Heavy Precipitation in the Oregon Coast Range: A Numerical Modeling Sensitivity Study

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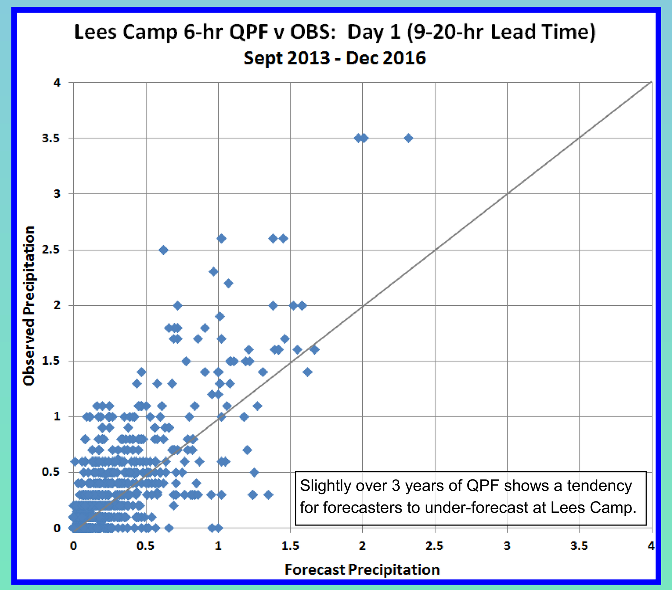
Introduction

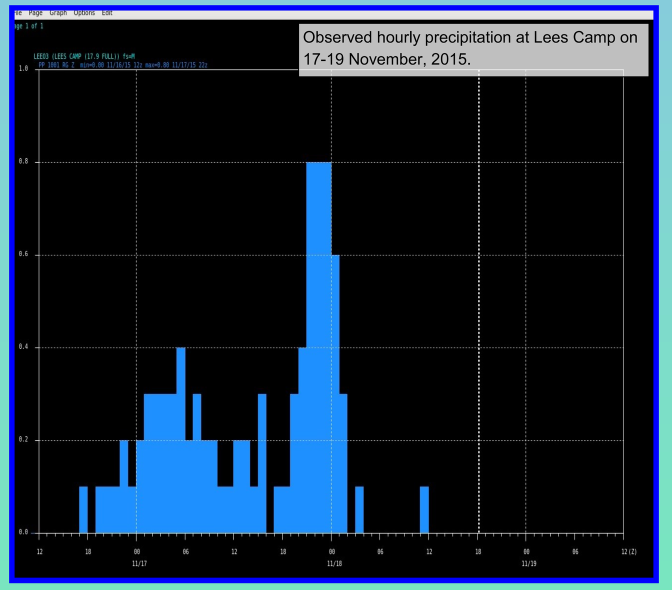
An atmospheric river event aided by the complex orography of the Coast Range of northwest Oregon produced particularly heavy rainfall over the Wilson River Basin on 17 November 2015. The Wilson River Basin is a relatively small basin covering an area slightly over 500 km^2. Topography of the basin ranges from peaks around 850 meters (2,800 ft) MSL to sea level at the river's mouth near Tillamook, Oregon. While operational models predicted moderate-to-heavy rainfall associated with the atmospheric river, QPFs at Lees Camp (located around 450 meters (1,500 ft) MSL in the northern Oregon Coast Range) were well below the observed 00Z 18 November accumulated 6-hour and 24-hour totals of 81 mm (3.19 in) and 180 mm (7.09 in), respectively. The official Wilson River forecasts produced by the National Weather Service and issued at 12 UTC 17 November predicted steady volumes over the next 24 hours. In reality though, a major flood occurred at 05 UTC 18 November, undoubtedly aided by the excessive rainfall during the 20-02 UTC period (102 mm (4.02 in) at Lees Camp) preceding the 05 UTC peak flow.

