Favorable Conditions for Severe Thunderstorm Formation in the Eureka, CA County Warning Area

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Introduction

The climate of Northwest California is dictated by a distinct wet (typically late fall, winter, early spring) and dry (typically late spring, summer, early fall) season. Most of the thunderstorms that occur in the Eureka County Warning Area (CWA) occur during the wet season in the winter and spring months when low pressure systems impact the west coast of the United States. Thunderstorms during the dry season, and in particular severe thunderstorms, are far less common. The focus of this research is to determine a list of average model parameters that forecast the conditions that lead to severe thunderstorms over the Eureka CWA. Severe thunderstorm activity is infrequent and difficult to diagnose due to the complex terrain found in Northwest California. Additionally, the proximity of the cool moist air from the Pacific Ocean often deters thunderstorm development. Though infrequent over the Eureka CWA, severe thunderstorms do produce damaging winds and large hail, and rarely tornadoes. These conditions pose a direct risk to life and property.

Synoptic and Mesoscale Features

Synoptic conditions favorable for severe thunderstorm development typically begin with an upper level low to the southwest of the Eureka CWA. The low is generally moving towards the coast or remaining nearly stationary. The circulation around the low aids in the transport of elevated moisture over the Eureka CWA. The moisture transport is usually from the south or southeast. There could be a vorticity spoke propagating around the low and an associated favorable jet streak position, which would enhance the upper-level support for convection. Having these conditions helps, but is not required. Obviously, the best synoptic conditions across the board will lead to the highest probability of severe thunderstorm development.

Conditions favorable for severe thunderstorm development generally involve the lack of a mid-level cap, low conditional stability, decent moisture, and increased bulk shear. Due to the proximity of the edge of the Pacific Ridge and the resultant subsidence inversion at the mid-levels, convection over the Eureka CWA is typically capped. The position of the upper level low to the southwest displaces this subsidence inversion to the west of the CWA. The southerly flow over Northern California to the east of the low brings low and mid-level moisture northward. This moist flow lowers the conditional stability. Due to the orientation of the terrain and the upper level low, southerly winds near the surface in conjunction with veering winds with height lead to increased bulk shear.

Case Study

The 2-3 June 2009 case illustrates the mean findings of this study well. With an upper level low to the west and good upper level support, the synoptic conditions were in place (Fig. 1 and 2). All of the lapse rates were in the favorable range (Fig. 3). All of the instability indices were favorable, and that combined with low CIN values allowed for focused convective initiation over the ridges (Fig. 4). There was plenty of moisture. 1000-500 mb RH peaked near 85% and the total column precipitable water (TPW) was about 0.75 to 1 inch. Bulk shear was very strong. The 0-1 km shear was about 5 to 15 kt and the 0-6 km shear was about 30 to 45 kt (Fig. 5).

A review of point model soundings and hodographs in the CWA is very important. A majority of the cases had plenty of CAPE, especially in the Hail Growth Zone (HGZ, -10 to -30 C). Since many of the storms in the Eureka CWA are higher-based, drier air at the lower levels needs to be monitored as inverted-V soundings are common. A simple look at the hodographs also gives forecasters a good idea of what type of storm evolution to expect (left-moving, right-moving, splitting, etc.). The 2-3 June 2009 case fit this pattern (Fig. 6).

As storms start developing, focus then shifts to radar and satellite data. Infrared (IR) satellite data showed widespread cloud top cooling to the range of -45 to -55 C. In radar imagery, the highest reflectivity reached 65 to 70 dBZ. These high reflectivity values did reach the height of the -15 C level. Additionally, the highest returns in the HGZ did reach 65 dBZ. Storm tops reached heights above 40,000 ft MSL with storm top divergence ranging from 60 to 95 kt. VILs were generally about 45 to 50 kg/m2.

Although dual-pol data was not available in this 2009 case and it was not reviewed in this study, dual-pol is very useful for determining large hail. This is more important for the Eureka CWA than other more populated CWA's given that most severe thunderstorms occur over our mountainous terrain with little or no population. Though rare for the Eureka CWA, three-body scatter spikes are used to determine large hail and dual-pol data makes them much easier to identify in real time. An example of this was on 21 August 2013 (Fig. 7-8). Despite not having ground truth with this particular storm, it is safe to assume it produced severe-sized hail.

Limitations and Cautions

It is important to note several things in this study. (1) The sample size used to put together this paper only consisted of nine cases. Only cases where Severe Thunderstorm Warnings (SVR's) were issued over the five year period from 2009-2013 were reviewed. These warnings were verified through either ground truth or clear radar indications over remote areas. Additional cases could not be used due to missing or incomplete data. There was minimal ground truth with all of these cases because most of the thunderstorms occurred over mountainous terrain with little or no population. Limiting the study to only cases where warnings were confirmed with ground truth would have netted a sample size too small to be statistically reliable. (2) The Eureka radar (KBHX) was upgraded with dual-pol technology in June 2012. Only four cases during the study period had dual-pol data available, which was less than half of the sample. A representative example is provided to encourage further study. (3) The following numbers are means and should not be considered absolute. The results of this study are applicable for the Eureka CWA, which covers Northwest California and the near shore coastal waters. The more parameters that exceed mean conditions, the higher the probability of severe thunderstorm development.

