WES Exercise - Western Washington Windstorms

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Introduction

This paper will examine two recent western Washington windstorms, using model simulations and observational data. The storms were representative of two types of high wind events that threaten western Washington. The operational staff at WFO Seattle recently went through an exercise using the Weather Event Simulator (WES) to solidify our understanding of the synoptic evolution and mesoscale features associated with each event.

The first event, which occurred on the morning of 27 December 2002, is an example of a ‘Puget Sound windstorm.’ Most of the well-know windstorms of western Washington are of this type. While they are relatively rare, these storms are noteworthy for their significant impact on the densely populated Puget Sound region. These events occur when the center of a cyclone travels northeast through the offshore waters and tracks inland across the northern interior of western Washington or southern British Columbia. This track is referred to in the forecast office as the ‘Ruscha track’ after (now-retired) lead forecaster Charles Ruscha, who assembled an aid for forecasting strong south winds in the Puget Sound lowlands in 1986.

The second event took place the morning of 2 January 2003, as an approaching frontal system produced a strong southeasterly pressure gradient across western Washington. This type of event – locally known as a ‘southeast sucker’ – usually brings high winds to just the coast and north interior of western Washington. Southeast suckers are relatively common events, normally occurring several times each winter.

The 27 December 2002 Puget Sound storm

A mature 989-mb cyclone moving northeast toward Washington can be seen in Fig. 1, which shows the initialization from the 1200 UTC 27 Dec 2002 GFS run. At 1600 UTC 27 December the low pressure center made landfall along the central Washington coast. The low gradually filled as it tracked northeast, crossing the northern Puget Sound region around 1800 UTC and moving into southern British Columbia around 2000 UTC. In comparison to more famous western Washington windstorms (for example, the Inauguration Day storm of 20 January 1993), this was a marginal event. In fact, observations verifying the high wind warning were sparse. The low (which was not terribly deep to begin with) filled slightly as it moved inland, but the path of the low was such that the storm struck the core of the Seattle metropolitan area. It knocked out power to more than 260,000 homes and led to the death of a 10-year-old boy, who stepped on a downed power line in Olympia.

The mesoscale effects produced by the interaction of the synoptic scale low-level flow with the orography of western Washington have been well documented during the past twenty years (e.g., Reed 1980, Mass and Ferber 1990, Ferber and Mass 1990, Steenburgh and Mass 1996). In the case of this storm, two well-known mesoscale features were present: a mesoscale low in the lee of the Olympic mountains preceding the front, and a Puget Sound Convergence Zone (PSCZ) following the front. As the south-southwesterly 850-mb flow rose to around 45 kt by 1500 UTC a mesolow formed in the lee of the Olympic mountains. The Eta 3-h forecast valid 1500 UTC is shown in Fig. 2(a) and shows very nicely the strong southwest flow at 700 mb and the mesoscale low in the lee of the Olympic mountains. The Eta correctly predicted the development of this feature, although the observed low appears to have been farther south and a bit deeper (possibly a result of the model’s incomplete resolution of the terrain).

As a result of enhanced pressure gradients associated with the mesolow, surface winds rose more or less simultaneously throughout the Puget Sound region, rather than in a southerly surge. At 1800 UTC the synoptic low moved into the north Puget Sound area, essentially merging with the mesolow (see Fig. 2(b)), and it was during the next couple of hours that the highest winds occurred in the Puget Sound region. As the low-level flow veered to westerly behind the front, the mesolow shifted southward into the central Puget Sound around 2100 UTC and acted as the western anchor of a PSCZ. This post-frontal transition is nicely depicted in the Eta forecast as shown in Fig. 2(c). The PSCZ formed at the boundary between the westerlies moving down the Strait of Juan de Fuca and the strong southerlies in the Puget Sound basin. The sharp PSCZ is clearly visible in the KATX composite reflectivity shown in Fig. 3.

