WES Winter Case: Small Stream and Urban Flood Scenario

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Introduction and Background

The Weather Event Simulator (WES) provides the training officer a great opportunity to walk forecasters through an event that in many ways is rather typical – yet actually contains a much less common twist that, when it occurs, is typically missed. The early winter WES case discussed here does just that in hopes that the less common twist will be more easily recognized by the staff in future cases and appropriate advisories issued.

Flooding is our CWA's most frequent high-impact weather and forecasters are much attuned to the favored synoptic pattern and river responses. As a result we miss few main-stem flooding events. However, small stream and urban flooding occurs less often and has not received as much attention as it warrants. This case highlights at least one scenario when heavy rainfall occurs across the Seattle metropolitan area that, if recognized, should allow forecasters to anticipate rather than react to the heavy rainfall.

The first flood episode of this season occurred on Election Day, 2 November 2004. In typical fashion the office had the appropriate watches out with plenty of lead time. Watches were upgraded to Warnings as the event evolved with five rivers eventually exceeding flood stage. Except for a few glitches with the new WHFS and RiverPro, the office performed well. Unfortunately, the part of the event that was not anticipated was the occurrence of 1 to 2 inches of rain in the matter of a few hours across the greater metropolitan area. The emphasis in the Seattle Times the following day was not the main-stem river flooding but rather the urban flooding. A large format photo of a car barely visible from spray rising up from a flooded intersection carried the caption: "Standing water at 3rd and Bell in downtown Seattle yesterday caught motorists by surprise as heavy rain inundated the city most of Election Day morning." More than 60 traffic accidents were reported the morning of the 2nd in King County and caused "by people either driving too fast or following too closely for the conditions."

Synoptic and Mesoscale Discussion

Figure 1 shows the synoptic evolution of this particular event. At 1200 UTC 1 November (panel a) a warm (and typically moist) flow from the sub-tropics can be seen surging northeast with and ahead of the approaching frontal system. This is rather typical of our flooding scenarios and is generically referred to by many as the "Pineapple Express" although no real rigorous definition of such a pattern exists. The most critical characteristics of such a setup are: very strong flow (to enhance orographic contributions) with 850-mb winds at around 50 kt, a pronounce tropical connection, and either slow progression or multiple waves to hold the heavy precipitation in place long enough to generate flood-producing amounts.