Favorable Conditions

The sample size used to put together this data was small. The following numbers are means and should not be considered absolute. The results of this study are applicable for the Eureka CWA, which covers Northwest California and the near shore coastal waters. The more parameters that exceed mean conditions the higher the probability of severe thunderstorm development.

Forecast Data	
0-1 km Lapse Rates	8 to 11 C/km
0-6 km Lapse Rates	6.5 to 8.5 C/km
850-500 mb Lapse Rates	6.5 to 8 C/km
700-500 mb Lapse Rates	6.5 to 8 C/km
Freezing Levels	12,000 to 13,000 ft MSL
PWATs	0.75 to 1 inches of H_2O
1000-500 mb RH	45 to 70%
Best LI's	-0.5 to -4.5 C
SBCAPE	300 to 1,400 J/kg
1000-500 mb MUCAPE	350 to 2,100 J/kg
DCAPE	100 to 1,050 J/kg
CIN	0 to -25 J/kg
0-1 km Bulk Shear	5 to 10 kt
0-6 km Bulk Shear	20 to 35 kt
6 km-EL Bulk Shear (500-300 MB)	15 to 30 kt

Real-Time Data	
Coldest IR Satellite Temperatures	-45 to -55 C
Highest Reflectivities	65 to 70 dBZ
Height of the Highest Reflectivities	Up to -15 C
Highest Reflectivities in the HGZ (-10 to -30 C)	65 dBZ
Storm Tops	Average 35,000 to 40,000 ft MSL
VILs	45 to 50 kg/m2
Storm Top Divergence	60 to 95 kt

Conclusion

Severe thunderstorms in the Eureka CWA during the dry season are rare. Severe thunderstorms do produce damaging winds and large hail, and rarely tornadoes, posing a risk to life and property. This empirical study provides a subjective forecast tool to aid forecasters in the warning decision. This decision aid is intended to help forecasters weigh the probability of severe thunderstorm development. It also serves to establish and maintain situational awareness.

Finally, SPC knowledge and products are very helpful when predicting the potential for severe thunderstorms and establishing and maintaining situational awareness. Out of the nine cases, seven of the cases fell into a "Slight Risk" or a "See Text" on SPC's Day 1 Convective Outlooks. The remaining two cases fell under the general thunderstorm risk. So while Northern California may not experience severe thunderstorms with the same frequency and ferocity as the Midwest, SPC guidance is a very valuable resource for forecasters to use.

