# Pacific Northwest Severe Weather: Where Theory Meets Reality

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## 1. Abstract

Severe thunderstorms characterized by their ability to produce hail diameters greater than 0.75” are a rarity in the Pacific Northwest. From 1950 to 2000, only 20 severe hail reports were received from storms in the Portland, Oregon County Warning Area, which encompasses Northwest Oregon and Southwest Washington. This work analyzes a severe hail event that occurred on 24 May 2008, and focuses on how two independent convective modes could occur simultaneously in close proximity to one another and still be resolved using the local Weather Research and Forecasting Model in concert with the Convective Storm Matrix.

## 2. Introduction

It is difficult to find a good example of severe weather behaving according to theory in the Pacific Northwest. Severe weather training for west coast National Weather Service Forecast Offices is often taken from severe events that occur east of the Rocky Mountains (Peterson et al. 1999; Hane et al., 1997; Koch and Ray, 1997). Very little information exists in the literature on hail in the Pacific Northwest (Tolleson, 1996; Changnon, 1972) and even less exists on severe hail storms west of the Cascades, perhaps none. The evening of 24 May 2008 provided a textbook example of two independent events occurring in the Portland, Oregon National Weather Service, County Warning Area (CWA): splitting storms and the formation of a north-south oriented Mesoscale Convective System (MCS). Both were accurately depicted using the Convective Storm Matrix packaged in the BUFKIT software (Niziol and Mahoney, 1997). This paper documents this severe hail event and demonstrates the usefulness of BUFKIT when united with the Weather and Research Forecast (WRF) model in predicting the convective mode.

## 3. Synoptic/Mesoscale Overview

During the evening of 24 May 2008, a broad upper level low was located over Northern California with a 850 mb theta-e ridge extending from Wyoming to Southwest Washington. Evening surface temperatures in the Willamette Valley were around 24 °C (75 °F) with surface dew points around 13 °C (55 °F). These temperatures translated to Convective Available Potential Energy (CAPE) values of 1500-2000 J/kg and Lifted Indexes (LI's) of -4 to -6 °C based on WRF model output. Boundary layer winds were onshore, with a marine push generating 10-15 kt west winds at Corvallis (KCVO) and Eugene (KEUG), Oregon at 01 UTC 25 May 2008. Figure 1a presents a BUFKIT BUFR sounding and hodograph from the 18 UTC run of the local 4 km WRF model valid at 02 UTC for a point in Clackamas County, Oregon. Figure 1b is similar but for Hillsboro, Oregon (KHIO) valid at 01 UTC. The layer from 3 to 8 km (9 to 35 kft) AGL contained weak southeast winds while surface winds were from the northwest.

## 4. Event Recap

*Feature I: The MCS*

Pulse convection was the dominant feature west of the Cascades until 0145 UTC when a cell developed in eastern Clackamas County, Oregon. Figure 2 displays the 0258 UTC 0.5° reflectivity from the northwest Oregon Weather Surveillance Radar (KRTX). The Clackamas County cell is labeled as "A"; the remaining cells will be discussed later. Cell A quickly attained a 65 dBZ reflectivity core for which a severe thunderstorm warning was issued, for large hail. Nearly simultaneously cell B in Multnomah County, Oregon developed 10 mi. to the north of Cell A and eclipsed its southern neighbor by nearly 10 dBZ prompting a second severe thunderstorm warning. Cell B moved west with a brief deviation to the east as it crossed the Columbia River into Skamania County, Washington. During this time, multiple spotter reports near Cell B indicated hail diameters ranging from 0.75" to 1.5". Cell B continued to slowly move west with VIL's in excess of 50 kg/m$^2$ and 1-hour radar-derived precipitation amounts of 2 to 4 inches, though these amounts were likely hail contaminated. Cell A continued to the west eventually merging with Cell B around KPDX forming a MCS that stretched from Vancouver, Washington (KVUO) to KCVO. Figure 3 shows a 0.5° reflectivity image at 0358 UTC near the time of the cell merger.