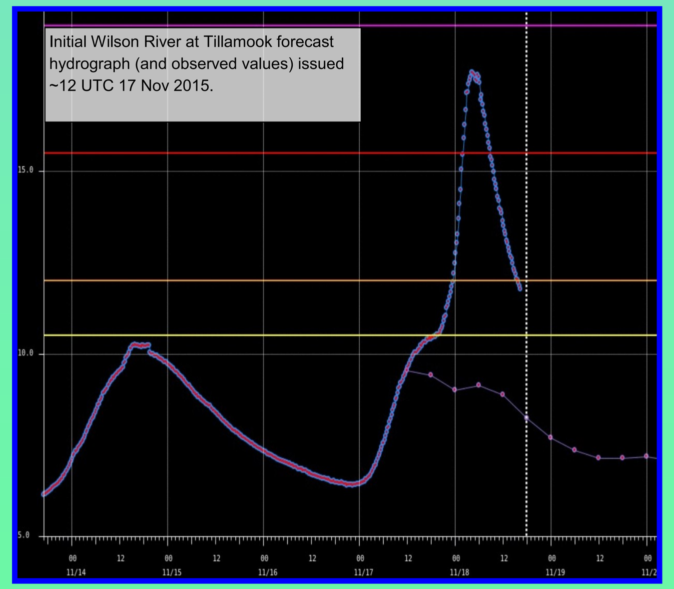
Google image showing approximate area of Wilson River Basin and location of Lees Camp.

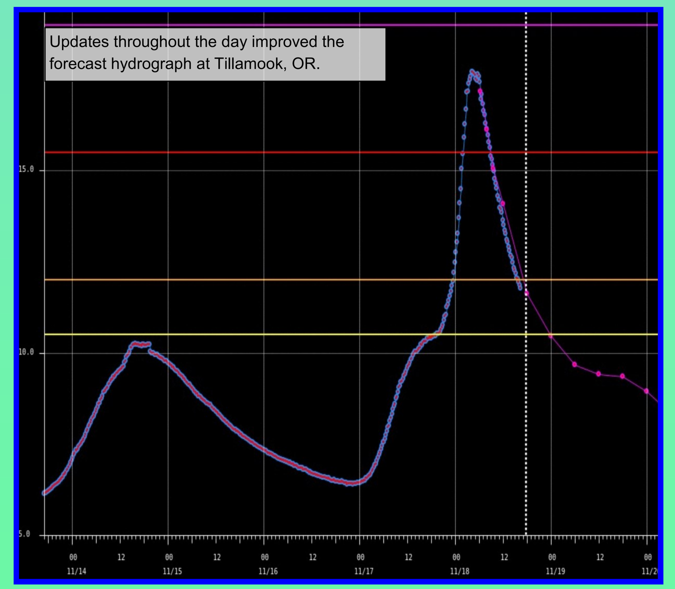

Donaldson Bar on Wilson River west of Tillamook, Oregon. Photo by Krista Jones of USGS.



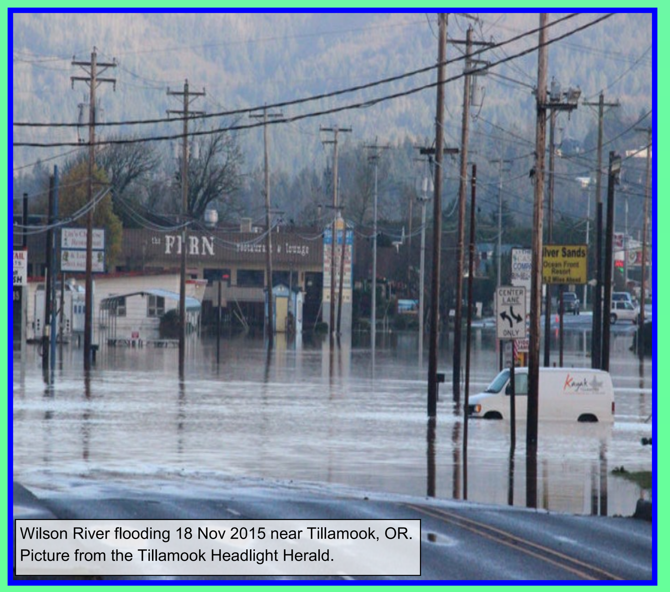
Slightly over 3 years of QPF shows a tendency for forecasters to under-forecast at Lees Camp.


Observed hourly precipitation at Lees Camp on 17-19 November, 2015.


