Northwest Windstorms

Although the Pacific Northwest escapes the threat of hurricanes and powerful tornadoes due to the cool water to its west, the region is no stranger to strong, damaging winds. Each winter season, several Pacific low pressure centers (or cyclones) make landfall upon the Northwest and British Columbia coasts, resulting in winds strong enough (40 to 60 mph) to produce power failures and modest damage west of the Cascades. Less frequently, perhaps two or three times a decade, windstorms of considerably greater magnitude occur, with winds gusting to 70 mph or more, extensive power failures affecting hundreds of thousands of homes, and damage reaching the tens or hundreds of millions of dollars. Even less frequently, roughly once every 30 years or so, the region experiences far more powerful storms, with hurricane-force winds and massive damage.

3.1. Most windstorm damage in the Northwest results from fallen trees, as illustrated by this photo of a home in north Seattle after the relatively weak windstorm of 30 March 1997
Along the coast, winds exceeding 100 mph, and occasionally 150 mph, have accompanied these major storms, particularly on exposed headlands such as Cape Blanco, on the Oregon Coast, and North Head, just north of the Columbia River. Such storms have winds equivalent to category 3, and occasionally category 4 hurricanes, and are generally far larger than their tropical cousins. In addition to regional windstorms produced by large midlatitude cyclones, there are also more localized high wind events associated with terrain features such as gap winds and high-amplitude mountain waves; such events are described in Chapter 7.

**Major Northwest Windstorms of the Past**

Native American legends recognized the occurrence of strong coastal winds and provided explanations of their origin. For example, the Quillayute tribe, which lived along the Quillayute River of the western Olympic Peninsula, told stories about the Thunderbird, a giant bird with wings twice as long as a war canoe. As it flapped its wings great winds were produced. The Quillayutes, like other coastal tribes, were aware that winter windstorms were more intense near the coast, and generally moved to more protected inland camps during the stormy winter months.

3.2 Northwest Indian graphic depicting the giant thunderbird carrying off a killer whale.
As non-Indian settlers moved into the Northwest during the later half of the nineteenth century, they learned that Northwest windstorms were a force to be reckoned with. In his memoir "Pioneer Days on Puget Sound" written in 1888, Seattle pioneer Arthur Denny noted that "the heaviest windstorm since the settlement of the country" occurred on 16 November 1875. Denny described the storm as "a strong gale which threw down considerable timber and overturned light structures, such as sheds and outbuildings."

9 January 1880

An even stronger storm struck the region on 9 January 1880. Regarded by the Portland Oregonian as "the most violent storm ...since its occupation by white men", the cyclone swept through northern Oregon and southern Washington toppling thousands of trees, many 5-8 ft in diameter. Sustained winds of 60 mph with gusts to 73 mph begin in Portland during the early afternoon, demolishing and unroofing many buildings, uprooting trees, felling telegraph wires, and killing one person. Scores of buildings throughout the Willamette Valley were destroyed and hundreds more, including large public buildings, were damaged. Part of the roof of the Oregon State Capital in Salem was blown off, allowing snow to accumulate inside the building. Rail traffic was halted in most of northwest Oregon, virtually all fences in the Willamette Valley that were aligned east-west were downed, and every barn near the coastal town of Newport, Oregon was destroyed. Wind gusts on the coast were estimated to have reached 138 mph. At Coos Bay, a 3-masted schooner dragged its anchor, was blown onto the beach, and broke in two.

The description of the storm by the Portland Oregonian on the tenth of January 1880 suggested a near apocalyptic scene:

"The most violent storm of wind which has visited this region since its occupation by white men occurred yesterday between the hours of 11 A.M. and 2:30 P.M. Not even among the traditions of the native Indian inhabitants of the country is there a record of a tempest so wild and furious in its aspect or so disastrous and terrible in its results... at 11 o'clock (it) increased to a storm, sweeping in a general direct course, but exhibiting whirls and eddies similar to the irregular movements of impetuous torrents of water. In half an hour the greater part of the male population of the city were on the streets busily engaged in the work of protecting property and viewing with fearful anxiety the terrors of the mad scene. By 12
o'clock the wind had reach a velocity of about fifty miles per hour, with occasional spurts at the extraordinary rate of sixty miles. The scene at this time, and for the succeeding two hours, was grand and terrible. The creaking of signs and buildings, the crash of falling awnings, the rumbling of tin roofs, the whistling chimes of electric wires, and above all and louder than all the fierce rage and roar of the tornado, united in a fearful and terrifying chorus. Men hurried hither and thither, eager, uncertain and fearful, women with white scared faces peered from the windows of their homes, dreading to remain yet knowing not whether to fly for safety, little children from the schools, which were soon dismissed, ran homeward with frightened haste, horses snorted in helpless fear, and even the dogs were affected with the universal terror."

