Wave climate in the Baltic Sea 2022

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Key message

The first half of the year 2022 tended to be in average rougher than usual across the Baltic Sea with some new monthly all-time records or values just below them. The second half of the year, on the other hand, was generally calmer than the long-term average.

Results and assessment

In 2022 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.

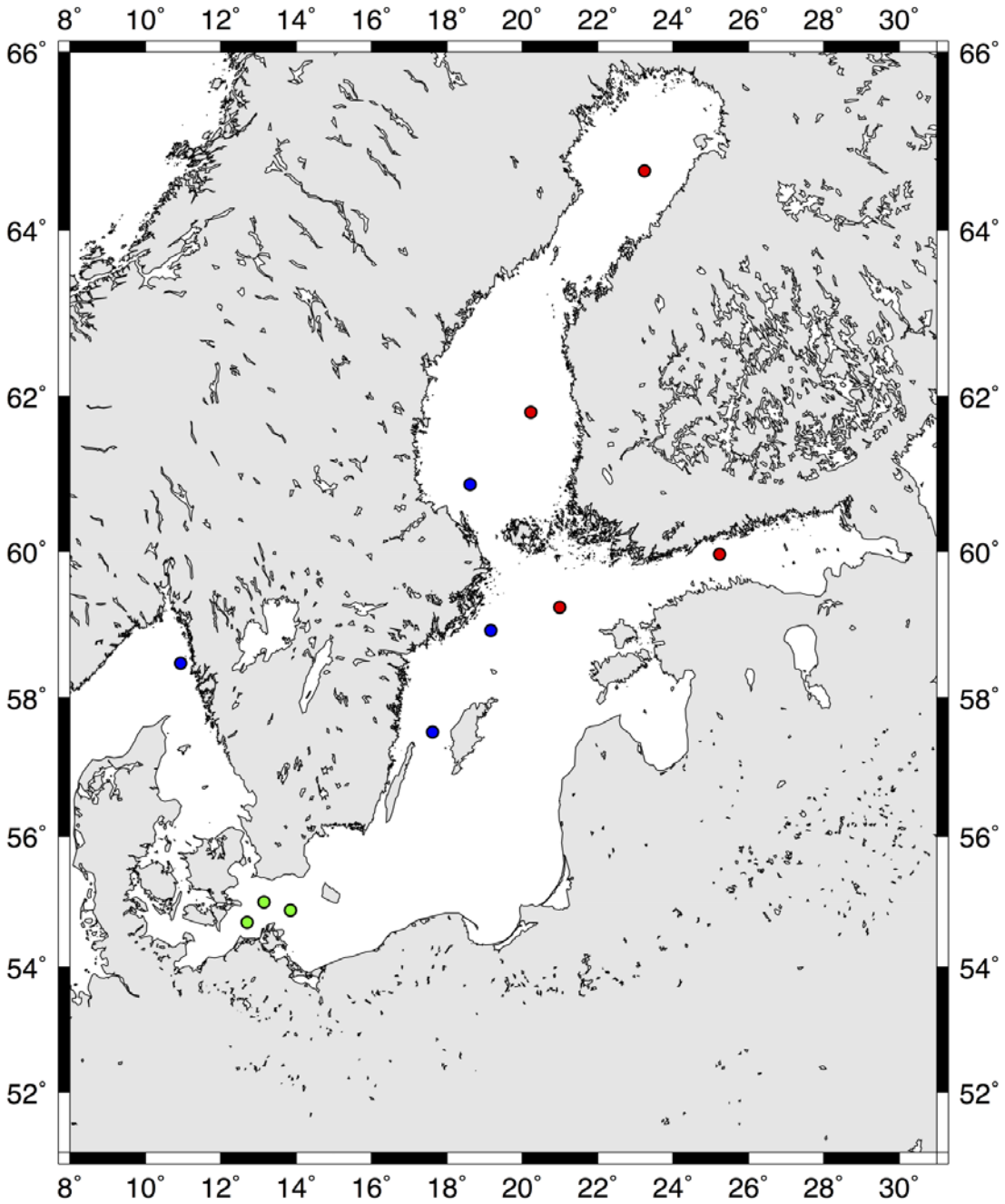

Figure 1. The positions of the wave monitoring stations in 2022. Red dots indicate FMI buoys in the Bay of Bothnia, in the Bothnian Sea, in the Northern Baltic Proper and in the Gulf of Finland (station Helsinki), blue dots SMHI buoys in the Southern Bothnian Sea (station Finngrundet), in the Baltic 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 2022 the wave buoy in the Bay of Bothnia was deployed 5 June and recovered 16 December. The measurement period was continuous.

