A Forecasters 5-year Climatology for Buoy 46029 Off the Columbia River Bar (2002-2006)

David B. Elson
NOAA/National Weather Service
Portland Oregon

1. INTRODUCTION

Forecasting wind, waves and temperatures accurately in the marine environment requires knowledge of local climatology, and some basic relationships between these elements. This paper presents a simple five-year climatology of observed conditions at buoy 46029. The following statistics and relationships are not intended to comprise a comprehensive climatology of buoy 46029[1]. The intent of this study is to explore relationships between forecast elements that will aid in forecasting.

Buoy 46029 is located approximately 20 nautical miles off the Columbia River Bar, west of the border between Washington and Oregon. During the five year period from 2002 through 2006, a little over 40,000 hourly observations (Table 1) were recorded. Analyses of these observations included statistics drawn from wind speed, wind direction, wind gusts, significant wave height (hereafter referred to simply as wave height), and air and water temperatures. There were intermittent periods of missing data. The most extensive of these was a 3 ½ month period from 8 December 2004 to 14 April 2005, which may have skewed some of the following results.

Weather Element	Number of Observations
Wind	40,576
Significant Wave Height	40,193

Table 1

2. THE DATA

2.1. WIND

In the Western Region of the National Weather Service, the threshold for a Small Craft Advisory (SCA) for winds is sustained winds or frequent gusts of 21-33 kts (National Weather Service, 2006). Sustained SCA winds were recorded in 3,470 observations, or about 8.6% of the time. Sustained gale force winds (34-47 kts) were much less frequent, occurring just 0.4% of the time. In this five year period, storm force (48-63 kts) or stronger sustained winds were not observed.

As might be expected, wind gusts reaching or exceeding SCA criteria were much more commonplace. SCA wind gusts occurred in 6,838 observations, or about 16.9% of the time. Gale force winds gusts occurred about 2.3% of the time. Storm force wind gusts were reached on 45 occasions, or 0.1% of the time. Finally, hurricane force wind gusts

(≥64 kts) were not recorded. Gale force or stronger gusts showed a strong prevalence for the period from late Fall through early Spring (Figure 1).

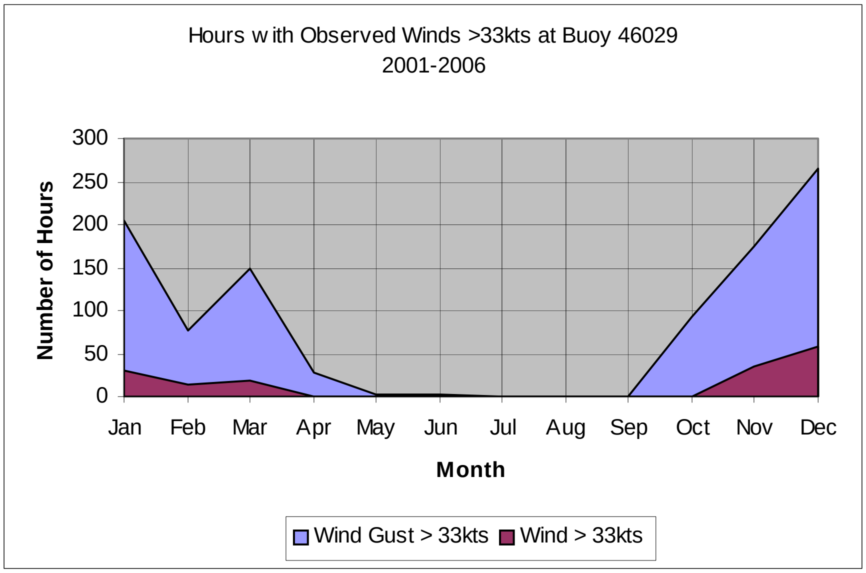


Figure 1. Number of hours with Gale Force or stronger wind gusts by month 2001-2006

For forecasting wind gusts, knowing the climatologic ratio of wind gust to wind speed may be helpful. The overall average wind gust to wind speed ratio in the five year period was 1.32. The average ratio for cases where the sustained wind exceeded 20 kts was slightly less (1.24), and varied little (Table 2).

Gust to Speed ratio	All Cases	Sustained wind speed < 21 kts	Sustained wind speed 21-33 kts	Sustained wind speed > 33 kts
Average	1.32	1.33	1.24	1.27
Median	1.23	1.23	1.23	1.27
Standard Deviation	0.44	0.46	0.05	0.05

Table 2.

Finally, seasonal wind roses reflect the pattern of a high pressure system dominating the northeast Pacific subtropics in the summer (Figure 2), and low pressure dominating the north Pacific in the winter (Figure 3)[2]. Specifically, the wintertime wind rose (Figure 4) shows a dominant south wind, with a secondary frequency indicating offshore east winds. Springtime (Figure 5) shows a transition from south winds to a dominant north wind pattern. The summer season (Figure 6) is strongly dominated by north or northwest winds, while the Fall season (Figure 7) indicates a transition from north to south winds.