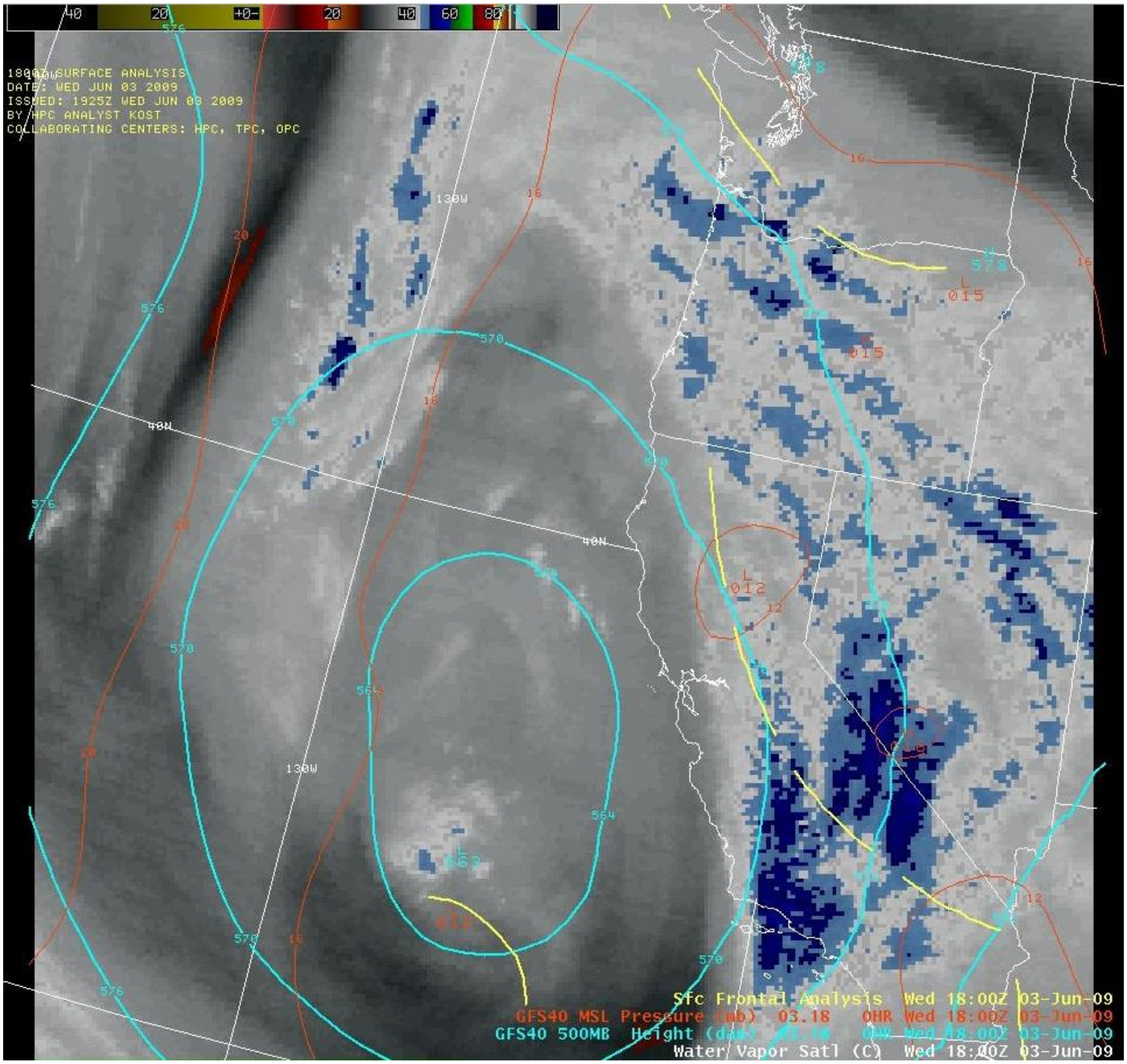

Figure 1—Synoptic conditions favorable for severe thunderstorm development. WPC surface frontal analysis (yellow). GFS MSL pressure (solid lines, red). GFS 500 mb height (solid lines, blue). Water vapor satellite (image).

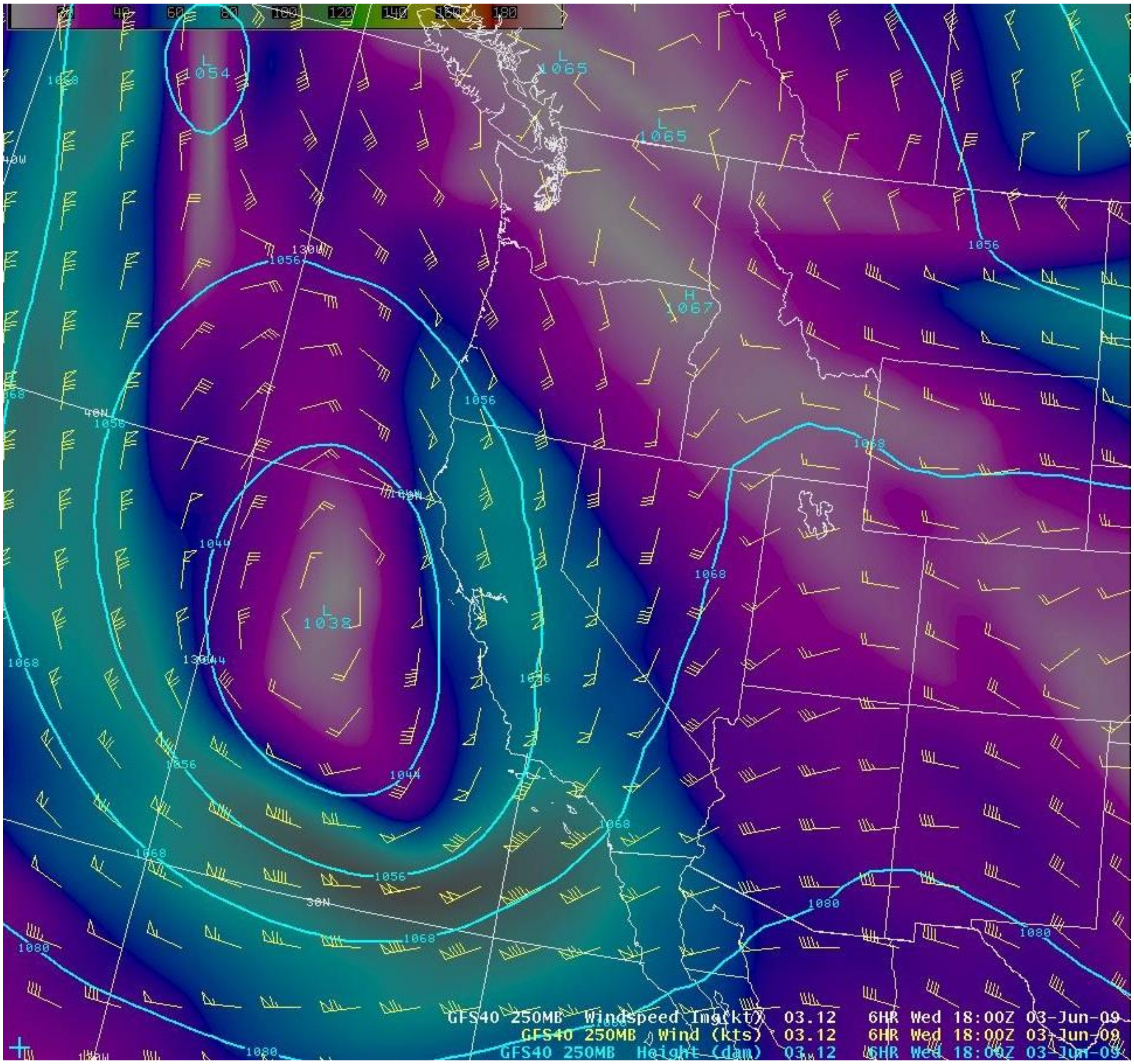

Figure 2—Jet stream favorable for severe thunderstorm development. GFS 250 mb height (solid lines, blue). GFS 250 mb wind (barbs, yellow). GFS 250 mb wind speed (image).

