6.8 FIRE WEATHER ASSOCIATED WITH THE NEW MEXICO (USA) JUNE 2012 LITTLE BEAR FIRE, LINCOLN NATIONAL FOREST, NEW MEXICO

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ABSTRACT: The lightning-ignited Little Bear (LB) Fire began June 4, 2012 on the Lincoln National Forest (LNF), Smokey Bear Ranger District (SBRD) in south central New Mexico in the Sierra Blanca Mountains, within the White Mountain Wilderness, above the town of Ruidoso. The fuels were mixed conifers and thick, high elevation mountain grasses in very steep, rocky terrain. After several days of mostly steady, successful fire suppression by ground forces, the fire exhibited extreme fire behavior and large fire growth on June 8, 2012. Due to high nighttime temperatures, abrupt surface drying, and strong, gusty winds, the fire escaped their control lines by means of single tree and group torching lobbing hot embers into receptive unburned fuel beds, in spite of aggressive suppression actions to contain these spot fires. The author hypothesizes that the dramatic and intense downhill and downslope fire behavior that followed was the result of "vorticity-driven lateral spread" and fire channeling described in Australian fire weather literature.

Dynamic dry intrusions and dry slot signatures were clearly visible on the satellite water vapor imagery (WVI) prior to the fire's escape and throughout its dramatic intense downslope fire behavior. These signatures are fairly well known to cause abrupt surface to near-surface drying and strong gusty winds as well as Haines 5/6. The Southwest area had experienced a prolonged drought.

On June 8th, a NOAA National Weather Service (NWS) Fire Weather Outlook had called for 'critical fire weather' in the Southwest with an approaching lee surface trough accompanied by a dry cold front. The forecaster(s) also acknowledged the "*deamplification*" of the persistent high pressure ridge affecting the fire; however, they failed to emphasize this fire weather phenomenon – the Breakdown of the Upper Ridge - recognized and accepted as one of the "*critical fire weather*' patterns in the United States (U.S.).

The nearby ROMAN RAWS readings and atmospheric skew-T soundings verify the satellite WVI signatures; and also reveal a history of high nighttime temperatures, low relative humidity and dew points, and strong, gusty winds that likely contributed to the extreme downslope fire behavior.

From the perspective of a wildland fire supervisor, satellite WVI is discussed and emphasized as a valuable tool in the realm of operational wildland fire weather forecasting and fire suppression. The first of ten Standard Fire Orders is "*Recognize current weather conditions and obtain forecasts*." The concept of the *'alignment of forces'* of wind, terrain, preheating, and relative humidity espoused in the Campbell Prediction System (CPS) is examined. With high confidence, the author holds that the fire conveys to you how it's going to behave *almost* every time; you just need to pay attention to the indicators, and adjust your tactics and strategy accordingly. Also discussed is the 1962 fire weather and fire behavior theory by Robert Bates that attributes high nighttime temperatures to extreme wildland fire behavior the day *following* the highest nighttime temperatures.

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1. INTRODUCTION and BACKGROUND:

1.1 The lightning-ignited LB Fire began 4 June 2012 in the White Mountain Wilderness of the LNF in south-central New Mexico (Fig. 1) and was initial attacked by the local Mescalero BIA Helitack Crew, and estimated at one-quarter acre in size. And yet amazingly, Ruidoso, NM public information officer (PIO) Kerry Gladden would declare in a news session: "*Based on fire acreage and conditions, we're not expecting this to be a large, complex fire*" (Ruidoso News 2012). This would later prove to be dreadfully inaccurate. The Sacramento Hot Shot Crew (IHC) and SBRD Engine Crew were also ordered and together with the Mescalero Helitack Crew, worked the fire for several days. During that time, the fire, still within its containment lines, grew to four acres burning in very steep and rocky terrain, on a northern aspect in heavy mountain grasses and dense mixed conifer fuels (Figs. 2 and 3).

The Sacramento IHC, while on the fireline on 8 June, frequently faced single digit relative humidities (RH) and stout, steady winds throughout the preceding night despite contrary Remote Automated Weather System (RAWS) data in Ruidoso indicating slightly higher RH's and less wind. Now 8-9 acres, the fire further increased intensity due to worse weather conditions that morning, e.g. very low RH's and strong downslope winds. Single tree torching led to group torching down low on the fireline, resulting in several long-distance spot fires over the ridge and beyond the IHC's position into the tall, thick cured grass. "*Between 1300 and 1400*" MDT, with very low RH, the fire behavior and spotting further intensified and the fire aggressively swept into the dense conifer thickets and very heavy dead and down fuels growing to 100 acres. The LB Fire intensity increased exponentially due to a combination of diurnal heating and drying, and strong downslope winds, Barone (2013). It eventually burned 44,330 acres total, destroyed 242 houses and commercial buildings, and was 95% contained on 30 June 2012.

Fig. 1. New Mexico map – Smart Traveler info

Fig. 2. Google earth image of LB Fire location

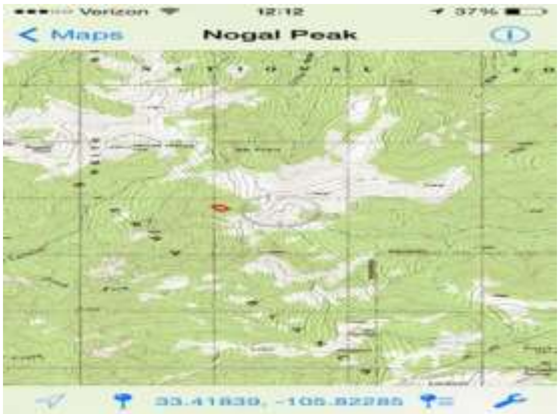


Fig. 3. LB Fire location topographic map; Matt Barone – Sacramento IHC

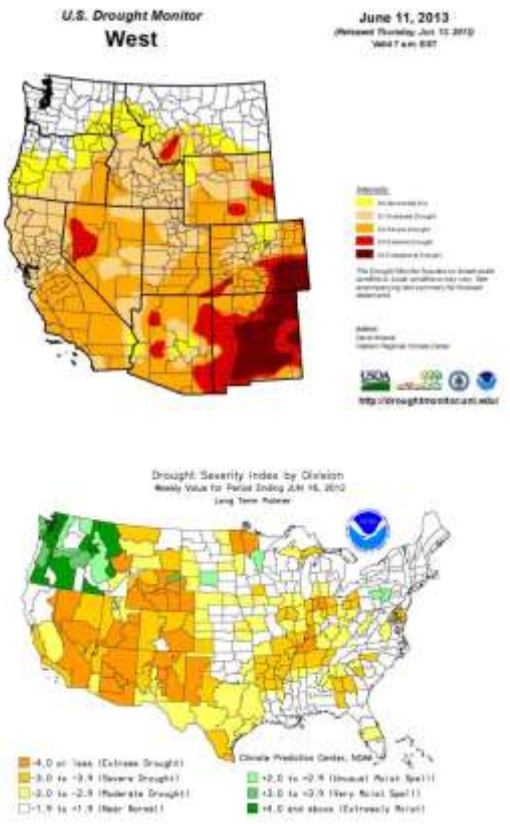


Fig. 4. U.S. Drought Monitor Western Region for 5 June 2012 (top); NOAA/NWS/NCEP/CPC Drought Severity Index ending 16 June 2012 (bottom); CPC, NOAA

Mountain snowpack data for the 2012 season (January to April) revealed an average to above average snowpack from January to March. The April snowpack dissipated fairly quickly (Fig. 6). Snowpack is important for maintaining high soil and fuel moistures which reduce the size and intensity of wildland fires. Lack of winter moisture leads to low soil moistures. Low soil moisture has been found to influence "*not only the surface but the entire lower atmosphere*," Fast and Heilman (1996).

The U.S. Drought Monitor map from 5 June 2012 revealed that the LB Fire area was in severe to extreme drought (Figure 4 - top.), substantiated on the Drought Severity Index map ending 16 June 2012 (Figure 4 - bottom).

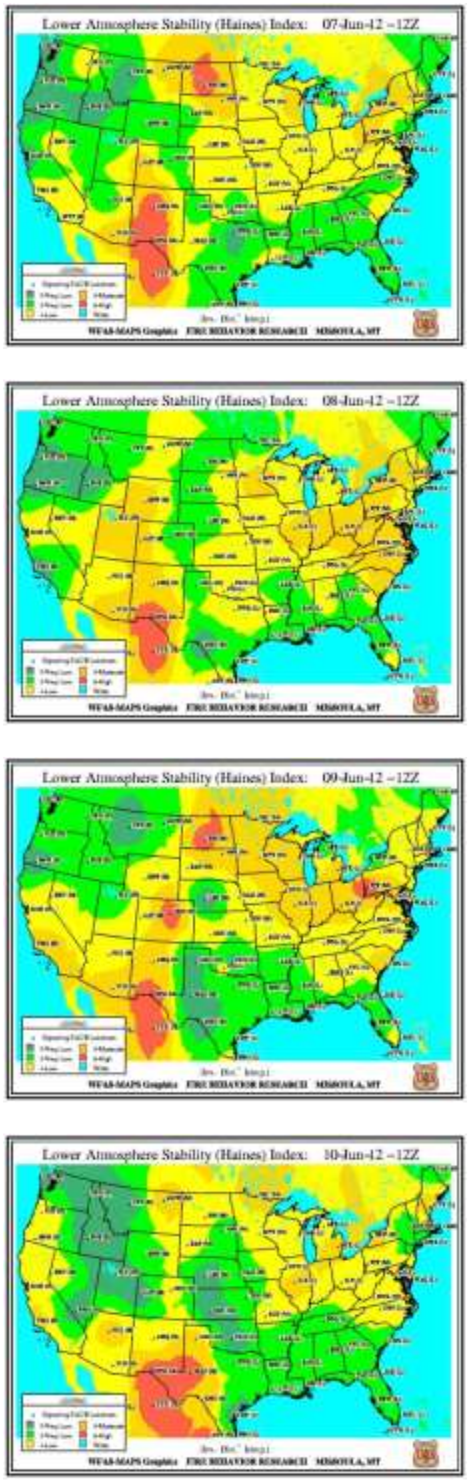
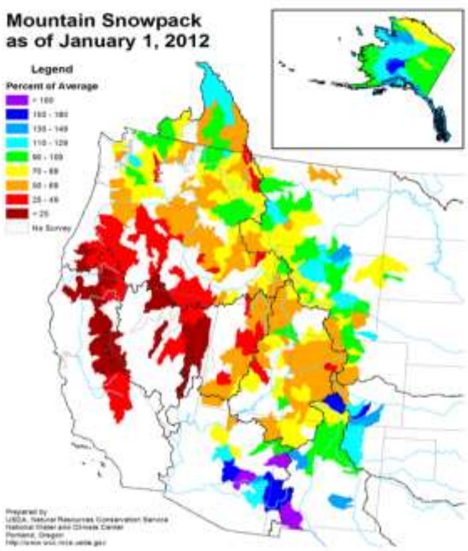


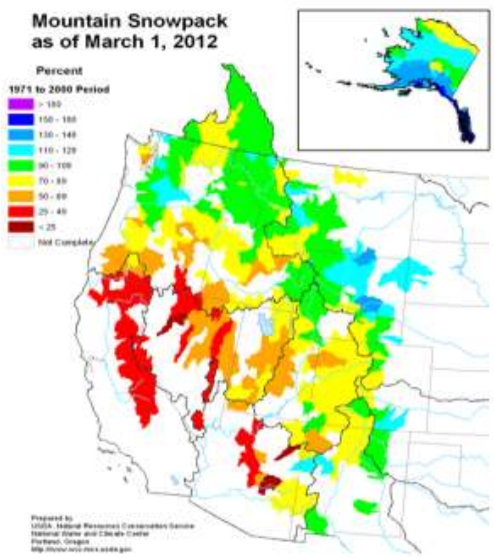
Fig. 5. Lower Atmospheric Stability (Haines) Index; 12Z from 7-10 (top to bottom) June 2012; WFAS-MAPS Fire behavior Research, Missoula, Montana

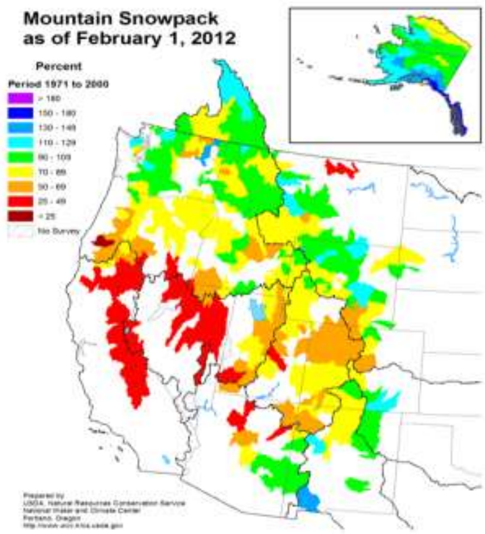
ANALYSIS OF FIRE AND WEATHER CONDITIONS AND FIRE WEATHER INDICATORS

a. Lower Atmospheric Stability (Haines) Index

The Lower Atmospheric Stability (Haines) Index revealed that the LB Fire area was in the Haines 5-6 range from 7-10 June 2012. The Haines Index is an atmospheric index used to indicate the potential for wildfire growth by measuring the stability and dryness of the air over a fire, calculated between 950-850mb, 850-700 mb, and 700-500 mb levels. A Haines of 2-3 is very low, Haines 4 is low, Haines 5 is moderate, and Haines 6 is high. Fires exhibit large fire growth and extreme fire behavior in Haines 5 and 6, Haines (1988) (Fig. 5).







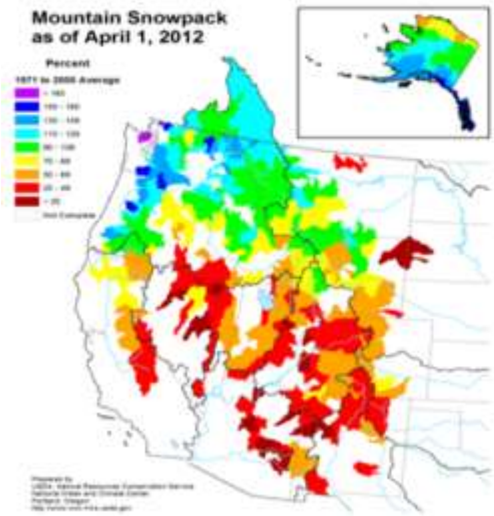


Fig. 6. Mountain snowpack maps for Western U.S. January to March 2012. USDA NRCS NWCC

b. Fire weather outlooks

The following five (1-5), 6 June to 8 June 2012 Fire Weather Outlooks indicated the synoptic weather that was forecast. The forecaster(s) maintained there were "*no critical areas*" and that the overall fire threat was low, needing no highlights. The forecaster(s) recognized and acknowledged the "*amplified upper-level ridge over the Central CONUS will begin to break down*" and again the following day regarding the "*deamplification of the ridge*." However, this was never underscored in any of the Outlooks as one of the Critical Fire Weather Patterns of the U.S. responsible for large fire growth. They did accurately predict the "*critical fire weather for … the Four Corners Region*" which included the Little Bear Fire area at 0302 CDT Friday, June 08 2012, valid for the 8 June 12Z to 9 June 12Z forecast period. They also accurately predicted the 0303 CDT Friday, June 08 2012, valid for the 9 June 12Z to 10 June 12Z forecast period for strong "*southwesterly winds of 20-30 mph gusting to 45 mph, possibly stronger, in favored downslope areas"* and "*low relative humidity values from 10-15 percent except parts of Arizona and New Mexico where lower values from 6-10 percent were possible."*

(1) 0331 CDT Wednesday, June 06 2012, Valid 071200Z - 081200Z - No Critical areas. *An amplified upper-level ridge over the Central CONUS will begin to break down, aided by a strong shortwave trough through the broad trough over the Western CONUS*. The overall Fire Weather threat is "*low with no areas needing highlights at this time*." Increased Southwesterly flow is also expected across eastern AZ and western NM but wind speeds should remain at or below 15 mph.

