Practical implementation of criteria in the oil and gas industry – Unmanning criteria for extreme storm events

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Chapter 14

ESTABLISHING UNMANNING CRITERIA FOR A JACKET STRUCTURE ON THE NCS

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Introduction

- In general, new bottom fixed installation are designed with positive airgap.
- Depletion of the oil reservoir may lead to subsidence of the seabed and thereby reduced air gap.
- New knowledge about the metocean conditions and new methodologies for predicting extreme crest heights can also indicate larger risk for wave in deck.
- If an existing structure does not meet the requirements, actions must be implemented to ensure target safety regarding crew safety, large economic losses, and pollutions of the environment.
- A possible approach is to shut down and unman the facility in case of forecasted extreme weather. A challenge is to establish a robust procedure for such a scenario.

Safety level

- A permanently manned installation shall withstand the abnormal metocean actions (ALS) with an annual probability of exceedance of $1x10^{-4}$.
- The shut-down and unmanning procedure shall be implemented to ensure that the structural reliability of the facility with personal on-board are not less than for permanently manned platforms.
- According to NORSOK N-006, it can be assumed that the same safety level is achieved by unmanning for a characteristic metocean action of $5x10^{-4}$ exceedance probability per year.
- Additionally, NORSOK recommends establishing a criterion related to the probability of exceeding the structural capacity in the forecasted extreme storm

Storm constraint

- NORSOK N-006 does not explicitly define the criterion.
- Commonly used criterion on the NCS:
  - Probability of exceeding the response during the maximum forecasted 3-hour sea state should not exceed 5%.
  - This corresponds to 10% probability of exceedance in a 6-hour rectangular storm.
- Alternative
  - E.g., requiring that the probability of exceeding the response for the forecasted storm should be less than $5x10^{-4}$, i.e a fractile of 0.9995 or for the $1x10^{-4}$, a fractile of 0.9999.

$$F_{C_{3h}}(c) = \frac{1}{\kappa} \int_{h_s=0}^{h_s=h_{s,thr}} \int_{t_p=0}^{\infty} F_{C_{3h|HsTp}}(c|h_s,t_p) f_{Hs,Tp}(h_s,t_p)\, dt_p\, dh_s$$

$$for\ q = 5x10^{-4}\ \ c_{lim} = 20.1\ \text{m}$$

$$for\ q = 1x10^{-4}\ \ c_{lim} = 21.5\ \text{m}$$

Storm constraint

$$c_{P95} = \alpha_C H_S \left[-ln\left(1 - 0.95^{\frac{1}{n_{3h}}}\right)\right]^{\frac{1}{\beta_C}} = 20.0\ \text{m}$$

$h_{s,thr}$ = 16 m

Unmanned installation

Hs/Tp	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22
21-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-21	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	1	1	1	0	0
19-20	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	1	3	3	2	1	0
18-19	0	0	0	0	0	0	0	0	2	6	9	8	4	1	0
17-18	0	0	0	0	0	0	0	2	11	25	29	18	7	2	0
16-17	0	0	0	0	0	0	2	15	55	89	73	34	9	2	0
15-16	0	0	0	0	0	1	16	95	232	260	151	50	10	1	0
14-15	0	0	0	0	0	11	123	484	789	611	252	61	9	1	0
13-14	0	0	0	0	5	113	783	1975	2142	1141	333	58	7	1	0
12-13	0	0	0	1	72	952	3958	6335	4573	1688	354	46	4	0	0
11-12	0	0	0	31	855	6205	15375	15704	7649	2000	310	31	2	0	0
10-11	0	0	10	582	7616	30115	44979	30004	10213	1979	239	19	1	0	0
9-10	0	3	326	7624	48011	105856	98841	45303	11492	1782	183	13	1	0	0
8-9	1	175	6822	65206	206723	268715	168141	57587	11999	1660	164	12	1	0	0
7-8	108	6213	81874	349177	607216	510538	237355	68066	13174	1853	202	18	1	0	0
6-7	6520	104535	544560	1180968	1273322	782860	306370	83456	17021	2758	373	44	5	0	0
5-6	145886	837568	2080873	2688624	2074119	1064497	396161	114537	27187	5539	1004	166	26	4	1
4-5	1325115	3482183	5013577	4544926	2881988	1386477	539060	177967	51868	13760	3404	800	182	40	9
3-4	5680791	8548794	8536236	6266839	3649375	1784474	765019	297196	107316	36736	12105	3886	1226	383	119
2-3	13469315	14006654	11206177	7406854	4256234	2206940	1061405	483335	211671	90217	37764	15634	6436	2646	1089
1-2	19303468	15938067	11267763	7140566	4187492	2324506	1241574	645804	330062	166867	83873	42074	21126	10642	5386
0-1	7626391	5573428	3701426	2304779	1373858	795238	451472	253183	140977	78237	43394	24105	13431	7515	4226

