

PACIFIC SOUTHWEST Forest and Range Experiment Station

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
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SLASH SMOKE DISPERSAL OVER WESTERN OREGON... a case study

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The Authors

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On October 20, 21, and 22, 1969, more than 350,000 tons of logging slash were burned in the Cascade Mountains above 2,600 feet mean sea level (m.s.l.¹)—yet the fires added almost no smoke to the already seriously contaminated air below that level in the populous Willamette Valley of western Oregon. At times, smoke in the mountains was dense, but winds carried it over the sparsely populated areas east of the Cascades. We reached this conclusion after a study of aerial observations made on the afternoons of October 20 and 22.

Because of national and local concern for air quality control, forest slash burning is being scrutinized critically as a contributor to air pollution in Oregon and Washington. Accumulated slash is potential fuel for the large, destructive conflagration, and presently the most practical treatment is controlled

burning. Foresters realize, nevertheless, that indiscriminate burning of debris without regard to location, time, atmospheric conditions, or fuel condition and arrangement can contaminate the air with smoke. They are learning that slash can be eliminated by prescribed burning with a minimal effect on air quality in high population centers.

This paper reports a study to determine if smoke from large-scale slash burning in the Cascade Range contaminated the atmosphere in the Willamette Valley during a 3-day period of stable air conditions. The weather conditions during this episode in October are typical for the autumn slash burning season in western Oregon. A detailed analysis of weather data is a part of the study, which is in effect a case history of burning conditions and smoke dispersal during a representative burning operation.

WEATHER PATTERNS

An anticyclone, or high pressure area, moved westward over Oregon during the period Saturday, October 18 to Wednesday, October 22 (*fig. 1*). It was accompanied by strong subsidence, or sinking, of the air mass, which caused marked stability at elevations below 10,000 feet (m.s.l.). The episode was followed by the arrival of cyclonic flow, upward motion, and a transition to an unstable air mass by Thursday, October 23.

At 1600 P.s.t. on Saturday, at 9,300 feet over Salem, in the central Willamette Valley, the temperature had risen to 35°F.—an increase of 15° since 0400 the same day (*fig. 2*). Wind flow below 5,000

feet became light. The subsidence and warming trend temporarily leveled off Saturday night, owing to the approach of a dissipated storm front, which moved around the northern portion of the High. Also, nighttime cooling occurred below 2,400 feet. By Sunday morning, the air over Salem was virtually isothermal from the surface to 7,500 feet, an example of marked stability (*fig. 2*).

Even though the High moved inland over Oregon, there were widespread clouds over the northern half of the State, and sprinkles in western Washington. Subsidence was renewed late Sunday night and continued over northwest Oregon for 36 hours (*fig. 2*). During the entire study period, with few exceptions, the winds were generally westerly (*fig. 3*).

At 0400 on Tuesday, October 21, an upper air

¹ All elevations used in this report refer to mean sea level unless otherwise noted.