(2) 0306 CDT Thursday, June 07 2012, Valid 071200Z - 081200Z. A shortwave trough set within a mean trough over the Western CONUS was aiding in the *deamplification of the ridge* which has persisted over the Central CONUS for most of the week.

(3) 0159 CDT Friday, 8 June 2012, Valid 091200Z – 101200Z. A lee surface trough will strengthen the winds and downslope flow will contribute to steepening the low level lapse rates and the deeply mixed boundary layer.

(4) 0302 CDT Friday, June 08 2012, Valid 081200Z - 091200Z. Critical fire weather conditions are expected for parts of the Great Basin and the Four Corners Region.

(5) 0303 CDT Friday, June 08 2012, Valid 091200Z - 101200Z. Expect southwesterly winds of 20-30 mph gusting to 45 mph, possibly stronger, in favored downslope areas. RH values generally will range from 10-15 percent except parts of AZ and NM where lower values from 6-10 percent are possible.

Source: Storm Prediction Center Archive Fire Weather Outlooks

c. Critical fire weather patterns in the U. S.

The Breakdown of the Upper Ridge is one of the Critical Fire Weather Patterns in the U.S. first identified by M. J. Schroeder and others in their 1964 research on the '*Synoptic Weather Types Associated With Critical Fire Weather*.' In 1966, Hull, O'Dell, and Schroeder also researched the *'Critical fire weather patterns—their frequency and levels of fire danger*.' In 1966, critical fire weather patterns were again emphasized by E. Brotak in 1977 in '*An Investigation of the Synoptic Situations Associated with Major Wildland Fires,*' focused in the Eastern U.S. In 1983, Canadian Nicholas Nimchuk researched '*Wildfire Behavior Associated With Upper Ridge Breakdown*.' And once again these critical fire weather patterns were examined in a 1999 National Weather Service Fire Weather Forecaster's Workshop in Boise, ID in '*Critical Fire Weather Patterns of the U.S*.' More recently, the Critical Fire Weather Patterns in the U.S. were again emphasized by Werth in fire weather research on the fatal 5 August 1949 Mann Gulch Fire near Helena, MT when 12 smokejumpers and a local firefighter were burned over and died (2007),

Fig. 7. Breakdown of the Upper Ridge, NWS 1999

The elements of the Breakdown of the Upper Ridge are as follows: (a) a short wave trough is approaching, trailed by breakdown/eastward shift of an upper ridge (Fig, 23 and 24); (b) Moderate (5) or High (6) Haines Index, either currently over the fire site or expected to be advected over the area (Fig. 5); (c) a surface thermal trough over or just west of fire (Fig. 13 and 18); (d) tongue(s) of dry air (WVI dry slot and/or dry intrusion) (Fig. 8 and 20); and (e) a subtropical jet (WVI 250 mb analysis) (Figs. 12 and 26). All of these fire weather signatures and elements were present from 7-10 June 2012 resulting in intense and extreme fire weather, including severe downslope winds, which led to intense fire behavior and large fire growth on the LB Fire from 8-10 June 2012.

3. WILDLAND FIREFIGHTING RULES AND GUIDELINES

a. Ten Standard Fire Orders and 18 Watch Out Situations

Safe, effective firefighting is accomplished by following what I call '*The Rules*.' We must know and then strictly follow the Ten Standard Fire Orders. We must also know, observe, heed, and then mitigate the 18 Watch Out Situations, NWCG (2014). One can violate 'The Fire Orders,' however; one <u>cannot</u> violate the 18 Watch Out Situations; only fail to know, recognize and mitigate them as they occur. The first of the Ten Standard Fire Orders deals strictly with the weather, because intuitively weather determines and influences fire behavior, i.e. "1. *Keep informed on fire weather conditions and forecasts*." The third Fire Order logically follows since weather definitely influences fire behavior, i.e. "*Base all actions on current and expected behavior of the fire*." Therefore, if you know the fire weather for your operational period, you should be able to have action plan(s) that will account for not only the current fire behavior, but also the *expected* fire behavior. Expected fire behavior is what catches most wildland firefighters off-guard. Scores of wildland firefighters have been burned over and/or killed by failing to comprehend the forecast fire weather, and then anticipate and plan for the *expected* fire behavior that ensues, Wildland Fire LLC (ongoing).

There are three of the 18 Watch Out Situations that deal specifically with weather. Number four states: "4. *Unfamiliar with weather and local factors influencing fire behavior*." This one is of special import for those wildland firefighters that travel to other locations to fight fires. There are a nearly infinite number of local weather factors influencing severe fire behavior, e.g. Sundowner winds on the Los Padres National Forest near Santa Barbara, California, the similar abrupt and intense downslope winds near Reno and Carson City, Nevada and Boulder, Colorado, and the intense downslope winds and consequential fire behavior on the June 2012 LB Fire.

Watch Out Situation numbers fourteen and fifteen deal with the temperature, relative humidity and dew point, and winds. "*14.*

Weather is getting hotter and drier." It should be quite obvious that fires will burn more intensely on hot days. However, my intent in this paper is to focus on the high *nighttime* temperatures from midnight (0000) to 0600 LST. High *nighttime* temperatures regularly influenced the LB Fire from 8-10 June 2012. This fire weather causal factor will be discussed in more detail later in the paper.

And the '*drier*' prong should also be evident because drier air, with lower relative humidity and lower dew points, reduces the live and dead fuel moistures in vegetation (fuels) and that drying process allows the fuels to burn more readily and more intensely. Fine fuels respond on time-scales on the order of an hour to changes in atmospheric moisture, and drying can significantly increase the flammability of fuel. The very dry air showed both at the surface and aloft from 8-10 June 2012 radically influenced the fire behavior on the LB Fire as evidenced in the 8 June satellite WVI in Fig. 8 (a-d), the RAWS and skew-T soundings in Figs. 9-11, and the 8 June surface dew point depression contour maps (Fig. 31); and the 9 June satellite WVI in Fig. 20 (a-d), the RAWS and skew-T soundings in Figs 21-23, and the 8-12 June meteograms for 8-12 June, Figs. 30-32. The 8-9 June photographs in Figs. 16, 17, 24, and 25 reveal the fire behavior on each of those days.

"15. *Wind increases and/or changes direction*." From a localized, mesoscale perspective, this "wind" Watch Out should be fairly obvious. Among other things, wind adds oxygen to the fire making it burn more intensely, winds regulate the fire shape, wind causes the preheating of fuels to their ignition point ahead of the flaming front, and the stronger the wind, the faster the fire spreads. Most importantly, the upper to mid-level synoptic winds are very influential regarding extreme and erratic fire behavior, e.g. Mills (2008), Charney (2007) and Charney and Keyser (2010). Sharples (2007, 2009) noted that the wind plays a rather small part in determining the fire's microclimate and the effect regarding fine fuels, however, its largest role is in transporting warmer and drier air masses over the fuels, rather than directly influencing fuel moisture content. The LB Fire obviously was powerfully influenced by strong downslope and eddying winds from 8-10 June 2012.

Wildland firefighting is "inherently dangerous," HR 4488 (2010). Undeniably, wildand fires can be very unpredictable during extreme weather and fire behavior conditions; however, I have found that the fire actually *signals* what it's going to do in almost all cases. One merely has to pay attention to those indicators, heed those forewarnings, and adjust your tactics and strategy accordingly. Good, accurate, and timely fire weather forecasting and observations help to ensure that as well.

b. High Nighttime Temperatures

In 1962, former Tonto National Forest District Ranger Robert Bates performed a preliminary study of several large wildland project fires from 1951 to 1961. He recognized that "*the night before each of these fires blew up were unusually warm.*" Hence, Bates hypothesized that high nighttime temperatures adversely influenced fire behavior on wildland fires in the Southwest in his research titled, "*Blow-up Conditions in the Southwest?*" Bates theorized that the day following the highest nighttime temperatures, followed by a hot day, experienced the most active fires and produced the most extreme fire behavior.

Bates established some parameters and determined that nighttime temperatures above 45 degrees F were critical and above 55 degrees F were blow-up. Temperatures on the nights preceding the start or blow-up of these fires varied from a high of 81 degrees F in the semi-desert to 52 degrees F in the pines above the Mogollon Rim. The Mogollon Rim ranges from 7,000 to almost 8,000 feet in elevation. He noted these temperatures were "*unusually high*" for the particular areas. I have consistently utilized this principle for over 30 years now, and found it to accurately pertain elsewhere in the U. S., except in the Southeastern Region with higher relative humidity and dew point values. I applied these temperature levels to the LB Fire and found them to be very accurate predictors of extreme fire behavior following the high temperatures at night on the June 2012 LB Fire.

c. Alignment of Forces Principle

The Campbell Prediction System (CPS) (2010) utilizes an *Alignment of Forces Principle*. Campbell describes it as when "*fire that is moving across the variations of topography will change speed and direction as dictated by the combination of steepness of slope, wind speed and direction, and fuel preheat/flammability. Predictions of fire behavior changes can be made by observing the alignment and strength of these forces in the fire's path. Where the forces are more aligned, the fire intensity will increase. Where the forces are less agreeably aligned, the fire intensity will decrease*," CPS (2010). The Australians follow a somewhat similar model and refer to it as "*terrain-fire interactions*," referenced in the Sharples and McCrae research (2007, 2013) cited in this paper.

The LB Fire was heavily influenced by the Alignment of Forces when the relative humidity, wind, preheating, and terrain aligned and the fire, influenced by the weather factors, exhibited intense and extreme fire behavior. This was particularly the case from 8-10 June 2012 when it escaped containment; and influenced by low relative humidity and dew points, very strong downslope winds, and the fire channeling in when radically affected by lee slope eddying and rotors, roared downslope toward the towns of Angus and Ruidoso, Figs. 14-15.

4. WATER VAPOR IMAGERY, DRY INTRUSIONS, and DRY SLOTS

Dry slots originate in the mid- to upper-troposphere and lower-stratosphere and manifest themselves quite distinctly in the WVI, Mills (2008). If the thermal mixing zone around a fire is deep enough and a dry slot passes over the fire region, then the very dry air aloft can be mixed down onto the fire and can cause explosive 'blow-up' conditions, McRae (2007).

Testing the accuracy of this at-the-time, "*dry slot theory*," Mills (2008) proposed that the abrupt surface dryings observed at the Canberra and Port Lincoln weather stations were due to, (1) deep upper to mid-tropospheric subsidence that generated a layer of extremely dry air in the mid-troposphere that was then advected over the station areas affected by the abrupt surface drying, and (2), the mixing of this dry air to the surface mainly by dry convective mixing in a very deep mixed layer. In Mills' study, the influence of frontal circulations on the lower tropospheric part of this exchange process was also noted. Frontal circulations were not the case during the LB Fire from 8-10 June, Mills (2008).

U. S. Forest Service researchers Charney (2007) and Charney and Keyser (2010) have very perceptively stated the importance of the use of tools such as satellite WVI. They were intently researching "*atmospheric conditions aloft*" for establishing better and "*more accurate fire weather and fire behavior predictions*" specifically for those potentially extreme and erratic fire behavior stages (2007, 2010). They recognized the importance of such structures as dry slots "*predictable hours or even days in advance of the event*" (2007, 2010). In due course, they seek to "*develop and implement indices and diagnostics into the operational fire weather and fire behavior forecasting that sense these conditions and communicate to the forecasters and the operational users of fire weather prediction when and where the potential exists for extreme fire behavior*" (all emphasis added) (2007 and 2010).

A brief consideration of the causes, contributing factors, indicators, precursors, and outcomes of dry slots addressed by all the fire weather researchers is worthwhile. Dry slots are basically columns of high, fast moving, dry air that descend rapidly down to or near the Earth's surface, affecting surface drying and intensifying the winds in Mills (2010) and Werth (2012, 2014). Dry slots are both an indicator and a cause of reduced relative humidity and dew points, both drying the air and drying the receptive fuels thus enhancing the combustion process.

