METEOROLOGICAL OFFICE

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No. 11

# SOME RESULTS FROM STANDARD-PROGRAMME TABULATIONS OF VISIBILITY AND HEIGHT OF CLOUD BASE

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1. Purpose of the paper

It is hoped that the paper will be useful in :

(1) demonstrating some ways of presenting local statistics from tabulations according to a standard programme, particularly the current version of this programme,

(2) giving offices receiving standard-programme tabulations some basis of comparison so that the local characteristics can be seen in a wider context, and

(3) stimulating discussion as to how improvement can be made in the basic data-processing (standard programme) and in the methods of presenting the data so that quick and useful reference can be made in day-to-day forecasting. (It is intended to produce statistics in collected form for as many aerodromes as possible when it is felt that the most satisfactory form of presentation has been achieved and can be accepted as a reasonable standard.)

2. Past development of the standard data-processing

The standard programme was devised with the object of specifying in detail data processing to provide aids for the local forecasting of such elements as visibility, surface wind and height of cloud base. An important aspect was that the standard data-processing should provide the most generally useful results, i.e. useful for places with widely differing local characteristics and for different operational standards (minimum landing conditions etc).

This paper describes use that can be made of item 1 (visibility) and item 2 (height of cloud base) of the standard programme. The data processing for these items is carried out by punched-card methods: the numbers of occasions are given of visibility and of height of cloud base in given ranges under different conditions e.g. of surface wind, humidity, time of day and of year. Thus much laborious work is saved in extracting data from Daily Registers or climatological returns. There remains, however, the task of summarizing tabulated data so that they are significant to the forecaster and can be readily referred to. The original version (1959) of the programme specified a complex breakdown, dividing the elements into numerous ranges and resulting in a large mass of tabulated data. The task of summarizing these data proved to be considerable and so the programme was simplified to some extent in 1962 (parts of this version, including items 1 and 2, are set out in Annex A p. 19). Tabulations according to this version, for either cloud height or visibility, were made for about 25 aerodromes. It was felt, however, that the tabulations were still too complex and so in 1964 the programme was again modified. A further simplification was made by reducing considerably the number of ranges of visibility and cloud height and giving results by seasons instead of by months. On the other hand the following types of analysis were made possible for the first time :-

(1) Visibility and height of cloud base according to the combined effects of the speed and direction of the surface wind.

(2) Visibility according to the combined effects of relative humidity and direction of the surface wind.

/Items

Items 1 and 2 of this, the current version of the standard programme, are set out in Annex B, p. 20.

Unless otherwise stated, results given in this paper are from tabulations according to the programmes of 1962 or 1964; note will be made of the type of results which are available from the latter version but not the former.

3. Use of the term "percentage probability"

In analysing the occurrence of poor visibility (and similar considerations apply to very low cloud) the obvious alternatives are :-

(1) to make a breakdown of all occurrences of poor visibility during the period of analysis into ranges of some related parameter or combination of parameters (say direction and speed of the surface wind),

or

(2) to express for each range of the related parameter (or combination of parameters) the numbers of occurrences of poor visibility as a percentage of all occurrences in that range, i.e. to give the percentage probability of the visibility being poor with the parameter(s) as specified.

The first line of attack has been taken in several published works (Ref. 1, 2 and 3) which present local weather statistics for aerodromes. Statistics of this sort are presumably useful to aircraft operators, e.g. in showing which runways are most likely to be in use under conditions of bad weather. However, the second line of attack has been adopted for the present purpose as being better related to the processes of forecasting: the forecaster first decides what the wind, humidity, etc. will be (at least within broad ranges) and accordingly forecasts the visibility and height of cloud base.

The term "percentage probability" has been used in this paper to make plain which of the two lines of attack has been taken. The term should not be interpreted too literally; when a percentage probability of zero has been given this means that under the specified conditions there were no occurrences of poor visibility (or very low cloud) amongst the observations analysed - there might be such occurrences from a different run of observations but the event should at least be rare. Use of "percentage probability" also gives some difficulty when it has been practical to group values of parameters in only broad ranges; this applies particularly to analyses of visibility according to relative humidity and will be dealt with when such results are discussed.

4. Use of surface wind as a parameter

The importance of wind as a parameter affecting visibility and height of cloud base is generally recognised but there may be some preference for the use of geostrophic rather than surface wind because the former can be more directly forecast (i.e. from a prognostic chart). A pilot analysis of cloud height according to geostrophic wind has been made for London (Heathrow) Airport (Ref. 4) but, for the standard programme, this sort of analysis is impracticable because geostrophic wind is not recorded as a routine with the observation.

It is appreciated that the forecasting of the surface wind itself can often be difficult. On the whole, though, it is probably carried out with sufficient accuracy for statistics based on surface wind to be fairly useful as a forecasting aid. The usefulness would be much enhanced if there were available accurate objective techniques for forecasting surface wind at each aerodrome starting, say, from

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a forecast of geostrophic wind. However, the work of data extraction (obtaining values of geostrophic wind for many places and at frequent intervals) would be considerable.

5. Standard diagrams of visibility

From standard-programme tabulations diagrams have been prepared in Met O 8 to show the major local characteristics of visibility at a number of aerodromes. These diagrams are to a standard form to facilitate comparison of characteristics for different stations. Only very simple analyses are presented, partly so that tabulations from either the 1962 or 1964 versions of the programme could be used to provide results for a wide selection of stations. But also it was thought that simple analyses were needed in the first instance to permit quick appraisal of the major characteristics. For convenience these diagrams will be referred to as "standard diagrams of visibility" but this is not meant to imply that the best and final form of presentation has been achieved - indeed it is hoped that forecasters will consider how the form of presentation might be improved.

