Chapter 6: Data collection

ct5308 Breakwaters and Closure Dams

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Faculty of Civil Engineering and Geosciences
Section Hydraulic Engineering

TU Delft
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Type of data to be collected

- Hydrographic data
  - bathymetry
  - tides
  - storm surges
  - waves
- meteorological data
- geotechnical data
- data needed for the construction
  - construction materials
  - equipment
  - labour

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Bathymetry

- Nautical Charts
  - reference level
  - list of symbols
  - date of production
- Topographical maps
- Satellite images
- Custom made maps
  - lead and sextant
  - echosounder and GPS

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tides

- **vertical tide**
- **horizontal tide**

tide tables (British admiralty)
internet (http://tbone.biol.sc.edu/tide/sitesel.html)
(http://easytide.ukho.gov.uk)
(http://www.shom.fr)
(www.getij.nl)

For horizontal tides:
see hydrographic atlases
or make Delft3D computation

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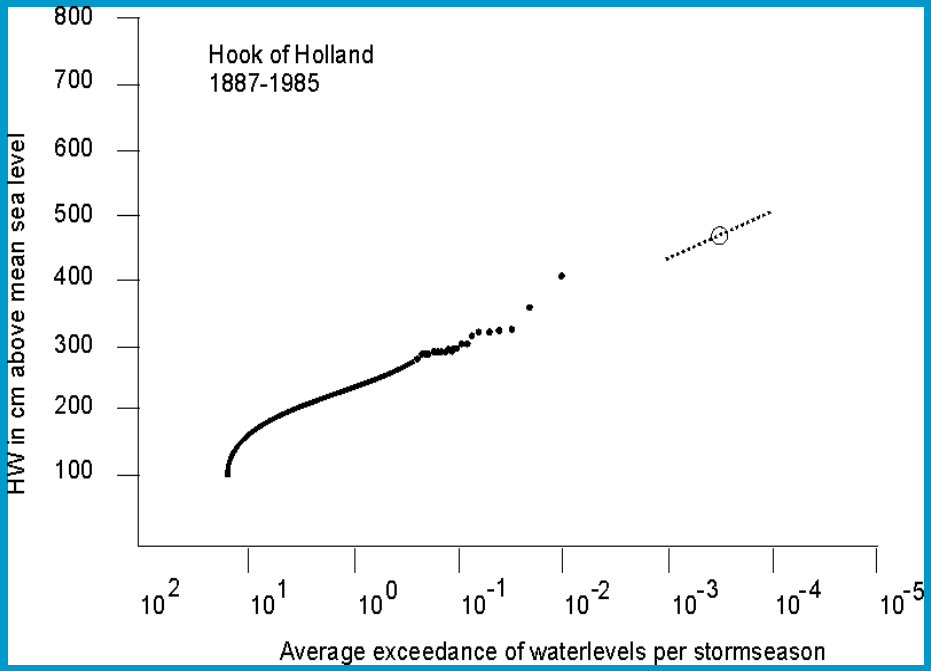
storm surges



http://www.hurricane.com

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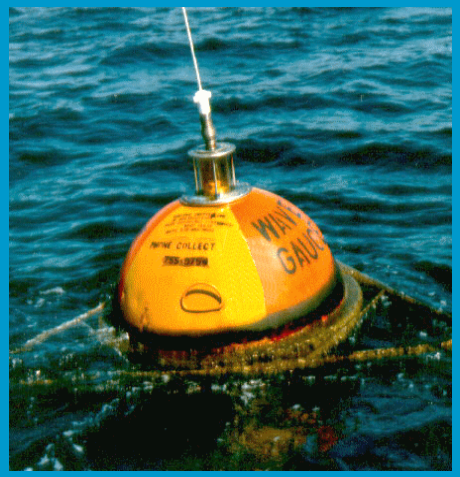
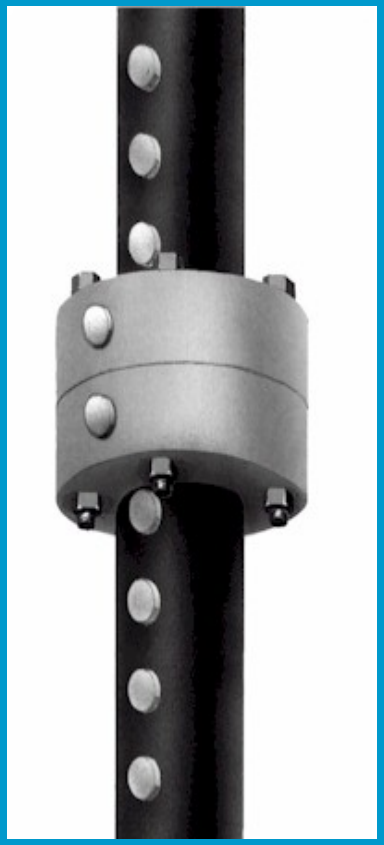
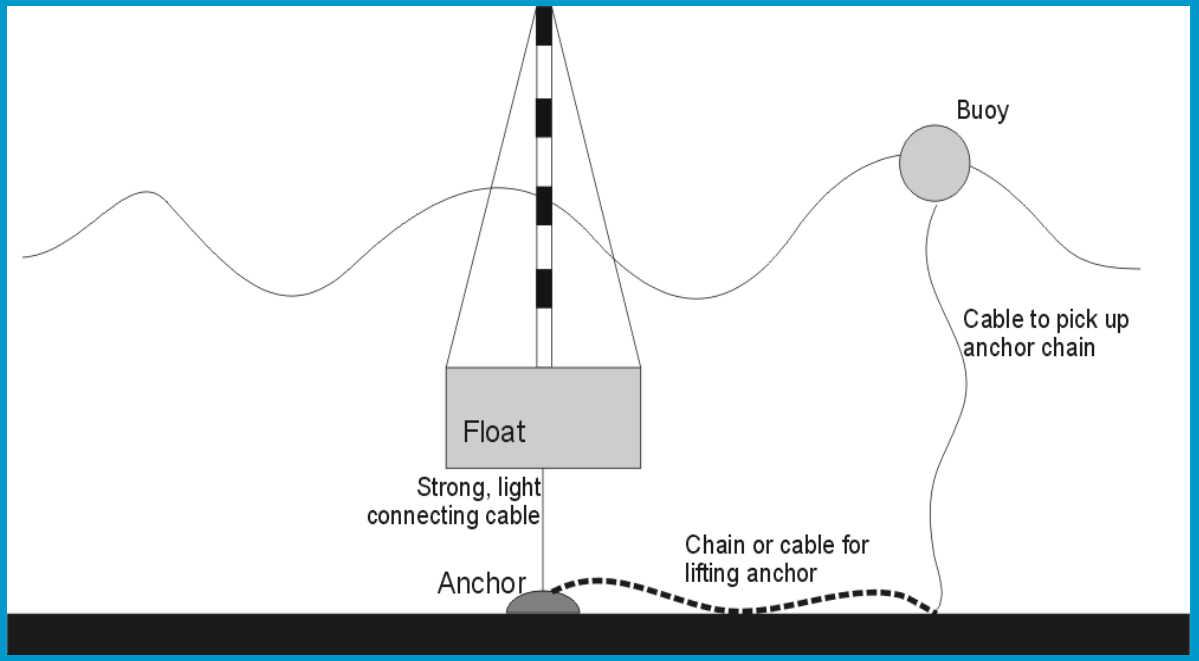
waves measurements







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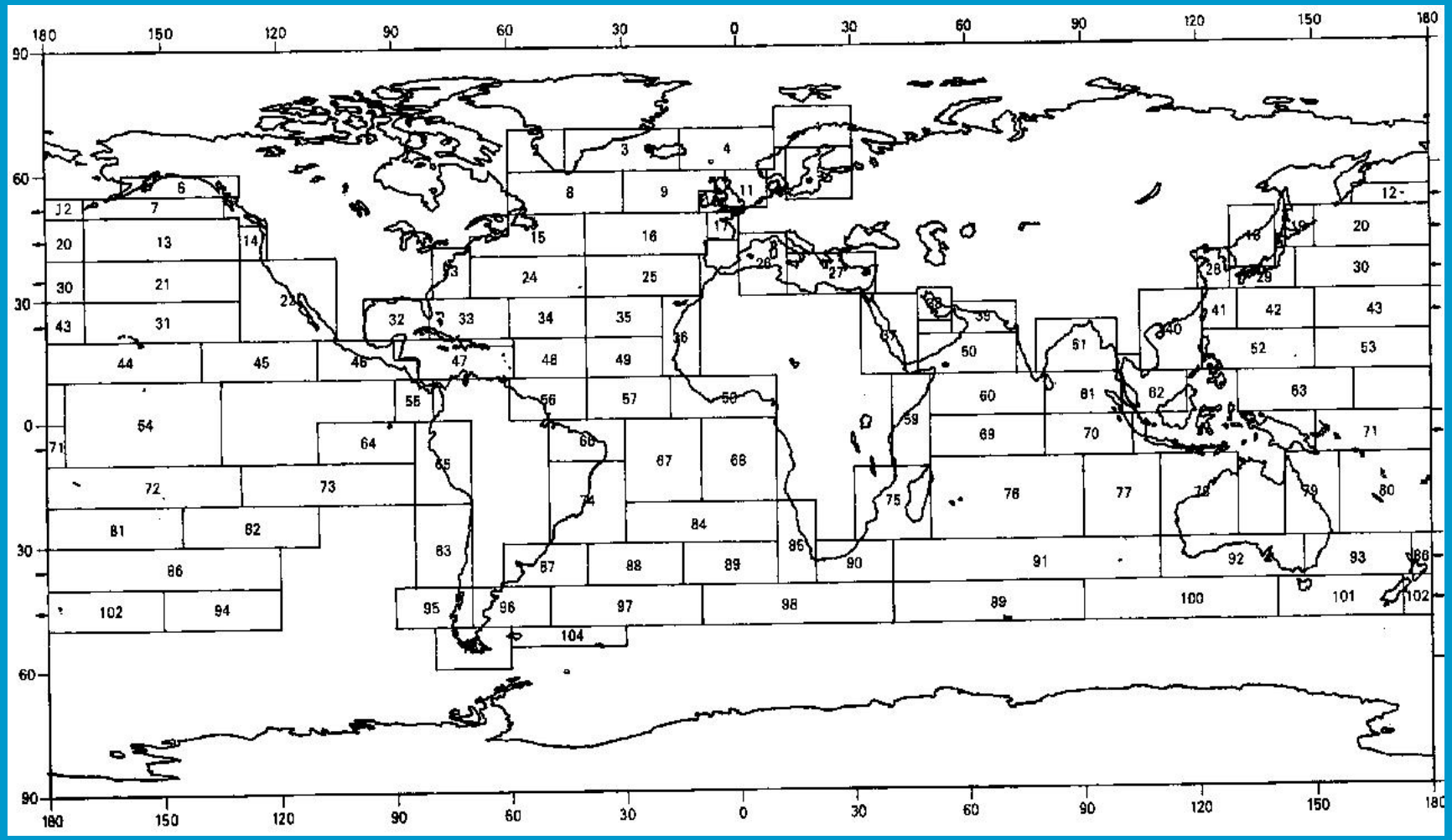
Global Wave Statistics (1)



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TOTAL NO. OF OBS. WIND/WAVE = 97823
ALL WIND = 884064

ANNUAL

AREA 74

NORTH WEST

PERCENTAGE OF OBS = 3.27%

INSUFFICIENT DATA

NORTH

PERCENTAGE OF OBS = 7.55%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	-
6-7	-	-	-	-	-	-	-	-	-	-	-	1
5-6	-	-	1	1	1	-	-	-	-	-	-	3
4-5	-	1	4	5	3	1	1	-	-	-	-	15
3-4	-	8	18	20	12	4	1	-	-	-	-	82
2-3	3	30	70	81	28	9	2	-	-	-	-	203
1-2	18	105	180	97	33	8	1	-	-	-	-	421
0-1	51	117	89	31	7	1	-	-	-	-	-	295
TOTAL	70	280	342	215	83	24	5	1	-	-	-	1000

ZERO CROSSING PERIOD (s)

NORTH EAST

PERCENTAGE OF OBS = 21.28%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	1
6-7	-	-	-	-	-	-	-	-	-	-	-	1
5-6	-	-	1	1	1	1	-	-	-	-	-	4
4-5	-	-	3	5	4	3	1	-	-	-	-	16
3-4	-	3	13	20	15	7	3	1	-	-	-	61
2-3	1	18	57	87	40	15	4	1	-	-	-	204
1-2	9	82	164	128	53	15	3	1	-	-	-	453
0-1	28	92	89	38	10	2	-	-	-	-	-	258
TOTAL	38	194	327	258	124	43	12	3	1	-	-	1000

ZERO CROSSING PERIOD (s)

WEST

PERCENTAGE OF OBS = 2.17%

INSUFFICIENT DATA

ALL DIRECTIONS

PERCENTAGE OF OBS = 100.00%
(INCLUDING 1.01% DIRECTION UNKNOWN)

