

Wave climate in the Baltic Sea 2021

Authors:

Heidi Pettersson, Marine Research, Finnish Meteorological Institute
Thorger Brüning, Bundesamt für Seeschifffahrt und Hydrographie
Magnus Larsson, Swedish Meteorological and Hydrological Institute

Key message

In 2021, June was the calmest month of the year for all the stations where measurements were available, except in Skagerrak. North of 58° N October was the roughest month, while at southern stations October - December were typical for the season. Some monthly records of significant wave height were observed, but no yearly record values were reached.

Results and assessment

In 2021 waves were measured in 10 locations in the Baltic Sea and Skagerrak (Figure 1) using buoys or a directional radar gauge. These measurement systems provide real time information of the sea state for professional and free time navigation. The wave measurements are also important for wave related research and wave model development. As waves contribute to the mixing of the surface layer and their influence can extend to the bottom (resuspension) the information about the yearly wave activity adds to the understanding of the physical environment of the Baltic Sea.

The monthly mean values of significant wave height (see the definition of significant wave height in section Metadata) are plotted in Figures 2 and 3, and the highest values of significant wave height are shown in Figures 4 and 5. Figures 6 and 7 show the year-to-year variation of the mean significant wave height in June-July and October-November.

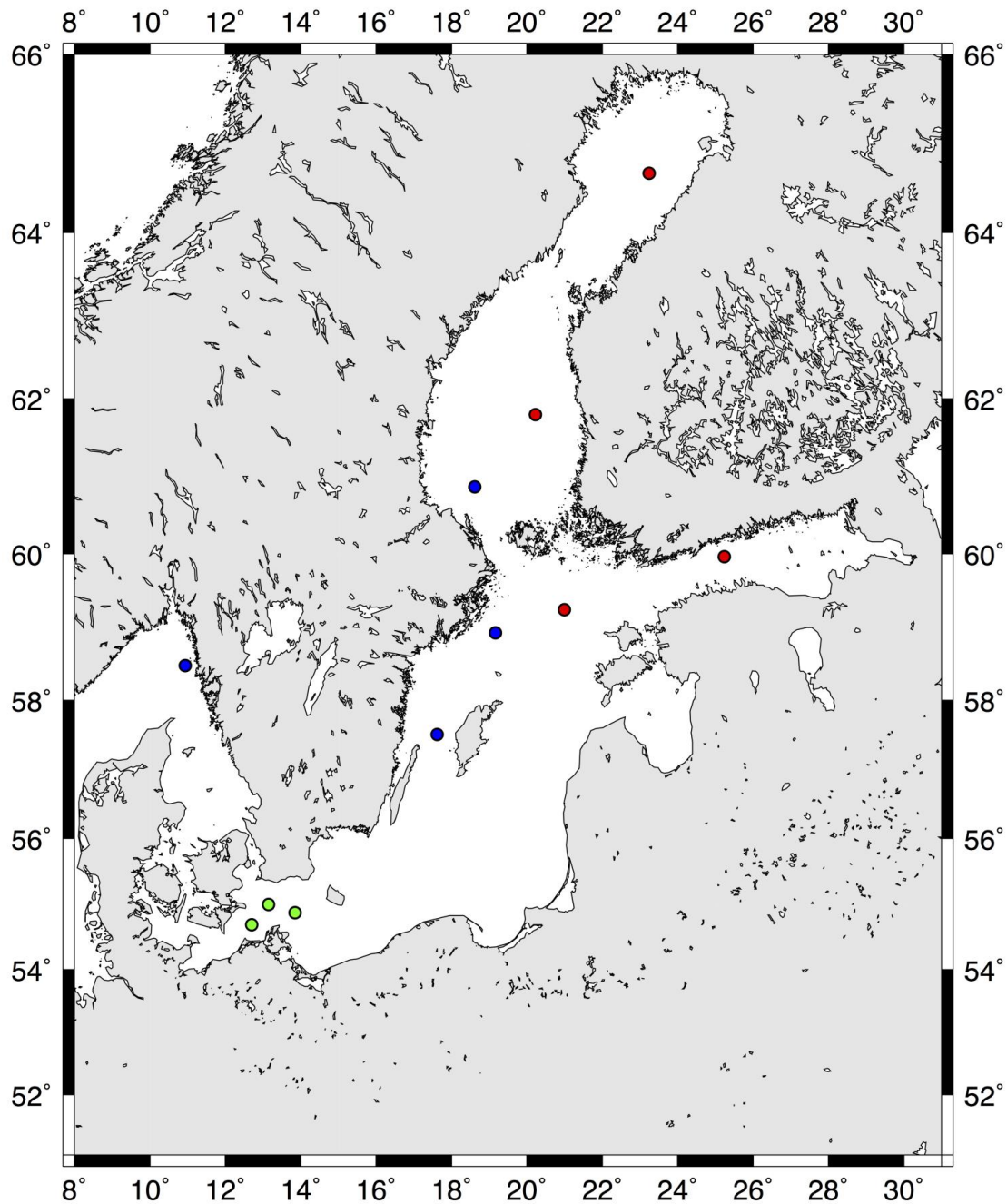


Figure 1. The positions of the wave monitoring stations in 2021. Red dots indicate FMI buoys in the Bay of Bothnia, in the Bothnian Sea, in the Northern Baltic Proper and in the Gulf of Finland (station Helsinki), blue dots SMHI buoys in the Southern Bothnian Sea (station Finngrundet), in the Baltic Proper (stations Huvudskär Ost and Knolls Grund) and in Skagerrak (station Väderöarna) and green dots the BSH stations in the Western Baltic Proper: Fino 2 (a directional radar gauge), off Cape Arkona and on the Darss Sill (buoys). See section Metadata for the exact coordinates of the locations.

