The Storm Wave Studies - An investigation into the data recovered from a 6m Moored NOMAD Buoy on Canada's East and West coasts.

By

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1.0 INTRODUCTION

The ability to forecast wave heights accurately during storm conditions is a prime objective for increasing marine and coastal safety. Accurate determination of wave properties during extreme weather is also essential to the development of design criteria for marine vessels, and coastal and offshore structures. Searches of the literature and discussions with experts in the field (Heidorn, 1993) have indicated that little is known about the airflow regime surrounding buoys, their motion in high seas, and the effects that averaging the data has on the reporting of a true wind speed.

As a result of the uncertainties concerning wind measurements in sea states where the height of the significant wave is significantly greater than the height of the anemometer, the Storm Wave Study-1 (SWS-1) was initiated. A 6 m ship-shaped NOMAD weather buoy was deployed off the West Coast of British Columbia (approximately 10 miles Southwest of Cape St. James) at the southern tip of the Queen Charlotte Islands in 2,000 m of water at WMO location #46147. This buoy, in addition to being part of the regular Canadian network of weather reporting buoys, was equipped with an additional payload designed to gather data (primarily wind speed and direction and wave height and period) at 2 Hz during storm periods, and store it directly without any averaging.

The buoy was successfully deployed and, in the winter of 1994/95, recorded a number of storms, the worst being associated with a significant wave of 9.4 m. The SWS-1 study found some important items with regard to wind and wave measurement and recommendations were made both for changes in the way the Environment Canada buoys report data as well as for a follow-on SWS-2 study to continue the research into areas requiring further study. In summary the data showed a number of interesting and important results. These were:

- wind speed and direction both demonstrated significant variability over individual waves. The so-called sheltering effect manifesting itself with reduced speeds and changes in wind direction in the wave troughs. This variability typically increased with increasing wave height. This variability were shown to have linear relationships with wave height;

- the effect of reporting vector mean winds as opposed to scalar mean winds seems to make a difference of only 3% or 4%. This is less than the 7% proposed by Gilhousen;

- the effect of the roll and pitch motions of the buoy had a negligible effect on the reported wind speeds;

- the strap-down accelerometer appears to read about 9% lower than the Datawell Mark II sensor under all wave conditions; and,

- the variability of wind and wave conditions within any one-hour is quite large. The data that are reported on the hourly satellite broadcast is thus a factor of the conditions encountered, the sampling and averaging interval, and the processing algorithms.

One of the main recommendations from SWS-1 were to carry out a follow-on program (SWS-2) on a NOMAD buoy deployed in the vicinity of a fixed platform for additional data verification and intercomparison. On Saturday October 25th 1997, the SWS-2 program was initiated with the deployment of an Environment Canada NOMAD buoy at 46°44.05'N, 48°48.13'W on the Grand Banks of Newfoundland in 81m of water on an all-chain mooring, 1.5 nautical miles to the south-west of the Hibernia platform. The buoy was on station until December 1st when the mooring parted. The buoy was redeployed on February 19th, 1998 and data was recorded until March 15th. In this paper Phase 1 refers to the first deployment period and Phase 2 refers to the second. Some of the key points of note for SWS-2 are:

- an additional strap down accelerometer was located as closely as possible to the Datawell heave sensor. A Systron Donner motion sensor (3 accelerometers and 3 rate sensors) was installed in the SWS-2 compartment; this resulted in the following wave sensors (see Figure 1):

Sensor	Location
Datawell (Heave & Accelerometer output)	Compartment 2
Strap-down Accelerometer co-located with Datawell	Compartment 2
Strap-down Accelerometer in SWS-2 package	Compartment 3
Systron Donner motion sensor in SWS-2 package	Compartment 3

- a Solent Windmaster acoustic anemometer, as well as an RMYoung 05305 AQ anemometer were installed the aft mast alongside the standard RMYoung 05106 anemometer;
- sampling at 2Hz was continuous for the period of deployment;
- The installation of a 3 Axis Solent Ultrasonic acoustic anemometer on the forward mast as part of a program being run by the Southampton Oceanography Centre;
- A Directional Datawell Waverider and a Minimet Buoy were located in the same vicinity as the SWS-2 NOMAD. The data being measured on the Hibernia platform included wind speed and direction, and wave height and direction from a MIROS wave radar.