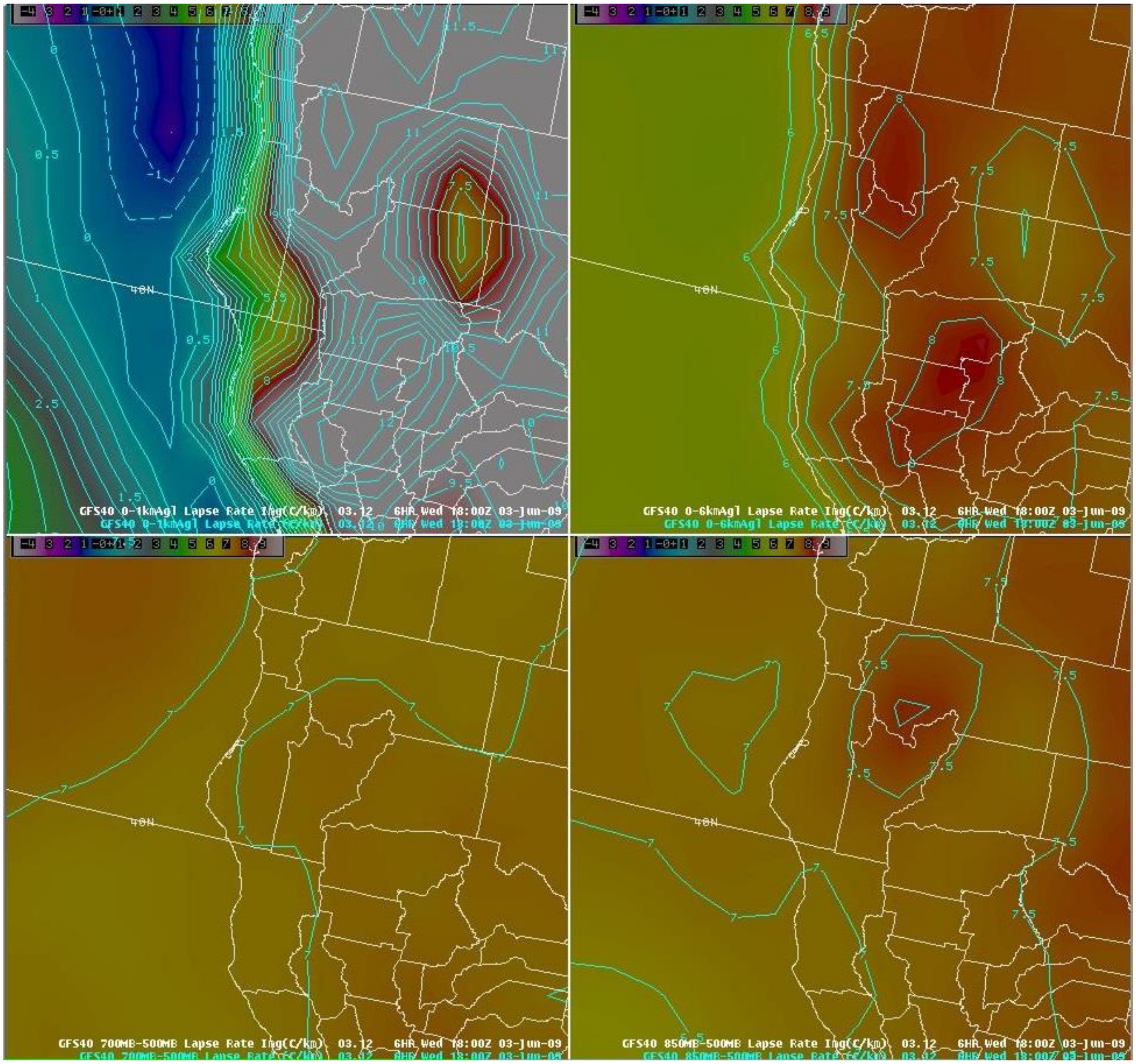

Figure 3—Vertical distribution of weak/low conditional stability favorable for severe thunderstorm development. Upper left: GFS 0-1 km lapse rates (solid lines, blue; image). Upper right: GFS 0-6 km lapse rates (solid lines, blue; image). Lower right: GFS 850-500 mb lapse rates (solid lines, blue; image). Lower left: GFS 700-500 mb lapse rates (solid lines, blue; image).