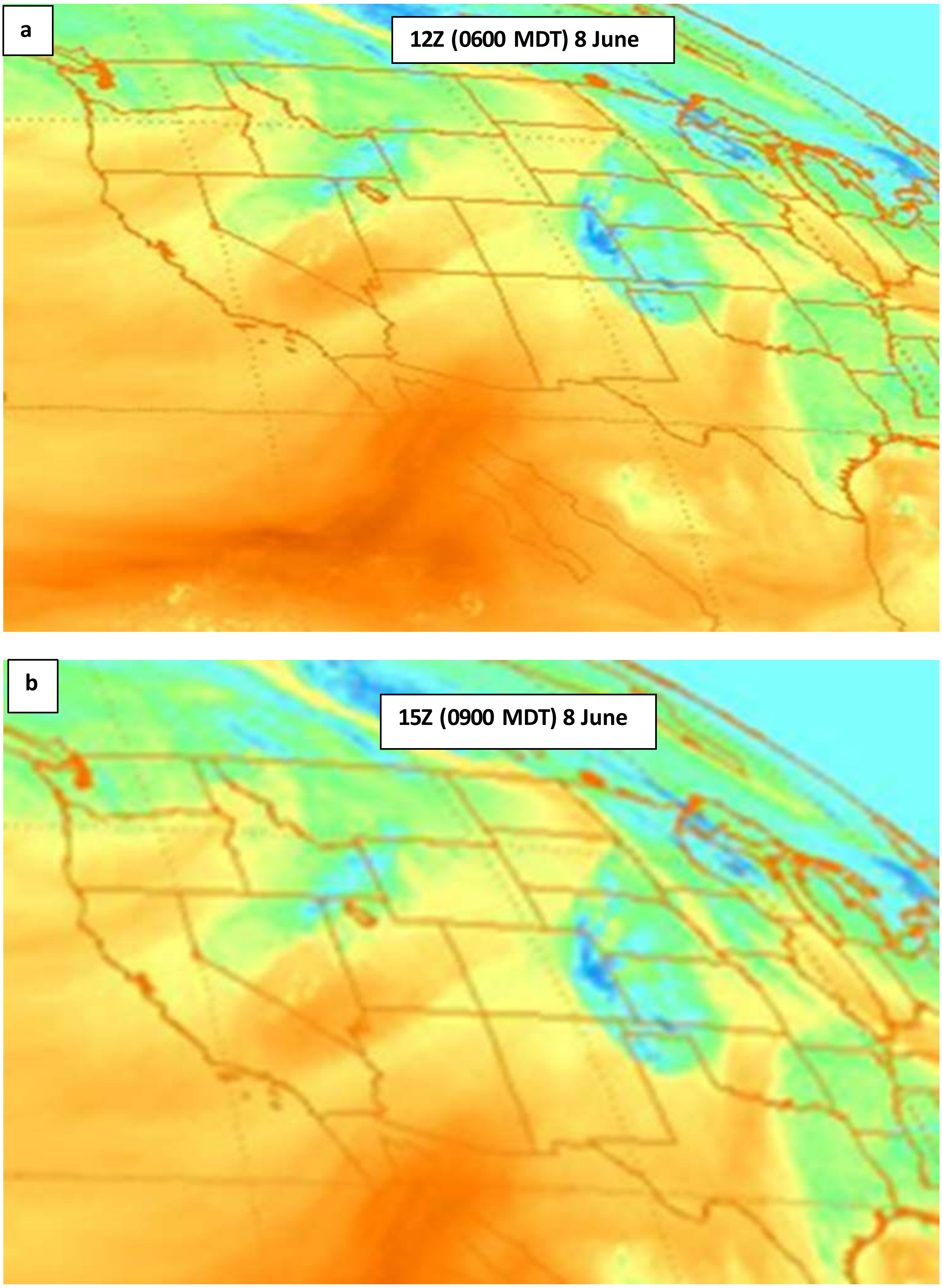
Stronger winds, and reduced fuel moistures are also a consequence of dry slots, Kaplan et al (2008) and Mills (2008). Generally, the darker the dry slot, the lower the humidity, e.g. Weldon and Holmes (1991). A general exception to this is with some of the newer color-enhanced WVI. In one variation, the driest signatures progressed from copper and gold-colored to brownish, and then to gray and black. The WVI used in this paper range from dark yellow and orange (warmest and driest) to yellow (dry) to bluish (cooler and moister). Since each water vapor image is "unique," I will utilize a sequence of previous images for better interpretation as suggested by Weldon and Holmes (1991).

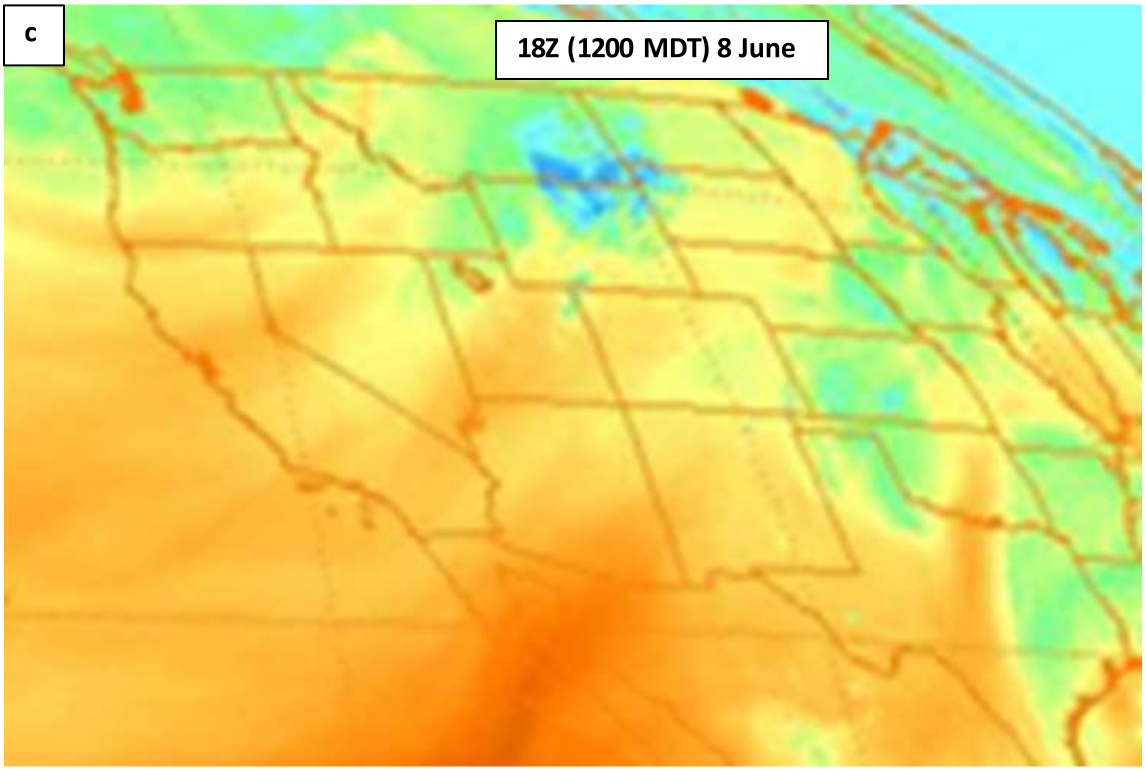
It is fairly well documented in the available wildland fire weather literature that surfacing lower-stratospheric and mid- to upper-tropospheric weather is responsible for dry air intrusions and descending dry air and subsidence. Most times, these dry intrusions manifest themselves as clearly visible dark bands in the satellite water vapor imagery. Advecting from these broader dry intrusions are more defined signatures, i.e. dry slots. These dry slots usually result in abrupt surface to near-surface drying, strong, gusty winds, and Haines 5/6, often drastically influencing wildland fire behavior and hence fire direction, intensity, and growth, Schoeffler (2010).

Satellite WVI clearly indicated very dry intrusions and dry slots advected from the southwest into Arizona on 7 June 2012 (not shown) and also on 8 June 2012 from 12Z to 21Z, Fig. 8 (a-d). These causal signatures, coincident with the atmospheric drying and intense fire behavior, clearly influenced the LB Fire with dry air and gusty winds, even with some of the color-enhanced, "*gray shade drying*" in (Fig.8 (a-d) as discovered by Weldon and Holmes (1991) and discussed in the NWS Fire Weather Forecaster's Workshop (1999).

5. DISCUSSION

a. 8 June 2012 Little Bear Fire


a
12Z (0600 MDT) 8 June
b
15Z (0900 MDT) 8 June



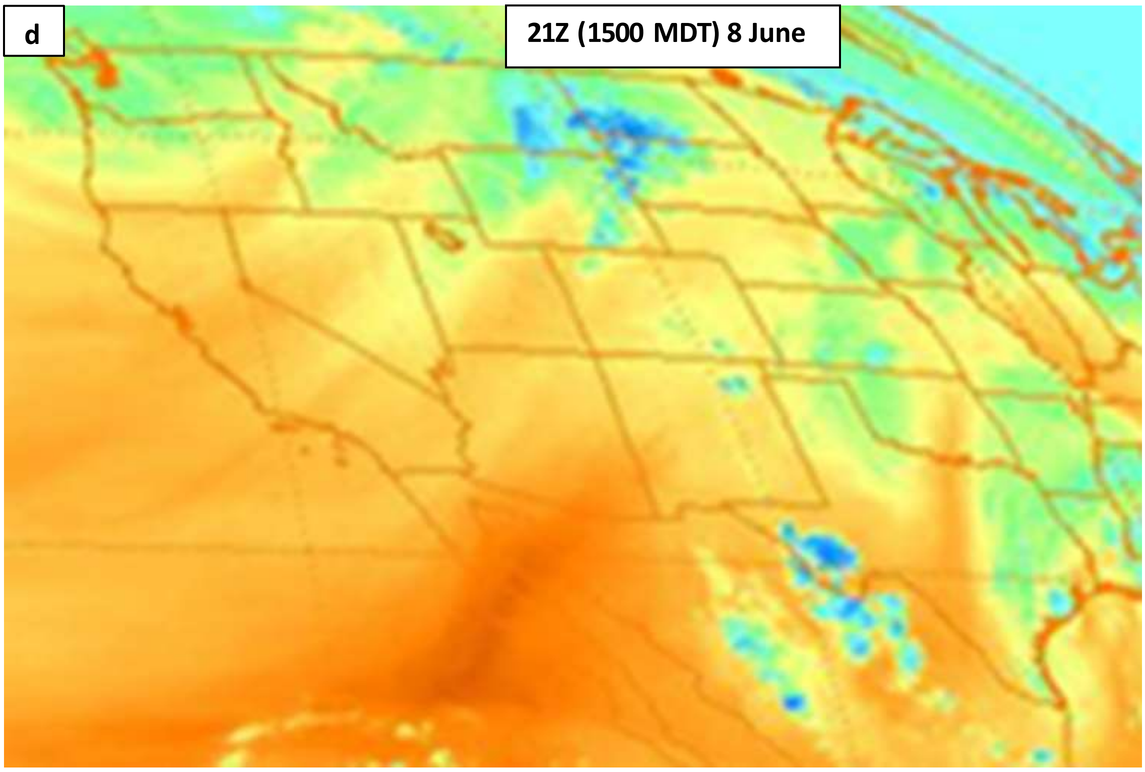


Fig. 8. NOAA GIBBS ISCCP B-1 Browse System - Water Vapor Imagery (WVI) - GOES-15; (a) 12Z (0600 MDT) 8 June; (b) 15Z (0900 MDT) 8 June; (c) 18Z (1200 MDT) 8 June; (d) 21Z (1500 MDT) 8 June 2012.

Time(GMT)	Temperature	Dew Point	Relative Humidity	Wind Speed	Wind Gust	Wind Direction	Quality check	Solar Radiation	Precipitation accumulated	Fuel Temperature
	° F	° F	%	mph	mph			W/m*m	in	° F
22:00	87.0	15.5	**7**	**12**	**26**	**SW**	OK	1021.0	2.80	99.0
21:00	87.0	18.6	**8**	**11**	**27**	**SW**	OK	1136.0	2.80	101.0
20:00	86.0	14.8	**7**	**12**	**24**	**SW**	OK	1188.0	2.80	102.0
19:00	86.0	14.8	**7**	**10**	**22**	**SW**	OK	1174.0	2.80	102.0
18:00	85.0	14.1	**7**	**11**	**22**	**SW**	OK	1081.0	2.80	96.0
17:00	83.0	12.6	**7**	**7**	**19**	**SW**	OK	942.0	2.80	99.0
16:00	81.0	11.1	**7**	**8**	**16**	**SW**	OK	751.0	2.80	94.0
15:00	75.0	29.9	19	2	5	NE	OK	518.0	2.80	77.0
14:00	63.0	33.4	33	2	4	NE	OK	285.0	2.80	68.0
13:00	53.0	29.3	40	1	3	ENE	OK	58.0	2.80	47.0
12:00	**48.0**	32.2	54	2	4	NE	OK	1.0	2.80	39.0
11:00	**48.0**	34.8	60	0	4	SSW	OK	0.0	2.80	37.0
10:00	**50.0**	35.8	58	4	5	NE	OK	0.0	2.80	42.0
9:00	**51.0**	36.7	58	3	6	WSW	OK	0.0	2.80	43.0
8:00	**55.0**	38.2	53	1	6	E	OK	0.0	2.80	44.0
7:00	**57.0**	39.5	52	2	4	ENE	OK	0.0	2.80	45.0
6:00	**61.0**	40.6	47	2	4	SSW	OK	0.0	2.80	49.0
5:00	62.0	38.6	42	4	7	SW	OK	0.0	2.80	54.0
4:00	64.0	37.9	38	2	5	SW	OK	0.0	2.80	54.0
3:00	68.0	34.6	29	2	6	N	OK	2.0	2.80	57.0
2:00	74.0	9.0	**8**	**4**	**16**	**SW**	OK	109.0	2.80	67.0
1:00	82.0	8.4	**6**	**7**	**17**	**SW**	OK	385.0	2.80	86.0
0:00	84.0	5.8	**5**	**8**	**23**	**SW**	OK	631.0	2.80	92.0
23:00	86.0	7.2	**5**	**13**	**26**	**SW**	OK	855.0	2.80	96.0
22:00	87.0	12.0	**6**	**11**	**25**	**SW**	OK	1035.0	2.80	99.0
21:00	87.0	12.0	**6**	**10**	**21**	**SW**	OK	1148.0	2.80	103.0

Fig. 9. 8 June 2012, Smokey Bear Ranger District, ROMAN RAWS, elevation 6900 feet; times in GMT

The 8 June 2012 ROMAN RAWS data revealed high nighttime temperatures from 06 GMT (midnight) to 12 GMT (0600 MDT) in the range of 61 degrees F to 48 degrees F respectively (bold red – left half). The LB Fire elevation was at 10,400 feet, so these SBRD readings would be at what would become the base of the fire by 9 June, these readings fall well within Bates' (1962) critical and blow-up thresholds of 45 degrees and 55 degrees F respectively. Also worth noting are the anomalously low daytime relative humidity values ranging from 5% to 8% from 16 GMT (0900 MDT) to 02 GMT (2000 MDT) (bold red – right half). Also of note are the southwest winds ranging from 4 to 13 knots, gusting from 16 to 27 knots during that same time period (bold red – right half). These dry, windy conditions coincide with the satellite WVI dry intrusions and dry slots as well.

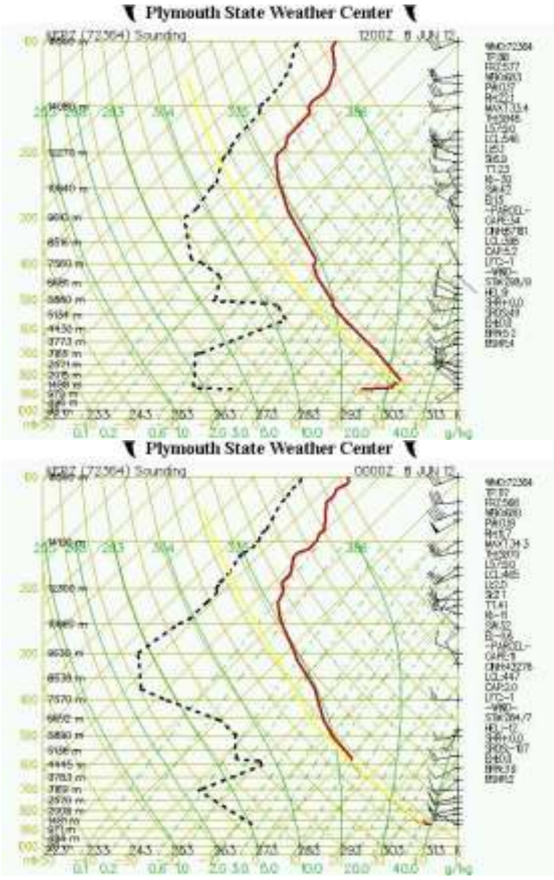


Fig. 10. Santa Teresa, NM (El Paso, TX) (KEPZ), skew-T soundings for 12Z 8 June 2012 (top) and 00Z 8 June 2012 (bottom).

