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UTILIZATION OF BUFKIT IN INCIDENT COMMAND OPERATIONS AND ITS APPLICATION IN THE LOCAL FIRE WEATHER FORECAST PROCESS

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1. INTRODUCTION

The National Weather Service (NWS) Incident Meteorologist (IMET) program provides on-site weather support for wildland or urban-wildland fires, land management coordination and dispatch centers, hazardous substance releases, and any special projects or incidents which fall under the mandate of the NWS (NWS 2003). In such events, a wide variety of hardware and software tools are used to assist the IMET in providing on-site forecast services. One software tool available to aid in the analysis of meteorological data is BUFKIT (BUFfalo toolKIT; Niziol and Mahoney [1997]). BUFKIT is a user friendly and highly interactive computer application which uses full vertical resolution numerical weather prediction grid point data. BUFKIT enhances data analysis, which can result in a better forecast of local meteorological phenomena. Its initial use was to help predict mesoscale lake effect snowstorms near the Great Lakes. However, BUFKIT has applications to assess other meteorological phenomena anywhere in the country, such as those associated with fire weather operations (Haines Index, Mixing Height, etc.).

This paper will examine the utilization of BUFKIT during wildland fire fighting operations at the Kelsay Complex (a wildland fire is called a complex when more than one fire is occurring in a given area) in southwest Oregon 30-31 July 2003 (Fig. 1). The use of BUFKIT proved critical in understanding the variable fire behavior (the manner inwhich a fire reacts to the influences of fuel, weather and topography) of the Kelsay Complex during this time period. The data from BUFKIT allowed the necessary information to be conveyed to the Incident Management Team (IMT) overseeing the fire.

Despite similar weather conditions on both days, BUFKIT illustrated more active burning may occur on only one of the two days. Furthermore, inspection of this case will show the value of BUFKIT's application to local NWS fire weather forecast operations anywhere in the country (i.e., its ability to display vertical profiles of temperature, wind, and moisture at a greater temporal resolution, and calculate fire weather indices and parameters).

2. METHODOLOGY

This study investigates two cases from 30-31 July 2003 to show how BUFKIT data was employed to understand the variable fire behavior of the Kelsay Complex in southwest Oregon. Forecast sounding profiles in BUFKIT for Medford, Oregon (MFR) at an elevation of 1382 feet (421m), roughly 80-90 nautical miles (nm) southwest of the Kelsay Complex, are used to compare the Eta model (Black 1994) forecast temperature and moisture profiles of the atmosphere with observed atmospheric sounding profiles. BUFKIT time height diagrams, which display meteorological information derived from the model forecast soundings, are used to display mixing height (the height to which relatively vigorous mixing of the atmosphere occurs) values, and the Haines Index (Haines 1988). The Haines Index utilizes the stability and dryness of the atmosphere toindicate the potential for wildfire growth. Values of the Haines Index range from 2 (very low potential) to 6 (high potential for a plume dominated or vertical developing fire).

Since the Haines Index is intended to be used over the entire United States, it is adaptable for three elevation regions: Low Elevation (near sea level), Middle Elevation (1000-3000 feet [305-914 meters]) and above 3000 feet (914 meters and above) for High Elevation (Saltenberger 2000). Based on this elevation criteria and that the elevation of the Kelsay Complex was near 5300 feet (1615 meters) mean sea level (MSL) , the High Elevation Haines Index (or High Haines) was evaluated for the Kelsay Complex. The equation for the High Haines Index is as follows:

$$\text{High Level Haines} = (T_{700hPa} - T_{500hPa}) + (T_{700hPa} - Td_{700hPa}) \quad (1)$$

where T_{700hPa} is the 700hPa temperature, T_{500hPa} is the 500hPa temperature, and Td_{700hPa} is the 700hPa dew point temperature.

3. RESULTS

a. Observed Meteorological Data On The Kelsay Complex

The Kelsay Complex in southwest Oregon began on 28 July 2003 as the result of lightning. The fire grew to about 500 acres by the morning of 30 July. The synoptic scale conditions at 1200 UTC on 30 July showed an area of high pressure at 500 hPa over northern California (Fig. 2a). A thermal ridge at 850 hPa was noted over southeast Oregon, northeast California, and portions of Idaho and Utah at 1200 UTC 30 July 30 2003 (not shown), but became most pronounced by 0000 UTC 31 July 2003 (Fig. 3a) near the time of maximum heating. Record heat resulted from these conditions, with temperatures in and around the fire's elevation in the lower 90s Fahrenheit (F) and lower elevation locations above 100ºF. MFR reported a record high temperature of 107ºF on 30 July. The net result of these conditions was the creation of a nearly dry adiabatic lapse rate from the surface to 500 hPa as seen on the 0000 UTC 31 July 2003 observed MFR sounding (Fig. 4a).

Calculation of the High Haines Index from the observed MFR sounding at 1200 UTC on 30 July 2003 yielded a value of 6 over portions of southwest Oregon, including the area where the Kelsay Complex was (Fig. 5a). As stated earlier, a value of six indicates a high potential for a plume dominated or vertical developing fire. The combination of dry and unstable conditions, and very low fuel moistures, led to the development of a plume dominated fire and its associated large smoke column over the fire area during the afternoon hours (Fig. 6a). The column began to develop around 2000 UTC (1300 LDT) on 30 July 2003 and continued shortly after 0000 UTC (1700 LDT) on 31 July 2003. The large smoke column was evident on the visible satellite imagery valid at 0000 UTC on 31 July 2003 (Fig. 7). The calculation of the High Haines Index from the observed MFR sounding at 1200 UTC on 31 July 2003 continued to show a value of 6 over southwest Oregon, including the Kelsay Complex area (Fig. 5b). The observed sounding from MFR also showed a temperature inversion in the low levels (Fig. 8). This was the result of the 850 hPa thermal ridge being displaced just to the east of the area. The 850 hPa analysis valid at 0000 UTC 1 August 2003 (Fig. 3b) shows the axis of warmer temperatures had shifted to the east of its previous position 24 hours ago (Fig. 3a). The 500 hPa analysis at 0000 UTC on 1 August 2003 (Fig. 2b) showed the high pressure center had become more compact over northern Nevada, but little change in meteorological conditions had taken place from 1200 UTC 30 July 2003. The inversion remained in place all day on 31 July, with the observed MFR sounding valid at 0000 UTC 1 August 2003 showing its presence (Fig. 9a). The inversion limited the height of the mixed layer and the instability above the inversion was never realized. As a result, no distinct smoke column developed over the fire (Fig. 6b).

