WEATHER RELATED UNUSUAL FIRE BEHAVIOR IN THE AWBREY HALL FIRE

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Abstract

The Awbrey Hall Fire, which occurred in central Oregon during 1990, displayed unusually intense nocturnal fire behavior. The vigorous nighttime activity was related to the meteorological conditions in the low- and mid-troposphere. The meteorological conditions before and during the fire are examined using upper air, satellite and gridded model forecast data, along with Haines Index values throughout the Pacific Northwest. Subtle features in the low-level flow may explain why an unusually strong convective column might form, and lead to rapid growth of the fire. The Haines Index values also agreed with the unusual fire behavior.

1. Introduction

On 4 August 1990, the Awbrey Hall Fire ignited and burned near the town of Bend in central Oregon. As it skirted the western edge of the city, this intense wildfire consumed 3353 acres and 22 homes within the urban/wildland interface. The fire halted its advance on the morning of 5 August, about 12 hours after it began its major run. Damage was estimated at $9 million, but there were no deaths or serious injuries and Bend narrowly escaped a major catastrophe.

Contrary to normal fire behavior, the Awbrey Hall Fire displayed its most rapid growth and extreme behavior after dark on the night of 4 August. Although winds in the area were light, the fire advanced several miles in a few hours. Subtle, yet important, meteorological conditions over central Oregon during this period may explain the unusual nighttime fire behavior. This paper will discuss the chronology and behavior of the fire as well as the meteorological conditions that led to the unusual fire behavior.

2. Terrain and Fuel Types

Bend lies east of the Cascade mountains near the geographical center of Oregon. The terrain is generally flat at an elevation of 3800 feet above Mean Sea Level. The crest of the Cascade mountains lies 50 miles to the west of Bend, with many peaks above 7000 feet. Figure 1 shows the area near the Deschutes River west of Bend that was burned during the fire. The shading in the figure indicates the spread of the fire at various times throughout the night. The Deschutes River flows northeast in this area, eventually flowing into the Columbia River 100 miles to the north.

Due to low precipitation during the four previous winters, the Long-Term Palmer Drought Severity Index categorized severe to extreme drought east of the Cascade Mountains of western Oregon, and throughout much of the western United States (Fig. 2). The summer heat and sparse precipitation of 1990 further depleted fuel moisture and steadily increased fire danger. By 4 August, the National Fire Danger Rating System reported that the timber and brushlands in central Oregon had reached their driest level of the year.

The primary wildland fuel type near Bend consisted of stands of second growth ponderosa pine and a nearly continuous bed of bitterbrush, cured annual grasses and four inches of accumulated pine needle litter. The pine needle litter is known to be particularly volatile because its internal chemical content can add considerable extra energy to a wildfire's combustion.

3. Fire Behavior and Chronology

The Awbrey Hall Fire began as an abandoned campfire that spread from a county park northwest of Bend shortly after 1500 Pacific Daylight Time (2200 UTC) 4 August 1990. The combination of high temperature, low relative humidity, and extremely dry fuel produced ideal conditions for extreme fire behavior and rapid growth. Despite flat terrain and light surface wind the fire grew to 350 acres by 1700 PDT (0000 UTC). Firefighters responded quickly but the intense flames soon overwhelmed their efforts. Heavy aerial bombardment of fire retardant also failed to halt its growth. The fire advanced primarily in the surface fuels but the intense flames frequently reached well into the tinder dry crowns of trees. Once established, crown fires burning in treetops have been known to move independently of surface fires. However, in this case, wherever the surface fire encountered an overstory of trees it expanded into a wall of flame 75 to 150 feet high. Entire stands of lodgepole and ponderosa pine burst into flame at once.

A towering convection column of rising smoke and hot gases built over the blaze. Veteran firefighters later remarked that it was one of the largest they had ever seen. Burning embers from the fire were rapidly swept aloft into the plume and then ejected southward into highly receptive fuel beds. These embers started numerous spot fires that helped propagate the main fire to the south and established a pulsating growth pattern.

