A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

ESSA Technical Memorandum WBTM WR 57

U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Weather Bureau

Preliminary Report on Agricultural Field Burning Vs. Atmospheric Visibility in the Willamette Valley of Oregon

EARL M. BATES AND DAVID O. CHILCOTE

Western Region

SALT LAKE CITY, UTAH

September 1970

WESTERN REGION TECHNICAL MEMORANDA

The Technical Memorandum series provide an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready, for formal publication in the standard journals. The series are used to report on work in progress, to describe technical procedures and practices, or to report to a limited audience. These Technical Memoranda will report on investigation devoted primarily to Regional and local problems of interest mainly to Western Region personnel, and hence will not be widely distributed.

These Memoranda are available from the Western Region Headquarters at the following address: Weather Bureau Western Region Headquarters, Attention SSD, P. O. Box 11188, Federal Building, Salt Lake City, Utah 84111.

The Western Region subseries of ESSA Technical Memoranda, No. 5 (revised edition), No. 10 and all others beginning with No. 24, are available also from the Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Sills Building, Port Royal Road, Springfield, Va. 22151. Price: $3.00 paper copy; $0.65 microfiche. Order by accession number shown in parentheses at end of each entry.

Western Region Technical Memoranda:

No. 1* Some Notes on Probability Forecasting. Edward D. Diemer. September 1965.
No. 2 Climatological Precipitation Probabilities. Compiled by Lucianne Miller. Dec. 1965.
No. 3 Western Region Pre- and Post-FP-3 Program. Edward D. Diemer. March 1966.
No. 4 Use of Meteorological Satellite Data. March 1966.
No. 5** Station Descriptions of Local Effects on Synoptic Weather Patterns. Philip Williams, Jr. October 1969 (Revised). (PB-178 000)
No. 6* Improvement of Forecast Wording and Format. C. L. Glenn. May 1966.
No. 7 Final Report on Precipitation Probability Test Programs. Edward D. Diemer. May 1966.
No. 8* Interpreting the RAREP. Herbert P. Benner. May 1966. (Revised January 1967.)
No. 9 A Collection of Papers Related to the 1966 NMC Primitive-Equation Model. June 1966.
No. 10* Sonic Boom. Loren Crow (6th Weather Wing, USAF, Pamphlet). June 1966. (AD-479 366)
No. 11 Some Electrical Processes in the Atmosphere. J. Latham. June 1966.
No. 12* A Comparison of Fog Incidence at Missoula, Montana, with Surrounding Locations. Richard A. Dightman. August 1966.
No. 13* A Collection of Technical Attachments on the 1966 NMC Primitive-Equation Model. Leonard W. Snellman. August 1966.
No. 14 Application of Net Radiometer Measurements to Short-Range Fog and Stratus Forecasting at Los Angeles. Frederick Thomas. September 1966.
No. 15 The Use of the Mean as an Estimate of "Normal" Precipitation in an Arid Region. Paul C. Kangieser. November 1966.
No. 16 Some Notes on Acclimatization in Man. Edited by Leonard W. Snellman. November 1966.
No. 17 A Digitalized Summary of Radar Echoes Within 100 Miles of Sacramento, California.
No. 18 Limitations of Selected Meteorological Data. December 1966.
No. 19* A Grid Method for Estimating Precipitation Amounts by Using the WSR-57 Radar. R. Granger. December 1966.
No. 20* Transmitting Radar Echo Locations to Local Fire Control Agencies for Lightning Fire Detection. Robert R. Peterson. March 1967.
No. 21 An Objective Aid for Forecasting the End of East Winds in the Columbia Gorge. D. John Coparanis. April 1967.
No. 22 Derivation of Radar Horizons in Mountainous Terrain. Roger C. Pappas. April 1967.
No. 23 "K" Chart Application to Thunderstorm Forecasts Over the Western United States. Richard E. Hambidge. May 1967.
No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967. (PB-178 071)
No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966-March 1967. W. W. Dickey. October 1967. (PB-176 240)
No. 26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis. Jan. 1968. (PB-177 830)
No. 27 Objective Minimum Temperature Forecasting for Helena, Montana. D. E. Olsen. Feb. 1968. (PB-177 827)

