A Study of the Pre-Frontal Jet Along the Southwest Oregon Coast

Brian Nieuwenhuis
NOAA/NWS, Medford, Oregon

1. Introduction

During the cool season, extratropical cyclones are a common occurrence for the Pacific Northwest. While providing the bulk of the precipitation the area receives during the year, these systems can also produce damaging windstorms, particularly for capes, headlands, and other exposed locations along the immediate coastline. In Southwest Oregon, these winds are most apparent at and in the vicinity of Cape Blanco, a prominent headland that is both a state park and the westernmost point in Oregon. Also nearby lays Port Orford, an important fishing and recreational port for the region, and Highway 101, a well-travelled corridor for commerce and recreation. Strong winds can adversely affect operations, recreation, and traffic, and most importantly, can threaten the lives and livelihoods of those living, working, and visiting the region. This study will look at around 40 cases of extratropical cyclones impacting the southwest Oregon coast during the years of 2005-2006 and 2011-2014, with the goal of producing operational forecast guidance that would increase confidence during the warning decision process. The improved forecast process should then ultimately enhance the National Weather Service support of local partners and better protect the lives, property, and commerce of the local populace.

2. Background

During wet-season storms, southwest winds will blow across the relatively smooth ocean surface before encountering the Oregon and California coastline, which offers a significant boundary in the coastal mountain ranges. Due to the relative stability of the marine air, these winds can be prevented from rising over the mountain barrier and instead are deflected and accelerated northward along the coastline, especially in the vicinity of, and downstream from, capes and headlands. Numerous studies have been performed regarding this phenomenon for coastlines around the world (Burk et al. 1999, Edwards et al. 2001, Haack et al. 2001, Tjernström et al. 2000). North wind events during the warm season along the western U.S. coast have been of particular interest, due to the effects of this flow on local ocean currents and upwelling. However, there have been few studies directly related to the south wind scenario, and as such, there is little in the way of forecast guidance. This study seeks to alleviate this problem for a frequently impacted section of the Southern Oregon coast.

3. Methodology

Data were gathered in real-time over the course of the 2013-2014 cool season, in order to collect observations from both high and low impact events. Also, several past events were examined from local records of High Wind Warning issuances spanning the years 2005-2006, and 2011-2013. The purpose of the investigation was to correlate observed MSL pressure gradients between North Bend, OR (KOTH) and Arcata, CA (KACV), and observed wind speeds at a few select stations along the coast. For the sake of simplicity in this analysis, Cape Blanco will be the primary focus, as it is there that the most extreme wind values are recorded. Similar results are available for both Port Orford and buoy 46015, which represent more populated and heavily traveled areas.

Maximum wind speeds were determined by analysis of the record of observations taken by the U.S. Coast Guard station at Cape Blanco. The site is located on the headland, at roughly 190 feet above MSL, and represents the winds that can be expected along exposed areas of the coastline. The highest sustained wind speed and highest gust speed during each event, which may have been measured at separate times, was recorded. Similar wind speed values were obtained from the National Ocean Service station at Port Orford, a sea-level port 7.5 miles southeast of Cape Blanco that is representative of more sheltered coastal locations, and maritime buoy 46015, an open-sea NOAA station located 15 nautical miles west of Port Orford. The highest winds for each station were usually recorded within one to two hours of each other.

The maximum pressure gradient was determined from the hourly MSL observations between the ASOS stations at North Bend, Oregon and Arcata, California, both stations located along the coast and straddling the area of concern. The gradient was analyzed for 6 hours before and after the time that the strongest winds were recorded at Cape Blanco. If data was not available for all relevant stations during a particular event, that event was not included in the study. Data was also limited by station observation times. For example, Cape Blanco wind measurements are reported in 15 minute increments, while all other stations report conditions every hour.

4. Analysis

A graph of greatest pressure gradient versus maximum sustained winds at Cape Blanco is given in Figure 1. Stronger pressure gradients generally resulted in higher wind speeds. However, there is a wide range of wind speeds for each gradient, sometimes varying by up to 20 mph. For example, on November 23, 2011 and December 1, 2012 both events reached a peak gradient of -8.8 mb, but the November event's sustained winds reach a peak of 72 mph, while the December event only reached 51 mph.