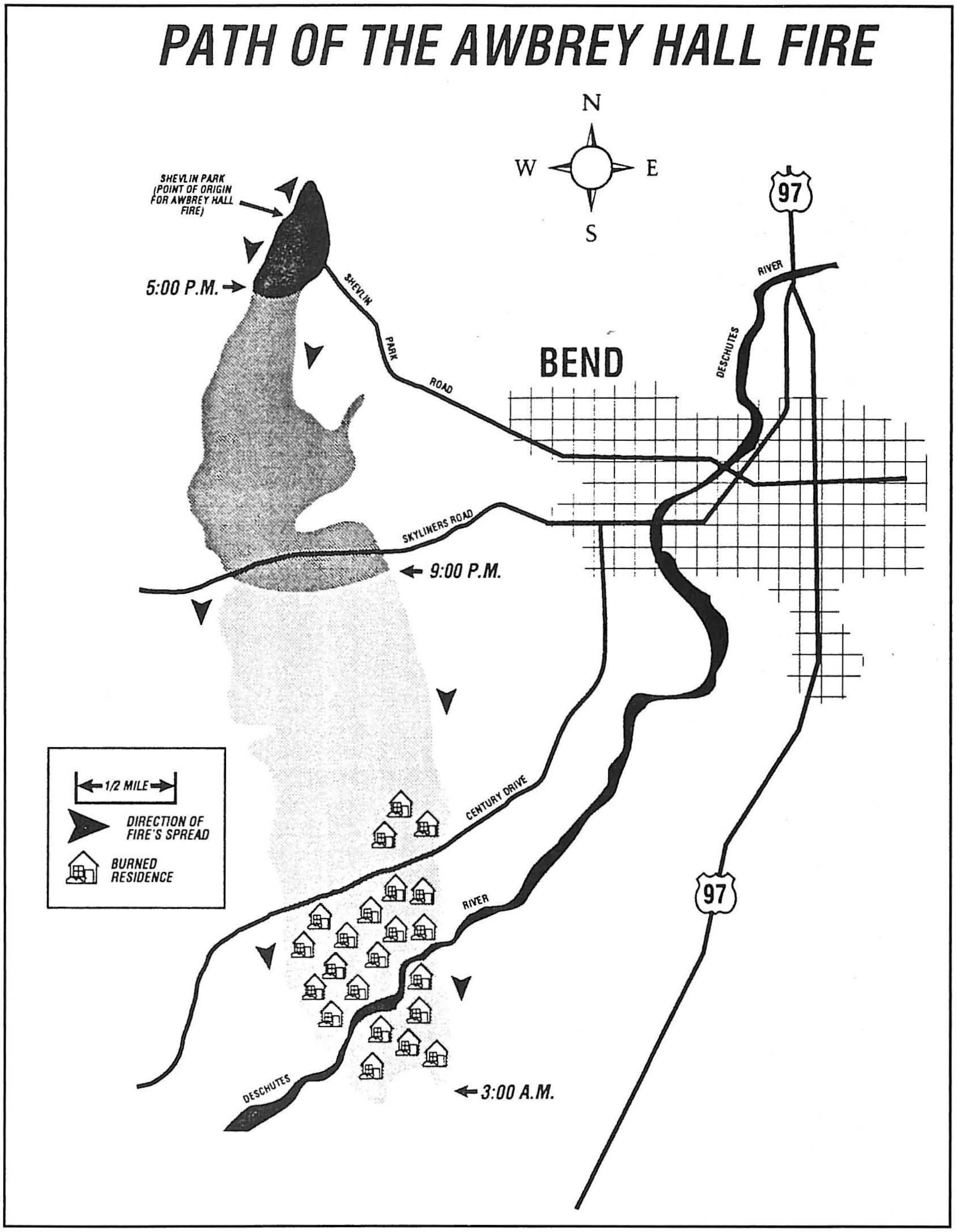

Figure 1. Map of Awbrey Hall Fire area and Bend, Oregon. Times shown along path are 4–5 August 1990 Pacific Daylight Times.

Contrary to normal fire behavior, the Awbrey Hall Fire accelerated its growth after dark. Since the fire's extreme rate of spread was not commensurate with the light winds observed in the area, it is likely that other atmospheric processes contributed to the increasing fire intensity. First, diurnal cooling occurred very slowly at the surface. This allowed relative humidity to stay below 20% for several hours after sunset. Low relative humidity permitted continued intense combustion in light fuels such as twigs and pine needles which are important in propagating a wildfire. Second, instability encouraged upward vertical motion in the convection plume. This set up a self-sustaining process in which air rushing in to replace rising gases in the convection plume fanned the fire to a greater intensity. Convergent indrafts overpowered the feeble surface winds allowing the fire's growth to be dominated by the strength of its convection plume. In this sense, the fire's convection column was more powerful than the local wind. This "plume dominated"

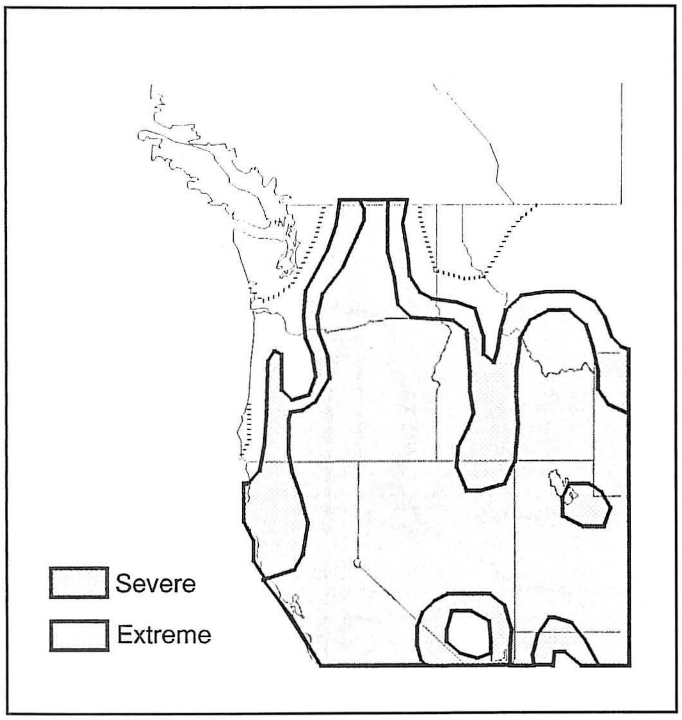

Figure 2. Palmer Drought Severity Index on 4 August 1990.

growth process contrasts with most other wildfires that are simply driven by the force of a strong wind (such as fires driven by the dry Santa Ana wind of Southern California).

It was not until long after midnight that the fire's intensity finally began to diminish. Discontinuous fuels and atmospheric trends finally began to oppose fire growth. Diurnal cooling gradually set in at the surface and allowed relative humidity to rise. Increasing stability lessened vertical motion in the convection column.

It was between 2100 and 2400 PDT 4 August (0400 and 0700 UTC 5 August) that the fire reached its peak intensity. During this period, the fire grew from 2000 to 3000 acres and advanced several miles south despite light winds. Firefighting resources streamed into the area from across the state, but the fire continued to defy control. Housing subdivisions and crowded resorts were evacuated over a ten mile wide area ahead of the fire. Despite a spirited defense by firefighters, sixteen homes on the southwest side of Bend were destroyed when flames 150 feet long raced across Century Drive. Spot fires jumped to the south side of the Deschutes River where six more homes were lost. During this interval, the fire's rate of spread averaged 175 feet per minute.