$$F_{C_{3h}}(c) = \frac{1}{\kappa} \int_{h_s=0}^{h_s=h_{s,thr}} \int_{t_p=0}^{\infty} F_{C_{3h|HsTp}}(c|h_s, t_p) f_{Hs,Tp}(h_s, t_p) dt_p dh_s$$

$h_{s,thr}$ = 17 m

Unmanned installation

Hs/Tp	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22
21-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-21	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	1	1	1	0	0
19-20	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	1	3	3	2	1	0
18-19	0	0	0	0	0	0	0	0	2	6	9	8	4	1	0
17-18	0	0	0	0	0	0	0	2	11	25	29	18	7	2	0
16-17	0	0	0	0	0	0	2	15	55	89	73	34	9	2	0
15-16	0	0	0	0	0	1	16	95	232	260	151	50	10	1	0
14-15	0	0	0	0	0	11	123	484	789	611	252	61	9	1	0
13-14	0	0	0	0	5	113	783	1975	2142	1141	333	58	7	1	0
12-13	0	0	0	1	72	952	3958	6335	4573	1688	354	46	4	0	0
11-12	0	0	0	31	855	6205	15375	15704	7649	2000	310	31	2	0	0
10-11	0	0	10	582	7616	30115	44979	30004	10213	1979	239	19	1	0	0
9-10	0	3	326	7624	48011	105856	98841	45303	11492	1782	183	13	1	0	0