Initial Wilson River at Tillamook forecast hydrograph (and observed values) issued ~12 UTC 17 Nov 2015.

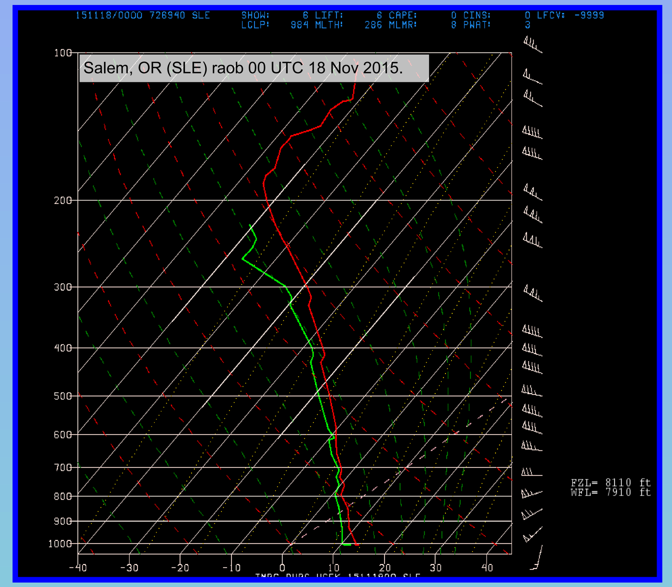

Updates throughout the day improved the forecast hydrograph at Tillamook, OR.

Wilson River flooding 18 Nov 2015 near Tillamook, OR. Picture from the Tillamook Headlight Herald.

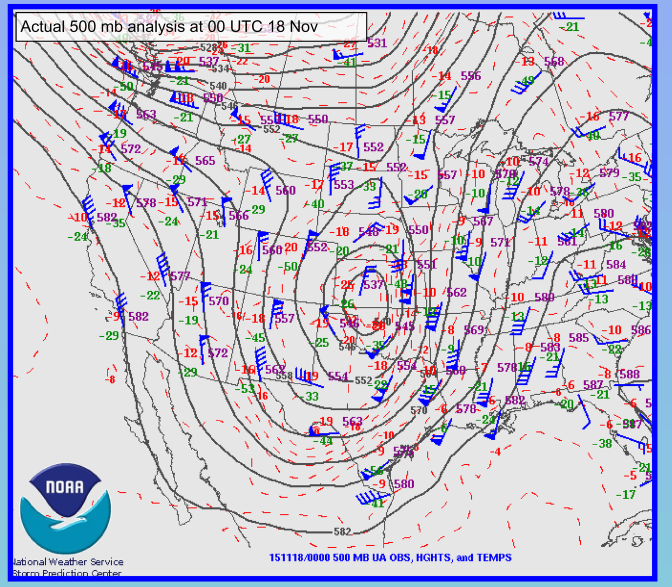

Wilson River flooding 18 Nov 2015 near Tillamook, OR. Picture from the Tillamook Headlight Herald.