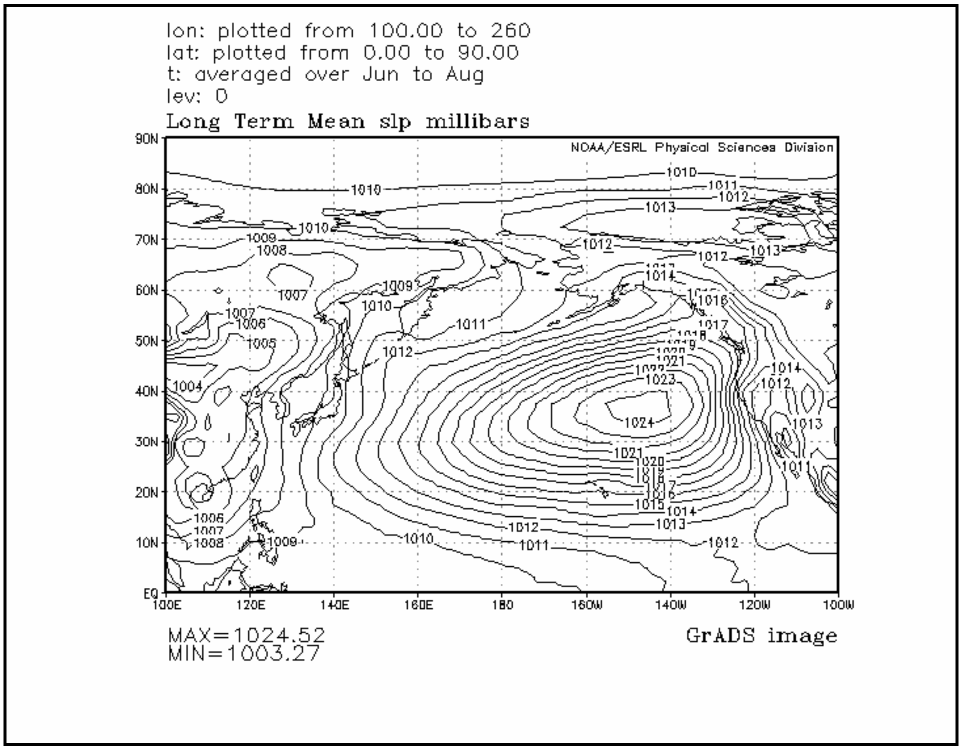


Figure 2. Mean Sea Level Pressure (mb) for the North Pacific Jun-Aug 1968-1996
Image source: NOAA Earth Systems Research Laboratory website at
http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.surface.html

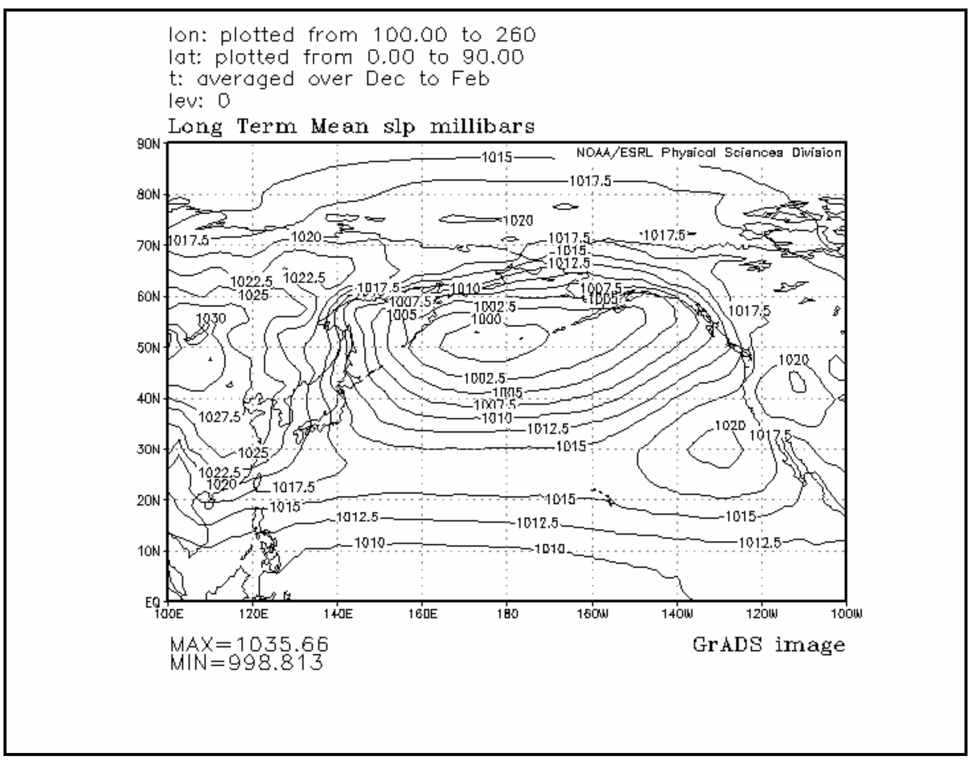
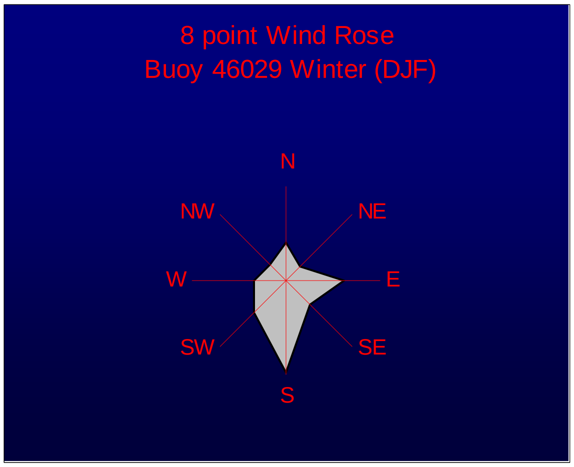