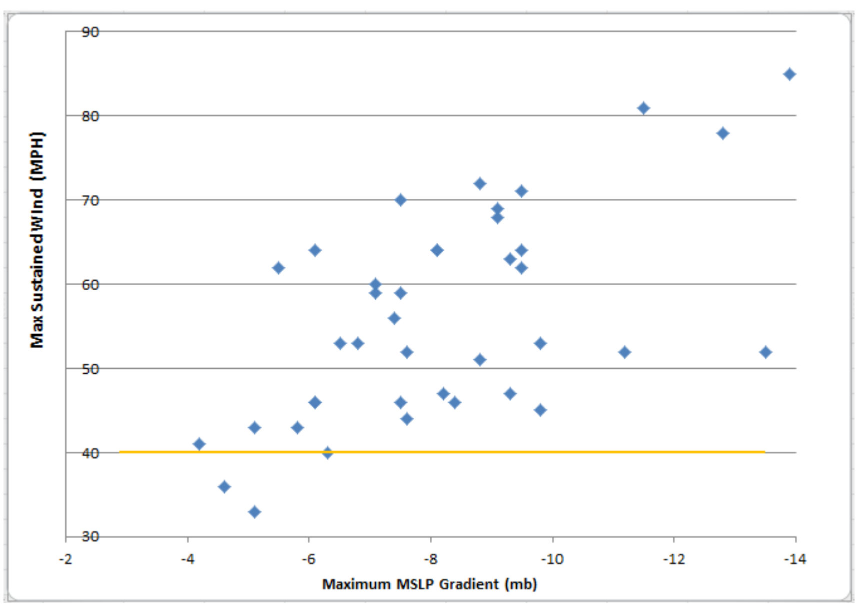


Figure 1. Maximum sustained winds at Cape Blanco vs maximum observed MSLP gradient between KOTH and KACV. Orange line denotes High Wind Warning criteria.

Figure 2 shows a surface analysis for both days. The major differences between the systems are the proximity of the surface low, the angle of incidence of the cold front to the coastline, and the angle of incidence of the isobars with the coastline. The 2011 system's low is much closer to the area of study and deepening, while the 2012 system's low is centered well to the north, off the area of the map. The 2011 system's front is also at an angle to the coastline, with the isobars aligned southwest to northeast. In 2012, the front (although curved) is more parallel to the coastline, but still at an angle due to its curvature. However, the isobars are aligned more west to east. Therefore, it is theorized that the dynamics of the closer surface low center, and the angle of the winds to the coast, produced a more "squeezed" wind flow between the front and the coastline, thereby producing a stronger channeling effect. This should be true as long as the low tracks to the north of the cape.