b. BUFKIT Data On The Kelsay Complex

To examine forecast meteorological data for the 30-31 July 2003 time period, the BUFKIT software program was used extensively. BUFKIT is capable of exhibiting point forecast sounding data at hourly intervals, a distinct advantage over traditional tools such as AWIPS, GEMPAK, web, etc., that commonly show soundings at only 3 and/or 6 hourly intervals. BUFKIT can also display forecast data in a time versus height format, but more importantly, can depict fire weather parameters that are typically only viewedin plan view. In addition, modifications to forecast surface temperature data can be made and fire weather parameters such as mixing height and transport winds in BUFKIT are automatically amended.

Forecast sounding information for MFR via BUFKIT from the 1200 UTC Eta model run on 30 July 2003 was studied. Analysis of hourly forecast soundings indicated a deep and dry adiabatic lapse rate was forecast to develop by 0000 UTC on 31 July 2003 (Fig. 10). The 12-hour forecast MFR sounding valid for 0000 UTC on 31 July 2003 (Fig. 4b) matched the observed MFR sounding (Fig. 4a) for that time period, thus indicating a correct model forecast. The 36- hour Eta model forecast sounding in BUFKIT (for MFR), valid at 0000 UTC 1 August 2003 is shown in Fig. 9b. Note the stable, warm layer above 5300 ft MSL (850 hPa), the elevation at which the fire was located. Checking the hourly forecast soundings in BUFKIT from 1200 UTC 31 July 2003 to 0000 UTC 1 August 2003, provided the ability to determine if the stable layer would remain in place (Fig. 11). The observed MFR sounding valid at 0000 UTC 1 August 2003 revealed this stable layer did exist (Fig. 9a). This stable layer (inversion) above the fire was also evident on the 24- hour Eta model forecast from the 0000 UTC 31 July 2003 model run (not shown) and the 12-hour Eta model forecast from the 1200 UTC 31 July 2003 model run (not shown).

The BUFKIT time height display of mixing height and Haines Index provides additional insight into the forecast challenge. Using the BUFKIT time height display to view hourly mixing height values (Fig. 12), a maximum height of 480 hPa (18,000 ft MSL) was forecast by 2300 UTC on 30 July 2003. The mixing height was then forecast to be considerably lower (about 780 hPa or about 6000 ft MSL) on 31 July 2003 as a result of the inversion (Fig. 12). Because mixing height values in BUFKIT are available on an hourly basis, a forecaster has the ability to see if in fact an inversion would break and at what time this would occur. Such information is critical to fire weather users. In the example of 30 July 2003, the mixing height value was forecast to change from about 4,000 ft MSL to 18,000 ft MSL between 2200 UTC and 2300 UTC, indicating an inversion would in fact break. Potential "what if" scenarios can also be developed in BUFKIT. Using the time height display to examine mixing height and transport winds for example, a forecaster has the ability to modify forecast surface temperatures, via the maximum temperature button, and see what temperature might be needed to break an inversion that is forecast to persist. When such changes are made, mixing height and transport wind values are automatically adjusted. Although no modifications to forecast surface temperatures were done for the cases of 30 and 31 July, such modification capabilities can enhance a forecasters' ability to make important forecast decisions and convey the necessary information to the appropriate fire weather users.

The display of forecast High Haines Index for MFR, from the 1200 UTC 30 July 2003 Eta model, utilizing the time height display section in BUFKIT, is shown in Fig. 13. A value of 6 is forecast for much of the day on 30 July and for the afternoon of 31 July. The 1200 UTC 31 July Eta model also showed a forecast value of 6 during the day (Fig. 14). The plan view displays of High Haines Index in Fig. 5 represented observed values of High Haines Index valid at 1200 UTC. In addition, a substantial amount of interpolation occurs to create such plan view displays. Employing BUFKIT to assess Haines

Index values is substantial in that it can provide hourly forecast values and can be calculated at a given point, thus negating any interpolation issues. Based on the actual High Haines Index values of 6 for both days, calculated from the observed 1200 UTC MFR soundings, the Eta model accurately forecast the High Haines Index values during this event. As stated earlier, the High Haines Index uses meteorological information from the 700 and 500 hPa levels for its calculation. The inversion that developed on 31 July, which was noted around 800 hPa, was below the data used in the High Haines Index calculation. While the inversion had no impact on the High Haines Index forecast of a dry and unstable air mass, it did negate the atmosphere's ability to realize this instability. Thus, no plume dominated or vertically growing fire developed on 31 July.

4. CONCLUSION

A large smoke column developed over the Kelsay Complex in southwest Oregon on 30 July 2003, largely due to a dry and increasingly unstable air mass over the area. With nearly similar conditions the following day, 31 July 2003, no smoke column was observed. On both 30 and 31 July 2003, High Haines Index values, a measure of the atmosphere's ability to generate plume dominated wildfire growth, from the observed MFR soundings at 1200 UTC were a 6, which indicates a high potential for plume dominated fire growth. Despite the High Haines Index values of 6 on both days, only one day (30 July) exhibited plume dominated wildfire growth.

