Correlating Upper Flow Patterns to Hydrologic Site QPF Using an Archived WES Case

Danny Mercer
Doug McDonnal
Weather Forecast Office, Seattle, WA

Introduction

River flooding is a frequent occurrence in Western Washington and is climatologically favored during the fall and winter months. Highly variable precipitation amounts are typical across the Seattle CWA due to the complex terrain interaction with the upper flow. It is well known that various flow regimes affect orographic rainfall to varying degrees, which has an enormous impact on precipitation distribution across the Seattle CWA.

Producing a high quality hydrologic site QPF product is integral to river forecasting operations. The Pacific Northwest River Forecast Center (NWRFC) relies heavily on the individual WFO produced QPF for input into the hydrology models. There are twelve forecast points in the Seattle CWA that are distributed across the coast, Puget Sound, foothills, and the Cascades. Because of the terrain complexity, it is important to understand the orographic contribution for each site.

An informal study previously conducted by WFO Seattle forecaster Doug McDonnal found significant correlations between specific flow regimes and precipitation amounts for the specific QPF sites. While these results are rather general in nature, they give forecasters another important tool in forecasting QPF for these remote hydrologic sites. To review these relationships, an archived WES flood event was used from November 1-2, 2004. This event was chosen since it was a widespread mountain and lowland flood event.

Background

In a previous local study, a simple quantitative precipitation climatology was developed for the 12 QPF sites in the WFO Seattle forecast area. This climatology was compiled from hourly precipitation data for a twenty year period (1978 to 1997), and also makes use of the 850 mb wind data from the Quillayute (UIL) WA upper air site. Only events that exceeded 25 kts in magnitude at 850 mb were used to help separate orographic contribution from other considerations. These rainfall amounts were then normalized to the Seattle (SEA) rainfall allowing ratios to be calculated for each wind direction on an 8-point compass. By doing this, a comparison of direction with wind speeds above 25 kts can be made between stations. The goal was to develop a QP climatology that would familiarize forecasters with the frequency and nature of 6-hour precipitation amounts; focusing, in particular, on flood-producing rain events.

The vast majority of flood-producing rain events in Western Washington occur in a similar synoptic pattern, where strong orographic forcing enhances heavy stratiform precipitation. Therefore, the climatological relationships between precipitation at QPF sites and the 850 mb UIL wind show up fairly well in individual synoptic events. This allows the climatology to serve as a forecast guide in preparation of the QPF.

Case Overview and Discussion

For the November 1-2, 2004 flood case, most of the 850 mb flow to QPF relationships held true. Data for the twelve hydro QPF sites were obtained and compared similarly to the UIL 850 mb wind and SEA rainfall totals. Ratios were then calculated for each QPF site allowing a comparison of both magnitude and direction for both pre-frontal and post-frontal flow. For simplicity reasons, two flow directions are assumed; pre-frontal as southwest flow and post-frontal as northwest flow. These were the average UIL 850 mb flows for the two distinct periods for this storm.

The first example used for comparison is Quillayute (UIL) to Seattle (SEA). For this site, a ratio of 7.8 was calculated for pre-frontal flow, while the ratio fell to .33 in post-frontal flow. In comparison, the climatology ratios are 2.9, and .7, respectively. While the ratio was considerably higher than climatology at UIL in pre-frontal flow, the directional contribution is clearly evident. Both the climatology and event ratios were much lower in northwest flow than in southwest flow. Interestingly, this indicates that northwest flow, on average, is not a heavy QP producer for UIL compared to SEA. This runs counter intuitive to thinking as a coastal site not shadowed by terrain might be expected to have a higher ratio. After further analysis it is theorized that this is attributed to large scale drying in northwest flow along the coast while convergence zone precipitation often boosts rainfall in the Puget Sound area. In addition, rain shadow effects are less evident in northwest flow than in southwesterly flow.

Another site that compared similarly with UIL was Wishkah (ABEW1). Wishkah is 20 miles NNE of Aberdeen WA on the south southwest facing slope of the Olympic Mountains at 900 feet msl. Again, the heaviest rainfall rates occurred in the stronger pre-frontal flow, rather than in weaker post-frontal flow. The ABEW1 to SEA ratios calculated for this event are 8.87, and 1, respectively. Climatology ratios are 4.0, and 1. For pre-frontal flow, the rainfall ratio was about double that of SEA implying that, again, flow strength dominated rainfall rates for this site. In addition, disparity in the pre-frontal flow can easily be attributed to the strength of the 850 mb wind, in this case 50 kts at the peak. Because the study encompasses magnitudes of 25 kts or higher, this event was likely at the higher end of events used in the study.

In contrast, Verlot (VERW1), 22 miles NE of Everett WA on the western slopes of the Cascades and susceptible to southerly upslope flow, received considerably more rainfall than SEA in the weaker post-frontal flow than in the much stronger flow that preceded the front. This suggests the 850 mb wind direction is a much stronger determinant on rainfall rates than the magnitude. The climate QP study clearly shows this relationship, in which Verlot on average receives nearly two times the rainfall in southwesterly flow when compared to SEA rainfall. Ratios for VERW1 to SEA for this event are 2.92, and 4.25, respectively. In comparison, climatology ratios are 3.1, and 3.6. Both the event ratios and climatology ratios suggest higher rainfall amounts at VERW1 compared to SEA in post-frontal flow than pre-frontal flow.

Not all sites compared as well for this event. It is understood that temporal and spatial variations play a large role in QP distribution in addition to orographics. This likely accounts for some of the discrepancies found in the site comparisons for this event. For example, ratios for Stampede Pass (SMP) were much higher than expected in the pre-frontal flow than the climatology ratios would indicate. The SMP to SEA ratios are 3.96, and 2.7, respectively, while the climatology ratios are 1.8, and 4.8. The climatology ratios indicate post-frontal northwest flow to be on average much more favorable than pre-frontal flow. A post mortem analysis did not clearly identify why the pre-frontal rainfall ratio at SMP was exceedingly high in this case. Given the strong vertical motion and moisture content associated with this system, it is possible these factors were the overcoming determinate. In addition, the westerly component of the pre-frontal wind may have aided in rainfall compared to a more common southerly pre-frontal wind direction. In any case, this example highlights the importance of understanding the limitations of the climatology QP as guidance. Forecasters must always take all considerations into account and adjust site QPF, accordingly.