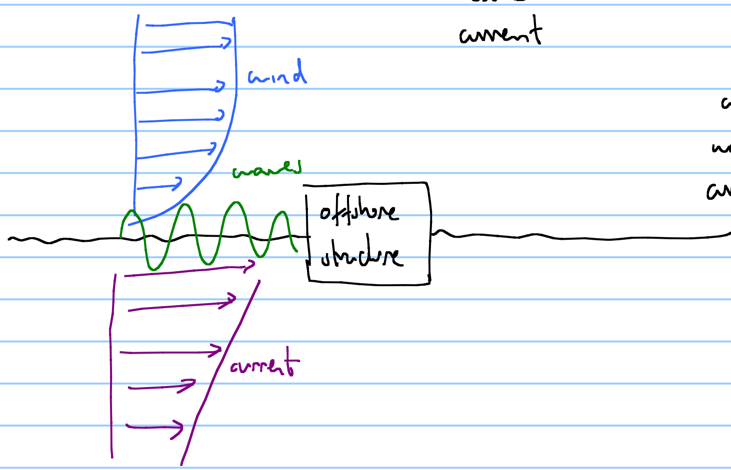
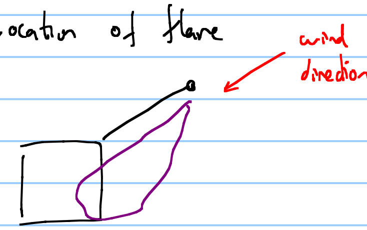
Offshore structures for oil and gas production

- effect of oceanographic environment: wind
  waves
  current

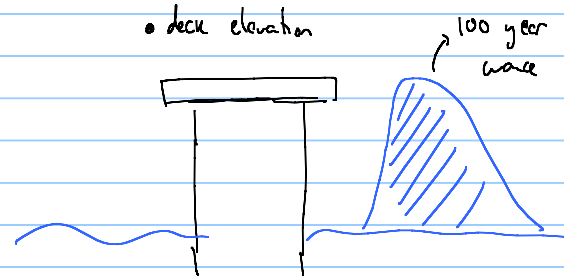


wind, waves, current must be taken into account when designing the offshore structure

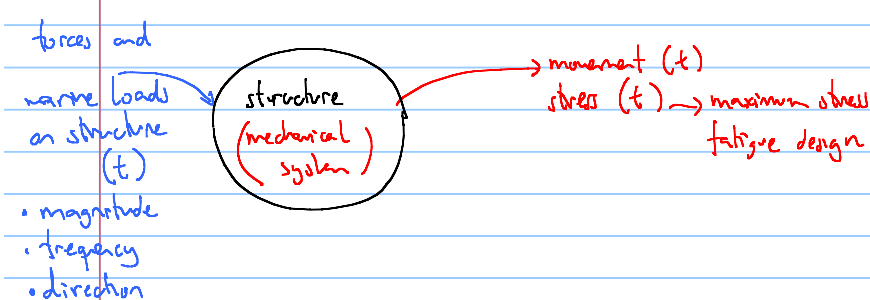
- Location of flare



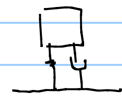
- deck elevation



- design wave, for a range of periods
  ↳ most likely in the area
- storm (100 year storm)
- long term variations → fatigue

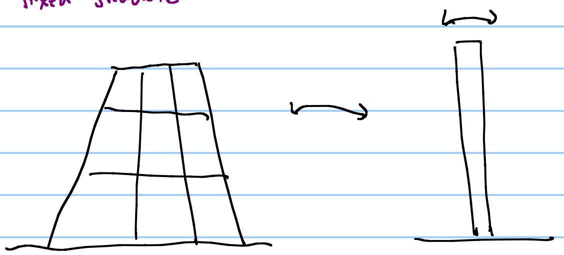


each structure, depending on it characteristics (mass, flexibility, dampening)