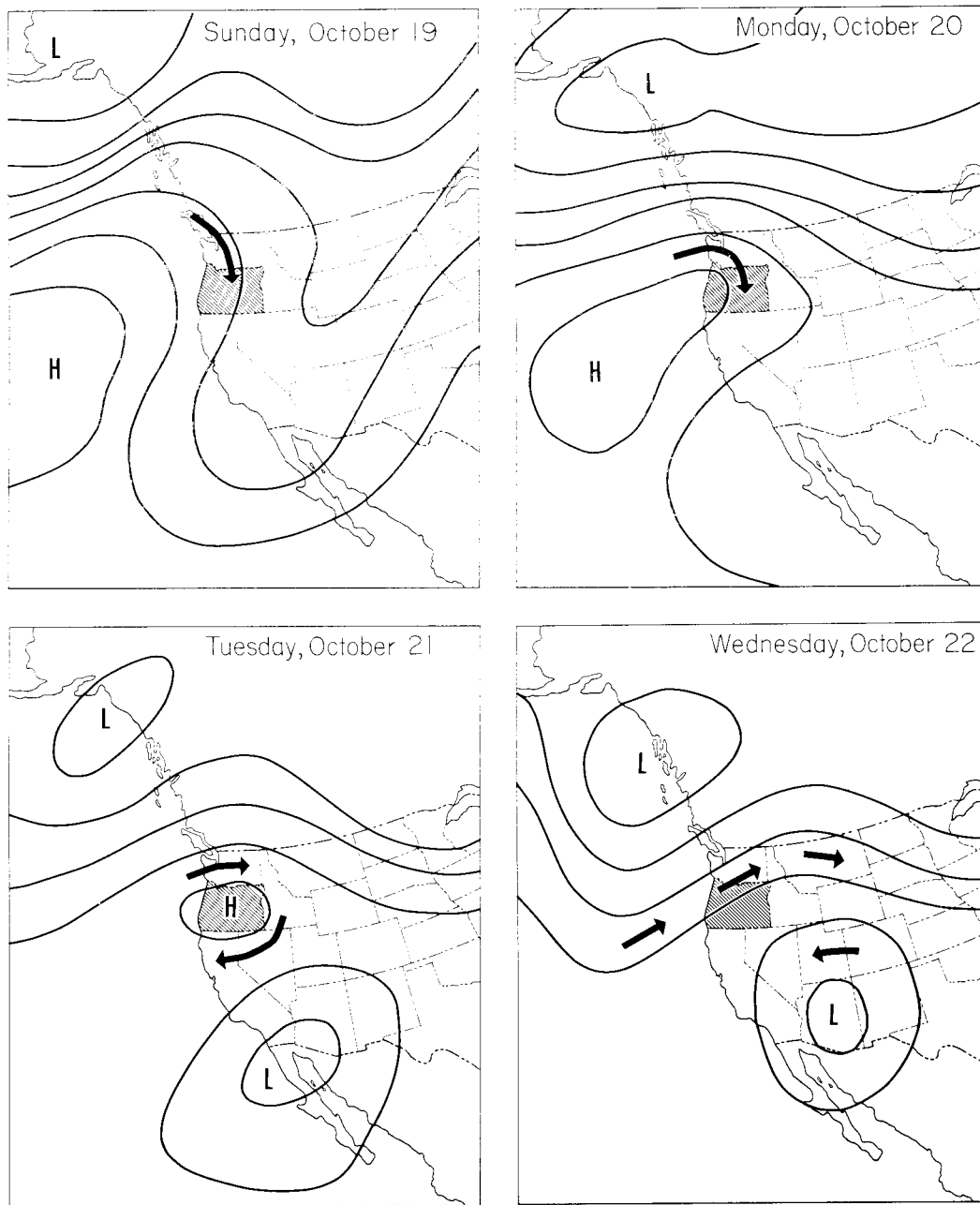


Figure 1—Wind flow at 10,000 feet (m.s.l.) varied widely on the mornings of the 4 days studied (October 10-22, 1969).

sounding from Salem showed a temperature of 39°F. at the ground and 65°F. at 2,600 feet—an inversion of 26°. From Sunday morning until Tuesday morning, winds below 5,000 feet in the Willamette Valley averaged less than 5 miles per hour.

By Tuesday afternoon, the center of the anticyclone at 5,000 feet was near Boise, Idaho—but high pressure still dominated northwest Oregon. Warming over Salem reached its climax as moderate south-

west winds 12-14 miles per hour (*fig. 3*), began to develop at 3,000 to 6,000 feet. The air mass above 2,800 feet had become less stable because of the warming at that level, with only negligible warming at the 10,000-foot level during the preceding 48 hours (*fig. 2*). The air mass below 2,800 feet remained highly stable.

A cooling process began Tuesday night and continued rather steadily during the rest of the period

