The Northern Nevada Dry Thunderstorm Event of 30 Sep 2011

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1. Overview:

A dry thunderstorm event during the afternoon and evening of Friday, September 30, 2011 sparked roughly 35 fires across the NWS Elko forecast area, most of which were located in fire weather zone 468 (Figs. 1 and 2). In all, there were 906 lightning strikes in the CWA between 19Z on the 30th and 06Z on 1 Oct 2011 (Table 1). Fire weather zone (FWZ) 468 had 159 lightning strikes, mostly between 00Z and 04Z on 1 Oct, which equates to about 27% coverage of the zone. The fires started that day burned more than 200,000 acres over the next several days.

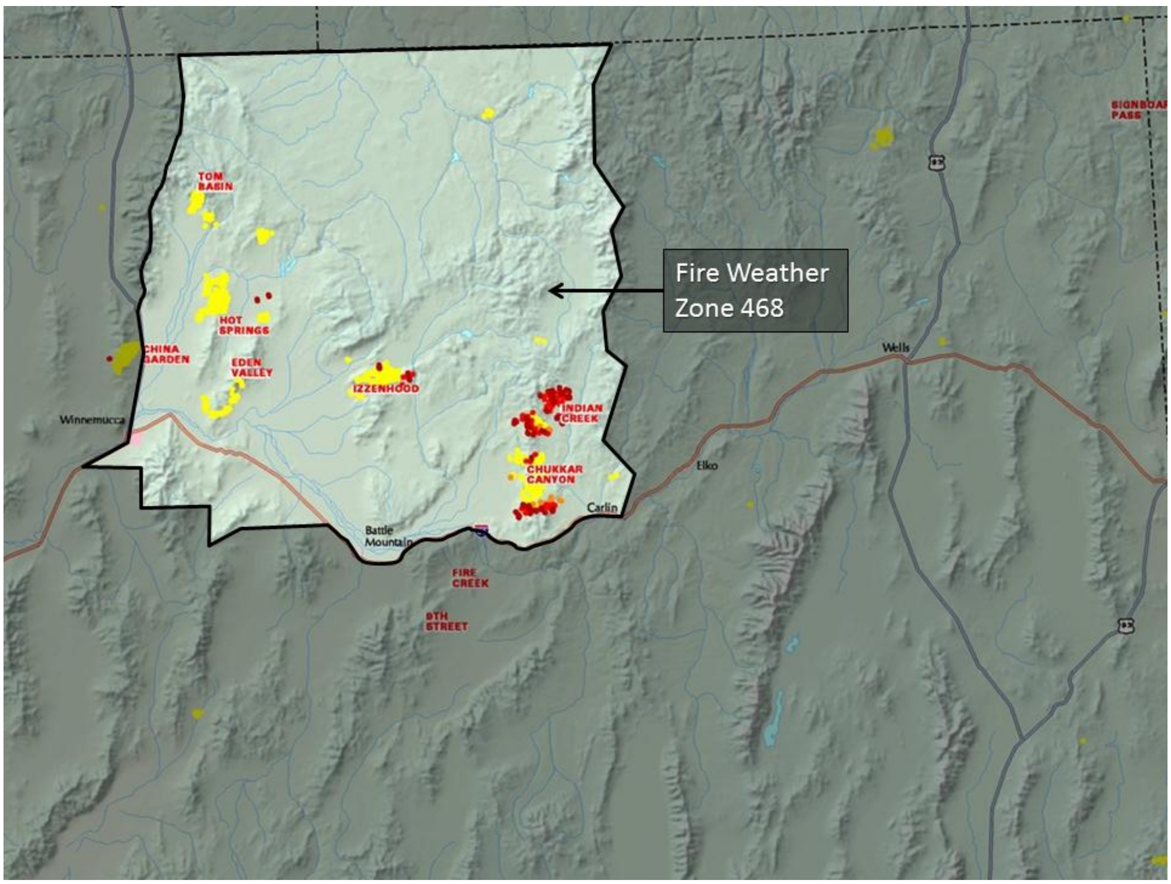

Figure 1: MODIS Fire Activity Map from 2 Oct 2011 showing the large complex of fires started by lightning on 30 Sep 2011.

2. Radar Analysis:

Radar imagery from KLRX at 00Z on 1 Oct shows relatively minor convection across the region (Fig. 3). By 01Z (Fig. 4) there is stronger activity in northern Lander and Eureka Counties, just south of FWZ 458, and also in the central part of the FWZ. The storms were moving to the north at around 23 kts. The cells were small and generally pulse storms of short duration. By 02Z, (Fig.

Figure 2: Hourly lightning strikes from 1 Oct 2011. Blue polygon is the approximate location of FWZ 468.

5), thunderstorm activity had decreased somewhat, and would continue to decrease later in the evening. The echoes around 20 kft MSL (or 450 mb) were relatively weak, but the associated thunderstorms were able to produce 40 to 50 lightning strikes per hour between 00Z and 03Z (Table 1). The bulk of the activity during the evening hours existed in north-central NV.

Date	Time Frame	FWZ467	FWZ468	FWZ469	FWZ470	FWZ454	FWZ455	FWZ457
30-Sep	19Z-20Z (30-Sep)	0	0	0	0	0	1	0
	20Z-21Z	0	0	0	0	0	38	0
	21Z-22Z	0	0	0	2	0	70	19
	22Z-23Z	0	0	0	45	23	38	58
	23Z-0Z	0	8	10	34	26	44	11
1-Oct	0Z-1Z (1-Oct)	0	43	36	41	121	0	0
	1Z-2Z	1	43	25	32	41	0	0
	2Z-3Z	20	48	4	0	1	0	0
	3Z-4Z	1	15	0	0	0	0	0
	4Z-5Z	2	2	0	0	0	0	0
	5Z-6Z	3	0	0	0	0	0	0
	TOTAL	27	159	75	154	212	191	88
	Percent Coverage	5%	27%	15%	16%	20%	21%	5%

Table 1: Lightning strike counts per FWZ between 19Z on 30 Sep 2011 and 06Z on 1 Oct 2011. Percent coverage calculated using the LightningTools (Knutsvig, 2008) smart tool package in GFE and a lightning strike radius of 5.1 km.

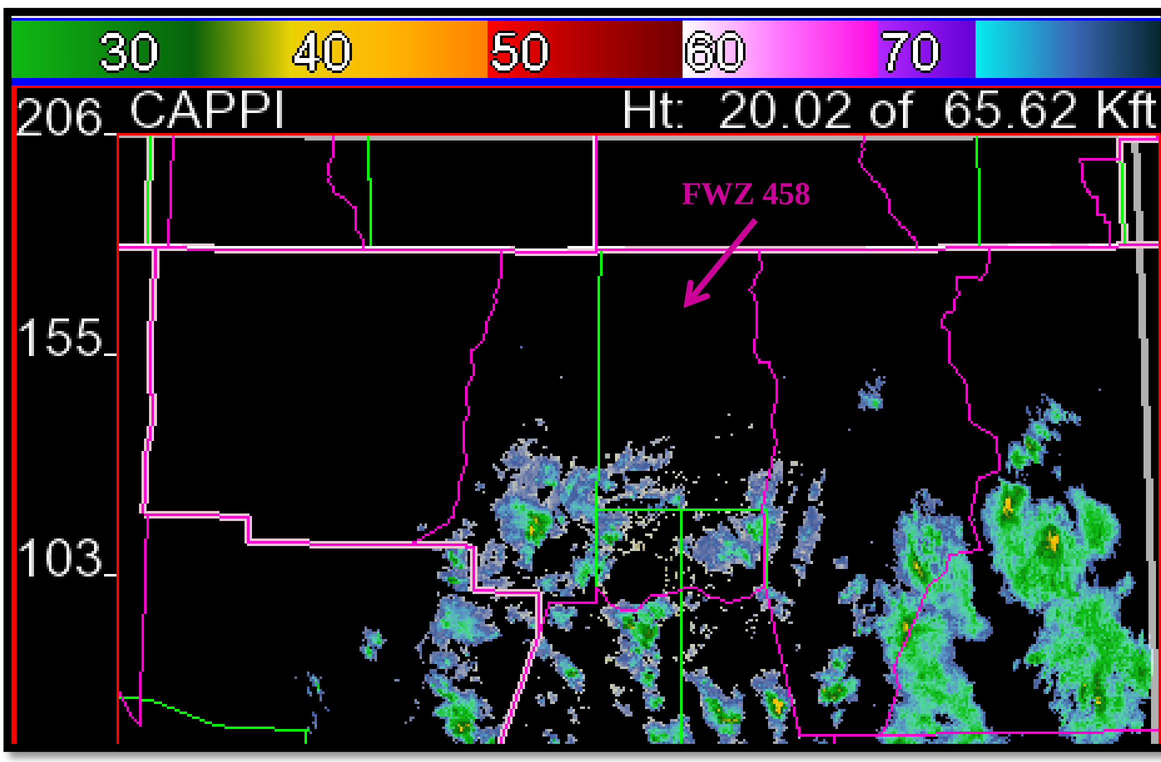

Figure 3: KLRX reflectivity at 20.02 kft MSL (CAPPI) valid at 00Z on 1 Oct 2011.