In addition to severe hail reports, rainfall amounts from the storm were impressive. Figure 4 presents a map of the Oregon Community Collaborative Rain, Hail and Snow (CoCoRaHS) network 24 hour precipitation reports from Oregon. Unfortunately Washington did not have a CoCoRaHS program at this time, as much of the precipitation from Cell B fell in Washington. However, an NWS employee in Vancouver, WA did report 1.40 inches of rain in 40 min. KPDX also reported a record 1-hour precipitation accumulation of 0.93 inches.

*Feature II: The Lone Split*

At 0150 UTC, while Cells A and B were materializing, a storm that would eventually become Cells C and D (Figure 2) developed 3 miles to the southwest of the Hillsboro, Oregon airport (KHIO). The storm remained nearly stationary for 60 minutes, containing a 65 dBZ reflectivity core. A severe thunderstorm warning was issued for this storm with the possibility of penny size hail (0.75"). Around an hour after developing, the storm slowly began to move west and quickly split into a south moving storm (D) and a west moving storm (C). Cell D appeared to be dominant while Cell C dissipated not too long after 0300 UTC. There were no reports of severe hail from either Cell C or D, both traveled over rural farmland.

## 5. Modeling the Convection

Forecast models performed well, accurately depicting the storm environment at least 24 hours before the event. The local WRF model forecast was exceptional. It consistently forecasted the development of convective rain along the central Oregon Cascades and moved the convection northwest across the Central Willamette Valley for at least three consecutive runs (06, 12, and 18 UTC). The Global Forecasting System (GFS) broad brushed the convection across the Cascades while the North American Model (NAM) placed the convection just south of Seattle, Washington (KSEA).

The cool, stable marine push at the surface in conjunction with weak but progressively stronger east winds aloft (see hodograph in Figure 1a and 1b) supported a storm profile that tilted towards the west with storm motion expected to be south-southeast to west-northwest. This indicated that the convective environment should stray from the usual pulse convection to that more conducive of supporting a long-lived updraft, thereby increasing the threat for hail growth. The CAPE profile was thin and narrow and could be classified as weak CAPE with equilibrium levels around 9 km (30 kft).

Forecasting the convective mode was aided by a very handy training module developed by COMET: The Convective Storm Matrix (Weisman, 2003). The Convective Storm Matrix succinctly summarizes the output from a cloud model initialized with common buoyancy and shear profiles and provides three-dimensional animations of rain water mixing ratio (analogous to reflectivity) and cold pool generation in addition to a brief summary of the expected convective development. The BUFKIT software includes this matrix in its analysis of model soundings, creating a valuable convective forecasting resource.

The 18 UTC run of the WRF model sounding for 01 UTC for Clackamas County on 24 May 2008 showed a linear hodograph with low CAPE values (Figure 1). This classification did not have a corresponding entry in the matrix. However, if you increase CAPE from low to moderate, the profile fits the D2 classification (moderate CAPE with a 30 m/s linear shear profile). The following is an excerpt from the Convective Storm Matrix on the D2 classification:

> The initial cell splits and produces mirror-image cyclonic and anticyclonic supercells in response to the moderately strong unidirectional shear. After 2 hours, the system evolves into a long-lived, north-south oriented squall line, as the balance between the low-level vertical wind shear and the cold pool circulation promotes sufficient lifting for cell regeneration along the downshear portion of the surface outflow. The original split supercells remain located on the northern and southern ends of this line. (Weisman, 2003)

The D2 evolution in the Convective Storm Matrix was nearly replicated by the evolution of Cells A and B. An exception to this match was that Cells A and B were in close proximity to one another as opposed to the singular splitting cell pattern depicted by the D2 classification. Increasing the CAPE from low to moderate, was quite reasonable for this event. The 00 UTC KSLE (Salem, Oregon) sounding showed weak CAPE and would have been influenced by the marine push which likely underestimated the amount of buoyancy present. Further, at this time of year solar insolation provided additional heating through 04 UTC enhancing the already rich theta-e environment and likely increased the CAPE enough to classify the atmospheric profile of Cells A and B as a D2 classification by the time convection initiated. Figure 5 shows the 02 UTC WRF output of 2 m surface temperatures; a local maximum is shown in the Portland metro lending more support for a mesoscale CAPE maximum.