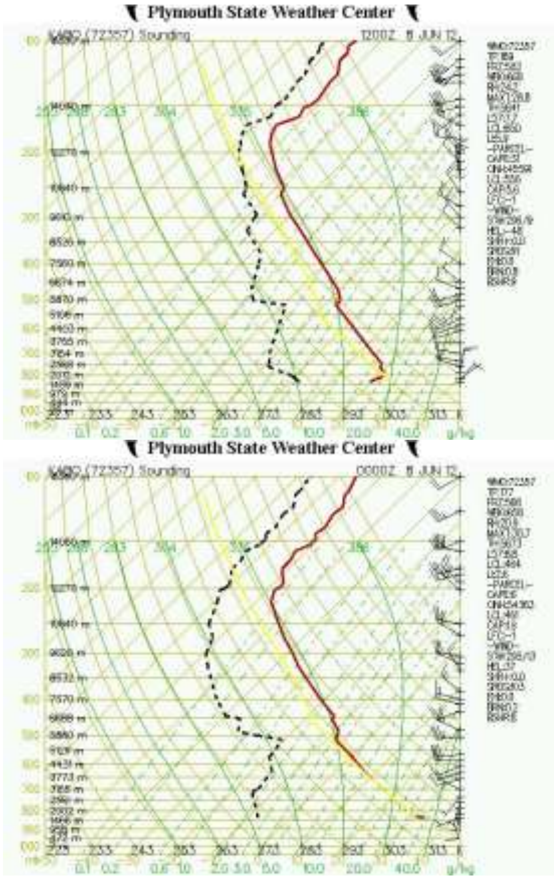
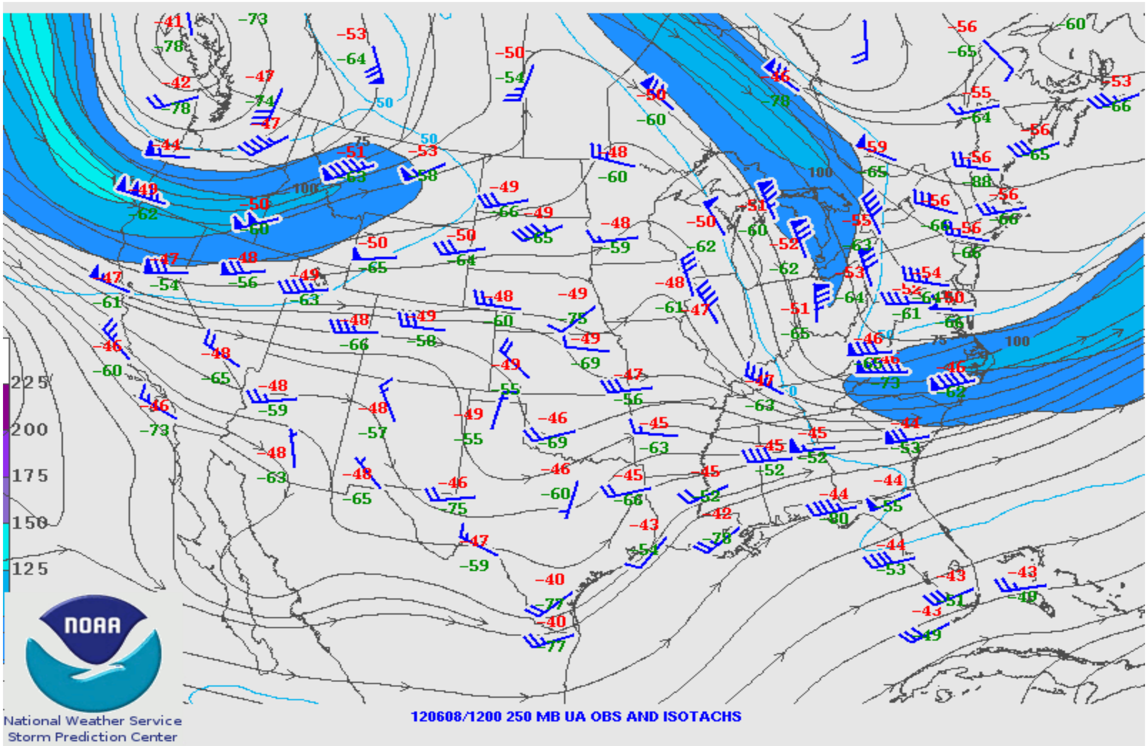


Fig. 11. Albuquerque, NM (KABQ) Skew-T soundings for 12Z 8 June 2012 (top) and 00Z 8 June 2012 (bottom).

The Santa Teresa, NM (El Paso, TX) 12Z and 00Z 8 June 2012, skew-T sounding text data in Figs. 10-11 denotes very dry air both at the surface and aloft, and westerly winds between 10 and 20 knots, notably at 700mb, the elevation of the LB Fire.

The Albuquerque sounding indicates several subsidence inversions, at both 12Z and 00Z, between 400-500mb. The relative humidity values between 400mb and 500mb were 17-25% at 12Z and 9% at 00Z between 300mb and 400mb! The Santa Teresa sounding indicates subsidence inversions at 400mb and 500mb respectively. The 12Z relative humidity values from 300mb to 500mb were anomalously low, ranging from 3-11%. And at 00Z, the relative humidity values are anomalously dry at 1-4% between 250mb and 400mb! Very dry air aloft was also indicated as dry intrusions and dry slots on the satellite WVI for the same time period (Fig. 8). Intense fire behavior and large fire growth occurred during, and as a result of, these dry and windy time periods.



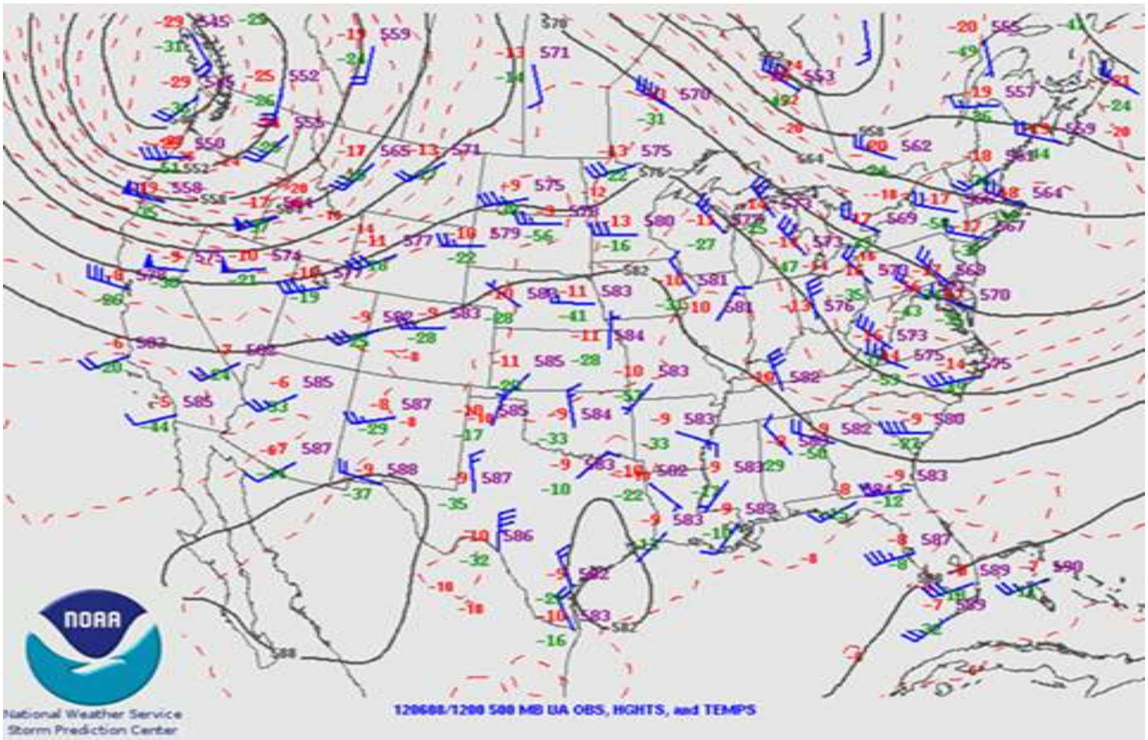


Fig. 12. 12Z (0600 MDT) 8 June 2012 - Little Bear Fire Upper Air Maps; 250mb (top) and 500mb (bottom)

b. 8 June 2012, Upper air map analysis

The 12Z (0600 MDT) 8 June 2012, 250 mb image (Fig. 10 - left) indicates a low pressure system over the Pacific Northwest (PNW) and a high over the Southwest. There are several separated and distinct jet streams with embedded jet streaks. There was jet maxima advecting into the PNW with winds from the west and northwest at 95-100 knot wind speeds and the imbedded jet streak wind speed was 125 knots. Westerly winds south of the PNW jet stream ranged from 30-70 knots, and more than likely had some influence on the LB Fire area. Northwest winds in New Mexico and over the LB Fire area were less, in the 5-15 knot range.

The 12Z (0600 MDT) 8 June 500mb image (Fig. 10 – left) indicates an increased low over the PNW and a decreased high pressure over the Southwest. Southwest winds advecting through Utah and Colorado, range from 25-30 knots. There are southwest winds advecting through the northern half of the Four Corners states of Arizona and New Mexico, including the LB Fire area, ranging from 10-25 knots.

The 12Z (0600 MDT) 700mb 8 June image (Fig. 11 – left) would be the approximate elevation of the LB Fire. The map indicates an increased low over the PNW and a decreased high over the Southwest. Southwest winds advecting through Arizona and Utah range from 15-30 knots. There are west to southwest winds advecting through New Mexico, including the LB Fire area, ranging from 10-15 knots.

The 12Z (0600 MDT) 850mb 8 June image (Fig. 11 – right) indicates a decreased low over the PNW and a diminishing high over the Southwest. West to southerly winds are advecting through Utah and Colorado, ranging from 25-30 knots. There are southwest winds advecting through the southern Nevada and California border area ranging from 10-20 knots. Northwest winds at 10 knots are located in southwestern New Mexico and the LB Fire area. The northern half of the Four Corners states of Arizona and New Mexico, including the LB Fire area, ranging from 10-25 knots. These winds are closely replicated as well in the SBRD meteogram below (Fig. 30).

The 00Z (1800 MDT) 8 June 2012 upper air map series (not shown) was considered. The 250mb map reflected similar westerly winds. The 500mb panel revealed reduced westerly winds in northern New Mexico and slightly higher, to 30 knots, in the LB Fire area. The 700mb panel indicated reduced winds in the earlier noted areas. And the 850mb panel denoted decreasing westerly winds in both Arizona and New Mexico.

I considered the NWS DIFAX Weather Map Archive site with Colorado State University, and comparing them with the SPC Archive Weather Maps revealed even clearer weather features and mechanisms for 8 June 2012 referenced but not shown in the paper. First, there was a cold front that passed to the southeast of the LB Fire area on a northeast-southwest axis from 07Z (0100 MDT) and clearing the state by 22Z (1600 MDT) (not shown). Next, a dryline appeared about 01Z (1900 MDT) almost due east of the LB Fire on a north-south axis and extended from southeast Wyoming south into Mexico that stayed well east of the LB Fire. It continued through 04Z (2200 MDT) (not shown). The Daily Minimum Temperature Weather Map for 8 June (not shown) revealed that the southwest corner of New Mexico and the southeast corner of Arizona had very high nighttime temperatures that ranged from the low 60’s in New Mexico to the mid 60’ to 70’s in Arizona. These high nighttime temperatures were well within the blow-up fire realm derived from Bates (1962), and therefore very likely contributed to the intense fire behavior of the 8 June 2012 LB Fire.

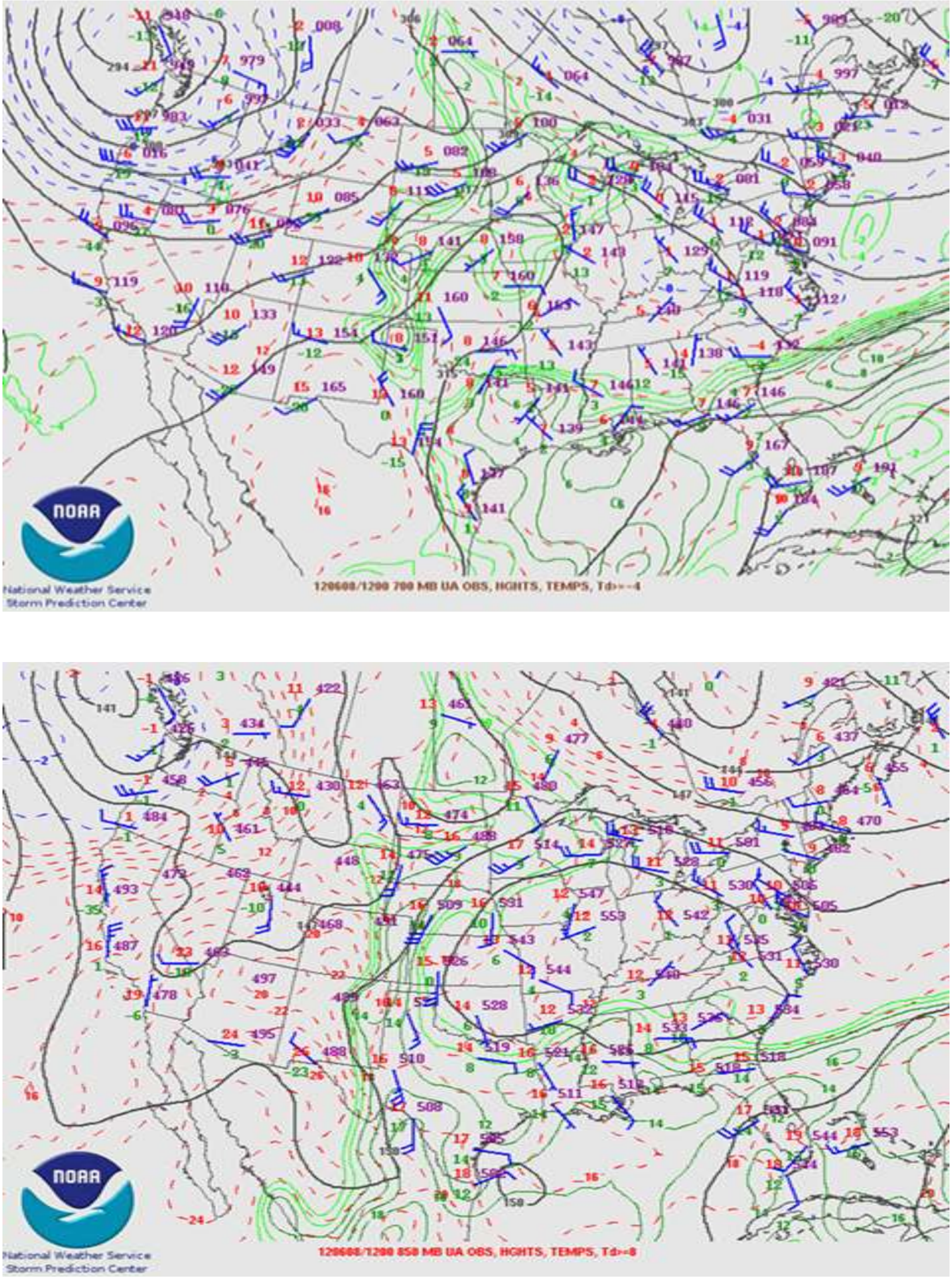


Fig. 13. 12Z (0600 MDT) 8 June 2012 - Little Bear Fire Upper Air Maps; 700mb (top) and 850mb (bottom)

