FIRE RESEARCH NOTE

NO. 522

THE RELATIONSHIP BETWEEN THE IGNITION OF FIRES IN BUILDINGS IN ENGLAND AND WALES AND CLIMATOLOGICAL VARIATIONS OVER THE PERIOD 1951 TO 1961

by

JANE M. HOGG

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May, 1963.

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Summary

The influence of weather on the occurrence of fire has most frequently been studied in relation to forest and bush areas. This note deals with the effect of weather on the number of fires which occurred in buildings in England and Wales during the years 1951 to 1961. The results obtained do not, in general, agree with results published in earlier studies undertaken in Japan and the United States of America. It is conceivable, however, that fires occurring under different conditions may be affected by different weather effects.

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Introduction

The influence of weather is acknowledged to be an important factor in the
ignition and spread of forest fires(1). Studies undertaken in the 1920s in
Japan(2) concluded that relative humidity is a factor influencing the chance of
a fire start in a building. An American publication(3) dealing with fires in
buildings in certain American cities also drew the conclusion that relative
humidity is a factor affecting the chance of ignition, but with the proviso that
dew-point temperature has a greater effect than relative humidity in the winter
months, while the air temperature also affects the chance of fire in buildings
during the winter months.

Interest in the effect of weather on the chance of ignition of fire in
buildings in the United Kingdom was aroused at the Joint Fire Research Organis­
tion when in 1959 there was a spectacular increase in the annual fire incidence
in the United Kingdom, both indoors and outdoors. Fires in buildings increased
by over 9,000 and outdoor fires by about 127,000 from 1958 to 1959.

Discussion of the model used to determine the effect of
weather upon fire frequencies in buildings

A study of the relationship between one or several weather effects and the
chance of occurrence of a fire in buildings will give misleading results if the
effects of other influences are not removed. For example, as the air temperature
falls more space heating appliances are used in buildings, which increases the
chance of a fire occurring in those buildings. The fall in temperature has thus
affected the chance of a fire indirectly through its effect upon human behaviour.
However, the actual number of fires which will occur within a month may also
depend directly upon weather conditions since the chance of a fire may change
with weather effects even without any change in human behaviour.

Since human behaviour changes with the seasons, the effect of weather on fire
frequencies must be tested within similar periods of the year, for example,
months. To do this several observations for the same set of months must be
obtained. This was achieved by taking observations over several years. However,
the weather effects must also be tested within years since the chance of a fire,
irrespective of weather conditions, changes each year.

The following mathematical model summarises the above:

\[ Z_{ij} = \mu + Y_i + M_j + \varepsilon_{ki} x_{ij} + \varepsilon_{ij} \]  \hspace{1cm} (1)

where \( Z_{ij} \) are the number of fires occurring in the \( i^{th} \) year and the \( j^{th} \) month;
\( x_{ij} = X_{ij} - \bar{X} \), where \( X_{ij} \) represents the value for a particular weather effect
in the \( i^{th} \) year and \( j^{th} \) month, the subscript \( k \) denoting which effect, and \( \bar{X}_k \)
represents the mean value experienced throughout for that effect;
\( Y_i \) and \( M_j \) are the year and month effects adjusted for the effect of the \( X \)'s.
\( \mu \) represents the overall population mean and is estimated by \( \bar{Z} \).
\( \beta_k \) represents the average straight line relationship between \( x_k \) and the 
s terms, and \( \varepsilon_{ij} = \bar{z}_{ij} - \bar{z} \). The assumptions are that there is no year-month 
interaction effect \((YM)_{ij} \)' and that the \( \varepsilon_{ij} \) are independent normally distrib-
uted variables with variance \( \sigma^2 \) for each set of \( X \)'s.

The \( \varepsilon_{ij} \) represent the error term.

A genuine cause and effect relationship between the weather effects and 
the frequencies will be provided by model (1) so long as changes in human 
behaviour remain proportionately constant between months and between years, 
since there can be only one set of observations for any month in any year 
(although \( z_{ij} \) can only occur once). The model has been checked to ensure 
that the possible month-year interaction effect is non-existent by separating 
it into two parts, one for the period 1951 to 1956 and the other for the years 
1957 to 1961; and then ascertaining that the same cause and effect relationship 
held for both periods.