Figure 5 also shows cooler air filtering through the Coast Range gaps of northwest Oregon signifying the marine intrusion. The marine boundary acted to decrease the CAPE and increase the low level shear. This can be seen on the WRF model hodograph at KHIO at 01 UTC (Figure 1b) which shows a shear/buoyancy profile similar to that of G1 in the Convective Storm Matrix. In the G1 profile, there is more directional shear and less CAPE in the lowest 2.5 km of the atmosphere resulting in a convective mode more conducive to splitting storms without the development of a MCS. Again, this feature revealed itself near KHIO around 02 UTC. Thus, the WRF model suggested that both the G1 and D2 modes were possible on 24 May 2008, and in reality both were present.

**6. Conclusions**

By using the Convective Storm Matrix packaged in BUFKIT concurrent with the local WRF model, a conceptual model of the storm types expected aided in predicting the convective modes for the 24 May 2008 storms. Convection in the Pacific Northwest is similar to that of the Midwest and Eastern regions; however, slight modifications to CAPE profiles may be necessary to identify the convective mode, in particular, when there are mesoscale interactions with features such as the marine layer.

## 7. Acknowledgements

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## 8. References

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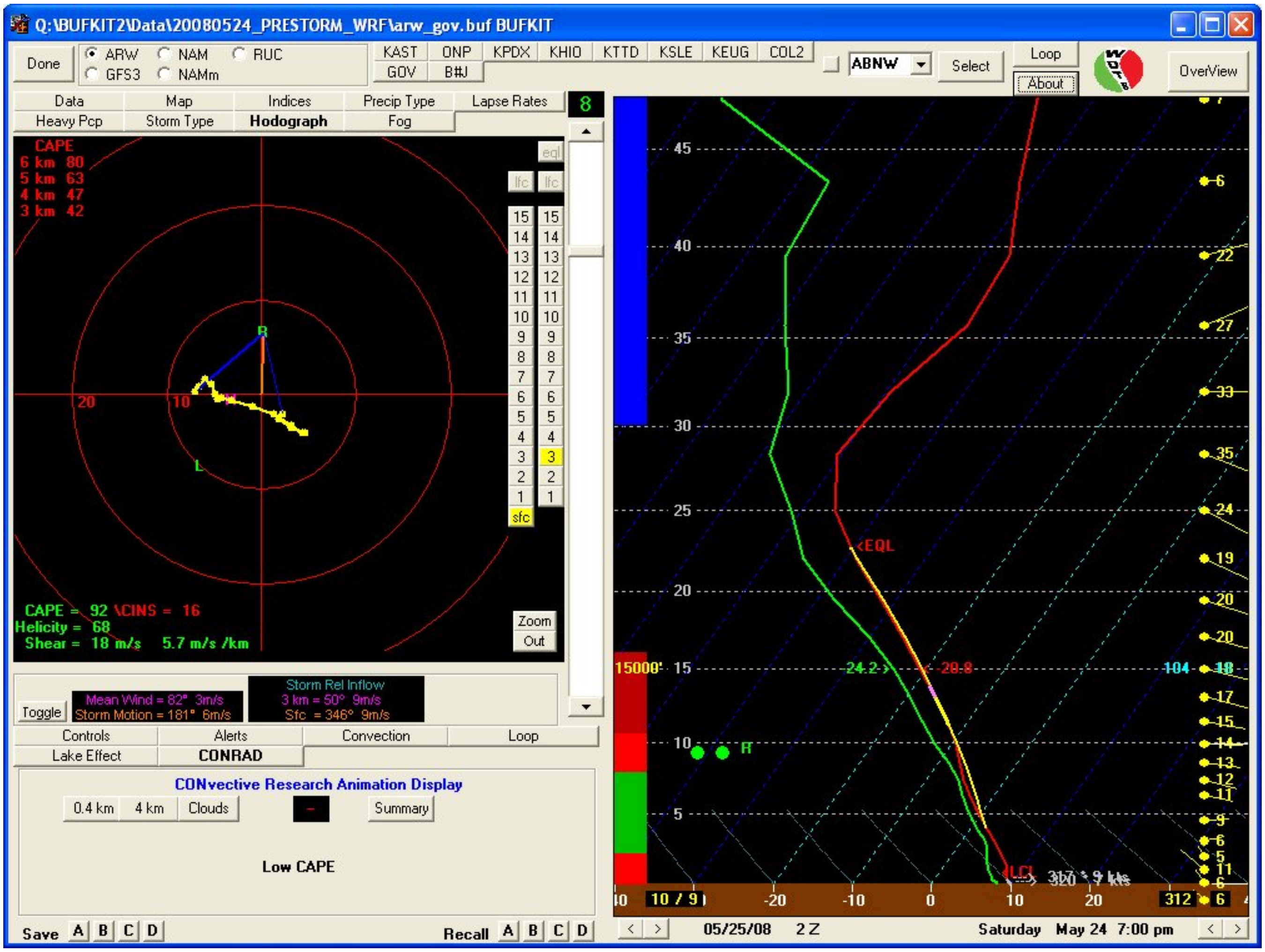