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	1
7-8	-	-	-	-	-	-	-	-	-	-	-	1
6-7	-	-	-	-	1	1	1	1	-	-	-	5
5-6	-	-	-	1	2	3	2	1	1	-	-	11
4-5	-	-	1	5	9	10	7	3	1	1	-	37
3-4	-	-	5	20	33	29	17	7	2	1	-	115
2-3	-	3	26	74	89	59	27	9	2	1	-	289
1-2	1	15	86	142	109	49	18	4	1	-	-	422
0-1	2	20	44	38	14	3	1	-	-	-	-	116
TOTAL	3	39	162	278	256	156	70	26	8	2	1	1000

ZERO CROSSING PERIOD (s)

EAST

PERCENTAGE OF OBS = 31.15%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	1
6-7	-	-	-	-	1	-	-	-	-	-	-	2
5-6	-	-	-	1	2	1	1	-	-	-	-	5
4-5	-	-	2	8	8	4	2	1	-	-	-	22
3-4	-	2	12	23	21	12	5	1	-	-	-	77
2-3	1	12	53	76	54	24	8	2	-	-	-	229
1-2	4	58	149	139	68	21	5	1	-	-	-	445
0-1	15	87	80	40	12	2	-	-	-	-	-	217
TOTAL	20	139	296	285	183	85	21	6	1	-	-	1000

ZERO CROSSING PERIOD (s)

SOUTH WEST

PERCENTAGE OF OBS = 3.73%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	1
9-10	-	-	-	-	-	-	-	-	-	-	-	1
8-9	-	-	-	-	-	1	1	-	-	-	-	2
7-8	-	-	-	-	1	1	1	1	-	-	-	5
6-7	-	-	-	1	2	3	2	1	1	-	-	11
5-6	-	-	1	3	8	7	5	3	1	-	-	28
4-5	-	-	1	8	15	18	11	5	2	1	-	59
3-4	-	-	5	21	38	33	19	8	3	1	-	128
2-3	-	1	18	54	74	54	28	9	3	1	-	238
1-2	-	6	48	105	101	54	20	5	1	-	-	341
0-1	2	21	59	83	34	11	3	1	-	-	-	192
TOTAL	2	28	129	255	270	182	88	34	11	3	1	1000

ZERO CROSSING PERIOD (s)

SOUTH

PERCENTAGE OF OBS = 8.55%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	1
6-7	-	-	-	-	1	1	1	1	-	-	-	3
5-6	-	-	-	1	2	3	2	1	1	-	-	11
4-5	-	-	1	5	10	11	7	4	1	1	-	40
3-4	-	-	5	21	34	30	17	7	3	1	-	119
2-3	-	2	24	68	85	59	27	9	3	1	-	277
1-2	-	12	72	125	106	52	18	5	1	-	-	394
0-1	3	22	52	46	21	6	1	-	-	-	-	152
TOTAL	3	37	154	270	259	162	74	27	9	2	1	1000

ZERO CROSSING PERIOD (s)

SOUTH EAST

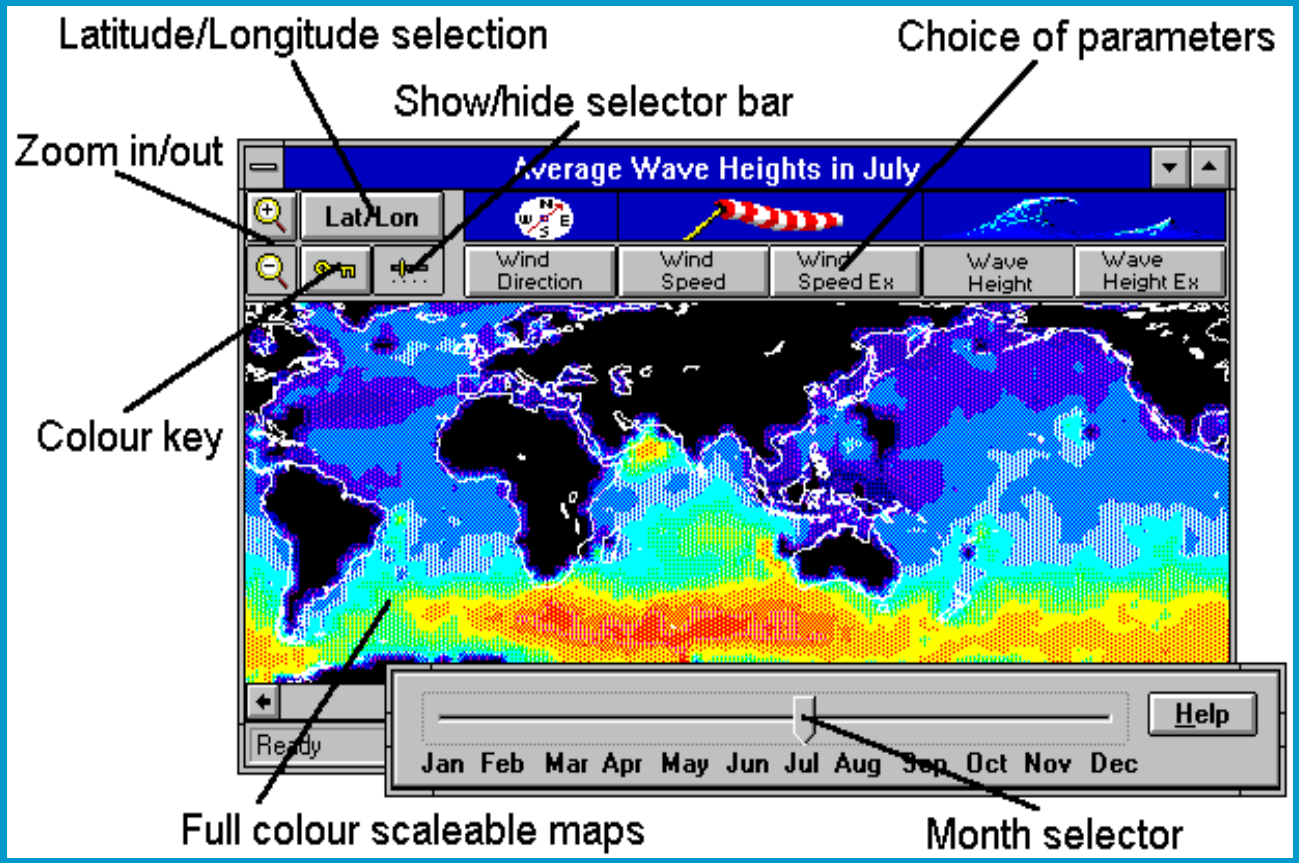
PERCENTAGE OF OBS = 21.28%

SIGNIFICANT WAVE HEIGHT (m)	TOTAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	TOTAL
>14	-	-	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-	-	-
12-13	-	-	-	-	-	-	-	-	-	-	-	-
11-12	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	1
6-7	-	-	-	-	1	1	-	-	-	-	-	2
5-6	-	-	-	1	2	2	1	1	-	-	-	7
4-5	-	-	2	7	9	6	3	1	-	-	-	29
3-4	-	1	11	27	28	15	8	3	1	-	-	99
2-3	-	9	48	68	70	34	12	3	1	-	-	264
1-2	2	39	128	142	78	27	7	1	-	-	-	425
0-1	9	46	66	38	12	3	-	-	-	-	-	173
TOTAL	11	96	256	300	201	91	32	9	2	1	-	1000

ZERO CROSSING PERIOD (s)

TABULATED PROBABILITIES ARE IN PARTS PER THOUSAND OF THE POPULATION IN EACH TABLE

processed data



Atlas of the Oceans,
Wind and Wave data

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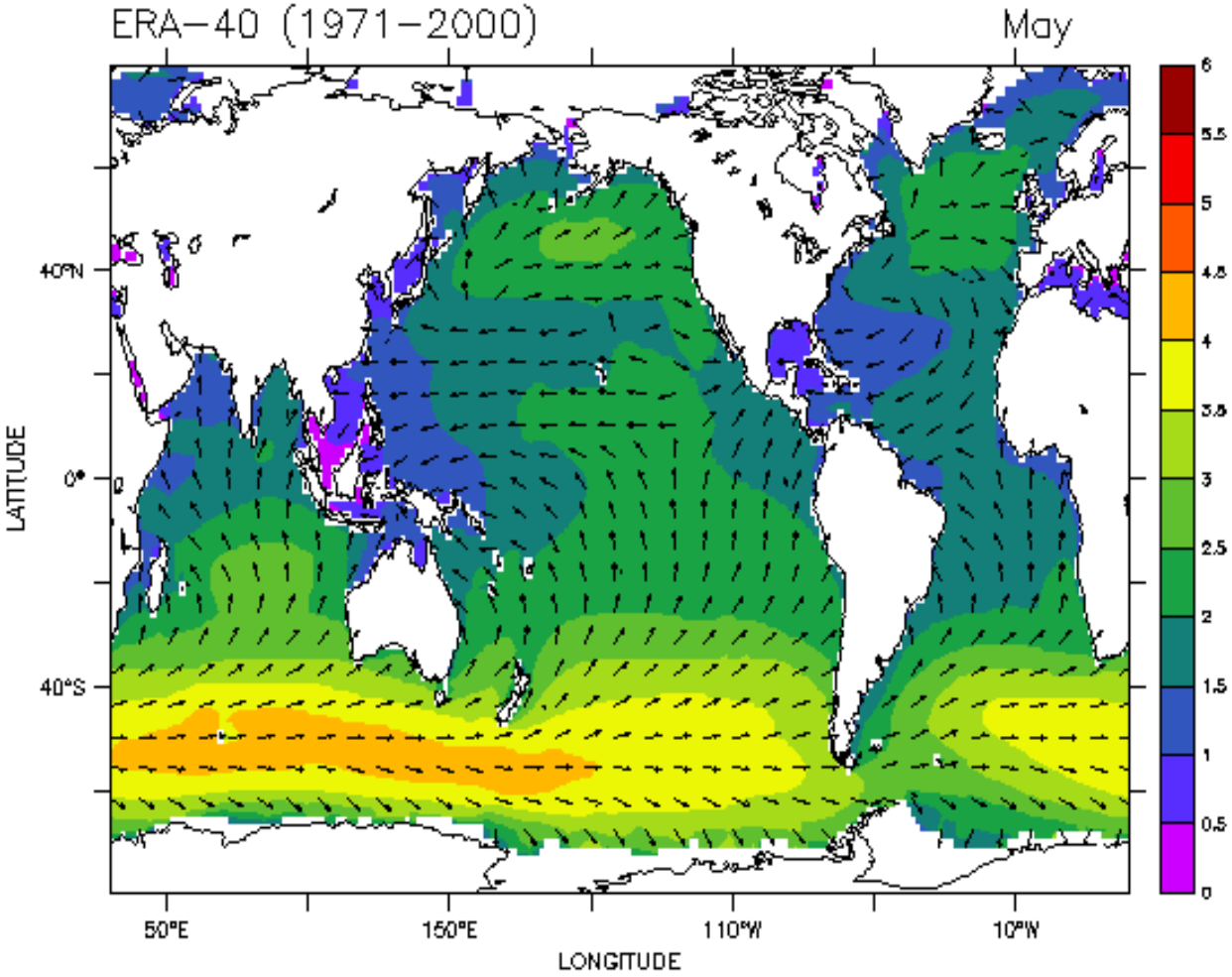

Significant wave height mean (m)

ERA-40 wave atlas

http://www.knmi.nl/onderzk/oceano/waves/era40

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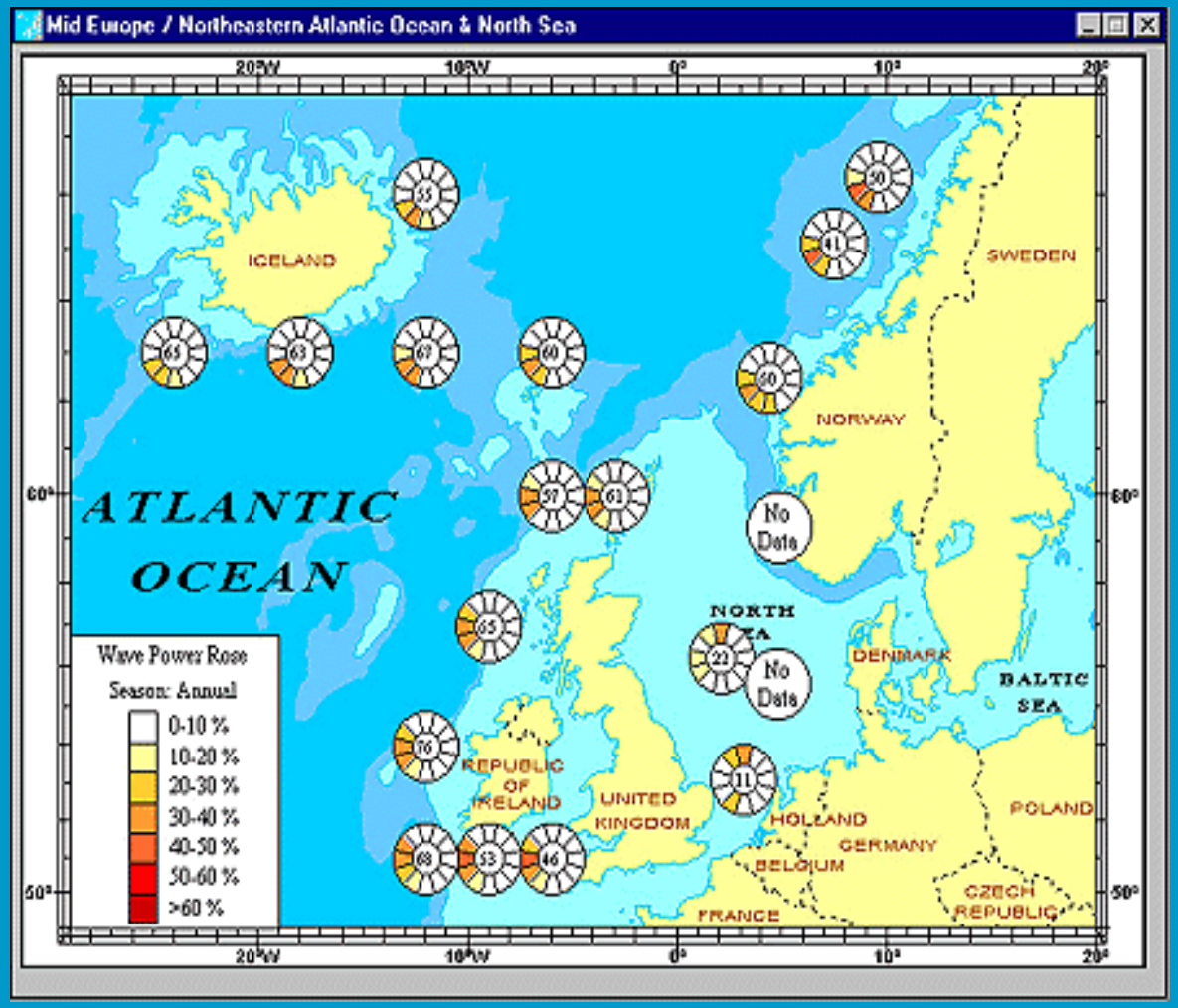
wave data for North Sea