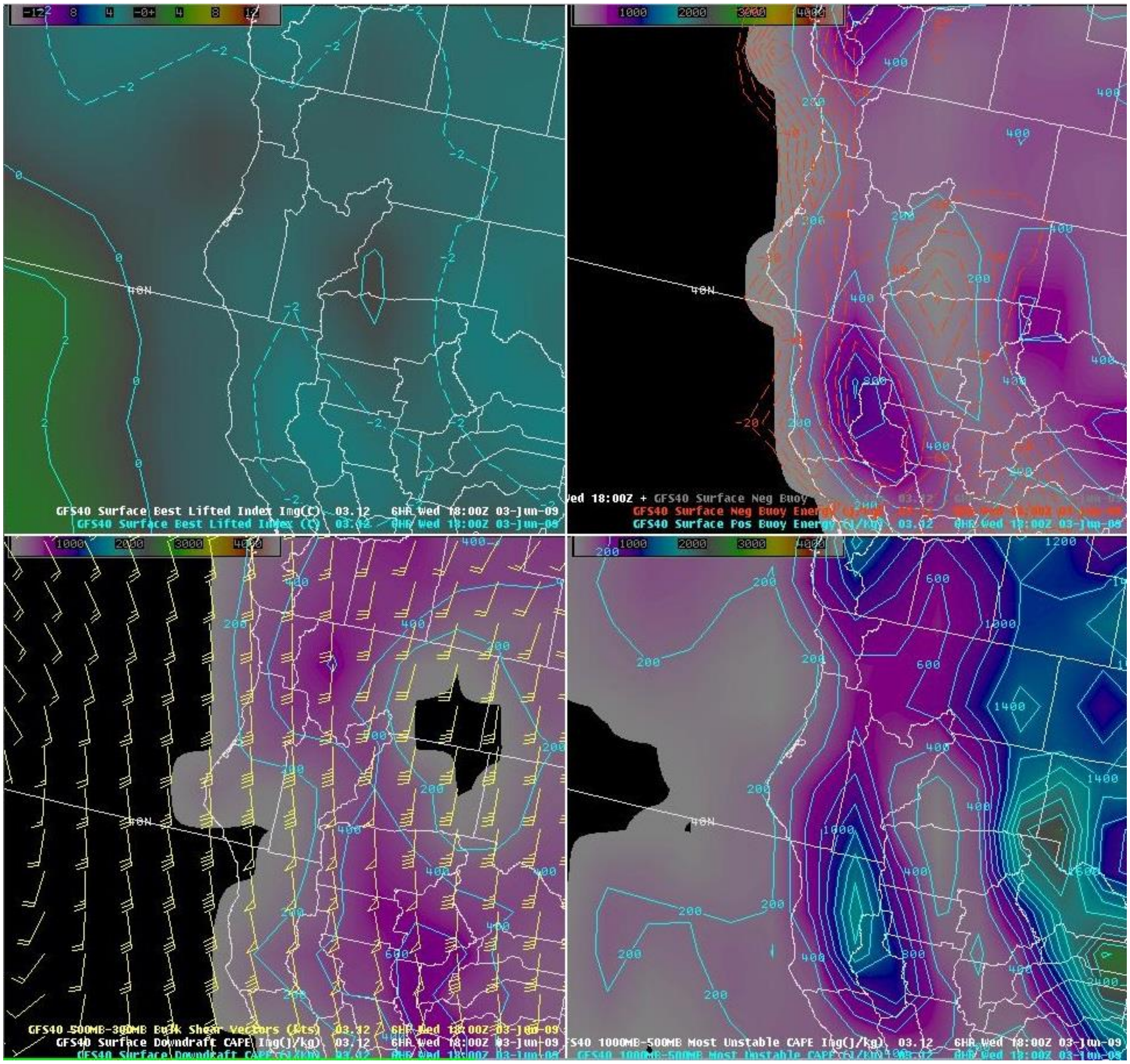

Figure 4—Weak/low conditional stability favorable for severe thunderstorm development. Upper left: GFS surface best lifted index (lines, blue; image). Upper right: GFS surface CAPE (solid lines, blue; image) and CIN (dashed lines, red). Lower right: GFS 1000-500 mb MUCAPE (solid lines, blue; image). Lower left: GFS downdraft CAPE (solid lines, blue; image) and 500-300 mb bulk shear (barbs, yellow).

