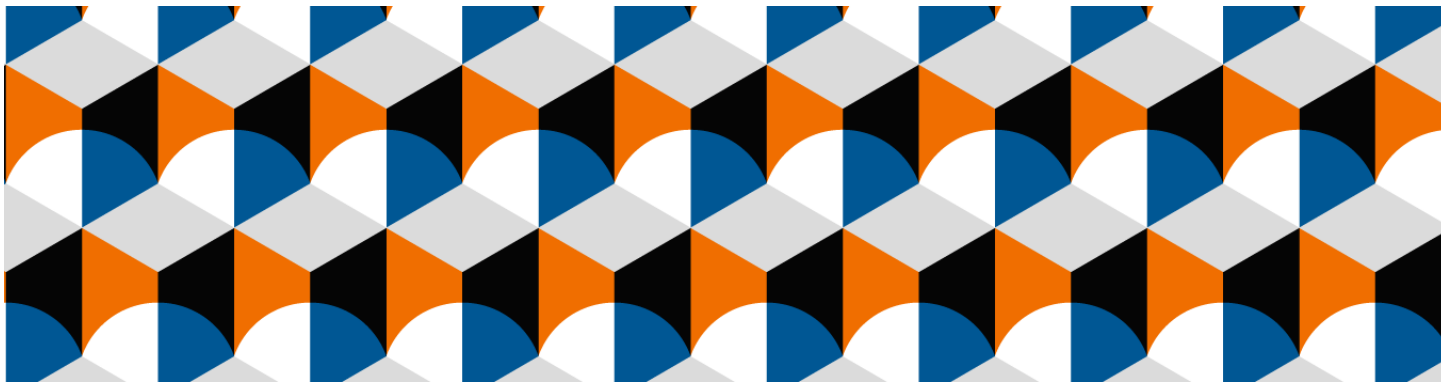


CUSTOMER REPORT VTT-CR-00867-23 DRAFT

Effects of weather and passing ships for a planned floating spa and sauna building in the port of Stockholm

Authors: Kai Happonen, Ville Viitanen, Jussi Martio, Ilkka Perälä

Confidentiality: Confidential

Version: 2.1.2024

VTT

beyond the obvious

Report's title	
Effects of weather and passing ships for a planned floating spa and sauna building in the port of Stockholm	
Customer, contact person, address	**Order reference**
Bluet Oy / Kimmo Saharinen Jaakonkatu 2, FIN-01620 VANTAA Finland	DocuSign 02 June 2023, Kimmo Saharinen
Project name	**Project number/Short name**
Elite23	137383/Elite23

Summary

Bluet Ltd is planning to design and construct a floating spa and sauna building in the Port of Stockholm. A two-day measurement and observation campaign was performed on a location of a planned floating building in the port of Stockholm (Nacka) Sweden. In addition, one wave buoy was measuring data for a longer time, about one month. The objective of the project is to find out realistic information of the wave and flow conditions on the planned location of the building. The waves, and also the local current speeds created by passing and manoeuvring ships, were measured near the planned location of the pool.

Ship traffic nearby the planned floating building is rather busy year around. Local commuter boats have a berthing pier in front of the hotel and bigger Viking Line passenger car ferries pass the position several times a day. International large cruise ships arrive weekly to the close-by berth during cruise season, May - September.

During the measurement time the weather conditions were mild to moderate, and no extreme wind or waves could be observed. Most waves range from ca. 8 to 17 cm in significant height, and some instances of larger waves occurred during the measurement period.

Fetch and duration of wind were used to estimate harsher conditions on site. As an example, for a fetch of 2 km, wind of 20 m/s blowing for one hour results in a significant wave height of 0.65 m. This means that single maximum wave heights of roughly two times this value, that is, 1.3 m, can be expected in this particular condition.

Estimation of motions and forces on the floating building using simplified methods requires design information of the floating structures, that is, mass and hydrostatic data. This estimation is anticipated to be carried out in a following phase if progress of the pool project is expected. Refined studies of the structures' responses to waves and currents can be carried out using theoretical methods and model-scale tests. Measurement data compiled in the present project can be utilised when planning a model-testing or numerical analyses campaigns for more detailed determination and analyses of expected responses of the floating construction to aid in design of the structure and possible mooring solutions. However, long term distributions and estimates of wave conditions require measurement or hindcast simulation data that spans preferably several years at the site.

Espoo

Written by	**Reviewed by**
Kai Happonen Ville Viitanen	Teemu Manderbacka Research Team Leader

Confidentiality	Confidential

VTT's contact address

kai.happonen@vtt.fi, P.O.Box 1000, FI-02044 VTT

Distribution (customer and VTT)

Customer 1 copy and a pdf copy VTT 1 copy and a pdf copy

The use of the name of VTT Technical Research Centre of Finland Ltd in advertising or publishing of a part of this report is only permissible with written authorisation from VTT Technical Research Centre of Finland Ltd.

Approval

VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD

Date:	
Signature:	
Name:	
Title:	

Contents

1. Introduction 5

2. Measurements at Port of Stockholm 6

3. Wave and environmental conditions 10

3.1. Conditions during on-site measurement campaign 10

3.2. Wave conditions based on measurements of one month 15

3.3. Estimation of ship propeller' induced currents on site 21

4. Estimation of wave induced motions of the floating building 25

5. Summary 26

6. References 27

7. Appendices 28

1. Introduction

Bluet Ltd is planning to design and construct a floating spa and sauna building in the port of Stockholm. Figure 1 shows a rendered sketch of the floating building in front of Elite Hotel Marina Tower in Port of Stockholm. The objective of the project is to find out realistic information of the wave and flow conditions on the planned location of the building. The following quantities were measured:

- Waves generated by wind and passing ships.
- Flow generated by ships near the building's planned location.

VTT has conducted measurements on-site during autumn 2023. A two-day measurement campaign was done in September during which the waves and local current speeds created by passing and manoeuvring ships were measured near the planned location of the pool. Additionally, a wave buoy was deployed that provided measurement data for a period of one month after the on-site campaign.

Based on the measurements and weather statistics, conditions are determined for the planned building area. Ship traffic statistics and main particulars of the largest visiting vessels are considered.



Figure 1. Rendered sketch of the floating building. Figure given by Bluet Ltd.

2. Measurements at Port of Stockholm

Measurements were carried out at the planned location of the floating structure. The floating building is planned to be constructed in front of Elite Hotel Marina Tower in Port of Stockholm. Figure 2 shows a satellite image near the location.

A two-day measurement campaign on site during 13-14 September. On Wednesday 13 September FlowTracker and Datawell buoy were used. On Thursday 14 September, Sofar Spotter was used, and the measurements were activated at 14.38 Swedish time. The Sofar Spotter wave buoy was used between September 14 – October 16. Datawell DWR-G4 buoy was used which records wave data at 1.28 Hz with a GPS receiver. Sofar Spotter records wave data at 2.5 Hz sampling rate. Time histories of motions produced by the buoys were filtered using the same ranges as defined in the buoys' technical reference manuals. That is, for Datawell the high-pass frequency is 0.033 Hz and for Spotter it is 0.030 Hz. Locations of the wave buoys are shown in Figure 5 and in Figure 6. Two-component flow velocity was measurement using FlowTracker device. The FlowTracker device was installed in an arm fixed to the right corner of the pier as shown in Figure 7. The measurement head was at depth of 1.2 m. In addition, Data from the Swedish Meteorological and Hydrological Institute (SMHI) were collected for wind speed and direction for two measurement stations near Stockholm.

Observation were made of typical ship berthing manoeuvres and propeller induced currents at the floating building position. Current sensor was attached close to the pier. Location of the measurement site is shown in Figure 2.

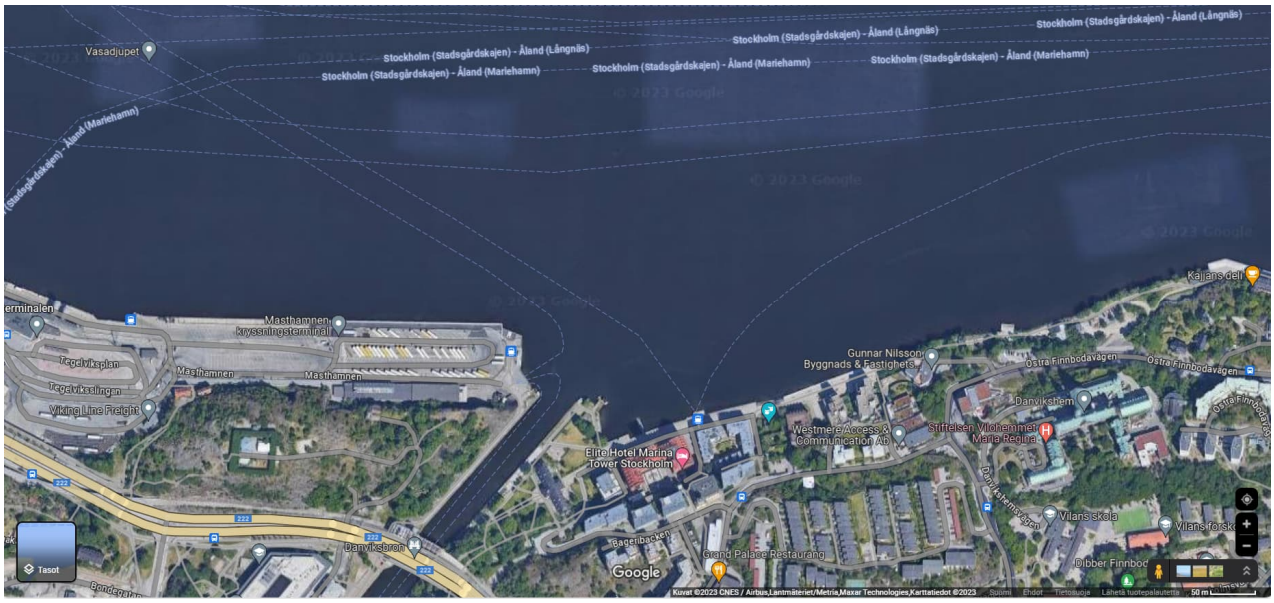


Figure 2. Satellite map near the planned location of the floating building showing also ship routes in the port area (Google Maps).