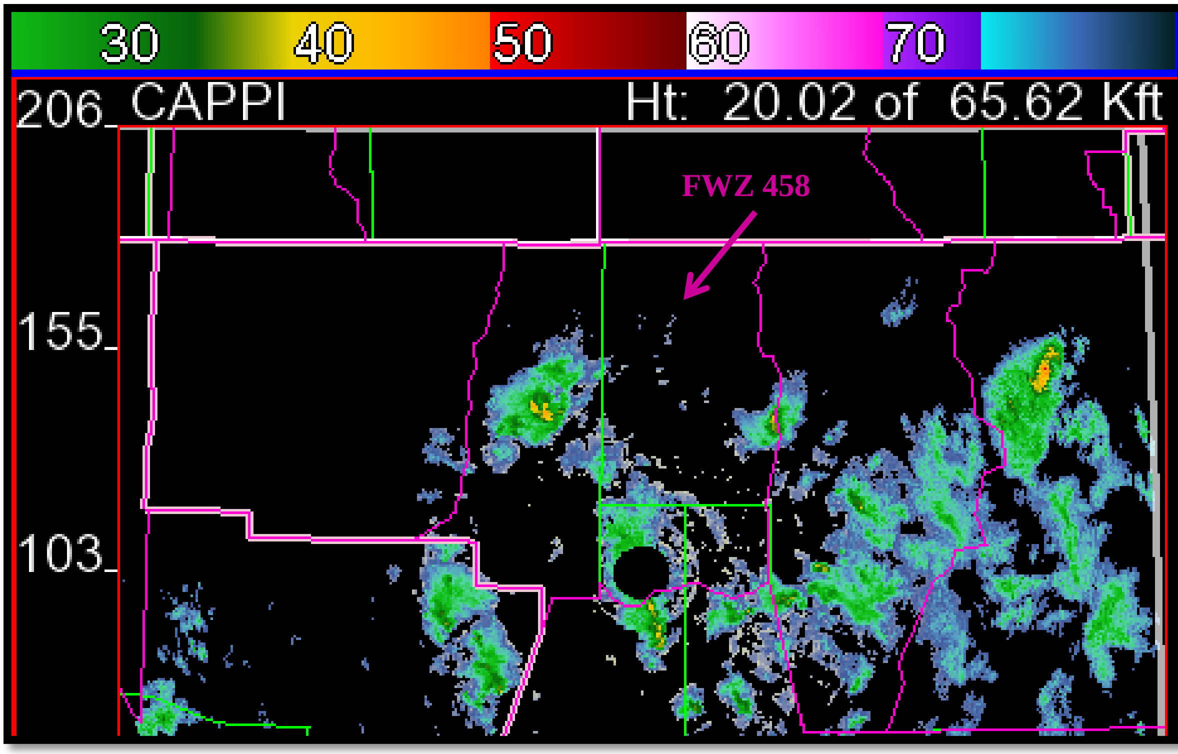

Figure 4: Same as Fig. 3, but valid at 01Z on 1 Oct 2011.

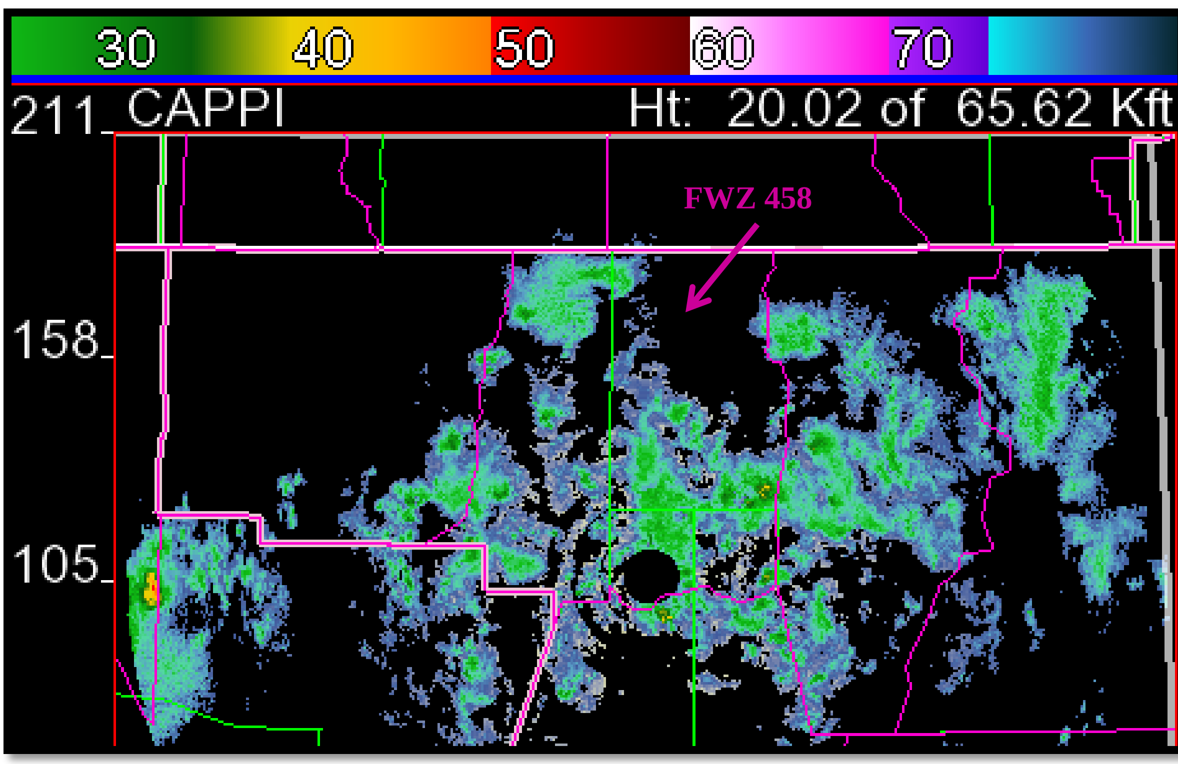

Figure 5: Same as Fig. 3, but valid at 02Z on 1 Oct 2011.

3. Upper Air Analysis:

a. 500 mb Analysis

Examining the GFS 500 mb analyses from 12Z on 30 Sep and 00Z on 1 Oct (Fig. 6) reveals that a trough axis pushed northeastward during the timeframe and reached the CA/NV border by 06Z on 1 Oct (not shown). It is believed that this trough had a significant influence on the longevity of the thunderstorm activity, maintaining a favorable environment later into the evening than normal.

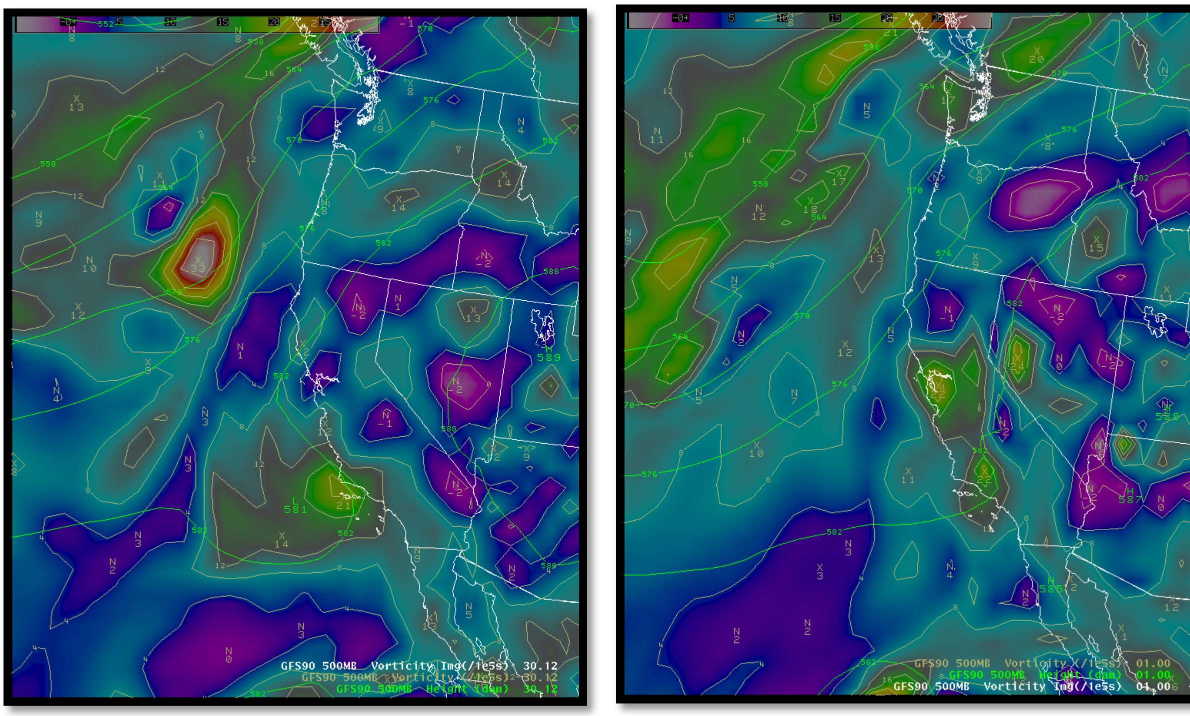

Figure 6: The GFS analysis of 500 mb geopotential heights (green) and vorticity (tan and image) from 12Z on 30 Sep 2011 (left) and from 00Z on 1 Oct 2011.

b. 700 mb Analysis

The 00Z 1 Oct 700 mb wind analysis (Fig. 7) shows southerly winds ranged from of 10 kts in the east to 35 kts in west-central NV. Also, the region had anomalously warm air (12-14°C) centered over the Great Basin at 700 mb. The Elko Regional Airport ASOS (EKO) reported a high of 90°F that day, which was 1 degree shy of the record for 30 Sep. With dew point temperatures in the upper 20s that afternoon, the Elko ASOS recorded a minimum relative humidity (RH) of 12%.

Taking a closer look at the GFS 00Z wind analysis (Fig. 7) reveals that there was a significant low level jet situated over western NV. The nose of this jet extended into Pershing County and north to the Humboldt County line. Convergence is also noted near the nose of this low level jet in southeast Humboldt County (Fig. 8), which helped support the thunderstorms in that area around 00Z. By 06Z (Fig. 9), the jet had progressed north-northeastward, and so had the area of convergence. This area of convergence not only strengthened in magnitude from -3 to near -8 (units of $1x10^5\ s^{-1}$), but it also moved north-northeast through FWZ 468 (Fig. 10). This strengthening convergence likely led to enhanced thunderstorm activity, extending the activity beyond the typical diurnal cycle for this time of year. Also, the locally enhanced wind at 700 mb likely resulted in stronger outflow wind from the thunderstorms.