Experiment

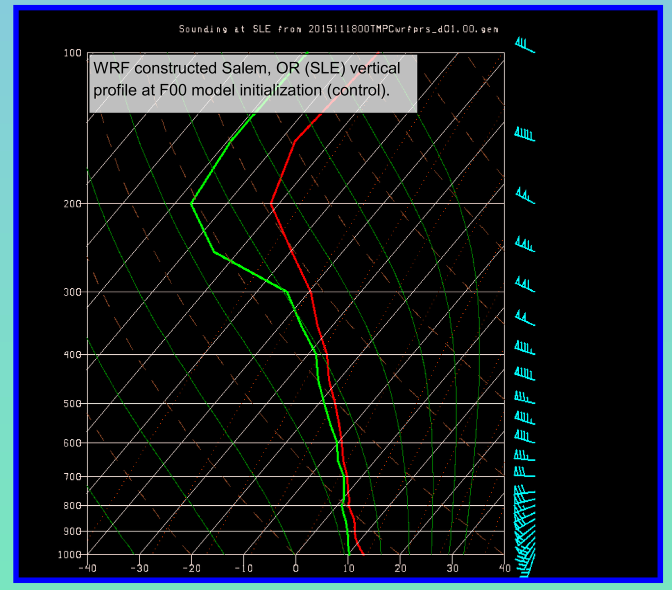
The experiment attempts to isolate the orographic enhancement of precipitation contributing to heavy precipitation in the Wilson River Basin. This study used the Weather Research and Forecasting (WRF) Model at 2 km grid spacing. The experiment consisted of very short-term (~ 3 hours) WRF sensitivity runs, initialized using only the observed 00 UTC 18 November 2015 raob from Salem, OR (SLE), and perturbations thereof. These perturbations were designed to assess the sensitivity of basin rainfall to the prevailing wind direction and speed. SLE raob data were extrapolated across the entire WRF domain at 25 hPA layers between 1000 and 100 hPA assuming constant velocity and relative humidity at each level. Geopotential height was derived assuming a geostrophic wind balance above 1 km AGL and a modified Ekman layer below 1 km, and the thermal wind relationship centered over 250 to 500 hPA layers provided horizontal temperature gradients. The model was run just long enough to spin-up up precipitation (determined to be 3-hrs) using constant lateral boundary conditions. The WRF configuration consisted of the Eulerian mass core with the following key physics: Ferrier microphysics, YSU PBL scheme, RRTM longwave and Dudhai shortwave radiation, respectively, and no parameterized convection.



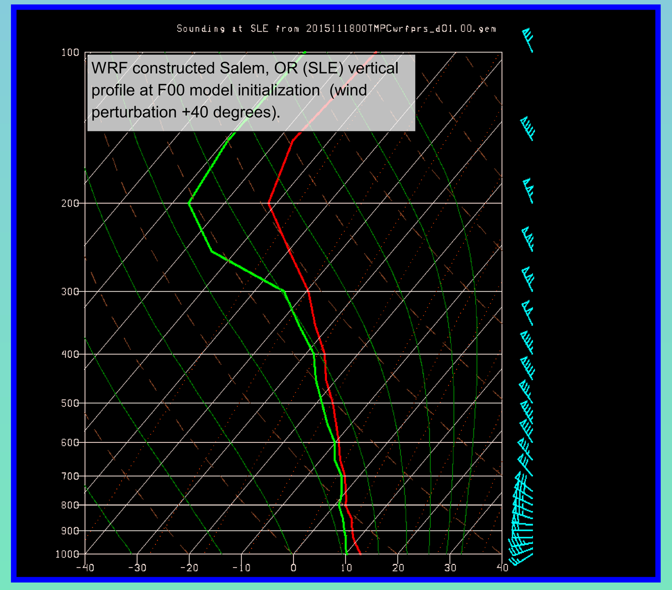
Salem, OR (SLE) raob 00 UTC 18 Nov 2015.



