LATE SUMMER GALE WINDS OFF COASTAL OREGON-WASHINGTON

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Abstract

Even a "weak" gale can bring trouble to experienced sailors in small boats. Friday morning, September 8, 1978, the tuna fleet fishing off the coast of Washington and Oregon was caught off-guard by sudden gale winds. The complex sequence of meteorological events which brought about gale winds, steep seas, and grief to the tuna fleet are documented.

Examining this case of gale winds brought about by the coastal low level jet stream, and examining synoptic conditions when gale warnings were issued during 1977-78, led to a simple rule of thumb for forecasting coastal gale winds. Whenever the surface atmospheric pressure at Astoria, Oregon is forecast to be 9 millibars or more higher than Buoy 46005, a gale warning is advisable. Gale winds can occur offshore, even when they are not observed by coastal stations.

1. INTRODUCTION

Coastal seas were unusually calm the week prior to the sudden development of gale winds offshore of Oregon and Washington on Friday September 8, 1978. Perhaps this along with good fishing contributed to the fact that the tuna fleet, which included many small boats 25-50 feet in length, ventured 50 miles out to sea.

Sailors normally keep a weather eye westward for gathering clouds on the horizon. Thursday evening, September 7, 1978, cirrus and altostratus began to increase about sundown. By early Friday morning, crews were awakened to gale winds, and in rough seas, struggled to reach a protected port. On Friday afternoon the Seattle Weather Service received an agitated ship to shore call from one of the ships that the tuna fleet was in trouble, experiencing gale winds of 40-knots with gusts as high as 60 knots. This gale would claim six of the smaller fishing boats, and tragically, two lives before subsiding.

It took the combined resources of all rescue services along the west coast from California to Washington to assist the ravaged tuna fleet to safe harbor. In all, there were 122 calls to the Coast Guard for assistance, involving 182 people. Their heroic effort was responsible for the saving of eleven lives. The rescue entailed the delivery of eight pumps and the towing of 37 vessels. One sailor who was forced to abandon ship was saved after spending 22 hours in the water. He was able to remain alive only because he wore a special survival suit which kept him afloat and preserved his body heat.

2. WEATHER PRIOR TO THE GALE

Several days before the gale, weather conditions offshore of the Oregon-Washington coast were deceptively peaceful. Both the Coast Guard coastal stations and the NOAA Environmental Data Buoys located about 250 miles offshore (46002, 46005) reported moderate winds and seas. Weak weather fronts had been moving eastward across the Gulf of Alaska toward the northwest coast. As they approached the Washington coast, these fronts stalled and continued to weaken offshore while the next front developed upstream, Figure 1.

The upper trough of low pressure lying off the West Coast was narrow and elongated along 125W, with a small center of low pressure off northern California near 40N 125W on the 850mb, 500mb and 300mb charts, Figures 2-4. As seen on these charts, there was a split in the westerlies near 50N 135W. A small 1000mb surface low center traveled along 50N and became stationary at the split exit, just off the Queen Charlotte Islands.
Figures 1-4. Surface, 850mb, 500mb, and 300mb Analyses for September 7, 1978 at 1200 GMT
A strong southerly jet stream aloft with winds speeds to 110 knots from eastern California to Washington was seen on the 300mb chart of September 7, 1978 at 1200 GMT. The jet stream shifted northeastward on the eastern side of the upper trough of low pressure and weakened to 70 knots over Montana by 1200 GMT on September 8th. At lower levels, the surface and 850mb levels, coastal winds were generally 15 knots or less from the southeast.

A small craft advisory was issued Friday morning (1636 GMT) for southerly winds 15 to 30 knots, seas 4 to 8 feet, with westerly swell 3 to 6 feet. By Friday afternoon, both the Seattle and Portland offices issued gale warnings for southerly winds 15 to 30 knots becoming 25 to 40 knots with higher gusts, decreasing Saturday.

A vigorous (for the season) short wave aloft caught up to remnants of weakened surface fronts which had stalled along 130W. The successive locations of the back edge of the cloud band of this weather system are given in Figure 7.