*Out of Print
**Revised

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-57

PRELIMINARY REPORT ON AGRICULTURAL FIELD BURNING VS. ATMOSPHERIC VISIBILITY IN THE WILLAMETTE VALLEY OF OREGON

Earl M. Bates
Weather Bureau Office
Corvallis, Oregon

David O. Chilcote
Professor of Plant Physiology
Department of Farm Crops
Oregon State University

WESTERN REGION
TECHNICAL MEMORANDUM NO. 57

SALT LAKE CITY, UTAH
SEPTEMBER 1970

TABLE OF CONTENTS

LIST OF FIGURE AND TABLES

PRELIMINARY REPORT ON AGRICULTURAL FIELD BURNING VS. ATMOSPHERIC VISIBILITY IN THE WILLAMETTE VALLEY OF OREGON

ABSTRACT

A model is presented for use in predicting the acreage of agricultural field residue that can be burned under certain meteorological conditions without reducing visibility to less than six miles in the southern Willamette Valley. Single variate analysis indicated no variable by itself to be a strong predictor. Acreage coupled with distance and wind direction plus variables which bear on atmospheric stability are found to be best.

I. SITE, SOURCE, BASIC DATA

About 300,000 acres of agricultural harvest residue are burned annually in the Willamette Valley. The residue is stubble and straw from a variety of grass seed and cereal crops. The acreage extends from Eugene, Oregon northward through the Willamette Valley to the vicinity of Portland. The period of burning is approximately August 1 to September 30. This is a season of generally fine weather with frequent morning inversions shown on the Salem, Oregon sounding at or somewhat lower than 3,500 feet. It is a time of prevailing northerly winds in the Willamette Valley.

Meland and Boubel [1] have designated particulate emission as the primary contribution of agricultural burning in grass fields to air pollution in the Willamette Valley. There is also need to know how transport of pollutants affects air loading by particulate matter in an area of occasional acute pollution problems and to evaluate a method of predicting acreage that can be burned consistent with good air quality. In this study, Weather Bureau visibility records at Eugene, Oregon airport were used as a measure of pollution caused by smoke from agricultural burning. This visibility measure was used because of an urgency for developing a forecast tool; urgency required use of available historic data.

Independent variables were acreage burned and meteorological parameters related to air transport. A record of acreages burned and their dates for 1967 and 1968 is to be found in most rural fire district offices in the valley. Atmospheric data were taken from the Salem, Oregon 4 a.m. upper-air sounding and the 7 a.m. surface observation at Eugene, Oregon.

The valley was divided into three zones. Zone one, centered on Eugene, has a radius of about 18 miles; zone two extends northward for the full width of the valley to include Albany, Oregon; zone three extends on northward to Oregon City. Using zones brings distance from source into the transport and diffusion problem, though distance as a specified variable does not appear in the model. Nine meteorological variables were considered: temperature difference 1000 to 900 mbs; 900 to 800 mbs; 800 to 700 mbs; inversion height; humidity at the next plotted point on the adiabatic diagram below and above the inversion; wind speed at 850 mbs; wind direction at 850 mbs; and maximum surface air temperature at Eugene, Oregon airport.

A step-wise multiple regression was run to determine how good a forecast could be made and to evaluate the variables. Single variates seemed poor. As shown by Lowry and Reiquam [2], pollution concentration depends not only on present accumulation rate but also on residual accumulation. This was evident in the data. Episodes of poor (less than 6 miles) visibility ran in groups of 3 to 5 days. Cultural practices enter this complexity, too. In the two seasons considered, the day's lowest visibility on Saturday was nearly always better than the lowest during week days. Sundays had visibility above six miles except in one case. Thus weekends seemed to be periods of little burning.