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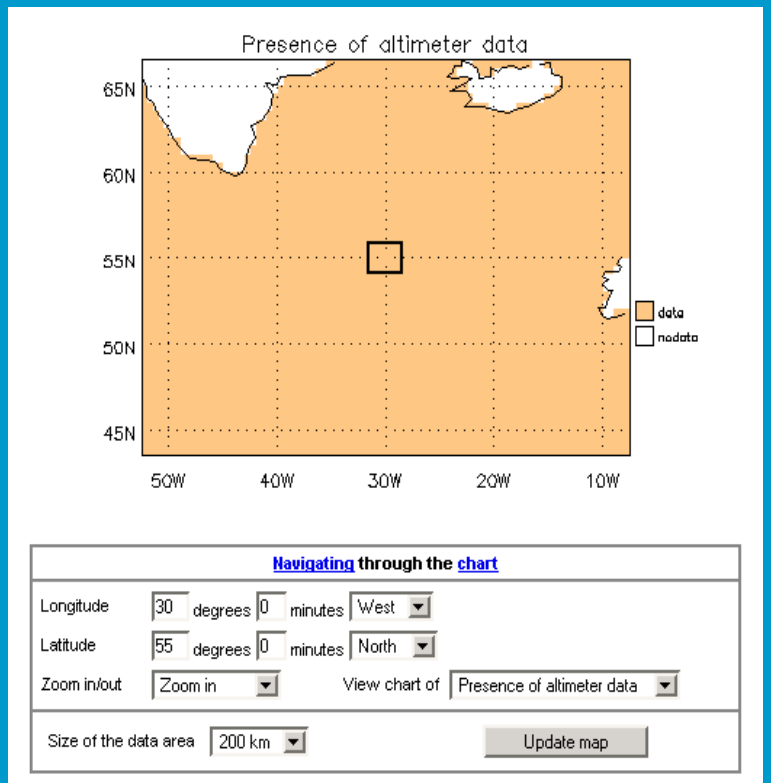
example from Argoss (www.waveclimate.com)

standard histogram

Percentage of occurrence of sign. wave height (m) in rows versus wave direction in columns

	N	NE	E	SE	S	SW	W	NW	
00:01	0	0.2	0	0.2	0	0	0	0.4	0.8
01:02	1.9	1.0	2.1	1.0	1.4	4.9	3.3	1.6	17.2
02:03	2.1	2.1	1.9	2.1	4.5	4.5	4.3	4.3	25.8
03:04	2.5	2.9	1.2	1.2	2.9	5.6	5.4	2.5	24.2
04:05	0.6	1.0	0.8	0.2	1.0	1.6	4.7	0.8	10.7
05:06	0.8	0.2	0.8	0.2	1.2	2.5	2.9	1.0	9.6
06:07	0	0	0.2	0	0.8	0.4	2.5	1.2	5.1
07:08	0.2	0.2	0	0	0.4	0.4	1.4	1.2	3.8
08:09	0	0	0	0	0	0.4	1.0	0	1.4
09:10	0	0	0	0	0	0	0	0.2	0.2
10:11	0	0	0	0	0	0	0.2	0.2	0.4
11:12	0	0	0	0	0	0	0	0	0.0
12:13	0	0	0	0	0	0.2	0	0	0.2
>=13	0	0	0	0	0	0	0	0	0.0
	8.1	7.6	7.0	4.9	12.2	20.5	25.7	13.4	



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exceedance table

Fractile sign. wave height (m) versus return period of 3 hour exceedance

return period	sign. wave height	lower limit	upper limit
month	11.5	11.0	11.9
1 yr	15.7	15.0	16.5
2	16.9	16.1	17.7
5	18.5	17.6	19.4
10	19.7	18.7	20.7
25	21.3	20.2	22.3
50	22.5	21.3	23.6
100	23.6	22.4	24.8
1000	27.6	26.2	29.0

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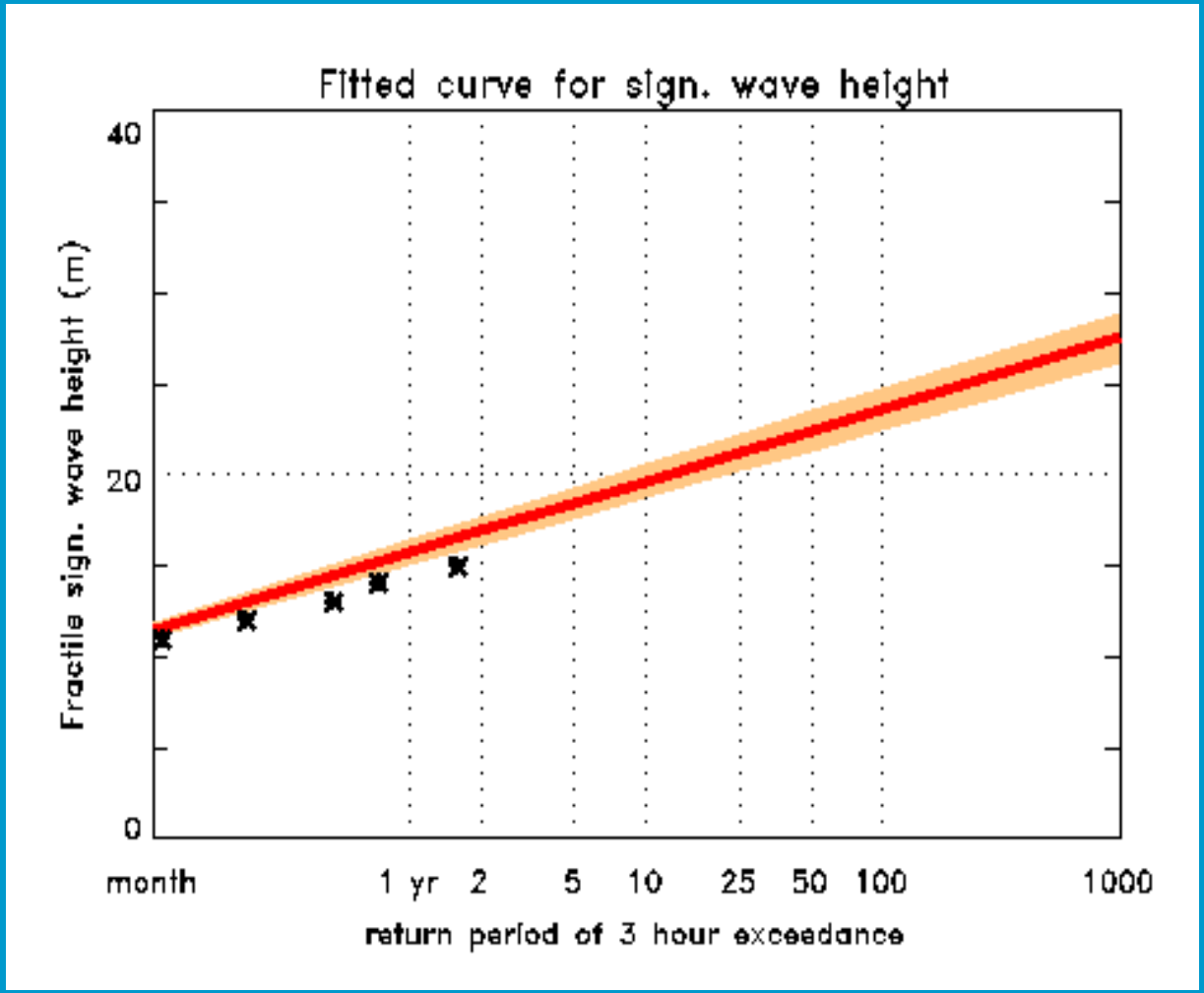
exceedance graph



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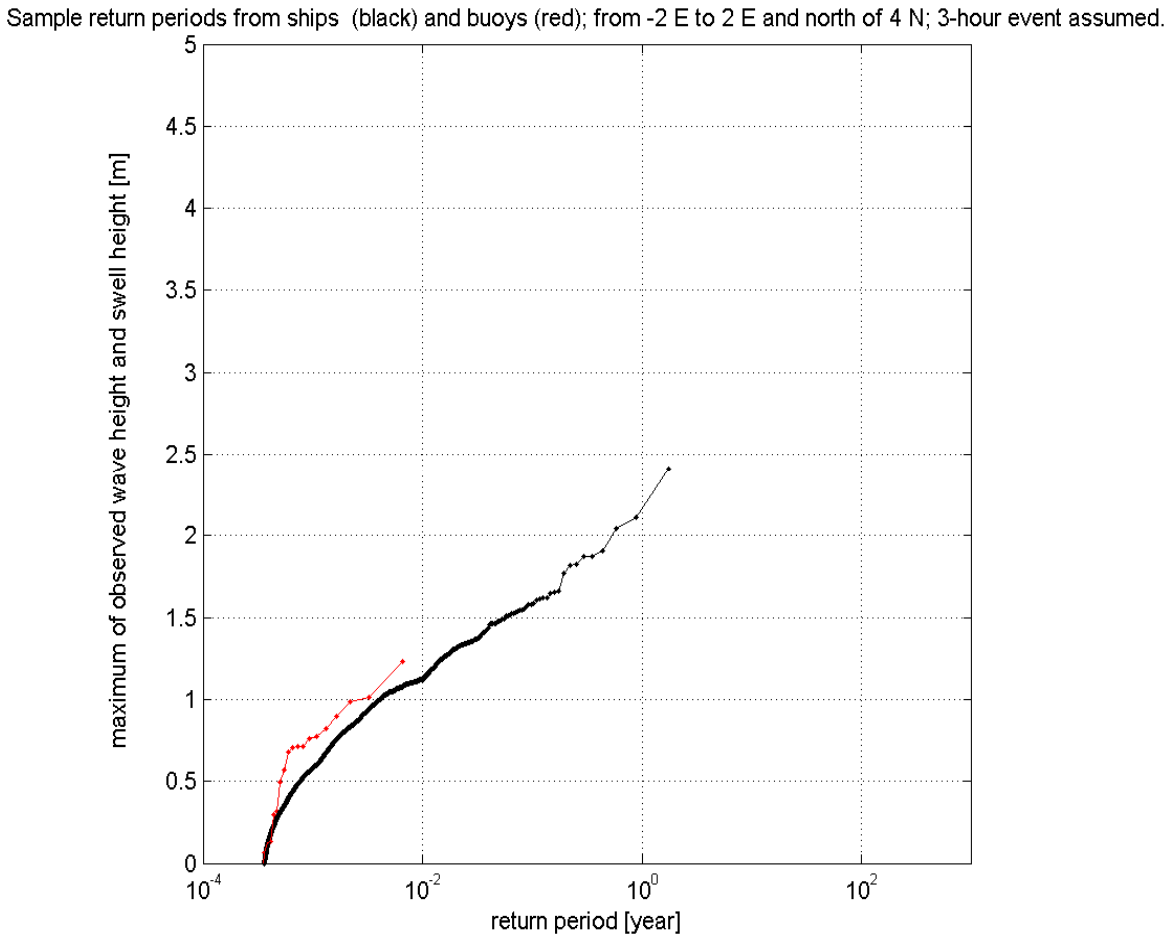
comparison buoys and ship data



