How to account for simultaneous occurrence of wind sea and swell when assessing extreme response of floating platform

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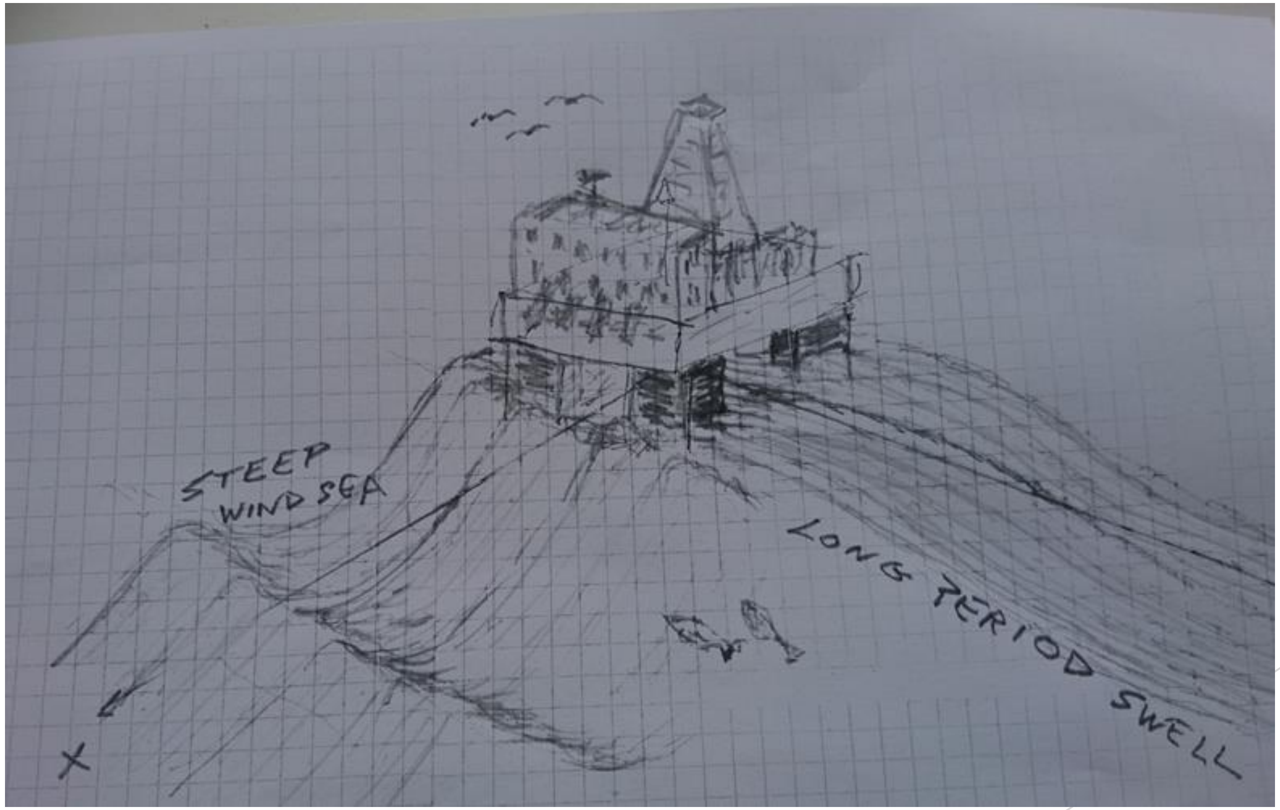
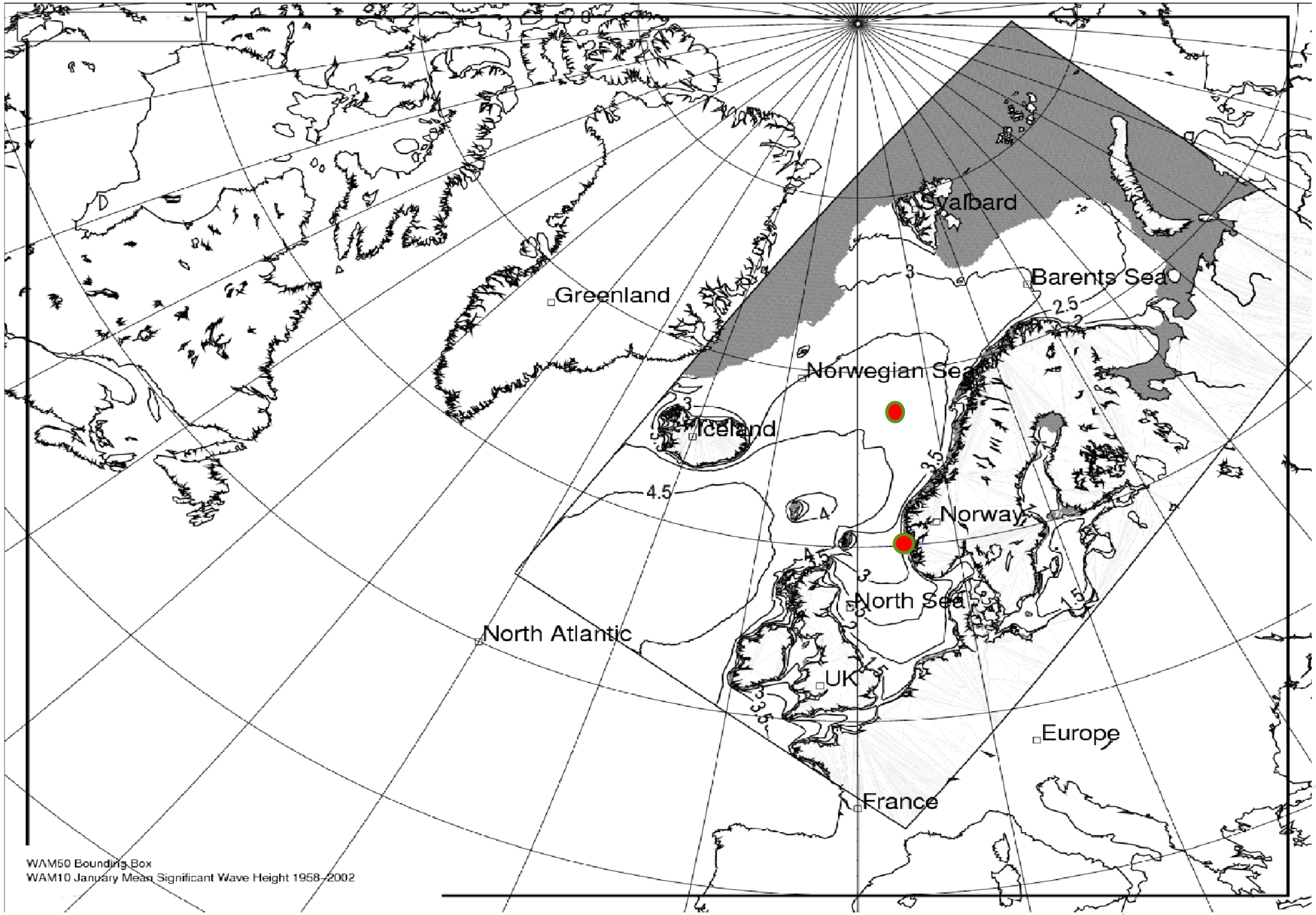