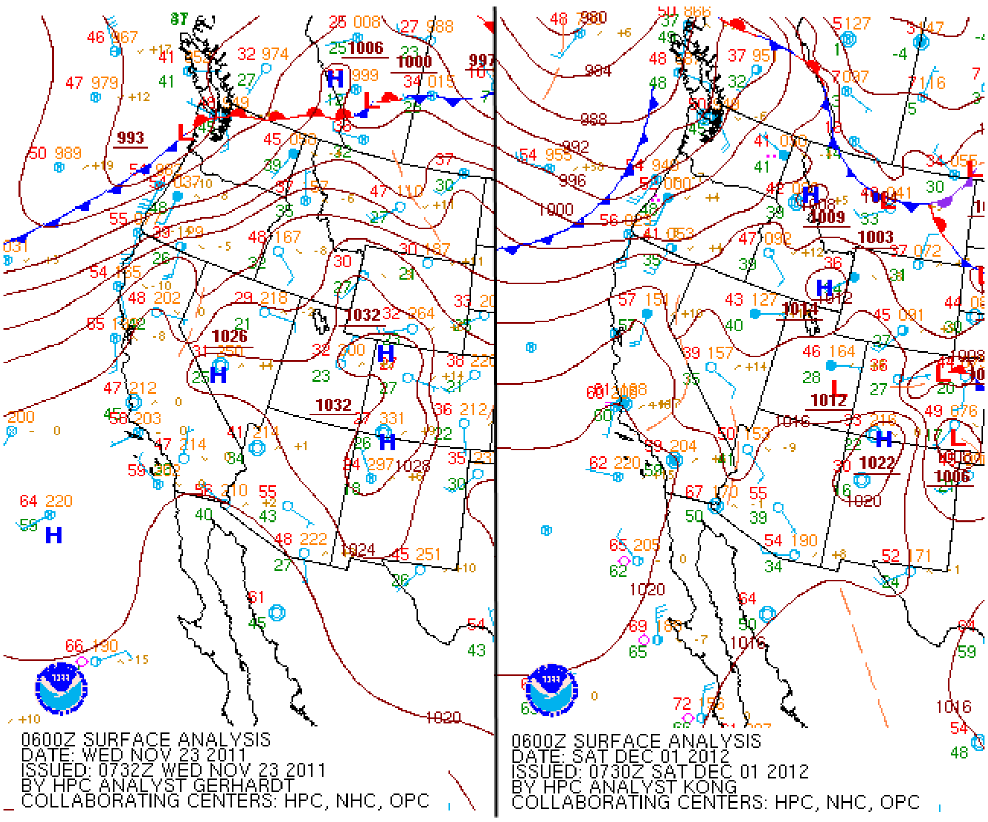


Figure 2. A comparison of the surface analyses for the Nov 23, 2011 event (left) and the Dec 1, 2012 event (right).

Another example of vastly different wind speeds with the same peak gradients can be seen when comparing the two events of November 18, 2013 and November 28, 2005, as both storms reached a gradient of -6.1 mb, but maximum sustained winds reached 46 mph and 64 mph respectively. Figure 3 depicts these two storms, and while both have a surface low center close to the area, the 2005 low is closer to the area of study and deepening at the time of peak winds, while the 2013 system is farther north and filling, as per 3 hour pressure tendencies, at the time of peak winds. The frontal boundaries and angle of isobars for both systems are similar. It could be hypothesized that a deepening low will produce stronger winds than one that is filling or weakening.

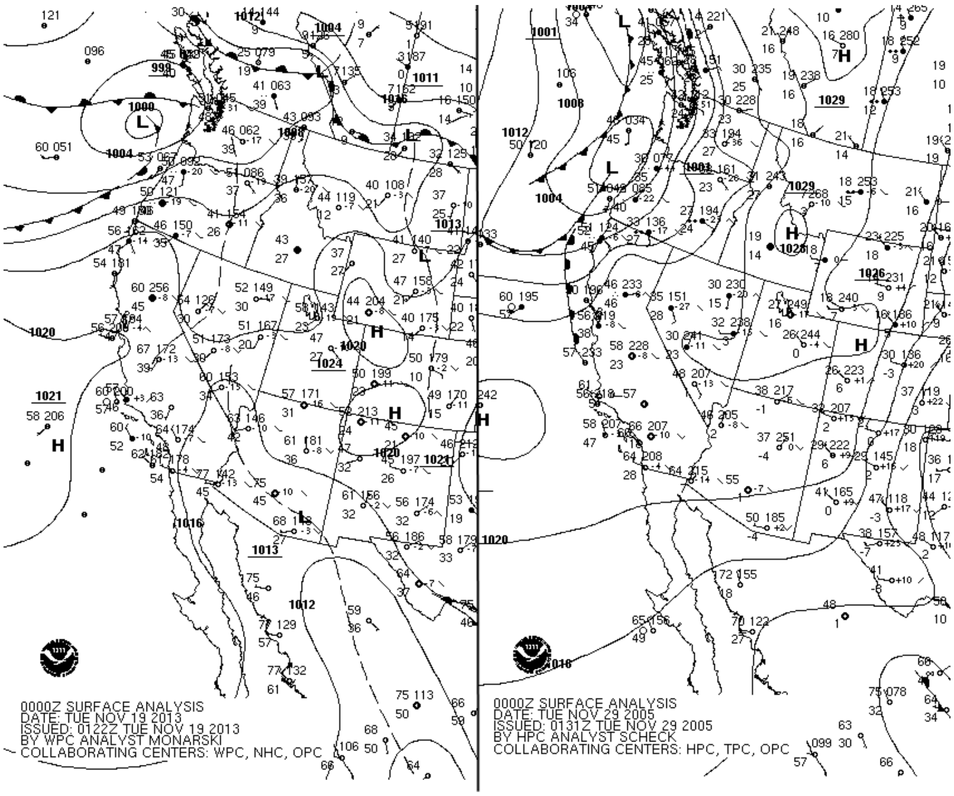


Figure 3. A comparison of the surface analyses for the Nov 18, 2013 event (left) and the Nov 28, 2005 event (right).