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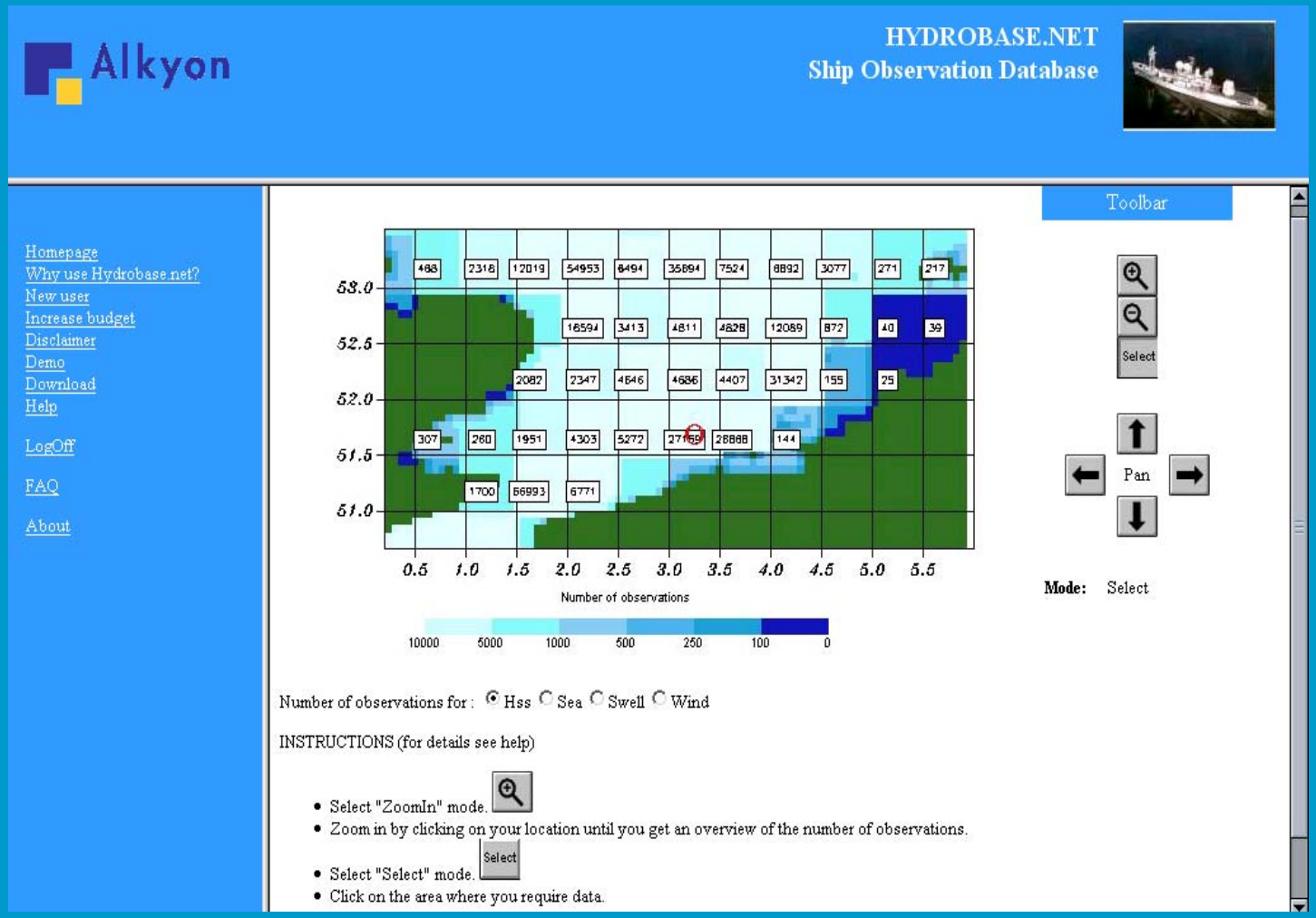
Data from www.hydrobase.net



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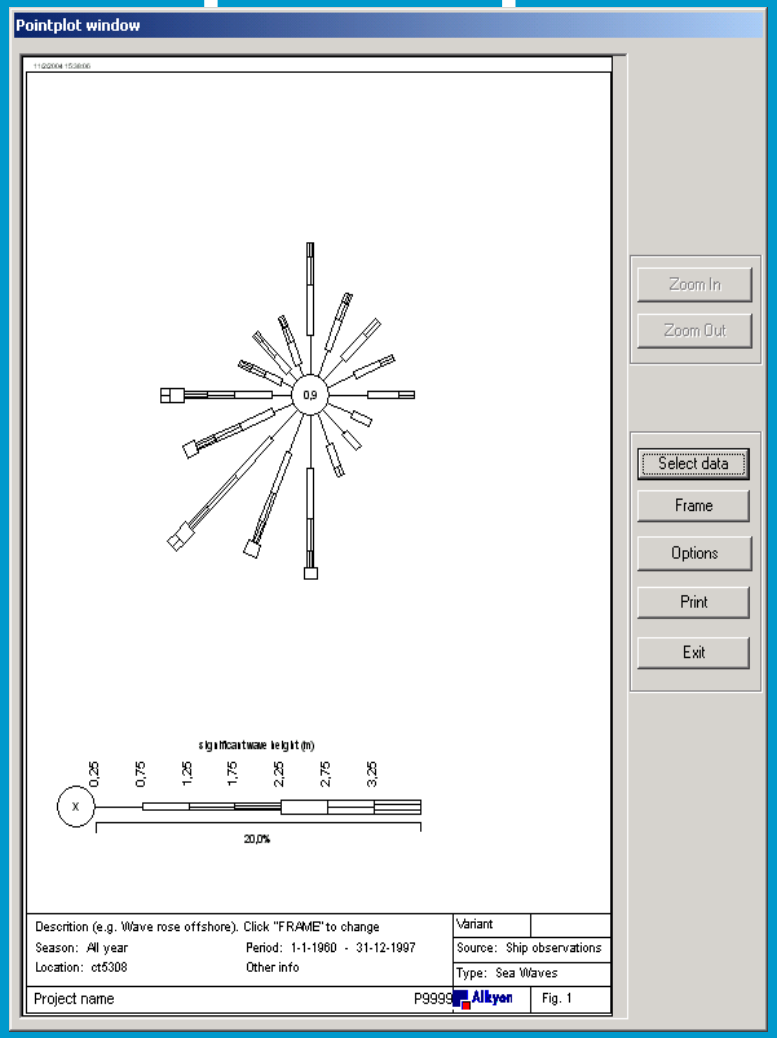
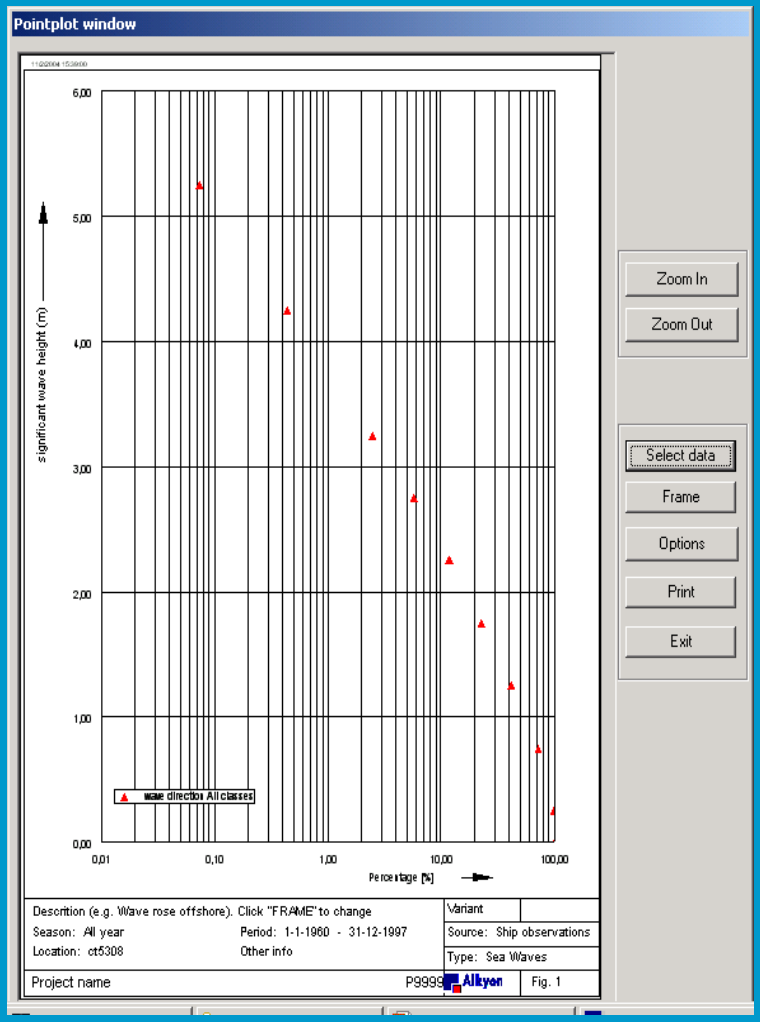
Sample output of Hydrobase





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Data from Hydrobase

Hydrobase - TF00000f10B4D4B200_Exceed.xls

File Edit View Insert Format Tools Data Window Help

A1 = Hs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Hs	wave direction (Deg)																
2	(m)	-11,25	11,25	33,75	56,25	78,75	101,25	123,75	146,25	168,75	191,25	213,75	236,25	258,75	281,25	303,75	326,25	
3		to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	Total
4		11,25	33,75	56,25	78,75	101,25	123,75	146,25	168,75	191,25	213,75	236,25	258,75	281,25	303,75	326,25	348,75	
5	<	8,45	5,40	5,57	4,96	5,63	3,26	3,30	3,96	9,52	9,12	11,24	7,90	8,56	4,48	4,35	4,28	100,00
6	,25	8,18	5,34	5,54	4,91	5,56	3,23	3,24	3,92	9,42	9,10	11,21	7,88	8,52	4,45	4,34	4,26	99,09
7	,75	6,00	3,83	3,87	3,11	3,23	1,65	1,45	2,09	6,46	6,81	8,97	6,61	7,31	3,72	3,66	3,57	72,33
8	1,25	3,15	1,96	1,95	1,42	1,32	,41	,25	,74	3,68	4,29	5,92	4,45	5,06	2,65	2,44	2,24	41,92
9	1,75	1,58	,92	,82	,58	,40	,05	,05	,19	1,87	2,55	3,45	2,69	3,33	1,68	1,26	1,32	22,74
10	2,25	,81	,36	,33	,25	,12	,02	,01	,07	,89	1,33	1,89	1,45	1,95	,94	,68	,73	11,82
11	2,75	,40	,19	,16	,06	,03	,01	,01	,01	,29	,54	,94	,73	1,06	,52	,33	,45	5,74
12	3,25	,21	,06	,06	,01	,01	.	,00	,00	,07	,18	,34	,33	,51	,28	,19	,21	2,49
13	4,25	,04	,00	,01	.	.	.	.	,00	,00	,02	,04	,05	,10	,07	,05	,06	,44
14	5,25	,01	.	,00	.	.	.	.	.	.	.	.	,01	,02	,01	,01	,02	,07
15	6,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	7,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17	8,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	9,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19	10,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	11,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	12,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	13,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23	14,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
24	15,25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25																		
26																		
27			Season:		All year													
28			Period:		1960 to 1997													
29			Location:		ct5308 (x = 3,00, y =51,50)													
30			Source:		Ship observations													
31			No. of obs.:		27058													
32			Type of data:		Sea Waves													
33			Tidal phase:		undefined level													
34			Record:		Ship Observations SEA data Season: All year													
35																		

T0001

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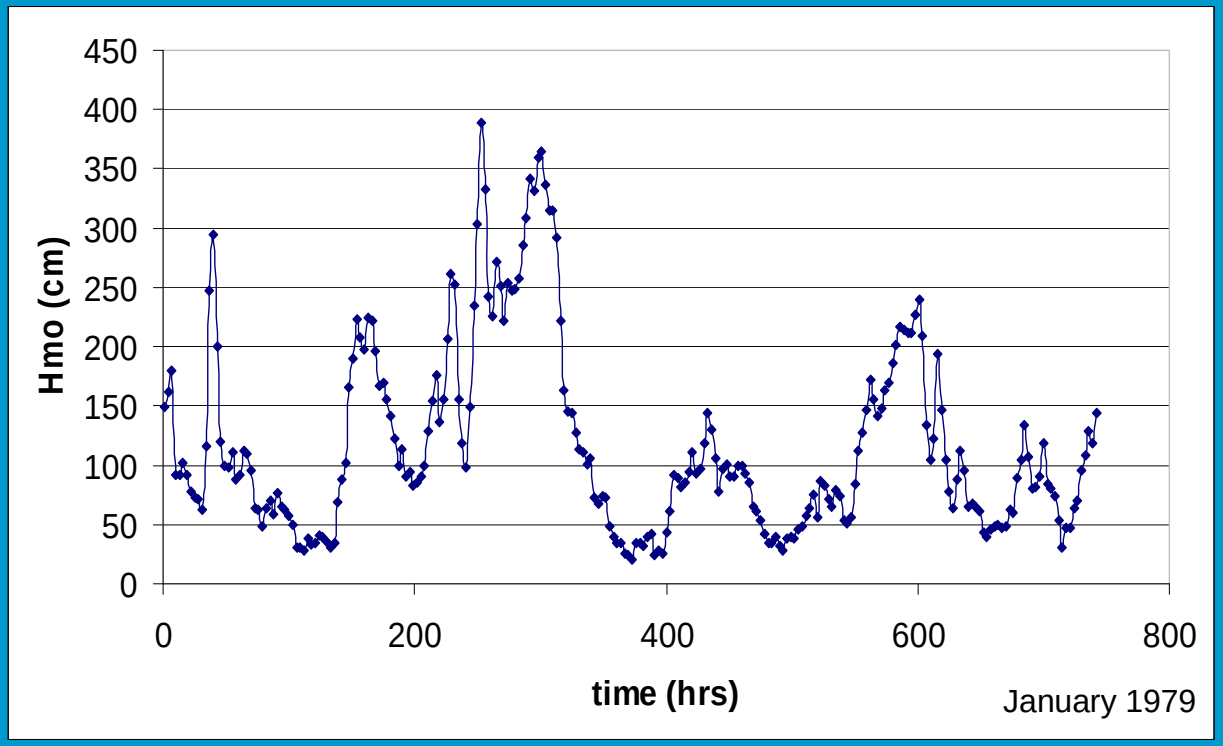
data from Meetpost Noordwijk



