Wave climate in the Baltic Sea 2019

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Key message

In the first days of 2019 a northern storm called "Aapeli"/"Alfrida" passed the Baltic Sea. A record high significant wave height, 8.1 m, was measured in the central Bothnian Sea and high values were observed also at other stations through the Baltic Sea. High values were also recorded in March in the western Baltic Proper and Skagerrak. At several stations November was calmer than usual.

Results and assessment

In 2019 waves were measured in 11 locations in the Baltic Sea and Skagerrak (Figure 1). These buoys 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 buoys in 2019. 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 and HZG buoys in the Western Baltic Proper: Fino2, off Cape Arkona and on the Darss Sill. See section Metadata for the exact coordinates of the buoys.

The Gulf of Bothnia

The Bay of Bothnia

The wave buoy in the Bay of Bothnia was operational from 1 June to 27 November 2019.

At the buoy location, the mean significant wave height remained close to the long-term mean values, from 0.5 m in June to 1.0 m in October. In November the wave climate was clearly calmer than is typical for the month and the mean significant wave height was only 0.8 m. The monthly maxima were 2.2 - 2.4 m, lower than the monthly maxima since 2012, except in October, when the significant wave height exceeded slightly monthly long-term maximum. It was the only time in the period June-November when the significant wave height reached 4.0 m (22 October).

The Central Bothnian Sea

In the beginning of 2019, the wave buoy in the Central Bothnian Sea was operational to 27 January. The buoy was redeployed in the beginning of March and was operational the rest of the year.

On New Year's Day there was a strong northern storm called "Aapeli"/"Alfrida" and the significant wave height grew to a record height of 8.1 m. This was the first time than a significant wave height this high was measured in the Gulf of Bothnia. The value is close to the measured maxima in the rougher Northern Baltic Proper (8.2 m in 2004) and Skagerrak (Väderöarna, 8.5 m in 2018). At this time of the year, the coastal areas and northern parts of the Bothnian Sea are typically frozen, but in 2019 the sea was open providing also a longer fetch, although the buoy is anchored in the middle parts of the Bothnian Sea. The rest of the month was calmer, and the mean significant wave height was only slightly higher than the long-term average. Like at the buoy location in the Bay of Bothnia, the mean significant wave height was close to the long-term mean values from May (0.8 m, 0.6 m in July) to October (1.1 m). Again, November was clearly calmer, 1.1 m, followed by a December that was slightly calmer than usual (1.4 m). After January, the significant wave height exceeded 4.0 m twice, on 8 - 9 April, when significant wave height remained 4.0-4.5 m for 30 hours, and on 11 December when the significant wave height reached 5.3 m.

The Southern Bothnian Sea, station Finngrundet

The wave buoy at station Finngrundet was operational in the beginning of 2019 until 30 January, then out of operation for almost 3 months during the winter period. From the end of April and onwards the wave buoy was fully operational.

On the rear of the storm "Aapeli"/"Alfrida" 1-2 January, the northerly storm of 29 m/s, generated a significant wave height of 6.4 m on 2 January. This was an equal to the old record high from 1 November 2006. For the month of May there was a new record high of 3.3 m on 2 May, slightly beating the old record

high of 3.1 m from 2017. Else there were no exceptional significant wave heights observed during 2019, but for the month of July, we noticed the third highest significant wave height of 2.8 m, since the start of the station in 2006.

The monthly averages of significant wave height were near the long-term averages, except for January when it was higher and December, when it was lower.

The Gulf of Finland

The middle parts of the Gulf of Finland, station Helsinki

Due to the risk of ice the wave buoy off Helsinki was recovered on 14 January 2019 and redeployed 11 March. The buoy was operational to the end of the year.

The monthly averages of significant wave height remained close to the long-term mean values in January (1.2 m) and from May (0.5 m) to October (1.0 m) and in December (1.3 m). In April and in November the monthly means were lower, 0.4 m and 1.0, respectively. During the months the buoy was operational, the maximum significant wave height remained under the long-term values. The highest significant wave height during the measurement period was 3.6 m (11 January). The next time the significant wave height exceeded three metres was on 5-6 (3.4 m) and 29 December (3.1 m).

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 2019.

Like in the Gulf of Finland and the Gulf of Bothnia the monthly mean significant wave heights in the Northern Baltic Proper remained close to the long-term values from May (0.8 m) to September (1.3 m). January (1.6 m), April (0.7 m), October (1.4 m) and November (1.5 m) were slightly calmer than usually. The monthly mean of the significant wave height was somewhat higher than usually in February (1.8 m), March (1.5 m) and December (2.0 m).