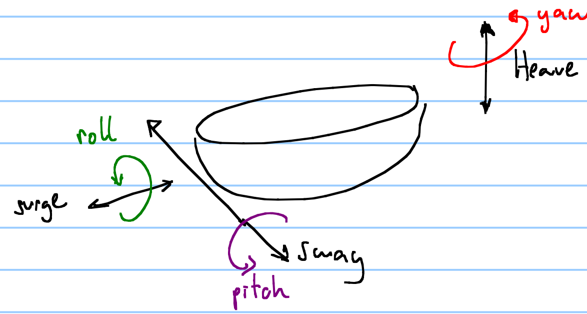


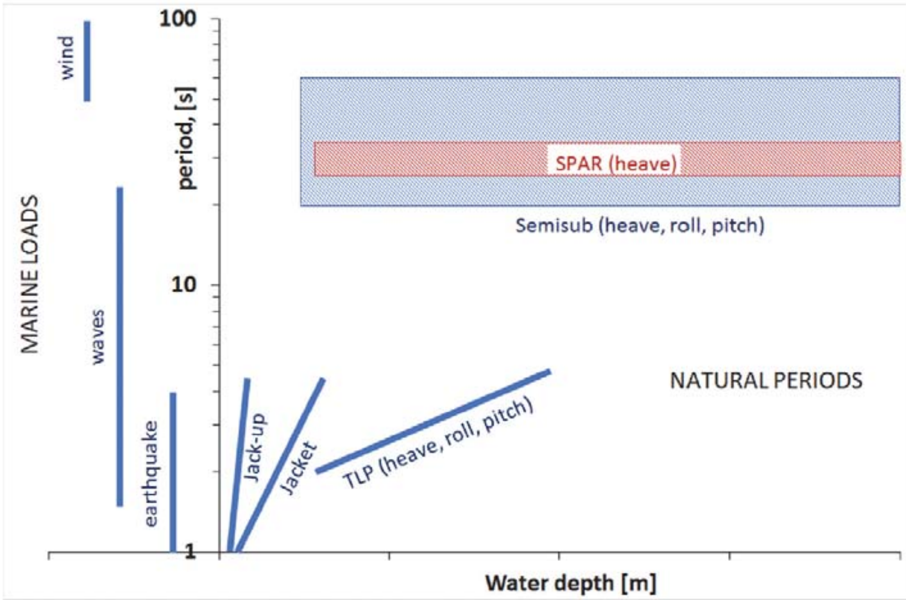
will have a natural frequency that if excited at this frequency might exhibit maximum movement and stress.

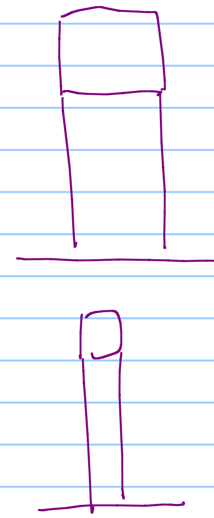
fixed structure

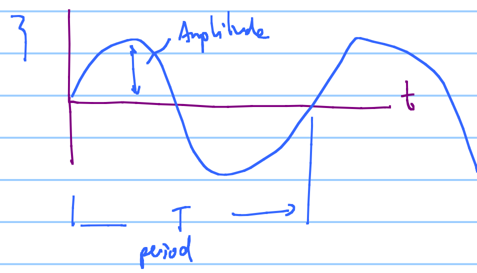


floating structure





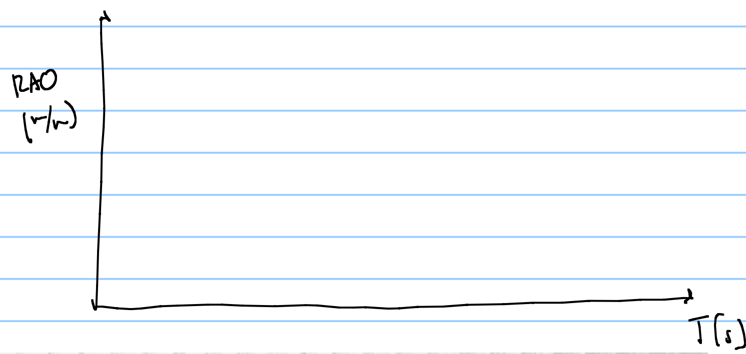




$$\text{Response amplitude operator (RAO)} = \frac{\text{amplitude of response}}{\text{amplitude of excitation}} = \frac{\text{Heave [m]}}{\text{wave amplitude [m]}}$$