Area covered by NORA10 hindcast



NORA10 DATA

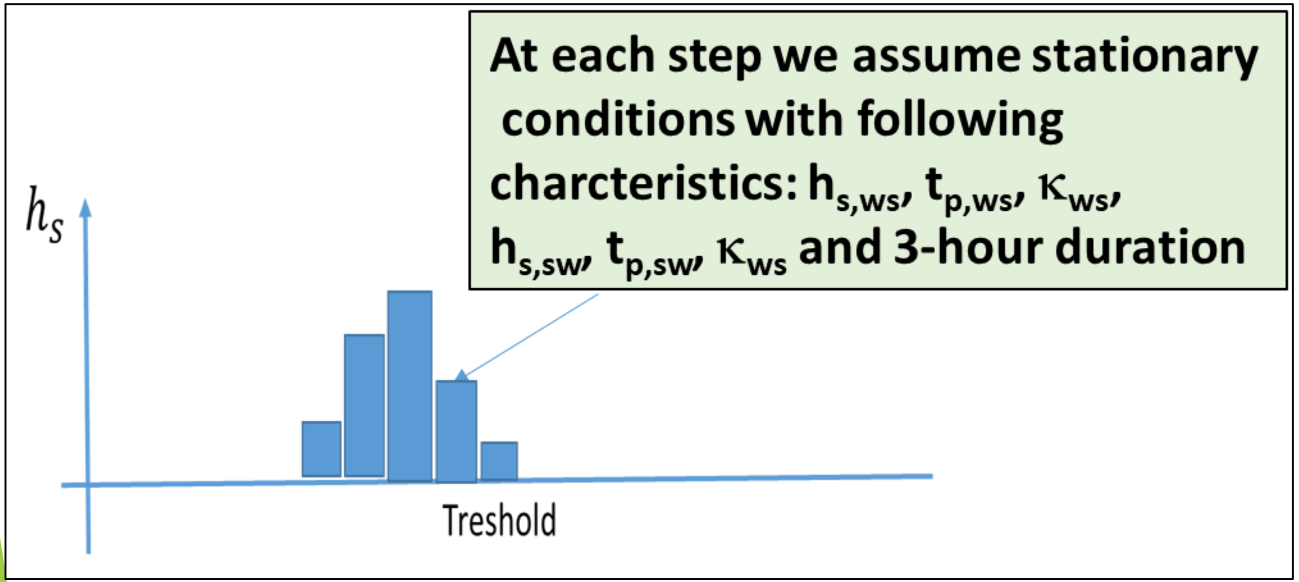
WAM WIND AND WAVES

				WIND		TOTAL SEA					WIND SEA			SWELL		
YEAR	M	D	H	WSP	DIR	HS	TP	TM	DIRP	DIRM	HS	TP	DIRP	HS	TP	DIRP
1957	9	1	6	1.7	348.	0.9	5.2	4.5	305.	317.	0.1	0.0	237.	0.9	5.2	305.
1957	9	1	9	1.5	340.	0.8	5.2	4.7	305.	316.	0.1	0.0	237.	0.8	5.2	305.
1957	9	1	12	2.8	330.	0.8	5.2	4.8	305.	315.	0.1	0.0	237.	0.8	5.2	305.
1957	9	1	15	2.2	24.	0.8	5.2	4.8	290.	313.	0.1	0.0	237.	0.8	5.2	290.
1957	9	1	18	2.5	88.	0.7	5.2	4.9	290.	312.	0.1	0.0	237.	0.7	5.2	290.
1957	9	1	21	4.2	122.	0.7	5.2	4.9	290.	310.	0.1	2.4	110.	0.7	5.2	290.
1957	9	2	0	3.2	96.	0.7	5.2	4.8	290.	309.	0.1	0.0	237.	0.7	5.2	290.
1957	9	2	3	5.0	90.	0.6	5.2	4.8	290.	306.	0.1	2.4	50.	0.6	5.2	290.
1957	9	2	6	5.2	105.	0.6	5.2	4.8	290.	304.	0.1	2.4	110.	0.6	5.2	290.
1957	9	2	9	6.1	94.	0.7	5.2	3.7	275.	295.	0.3	2.7	140.	0.6	5.2	275.
1957	9	2	12	6.8	81.	0.7	5.2	3.8	275.	272.	0.4	3.2	110.	0.6	5.2	275.
1957	9	2	15	7.3	92.	0.8	3.9	3.7	110.	103.	0.6	3.6	110.	0.5	5.2	275.
1957	9	2	18	7.2	81.	0.8	3.9	3.7	95.	98.	0.6	3.9	95.	0.5	4.7	140.
1957	9	2	21	6.7	89.	0.8	4.3	3.7	95.	96.	0.6	3.9	95.	0.5	5.2	125.
1957	9	3	0	5.3	82.	0.7	4.3	3.8	95.	93.	0.4	3.9	80.	0.6	4.7	110.

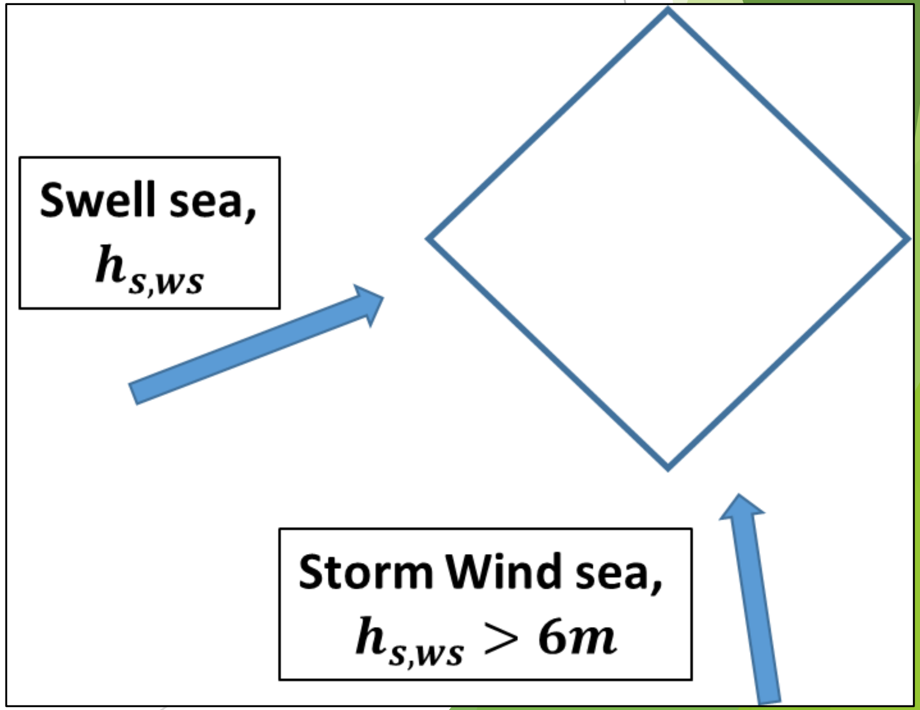
Approach 1: Wind sea storms above threshhold

Based on work by Bratland, Patino & Haver, Haver and Patiño (2019), OMAE2019, Glasgow

Simplified Storm Profile



Sea conditions for a 3-hour event of a storm

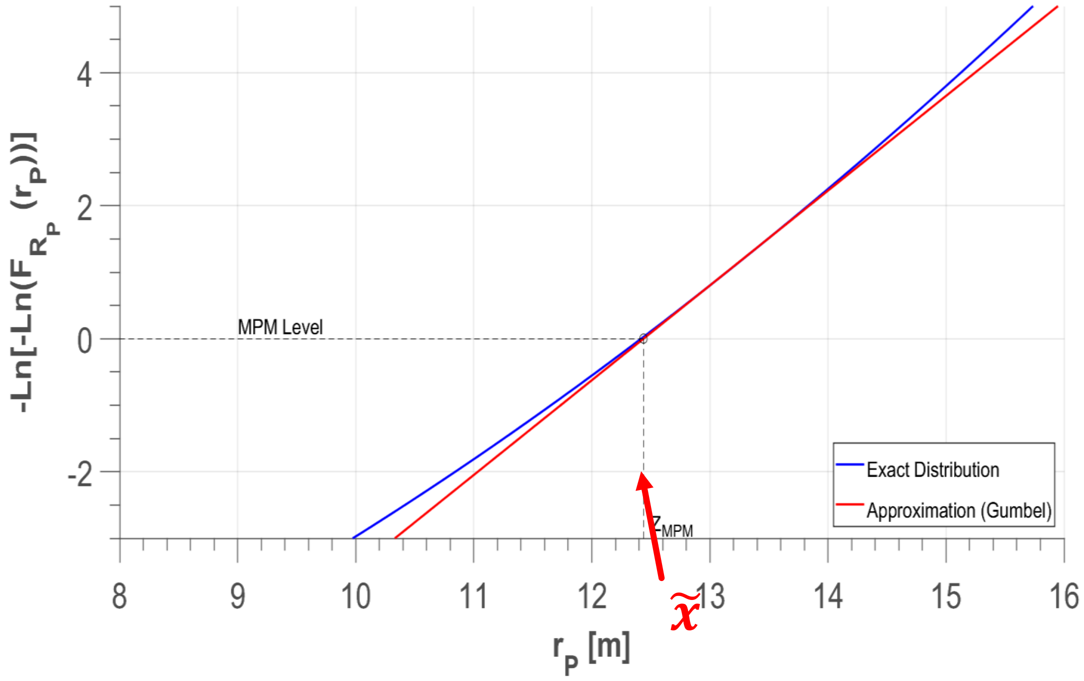


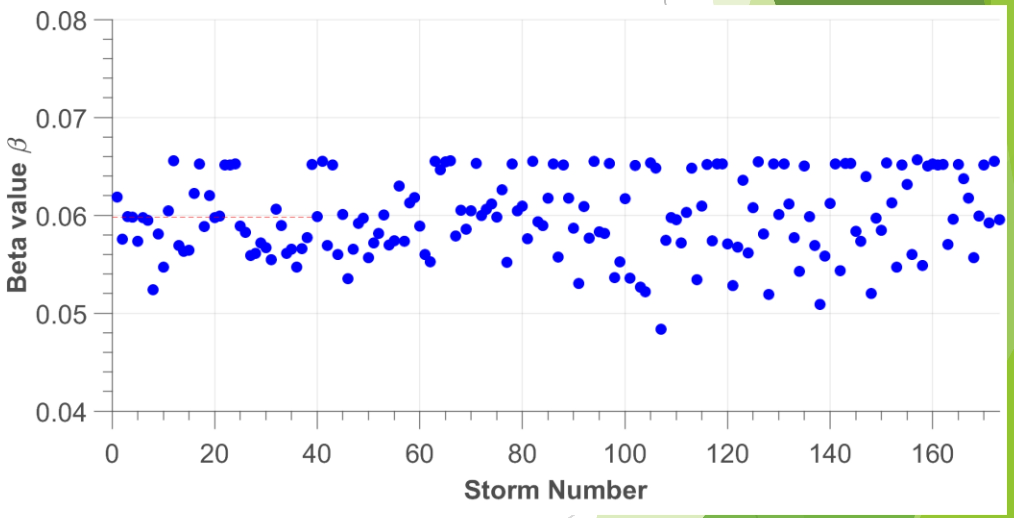
Gumbel approximation for storm maximum response

Conditional distribution: $$F_{C_{R,s}|\tilde{C}}(c|\tilde{c}) \approx exp\left\{- exp\left\{- \frac{c-\tilde{c}}{\beta\tilde{c}}\right\}\right\}$$

Long term distribution of $\tilde{C}$: $F_{\tilde{C}}(\tilde{c})$

Long term integral: $F_{C_{R,s}}(c) = \int_{\tilde{c}} F_{C_{R,s}|\tilde{C}}(c|\tilde{c})\ f_{\tilde{C}}(\tilde{c})\ \tilde{c}$





$\beta = \overline{\beta} = 0.059$ is used in the following

Results for q-probability relative crest height

Southern corner

TABLE 1 q-probability relative crest height, southern corner (431).