Further analysis for all of the events within the case study was therefore needed to determine a possible reason for the wide variation in wind speeds. Cases were sorted based on the characteristics of the surface low pressure (deepening or filling), the location of the surface low center relative to the coastline of southwestern Oregon, and the characteristics of the surface fronts and winds (angle of incidence to the coastline). Events with a deepening surface low in close proximity to Cape Blanco, and those with a front and surface isobars at a sharper angle to the coast were noted and highlighted in an updated chart. Regarding the angle of onshore flow, as illustrated by the angle of the surface isobars, it was found that lower angles (closer to parallel with the coastline) usually produced stronger winds, but those with higher angles (more perpendicular) were relatively weaker. An example of a high angle of incidence can be seen in Figure 4.

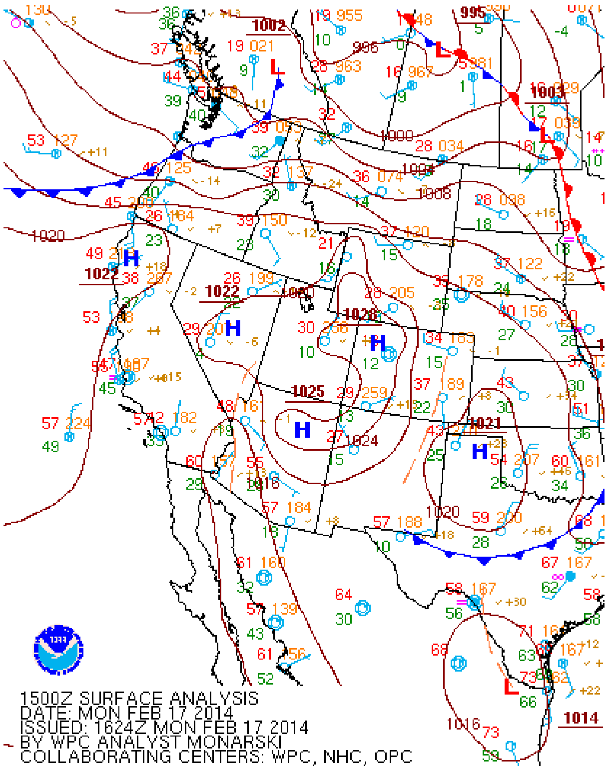


Figure 4. An example of high angle of incidence to the coastline.

5. Conclusion

Figure 5 shows the maximum sustained winds and maximum gusts compared to the maximum observed sea level pressure gradient at Cape Blanco. The data points are divided as mentioned above, with the red points and trend line denoting the systems with deepening lows and/or sharper angles of incidence. All other events are denoted in blue, including but not limited to: filling lows, distant lows, high angles of incidence, and stalled or dissipating fronts. Also, a line has been added to the charts denoting High Wind Warning criteria. Figures 6 and 7 depict similar charts for buoy 46015 and Port Orford.

Using the data gathered, a warning decision tree (Figure 8) was determined for the southwest Oregon coast. According to the data, nearly all systems should produce high winds at the cape and other area headlands, but much fewer will reach criteria in more sheltered, and also more impactful, areas such as Port Orford. The tree should result in increased confidence in the warning decision process, as long as the forecaster is aware of local effects and the degree of representation each site provides.

Overall, given a forecasted pressure gradient and the expected nature of the surface and low level conditions, a forecaster should have more confidence in the High Wind Warning decision, and be able to produce more accurate and timely public and marine wind forecasts.