Figure 3. Mean Sea Level Pressure (mb) for the North Pacific Dec-Feb 1968-1996
Image source: NOAA Earth Systems Research Laboratory website at
http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.surface.html



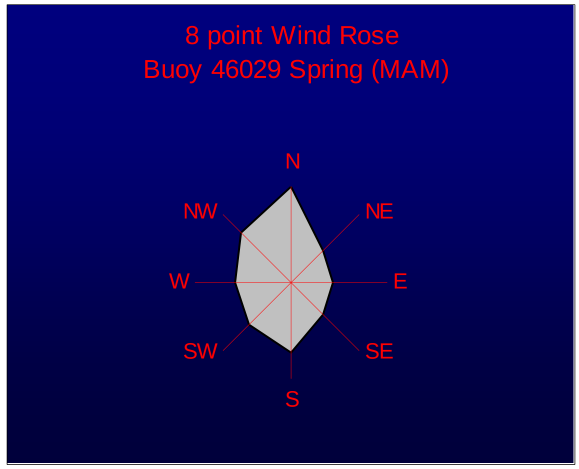
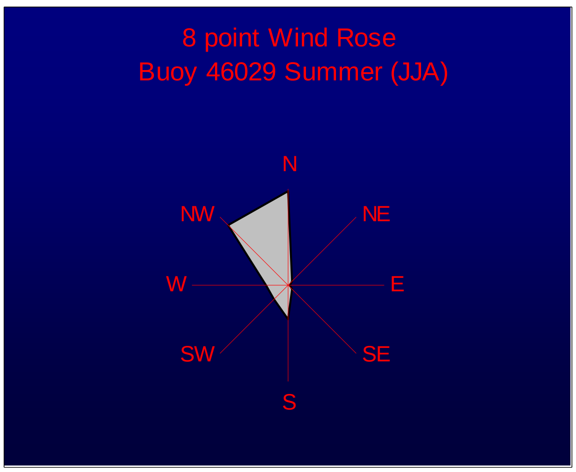


Figure 4. Winter Wind Rose
Buoy 46029, 2001-2006

Figure 5. Spring Wind Rose
Buoy 46029, 2001-2006



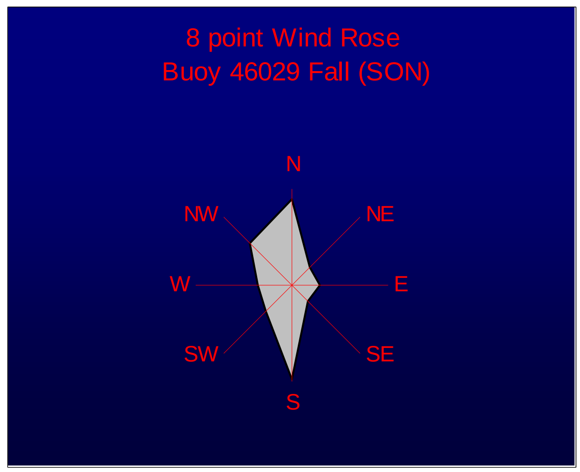


Figure 6. Summer Wind Rose
Buoy 46029, 2001-2006

Figure 7. Fall Wind Rose
Buoy 46029, 2001-2006

2.2. WIND AND SIGNIFICANT WAVE HEIGHT RELATIONSHIPS

Generation of waves is dependent on the wind. With this in mind, a comparison of observed wind with wave height at buoy 46029 follows. For these purposes, wave heights consist of a combination of wind-waves and swell. Local wind accounts for only a portion of the wave height measured at buoy 46029, so it is not surprising to find a large spread in the range of observed wave heights with various wind regimes. However, there is often a correlation between the local winds and the incoming swell, especially in the case of stronger storms. This is because the dominant storm track for the region often brings swell in from the same direction as the storm itself.