All variables were plotted individually in scatter diagrams (not shown) against visibility. Correlation between zone three acreage burned and Eugene visibility was so poor that zone three was dropped from further consideration. This poor correlation is likely due to the great distance to Eugene (over 60 miles). Also, total acreage burned was much less in zone three than in zone two.

Variables were related to two visibility groups, "high" >6 miles, and "low" ≤6 miles. The lowest visibility during the 24-hour period (midnight to midnight) determined the classification for the day. This analysis showed 850-mb wind direction and acreage burned in zone two and temperature difference between 900 and 800 mbs. to have the best relationship.

However, it was evident that terms higher than first order and combinations rather than single variates would have to be used in order to give significant results. Another multiple regression of several such variables was performed. (See Table I for rank of variables tested.) Wind speed ranked 7th and it was retained because it has a relation to air stability. Terms including temperature difference terms ranked 11th and 12th.

Figure 1 shows the change in the temperature aloft and increase in wind speed between August 26 and August 27, 1969. These were days of contrast in smoke dispersal in the Willamette Valley. On August 26 smoke plumes rose to a little over 3000 feet and there was looping of the plumes. On August 27 ventilation was good in the valley with plumes rising in "clean" edged tall towers to over 6000 feet capped by small cumulus clouds. This indicates the importance of the term including wind speed and temperature difference 900-800 mb. The latter was 1°C on August 26 and 7°C on August 27.

II. THE MODEL

At the suggestion of statistician Mr. David Bogdanoff, the early morning visibility at Eugene, Oregon airport was also considered as a predictor. Surface visibility at 0700h at Eugene is important in this study because it is an indication of background pollution from many unidentified sources. This is true because agricultural burning was prohibited until 1000h. Of course, this background pollution may be partially made up of "yesterday's" agricultural burning.

Using a step-wise discriminant analysis for two groups, variables were screened again, with 0700 visibility included in the screening. The following model was developed:

<u>Equation I</u>

$$D(x) = -5.344 \times 10^{-11} \times (WD \times II)^2 + 8.39 \times 10^{-3} \times I - 6.94 \times 10^{-5} \times (WD \times I) - 4.134 \times 10^{-9} \times (WD \times I)^2 + 1.71 \times 10^{-1} \times (WS) + .0233 \times (WD) - 1.728 \times 10^{-1} \times (V) - .369.$$

Here WD and WS are 850-mb wind direction and speed at Salem; I and II are acreages burned in zone one and two and V is the Eugene airport 0700h visibility.

If $D(x) > 0$, the day is classified into the low visibility group; that is, a day with minimum visibility 6 miles or less. If $D(x) \leq 0$, the day is classified into the high visibility group--minimum visibility seven miles or greater. For the dependent data sample, August and September 1967-68 (acreage burned was missing on a number of days), this model was quite successful. Predictions by the model verified as shown in Table II. Forecasts were 84% correct. For observed cases with low visibility, forecasts were 82% correct; for high visibility cases, 85% correct.

The total acreage in zone one is small compared to that in zone two. The analysis by grouping indicated that burning of significant acreage in zones two and one on the same day did not often occur. Because of this, it seems the low visibility at Eugene, and hence high pollution concentration due to agricultural burning, is a matter of transport. Wind speed does have a relationship to stability, but stability does not otherwise come into the model. Panofsky and Prasad [3] indicate that fluctuations in concentrations in pollution are fairly well explained by wind speed and vertical velocity. In their sample, wind direction was only important on special occasions. Because Eugene and the southern Willamette Valley are downwind (using the seasonal prevailing direction) from the important zone two, wind direction is important in this study. It is convenient to hold acreage burned in zone one constant to develop an equation useful in daily forecast operations.