Case	Extreme relative crest height (m)		Extreme mpm relative crest height (m)	
Annual prob.	10^{-2}	10^{-4}	10^{-2}	10^{-4}
Wind sea + swell				
135° – 225°	18.5	22.8	16.5	18.5
All dir.	18.5	22.3	17.6	20.4
Wind sea only				
135° – 225°	18.5	22.8	16.6	18.6
All dir.	18.5	22.2	17.6	20.3

➔ Swell does not seem to effect long term air gap extremes significantly

Approach 2:
Joint probability distribution of wind sea and swell

a)Troll field, Southern sector: Brattland & Haver,

b) Norwegian Sea, Western sector: Li & Haver

Sea state characteristics:

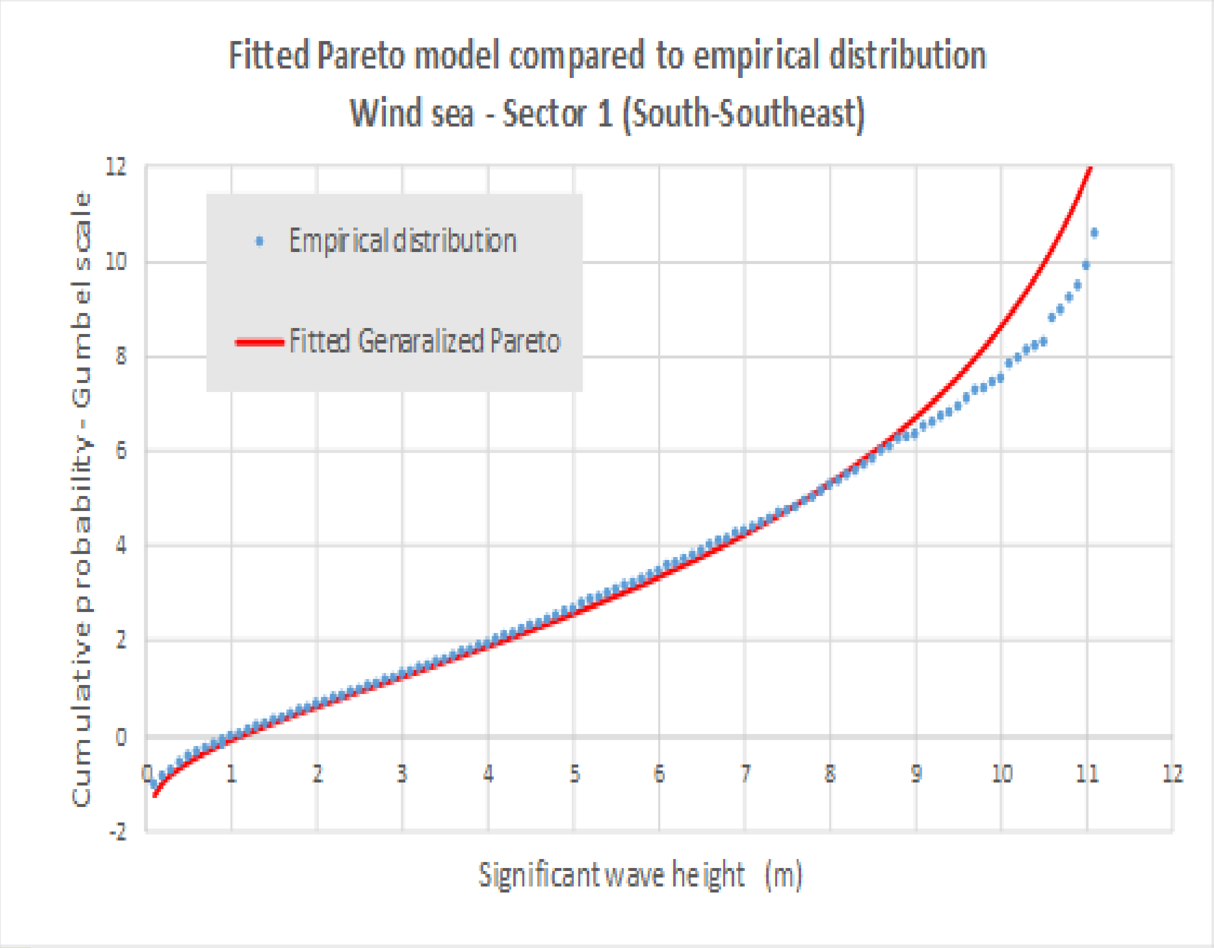
$$H_{s,ws}, T_{p,ws}, H_{s,sw}, T_{p,sw} \text{ and } \Delta = K_{sw} - K_{ws}$$

Conditional probability density function for sea state characteristcs given wind sea direction, K_{ws}:

$$f_{H_{sws}T_{pws}H_{ssw}T_{psw}\Delta|K_{ws}}(h_{ws}, t_{pws}, h_{ssw}, t_{psw}, \delta|\kappa_{ws})$$
$$= f_{H_{sws}T_{Pws}|K_{ws}}(h_{ws}, t_{pws}|\kappa_{ws}) f_{H_{ssw}T_{psw}\Delta|K_{WS}T_{pws}}(h_{ssw}, t_{psw}, \delta|\kappa_{ws}. t_{pws})$$

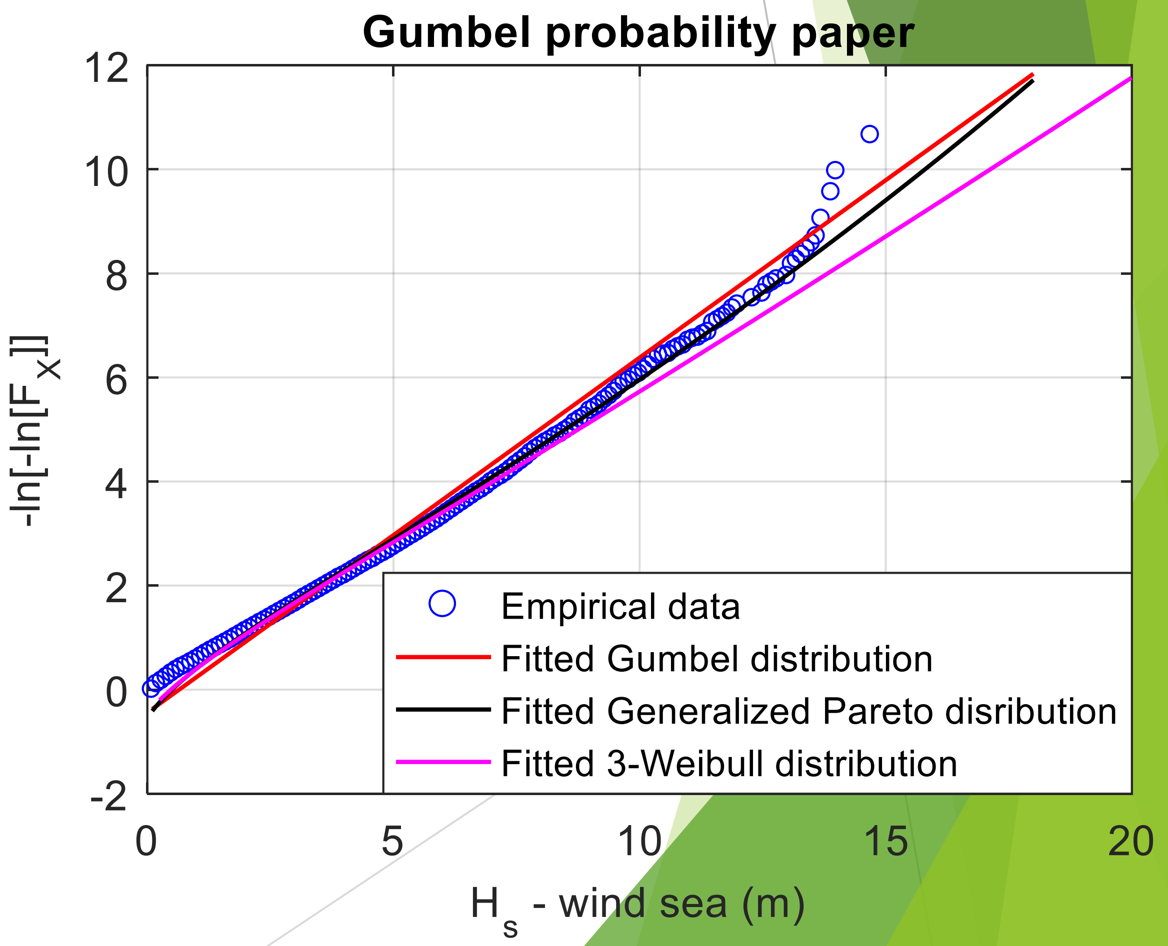
Marginal distribution for $H_{s,ws}$ and $H_{s,sw}$

