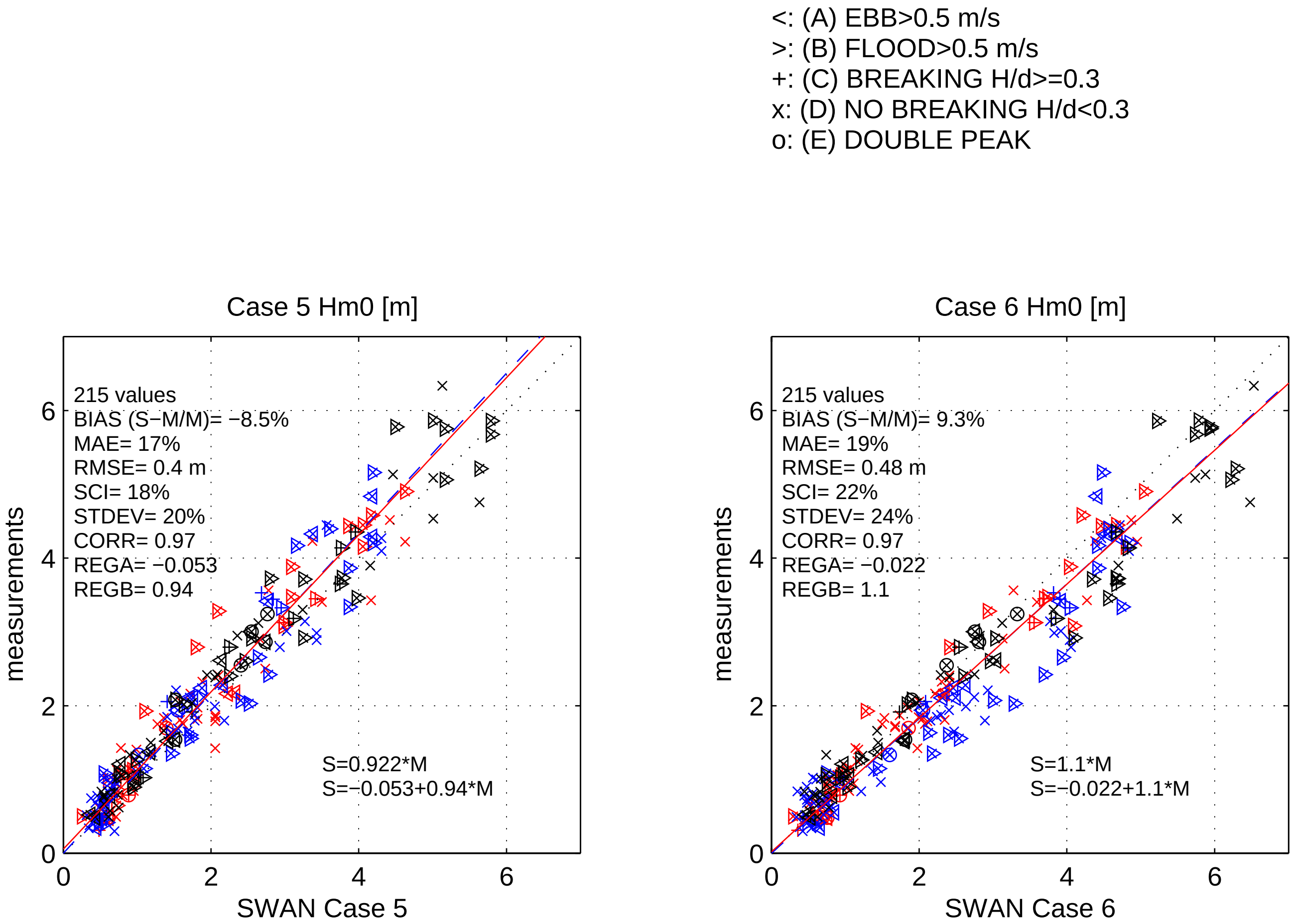
Computed statistical parameters for case : s17str01
Number of stations at which computed data is available : 21

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.318	3.318	6.305	6.305	5.340	5.340	7.665	7.665	9.373	9.373	9.114	9.114	8.694	8.694	9.268	9.268
bias	-0.241	0.594	-0.155	0.439	-0.096	0.525	-0.434	0.216	-0.621	-0.292	-0.378	-0.064	-0.274	0.357	-0.532	-0.218
mae	0.413	0.611	0.395	0.639	0.464	0.813	0.514	0.393	0.740	0.491	0.534	0.599	0.616	0.776	0.675	0.707
rmse	0.480	0.735	0.478	0.758	0.608	0.973	0.642	0.487	0.934	0.665	0.662	0.745	1.045	0.942	1.034	0.946
sci	0.145	0.221	0.076	0.120	0.114	0.182	0.084	0.064	0.100	0.071	0.073	0.082	0.120	0.108	0.112	0.102
std	0.425	0.443	0.463	0.633	0.615	0.840	0.484	0.447	0.716	0.612	0.557	0.760	1.034	0.893	0.908	0.943

Computed statistical parameters for case : total
Number of stations at which computed data is available : 97

	Hm0 [m]		Tm01 [s]		Tm02 [s]		Tm-10 [s]		Tp [s]		Tpb [s]		Tpbeq [s]		Tpm [s]	
SWAN	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+	40.20	40.20+
mean	3.099	3.099	6.627	6.627	5.501	5.501	8.431	8.431	10.497	10.497	9.826	9.826	10.443	10.443	10.712	10.712
bias	-0.260	0.150	0.000	0.201	-0.080	0.243	-0.278	-0.031	-0.112	-0.035	0.502	-0.153	-0.758	-0.658	-0.384	-0.898
mae	0.457	0.417	0.766	0.694	0.926	0.798	0.729	0.504	1.580	1.400	1.127	0.795	1.349	1.255	1.204	1.223
rmse	0.610	0.519	1.036	0.878	1.232	1.015	0.994	0.698	3.015	2.894	1.590	1.065	2.307	2.123	2.031	2.104
sci	0.197	0.167	0.156	0.133	0.224	0.185	0.118	0.083	0.287	0.276	0.162	0.108	0.221	0.203	0.190	0.196
std	0.555	0.499	1.041	0.859	1.236	0.991	0.960	0.701	3.029	2.908	1.517	1.059	2.191	2.029	2.005	1.913

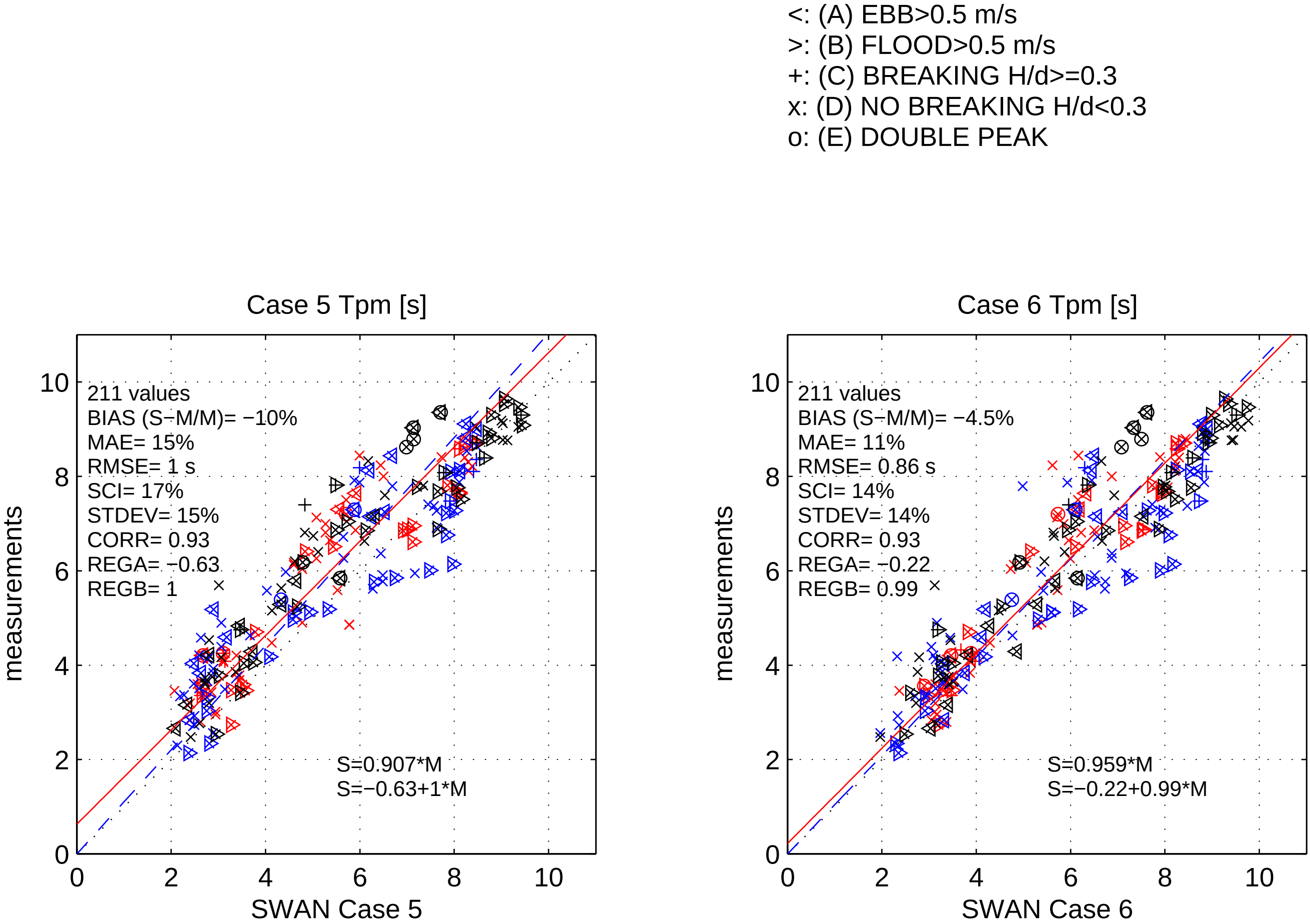
E Scatter plots Westerschelde hindcast



Parameter: Hm0 [m]   Cases 5 and 6   FIGURE 4.1

red=storm A; blue=storm B; black=storm C   A1200

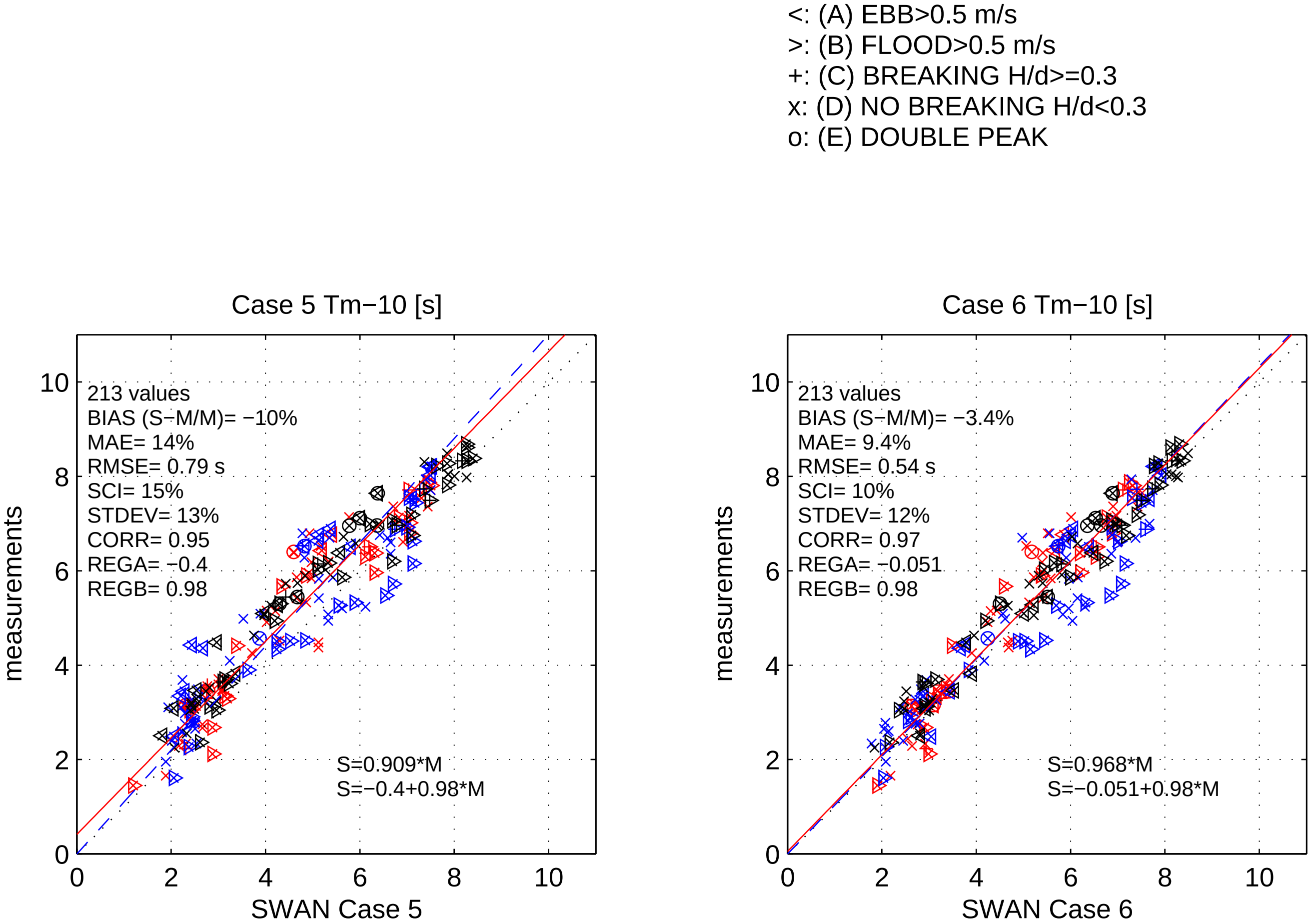
ALKYON HYDRAULIC CONSULTANCY & RESEARCH   18−Nov−2003