$f = \frac{1}{T}$ $\frac{\text{cycle}}{\text{s}}$

RAO = 2



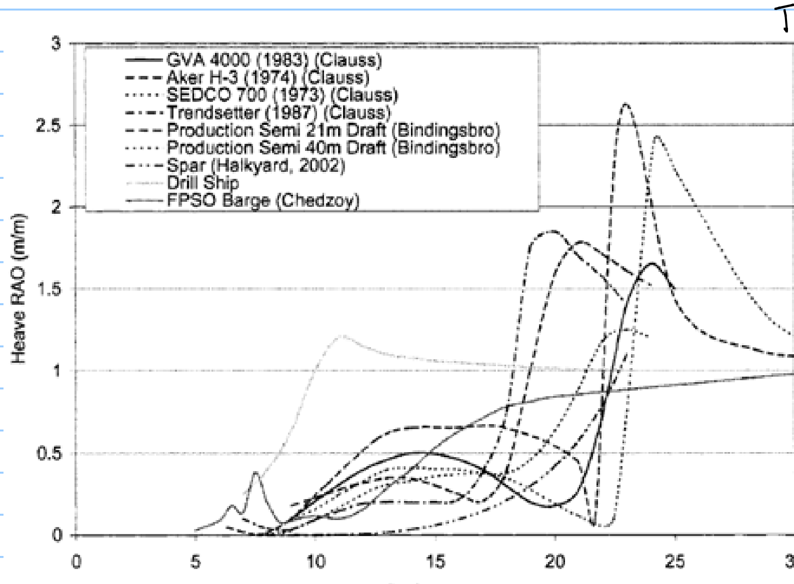
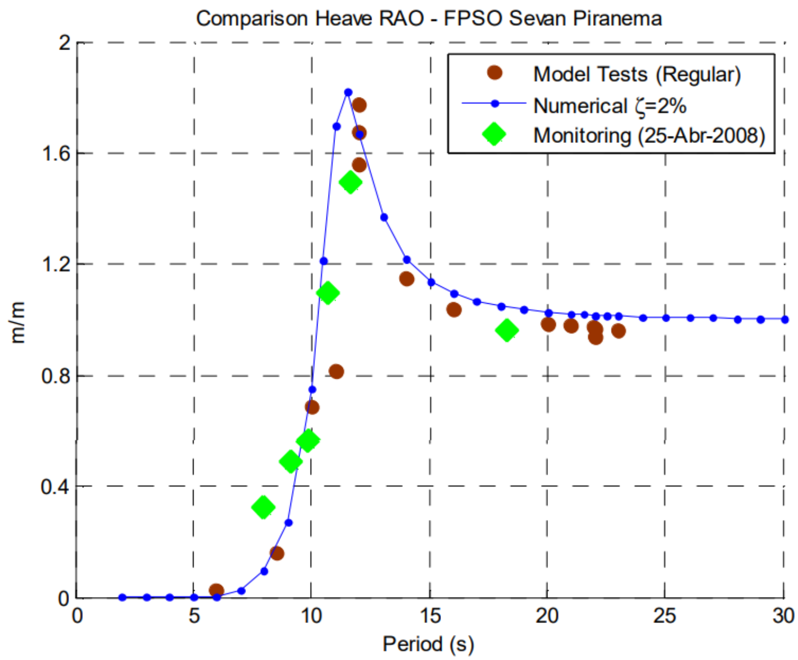