The use of BUFKIT to examine Eta model hourly forecast soundings, was crucial in recognizing the differences in how the fire behaved (development of a large smoke column versus no smoke column) on 30-31 July 2003. Forecast sounding data for MFR clearly showed the deep, dry adiabatic lapse rate that contributed to the development of a large smoke column over the fire on 30 July, then accurately showed an inversion over the fire area that inhibited the development of a large smoke column on 31 July. High mixing height values, which resulted from the deep, dry adiabatic lapse rates on 30 July, were considerably lower on 31 July. The existence of the capping inversion limited the height of the mixed layer, and BUFKIT data clearly depicted this change in mixing height values. Observed High Haines Index values (at 1200 UTC) were a 6 on both 30 and 31 July. Forecast soundings in BUFKIT were able to show that these values would remain at the 6 level on both days. In addition, the examination of High Haines Index in BUFKIT allows the forecaster the ability to measure values at a given point that is more representative of the area. Plan view displays of observed High Haines Index values can typically employ a substantial amount of interpolation to populate the field, thus limiting the accuracy of the data.

The use of BUFKIT has many advantages. BUFKIT has the ability to display forecast sounding data on an hourly basis, while other conventional tools to examine meteorological data (AWIPS, GEMPAK, web, etc.) typically display 3 and/or 6 hourly forecast soundings. In addition, BUFKIT allows for modification of forecast surface temperature data which can help depict more correct assessments of atmospheric profiles. When such changes are made, the necessary modifications to other fire weather parameters, for example mixing height and transport wind, are automatically made in BUFKIT. The time height display capability in BUFKIT allows for examination of a variety of fire weather parameters, such as Mixing Height, Transport Wind, Ventilation Rate, and Haines Index, that are not easily calculated and displayed in other meteorological viewing tools.

The utility of BUFKIT's application to the local fire weather forecast process is clear. Many of the fire weather forecast elements that NWS forecasters are tasked to provide are available in BUFKIT. The use of BUFKIT can provide the fire weather usercommunity specific information with respect to fire suppression efforts or prescribed burning, for example, the time at which the mixing height will be at its maximum or at what time a wind shift will occur. The strength of the BUFKIT program, its ability to display hourly forecast sounding profiles and fire and meteorological information in a time versus height display, assists the NWS fire weather forecaster with the ability to more accurately provide important fire weather information.

Within a local NWS office, much of the data in AWIPS is presented in a plan view format. As in the case of the Kelsay Complex, where one fire weather parameter (Haines Index) displayed in plan view mode indicated the potential for a plume dominated or vertically growing fire, the use of hourly and adjustable forecast sounding information in BUFKIT helped recognize that the instability of the atmosphere may never be realized due to a capping inversion forecast over the fire. This is similar to severe weather forecasting where a plan view of Convective Available Potential Energy (CAPE) may reveal a substantial amount of instability exists over a given area, yet whether the instability will be realized needs to be determined. Thus assessing hourly atmospheric sounding profiles and/or meteorological information in a time versus height display can be of use in making such a determination.

ACKNOWLEDGMENTS

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FIGURES

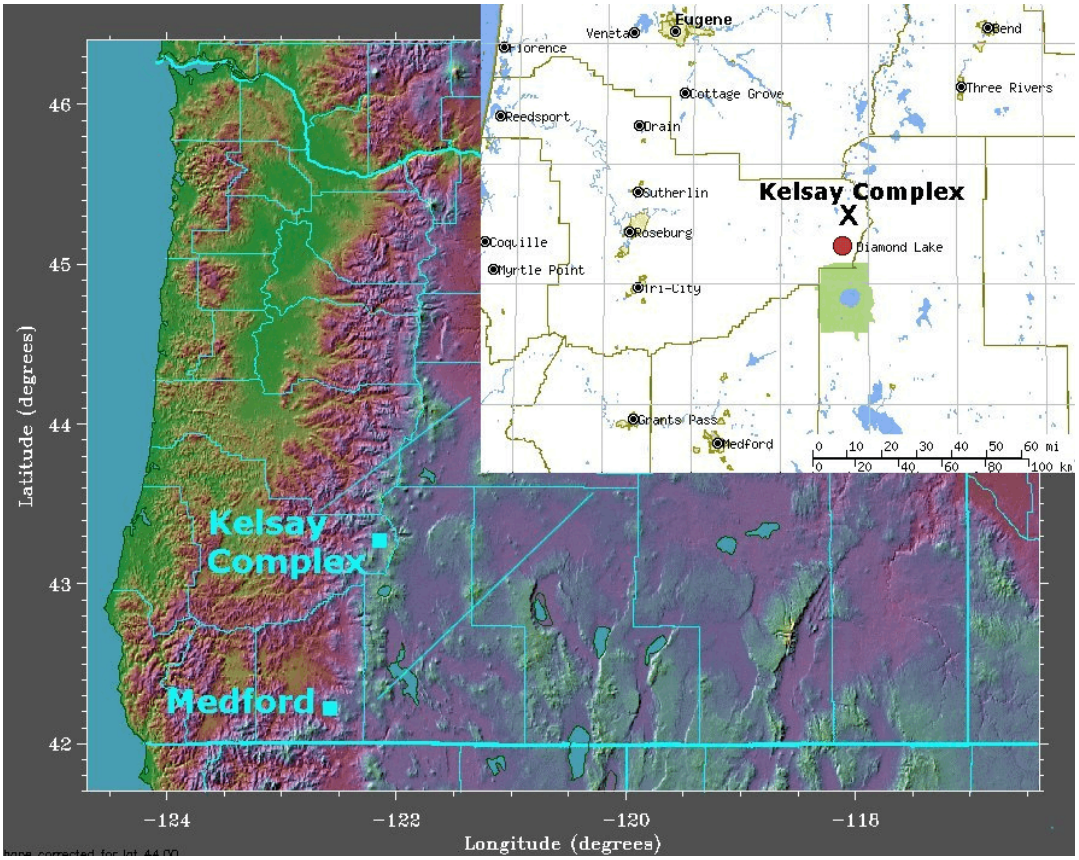

Figure 1 Map of Oregon with Medford and Kelsay Complex locations indicated. Inset map shows greater resolution illustrating difference in distance between Medford (upper air sounding location), Diamond Lake (location of Incident Command Operations for the Kelsay Complex), and the Kelsay Complex. Fire is roughly 10 to 15 nautical miles north-northeast of Diamond Lake.