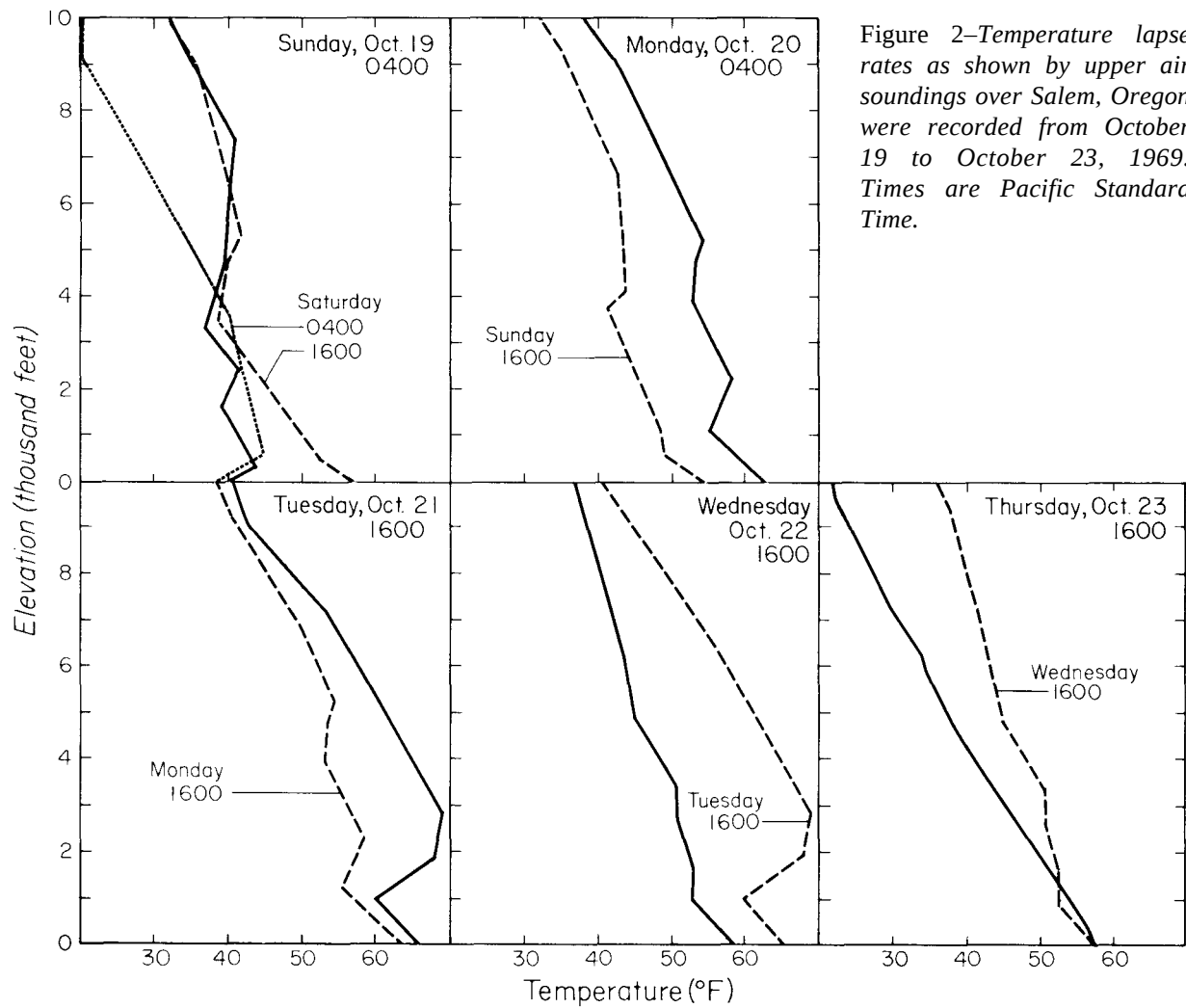


Figure 2—Temperature lapse rates as shown by upper air soundings over Salem, Oregon were recorded from October 19 to October 23, 1969. Times are Pacific Standard Time.