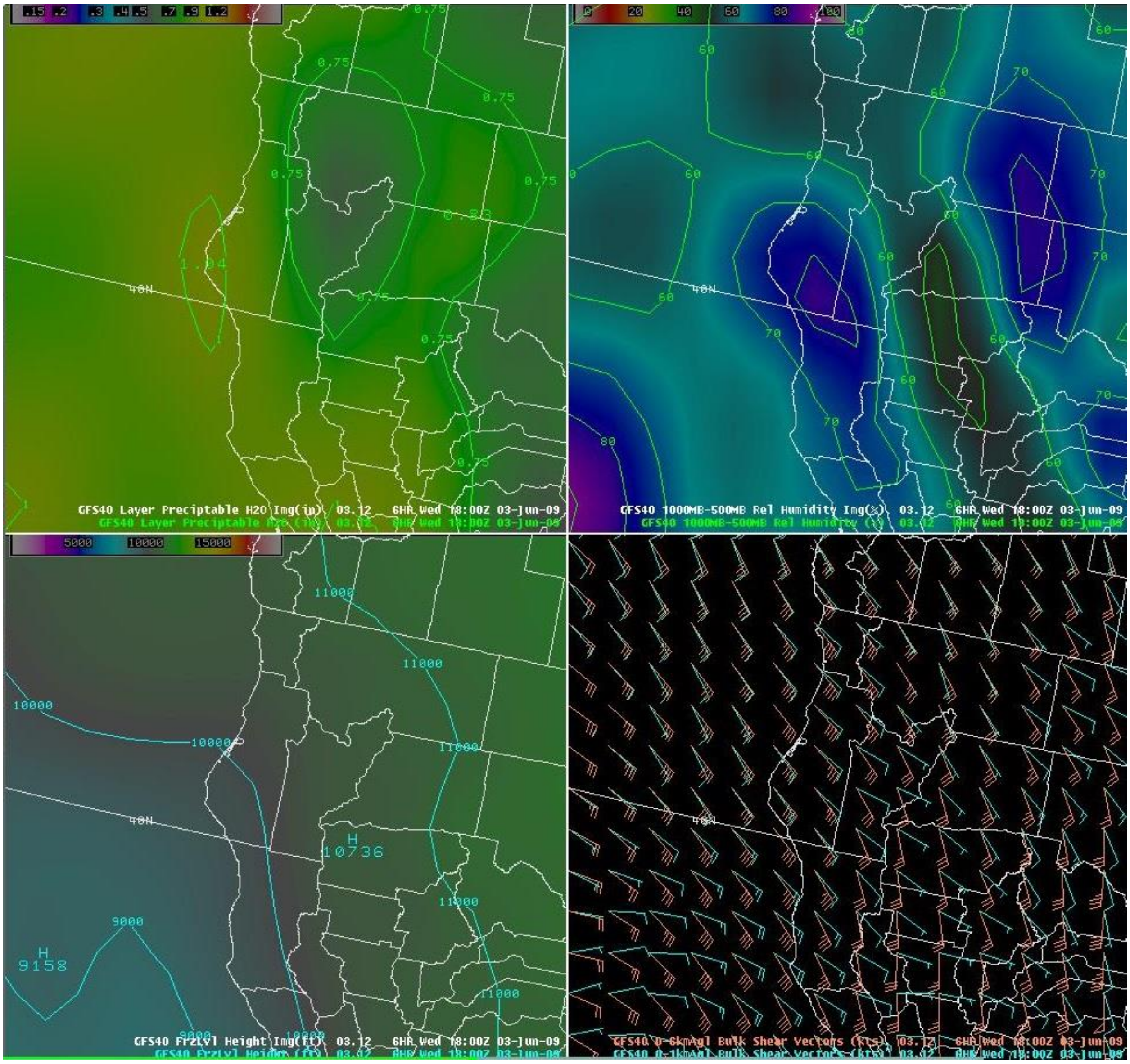

Figure 5—Moisture and bulk shear conditions favorable for severe thunderstorm development. Upper left: GFS precipitable H2O (solid lines, green; image). Upper right: GFS 1000-500 mb RH (solid lines, green; image). Lower right: GFS 0-1 km (barbs, blue) and 0-6 km bulk shear (barbs, orange). Lower left: GFS freezing level height (solid lines, blue; image).