The Gulf of Bothnia

The Bay of Bothnia

In 2021 the wave buoy in the Bay of Bothnia was recovered 9 January, redeployed 6 June, and recovered again 25 November.

At the buoy location, the mean significant wave height during summer months remained close to the long-term mean values. From September to November slightly calmer-than-average months alternated with rougher-than-average months and the roughest month of the measurement period was October with a mean significant wave height of 1.2 m. The monthly maxima remained below the maxima since 2012, increasing steadily towards November: the highest significant wave height for the measuring period was 3.5 m on 15 November.

The Central Bothnian Sea

The wave buoy in the Central Bothnian Sea was operational throughout the year 2021.

The first two months of the year 2021 were calmer than usual followed by rougher March and April. The summer months were typical for the season. Like in the Bay of Bothnia, the roughest month was October when the mean significant wave height was 1.6 m. December was slightly calmer than usual. The highest significant wave height, 5.3 m, was measured on 12 January during south-east high winds. A new monthly record, 4.9 m, was measured twice during a north-western storm, on 6 and 7 March, while in February, the significant wave height did not exceed 2.9 m (13 February).

The Southern Bothnian Sea, station Finngrundet

The wave buoy at station Finngrundet was in 2021 operational in January and from the end of April onwards. During most of February, March and April the station was out of operation.

In general the station had no extreme wave heights recorded during the year and the mean significant wave heights were near the normal in most months, in May, August, October and December slightly above the normal. The roughest months of the year were October and December with a mean significant wave height of 1.2 m. Notable is also August with its 1.0 m mean significant wave height.

January was near normal, but a deep low over central Scandinavia 11-12 January caused this year's highest significant wave height at the station with 3.6 m. This is far from the overall highest significant wave height of 6.4 m, recorded in January 2019.

Other dates with significant wave heights of around 3 m was 27 May (3.2 m), 26 August (2.9 m), 15 October (3.4 m) and 19 December (3.5 m).

The Gulf of Finland

The middle parts of the Gulf of Finland, station Helsinki

The wave buoy in the Gulf of Finland was recovered 18 January and redeployed 1 April. The buoy was operational to the end of the year 2021.

The wave conditions at this station were rather typical, slightly calmer months alternated with the slightly rougher ones. June was rather calm with a mean significant wave height of 0.4 m and August clearly rougher than usual (0.9 m). Like in the other stations around the Finnish coast, October was the roughest month of the measuring period with a 1.2 m mean significant wave height. Monthly records since 2001 were measured on 26 May (3.4 m) and on 22 October (4.6 m). The latter was also the highest significant wave height for the measuring period.

The Baltic Proper

The Northern Baltic Proper, stations Northern Baltic Proper and Huvudskär Ost

The wave buoy at station Northern Baltic Proper was operational through 2021.

Similarly to the conditions in the Gulf of Finland and the Bothnian Sea, the monthly mean significant wave heights in the Northern Baltic Proper were lower than in the average during the first two months of the year followed by a rougher March and April. From June to December the pattern with alternating slightly calmer and rougher months was observed. June was the calmest month of the year, the mean significant wave height was 0.5 m and October was the roughest month of the year with a mean significant wave height of 1.8 m. The highest significant wave height at this station was measured on 12 January, 6.2 m during strong southerly winds. A new monthly record was observed on 9 April, 5.9 m. In February, the significant wave height exceeded 0.6 m most of the time but remained under 2.3 m (26 February). This value was the lowest monthly maximum in 2021.

The wave buoy at station Huvudskär Ost was 2021 fully operational from 18 March until 9 November. The buoy was out of operation in the beginning and end of the year.

As was the case with the buoys in Gulf of Finland and the Bothnian Sea, April was a rougher than normal month with a mean significant wave height of 1.0 m. Also August was rougher than normal (1.1 m). The roughest month of the year was October with a mean wave height of 1.5 m. Else during the operational period, the mean significant wave heights were near or just below the normal. June was the calmest month, with a mean significant wave height of 0.5 m.

The highest significant wave height this year was recorded on 9 April, 4.6 m due to strong southwesterly winds. This was also a new monthly record high for April, but well below the overall record high for this station, 5.7 m, recorded in November 2010.

Central Baltic Proper, station Knolls Grund

The wave buoy at station Knolls Grund was operational the entire 2021 except for some minor gaps in the measurements in December.

The mean significant wave height was near the normal during most months with the calmest period May to July. June had the lowest mean significant wave height this year with 0.5 m. The roughest months this year were January and December with 1.3 m mean significant wave height. As with the stations further north, April and August were rougher than normal, with 1.0 m and 0.9 m respectively.

The highest significant wave height this year was measured on 11 March, 4.9 m, due to strong southerly winds. This is a new monthly record high, but still below the overall record high of 6.0 m from January 2018. In April the old monthly record high of 3.5 m was reached on 9 April.