Figure 3. Depth curves and underwater pipelines in the area. Figure given by Bluet Ltd.



Figure 4. Preparation works on the pier.



Figure 5. Location of the Sofar Spotter wave buoy near the planned area of the floating structure.



Figure 6. Locations of Spotter (blue arrow) and Datawell (orange arrow) buoys.



Figure 7. FlowTracker installation on the right corner of the pier. The measurement head was at depth of 1.2 m.



Figure 8. Locations of SMHI observations at Bromma airport (left) and Skarpö (right) (smhi.se/data).

3. Wave and environmental conditions

Wave buoy measurements are analysed based on time domain and frequency domain methods to provide insight and statistics into wave conditions on the measurement site. The analysis procedures are described in Appendix 2. Results of measurements are given in Appendix 3 in tabulated form from time history and spectral analyses. Appendix 4 and 5 give results in graphical form from Datawell buoy from Sofar Spotter buoy, respectively. Data from SMHI were collected for wind speed and direction for two measurement stations near Stockholm.

3.1. Conditions during on-site measurement campaign

Recorded events during on-site measurement campaign on September 13th-14th are listed in Table 1. Graphs from Datawell buoy measurements are given in Appendix 4.

Table 1. Recorded events during on-site measurement campaign on September 13th-14th. Time stamps are in Swedish time zone.

Time	Event	Comments
Wednesday 13.9.2023		
08:00	Buoys deployed	
09:00	Mein Schiff 4 arrives	
09:45	Viking Line Gabriella arrives	
09:55	Aquador leaves the hotel's pier	
09:59	Waxholmbåt passing inw.	
10:00	Tow and barge enter canal	
16:25	Viking Line Gabriella leaves	
16:30	Mein Schiff 4 leaves	MS turning manoeuvre bow to South. Flow tracker recorded flow speeds ~20 cm/s. During turning manoeuvre also smaller vessels passed the site.
Thursday 14.9.2023		
09:00	Sofar buoy started	
09:00	Mein Schiff 1 arrived	At 09:15 MS1 pushed against pier using thrusters
09:43	Waxholmbåt passing	
09:43	RIB boat to canal	Passes near the site
09:55	Waxholm leaves canal	
16:20	Mein Schiff 1 leaves	
16:30	Boat arrives	Datawell buoy off, Flowtracker off

Figure 9 shows wave elevation time history for Wednesday 13.9. between 09-17 Swedish time. Furthermore, the figure shows the significant wave height based on 20 min of moving rms. values. During that time, minimum value was 0.18 m and maximum value was 0.26 m, and maximum wave amplitude occurred at roughly 12 o'clock. A short calmer period takes place just after 12 o'clock. During afternoon hours the wave levels are around 0.06-0.20 m based on the short-time windows. Some time instances of elevated wave recording can be observed, e.g., during morning, around noon and 17 o'clock some elevated wave level occurs. These are examined in more detail in the following.

Figure 10 shows wave time history and spectra on Wednesday 13.9. A two-peaked shape of the wave spectrum is seen with peaks at 0.04 Hz and at 0.34 Hz, corresponding to wave periods of 25 s and 2.94 s. The longer period corresponds to a wave length of roughly 1 km (in deep water), and might indicate that there could be a standing wave not easily visible to the eyes. Distance to the facing shore is roughly half a kilometre, which would fit for a standing wave. The significant wave height for this day was 0.09 m and a maximum absolute amplitude of the wave was roughly 0.2 m.

Figure 11 shows wave spectra analysed for three-hour windows during the measurement day. Especially in the morning hours a low frequency waves persists. Main spectral peaks occur around 0.34-0.36 Hz. During the day, elevated levels occur from roughly 0.2 Hz upwards with variations of the secondary wave spectral peaks in terms of both magnitude and frequency, depending on the considered time window. Wave spectral magnitudes start to diminish as one proceeds from 21 o'clock towards the night.

Figure 12 shows a spectrogram of wave elevation on Wednesday 13.9. between 08.45-10.45 and 08.45-09.15. Mein Schiff 4 arrived at the port at 09.00, and Viking Line Gabriella arrived at 09.45. Figure 13 shows corresponding wave time histories and spectra. Wave formations are observed during these time windows although it is not very significant. Differences in wave spectra for a two-hour or for whole day are minor, minutely elevated magnitudes being visible at around 0.34 Hz. The significant wave height evaluated for the whole day time history was 0.09 m and for the two-hour window it was also 0.09 m, so there was no change at all. For the one-hour window, slightly elevated magnitudes are seen in the wave spectrum, at 0.24, 0.34 and 0.44 Hz, and the significant wave height for this period was 0.11 m. Note that other vessel traffic was present throughout the day in area and observations are not only for those of the two cruise vessels.

Figure 14 shows wave elevation time histories and spectra for whole day September 13 and between 09.45-10.15 o'clock. During this shorter time window, an Aquador motorboat left the hotel's pier, Waxholmbåt passed by, and also a tow and barge entered the canal.

Notable wave formation occurred near 12 o'clock. Figure 15 shows wave elevation time histories and spectra for whole measurement day and near this time, between 11.30-12.30. Significant wave height was increased for this one-hour window, being 0.12 m. Wave spectral peak is pronounced at 0.32 Hz, and a smaller magnitude peak at 0.52 Hz is seen. Also, the low-frequency spectral peak is notably greater for this time window. In the records and notes taken in the measurement day, no observations were made during this time period. Shortly after 12 o'clock the recorded wave elevation fades, including also the low-frequency component until around 12.30 o'clock.

Figure 16 shows spectrogram of wave elevation on Wednesday 13.9. between 16-18. Figure 17 shows wave elevation time histories and spectra for whole day, between 16-18 and between 17.00-17.30. At 16.30 o'clock cruise ship Mein Schiff undertook a turning manoeuvre turning her bow to South. At this time, Flow tracker measurement recorded flow speeds ~20 cm/s. During the turning manoeuvre also smaller vessels passed the site that contributed to the wave elevation. For the shorter two-hour time window, slightly higher magnitudes are seen in the wave spectrum, e.g., at 0.26 and 0.36 Hz, also higher-frequency part being generally a bit elevated. The significant wave height for this period was 0.11 m. Between 17.00-17.30 also a spectral peak at around 0.28 Hz is elevated, at the same time the low-frequency peak being smaller, and the significant wave height for this half-hour period was 0.12 m.

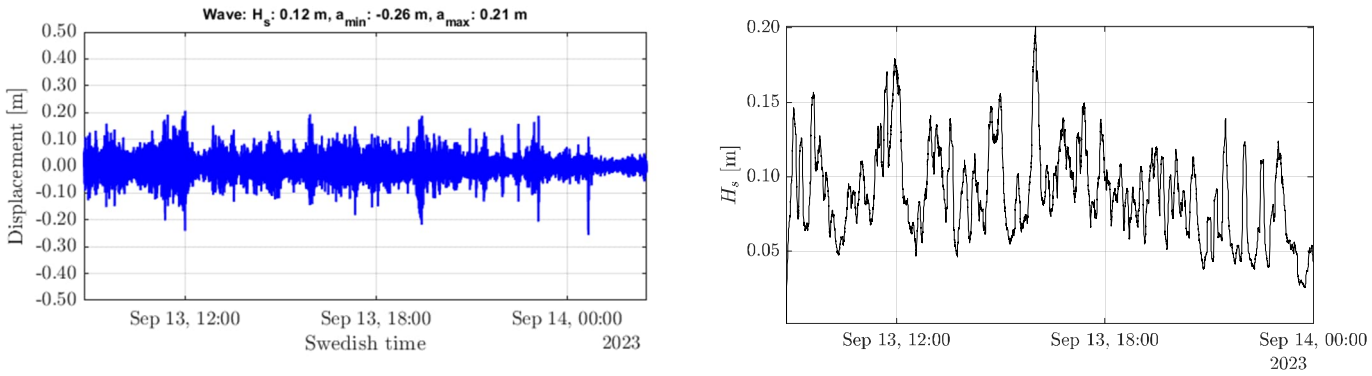


Figure 9. Wave time history and significant wave height based on 20 min of moving rms. Recorded with Datawell buoy.

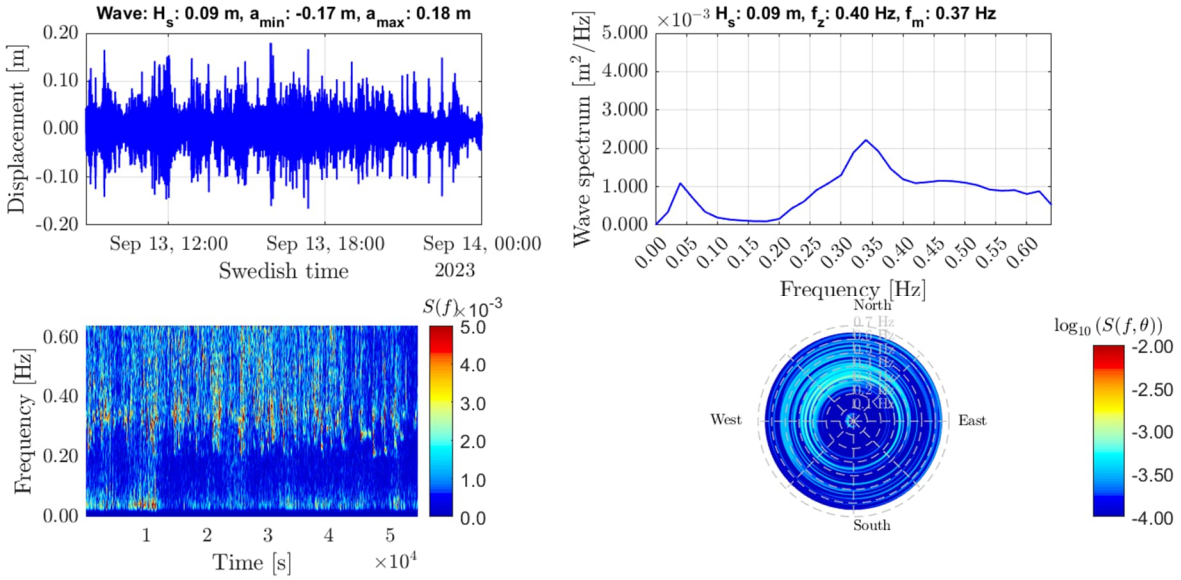


Figure 10. Wave time history and spectra for Wednesday 13.9.