Troll



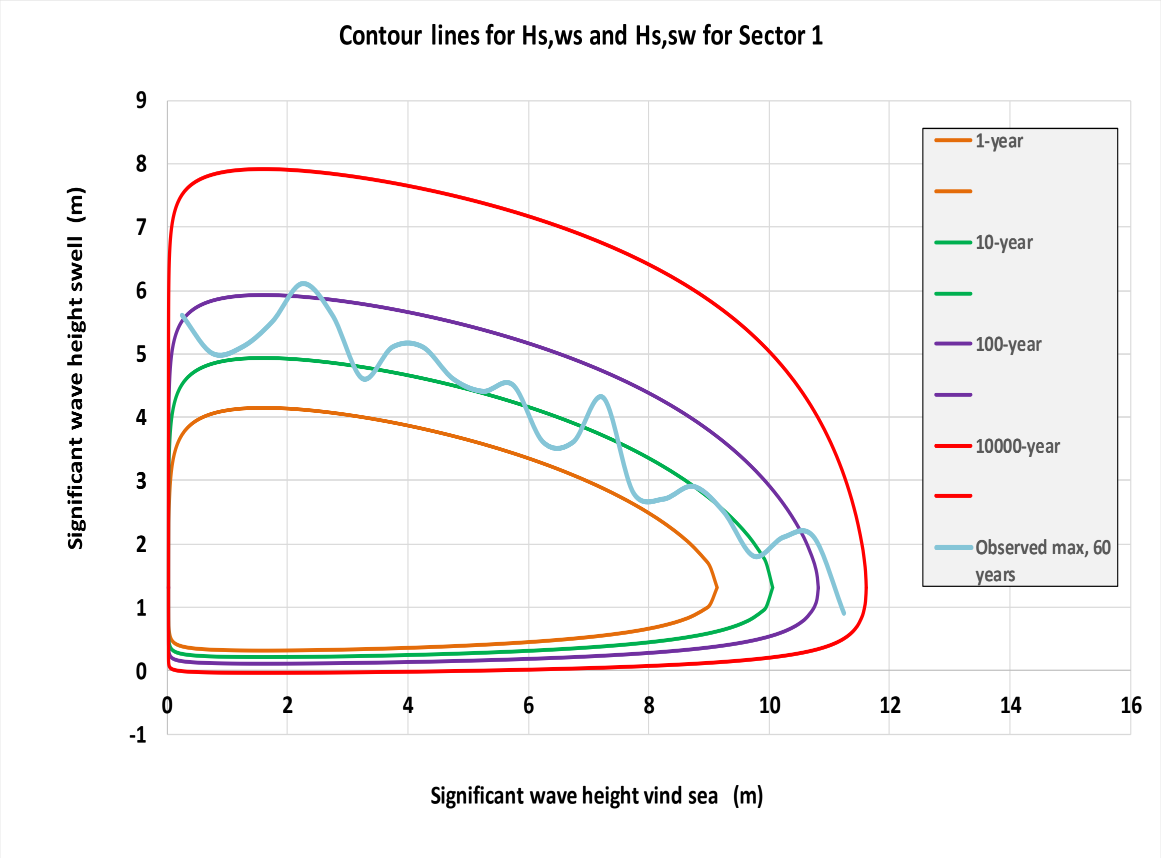
Norwegian Sea

West-Southwest Sector

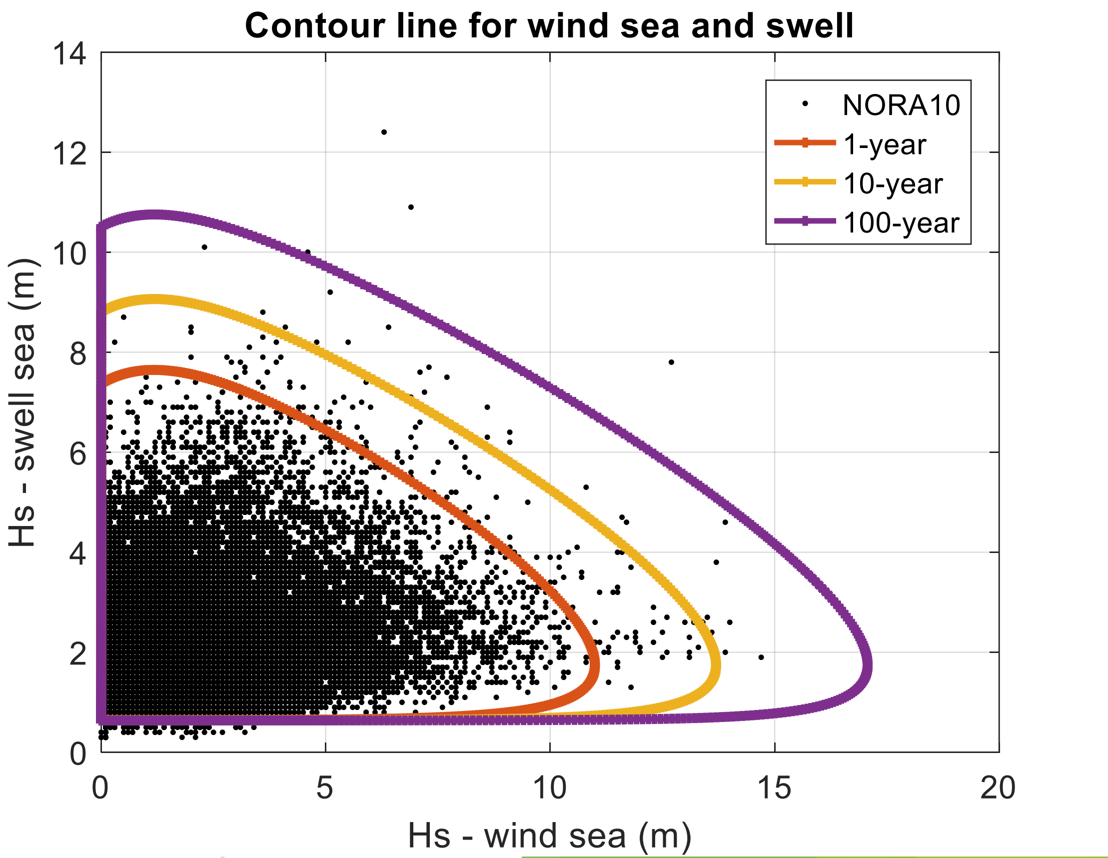


Joint modelling $H_{s,ws}$ & $H_{s,sw}$

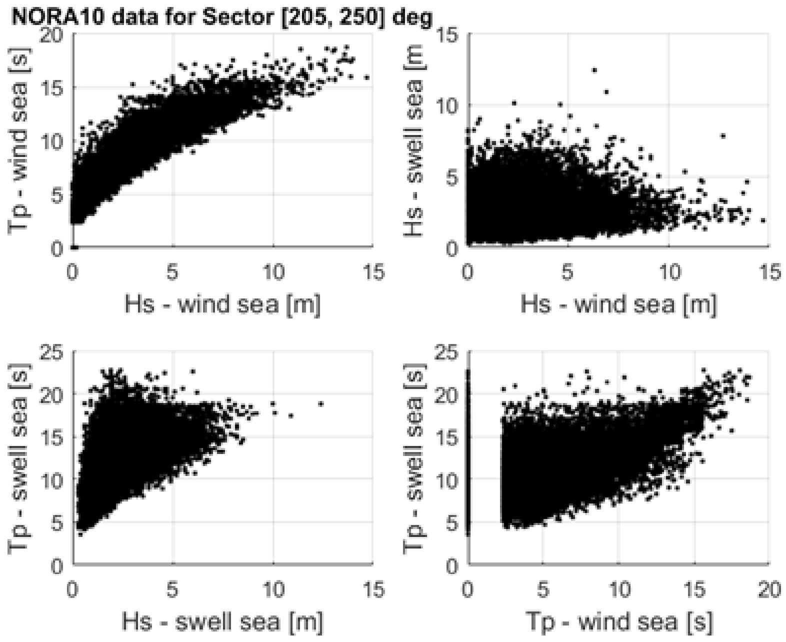
Troll



Norwegian Sea

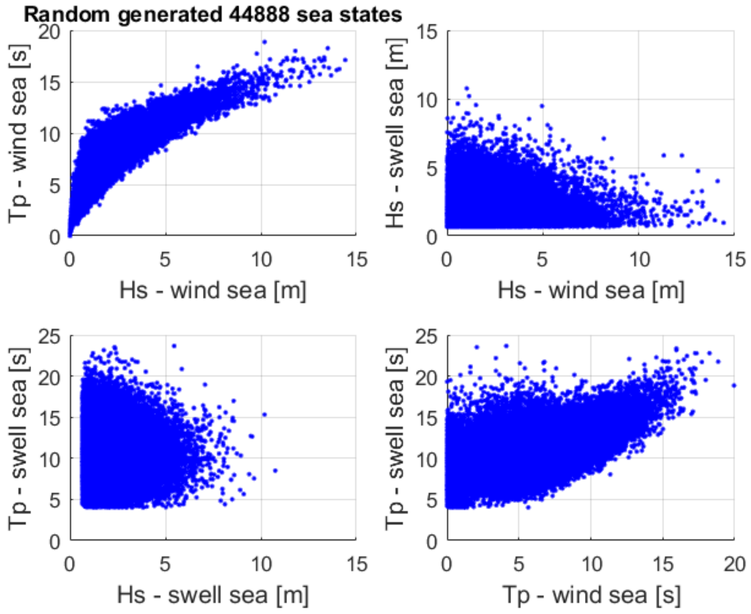


Afequacy of MC simulated joint characterostics of wind sea and swell

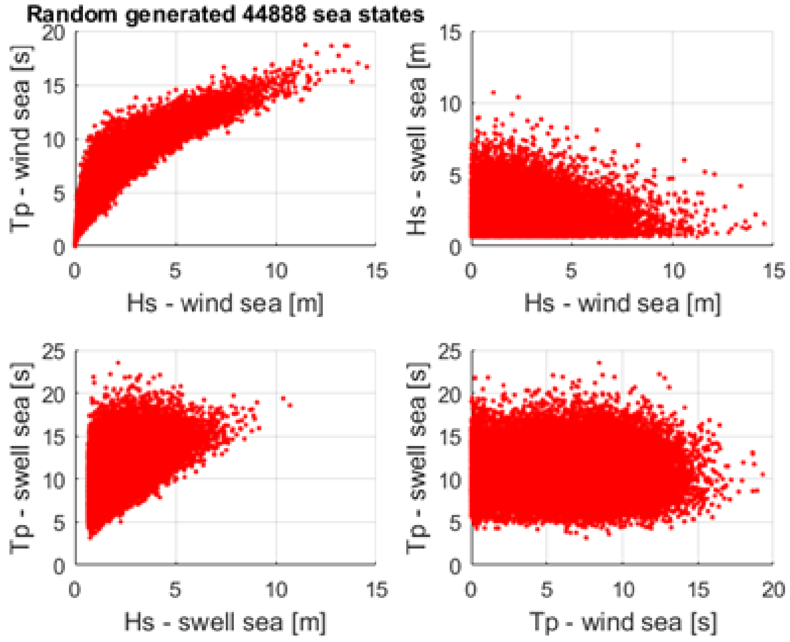


NORA10 data

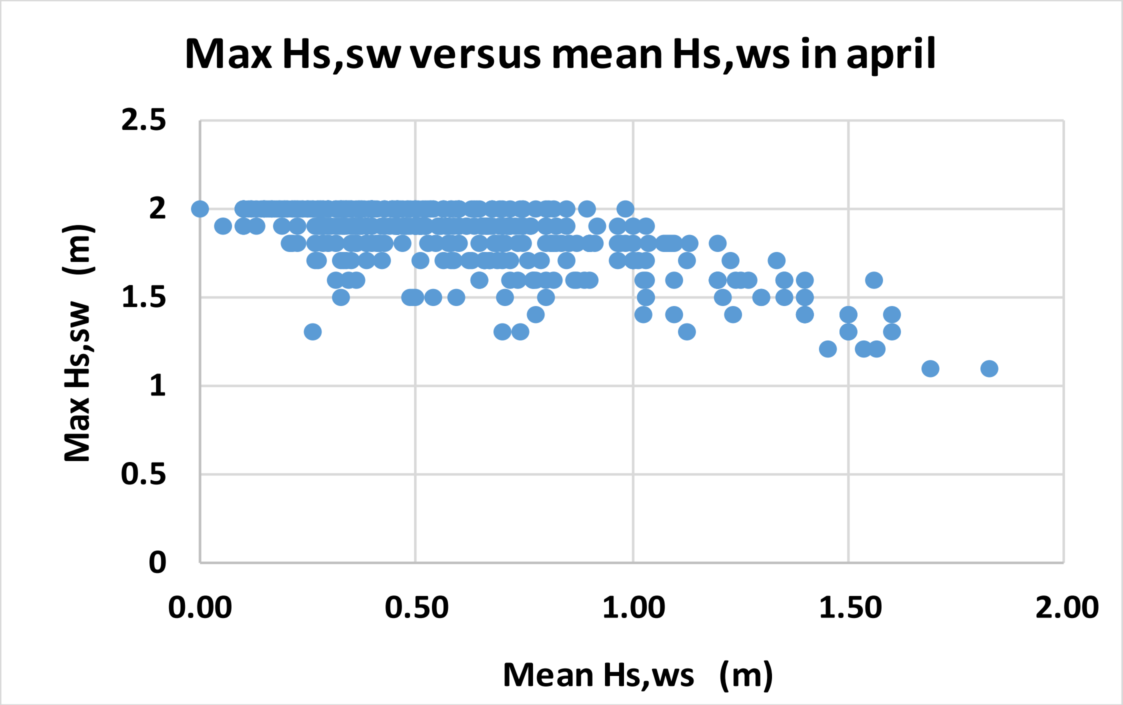
Tp,sw |Tp,ws



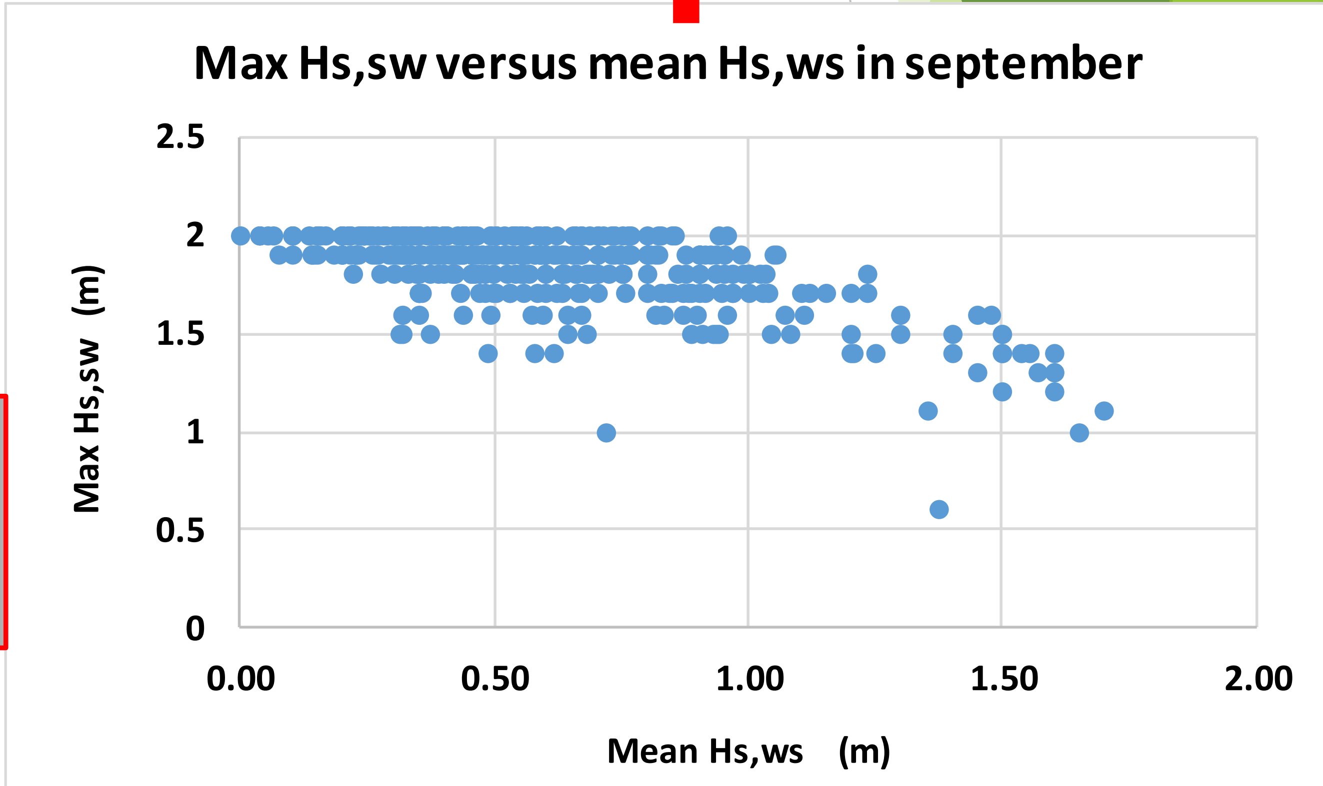
Tp,sw |Hs,sw



Max Swell Sea versus mean Wind Sea for Hs,tot < 2m



Modelling of swell sea spectra is very important for marine operations in the Norwegian Sea due to its exposure from North Atlantic.



What is the adequacy of swell sea as presented in e.g. NORA10 (WAM). Has hindcast swell Hs ever been compared to measured swell Hs e.g. from Miros Radar or directional buoy.

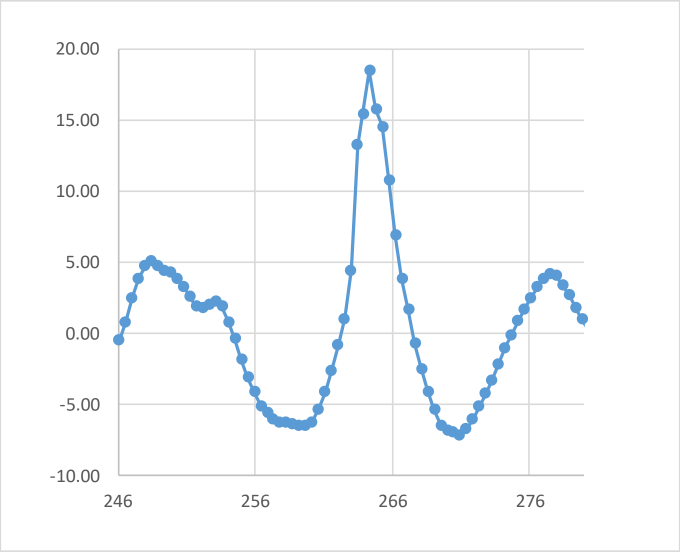
Jubelees:

My tenth partitication of workshop

1986,1989,1992,1995,1998,2002,2006,2009,2013, 2019

Draupner wave 25 years (soon)

Born in North Sea, January 1st 1995



Figures related to the various topics not presented

3-hour short term assessments