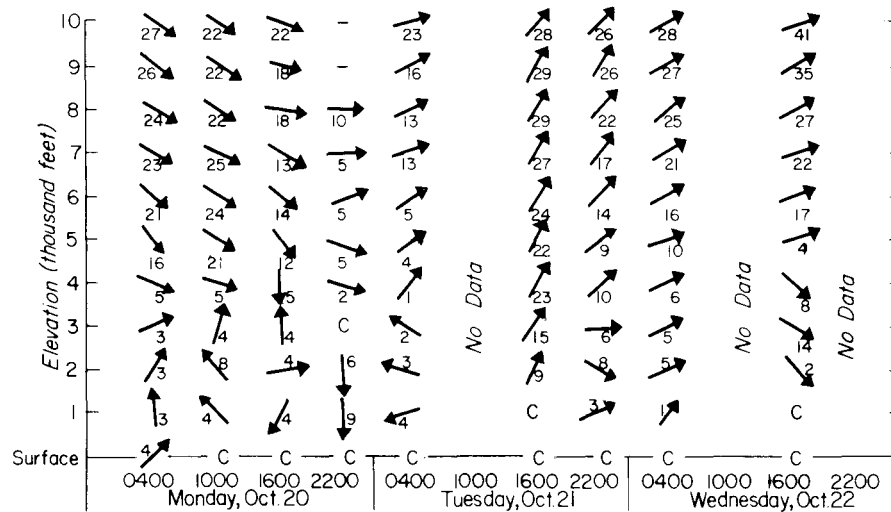


Figure 3—Wind speeds and directions taken at Salem, Oregon to 10,000 feet (m.s.l.) from October 20 to 22, 1969.

and beyond. This condition was caused by the eastward movement of the High away from western Oregon and the approach of cyclonic, or low-pressure, flow from the west. Subsidence in the High gave way to rising air in the Low (*fig. 2*). At first the

cooling was mainly in the lower levels, rendering the air mass more stable. During Wednesday night and Thursday, the cooling was mainly in the upper levels. The stagnant air in the Willamette Valley was dispersed by Thursday, October 23.

SLASH BURNING AND SMOKE DISPERSAL

Almost no slash burning was done in western Oregon on the two days preceding Monday. Since midsummer there had been 6 to 8 inches of rain in the Cascades. During the 3-day period studied, varying amounts of slash were burned (*table 1*). Burn

locations for each day are shown in *figure 4*. No slash was burned in the coast range west of the Valley during this period.

Very stable air conditions caused serious air pollution at this time in the Valley area below 2,600 feet. Visibility was at times less than 1 mile because of fog and smoke from local sources (*table 2*). On Tuesday afternoon, October 21, the Columbia-Willamette Air Pollution Authority announced pollutants in the air over Portland registered 98 on a haze index scale of 0-100. The haze index is a relative measure of visibility-reducing contaminants in the air; a value of 0 indicates the lowest level of contaminants, and 100 the highest expected during the year. The index is the weighted average of individual indexes for suspended particulate (smoke and dust) and nitrogen dioxide, with the two contaminants given 85 percent and 15 percent weightings.

Table 1—*Slash burned in western Oregon during the study period, October 20-22, 1969*

Date	Acres burned ¹	Fuel consumed
		Tons
October 20	819	54,850
October 21	2,936	192,200
October 22	2,225	139,250
Total	5,980	386,300

¹ For western Oregon and southern districts of Gifford Pinchot National Forest, Washington.

Table 2—*Visibility in the Willamette Valley and adjacent areas during the 3-day study period (P.s. t.)*

Location	Visibility											
	October 20, 1969				October 21, 1969				October 22, 1969			
	0800	1200	1600	1800	0800	1200	1600	1800	0800	1200	1600	1800
Portland, north end of Willamette Valley	3 mi. Smoke	5 mi. Smoke	7 mi. Smoke	15 mi.	1/16 mi. Fog and smoke	3 mi. Smoke	6 mi. Smoke	6 mi. Smoke	3/4 mi. Fog and smoke	2 mi. Fog and smoke	4 mi. Smoke	4 mi. Smoke
Salem, central Willamette Valley	1½ mi. Ground fog and smoke	4 mi. Smoke	6 mi. Smoke	6 mi. Smoke	Zero Fog and smoke	2½ mi. Smoke	5 mi. Smoke	5 mi. Smoke	1/8 mi. Fog and smoke	1 mi. Fog and smoke	3 mi. Smoke	4 mi. Smoke
Eugene, south end of Willamette Valley	1/8 mi. Fog and smoke	3 mi. Smoke	8 mi.	2 mi. Smoke	1/8 mi. Fog and smoke	1½ mi. Fog and smoke	4 mi. Smoke	2 mi. Ground fog and smoke	1/8 mi. Drizzle, fog and smoke	1 mi. Fog and smoke	2 mi. Fog and smoke	2 mi. Ground fog and smoke
Redmond, central Oregon, 35 miles east of Cascade crest	45 mi.	45 mi.	45 mi.	15 mi.	35 mi.	45 mi.	45 mi.	15 mi.	45 mi. Smoky in west quadrant	45 mi. Smoky in west quadrant	15 mi. Smoke	4 mi. Smoke
The Dalles, northern Oregon, Columbia River, 30 miles east of Cascade crest	30 mi.	30 mi.	30 mi.	15 mi.	30 mi.	30 mi.	30 mi.	30 mi.	30 mi.	20 mi.	30 mi.	15 mi.

