A METHOD OF REPRESENTING THE DISTRIBUTION OF CLOUD AMOUNT IN AUSTRALIA

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ABSTRACT

A method is developed to enable the representation of cloud amount distributions by two parameters. This is effected by a transformation based on mean Australian cloud distributions for each of five cloud types. Thus a distribution of observed frequencies is transformed to a normal distribution, which is determined by its mean and standard deviation. The accuracy of the method is indicated by the retrieval of the original distribution with a typical error of 14 per cent in the frequency of each okta of cloud amount.

INTRODUCTION

Routine observations of cloud amount and type made by observers at the surface remain a unique data source even after the advent of satellites. The classification of cloud by type is important because certain meteorological processes may be associated with each type. A considerable volume of these data exists and they have generally been represented statistically by the mean cloud amount, a parameter whose utility is limited by the nature of the cloud distribution. For example, the frequency of overcast or clear conditions cannot be determined from a mean cloud amount. To overcome these limitations the entire cloud distribution must be known.

Some methods of describing such a distribution are (i) by the use of quantiles, (ii) by fitting a function directly to the data, and (iii) by transforming the distribution to another with desirable properties. If it is required to treat a number of such sets of data with a view to making comparisons, it is convenient to be able to describe the distribution of each set by a manageable number of parameters, preferably not more than two. In the case of highly non-normal distributions such as that of cloud amount, methods (ii) and (iii) appear preferable. Some results are presented following a limited investigation of method (iii).

TRANSFORMATION OF THE CLOUD AMOUNT DISTRIBUTION

The amount of cloud is taken as the fraction of the sky covered by that cloud. Thus the frequency distribution of cloud amount when it is measured in this way is doubly bounded, at 0 and 1. These bounds produce practical difficulties when describing such a distribution by the first and second moment only, unless the distribution does not differ too much from one like the normal, for which all higher moments are functions of the first and second. Further, the cloud frequency density does not vanish near the bounds but rises to a maximum near at least one bound.

This method aims to transform the continuous cloud cover parameter x, whose frequency density is \( f(x) \), into another variable y, which is normally distributed. The conservation of frequency is expressed as

\[
 f(x) \, dx = N \, dy
 \]

... 1
for all x and y, where N is the normal frequency density function, with mean μ and standard deviation σ. The transformation is

\[ y = T(x) \]

When μ and σ are estimated by m and s, the original frequency density \( f \) can be estimated by \( \phi(x) \) where

\[ \phi(x) = N(m, s) \frac{dT}{dx} \]

One form of T considered by Kendall and Stuart (1958) and by Hisdal (1974) is.

\[ T(x) = \ln \left( \frac{x}{1-x} \right) \]

An example will demonstrate this method. This related to the distribution of total cloud amount at Essendon, Victoria, comprising 14 162 observations taken every three hours between 0600 and 2100 LST in the years 1965 to 1971. Each observation is recorded by the observer in eighths of sky covered (oktas), which is essentially the classification of cloud amount into nine classes (0 to 8 oktas). The boundaries of each class are not precisely determined and the distribution of cloud amounts within each class is unknown. Hence it will be assumed that the boundaries of these nine classes are at the midpoints between the nominal values, i.e., 0, 1/16, 3/16, ..., 15/16, 1, and that the frequencies are constant within each class (Fig 1).

Transformation of the independent variable x, according to Eqn 2, results in a distribution g which is to be approximated by a normal distribution \( N(n, s) \). m and s can be determined in two ways with varying results. They can be put equal to the mean and standard deviation of the distribution g, or they can be taken as the mean and standard deviation of the normal distribution which best fits g. Because of the additional computation involved with the second method and the small differences in the results obtained in a number of trial comparisons, m and s were determined directly by integration of g to be 0.7273 and 2.4502, respectively.

The original distribution is then estimated by Eqn 2 and is shown in Fig 1(a). The fit is not very good and in this and other trials was consistently poorest at the higher and lower sections of the range. This effect is more marked with distributions of particular cloud types, such as cumulus, which is shown in Fig 1(b). In these cases the fit is poor, leading to considerable inaccuracy for low cloud amounts. It is concluded that the transformation (Eqn 3) is an important cause of the poor fit.