- Spectrum for relative surface process:

$$s_{R_pR_p}(f) = \left|h_{HR_p}(f;\kappa_{ws})\right|^2 s_{HH}^{(ws)}(f;\kappa_{ws}) + \left|h_{HR_p}(f;\kappa_{sw})\right|^2 s_{HH}^{(sw)}(f;\kappa_{sw})$$

Standard deviation of relative process: $\sigma_{R_p} = m_{R_pR_p,0}$

Expected zero-up-crossing period of process: $\bar{t}_{R_p,z} = \sqrt{m_{R_pR_p,0}/m_{R_pR_p,2}}$

- Distribution function of 3-hour maximum relative crest height, $C_{R_p,3h}$:

$$F_{C_{R_p,3h}}(c) = \left\{1 - exp\left[-0.5\left(\frac{c}{\sigma_{R_p}}\right)^2\right]\right\}^{n_{3h}}$$

where: $n_{3h} = \frac{10800}{\bar{t}_{R_p,z}}$

Long term extremes

- **Storm analysis**
  Distribution function for storm maximum relative crest height:

  $$(A):\ F_{C_{R,s}}(c) = \prod_{i=1}^{n_s}\left\{1 - exp\left[-\frac{1}{2}\left(\frac{c}{\sigma_{R_{p,i}}}\right)^2\right]\right\}^{n_{3h,i}} \Rightarrow \tilde{c} = F_{C_{R,s}}^{-1}(0.368)$$

  We will assume:

  $$(B):\ F_{C_{R,s}}(c) \approx exp\left\{-\ exp\left\{-\ \frac{c-\tilde{c}}{\beta\tilde{c}}\right\}\right\}$$, $\tilde{c}$ determined for all storms as above,

  β is determined by requiring variance the same for (A) and (B).