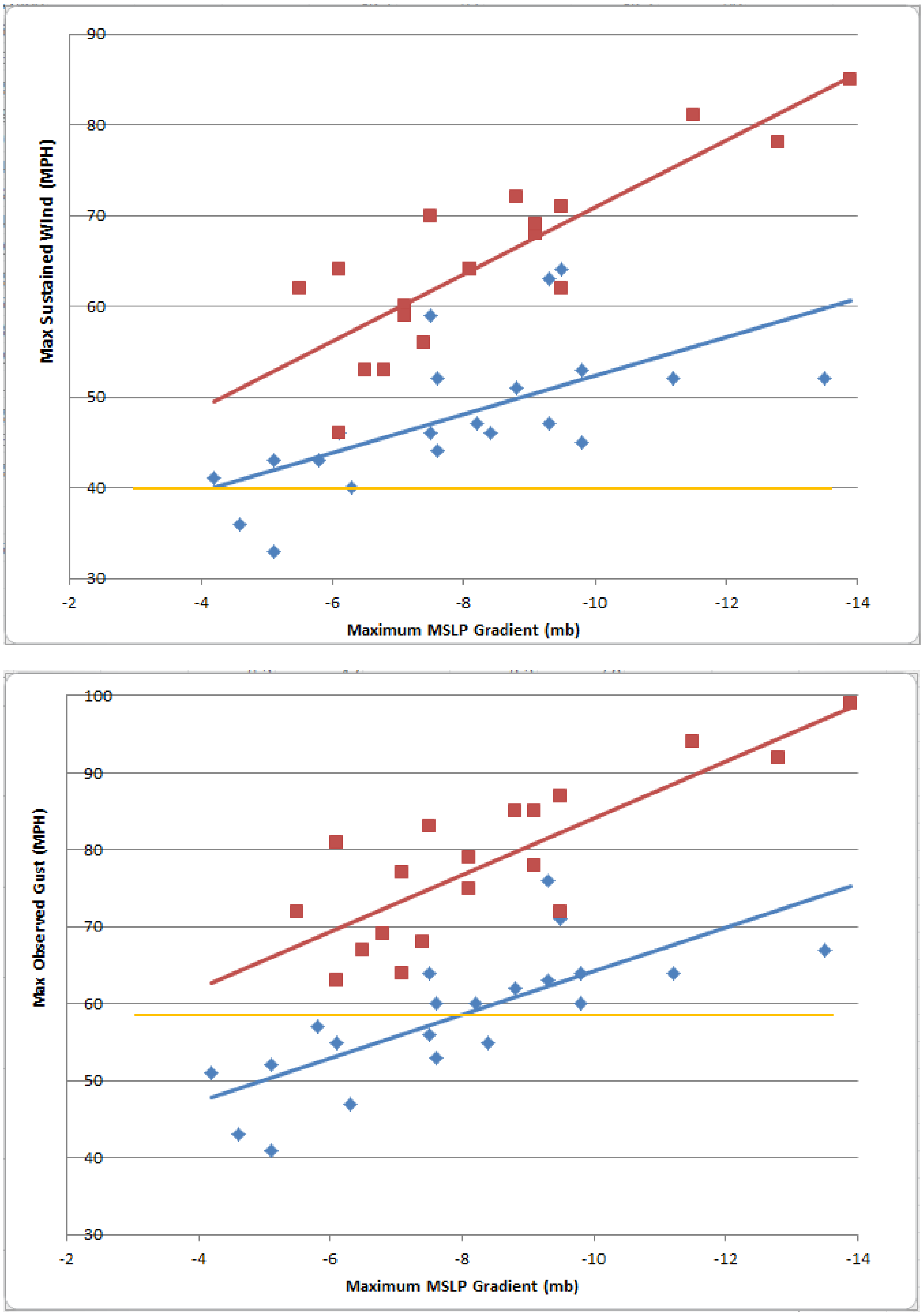


Figure 5. Cape Blanco. Categorized charts for maximum sustained winds (top) and maximum wind gusts (bottom) versus maximum pressure gradient. Red points and trendline denote events with deepening surface low or sharp angle of incidence to the coastline. Blue points and trendline denote all other events. Orange lines denote High Wind Warning criteria.