Parameter: Tpm [s]   Cases 5 and 6   FIGURE 4.2

red=storm A; blue=storm B; black=storm C   A1200

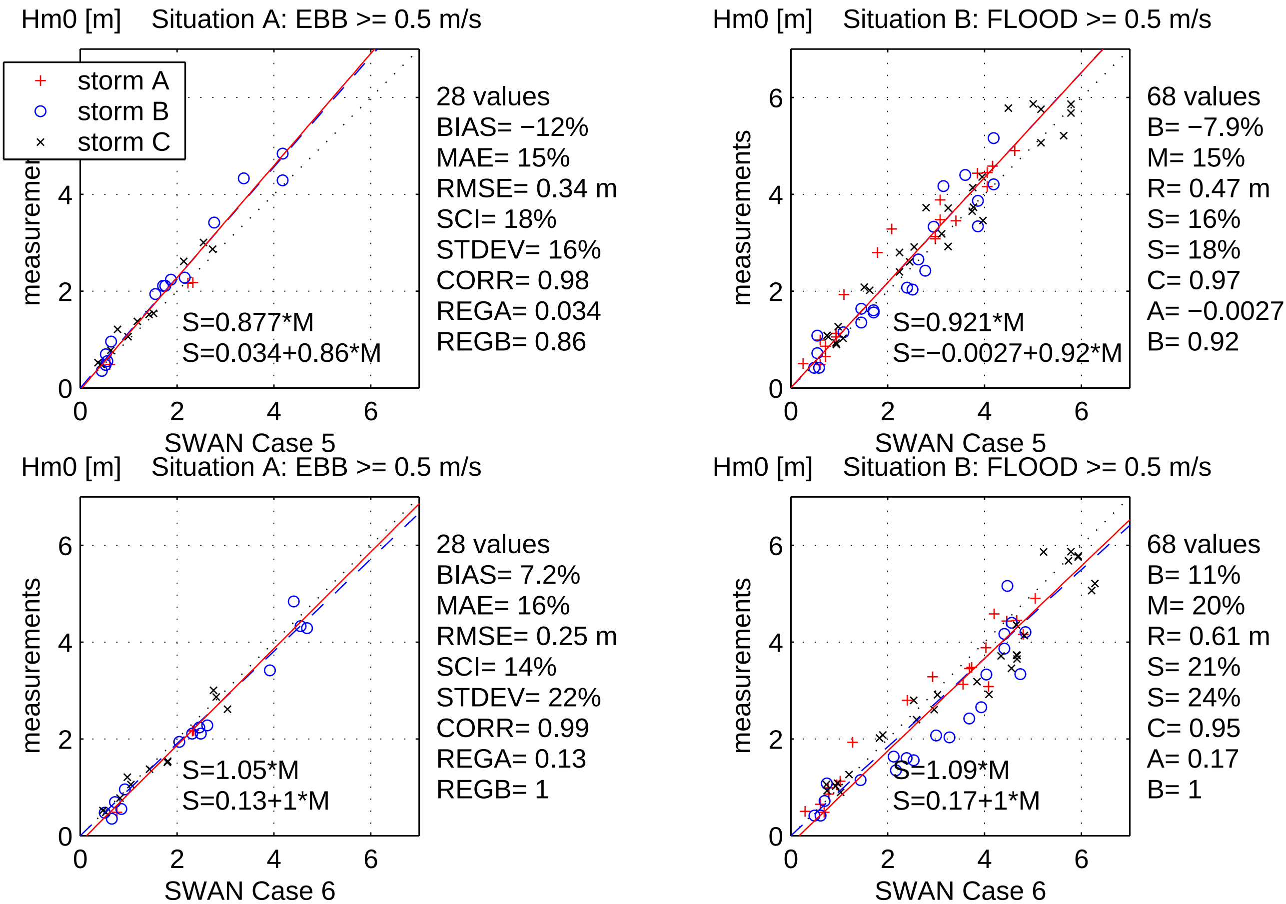
ALKYON HYDRAULIC CONSULTANCY & RESEARCH   18-Nov-2003



Parameter: Tm-10 [s] Cases 5 and 6 **FIGURE 4.3**

red=storm A; blue=storm B; black=storm C A1200

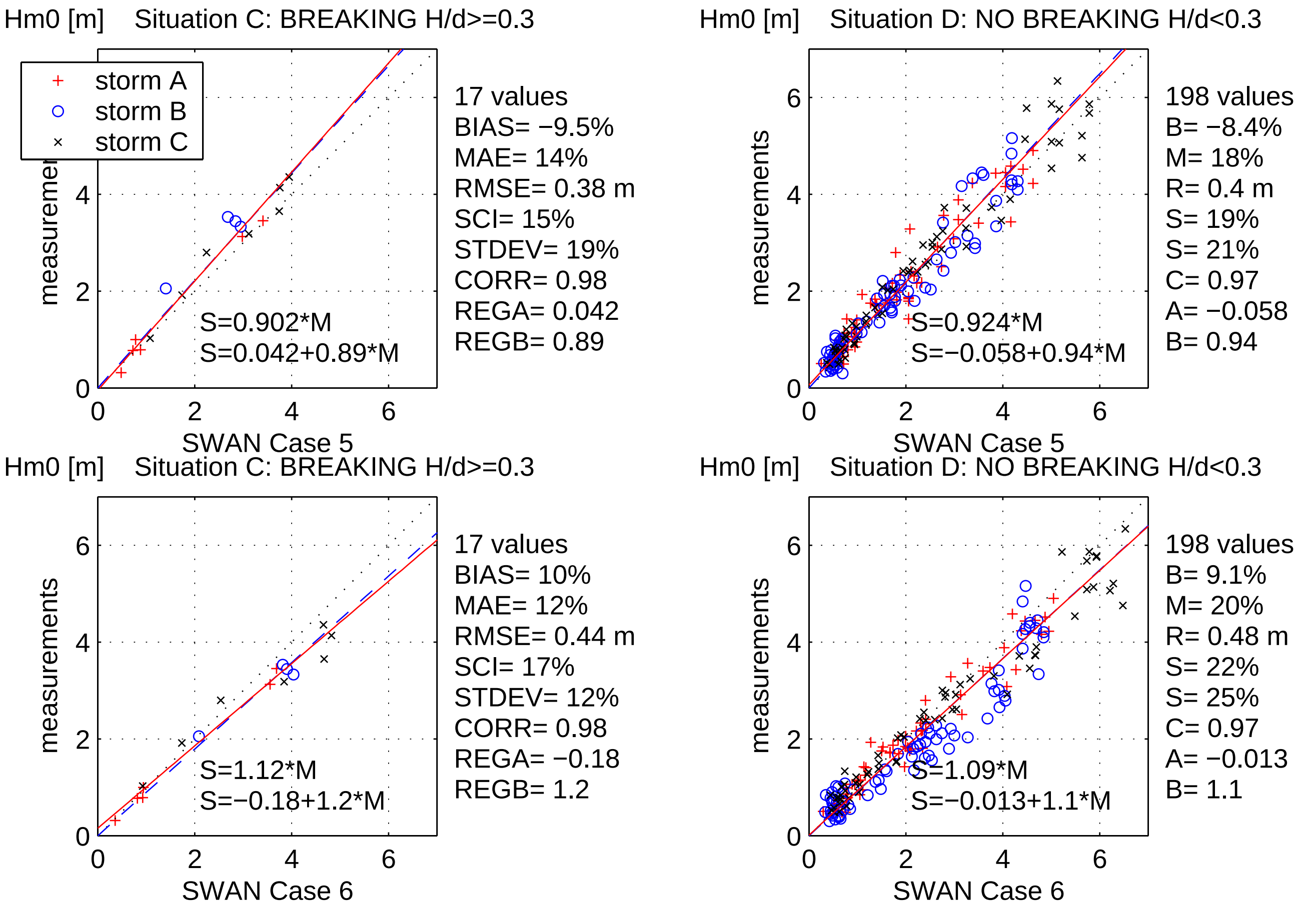
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Hm0 [m] **FIGURE 4.4**

A: EBB >= 0.5 m/s & B: FLOOD >= 0.5 m/s A1200

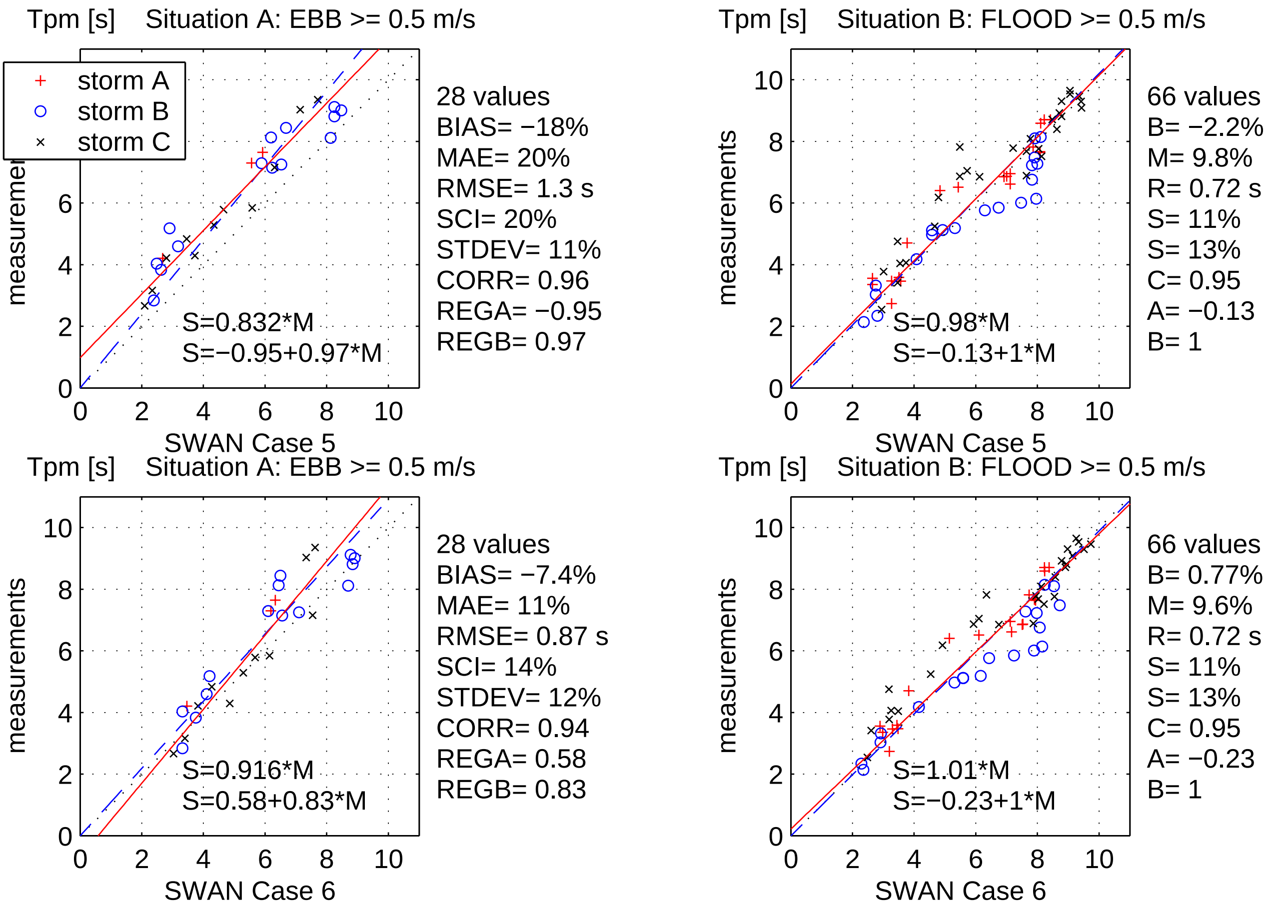
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Hm0 [m] FIGURE 4.5

C: BREAKING H/d>=0.3 & D: NO BREAKING H/d<0.3 A1200

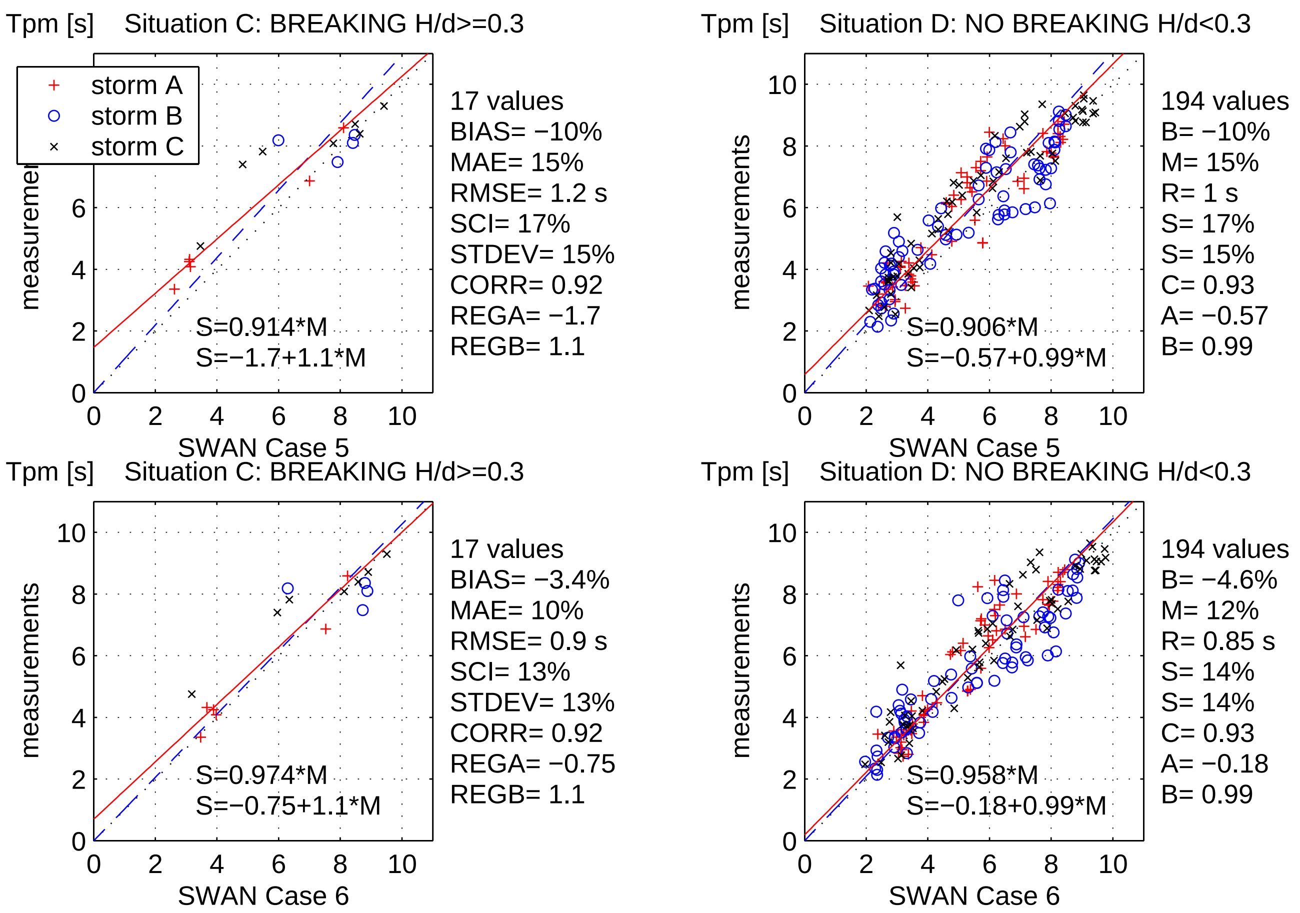
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Tpm [s] **FIGURE 4.6**