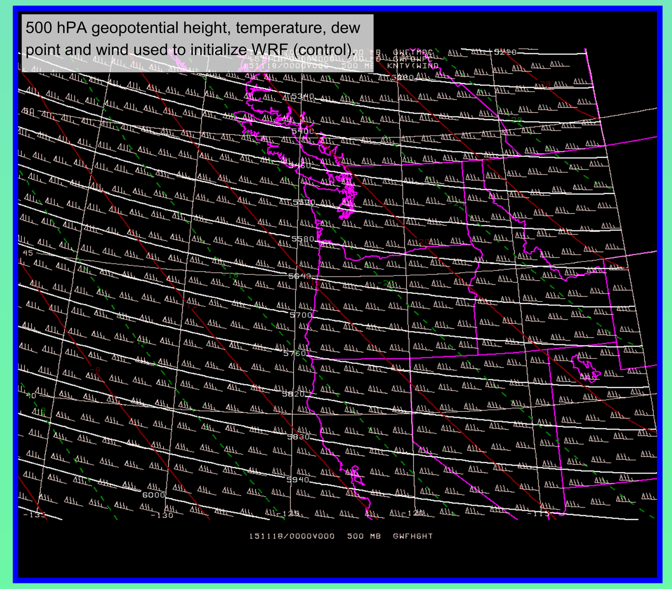
Actual 500 mb analysis at 00 UTC 18 Nov

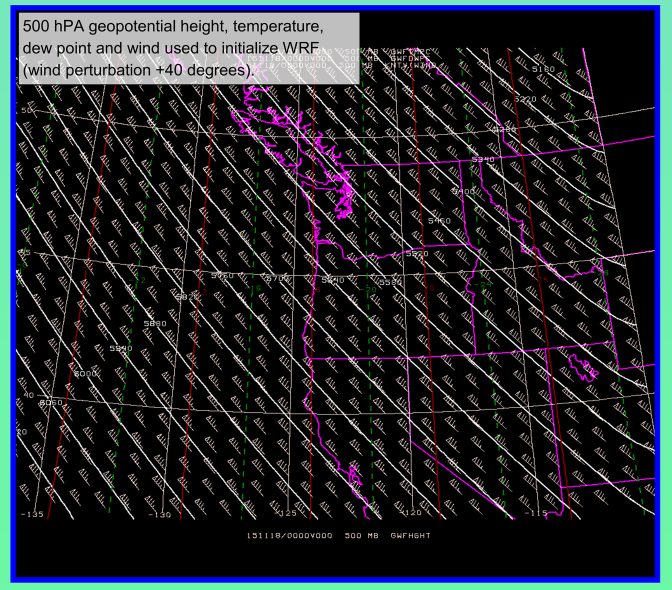


WRF constructed Salem, OR (SLE) vertical profile at F00 model initialization (control).



WRF constructed Salem, OR (SLE) vertical profile at F00 model initialization (wind perturbation +40 degrees).