Figure 7.3 Example heave RAOs of various floaters



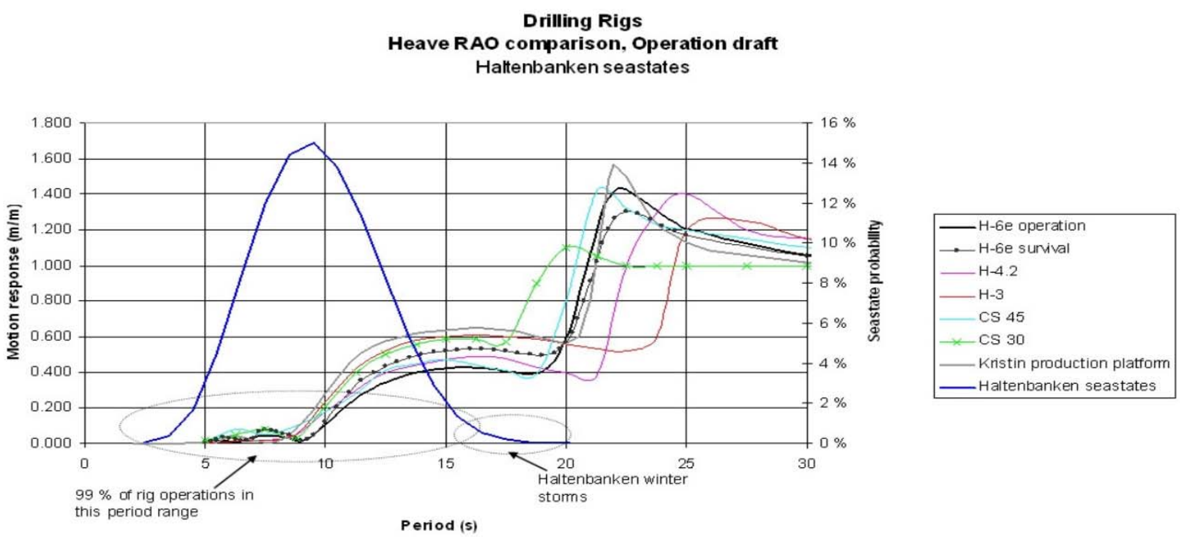


Figure 16.2: *RAO published on the AKER Drilling website.*

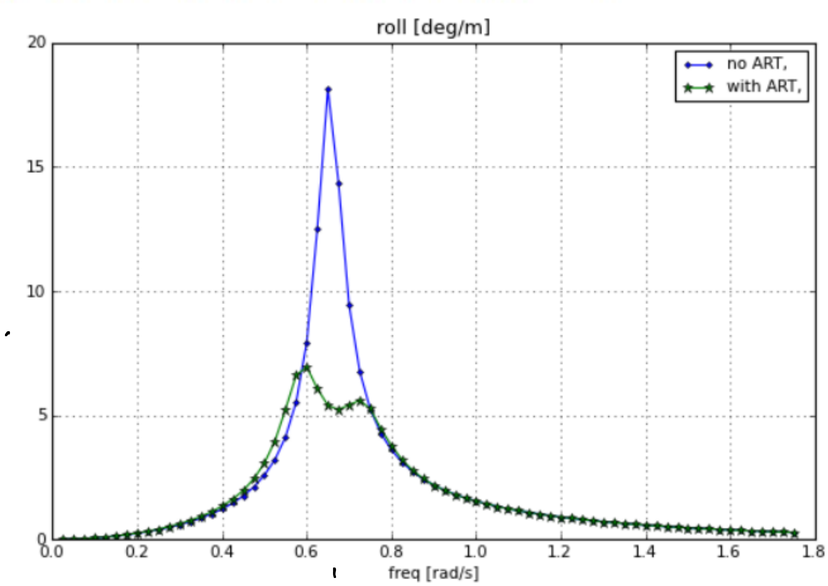
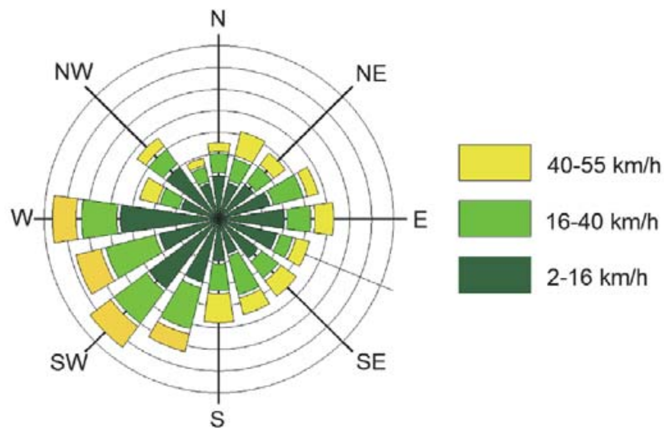


Figure 1: Typical RAO of roll of a ship with and without ART.