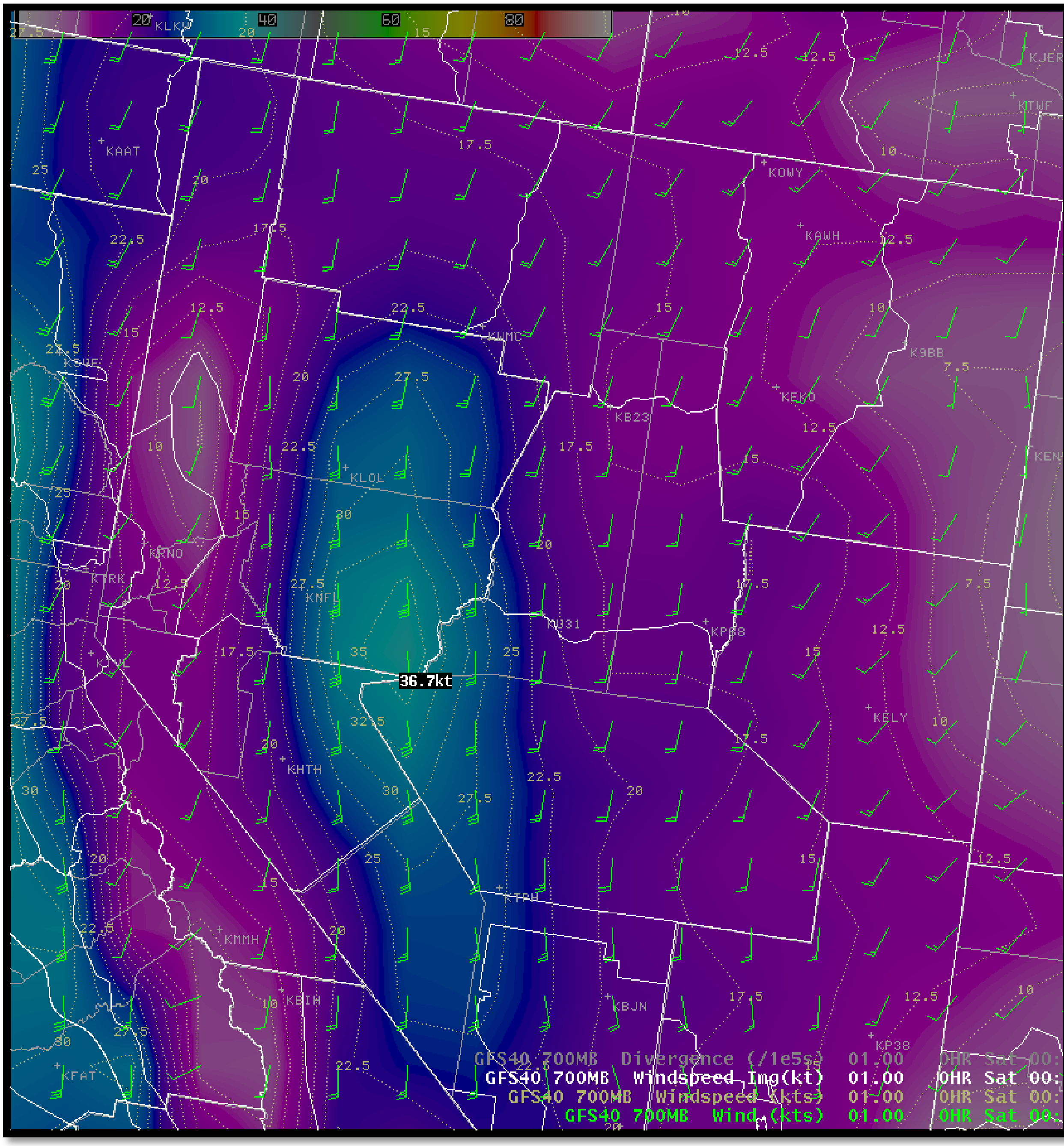

Figure 7: The 700 mb GFS analysis valid at 00Z on 1 Oct 2011. Wind speed is the image and tan dotted contours (kts) and wind barbs are in green (kts).

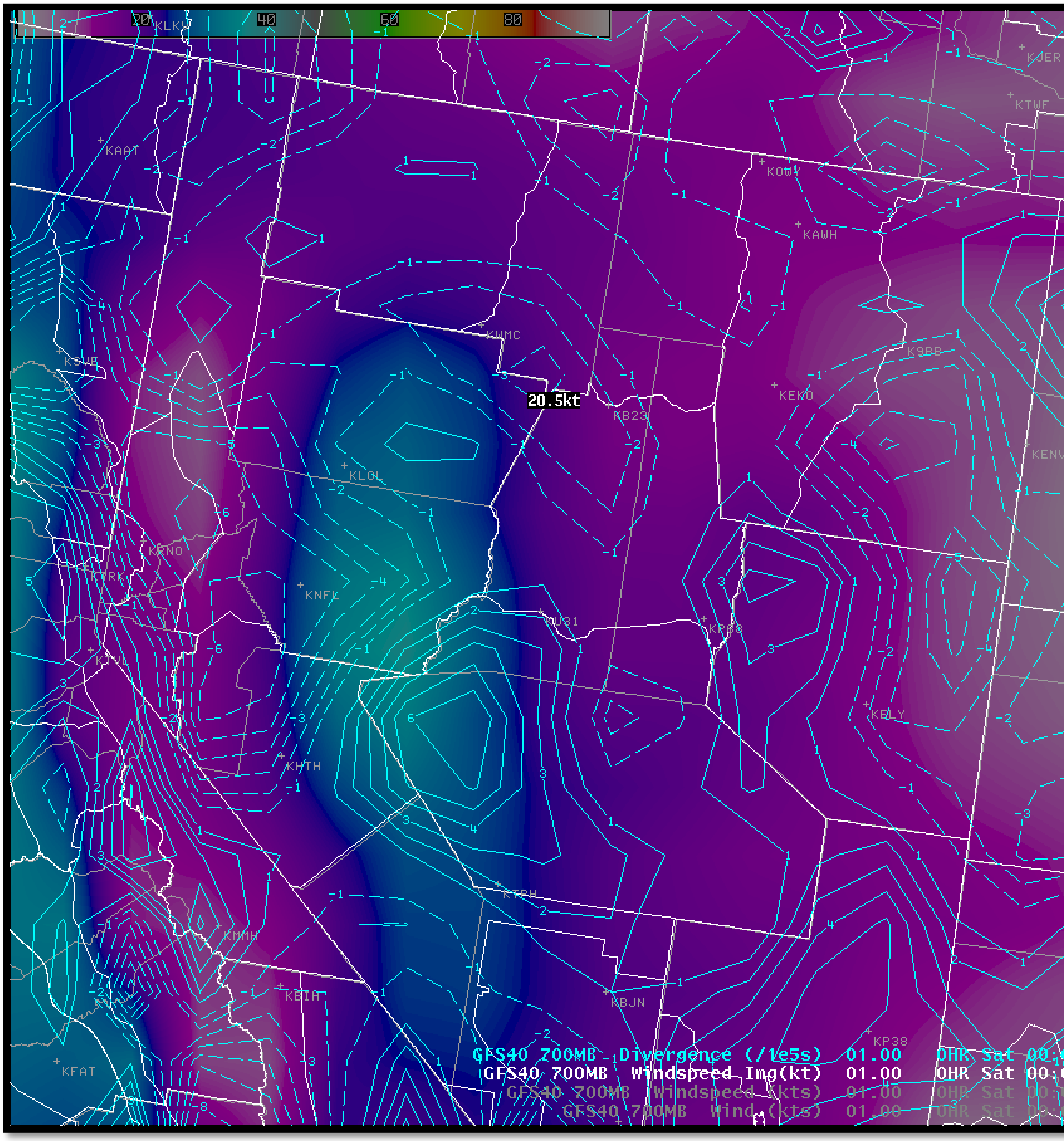

Figure 8: The 700 mb GFS analysis valid at 00Z on 1 Oct 2011. Wind speed is the image (kts) and divergence is blue ($1x10^5$ s^{-1}).

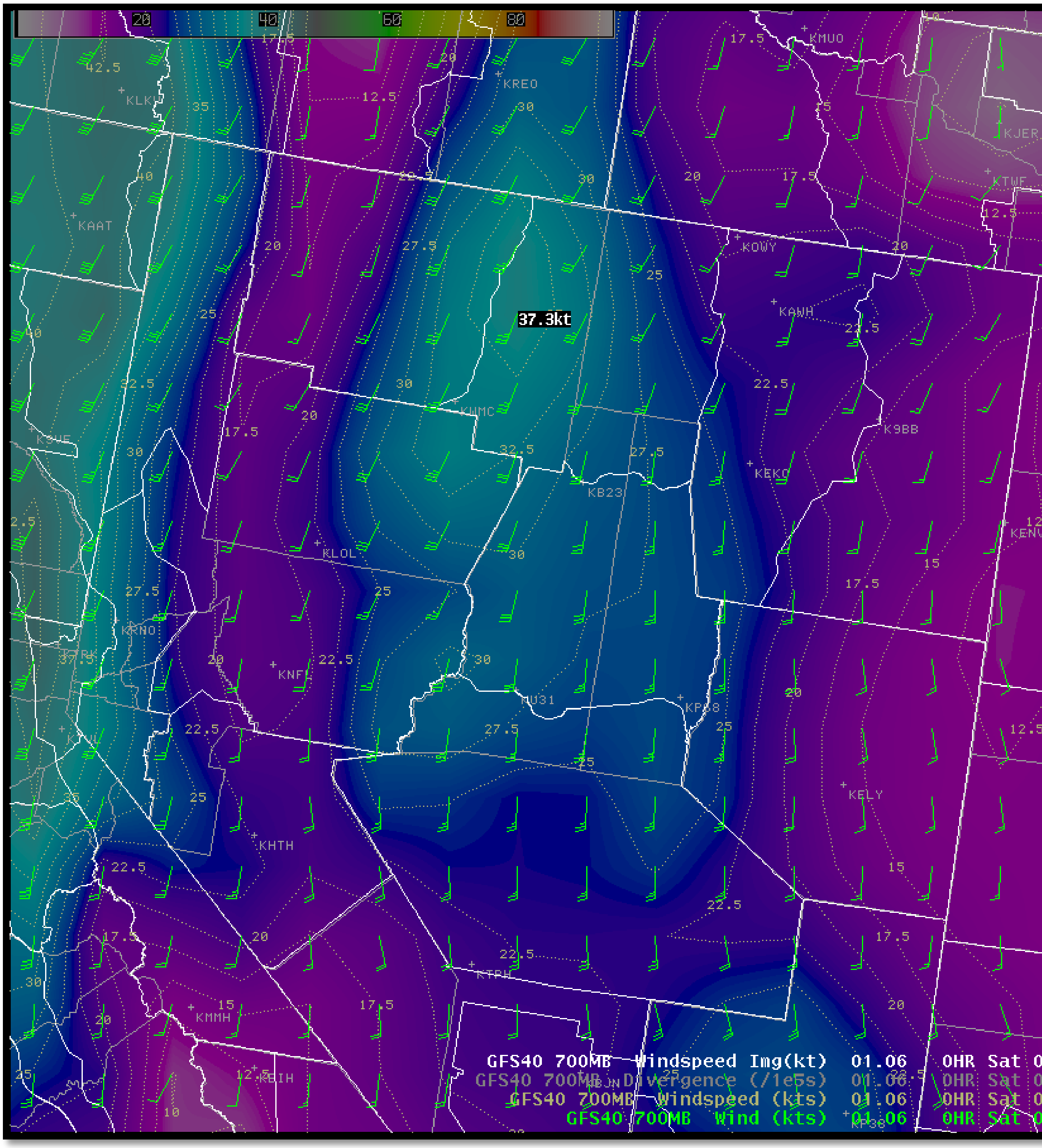

Figure 9: Same as Fig. 7, but valid at 06Z on 1 Oct 2011.