AN EMPIRICALLY DERIVED TRANSFORMATION

The accuracy of the representation of cloud amount distributions can be improved by an empirically derived transformation, which will produce a transformed frequency density g that is more similar to the normal distribution, N. Let the observed frequency density \( f(x) \) be dependent on some parameters, say \( z_i \), i=1,n. These could represent such factors as season, latitude, etc. Then Eqn 2 can be rewritten as

\[ \phi(z_1, z_2, ..., z_n)(x) = N(m, s) \frac{dT_1, z_2, ..., z_n}{dx} \]

According to this model, the transformation T depends on the parameters \( z_i \), rather than on being a fixed function as in Eqn 3. However, it is desirable that the list of parameters \( z_i \) be as short as practicable. For cloud parameters, cloud type \( t \), month group \( n \), hour of day \( h \), and geographical location \( l \) were examined (see Appendix) and it was found that cloud type was a dominant parameter and that these four taken together accounted for almost all the variance of the observed frequencies of cloud amount. Thus Eqn 4 can be replaced by the simpler equation

\[ \phi_t(x) = N(m, s) \frac{dT_t}{dx} \]
Fig 1 Comparison of observed frequency density (solid lines) and estimated frequency densities (dashed lines) for (a) total cloud and (b) cumulus cloud amount at Essendon, Victoria. Estimated frequencies calculated according to the transformation $y = \ln(|x| - x)$. Data comprises 14,162 daylight observations from 1965 to 1971.
The cloud type dependent transformation $T_t$ was determined empirically such that it would transform the mean observed cloud amount frequency density into the normal frequency density with mean equal to zero and a standard deviation equal to one. This was done as follows. All the data of the type described earlier for 52 stations in Australia (see Fig 5(a)) were used to determine average frequencies, $F_j$ \((j=0,8)\), for each of five cloud types: total, cumulus, stratocumulus, middle and high, as shown in Table 1. Middle cloud includes altocumulus and nimbostratus. High cloud includes all cirroform cloud. This grouping, based on the system used operationally in Australia (Bureau of Meteorology 1975), was necessary to produce adequately sized samples of relatively infrequent cloud types. Stratus and cumulo-nimbus were not considered as reports of these were too scarce to provide tractable distributions. For each cloud type the average frequencies were used to determine eight values of the normal variant, in addition to $y_0 \left(= \infty \right)$ and $y_10 \left(= \infty \right)$ according to the equations

\[
F_j = \int_{y_j}^{y_{j+1}} N(0,1) \, dy, \quad (j=0,8)
\]

which express the conservation of frequency. Thus, these ten values of $y$ correspond to the transformed values of $x$ at the okta boundaries, 0, 1/16, 3/16, ..., 1. The interpolated curves for each cloud type are shown in Fig 2.

Table 1  Mean frequency of each okta of cloud cover $F_j$ based on the 3-hourly observations between 0600 LST and 2100 LST at 52 Australian stations for the period 1965 to 1971. Observations are grouped according to five cloud types.

<table>
<thead>
<tr>
<th>Cloud type</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.220</td>
<td>0.140</td>
<td>0.083</td>
<td>0.077</td>
<td>0.064</td>
<td>0.069</td>
<td>0.091</td>
<td>0.155</td>
<td>0.101</td>
</tr>
<tr>
<td>Cumulus</td>
<td>0.608</td>
<td>0.143</td>
<td>0.108</td>
<td>0.060</td>
<td>0.038</td>
<td>0.024</td>
<td>0.013</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td>Stratocumulus</td>
<td>0.684</td>
<td>0.091</td>
<td>0.055</td>
<td>0.048</td>
<td>0.033</td>
<td>0.027</td>
<td>0.022</td>
<td>0.025</td>
<td>0.015</td>
</tr>
<tr>
<td>Middle</td>
<td>0.711</td>
<td>0.082</td>
<td>0.047</td>
<td>0.036</td>
<td>0.025</td>
<td>0.023</td>
<td>0.020</td>
<td>0.026</td>
<td>0.030</td>
</tr>
<tr>
<td>High</td>
<td>0.722</td>
<td>0.088</td>
<td>0.049</td>
<td>0.036</td>
<td>0.024</td>
<td>0.027</td>
<td>0.022</td>
<td>0.021</td>
<td>0.011</td>
</tr>
</tbody>
</table>