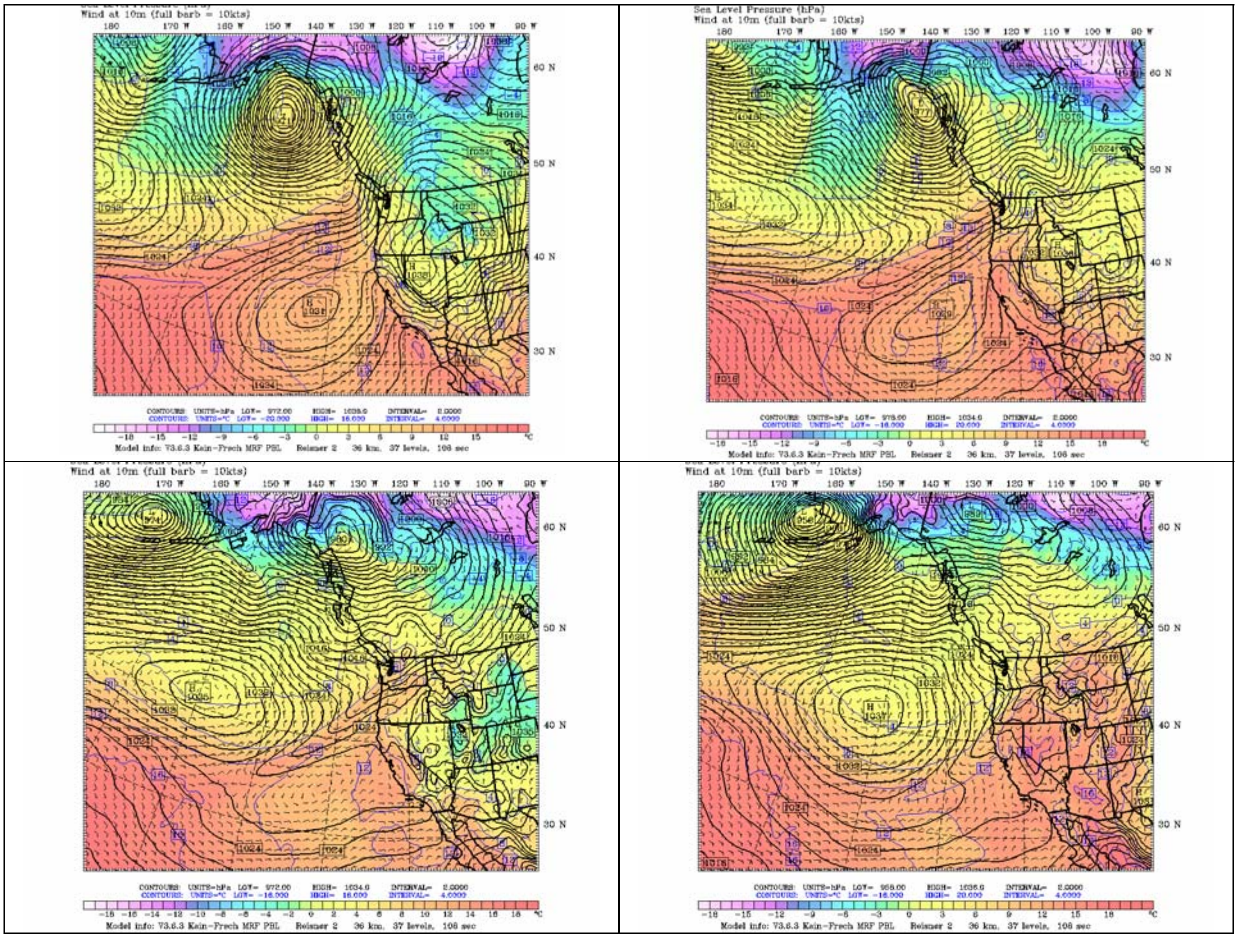

Figure 1: MM5-GFS analyses of 925-mb temperature (color fill), sea-level pressure (black contours – 2mb increments), and 10-m winds (barbs) for: (a) 1200 UTC 1 November 2004, (b) 0000 UTC 2 November 2004, (c) 1200 UTC 2 November 2004, and (d) 0000 UTC 3 November 2004.

The end of the event is typically marked by the warm, moist flow being displaced south by cooler mP air in post frontal flow. The large parent cyclone in the northeast Pacific often remains with continued west or southwest flow across the Pacific Northwest. In this particular case, an important evolution is very visible in Figure 1 as the intense cyclone (initially near 970 mb) is rapidly replaced by a building surface ridge. Locally, in the Pacific Northwest, the flow rapidly veers from southwest to northwest with the passage of the front. It is this evolution that is responsible for the urban flooding.

The rapid transition from moist southwesterly flow to cooler northwest flow is clear from the IR satellite imagery shown in Figure 2. At 1130 UTC 2 November heavy precipitation is already occurring on the Olympic Peninsula with 0.66 inches of rain in the past hour at HQM on the coast (not shown). By late that afternoon (2315 UTC) the front is displace south and cold cumulus are visible off the Washington coast.