500 hPA geopotential height, temperature, dew point and wind used to initialize WRF (control).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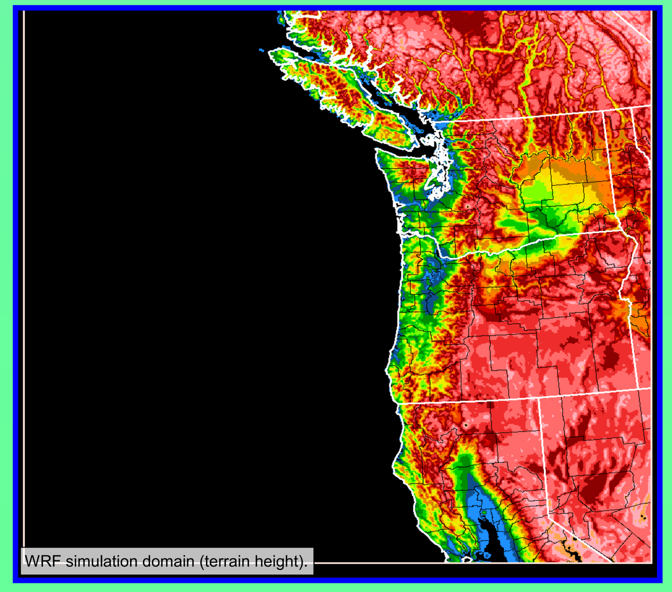
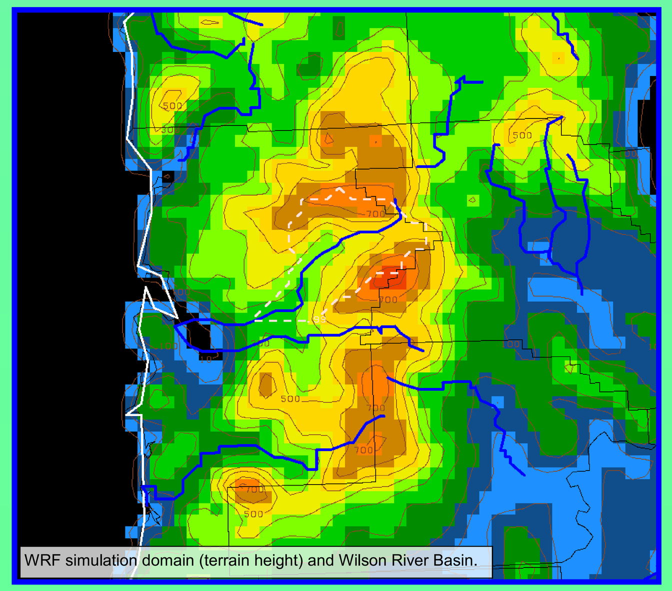
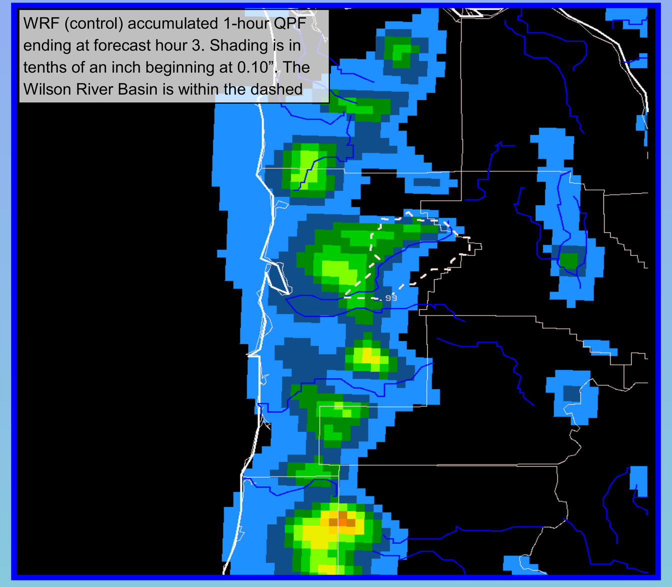
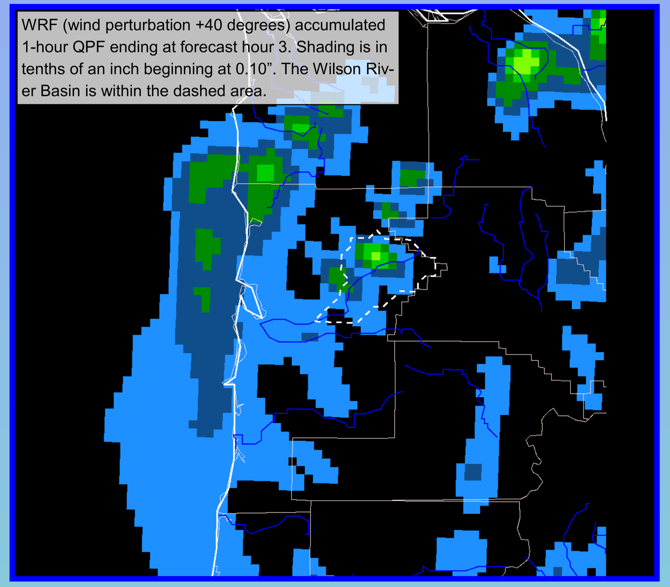