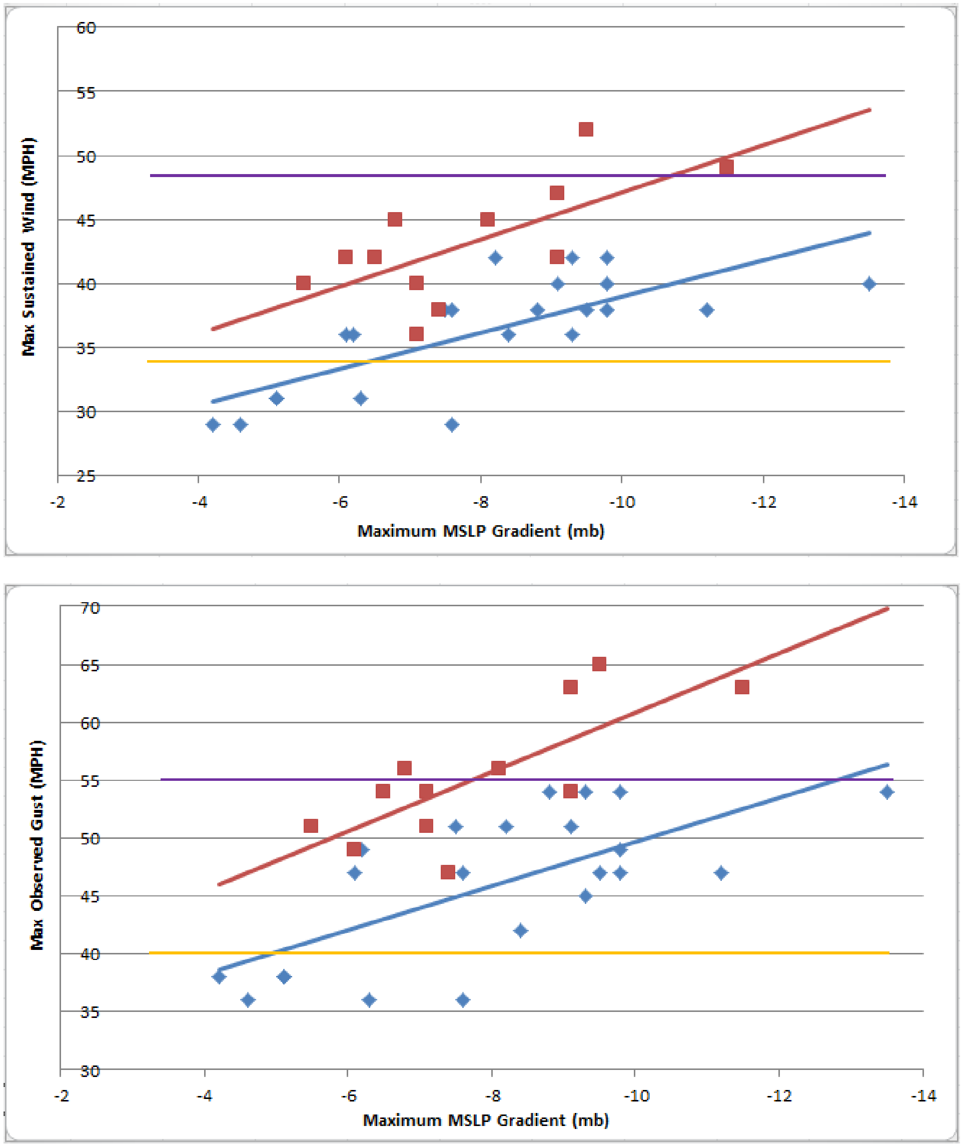
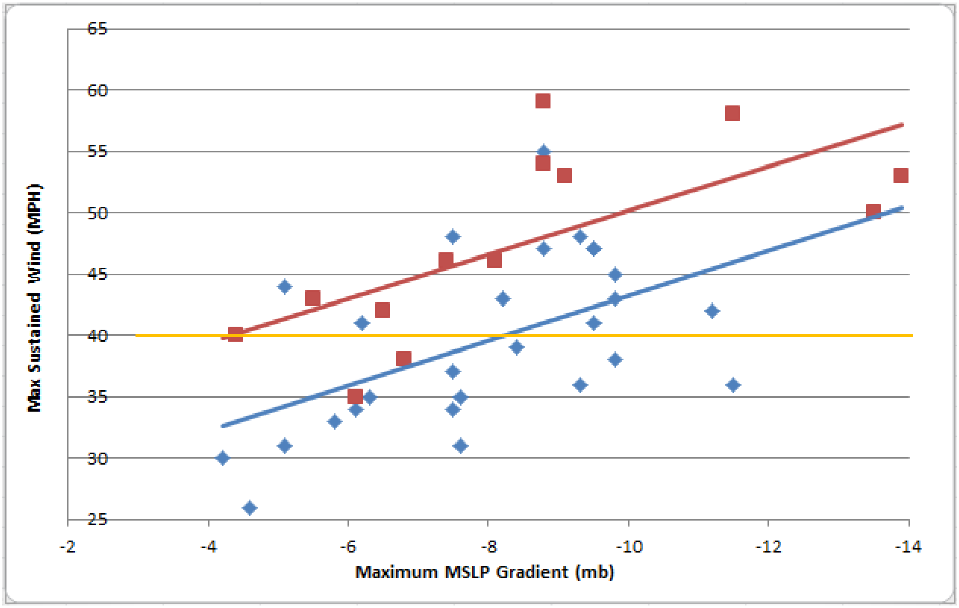