As surface high pressure built into western Washington from the southwest behind the front, the southward drift of the mesolow also increased pressure gradients and isallobaric forcing over the south and central parts of the Puget Sound. Mathematically the isallobaric wind is given by:

$$POD = \frac{Correct\_Advisories}{Total\_Events}$$

where ρ is the density of air and f is the Coriolis parameter. Using finite differences, the component of the isallobaric wind (U_{in}) along the Puget Sound channel is approximated by:

$$FAR = \frac{Incorrect\_Advisories}{Total\_Advisories}$$

where the subscripts OLM and SEA refer to the observation sites at Olympia and SeaTac and $D_{n(OLM\text{-}SEA)}$ is the distance between Olympia and SeaTac. Observed pressure reports in Puget Sound show that the isallobaric component of the ageostrophic wind rose sharply beginning at 1900 UTC and peaked at 45 kt at 2200 UTC. This is consistent with sustained windy conditions into the afternoon; West Point in Seattle recorded a south-southwest wind of 39 kt at 2120 UTC – its strongest wind of the event.

The 2 January 2003 southeast sucker

At 0900 UTC 02 January a 982 mb low tracked north-northeast over the Washington offshore waters, about 425 nm west of the coast, reaching the Queen Charlotte islands of British Columbia around 2000 UTC. See Fig. 4, which shows the surface low and an associated strong cold front just offshore Washington at 1200 UTC. This system produced a strong southeast pressure gradient over western Washington that was enhanced by a pre-existing surface ridge extending north-northwest from Idaho through eastern British Columbia. Satellite imagery suggests that a small jet max moved north along the frontal boundary about the time it reached the coast at 1200 UTC. Marginally high winds occurred along the coast coincidental with or just after the frontal passage. The front moved rapidly through the interior lowlands of western Washington by 1400 UTC and east of the Cascade crest by 1600 UTC. The pressure gradient between Bellingham and Port Hardy, British Columbia, (BLI-YZT) peaked at 13.4 mb from 1400 UTC to 1600 UTC, with high winds in the north interior of western Washington between 1700 UTC and 1800 UTC. While the BLI-YZT pressure gradient commonly observed during verifying southeast suckers has not been documented, its magnitude during this event appears to be atypically small.

The strong southeast pressure gradient associated with southeast suckers does not usually threaten the Puget Sound lowlands with damaging winds. This is due to the fact that the pressure gradient along the channel is usually small, and the narrowness of the channel – around 90 km – prevents the surface wind in the Puget Sound from approximating the geostrophic wind. In theory, an obstacle perturbs geostrophic balance upstream by the distance of the Rossby radius. Additionally, for any flow constrained by a channel or strait to be in geostrophic balance the channel must be greater than a Rossby radius, which is given by:

$$CSI = \frac{Correct\_Advisories}{Total\_Events + Incorrect\_Advisories}$$

where *N* is the Brunt Vaisala frequency (an indication of stability), *H* is the layer depth, and *f* is the Coriolis parameter. By considering a layer depth of 1000 m, using $f = 10^{-4}\ s^{-1}$, and taking $N = 0.013\ s^{-1}$ (typical of a stable air mass), we can estimate that the Rossby radius in a stable pre-frontal environment is around 130 km. This is greater than the 90 km width of the Puget Sound channel. It is interesting to note that as the stability of an air mass decreases (a decrease in N) the Rossby radius decreases. So, with decreasing stability there is a point at which the Rossby radius drops below the width of the Puget Sound channel and near-geostrophic flow is possible. Although, unusual, there have been events where this seems to have happened.