First consider the case for sustained winds compared with the simultaneously occurring wave height (Figure 8). A large spread in the distribution of wave heights is observed, primarily because of variations in the magnitude of non-locally generated swell. However, average wave heights reveal a distinct trend for the wave heights to increase with the winds. With this in mind, a forecaster can assess a range of wave heights that is reasonable for a forecast wind speed. A comparison of simultaneously occurring wind gusts and wave height (Figure 9) yields similar results. The standard deviations for both these situations range from 4 to 6 feet.

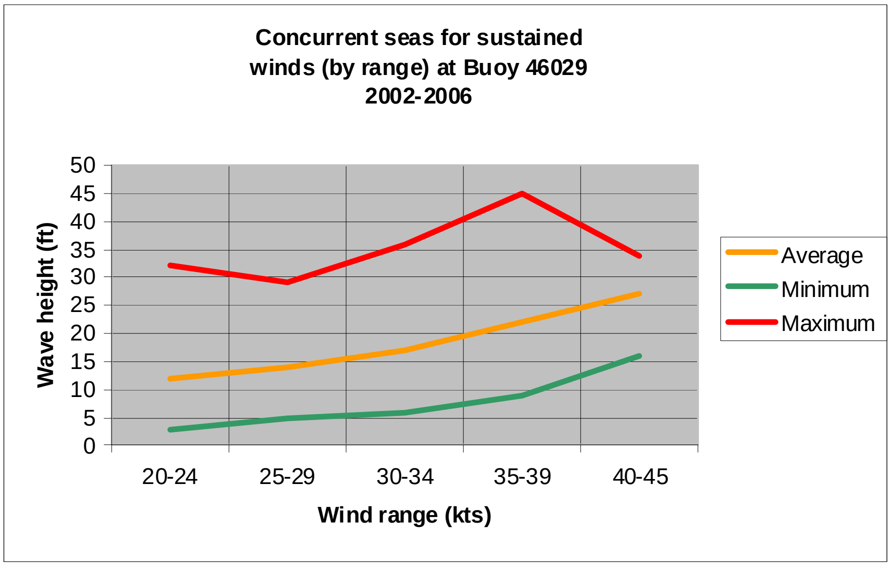


Figure 8. Concurrent winds and wave heights for buoy 46029, 2001-2006

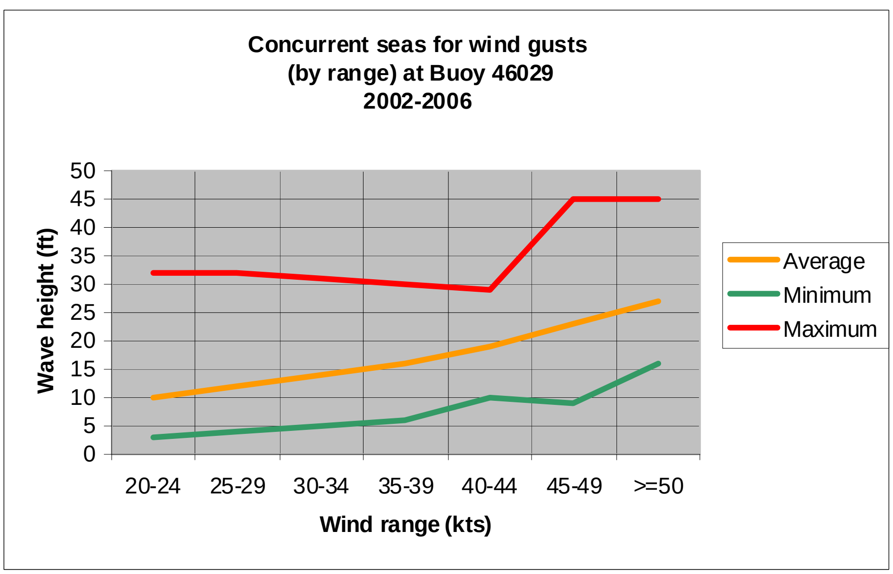


Figure 9. Concurrent wind gusts and wave heights for buoy 46029, 2001-2006

For a given wind, it takes a number of hours before fully developed seas are generated. As an example, for a wind of 25 kts blowing over a fetch of 200 nm, it would take about 20 hours before seas became fully developed at 13 ft (U.S. Army Corps of Engineers, 1984). This makes it logical to compare the winds with the observed wave heights over several hours. Comparing wind speed (Figure 10) and wind gust (Figure 11) with the highest wave height for the next three hours shows that wave heights increase as wind speeds increase. From the forecaster's perspective, a 3 hour window for wave height provides a more useful relationship of wind speed to wave height than the concurrent observations discussed earlier. This is because the forecaster is generally interested in the greatest wave height reached, as opposed to the simultaneously occurring wave height. Standard deviations range from 4 to 7 feet, with the larger standard deviations occurring with the higher wind speeds.