If we let burning in zone one = 100 acres, then:

Equation 2

$$D_1(x) = 5.344 \times 10^{-11} \times (WD \times 11)^2 + .839 - .00694 \times (WD) - 4.134 \times 10^{-5} \times (WD)^2 + .1171 \times (WS) + .0233 \times (WD) - .173 \times (V) - .369.$$

By combining terms involving WD, we have:

Equation 3

$$D_2(x) = 5.344 \times 10^{-11} \times (WD \times 11)^2 - 4.134 \times 10^{-5} \times (WD)^2 + 1.64 \times 10^{-2} \times (WD) + .117 \times (WS) - .173 \times (V) + .47.$$

Equation 3 can now be used for forecasting the maximum number of acres of field grass which can be burned with the visibility at Eugene remaining above six miles (high grouping). The discriminant of (X) runs from less than zero to zero for "high" visibility conditions and is greater than zero for "low" visibility conditions. Because we are interested in maintaining a "high" condition, we let $D_2(X) = 0$ and solve for zone two. The result is allowable acreage for burning in that zone.

III. DISCUSSION

Equation 3 was used to make forecasts each day of the burning season in 1969. Table III shows the verification of these forecasts made on independent data. Forecasts were 78% correct. For cases with low visibility, predictions were 76% correct and for the high visibility, predictions were 80% correct. While these predictions are nearly as accurate as those verified in Table II for dependent data, one source of error is the assumption of a constant acreage burned in zone I.

This has been a pilot project leading to a thorough analysis of data systematically recorded for the 1969 agricultural burning season in the Willamette Valley. The method described above provides a useful tool to persons charged with environmental quality control in the valley.

IV. ACKNOWLEDGMENT

The writers are deeply indebted to Dr. Lyle Calvin and to Dr. David Bogdanoff of Oregon State University Statistics Department for the statistical analysis. Dr. William Lowry of Oregon State University Atmospheric Sciences Department gave counseling on upper-air variables to consider. Our thanks go to Mrs. Marilyn Paquin of Oregon State University Air Resources Center for collection and assembling of data. Mr. Robert Alexander made this study possible by securing funds through Oregon State University Air Resources Center. The Department of Environmental Quality, State of Oregon, provided some of the record material.

V. REFERENCES

1. Meland, B., and Boubel, R., "A Study of Field Burning Under Varying Environmental Conditions", Journal of the <u>Air Pollution Control Association</u>, Volume 16, No. 9, September 1966.

2. Lowry, W. P., and Reiquam, H. E., "An Index for Analysis of the Buildup of Air Pollution Potential", paper presented at 5th Annual Meeting of the Pacific Northwest International Section, Air Pollution Control Association, Salem, Oregon, November 1967.

3. Panofsky, H. A., and Prasad, B., "The Effect of Meteorological Factors on Air Pollution in a Narrow Valley", Journal of Applied Meteorology, Volume 6, No. 3, June 1967.