29 January 1921

The "Great Olympic Blowdown" of 29 January 1921 produced hurricane-force winds along the northern Oregon and Washington coastlines and an extraordinary loss of timber on the Olympic Peninsula. As shown on the accompanying figure, over 40% of the trees were blown down over the southwest flanks of the Olympic Mountains, with at least a 20% loss along the entire Olympic coastline. Billions of board feet of timber were uprooted or otherwise thrown down, much of it in remote regions that made salvage impossible. An official report at North Head, on the north side of the mouth of the Columbia River, indicated a sustained wind of 113 mph, with estimated gusts to 150 mph before the instrument was carried away by the wind. Although the coastal bluff seaward of the North Head observation site may have accelerated the winds above those observed over the nearby Pacific, the huge loss of timber along the Washington coast (eight times more than felled by the eruption of Mt. St. Helens in 1980) is consistent with a singular event.

Figure 3.3. The lighthouse at North Head, Washington in 1910. On 29 January 1921, sustained winds reached 113 mph with gust estimated to 150 mph occurred at this site, the strongest winds ever observed over Washington State. Extraordinary damage occurred over much of coastal Washington during this event.

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1 This sustained wind report is actually the "fastest mile," which is the wind speed associated with the period in which a mile of air moved past the anemometer most rapidly. With a fastest mile wind speed of 113 mph, this implies a period of approximately 30 seconds.
The report of a Weather Bureau observer at the North Head station reveals the ferocity and sudden onset of the event. After pressure fell to its lowest level and wind speed temporarily dropped below 30 mph, he and a staff member of the station, Mrs. Hill, decided to travel to the nearby town of Ilwaco for supplies and mail. On the return trip from Ilwaco to North Head the errand became a life-threatening adventure:

"The road from Ilwaco to North Head is through a heavy forest of spruce and hemlock for some distance. On the return trip, shortly before reaching the heavy timber, the wind came with quite a heavy gust. We saw the top of a rotted tree break off and fall out of sight in the brush. ... We proceeded very slowly and with great care, passing over some large limbs that had fallen and through showers of spruce and hemlock twigs and small limbs blown from the trees. We soon came to a telephone pole across the roadway and brought the car to a stop, for a short distance beyond the pole an immense spruce tree lay across the road. We left the machine and started to run down the road toward a space in the forest where the timber was lighter. Just after leaving the car, I chanced to look up and saw a limb sailing through the air toward us; I caught Mrs. Hill by the hand and we ran; an instant later the limb, which was about 12 inches in diameter crashed where we had stood. In three or four minutes we had climbed over two immense tree trunks and reached the place in which I thought was our only chance to escape serious injury or possibly death. The southeast wind roared through the forest, the falling trees crashed to the ground in every direction from where we stood. Many were broken off where their diameter was as much as 4 feet. A giant spruce fell across the roadway burying itself through the planks within 10 feet of where we stood. Treetops broke off and sailed through the air, some of the trees fell with a crash, others toppled over slowly as their roots were torn from the earth. In a few minutes there were but two trees standing that were dangerous to us and we watched every movement of their large trunks and comparatively small tops.

Between 3:45 and 3:50 p.m., the wind shifted to the south and the velocity decreased to probably 100 mph or it may have been as low as 90 mph. Shortly after 3:50 p.m. we started toward North Head. We climbed over some of the fallen trunks, crawled under others, and pushed our way through tangled masses of tops that lined the roadway. We supposed that all the houses at North Head had been leveled and the wireless station demolished for we knew that the storm was the most severe that had occurred in the vicinity of the mouth of the Columbia with the last 200 years."

It was estimated that 80% of the mature timber near North Head was razed during this storm. In addition, the wireless tower was demolished and all roofs in the vicinity were lifted from their structures. At the nearby town of Ilwaco, dozens of boats were torn from their moorings and dashed to pieces on beach bulkheads. Nearly all roads in the area were impassable. The storm took particular vengeance on local bird life, with a canvasback duck blown through a plate-glass window and Ilwaco chicken farmers finding their charges blown miles away. At Astoria, on the south side of the Columbia, there were unofficial
reports of gusts to 130 mph, while at Tatoosh Island, located at the Northwest tip of Washington, the winds reached 110 mph. Very strong, but lesser, winds were observed over Oregon’s Willamette Valley and Puget Sound, with maximum gusts ranging from 50 to 60 mph. In Seattle's Elliott Bay twenty-one barges broke their mooring lines and were driven into Puget Sound, while on land a number of greenhouses were destroyed and several dozen fires were ignited as a result of the strong winds. Powerlines and telephone lines were downed across western Washington.