However, for $F_j$, a general set of frequencies, it is merely required to calculate $m$ and $s$, the mean and standard deviation of the distribution resulting from this transformation. This requires that appropriate class 'centroids' and 'radii of gyration' be known, and these will vary only with the transformation to a high degree of accuracy. For the first moment, nine values of $y$ were found, denoted by $v_j$ \((j=0,8)\), such that

\[
F_j \cdot v_j = \int_{y_j}^{y_{j+1}} N(0,1) \, dy
\]

and similarly for the second moments to determine another nine values of $y$, denoted by $w_j$. Then $m$ and $s$ can be determined directly as
Fig 2 Curves expressing the empirical transformation from x to y coordinates for each of five cloud types. Curves are hand drawn interpolations of calculated values of y at the x values corresponding to boundaries of each okta class.
with \( v_j \) and \( w_j \) appropriately chosen for the cloud type. Thus, provided the transformed distribution remains approximately normal, the nine frequencies \( f_j \) may be estimated from the two numbers \( m \) and \( s \) which express the deviation of \( f_j \) from the mean frequencies \( F_j \). The values of \( v_j \) and \( w_j \) are tabulated in Table 2 for each cloud type considered.

Table 2  Weights \( v \) and \( w \) used for the calculation of \( m \) and \( s \), as defined by Eqns 8 and 9, for each cloud type.

<table>
<thead>
<tr>
<th>Cloud type</th>
<th>Okta</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>v-1.349</td>
<td>-0.559</td>
<td>-0.251</td>
<td>-0.048</td>
<td>0.129</td>
<td>0.300</td>
<td>0.521</td>
<td>0.936</td>
</tr>
<tr>
<td></td>
<td>w-1.430</td>
<td>-0.570</td>
<td>-0.257</td>
<td>-0.068</td>
<td>0.135</td>
<td>0.304</td>
<td>0.525</td>
<td>0.952</td>
</tr>
<tr>
<td>Cumulus</td>
<td>v-0.633</td>
<td>0.470</td>
<td>0.868</td>
<td>1.231</td>
<td>1.548</td>
<td>1.879</td>
<td>2.250</td>
<td>2.698</td>
</tr>
<tr>
<td></td>
<td>w-0.910</td>
<td>0.483</td>
<td>0.874</td>
<td>1.233</td>
<td>1.550</td>
<td>1.879</td>
<td>2.250</td>
<td>2.696</td>
</tr>
<tr>
<td>Strato-cumulus</td>
<td>v-0.521</td>
<td>0.613</td>
<td>0.850</td>
<td>1.053</td>
<td>1.248</td>
<td>1.432</td>
<td>1.632</td>
<td>1.919</td>
</tr>
<tr>
<td></td>
<td>w-0.867</td>
<td>0.616</td>
<td>0.851</td>
<td>1.054</td>
<td>1.248</td>
<td>1.432</td>
<td>1.631</td>
<td>1.921</td>
</tr>
<tr>
<td>Middle</td>
<td>v-0.482</td>
<td>0.683</td>
<td>0.903</td>
<td>1.071</td>
<td>1.218</td>
<td>1.354</td>
<td>1.504</td>
<td>1.725</td>
</tr>
<tr>
<td></td>
<td>w-0.856</td>
<td>0.686</td>
<td>0.904</td>
<td>1.072</td>
<td>1.218</td>
<td>1.354</td>
<td>1.504</td>
<td>1.724</td>
</tr>
<tr>
<td>Cirrus</td>
<td>v-0.465</td>
<td>0.731</td>
<td>0.977</td>
<td>1.166</td>
<td>1.328</td>
<td>1.506</td>
<td>1.734</td>
<td>2.054</td>
</tr>
<tr>
<td></td>
<td>w-0.852</td>
<td>0.734</td>
<td>0.978</td>
<td>1.166</td>
<td>1.328</td>
<td>1.506</td>
<td>1.734</td>
<td>2.055</td>
</tr>
</tbody>
</table>

**ACCURACY OF THE METHOD**

The accuracy of the method can be judged by the degree to which the original frequencies can be retrieved given only the cloud type, i.e., the transformation, and the values of \( m \) and \( s \). Inaccuracy stems from the fact that the transformed distribution is not strictly normal as assumed, partly because of the effects of the unaccounted parameters (e.g., time, location, etc.). This inaccuracy generally increases as the original distribution diverges from the mean distribution for the cloud type. The utility of this method therefore rests with similarity of actual distributions to the mean distributions, and therefore a direct examination of the method's accuracy is required.