After 0300 PDT (1000 UTC) 5 August, the convection plume dissipated and fire activity declined significantly. Flame intensity and spot fires decreased dramatically and dense smoke began to accumulate at the surface as a nocturnal inversion formed. The fire continued to smolder, but lack of extreme behavior allowed firefighters to establish control lines around the blaze. Its advance was halted six miles south of its origin.

The fire experienced periodic, vigorous flareups on subsequent afternoons. There were several tense hours each day as flames rekindled and threatened to jump control lines, however, more than a thousand firefighters and numerous supporting aircraft were able to keep the blaze from spreading. The fire finally burned itself out within the control lines, but without the efforts of the firefighters it certainly would have grown out of control again. The firefighters were aided by the fact that the fire never again displayed unusual nocturnal behavior and subsided normally each evening until it was completely extinguished on 22 August 1990.

4. Weather

a. Upper air

During the first week of August 1990, an intense long-wave ridge had developed over western North America. Warming and drying peaked on 4 August as the upper ridge axis passed over central Oregon. Figure 3 shows the 50 kPa height analysis over the Pacific Northwest at 1700 PDT 4 August (0000 UTC 5 August). The upper ridge axis was located near the Idaho/Oregon border where heights generally exceeded 5900 m.

Nearly every upper air station in the region reported extremely low humidity aloft. Figure 4 shows the 0000 UTC 5 August radiosonde reports from Boise, in southwest Idaho, Medford, in southwest Oregon, and Salem, in northwest Oregon. Winds aloft were mostly southerly or southwesterly at Medford and Salem, but in the lowest 20 kPa light north to northwesterly flow was evident.

b. Surface

Subsidence from high pressure east of the Cascades and a weak surface thermal trough to the west left central Oregon with light winds and warm temperatures. Figure 5 shows a surface chart for Oregon at 1300 PDT (2000 UTC) 4 August 1990. Observations taken from an automated reporting station near Bend on the afternoon of 4 August reported a high temperature of 95°F, and relative humidity at 15%. Northerly afternoon surface winds at this exposed site remained less than 8 mph during the night of 4–5 August.

c. Satellite Imagery

GOES imagery revealed a fast-moving high-level shortwave impulse pushing northeast along the Oregon coast at 45 knots during the evening of 4 August. Water vapor imagery at 0301 UTC 5 August (Fig. 6) showed the feature moving over Vancouver Island and producing some clouds over Washington. Darkening in the dry slot behind the shortwave implied increasing subsidence behind it (Weldon and Holmes 1991).

d. Gridded Data

As discussed by Keyser and Uccellini (1987), gridded data output from regional forecast models can be a valuable tool for investigating phenomena that occur on time or space scales shorter than the normal synoptic observing network. In this case, the fire was a fair distance away from the nearest radiosonde station, and displayed its most unusual behavior in the middle of the night around 0600 UTC. Thus, gridded forecast data from the NWS National Meteorological Center's Nested Grid Model (NGM) was used as a proxy for detailed upper air observations during the night. Figure 7 shows 6-hour forecasted 85 kPa temperatures and streamlines valid at 0600 UTC 5 August. Horizontal deformation is evident with a dilatation axis on a northwest/southeast orientation through Oregon. The temperature gradient roughly normal to the dilatation axis resulted in frontogenesis. The orientation of streamlines and isotherms in Fig. 7

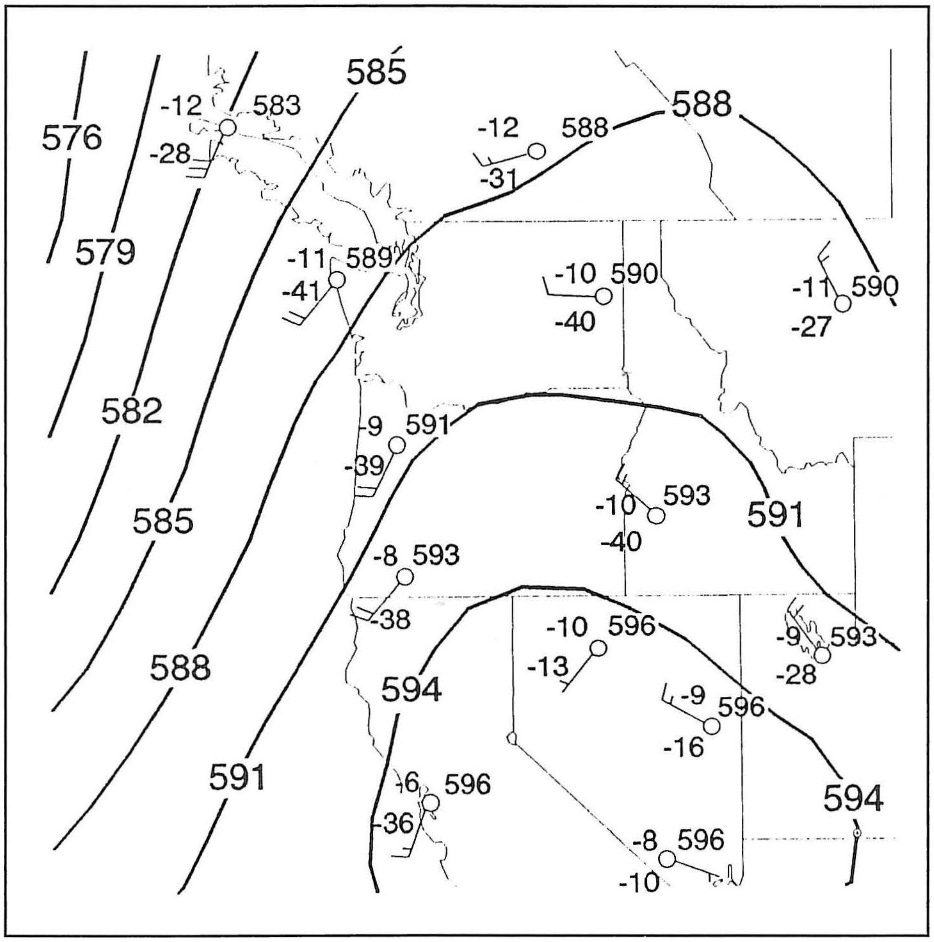

Figure 3. 50 kPa analysis for 0000 UTC 5 August 1990. Contour interval is 30m.

show the warm advection near the upper ridge and cold advection associated with the trough offshore.