![Olympic National Forest: Blow of 1921](image)

**Fig. 3.4:** The windstorm of January 1921 produced a devastating loss of timber along the coast of the Olympic Peninsula, but only minor damage in the interior of western Washington.

The focus of the windstorm's greatest damage was to the southwest of the Olympics. Recent research (see Ferber and Mass 1990, references at the end of the chapter) has shown that when air approaches the Olympics a localized area of higher pressure (called a windward “ridge”) is formed on the Olympic slopes facing towards the wind, while on the other side of the barrier descending air causes a drop in pressure (a lee trough). During the 1921 windstorm, the flow off the Pacific was probably from the south, producing a windward ridge to the south of the Olympics and a lee trough to the north; this

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2 This account, as well as other information on the 1921 storm, is found in two short articles on pages 34 and 37 in the January 1921 issue of *Monthly Weather Review*. 
local area of high pressure forced air approaching the mountains to be deflected to the northwest and accelerated, since wind speed increases as air moves from high to lower pressure (see Figure below).

![Map showing pressure systems and wind directions](image)

Fig. 3.5: With southerly winds, a windward ridge (high pressure) forms south of the Olympics, with a lee trough (low pressure) builds to the north. Such a pressure pattern tends to accelerate air along the southwestern slopes of the Olympics, sometimes to extraordinary speeds.

21 October 1934

Wind gusts of 60-70 mph hit the interior of western Oregon and Washington, with higher winds on the coast, including an 87 mph gust at North Head. The storm removed roofs, overturned fishing boats, and lifted a hanger at Boeing Field off the ground that fell upon and destroyed four aircraft. Large swaths of forest were downed and waves on Puget Sound and in the Strait of Juan de Fuca reached extraordinary heights of 20 ft. Five Seattle fishermen drowned when their boat (the Agnes) floundered in heavy seas near Port Townsend. On the Seattle waterfront, the Pacific liner President Madison became unmoored, hit and sunk two other ships, and then smashed into a dock before coming to rest. The smokestack of the central heating plant at the Church of the Immaculate in Seattle toppled and crashed through the dome of the sanctuary, from which parishioners had left only ten minutes before. Winds
gusted to 70 mph at Seattle's Boeing Field and 83 mph in Tacoma. In addition to the loss of power and telephone lines throughout western Washington, the winds caused numerous fires throughout the region---making it the busiest day in the history of the Seattle Fire Department until that time. Large display signs were ripped from buildings across the city, and dozens of buildings collapsed as a result of the strong winds. Twenty-two people in Washington and Oregon lost their lives due to the storm.

The 1934 windstorm was associated with a deep low center that was located about 800 miles off of a Eureka, California the previous day; subsequently, it moved rapidly towards the northeast, making landfall over southern Vancouver Island. At Tatoosh Island, along the northwest tip of the Olympic Peninsula, sea level pressure dropped to 28.85 inches (977 mb) as the storm passed to the west.

Fig 3.6: The Seattle Times documents the great 1934 windstorm’s effects.

3-4 November 1958
This event was rather unusual in that both strong southerly and northerly winds were observed over western Washington. An intense Pacific storm crossed the southwest Washington coast during the late afternoon of the 3rd, passing near Olympia and Mt. Rainier during the evening hours. Extraordinary northerly winds of 45-65 mph were reported over Puget Sound north of Tacoma, while southwesterly winds of 60-80 knots were observed south of Olympia. A peak gust of 161 mph was reported at the Naselle radar site on a 2000 ft peak near the southwest Washington coast. Virtually every major highway along the coast of Oregon was blocked by fallen trees at some point during this storm. Steady winds of 51 mph with a peak gust of 71 mph were observed at Portland. Astoria had a maximum gust of 75 mph, the Columbia lightship reached 90 mph, and Mt. Hebo Air Force Radar Station, at an elevation of 3174 ft in the coastal mountains of Oregon, recorded several gusts of 130 mph, the maximum wind speed possible on that instrument.