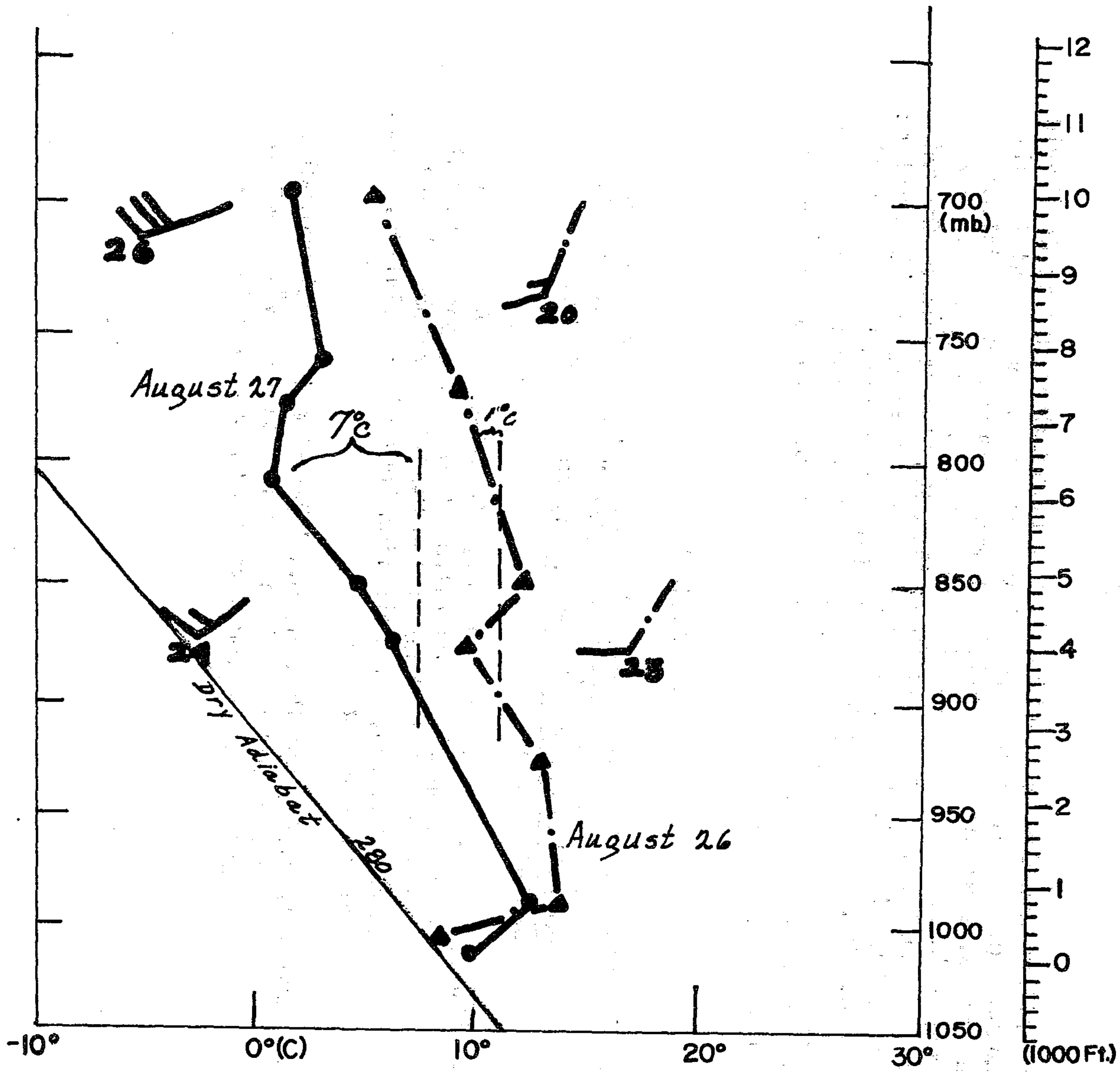

FIGURE 1. SALEM, OREGON TEMPERATURE SOUNDINGS FOR AUGUST 26, 1969 (DASHED-DOT LINE) AND AUGUST 27, 1969 (SOLID LINE). WIND VELOCITIES AT 850 AND 700 MBS ARE ALSO SHOWN.

TABLE I

ORDER OF SELECTION OF VARIABLES BY SCREENING

Variable	Rank
Acreage, zone II	1
Wind direction x zone II	2
(Wind direction x zone II)^2	3
Zone I	4
Wind direction x zone I	5
(Wind direction x zone I)^2	6
Wind speed	7
Wind direction	8
Wind speed x inversion height	9
(Wind speed x inversion height)^2	10
Wind speed x (900-800 mb temperature difference)	11
Wind speed x (900-800 mb temperature difference)^2	12

TABLE II

Observed Classification	Forecast Classification Low	High	Total
Low	28	6	34
High	5	29	34
Total	33	35	68