The concurrent 6-hour forecast of the 70 kPa vertical motion (omega) field valid at 0600 UTC 5 August is shown in Fig. 8. Negative values of omega indicate upward vertical motion. An ageostrophic circulation associated with the low level frontogenesis probably led to the maximum in the omega field that lies nearly parallel to the dilatation axis shown in Fig. 7 (Holton 1979). The 18-hour omega field from the 1200 UTC NGM run (not shown) also had a weak upward motion maximum oriented along the deformation zone at this same time. Figure 9 shows a time/height profile of omega at a grid point near the fire's location from the 1200 UTC 4 August 1990 run of the NGM. The model forecasted omega reached a maximum near 70 kPa between 0300 and 0600 UTC 5 August which coincided with the fire's maximum intensity. Similar time/height profiles from the 0000 UTC NGM run also had the maximum vertical motion occurring around 0600 UTC, but with much higher values. By 1200 UTC 5 August, the upward vertical motion field had largely dissipated in both model runs, which corresponds with the time when fire activity had rapidly declined. While there is the possibility that the model data is showing a feature that did not exist in the real atmosphere, horizontal plots of model data at 0000 UTC 5 August correspond well with the radiosonde data in the area (not shown). Indeed, frontogenesis across central Oregon can be inferred solely from the radiosonde data at 0000 UTC 5 August and, thus, we believe the model forecasts for 0600 UTC are fairly credible.

The frontogenesis over central Oregon probably resulted from the influence of the upper shortwave brushing by just offshore. Low-level streamlines for times other than the one shown in Fig. 7, indicate that the deformation zone only developed briefly during the evening of 4 August and dissipated by the morning of 5 August. Figure 10 shows the radiosonde reports from 1200 UTC 5 August for Medford, Salem and Boise. Comparing this figure to Fig. 4 reveals that the shortwave had very little influence at far inland stations such as Boise. However, at Medford and Salem, there was an increase in low-level moisture and a slight increase in stability due to low-level cooling.

It is unlikely that low-level moisture reached east of the Cascades because surface dew point observations at the automated reporting site near Bend showed no increase during the night. Fire growth probably declined because of the diurnal increase of stability and relative humidity after dynamic forcing had ceased.

5. Haines Index

The Haines Index (Haines 1988) is a tool intended to quantify the atmospheric contribution to the growth potential of existing wildfires. The Haines Index combines two key atmospheric factors known to have a significant effect on

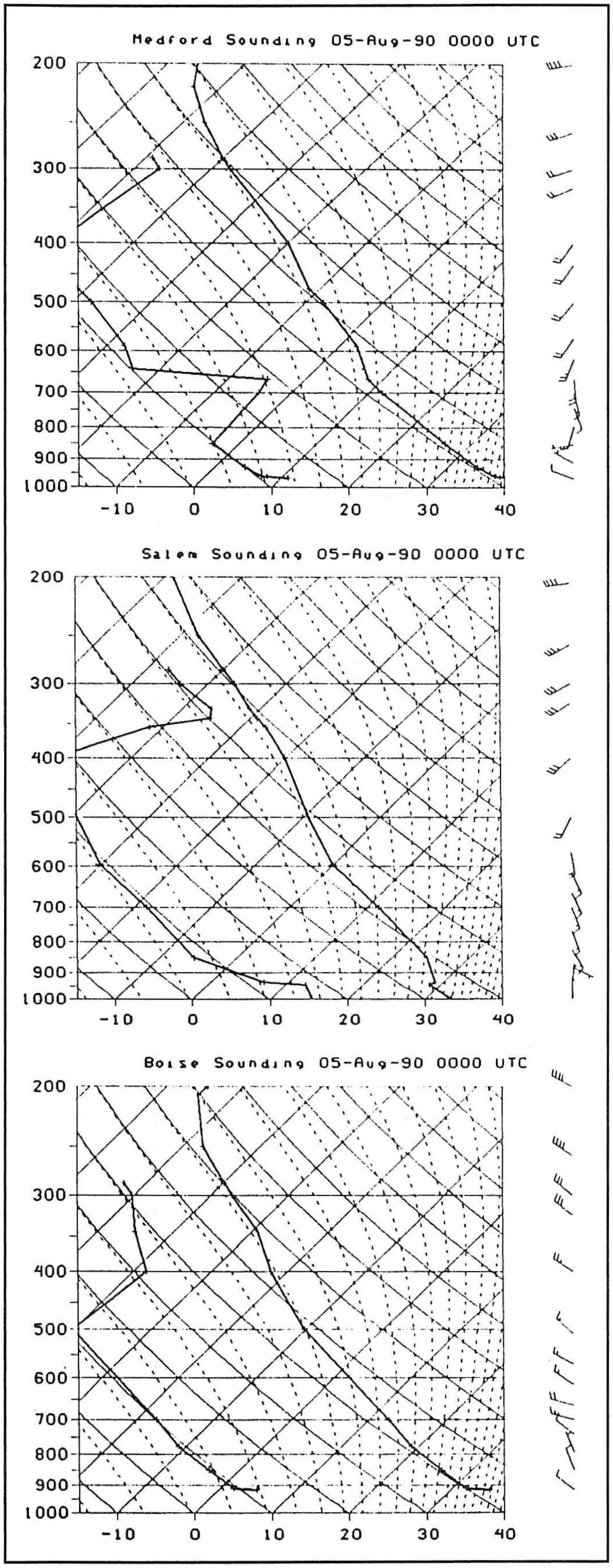

Figure 4. Skew-T/Log-p plots of 0000 UTC 5 August 1990 radiosonde ascents at: a) Medford, OR; b) Salem, OR; and c) Boise, ID.