12 October 1962: The Columbus Day Storm

By all accounts, the Columbus Day Storm was the most damaging windstorm to strike the Pacific Northwest in 150 years. An extensive area, stretching from northern California to southern British Columbia experienced hurricane-force winds, massive treefalls, and power outages. In Oregon and Washington, 46 died and 317 required hospitalization as a result of the storm. Fifteen billion board feet of timber (more than a year's annual cut) worth 750 million 1962 dollars were downed, 53,000 homes were damaged, thousands of utility poles were toppled, part of the roof of Portland’s Multnomah stadium was torn off, and the twin 520 ft steel towers that carried the main power lines of Portland were crumpled. At the height of the storm approximately one million homes were without power in the two states, with total damage was conservatively estimated at a quarter of a billion (1962) dollars.
The Columbus Day Storm began east of the Philippines as a tropical storm--Typhoon Freda. As it moved eastward into the mid-Pacific on 8-10 October, the storm transitioned into an extratropical (midlatitude) cyclone. Twelve hundred miles west of Los Angeles, the storm abruptly turned northward and began to deepen rapidly, reaching its lowest pressure (approximately 955 mb, 28.20 inches of mercury) approximately 300 miles southwest of Brookings, Oregon at around 7 A.M. on 12 October (see Fig. 3.10 for the storm track). Maintaining its intensity, the cyclone paralleled the coast for the next twelve hours, reached the Columbia River at approximately 5 P.M. with a central pressure of 956 mb, and crossed the northwestern tip of the Olympic Peninsula just before midnight. At most locations the strongest winds following the passage of an occluded front that extended outward from the storm's low center.

Over coastal regions and the offshore waters the winds gusted well over 100 mph, with 60-90 mph gusts over the western interiors of Oregon and Washington. At the Cape Blanco Loran Station sustained winds were estimated to reach 150 mph with gusts to 179 mph, at the Naselle radar site in the coastal mountains of southwest Washington gusts reached 160 mph, and a 131 mph gust was observed at Oregon's Mount Hebo Air Force Station. The winds at these three locations were undoubtedly enhanced
by local terrain features, but clearly were extraordinary. Away from the coast, winds gusted to 116 mph at Portland's Morrison Street Bridge, 90 mph in Salem OR, 100 mph at Renton WA, 80 mph at Whidbey Island Naval Air Station, 80 mph at Paine Field, 113 mph in Bellingham, 88 mph in Tacoma, 89 mph at Toledo WA, and 83 mph at West Point in Seattle. Even in California fierce winds were observed, with sustained winds of 68 mph in Red Bluff, in the Central Valley, and gusts of 120 mph at Mt. Tamalpais, just north of California. As is characteristic of most Northwest windstorms, both the storm and its associated winds weakened rapidly after landfall as the low center moved into British Columbia.

With sustained winds at some coastal locations exceeding 110 mph, the Columbus Day Storm was equivalent to a category 3 hurricane on the famous Saffir-Simpson scale, similar to Hurricane Rita that struck the southeast U.S. in September 2005. But since the size of the Columbus Day Storm, like most midlatitude cyclones, far exceed Rita or other hurricanes, and its path paralleled the coast, this storm caused far more extensive damage that possible from a hurricane, with destruction stretching from central California to southern British Columbia.

A number of papers have been written about the Columbus Day storm, with an article in Monthly Weather Review by Lynott and Cramer (1966) being the most comprehensive. A less technical discussion of the blow is found in Weatherwise Magazine (1962) by Decker, Cramer, and Harper.

13 February 1979: The Hood Canal Storm

Due to its offshore track, this storm caused less widespread damage over the Northwest than most events reviewed in this chapter. However, the interaction of strong southwesterly coastal winds with the high terrain of the Olympic Peninsula produced a small, but intense, low-pressure area to the northeast of the Olympics that accelerated southerly winds near the Hood Canal to over 100 mph. The result was the loss of the 3200 ft western section of the floating Hood Canal Bridge and a massive blowdown of timber that was surpassed only by the great storm of 1921. In some areas surrounding the Hood Canal Bridge
over 80% of the trees were downed. For example, on the nearby Pope and Talbot tree farm, 26 million board feet were blown down, four to five times the amount that fell during the Columbus Day storm of 1962—the most destructive storm of modern times.

Figure 3.8: Winds of over 100 mph resulted in the failure of the western section of the Hood Canal Bridge on 13 February 1979.

During the day preceding landfall, the cyclone center headed to the northeast, reaching its lowest pressure (965 mb) on the afternoon (4 PM) of the 12th, when the storm was 600 km west of the Oregon coast. Weakening as it continued on its northeasterly path, the storm made landfall over north-central Vancouver Island at approximately 4 A.M. on 13 February. Despite an overall decrease in the storm's intensity, an arc-shaped region of strong southerly winds persisted to the south of the low center and reached the Washington coast about this time.