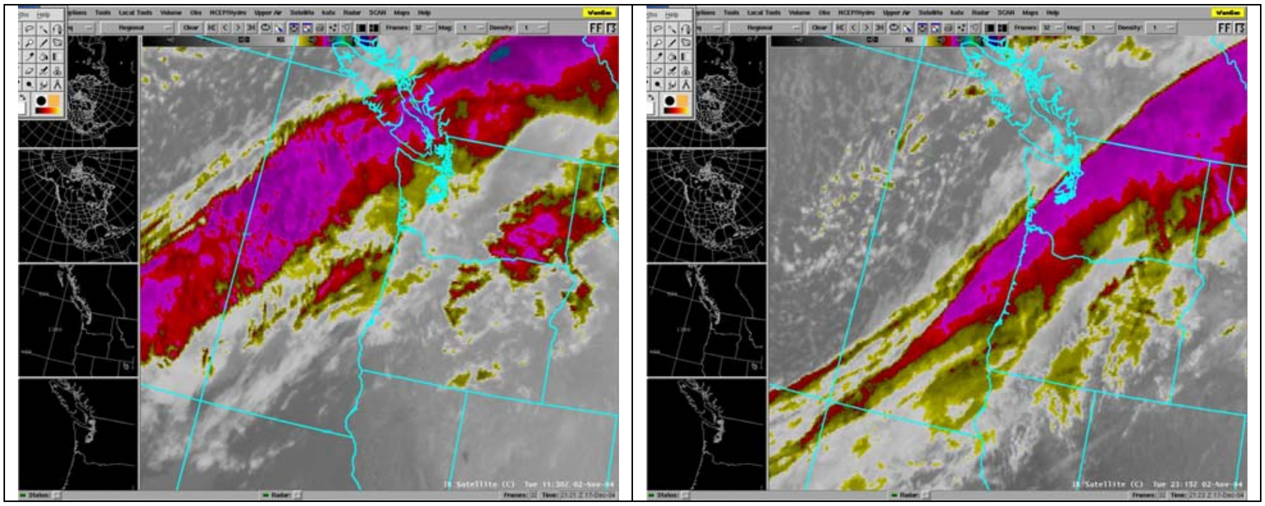

Figure 2: Regional IR satellite imagery (a) 1130 UTC 2 November 2004, and (b) 2315 UTC 2 November 2004.