The paper includes data and analysis of the unique data sets from both SWS-1 and SWS-2. Particular attention is given to the output from the variety of wave sensors tested on the buoy, the variability of wind speed and direction and the differences between vector and scalar averaging of wind speeds with

wave height. A gust factor analysis will also be shown. The importance of co-operation between Environment Canada's Operational programs, their Climate Research Branch, the private sector and the oil industry is noted.

Analysis

Anemometers

SWS-2 tested three different anemometers. The anemometer used on all the Environment Canada buoys is the RMYoung 05106 (marine version). For SWS-2 two alternative sensors were evaluated. The first was the more sensitive RMYoung AQ and the second was a sonic Solent Windmaster. The RMYoung AQ has a threshold of 0.4 m/s as compared with the 1.1 m/s for the 05106. These three anemometers were mounted on the aft mast. An additional high frequency Sonic anemometer was mounted on the forward mast for studies being carried out by Southampton Oceanography Center (SOC). The results from their program are discussed separately.

Figure 2 shows a scatter plot between the two RMYoungs. The data show that they are in very close agreement. Both anemometers behaved well during the trial. From this data there is no evidence to suggest that the anemometer of choice should change from the RMYoung 05106.

Figure 3 shows the percentage difference between the two RMYoungs versus wind speed.

Figure 4 shows a scatter plot between the 05106 and the sonic Solent Windmaster. There is considerable scatter here. On a more detailed examination of the data it appears that the sonic is being affected by short-term events that last from a few seconds to a few minutes. Although this effect is interesting and worthy of further investigation, the Windmaster does not give any additional information that addresses the key questions of the SWS program. Given this and the short record length from the anemometer, no further analysis with the sonic data is considered.

Vector/scalar vs wind speed

In SWS-1 only data during the peak of storm events were recorded and analysed. In SWS-2 a continuous data stream was recorded and analysed. Figure 5 shows that the percent difference between scalar and vector averaging has a greater variation than was experienced during SWS-1. A range of 2 to 15+% seems to be evident if the data for wind speeds greater than 5 m/s higher wind speeds is examined. Synoptic events still cause the largest difference in the vector/scalar quantities.

All the Environment Canada buoys now report scalar values of wind speed.

Gust Factors vs Gust Length

The SWS-1 data showed that a gust factor for a 1 second mean scalar wind (effectively the instantaneous wind speed) was approximately 1.45 times the value of the 10 minute mean scalar wind. This factor is shown to be 1.6 for SWS-2. However the SWS-2 data set includes the complete data set, not just the winds associated with the high wave events. Figure 6 shows the gust length vs the 10 minute mean scalar wind. It is independent of wind speed and includes the $\pm$ one standard deviation error bars.

Effects of Wave Height on Measured Wind Parameters

As noted earlier wave height was measured from many sensors on the buoy. The time series of the wave data from the Datawell heave sensor for the time of deployment is shown in Figures 7 and 8. In SWS-1 the accelerometer data from Compartment 3 was compared to the Datawell Heave output.

In SWS-2 an additional accelerometer was co-located with the Datawell.

Scatter diagrams of the various sensors have been plotted using the Datawell heave sensor as the standard. The results from these diagrams are:

Comparisons of Scatter of Hs with Heave Output from Datawell Sensor

Sensor	Phase	Slope	Intercept	R^2
Accelerometer (compartment 2)	1	0.9468	0.0925	0.9864
	2	0.9794	-0.0406	0.9857
SWS-2 Accelerometer (compartment 3)	1			
	2	0.9847	-0.0317	0.9857
Systron Donner Z accelerometer (compartment 3)	1	.9335	0.1509	0.988
	2	0.9668	0.0183	0.9855

The data show that the SWS-2 accelerometer and the accelerometer in compartment 2 give very similar results. The difference between them and the Datawell sensor are in the 2% to 5% range. This is less than the 9 to 10% reported in SWS-1. The data include wave heights from 1.5 to 9 m. Unlike SWS-1 there are few data points beyond 8m. However SWS-2 confirms, as might be expected, that the accelerometer records values that are lower than the Datawell values. It should be remembered that NOMAD weather buoys on the East coast of Canada use a strap-down accelerometer and all the NOMAD buoys on the West Coast use a Datawell.

Figures 9 and 10 show the variation of gust factor and scalar/vector quantities with wave height. Similar details were reported from the SWS-1 data.