This approaching final weather system caught up to an inactive front which was lying nearly stationary along 135W and extended through a weak 1003mb low, Figure 8. The low center deepened to 993mb by September 9 at 0000 GMT. Upstream, a new low pressure center continued to deepen from 998mb on Thursday to 988mb Saturday, traveling in the southern branch of the split in the westerlies. The upstream low pressure center that was about 800 miles west of the initial weaker low September 7 at 1200 GMT, moved eastward, and was about 400 miles west-

![Enhanced Satellite Images for September 8 and 9, 1978 at 0515 GMT](image)

The coastal marine forecast is limited to an area from the coast out to 20 miles seaward. Nevertheless, many sailors listen and depend on the coastal marine forecast even when they go farther out to sea. Hopefully, this review of the synoptic events during the unusual gale will help alert forecasters to similar circumstances which may precede such events in the future.

### 3. WEATHER DURING THE GALE

Perhaps the best visual summary of synoptic conditions which occurred can be seen on enhanced satellite pictures, Figures 5 and 6. Sweeping across the Gulf of Alaska at better than 35 knots, southwest of the initial low center September 8 at 1200 GMT. By Friday evening both low centers consolidated into a single large low pressure system, Figures 8-11.

The Limited Fine Mesh computer model (LFM) forecasts of surface cyclone central pressure are given in Table 1. Average errors of cyclone central pressure for 24 and 48 hour forecasts are 9mb and 19mb respectively, which agree with previous studies (Zimmerman, Ruscha, 1979).

It is important to keep in mind that the area where gale winds created rough seas for the smaller fishing boats was ahead of the initial weaker fronts, roughly the area from 42N to 49N between...
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124W and 127W (Figure 12). Winds began to increase about 1200 GMT on September 8 when the developing low center was still about 400 miles to the west of the initial low pressure center. In fact, it is also important to realize that the buoys, 46005 and 46002, located at 46N 136W and 42.5N 130W respectively, never reported winds above 30 knots. Nor did any of the coastal stations, except Cape Disappointment, report winds above 20 knots while boats offshore were in distress (Figure 13). In other words, it appears that the gale winds were confined to an offshore area parallel to the coast and ahead of inactive old frontal systems.

Most of the wave energy measured by the buoys was in the high frequency (seas) portion of the spectrum. The highest significant wave height observed (46005) was only 7 feet with an average period of 6 seconds. This wave height is what would be expected with 20 knot winds (Figures 14 and 15). Small craft advisories are issued when wind speeds are expected to exceed 20 knots!

Figure 7. Successive Locations from Satellite Images of the Cloud System, September 7-8, 1978

Figure 12. Area of Gale Winds and Location of Buoys and Coastal Stations
Figures 8-11. Surface Analyses for September 8, 1978 at 0000 GMT to September 9, 1978 at 1200 GMT
Figures 8-11. Surface Analyses for September 8, 1978 at 0000 GMT to September 9, 1978 at 1200 GMT
Figure 13. Wind Speeds for September 7-9, 1978 at Ship PAPA, Buoys, and Coast Guard Stations
4. UPPER AIR FEATURES DURING THE GALE

The final short wave to enter the eastern Pacific was stronger than the previous systems. On the 700mb level, the final low center to move into the long wave trough is found near 58N 160W September 7 at 1200 GMT. This low center dropped south-eastward to 52N 147W September 8 at 1200 GMT, just prior to the time winds increased off the coast of Washington and Oregon. The cyclone center continued its movement east-southeastward to 48N 132W September 9 at 1200, as gale force winds were reported along the coast, Figures 16 a-e.

As the last short wave system of this series moved towards Vancouver Island, the small, upper stationary low center off northern California at the 700mb level moved north-northeastward, and by September 8 at 1200 GMT was northeast of Idaho, Figure 16c. The ejection of the California upper low center inland as the short wave moved southeastward into the eastern Pacific from the Gulf of Alaska is an example of "Henry's Rule". This rule, which applies to cutoff low centers over the southwestern United States, states that cutoff lows will be kicked northeastward whenever a significantly strong short wave just west of Vancouver of the Queen Charlotte Islands moves
southeastward. The location of the upper air features in this case fulfilled the criteria for "Henry's Rule" (Henry, 1978). The final low center continued to deepen and became the primary weather system off Vancouver Island.

The effect of the inland movement of the California upper low center was to remove the split in the flow of the westerlies west of Vancouver Island. Because of this, instead of weak winds in the exit of the split along the Washington-Oregon coast, winds were increased from the south-southwest.

Figures 16 a-e. 700mb Analyses for September 7, 1978 at 1200 GMT to September 9, 1978 at 1200 GMT
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Table I. LFM 24, 36, and 48 Hour Forecasts of Cyclone Central Pressure, (Pressure in Millibars).