- **Longterm analyses**
  Long term integral: $F_{C_{R,s}}(c) = \int_{\tilde{c}} F_{C_{R,s}|\tilde{C}_{R,s}}(c|\tilde{c})\ f_{\tilde{C}_{R,s}}(\tilde{c})d\tilde{c}$

  Estimate of q- annual probability extremes: $1 - F_{C_{R,s}}(c) = \frac{q}{n_{s,1y}}$;

  $n_{s,1y}$ is expected annual no. of storms above selected threshold.

Example Problem:
Necessary deck height to avoid deck impact

Assumptions:

- For calculation of platform motions, surface processes (wind sea and swell) are assumed to be Gaussian and piecewise stationary.

- Platform motions are assumed to be linear functions of surface processes, i.e. characterized by the complex transfer functions.

- Response amplitude operators are established for a target point under deck, P(x,y), using the global heave, pitch and roll transfer functions together with transfer function for diffracted wave field. Horisontal modes of motions are neglected.

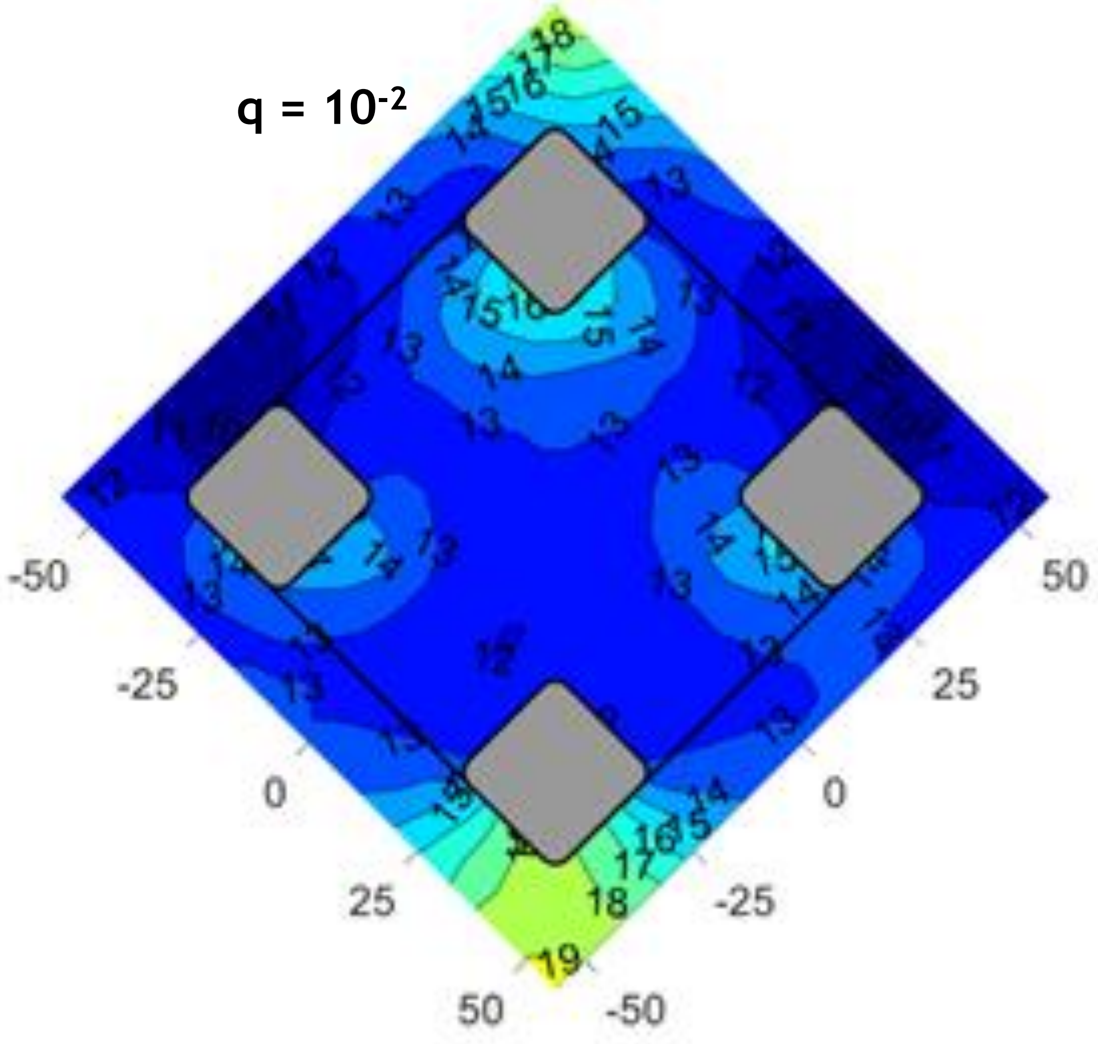
- The relative surface process in a point, P, is written:

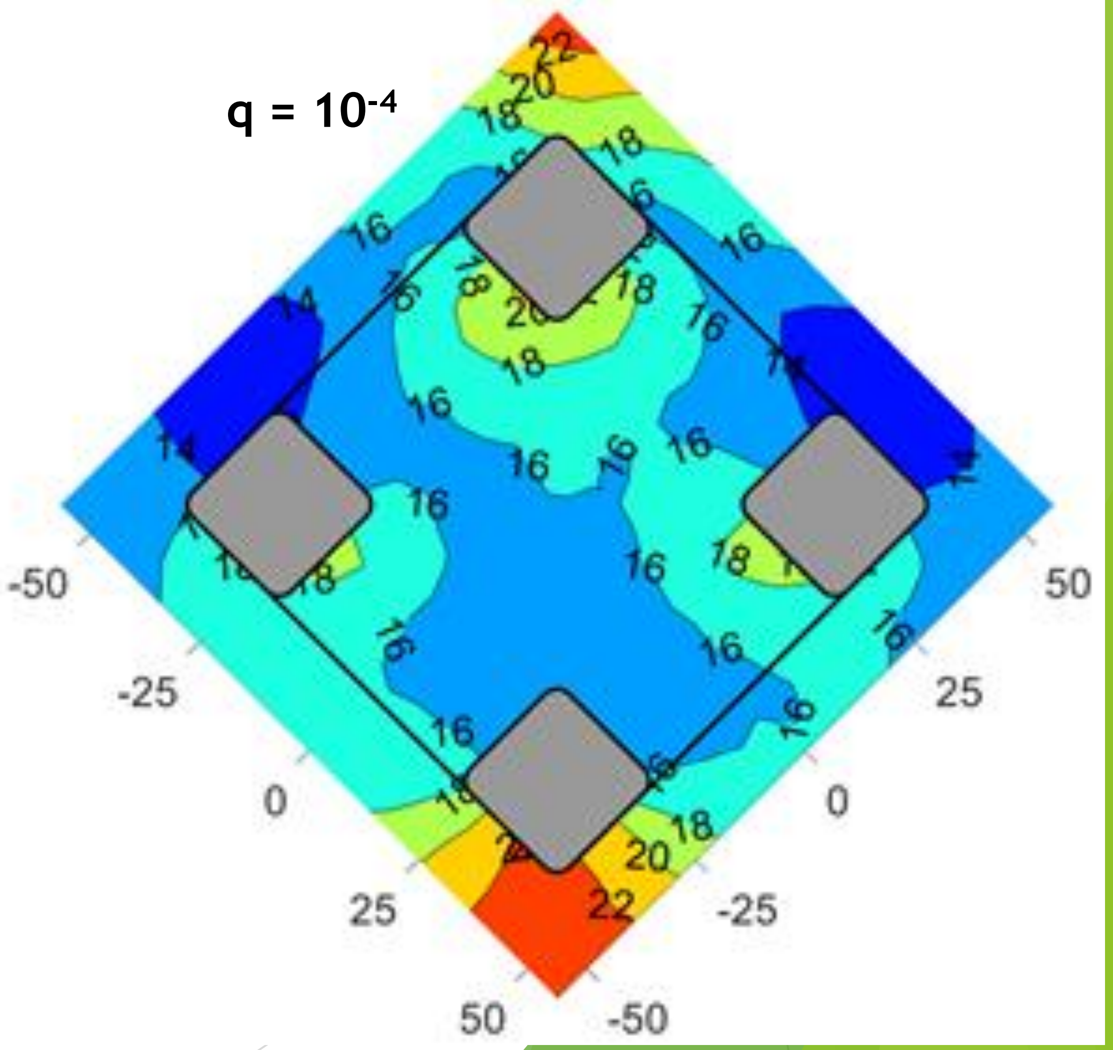
$$R_P(t; x, y) = a(x, y)H_p(t; x, y) - Z_p(t; x, y)$$

$a(x, y) \equiv 1$ for Gaussian surface process and this is applied for swell sea. In order to account approximately for non-linarity in extreme wind sea waves, $a(x, y) = 1.2$ is introduced for the wind sea for values of x and y.