8-9	1	175	6822	65206	206723	268715	168141	57587	11999	1660	164	12	1	0	0
7-8	108	6213	81874	349177	607216	510538	237355	68066	13174	1853	202	18	1	0	0
6-7	6520	104535	544560	1180968	1273322	782860	306370	83456	17021	2758	373	44	5	0	0
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4-5	1325115	3482183	5013577	4544926	2881988	1386477	539060	177967	51868	13760	3404	800	182	40	9
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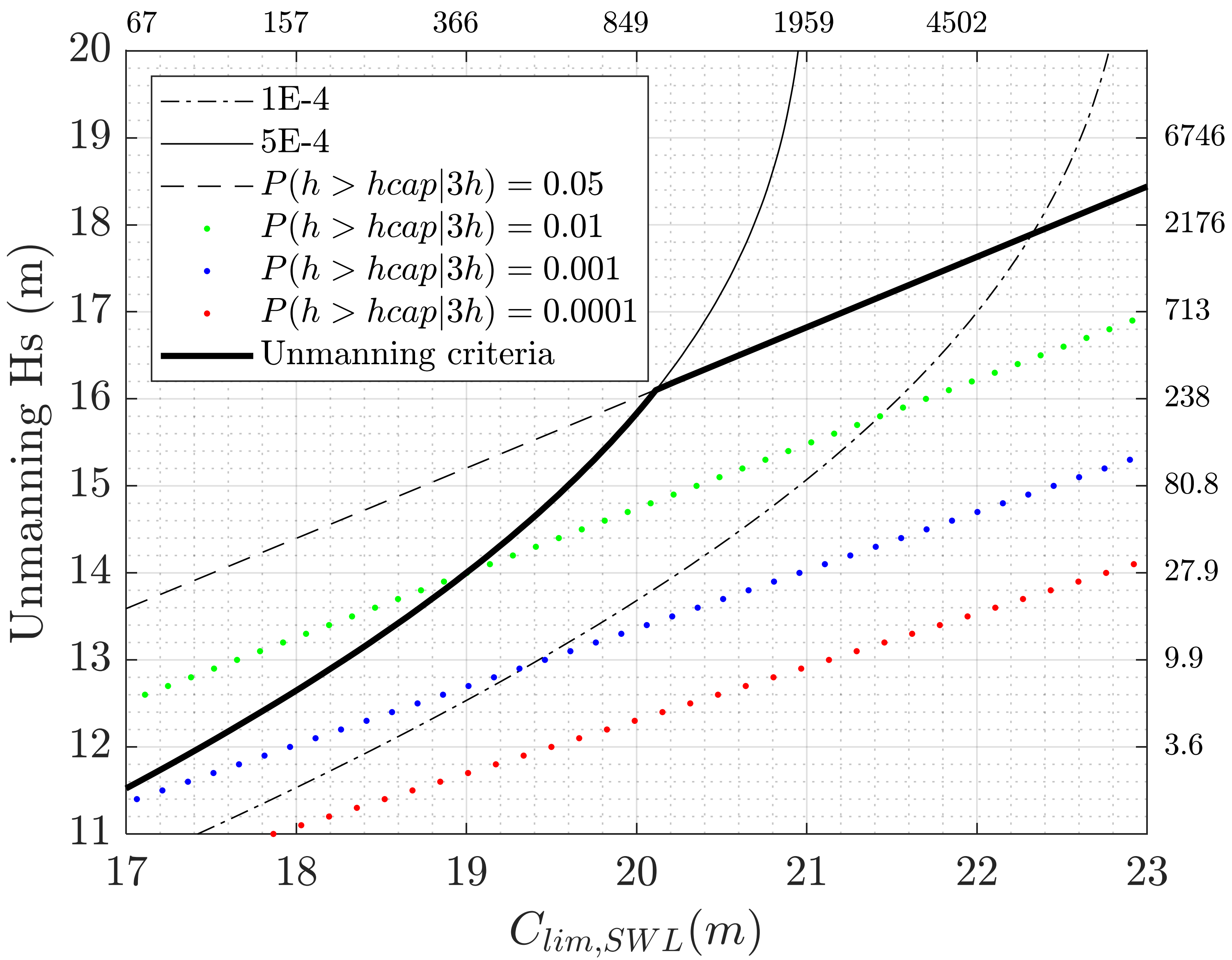
$for\ q = 5x10^{-4}\ \ c_{lim} = 20.4$ m

$for\ q = 1x10^{-4}\ \ c_{lim} = 22.0$ m

Storm constraint

$$c_{P95} = \alpha_C H_S \left[-ln\left(1 - 0.95^{\frac{1}{n_{3h}}}\right)\right]^{\frac{1}{\beta_C}} = 21.2 \text{ m}$$



67
157
366
849
1959
4502
6746
2176
713
238
80.8
27.9
9.9
3.6
20
19
18
17
16
15
14
13
12
11
Unmanning Hs (m)
17
18
19
20
21
22
23
$C_{lim,SWL}(m)$
1E-4
5E-4
$P(h > hcap|3h) = 0.05$
$P(h > hcap|3h) = 0.01$
$P(h > hcap|3h) = 0.001$
$P(h > hcap|3h) = 0.0001$
Unmanning criteria