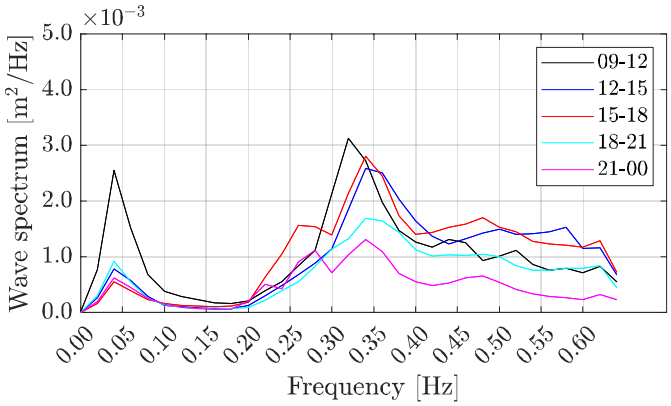


Figure 11. Wave spectra at different three-hour time windows for Wednesday 13.9.

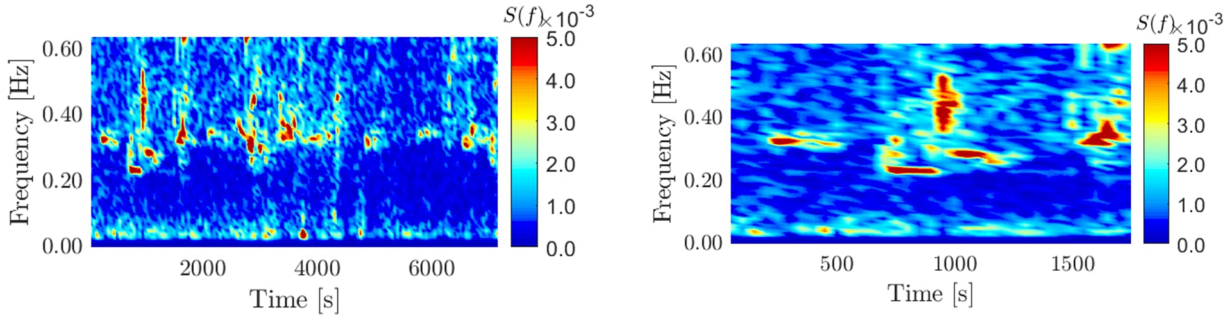


Figure 12. Spectrogram of wave elevation on Wednesday 13.9. between 08.45-10.45 (left) and 08.45-09.15 (right).

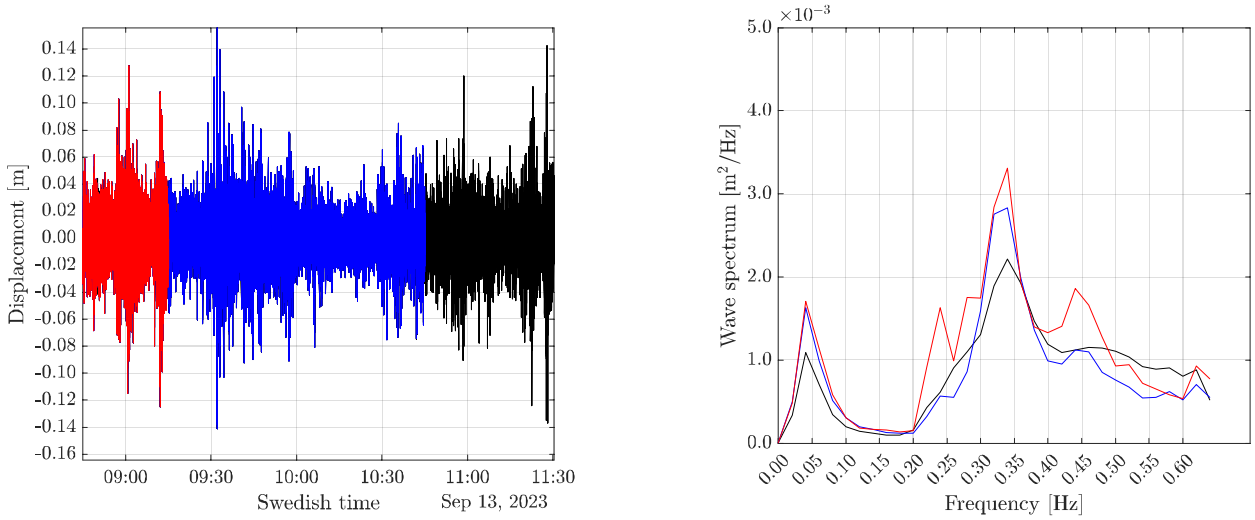


Figure 13. Wave elevation time histories and spectra for whole September 13 (black) and between 08.45-10.45 (blue) and between 08.45-09.15 (red).

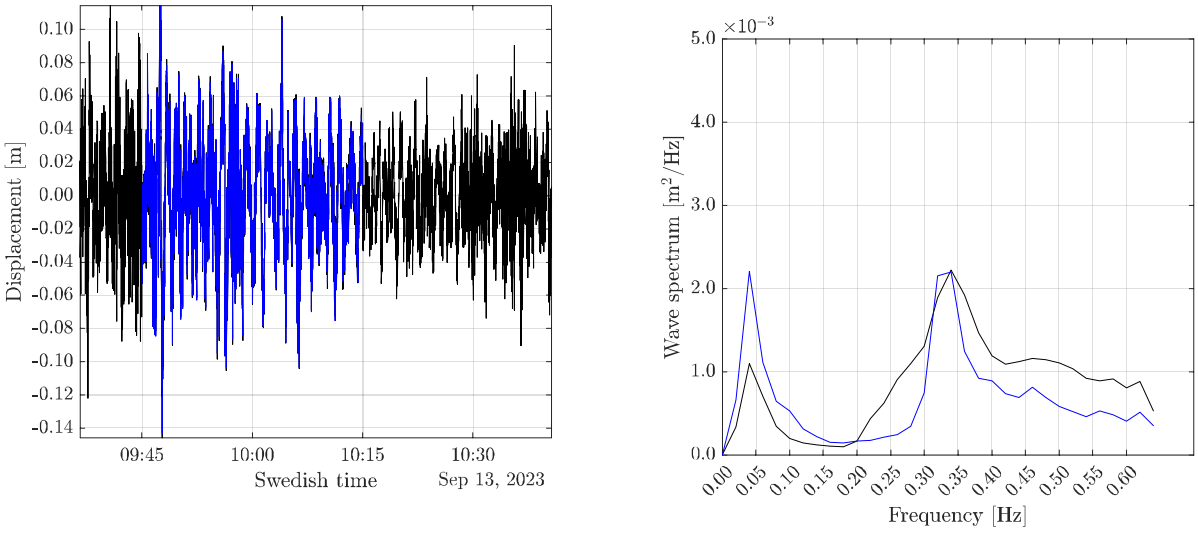


Figure 14. Wave elevation time histories and spectra for whole September 13 (black) and between 09.45-10.15 (blue).

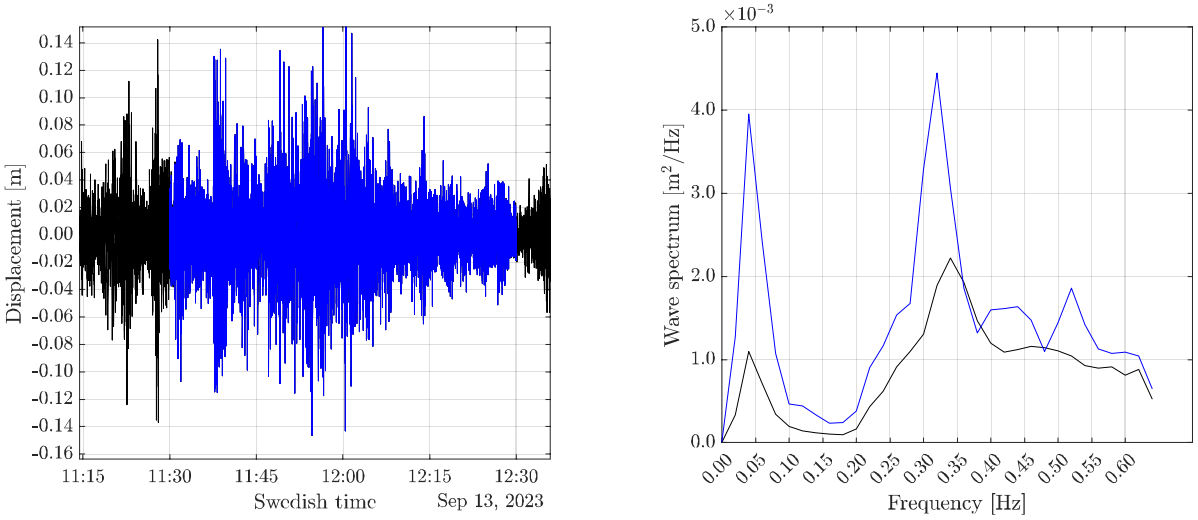


Figure 15. Wave elevation time histories and spectra for whole September 13 (black) and between 11.30-12.30 (blue).