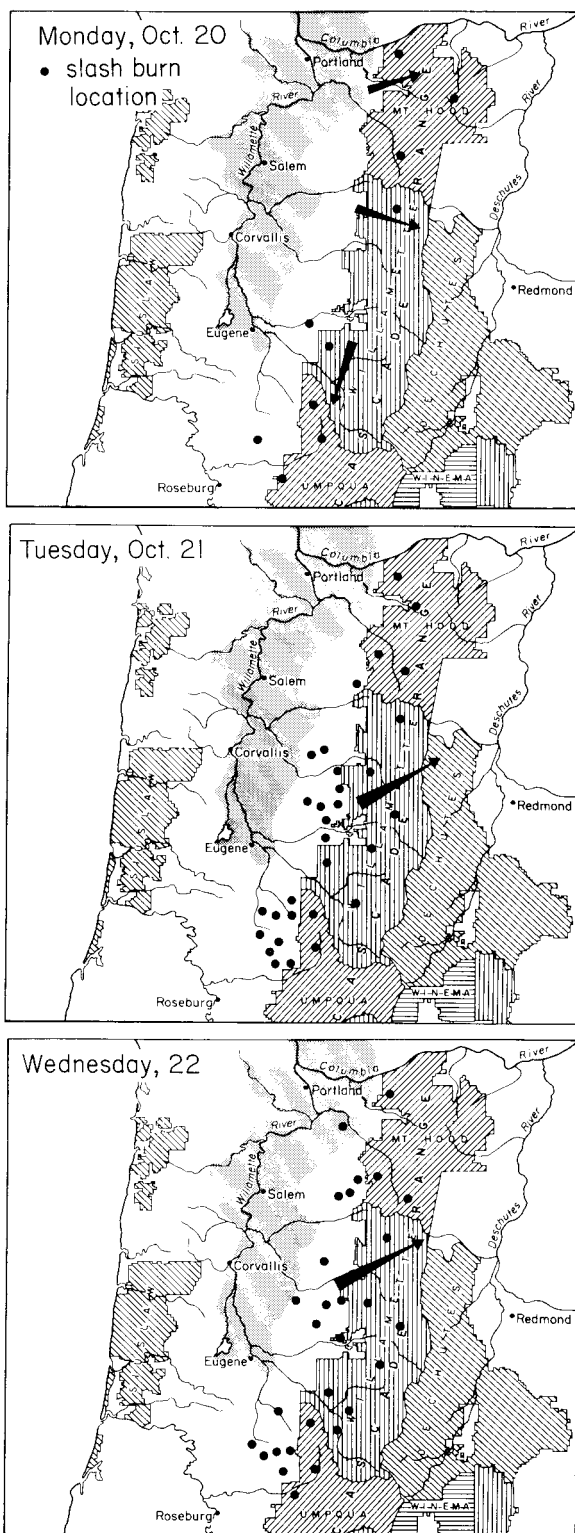


Figure 4—Arrows show general smoke drift from slash burns as observed from aircraft during the 3-day study period. Shaded area is the Willamette Valley, in western Oregon.

Monday, October 20

On this day, 819 acres of slash were broadcast burned at widespread locations in the Cascades (*fig. 4*). About 54,850 tons of fuel (67 tons per acre) were consumed in these burns. Peak smoke discharge was reached sometime between 1500 and 1700.

At 1600 in Salem, visibility was 6 miles in smoke from local sources in the Valley (*table 2*). The top of a lower inversion layer was at 2,200 feet, with another inversion between 3,900 feet and 5,300 feet (*fig. 3*).

