An Investigation of the Puget Sound Convergence Zone Using WES

Doug McDonnal and Brad Colman
WFO Seattle WA

Introduction

The Puget Sound Convergence Zone (PSCZ) � a mesoscale phenomenon produced by the interaction of synoptic-scale low and mid-level flow with the orography of western Washington � is one of the more interesting weather events of the Puget Sound metropolitan area.� Due to its prominence in the local meteorology and climatology, and the challenge it frequently presents to forecasters, the PSCZ has been the subject of much research over the past quarter-century (e.g., Mass 1980, Ferber and Mass 1990, Whitney et al. 1997).� Of course, it is critically important that everyone on the operational staff at WFO Seattle has an understanding of its physical causes and a familiarity with its effects.� For these reasons, the investigation of an actual PSCZ is an ideal application of the Weather Event Simulator (WES) as a training tool.

A PSCZ developed on 14 May 2003 and remained intermittently active through 17 May 2003.� In many respects this was a classic convergence zone episode, lending itself nicely to investigation using WES.� Its formation and duration was typical within the context of the evolution of the synoptic-scale features.� Specifically, it developed shortly after a surface front moved through western Washington and lingered over the north Puget Sound area until the arrival of the associated upper-trough axis; following the passage of the trough axis, the PSCZ moved south through the Puget Sound as it weakened and died.� A weak mesoscale low serving as the western anchor of the PSCZ was present at times during the episode.� In this event the PSCZ produced many of the sensible weather elements most commonly associated with its occurrence -- especially a spring event � including heavy showers, thunderstorms with small hail, snow accumulation on the Stevens and Snoqualmie Pass highways, and generally clear skies over the south Puget Sound.

Discussion

A weak Pacific cold front made landfall on the Washington coast during the morning hours of 14 May 2003 and moved through the interior lowlands and across the Cascades by the early afternoon.� A cold upper-level trough was off the Pacific Northwest coast along 130W moving slowly east, and satellite imagery showed two conspicuous vorticity lobes rotating through the trough.� This general synoptic pattern is shown well in Fig. 1 (see below), with the 500 mb height and vorticity fields, and the MSLP and surface winds.� A weak PSCZ formed over the north Puget Sound several hours after frontal passage, as surface high pressure built into western Washington from the southwest and the low-level flow veered to westerly.

The activity of the PSCZ reached its climax during the afternoon and evening hours of 16 May, as the mesoscale and diurnal forcing combined with synoptic-scale dynamics. (The time shown in Fig. 1.)� The 500-mb temperature had fallen to around -33C over western Washington as the trough was approaching the coast, while the 0000 UTC 17 May 2003 sounding at Quillayute (on the north Washington coast) indicated a freezing level of 3,500 feet.� ACARS data and model simulations suggested a lifted index of around -2 C over the Seattle area, with CAPE values between 300 and 500 Jkg^{-1}.� In addition, a vorticity lobe was rotating around the east side of the trough, revealed in the satellite imagery (not shown) as a comma-shaped cloud feature.� A 140 knot jet moving onto the Oregon coast placed western Washington in the vicinity of its left exit region.