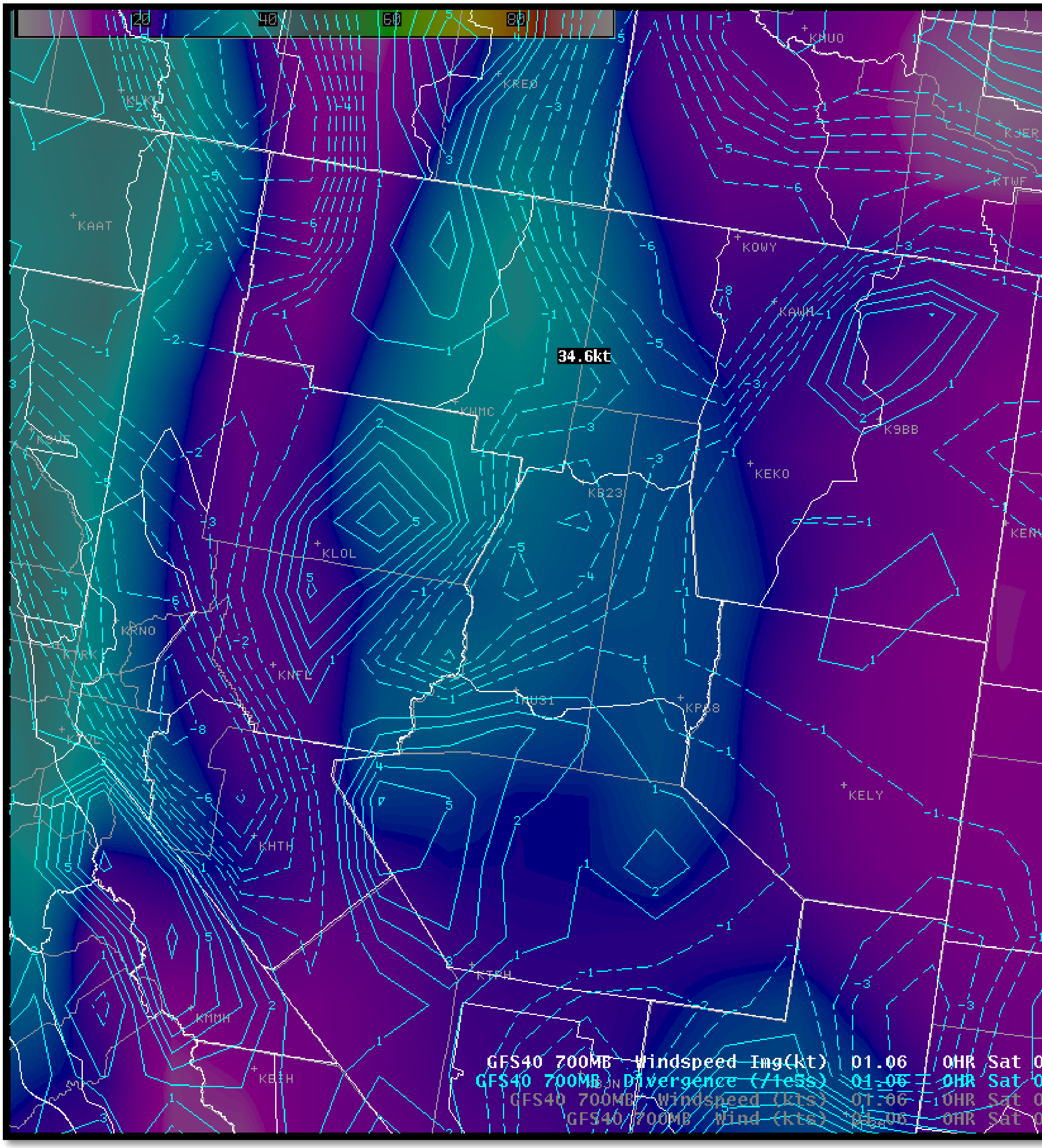

Figure 10: Same as Fig. 8, but valid at 06Z on 1 Oct 2011.

c. Soundings

The forecast soundings from the 12Z model runs on 30 Sep show that the best instability existed across parts of east-central NV (ELY/P68 area) and northeastern NV (AWH area). Convective available potential energy (CAPE) values were expected to be between 200 and 400 J/kg in these areas by 21Z (Tables 2 and 3). WMC (Winnemucca) is near the southwestern edge of FWZ 468, while AWH and EKO are near the northeastern and southeastern corners, respectively. Also, looking at SPC's mesoanalysis data, the CAPE in FWZ 468 at 21Z was likely between 200 and 350 J/kg, roughly (Fig. 11). This amount of CAPE, combined with high convective condensation levels (CCLs) between 500 and 550 mb, yielded a good environment for dry thunderstorms. The height of the forecast cloud base at Wildhorse, NV can be seen in the image below (Fig. 12).

Lastly, the bulk of the CAPE can be found in the -10° to -40° C layer, which is favorable for electrification. According to Bright et al. (2004), the convective updraft must be strong enough to ensure supercooled liquid water is replenished and graupel is lifted above the charge-reversal temperature zone (-15° C to -20° C). Bright provides three additional basic ingredients that help lead to electrification in cumulonimbus clouds. These include a lifting condensation level below the -10° C level, 100 to 200 j/kg CAPE in the 0° to -20° C layer, and an equilibrium level temperature colder than -20° C. The majority of the soundings in this event meet these criteria.

21Z NAM Bufr Sounding Data

	WMC	EKO	AWH	ELY	ENV	P68	TPH
PW	0.53	0.50	0.48	0.46	0.57	0.46	0.54
LI	0	-0.7	-1.2	-1.8	0.6	-1.4	-0.8
CAPE	123	224	270	388	93	358	95
CCL (mb)	528	517	530	530	535	519	535
CCL (ft msl)	17798	18413	17757	17798	17531	18290	17470
T	88	86	79	78	86	80	82
Td	27	26	28	27	32	25	27

Table 2: NAM Bufr sounding data from the 12Z model run on 30 Sep 2011 valid at 21Z. Red values indicate CAPE values between 200 and 400 J/kg. Acronyms are as follows: WMC=Winnemucca, NV; EKO=Elko NV, AWH=Wildhorse, NV; ELY=Ely, NV; ENV=Wendover, UT, P68=Eureka, NV; TPH=Tonopah, NV; PW=precipitable water.

21Z GFS Bufr Sounding Data

	WMC	EKO	AWH	ELY	ENV	P68	TPH
PW	0.54	0.65	0.54	0.61	0.64	0.52	0.6
LI	1.5	-0.5	-0.8	-1.1	0.7	-0.2	0.7
CAPE	13	204	223	319	82	192	0
CCL (mb)	497	538	536	547	529	540	523
CCL (ft msl)	19274	17203	17244	16691	17675	16978	17839
T	89	86	81	80	88	77	81
Td	26	30	28	31	32	29	27

Table 3: Same as Table 2, but for the GFS model.