This was done by computing a goodness-of-fit parameter using the observed frequencies \( f_j \) (\( j=0,8 \)), and the frequencies estimated by the methods described \( \theta_j \). The parameter is essentially the chi-square statistic

\[
C = \sum_{j=0}^{8} n(f_j - \theta_j)^2/f_j
\]

where \( n \) is the number of observations for the set, which comprises data grouped according to location, type and month, and is about 2520.
First, a comparison was made between the accuracy of this empirical method and that of the method utilising Eqn 3, using all the data from three climatically different stations, Essendon (38°S, 145°E), Cairns (17°S, 146°E), and Giles (25°S, 128°E). Cumulative distributions for C for both methods are shown in Fig 3. The empirical method appears superior with an average C value of 93.4, whereas the other method gave 319.4. This is equivalent to an average error of ±19 and ±35 per cent, respectively, in the frequency of each okta.

Second, the accuracy of the empirical method was examined for all the data at all stations. The cumulative distribution of C values is shown in Fig 4. In 50 per cent of all cases C was less than 50, and less than 190 in 90 per cent of cases. This is equivalent to an average error of 14 and 26 per cent, respectively, in the frequency of each okta. The mode for C was equivalent to an average error of 8 per cent per okta, with a third of all cases being more accurate than this.

It must be noted that these results are strongly dependent on the way that cloud amount is measured. If, instead of expressing cloud amount in eighths (oktas), it was expressed in quarters, corresponding to 0, (1+2), (3+4), (5+6), (7+8) oktas, then the average percentage error for each of these five divisions decreases by almost two-thirds to less than 10 per cent in 90 per cent of cases, compared with 26 per cent in the case of oktas. This effect is due to the smoothing effect by the transformation, which may be desirable, particularly if there is reason to believe that certain okta values are 'favoured' by observers.

Examination of the method's accuracy according to cloud type reveals that total, middle, and high are the cloud types most accurately represented with a mean error per okta of 10 and 15 per cent in half the cases, while with cumulus and stratocumulus this average error increases to 15 to 20 per cent. This is as expected in view of the marked skewness of the distributions of the latter types, but may also be explained by a greater divergence from the mean distribution with these cloud types. Location also affects accuracy, with better results generally in the southeast of the continent. This may in part be due to the higher density of observing stations there dominatingly influencing the mean frequency distributions.

RESULTS

This empirical method results in the calculation of two parameters, the mean \(m\) and the standard deviation \(s\) of the transformed distribution, which is assumed to be normal. It was hoped that the number of parameters required to specify the normal distribution could in effect be reduced from two to one either by setting one to a constant value, or by finding a useful relationship between \(m\) and \(s\). This proved impossible without a doubling of the inaccuracy of the method. In the first case, putting \(s\) equal to 1.0 in each case leads to unacceptably high inaccuracies at the extremes of the range of cloud cover, namely, 0,1,7,8 oktas for total cloud type and 6,7,8 oktas for other types. The fractional change in frequency \(f\) with a change in \(s\) is given by

\[
\frac{\Delta f}{f} = \left( \frac{\Delta s}{s} \right) \left( 1 - 1.5(x-m)^2/s^2 \right)
\]

whereas the corresponding change for \(m\) is

\[
\frac{\Delta f}{f} = -\Delta m(x-m)/s^2.
\]