Figure 1a -  Model sounding and hodograph from the 18 UTC 24 March 2008 run of the WRF model shown in BUFKIT valid at 0200 UTC 25 May 2008 for Clackamas County.

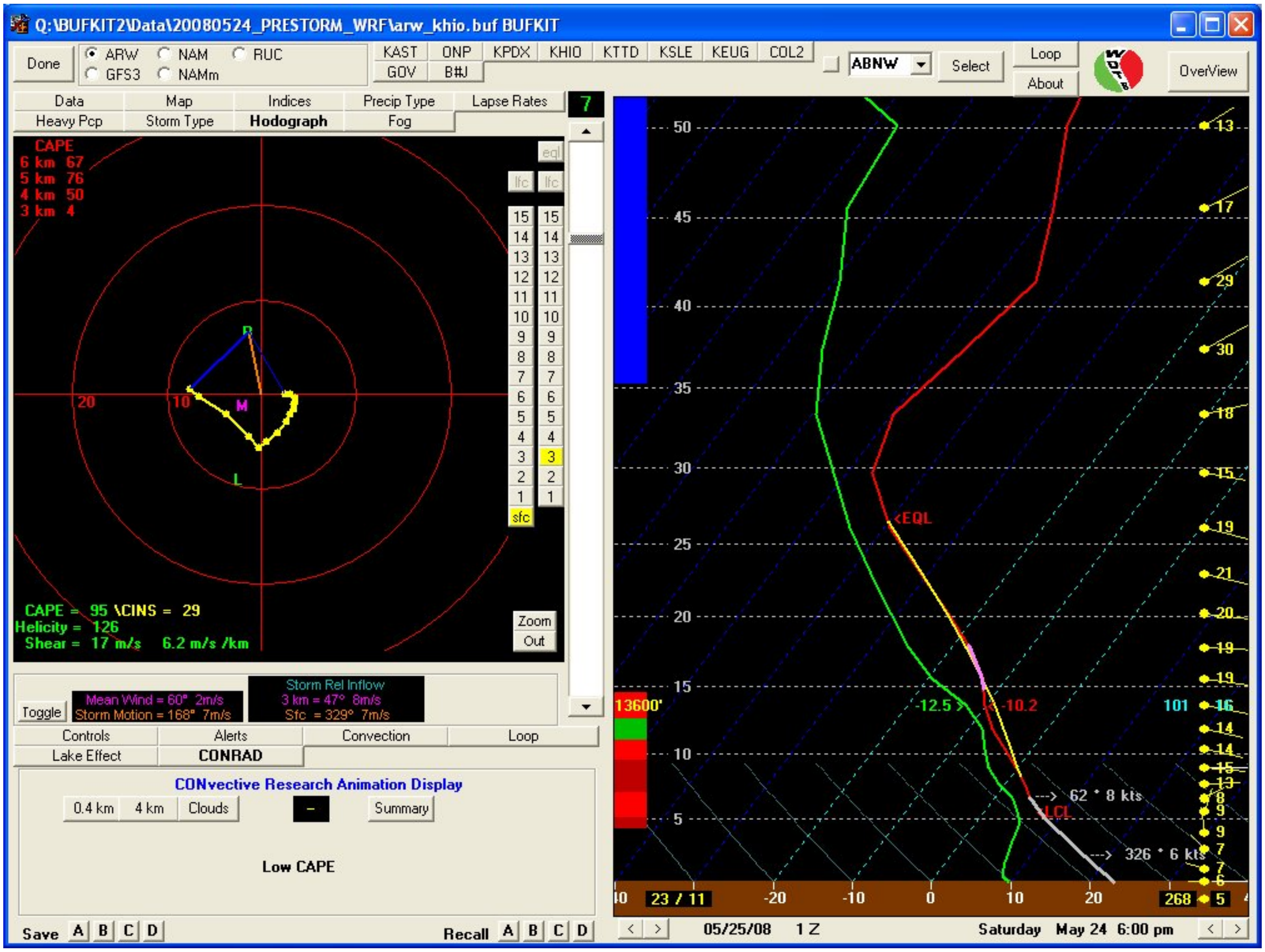

Figure 1b - Model sounding and hodograph from the 18 UTC 24 March 2008 run of the WRF model shown in BUFKIT valid at 0100 UTC 25 May 2008 for KHIO.