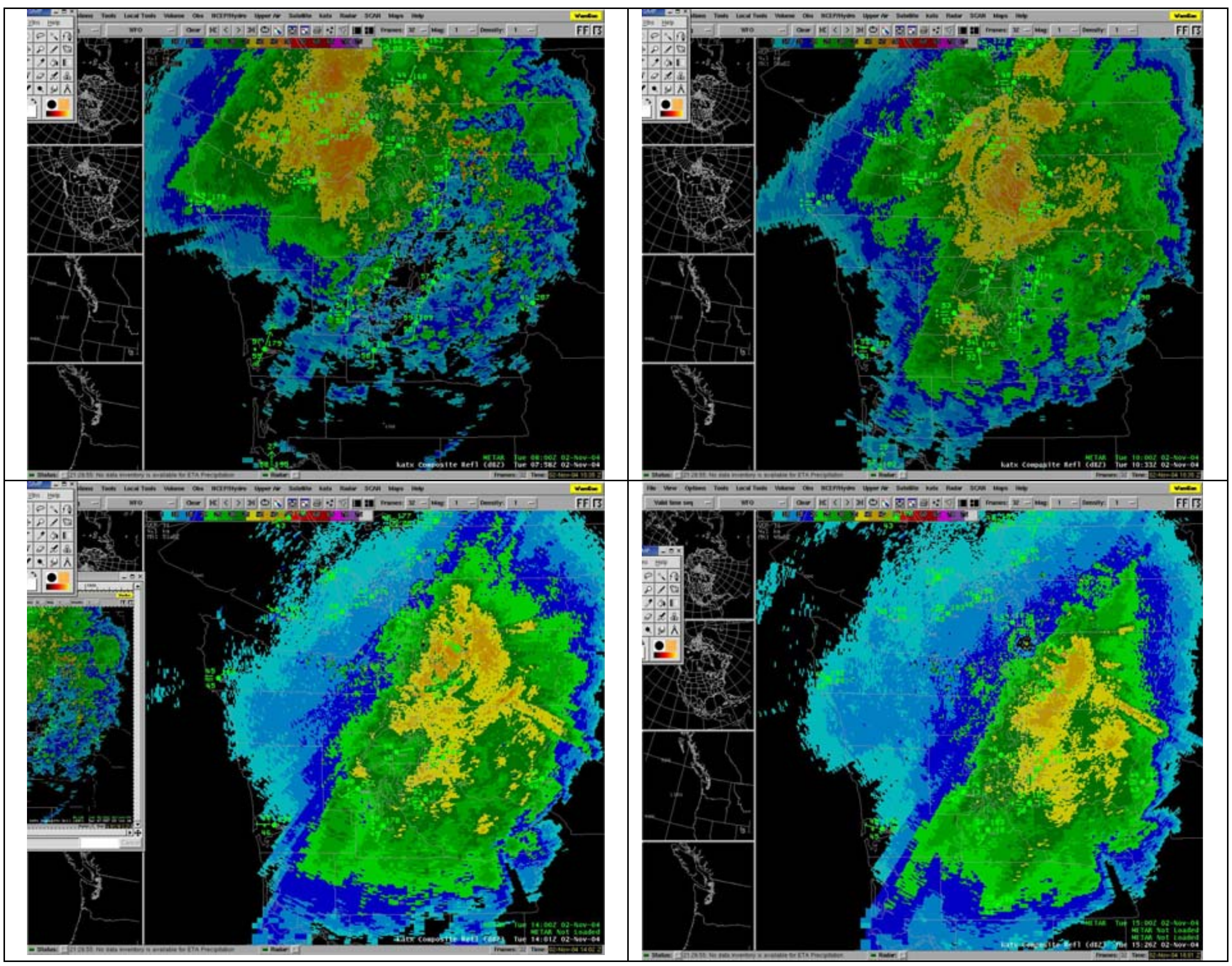

Figure 3: KATX radar reflectivity imagery from 2 November 2004, with synoptic stations over plotted. (a) 0800 UTC; (b) 1000 UTC; (c) 1400 UTC; and (d) 1500 UTC.

Radar data in Figure 3 display the evolution of the heavy precipitation from early in the event to late in the event. In panel (a) a more typical rainfall distribution is visible. Strong southwest flow is placing heavy rain along the south slopes of the Olympic Mountains (not visible due to beam blockage). Rainfall is also beginning to increase over the north and central Cascade Mountains. What is important to recognize in the first couple of panels is the near-absence of rainfall across the central Puget Sound lowlands. This is rather typical as there is often southeast flow in the lower levels that is somewhat drying for the central Puget Sound lowlands and with southwest flow at 850 mb there is some additional influence of downslope across the area. A typical flood event across western Washington is most notable for the very heavy amounts in the mountains and only modest precipitation in the lowlands.

Toward the later stages of this event heavy precipitation develops very rapidly across Puget Sound. This evolution can be seen in Figure 3 (panels c and d). The rapid onset and extent of rainfall in the Seattle metropolitan area can be seen in the time series plot of rainfall from the University of Washington station shown in Figure 4 (top panel). The surface wind direction is shown in the lower panel and shows that the heavy rainfall immediately follows a wind switch from south to north.