A: EBB >= 0.5 m/s & B: FLOOD >= 0.5 m/s A1200

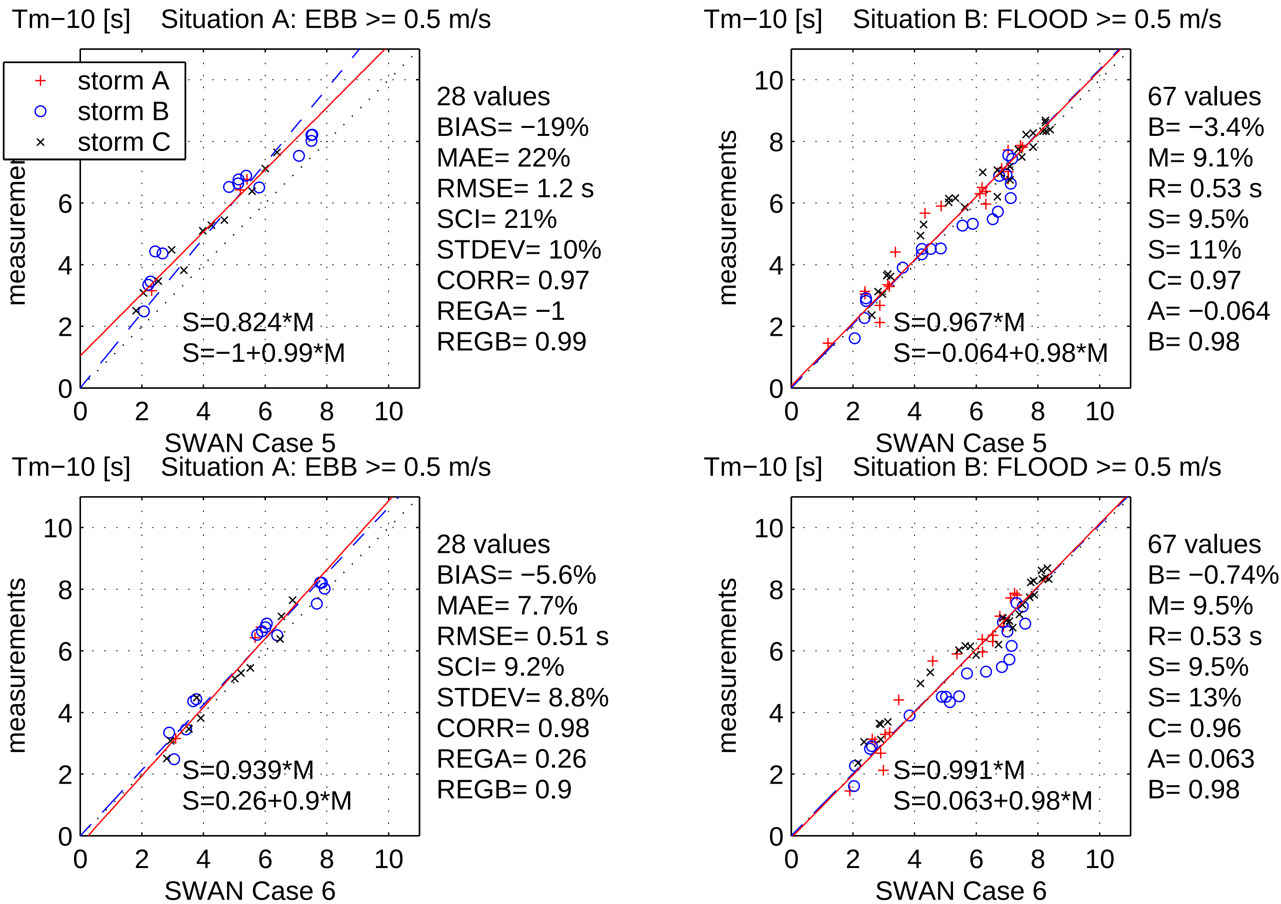
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Tpm [s] **FIGURE 4.7**

C: BREAKING H/d>=0.3 & D: NO BREAKING H/d<0.3 A1200

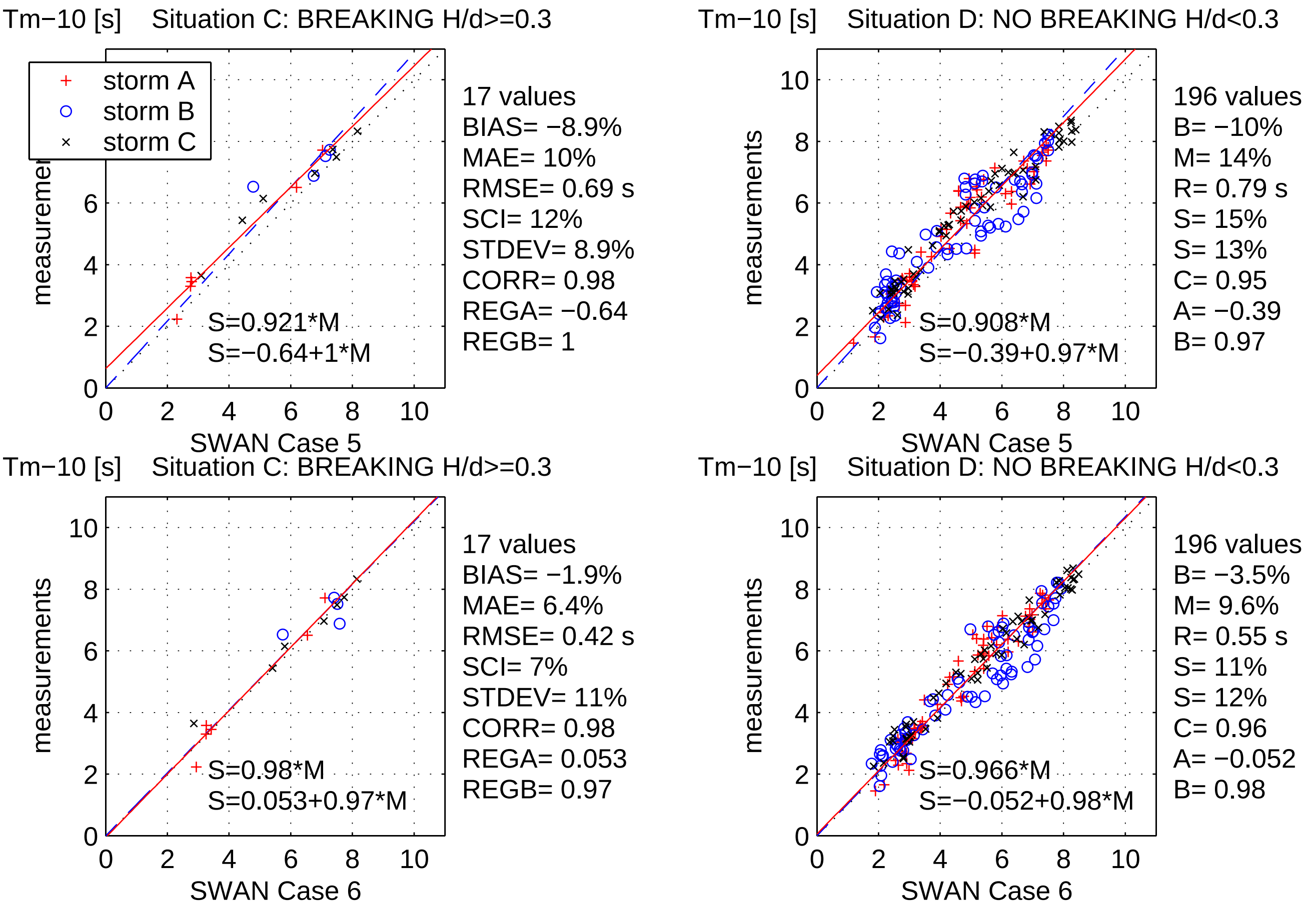
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Tm-10 [s] FIGURE 4.8

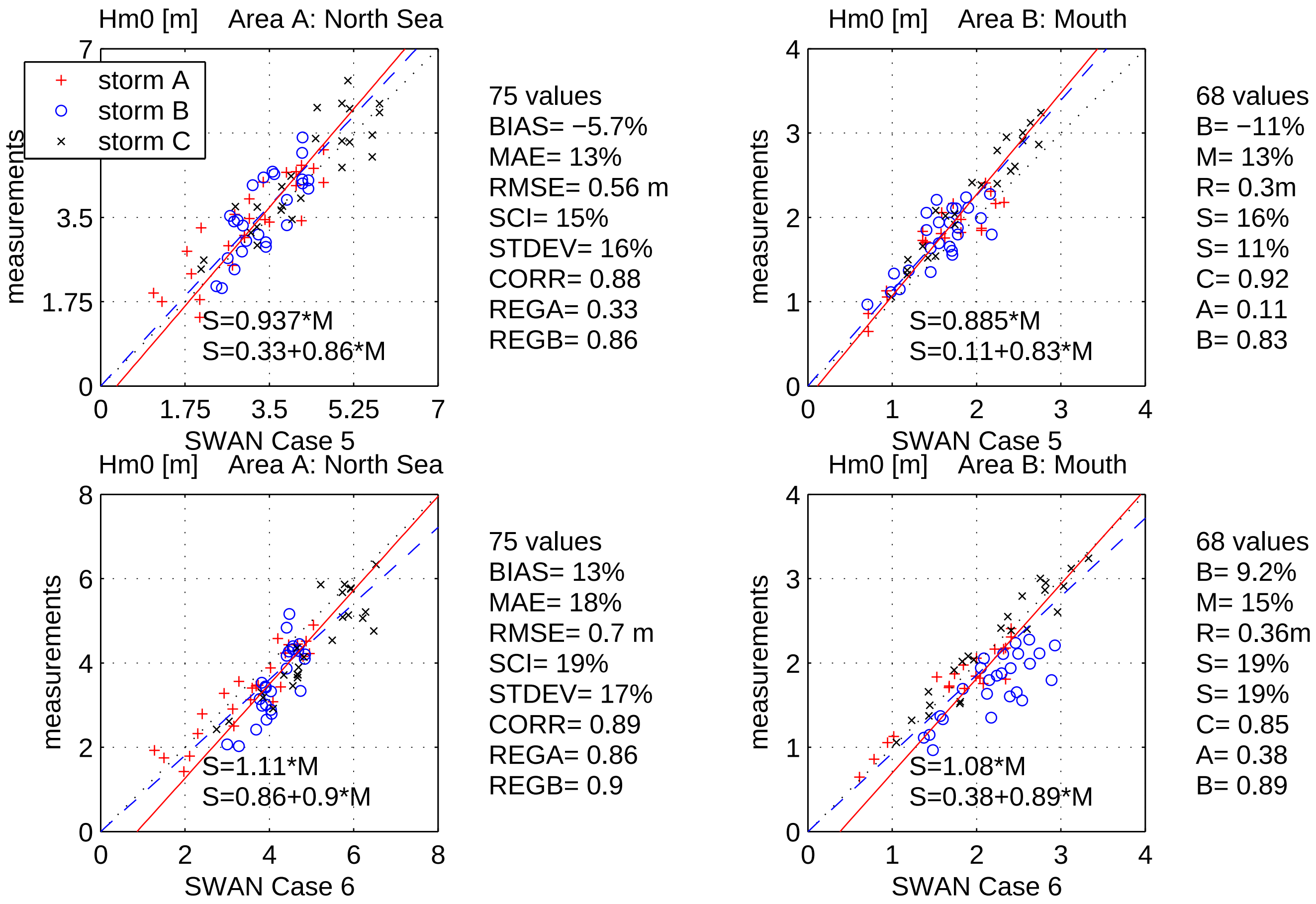
A: EBB >= 0.5 m/s & B: FLOOD >= 0.5 m/s A1200

ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Scatterplots Meas. - SWAN Case 5, 6; parameter: Tm-10 [s] FIGURE 4.9

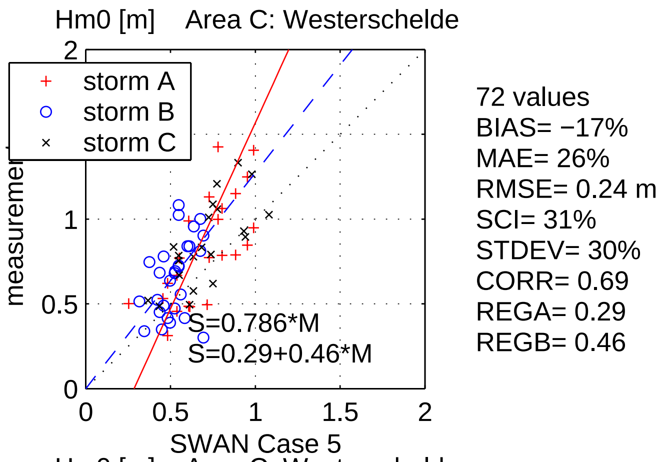
C: BREAKING H/d>=0.3 & D: NO BREAKING H/d<0.3 A1200