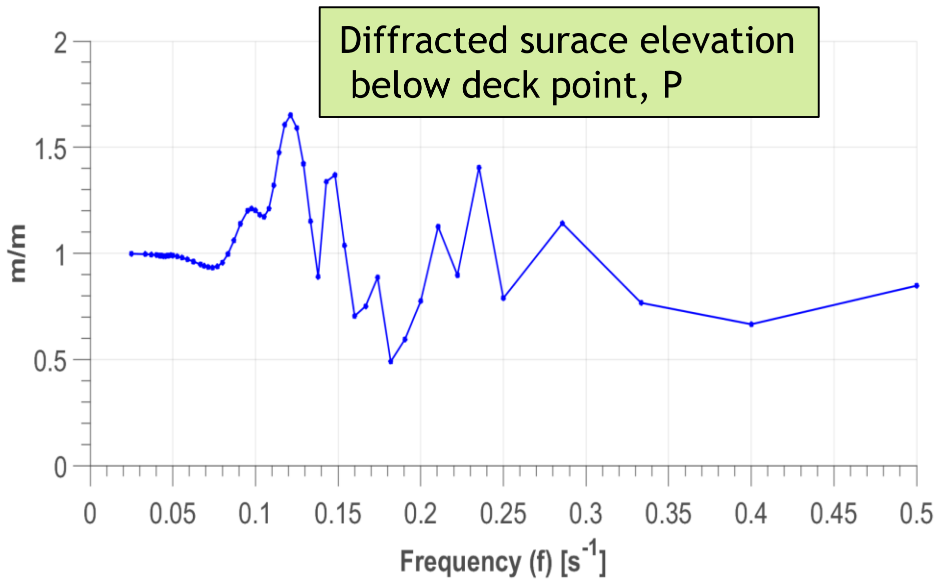
Results for q-probability relative crest height