Conclusions

The analysis of the SWS-2 data is not complete. Nonetheless the analysis that has been completed shows that there are both similarities and differences between the two studies. It is too early to comment on the reasons.

Wind Sensors

The RMYoung 05106, which is used throughout the Environment Canada weather buoy network, provides data that matches well with the RMYoung AQ. Thus there is no reason to warrant changing the present standard anemometer. The performance of the sonic was no better, with some, as yet, unexplained periods of spiky data.

Wave Sensors

The data from the two strap down accelerometers (one in compartment 3 and the other co-located with the Datawell in compartment 2) was very similar. The difference between the values reported from these sensors and the Datawell was only 2 to 5%. This is less than the 10% noted from SWS-1.

The data from the vertical accelerometer in the Systron Donner motion sensor gives similar values to the other two strap-down accelerometers. Further analysis of the compensated motion from the Systron Donner is being carried out.

References

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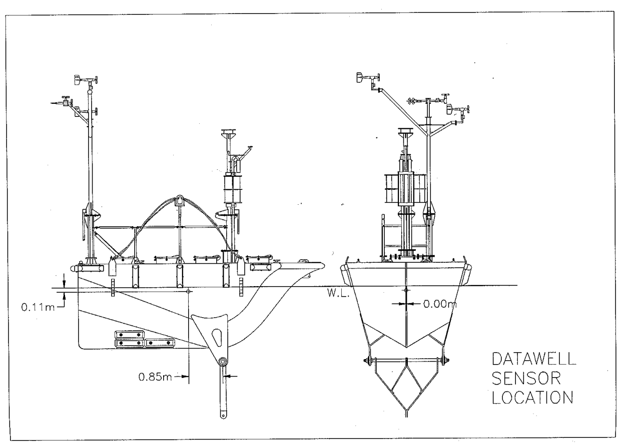
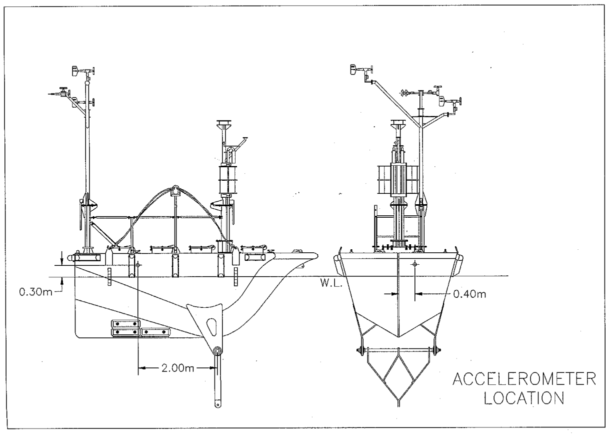
Heidorn, K.C. 1993. The Influence of High Waves on Buoy-Measured Wind Speeds. Climate Research Branch, Atmospheric Environment Service, Environment Canada, Downsview, Ontario.

Skey, S.G.P., K. Berger-North, V.R. Swail. 1998. Measurement of winds and waves from a NOMAD buoy in high seastates. Proceedings of the 5th International Workshop on Wave Hindcasting and Forecasting, Melbourne, Florida, January 26 – 30, 1998. Climate Research Branch, Atmospheric Environment Service, Environment Canada, Downsview, Ontario pp. 163-175.