Over most of western Washington, the wind speeds associated with this event were not extraordinary for a winter windstorm. Maximum sustained (one-minute average) winds at most locations were around 40 mph with gusts under 75 mph. On the coast the winds were somewhat higher, with the Cape Flattery Coast Guard Station experiencing a maximum sustained wind of 56 mph, with a peak gust
of 98 mph. Astoria OR had a sustained wind of 54 mph, and five crew members of a 15,000 ton ship were washed to their deaths off Coos Bay, OR

In a detailed study of the storm by Professor Richard Reed of the University of Washington (Bulletin of the American Meteorological Society, 1980) it was shown that the extraordinary high winds near the Hood Canal bridge were associated with a very small low pressure center--termed a mesolow--to the northeast of the Olympic Mountains (see Fig. 3.8). Just as water passing over a large rock in a stream plunges downward after it passes the rock--with associated vortices and eddies immediately downstream of the rock, a similar phenomenon can occur in the atmosphere when the conditions are right. Specifically, when the winds approaching the crest of the Olympics are strong enough and the vertical stability of the air (the tendency for the air to return to its initial altitude when displaced vertically) is relatively low, an intense, but small (20-40 miles in width) low center forms downstream of the barrier. From theoretical studies, it appears that the conditions on 13 February 1979 were ideal for such a leeside eddy to form.

Air increases in speed as it moves from higher to lower pressure. Thus, already strong (30-40 mph) winds over southern Puget Sound accelerated rapidly over the Hood Canal area as they approached the small low center, which was centered near Port Townsend. Although the anemometer on the bridge was eventually lost, bridge tenders reported that wind gusts repeatedly attained their instrument's maximum reading (100 mph) before they were forced to abandon their station. They also noted that sustained winds of 80 mph were observed for the two hours before the bridge failed. The Hood Canal Bridge was later replaced at a cost of over 140 million dollars.
The Hood Canal Storm was also associated with lesser, but damaging winds near Enumclaw, a town near the western foothills of the Cascades. Enumclaw is downstream of a "weakness" in the Cascades, and when low-pressure centers approach the coast, this town and its environs often experience strong easterly winds accelerating down the Cascade foothills (see chapter 7 of this book for more detail on Enumclaw winds). With high pressure to the east of the Cascades and the large low pressure center of the Hood Canal storm to the southwest, easterly winds gusted above 65 mph were observed in Enumclaw prior to the more general windstorm.

13-14 November 1981

A number of Northwest windstorms have come in pairs or even triplets, and this event was an example of such back-to-back windstorms. Two major storms traversed the Northwest during a 48-h
period, with the first producing the most serious damage. The first low center followed a similar course to that of the Columbus Day Storm, except that it tracked about 90 miles farther offshore, with landfall on central Vancouver Island. Over the eastern Pacific this storm increased in intensity at an extraordinary rate, deepening by approximately 50 mb (1.48 inches of mercury) during the 24-h period ending 4 P.M. PST 13 November. At its peak the storm attained a central pressure of just under 950 mb, with two nearby ships reporting gusts of 100 mph. The second, but weaker, storm followed a nearly identical path a day later, with a central pressure reaching only 988 mb

Over land, the maximum gusts from the first storm ranged from approximately 100 mph over coastal Oregon to nearly 70 mph over the interiors of western Oregon and Washington. Winds exceeding 50 mph spread into coastal northern California after 4 PM on 13 November. Subsequently, Brookings OR experienced sustained winds of 82 mph, followed by 92 mph gusts at North Bend OR and 97 mph gusts at Coos Bay. At the Coast Guard air station in North Bend there was an unofficial report of a gust exceeding 120 mph, and a ship 250 miles off the southern Oregon coast reported 33 ft seas. By the early morning hours of the 14th strong winds hit the Willamette Valley and the northern Oregon coast, and a few hours later winds rapidly increased over western Washington. At Seattle's Evergreen Point Bridge sustained winds of 45 mph with gusts to 75 mph, resulted in damage of nearly $400,000 and an 11-h closure. Maximum gusts achieved 67 mph at Seattle-Tacoma Airport. By the late afternoon of 14 November the winds were dying down over western Washington, only to accelerate again during the afternoon of the 15th as the second, but generally weaker storm tracked offshore. During the second storm the winds gusted to 62 mph at Medford, 92 mph at North Bend, 75 mph at Astoria, 71 mph at Salem and Portland, 52 mph at Seattle-Tacoma Airport, 79 mph at the Evergreen Point Bridge, and 66 mph at Camano Island. Three people were killed as a result of the second storm, and additional power outages were incurred. Paradoxically, the second weaker storm did more damage to trees, perhaps because the first storm had already weakened or partially dislodged tree roots.
The first November 1981 Northwest windstorm was far more intense and deadly than the famed “Perfect Storm” that hit the northeast U.S in late October 1991. Thirteen fatalities were directly related to the 1981 storm: five in western WA and eight in Oregon. Most were from falling trees, but four died in Coos Bay, Oregon when a Coast Guard helicopter crashed while searching for a fishing vessel that was encountering 30 ft waves and 80 mph winds. The fishermen were never found. The first storm resulted in massive power outages, with 400,000 Puget Power customers losing electricity. In downtown Seattle, a 70-ft cable-relay tower was blown down, while across the Sound in Bremerton winds blew the USS Oriskey from its moorage in the Puget Sound Naval Shipyard. All ferry runs were cancelled and all major bridges were closed.