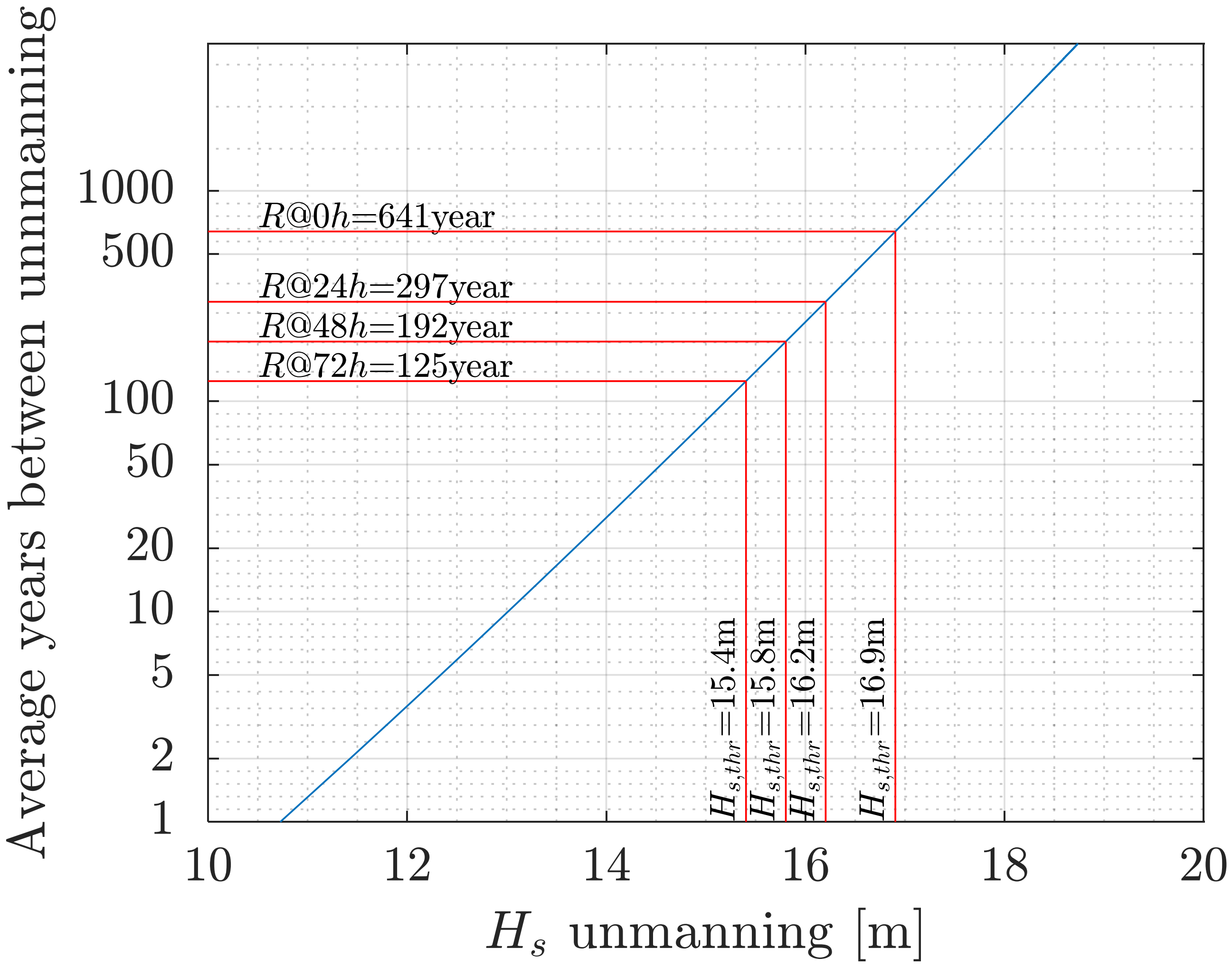
$h_{s,thr}$	c_{lim} $q = 5x10^{-4}$	c_{lim} $q = 1x10^{-4}$	c_{lim} P95	Return Period $h_{s.thr}$	Fractile c_{lim} for $q = 5x10^{-4}$	Fractile c_{lim} for $q = 1x10^{-4}$
12	**17.4**	18.5	15.0	3.6	0.9979	0.9995
13	**18.3**	19.4	16.3	9.9	0.9954	0.9990
14	**19.0**	20.2	17.5	27.9	0.9900	0.9976
14.5	**19.3**	20.6	18.1	47.4	0.9852	0.9965
15	**19.6**	21.0	18.7	80.8	0.9782	0.9947
15.5	**19.8**	21.3	19.4	138.3	0.9682	0.9921
16	**20.1**	21.5	20.0	237.9	0.9538	0.9883
16.5	20.3	21.8	**20.6**	411.0	0.9335	0.9826
17	20.4	22.0	**21.2**	713.2	0.9052	0.9744
17.5	20.6	22.2	**21.8**	1243.1	0.8666	0.9626
18	20.7	22.4	**22.5**	2175.7	0.8155	0.9459
18.5	20.8	22.5	**23.1***	3823.5	0.7501	0.9226