Availability of data

Climatological data are published in monthly form (4) for the daily mean 
air temperature, inches of rainfall, and sunshine (mean hours per day): additional data had therefore to be specially compiled.

Data for dry bulb temperature, wet bulb temperature, dew point temperature, 
vapour pressure, wind and cloud are recorded at certain climatological stations 
at three hourly intervals, and were available from the Meteorological Office. 
A preliminary analysis was therefore undertaken using observations at the towns 
of Blackpool, Liverpool, Nottingham, Birmingham and Bristol at three hourly 
intervals, from 0600 hours to 2100 hours inclusive. Averages were obtained 
for three monthly periods over the three years 1958, 1959 and 1960. As it was 
conceivable that the cause and effect relationship between weather effects and 
fire frequencies might vary for different seasons of the year two models were 
used, one comprising the winter months of January, February and March, the other 
the summer months, June, July and August. (Appendix I).

The preliminary analysis revealed a relationship between both vapour 
pressure and dew point temperature and the chance of fire in dwellings in the 
five towns in both the winter and summer seasons. (Vapour pressure and dew 
point temperature measure an identical weather phenomenon but use different 
scales, so that making use of vapour pressure for forecasting the number of fires 
in dwellings precludes the use of dew point temperature. Vapour pressure data 
are used, hereafter, since the error terms appear to be more normally randomly 
distributed about this scale than that of the dew point temperature). None of 
the other weather effects examined appeared to have any effect on the three hourly 
average frequencies of fires in dwellings in the towns used in the analysis.

Average monthly values of vapour pressure have been compiled for England and 
Wales for the period 1951 to 1961 inclusive, and are shown in Table 1, Appendix 
II. Sunshine and rainfall data are given in Tables 2 and 3, while Table 4 gives 
the monthly fire incidence in buildings in England and Wales.

The results of the analysis

A multiple regression using the analysis of covariance model (1) showed that 
varyations in the monthly frequency of fires were most highly dependent upon the 
amount of sunshine occurring in the month, and that the residual variation was 
more dependent upon the vapour pressure level than upon the amount of rainfall; 
nevertheless, the amount of rainfall had some effect on the fire frequencies even 
after the effects of both sunshine and vapour pressure had been taken into account.
The multiple correlation coefficient for all the three weather effects (sunshine, vapour pressure and rainfall) and the occurrence of fires was 0.75. The correlation coefficient for sunshine and fire frequencies was 0.55; the partial correlation coefficient for vapour pressure and fire frequencies, given the amount of sunshine, was 0.49, while the partial correlation coefficient for rainfall and fire frequencies, given the amounts of both sunshine and vapour pressure, was 0.41. The values for these respective correlation coefficients could have occurred individually by chance less than once in a thousand times.

Figure 1 shows both the actual annual fire incidence in buildings in England and Wales over the period 1951 to 1961 inclusive, and the adjusted frequencies calculated by correcting for the differences between the annual mean values and the overall mean values of sunshine, vapour pressure and rainfall, using the estimated regression coefficients. From these curves it appears that the increase in the annual fire incidence observed between 1958 and 1959 was due less to the weather conditions of 1959 than to those pertaining in 1958 which resulted in a lower fire frequency than would normally occur.

Conclusion

The weather effects which had a direct relationship upon the number of fires which occurred in buildings in England and Wales from 1951 to 1961 inclusive were sunshine, vapour pressure and rainfall. Fire frequencies in buildings are correlated most with changes in the amount of sunshine, next with changes in vapour pressure, and least with changes in the amount of rainfall. The increase in the annual frequency of fire observed between 1958 and 1959 was due to weather conditions affecting fire frequencies so that they were well below the number which would have been expected from the trend line in 1958, and slightly above the number expected in 1959. Although it is clear from this analysis that weather conditions play an important role in the occurrence of fire, it is unlikely that it will be possible to predict bad fire spells until longer range weather forecasting can be achieved.