Western Baltic Proper, stations Darss Sill, Arkona and Fino 2

In 2021, only two of the three stations in the western Baltic Proper recorded data. The Darss buoy was unfortunately not in operation for the entire year. At the Arkona buoy and the Fino 2 radar gauge, on the other hand, there were only very short interruptions in the measurements, so that statistics are available for the entire year at these two stations.

Overall, 2021 can be described as a rather calm year in the western Baltic Proper. The months of January to March, June and September were significantly calmer than the long-term average. Only the months of April and August were somewhat rougher than usual.

The highest significant wave height measured in the Western Baltic Proper in 2021 was just under 4.0 metres at Arkona station in the night from 21 to 22 October – a value significantly below the long-term maximum. The radar gauge at Fino 2 measured a significant wave height of 3.0 metres during the same event. The highest significant wave height measured at Fino 2 was recorded on 8 February with 3.8 metres. In particular, it is worth mentioning that at Fino 2 significant wave heights above 3 metres were recorded almost continuously throughout this day - unfortunately the Arkona buoy was down during this event, but it did record a significant wave of 3.1 metres on 4 February. Also noteworthy were a storm event on 23 September, when 3.5 metres were measured at Arkona and just under 3.0 metres at Fino 2, as well as the first days of December, when 3.1 metres were recorded at Fino 2 (5 December) and 3.4 metres at Arkona (2 December).

There were no new long-term maxima at Arkona station - all significant wave heights measured were clearly below the all-time records. At Fino 2, just under 3.0 metres was a new September record. However, due to the still very short time series at this station, it can be assumed that this value is not exceptionally high.

Skagerrak

Skagerrak, station Väderöarna

The wave buoy at station Väderöarna was almost fully operational the entire 2021, except for some small gaps in October and December.

There were no extremes in the mean significant wave heights this year and several months (January, February, May, July, August, September, November and December) were calmer than normal. The roughest month was October with 1.5 m, followed by November (1.3 m) and March (1.2 m). The calmest months were May and July with 0.7 m.

Despite the low mean significant wave height in January, the highest significant wave height this year was recorded on 22 January, 6.4 m. This was due to an intense low passing northeast over western Scandinavia. The overall record high is from September 2018 (8.5 m). In April the old monthly record high of 5.2 m from 2020, was reached on 9 April.