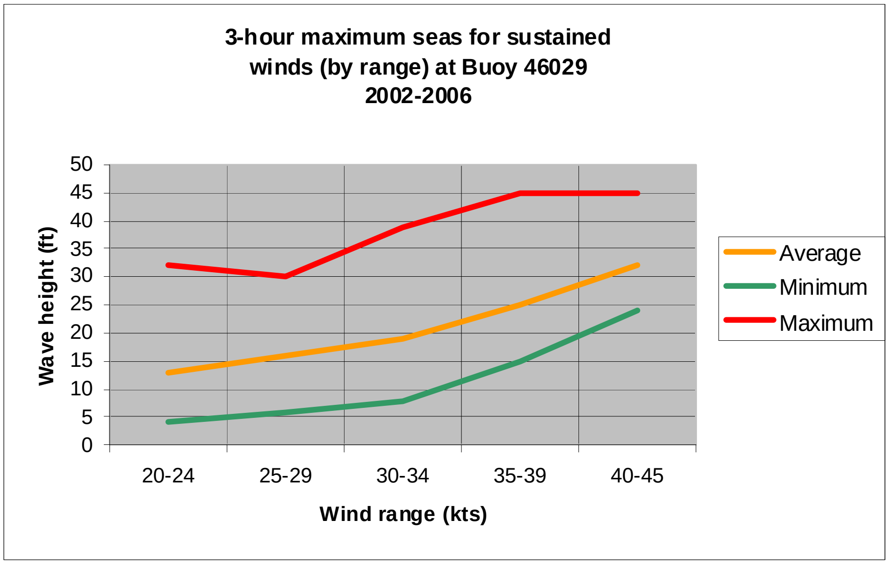


Figure 10. Wind vs. subsequent 3-hour maximum wave height for buoy 46029, 2001-2006

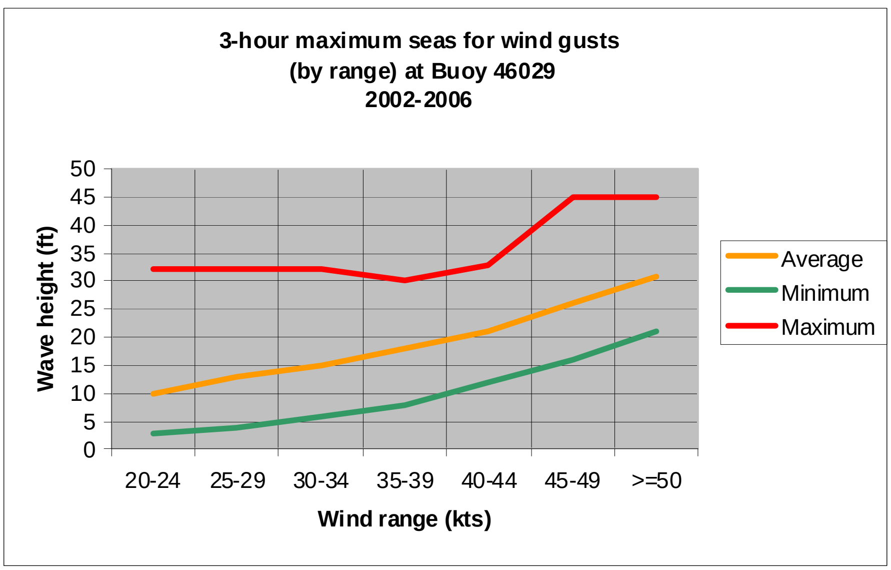


Figure 11. Wind gust vs. subsequent 3-hour maximum wave height for buoy 46029, 2001-2006

The idea of wind duration and the lag in wave development can be taken a step further. Comparing the 3 hour maximum wave height with the average sustained wind speed over that same 3 hour period (Figure 12) yields little new information. Standard deviations similarly range from 4 to 7 feet, with larger standard deviations occurring with higher wind speeds.

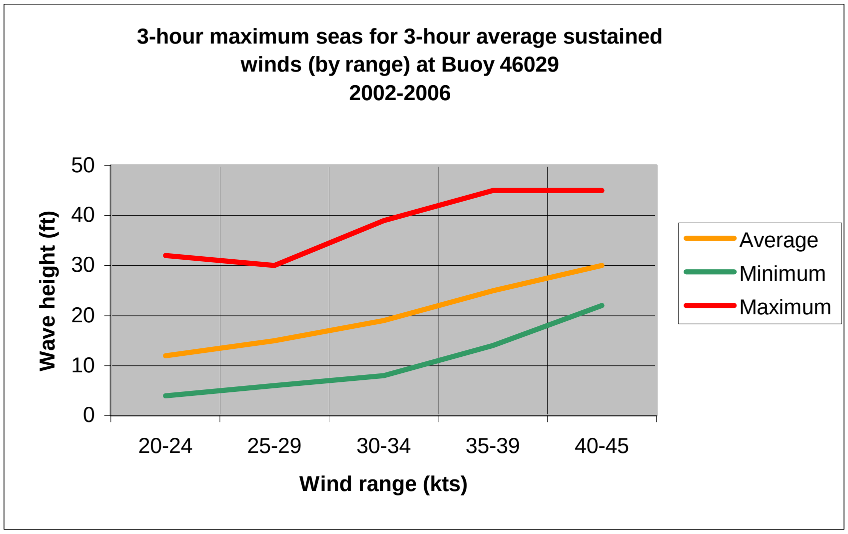


Figure 12. 3-hour average wind vs 3-hour maximum wave height for buoy 46029, 2001-2006

Finally, allowing an even greater lag in wave development can help identify situations with the highest peak wave heights. In this case, comparing a mean 3-hour sustained wind of 40 to 45 kts, shows that the average 6-hour greatest wave height (Figure 13) is 4 feet greater than the average 3-hour greatest wave height (Figure 12). The standard deviation for the 6-hour maximum wave heights ranged from 4 to 8 feet, with larger values occurring with higher winds.