* limited to the $q=10^{-4}$ crest height of 23 m.

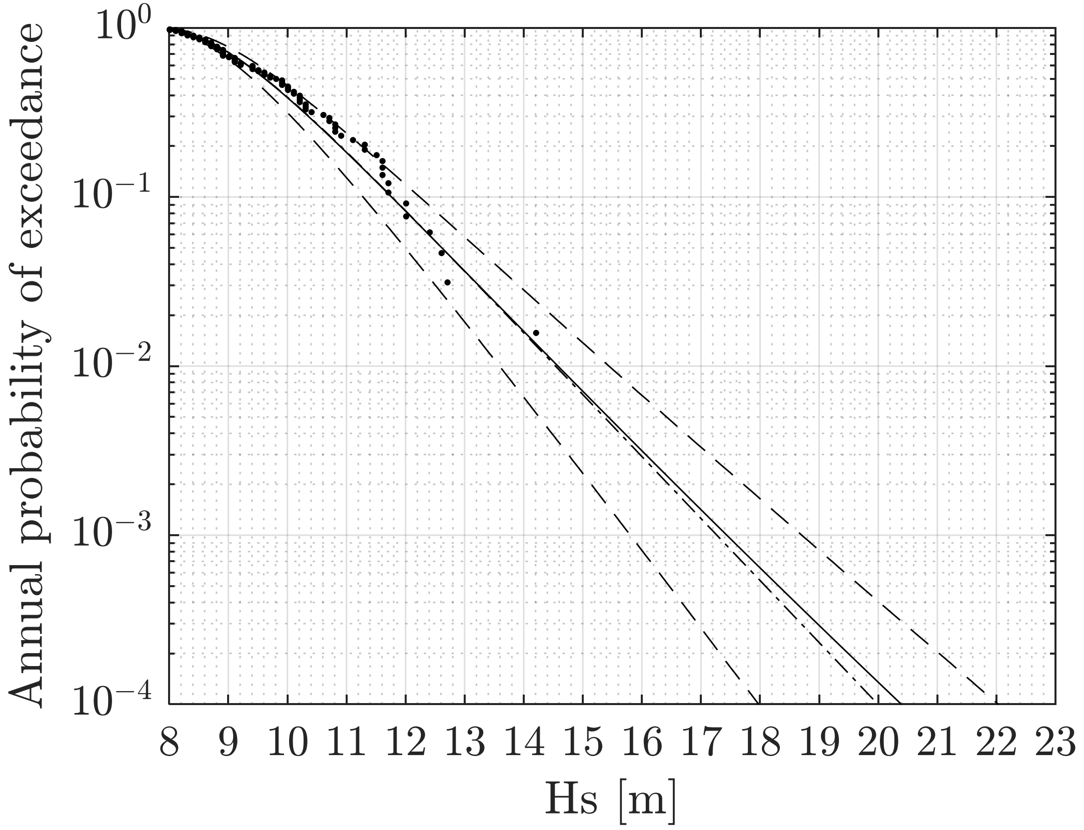
Unmanning procedure for $C_{lim,SWL}$ of 21.1m