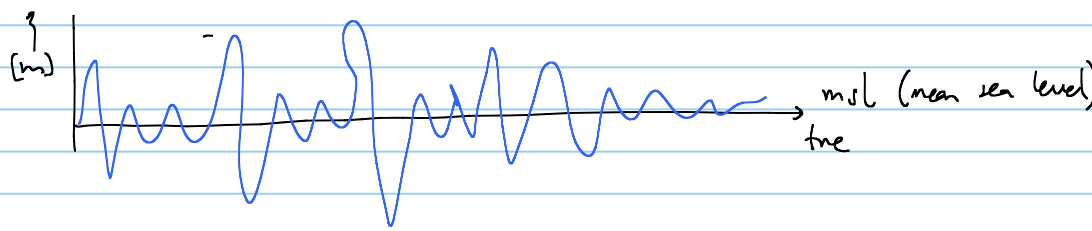
Wind

wind rose



wind and current are typically assumed constant and using the maximum value. (wind direction also must be taken into account)

Waves



Fourier

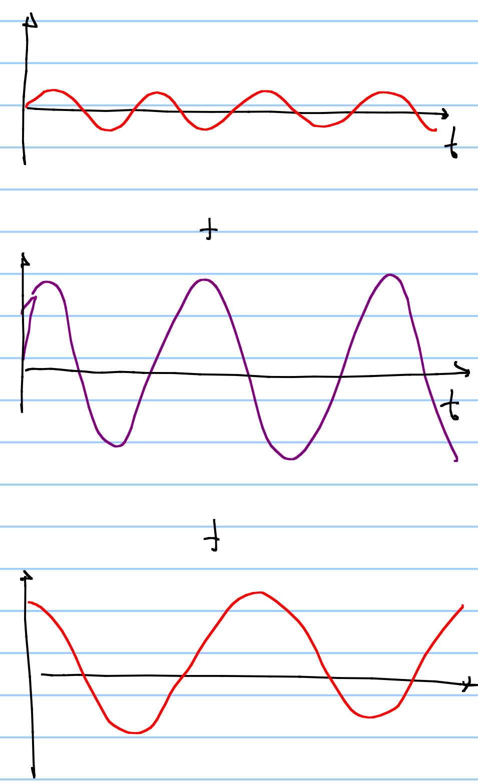
$$f(t) = \sum_{i=1}^{N} A_i \sin(\omega_i t + \phi_i)$$

phase shift (ϕ_i)

amplitude (m) (A_i)

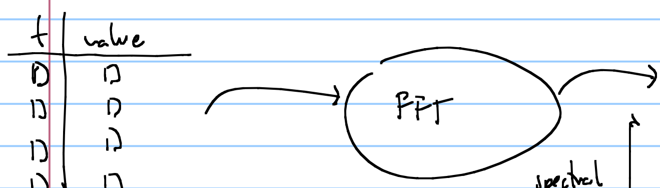
angular frequency $\omega_i = 2\pi f_i$

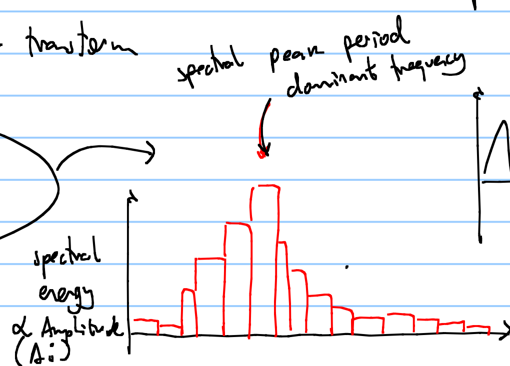
$\omega_i = \frac{rad}{s}$ $\left[\frac{cycle}{s}\right]\left[\frac{2\pi\ rad}{1\ cycle}\right]$