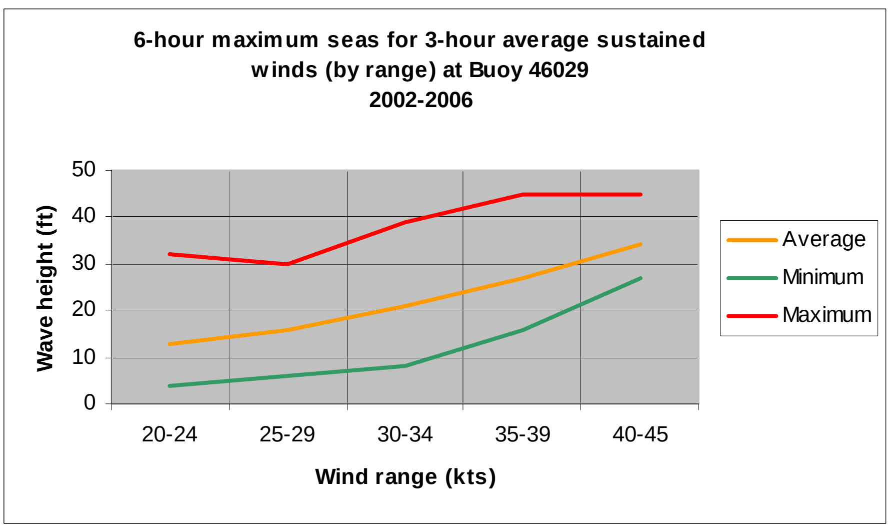


Figure 13. 3-hour average wind vs subsequent 6-hour maximum wave height Buoy 46029, 2001-2006

Comparing seasonal 3-hour maximum seas with sustained winds (Figure 14) reveals a few more interesting results. Not surprisingly, the biggest storms generally occur in the winter. During the summer high seas are infrequent, and average wave heights for the same wind speeds are less compared to seas in the winter, spring and fall. The seasonal variations between wave heights for a given range of wind speeds may best be attributed to seasonal variations in storm characteristics. As cold season storms off the coast of Washington and Oregon tend to be more extensive and persistent than warm season storms, it follows that seas would have a better opportunity to develop closer to a fully arisen height in the cold season.