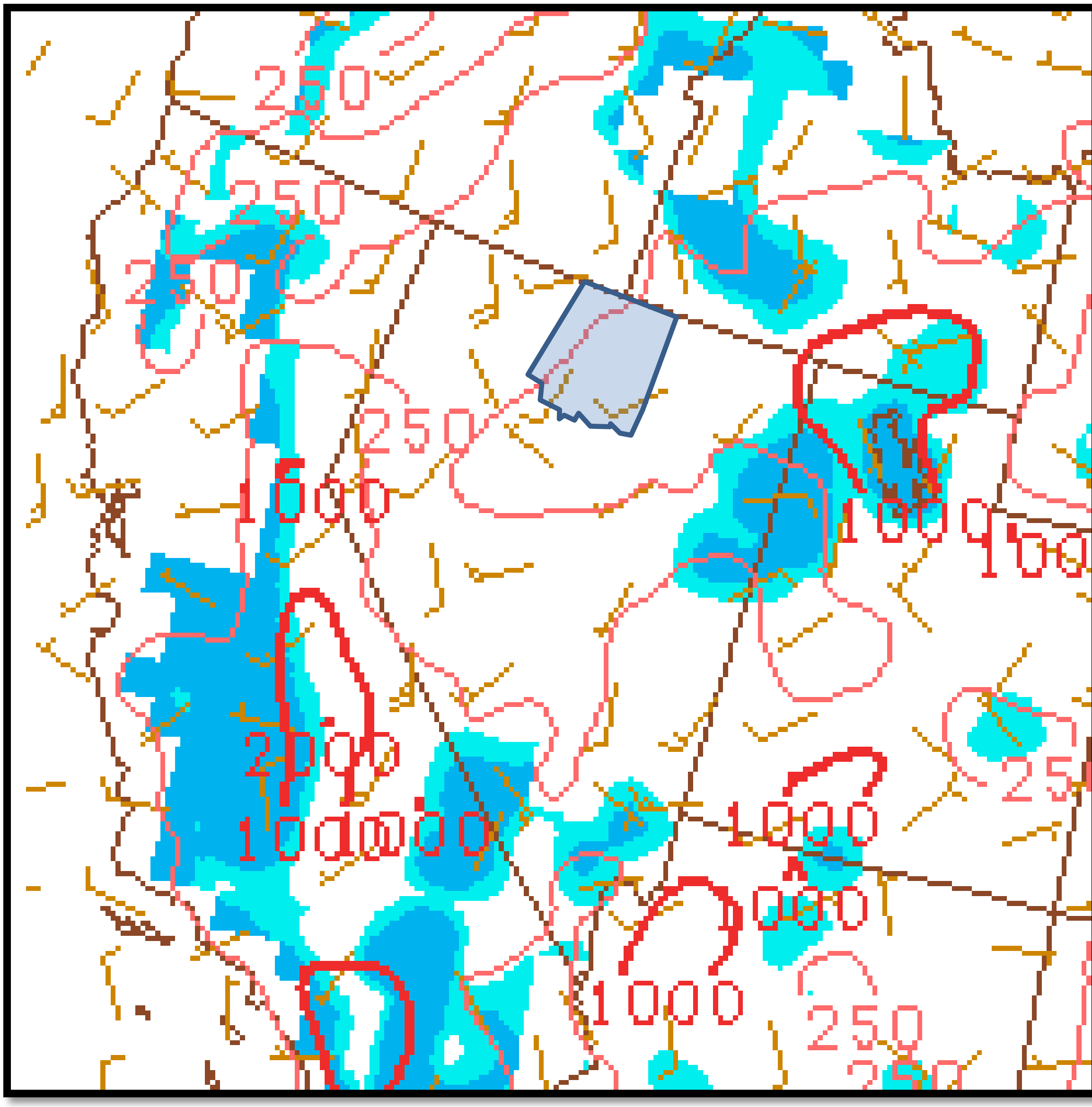

Figure 11: SPC mesoanalysis graphic for SBCAPE in J/kg (contours) and CIN in J/kg (light blue shading is 25-100 and darker blue shading is >100 J/kg). The blue polygon is the approximate location of FWZ 468.

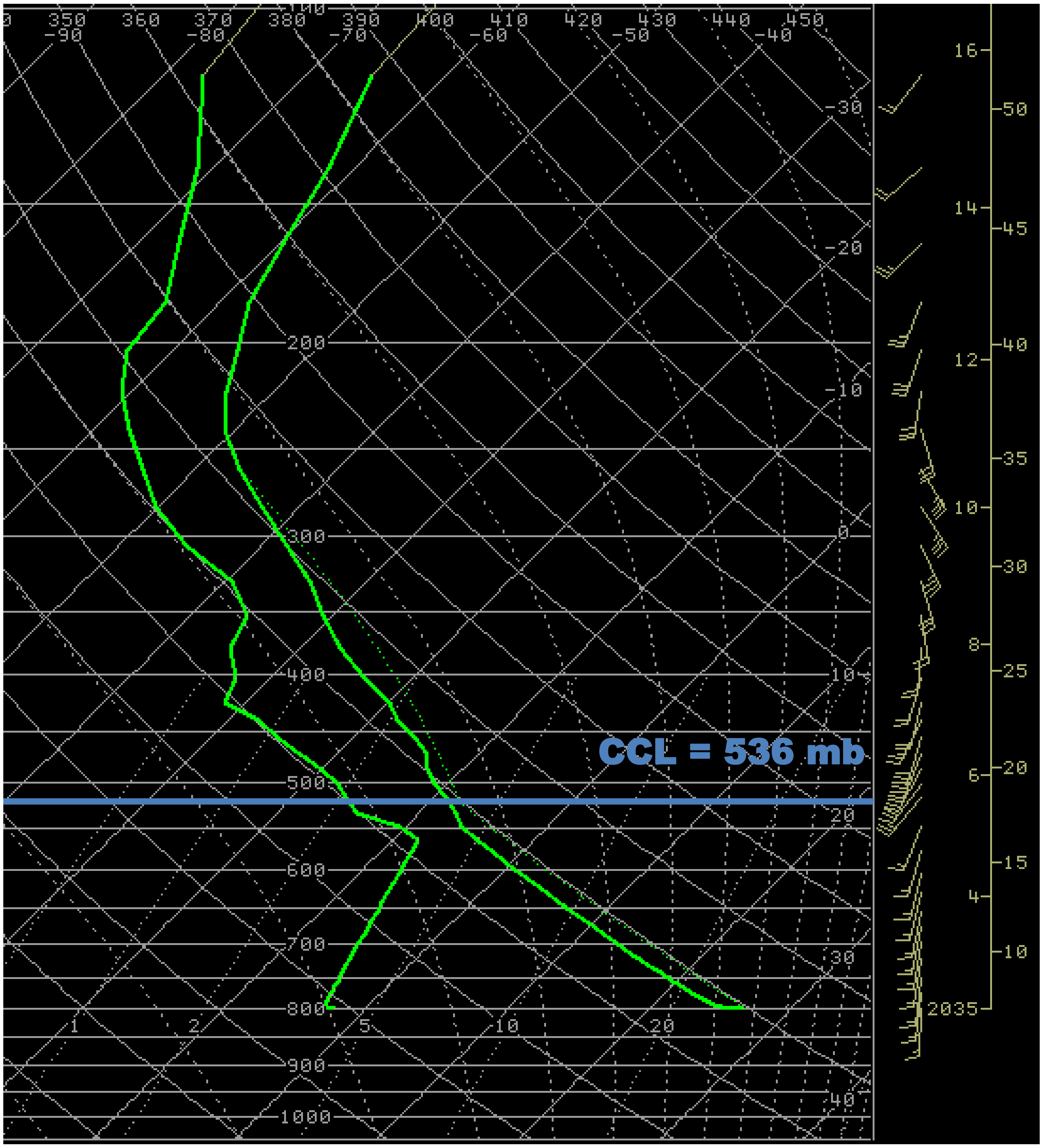

Figure 12: GFS Bufr forecast sounding from the 12Z run on 30 Sep 11 valid at Wildhorse, NV (AWH) at 21Z.

4. Fire Weather Indices:

Looking at the high level total totals index (HLTT) valid at 00Z on 1 Oct (Fig. 13), the values ranged from 28 to 34 across the area with the highest values in White Pine County. Across FWZ 468, values ranged from 28 to 32, and then increased slightly to 30 to 32 by 06Z (Fig. 14). HLTT has been found useful for forecasting dry thunderstorm outbreaks across western NV (Milne, 2004). HLTT values between 31 and 32 have been found to promote isolated to scattered thunderstorms (Table 4).

Favorable summertime PW values for dry thunderstorms across central and northern NV have been found to be between 0.50” and 0.75” based on local rules of thumb at NWS Elko. For this event, the PWs were generally between 0.50” and 0.60”.

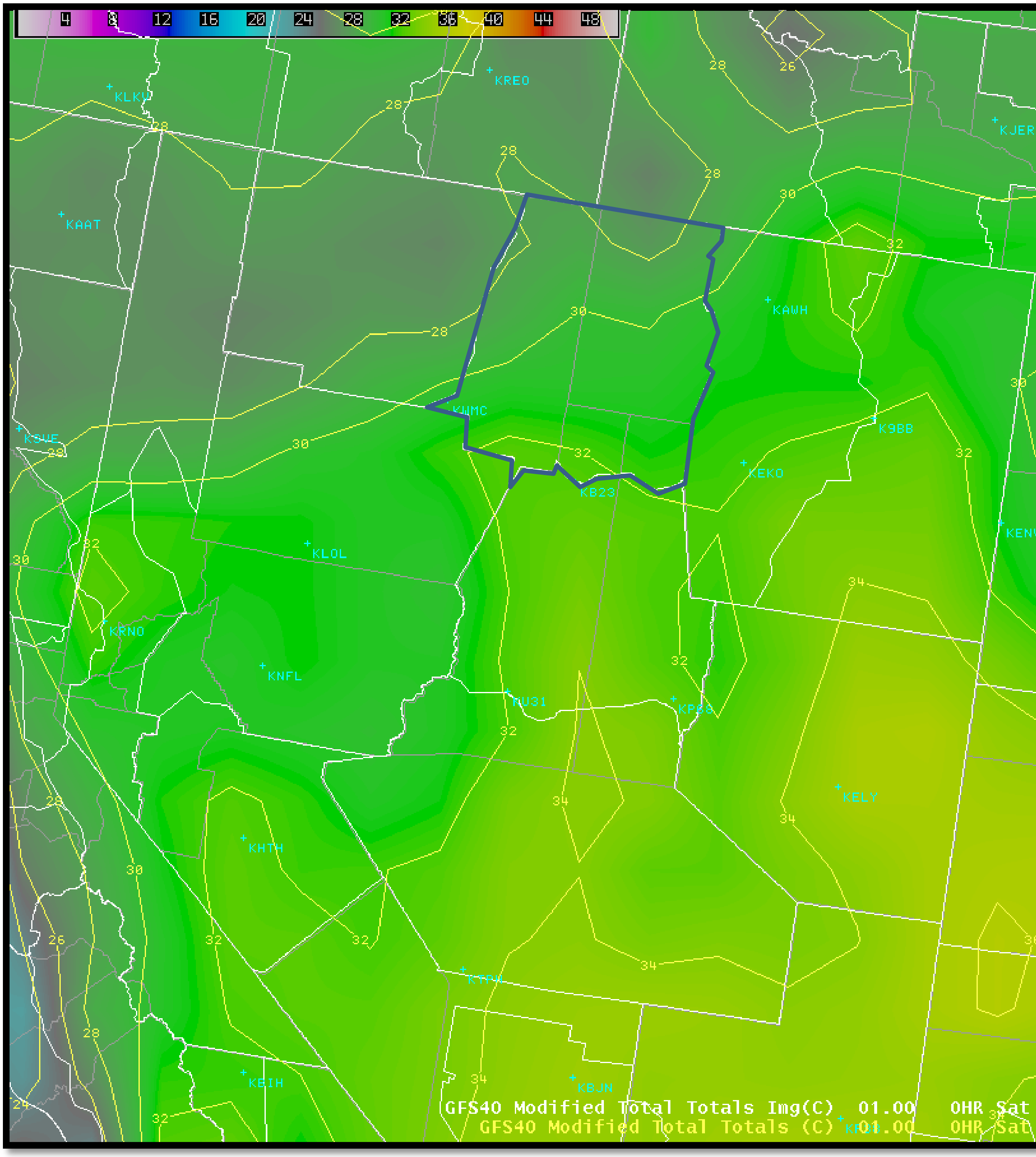

Figure 13: GFS analysis of the high level total totals index valid at 00Z on 1 Oct 2011. The blue polygon is the location of FWZ 468.