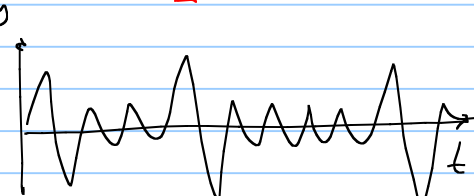


Discrete Fourier transform

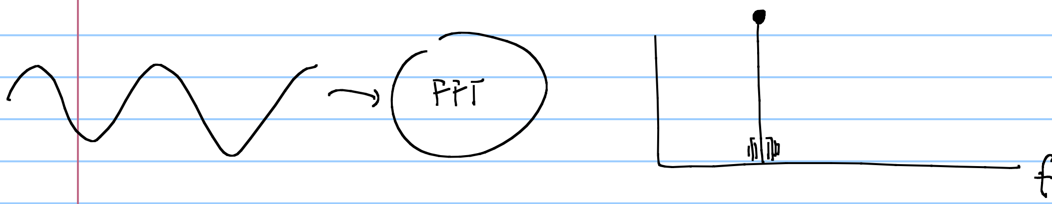
FFT Fast fourier transform







→ sometimes analytical equations are used
Pierson Moskowitz, JONSWAP

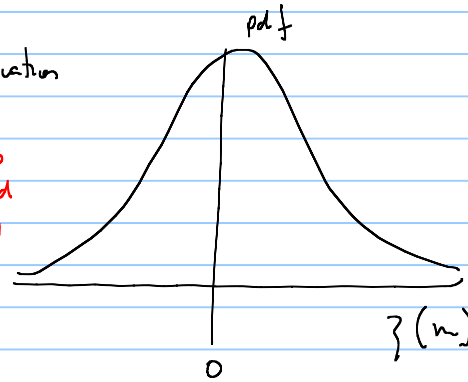


to deal with the variability of waves in time, we apply FFT on the signal and report spectral peak period

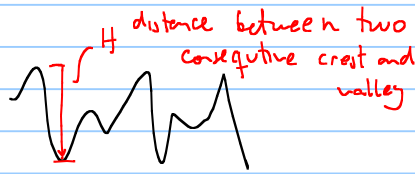
the spectral peak period does not change significantly in 3 hours (sea state)

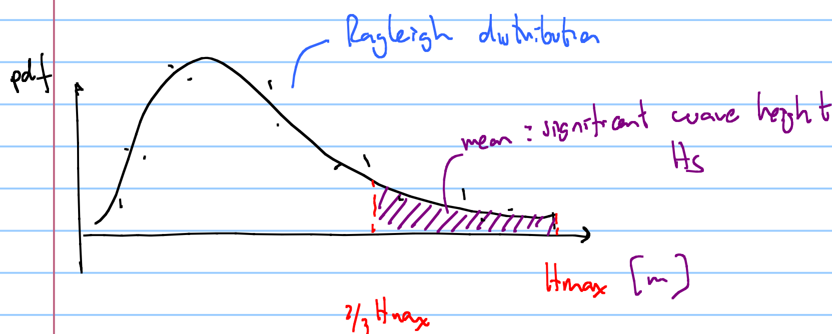
what to do with amplitudes?

statistics on wave elevation



wave height



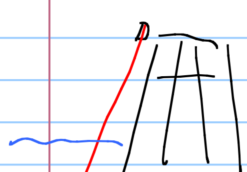


to characterize a sea state (3 hrs) Hs and Tp are used

wave Data must be gathered for at least 2 years to obtain a representative sample of wave conditions in the area