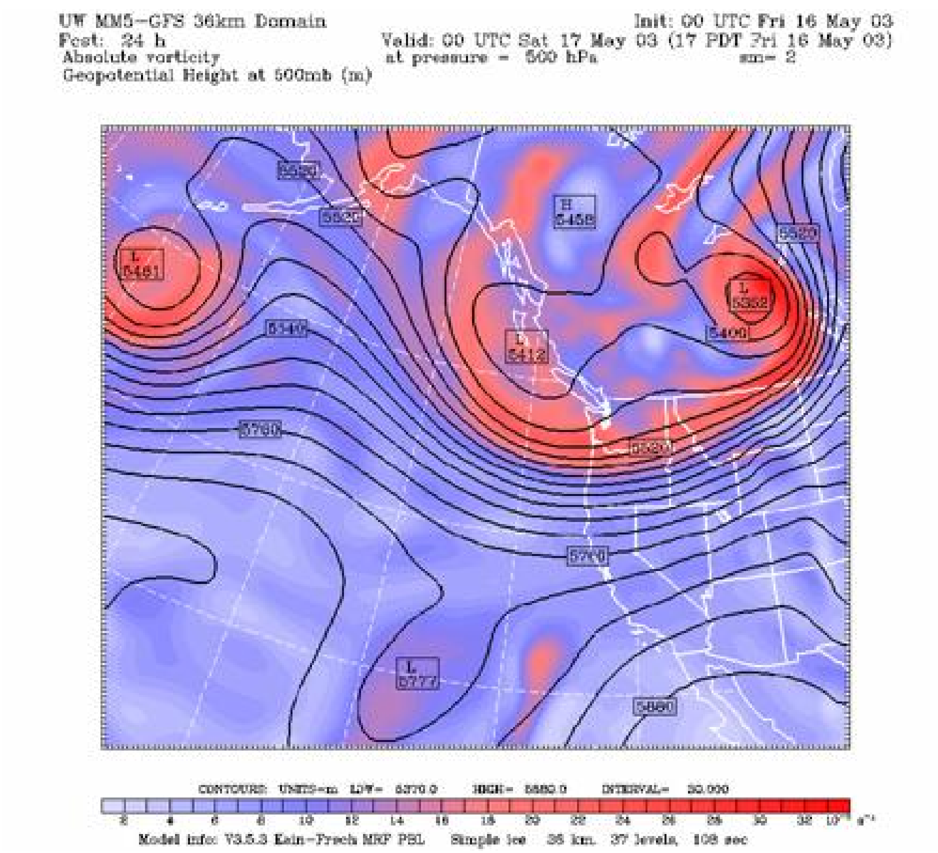
The PSCZ focused convection along a band that extended east-southeast from the east entrance of the Strait of Juan de Fuca across western Snohomish County and into the Cascades.� The KATX radar (on Camano Island in the north Puget Sound) showed maximum echoes around 60 dBZ, and lightning detection equipment showed numerous thunderstorms.� Spotter reports confirmed that some of the storms had up to quarter-inch hail, and one spotter reported that hail had accumulated on the ground to a depth of half-inch.� The Quillayute sounding suggested an ambient snow level of around 2,500 feet, and evaporational cooling within the heavier precipitation of the PSCZ likely forced it lower.� Imagery from web cameras at the two most important highway passes (Stevens Pass and Snoqualmie Pass) on the morning of 17 May showed overnight snowfall accumulation, perhaps enough to warrant a late-season snow advisory.

The convergence zone weakened as it moved south through the Puget Sound during the day on 17 May, coincidental with the passage of the upper-level trough axis.� Given the rather slow progression of the upper trough (which moved through western Washington approximately 72 hours after the surface front), this was an unusually long-lived PSCZ.� However, the activity and apparent structural integrity of the feature was far from constant.� There was a clear diurnal cycle, with the convergence zone gaining strength each day and peaking in the late afternoon and evening hours.� It weakened each night, becoming difficult to identify by sunrise.� This was obviously due in part to instability driven by insolation, but the diurnal sea breeze circulation probably also played a significant role.

As we transition our forecasting to the gridded environment, we need to assess what is the most skillful way to present mesoscale features similar to the PSCZ.� High resolution NWP simulations are often dramatic and compelling with respect to timing and details of such structures.� This particular WES case lends itself to emphasizing the difficulty in maintaining a balance of expected skill (in timing, location, and intensity) and available detailed forecast grids.� In Fig. 2 below we present two 3-h forecasts of accumulated precipitation valid at the same time, one from a 12-km grid and the second from a 4-km grid.� Casual inspection reveals dramatic differences in the details.� Unfortunately, it has not been shown that we have skill at the resolutions of these features.� For example, the PSCZ often shifts locations based on outflow boundaries, which are not resolved in these simulations.� As an alternative to deterministic presentations of these features we argue for a broader, less explicit forecast.� In our office, in addition to the high-resolution MM5 forecasts, forecasters have the option of pulling in probability forecasts generated from our locally run MM5 ensemble.� In Fig. 3 below we show the 3-h PoP for 0.01 inches or greater.� This image reveals a broader PSCZ and an overall farther south position than seen in Fig. 2, which is in better agreement to the actual observed position.� This forecast more correctly takes into account both large-scale uncertainties and those related to model physical parameterizations than a single high resolution run.