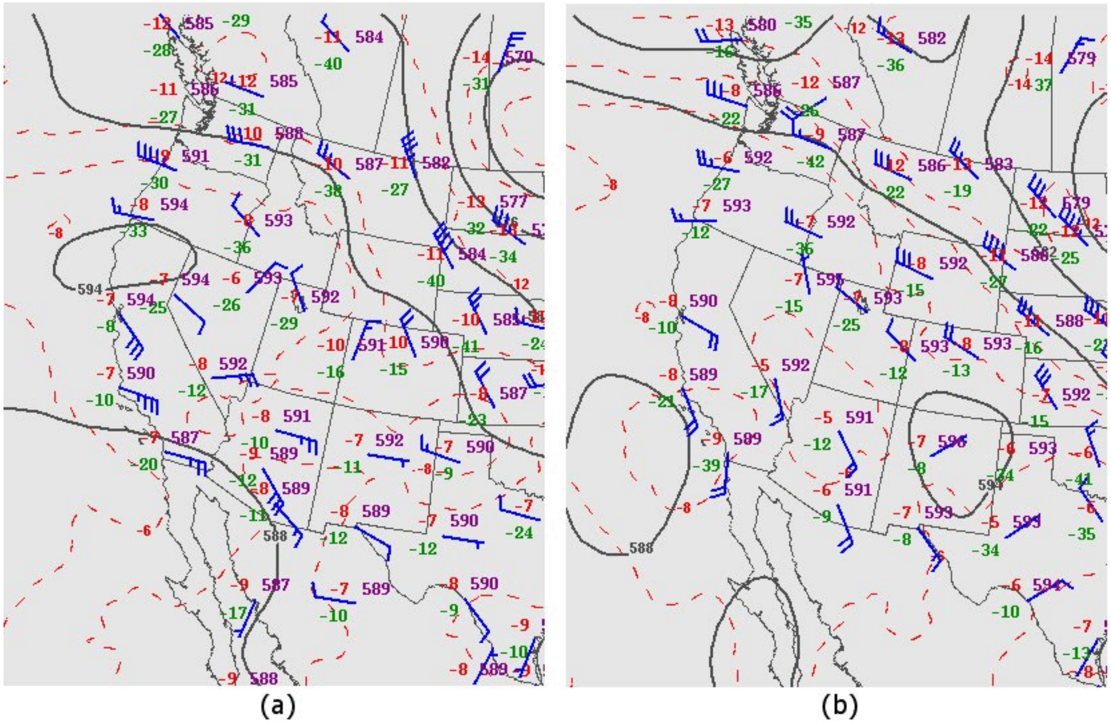

Figure 2 500 hPa analysis valid at a) 1200 UTC 30 July 2003 and b) 0000 UTC 1 August 2003. Solid lines represent heights, contoured every 60 meters. Dashed red lines are isotherms, contoured every 2º Celsius (C). Wind barbs are in blue, standard convention (knots).

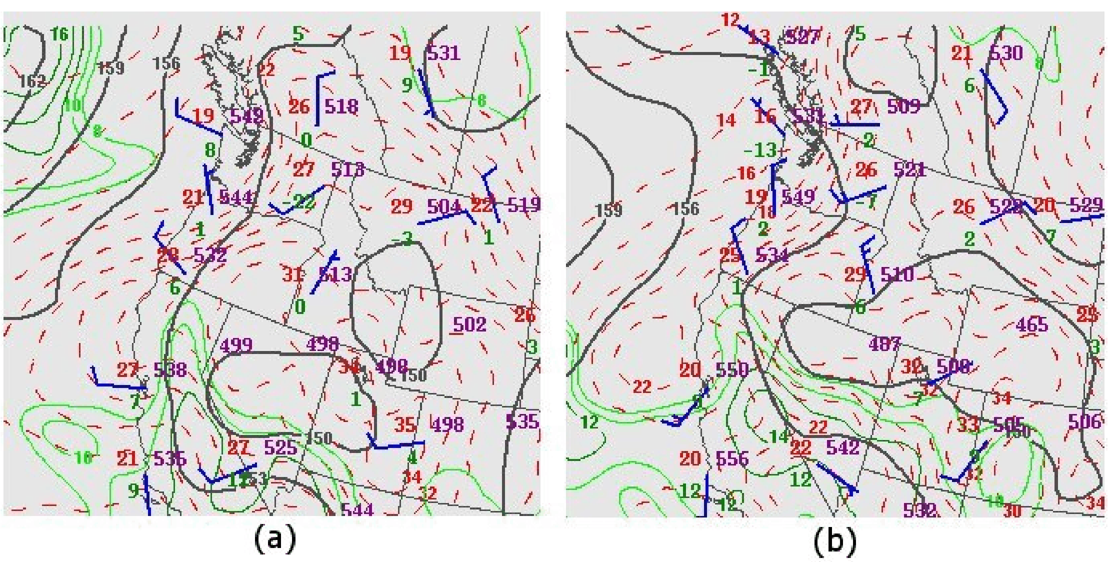

Figure 3 850 hPa analysis valid at a) 0000 UTC 31 July 2003 and b) 0000 UTC 1 August 2003. Solid black lines represent heights, contoured every 30 meters. Dashed red lines are isotherms, contoured every 2ºC. Light green lines represent dew point values, contoured every 2ºC. Wind barbs are in blue, standard convention (knots).