References

(1) PIRSKO, Arthur R. The history, development and current use of forest fire danger meters in the United States and Canada. University of Michigan, School of Forestry and Conservation, Michigan, 1950, pp.121.

(2) SUZUKO, Seitaro. The fires and the weather. J. Dept. Agric. Kyushu Imperial University, 1928, 2 (1) 1-73.


(4) Annual Abstract of Statistics,
# APPENDIX I

**BETWEEN TOWNS, BETWEEN TIMES AND RESIDUAL VARIATIONS AND COVARIATIONS - WINTER**

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<thead>
<tr>
<th>Source of Variation</th>
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<th>Sum of Squares</th>
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## APPENDIX I

**BETWEEN TOWNS, BETWEEN TIMES AND RESIDUAL VARIATIONS AND COVARIATIONS - SUMMER**

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<tr>
<th>Source of Variation</th>
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<th>Dew Point Temperature ($x_3$)</th>
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<th>Wind ($x_5$)</th>
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<td>35.5</td>
<td>29.6</td>
<td>42.7</td>
<td>30.9</td>
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### Table 4

**Monthly fire incidence in England and Wales**

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<td>Jan.</td>
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<td>4,008</td>
<td>3,965</td>
<td>5,236</td>
<td>4,536</td>
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<td>4,480</td>
<td>5,404</td>
<td>5,168</td>
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<td>3,610</td>
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<td>3,250</td>
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<td>3,924</td>
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<td>2,628</td>
<td>2,520</td>
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<td>2,720</td>
<td>2,920</td>
<td>4,317</td>
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<td>2,778</td>
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<td>2,405</td>
<td>2,524</td>
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<td>2,845</td>
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<td>Nov.</td>
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<td>3,700</td>
<td>4,176</td>
<td>4,253</td>
<td>4,044</td>
<td>4,564</td>
<td>4,564</td>
<td>5,700</td>
<td>44,633</td>
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<td>Dec.</td>
<td>3,522</td>
<td>4,488</td>
<td>3,530</td>
<td>3,756</td>
<td>4,016</td>
<td>3,940</td>
<td>4,651</td>
<td>4,376</td>
<td>4,604</td>
<td>5,088</td>
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<td>48,475</td>
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<td>36,456</td>
<td>40,388</td>
<td>38,010</td>
<td>39,828</td>
<td>43,176</td>
<td>44,252</td>
<td>43,823</td>
<td>44,816</td>
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APPENDIX 2

BETWEEN YEARS, BETWEEN MONTHS AND RESIDUAL VARIATIONS AND COVARIATIONS

Analysis of Variance

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<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
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</thead>
<tbody>
<tr>
<td>Source of Variation</td>
<td>Degrees of freedom</td>
<td>Sunshine ( x_1 )</td>
<td>Vapour pressure ( x_2 )</td>
<td>Rainfall ( x_3 )</td>
<td>Fire frequencies ( f )</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
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<tr>
<td>Between years</td>
<td>10</td>
<td>13,9535</td>
<td>151.93</td>
<td>28.039</td>
<td>46,341,102</td>
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<tr>
<td>Between months</td>
<td>11</td>
<td>433,4509</td>
<td>41.38041</td>
<td>59.112</td>
<td>33,518,660</td>
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<tr>
<td>Residual</td>
<td>110</td>
<td>78,2074</td>
<td>1,172.10</td>
<td>184.319</td>
<td>22,464,346</td>
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<tr>
<td>Total</td>
<td>131</td>
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<td>15,704-74</td>
<td>271.470</td>
<td>102,324,108</td>
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Analysis of Covariance

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<th>Sunne of Covariation自由度</th>
<th>Products of ( x_1 ) and ( z )</th>
<th>Products of ( x_2 ) and ( z )</th>
<th>Products of ( x_3 ) and ( z )</th>
<th>Products of ( x_1 ) and ( x_2 )</th>
<th>Products of ( x_1 ) and ( x_3 )</th>
<th>Products of ( x_2 ) and ( x_3 )</th>
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<td>+6,028.18</td>
<td>+36,929.7</td>
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<tr>
<td>Between months</td>
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<td>-90,769.03</td>
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<td>+22,962.03</td>
<td>-82,635.7</td>
<td>-31,555.8</td>
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<tr>
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Single regressions of $z$ on $x_1$, $x_2$ and $x_3$.