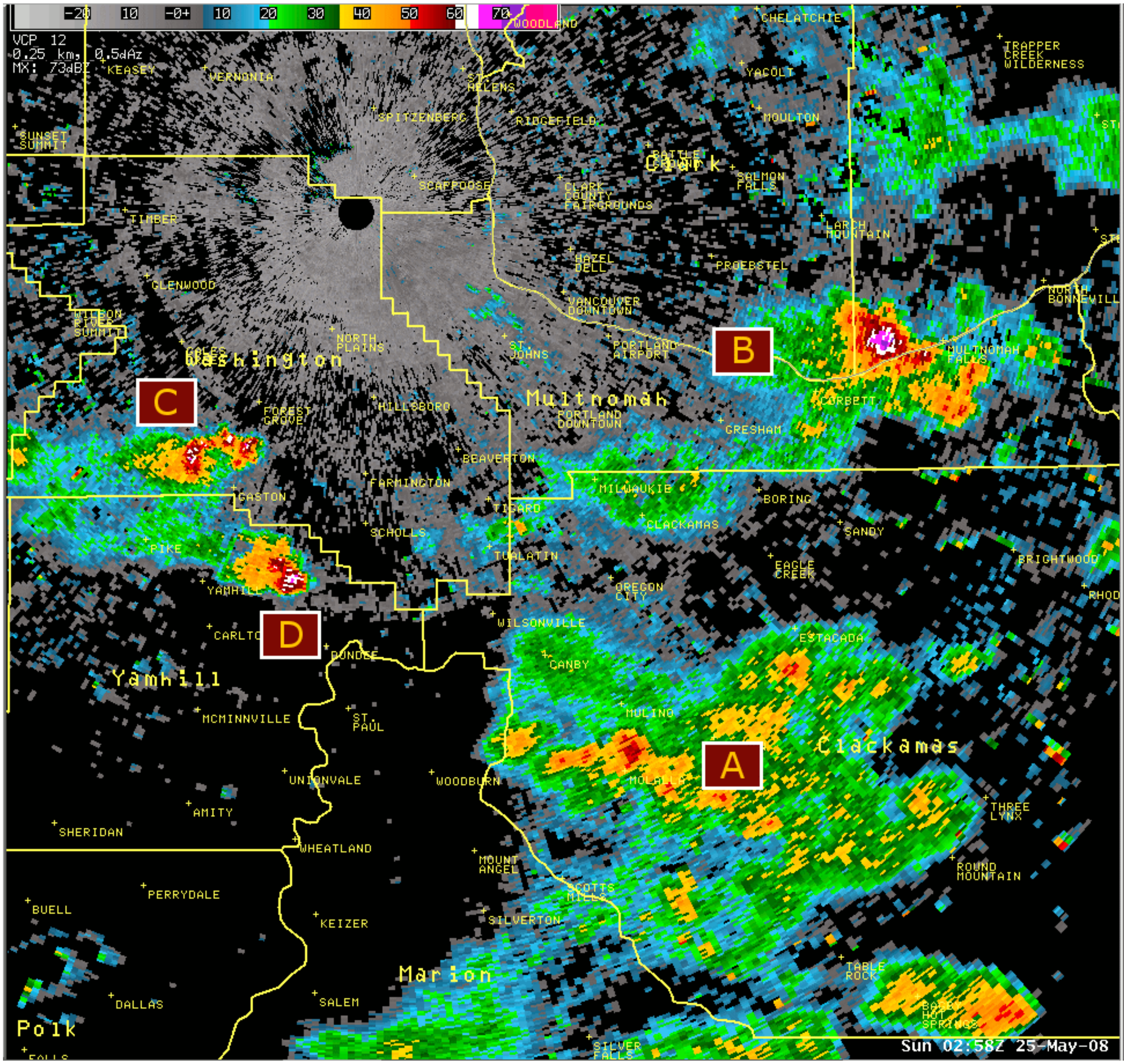


Figure 2 – Reflectivity image from the 0.5° elevation angle from the Portland Weather Surveillance Radar (KRTX) at 0258 UTC 25 May 2008. The four “Cells” referred to in this paper are labeled.