c. Lee slope eddying, lee rotors, and fire channeling

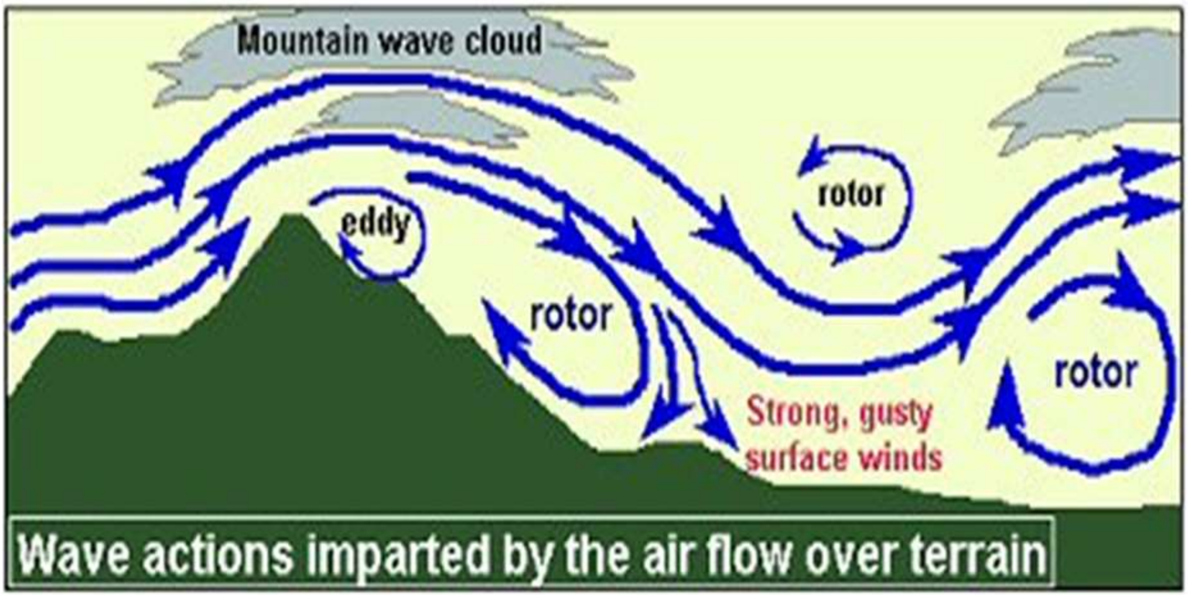


Fig. 14. Idealized schematic of lee slope eddy and rotor effects in mountainous terrain, NWCG (2007)

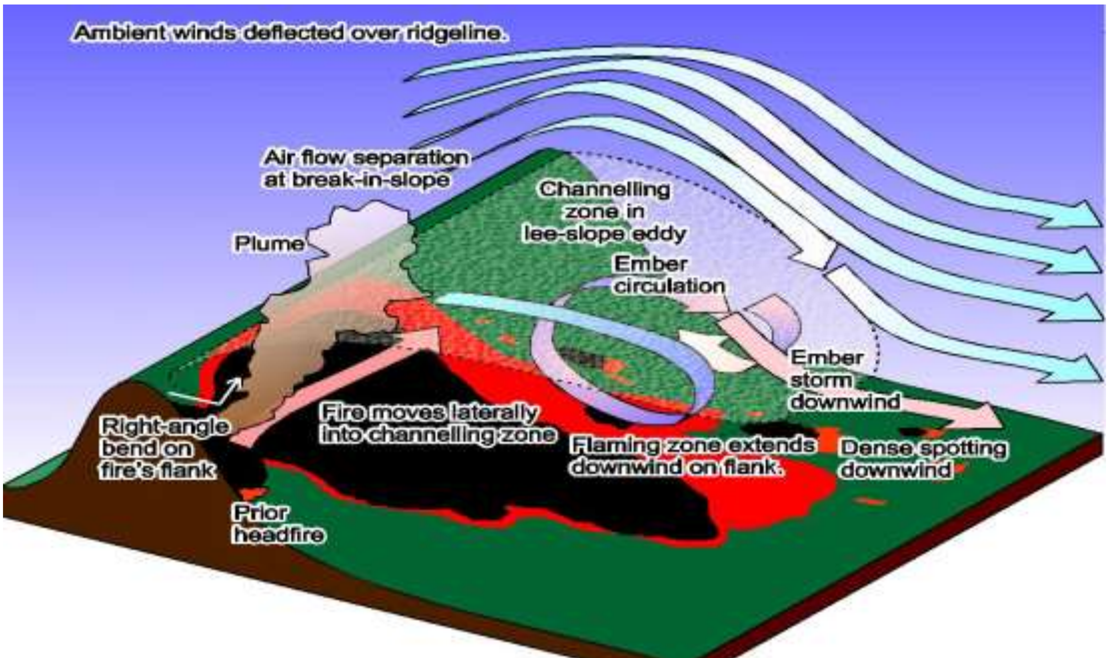


Fig. 15. Idealized schematic diagram illustrating the hypothetical vorticity-driven lateral fire spread and fire channeling mechanism. The fire channeling phenomenon is produced by an interaction between a fire and a lee-rotor. The white shaded area, framed by a dashed line denotes the channeling zone of separated airflow in the lee of the ridge. The arrow colors indicate the relative temperature of the moving air: red is hotter and blue/white is cooler, Sharples, McRae, and Wilkes (2012).

d. Fire weather, flow separation

The LB Fire was located in the 700mb elevation range at 10,400' elevation. The12Z (0600 MDT) 8 June 2012 and 00Z (1800 MDT) atmospheric soundings for southern New Mexico (Santa Teresa - KEPZ) (El Paso, TX) and northern New Mexico (Albuquerque, NM – KABQ) revealed very dry air at the surface and in the Planetary Boundary Layer (PBL) on up to the jet stream level above 300 mb, in all but the 12Z KABQ sounding, (Figs. 10-11). The right vertical line is the temperature and the left vertical line is the dew point. The farther apart these are, the drier the air. The southwesterly winds are indicated along the right, signifying direction and speed, with a full barb as 10 knots, a half barb as 5 knots, and a pendent as 50 knots. The atmospheric soundings from both Albuquerque and Santa Teresa, NM reveal very dry air was equally to the north and south of the Little Bear Fire area. These skew-T sounding readings were more-or-less verified as very low relative humidity and steady winds in the SBRD RAWS and notably on the fireline, causing ever-increased fire behavior shown in Figs 15-16. These dry air and windy conditions are also manifested as dry intrusion and dry slot signatures in the satellite WVI, Fig. 8 (a-d).

The fire and lee rotor interaction are formed through leeward flow separation, Sharples (2009. It is further inferred that the lateral fire spread is driven by thermal expansion of the air within the lee rotor as heat is added to it from the fire, with the ensuing lateral atmospheric flow rather naturally following a path of least resistance, Figs. 14-15. This is a wildland firefighter and public safety concern. The largest channeling-driven fire events have all arisen off contained as well as cool fire edges, Sharples, McRae, and Wilkes (2012). This accurately described what occurred on the LB Fire after it intensified and escaped its containment lines on 8 June 2012, and continued through 10 June, due to abrupt drying and very strong, sustained downslope winds as evidenced in Figs. 16-17. In Fig. 17 note the similarity to the idealized schematic diagram (Fig. 15) and the intensifying fire behavior in the center of the photo (Fig. 17), and note the curling, rotor-like smoke in the smoke column in the left-center of the photo.

Davis (1959) noted that friction slowed the surface winds but it also transmitted this effect upward by "*eddy diffusion*" through successive layers of air to 1,500 to 2,000 feet or more above the surface before wind had the expected surface pressure gradient speed. This layer of air is much deeper in mountainous terrain. This effect also very likely contributed to the intense 8-10 June downslope winds, fire behavior, and large fire growth evident in Figs. 16, 17, and 28.

Eddying and wind reversal occur when both the windward and leeward slopes have wind and slope effects in alignment and thus both contribute to fire intensity in a similar way, Sharples (2009). Furthermore, there are very dynamic interactions between the wind, terrain and fire which can lead to atypical fire spread, Sharples and McCrae (2013). This fire weather and fire behavior was manifested from 8-10 June 2012 on the LB Fire in Fig. 13, 14, 22, and Barone (2013).

When a dry, stable air flow is lifted over a ridge, the air tends to return to its initial elevation. Under these conditions, the winds on the immediate lee side of the ridgetop will be extremely gusty and variable due to the eddy effect, whereas the winds a half mile to a mile away may be strong downslope. A fire could easily spot over the ridge under these conditions and conceivably could be carried downslope under the influence of very stable air, Davis (1959) as in the case of the LB fire from 8-10 June 2012, Barone (2013).

Mountainous regions can influence the wind and other weather variables due to the strong stable stratification of the atmosphere that inhibits vertical displacement. The buoyancy effect will return vertically displaced air parcels to their equilibrium level even if it requires a broad horizontal deviation or the production of strong winds, Sharples (2009), as occurred on the LB Fire from 8-10 June 2012, Barone (2013).

"In the case of strong geostrophic winds, especially those with strong vertical shear, airflows resembling dynamic channeling can also occur along lee slopes in mountainous terrain. In these occurrences, the winds are

Fig. 16. 8 June 2012 LB Fire, Lee slope eddying and fire channeling resulting in forceful downslope fire behavior; courtesy of pearlsinkindergarten.blogspot.com

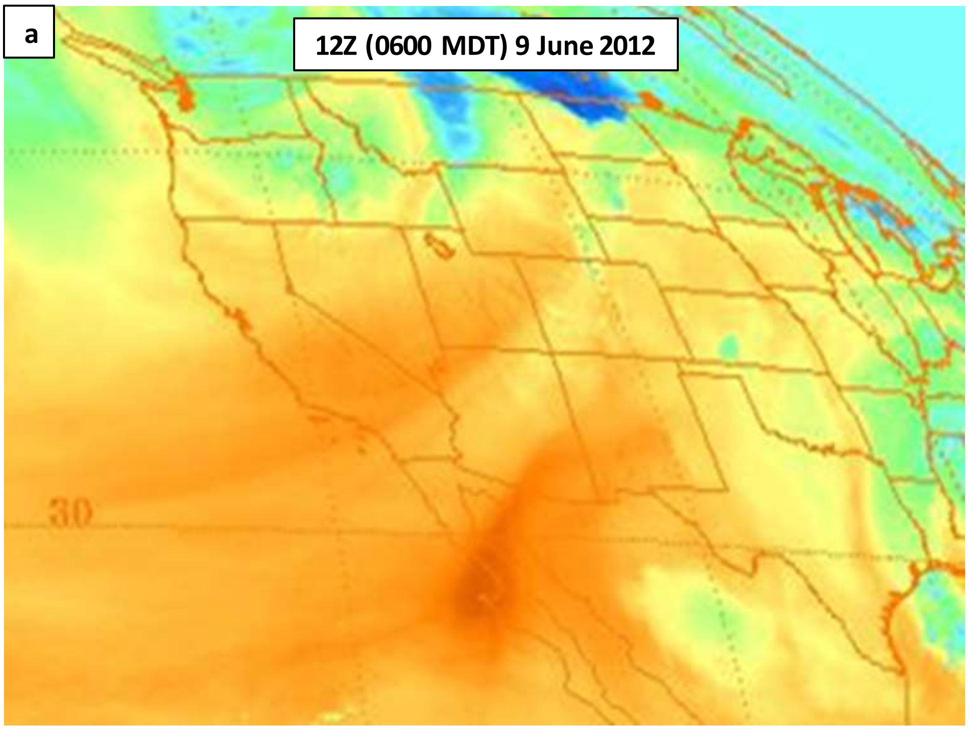
Fig. 17. LB Fire, 1800 MDT, 8 June 2012, vorticity-driven lateral spread and fire channeling, indicating downslope fire behavior, courtesy of R. Cheney, krqe.com, News 13.

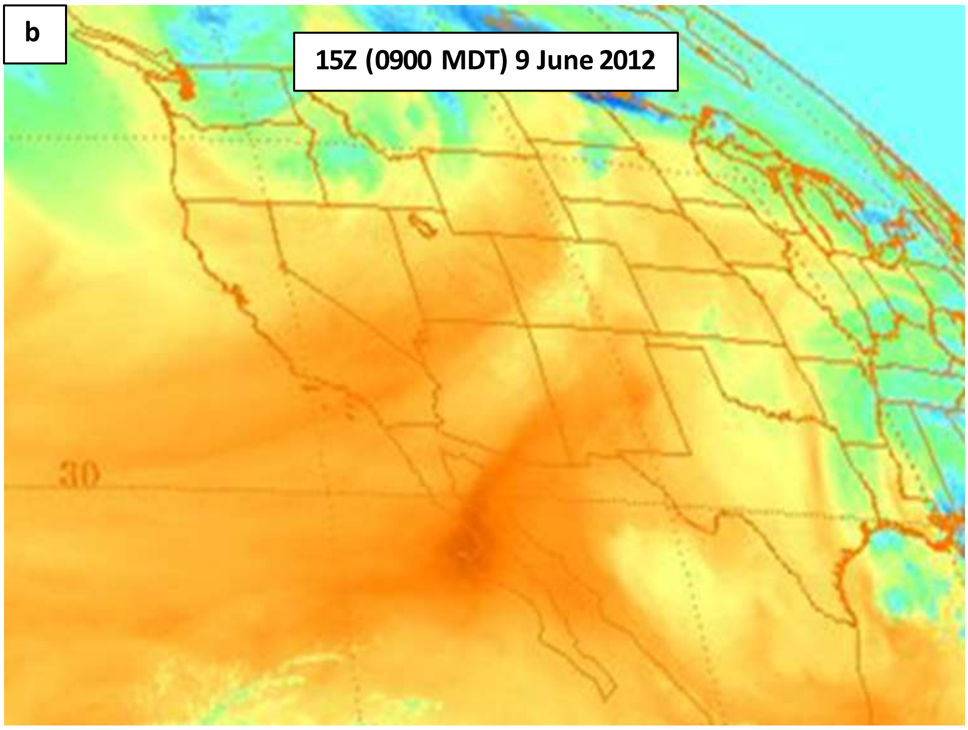
forced up and over ridgelines and often result in flow separations or separation eddies in the lee of the ridge where the flow overturns on itself" as in Fig.15. "*These horizontal-axis eddies can extend along the entire length of the ridge*" (Whiteman 2000). These similar mechanisms influenced the 8-10 June, LB Fire due to the local desert weather influence of the Tularosa Basin below the White Mountains and tend to advect hot, dry air from the basin below according to Barone (2013).