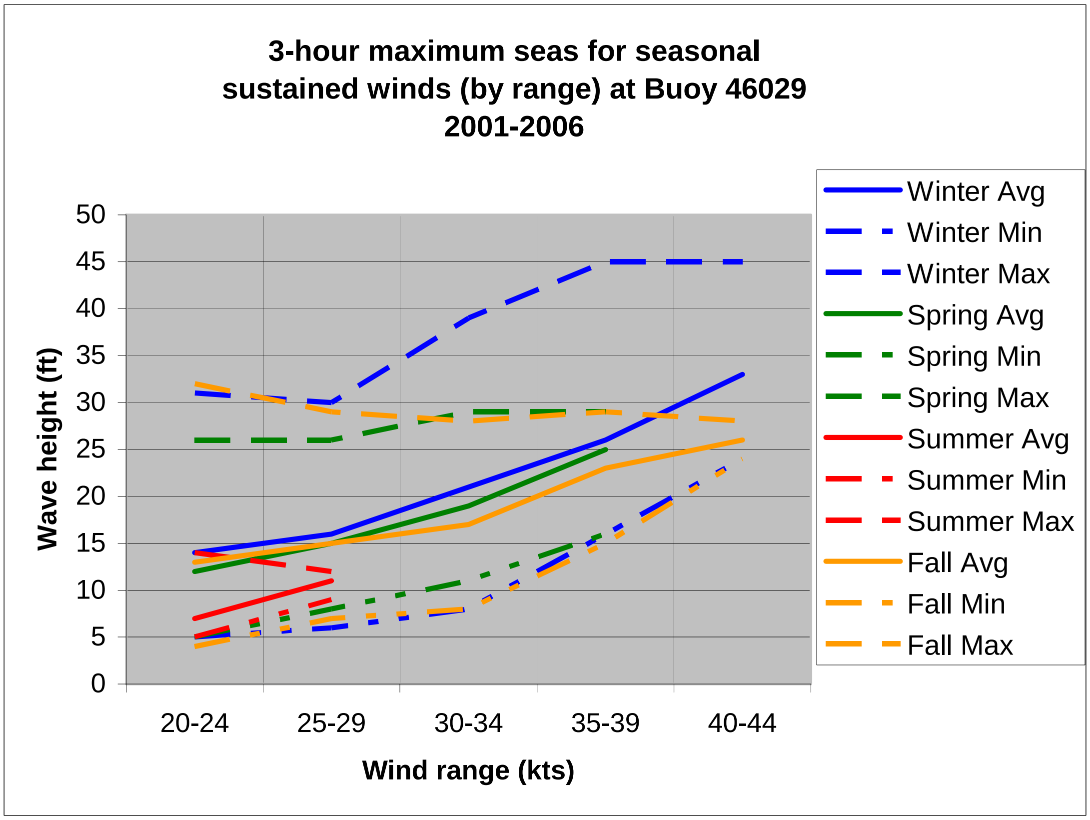


Figure 14. Winds vs. subsequent 3-hour maximum wave height for buoy 46029, 2001-2006

2.3. AIR AND WATER TEMPERATURE RELATIONSHIPS WITH WIND DIRECTION

Data comparing seasonal air and water temperatures with wind direction exhibits little correlation between wind direction and temperatures in the summer months (June, July and August, Figure 15). Data from the rest of the year (Figures, 16, 17 and 18) showed that normal temperatures for both air and water tended to be several degrees cooler when winds were from the north through the east. Conversely, the warmest temperatures occurred with winds from the south or southwest. The winter and summer seasons normally have a smaller spread in the distribution of directionally specific temperatures (standard deviations between 1 and 2 degrees) compared to the spring and fall seasons (standard deviations between 2 and 3 degrees).

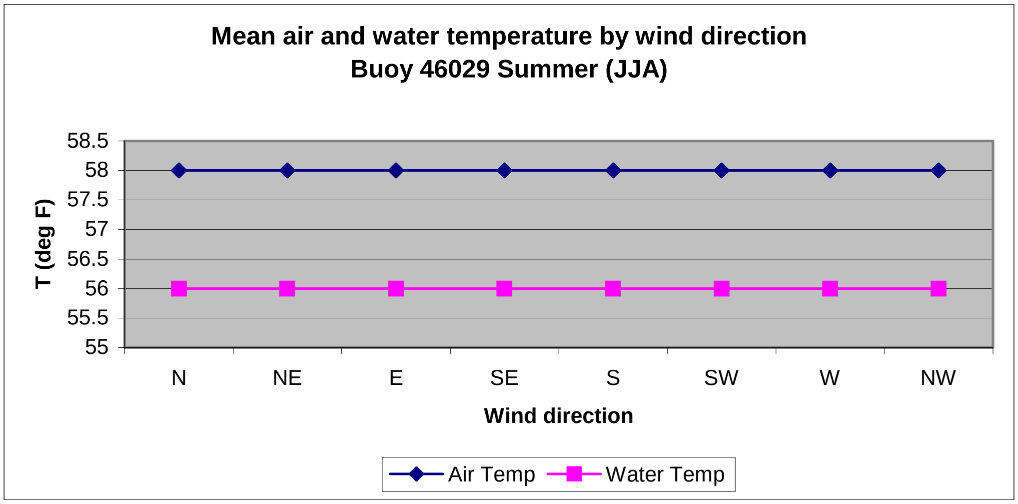


Figure 15. Mean air and water temperature by wind direction for buoy 46029, Summer 2001-2006

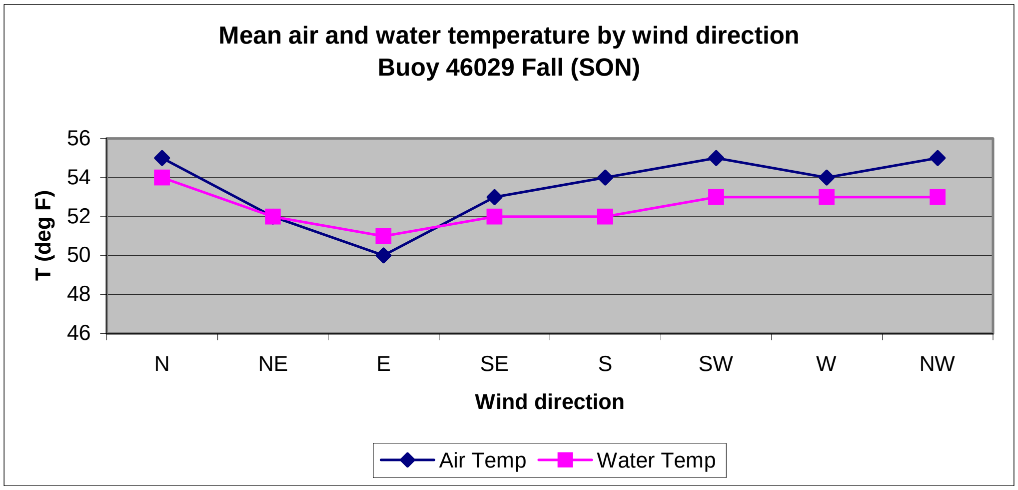


Figure 16. Mean air and water temperature by wind direction for buoy 46029, Fall 2001-2006