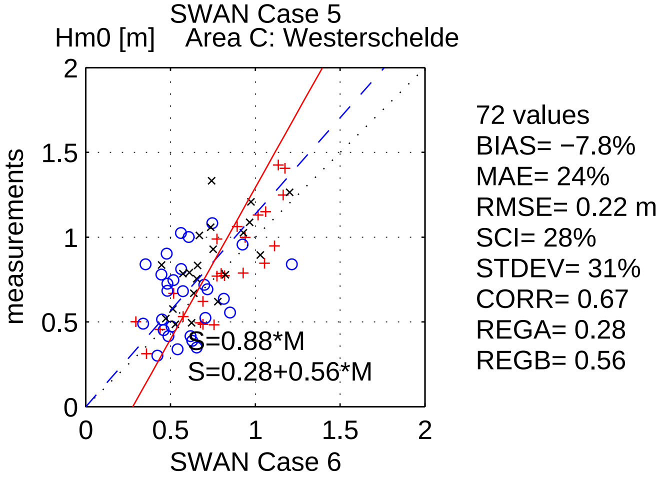


Scatterplots Meas. - SWAN Case 5,6; parameter:Hm0 [m] **FIGURE 4.10**

North Sea & Mouth A1200

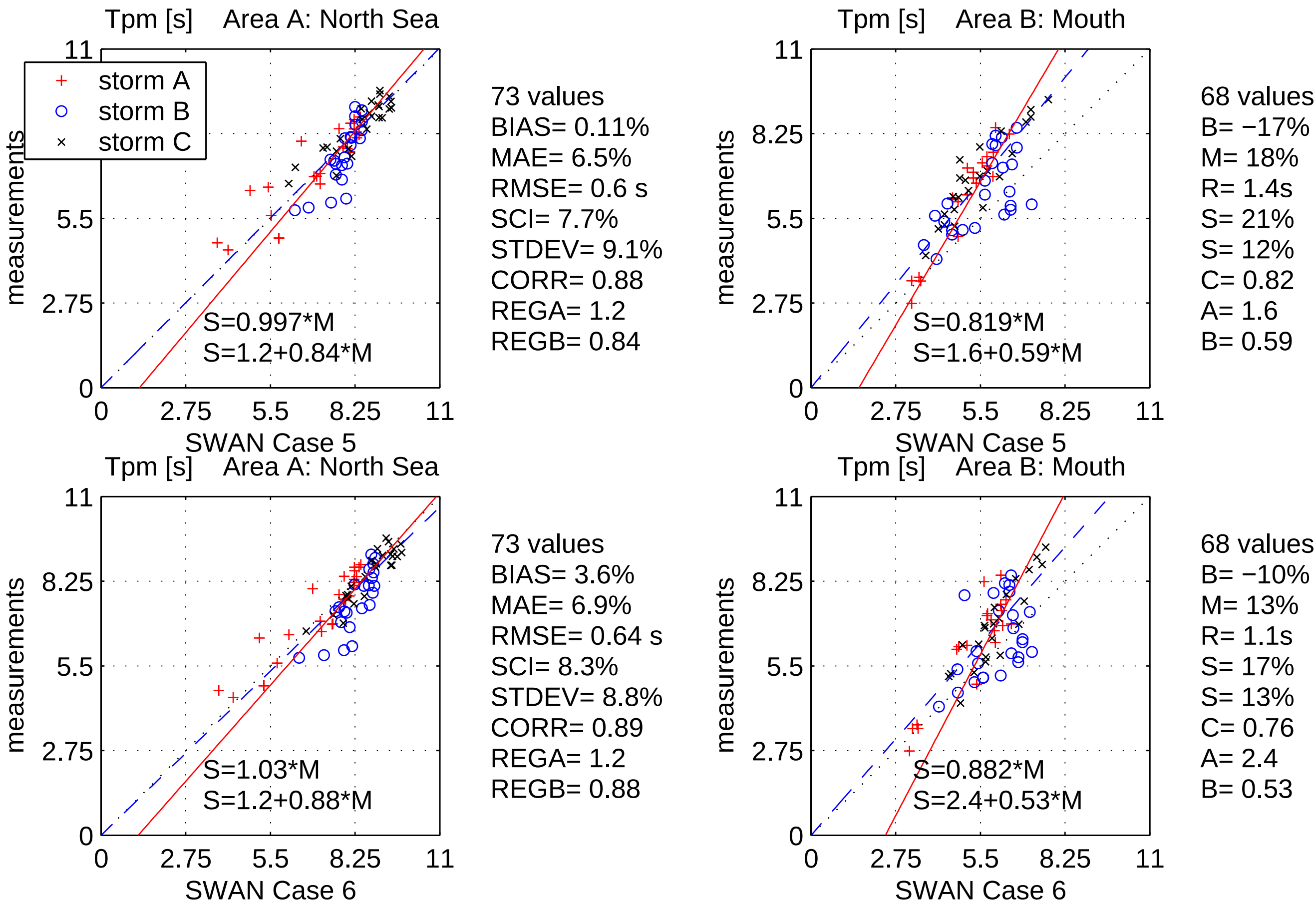
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003





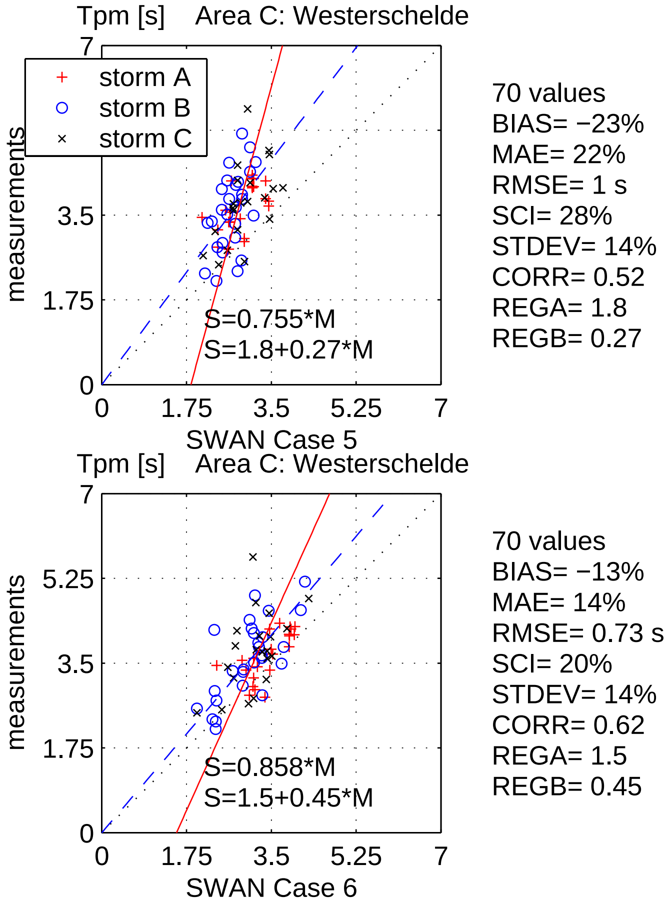
Scatterplots Meas. - SWAN Case 5,6; parameter:Hm0 [m]   FIGURE 4.11

Westerschelde   A1200



Scatterplots Meas. - SWAN Case 5,6; parameter:Tpm [s] **FIGURE 4.12**

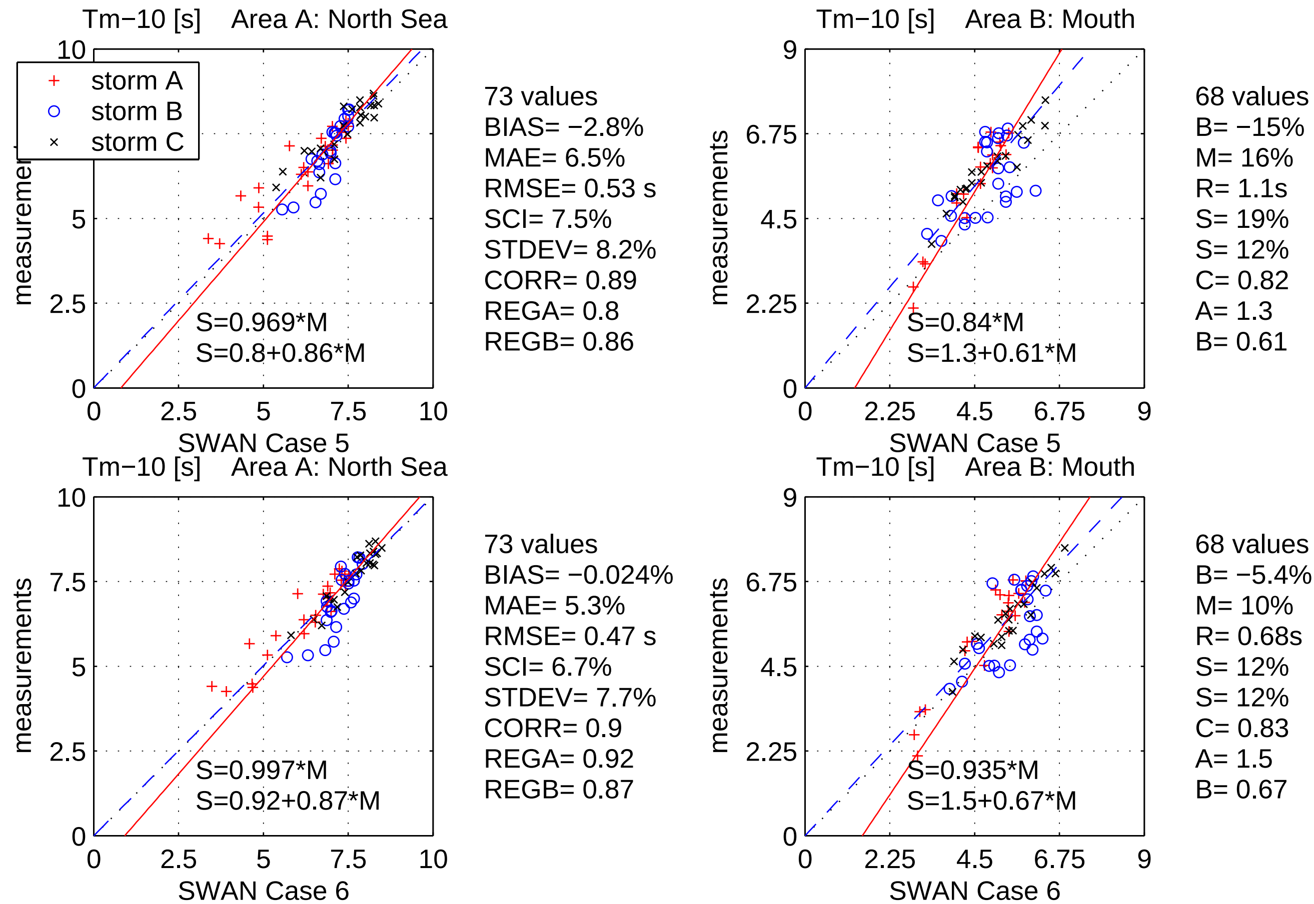
North Sea & Mouth A1200



Scatterplots Meas. - SWAN Case 5,6; parameter:Tpm [s] **FIGURE 4.13**

Westerschelde A1200

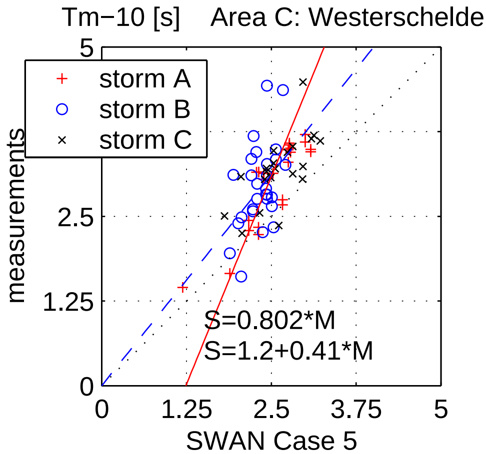
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



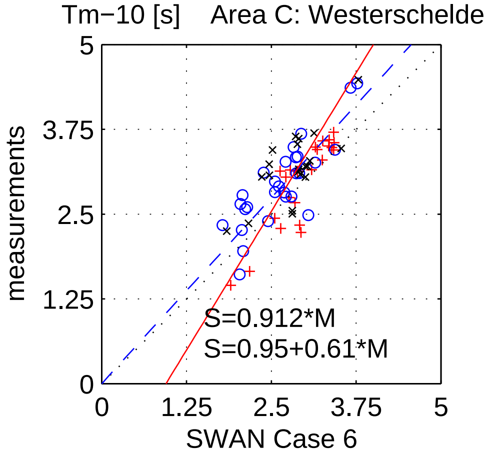
Scatterplots Meas. - SWAN Case 5,6; parameter:Tm-10 [s] FIGURE 4.14