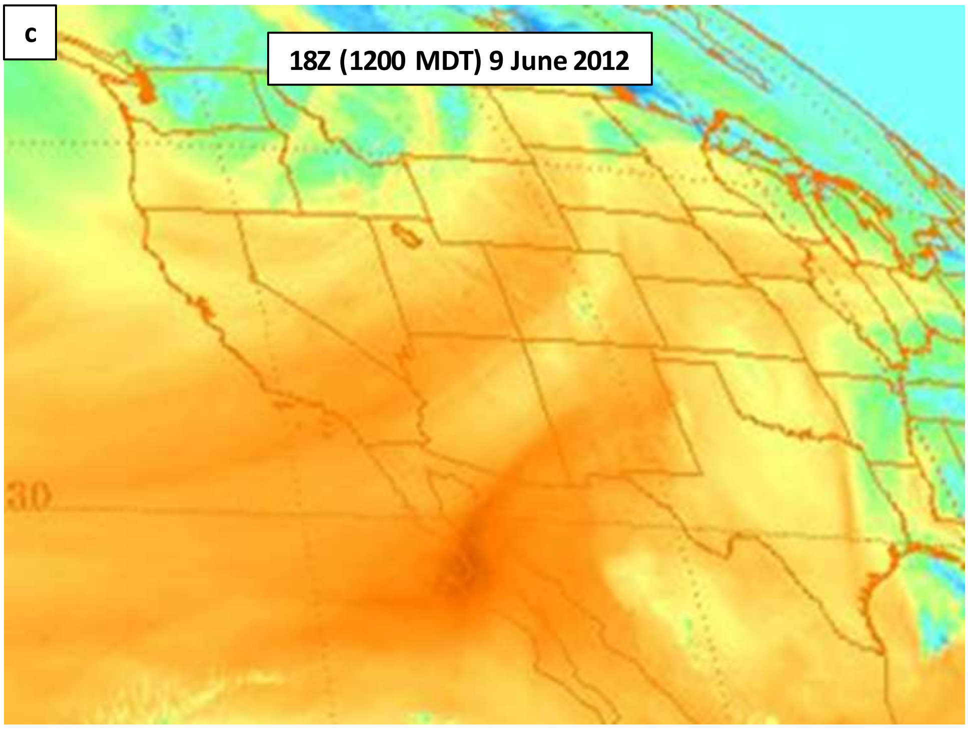
Such features are a consequence of the partial decoupling of the geostrophic winds and the near-surface winds in the lee of the ridge-line (Sharples 2009 citing others). "*The partial decoupling of the near-surface and upper winds in the lee of ridge-lines also permits air to flow horizontally in a direction dictated by local pressure gradients or thermal influences, essentially independent of the geostrophic wind direction. The net effect is for the air to follow a spiral or corkscrew pattern about a horizontal axis aligned approximately parallel to the ridge-line. Such a process is typically referred to as a lee-slope rotor or lee-slope eddy, but … the process could be termed lee-slope channeling*" (Sharples et al 2012, 2013). This is well depicted in the idealized schematic in Fig. 15.

Due to the complex nature of these fire weather phenomena and the prior work by qualified meteorologists, I closely cited the texts of their previous works so as to retain as close as possible their original intents and conclusions.

e. 9 June 2012 Little Bear Fire




b
15Z (0900 MDT) 9 June 2012
30


c
18Z (1200 MDT) 9 June 2012
30

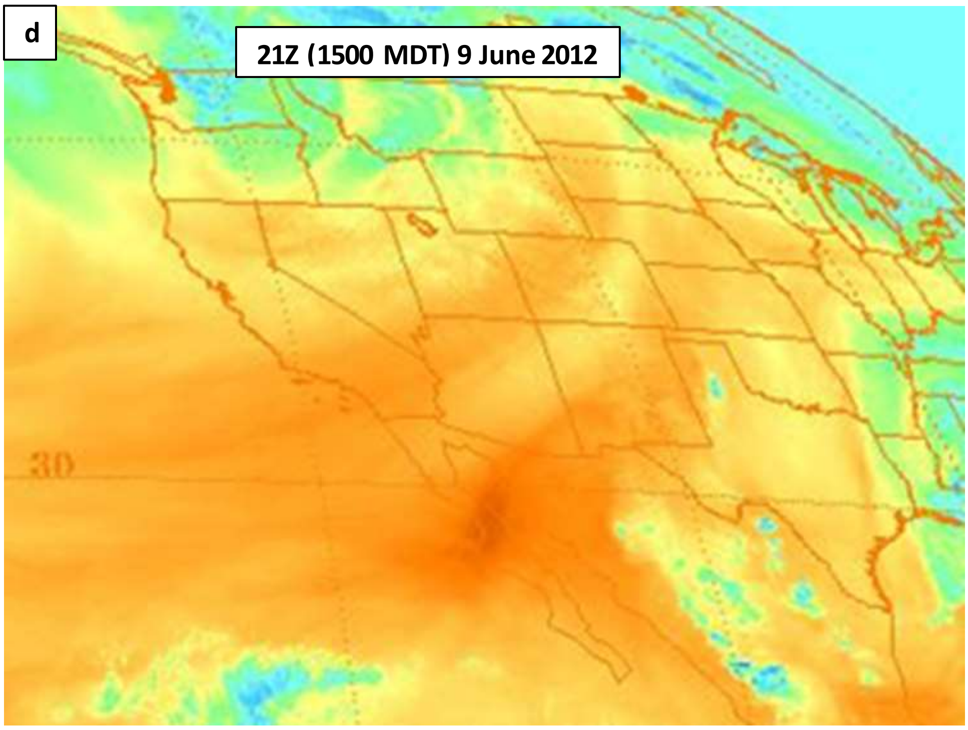


Fig. 20. NOAA GIBBS ISCCP B-1 Browse System - Water Vapor Imagery (WVI) - GOES-15; (a) 12Z (0600 MDT) 9 June; (b) 15Z (0900 MDT) 9 June; (c) 18Z (1200 MDT) 9 June; (d) 21Z (1500 MDT) 9 June 2012.

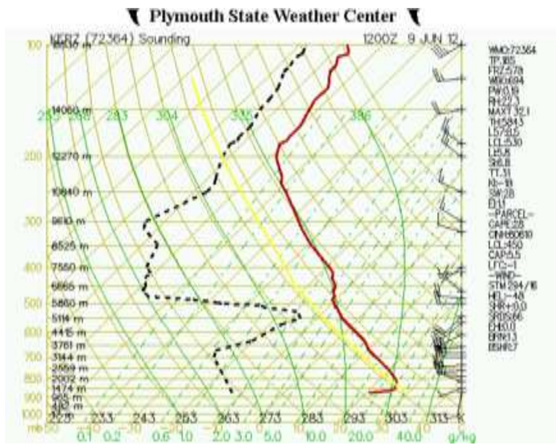
Time(GMT)	Temperature	Dew Point	Relative Humidity	Wind Speed	Wind Gust	Wind Direction	Quality check	Solar Radiation	Precipitation accumulated	Fuel Temperature
	° F	° F	%	mph	mph			W/m*m	in	° F
22:00	86.0	7.2	5	20	35	SW	OK	1033.0	2.80	97.0
21:00	85.0	14.1	7	16	32	SW	OK	1165.0	2.80	98.0
20:00	85.0	6.5	5	14	34	SW	OK	1202.0	2.80	99.0
19:00	84.0	5.8	5	16	32	SW	OK	1192.0	2.80	97.0
18:00	80.0	3.0	5	17	33	WSW	OK	1113.0	2.80	90.0
17:00	78.0	5.6	6	17	34	SW	OK	962.0	2.80	91.0
16:00	77.0	8.2	7	16	27	SW	OK	756.0	2.80	88.0
15:00	74.0	11.6	9	12	19	SW	OK	523.0	2.80	77.0
14:00	70.0	16.9	13	7	11	SW	OK	283.0	2.80	73.0
13:00	59.0	11.4	15	4	5	SW	OK	59.0	2.80	52.0
12:00	59.0	6.5	12	1	6	SW	OK	1.0	2.80	45.0
11:00	61.0	4.1	10	3	7	SW	OK	0.0	2.80	48.0
10:00	63.0	3.3	9	4	10	SW	OK	0.0	2.80	51.0
9:00	59.0	4.6	11	4	13	SW	OK	0.0	2.80	48.0
8:00	69.0	2.4	7	11	18	SW	OK	0.0	2.80	63.0
7:00	64.0	4.1	9	8	15	SW	OK	0.0	2.80	55.0
6:00	67.0	6.3	9	5	12	SW	OK	0.0	2.80	58.0

5:00	71.0	9.4	**9**	**6**	**18**	**SW**	OK	0.0	2.80	65.0
4:00	71.0	11.7	**10**	**6**	**12**	**SW**	OK	0.0	2.80	65.0
3:00	72.0	12.5	**10**	**7**	**13**	**SW**	OK	5.0	2.80	67.0
2:00	78.0	11.9	**8**	**10**	**20**	**SW**	OK	122.0	2.80	75.0
1:00	83.0	12.6	**7**	**7**	**24**	**SW**	OK	379.0	2.80	86.0
0:00	84.0	9.9	**6**	**10**	**24**	**SW**	OK	627.0	2.80	92.0
23:00	85.0	10.6	**6**	**14**	**26**	**SW**	OK	849.0	2.80	95.0
22:00	87.0	15.5	**7**	**12**	**26**	**SW**	OK	1021.0	2.80	99.0
21:00	87.0	18.6	**8**	**11**	**27**	**SW**	OK	1136.0	2.80	101.0

Fig. 21 9 June 2012, Smokey Bear Ranger District, ROMAN RAWS, elevation 6900 feet; times in GMT

The 9 June 2012 ROMAN RAWS data revealed high nighttime temperatures from 06 GMT (midnight) to 12 GMT (0600 MDT) in the range of 67 degrees F to 59 degrees F respectively; and the very low nighttime relative humidity values (bold red – left half). The LB Fire elevation was at 10,400 feet, so these SBRD readings would be at what would become the head of the fire by 9 June, as it burned downslope toward Angus and Ruidoso below. These readings fall well within Bates' (1962) blow-up threshold of 55 degrees F. The anomalously low daytime relative humidity values ranged from 5% to 8% from 14 GMT (0800 MDT) to 05 GMT (2300 MDT) (bold red – right half) – basically all day and into the evening hours. The anomalously low *nighttime* relative humidity and dew point values were much lower than 8 June. Also of note are the southwest winds ranging from 4 to 20 knots, gusting from 10 to 35 knots during that same time period (bold red – right half). These dry, windy conditions also match the satellite WVI dry intrusions and dry slots.

Both the 8 and 9 June RAWS readings were conducive to very extreme fire behavior.



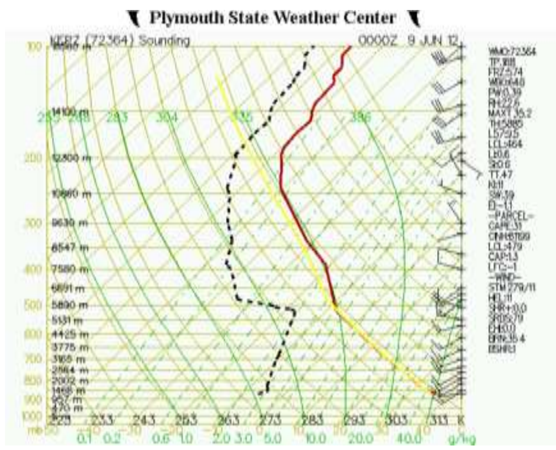
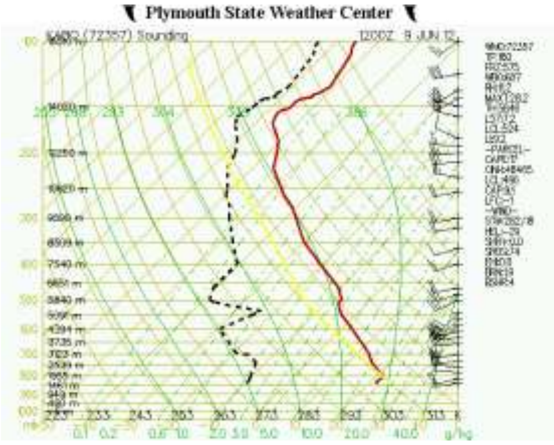


Fig. 22. Santa Teresa, NM (El Paso, TX) (KEPZ) Skew-T soundings for 12Z 9 June 2012 (left) and 00Z 9 June 2012 (right).



The Santa Teresa, NM (El Paso, TX) 12Z and 00Z 8 June 2012, skew-T soundings in Figs. 10-11 denotes very dry air both at the surface and aloft, and westerly winds between 10 and 20 knots, notably at 700mb, the elevation of the LB Fire. The Santa Teresa soundings indicated subsidence inversions in the 400mb and 500mb range. The 12Z relative humidity text data values from 250mb to 500mb are anomalously dry, ranging from % to 9%; with the 1% value solid between 300mb and 480mb!. And at 00Z, the values are anomalously dry at 1-4% between 250mb and 400mb! Very dry air aloft was also indicated on the satellite WVI for the same time period in Fig.20.

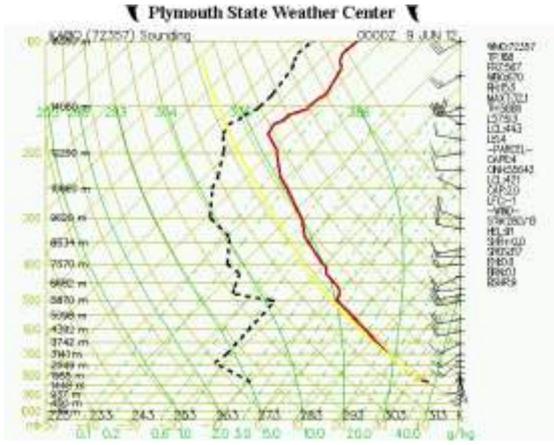


Fig. 23. Albuquerque, NM (KABQ) Skew-T soundings for 12Z 9 June 2012 (left) and 00Z 9 June 2012 (right

The Albuquerque sounding indicated several subsidence inversions, at both 12Z and 00Z, between 400-500mb, and also in the 350mb range. The relative humidity values between 350mb and 500mb were 6% to 18% at 12Z; and 6% to 7% on either side of 500mb. At 00Z, the relative humidity was 8% to 14% between 250mb and 479mb. 8-9 June 2012 skew-t soundings and data reveal very dry air at the surface and aloft, and these signatures were also indicated on the satellite WVI for the same time period.