Even though the root mean square (rms) deviation of \(s\) from 1.0 is generally much smaller than the rms deviation of \(m\) from 0.0, it is evident that the effect of even a small change in \(s\) can be important at the extremes of the cloud cover range, i.e., where \(|(x-m)/s|>2\). In the second case, meaningful general relationships between \(m\) and \(s\) could not be established. Although there is a general tendency for \(s\) to increase with decreasing \(m\) for total cloud type, and for \(s\) to increase with increasing \(m\) for other types, correlation coefficients calculated from data from all stations remained below about 0.7. Other approaches, such as transforming the cloud amount distribution to a normal distribution with unit standard deviation, proved similarly inaccurate.
Fig 3 Cumulative frequency distributions of the parameter C expressing goodness-of-fit of estimated frequencies to observed frequencies. Curve (i) relates to frequencies obtained by the transformation $y = \ln(x/(1-x))$ and curve (ii) to those obtained by the empirical transformation.
Fig 4 Cumulative frequency distribution of the parameter C expressing goodness-of-fit of frequencies estimated by the empirical transformation to observed frequencies, based on all available data from the 52 Australian stations from 1965 to 1971.
Isopleths of m and s for Australia for each of the five cloud types at 1500 LST for the two-month groups January-February and July-August are shown in Fig 5. The sign and the magnitude of m imply the sense and magnitude of the anomaly of cloud amount relative to the mean distribution for that cloud type. s is a measure of the degree to which the cloud distribution is 'U-shaped' relative to the mean distribution for that type. Values of s in excess of 1.0 imply a predominance of clear sky or overcast sky conditions or both. Values below 1.0 imply a predominance of partially cloudy conditions. It follows from Eqns 8 and 9 that for each cloud type m and s cannot exceed particular bounds, i.e., clear conditions correspond to $m = v_0$ and $s = w_0$, and overcast conditions correspond to $m = v_8$ and $s = w_8$. This is a consequence of the fact that each okta extends over a finite range of cloud amount.

The main features of the diurnal variation are shown for Essendon ($38^\circ$S, $145^\circ$E), Coffs Harbour ($30^\circ$S, $152^\circ$E), and Cairns ($17^\circ$S, $146^\circ$E), in Fig 6 for total, cumulus, stratocumulus, and cirriform cloud, for each of the six two-month groups. Middle cloud exhibits negligible diurnal variations and is not shown. It is evident that at Cairns the monthly variation is stronger than the diurnal whereas at the higher latitude stations the diurnal variation predominates.

**SUMMARY**

An empirical transformation has been obtained based on an average cloud cover frequency distribution, which enables the 'U-shaped' cloud distribution to be represented by a normal distribution with mean m and standard deviation s.

It was determined that cloud type was a dominant factor affecting the shape of the cloud cover distribution, and accordingly a separate transformation was calculated for each cloud type. Three other factors (location, month, and hour) were considered and described by variations in m and s.

The method was shown to be superior to that using the transformation $y = \ln(x/(1-x))$, and resulted in the representation of the frequency of each okta to within 14 per cent in half the cases, and to within 26 per cent in nine out of ten cases.

Isopleths of m and s are presented for each cloud type for summer and winter months for the Australian continent, and typical diurnal variations of m are shown for three stations representing three climate zones.

**ACKNOWLEDGMENT**

The author is indebted to Mr Alan Jonas for his assistance with the numerical processing of the data.

**REFERENCES**


Fig. 5  Isopleths of the mean m (full lines) and standard deviation s (broken lines) of the normal distribution obtained by transforming the observed distributions of cloud amount. Data used refers to stations shown and is for 1500 LST.

(a) Total cloud for Jan-Feb
(b) Total cloud for Jul-Aug
Fig 5 Isopteths of the mean m (full lines) and standard deviation s (broken lines) of the normal distribution obtained by transforming the observed distributions of cloud amount. Data used refers to stations shown and is for 1500 LST.
(c) Cumulus for Jan-Feb
(d) Cumulus for Jul-Aug
Fig 5: Isoptets of the mean m (full lines) and standard deviation s (broken lines) of the normal distribution obtained by transforming the observed distributions of cloud amount. Data used refers to stations shown and is for 1500 LST.
(e) Stratocumulus for Jan-Feb
(f) Stratocumulus for Jul-Aug
Fig. 5 Isopleths of the mean m (full lines) and standard deviation s (broken lines) of the normal distribution obtained by transforming the observed distributions of cloud amount. Data used refers to stations shown and is for 1500 LST.