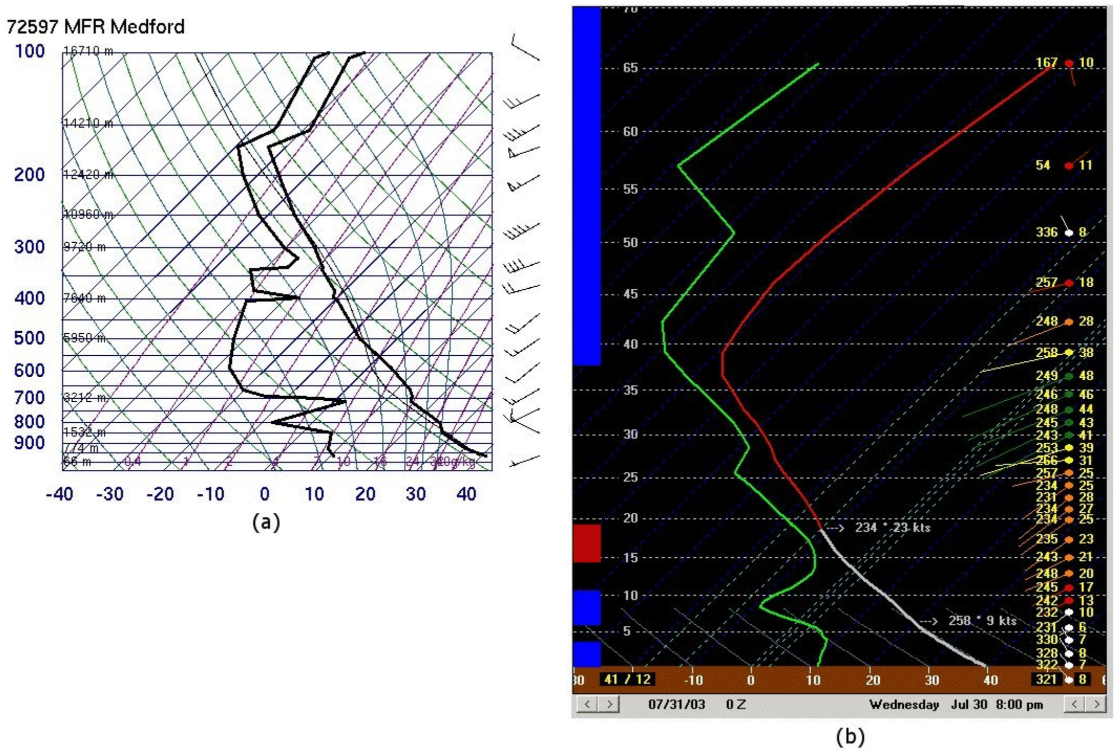

Figure 4 Sounding information for a) observed Medford, Oregon (MFR) sounding valid at 0000 UTC 31 July 2003 and b) BUFKIT display of Medford, Oregon (MFR) 12 hour Eta model forecast sounding valid at 0000 UTC 31 July 2003.

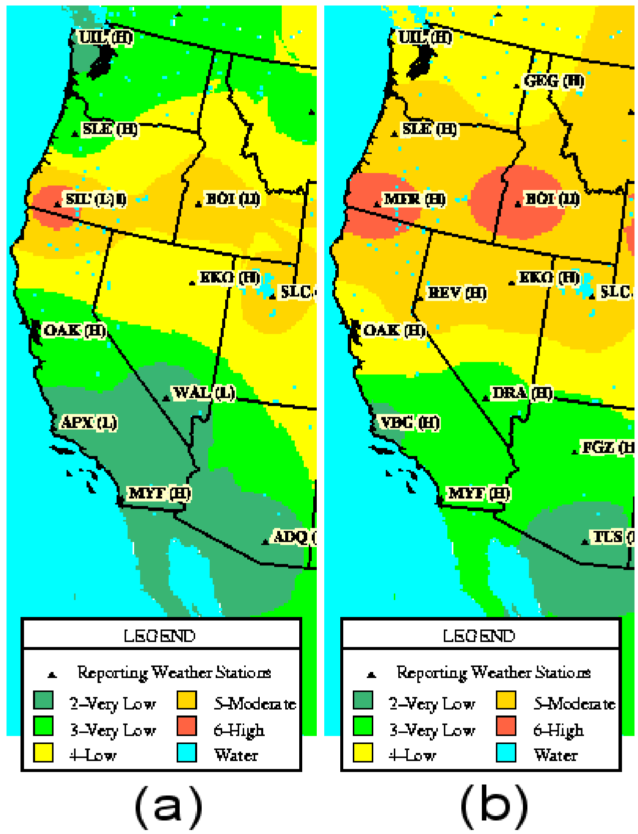

Figure 5 Observed High Haines Index values at a) 1200 UTC 30 July 2003 and b) 1200 UTC 31 July 2003.

(A)

(B)

Figure 6 Visual displays of a) Large smoke column over the Kelsay Complex in southwest Oregon during the late afternoon hours on 30 July 2003 and b) minimal fire activity over the Kelsay Complex in southwest Oregon during the afternoon hours on 31 July 2003.