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basic data

date	time	H_{m0}	accur.	$H_{1/3}$	T_{TE3}	T_{m02}	$T_{H1/3}$	wave dir.	wind dir.	wind speed	level	setup
		cm	cm	cm	.1 s	.1 s	.1 s	degr	degr	.1 m/s	cm	cm
19980101	0100	70	4	64	6	39	49	261	210	60	-27	27	222224000
19980101	0400	72	4	65	8	36	45	264	210	70	91	24	222224000
19980101	0700	62	4	56	8	36	46	258	200	80	58	11	222224000
19980101	1000	93	5	85	11	40	48	234	190	90	-31	6	222224000
19980101	1300	110	5	102	14	44	51	230	200	90	-83	-5	222224000
19980101	1600	162	7	148	17	42	52	230	200	120	43	-12	222224000
19980101	1900	132	6	121	11	40	48	224	190	130	40	-37	222224000
19980101	2200	205	8	190	18	51	61	220	190	170	-39	-33	222224000
19980102	0100	247	10	230	37	56	68	229	190	170	-114	-57	222224000
19980102	0400	275	11	255	40	55	68	236	210	160	-1	-1	222224000
19980102	0700	208	8	193	20	50	63	234	200	140	-2	-72	222224000
19980102	1000	142	6	132	14	47	59	227	190	120	-59	-13	222224000
19980102	1300	130	6	120	14	50	64	223	160	110	-97	-22	222224000
19980102	1600	117	5	108	13	43	53	213	170	100	73	87	222224000
19980102	1900	91	5	84	10	39	49	232	210	100	152	58	222224000
19980102	2200	243	10	226	22	52	62	267	280	150	119	118	222224000
19980103	0100	287	12	269	32	59	70	269	260	110	25	73	222224000
19980103	0400	240	10	224	21	55	66	265	230	90	28	60	222224000

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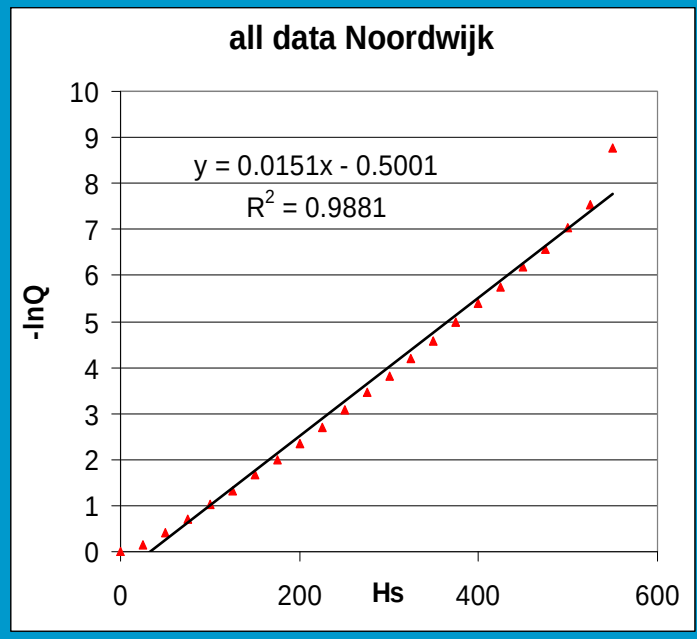
sort data in classes

Waveheight class H_s (cm)		Number of observations		P	Q	-ln(Q)
0	25	35	35	0.000599	0.999401	0.000599
25	50	8260	8295	0.141940	0.858060	0.153082
50	75	11424	19719	0.337423	0.662577	0.411618
75	100	10004	29723	0.508607	0.491393	0.710511
100	125	7649	37372	0.639493	0.360507	1.020245
125	150	5563	42935	0.734685	0.265315	1.326838
150	175	4389	47324	0.809788	0.190212	1.659615
175	200	3167	50491	0.863980	0.136020	1.994954
200	225	2360	52851	0.904363	0.095637	2.347200
225	250	1671	54522	0.932957	0.067043	2.702419
250	275	1234	55756	0.954073	0.045927	3.080692
275	300	851	56607	0.968634	0.031366	3.462047
300	325	556	57163	0.978149	0.021851	3.823487
325	350	392	57555	0.984856	0.015144	4.190168
350	375	276	57831	0.989579	0.010421	4.563938
375	400	206	58037	0.993104	0.006896	4.976819
400	425	136	58173	0.995431	0.004569	5.388507
425	450	82	58255	0.996834	0.003166	5.755400
450	475	66	58321	0.997964	0.002036	6.196632
475	500	38	58359	0.998614	0.001386	6.581307
500	525	30	58389	0.999127	0.000873	7.043930
525	550	20	58409	0.999470	0.000530	7.541769
550	575	22	58431	0.999846	0.000154	8.778531
575	600	9	58440	1.000000	0.000000	
		58440				

$$P = P(H_s' \leq H_s)$$

$$Q = Q(H_s' > H_s) = 1 - P$$



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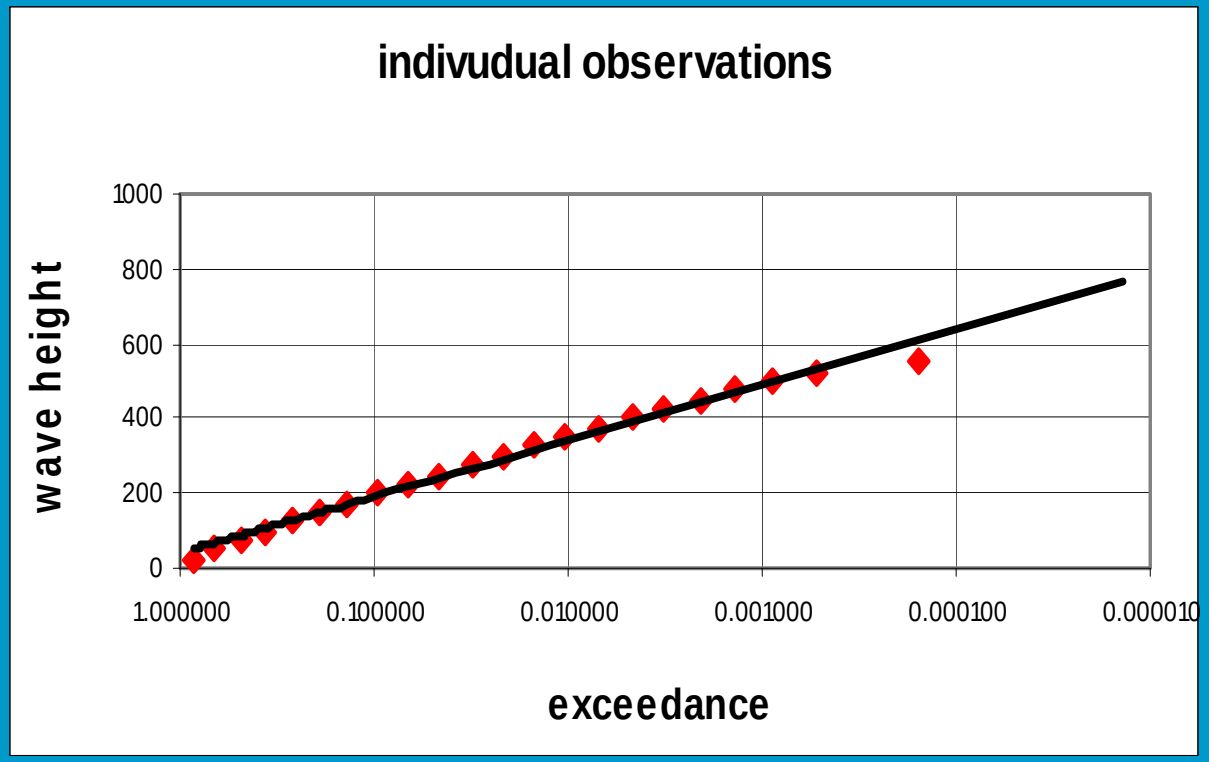
exceedance graph for Noordwijk



But what means that in a year during 0.1 % of the time the H_s is larger than 5 m ?

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Peak over Threshold method

A storm is defined as a time that the wave is higher than a certain value; the height of the storm H_{ss} is equal to the highest observed H_s during that storm

Threshold = 1.5
In this period 9 storms observed:

nr.	H_{ss}
1	1.80 m
2	2.94 m
3	2.25 m
4	1.76 m
5	2.61 m
6	3.89 m
7	1.72 m
8	2.40 m
9	1.94 m

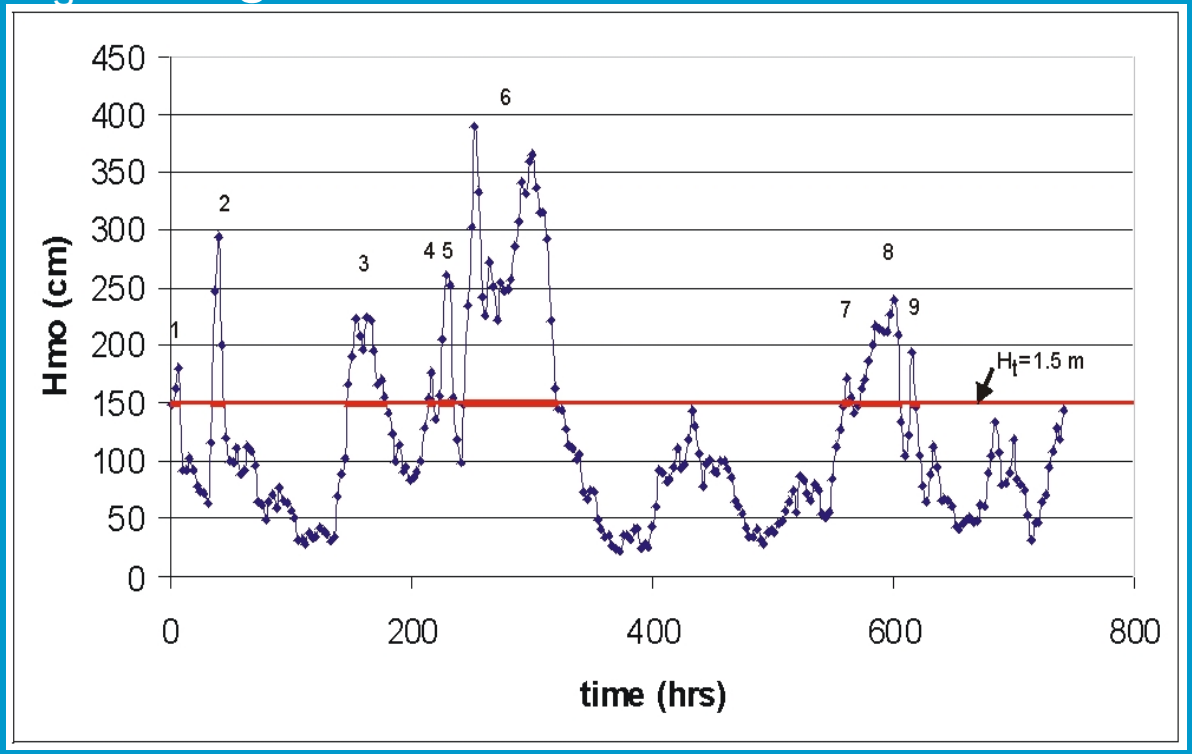

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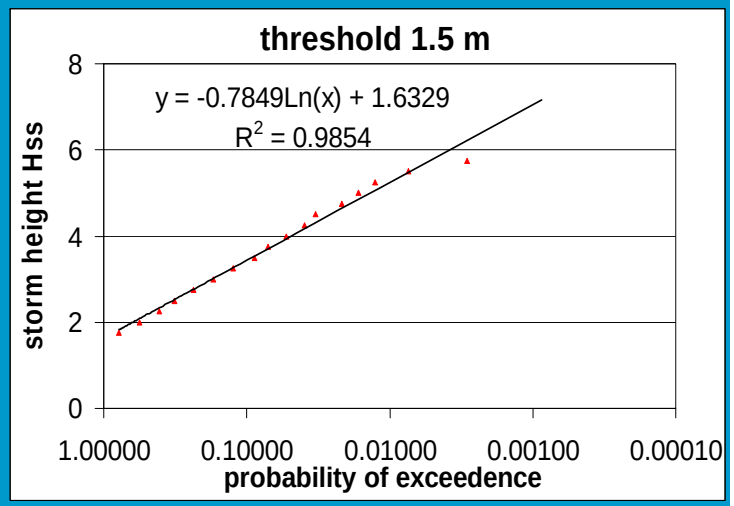
Table with H_{ss} classes