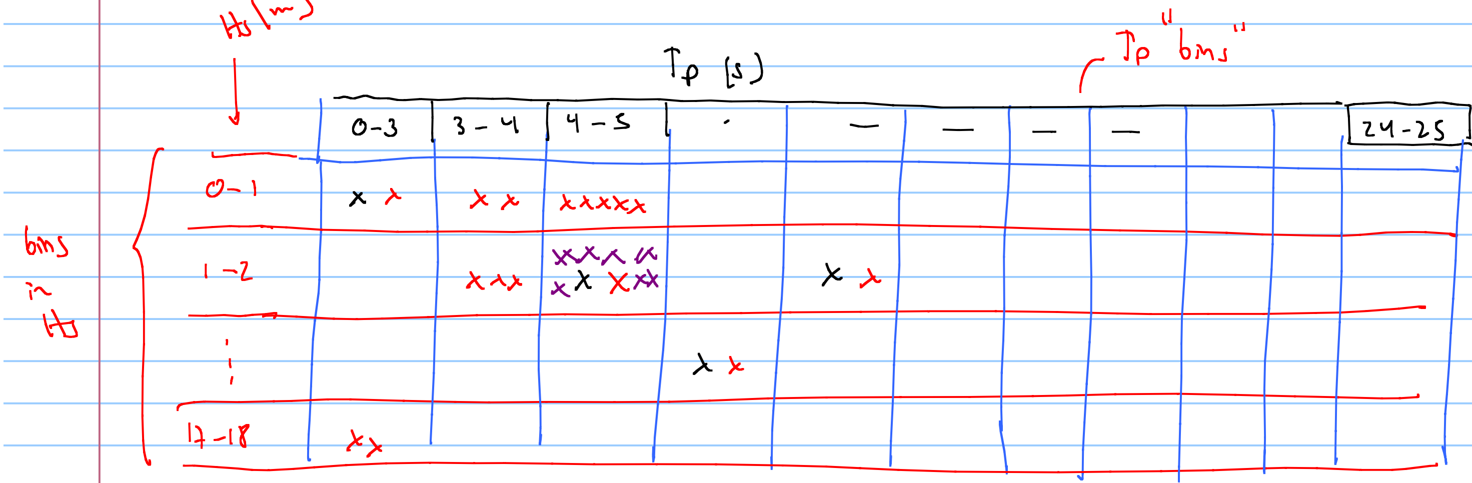
How many sea states are in 2 years

$$2\ \text{years} \cdot \frac{365\ \text{day}}{\text{year}} \cdot \frac{24\ \text{hrs}}{1\ \text{day}} \cdot \frac{1\ \text{sea state}}{3\ \text{hr}} = 5840$$



with all measured data, compute Tp, Hs for all

Scatter diagram of long term wave statistics



classify each data point I have in each box

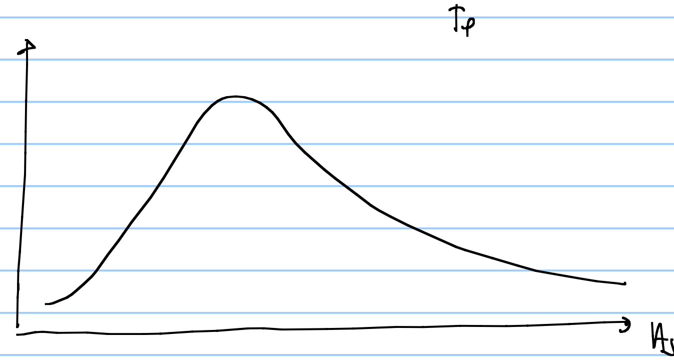
Hs [m]	Spectral Peak period (T_p) [s]																								
Hs [m]	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	Sum
0-1	15	290	1367	2876	3716	3527	2734	1849	1138	656	362	192	101	52	26	13	7	3	2	1	0	0	0	18927
1-2	1	81	1153	5308	12083	17323	18143	15262	10980	7053	4169	2316	1229	631	315	155	75	36	17	8	4	5	1	96348
2-3	0	2	94	1050	4532	10304	15020	15953	13457	9752	5991	3403	1795	894	426	197	88	39	17	7	3	1	1	83026
3-4	0	0	2	72	686	2782	6171	8847	9139	7493	5082	2991	1577	762	345	148	61	24	9	4	1	0	0	46246
4-5	0	0	0	2	51	433	1645	3495	4807	4750	3638	2286	1229	584	251	100	37	13	5	1	0	0	0	23327
5-6	0	0	0	0	2	39	294	1037	2069	2664	2440	1709	968	463	193	72	25	8	2	1	0	0	0	11986
6-7	0	0	0	0	0	2	32	215	692	1264	1485	1228	767	382	159	57	18	5	1	0	0	0	0	6307
7-8	0	0	0	0	0	0	2	27	157	447	730	762	555	302	130	46	14	4	1	0	0	0	0	3177
8-9	0	0	0	0	0	0	0	2	23	112	276	392	355	223	104	38	11	3	1	0	0	0	0	1540
9-10	0	0	0	0	0	0	0	0	2	19	77	160	192	148	79	31	9	2	0	0	0	0	0	719
10-11	0	0	0	0	0	0	0	0	0	2	16	50	85	85	55	24	8	2	0	0	0	0	0	327
11-12	0	0	0	0	0	0	0	0	0	0	2	12	29	40	33	18	7	2	0	0	0	0	0	143
12-13	0	0	0	0	0	0	0	0	0	0	0	2	8	15	17	12	5	2	0	0	0	0	0	61
13-14	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	6	4	1	0	0	0	0	0	25
14-15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0	9
15-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	4
16-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	16	373	2616	9308	21070	34410	44041	46687	42514	34212	24268	15503	8892	4587	2143	921	372	146	55	22	8	6	2	292172