At the buoy location, the monthly mean significant wave heights from June to October were close to the long term mean values. November was exceptionally calm, and the mean significant wave height was 0.70 metres. The highest significant wave height during the six-month measuring period was 3.4 metres, measured on 22 October.

The Central Bothnian Sea

The wave buoy in the Central Bothnian Sea was operational throughout the year 2022.

At this station January was clearly rougher than usual with a monthly mean of 1.9 metres. From February to June the wave climate was typical for the season followed by a rougher July. From August to September the wave climate was slightly calmer than usual. Like in the Bothnian Bay, November was clearly calmer with a monthly mean of 1 metre. Also, December was calm for the season. No record high significant wave heights were observed, the significant wave height reached twice 5.1 metres, on 14 and 20 January, both during northwestern storms.

The Southern Bothnian Sea, station Finngrundet

The wave buoy at station Finngrundet was fully operational during 2022. In general, the year for this station can be considered as quite calm although February and December both reached their old record of maximum significant wave height.

The roughest month of the year was January followed by February with mean significant wave height of 1.5 and 1.1 m respectively. This is rougher, or slightly rougher than usual due to several low pressures, some quite severe. April to September was near normal except for July which was slightly rougher. March and November stand out as notably calmer.

The highest maximum significant wave height for the station occurred in mid-January when 4.5 m was noted in strong northerly gale. This is far from this station's overall highest significant wave height of 6.4 m which occurred in January 2019. Late February in strong north-easterly gale the station reached the old monthly record value of 4.4 m, last noted in 2015. December also reached its monthly record high of 4.5 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 29 January and redeployed 4 April. The buoy was operational to the end of the year 2022.

The monthly means of significant wave height where close to the long-term values, with a slightly rougher spring and calmer autumn. At this station September, however, was clearly calmer, with a monthly mean of 0.6 metres. The monthly maxima stayed well under the long-term maxima, except on 5 April, when the significant wave height reached 2.9 m, close to the previous maximum, 3.0 metres. The significant wave height reached 3.0 metres on 17 October and 19 November, and 3.1 metres on 12 December which was also the highest significant wave height in the measurement 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 2022. Due to malfunction of the sensor, there is no data from July.

The two first months of the year were rougher than usual followed by a calmer February. From March to June the monthly means of significant wave height were close to the long-term mean values, while the rest of the year, from August onwards was calmer than usual. The pattern corresponded to the behaviour of the monthly means observed in the central Gulf of Finland. Monthly maxima of significant wave heights remained well below the long-term maxima. The highest significant wave height for this station was measured on 20 January, 5.7 metres, during the same north-western storm than in the middle of Bothnian Sea.

The wave buoy at station Huvudskär Ost was fully operational April to October. For January, February and December there is no data and there is a period of missing data in March and November.

The mean significant wave height for the months available were close to normal and the maximum significant wave height was far from any record value.

Central Baltic Proper, station Knolls Grund

The wave buoy at station Knolls Grund was operational the entire 2022. The mean significant wave height was in general near or below normal. Two new monthly records were noted.

January and February were rougher than usual with a mean significant wave height of 1.5 and 1.4 m respectively. April and July were just slightly above normal. Apart from mentioned months the mean significant wave height was below normal. March and November with significant wave heights of 0.6 m and 0.9 m were notably calmer than usual.

In the beginning of April southerly gale force winds induced a significant wave height of 4.3 m which resulted in a new monthly record height. The old record value, 3.5 m was noted both in 2021 and 2012. Another new monthly record was noted in August with 3.1 m, only 0.2 m above the old record from 2016. The year's highest significant wave height of 4.4 m occurred at the end of January in northerly strong gale.

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

In contrast to previous years, measurements from all three stations were available again in 2022. While the Arkona buoy was in operation for the entire year 2022, data for 5 months are available from the Darss Sill buoy (April to August) as well as data for 9 months from the radar gauge of the Fino 2 station (January, March to June and September to December).

Although three new all-time monthly maxima of significant wave height were recorded in 2022, overall 2022 was in line with or even somewhat calmer than the long-term average.