Between 1200 UTC and 1400 UTC during the 02 January southeast sucker, two NWS spotters in Thurston County (in the southern Puget Sound region) reported winds gusting into the 60 to 70 mph range. While model solutions indicate that the 1000 mb geostrophic wind was reaching its maximum value of 60 kt for this event around 1200 UTC, it is unlikely that the winds in the boundary layer locally reflected geostrophic balance for a brief interval. The winds occurred immediately downstream from Porcupine Ridge, a roughly 2000 foot high ridge that extends westward (perpendicularly) from the main Cascade range. In addition, radar imagery shows that a band of heavy rain (40 to 45 dBZ) was moving northward into the south Puget Sound region when the strong winds began. So a more likely explanation is that either the interaction of the strong low-level flow with Porcupine Ridge, or the onset of heavy rain (or both), transported the strong winds downward to the surface for a brief period. It's also possible that the jet max mentioned above played a role. The heavy rain band evident across the Kitsap Peninsula (Fig. 5) is likely the frontal band. This image is nearly coincident with the strong winds in Thurston County.

Figure 1: Global Forecast System (GFS) initialization of 500 height (dam) and mean sea-level pressure (mb) for 1200 UTC 27 Dec 2002.

Figure 2: Eta forecast of 700-mb wind and mslp. (a) 3-h forecast valid 1500 UTC 27 Dec 2002; (b) 6-h forecast valid 1800 UTC; and (c) 9-h forecast valid 2100 UTC.

Figure 3: KATX composite reflectivity from 2227 UTC and Eta 9-h forecast of mean sea-level pressure (mb) valid 2100 UTC 27 Dec 2002.

Figure 4: Eta initialization of 500 height (dam) and mean sea-level pressure (mb) for 1200 UTC 02 Jan 2003. Image is IR satellite for 1200 UTC.

Figure 5: KATX composite reflectivity from 1207 UTC 02 Jan 2003.

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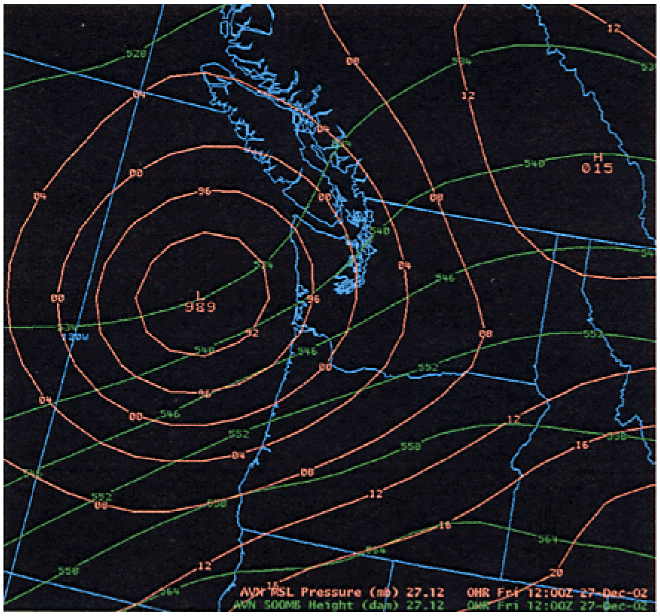
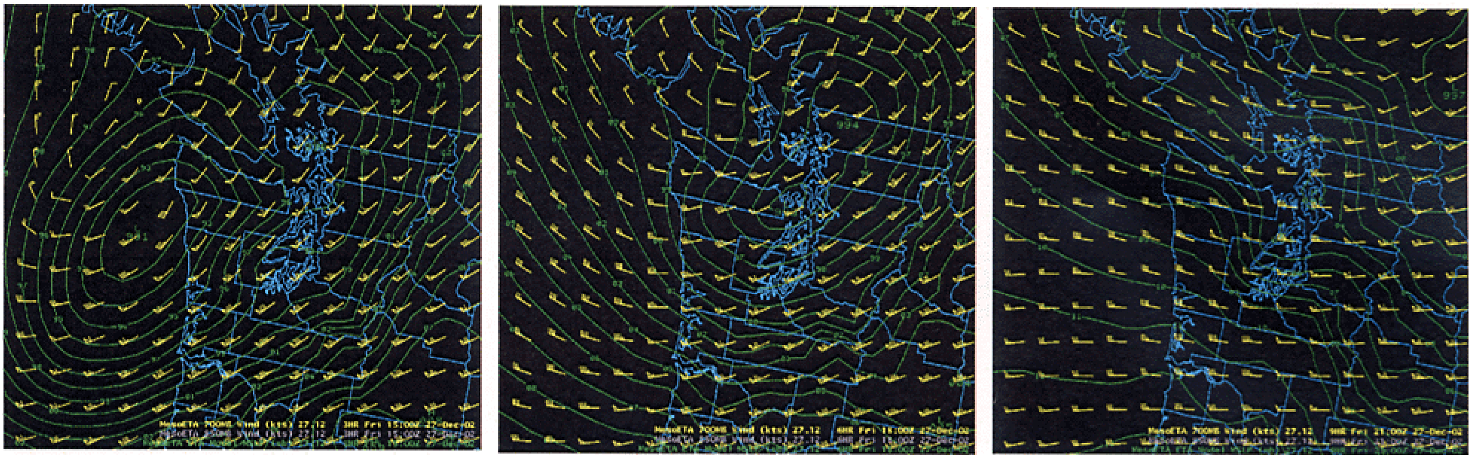