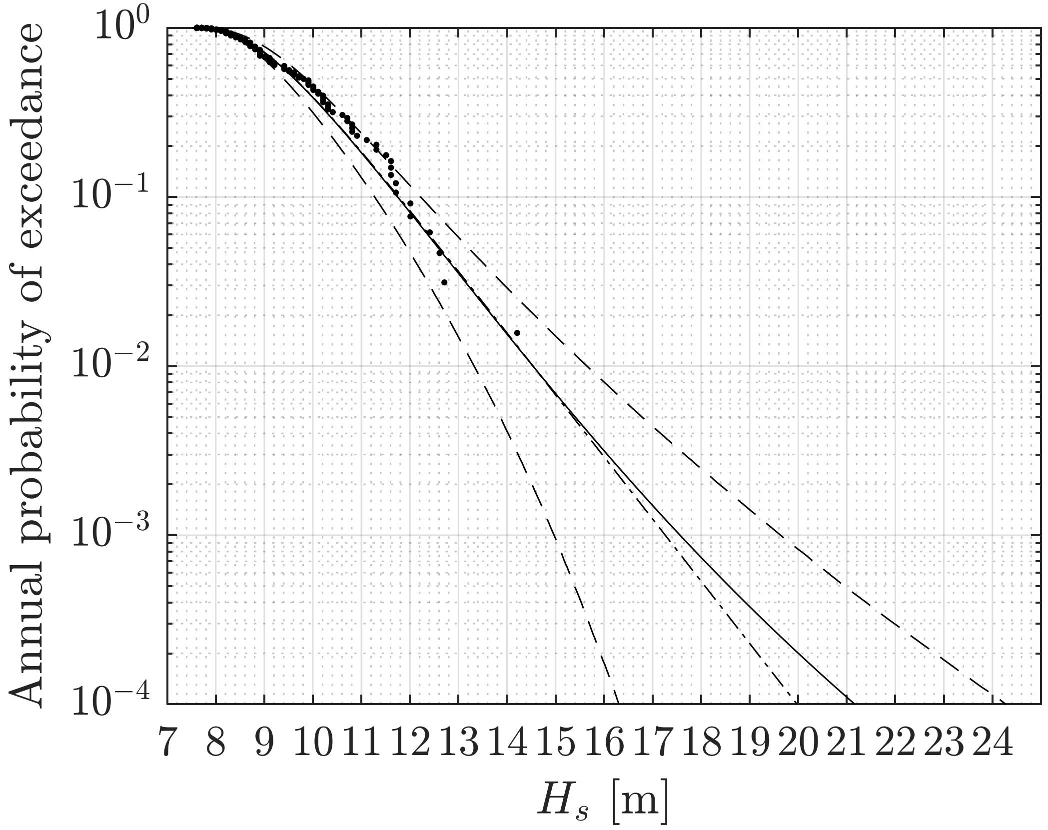
Forecast uncertainty recommended in NORSOK N-006:

72 h forecast 1.5 m reduction of $h_{s,thr}$
48 h forecast 1.1 m reduction of $h_{s,thr}$
24 h forecast 0.7 m reduction of $h_{s,thr}$