Figure 6. Buoy 46015. Categorized charts for maximum sustained winds (top) and maximum wind gusts (bottom) versus maximum pressure gradient. Red points and trendline denote events with deepening surface low or sharp angle of incidence to the coastline. Blue points and trendline denote all other events. Orange line denotes Gale Warning criteria. Purple line denotes Storm Warning criteria.



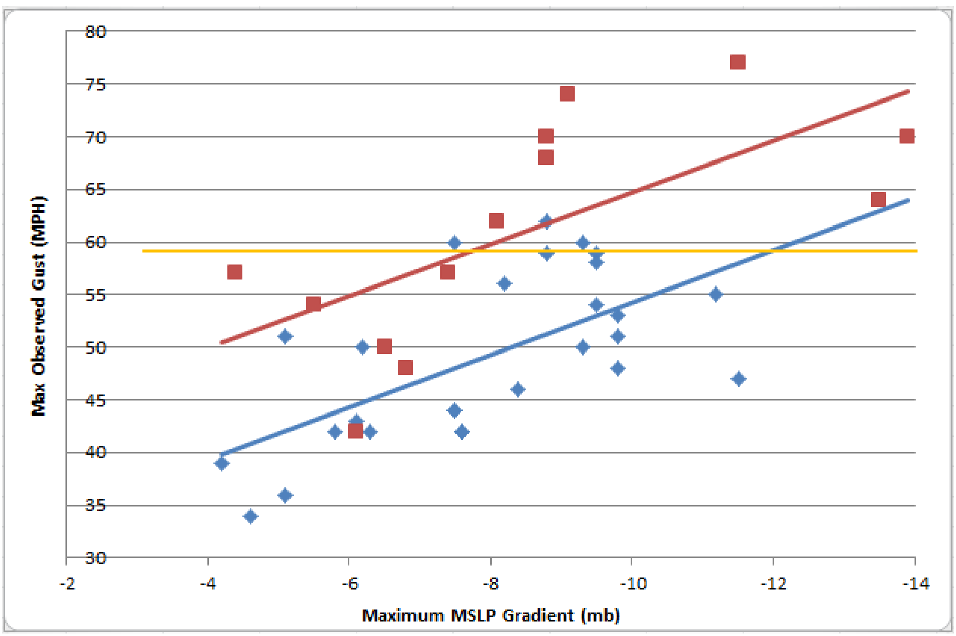


Figure 7. Port Orford. Categorized charts for maximum sustained winds (top) and maximum wind gusts (bottom) versus maximum pressure gradient. Red points and trendline denote events with deepening surface low or sharp angle of incidence to the coastline. Blue points and trendline denote all other events.