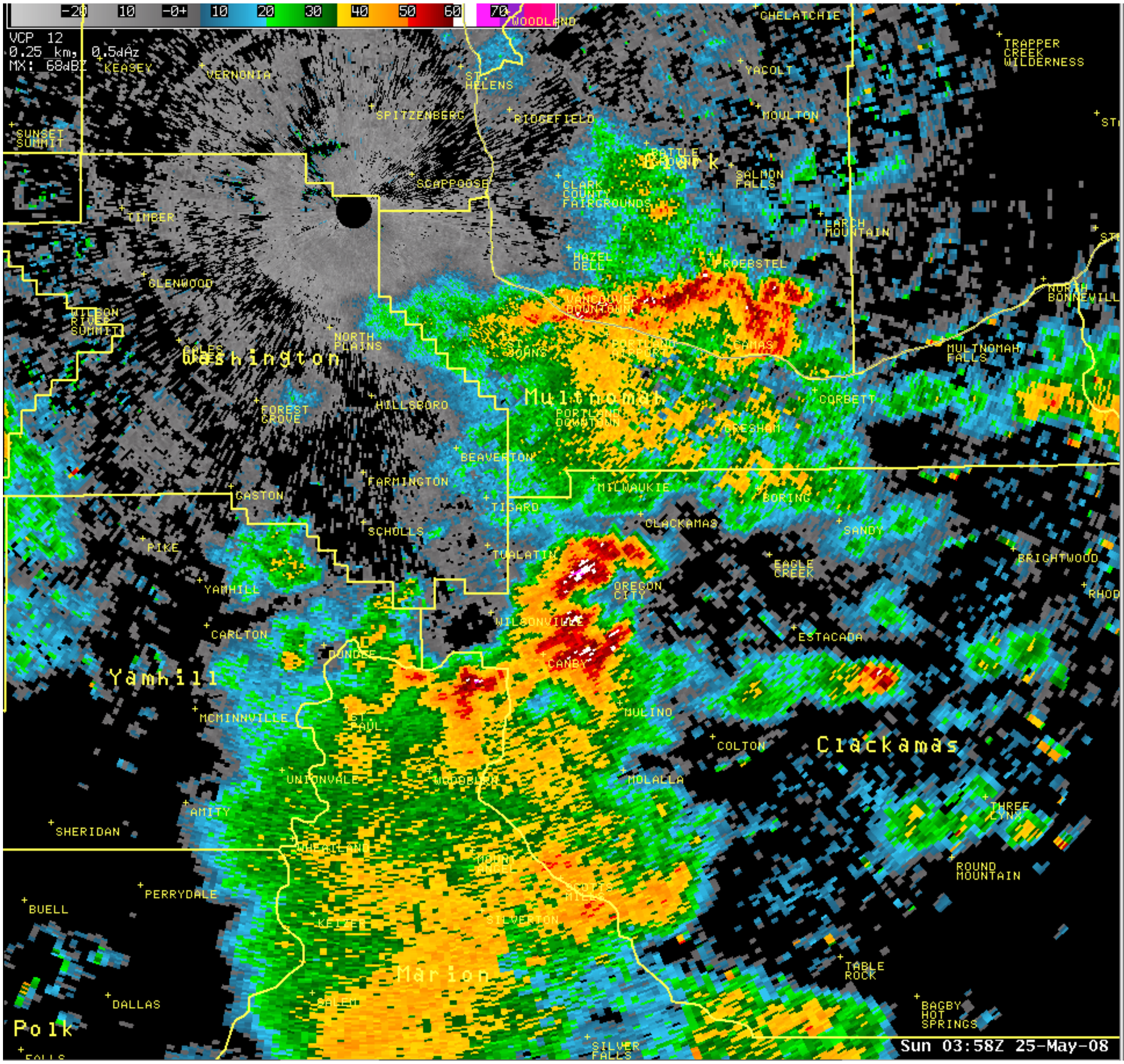


Figure 3 – Reflectivity image from the 0.5° elevation angle from the Portland Weather Surveillance Radar (KRTX) at 0358 UTC 25 May 2008. Image shows the storms merging into an MCS.