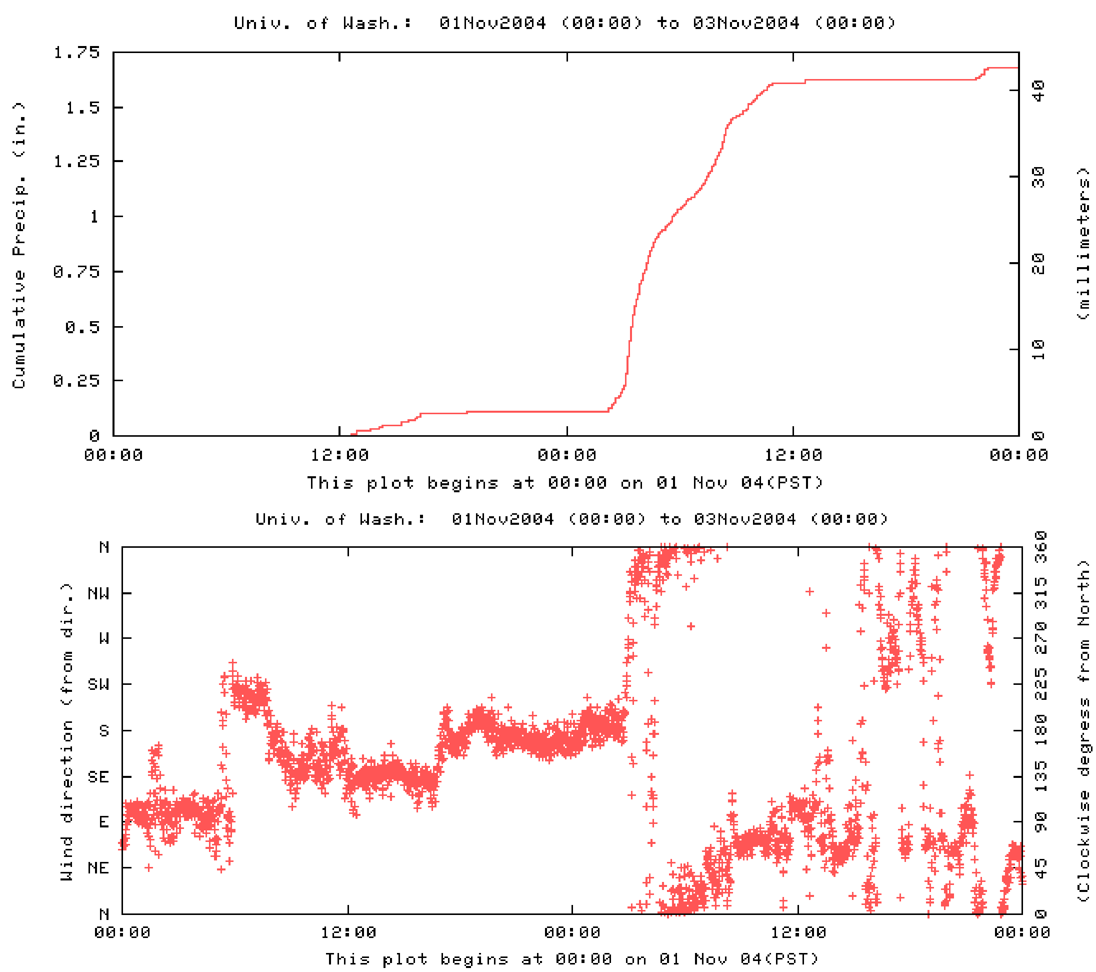

Figure 4: Time series of 1-minute data from the University of Washington (abscissa labeled in PST): (a) cumulative precipitation (inches) and (b) wind direction.

The wind switch reflects the rapid transition from southwest to northwest flow with the front that was discussed earlier. The frontal passage along the north coast and north interior was immediately followed by a surge of west and northwest flow down the Strait of Juan de Fuca. This flow entered the Puget Sound with the front and generated strong low-level convergence to enhance ascent across the Puget Sound basin while warm and moist air was still present. A more typical evolution separates these two features by several hours or even longer.

Figure 5 is the KATX velocity data from 0.5 degrees and shows very nicely the strongly convergent pattern in the central Puget Sound area. This late-storm shift to lowland rainfall generated between 1 and 2 inches of rain across the metropolitan area and created the urban and small stream flooding situation. In addition, fallen leaves and clogged drains aggravated the situation.