Conclusion

While the PSCZ is relatively well understood, accurately forecasting its spatial and temporal details remains a significant challenge.� This challenge is even greater in light of our new forecast process.� When mesoscale models portray this feature in a realistic way (at least according to our concept of it), forecasters have a great temptation to use the model solution in a deterministic way and now have the ability to use these as initializations in the GFE.� One of the goals of this WES exercise, though, is to show how this has its pitfalls.� It�s also important to note that forecasters have struggled for at least the past twenty years to write a zone forecast that meaningfully depicts the PSCZ; it often produces heavy rain in the north end of the Tacoma-Seattle-Everett area zone, while mostly sunny skies prevail from Seattle southward.� Gridded forecasts may provide an opportunity to solve this long-standing problem, as long as we maintain a proper balance between resolution and uncertainty.



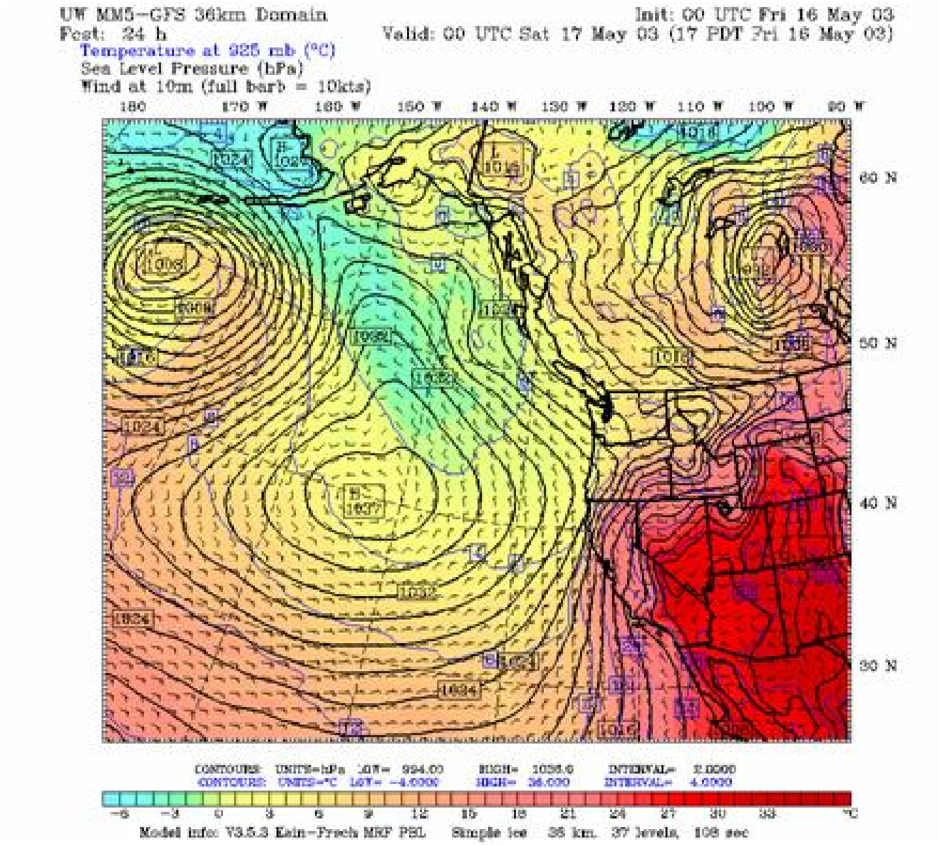
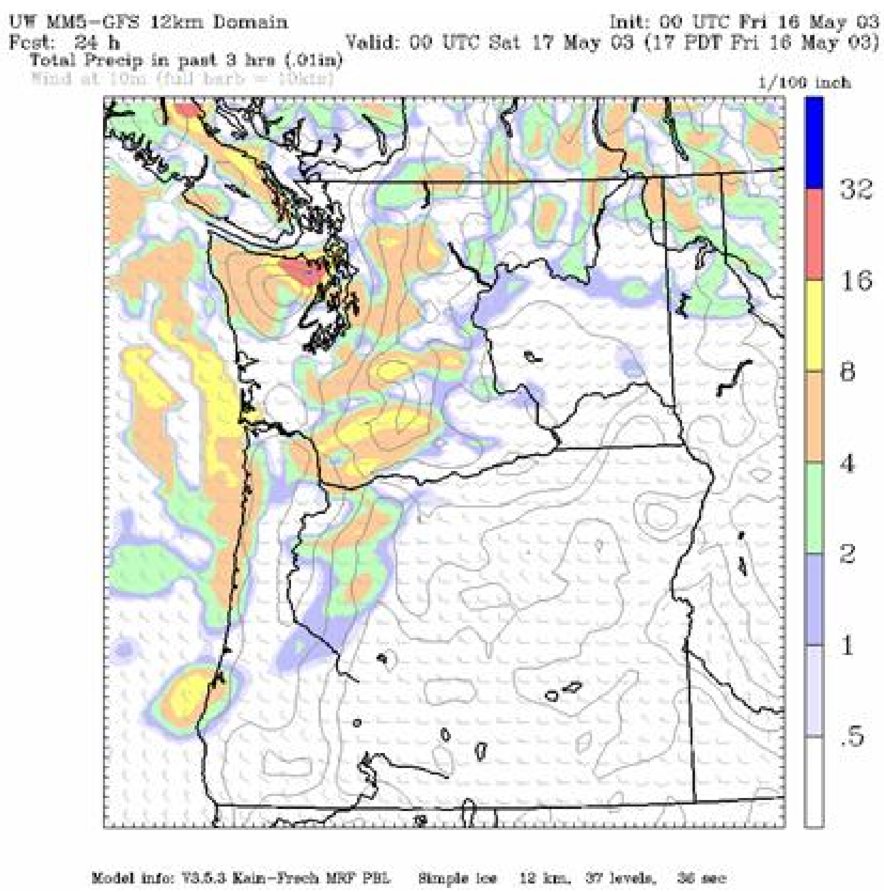


Figure 1:� MM5 24-hr forecasts valid 0000 UTC, 17 May 2003:� (a) 500-mb heights and vorticity, (b) MSLP and surface wind.