Wave height class		150	cumul	P	Q	Q_s	α = 1.24 W
1.50	1.75	384	384	0.21993	0.78007	68.10	0.32522
1.75	2.00	381	765	0.43814	0.56186	49.05	0.64136
2.00	2.25	266	1031	0.59049	0.40951	35.75	0.91261
2.25	2.50	157	1188	0.68041	0.31959	27.90	1.11202
2.50	2.75	148	1336	0.76518	0.23482	20.50	1.34858
2.75	3.00	111	1447	0.82875	0.17125	14.95	1.58094
3.00	3.25	81	1528	0.87514	0.12486	10.90	1.80552
3.25	3.50	63	1591	0.91123	0.08877	7.75	2.04065
3.50	3.75	31	1622	0.92898	0.07102	6.20	2.19099
3.75	4.00	32	1654	0.94731	0.05269	4.60	2.38832
4.00	4.25	23	1677	0.96048	0.03952	3.45	2.57486
4.25	4.50	11	1688	0.96678	0.03322	2.90	2.68590
4.50	4.75	20	1708	0.97824	0.02176	1.90	2.95184
4.75	5.00	9	1717	0.98339	0.01661	1.45	3.11883
5.00	5.25	7	1724	0.98740	0.01260	1.10	3.28731
5.25	5.50	9	1733	0.99255	0.00745	0.65	3.60263
5.50	5.75	8	1741	0.99714	0.00286	0.25	4.15922
5.75	6.00	5	1746	1	0	0.00	#DIV/0!
		1746					
20	year	87.3				Slope	0.85586
						Intercept	-1.04906
						correlation	0.99524
						beta	1.16842
						gamma	1.22575
		H_{ss} for condition 1/		10			6.68997

$$P = P(H_{ss}^{'} \le H_{ss})$$

$$Q = Q\left(H_{ss}^{'} > H_{ss}\right) = 1 - P$$



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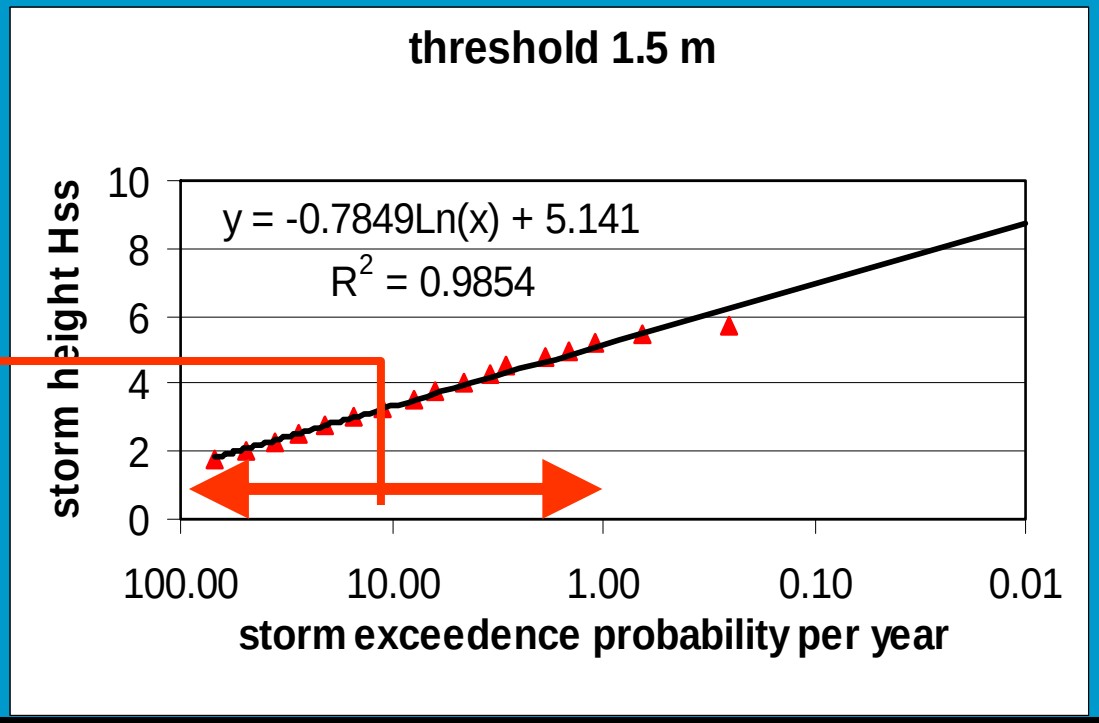
How to get storm exceedance ?

Q = probability of exceedance of a wave
Q_s = probability of exceedance of a storm

$$Q_s = N_s Q$$

Statistically nonsense



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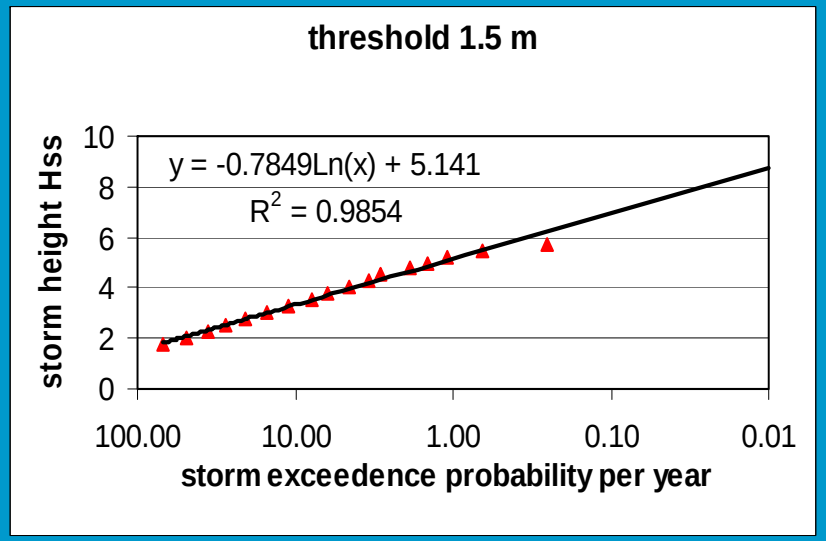
The “once in 500 years storm”

$$H_{ss} = -0.785 \ln(Q_s)$$

$$= -0.785 \ln\left(\frac{1}{500}\right) + 5.141$$

$$= 10.0\, m$$



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Using the Gumbel distribution

$$P = \exp\left[-\exp\left(-\frac{H_{ss} - \gamma}{\beta} \right) \right]$$

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determination of β and γ

$$\ln P = -\exp\left(-\frac{H_{ss}-\gamma}{\beta}\right)$$

$$\underbrace{-\ln\left(-\ln P\right)}_{G} = \frac{H_{ss}-\gamma}{\beta} = \underbrace{\frac{1}{\beta}H_{ss} - \frac{\gamma}{\beta}}_{AH_{ss}-B}$$

$$G = -\ln\left(\ln\frac{1}{P}\right)$$

Perform linear regression for $G = A\,H_{ss} - B$

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data for calculation of Gumbel

		150	cumul	P	Q	ln(Qs)	-ln(H)	Qs	G
1,50	1,75	384	384	0,21993	0,78007	4,22098	-0,56	68,10	-0,415046
1,75	2,00	381	765	0,43814	0,56186	3,89284	-0,69	49,05	0,192121
2,00	2,25	266	1031	0,59049	0,40951	3,57655	-0,81	35,75	0,640938
2,25	2,50	157	1188	0,68041	0,31959	3,32863	-0,92	27,90	0,954366
2,50	2,75	148	1336	0,76518	0,23482	3,02042	-1,01	20,50	1,318085
2,75	3,00	111	1447	0,82875	0,17125	2,70471	-1,1	14,95	1,672191
3,00	3,25	81	1528	0,87514	0,12486	2,38876	-1,18	10,90	2,014645
3,25	3,50	63	1591	0,91123	0,08877	2,04769	-1,25	7,75	2,375535
3,50	3,75	31	1622	0,92898	0,07102	1,82455	-1,32	6,20	2,608194
3,75	4,00	32	1654	0,94731	0,05269	1,52606	-1,39	4,60	2,916351
4,00	4,25	23	1677	0,96048	0,03952	1,23837	-1,45	3,45	3,210883
4,25	4,50	11	1688	0,96678	0,03322	1,06471	-1,5	2,90	3,387796
4,50	4,75	20	1708	0,97824	0,02176	0,64185	-1,56	1,90	3,816515
4,75	5,00	9	1717	0,98339	0,01661	0,37156	-1,61	1,45	4,089424
5,00	5,25	7	1724	0,98740	0,01260	0,09531	-1,66	1,10	4,367707
5,25	5,50	9	1733	0,99255	0,00745	-0,43078	-1,7	0,65	4,896399
5,50	5,75	8	1741	0,99714	0,00286	-1,38629	-1,75	0,25	5,854211
5,75	6,00	5	1746	1	0	#NUM!	-1,79	0,00	#NUM!

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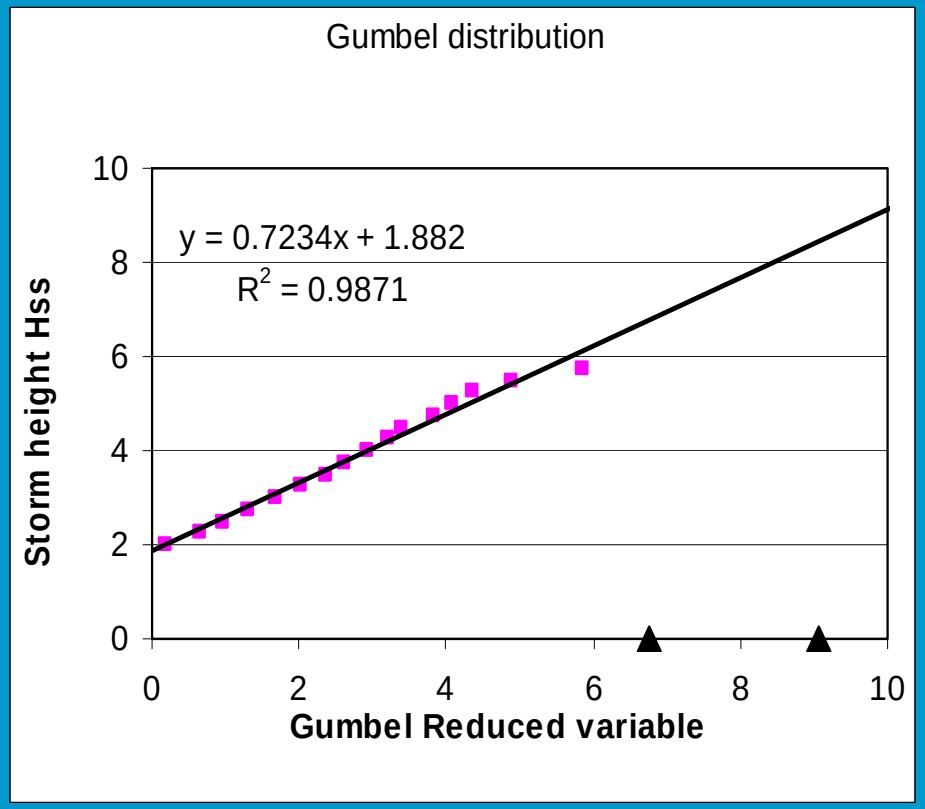
Gumbel exceedance graph



$$G = AH_{ss} + B$$

$\beta = 1/A = 0.723$

$\gamma = \beta B = 1.882$

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calculation of a value

$$H_{ss} = \gamma - \beta \ln\left(\ln \frac{1}{P}\right)$$

$$= \gamma - \beta \ln\left(\ln \frac{1}{1-Q}\right)$$

$$= \gamma - \beta \ln\left(\ln \frac{1}{1-Q_s/N_s}\right)$$

$$= \gamma - \beta \ln\left(\ln \frac{N_s}{N_s - Q_s}\right)$$

$\beta = 1/A = 0.73$

$\gamma = \beta B = 1.88$

$$H_{s\,1/500} = 1.88 - 0.73 \ln\left(\ln \frac{87.3}{87.3 - 1/500}\right) = 9.67$$