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UIL 19057 27553 27054 29038 33035 28559
SLE 190110 29053 M 29046 24540 19555

Table II. Wind Direction and Speed (kts) of the 300 Millibar Level For Quillayute and Salem.

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* = low pressure trough east of Buoy 46005

Table III. Pressure Gradients from Astoria to Buoy 46005 and from Astoria to Quillayute, (Pressure in Millibars).
5. THE COASTAL LOW LEVEL JET STREAM

Evidence that the strongest winds were just off the Washington and Oregon coasts can be seen in vertical time sections for Ship Papa (C7P), Quillayute (U1L), and Salem (SLE), Figures 17-19. For this period, Ship Papa, on the west side of the upper trough of low pressure, never reported surface wind speeds greater than 30 knots. Both the time sections for Quillayute and Salem showed strong winds aloft just before the upper trough of low pressure moved across the west coast.

Figures 17-19. Time Sections for Ship PAPA, Quillayute and Salem for September 7-9, 1978

The 70 knot isotach at the 300mb level, which is shown in Figure 20, moved southeastward towards California. During the period when gale winds were experienced, the approaching jet stream aloft was west of the northwest coast (shaded area of Figure 20). Table II shows reported 300mb winds for Quillayute and Salem. When surface gale winds occurred off the coast, winds on the 300mb level were lightest.

It is observed by sailors of the northwest that winds over open water a few miles offshore are frequently stronger than winds reported by coastal weather stations. During the gale, Bob Jackson, a forecaster from WSFO Seattle, happened to be with the fishing fleet. It was his observation that winds were much lighter once they came to within 3 miles of shore. In fact, small charter boats were salmon fishing in the comparatively quiet waters within a few miles of the coast.

This observation is also confirmed by coastal reports drawn in Figure 13, and also by ship data plotted on surface charts, Figures 8-11.

To some extent what follows is speculation, but it is offered as an additional mechanism that played a role in the sudden increase in winds to gale speeds. On the surface chart (and on satellite images), a weakening front is seen nearly stationary along 130W. A second front was located about 500 miles west of this front. As the upstream short wave approached, the initial front was pushed eastward towards the west coast, and winds ahead of the front increased to gale strength, Figures 8-11. It would appear that, as this inactive frontal boundary was moved towards...
high coastal terrain, a north-south channel was created for the airflow between the initial front and the coast.

Consequently wind flowing in the channel speeded up as would occur with a Venturi-type constriction. This is illustrated in Figure 21.

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**Figure 20.** Jet Stream 70-Knot Isotachs September 8–9, 1978

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6. SIMPLE RULES OF THUMB

Informal investigation of weather conditions (Fall through Spring) has led to a simple rule of thumb: forecast gale winds whenever a moderate front is expected to reach the northwest coast (Goree 1978). During 1970–72, this rule of thumb verified about 90 percent of the time.

As seen in the previous discussion, winds of gale force can develop over the northwest coast undetected by coastal weather stations. An old meteorological technique to estimate wind speed in the absence of data, often ignored in this computer age, is to measure the atmospheric pressure gradient. The wind speed, is, of course, related to pressure gradient by means of the gradient wind relationship.

In order to develop simple, offshore wind to pressure gradient rules of thumb, coastal marine warnings for the past two years (1977–78) were reviewed whenever windflow was from the south, that is, parallel to the coast. For these cases, surface pressure gradients were measured from Astoria, Oregon to Buoy 46005 located at latitude 46N and longitude 131W. Not included in this study were a few cases of strong northerly winds around the Eastern Pacific High. Nearly all of the gale warnings issued during 1977-78 were when winds along the west coast were southerly.

Verification of 1977–78 marine forecasts was done by checking surface observations from ships near the Washington Coast plotted on surface weather charts and from data collected by Coast Guard ships and stations. Most of the wind verification data were obtained from observations taken at Cape Disappointment and the Columbia River Lightship (NNCR).

As shown in Table III, gale winds occurred when the difference in pressure between Astoria and Buoy 46005 was 9 millibars or greater during the September 1978 gale. This was generally true of about 90 percent of the marine warnings that were issued during 1977–78. In Figure 22, it is seen that whenever the difference in pressure from Astoria to Buoy 46005 was 5 millibars or greater, small craft advisory winds generally verified. Whenever this difference in pressure was 9 millibars or greater, gale warning winds generally verified.