Datawell and Strap-down Accelerometer in Compartment 2

Figure 1a



SWS-2 Accelerometer and Systron Donner in Compartment 3

Figure 1b

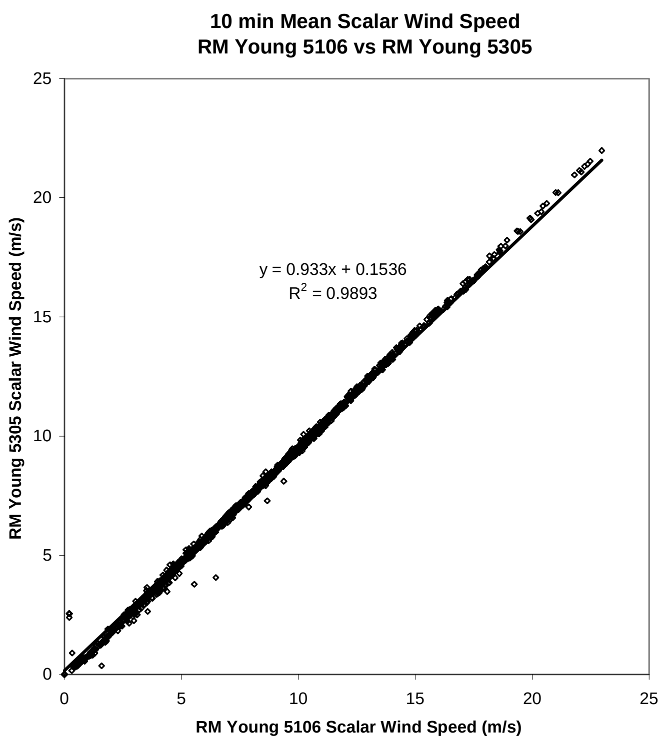


Figure 2

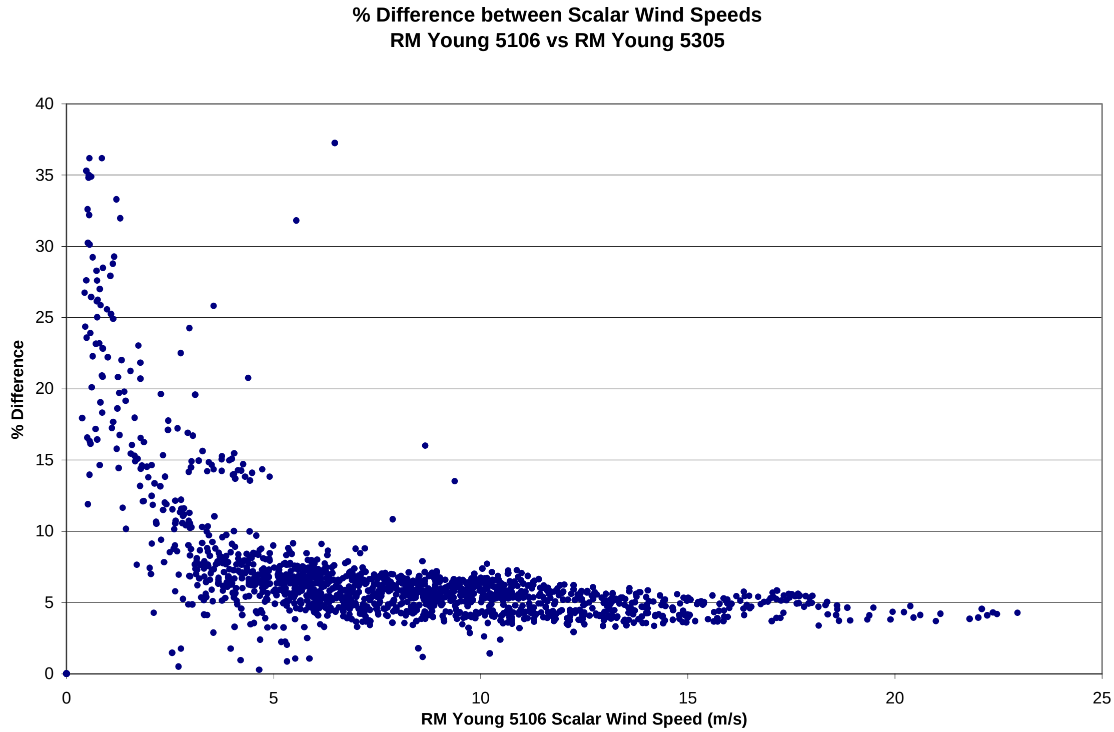


Figure 3