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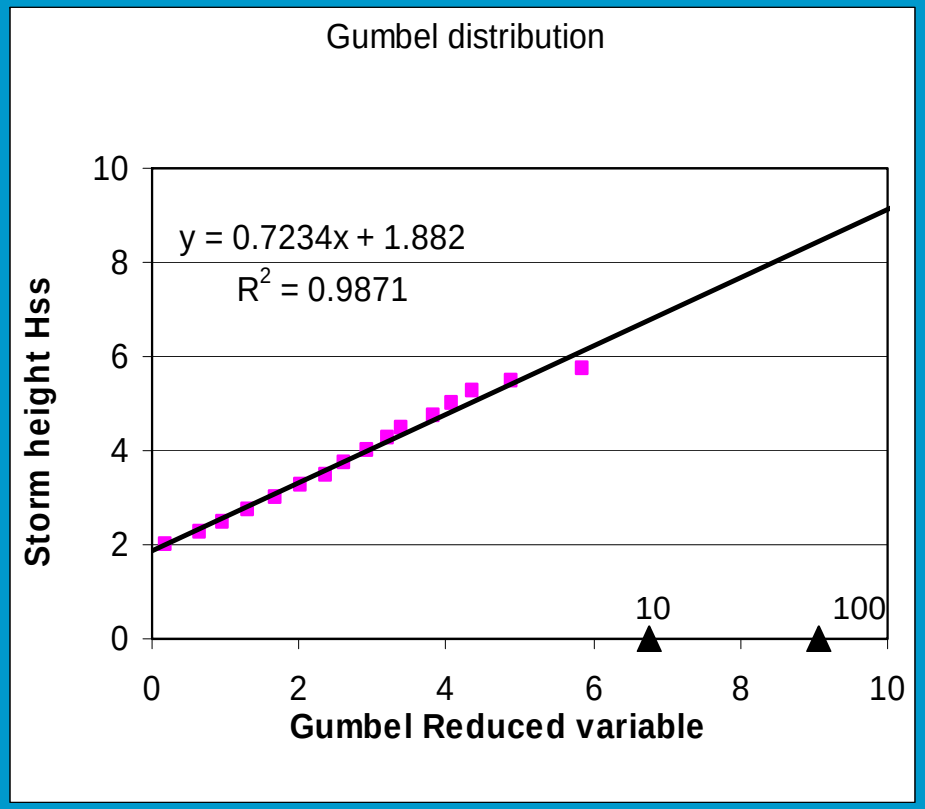
transformation of the axis



$$G = -\ln\left(\ln\frac{N_s}{N_s - Q_s}\right)$$

N_s = 87.3 storms per year

Q_s	G
1/10	6.77
1/100	9.07
1/1000	11.38
1/10000	13.68

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Weibull distribution

$$Q = \exp\left[-\left\{ \frac{H_{ss} - \gamma}{\beta} \right\}^{\alpha} \right]$$

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determination of the reduced variable

$$-\ln Q = \left[\frac{H_{ss}-\gamma}{\beta}\right]^{\alpha}$$

$$\left(-\ln Q\right)^{1/\alpha} = \frac{H_{ss}-\gamma}{\beta}$$

$$\underbrace{\left(-\ln Q\right)^{1/\alpha}}_{W} = \underbrace{\frac{1}{\beta}H_{ss} - \frac{\gamma}{\beta}}_{AH_{ss}-B}$$

$$W = -\left(\ln Q\right)^{1/\alpha}$$

Three variables:
α, β and γ
So: iteration is needed

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								alfa=	1,24
		150	cumul	P	Q	ln(Qs)	-ln(H)	Qs	W
1,50	1,75	384	384	0,21993	0,78007	4,22098	-0,56	68,10	0,32522
1,75	2,00	381	765	0,43814	0,56186	3,89284	-0,69	49,05	0,64136
2,00	2,25	266	1031	0,59049	0,40951	3,57655	-0,81	35,75	0,91261
2,25	2,50	157	1188	0,68041	0,31959	3,32863	-0,92	27,90	1,11202
2,50	2,75	148	1336	0,76518	0,23482	3,02042	-1,01	20,50	1,34858
2,75	3,00	111	1447	0,82875	0,17125	2,70471	-1,1	14,95	1,58094
3,00	3,25	81	1528	0,87514	0,12486	2,38876	-1,18	10,90	1,80552
3,25	3,50	63	1591	0,91123	0,08877	2,04769	-1,25	7,75	2,04065
3,50	3,75	31	1622	0,92898	0,07102	1,82455	-1,32	6,20	2,19099
3,75	4,00	32	1654	0,94731	0,05269	1,52606	-1,39	4,60	2,38832
4,00	4,25	23	1677	0,96048	0,03952	1,23837	-1,45	3,45	2,57486
4,25	4,50	11	1688	0,96678	0,03322	1,06471	-1,5	2,90	2,68590
4,50	4,75	20	1708	0,97824	0,02176	0,64185	-1,56	1,90	2,95184
4,75	5,00	9	1717	0,98339	0,01661	0,37156	-1,61	1,45	3,11883
5,00	5,25	7	1724	0,98740	0,01260	0,09531	-1,66	1,10	3,28731
5,25	5,50	9	1733	0,99255	0,00745	-0,43078	-1,7	0,65	3,60263
5,50	5,75	8	1741	0,99714	0,00286	-1,38629	-1,75	0,25	4,15922
5,75	6,00	5	1746	1	0	#NUM!	-1,79	0,00	#DIV/0!
		1746							
20	year	87,3							0,85586
									-1,04906
									0,99524
						-0,7849			
						5,41		beta	1,16842
								gamma	1,22575
	Hs for condition 1/			500		10,28785			9,11838

$$H_{s,s} = \gamma + \beta\left\{-\ln Q_s\right\}^{1/\alpha}$$

calculation for Weibull

$$H_{ss} = \gamma + \beta\left\{-\ln\left(\frac{Q_s}{N_s}\right)\right\}^{1/\alpha}$$

$$H_{s1/500} = 1.22 + 1.17\left\{-\ln\left(\frac{1/500}{87.3}\right)\right\}^{1/1.24}$$

$$= 1.22 + 1.17 \cdot 6.75$$

$$= 9.12\,m$$

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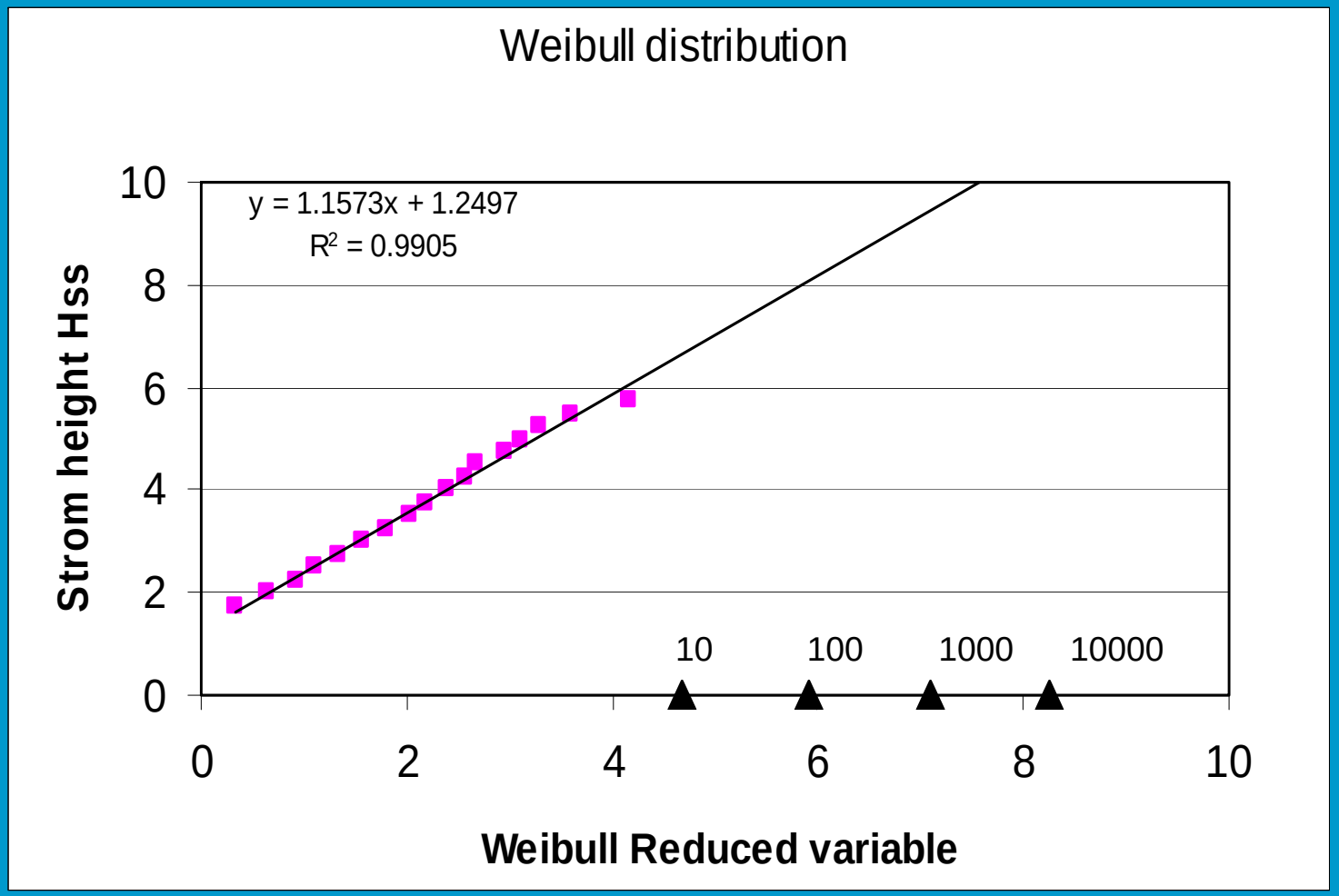
Weibull exceedance graph



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Summary

H_T threshold value	1.50 m
γ Exponential	1.63 m
γ Gumbel	1.36 m
γ Weibull	1.22 m

H_T	1.50	2.00	2.50	3.00	3.50	4.00
N_s	87.3	59.6	38.9	19.4	10.8	5.3
$H_{s\ 1/500}$ Exponential	10.00	10.09	9.48	9.39	9.08	8.76
$H_{s\ 1/500}$ Gumbel	9.69	9.50	9.17	8.93	8.86	8.18
$H_{s\ 1/500}$ Weibull	9.12	9.90	9.63	9.48	9.17	8.90

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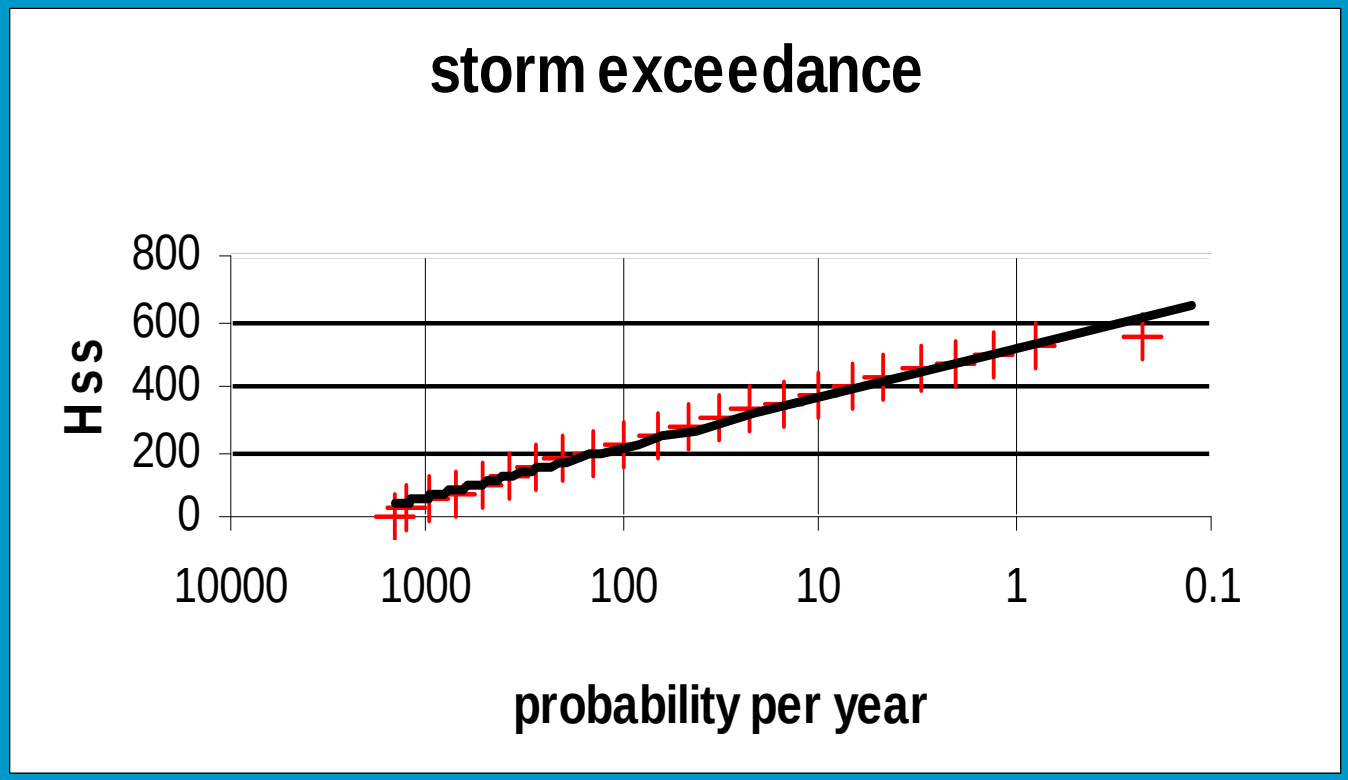
What to do if only random data are available ??