FIGURE 6-18. SCATTER DIAGRAM OF LONG TERM WAVE STATISTICS

$$\frac{292172}{2420\left(\frac{\text{states}}{1\text{ year}}\right)} \approx 120 \text{ years}$$

for a fixed wave Hs

for a fixed Tp



Class exercise

Wave statistics for the Aasta Hansteen area.

You have been invited onboard the R/V Gunnerus, a ship that belongs to NTNU that will carry several research activities on a trip to the Norwegian Sea. The vessel will be visiting the area where the Aasta Hansteen field will be located (67° Latitude and 7°Longitude). Equinor sponsors your stay and place on the ship. The ship is equipped with a buoy that measures wave elevation every 0.5 s.

Part 3.1. To show your gratitude to Equinor, you intend to process the wave elevation data that has been gathered for a period of 2047.5 s during the trip (See the excel data attached). The tasks are as follow:

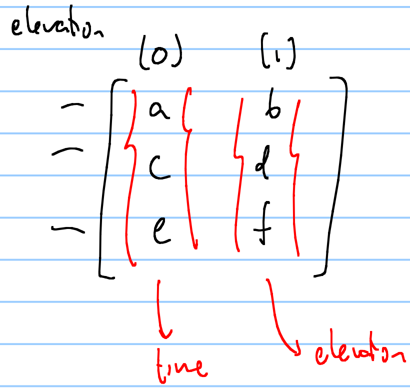
- Perform an FFT of the data provided. Do this in Python. We will follow the instructions in the document "Frequency Domain Using Excel" written by Larry Klingenberg, from San Francisco State University. Please note that the procedure provided by Prof. Klingenberg already calculates the amplitude (wave elevation, in m), **NOT** the spectral energy.
  Plot the wave spectrum (amplitude in m vs frequency), provide the periods with the highest amplitude on a table and report the peak spectral period (the period with the highest amplitude). Is it possible to reconstruct the original wave elevation data with this plot?

How to do discrete fourier Transform https://www.youtube.com/watch?v=mkGsMWi_j4Q

all rows

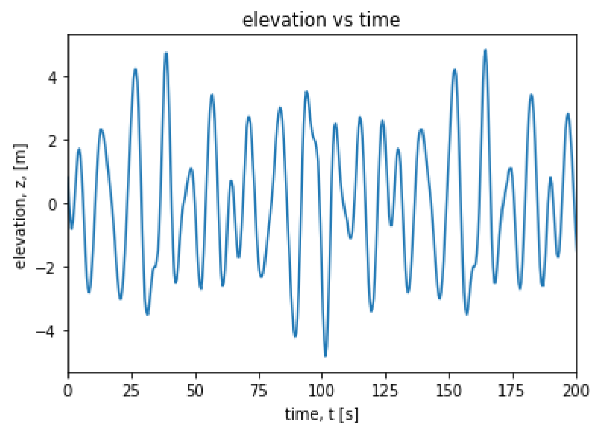
time=elevation[:,0]

← take only column 0



In [24]:
```python
#importing needed libraries
import numpy as np
import matplotlib.pyplot as plt
```

In [38]:
```python
#reading and plotting wave elevation measured data
elevation=np.loadtxt('elevation_vs_time.txt')
time=elevation[:,0]
elevation=elevation[:,1]
n_points=time.size
plt.plot(time,elevation)
plt.xlim(0,200)
plt.title('elevation vs time')
plt.xlabel('time, t [s]')
plt.ylabel('elevation, z, [m]')
plt.show()
```



In [39]:
```python
fft_mag=np.abs(np.fft.fft(elevation))*2/n_points
fft_freq=np.fft.fftfreq(n_points,time[1]-time[0])
plt.plot(fft_freq,fft_mag)
plt.xlim(0)
plt.title('amplitude vs frequency')
plt.xlabel('frequency, f [Hz]')
plt.ylabel('amplitude, [m]')
plt.show()
```