North Sea & Mouth A1200

ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



72 values
BIAS= −18%
MAE= 18%
RMSE= 0.71 s
SCI= 23%
STDEV= 13%
CORR= 0.68
REGA= 1.2
REGB= 0.41

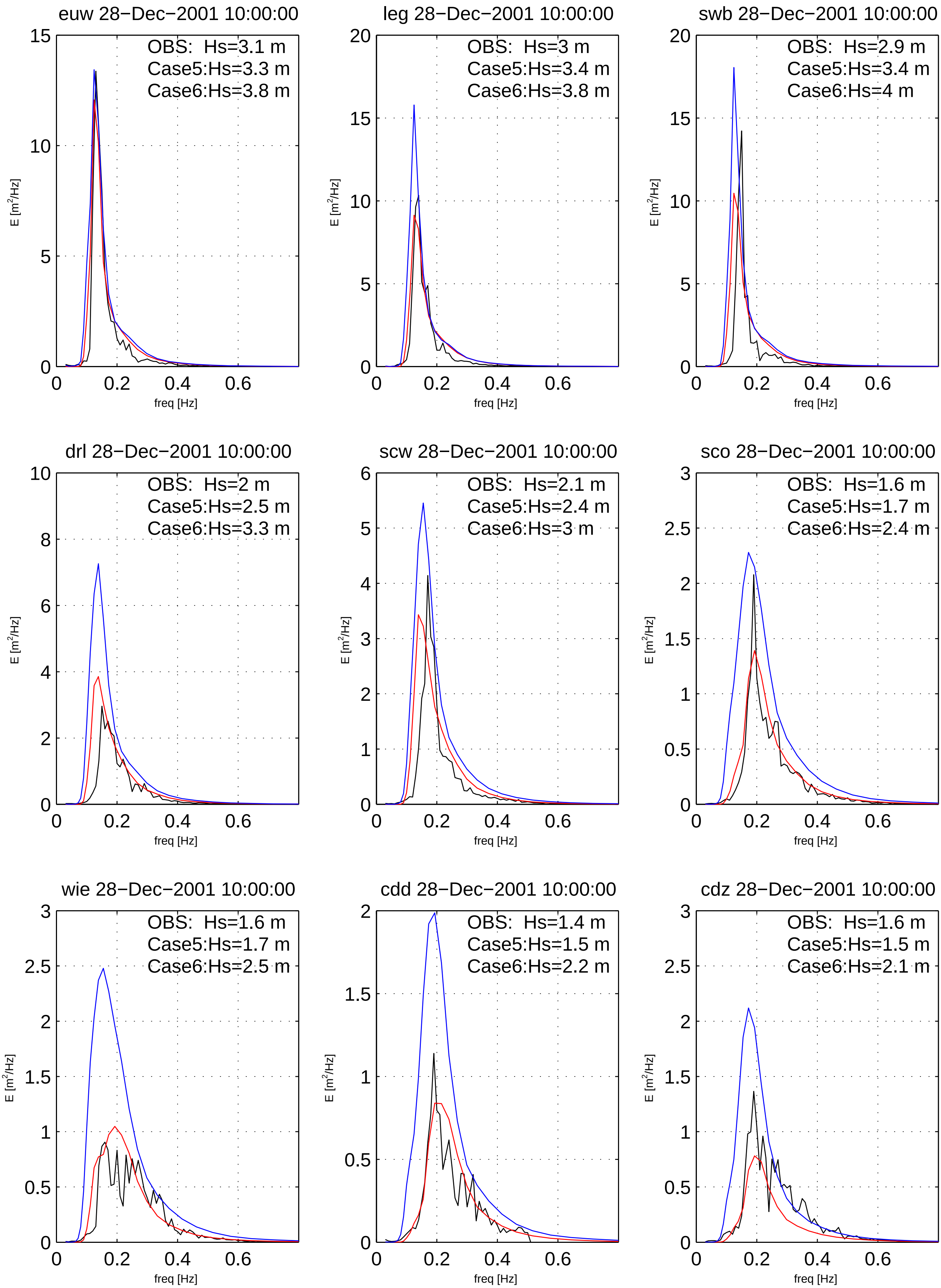


72 values
BIAS= −7.6%
MAE= 12%
RMSE= 0.43 s
SCI= 14%
STDEV= 14%
CORR= 0.78
REGA= 0.95
REGB= 0.61

Scatterplots Meas. - SWAN Case 5,6; parameter:Tm-10 [s] **FIGURE 4.15**

Westerschelde A1200

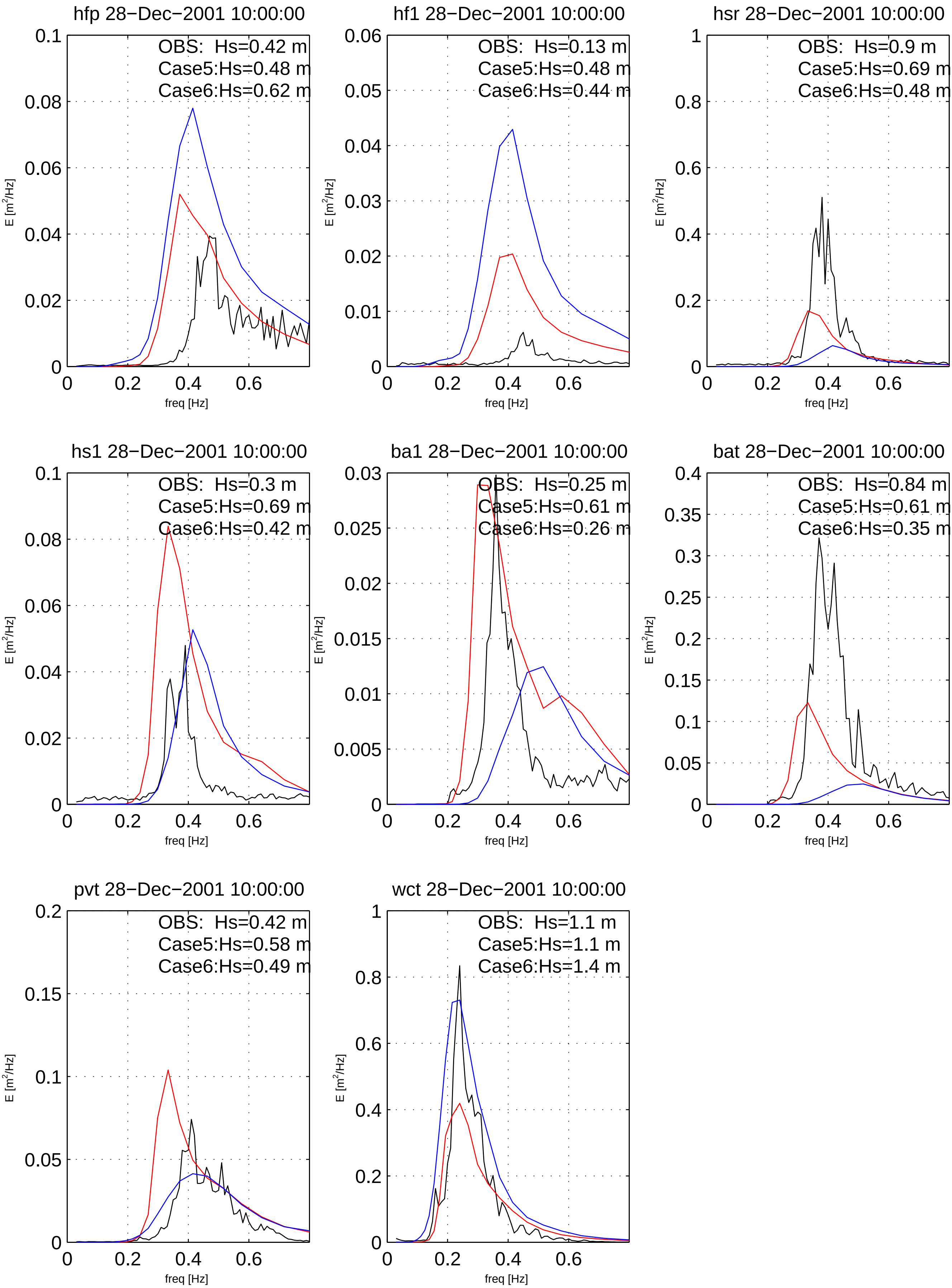
F Spectra for Westerschelde hindcast



Spectra storm B, point of time 1, Cases 5 and 6 **FIGURE 4.16a**

black=measurements; red=C5, blue=C6 A1200

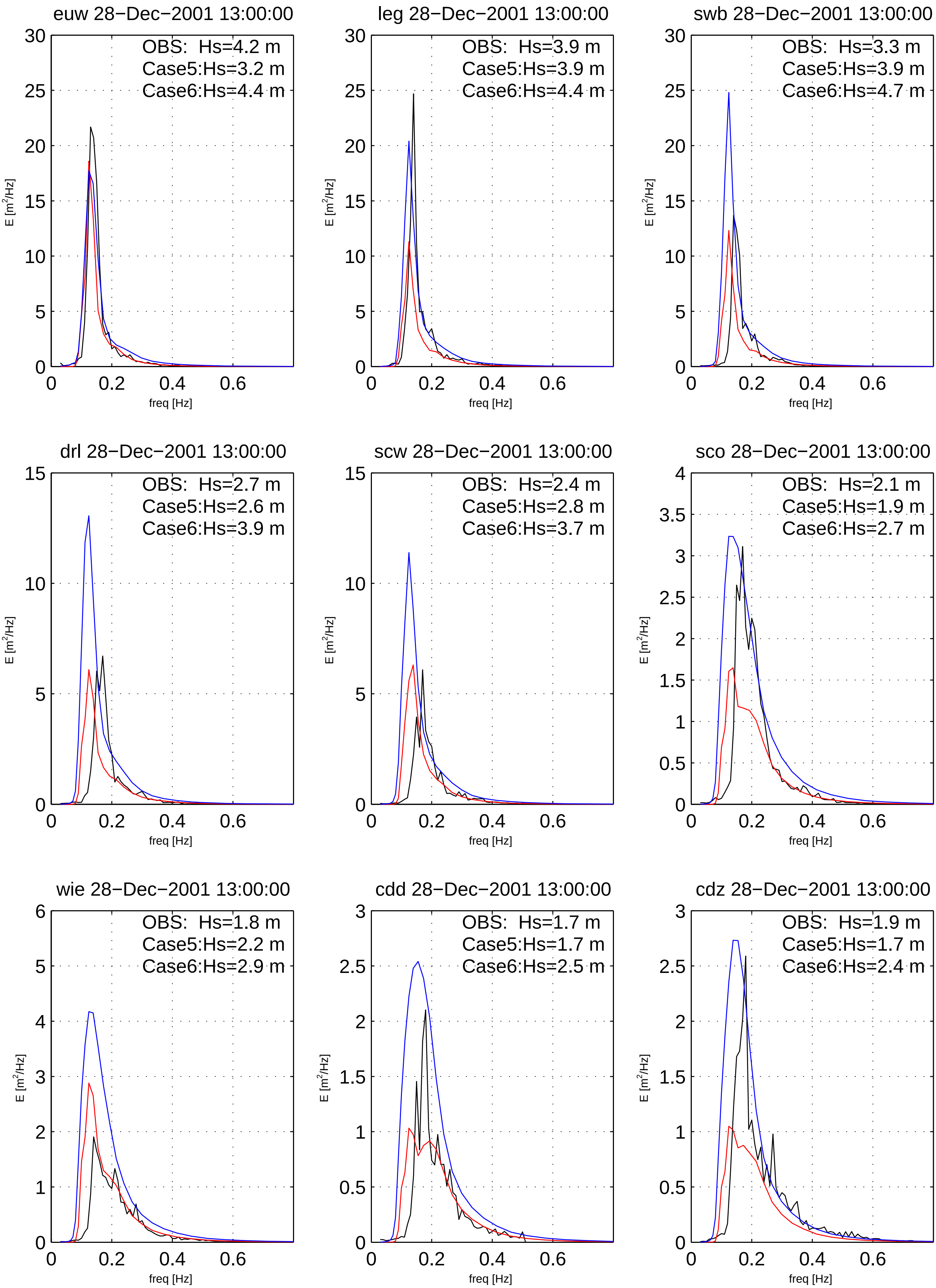
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 1, Cases 5 and 6 **FIGURE 4.16b**

black=measurements; red=C5; blue=C6 A1200

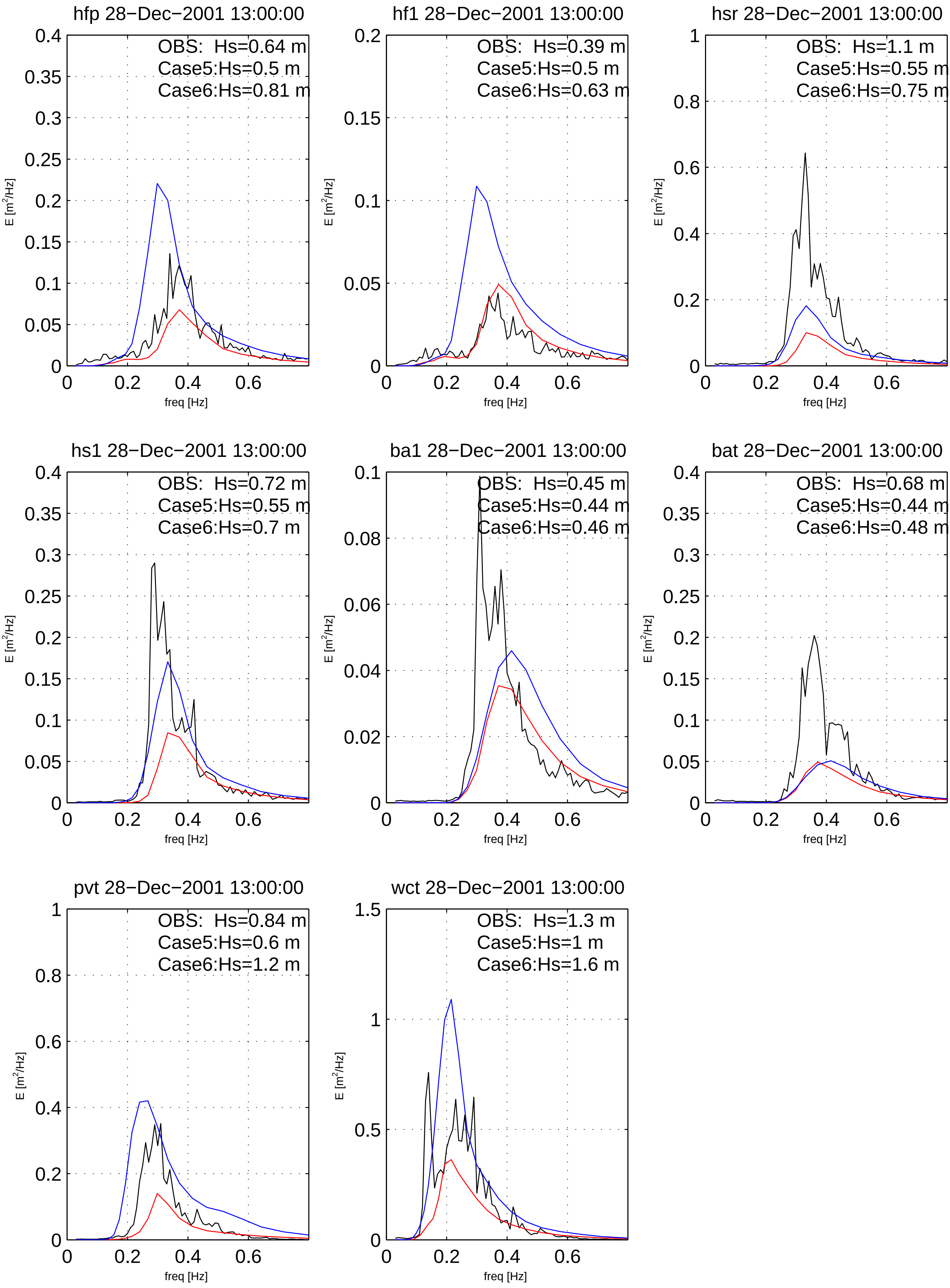
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 2, Cases 5 and 6 **FIGURE 4.17a**