With 5.0 metres, the highest significant wave height measured in 2022 in the Western Baltic Proper was measured in the night from 29 to 30 January at Arkona station. This value also meant a new all-time January record at this station. Unfortunately, this storm event was only recorded at Arkona, as both Fino2 and Darss Sill were out of operation at that time. Without data from what was probably the strongest storm event of the year, the highest significant wave height at Fino2 was 3.7 m on 17 January - at Arkona a value of 4.0 m was measured during this event.

However, despite these relatively high values in January, January as a whole was quite close to the long-term average, which was also true for the months of July, September and November. The months of March, May, June, August, October and December, on the other hand, were clearly calmer than the long-term average. Only the months of February and especially April were somewhat rougher. Another stronger storm on 4 April with a wave height of 3.8 m at Arkona resulted in another all-time monthly record at this station. At Fino2, 3.6 m were measured during this event, which is also the monthly record at this station.

Also worth mentioning is the new September record at the Fino2 station: On 8 September, a significant wave height of 3.0 m was measured here - in view of the still short time series at Fono2, however, probably not a very high value. On the same day, 2.8 m was measured at Arkona, which was clearly below the all-time record for the month of September at this station. At the Darss Sill station, unfortunately, data could not be recorded for any of these events, so that all values at Darss Sill were far below the long-term record values.

Skagerrak

Skagerrak, station Väderöarna

The wave buoy at station Väderöarna was fully operational during 2022. February stand out with in general rough conditions but no records were broken.

The mean significant wave height varies a lot with periods above and below normal. January and February were notably rougher than usual with 1.8 m and 2 m respectively. May, June, July and October were also rougher but not as far from normal as January and February. March, September and December were notably calmer than usual. April, August and November were also calmer. All in all, six

months above normal and six below. The only months that was fairly close to normal were July, October and November.

The highest significant wave height was noted on 30 January, 5.3 m in westerly storm. Two other highs were noted with 4.8 m on 13 and 22 February, both in northerly gale winds.

