'Significant Wave Height'
A closer look at wave forecasts

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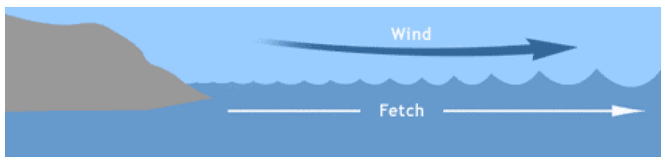
NOAA's National Weather Service (NWS) marine weather forecasts include information about prevailing wind speed and direction, and significant wave height. The term "significant wave height" is not as well understood as the wind information. Anyone using marine weather information should have a clear understanding of what significant wave height means. Let's review basic ocean wave characteristics so that you can interpret marine weather forecasts as NWS forecasters intended.

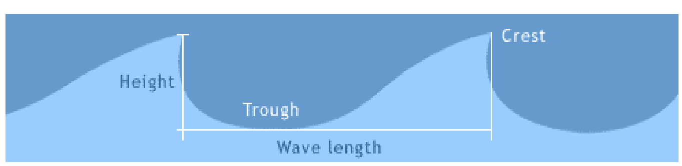
Wave Formation: Waves are formed by wind blowing along the water's surface. Wave height is dependent on a) wind speed; b) fetch length; and c) duration of time the wind blows consistently over the fetch. Wind 'fetch' is the distance the wind blows over water with similar speed and direction. High wind speeds blowing for long periods of time over long stretches of water result in the highest waves. Waves caused directly by the local wind are called wind waves. Wind waves are short, choppy, and tend to break (white cap) when winds reach approximately 15 knots. These are the most common waves on lakes, ponds and in the confined, narrow stretches of southeast Alaska's inner channels.



Graphic courtesy of Tammy Pelletier, WA State Dept of Ecology

Wave patterns become more complex in the open ocean. Waves are still formed by the local wind but once formed ocean waves continue to travel for thousands of miles. Waves that travel outside of their generation area, and are no longer the result of the local wind, are called 'swell'. Compared to wind waves, swell are longer waves with smoother crests. Over time, swell travel great distances, converge with other waves caused by distant storms and traveling in different directions, and refract off coastlines. Therefore, ocean surfaces are comprised of *thousands* of interacting waves that originated in different places and traveled in different directions at different speeds. This is known as a "wave spectrum": a combination of waves with different heights, frequencies and direction of movement.

Wave Dimensions: The magnitude of a wave is determined by three components: height; length; period (or frequency). A fourth wave component is steepness. Wave height is the distance measured from the trough to the crest of the wave. Wave length is the distance between successive crests (or troughs). Wave period is the time that elapses between the passing of successive crests (or troughs). Wind waves tend to have smaller heights and have shorter periods than swell.



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Wave steepness is the slope determined by the ratio between wave height and wave length. Wave steepness can be inferred from buoy measurements of wave height and period. When wind wave heights and periods are close to the same value (e.g., six foot seas every six seconds) wave steepness is severe. Pitch poling and capsizing becomes real possibilities for smaller vessels when wave steepness is severe. As waves move farther away from their source region, their wave length and period gradually increase. Therefore, waves with long periods, greater than 10 or 12 seconds, are arriving from a distant source and are considered swell.

Significant Wave Height: By now you know a wave spectrum is an extremely complex fluid phenomenon. The spectrum is literally made up of waves on top of waves (on top of waves!). It is extremely important for mariners to understand how this spectrum of wave heights is conveyed in marine weather information. The wave height value in a NOAA forecast and reported by ships and buoys is called the *significant wave height*. Significant wave height (Hs) is defined as the average height of the highest one-third waves in a wave spectrum. This happens to correlate very well with the wave height a skilled observer perceives in a wave spectrum.

What do we mean by "highest one-third waves"? Remember, a wavy water surface is comprised of thousands of interacting waves that originated in different places and traveled in different directions at different speeds. If a person could filter out and plot on a graph all of the waves within a spectrum, the distribution of waves with different heights would result in a "bell curve" graph similar to the one in the figure to the right. Each dot represents a wave in the spectrum with a height of H. The graph shows there are a relatively low number of small waves (left side of graph) and a low number of very large waves (right side of graph). The greatest number of waves (N) in this spectrum is in the mid range of heights (centered under Hm). The highest one-third (33.3%) number of waves in this spectrum is shaded on the graph. The average height of waves in this shaded group is the significant wave height, Hs.

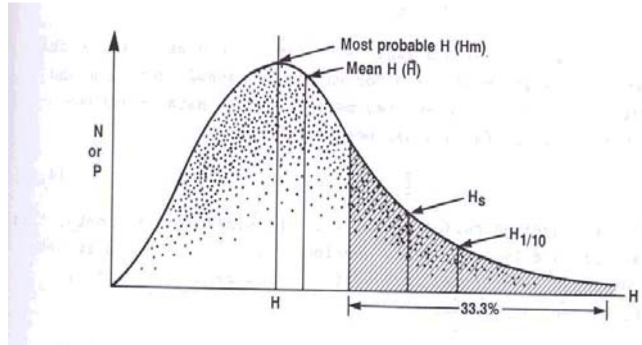

Figure 4.9: The statistical distribution of wave heights showing various parameters (from Bretschneider, 1964)

Also shown are the mean wave height (H), most probable wave height (Hm), and the height of the highest 10% of waves (H1/10). The mean wave height H is approximately equal to 2/3rds (0.64 or 64%) the value of Hs and H1/10 is approximately equal to 1.27 times (127%) the value of Hs. In addition, the height of the highest 1% of waves (H1/100) is approximately equal to 1.67 times (167%) Hs and a theoretical maximum wave height (Hmax) are approximately equal to *two times Hs*. This range is narrower in the inner channels where the contribution of ocean swell is less.

Quiz Time! Let's put all these wave parameters into perspective by practicing how to derive pertinent wave characteristics. If you received a marine weather forecast predicting "SEAS 10 FT" in the coastal or offshore waters, what is really being conveyed in that forecast?

- Hs = 10 ft
- H (mean) = 0.64 times Hs = 6.4 ft
- H (most probable) (slightly less that H mean) = 6 ft
- H1/10 (10% highest waves) = 1.27 times Hs = 12.7 ft
- H1/100 (1% highest waves) = 1.67 times Hs = 16.7 ft
- Hmax (highest wave you should be on the alert for) = approximately 2 times Hs = 20 ft!

Therefore, a forecast of 10-foot seas in open waters means a mariner should expect to encounter a wave spectrum with many waves between 6 and 10 feet along with a small percentage of waves up to 16 feet and possibly even as large as 20 feet! During the Gulf of Alaska storm on March 10, 2005, buoys observed waves heights as high as 47 feet in the northern Gulf. In a wave spectrum with a significant wave height of 47 feet, the highest 10% of waves (H1/10) would equal 1.27 x 47 = 60 ft. And the theoretical maximum wave height in that spectrum is 94 feet (2 times Hs)!!

Prudent mariners know the physical limits of their vessels with respect to wind speed and wave height. The marine weather forecasts provide both wind velocity (speed and direction) information and wave height information. Wave height values, both predicted and observed, are defined as the significant wave height, Hs. Hs is not a single value but rather a value which implies a range of heights, from approximately 60% of Hs to 200% of Hs in the open ocean (narrower range in the inner channels), occurring in a wave spectrum! Mariners should not focus on the single significant wave value in a forecast or observation but recognize the concept of the wave spectrum, know the definition of significant wave height, and be able to determine the expected range of wave heights.