An interesting aspect of the November 81 windstorms dealt with the storm insurance policy held by Puget Power. Puget Power had sustained massive damage from the weekend's storms that totaled in the millions of dollars. They did have an insurance policy, but with a deductible of one-million dollars per event. The whole issue went to court, where a jury decided that it really was one "storm," even though there were two low-pressure centers. Clearly, the legal and meteorological definitions of a storm are not always the same.

The guidance by National Weather Service computer models was nearly useless during the first event, with the 24-h forecasts providing little hint of intensification. The Seattle National Weather Service (NWS) office was able to make a timely (8h lead time) forecast only because Harry Wappler, the chief meteorologist at KIRO-TV in Seattle at that time, rushed over with a video tape containing the latest satellite animation, allowing NWS forecasters to extrapolate the future trajectory of the intense system (this was before NWS offices were equipped with weather satellite animation capabilities).

As in many of the great windstorms, there was a rapid increase in pressure accompanying the initiation of strong winds over the interiors of western Oregon and Washington. At a number of locations the pressure rose over 10 mb in three hours. With pressure falling ahead of the low center and rapidly
rising behind, extremely large horizontal pressure differences developed over the region (e.g., 20.3 mb between Salem and Bellingham at 9:30 PST on 14 November).


**20 January 1993: The Inauguration Day Windstorm**

Probably the second most damaging storm during the past 50 years (with the Columbus Day Storm being number one) struck the Northwest on the Inauguration Day of President Bill Clinton (20 January 1993). Winds of over 100 mph were observed at exposed sites in the coastal mountains and the Cascades, with speeds exceeding 80 mph along the coast and in the interior of western Washington. In Washington State six people died, approximately 870,000 customers lost power, 79 homes and 4 apartment buildings were destroyed, 581 dwellings sustained major damage, and insured damage was estimated at 159 million.

The Inauguration Day Storm rapidly intensified in the day preceding landfall on the northern Washington coast. At 4 P.M. PST on January 19th, the low-pressure center was approximately 600 miles east of the northern California coast with a central sea level pressure of 990 mb. The storm then entered a period of rapid intensification, with the central pressure reaching its lowest value (976 mb) at 7 A.M. on January 20th, when it was located about 20 miles east of the outlet of the Columbia River. A secondary trough of low pressure extended south of the low center, and within this trough the pressure differences (horizontal pressure gradients) and associated winds were very large. During the next six hours, as the low center passed west and north of the Puget Sound area, the secondary trough moved northwestward across northwest Oregon and western Washington, bringing hurricane force winds and considerable destruction.
As the storm moved along the Oregon coast, winds gusted to 86 mph at Cape Blanco and 84 mph at Arch Cape, with unofficial reports of gusts in excess of 100 mph over northwest Oregon. These hurricane-force winds produced widespread power outages over coastal Oregon and the loss of millions of dollars of timber within the coastal mountains southeast of Astoria. As the storm moved northward along the Washington coast, winds gusted to 98 mph at Cape Disappointment at the western terminus of the Columbia River, 94 mph at the Hood Canal Bridge, 75 mph at Alki Point, 80 mph at Enunclaw near the Cascade foothills, and a record 88 mph on the roof of the Atmospheric Sciences building at the University of Washington (Seattle). The 64 mph gust at Seattle-Tacoma Airport was the second strongest in 50 years (the record was 67 mph during the 14 November 1981 storm). Near the Cascade crest, winds exceeded 100 mph several times over a two-hour period at Stampede Pass and reached 116 mph at the Alpental ski area in Snoqualmie Pass. For the first time ever, both floating bridges across Lake Washington were closed, as was the Tacoma Narrows suspension bridge. The massive power outages accompanying the storm caused businesses and schools throughout western Washington to close midday; with some schools sending children home when dangerous winds were still pummeling the region (a big mistake). A power
outage north of Seattle in Edmonds resulted in nine million gallons of raw sewage inundating city streets, while near Toledo, Washington Interstate 5 was closed when power lines were downed over four of the lanes.