During the observation flights made at this time, a layer of smoke could be seen near the floor of the Valley. Visibility was excellent throughout the Cascades, except for the lowest western slopes, and where scattered plumes of slash smoke were observed (*fig. 5*). A few of these appeared to be discharging into nearly calm air, with little smoke drift. However, all plumes were drifting away from the Willamette Valley. Over the Mt. Hood National Forest, the smoke drift was east-northeast. Over the northern Willamette National Forest, the drift was east-southeast. Smoke from 434 acres of slash burning on National Forest and State land south and east of Eugene (*fig. 4*) was drifting south-southwest. All smoke plumes rose only about 500 to 1,000 feet above the ground and then drifted horizontally. The slash fires were widely spaced, and smoke impaired visibility only in the immediate areas of the burns.

The variety in direction of smoke drift in the Cascades on Monday, and the lack of correlation with observed winds over Salem (*fig. 3*), in the Willamette Valley, is of special interest. Evidently, pilot balloon observations from stations some miles removed from mountain areas are not necessarily representative of wind flow over the mountains—at least during periods of light upper winds (say less than 12 miles per hour).

Further research must determine if reliable analyses can be made from existing observation stations, or if additional pilot balloon observations in mountain areas are needed for better smoke management.

Tuesday, October 21

On this day, about 1500, slash burning activity reached its peak for the 3-day period—especially on State lands in eastern Linn, Lane, and Douglas counties (*fig. 4*). We made no aerial observations, but a Forest Service pilot reported that smoke was dense in the Cascades, and smoke drift was again away from the Willamette Valley. On this day, 192,200 tons of slash were consumed on numerous clearcut units

totaling 2,936 acres. The Mount Hood and Willamette National Forests burned a combined total of 1,475 acres—about half the acres burned in western Oregon for the day.

At 1600, the top of the Willamette Valley inversion was 2,800 feet (*fig. 2*). On the floor of the Valley, visibility was 4 to 6 miles in smoke from local sources.

Wednesday, October 22

Slash burn reports for Wednesday indicated that 139,250 tons of slash were consumed on 2,225 acres (*fig. 4*). Once again, peak burning activity was in late afternoon about 1600.

At this time, a reconnaissance flight was again made from Portland to the Eugene-Springfield area—south over the Cascades and back north to Portland over the Willamette Valley.

The situation was then rather complex. Over the Willamette Valley hung a shallow layer of low clouds with tops about 1,200 feet or possibly lower (*fig. 6*).

This layer was breaking up, revealing considerable smoke near the floor of the Valley. Immediately above this layer, visibility was excellent and the lower foothills of the Cascades were clearly visible.

Numerous smoke plumes were observed along the flight path over the west slopes of the Cascades. A few rose vertically for 1,000 feet or a little more, but most drifted almost horizontally from the source. All smoke drift was toward the east, and a dense pall covered most of the crest of the Cascades and eastward for at least 50 miles over central Oregon (*fig. 7*). Visibility in Redmond (elevation 3,071 feet) at 1800 was only 4 miles because of smoke from slash (*table 2*). Peaks above the 8,000-foot level were clearly visible. All slash burning was limited to areas above 2,500 feet.

From 2,500 feet to 8,000 feet, smoke was dense and widespread, although it was in two or more layers, varying with location, and with good visibility between layers. It was obvious to us that there was no relation between the slash smoke in the Cascades and the smoke on the Willamette Valley floor.