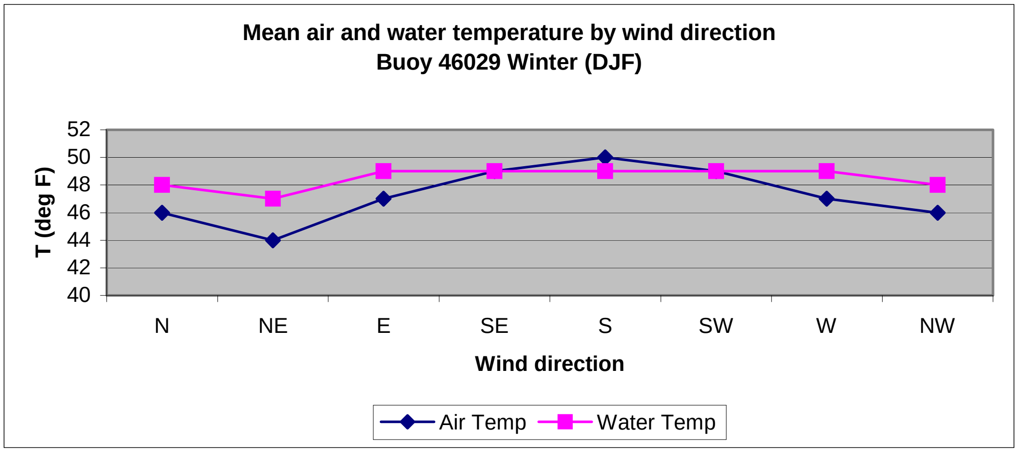


Figure 17. Mean air and water temperature by wind direction for buoy 46029, Winter 2001-2006

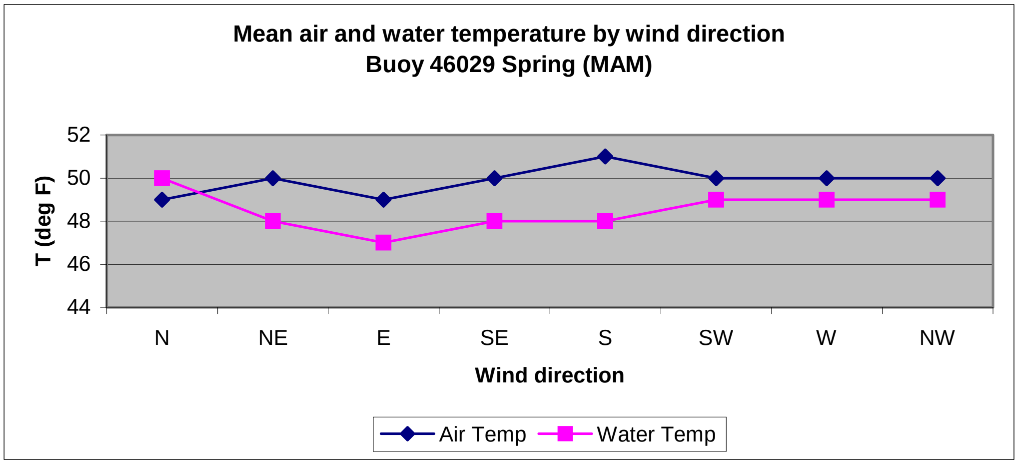


Figure 18. Mean air and water temperature by wind direction for buoy 46029, Spring 2001-2006

3. OBSERVATIONS FROM 2007

One of the biggest coastal storms in Washington and Oregon recorded history occurred in December 2007. Buoy 46029 has never recorded a hurricane force wind gust in approximately 20 years of operation. On 3 December a gust of 59 kts was measured, just before the buoy failed. This was the second strongest gust in the buoy's history. The strongest gust was 60 kts, and occurred in January 2000. Wave heights with the December 2007 storm reached 40 ft before the buoy stopped recording data.

4. ACKNOWLEDGEMENTS

I would like to express my appreciation to Kirsten Elson and Bill Schneider, both of the National Weather Service in Portland, OR for their comments and criticisms which greatly enhanced the readability of this paper.

5. REFERENCES

1 As of this writing, the National Data Buoy Center maintains a website at www.ndbc.noaa.gov, offering complete historical data including a complete climatic summary, as well as current data for buoys maintained by the National Data Buoy Center in the United States, including buoy 46029.

2 As of this writing, the NOAA Earth Systems Research Laboratory maintains a website at http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.surface.html from which NCEP/NCAR Reanalysis Monthly Means are available for the period 1968-1996.

National Weather Service, 2006: National Weather Service Directives, National Weather Service Instruction 10-301. NOAA.

3 U.S. Army Corps of Engineers, 1984: *Shore Protection Manual* Vol. 1, U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, 1,088 pp.