Other parameters examined include the Haines index, storm motion, 500-300 mb lapse rate, and the PV anomaly. The Haines index was five based on the GFS analyses. The moisture parameter yielded a two in the calculations. A Haines value of five indicates a moderate potential for large fire growth. Based on the GFS model's 00Z analysis, the estimated storm motion (3-6 km wind) across the NWS Elko forecast area ranged from south at 15 kts in the east to south at 35 kts in

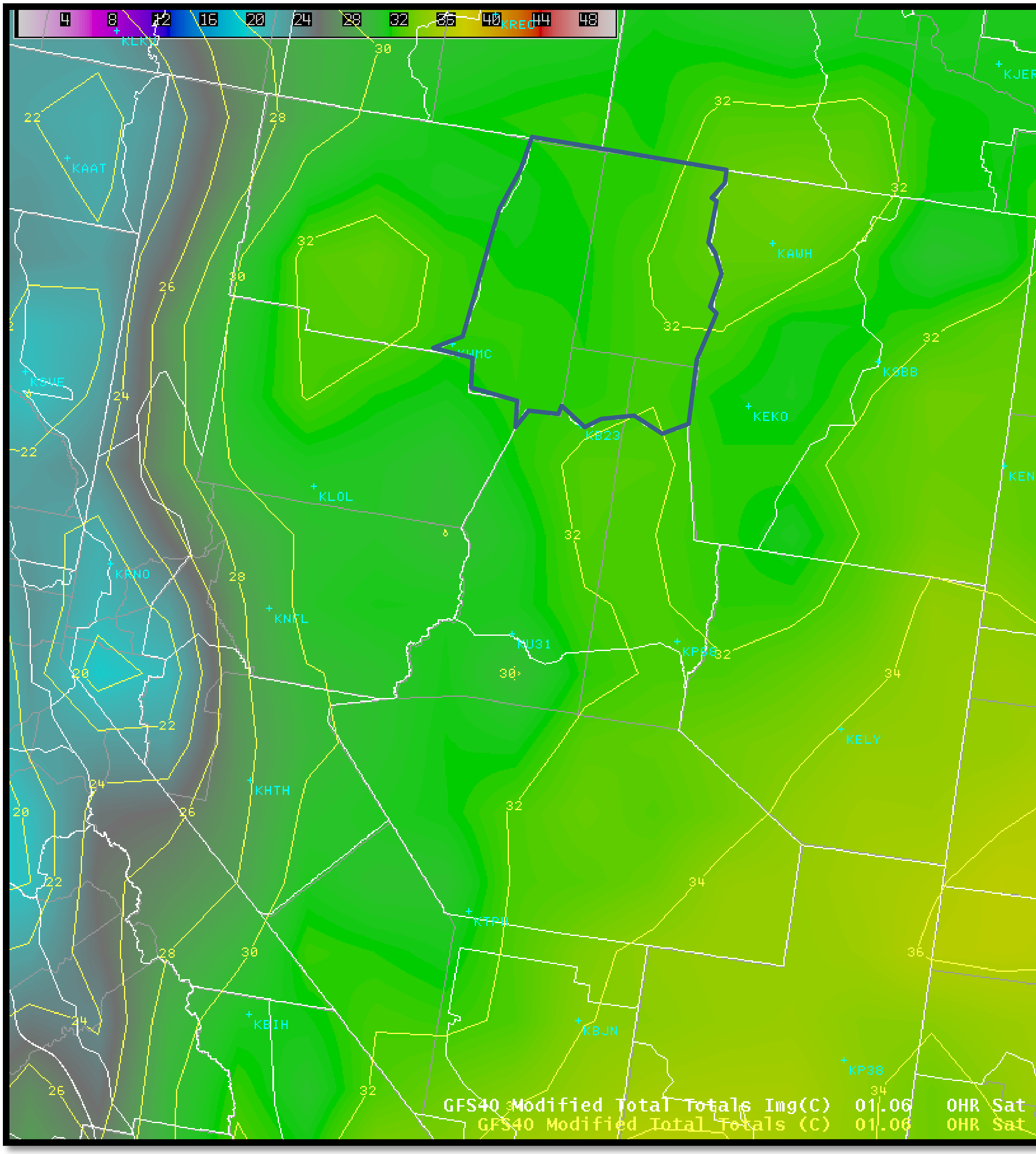

Figure 14: Same as Fig. 15, but valid at 06Z on 1 Oct 2011.

the west. Over FWZ 468, the estimated storm motion was analyzed by the GFS being from the south at 25 kts. Also, the 500-300 mb lapse rate was analyzed to be 7.5 to 8 deg/km across the region at 00Z. Lastly, there was a weak PV anomaly associated with the short wave that pushed across the region between 00Z and 06Z (Fig. 15).

Forecast	High Level TT
Isolated thunderstorm possible	28-29
Isolated thunderstorms	29-30
Isolated to scattered thunderstorms	31-32
Scattered to numerous thunderstorms	>= 33

Table 4: Table from Milne (2004) describing relationship between thunderstorm coverage and HLTT.

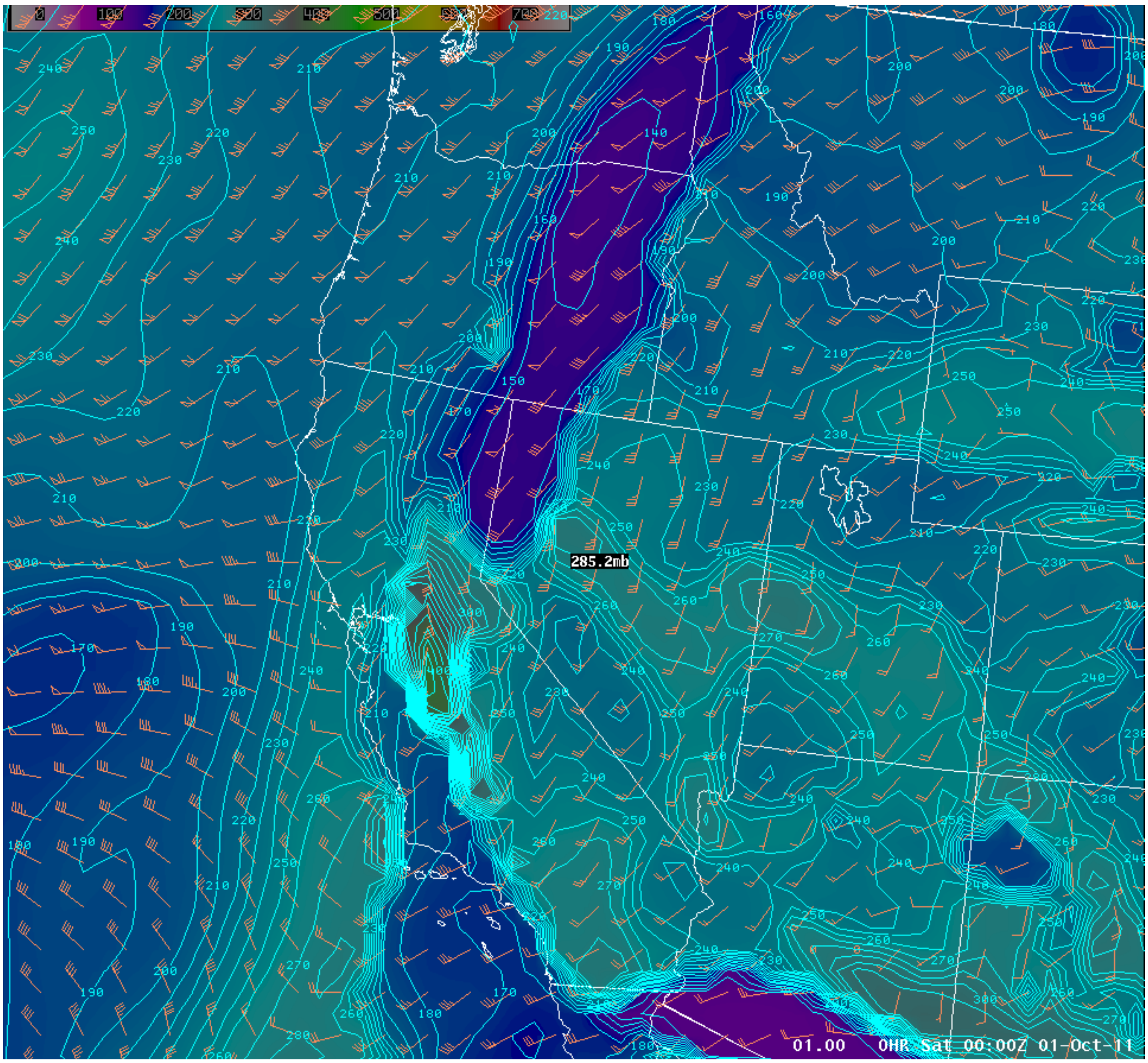

Figure 15: GFS analysis of pressure and wind on the potential vorticity 1.5 surface valid at 00Z on 1 Oct 2011.

5. Surface Observations:

In general, the observations in FWZ 468 had marginal RFW conditions due to winds and relative humidity. While most of the FWZs had gusty winds that day, the strongest gusts were primarily due to thunderstorm outflow winds and were short-lived. Wind gusts were generally in the mid 20s to mid 30s (mph) during the afternoon hours, but gusts as high as 60 mph were observed at some RAWS sites. Again, minimum RHs were in the upper single digits to mid-teens across the forecast area.