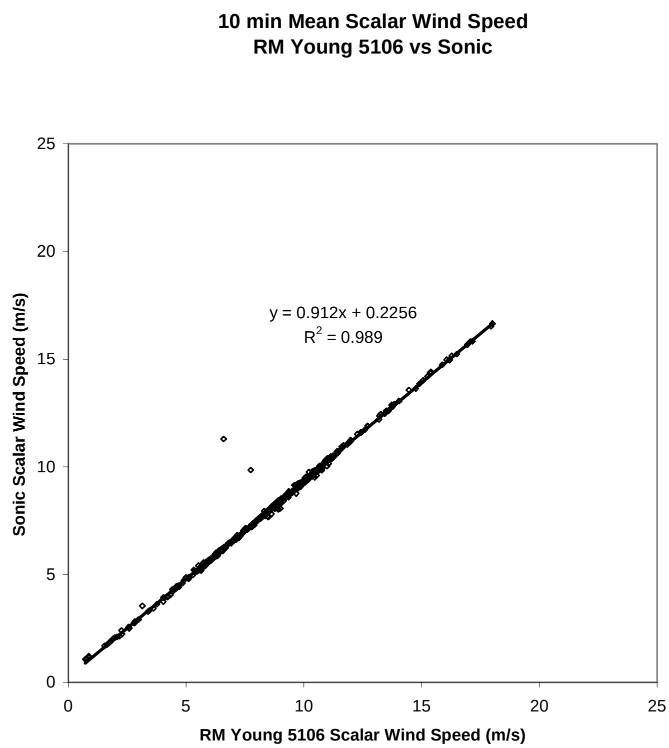


Figure 4

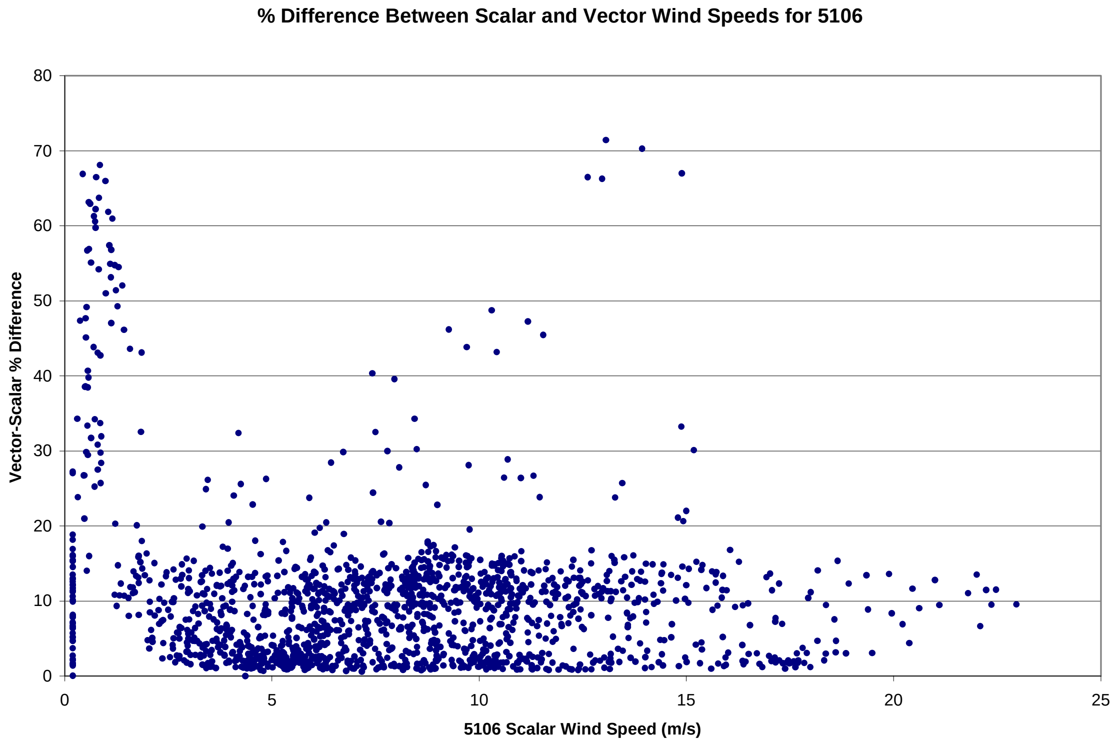


Figure 5