Data

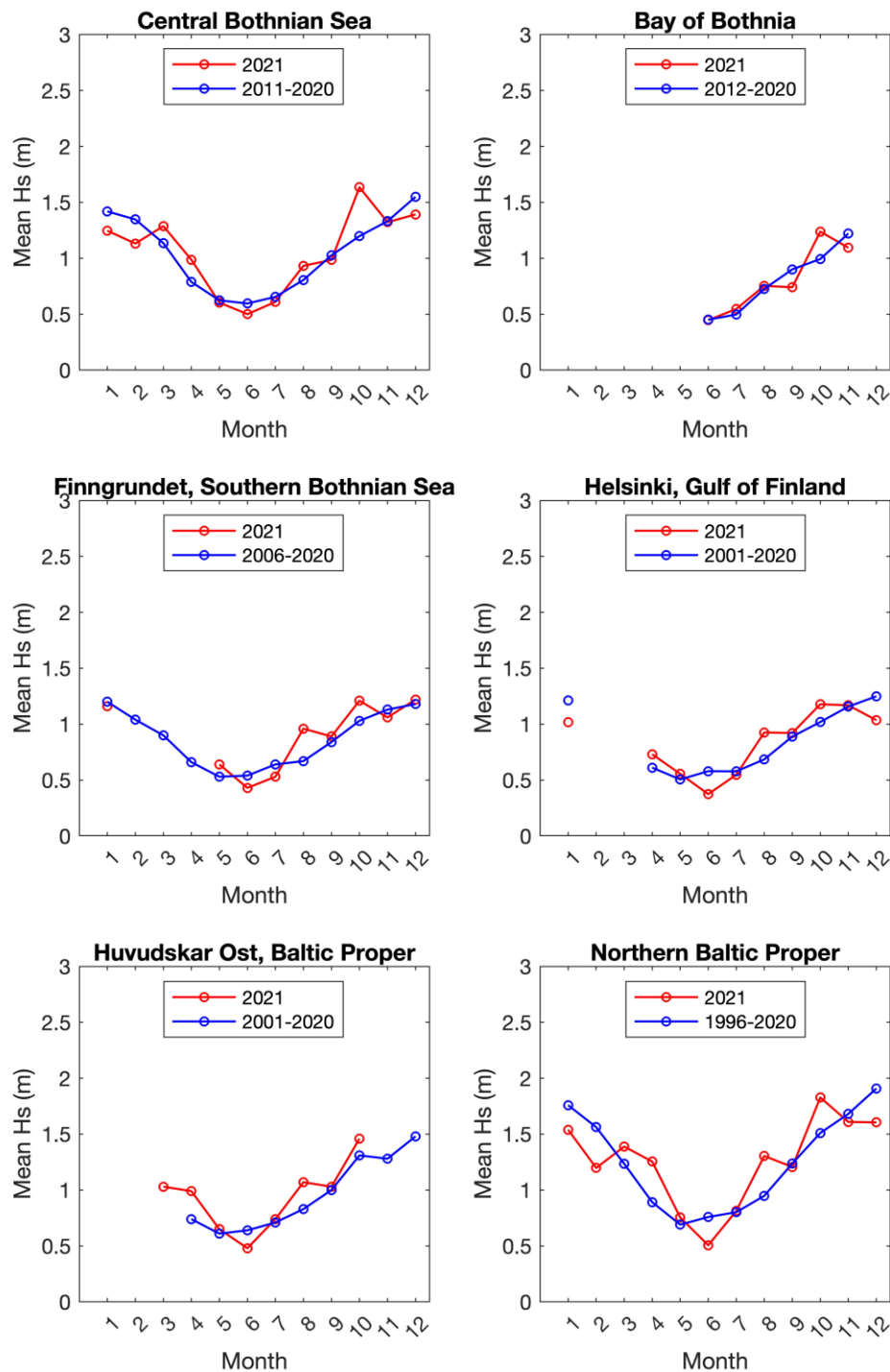


Figure 2. The monthly means of significant wave heights in the Bothnian Sea, the Gulf of Finland and the Northern and Central Baltic Proper. In some months the long-term statistics are calculated over fewer years (but at least over four years) than indicated in the legend.

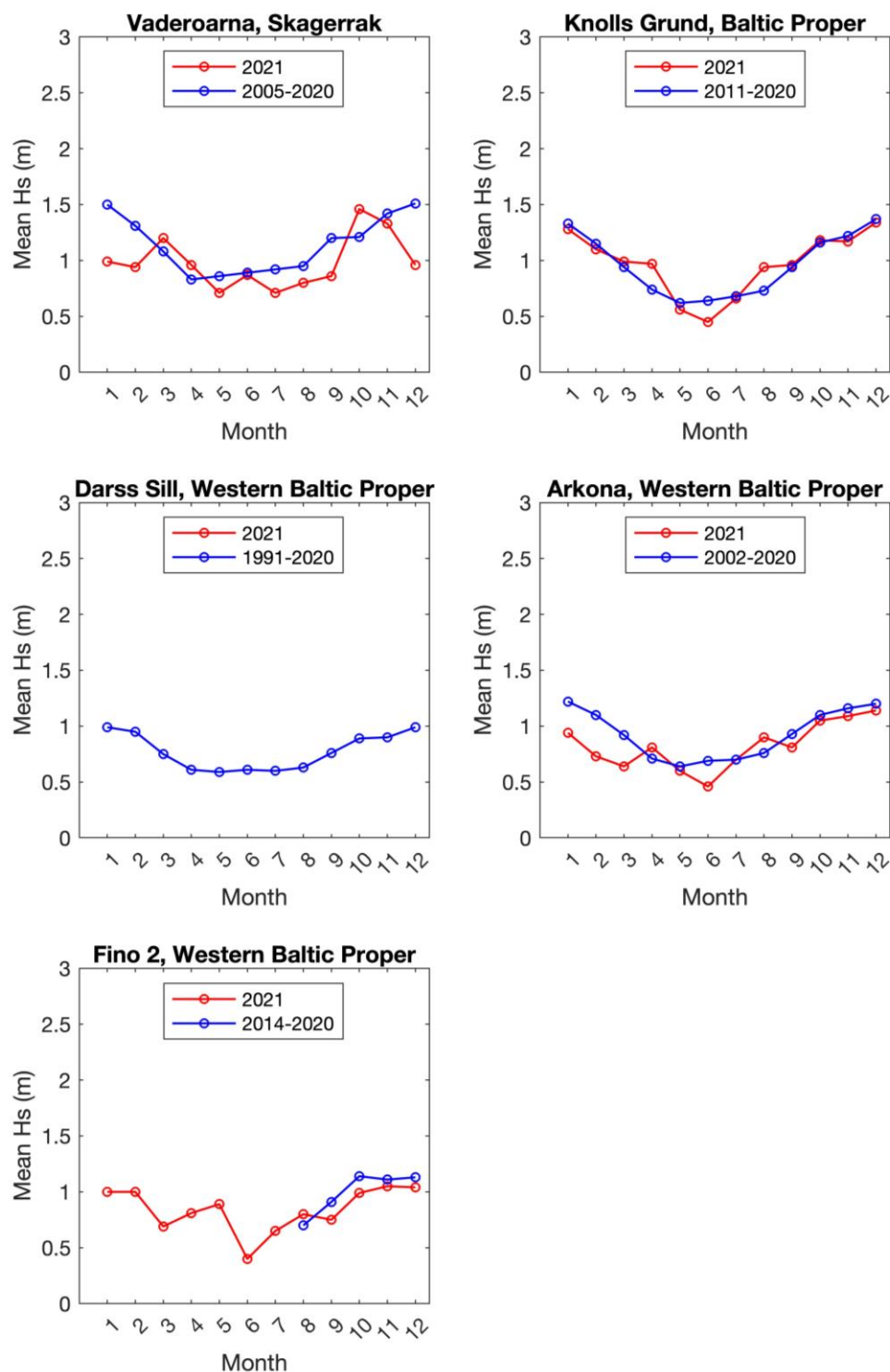


Figure 3. The monthly means of significant wave heights in Skagerrak, Central and Western Baltic Proper. In some months the long-term statistics are calculated over fewer years (but at least over four years) than indicated in the legend.