Fig. 24. 9 June 2012 LB Fire, early morning fire behavior, courtesy of Larry Pardue, www.cbsnews.com

Fig. 25. 9 June 2012 LB Fire, intensifying fire behavior influenced by downslope winds, courtesy of theowlunderground.wordpress.com

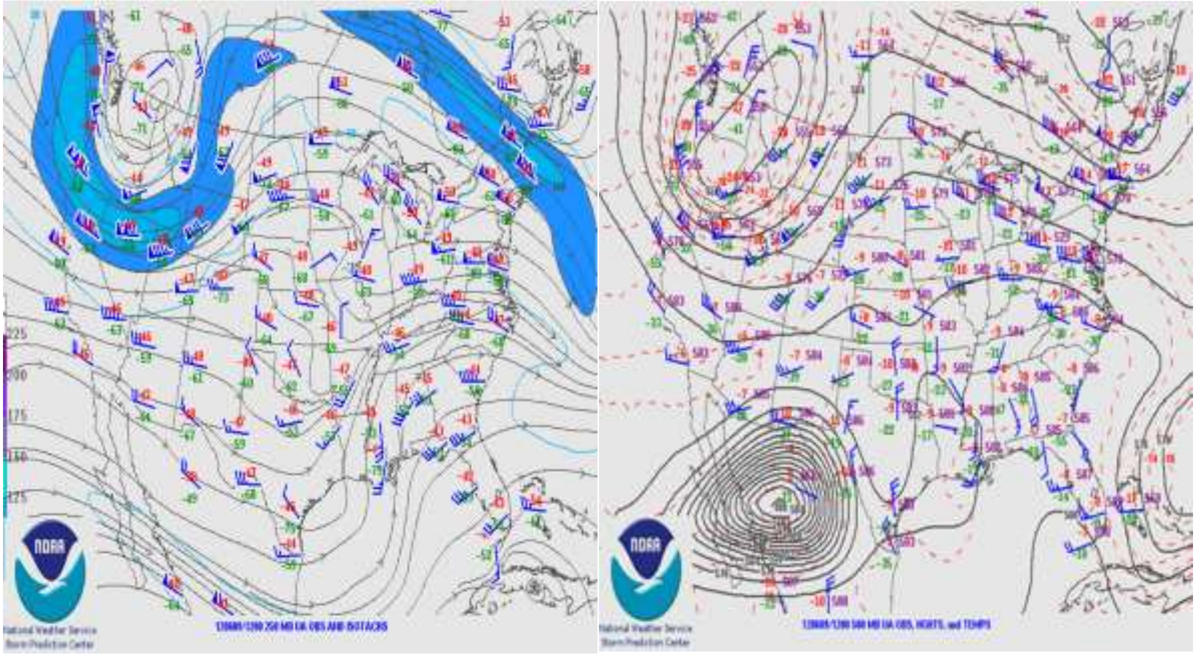


Fig. 26. 12Z (0600 MDT) 9 June 2012 - Little Bear Fire Upper Air Maps; 250mb (left) and 500mb (right)

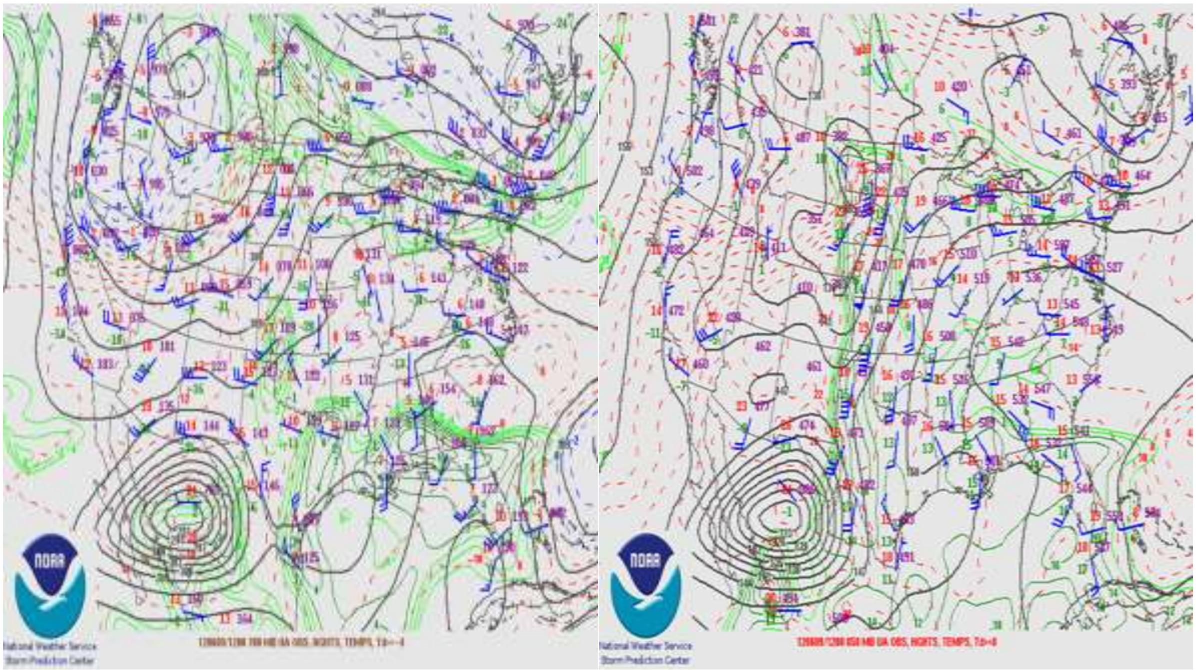


Fig. 27. 12Z (0600 MDT) 9 June 2012 - Little Bear Fire Upper Air Maps; 700mb (left) and 850mb (right)

f. 9 June 2012, Upper air maps - winds

The 12Z (0600 MDT0 9 June, 250 mb map (Fig. 26 - left) indicates a low pressure system over the Pacific Northwest (PNW) encircled by a fairly U-shaped jet stream that cuts into the far northwest corner of the Four Corner region in Utah and up through northwestern Wyoming. The winds are westerly in the 95 knot range. An embedded jet streak has much stronger winds in the 120 to 130 knot range. In Colorado and Utah, there are 25 to 50 knot southwesterly winds respectively. Further south, in Arizona and New Mexico and the LB Fire area, the winds are westerly between 25 and 30 knots in northern Arizona and New Mexico and 15 and 20 knots in the southern regions of those states, including the LB Fire area.

The 12Z (0600 MDT) 9 June, 500mb map (Fig. 26 – right) reveals a continuing low pressure system in the PNW and a fairly robust low pressure trough to the south of Arizona and New Mexico with the northern tangent of the low in southern Arizona and New Mexico and the LB Fire area. The winds south of the PNW low are westerly in the 60 to 70 knot range. Winds further south in Colorado and Utah are southwesterly at 20 to 40 knots respectively. The winds in Arizona and New Mexico are southwesterly and range from 25 to 35 knots in northern Arizona and New Mexico to 20 to 35 knots in the southern half of those states.

The 12Z (0600 MDT) 9 June, 700mb map (Fig. 27 – left) designates the continuing low pressure system in the PNW advecting south into the Four Corners area. The winds there are mostly westerly in the 20 to 30 knot range. In Utah, the winds are southerly 15 to25 knots. In Colorado, the reduced winds are westerly at 10 knots. Dropping into Arizona and New Mexico, the winds are stronger, westerly in the 20 to 40 knot range. Further south there is the ongoing low pressure trough with the northern tangent of the low in southern Arizona and New Mexico and the LB Fire area.

The 12Z (0600 MDT) 850mb map (Fig. 27 – right) indicates the low pressure system holding in the PNW and advecting further north into Canada. The PNW winds are northerly along the coast and light at 5 to 10 knots, and they increase and turn more westerly toward the Rocky Mountains, ranging from 10 to 30 knots. There are light north winds in northern Utah and fairly calm in Colorado. Further south in Arizona and New Mexico, the only winds indicated are on the northern border of Mexico, southerly at 5 to 20 knots as a result of the ongoing low pressure trough in that region. These winds are closely reflected as well in the SBRD meteogram below (Fig. 30).

The 00Z (1800 MDT) 9 June panel series (not shown) was considered. The 250mb map indicated an intensified low pressure system in the PNW with the jet maxima retaining somewhat of its U-shape with similar winds speeds from the 12Z map and reduced jet streak wind speeds to the 95 and 100 knot range as well. The 500mb map revealed an intensified PHW low pressure system with reduced southwesterly winds in Colorado and Utah, very similar westerly winds in Arizona and New Mexico. The low pressure trough to the south in Mexico had dissipated considerably.

I again considered the NWS DIFAX Weather Map Archive site with Colorado State University, and compared them with the SPC Archive Weather Maps for 9 June 2012, referenced but not shown in the paper. The previously referenced 8 June dryline continued from 10Z (0400 MDT) due east of the LB Fire on a north-south axis and extended from southeast Wyoming south into Mexico that stayed well east of the LB Fire. It continued into the state from 04Z (2200 MDT) and finally exited New Mexico to the east about 16Z (1000 MDT) (not shown). The Daily Minimum Temperature Weather Map for 9 June (not shown) revealed continued warm temperatures in the southwest corner and south-central portions of New Mexico and the southeast corner of Arizona where very high nighttime temperatures ranged from the mid-50's to mid-60's in New Mexico to the low to mid-60' in Arizona. These high nighttime temperatures were well within the blow-up fire realm from Bates (1962), and therefore likely contributed to the intense fire behavior of the 8 June 2012 LB Fire.

b. Meteograms, fire progression; skew-T sounding data

The 8-12 June 2012 SBRD meteogram readings recorded in Fig. 30 below indicate and reflect the accuracy of other temperature, relative humidity, and wind data sources and interpretations for the time period. The 8 June early morning temperatures were in the critical threshold of 48 degrees F in the early morning hours, and the blow-up conditions threshold in the 58 degrees F to 64 degrees F range in the early morning hours of 9 June 2012 when maximum fire growth occurred (InciWeb 2012), Fig. 28. On 8 June, the fire grew <9,000 acres, on 9 June it grew 17,482 acres, and on 10 June it grew 7707 acres, Fig. 28. The 9 June acreage was the "*day after the highest nighttime temperatures*," (Bates 1962).

Consider Fig. 24 and focus on the upper left of the photograph. Note the intensified fire behavior with thicker smoke columns and darker colored smoke. Now consider fire behavior photographs in Figs. 16 and 25. Note the smoke columns influenced by the downslope winds. These smoke columns would literally be raining down hot embers, as spotfires, in the unburned fuel beds below them, as in Figs. 11-12 and the fire behavior depicted in those photographs.

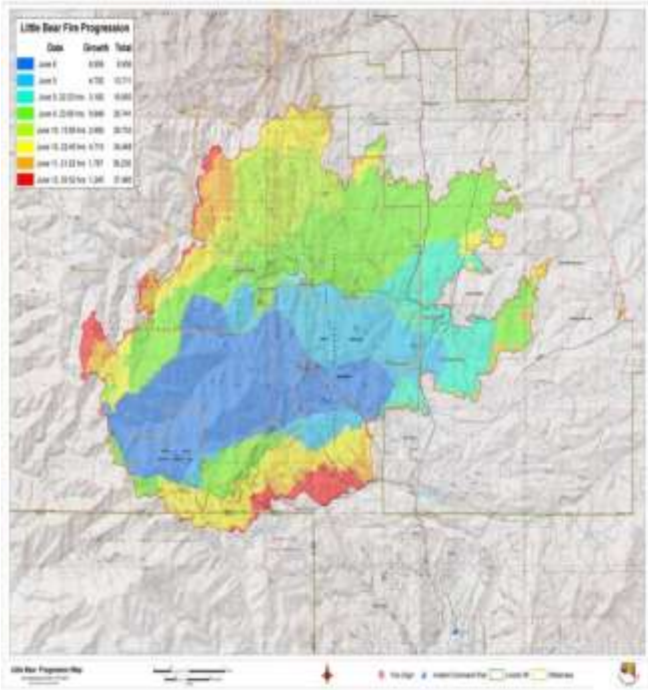


Fig. 28. LB Fire, fire progression map for 8-10 June 2012, InciWeb.

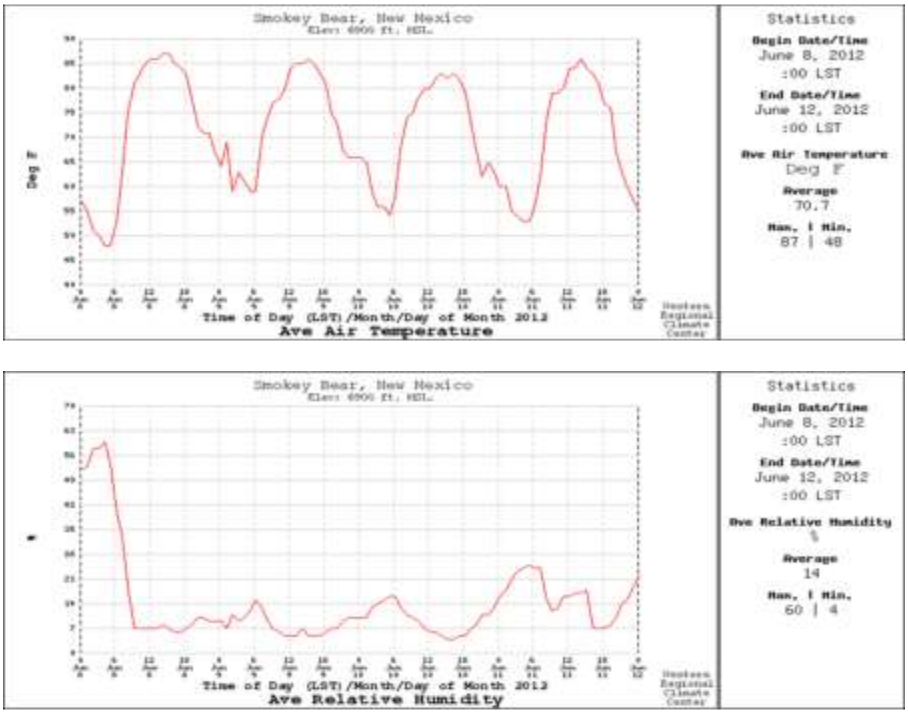


Fig. 29. Smokey Bear RD (6900') RAWS USA Meteogram – 00 LST 8 June to 00 LST 12 June 2012 – Average Air Temperature (above) and Average Relative Humidity (below).