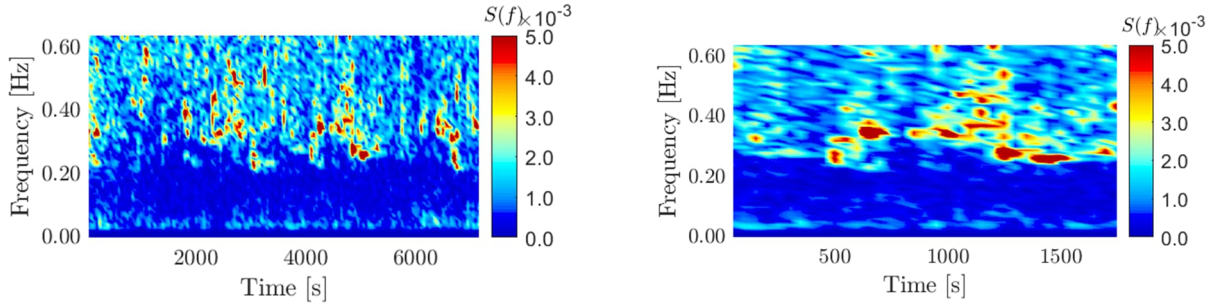


Figure 16. Spectrogram of wave elevation on Wednesday 13.9. between 16-18 on the left, and between 17.00-17.30 on the right. Vertical axis shows time in seconds together with the local Swedish time.

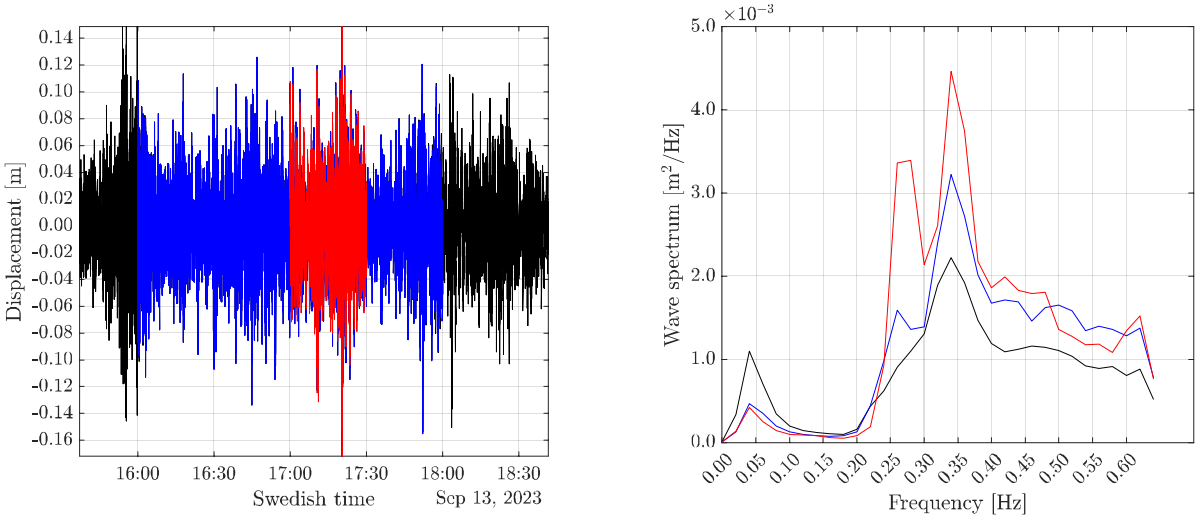


Figure 17. Wave elevation time histories and spectra for whole September 13 (black), between 16.00-18.00 (blue), and between 17.00-17.30 (red).

3.2. Wave conditions based on measurements of one month

Sofar Spotter wave buoy was deployed between September 14 – October 16. Wave spectra from Sofar Spotter buoy measurements are collected in Appendix 5. Scatter diagram based on significant wave height and mean wave period and the directional distribution of the significant wave height, are shown in Figure 18. Figure 19 shows histograms of significant wave height, mean wave period and direction. Figure 20 shows significant wave height recorded with Sofar Spotter based on 30 min segments, and Figure 21 the corresponding mean wave period.

Data from the Swedish Meteorological and Hydrological Institute SMHI were collected for wind speed and direction for two measurement stations near Stockholm. The locations of the measurement stations were shown in Figure 8. Figure 24 shows wind speed and direction for Bromma and Skarpö observations between September 13 – October 16, 2023. Figure 25 shows wind speed and direction distributions based on observations at Bromma and Skarpö.

Most waves occur between roughly 8 – 17 cm with mean periods between 2-4 s (0.5-0.25 Hz). Some instances of significant wave height being greater than 30 cm occur during the measurement period as seen in Figure 19. Waves also occur at greater periods between 8-10 s (0.125-0.1 Hz). Typical wave direction is from roughly 315-45 degrees sector, centering mainly around North or between North-Northeast. Low-frequency spectral content at around 0.04-0.06 Hz corresponding roughly to 24-26 seconds persists in the measurements, and, in addition, elevated spectral magnitude occurs typically between roughly 0.2-0.7 Hz depending on analysed time period. The higher-frequency spectral peaks' locations also vary by the temporal window under consideration.

Figure 22 shows distributions of wave amplitude maxima and minima recorded by Spotter buoy between September 14 – October 16. The global recorded maximum value was 0.52 m and minimum was -0.51 m. The greatest global maximum amplitude value occurred on September 24 at around 14.15, and the greatest global minimum on October 7 at around 09.22. These are illustrated in Figure 23.

Greatest significant wave height of 0.34 m recorded by the Spotter buoy occurred on October 7th at 07.37 UTC time, corresponding to 09.37 Swedish time. Figure 26 shows wave time history and short-term spectra around that time. Based on weather data from Stockholm in October (Figure 24) elevated wind levels were recorded which can explain observed increase in the significant wave heights in Figure 20.

Figure 26 shows wave elevation time history and spectrogram between October 6-9. Observing these graphs together with the development of the significant wave height, shown in Figure 20 with corresponding mean wave period in Figure 21, in the beginning of October reveals an increase as we proceed few days ahead from October 6. Furthermore, Figure 27 shows wave time history and significant wave height based on 20 min of moving rms. Values for October 7 between 08-18 Swedish time. Figure 29 displays wind speed and direction for Bromma and Skarpö observations between roughly October 6-10, 2023. Prevailing wind direction was mainly from 270-315 degrees sector, corresponding roughly to West-Northwest.

Figure 30 shows wave time history and spectral representations on October 7 between 16.45-17.15 (30 min period). A triple-peaked shape of the wave spectrum is observed for this particular instant with spectral peaks at 0.08 Hz, 0.27 Hz and 0.59 Hz, corresponding to periods of roughly 12.5 s, 3.7 s and 1.7 s. For reference, wave spectrum and spectrogram for October 7 between 08-18 Swedish time are shown in Figure 28 for which duration a two-peaked spectrum is pronounced with the middle peak attenuated. Based on SMHI data, elevated wind speed levels are also observed to occur also later on in October, but these did not result in similar clear increase in the measured wave elevation for the particular duration.

Sea spectra can be used to establish mean wave characteristics, which describe a sea condition created across a sea area by a wind blowing at a specific strength and duration. For example, the sea state that results from a wind blowing with a certain magnitude for a specific duration across a particular sea area, or the fetch, can be defined using wave height and wave period. Figure 31 shows significant wave height versus wind speed at different fetches and durations determined based on an on-line calculator[1]. Estimations of fetches for the site are drawn in Figure 32. Longest possible open fetch for the wind is from East-Northeast, being ca. 2 km. In Figure 31, fetches 2 and 3 km are evaluated at different durations. As an example, for a fetch of 2 km, wind of 20 m/s blowing for one hour results in a significant wave height of 0.65 m and the peak period was 2.4 s, or a fetch of 3 km with wind of 26 m/s blowing for one hour the estimated significant wave height is 1.09 m with a peak period of 3.0 s.