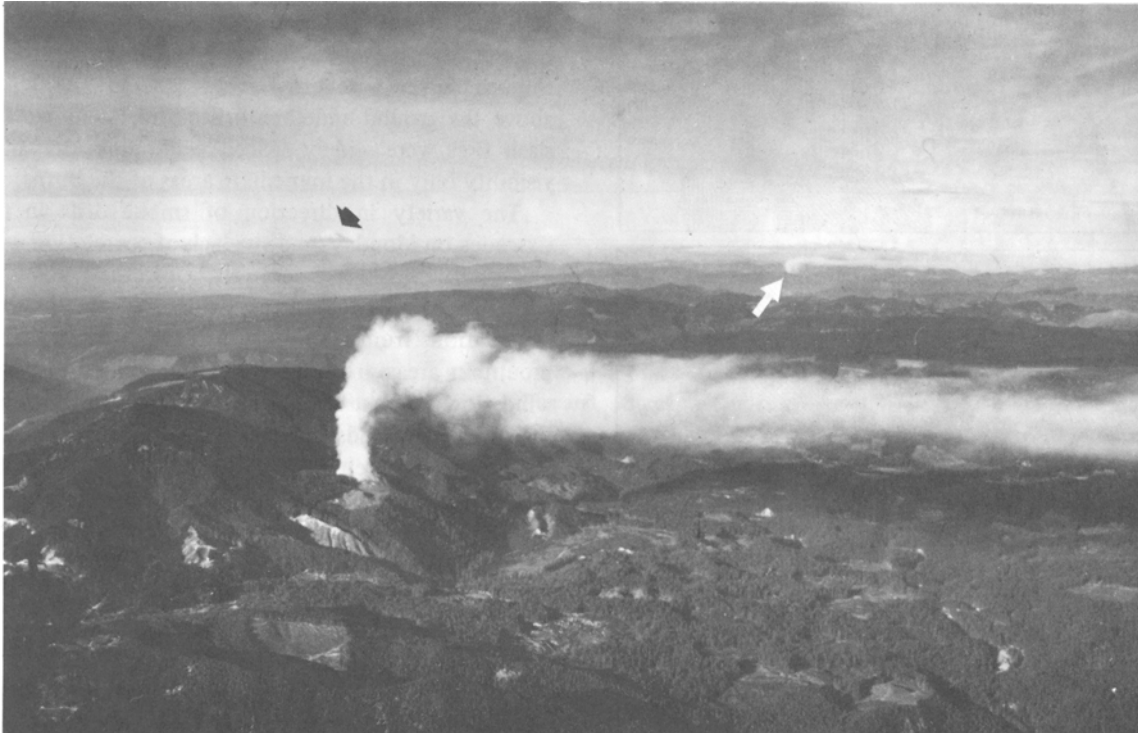


Figure 5—Aerial view looking north, showing excellent visibility over the Mt. Hood National Forest at 1600 on Monday, October 20. Mt. St. Helens (black arrow; elevation 9,677 feet) is approximately 100 miles distant. The smoke from the slash fire, in the foreground, is being carried eastward.