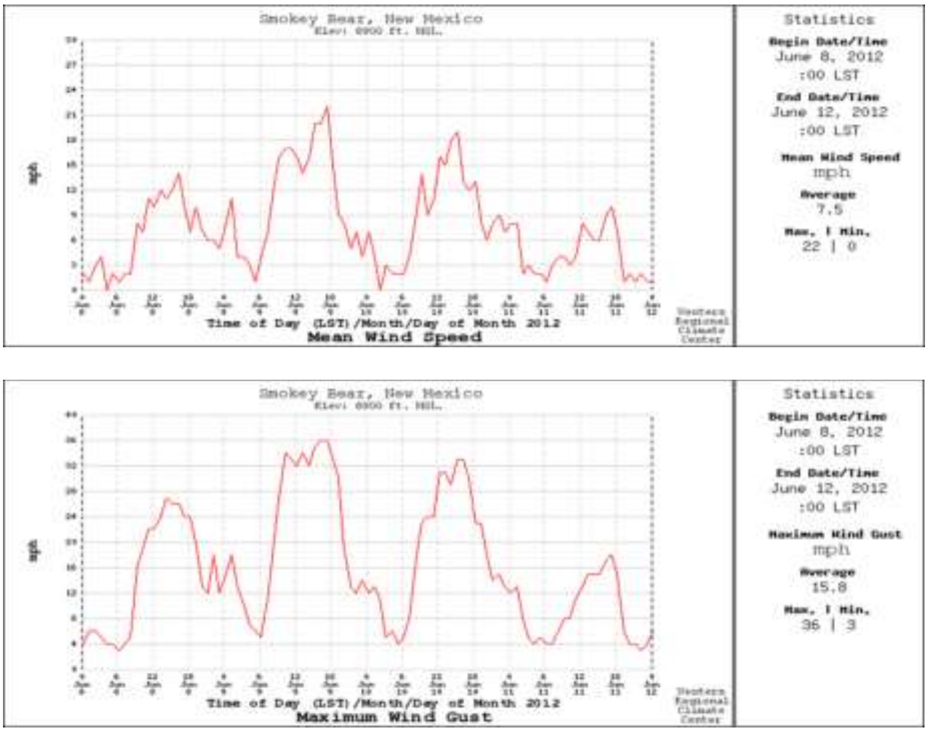


Fig. 30. Smokey Bear RD (6900') RAWS USA Meteogram – 00 LST 8 June to 00 LST 12 June 2012 – Mean Wind Speed (above) and Maximum Wind Gust (below).

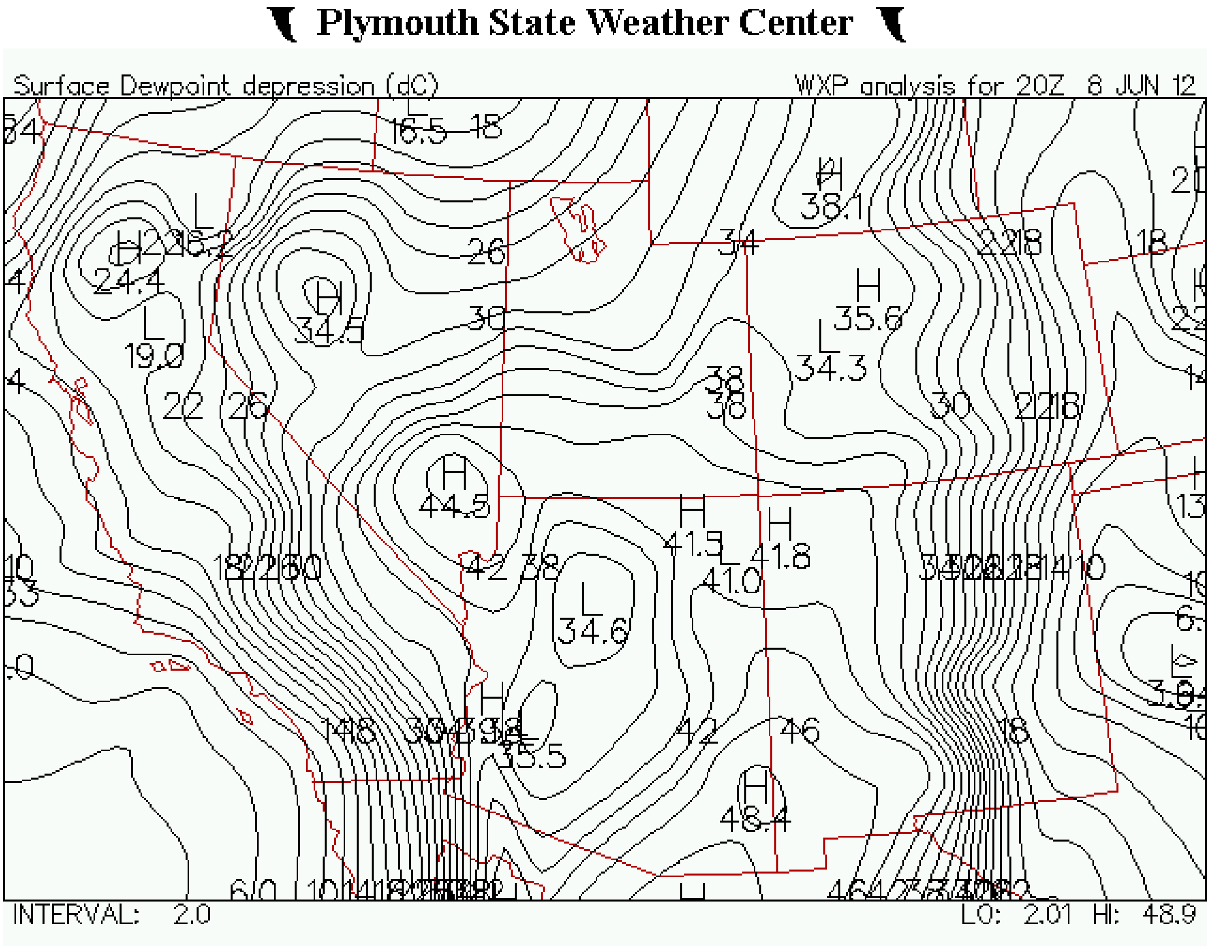
One of the factors contributing to extreme fire behavior has been a Dew Point Depression (Tdd) of 10 degrees C at 850mb, according to NWS meteorologists Smith et al (2008) researching a 2008 high winds and an associated wildland fire event. The Plymouth Archived Surface Data Maps provided contoured surface dew point depression (Tdd) maps for 20Z (1400 MDT) 8 June 2012 (Fig. 31, top), (high 30's degrees C with very steep gradient), 15Z (35 degrees C), 18Z (45 degrees C), and 21Z (52 degrees C) for 8 June 2012 (not shown) reveal quite large Tdd values. The 20Z (1400 MDT) 9 June 2012 dew point depression map (Fig. 31 (bottom) revealed mid to high 40's C in southwestern and south-central New Mexico, and the LB Fire areas. Repeatedly, the largest gradients and the highest Tdd readings were in southwestern and south-central New Mexico and the LB Fire areas (Fig. 31).

The skew-T sounding text data for that period revealed the following dew point depressions (Tdd), relative humidity, and wind data from the 8-9 June 2012 time period. The 8 June Santa Teresa 12Z, 700mb soundings indicated a Tdd of 36.4 degrees C, and an anomalous 4% relative humidity with 9 knot southwest winds. The 700mb 00Z sounding indicated a Tdd of 43 degrees C and an anomalous 4% relative humidity with 9 knot west winds. Further north, the Albuquerque 12Z, 700mb sounding revealed a Tdd of 25 degrees C and a 16% relative humidity with 13 knot west winds. The 700mb, 00Z, sounding indicated a Tdd of 30 degrees C and an 11% relative humidity with 4 knot northwest winds.

The 9 June, Santa Teresa 700mb, 12Z sounding revealed a Tdd of 39 degrees C and a relative humidity of 12% with strong west winds at 31 knots. The 700mb, 00Z sounding indicated a Tdd of 27 degrees C and a relative humidity of 15% with southwest winds at 13 knots. Albuquerque 12Z sounding at 700mb, showed a Tdd of 29 degrees C and a 12% relative humidity with strong west winds at 28 knots. The 00Z Albuquerque sounding indicated a Tdd of 39 degrees C and an anomalously low 5% relative humidity with southwest winds at 17 knots.

Likewise, according to a NWS (2005) 'Surface, Upper Air, and Composite Charts' document, the Tdd at 700 mb for extreme weather is a pressure systems, can bring dry upper air down towards hilltops producing very low dew point temperatures between midnight and dawn. The 8-9 June dew point and relative humidity readings from midnight to 0600 MDT were not very dry. However, these 8-9 June 2012 readings were well within the realm of extreme fire weather.

value that's greater than 6 degrees C. This may result in significant dry air leading to subsidence and strong downdrafts. This is what occurred for several days and nights on the LB Fire, Barone (2013).



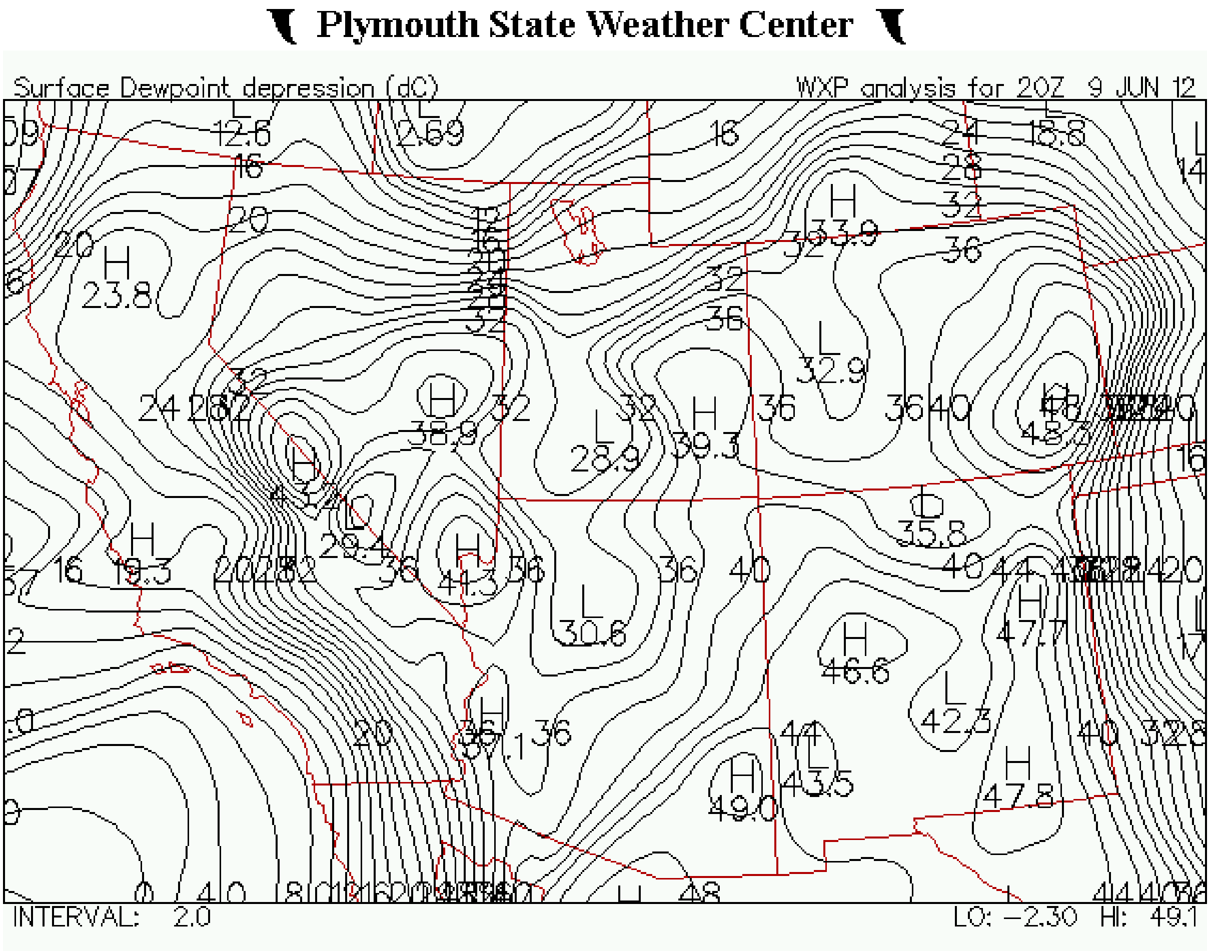


Fig. 31. Plymouth State Weather, Archive Weather Data, 2014: 20Z (1400 MDT) 8 June 2012 (above) and 9 June (bottom), Little Bear Fire Dew Point Depressions.

6. SUMMARY and CONCLUSION

The LB Fire was ignited by lightning 4 June 2012 in the White Mountain Wilderness of the LNF in south-central New Mexico (Fig. 1). It was initial attacked by the local Mescalero BIA Helitack Crew, and estimated at one-quarter acre in size. Shortly thereafter, the LNF SBRD Engine Crew and the Sacramento IHC were assigned to the fire, in very steep and rocky terrain, on a northern aspect in heavy mountain grasses and dense mixed conifer fuels (Figs. 2 and 3). They constructed handline and held the fire within its containment lines for the next four days, from 4-8 June 2012.

On 8 June, influenced by the alignment of several factors such as low soil moistures due to the lack of winter precipitation and the prolonged drought, as well as a Haines 5/6, the fire weather changed drastically and the intense fire behavior followed in time scales of minutes to hours. The satellite WVI revealed a persistent incursion of dry intrusions and dry slots, responsible for abrupt surface to near-surface drying, strong, gusty winds, and reduced fuels moistures. This resulted in severe fire behavior that persisted for the next several days and nights.

With higher nighttime and daytime temperatures, much lower relative humidity and dew points, and much stronger winds, including intense downslope winds and subsidence, the fire exponentially increased in intensity. The LB Fire intensity increased exponentially due to a combination of diurnal heating and drying, and strong downslope winds. Fire behavior progressed from single tree torching to group torching down low on the fireline, which resulted in several long-distance spot fires over the ridge and beyond the IHC's position into the tall, thick cured grass. Barone stated that "b*etween 1300 and 1400*" MDT, with very low RH, the fire behavior and spotting further intensified and the fire aggressively swept into the dense conifer thickets and very heavy dead and down fuels growing to 100 acres, and then it virtually exploded and ran downhill toward the towns of Alto and Ruidoso. It eventually burned 44,330 acres total, destroyed 242 houses and commercial buildings, and was 95% contained on 30 June 2012.

On the whole, the fireline supervisors and firefighters involved did a remarkable job battling the Little Bear Fire without any serious accidents, deaths, or injuries; without any fire vehicles burning up; and without any fire shelter deployments - a highly commendable endeavor in spite of intense downslope fire behavior in complex wildland urban interfaces.

Further research is necessary to fulfill what the U. S. Forest Service researchers Charney (2007) and Charney and Keyser (2010) have very perceptively stated the importance of the use of tools such as satellite WVI. They intently researched "*atmospheric conditions aloft*" for establishing better and "*more accurate fire weather and fire behavior predictions*" specifically for those potentially extreme and erratic fire behavior stages (2007, 2010). They recognized the importance of such structures as dry slots "*predictable hours or even days in advance of the event*" (2007, 2010). In due time, they seek to "*develop and implement indices and diagnostics into the operational fire weather and fire behavior forecasting that sense these conditions and communicate to the forecasters and the operational users of fire weather prediction when and where the potential exists for extreme fire behavior"* (all emphasis added) (2007 and 2010).

Fire weather forecasters would benefit from the prior intensive and comprehensive fire weather research of Brotak, Byram, Schroeder, and others, by incorporating the Critical Fire Weather Patterns in the U. S. into the Storm Prediction Center (SPC) Outlooks protocols. This would lend tremendous support and guidance to forecasters and end-users for more accurate and better fire weather forecasts that result in expected fire behavior.

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