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**Figure 21.** Idealized Front Creating Channel of Strong Windflow Off the Northwest Coast
Another rule of thumb applicable to areas of mountainous terrain is that wind speed will be proportional to, and blow non-geostrophically in the direction of, the pressure gradient. Thus, for the Strait of Juan de Fuca, gale warnings are generally issued if the pressure difference from Quillayute (UIL) to Bellingham (BLI) is 4 millibars or greater. This is also true of Inland Waters (Puget Sound), where gale winds are issued if the gradient from Bellingham (BLI) to Olympia (OLM) is 4 millibars or greater. Informally, this rule has also been applied to Coastal Waters using the Astoria (AST) to Quillayute (UIL), south to north pressure gradient. If this pressure difference is greater than 4 millibars, gale warnings are generally issued. In Figure 2, five gale warnings were issued and verified when the Astoria (AST) to Buoy 46005 pressure difference was less than 9 millibars. In these cases, the pressure between Astoria (AST) to Quillayute (UIL) was 4 millibars or more. However, most of the gale warnings which verified in 1977-78 (39 versus 5 cases), occurred when the Astoria (AST) to Buoy 46005 pressure difference was 9 millibars or more, and there was little pressure difference between Astoria (AST) to Quillayute (UIL).

Figure 22. Pressure Difference Astoria to Buoy 46005 (Millibars) and Type of Marine Warning (Advisory). Only southerly wind cases were considered.
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In situations where both the south-to-north and east-to-west gradient were above gale limits, the east-to-west (AST-46005) gradient occurred before coastal winds rose to gale force. As the weather front moved inland, the south to north gradient (AST-UIL) then also became 4 millibars or greater. Thus, the east-to-west pressure gradient can be used as a precursor to coastal gale winds, whereas the south-to-north (AST-UIL) pressure gradient is excellent to "now" forecast coastal winds. The south-north pressure gradient between Astoria and Quillayute is less than the geostrophic pressure gradient for gale winds. With geostrophic gale winds, one would expect a pressure difference of 12 millibars or greater between Astoria and Quillayute.

Thus, suggested simple rules of thumb to forecast coastal gale winds are:

1. In winter, forecast gale winds whenever a strong front is expected to move inland across the northwest coast.

2. Forecast gale winds whenever the difference of pressure between Astoria and Buoy 46005 is expected to be 9 millibars or greater.

3. Forecast gale winds whenever the difference of pressure between Astoria and Quillayute is expected to be greater than 4 millibars.

These simple rules can help the forecaster predict gale weather rather than experience the embarrassment of having to react to unexpected reports of gale winds.

7. SUMMARY

Small boats 50 feet in length and under can be swamped by steep choppy seas less than 10 feet high. These rough seas, whose wave lengths are comparable to the length of smaller boats, can be quickly generated by gale winds. In this case, sailors slept after an arduous day of fishing while dangerous seas developed before dawn. Many small boats drifted out to sea during the night. A long period of calm weather prior to the gale undoubtedly had given them a false sense of security.

A split of the westerlies can cause weather systems to stall and lie inactive off the northwest coast. As occurred in this case, the split of westerlies is replaced by a vigorous short wave, the circulation of this short wave can cause stalled fronts to be pushed inland, and winds to increase in speed prior to the arrival of the final short wave. This sequence of upper air events follows "Henry's Rule". Along the U.S. Pacific northwest coast, mountainous terrain and fast approaching weather systems can create a north-south channel airflow. In this channel, winds may develop with speeds 5 to 20 knots higher than otherwise. This channel of strong winds may not be observed at coastal stations, but can cause havoc a few miles offshore.

When a vigorous short wave approaches the coast, gale winds can develop ahead of an inactive front stalled along the coast, while the new and old systems are consolidating. Thus, coastal winds may increase much earlier than expected, many hours before the arrival of the final short wave system.

A suggested good rule of thumb to alert forecasters of possible gale winds is to monitor the Astoria to Buoy 46005 surface pressure difference. If this difference is forecast to be 9 millibars or greater, gale winds are likely several miles off the coast, even when not observed by coastal weather stations.

Weak interacting weather systems create difficult forecasting problems. Such weather, although not severe, can, as it did for many small fishing boats the Friday after Labor Day 1978, endanger life and property.

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