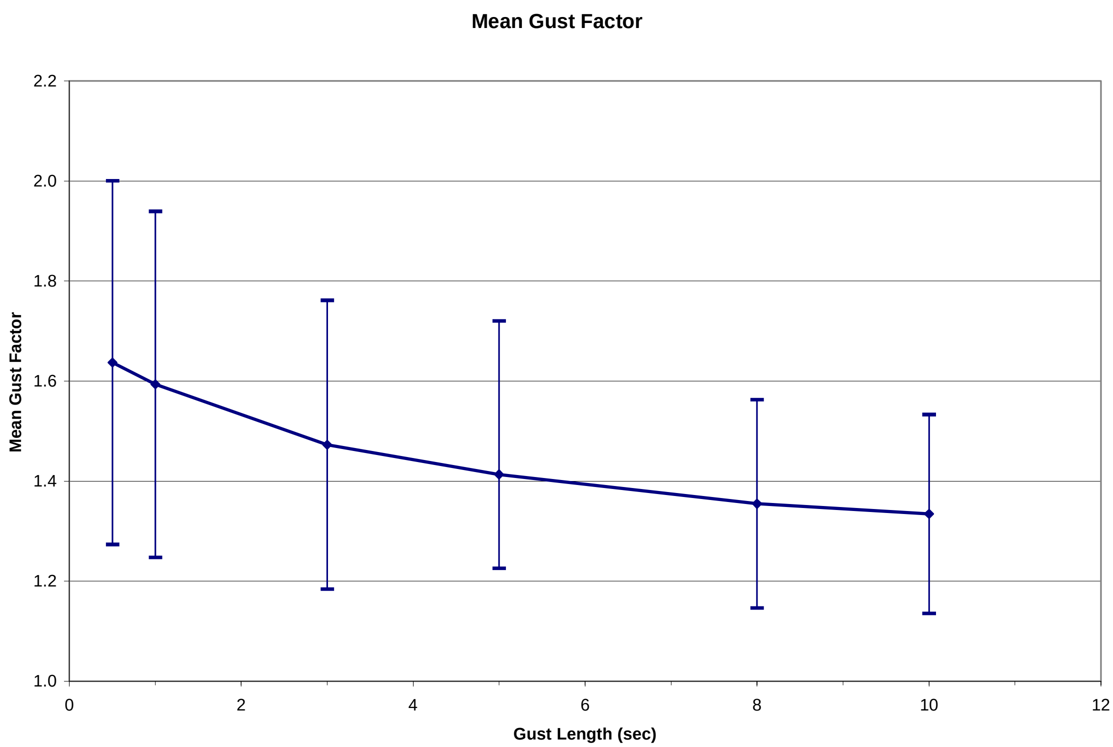


Figure 6

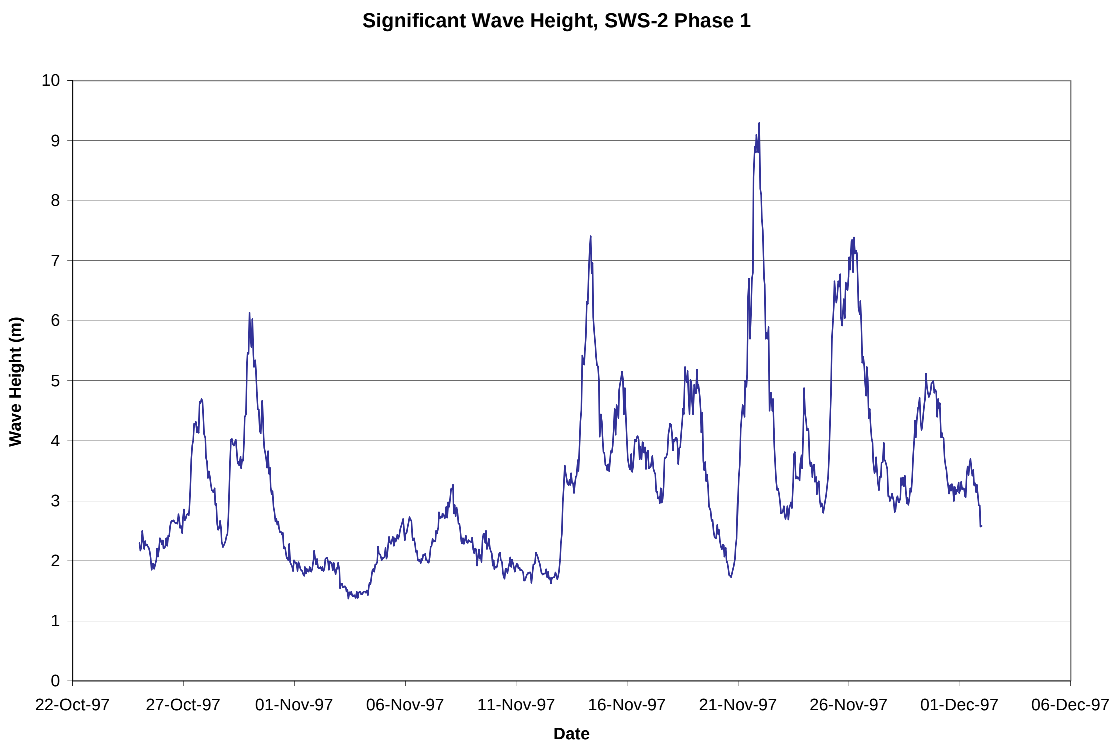


Figure 7

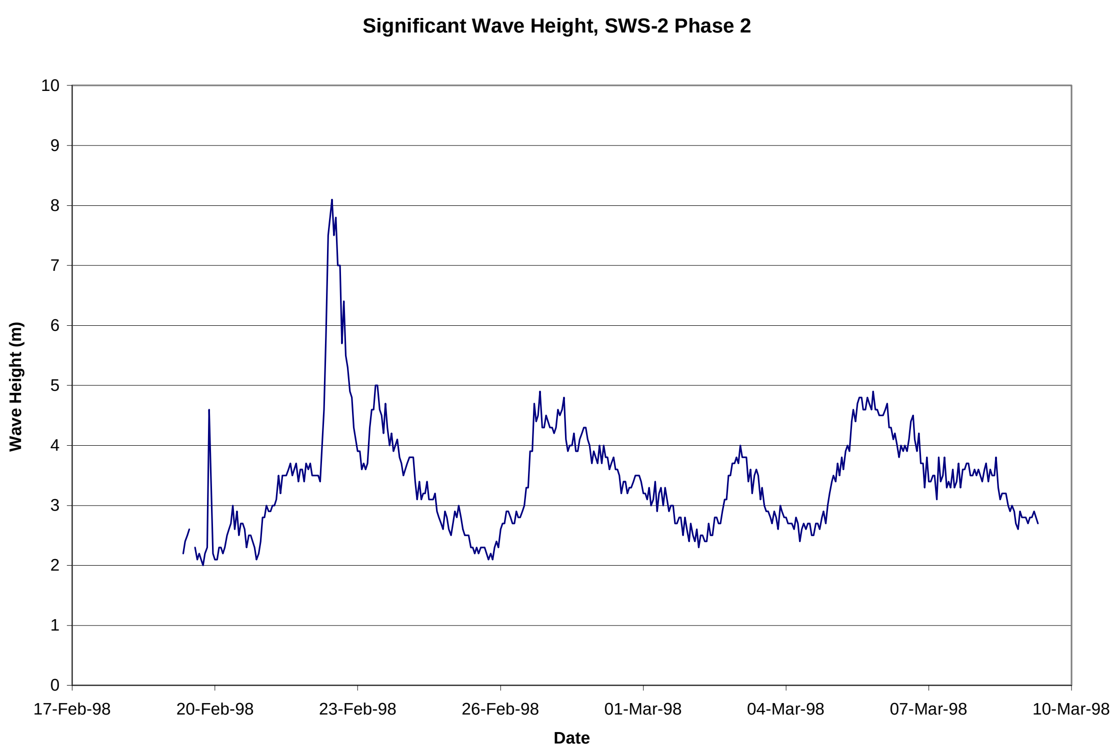