6. Antecedent Conditions:

Another contributing factor to the severity of this event was the fact that September was dry and hot across northern NV. Winnemucca, in the southeastern corner of FWZ 468, had the seventh warmest September on record. Elko, just east of FWZ 468, had the fifth warmest September on record. Precipitation was also limited in September with Elko receiving 0.38" of rain (0.19" below the normal value of 0.57") and Winnemucca receiving 0.15" of rain (0.29" below the normal value of 0.44").

As a result of the dry conditions, the relative greenness was below normal (Fig. 16) compared to the 1989-2003 average. Also, the fire danger was in the "Very High" to "Extreme" category across FWZ 468 (Fig. 17). These extraordinarily dry and warm conditions likely resulted in a more favorable environment for fuel ignition due to lightning.

7. Post-event Winds:

Another aspect that made this event unique was the magnitude of the surface winds after the event. The low level (700 mb) flow from the 1st through the 4th of Oct was 15 to 30 kts from the southwest (Fig. 18). These winds mixed down every afternoon, resulting in winds of 12 mph gusting to 23 mph on average (Table 5).

A cold front moved through the area on 5 Oct, shifting winds to the northwest. Winds ahead of the front increased from the southwest on the 5th, while winds behind the front on the 6th were gusty from the northwest during the afternoon hours also. MODIS imagery before and after the event can be found in Figures 19 and 20, respectively, and indicate the extent of the burn scars.

8. Societal Impacts:

As previously mentioned, many fires were started by this lightning outbreak. The largest of which was the Indian Creek fire, which topped 110,000 acres before being contained. The city of Tuscarora was threatened by the Indian Creek fire and a mandatory evacuation was enforced for one night. A few older buildings and an RV were destroyed. In addition, a number of livestock were lost at nearby ranches. With all fires combined, more than 200,000 acres were burned over the next week, as the fires were partially driven by the strong winds.

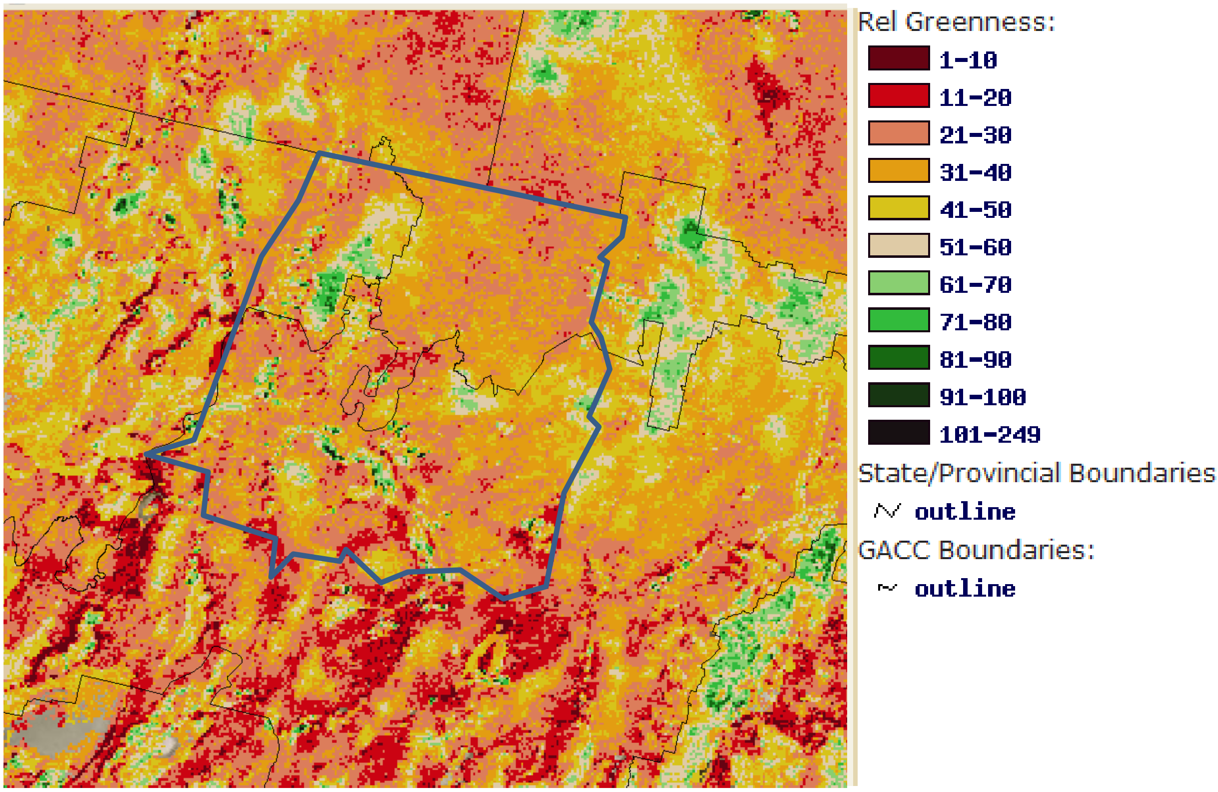

Figure 16: The U.S. Forest Service Wildland Fire Assessment System's Relative Greenness analysis valid on 30 Sep 2011. The blue polygon is the approximate location of FWZ 468.

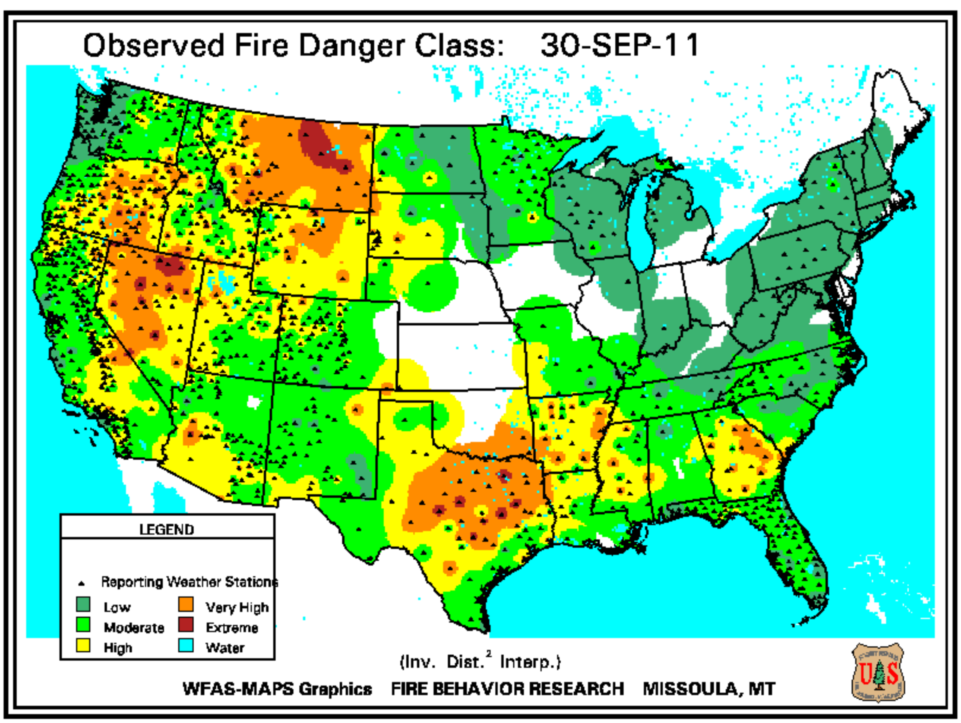

Figure 17: The U.S. Forest Service Wildland Fire Assessment System's Observed Fire Danger Class valid on 30 Sep 2011. FWZ 468 was in the "Very High" to "Extreme" category.