The highest significant wave height in 2019 at this location was 6.0 m, measured on 2 January during the same northern storm "Aapeli"/"Alfrida" when an exceptionally high 8.1 m was measured in the Central Bothnian Sea and 6.4 metres was measured at the station Finngrundet. Four metres were exceeded on 8-9 March (4.1 m), 12 and 15 September (4.1 m and 5.1 m, respectively), 26 October (4.2 m), 5-8 December (4.0 - 4.7 m), 11 December (5.4 m) and 18 December (4.3), all during high south-southwestern winds.

The wave buoy at station Huvudskär Ost was only partly working in January 2019, then out of operation during the winter period until 26 April. For the rest of the year the station was fully operational.

Despite the low availability in January, there was a maximum measurement of significant wave height in January of 3.8 m, third highest for the month since the start of measurements in 2001. This measurement was also in the beginning of the month as storm "Aapeli"/"Alfrida" was passing. In May there was a new maximum record for the month with 3.1 m on 30 May, when a deep low moved northeast over Scandinavia, generating strong southwesterly winds. On 11 December a significant wave height of 4.7 m was noted, as a vast low on the Norwegian Sea generated strong southerly winds over the Baltic Proper. This is the second highest record for the month, only beaten by 5.0 m from 2006. The highest significant wave height ever recorded for this station is from 9 November 2010 with 5.7 m.

The monthly averages of significant wave height 2019 were near the long term averages, except for December, when it was slightly higher. For January to March, there are no long term averages to compare with, due to lack of observation data.

Central Baltic Proper, station Knolls Grund

The wave buoy at station Knoll Grund was operational entire 2019, with only some minor gaps in the measurements. Lowest availability was 97 percent during June to August.

There were no overall new record highs, but at the situation for the "Aapeli"/"Alfrida" storm, the highest significant wave height 2019 was measured with 5.9 m on 2 January. This is the second highest overall record for this station only beaten by 6.0 m on 16 January 2018. During the rest of the year there were no extreme measurements and the maximum significant wave heights were well below the record notations for each month.

The monthly averages of significant wave height were near the long term averages, except for March, September and November when they were slightly higher. In April, June, August and October they were slightly lower.

Western Baltic Proper, stations Darss Sill, Arkona and Fino2

The data availability of the three stations in the Western Baltic Proper in 2019 is relatively good. The station Arkona recorded data in 11 months (January to November) and the station Darss Sill recorded data in 10 months (January to March and May to November). As in previous years, the Fino 2 buoy was broken away several times, so that only data of 7 months were recorded (February to April and August to November). Unfortunately, however, in 2019, December is the month in which none of the three buoys recorded data.

All in all 2019 was in good agreement with the long-term average at all three buoys, with spring (March to May) and September being somewhat rougher, August and autumn (October/November) somewhat calmer.

There were no new records in 2019 for maximum significant wave heights measured. The highest measured significant wave heights were recorded during a storm directly on 1 January. At the station Arkona a significant wave height of 4.0 m was measured and at Darss Sill a significant wave height of 2.9 m was measured. Also worth mentioning is the storm event on 15 March, when a significant wave height of 3.8 m was measured at Arkona and 3.6 m was measured at Fino 2. The buoy at Darss Sill unfortunately did not record this event due to a temporary downtime. However, all these values were clearly below the monthly all-time maxima.

Skagerrak

Skagerrak, station Väderöarna

The wave buoy at station Väderöarna was out of operation in the beginning of 2019 until 21 February, then fully operational during the rest of the year.

There were no overall new record high values, but the highest significant wave height during 2019 was measured on 17 March with 6.6 m, when a deep low was passing northeast over southern Scandinavia. This was a new record high for the month of March, since the measurements started in 2005. Second highest notation for this year was in September as the remnants of tropical cyclone Dorian affected northern Europe. Strong southwesterly winds generated a significant wave height of 4.6 m at Väderöarna on 15 September. This is the fourth highest September value since the start of the station. During the rest of the year there were no extreme measurements and the maximum significant wave heights were well below the record notations for each month.

The monthly average of significant wave height was higher than the normal in March due to the windy conditions. Other months, with higher than the normal averages were May, August and September. Months with lower averages than the normal were April, October, November and December, with exceptionally low means in April and November.





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 2019 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 Geesthacht - Zentrum für Material- und Küstenforschung GmbH (HZG) was 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. Long-term climatological wave data are not yet available at the latter position. 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 wave height.

The waves at each station are measured with surface following buoys, Seawatch, Watchmate (at Huvudskär Ost), Directional Waveriders, and Waveriders. Measurements were collected 0.5 - 1 hour via Iridium, HF link, Argos-satellite, Orbcomm system and dataloggers. The significant wave height is calculated as H_{m0} on board the buoys over 1600 s or 1800 s time series of surface displacement and the quality of the measurements were 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 2019 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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