Data

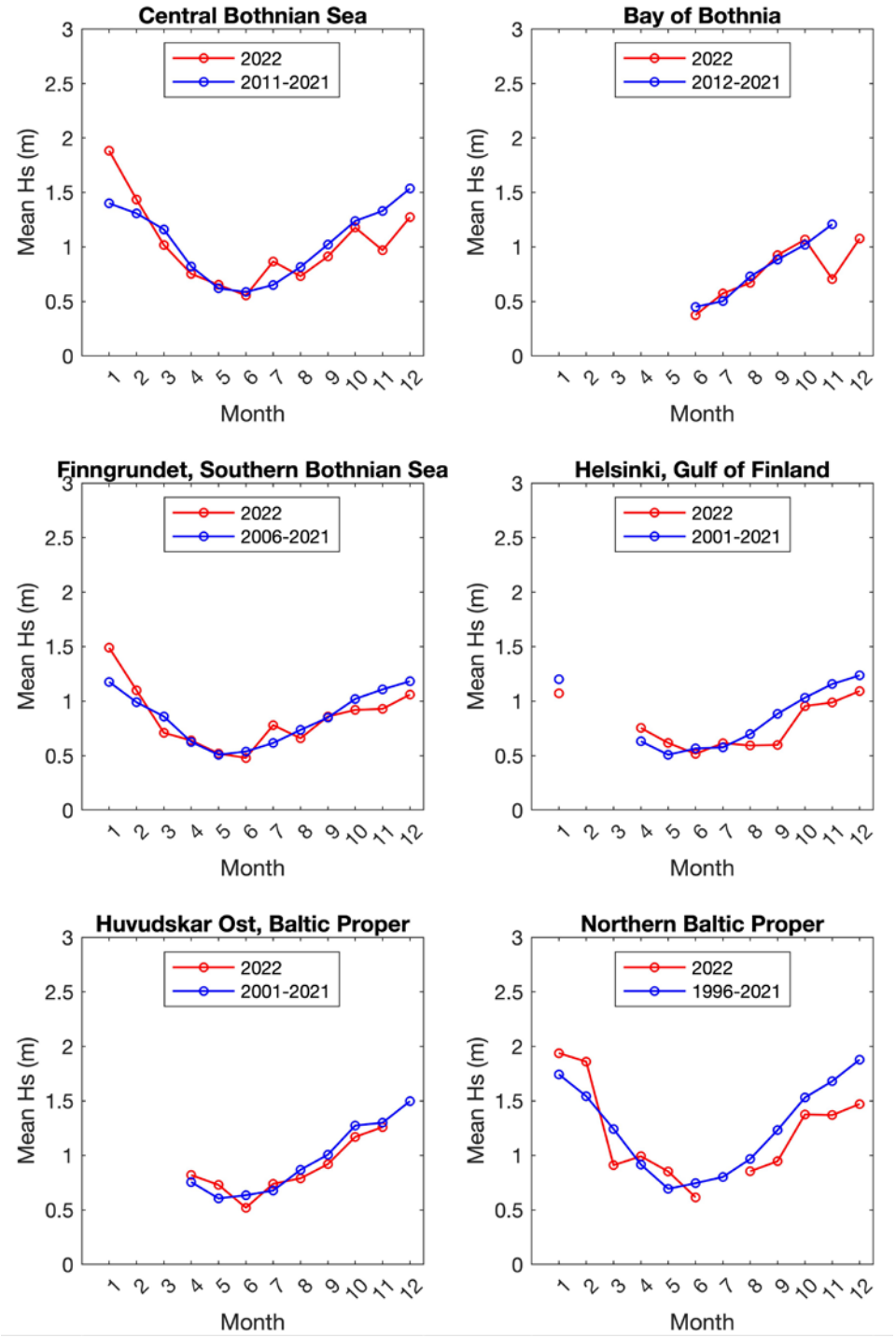

Figure 2. The monthly means of significant wave heights in the Bothnian Sea, the Gulf of Finland and the Northern and Central Baltic Proper. In some months the long-term statistics are calculated over fewer years (but at least over four years) than indicated in the legend.