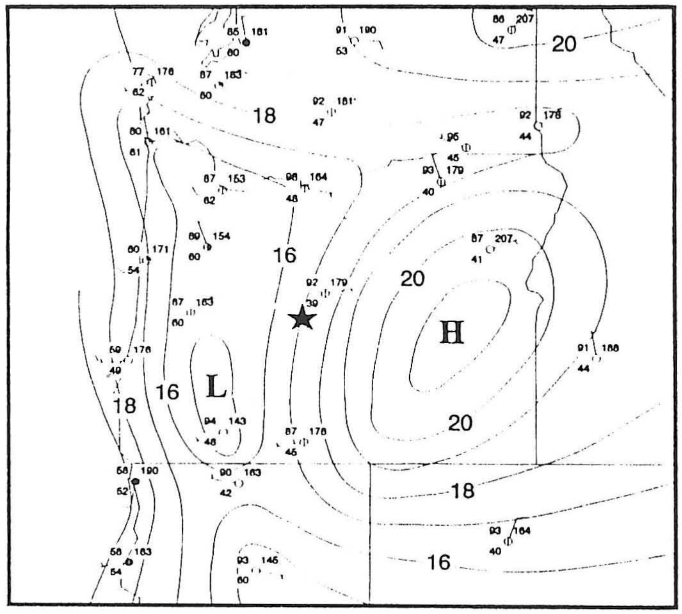

Figure 5. Surface chart at 2000 UTC 4 August 1990. Isobars drawn at 1mb intervals. Location of the fire denoted by the star.

the growth of wildfires: moisture and stability. Low moisture adds to the combustive energy released, while instability promotes vertical motion in a convection column. The Haines Index is determined by using an upper air sounding to calculate temperature lapse rate (stability) and dew point depression (moisture) at various levels of the atmosphere.

Large elevation and climatic differences across North America require that the Haines Index be adaptable to different altitude regimes to minimize diurnal effects. Depending on the elevation of the fire, a Haines Index variation can be calculated for three altitude regimes: Low, Mid and High (see appendix). Since the Awbrey Hall fire occurred on the central Oregon plateau, the high-level index is employed in this paper.

A Haines Index of two or three represents very low potential for fire growth while four represents low potential. Five indicates moderate potential and six represents the highest value possible. Previous studies (Haines 1988, Werth and Ochoa 1989) suggest that high values occur on less than ten percent of the days during fire season. However, it is on such days that extreme fire behavior and rapid growth are observed and the majority of acreage is consumed.

Figure 11 shows that on the morning of 4 August, Haines Index values displayed great variation around the western states. The 1200 UTC 4 August values in and near Oregon ranged from low at Medford to moderate and high at Boise and Salem, respectively. Very warm and dry air raised the Haines Index values at 0000 UTC 5 August to high at Boise and other Great Basin locations while Salem's barely fell into the moderate category. Medford's low value remained unchanged. It was at this time that the Awbrey Hall Fire displayed extreme behavior and rapid growth. By 1200 UTC 5 August, Haines Index values had dropped significantly to very low at Medford and low at Salem while Boise and other inland stations remained unchanged. At 0000 UTC 6 August values had returned to levels similar to the previous afternoon's.

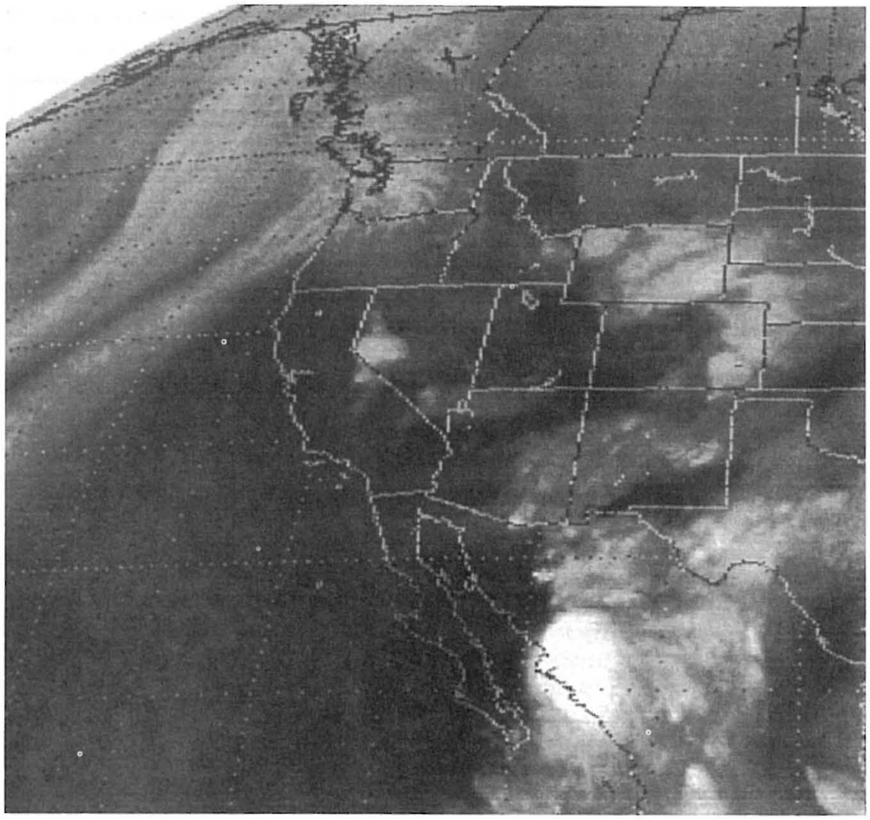

Figure 6. GOES water vapor imagery for 0301 UTC 5 August 1990.