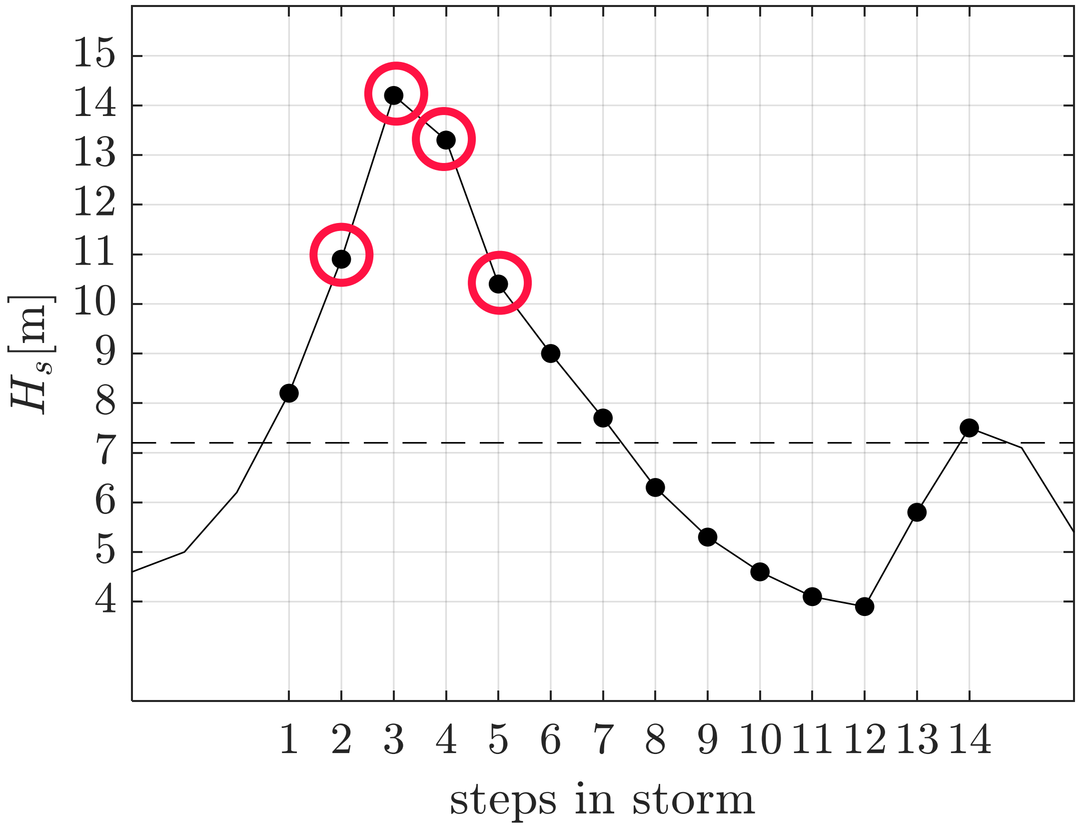
Peak over threshold (POT) to estimate q-annual significant wave height (H_s)