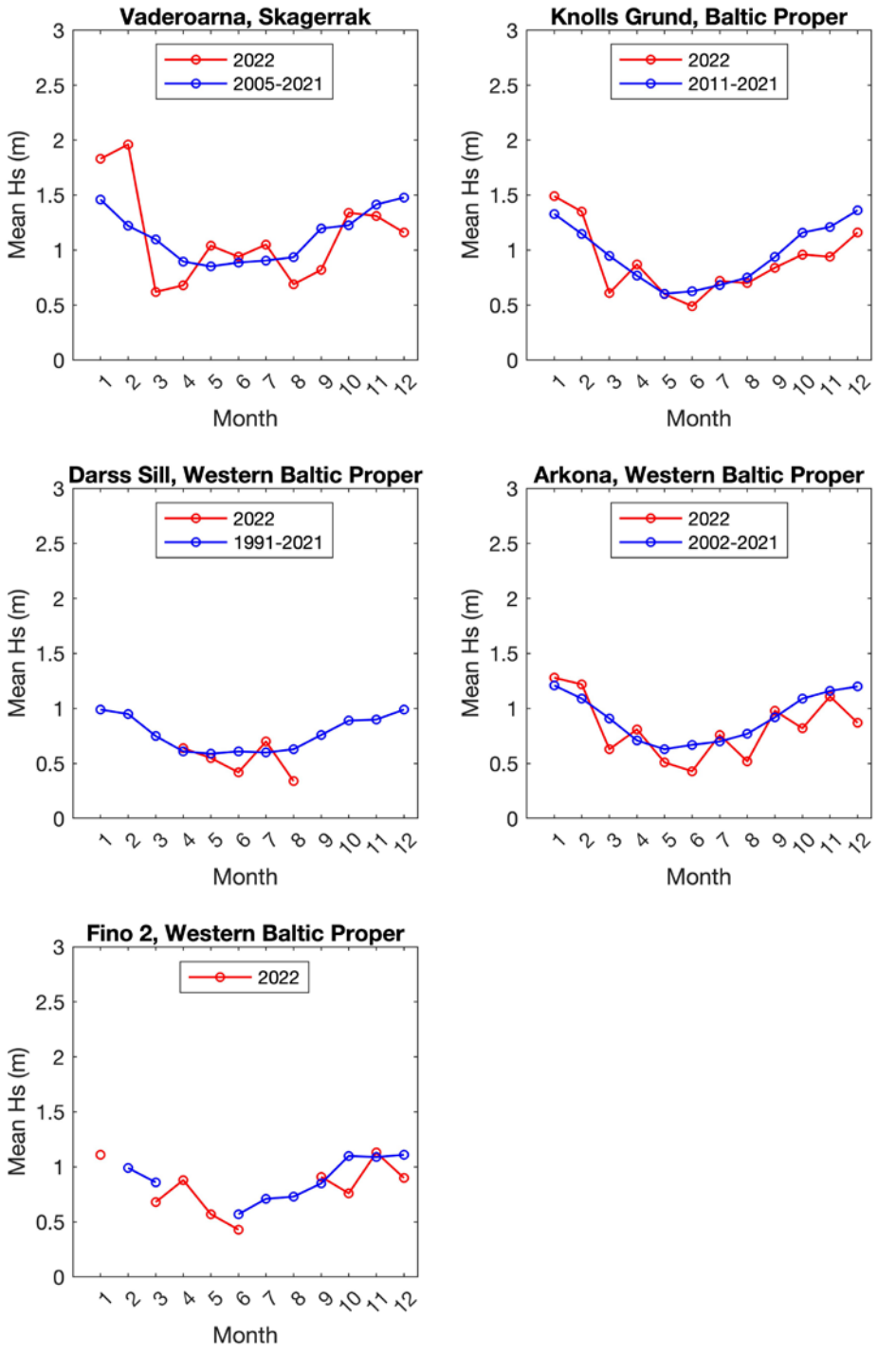

Figure 3. The monthly means of significant wave heights in Skagerrak, Central and Western Baltic Proper. In some months the long-term statistics are calculated over fewer years (but at least over four years) than indicated in the legend.