Official National Weather Service forecasts were generally quite good, with the release of a high wind watch at 1:30 PM PST and a high wind warning at 10 P.M. the day before (19 January). These excellent forecasts were generally ignored by media, which were busy covering Clinton’s Inaugural. The skillful forecast of this event reflected the substantial improvement in numerical weather prediction that had occurred during the previous ten years. While nearly every major windstorm was poorly predicted prior to 1990, advances in observations, data assimilation, and numerical modeling have resulted in consistently better forecasts of major storm systems in recent years.

A considerable amount of research has examined the interaction of the Inauguration Day cyclone with the substantial terrain of the Pacific Northwest. Steenburgh and Mass (1996) showed that as strong southwesterly winds associated with the storm passed over and down the Olympic Mountains an area of low pressure formed on the northeast side of the barrier. With higher pressure to the south, this mountain-induced low pressure helped maintain strong southerly flow over Puget Sound as the low center moved to the northeast. Another major characteristic of this storm (one shared with other big events) was an exceptional rise in pressure as strong winds moved into the region. For example, between 7 A.M. and 10 A.M. on 20 January the sea level pressure rose 16 mb at Astoria, Oregon, while pressure was nearly steady over Puget Sound. With pressure surging to the south and steady to the north, a tremendous north-south pressure differential was established that produced hurricane-force gusts throughout the region, with the strongest winds over south-central Puget Sound.

12 December 1995
Of all the major windstorms to strike the Pacific Northwest, none was better forecast nor more intensively studied than the 12 December 1995 event. Hurricane-force gusts and substantial damage covered an extraordinarily large area from San Francisco Bay to southern British Columbia, resulting in five fatalities and over 200 millions dollars damage. Early in the day, the storm struck northern California with gusts of 103 mph at San Francisco, 75 mph at Eureka, and 75 mph in Oakland, resulting in numerous tree falls and three deaths. In Oregon, winds at Sea Lion Caves near Florence reached 119 mph before the anemometer failed, at North Bend winds gusted to 86 mph, Newport winds attained 107 mph, and both Cape Blanco and Astoria had maximum winds that just exceeded 100 mph. Sea level pressure at Astoria dropped to 28.51 inches (965 mb), an all-time record low for that observing site. Winds within the Willamette Valley surpassed 60 mph at several locations, and with very wet soil from an unusually rainy fall, many large trees were uprooted.

![Figure 3.10](image1.png)

**Fig. 3.10.** Throughout Oregon and Washington thousands of trees were toppled during the 12 December 1995 storm. This picture was taken in Salem, Oregon.

Over western Washington sustained winds reached 30-50 mph, with gusts of 50-80 mph. North Bend and Seattle experienced maximum gusts of 78 mph and 59 mph, respectively, with the latter location experienced its all-time record low pressure (970 mb, 28.65 mb). Over the waters of Puget Sound the winds were greatly enhanced compared to land values: a ship just outside of Elliott Bay
reported sustained winds of 60-70 mph with gusts to 90 mph, the ferry terminal at Mukilteo reported sustained winds of 60-70 mph with a gust to 86 mph, and gusts attained 76 mph on the Hood Canal Bridge. Approximately 400,000 homes lost power in western Washington, with nearly complete blackouts on Bainbridge, Vashon, and Mercer Islands. To the south, 205,000 customers lost power in Oregon while in northern California the total was 714,000.

The 12 December 1995 event was the most skillfully forecast windstorm in Northwest history. The computer weather models began predicting an intense event 3-4 days ahead of time, and the day before it struck the National Weather Service provided a strongly worded warning for a powerful, damaging windstorm. The media went wild, with television reporters reporting live from seemingly dozens of locations. Government, educational institutions, and businesses took the warnings seriously, protecting property and closing down early. The forecasts released the morning of 12 December not only correctly predicted storm strength, but provided timing that was accurate to within an hour.

As luck would have it, a major atmospheric field program called COAST was underway during the December windstorm, and a National Oceanic and Atmospheric Administration (NOAA) research aircraft, the P3, was used to study the structure of the storm both offshore and as it crossed the coastal mountains of Oregon and Washington. The P3, which is also used for hurricane reconnaissance, not only observes the weather along its flight path, but its Doppler radars describe the three-dimensional wind and precipitation fields around the plane for a distance of 50-100 miles. Flying offshore of the Oregon coast at around 4000 ft, the plane experienced winds of 100-120 mph in a highly turbulent environment, with salt spray reaching the plane's windshield as high as 2000 ft above the wind-whipped seas.