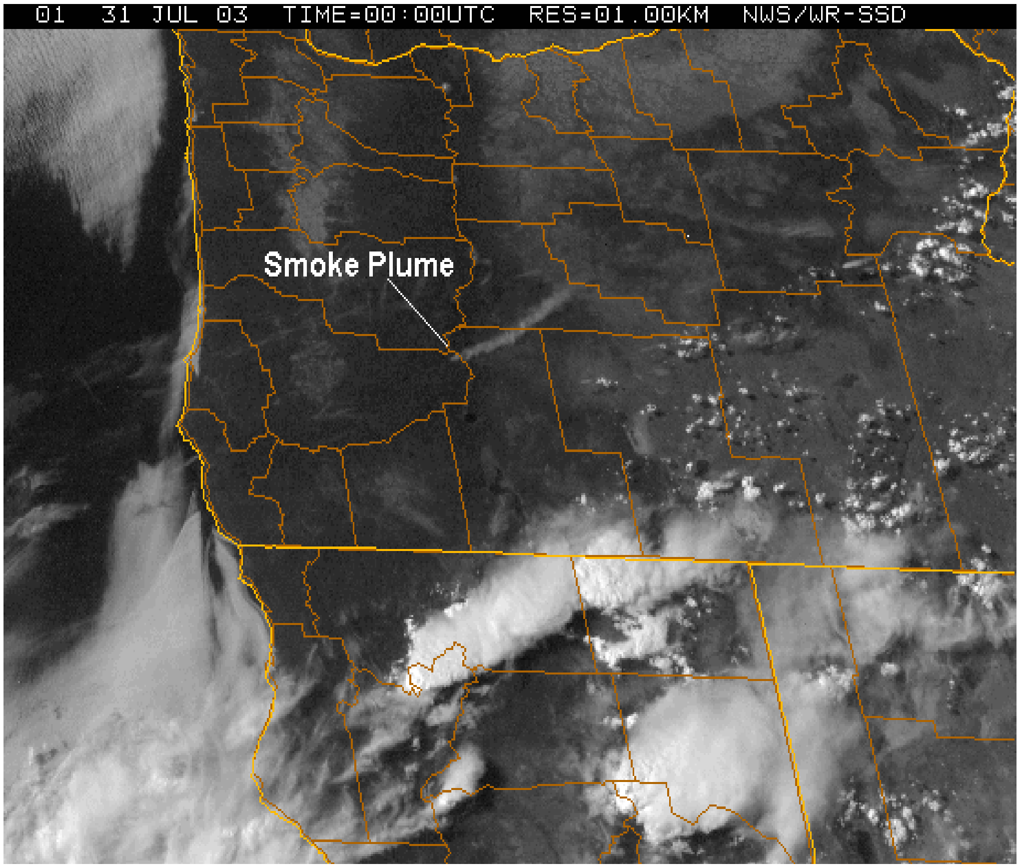

Figure 7 Visible satellite imagery of smoke column over Kelsay Complex in southwest Oregon valid at 0000 UTC 31 July 2003.

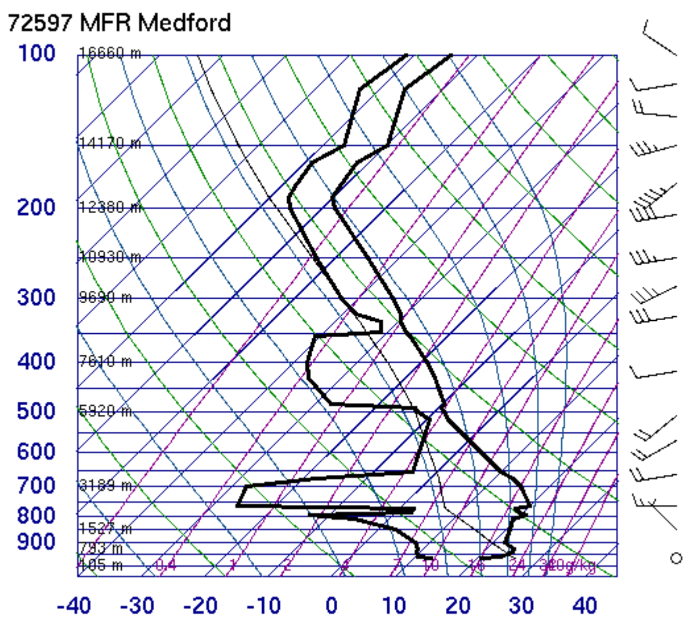

Figure 8 Observed Medford, Oregon (MFR) sounding valid at 1200 UTC 31 July 2003.

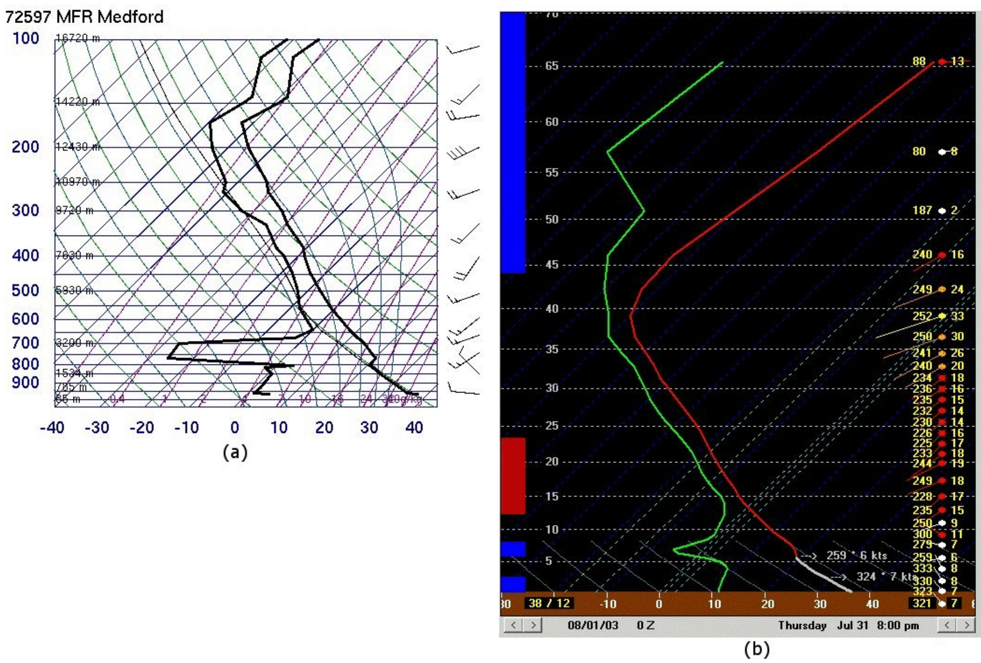

Figure 9 Sounding information for a) observed Medford, Oregon (MFR) sounding valid at 0000 UTC 1 August 2003 and b) BUFKIT display of Medford, Oregon (MFR) 36 hour Eta model forecast sounding valid at 0000 UTC 1 August 2003.