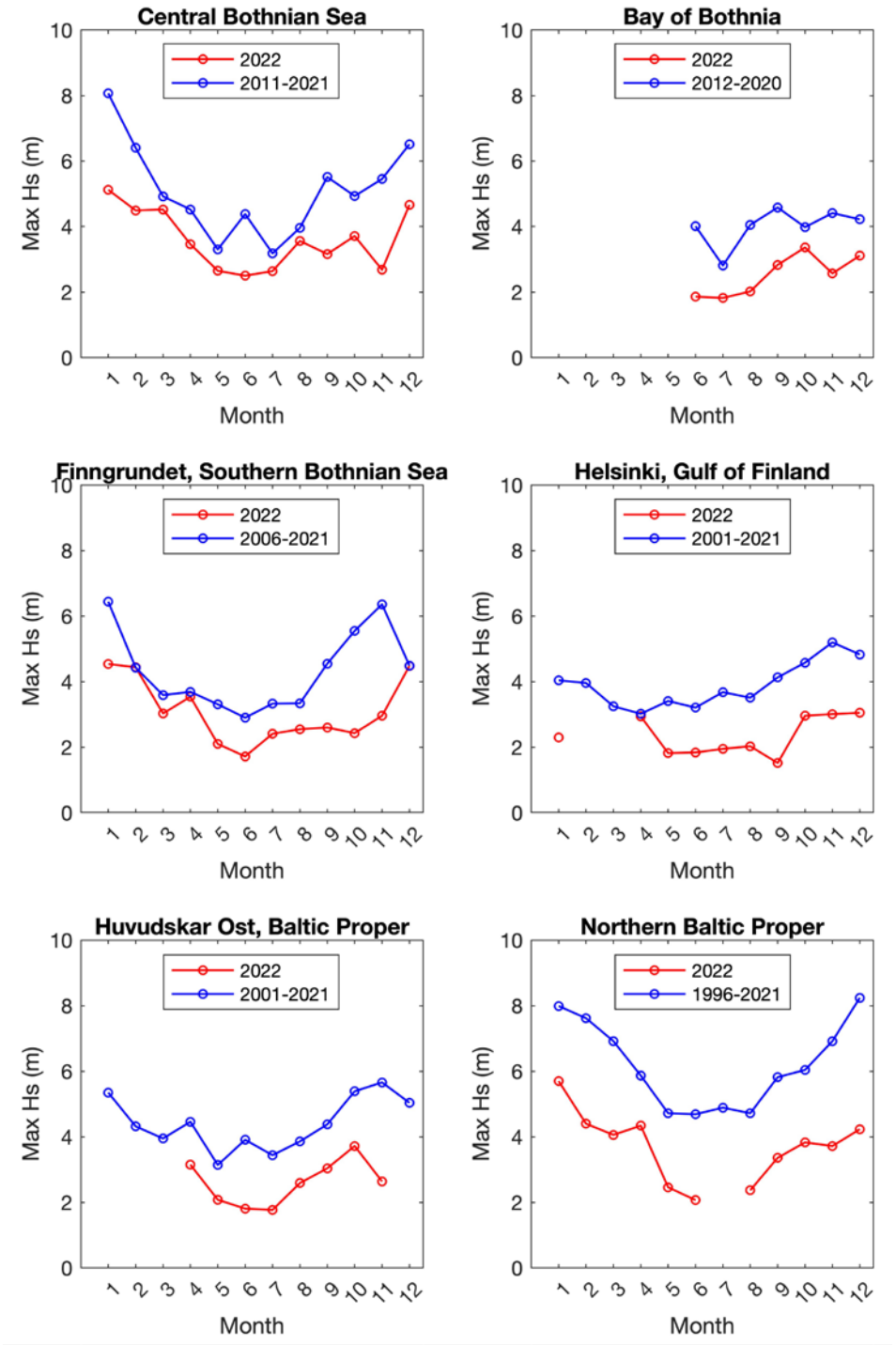

Figure 4. The monthly maxima of significant wave heights in the Gulf of Bothnia, the Gulf of Finland and the Northern Baltic Proper. Data gaps occur in some of the months.

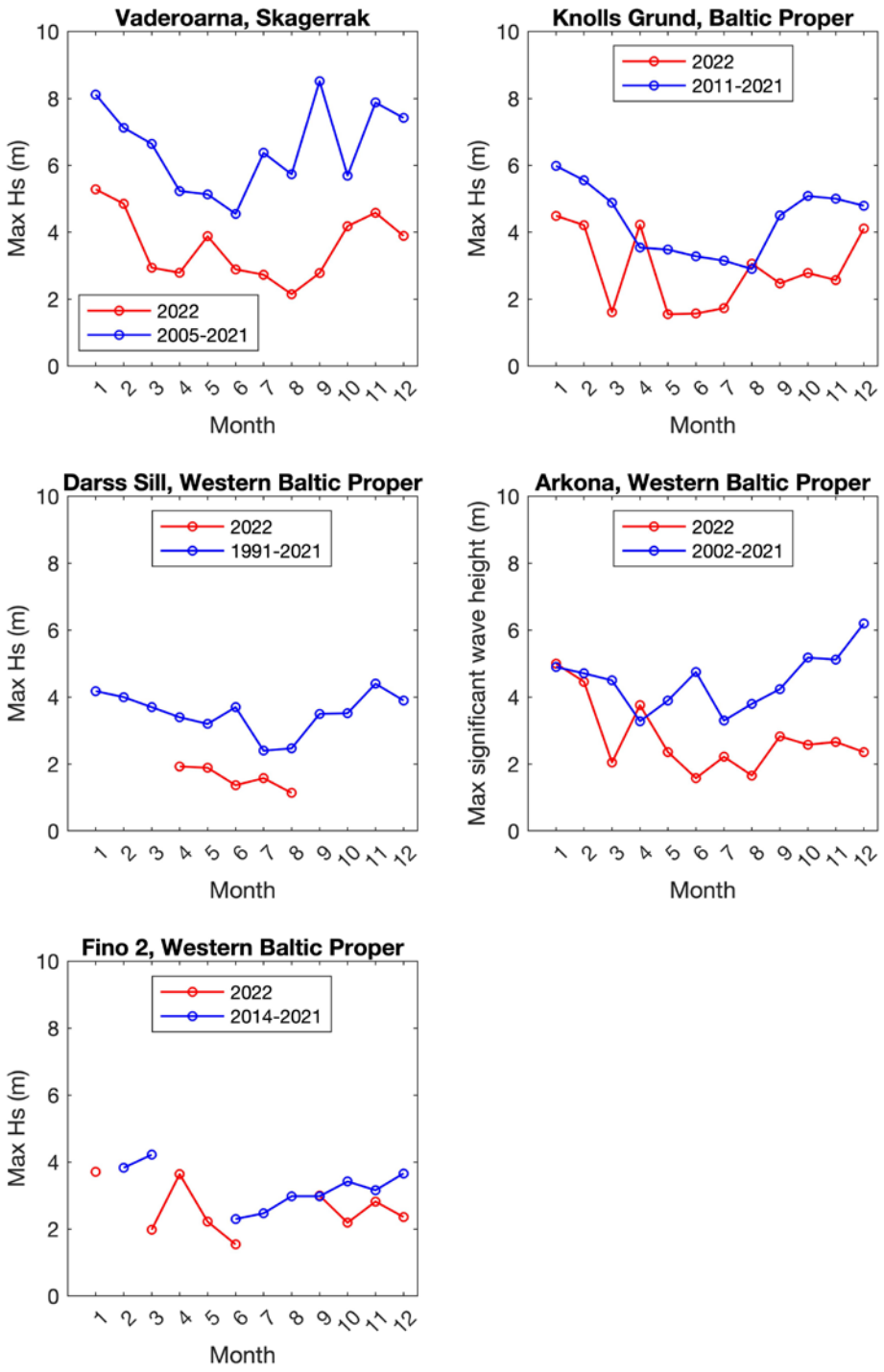

Figure 5. The monthly maxima of significant wave heights in Skagerrak, the Central and the Western Baltic Proper. Data gaps occur in some of the months.