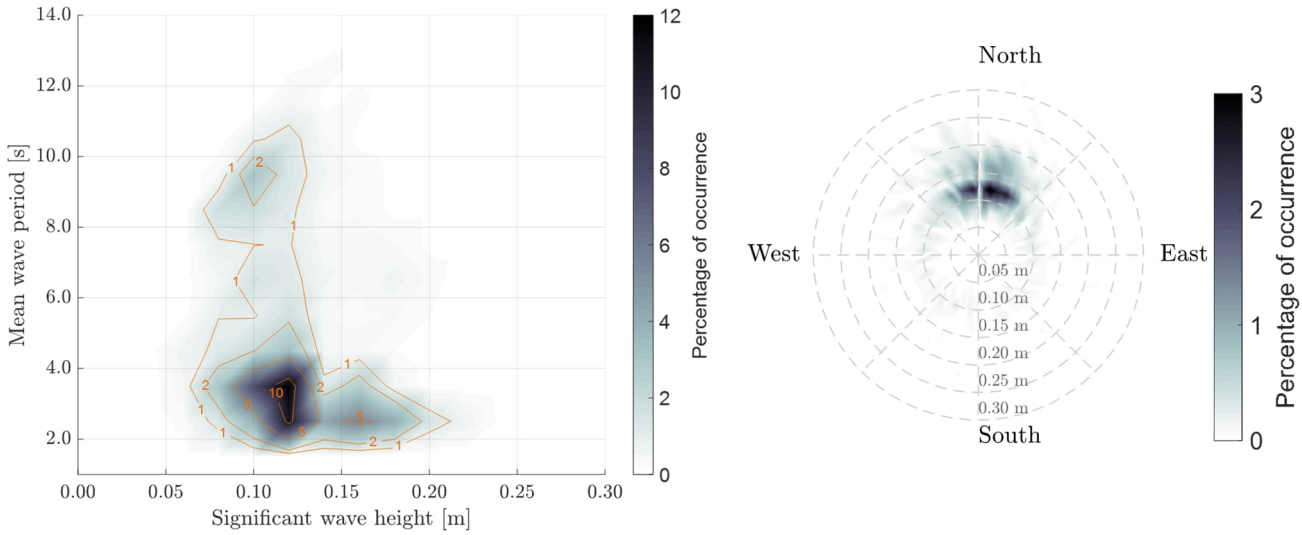
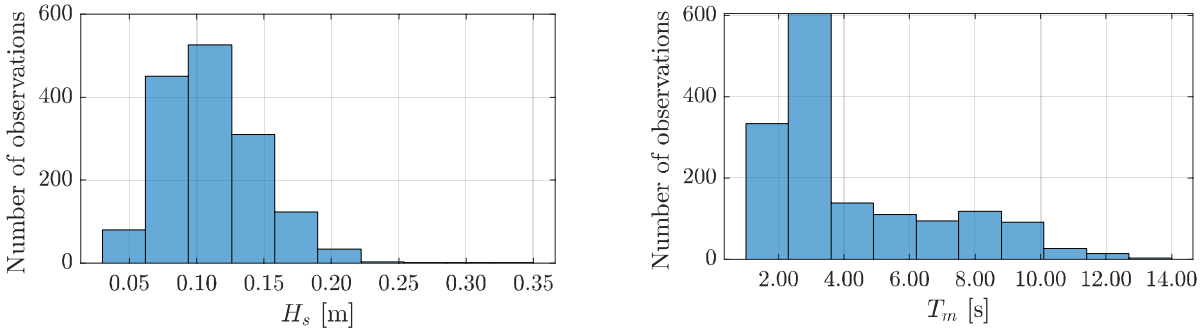


Figure 18. Scatter diagram of mean wave period and significant wave height, and wave direction from Sofar Spotter buoy based on 30 min segments. On the left, the radii depict the H_s values.



[1] https://swellbeat.com/

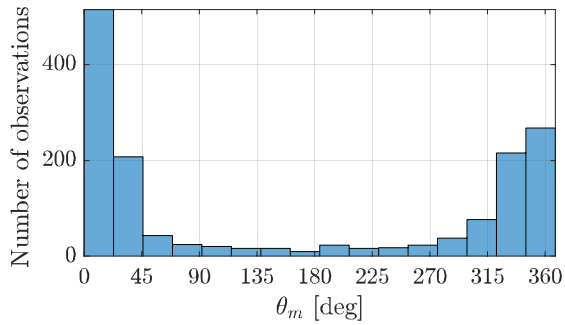


Figure 19. Histogram of significant wave height, mean wave period and direction recorded with Sofar Spotter based on 30 min segments.

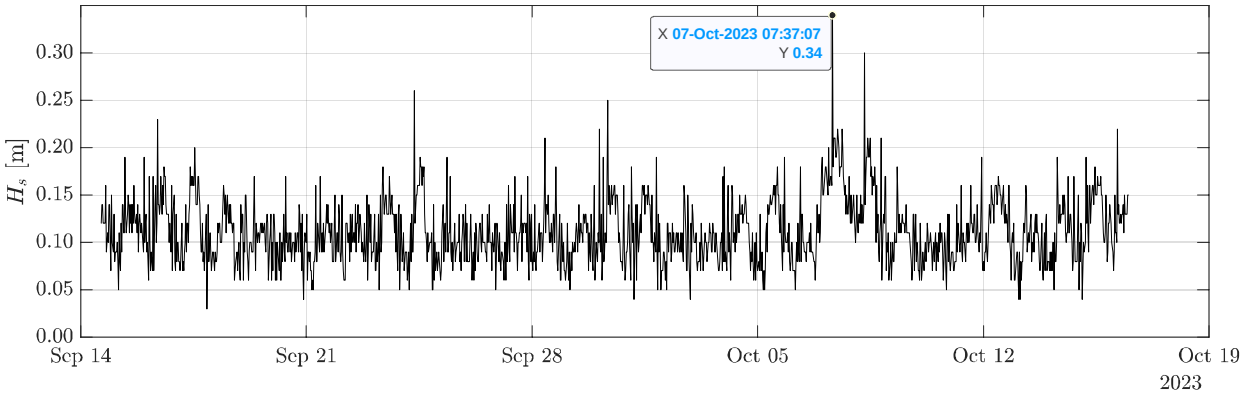


Figure 20. Significant wave height recorded with Sofar Spotter based on 30 min segments. Occurrence of greatest recorded significant wave height is also highlighted. X-axis is in UTC time (Swedish time -2 hrs.).

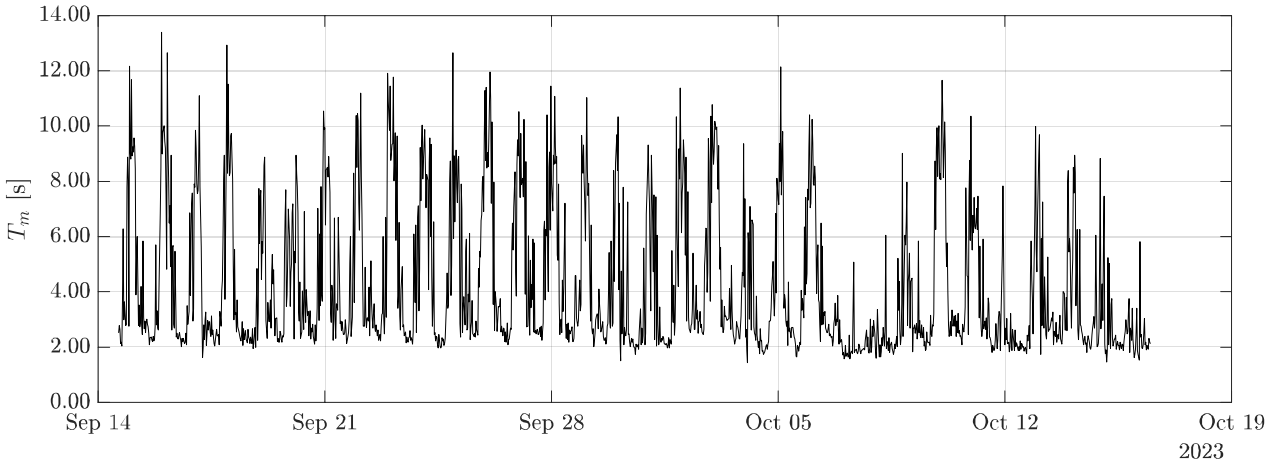


Figure 21. Mean wave period recorded with Sofar Spotter based on 30 min segments.

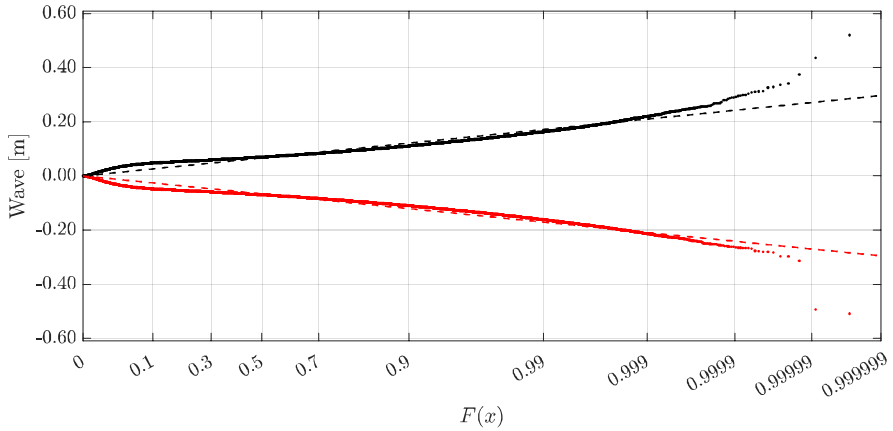


Figure 22. Distributions of wave maxima and minima recorded by Spotter buoy between September 14 – October 16. Corresponding theoretical Rayleigh distributions are also shown as the dashed lines.

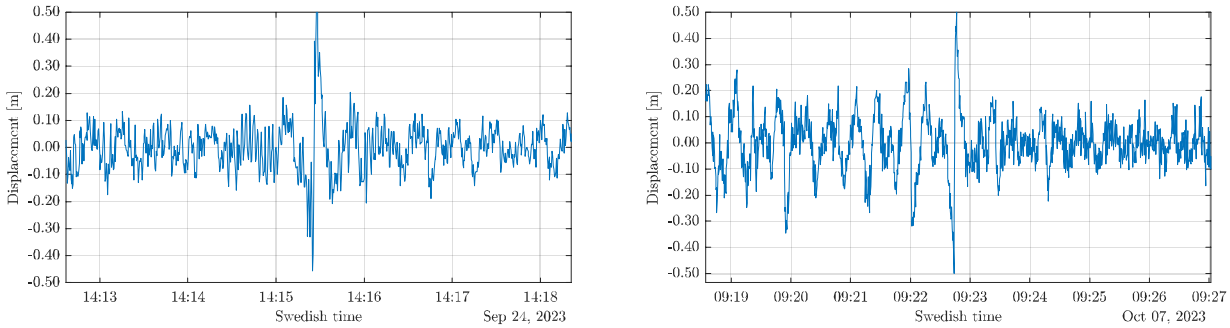


Figure 23. Occurrences of greatest global maximum (left) and minimum (right) wave amplitudes.