black=measurements; red=C5, blue=C6 A1200

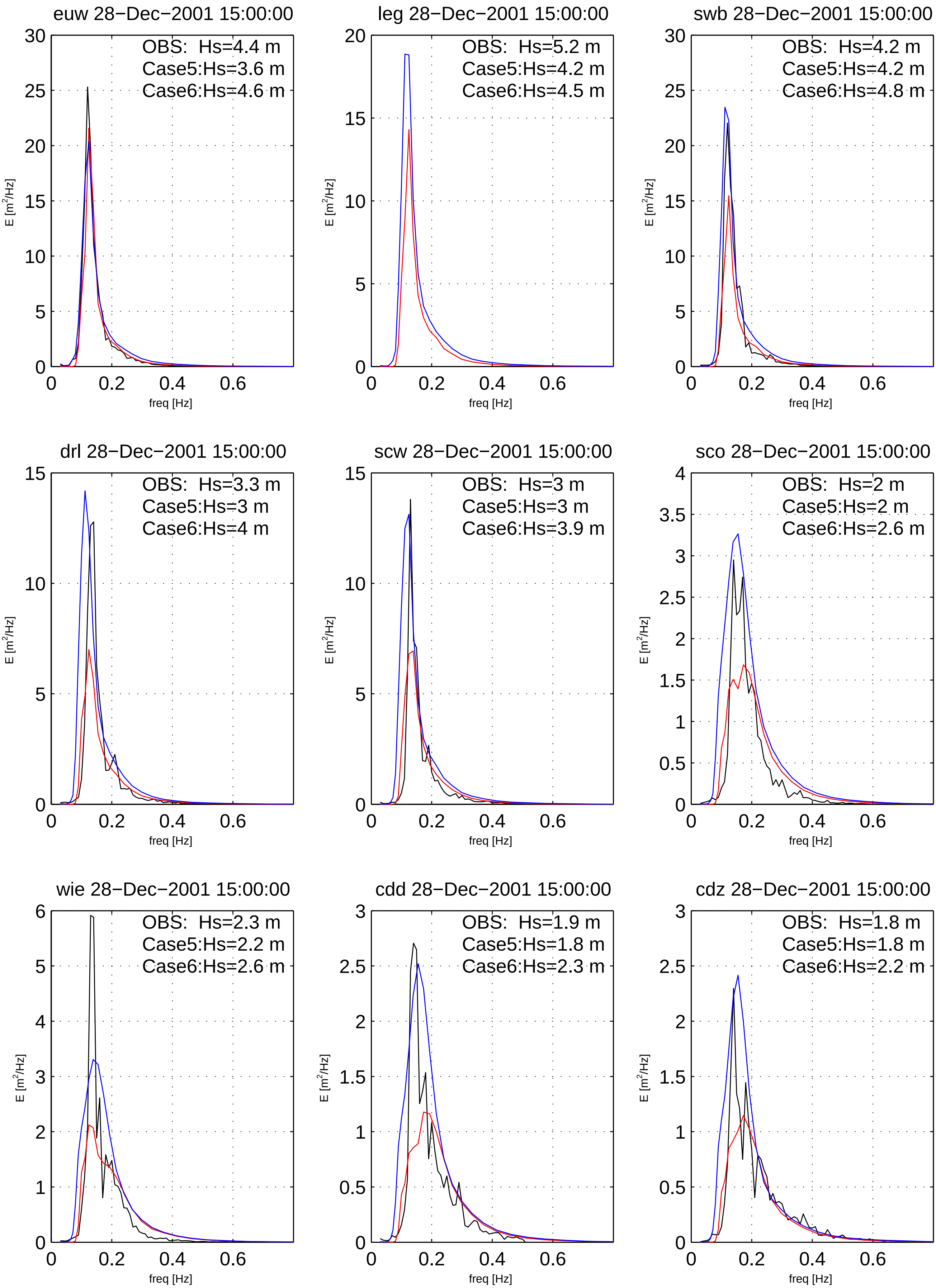
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 2, Cases 5 and 6 **FIGURE 4.17b**

black=measurements; red=C5; blue=C6 A1200

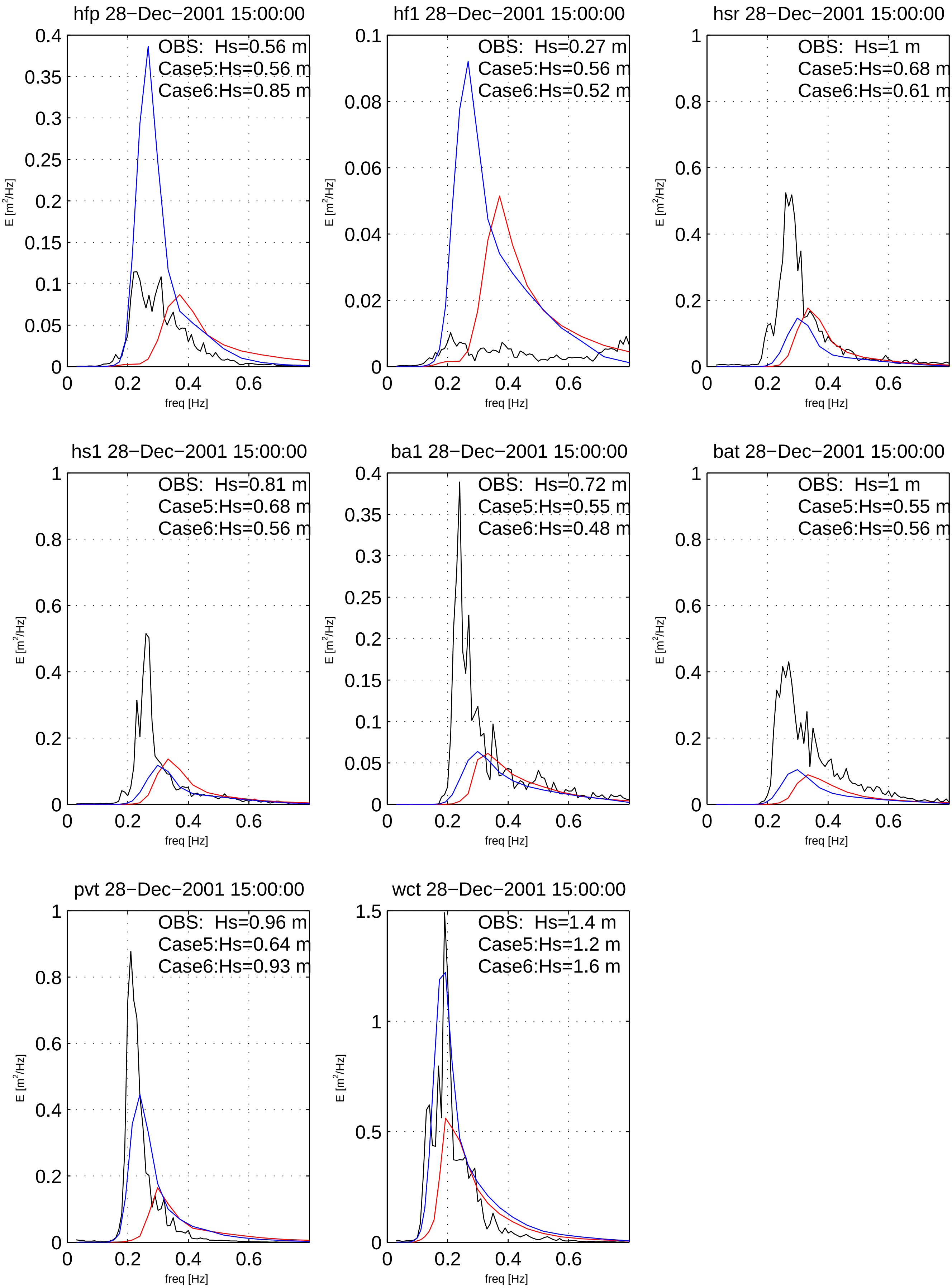
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 3, Cases 5 and 6 **FIGURE 4.18a**

black=measurements; red=C5, blue=C6 A1200

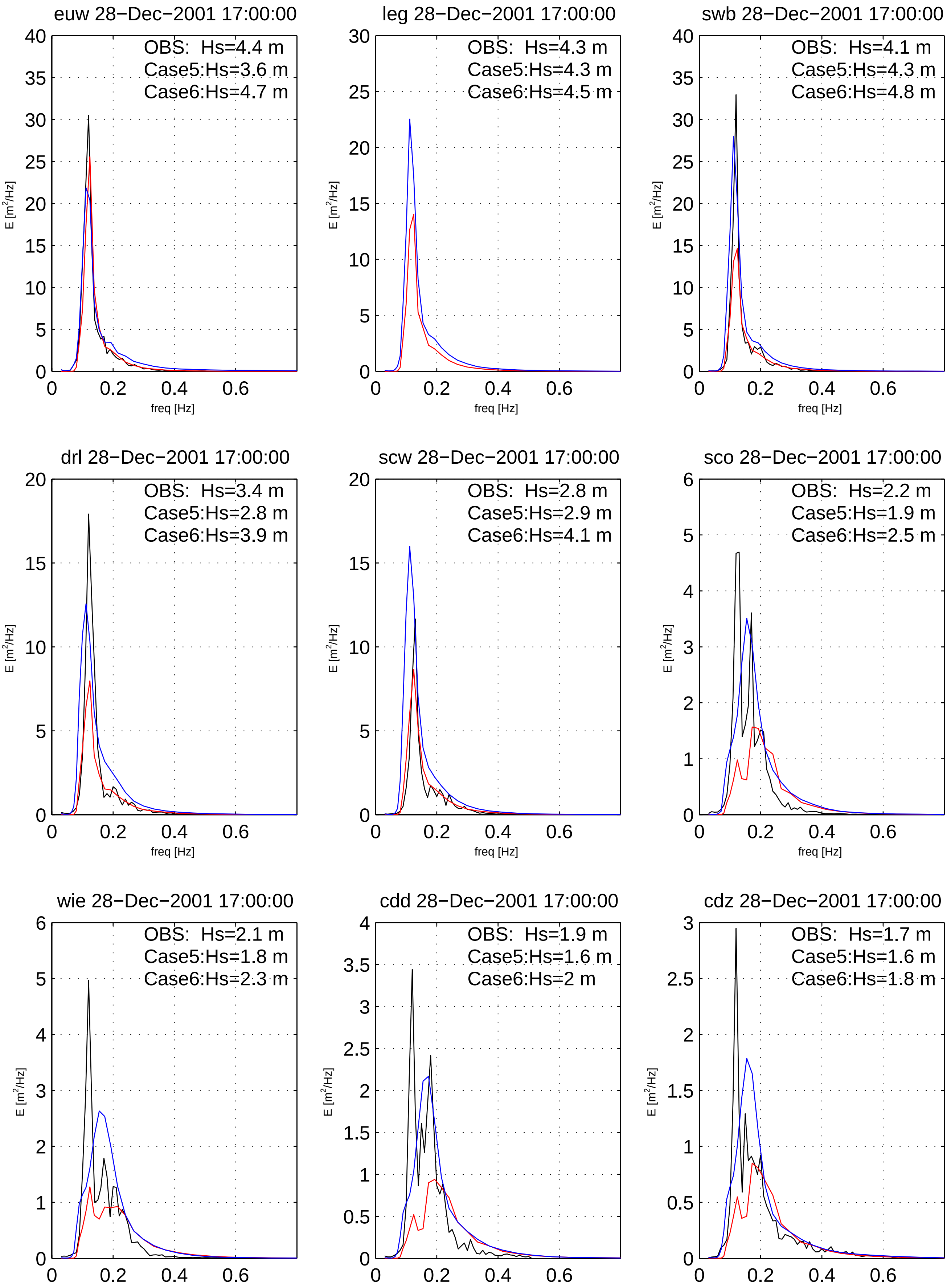
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 3, Cases 5 and 6 **FIGURE 4.18b**