<table>
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<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>SUM OF SQUARES</th>
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</thead>
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<td>$z$ on $x_1$</td>
<td>$z$ on $x_2$</td>
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<tr>
<td>Due to regression</td>
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<tr>
<td>Residual</td>
<td>109</td>
<td>15,728,021</td>
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<tr>
<td>Total*</td>
<td>110</td>
<td>22,464,346</td>
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Double regressions of $z$ on $x_1$ and $x_2$ and $z$ on $x_1$, $x_2$, and $x_3$.

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<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>SUM OF SQUARES</th>
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</thead>
<tbody>
<tr>
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<td>$z$ on $x_1$ and $x_2$</td>
<td>$z$ on $x_1$, $x_2$, and $x_3$</td>
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<tr>
<td>Due to regression</td>
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<tr>
<td>Residual</td>
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<td>11,875,437</td>
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<tr>
<td>Total*</td>
<td>110</td>
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Total* = residual sum of squares of fire frequencies from above analysis of variance.
**APPENDIX 2**

**CALCULATIONS FOR ADJUSTED FREQUENCIES IN FIG. 1.**

\[ z_{i,j} = \mu + y_{i}^* + \eta_{i}^* + \varepsilon_{i,k} \]  

where \( \beta_k \) is estimates by \( b_k \)

and \( b_1 = +178.265 \)

\( b_2 = -59.0586 \)

\( b_3 = -113.7368 \)

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<td>Difference from overall mean</td>
<td>-0.009</td>
<td>-0.072</td>
<td>-0.011</td>
<td>-0.468</td>
<td>+0.472</td>
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<td>+0.016</td>
<td>-0.499</td>
<td>+0.518</td>
<td>-0.159</td>
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<td>Resultant additional fire frequencies</td>
<td>+1.604</td>
<td>-12.835</td>
<td>-1.961</td>
<td>+83.128</td>
<td>-64.141</td>
<td>+24.601</td>
<td>-2.852</td>
<td>+88.954</td>
<td>-45.516</td>
<td>+28.344</td>
<td>-9.092</td>
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<tr>
<td>Vapour pressure</td>
<td>4.012</td>
<td>39.14</td>
<td>41.89</td>
<td>40.13</td>
<td>39.90</td>
<td>41.54</td>
<td>41.81</td>
<td>42.12</td>
<td>41.41</td>
<td>41.43</td>
<td>40.78</td>
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<td>+1.11</td>
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<td>-0.88</td>
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<td>+1.34</td>
<td>+0.63</td>
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<td>Resultant additional fire frequencies</td>
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<td>-51.972</td>
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<td>+79.139</td>
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<td>+38.388</td>
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<td>Rainfall</td>
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<td>2.48</td>
<td>3.56</td>
<td>2.57</td>
<td>2.85</td>
<td>2.97</td>
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<td>2.67</td>
<td>3.96</td>
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<tr>
<td>Difference from overall mean</td>
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<td>-0.14</td>
<td>-0.62</td>
<td>+0.46</td>
<td>-0.53</td>
<td>-0.25</td>
<td>-0.13</td>
<td>+0.37</td>
<td>-0.43</td>
<td>+0.86</td>
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<tr>
<td>All three weather variables Resultant addition of fire frequencies for 12 months</td>
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<td>-83</td>
<td>+1.168</td>
<td>-2.357</td>
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<td>+327</td>
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<td>-1.023</td>
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Fire frequencies obtained from regression: 36.785, 38.881, 37.927, 40.996, 40.819, 43.008, 44.150, 47.118, 52.061, 55.712, 60.646.
FIG. 1. ANNUAL FIRE FREQUENCIES IN BUILDINGS IN ENGLAND AND WALES COMPARED WITH THE CORRECTED FREQUENCIES CALCULATED USING THE ESTIMATED REGRESSION COEFFICIENTS AND THE OVERALL MEAN VALUES FOR SUNSHINE, VAPOUR PRESSURE AND RAINFALL.