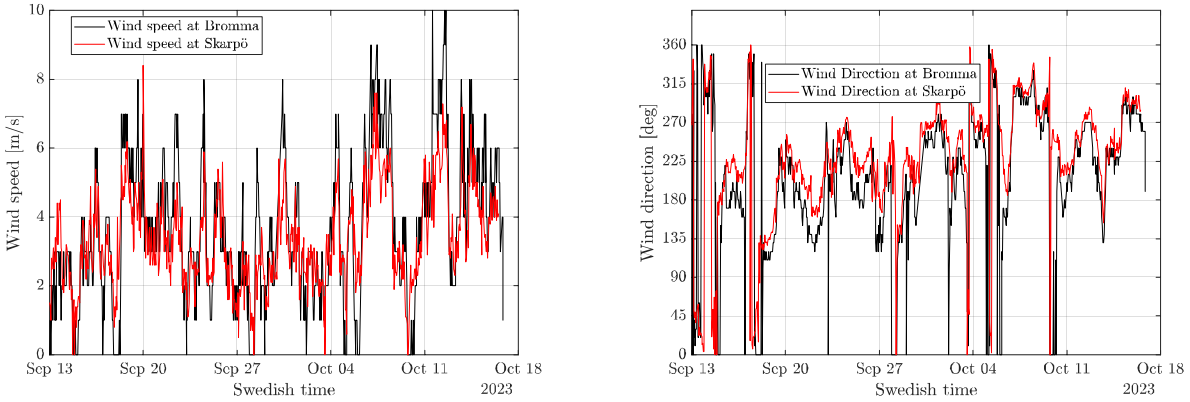


Figure 24. Wind speed and direction for Bromma and Skarpö observations between September 13 – October 16 2023.

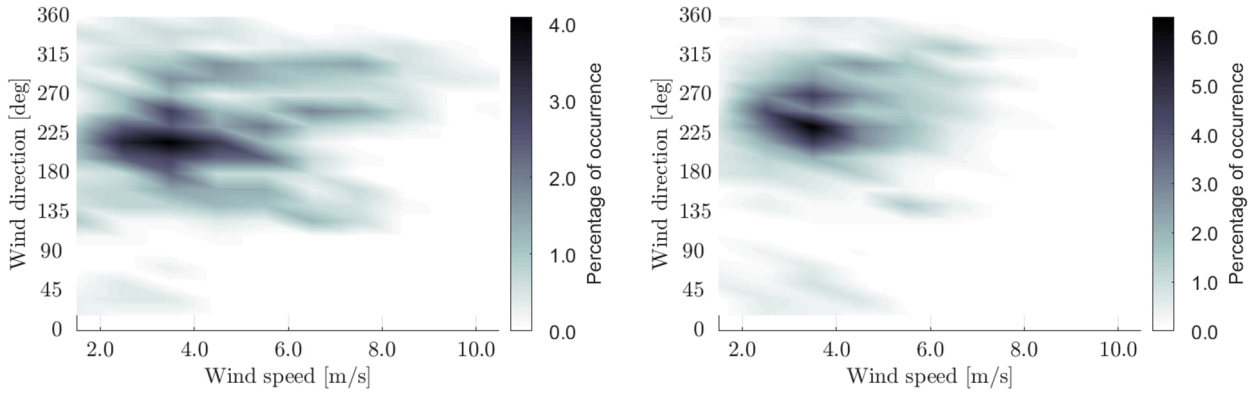


Figure 25. Wind speed and direction distributions for Bromma (left) and Skarpö (right) observations. North corresponds to 0 / 360 degrees, West to 270 degrees, South to 180 degrees and East to 90 degrees.

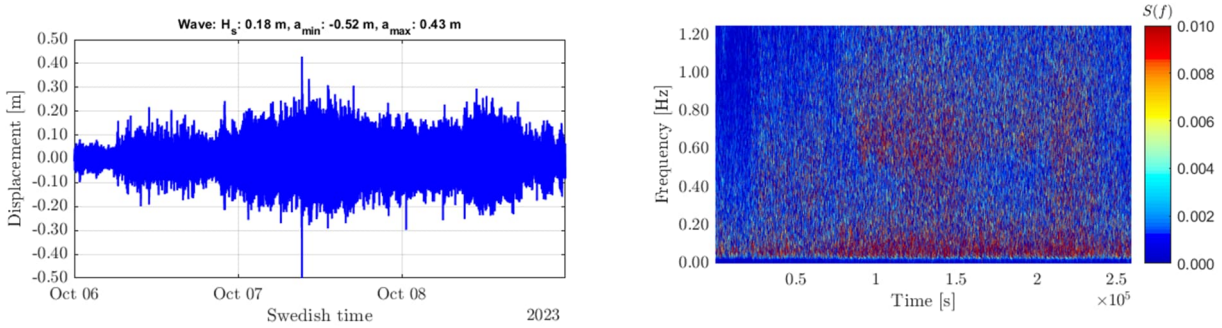


Figure 26. Wave elevation time history and spectrogram between October 6-9.

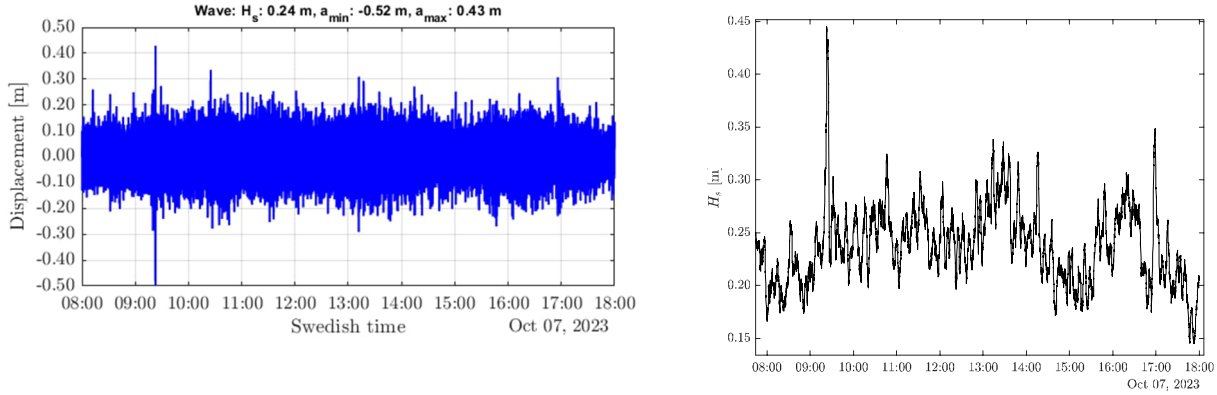


Figure 27. Wave time history and significant wave height based on 20 min of moving rms. Values for October 7 between 08-18 Swedish time.

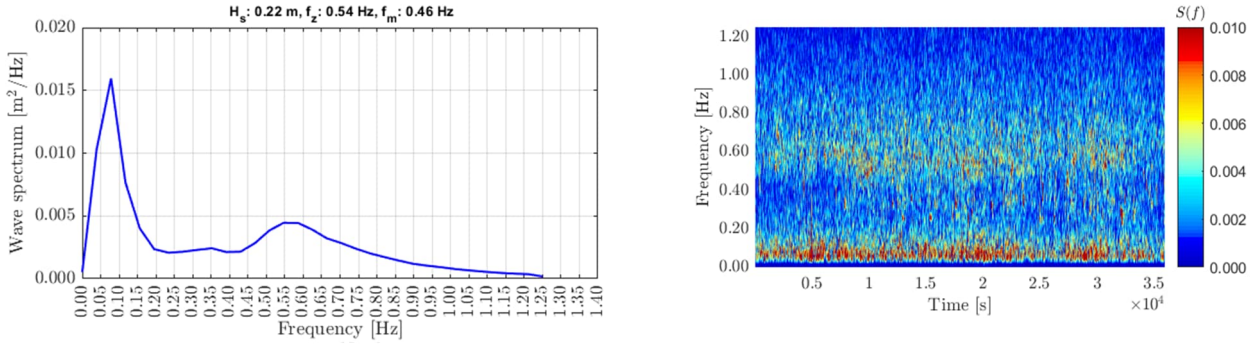


Figure 28. Wave spectrum and spectrogram for October 7 between 08-18 Swedish time.

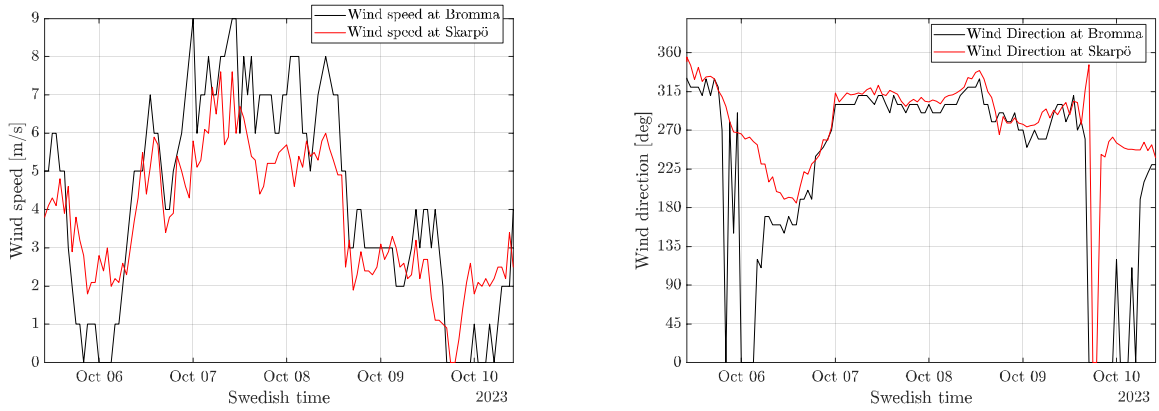


Figure 29. Wind speed and direction for Bromma and Skarpö observations between roughly October 6-10, 2023.