black=measurements; red=C5; blue=C6 A1200

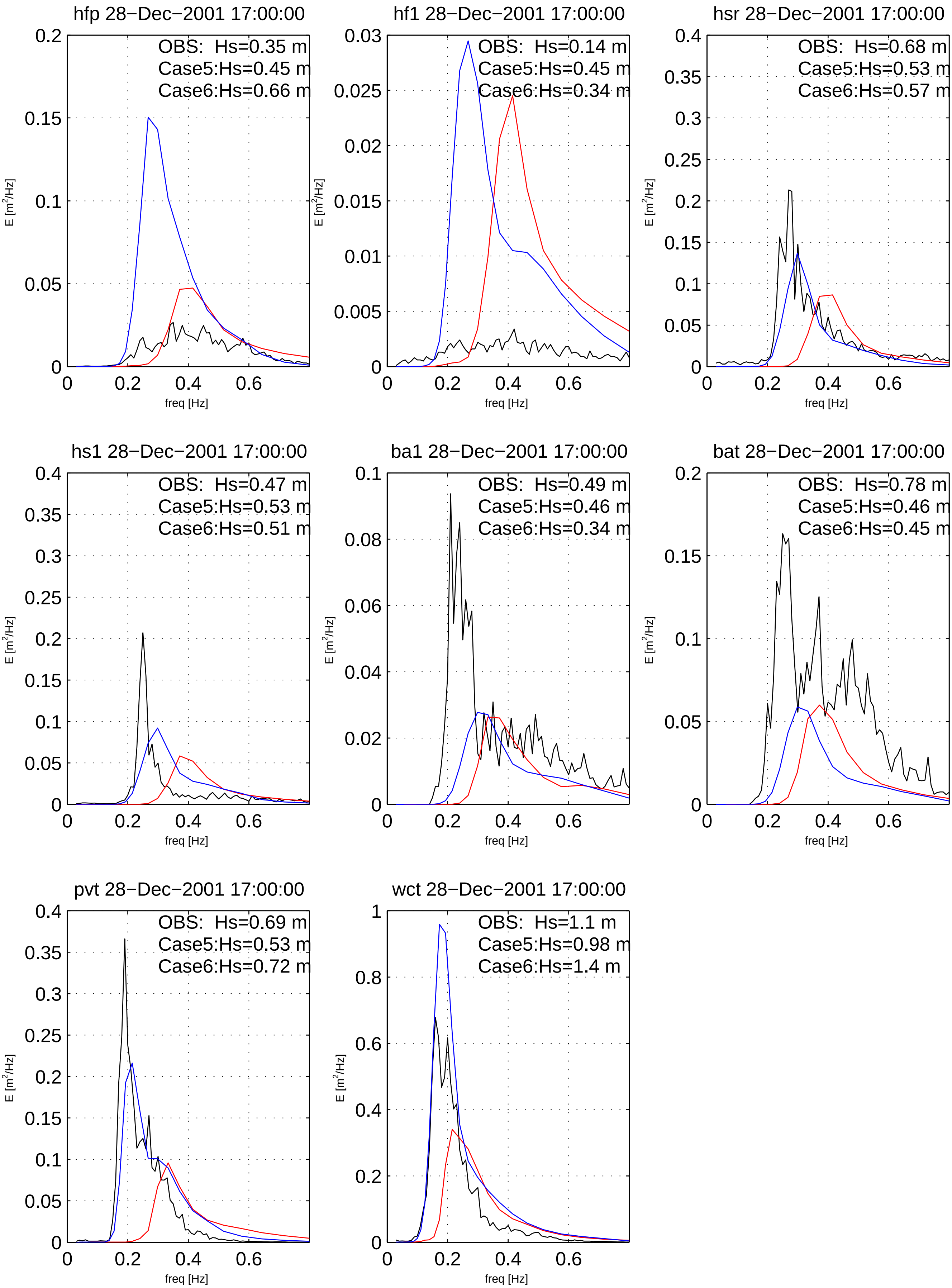
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 4, Cases 5 and 6 **FIGURE 4.19a**

black=measurements; red=C5, blue=C6 A1200

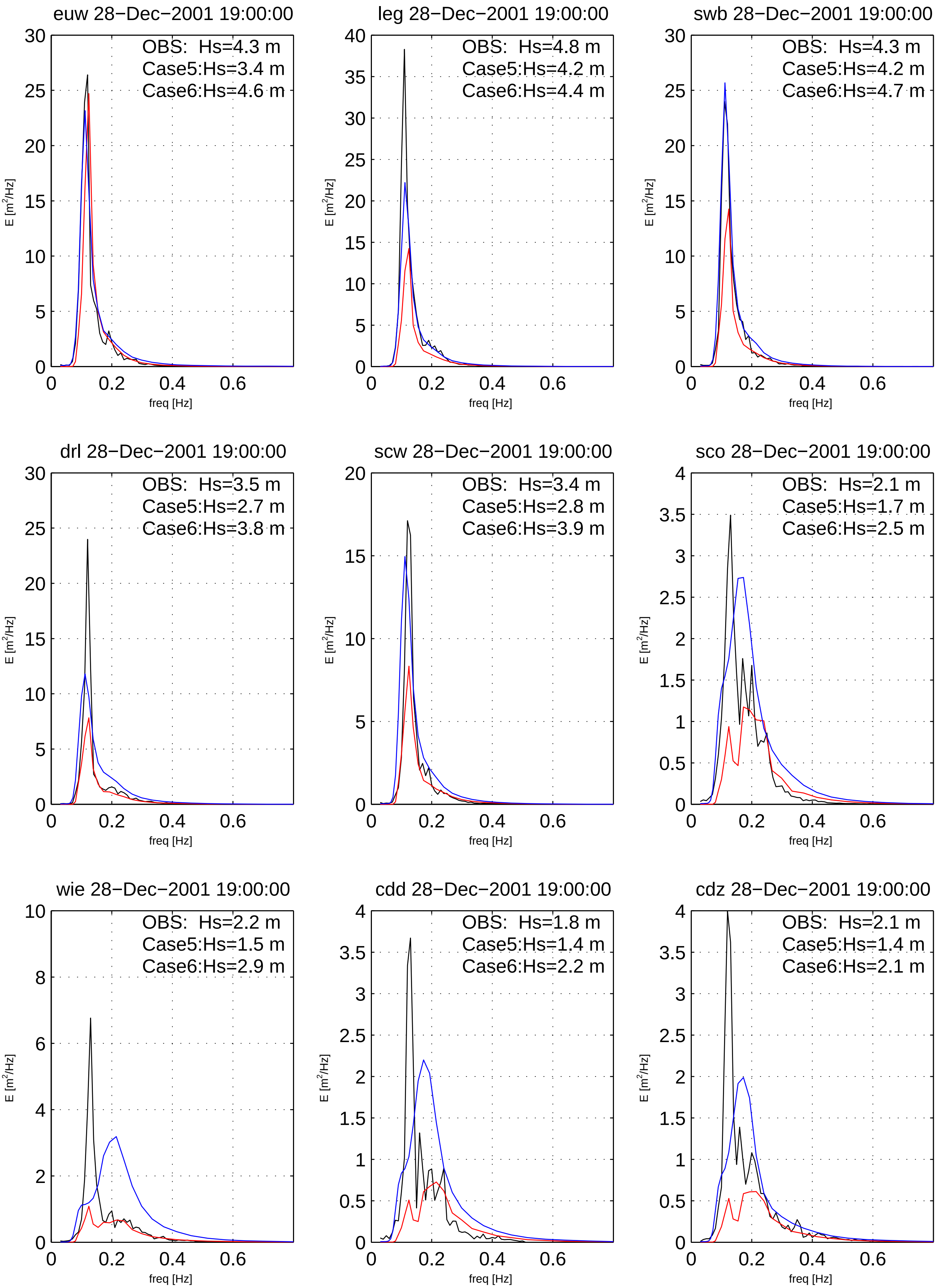
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 4, Cases 5 and 6 **FIGURE 4.19b**

black=measurements; red=C5; blue=C6 A1200

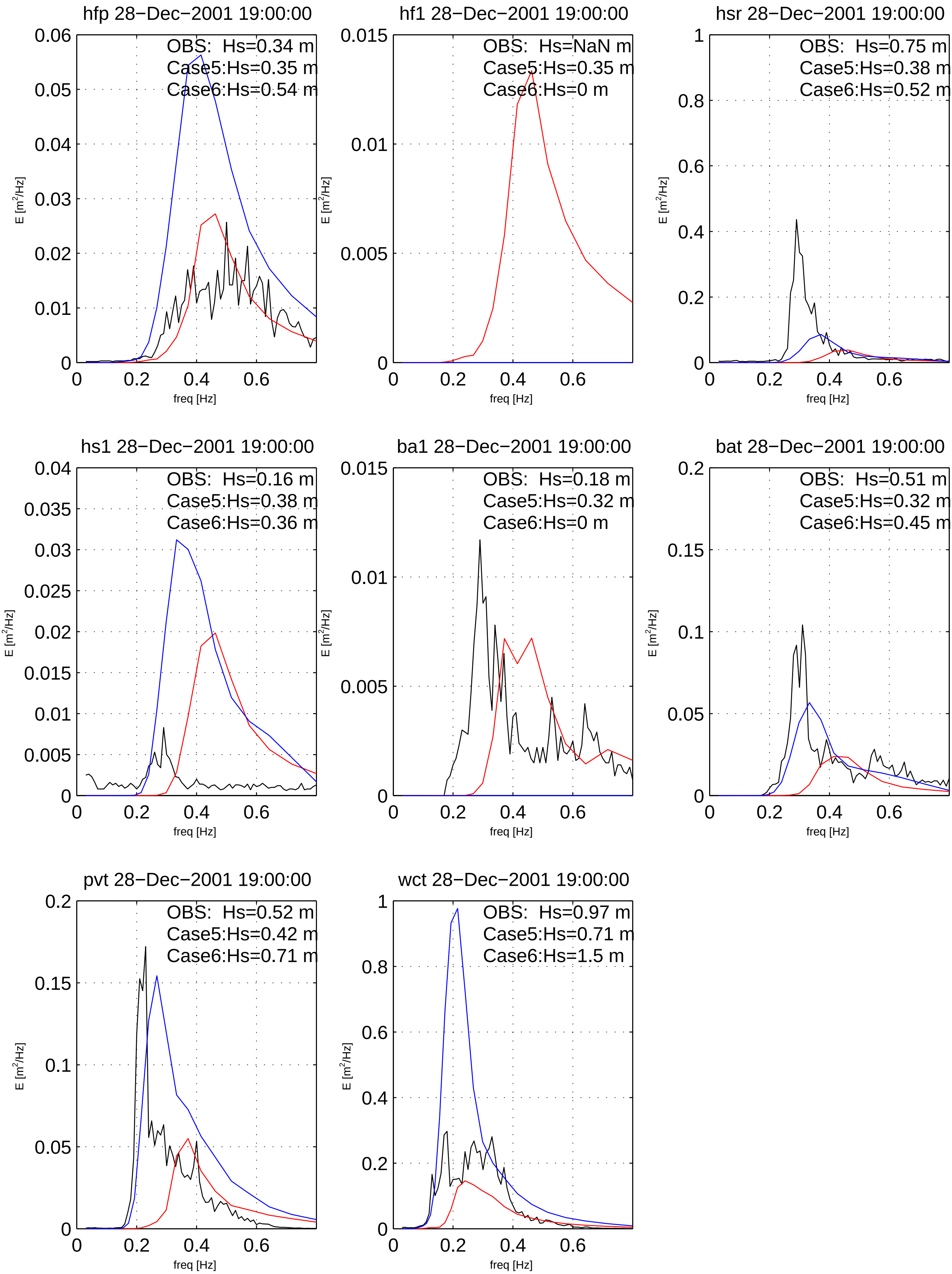
ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 5, Cases 5 and 6 **FIGURE 4.20a**

black=measurements; red=C5, blue=C6 A1200

ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003



Spectra storm B, point of time 5, Cases 5 and 6 **FIGURE 4.20b**

black=measurements; red=C5; blue=C6 A1200

ALKYON HYDRAULIC CONSULTANCY & RESEARCH 18-Nov-2003

G Statistical parameters Westerschelde

C5 ts=0	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-8.51	-11.82	-15.78	-8.13	-9.21	-8.33	-10.46	-10.04
mae %	17.25	14.10	16.72	15.90	14.44	14.73	15.42	13.68
rmse	0.40	0.76	0.87	1.22	1.07	0.94	1.04	0.79
sci %	18.22	16.47	20.51	20.48	18.44	16.03	17.41	15.08
mpi	0.84	0.74	0.69	0.59	0.66	0.66	0.63	0.73
opi	0.09	0.11	0.13	0.15	0.12	0.12	0.13	0.10
std %	20.49	12.48	13.55	19.89	16.28	15.12	14.98	12.59
s-b %	28.99	24.30	29.32	28.02	25.48	23.45	25.44	22.63
Number	215	213	215	213	213	211	211	213

C5 ts=A	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-11.77	-22.77	-27.72	-17.42	-19.50	-15.93	-18.37	-19.45
mae %	15.29	24.63	29.23	18.58	20.41	18.52	20.25	21.55
rmse	0.34	1.21	1.37	1.44	1.40	1.09	1.28	1.15
sci %	18.20	24.45	29.83	22.62	22.94	17.94	20.47	20.91
mpi	0.85	0.33	0.21	0.40	0.43	0.16	0.24	0.33
opi	0.06	0.17	0.21	0.18	0.15	0.13	0.15	0.15
std %	15.56	10.43	11.22	13.80	11.25	11.40	10.88	10.22
s-b %	27.33	33.20	38.94	31.23	30.75	27.33	29.25	29.68
Aantal	28	28	28	28	28	28	28	28

C5 ts=B	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-7.90	-5.94	-10.79	-0.05	-0.00	-0.50	-2.16	-3.40
mae %	14.81	9.80	13.02	12.07	9.75	10.07	9.78	9.08
rmse	0.47	0.53	0.67	0.86	0.69	0.72	0.72	0.53
sci %	16.37	10.41	14.19	13.66	11.27	11.49	11.44	9.50
mpi	0.41	-0.30	-0.66	-0.07	0.20	0.32	0.18	0.11
opi	0.12	0.08	0.11	0.10	0.08	0.08	0.08	0.07
std %	17.62	11.48	11.96	18.06	14.50	12.83	12.64	11.47
s-b %	25.53	17.43	22.75	18.12	14.51	13.32	14.80	14.87
Number	68	67	68	67	67	66	66	67

C5 ts=C	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-9.49	-9.09	-11.35	-10.71	-10.65	-6.16	-10.26	-8.91
mae %	14.17	10.23	12.17	15.19	14.51	12.57	14.56	10.36
rmse	0.38	0.59	0.71	1.38	1.31	0.92	1.18	0.69
sci %	14.90	11.47	15.32	19.62	19.05	13.83	16.93	11.55
mpi	0.87	0.73	0.75	0.52	-0.14	0.50	0.08	0.60
opi	0.06	0.08	0.09	0.18	0.17	0.12	0.15	0.10
std %	19.05	8.78	12.11	16.36	15.75	14.15	14.81	8.94
s-b %	28.54	17.88	23.46	27.07	26.40	20.31	25.07	17.85
Number	17	17	17	17	17	17	17	17

C5 ts=D	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-8.41	-12.09	-16.19	-7.86	-9.05	-8.55	-10.48	-10.15
mae %	17.52	14.43	17.11	15.96	14.44	14.92	15.49	13.97
rmse	0.40	0.77	0.89	1.21	1.04	0.94	1.03	0.79
sci %	18.56	16.92	20.96	20.56	18.32	16.25	17.45	15.43
mpi	0.83	0.73	0.68	0.59	0.67	0.65	0.64	0.72
opi	0.09	0.11	0.13	0.14	0.12	0.12	0.12	0.10
std %	20.62	12.72	13.54	20.12	16.33	15.23	15.03	12.87
s-b %	29.03	24.81	29.73	27.98	25.38	23.78	25.51	23.02
Number	198	196	198	196	196	194	194	196