Verification of Forecasts Based on 1967 - 68 Data

TABLE III

Observed Classification	Forecast Classification Low	High	Total
Low	29	9	38
High	6	24	30
Total	35	33	68

Verification of Forecasts Based on 1969 Data

Western Region Technical Memoranda: (Continued)

No. 28** Weather Extremes. R. J. Schmidli. April 1968. (PB-178 928)
No. 29 Small-Scale Analysis and Prediction. Philip Williams, Jr. May 1968. (PB-178 425)
No. 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, U.S.A.F. May 1968. (AD-673 365)
No. 31* Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky. July 1968. (PB-179 084)
No. 32 Probability Forecasting in the Portland Fire Weather District. Harold S. Ayer. July 1968. (PB-179 289)
No. 33 Objective Forecasting. Philip Williams, Jr. August 1968. (AD-680 425)
No. 34 The WSR-57 Radar Program at Missoula, Montana. R. Granger. October 1968. (PB-180 292)
No. 35** Joint ESSA/FAA ARTC Radar Weather Surveillance Program. Herbert P. Benner and DeVon B. Smith. December 1968. (AD-681 857)
No. 36* Temperature Trends in Sacramento--Another Heat Island. Anthony D. Lentini. February 1969. (PB-183 055)
No. 37 Disposal of Logging Residues Without Damage to Air Quality. Owen P. Cramer. March 1969. (PB-183 057)
No. 38 Climate of Phoenix, Arizona. R. J. Schmidli, P. C. Kangieser, and R. S. Ingram. April 1969. (PB-184 295)
No. 39 Upper-Air Lows Over Northwestern United States. A. L. Jacobson. April 1969. (PB-184 296)
No. 40 The Man-Machine Mix in Applied Weather Forecasting in the 1970s. L. W. Snellman. August 1969. (PB-185 068)
No. 41 High Resolution Radiosonde Observations. W. W. Johnson. August 1969. (PB-185 673)
No. 42 Analysis of the Southern California Santa Ana of January 15-17, 1966. Barry B. Aronovitch. August 1969. (PB-185 670)
No. 43 Forecasting Maximum Temperatures at Helena, Montana. David E. Olsen. October 1969. (PB-185 762)
No. 44 Estimated Return Periods for Short-Duration Precipitation in Arizona. Paul C. Kangieser. October 1969. (PB-187 763)
No. 45/1 Precipitation Probabilities in the Western Region Associated with Winter 500-mb Map Types. Richard P. Augulis. December 1969. (PB-188 248)
No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 434)
No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 414)
No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis. January 1970. (PB-189 435)
No. 46 Applications of the Net Radiometer to Short-Range Fog and Stratus Forecasting at Eugene, Oregon. L. Yee and E. Bates. December 1969. (PB-190 476)
No. 47 Statistical Analysis as a Flood Routing Tool. Robert J. C. Burnash. December 1969. (PB-188 744)
No. 48 Tsunami. Richard P. Augulis. February 1970. (PB-190 157)
No. 49 Predicting Precipitation Type. Robert J. C. Burnash and Floyd E. Hug. March 1970. (PB-190 962)
No. 50 Statistical Report of Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona 1969. Wayne S. Johnson. April 1970. (PB-191 743)
No. 51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell. July 1970. (PB-193 102)
No. 52 Sacramento Weather Radar Climatology. R. G. Pappas and C. M. Veliquette. July 1970. (PB-193 347)
No. 53 Experimental Air Quality Forecasts in the Sacramento Valley. Norman S. Benes. August 1970.
No. 54 A Refinement of the Vorticity Field to Delineate Areas of Significant Precipitation. Barry B. Aronovitch. August 1970.

No. 55 Application of the SSARR Model to a Basin Without Discharge Record. Vail Schermerhorn and Donald W. Kuehl. August 1970.

No. 56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr. and Werner J. Heck. September 1970.

* Out of Print
**Revised