(g) Middle for Jan-Feb
(h) Middle for Jul-Aug
Fig 5 Isopleths of the mean m (full lines) and standard deviation s (broken lines) of the normal distribution obtained by transforming the observed distributions of cloud amount. Data used refers to stations shown and is for 1500 LST.
(i) High for Jan-Feb
(i) High for Jul-Aug
Fig 6 Variation of cloud mean parameter m with hour (daylight)
(a) Essendon: total cloud
(b) Essendon: cumulus cloud
Fig 6 Variation of cloud mean parameter m with hour (daylight)
(c) Essendon: stratocumulus cloud
(d) Essendon: high cloud
Fig 6  Variation of cloud mean parameter m with hour (daylight)
(e) Coffs Harbour: total cloud
(f) Coffs Harbour: cumulus cloud
Fig 6 Variation cloud mean parameter m with hour (daylight)

6 (g) Coffs Harbour: stratocumulus cloud
6 (h) Coffs Harbour: high cloud
Fig 6 Variation cloud mean parameter m with hour (daylight)
(i) Cairns: total cloud
(j) Cairns: cumulus cloud
Fig 6 Variation cloud mean parameter m with hour (daylight)
(k) Cairns : stratocumulus cloud
(l) Cairns : high cloud
APPENDIX

Analysis of Variance of Frequencies of Cloud Amounts

The purpose of this analysis is to examine the main identifiable factors affecting the cloud amount distribution. These were initially taken as cloud type, month, hour of day and geographical location. As described previously, cloud type comprises five types, total, cumulus, stratocumulus, middle, and high. For convenience months were grouped in pairs, e.g., January-February, etc. Hour of day comprises the hours 6, 9, 12, 15, 18, and 21 LST (being hours of synoptic observations) and geographical location ranges through 52 observing stations throughout the continent (see Fig 5(a)).

Visual inspection of frequencies of cloud amount for data grouped by month, hour, and type for all stations revealed that in general the greatest variation in frequencies due to variations with type (t) occurred between total and cumulus; with month (m) between January-February and July-August; with hour of day (h) between 0500 and 1500 LST. With location (l) Essendon, Giles, and Cairns were taken as representing extremes. These values of each factor were used to determine the importance of each factor.

The contribution of the variance of the cloud amount by each of these four factors was analysed separately for each okta by means of the standard analysis of variance technique (e.g., see Moroney 1951). These data were accordingly considered as simple factorial experiments with four main factors, 1, t, m, and h at 3, 2, 2, and 2 levels, respectively. To allow for the estimation of the importance of any other factors the experiments need to be repeated at least once (two replications). This was achieved by taking another two levels for month groups (November-December and May-June) as the second replication. In so doing, the effects of any other additional factors are confounded with the variation due to this difference in month groups. However, since consecutive month groups are involved this latter variation was estimated to be very small.

As is usual with this type of analysis the contribution to variance by each factor or factor combination was compared with the residual or unexplained variance, which if considered to be due to experimental 'noise' allows a judgment to be made about the significance of the contributed variance. The null hypothesis was made that the contributed variance was not statistically different from the unexplained variance and Fisher's F test (e.g., see Moroney 1951) was used in determining the probability of this being true. Relevant values of the F statistic for each okta and for each factor or factor combination are tabulated in Table A1.

This analysis confirms that almost all the variance of the frequency of each okta of cloud amount can be explained as being contributed by the four factors individually or in combination. There do not appear to be important additional factors influencing the distributions. Considering those F values for the highest order significant (at the 99 per cent level) interactions only (underlined in Table A1), it appears that the interaction it occurs most frequently among all the okta classes. This confirms that 1 and t are the most important factors, as was apparent from visual inspection of the data. It is also apparent from Table A1 that since in all okta classes, except the fifth and sixth, the highest order significant interaction is of at least the second order, no inferences can be drawn about the factors singly. However, since all the four factors 1, t, m, and h are significant at least once either singly or in combination, it was decided to treat each as a valid parameter in the parameterisation.
Table A1  Fisher's F ratio with v and 24 degrees of freedom for the factors location l, type t, month group n, hour of day h, and combinations thereof. Underlined values are the highest order significant values at the 99% level, in each okta class. Values in brackets are those at the 95% level where these precede those significant at the 99% level in descending order of combination of factors. The percentage of total variance explained by all the combinations taken together for each okta class is also shown.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F. (v)</th>
<th>F(v, 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oktas=0</td>
</tr>
<tr>
<td>l</td>
<td>2</td>
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<td>lt</td>
<td>2</td>
<td>23.4</td>
</tr>
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<td>ln</td>
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</tr>
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Percentage of total variance explained

|          | 97  | 93  | 97  | 92  | 89  | 93  | 96  | 96  | 90  |