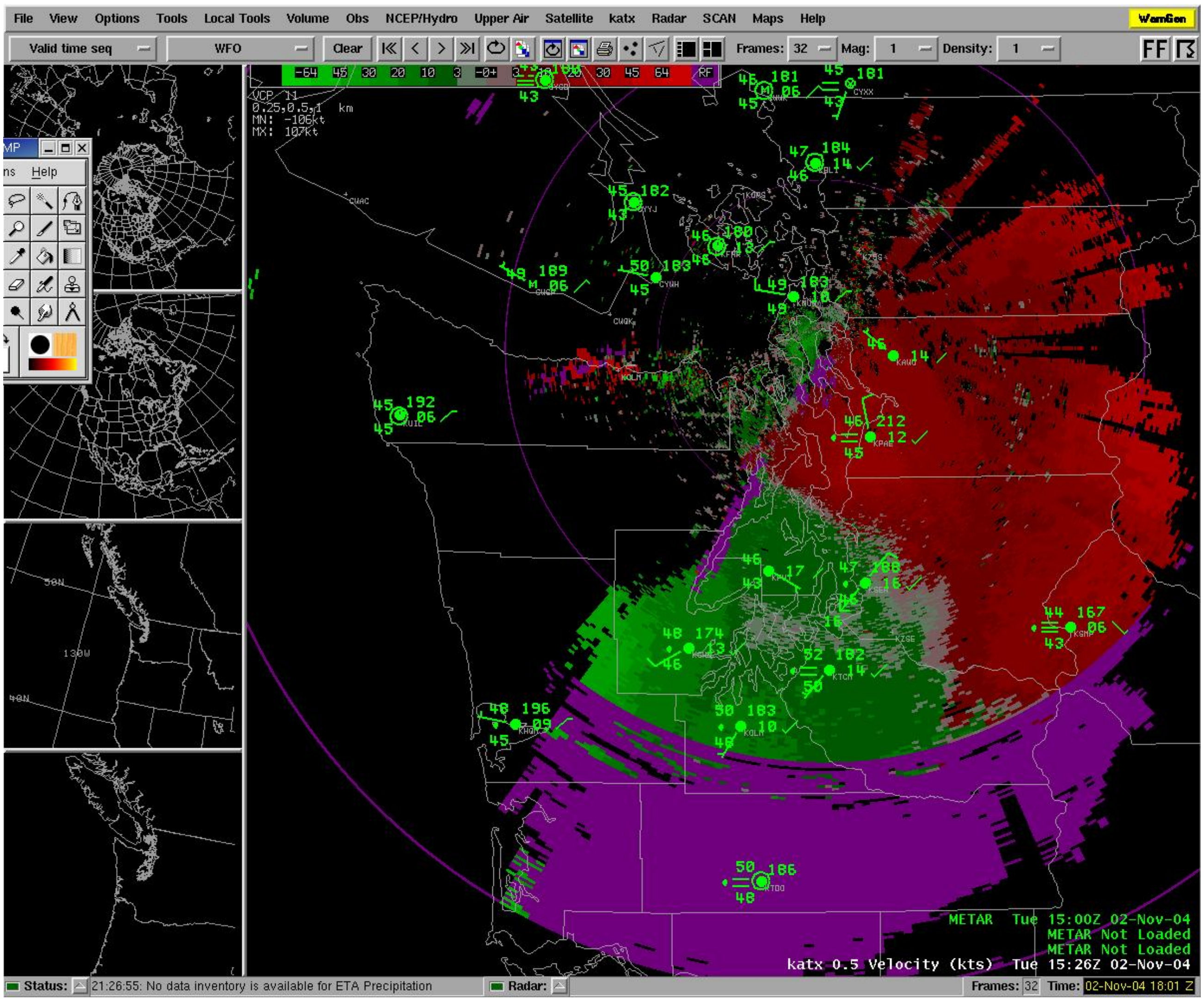

***Figure 5:** KATX radar velocity imagery from 2 November 2004, with synoptic stations over plotted, for 1500 UTC 2 November 2004.*

WES exercise overview

For this exercise we identified three objectives:

1. Identify and understand the processes that can result in heavy rainfall and urban flooding across the Seattle metropolitan area.
2. Successfully demonstrate the evolution of such an event using model and observed data from a recent event.
3. Get forecasters to explicitly consider the urban flood potential during future main-stem flooding events.

The case is conducted with two stopped-clock periods. The first is early in the event when the focus is on the impending flooding episode. This period is good review for experienced forecasters, and training for newer ones, of the typical flood-producing pattern. It also allows the trainer to ask questions about whether or not any other noteworthy event(s) should be expected. Self discovery of critical signatures in satellite imagery, models, and surface data is prompted through a series of questions. The second period is conducted as the heavy rainfall is occurring across the Seattle metropolitan area. For this part the forecaster is asked to critique their earlier analysis and forecast, and to issue any appropriate statements or advisories.