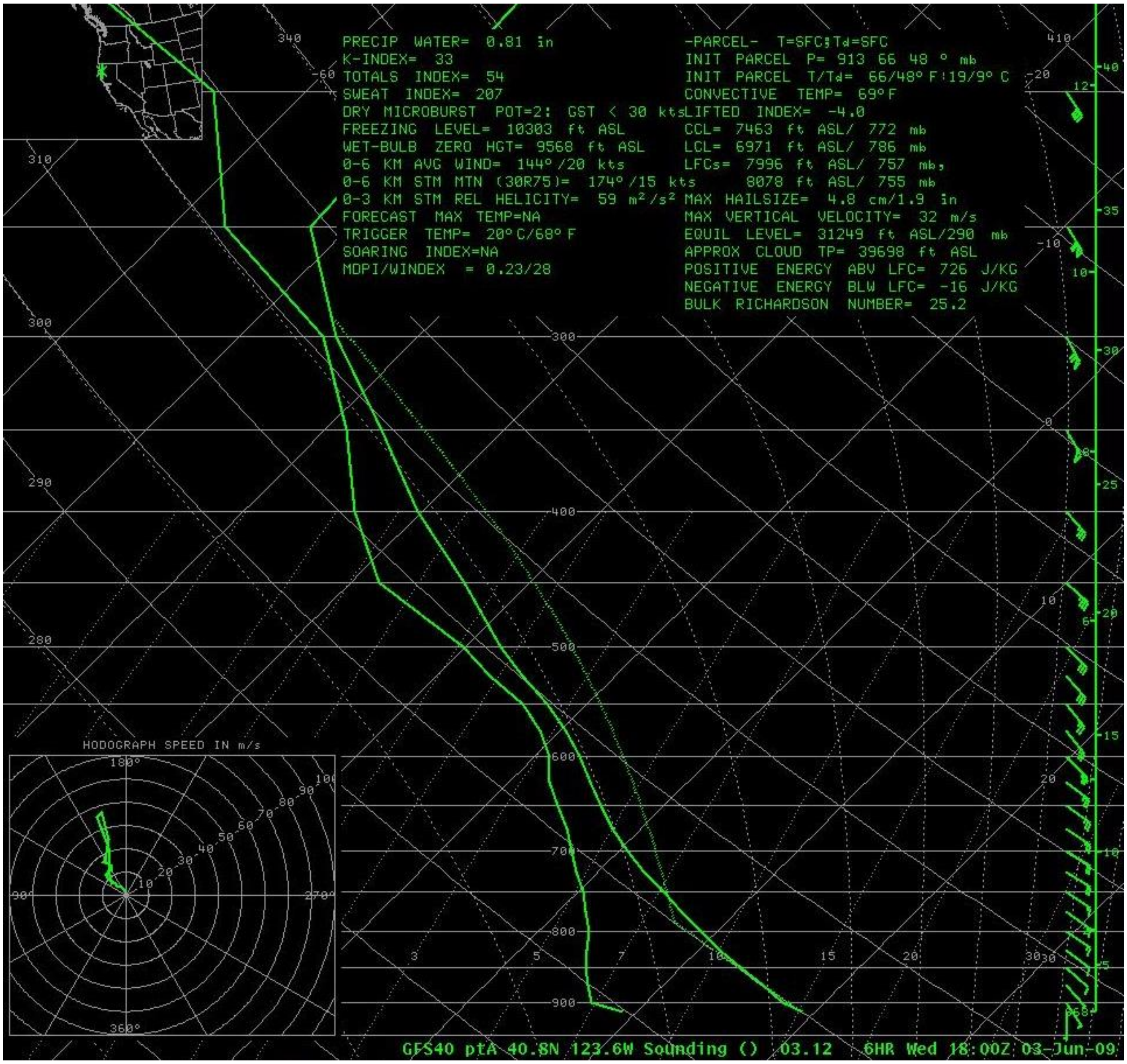

Figure 6—GFS40 model sounding from the morning of 3 June 2009. This sounding is representative of the cases studied.