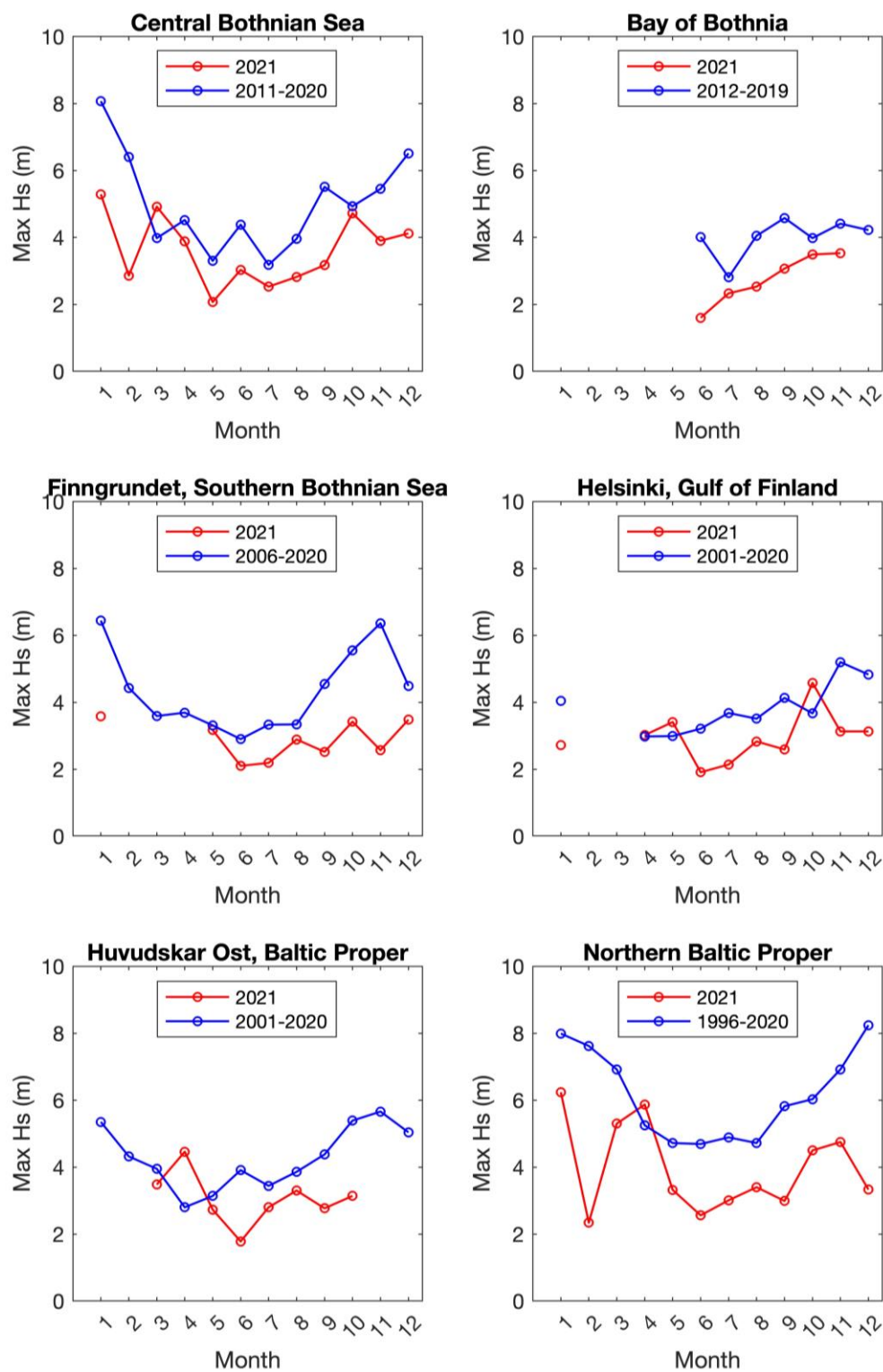


Figure 4. The monthly maxima of significant wave heights in the Gulf of Bothnia, the

Gulf of Finland and the Northern Baltic Proper. Data gaps occur in some of the months.