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Example of long term data

This are H_s-classes

Height (m)	Observations			Percentage of total			total %	cum. %
	NW	N	NE	NW	N	NE		
9-10		1			.010		.01	.01
8-9		2	1		.020	.022	.04	.05
7-8		3	1		.030	.022	.05	.10
6-7	1	7	4	.006	.070	.090	.16	.26
5-6	1	14	11	.006	.140	.246	.39	.65
4-5	5	30	32	.030	.301	.717	1.05	1.70
3-4	22	72	91	.132	.723	2.039	2.89	4.59
2-3	91	82	217	.548	1.827	4.863	7.23	11.82
1-2	318	329	273	1.914	3.303	6.118	11.33	23.15
0-1	569	382	278	3.425	3.835	6.230	13.49	36.64
						Other directions:		63.36
Total	1000	1000	1000					100.0
	6.02%	10.04%	22.41%					

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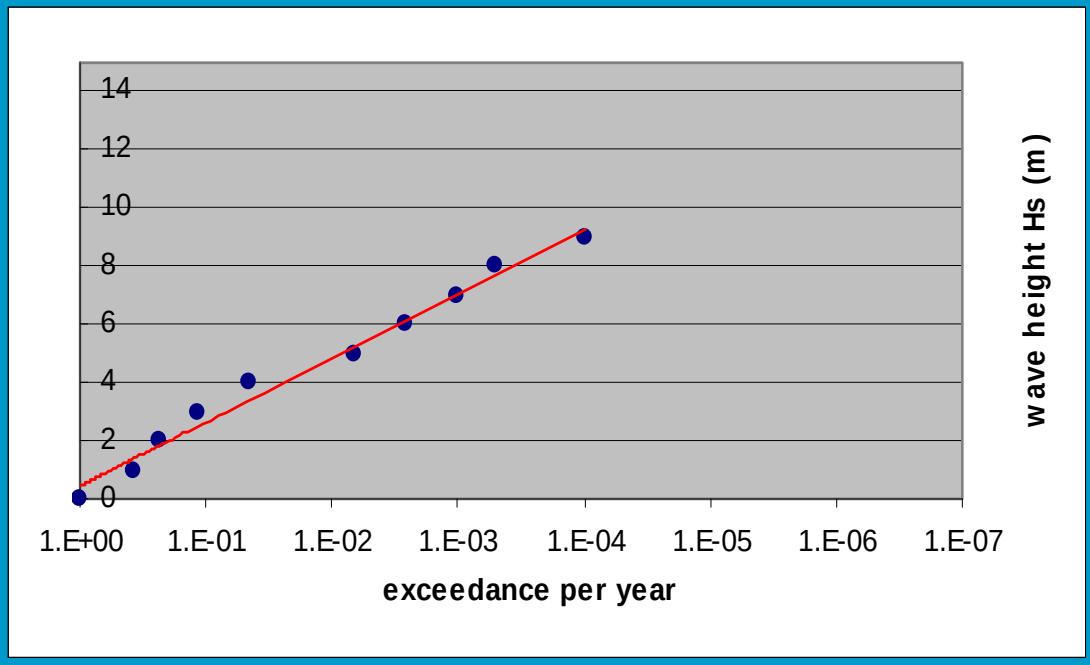
Long term (continuation)

So from this last column we can conclude:
100 % of time $H > 0$ m s
23 % of time $H > 1$ m s
12 % of time $H > 2$ m s
: :
: :
0.01 % of time $H > 9$ m s
.



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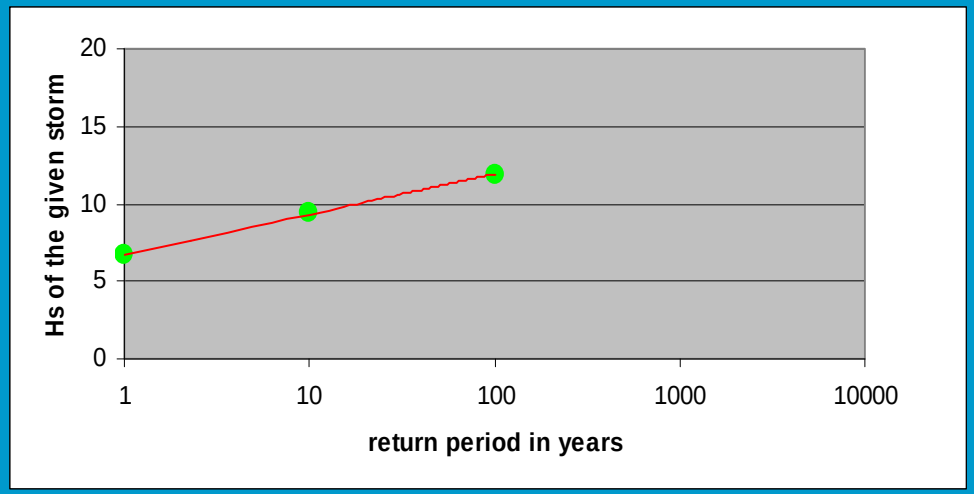
From probability of waves to probability of storms

Suppose a “storm” lasts for 12 hrs.
===> 730 storms/year
once per year storm = 100/730 = 0.13 % => 6.7 m
once per 10 year storm = 0.013 % => 9.4 m
once per 100 year storm = 0.0013 % => 11.9 m



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Meteorological data

- Not of direct importance for design
- Can be important for hindcast of wave data and storm surge
- Extremely important for the execution of the works (workability)

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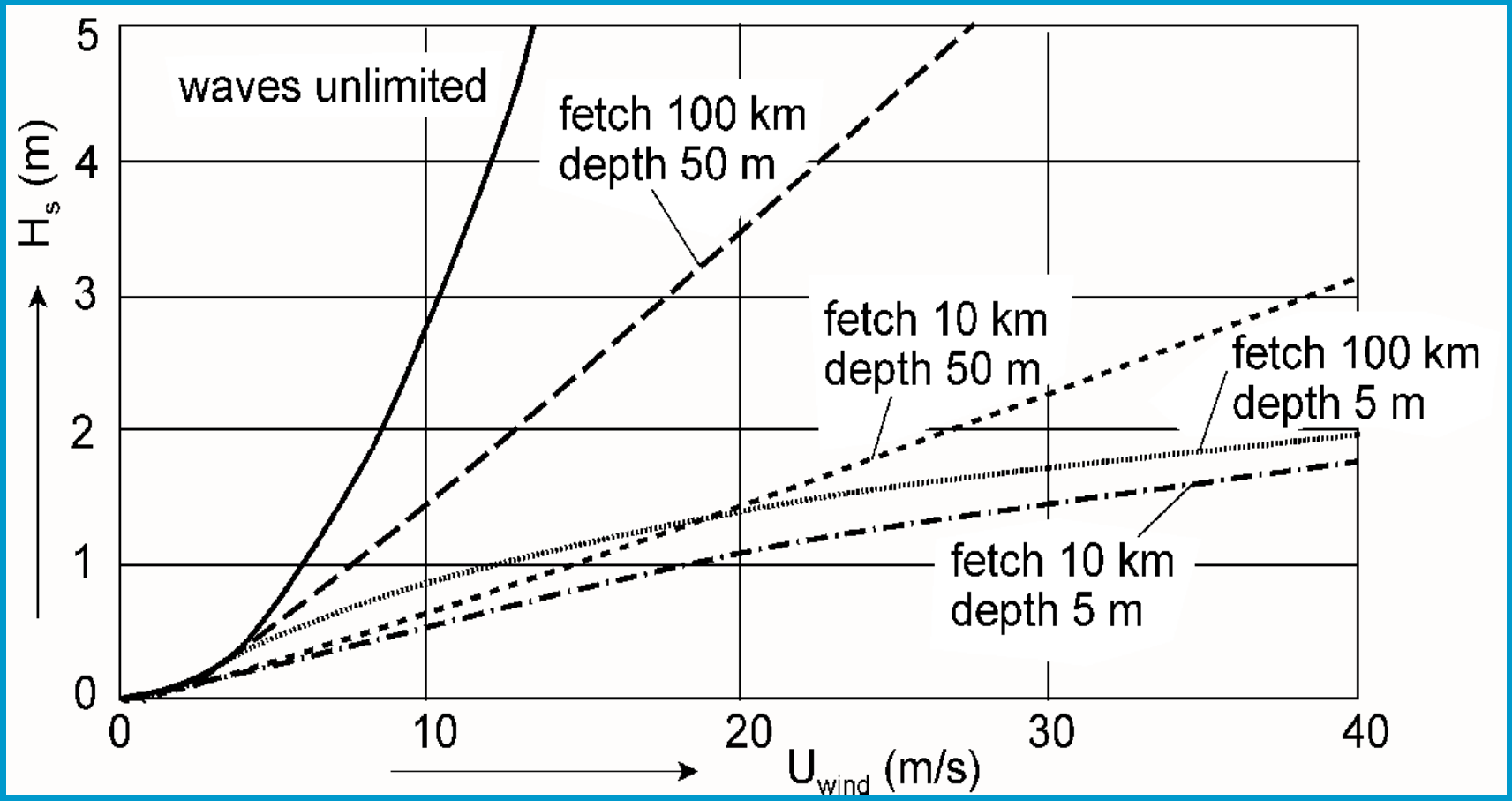
Waves from Wind (Brettschneider)



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required soil data

Geotechnical limit states

Macro instability			Macro-failure	Micro-instability	Geotechnical information	
Slip failure	Lique-faction	Dynamic failure	Settle-ments	Filter-erosion	Name	Symbol
A	A	A	A	A	Soil profile	-
A	A	A	A	A	Classification/grain size	D
A	A	A	B	A	Piezometric pressure	p
B	B	B	A	A	Permeability	k
A	B	B	A	B	Dry/wet density	$\rho_d, \rho_{sat}, \rho_{sub}, \gamma = \rho g$
-	A	B	-	-	Relative density, porosity	n, n_{cr}
A	B	B	-	C	Drained shear strength	c', ϕ
A	-	-	-	C	Undrained shear strength	s_u
B	-	-	A	-	Compressibility	C_c, C_s
A	-	-	A	-	Consolidation coefficient	c_v
B	B	A	A	-	Moduli of elasticity	G, E
B	A	A	A	-	*In situ* stress	σ
-	A	B	A	-	Stress history	OCR
B	A	A	B	-	Stress/strain curve	G, E

A: Very important B: Important C: Less important

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in situ test methods

Site investigations methods

	Geophysical methods (Section C.1)				Penetration methods (Section C.1.2)					Borings (Section C.1.3)			
	Seismic	Electr. resist.	Electro-magnetic	nuclear	Cone penetr. test (CPT)	Piezo cone test (CPTU)	Stand. penetr. test (SPT)	Field vane test (VST)	Press. meter test (PMT)	Dilato meter test (DMT)	Dist. samples	Undist. samples + Lab. tests	Moni-ring wells
Soil profile	C	C	C	-	A	A	A	B	B	A	A	A	-
Classification	-	-	-	-	B	B	B	B	B	B	A	A	-
Piezometric pressure	-	-	-	-	-	A	-	-	B	-	-	-	A
Permeability	-	-	-	-	-	B	-	-	B	-	C	A	C
Dry/wet density	-	-	-	A	C	C	C	-	-	-	C	A	-
Relative/density	-	-	-	-	B	B	B	-	C	C	-	A	-
Friction angle	-	-	-	-	B	B	B	C	C	C	-	A	-
Undr. shear strength	-	-	-	-	B	B	C	A	B	B	-	A	-
Compressibility	-	-	-	-	C	C	-	-	C	C	-	A	-
Rate of consolidation	-	-	-	-	-	A	-	-	A	-	-	A	C
Moduli of elasticity	A	-	-	-	B	B	B	B	B	B	-	A	-
In-situ stress	-	-	-	-	C	C	-	C	B	B	-	A	-
Stress history OCR	-	-	-	-	C	C	C	B	B	B	-	A	-
Stress/strain curve	-	-	-	-	-	C	-	B	B	C	-	A	-
Ground conditions													
Hard rock	A	-	A	A	-	-	-	-	A	-	A	A	C
Soft rock-till, etc.	A	-	A	A	C	C	C	-	A	C	A	A	A
Gravel	A	B	A	A	C	C	B	-	B	-	A	C	A
Sand	A	A	A	A	A	A	A	-	B	A	A	C	A
Silt	A	A	A	A	A	A	B	B	B	A	A	A	A
Clay	A	A	A	A	A	A	C	A	A	A	A	A	A
Peat-organics	C	A	A	A	A	A	C	B	B	A	A	A	A

A: High applicability B: moderate applicability C: Limited applicability

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During construction

- Quarry stone
- Concrete
- Local Equipment ????
- Labour
  - skilled
  - cost
  - availability
  - expatriates

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