Figure 8

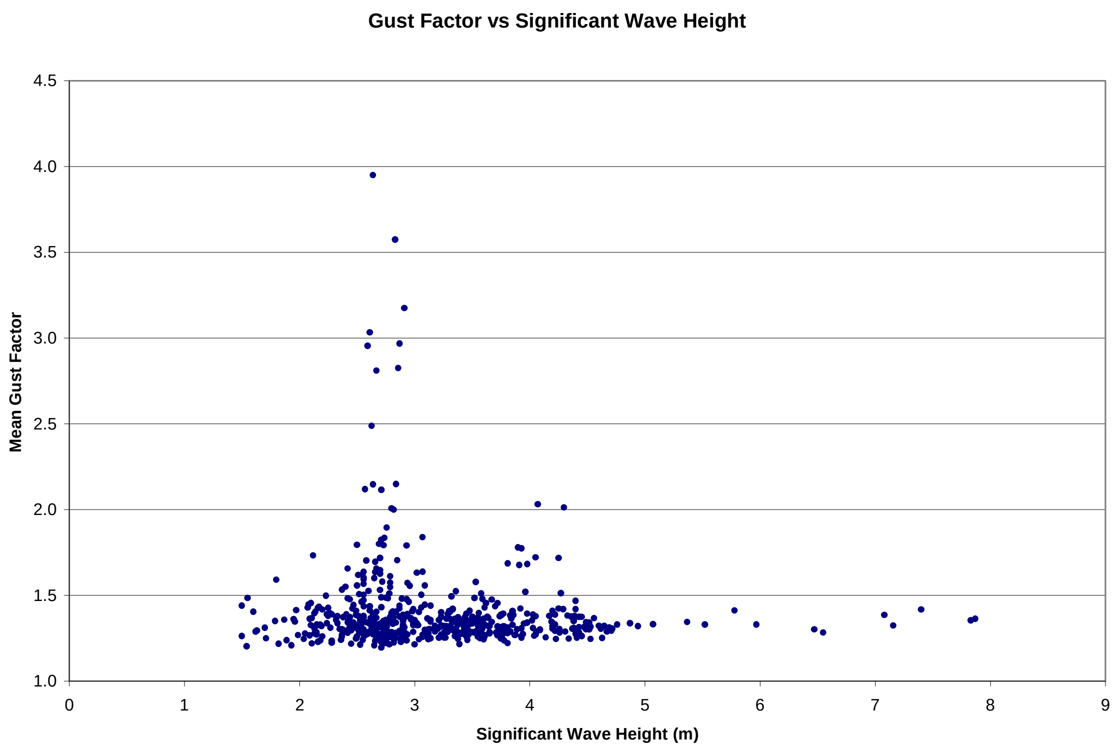


Figure 9

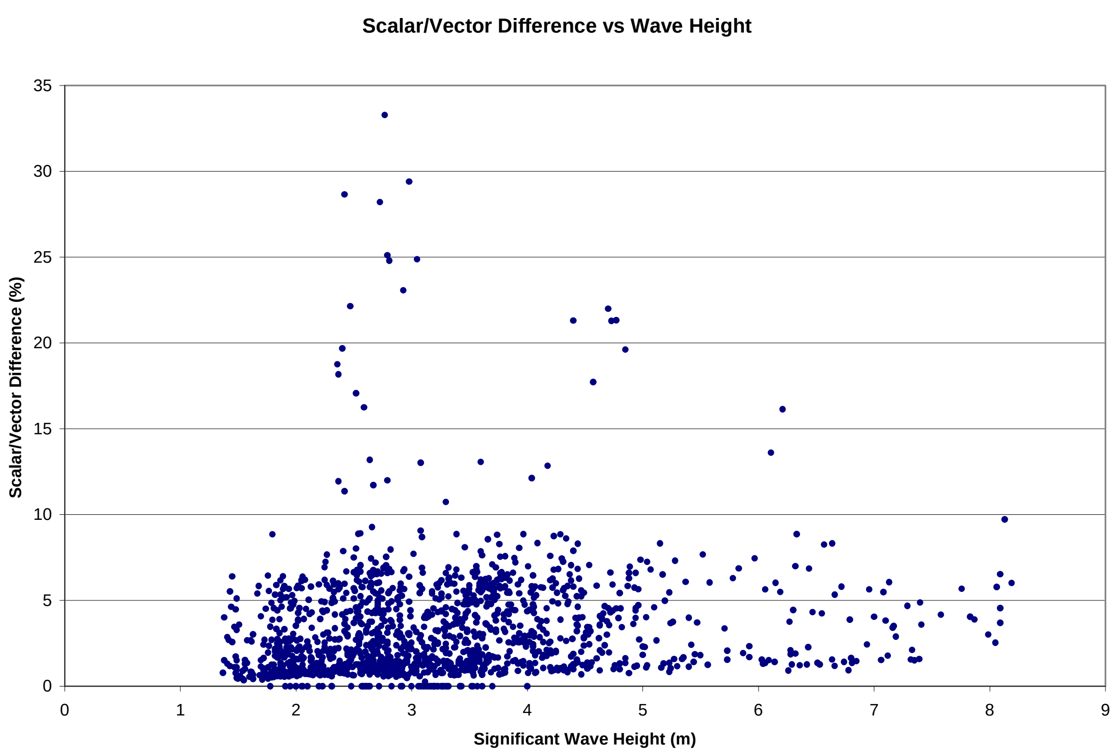


Figure 10