Figure 2(a)(b)(c): Eta forecast of 700-mb wind and mslp. (a) 3-h forecast valid 1500 UTC 27 Dec 2002; (b) 6-h forecast valid 1800 UTC; and (c) 9-h forecast valid 2100 UTC.



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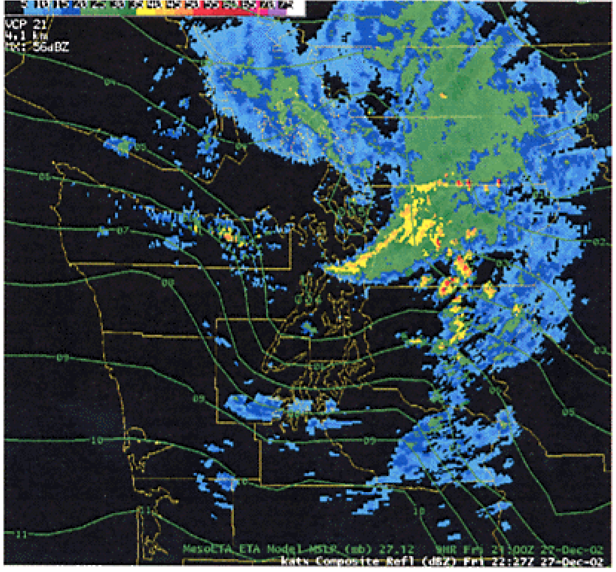

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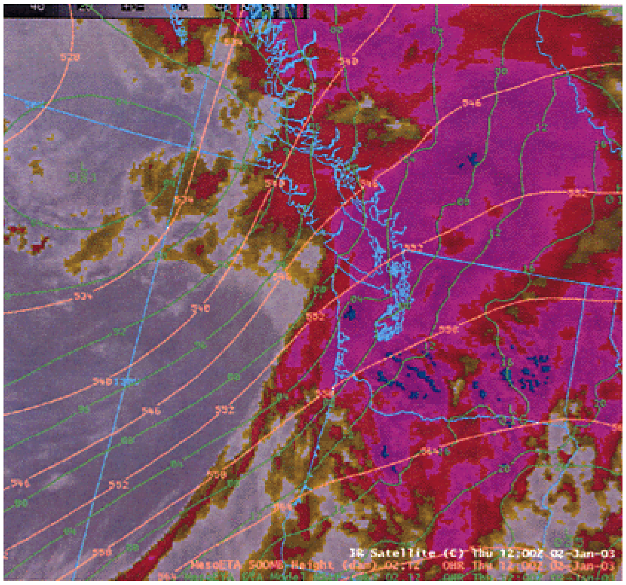

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