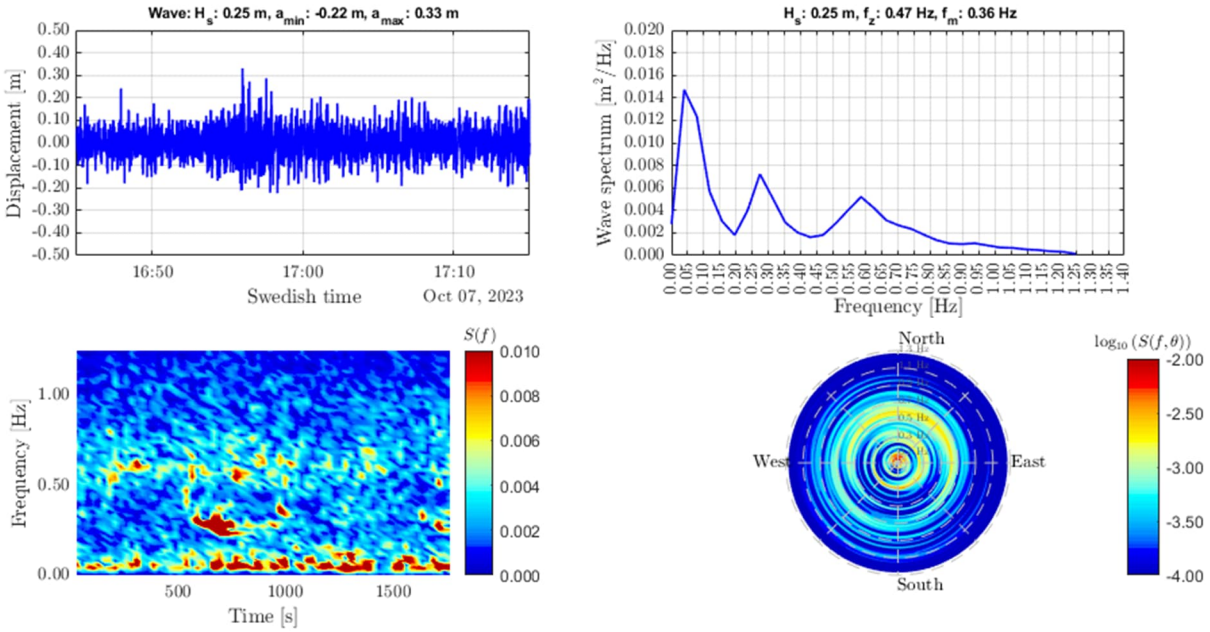


Figure 30. Wave time history and spectral representations on October 7 between 16.45-17.15 (30 min period).

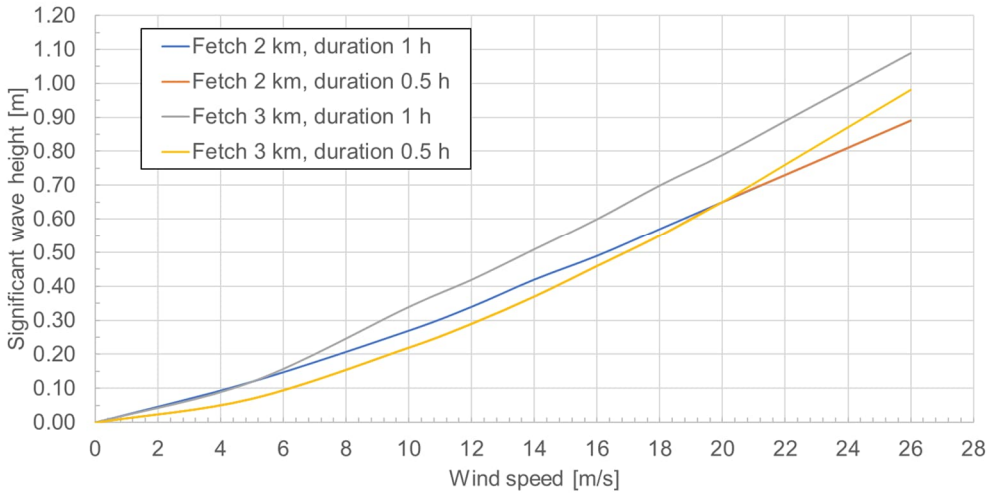


Figure 31. Significant wave height versus wind speed at different fetches and durations.

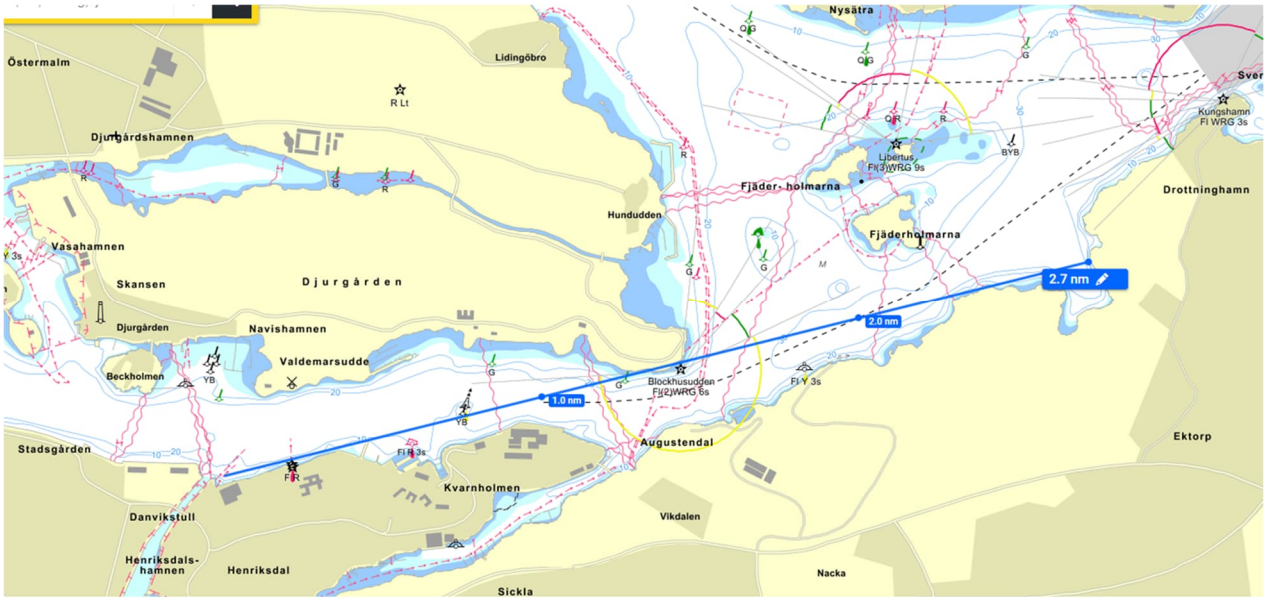


Figure 32. Estimation of maximum fetch values for the site. One nautical mile (nm) corresponds to 1.852 km (Eniro Sjökort).

3.3. Water flows on site

The Elite hotel and the planned floating spa and sauna building are located on a side of a very busy waterway. Local commuter ferries are passing by several times an hour. A pier for commuter traffic is located next to the planned floating building. Bigger Viking Line ferries sail past the hotel every morning and evening. Also, a cruise ship terminal for large passenger cruisers is located only 200 m west from the site. In Figure 33 is a screenshot from the Marinetraffic-web page when a large cruise ship was turning around ahead of the hotel.

During the measurement days in September two large TUI-cruisers, namely Mein Schiff 1 and Mein Schiff 4, turned around in front of the Elite hotel. Since wind was almost calm the ships did not have to use large power settings for turnaround. Also, both ships turned around counterclockwise, i.e., bow towards south, so that the main propeller's flow headed north and only the bow propellers caused some water flow towards the hotel pier. Distance from the measuring point to the ship bow was around 100 m, Figure 34.

Propeller induced flow is depending on the power used by the propeller of the ship for manoeuvring situations. No significant flow velocity magnitudes were recorded in the on-site measurements. Figure 35 shows time history of recorded speed during departure of MS1. Maximum measured flow speed was 0.15 m/s. If a large ship turns around so that her bow is heading North and the main propellers are close to the site, it is possible that the local flow speeds are much higher, up to ten metres per second.

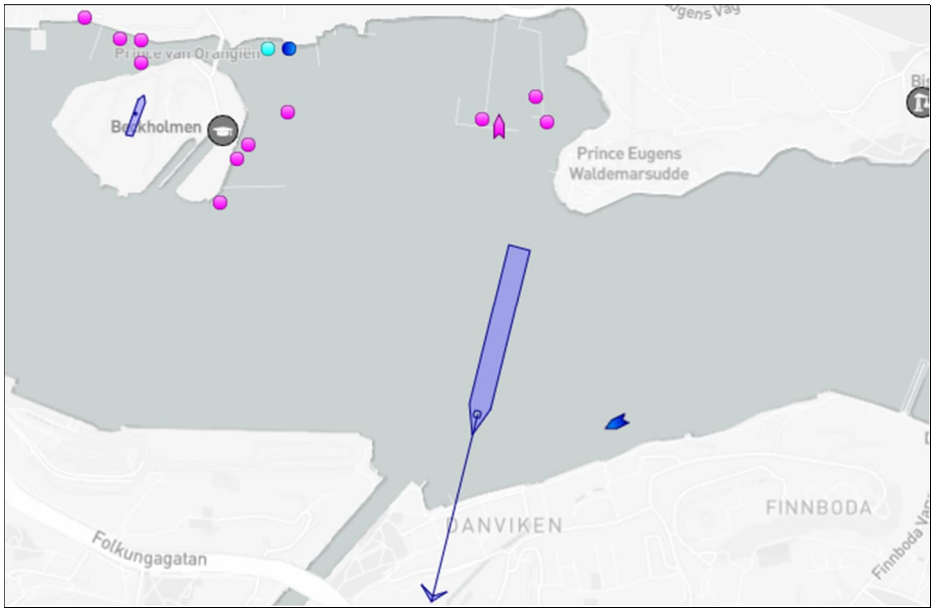


Figure 33. A 315 m long cruise ship turning around on the Saltsjön (Marinetraffic.com).