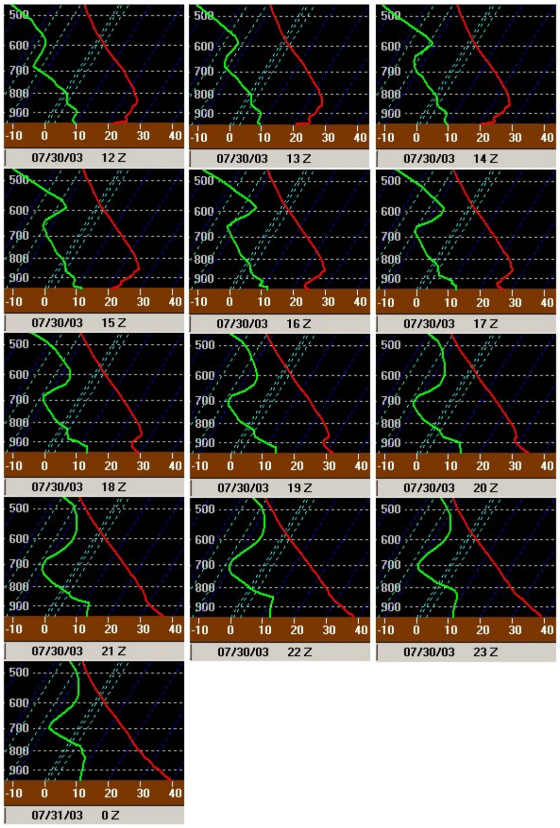

Figure 10 Hourly forecast sounding profiles from 1200 UTC 30 July 2003 to 0000 UTC 31 July 2003 for Medford, Oregon (MFR). Horizontal axis indicates temperature in degrees Celsius (C). Vertical axis indicates values of height (hPa).

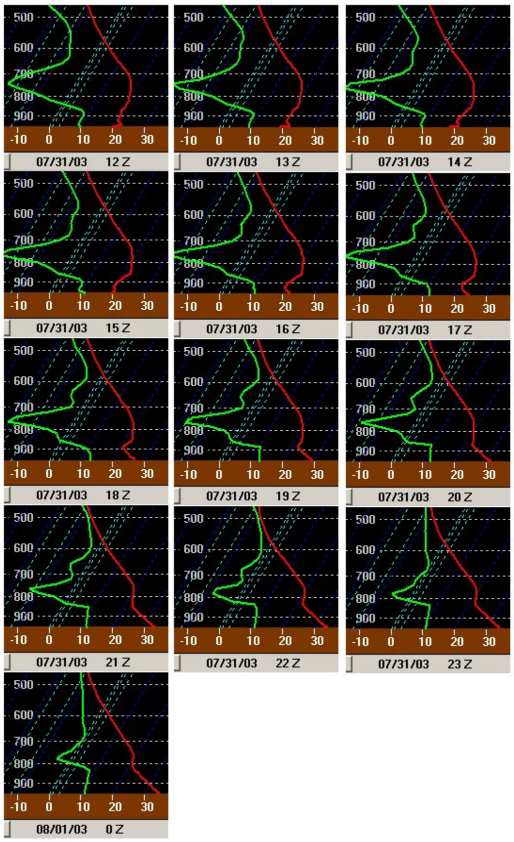

Figure 11 As in Figure 10, except from 1200 UTC 31 July 2003 to 0000 UTC 1 August 2003.

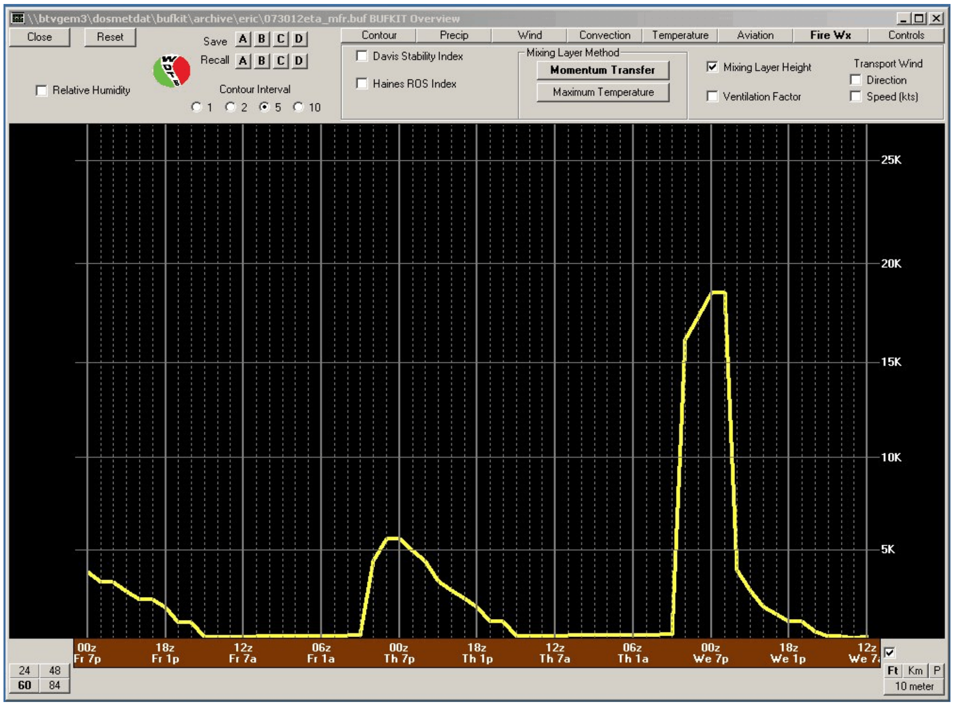

Figure 12 BUFKIT time height display of Mixing Height from 1200 UTC 30 July 2003 to 0000 UTC 2 August 2003. Timeline begins with 1200 UTC 30 July 2003 on the right and ends with 0000 UTC 3 August 2003 on the left. Mixing height values are denoted by thick yellow line and are in thousands of feet.