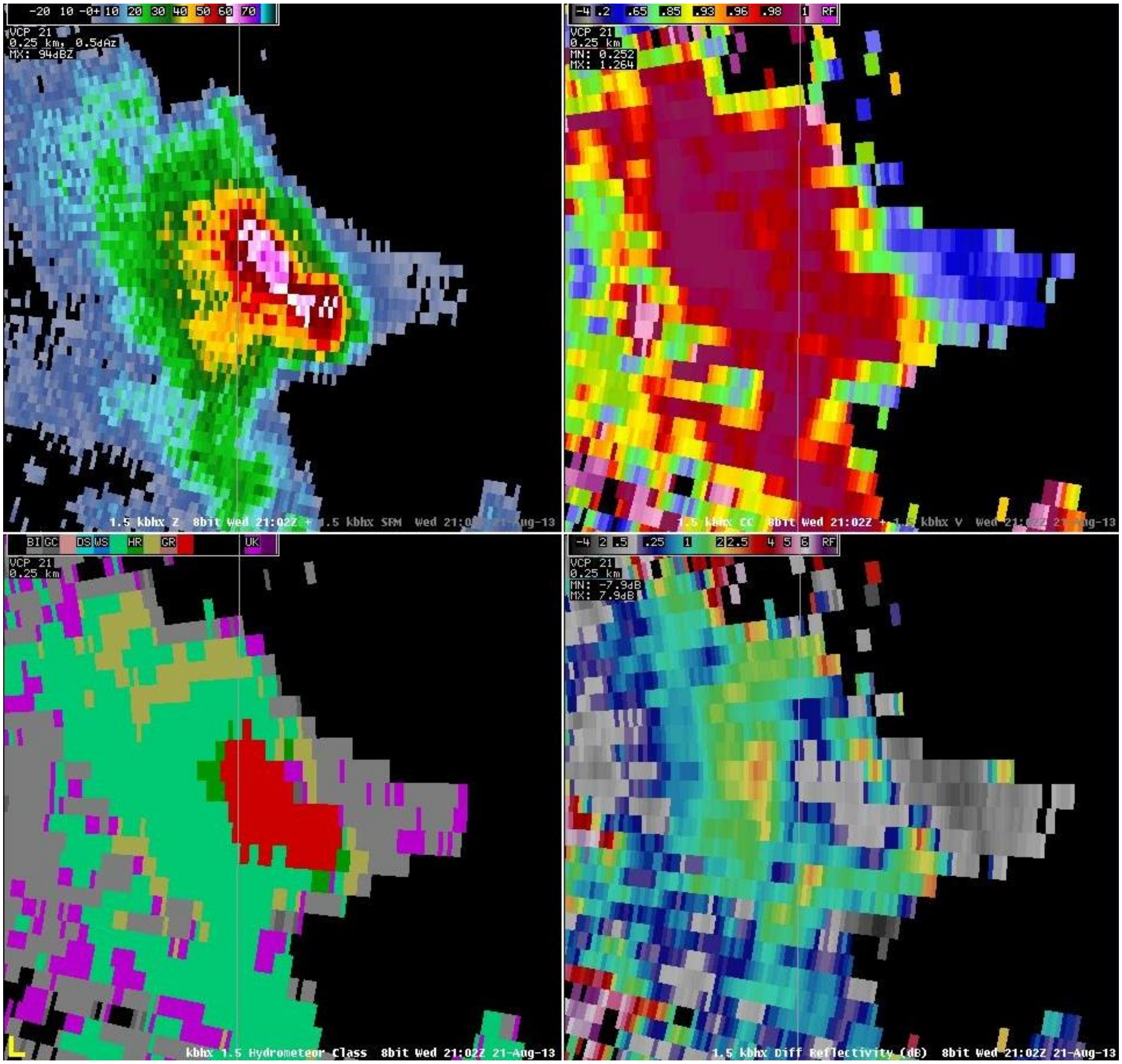

Figure 7—Three body scatter spike clearly identified in the upper right CC. Upper left: Reflectivity (Z). Upper right: Correlation Coefficient (CC). Lower right: Differential Reflectivity (ZDR). Lower left: Hydrometeor Classification (HC).

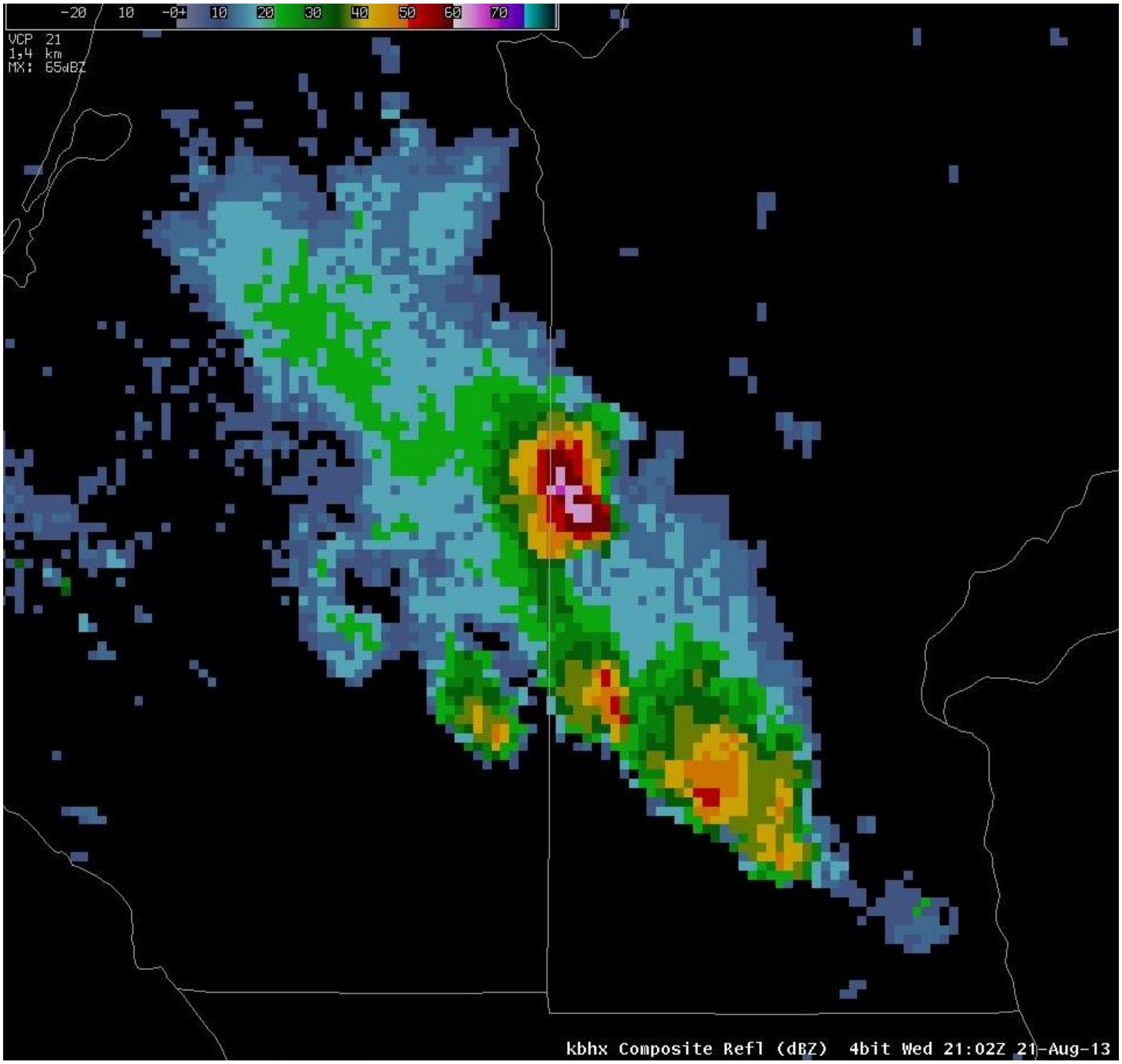

Figure 8—Composite Reflectivity (CZ) of the severe thunderstorm. Image given as an example of the severe thunderstorms strength compared to surrounding storms.