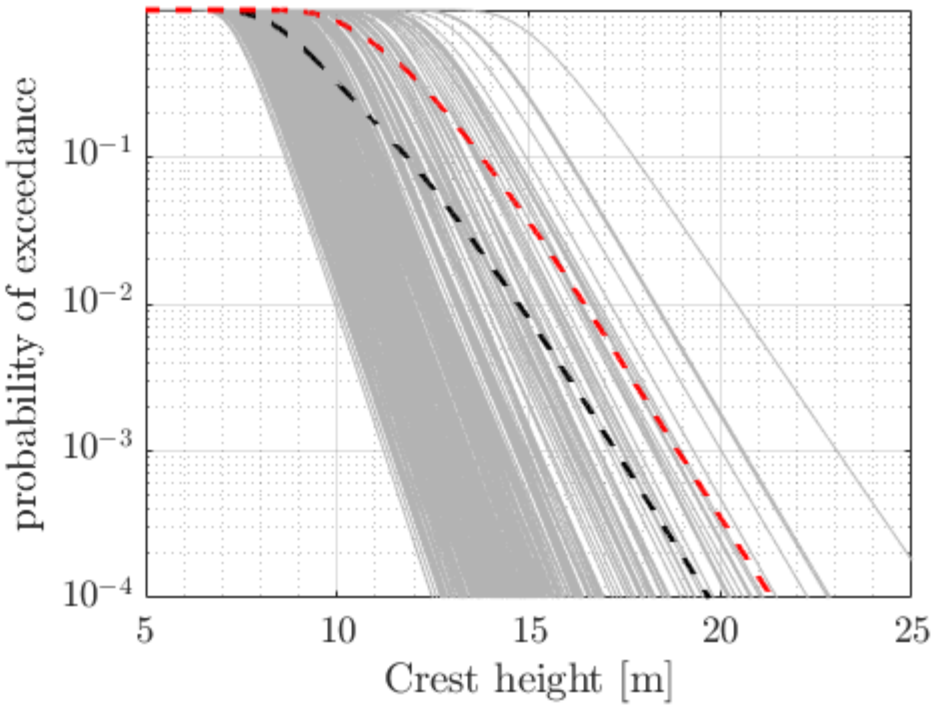


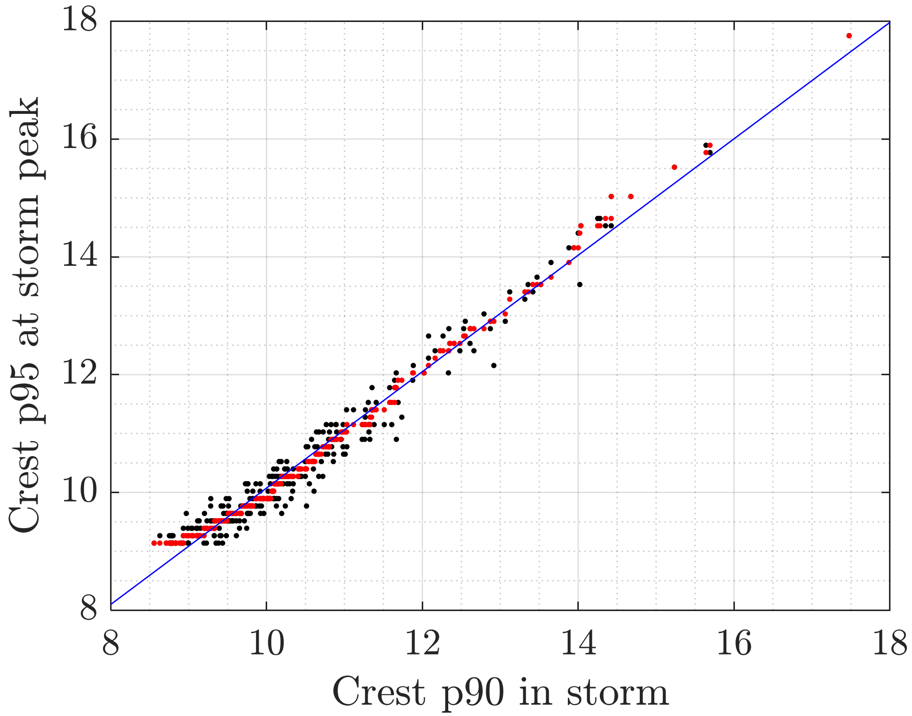
equinor

Random storm approach



$$F_{Y|k}(y|\mathrm{k})$$
$$= P\left[\left(Y_{1_k} \leq y\right) \cap \left(Y_{2_k} \leq y\right) \cap \cdots \left(Y_{m_k} \leq y\right)|k\right]$$
$$= \prod_{m=1}^{m_k} F_{Y_{3h}m|k}(y|m,\mathrm{k})$$





$$F_Y(y) = \frac{1}{k_0}\sum_k F_{Y|k}(y|k) \qquad F_{Y_{1y}}(y) = F_Y^{\lambda}(y)$$

$$c_p = (-\ln(-\ln p)\psi + 1)c_{MPM}$$