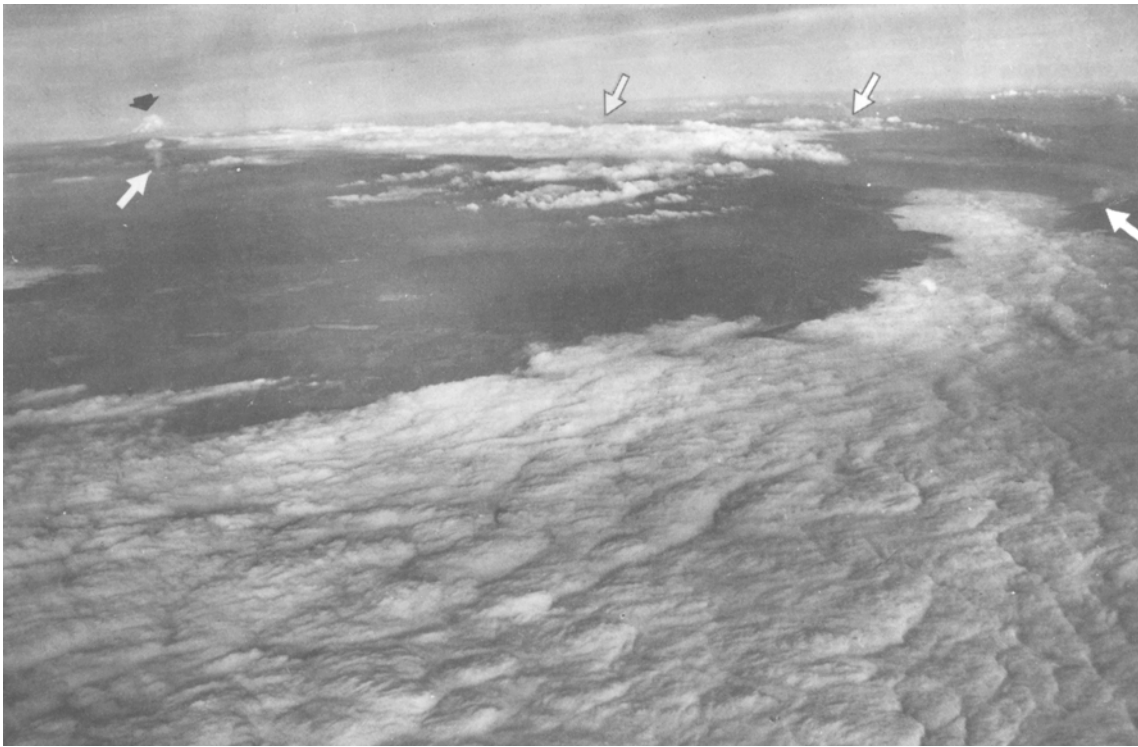


Figure 6—Aerial view of the Willamette Valley at 1700 on Wednesday, October 22, looking northeast toward Mt. Hood (black arrow). It shows that slash smokes (white arrows) in the Cascades are not mixing with low-level clouds and smoke in the foreground area.

DISCUSSION

The fundamental principles governing smoke dispersion are rather simple, but the practical application of these principles to smoke management poses new problems to both meteorologists and foresters; in a sense, both are beginners.

Atmospheric stability is important to smoke dispersion. However, this study clearly shows that wind direction was also a key factor in keeping slash smoke out of the Willamette Valley. Systematic observations of slash smoke plumes should help those responsible for smoke management to increase their skills. Visual evidence should be correlated with data on both wind and stability.

The dense smoke covering the Cascades on Tuesday and Wednesday (*fig. 7*) suggests that more restrictive limitations on burn acreages and locations may be necessary. Although winds aloft carried slash smoke away from the populated Willamette Valley, the smoke was concentrated over smaller com-

munities east of the mountains, and in the Cascades themselves. This problem although not as serious as valley pollution, must also be reckoned with.

This study did not explore the possible drift of smoke downcanyon at night. Air pollution investigators are interested in this possibility, and information should be sought. The downhill drift of smoke into the Valley in this instance was probably negligible. The marked stratification of air layers resulting from the persistent temperature inversion rendered such flow unlikely.

Limiting the number of smoke sources over the burn area should increase the likelihood of effective smoke dispersion. Exactly what this distribution should be can only be determined by further study. Amount and area of slash smoke at any given time can be described, as shown in this paper, and the best level of smoke management can be determined.



Figure 7—Aerial photos taken on two different days over the Willamette National Forest. Both views are from the same elevation and general location, looking southeast. The arrow in each photo points to the Three Sisters peaks (elevation 10,354 feet) about 60 miles distant. Top, Monday, October 20; scattered smokes from 50 acres of burning slash (approximately 5,000 tons of available fuel). Bottom, Wednesday, October 22; smoke density from 1,250 acres of burning slash on numerous scattered clearcuts on the Willamette National Forest and adjacent state lands. The smoke shown in the photo is from approximately 80,000 tons of consumed slash fuel.

Color 35-mm. photographs taken from light aircraft provide inexpensive case history documentation. Careful noting of camera direction and elevation helps to orient the photography. Temperature readings from a wing-tip sensor, made during ascent and

descent, provide lapse rate data.

Analysis of daily slash burning reports provides useful information on smoke sources, acreages burned, and fuels consumed. This information, correlated with weather data and photo documentation,

can provide the forester with a clearer picture of smoke quantity in relation to source. Such knowledge can be directly applied to effective smoke control for prescribed burning operations.

An educational program is very much needed to

dispel public misunderstanding, to assist foresters responsible for slash disposal, and to provide weather forecasters with localized data for sharpening their skill in their new responsibility as smoke management advisors.

SUMMARY

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A study during a 3-day period in October determined if slash burning in the Cascade Mountains of western Oregon contributed to air pollution in the Willamette Valley during very stable air conditions. Flights were made during peak slash burning periods to observe smoke density, direction of smoke drift, and effect, if any, on air quality in the Valley. Pertinent weather data for the period were analyzed for their relation to local conditions. During the 3

days, over 350,000 tons of slash was burned on clearcut areas totaling 5,980 acres.

We found that slash smoke dispersed away from the Willamette Valley, and had little influence on the already contaminated air of the Valley. Weather data for the period provides support to these observations. Case history studies such as this are valuable for improving slash smoke management techniques, and there is great need for continuing research.



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The Pacific Southwest Forest and Range Experiment Station

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