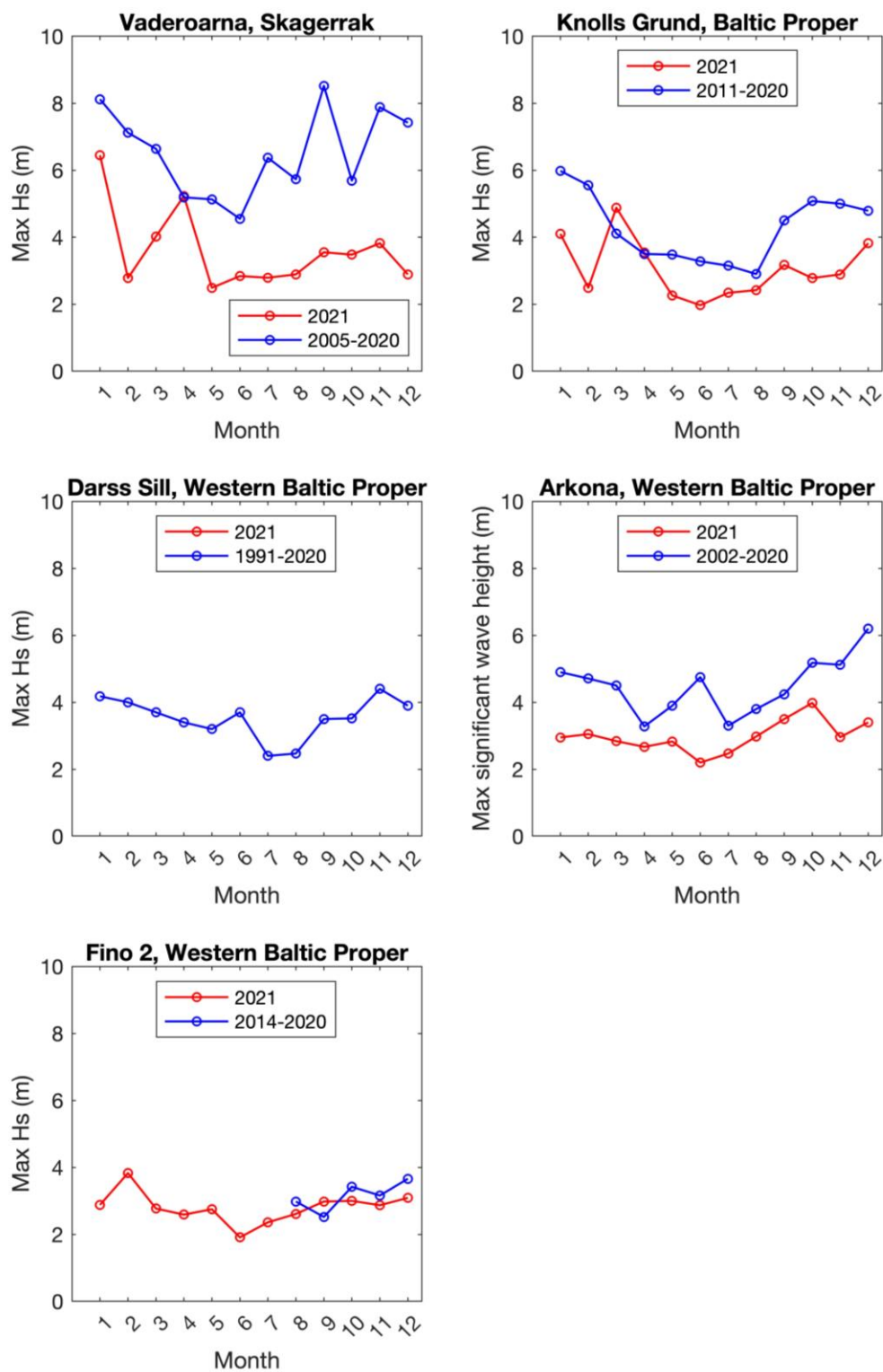


Figure 5. The monthly maxima of significant wave heights in Skagerrak, the Central and the Western Baltic Proper. Data gaps occur in some of the months.