C5 ts=E	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-11.09	-20.60	-25.17	-23.01	-22.86	-16.41	-20.11	-18.56
mae %	16.20	20.31	23.95	21.08	21.57	17.94	21.00	19.15
rmse	0.31	1.09	1.24	2.05	1.69	1.10	1.40	1.10
sci %	17.01	22.70	28.17	30.24	26.42	17.34	21.08	19.79
mpi	0.87	0.42	0.33	0.83	-3.07	-0.04	-2.19	0.31
opi	0.07	0.13	0.17	0.16	0.20	0.12	0.18	0.12
std %	18.26	6.89	9.58	16.12	10.83	8.85	7.35	5.89
s-b %	29.35	27.49	34.75	39.14	33.68	25.26	27.45	24.45
Number	12	12	12	12	12	12	12	12

Table 4.1a Statistical parameters Case 5 for typical situations ts=A (ebb), ts=B (flood), ts=C (breaking waves), ts=D (non-breaking waves) and ts=E (double peaked)

C6 ts=0	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	9.26	-7.39	-13.80	-3.41	-1.71	-2.20	-4.46	-3.36
mae %	19.21	11.21	15.94	14.45	11.28	11.21	11.44	9.35
rmse	0.48	0.59	0.84	1.05	0.80	0.77	0.86	0.54
sci %	21.93	12.75	19.58	17.51	13.78	13.20	14.31	10.30
mpi	0.82	0.79	0.71	0.65	0.74	0.73	0.71	0.82
opi	0.11	0.08	0.12	0.13	0.10	0.09	0.10	0.07
std %	23.98	12.48	14.99	20.56	15.23	13.76	13.71	11.73
s-b %	14.73	19.87	28.79	23.98	16.94	15.95	18.18	15.08
Number	215	213	215	213	213	211	211	213

C6 ts=A	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	7.17	-9.48	-15.23	-8.54	-5.53	-4.65	-7.43	-5.64
mae %	15.56	11.93	18.69	15.19	11.17	9.22	10.86	7.74
rmse	0.25	0.66	0.95	1.14	0.83	0.63	0.87	0.51
sci %	13.57	13.47	20.62	17.96	13.65	10.46	14.03	9.22
mpi	0.88	0.58	0.38	0.51	0.69	0.45	0.50	0.67
opi	0.05	0.10	0.14	0.14	0.08	0.07	0.09	0.07
std %	21.77	11.75	16.66	17.07	13.37	10.32	11.70	8.82
s-b %	14.60	21.23	31.89	25.61	18.90	14.98	19.13	14.45
Number	28	28	28	28	28	28	28	28

C6 ts=B	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	10.65	-6.45	-14.70	1.97	3.18	2.49	0.77	-0.74
mae %	20.06	11.32	16.39	12.61	11.30	10.12	9.63	9.48
rmse	0.61	0.58	0.88	0.82	0.74	0.74	0.72	0.53
sci %	21.38	11.43	18.54	13.05	12.15	11.92	11.39	9.52
mpi	0.38	-0.59	-1.38	0.02	0.15	0.24	0.15	0.17
opi	0.14	0.09	0.14	0.10	0.09	0.09	0.08	0.07
std %	23.85	12.78	13.00	21.45	16.76	13.00	12.79	12.78
s-b %	13.19	19.23	27.70	19.49	13.57	10.51	12.02	13.52
Number	68	67	68	67	67	66	66	67

C6 ts=C	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	10.47	-4.76	-9.69	-2.35	-2.57	1.07	-3.35	-1.87
mae %	12.33	9.89	14.85	10.71	9.59	11.12	10.39	6.44
rmse	0.44	0.50	0.74	1.05	0.84	0.80	0.90	0.42
sci %	17.28	9.61	16.12	14.95	12.24	12.03	13.01	7.02
mpi	0.87	0.81	0.75	0.73	0.35	0.68	0.32	0.83
opi	0.07	0.06	0.10	0.11	0.10	0.07	0.10	0.04
std %	11.58	13.76	18.06	14.06	12.09	15.01	13.43	10.87
s-b %	1.11	18.51	27.75	16.42	14.67	13.94	16.78	12.75
Number	17	17	17	17	17	17	17	17

C6 ts=D	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	9.13	-7.64	-14.18	-3.52	-1.61	-2.52	-4.58	-3.50
mae %	19.80	11.33	16.04	14.78	11.42	11.22	11.53	9.61
rmse	0.48	0.60	0.84	1.04	0.79	0.77	0.85	0.55
sci %	22.39	13.04	19.89	17.77	13.94	13.32	14.44	10.61
mpi	0.82	0.79	0.70	0.65	0.75	0.73	0.71	0.81
opi	0.11	0.09	0.13	0.13	0.09	0.09	0.10	0.07
std %	24.78	12.34	14.61	21.05	15.48	13.63	13.77	11.81
s-b %	15.64	19.99	28.80	24.58	17.10	16.16	18.35	15.31
Number	198	196	198	196	196	194	194	196

C6 ts=E	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	3.90	-11.94	-17.66	-19.35	-12.04	-11.49	-15.41	-8.84
mae %	16.51	12.43	18.77	19.36	12.32	12.53	15.73	8.71
rmse	0.19	0.74	0.99	1.78	1.05	0.87	1.18	0.61
sci %	10.60	15.39	22.34	26.26	16.40	13.67	17.75	11.00
mpi	0.95	0.56	0.41	0.70	-1.86	0.06	-2.01	0.59
opi	0.03	0.10	0.15	0.20	0.14	0.10	0.16	0.08
std %	20.42	9.48	14.05	16.73	9.42	7.72	7.21	6.37
s-b %	16.52	21.42	31.71	36.09	21.46	19.21	22.62	15.21
Number	12	12	12	12	12	12	12	12

Table 4.1b Statistical parameters Case 6 for typical situations ts=A (ebb), ts=B (flood), ts=C (breaking waves), ts=D (non-breaking waves) and ts=E (double peaked)

C5 ALL	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-8.51	-11.82	-15.78	-8.13	-9.21	-8.33	-10.46	-10.04
mae %	17.25	14.10	16.72	15.90	14.44	14.73	15.42	13.68
rmse	0.40	0.76	0.87	1.22	1.07	0.94	1.04	0.79
sci %	18.22	16.47	20.51	20.48	18.44	16.03	17.41	15.08
mpi	0.84	0.74	0.69	0.59	0.66	0.66	0.63	0.73
opi	0.09	0.11	0.13	0.15	0.12	0.12	0.13	0.10
std %	20.49	12.48	13.55	19.89	16.28	15.12	14.98	12.59
s-b %	28.99	24.30	29.32	28.02	25.48	23.45	25.44	22.63
Number	215	213	215	213	213	211	211	213

C5 NZ	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-5.67	-6.24	-11.52	-0.17	0.46	2.40	0.11	-2.81
mae %	12.79	8.30	12.15	8.74	6.79	7.16	6.48	6.51
rmse	0.56	0.61	0.82	0.80	0.62	0.62	0.60	0.53
sci %	14.83	9.43	13.55	10.16	8.04	8.13	7.71	7.52
mpi	0.32	-0.25	-0.58	-0.40	-0.02	0.07	-0.03	-0.05
opi	0.13	0.09	0.12	0.10	0.07	0.07	0.07	0.07
std %	15.61	8.02	7.71	12.04	9.75	9.08	9.13	8.23
s-b %	21.28	14.26	19.23	12.21	9.29	6.67	9.02	11.04
Number	75	73	75	73	73	73	73	73

C5 MON	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-11.00	-17.39	-21.95	-15.05	-17.54	-14.16	-16.96	-15.12
mae %	13.27	17.87	21.80	20.89	19.26	15.73	17.88	16.37
rmse	0.30	1.02	1.13	1.80	1.56	1.13	1.38	1.05
sci %	15.90	20.95	25.48	27.28	25.07	18.12	21.27	18.93
mpi	0.88	0.52	0.48	-0.78	0.14	0.26	0.09	0.44
opi	0.06	0.13	0.16	0.21	0.17	0.13	0.16	0.13
std %	11.04	11.98	12.55	24.32	18.11	11.38	12.05	11.70
s-b %	22.04	29.37	34.50	39.37	35.65	25.54	29.01	26.82
Number	68	68	68	68	68	68	68	68

C5 WS	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-17.16	-16.04	-16.18	-14.03	-17.12	-21.98	-22.67	-18.25
mae %	25.66	16.41	16.69	18.45	17.64	21.67	22.35	18.40
rmse	0.24	0.61	0.61	0.85	0.81	1.00	1.03	0.71
sci %	31.15	23.52	27.27	24.50	24.09	27.57	28.15	23.28
mpi	0.93	0.88	0.88	0.84	0.85	0.78	0.78	0.86
opi	0.06	0.08	0.08	0.09	0.08	0.11	0.12	0.08
std %	29.51	14.48	17.17	19.62	14.97	14.22	14.19	12.79
s-b %	46.67	30.52	33.35	33.66	32.09	36.21	36.86	31.04
Number	72	72	72	72	72	70	70	72

Table 4.1c Statistical parameters Case 5 for typical areas ALL, NZ (North Sea), MON (mooth) and WS (Westerschelde)

C6 ALL	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	9.26	-7.39	-13.80	-3.41	-1.71	-2.20	-4.46	-3.36
mae %	19.21	11.21	15.94	14.45	11.28	11.21	11.44	9.35
rmse	0.48	0.59	0.84	1.05	0.80	0.77	0.86	0.54
sci %	21.93	12.75	19.58	17.51	13.78	13.20	14.31	10.30
mpi	0.82	0.79	0.71	0.65	0.74	0.73	0.71	0.82
opi	0.11	0.08	0.12	0.13	0.10	0.09	0.10	0.07
std %	23.98	12.48	14.99	20.56	15.23	13.76	13.71	11.73
s-b %	14.73	19.87	28.79	23.98	16.94	15.95	18.18	15.08
Number	215	213	215	213	213	211	211	213

C6 NZ	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	12.64	-6.40	-15.18	3.47	3.97	5.98	3.62	-0.02
mae %	17.75	8.03	15.30	8.12	7.32	8.05	6.87	5.30
rmse	0.70	0.61	1.04	0.77	0.67	0.72	0.64	0.47
sci %	18.59	9.52	17.19	9.78	8.72	9.52	8.29	6.66
mpi	0.25	-0.36	-1.08	-0.35	-0.09	-0.08	-0.08	0.09
opi	0.16	0.09	0.15	0.09	0.08	0.08	0.07	0.06
std %	17.24	7.56	7.65	10.64	9.28	8.66	8.80	7.74
s-b %	4.60	13.96	22.83	7.17	5.30	2.68	5.18	7.77
Number	75	73	75	73	73	73	73	73

C6 MON	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	9.16	-9.84	-16.35	-11.82	-6.78	-7.07	-10.10	-5.43
mae %	15.25	12.37	17.25	18.55	13.95	11.44	13.39	10.47
rmse	0.36	0.72	0.90	1.53	1.10	0.87	1.13	0.68
sci %	18.77	14.80	20.18	23.26	17.71	13.84	17.48	12.30
mpi	0.87	0.66	0.58	-0.48	0.39	0.44	0.25	0.63
opi	0.07	0.10	0.13	0.18	0.13	0.10	0.12	0.09
std %	19.07	11.52	11.47	22.20	18.09	11.88	13.31	12.02
s-b %	9.92	21.36	27.83	34.02	24.87	18.95	23.41	17.45
Number	68	68	68	68	68	68	68	68

C6 WS	Hs	Tm01	Tm02	Tp	Tpb	Tpbeq	Tpm	Tm_10
bias %	-7.84	-5.51	-5.07	-4.13	-6.05	-11.88	-12.65	-7.60
mae %	24.46	13.35	15.38	17.00	12.76	14.29	14.31	12.41
rmse	0.22	0.40	0.44	0.64	0.51	0.72	0.73	0.43
sci %	28.33	15.55	19.71	18.48	15.26	19.91	19.99	14.32
mpi	0.94	0.91	0.90	0.86	0.90	0.85	0.85	0.91
opi	0.05	0.06	0.07	0.08	0.06	0.08	0.08	0.06
std %	30.50	16.39	19.41	24.83	15.90	14.49	13.67	13.88
s-b %	38.34	21.90	24.48	28.97	21.94	26.37	26.32	21.47
Number	72	72	72	72	72	70	70	72

Table 4.1d Statistical parameters Case 6 for typical areas ALL, NZ (North Sea), MON (mooth) and WS (Westerschelde)

H Example of computation of relative standard deviations

In some tables with results of the statistical analysis of the Petten hindcast, the relative standard deviation of the total is larger than the maximum standard deviation of a specific case, e.g. in Table 3.2c. This result appears somewhat surprising but it is easily explained by the following example and the notion that the standard deviation is a measure for the spreading in a group of data points.

In this example two locations P1 and P2 are considered each with two pairs of computed and measured data points. As can be seen in the table below the mean of computed and measured data differs per location, whereas the spreading in each group of data points is rather small. Consequently, both the absolute and relative standard deviations are small for each location. Considering the data for both points together results in larger absolute and relative standard deviations. This increase is due to the fact that the difference between the average position of each group contributes to the standard deviation.

		x	**y**					
		Computation	**Measurement**	***y-x***	**bias**	$(y_i - x_i - bias)^2$	**std**	**rel std**
P1	1	8	9	1.00		0.25		
	2	9	9	0.00		0.25		
	Mean	8.5	9	0.50	0.5		0.71	7.86%
P2	1	9	12	3.00		0.25		
	2	10	12	2.00		0.25		
	Mean	9.5	12	2.50	2.5		0.71	5.89%
Total	1	8	9	1.00		0.25		
	2	9	9	0.00		2.25		
	3	9	12	3.00		2.25		
	4	10	12	2.00		0.25		
	Mean	9	10.5	1.50	1.5		1.29	12.30%