WRF simulation domain (terrain height).

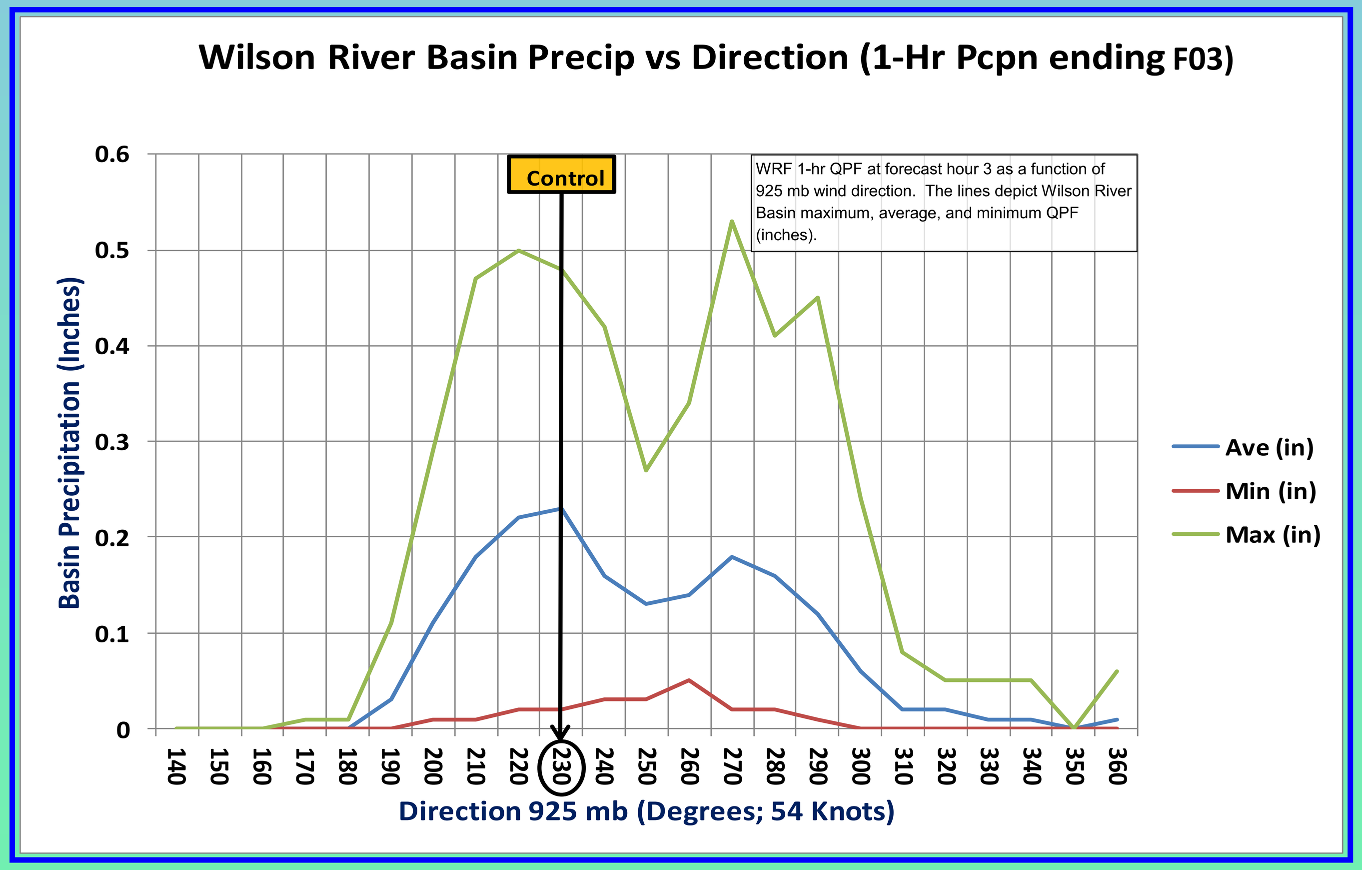

WRF simulation domain (terrain height) and Wilson River Basin.