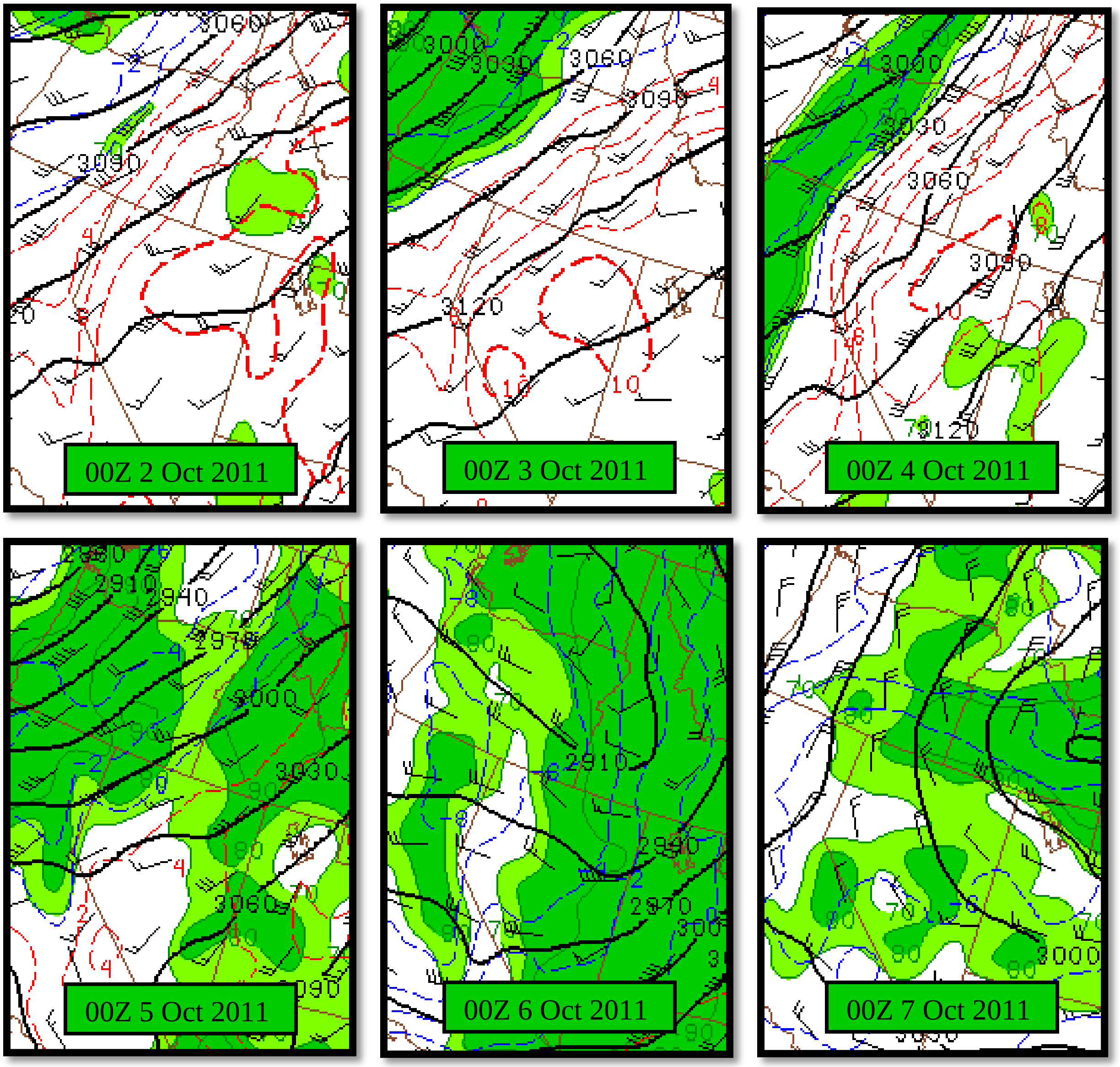

Figure 18: A mosaic of 00Z 700 mb analyses from 2 Oct (upper left) through 7 Oct (lower right). Light green shading begins at 70% RH and dark green shading begins at 80% RH. Black lines are geopotential heights (m), wind barbs are winds in kts, and red/blue lines are temperatures (C).

Oct 1-4th	wind speed (mph)	wind gust (mph)
03Z to 17Z	7.1	16.2
18Z to 02Z	12.2	22.8

Oct 5-6th	wind speed (mph)	wind gust (mph)
03Z to 17Z	5.9	11.7
18Z to 02Z	13.3	25.1

Table 5: Average winds for the period indicated for RAWS sites in FWZ 468. (The 00Z-02Z observations are technically on the next day in Z time.)

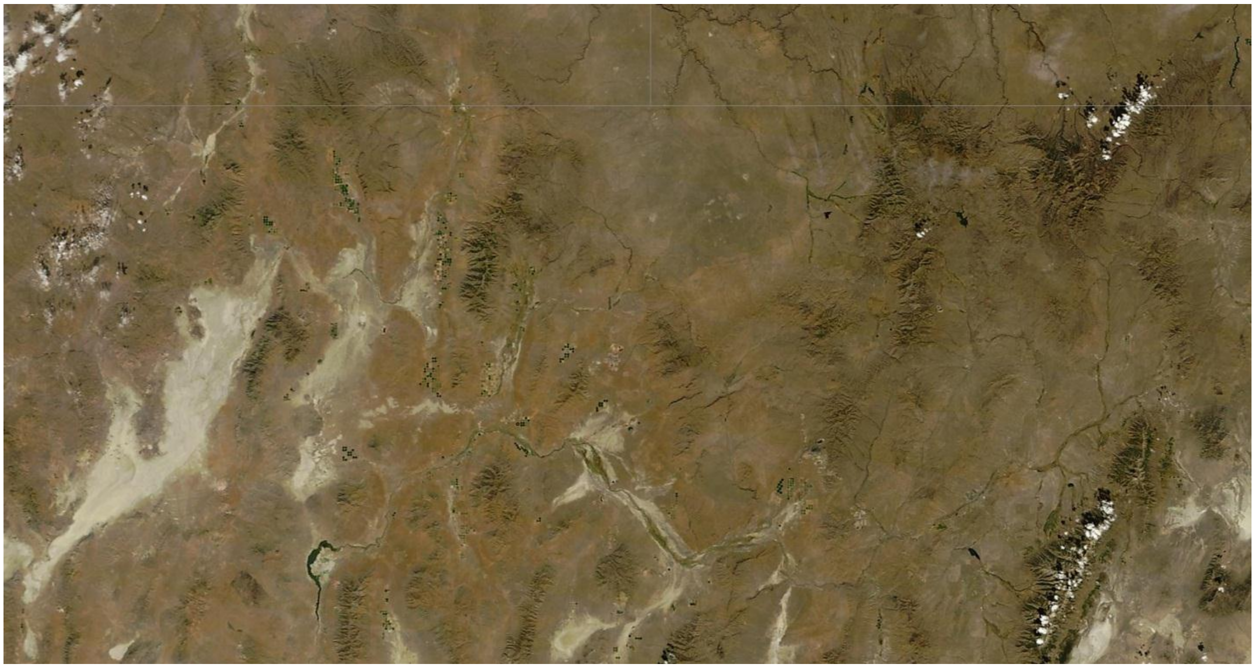
Figure 19: MODIS satellite imagery before the event.

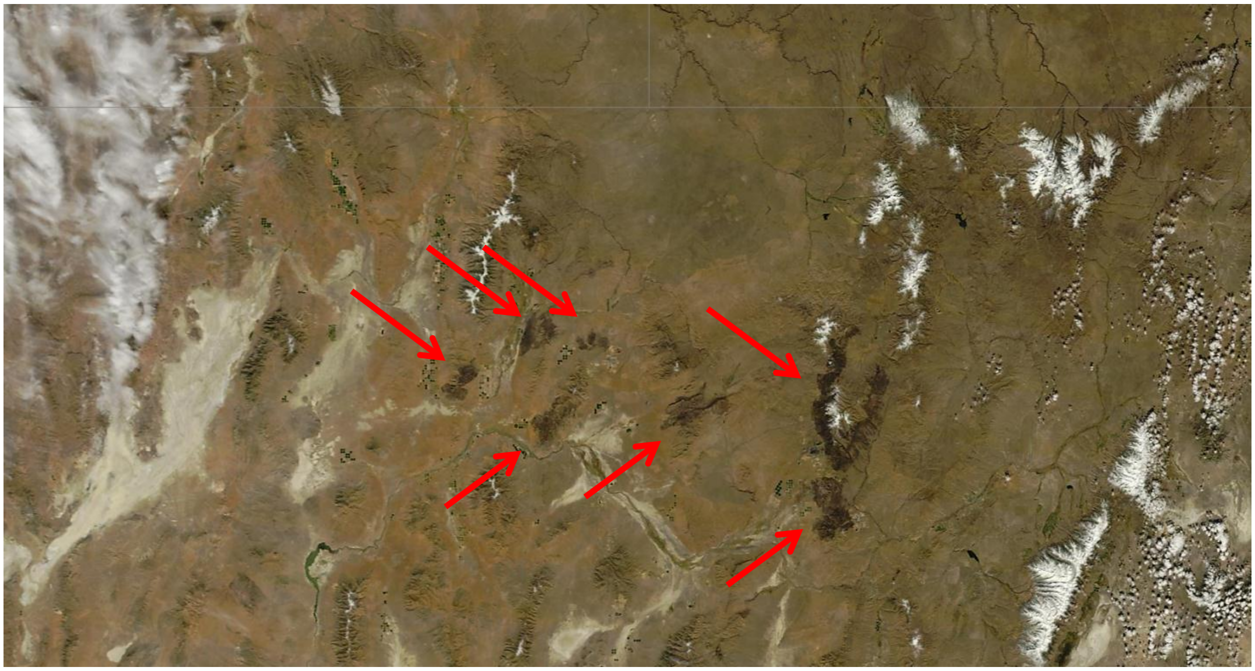
Figure 20: MODIS satellite imagery after the event. Burn scars are indicated by the red arrows.

9. Conclusions:

The thermodynamic environment in place for this event was not that unusual for a summer day in NV. However, it was early fall so the values were well above average. CAPE around 200-350 J/kg and CCLs of 550 mb or higher in the atmosphere are good conditions for dry thunderstorms based on local rules of thumb.

This event had two subtle features. The first was the influence of the weak shortwave approaching from the southwest. The weak PV anomaly indicated that there was some upper support over north-central NV during the evening hours. This upper support provided additional lift after 00Z, helping to enhance the convection. The low level jet and associated area of convergence also aided in thunderstorm development. This area of convergence shifted north-northeastward during the evening hours. The instability parameters and CCL heights were rather clear that high-based thunderstorms were likely that day. However, uncertainty existed with the amount of coverage.

Lastly, the post-event winds played a big role in increasing the amount of acres burned over the next several days. Afternoon winds from the 1st through the 6th averaged 12 to 16 mph with gusts to around 25 mph.

To summarize, this event highlights that forecasters should examine:

1. Forcing – Often the primary difference between typical isolated dry thunderstorms and scattered dry thunderstorm outbreaks is that there are some key features of support that help promote the increased coverage of convection. Key features to look for include low level forcing (low level jet, frontogenesis, etc.) and upper support (PV anomaly, jet dynamics, etc.). In addition, cloud electrification should be considered by viewing upper level instability and temperatures.
2. Instability - CAPE around 200-350 J/kg and CCLs of 550 mb or higher in the atmosphere are good conditions for dry thunderstorms based on local rules of thumb.
3. Fuels – Abnormally dry conditions will increase the chance of lightning strikes starting new fires.
4. Post-event conditions – Prolonged increased wind following a dry lightning event will result in an increased threat for larger impacts due to the persistent and rapid spread of the fire.

10. References:

Knutsvig, R, 2008: LightningTools: Accessed from NWS Smart Tool Repository on 12/1/11. http://www.mdl.nws.noaa.gov/~applications/STR/generalappinfoout.php3?appnum=1249

Bright, D. R., M. S. Wandishin, R. E. Jewell, and S. J. Weiss, 2004: A physically based parameter for lightning prediction and its calibration in ensemble forecasts. Preprints, *22nd Conf. on Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc., 4.3. http://ams.confex.com/ams/pdfpapers/84173.pdf.

Milne, R, 2004: A Modified Total Totals Index for Thunderstorm Potential Over the Intermountain West. Western Region Technical Attachment No. 04-04 http://www.wrh.noaa.gov/wrh/04TAs/ta0404.pdf.