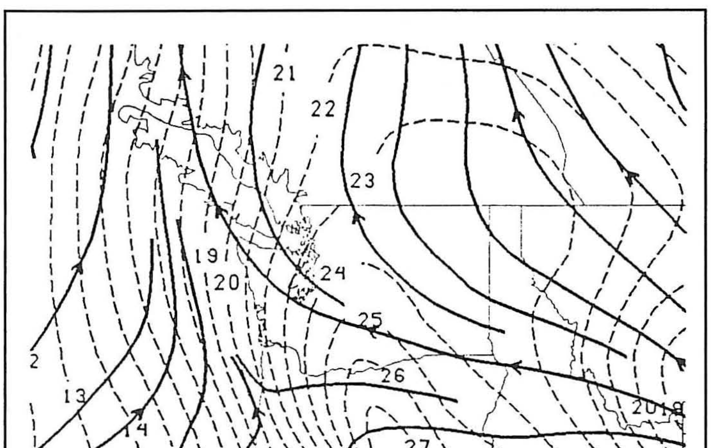

Figure 7. 6-hour NGM 85 kPa temperature and streamline forecast, valid at 0600 UTC 5 August 1990. Temperature contour interval is 1°C.

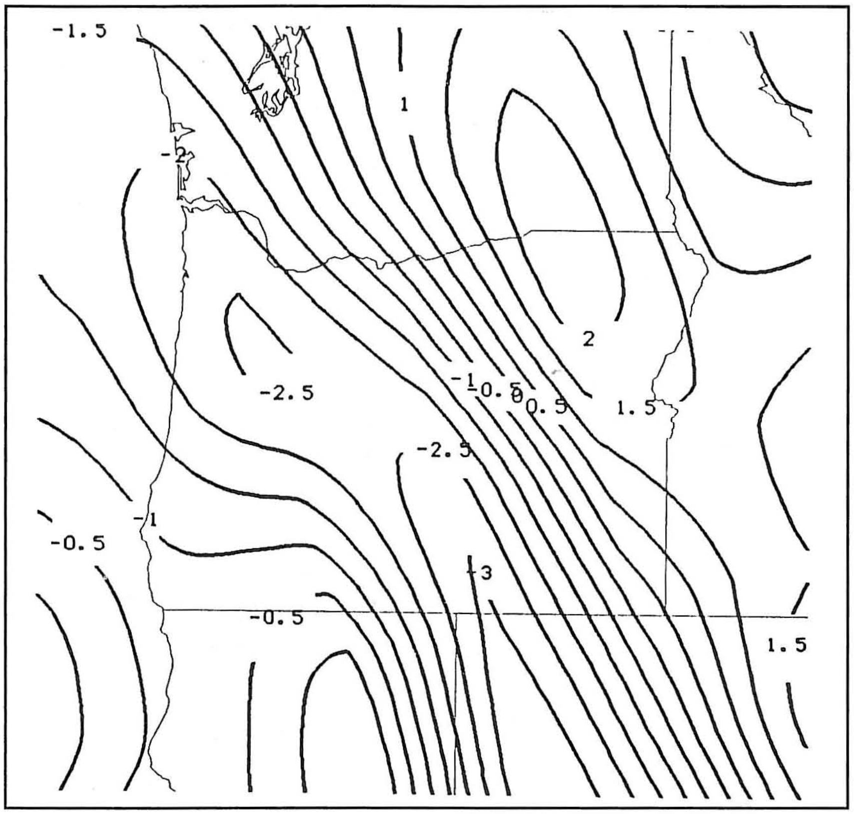

Figure 8. 6-hour NGM 70 kPa vertical motion (omega) forecast, valid at 0600 UTC 5 August 1990. Contour interval is 0.5 μb s^{-1}.