Figure 34. Mein Schiff 4 turning around close to the Elite hotel.

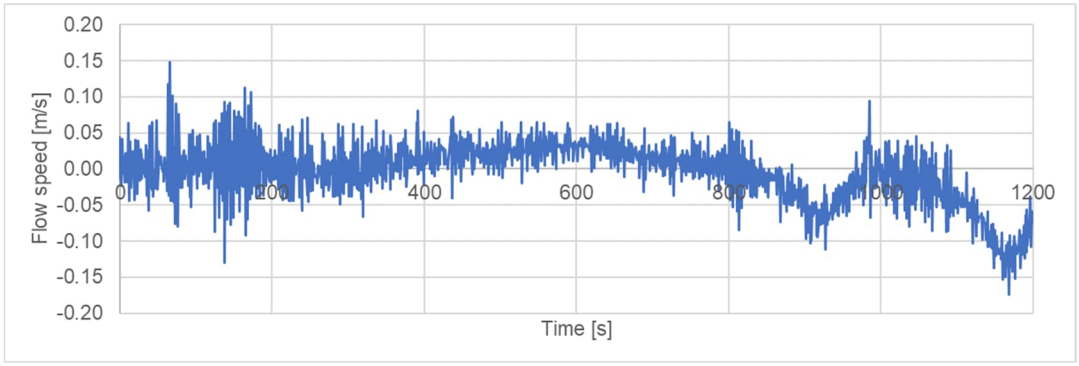


Figure 35. Time history of flow speed during departure of MS1.

In the Baltic Sea, the tidal phenomenon is practically negligible. The sea water level varies depending on weather conditions, e.g., wind direction, atmospheric pressure, precipitation. Sea water level of the Saltsjön may vary around ±100 cm.

Outflow from the lake Mälaren comes mostly through the city of Stockholm and flows pass the Elite hotel. Major part of the flow from Mälaren comes through Saltsjön via Slussen and Norrström. A part of the outflow from Mälaren flows via Danvikskanalen next to the Elite hotel. During the measurement days the water flow through Danvikskanalen was visually noticed but it was not observed to reach the measurement position. According to the SMHI statistics the total flow from lake Mälaren was around 400 m^3/s during the measurement days which is shown in Figure 36.

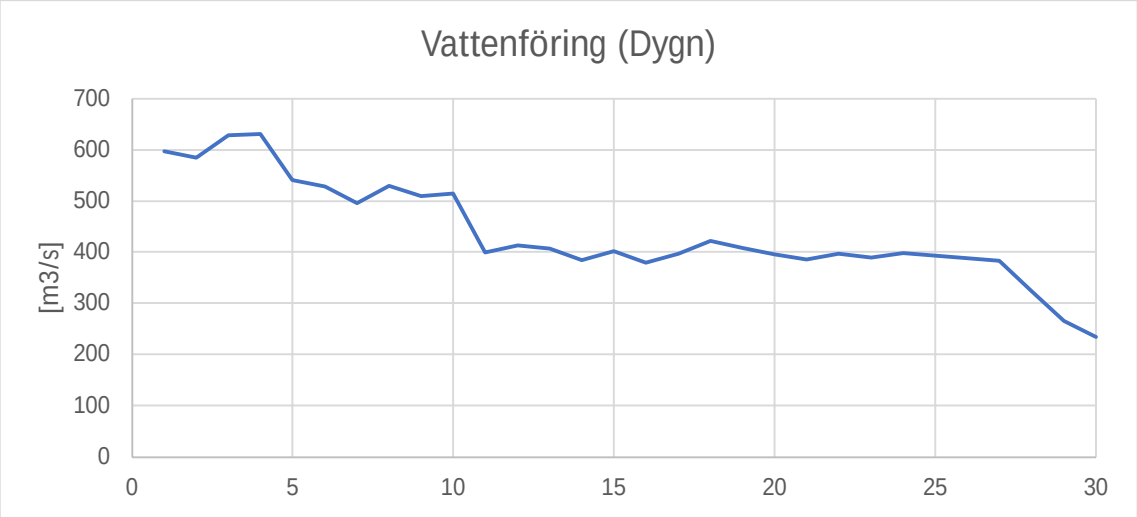


Figure 36.Outflow from Mälaren in September 2023. X-axis shows days.

The cross section area of the main channel (Saltsjön), when viewed to the opposite shore at the hotel, can be estimated to be 8000 m^2. Using this cross-section area, the main flow velocity can be calculated. In September during the measurement days the mean flow speed was 0.05 m/s. The planned maximum flow rate from lake Mälaren through city of Stockholm can be around 1950 m^3/s, which gives mean flow speed of 0.24 m/s (Andréasson et al., 2011).

The position of the planned spa and sauna building is relatively well protected against the natural current effects from Mälaren, since it is sheltered by the small point between the Danvikskanalen and the hotel front.

4. Responses of the floating building

Wave induced motions of the floating building can be predicted based on the main dimensions and other design data of the floating building. The wave measurements carried out in the present study revealed mostly relatively mild conditions. In general, long-term distributions and estimates of wave heights and periods require measurement or hindcast simulation data that spans preferably several years at the site. It is generally necessary that measurement span covers at least one, or more, complete climatic cycle. Using long-term data seasonal variations can be detected and identified, and the more comprehensive set of measurements can be used to compile scatter diagrams and directional distributions, and prognoses can be derived for extreme values and their probabilities of exceedance.

Moreover, forces on the floating building, caused by the ship propellers and natural flow, can be estimated once the general shape and characteristics of the structure are known. Estimation of forces as well as motions and their periods using simplified methods requires design information of the floating structures, that is, mass and hydrostatic data. This estimation is anticipated to be carried out in a following phase if progress of the pool design project is expected. Refined studies of the structures' responses to waves and currents can be carried out using theoretical methods and model-scale tests.

5. Summary

Bluet Ltd is planning to design and construct a floating spa and sauna building in the port of Stockholm. To study environmental and wave conditions on site, VTT has carried out measurements during autumn 2023. A two-day measurement campaign took place in September. Additionally, VTT's wave buoy was deployed that provided measurement data for a period of one month after the on-site campaign. Additionally, data from SMHI was compiled for wind speed and direction for two measurement stations near Stockholm, and flow rates in the port area.

The Elite hotel and the planned floating spa and sauna building are situated near a busy waterway. Local commuter ferries pass by several times an hour, and in addition, a pier for commuter traffic is located next to the planned floating building. Bigger Viking Line ferries sail past the hotel every morning and evening. A cruise ship terminal for large passenger cruisers is located only 200 m west from the site. Risk of ship collision or loads due to sea ice are not included in the present study.

The position of the planned floating building is relatively well protected against the natural current effects from Mälaren, since it is sheltered by the small point between the Danvikskanalen and the hotel front. Outflow from the lake Mälaren comes mostly through the city of Stockholm and flows pass the hotel. During the measurement days, water flow through Danvikskanalen was observed visually.

In the Baltic Sea, the tidal phenomenon is practically negligible, and the sea water level varies depending on weather conditions. Sea water level of the Saltsjön may vary around ±1 m.

Wave buoy measurements are analysed based on time domain and frequency domain methods to provide insight and statistics into wave conditions on the measurement site. Majority of waves range from 8 to 17 cm in significant height, with mean periods of 2 to 4 s (0.25-0.50 Hz). Some instances of significant wave height being greater than 30 cm occurred during the measurement period. Waves also were observed at greater periods between 8-10 s (0.10-0.13 Hz), and wave spectra showed contributions of even longer waves with periods of 17-25 s (0.04-0.06 Hz). Varying magnitudes of wave spectra and spectral peaks can be seen at different frequencies depending on used length of the analysis time window. Based on also the in-situ observations, the cruise ships arrive and depart the port at slow speed, where the wave making of the ships Is generally negligible. Typical wave direction centred mainly around North or between North-Northeast.

Fetch and duration of wind were used to estimate harsher conditions on site. As an example, for a fetch of 2 km, wind of 20 m/s blowing for one hour results in a significant wave height of 0.65 m. This means that single maximum wave heights of roughly two times this value, that is, 1.3 m, can be expected in this particular condition.

Estimation of motion periods for floating structures using simplified theoretical methods requires design information of the structures, that is, mass and hydrostatic data. This estimation is anticipated to be carried out in a following phase if progress of the pool design is expected. Refined studies of the structures' responses to waves and currents can be carried out using theoretical methods and model-scale tests.

Measurement data compiled in the present project can be utilised when planning a model-testing or numerical analyses campaigns for more detailed determination and analyses of expected motions of the floating construction to aid in design of the structure and possible mooring solutions. However, long term distributions and estimates of wave heights and periods require measurement or hindcast simulation data that spans preferably several years at the site. It is generally necessary that measurement span covers at least one, or more, complete climatic cycle. Using long-term data seasonal variations can be detected and identified and the more comprehensive set of

measurements used to compile scatter diagrams and directional distributions, and prognoses derived for extreme events and their probabilities of exceedance.

6. References

Andréasson, J., Gustavsson, H., Bergström, S. (2011). Projekt Slussen – Förslag till ny reglering av Mälaren. SMHI Rapport Nr. 2011-64.

SMHI, Sveriges meteorologiska och hydrologiska institute. Open data. smhi.se/data.

7. Appendices

Appendix 1	List of Symbols
Appendix 2	Analysis procedures
Appendix 3	Results of wave measurements at Port of Stockholm 2023
Appendix 4	Results of wave measurements at Port of Stockholm 2023 Graphs from Datawell buoy measurements
Appendix 5	Results of wave measurements at Port of Stockholm 2023 Graphs from Sofar Spotter buoy measurements