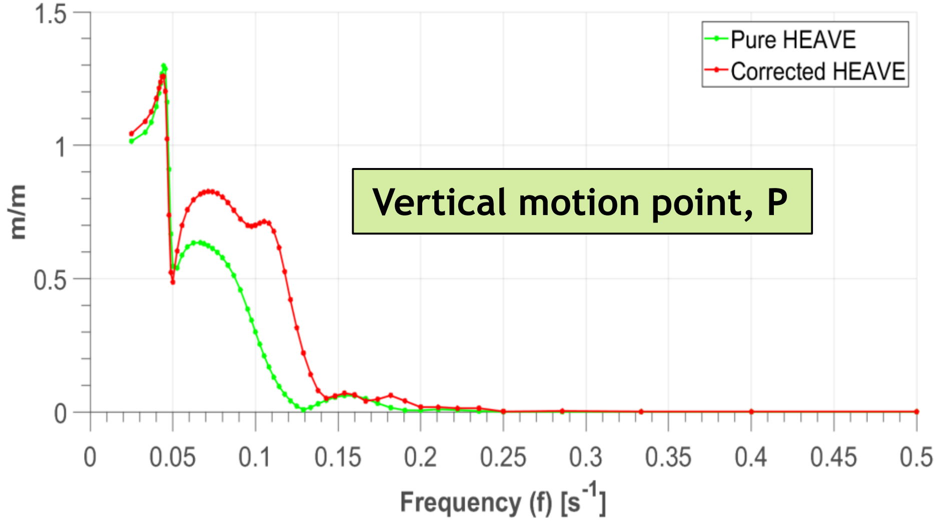
Simultaneous wind sea and swell

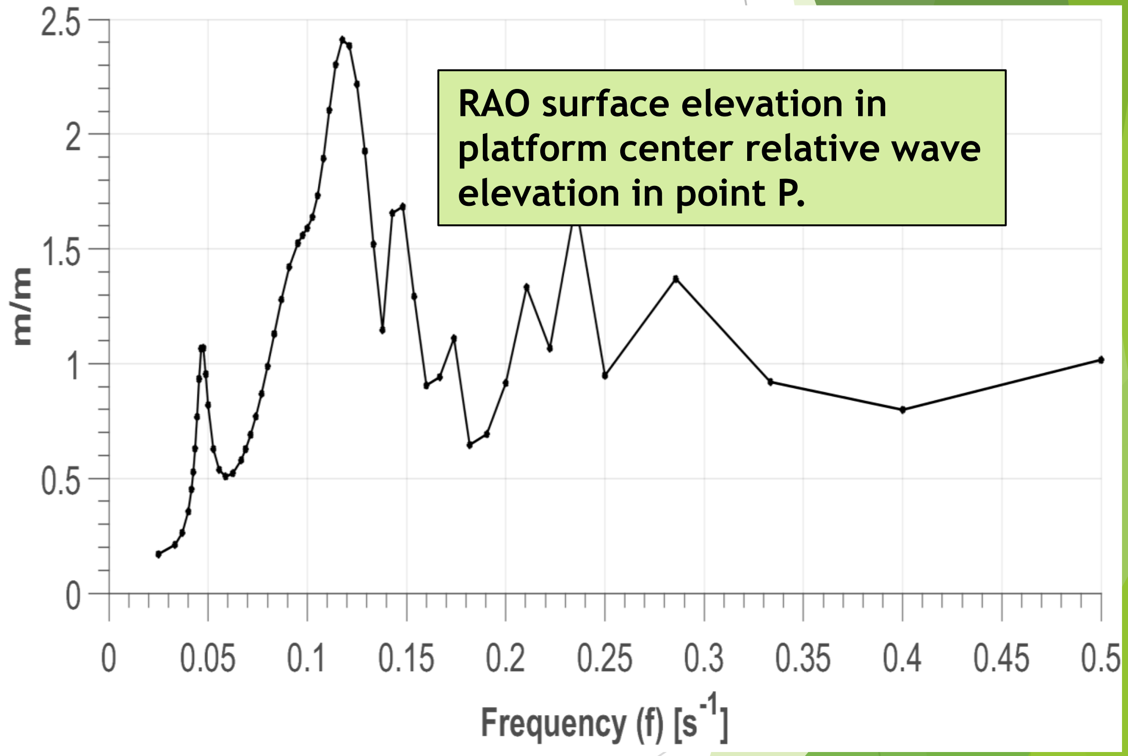




RAO (= |transfer function|) of corner point for a given wave direction

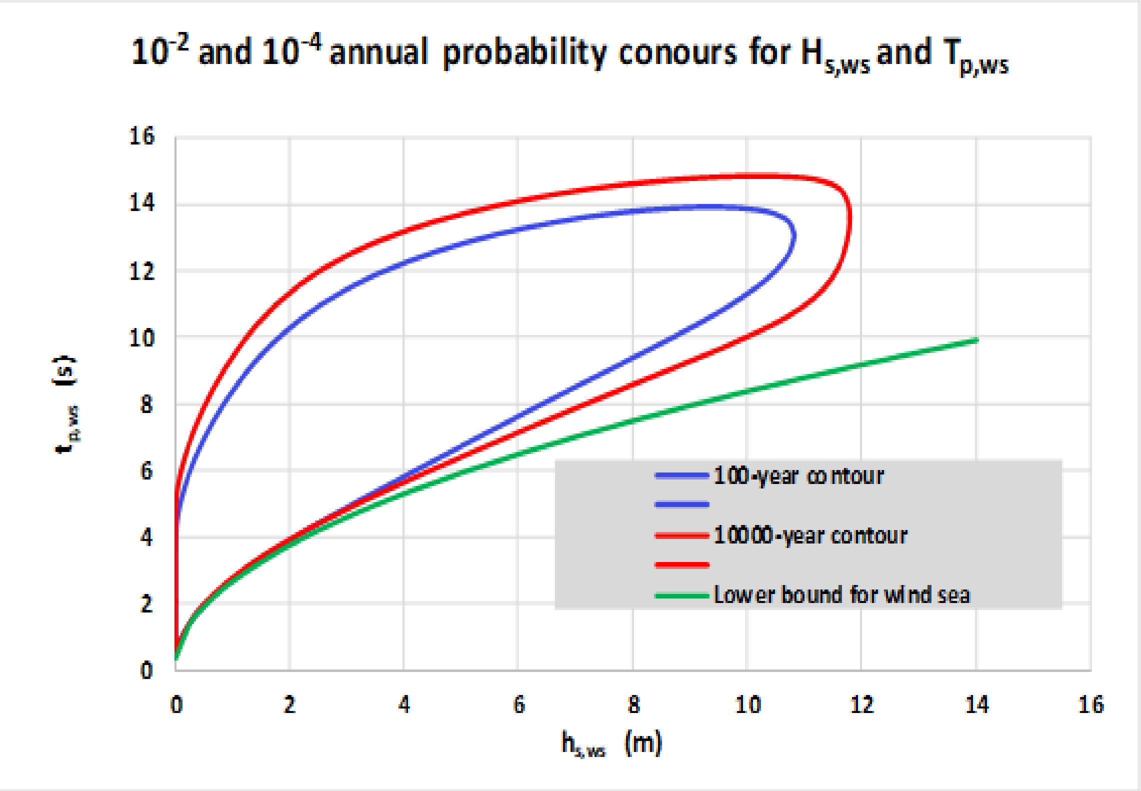




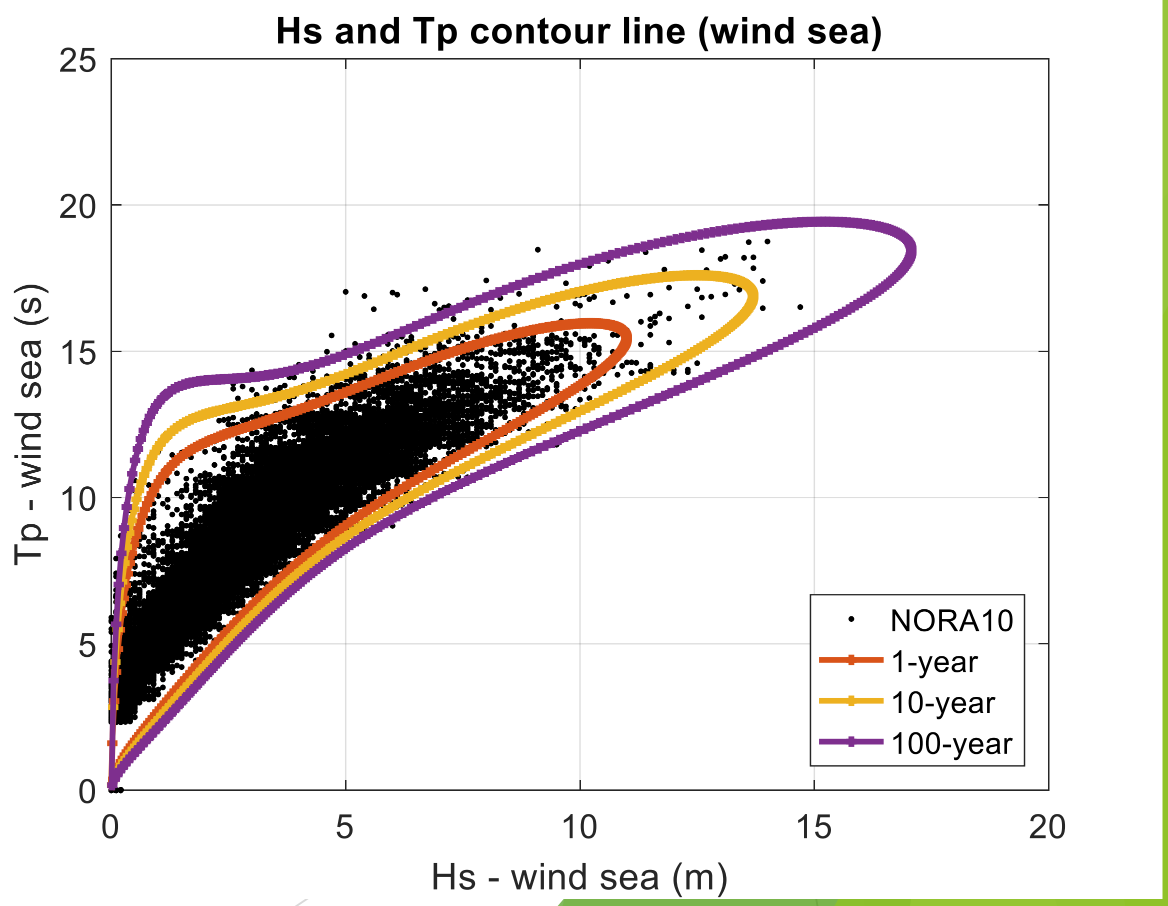


Joint model $H_{s,ws}$ and $T_{p,ws}$

Troll

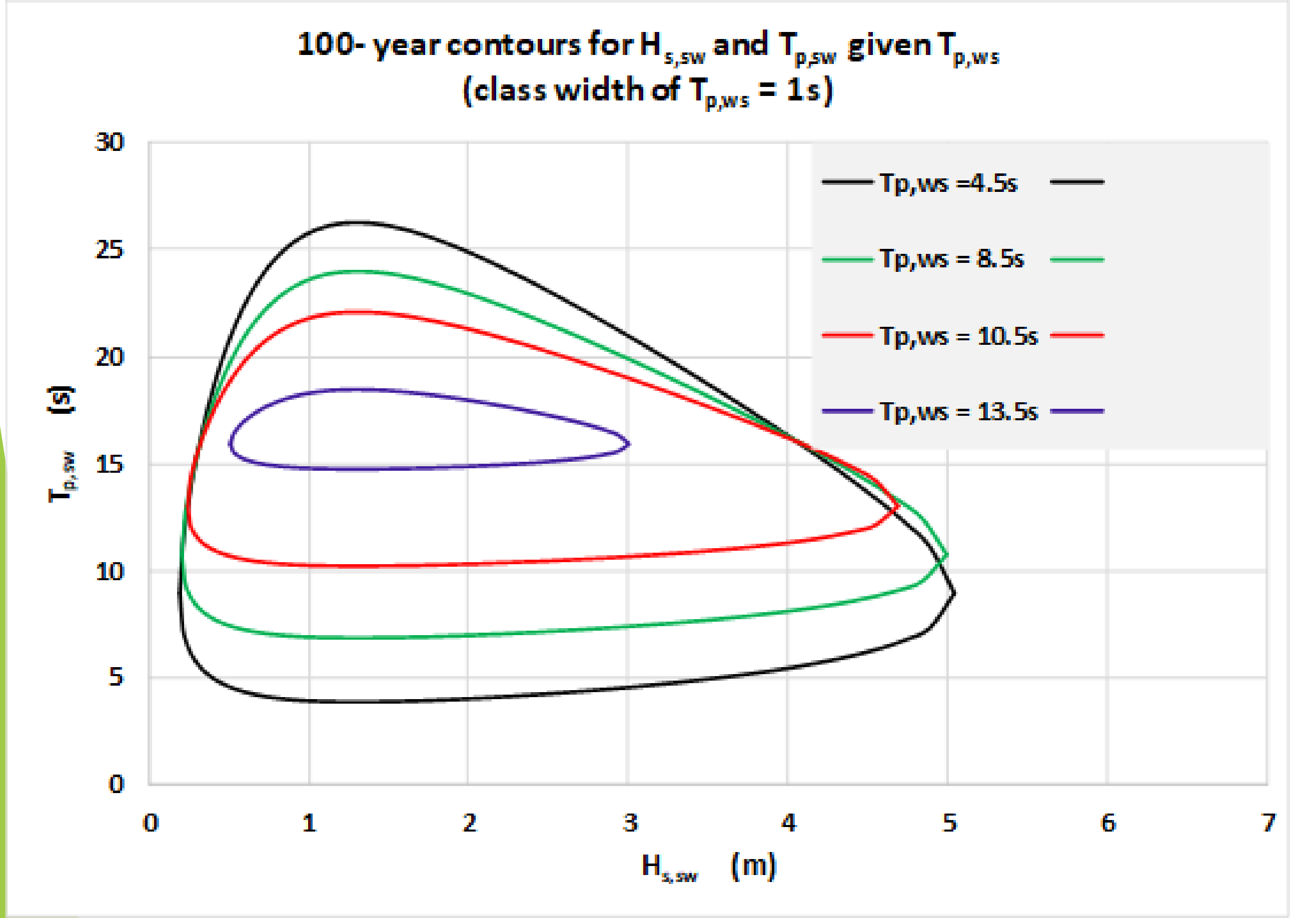


Norwegian Sea

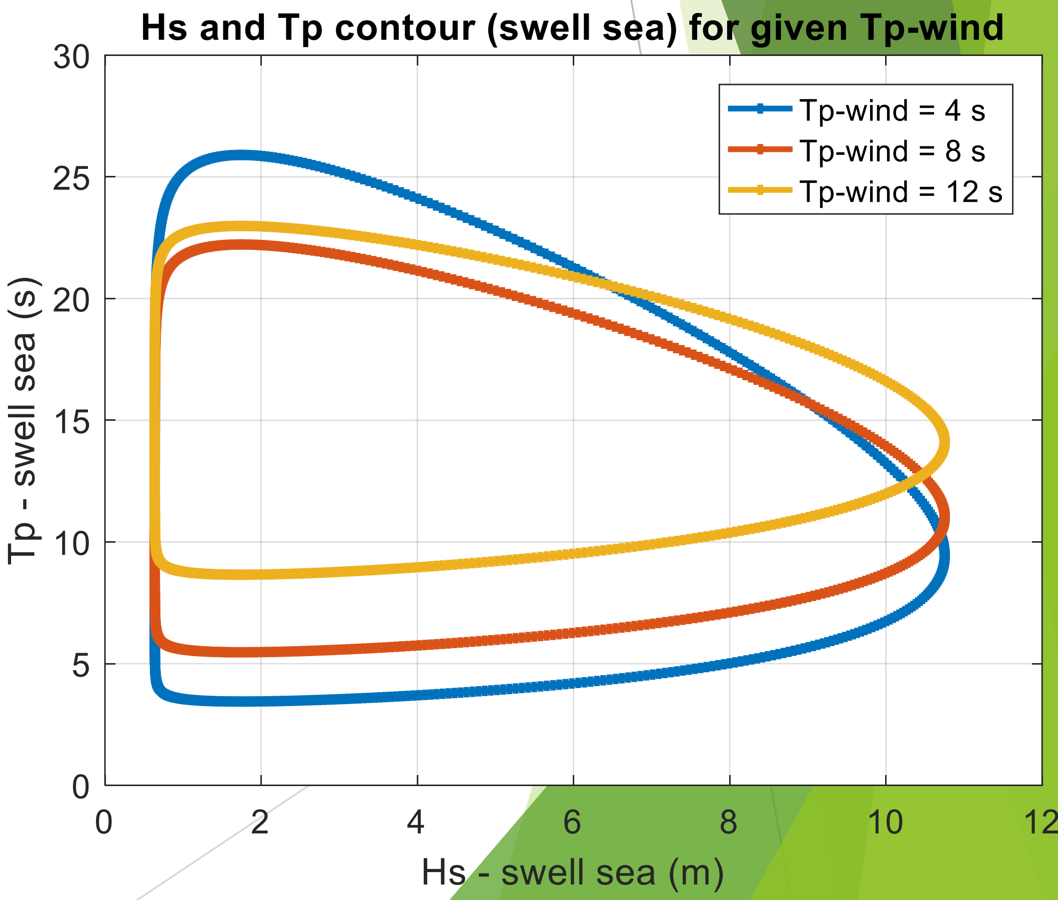


Joint model $H_{s,sw}$ & $T_{p,sw}$ conditional $T_{p,ws}$

Troll



Norwegian Sea



NORA10 results for $H_{s,tot}$ < 2m

Work: Lin Li & Sverre Haver

	April	May	June	July	August	September
No of years	61	61	61	61	61	61
No of windows	423	407	348	313	338	417
Mean annual numbers of events with Hs,tot<2m	6.93	6.67	5.70	5.13	5.54	6.84
Mean	43.28	74.16	93.78	118.09	102.04	51.58
Max	261	759	639	807	600	423
Expected total duration < 2m per year	300.10	494.78	535.03	605.94	565.38	352.62
Total no of hours in month	720	744	720	744	744	720

A good weather event must last for not less than 36 hours to do operation in one og

Is swell important for marine operation at Haltenbanken?.