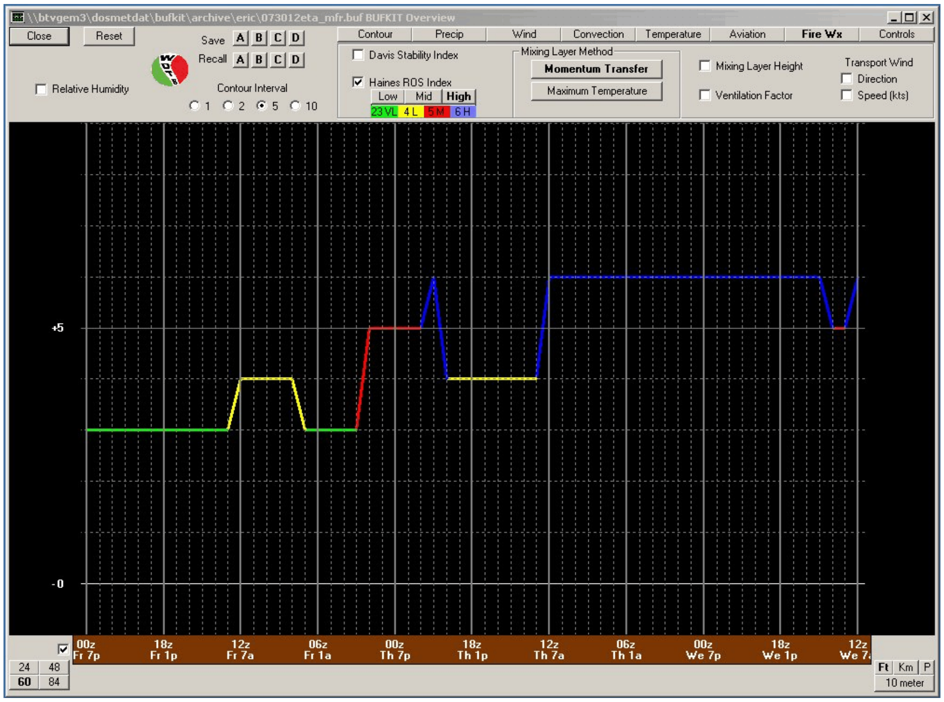

Figure 13 BUFKIT display of forecast High Haines Index values from 1200 UTC 30 July 2003 (Wednesday) Eta model run. Haines Index values indicate the potential for plume dominated fires. Values of 6 (high potential) are in blue and are forecast at that level for much of 30 July 2003 and for the afternoon hours on 31 July 2003 (Thursday). Value colors are as follows: 5 is red (moderate potential), 4 is yellow (low potential), and 2 or 3 is green (very low potential). Note that when values change, such as 6 to 4, the line remains blue until the value of 4 remains persistent for a given period of time.

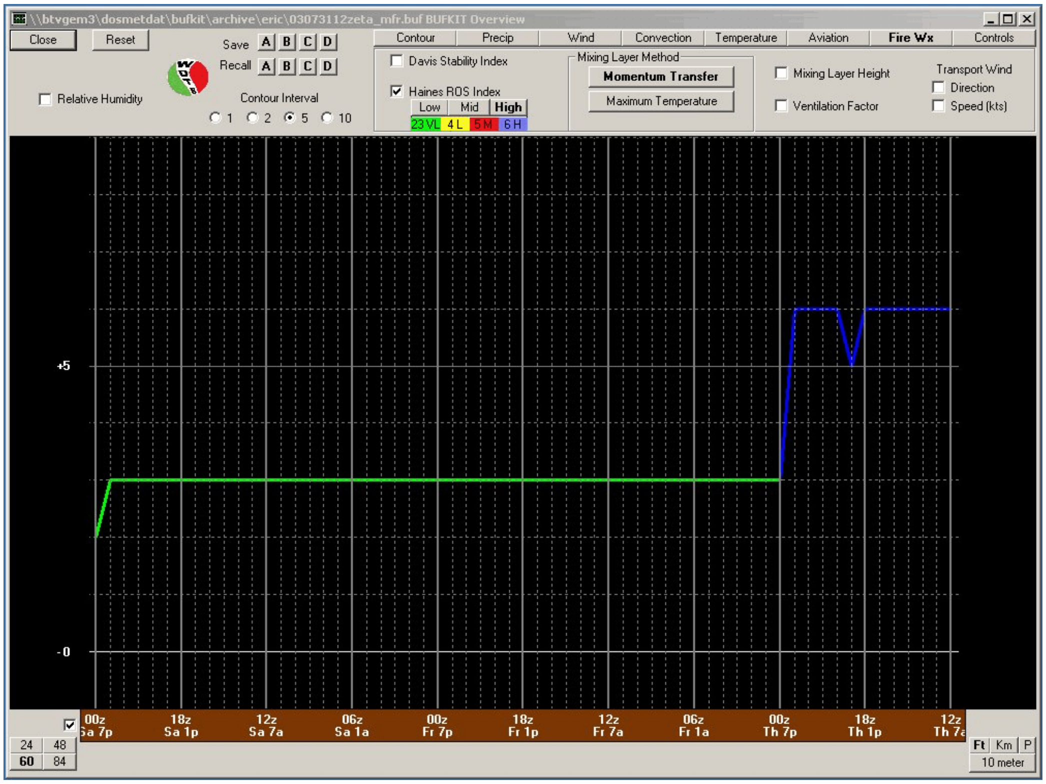

Figure 14 As in Figure 13, except from 1200 UTC 31 July 2003 (Thursday) Eta model run.