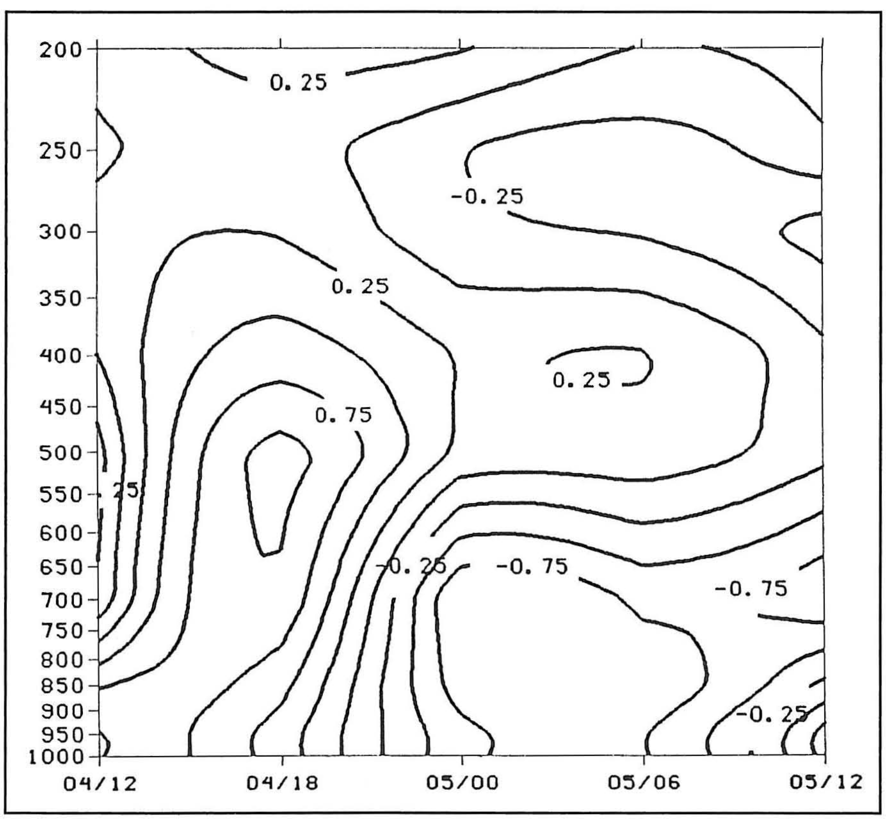

Figure 9. NGM Time-Height section of forecasted vertical motion (omega) for a gridpoint near Bend, OR (from the NGM run initialized at 1200 UTC 4 August 1990). Contour interval is 0.25 μb s^{-1}.

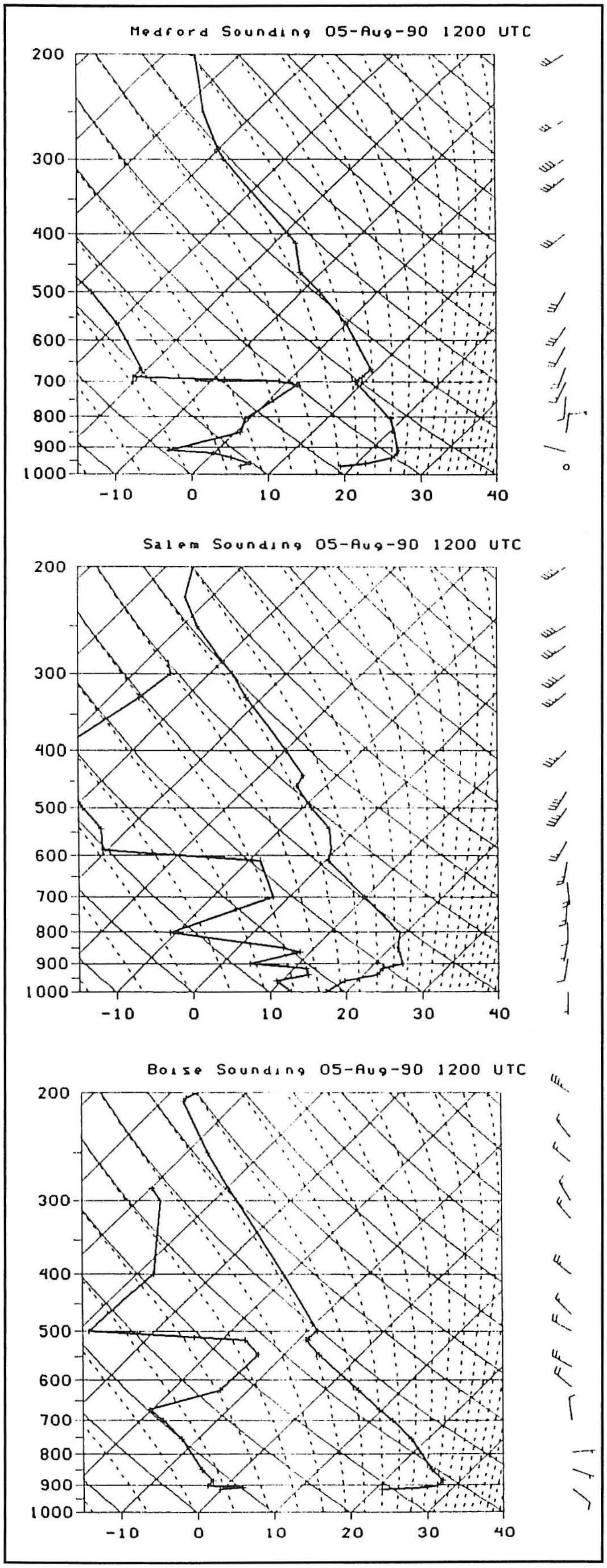

Figure 10. Skew-T/Log-p plots of 1200 UTC 5 August 1990 radiosonde ascents at: a) Medford, OR; b) Salem, OR; and c) Boise, ID.

6. Conclusions

Plume dominated wildfires are not fully understood and it is the intention of this paper to suggest some factors which probably contributed to the extreme fire behavior of the Awbrey Hall Fire. The authors believe that this plume dominated wildfire became severe because of an ideal combination of fuels and weather. Extreme drought assured dry fuels while dynamic forcing contributed upward vertical motion and instability to the hot air mass over central Oregon. As a result, the fire was dominated by its convection column much longer into the night than might otherwise have been expected. Fire behavior diminished normally when dynamic forcing decreased in the early morning hours of 5 August. Lack of dynamic forcing on subsequent nights and extensive fire suppression efforts probably prevented a recurrence of the severe fire behavior.

The Haines Index performed well during the Awbrey Hall Fire. When the index indicated moderate to high growth potential the fire displayed extreme behavior and rapid growth. Later, increasing moisture and stability caused the index to decline and fire severity diminished significantly. On subsequent afternoons the Haines Index again indicated moderate to high growth potential but fire activity, without the support of upper dynamic forcing, was held in check by the efforts of firefighters. Accurate forecasts of upper level temperature and moisture may allow the Haines Index to be used in a predictive sense.