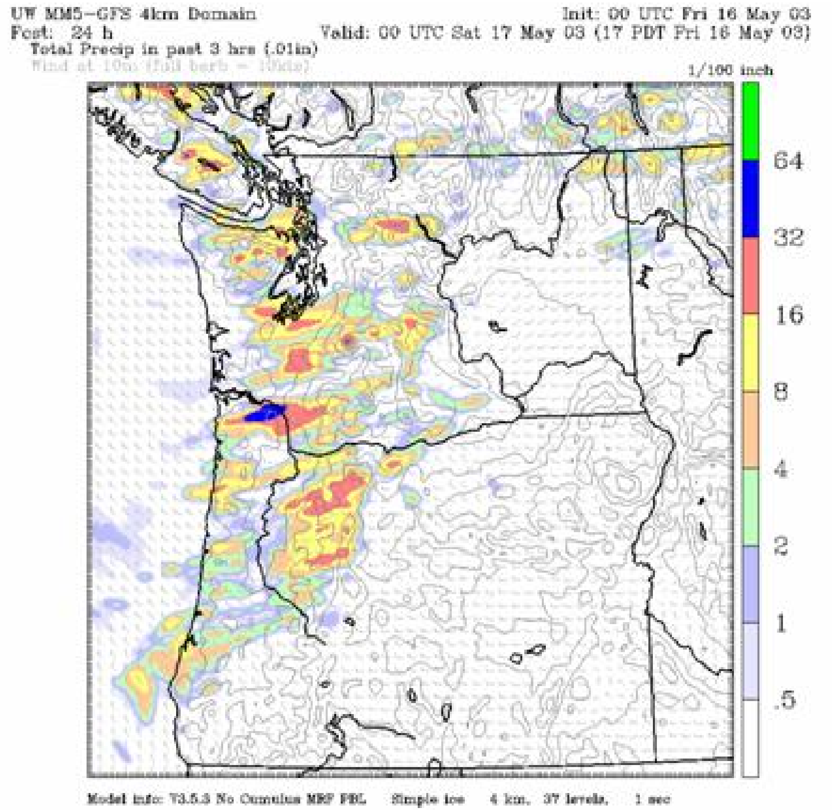


Figure 2:� MM5 3-h precipitation forecasts valid for 0000 UTC 17 May 2003. (a) 12-km grid resolution, and (b) 4-km grid resolution.

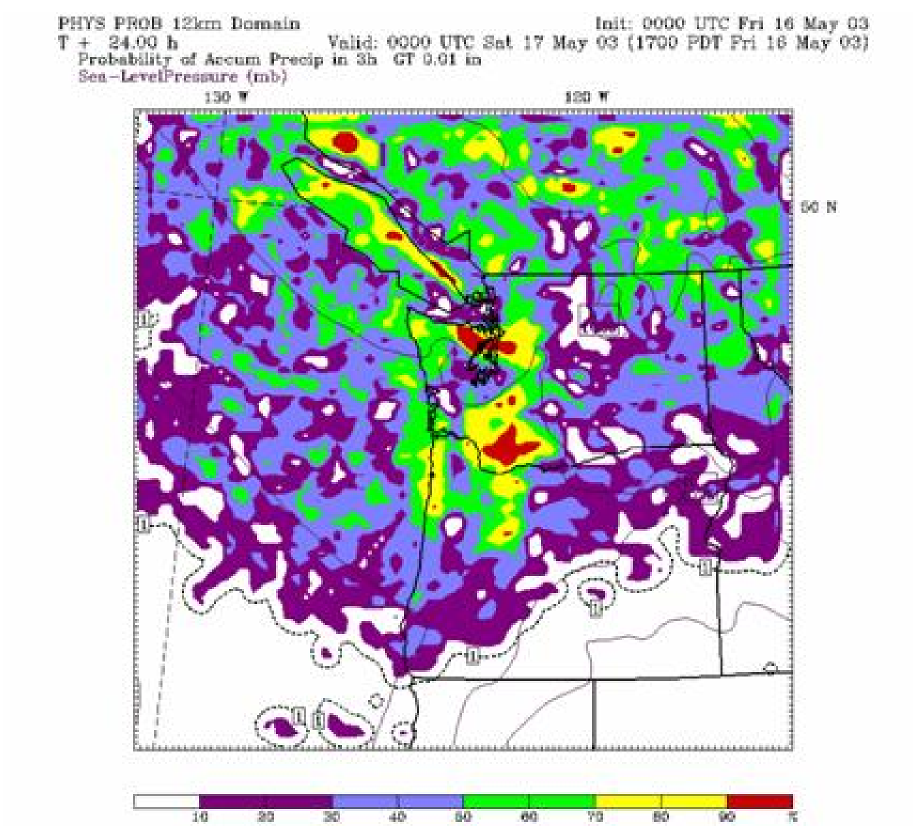


Figure 3:� 3-h PoP derived from the MM5 12-km ensemble (including physics perturbation runs).� The forecast is valid at 0000 UTC 17 May 2003.