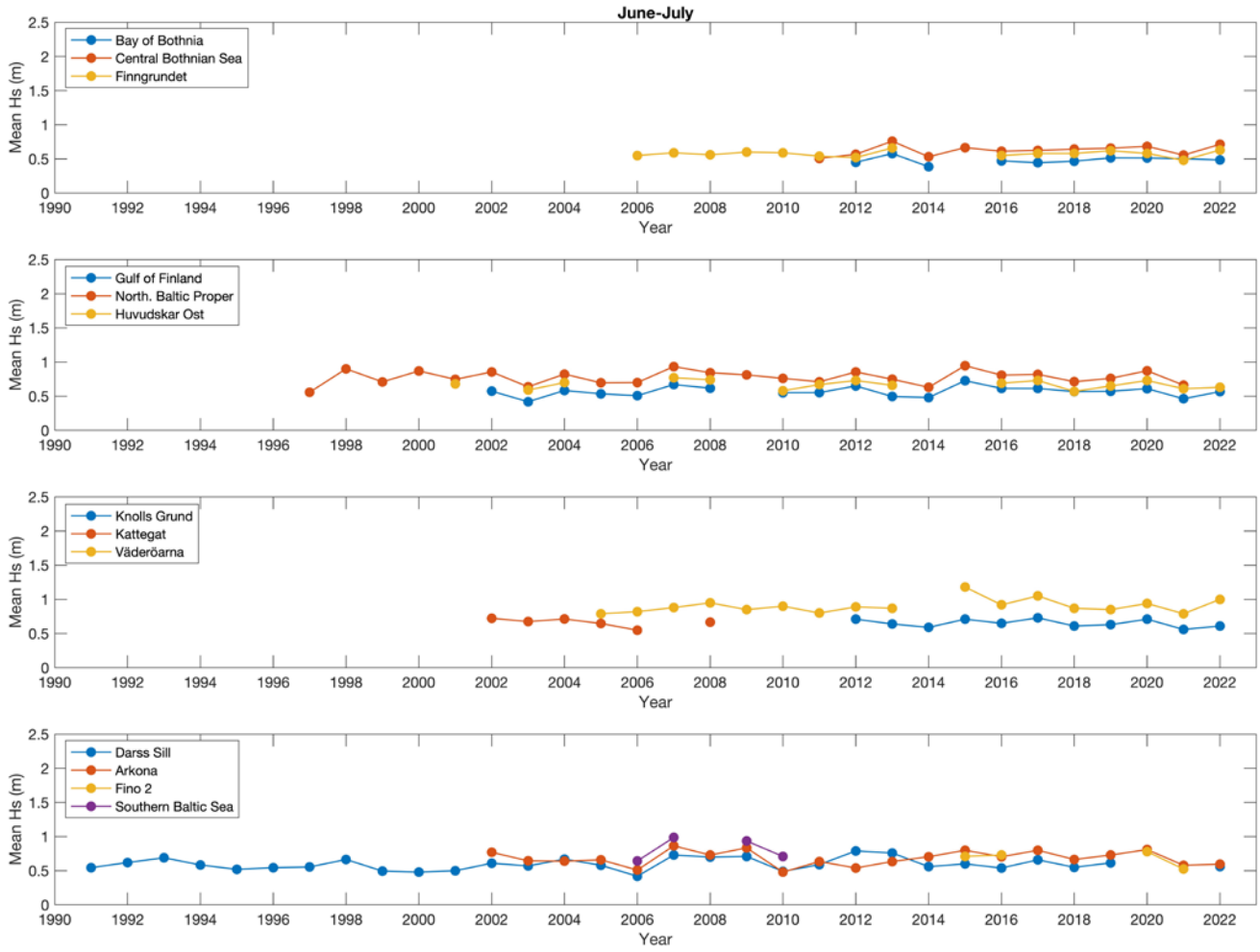

Figure 6. The yearly variation of the mean significant wave height Hs in the period of June-July. In some years the data do not fully cover the whole period.