Availability of gridded model data for research allowed a much closer look at the details of the dynamic situation than might not otherwise have been noted. The capability to create time/height displays and cross sections greatly added to the authors' understanding of the subtle and rapidly evolving features. The ability to forecast such features may well be enhanced when gridded data is made more available to field units.

Acknowledgments

Thanks are extended to Keith Brill, National Meteorological Center, who helped in obtaining the gridded data, and Elaine Robinson, NWS/Western Region Headquarters, Scientific Services Division, who helped with the manuscript preparation. Thanks are also extended to James Holroyd of the USDA Forest Service and James Steel of the USDI Bureau of Indian Affairs for information regarding fire danger rating and fire behavior.

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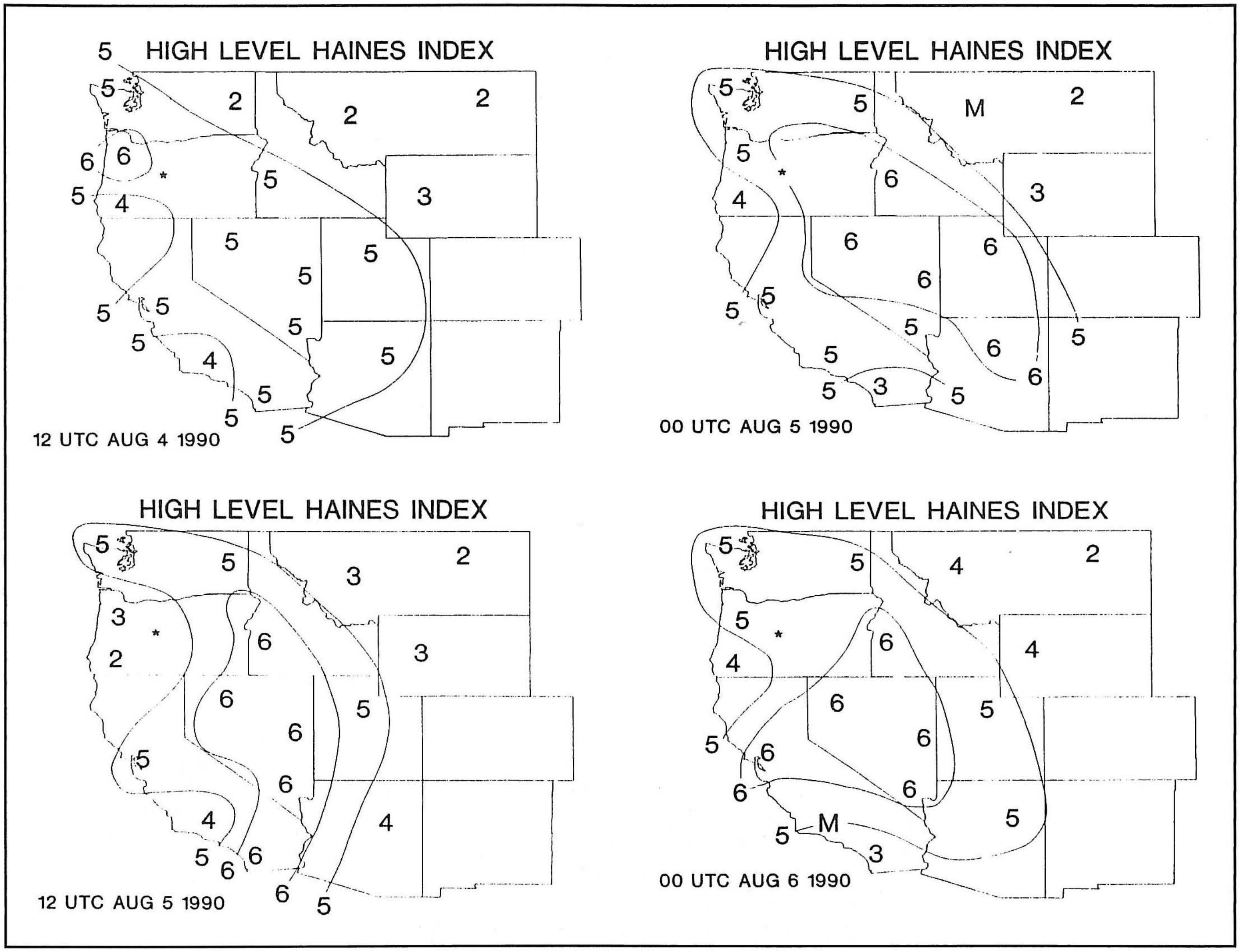

Figure 11. Haines Index for: a) 1200 UTC 4 August; b) 0000 UTC 5 August; c) 1200 UTC 5 August; and d) 0000 UTC 6 August 1990. Location of the fire denoted by the star.

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Appendix

Haines Index	=	Stability Term:	+	Moisture Term:
	=	A	+	B

Altitude	*Stability Term:*		*Moisture Term:*	
Low	*A*	*95-85 kPa Temp (°C)*	*B*	*85 kPa Temp—Dew Point (°C)*
	1	≤ 3	1	≤ 5
	2	4-7	2	6–9
	3	≥ 8	3	≥ 10
Mid	*A*	*85-70 kPa Temp (°C)*	*B*	*85 kPa Temp—Dew Point (°C)*
	1	≤ 5	1	≤ 5
	2	6–10	2	6–12
	3	≥ 11	3	≥ 13
High	*A*	*70-50 kPa Temp (°C)*	*B*	*70 kPa Temp—Dew Point (°C)*
	1	≤ 17	1	≤ 14
	2	18–21	2	15–20
	3	≥ 22	3	≥ 21

HAINES INDEX	*POTENTIAL FOR FIRE GROWTH*
2 or 3	Very Low
4	Low
5	Moderate
6	High