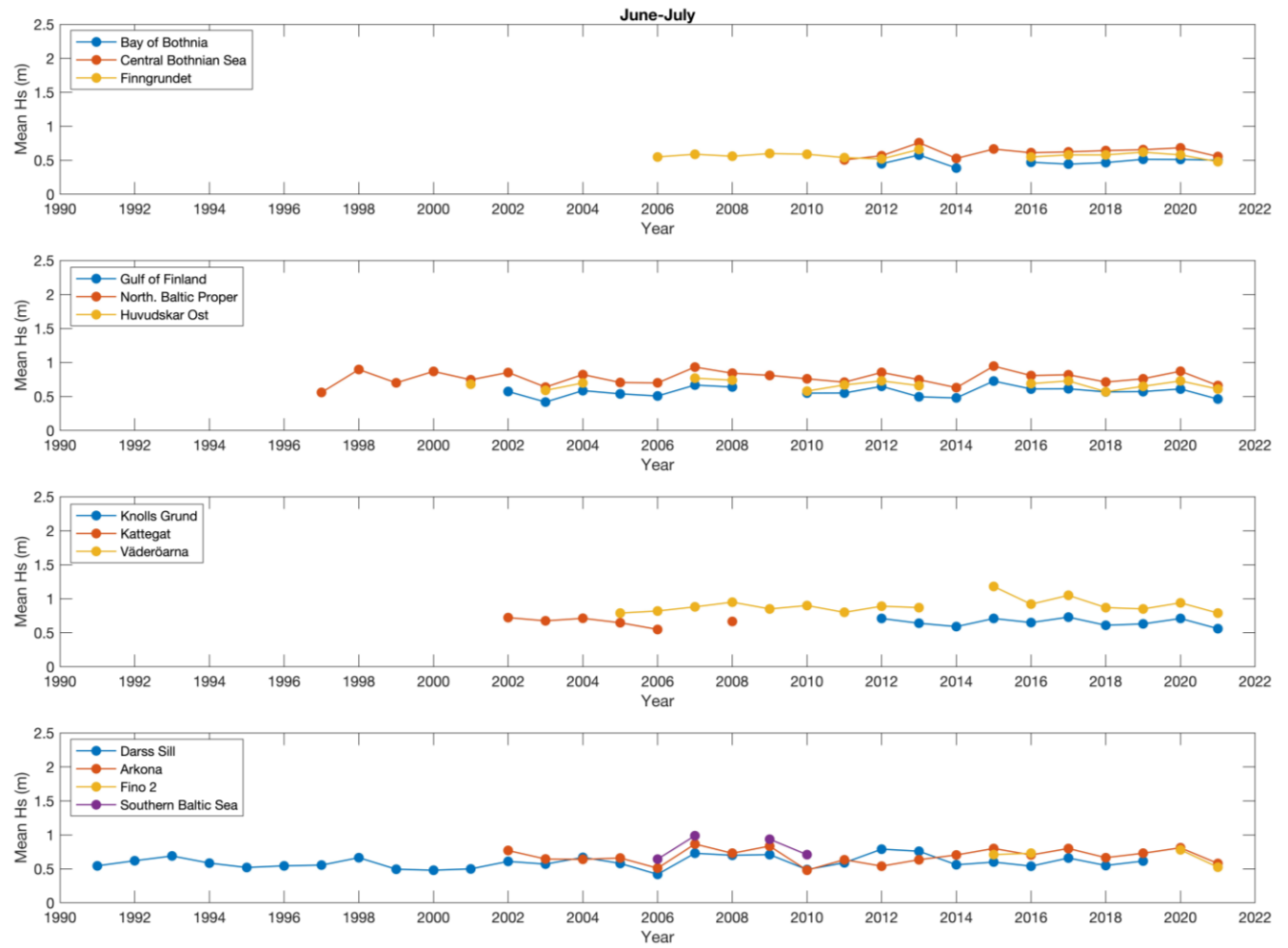


Figure 6. The yearly variation of the mean significant wave height H_s in the period of June-July. In some years the data do not fully cover the whole period.

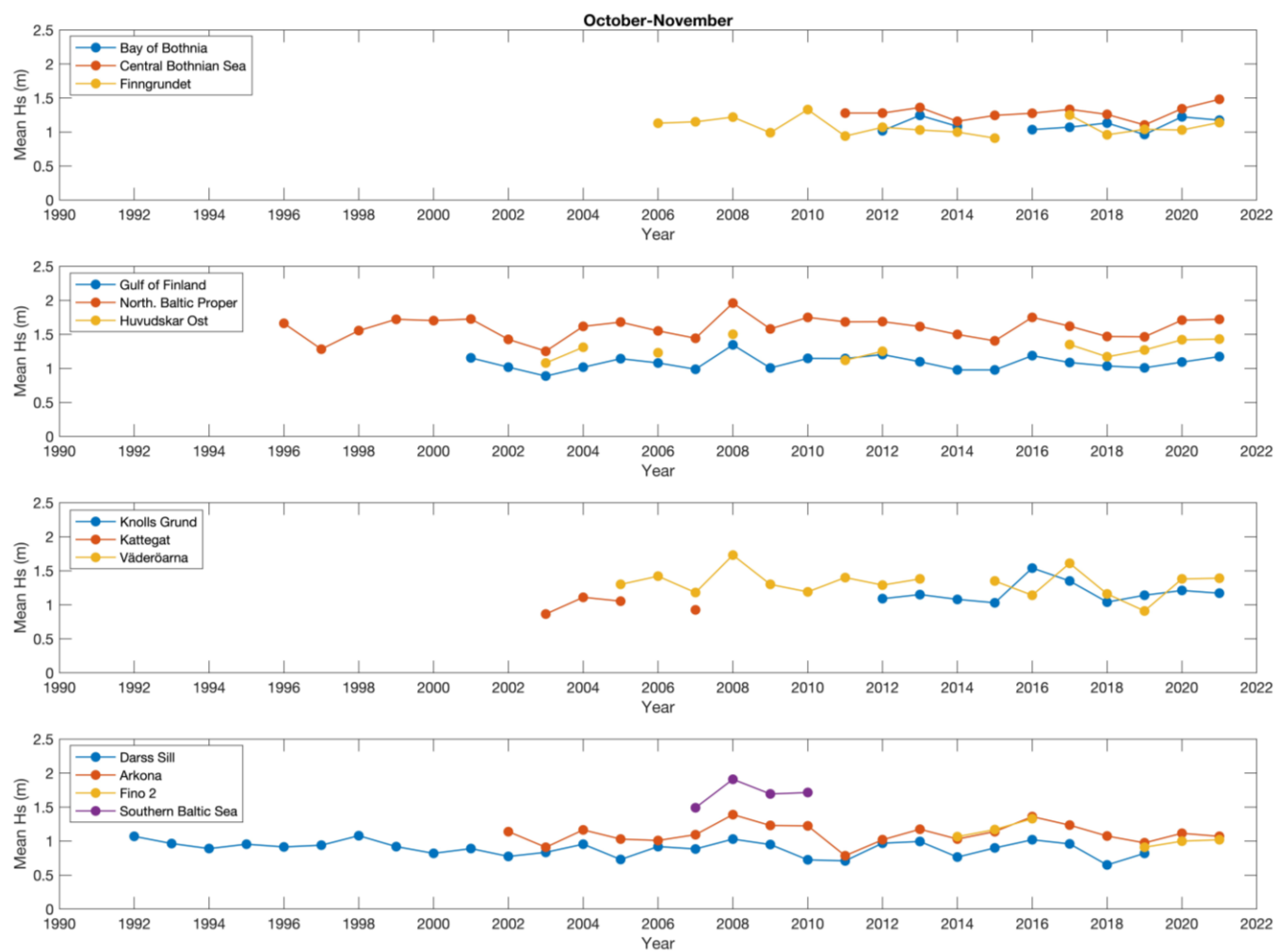


Figure 7. The yearly variation of the mean significant wave height H_s in the period of October-November. In some years the data do not fully cover the whole period. Especially at station Huvudskär Ost, the gaps in the data in years 2011 and 2012 might have left the mean value lower than it should be.