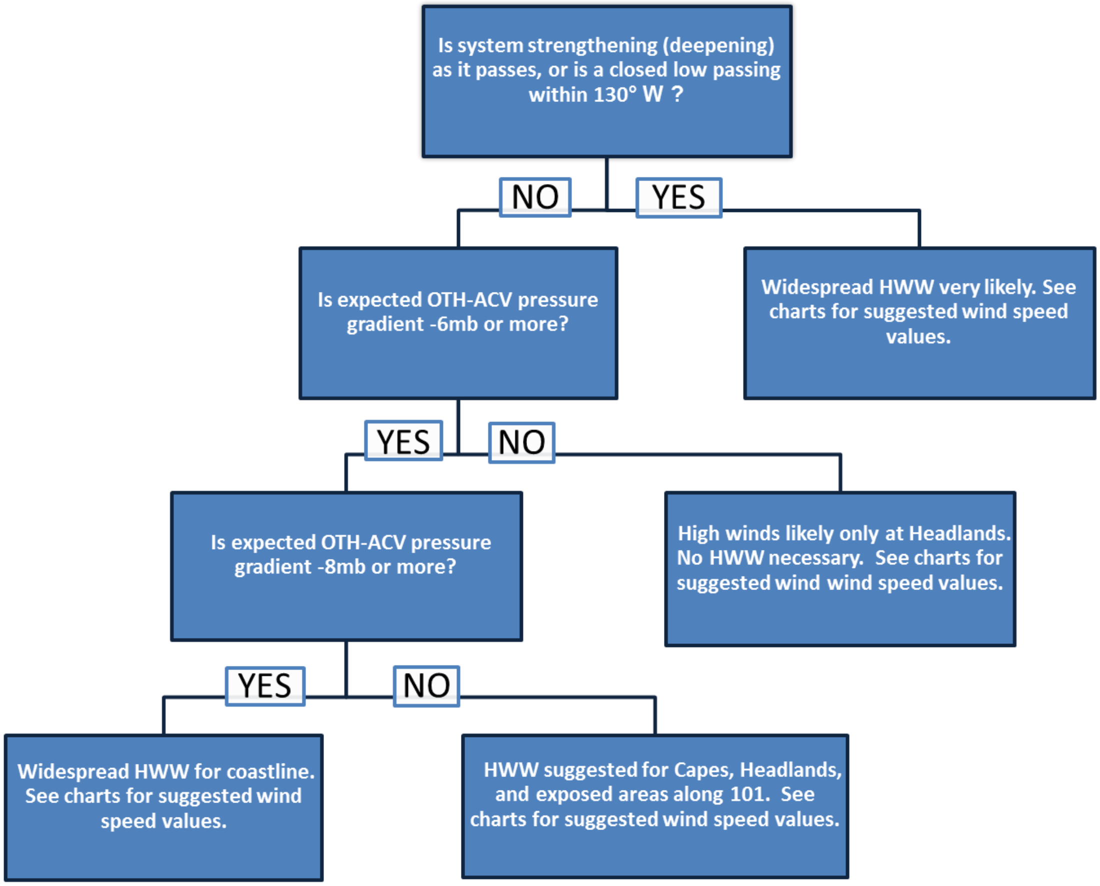


Figure 8. High Wind Warning decision tree for Southwest Oregon Coastal zones.

6. Additional Discussion

A wide range of conditions has been shown to occur at the three study sites. A possible reason for this lies in the vastly different setting of the three stations. While the Cape Blanco station sits atop an exposed headland, buoy 46015 lies in open waters, and Port Orford is near sea level in a sheltered cove. Buoy 46015 usually lies beyond the main belt of the coastal jet, but sometimes may be in the periphery of the strongest winds, given the right circumstances. Meanwhile, Port Orford is very sensitive to wind direction and interactions with the local geography. Cape Blanco was used as the primary focus of this study, as its location better represented the open air conditions and those that may be expected just offshore. Each site could potentially have its own study, focusing on other more localized effects such as topography or wind direction. Further study may also clarify the relationship between storm strength and the characteristics of the low and/or angle of incidence to the coast.

References

Burk, S. D., T. Haack, and R. M. Samelson, 1999: Mesoscale simulation of supercritical, subcritical, and transcritical flow along coastal topography. J. Atmos. Sci., 56, 2780–2795.

Edwards, K. A., A. M. Rogerson, C. D. Winant, and D. P. Rogers, 2001: Adjustment of the marine atmospheric boundary layer to a coastal cape. J. Atmos. Sci., 58, 1511–1528.

Haack, T., S. D. Burk, C. Dorman, and D. Rodgers, 2001: Supercritical flow interaction within the Cape Blanco–Cape Mendocino orographic complex. *Mon. Wea. Rev.*, **129**, 688–708.

Tjernström, M., and B. Grisogono, 2000: Simulations of supercritical flow around points and capes in a coastal atmosphere. *J. Atmos. Sci.*, **57**, 108–135.