**General Windstorm Characteristics**

**Windstorm Paths**

Most of the great Northwest windstorms over western Washington have followed similar tracks over the eastern Pacific. Starting over the subtropical central Pacific west of southern California, such storms usually move eastward before swinging up towards the north or northeast as they approach the West Coast (see figure 3.11).
These storms then roughly parallel the Oregon and Washington coasts before making landfall over northern Washington or Vancouver Island. Strongest southerly winds in western Oregon or Washington generally occur when intense low centers pass north of the location in question. Thus, the strongest southerly winds in the Puget Sound region typically occur when a deep low center moves from southwest to northeast and crosses the coast between the northern tip of the Olympic Peninsula to central Vancouver Island (Fig. 3.12). Lows passing farther north are too far away to produce the strongest winds over western Washington. For strong winds in Portland or Eugene, this path needs to be displaced southwards, so that the low center passes immediately to the north. Interestingly, a number of the strongest Northwest storms can be traced to tropical disturbances that move northward and get transformed into midlatitude systems.
3.12 Typical path of low centers that bring strong southerly winds to Puget Sound.

**Major Northwest Windstorms, El Nino, and La Nina**

Recent research has revealed a connection between the surface temperatures of the tropical Pacific and weather over the western U.S. When tropical sea surface temperatures (SSTs) are warmer than normal (El Nino periods), the Northwest tends to be warmer and slightly drier than usual during the winter, while cooler tropical SSTs (associated with La Nina conditions) bring wetter than normal winters, with somewhat cooler and snowier conditions during the latter half of the winter. The tendency to alternate between El Nino and La Nina conditions over a period of three to seven years is termed the El Nino Southern Oscillation (ENSO), with the intervening "neutral" years having near-normal SST conditions.
ENSO appears to influence the frequency of major Northwest windstorms, with the greatest windstorms occurring in neutral (neither El Nino nor La Nina) years. To illustrate this fact, the figure below shows the variation of sea surface temperature for November through February for a region in the eastern tropical Pacific (called the Nino 3.4 area). Temperatures are shown as differences from average temperature over the period (1856-1997). El Nino (La Nina) years are associated with warm (cold) anomalies of approximately 1°C or more. The temperature differences are indicated by blue diamonds except for the temperatures of major windstorm\(^3\) years, which are indicated by red squares. Clearly, the major windstorms are all in neutral years. Since there were only a small number of major windstorms during the past century our sample size is relatively small; thus, this ENSO/windstorm relationship should be considered suggestive, but not definitive.

The lack of major windstorms in El Nino years is not surprising since a number of researchers have found that El Nino periods are often associated with "split flow" over the eastern Pacific, with the Pacific jet stream dividing, with one portion going into Alaska and the other heading towards California. Such conditions tend to shear weather systems apart as they approach the Northwest--which lessens the chance for strong windstorm development. La Nina years often have periods with enhanced high pressure in the eastern Pacific (termed "ridging") that produces enhanced cool flow from the north that is quite different than the typical windstorm pattern in which strong southwesterly flow heads directly into the Pacific Northwest.

Since the transition between El Nino to La Nina occurs relatively slowly and can often be predicted at least six months in advance, the connection between ENSO and major windstorms provides a several month "heads up" regarding the probability of a significant wind event.

\(^3\) The major windstorms that were selected all produced massive damage over the Northwest with winds of 60 mph and greater. The storms were 9 January 1921, 29 January 1921, 21 October 1934, 3-4 November 1958, 12 October 1962, 13-15 November 1981, 20 January 1993, and 12 December 1995.
3.13 Sea-surface temperature anomalies over the eastern tropical Pacific (Nino 3.4 region) for November through February. Years with major windstorms are indicated by red squares, with non-windstorm years shown by blue diamonds. It appears that major windstorms avoid El Nino and La Nina years.

**Focus Section: Windstorm Fireworks**

When a Northwest windstorm strikes at night, local residents are often provided with a colorful display of sky-filling light flashes accompanied by loud booms—not unlike summertime fireworks. The cause of the bright lights and explosions is the failure of transformer fuses. As winds increase to about 30 to 40 mph, branches begin to either break or move sufficiently that they touch power lines, causing them to be grounded. If the tree limb does not either burn through or fall away in a few seconds, the large current associated with the grounded circuit causes a nearby transformer fuse to blow, with an explosive charge opening the circuit with a bright flash and a thunderous sound. The author has sat spell-bound on
Figure 3.14. A transformer power fuse. When a powerline is grounded, a small charge on a transformer fuse is ignited, resulting in a break in the line and a power outage for nearby homes.

many a windstorm night, watching as low clouds were illuminated by exploding fuses. With each flash a neighborhood goes dark, greatly adding to the entertainment.

During the late nineteenth and early twentieth century, Northwest windstorms were often accompanied by a different type of light show--real fires. With gas and wood-fueled fires used extensively for heating and illumination, strong winds frequently resulted in structural damage that in turn initiated building fires.
Windstorm References