Metadata

In 2021 Finnish Meteorological Institute (FMI) made real time wave measurements at four locations in the Baltic Sea, in the Bay of Bothnia (station Bay of Bothnia, 64° 41.1' N, 23° 14.4' E), in the Central Bothnian Sea (station Bothnian Sea, 61° 48.0' N, 20° 14.0' E), in the Northern Baltic Proper (station Northern Baltic Proper, 59° 15.0' N, 21° 00.0' E) and in the Gulf of Finland (station Helsinki, 59° 57.9' N, 25° 14.1' E). The northern parts of the Baltic Sea freeze every year. The length of the measuring periods varies every year depending on the extent of the ice cover.

The Swedish Meteorological and Hydrological Institute (SMHI) made wave measurements at four locations, in the Southern Bothnian Sea (station Finngrundet, 60° 53' N, 18° 37' E), in the Northern Baltic Proper (station Huvudskär Ost, 58° 56' N, 19° 10' E), in the Central Baltic Proper (station Knolls Grund 57° 31' N, 17° 37' E) and in Skagerrak (station Väderöarna, 58° 29' N, 10° 56' E). To prevent the loss of both instruments and data due to trawling activities in the area the position of the buoy at Finngrundet has been adjusted twice since 2012. Today the position is still south of the eastern bank in waters of comparable depth but approximately 1 km further to the southwest of the previous position. The positions of the buoys operational in earlier years (shown in Figures 6 and 7) are: Kattegat 57° 11' N, 11° 32' E and Southern Baltic Proper 55° 55' N, 18° 47' E.

Since 1991, wave measurements in the western Baltic Sea have been carried out at a station located at 54° 41.9'N, 12° 42.0'E in the area of Darss Sill. Until November 26 2019 the Helmholtz-Zentrum Hereon was the operator of this buoy. Since November 26, 2019 the buoy is operated by the Federal Maritime and Hydrographic Agency of Germany (BSH). Beyond that, the BSH has performed measurements at a station northwest of Cape Arkona (54° 52.9'N, 13° 51.5'E) since 2002 and at the Fino 2 research platform located at 55° 00.5'N, 13° 09.3'E since 2014. For the latter position, mostly no long-term climatological wave data are available so far, as the buoy has been torn down very often. Finally, in October 2020, the classic wave buoy was replaced by a directional radar gauge. Up to now, measurement interruptions due to ice coverage or drift ice occurred only in the winter of 1995/1996 at the Darss Sill measuring station, and in February and March 2010 at the Arkona Basin station.

The significant wave height, usually denoted by H_s is, confusingly, defined in several ways. The most common way today is to calculate it from the variance of spectral density, also denoted by H_{m0} : $H_{m0} = 4\sqrt{\sigma^2}$, where $\sigma^2 = \int_0^\infty S(f)df$, $S(f)$ is the wave spectrum and f frequency. Another, older definition of H_s is the average height of the highest third of the waves, also denoted by $H_{1/3}$. In water that is deep for the waves (deeper than half of the wavelength) H_{m0} and $H_{1/3}$ are nearly equal. Both definitions are chosen to reflect how an experienced observer would visually estimate the sea state, which is the third, and probably the oldest definition of the significant wave height: a measure of the sea state that is significant to seafarers. The highest individual wave is approximately 1.6-2.0 times higher than the significant wave height.

The waves at each station except for Fino 2 are measured with surface following buoys, Seawatch, Watchmate (at Huvudskär Ost), Directional Waveriders, and Waveriders. Buoy measurements were collected 0.5 - 1 hour via Iridium, HF link, Argos-satellite, Orbcomm system and dataloggers with significant wave height calculated as H_{m0} on board the buoys over 1600 s or 1800 s time series of surface displacement. At Fino 2, the waves are measured by a radar gauge, which calculates H_{m0} every minute over the last 1200s time series of surface displacement. For the calculation of the statistics used in this report, values were taken every 20 minutes, so that each measured value of the surface displacement is reflected in exactly one value of significant wave height. The quality of the measurements was checked according to the routines at each of the responsible Institutes. All measurement data referred to in the text are significant wave heights, namely monthly averages and maxima unless otherwise stated.

The lengths of the deployment periods in 2021 are indicated in the text. The length of the period at each station depends on the extent of the ice cover, maintenance and deployment logistics and possible instrument damages. As a consequence, measurements are not always available for 12 months per year for the long-term statistics. The years given in the Figures 2 - 4 indicate the start of the measurements: in some months the statistics are over fewer years but only statistics over at least four years are plotted in the Figures. The monthly means are given when there are measurements over half of the month. Because of data gaps, the maximum values do not necessarily constitute the true monthly maximum, whereas the mean values are largely reliable. Due to the variation of the lengths of the time series in the statistics they should be used with caution.

For reference purposes, please cite this Baltic Sea environment fact sheet as follows:

[Author's name(s)], [Year]. [Baltic Sea environment fact sheet title]. HELCOM Baltic Sea Environment Fact Sheets. Online. [Date Viewed], <http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/>.

Last updated 07.10.2022