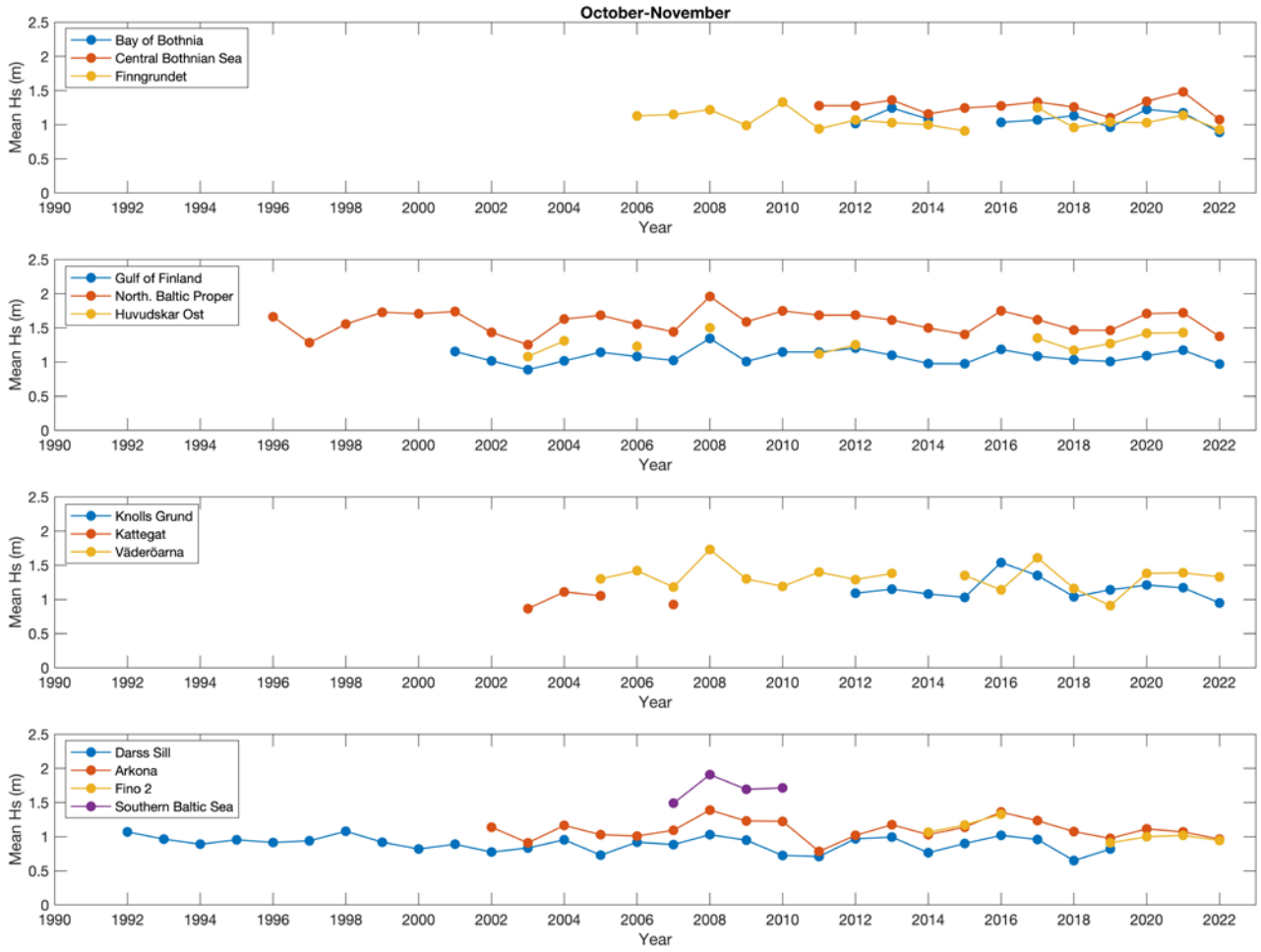

Figure 7. The yearly variation of the mean significant wave height Hs in the period of October-November. In some years the data do not fully cover the whole period. Especially at station Huvudskär Ost, the gaps in the data in years 2011 and 2012 might have left the mean value lower than it should be.

Metadata

In 2022 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 2022 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.

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