Results

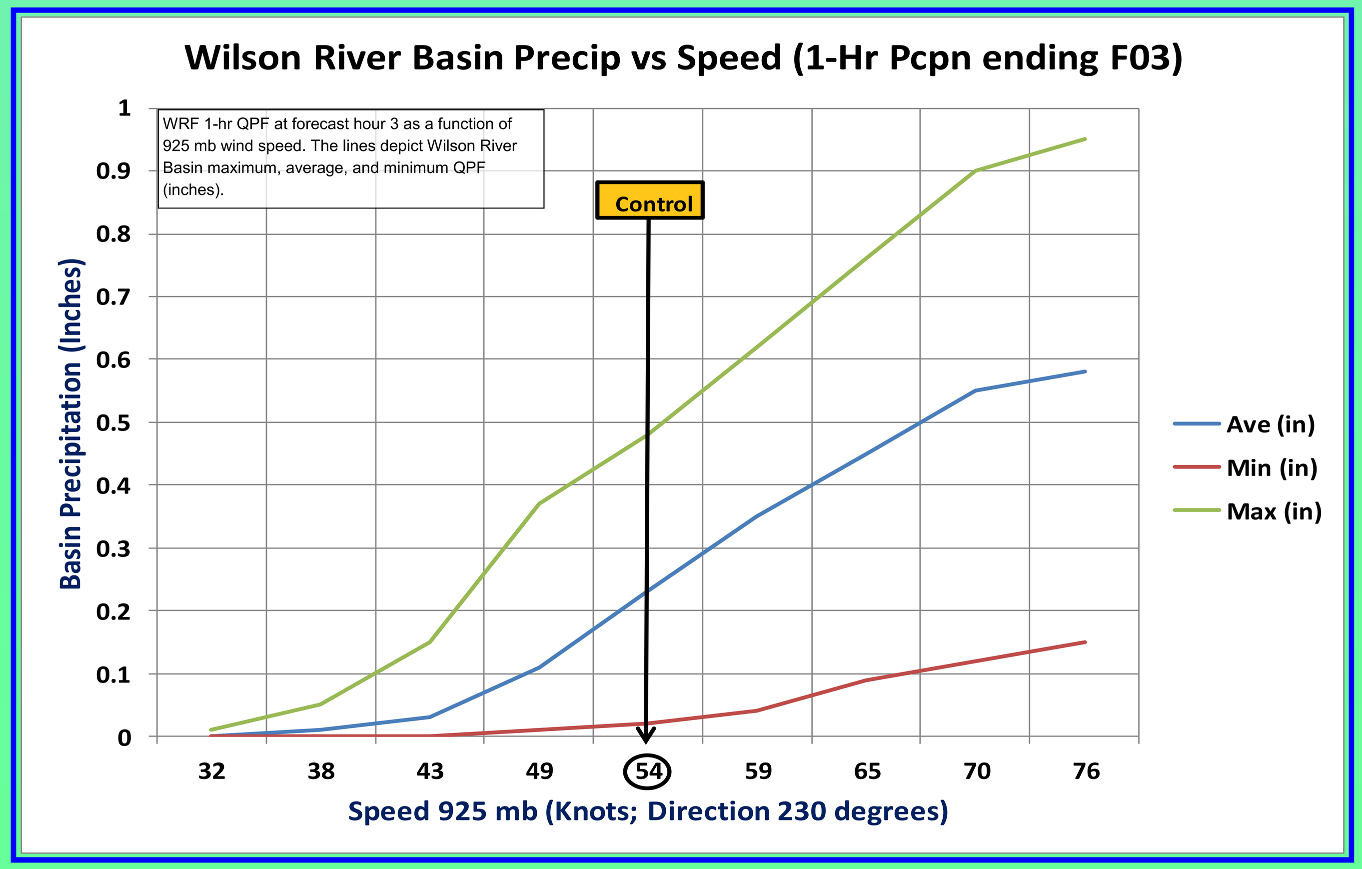
The WRF was run for 3-hours using the "control" 00 UTC 18 November 2015 raob from SLE. The raob was extrapolated to the 3-D grid as described in the previous section. By 3-hours into the simulation, it appears the model reached a steady state with regard to precipitation over the Coast Range. The accumulated 1-hour precipitation ending at forecast hour 3 is presented below. Wind direction was altered +/- 90 degrees off the control direction at 10 degree increments through the entire sounding. Similarly, speed was varied at +/-40% of control at 10% increments. The 925 hPA level is roughly the midpoint of the Wilson River Basin (~300 m), and is therefore the level plotted as the independent variable below. The results show that altering the wind direction produced a bimodal "sweet spot" for maximizing basin precipitation, at approximately 220 degrees (southwest) and at about 270 degrees (west). Using the control direction (230 degrees at 925 mb) and altering the speed found precipitation increases most favorably when 925 mb speeds exceed 40 to 45 kts. It appears the WRF model can be used to determine the most favorable environments for heavy precipitation in basins of complex orography. Future work includes co-varying the speed and direction simultaneously, and increasing basin resolution using WRF grid spacing of ~1 km.


WRF (control) accumulated 1-hour QPF ending at forecast hour 3. Shading is in tenths of an inch beginning at 0.10". The Wilson River Basin is within the dashed


WRF (wind perturbation +40 degrees) accumulated 1-hour QPF ending at forecast hour 3. Shading is in tenths of an inch beginning at 0.10". The Wilson River Basin is within the dashed area.



WRF 1-hr QPF at forecast hour 3 as a function of 925 mb wind direction. The lines depict Wilson River Basin maximum, average, and minimum QPF (inches).



WRF 1-hr QPF at forecast hour 3 as a function of 925 mb wind speed. The lines depict Wilson River Basin maximum, average, and minimum QPF (inches).