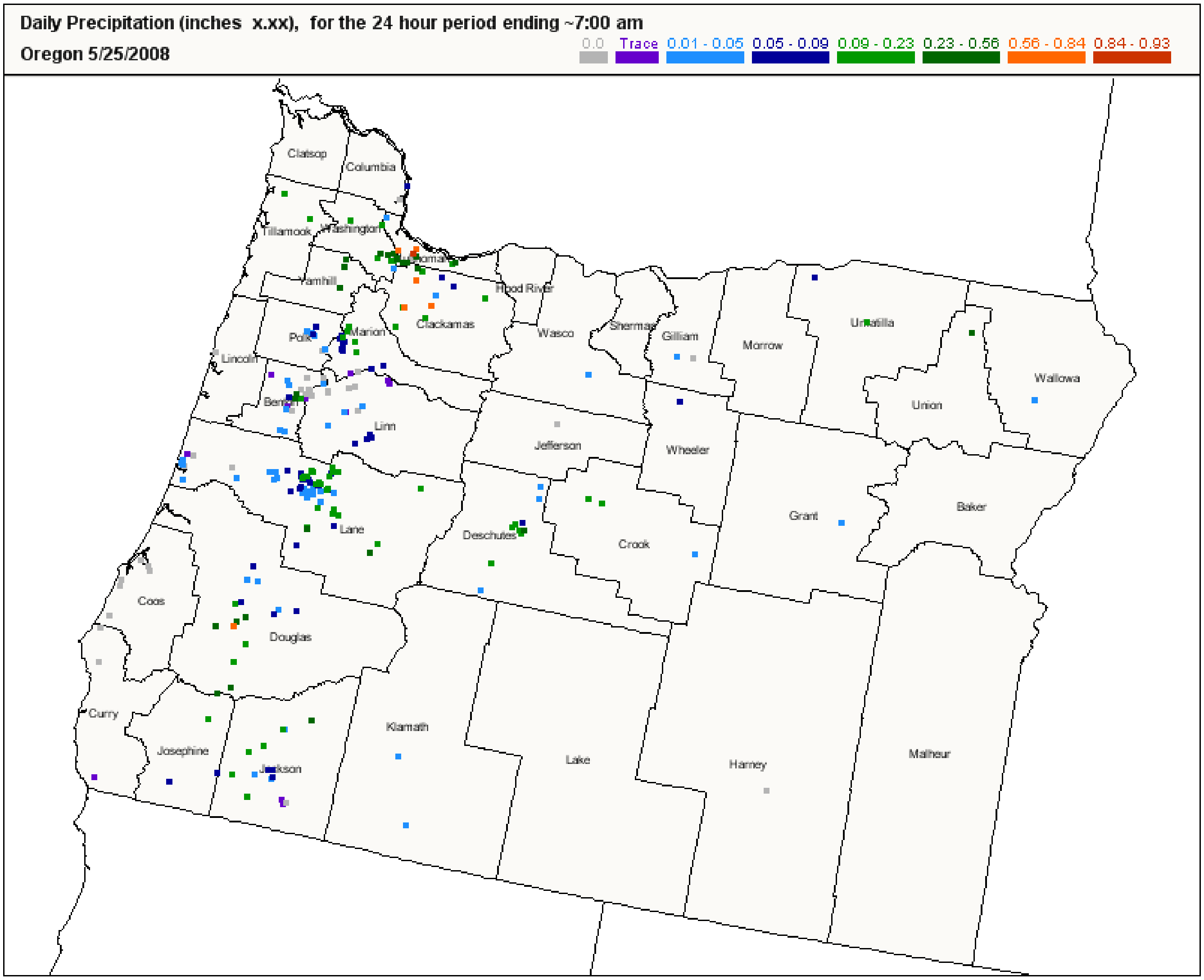

Figure 4 - CoCoRaHS 24 hour precipitation ending 14 UTC on 25 May 2008.

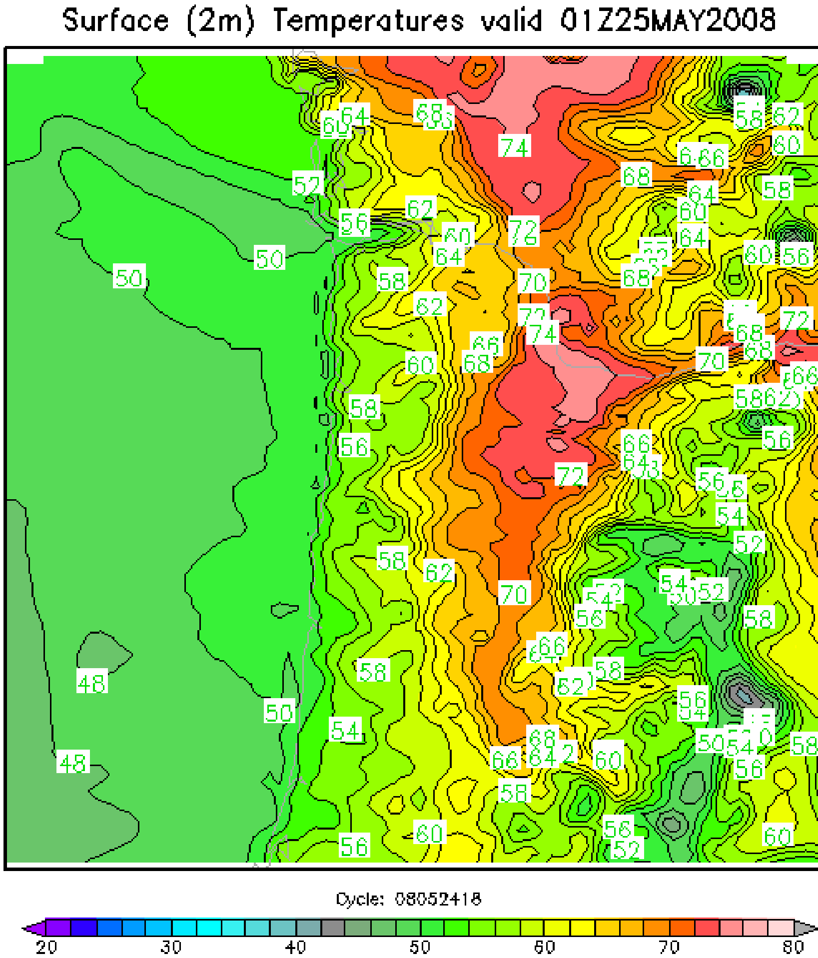

Figure 5 – 18 UTC run of the WRF model showing forecasted 2 m surface temperatures valid at 01 UTC on May 25, 2008.