An example of a complete standard diagram of visibility, for Waddington, is given in Figure 1. (For reproduction in this paper the arrangement of the sections has been changed from that of diagrams which have previously been sent to several stations.) The section giving frequencies of visibility less than 1100 yards according to month and time of day is similar to diagrams given in a number of published articles - see, for example, Section 17.12 of the Handbook of Weather Forecasting (Ref. 5). In the standard diagrams for most places (as in the example for Waddington) the sections giving percentage probabilities of poor visibility with different wind directions, wind speeds and relative humidities, refer to the winter half-year (October-March) only. This is because of the small frequencies of poor visibility at other times of year. For some places, however, (for instance where haars are important) poor visibility is more common during the summer than the winter and so effects of wind and humidity have been shown for the summer half-year (April-September). At a few places poor visibility is infrequent at any time of year and in the standard diagrams for these places the effects of wind and humidity have been shown for the year as a whole.

Complete standard diagrams of visibility for stations other than Waddington are not shown here, but so that comparisons can be made each of Figures 2-5 shows a particular section from the standard diagrams for several selected stations.

5.1. Annual and diurnal variations in fog frequency

For places for which hourly observations are punched on cards annual and diurnal variations can be shown in detail, as in Figures 2a-d. For many stations, however, only three-hourly observations are recorded on punched cards; for such places the individual percentage for each synoptic hour is given in the standard diagrams, as in the example at Figure 2e.

Some of the minor variations shown in Figure 2 may be due to inadequate sampling, for instance in Figure 2d the 1% isopleth could probably have been drawn more simply if percentages had been based on a longer run of data. A certain amount of smoothing is probably justifiable and necessary in drawing isopleths based on percentages from as short a period as five years. For the immediate purpose this is of little importance since discussion will be restricted to the broader

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trends. Figure 2 shows interesting variations from place to place in visibility trends according to time of year and time of day, for instance :-

Mildenhall - Fig. 2a

As at Waddington (Fig. 1) fogs occur predominantly during the winter half-year. Fog frequencies are in general rather lower than at Waddington. During winter, fog is notably less frequent in the late morning, afternoon and early evening than at Waddington.

Renfrew - Fig. 2b

Again fog is a phenomenon mainly of the winter half-year but the diurnal pattern then is quite different from patterns at Waddington and Mildenhall: fog is least frequent during the six hours or so before dawn and most frequent towards the end of the morning.

Turnhouse - Fig. 2c

The diurnal trends in December are interesting, fog being more frequent in the afternoon and early evening than at other times of day.

Wick - Fig. 2d

Fog is more frequent in summer than in winter.

Benbecula - Fig. 2d

Fog is infrequent at any time of year or of day.

The current standard programme permits analysis of annual and diurnal variations for four ranges of visibility. The range less than 1100 yards was chosen for the analysis of the standard diagram because this range was thought to be of fairly general interest for aviation purposes (though perhaps lower ranges of visibility would have more significance for civil aviation).

5.2. Effects of wind direction on visibility

Effects of wind direction on visibility at six aerodromes are illustrated in Figure 3 and can be compared with effects at Waddington as shown in the appropriate section of Figure 1.

At Mildenhall during the winter half-year (Fig. 3a) the relative importance of the different wind directions is rather similar to that at Waddington: there is no wind direction which gives a very low probability of poor visibility; winds from the south-east are more likely to give poor visibility than winds from other directions. For all wind directions the respective percentages are lower at Mildenhall than at Waddington.

The comparison throws fresh light on the features already shown for Waddington. The tendency for poor visibility there with winds from the south-east might have been accounted for solely by local geography - such winds coming from the moist area of the Fens and giving upslope motion in the immediate vicinity of the aerodrome. No doubt such factors are of great importance but they appear not to be the only factors; there is a tendency for south-easterly winds to be accompanied

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by poor visibility also at Mildenhall which lies south-east of the Fens and is only 15 feet above sea level. Thus it seems there might be some synoptic reason why south-easterly winds tend to be accompanied by poor visibility in the area around the Fens during winter.

Effects of wind direction can be more striking than at Waddington and Mildenhall. Thus at Wick (Fig. 3b), Renfrew (Fig. 3c), Liverpool Airport (Fig. 3e) and Rhoose (Fig. 3f) there are notable contrasts between the probabilities of poor visibility with winds from different directions.

5.3. Effects of wind speed on visibility

From Figure 4 a trend is seen for poor visibility to be very unlikely with wind speeds in the higher ranges. At some places (e.g. Benbecula - Fig. 4d) the probabilities of poor visibility are low even with light winds or calms. There is considerable variation from place to place in the speed of surface wind above which the probability of fog becomes very low, say 1% or less: for Renfrew (Fig. 4c) this value is 6 knots, for Mildenhall (Fig. 4a) 10 knots, for Waddington (Fig. 1) 14 knots, but for Rhoose (Fig. 4f) the probability of visibility being below 1100 yards is more than 1% even with winds in the range 20 knots or more.

As has already been mentioned, the usefulness of results such as these must depend on how well the surface wind can be forecast. Local behaviour of surface wind may have critical effect as at Renfrew where, under certain conditions, winds can remain light at the surface with pressure gradients which would give moderate or fresh winds at most places.

5.4. Effects of relative humidity on visibility

The representation of effects of relative humidity given in Figure 5 is not considered altogether satisfactory because a false impression is left of abrupt changes in probability from one class to another, particularly from 90-96% to 97-100%. The difficulty arises from the broad ranges of relative humidity specified in the standard programme. Nevertheless some interesting features are shown in Figure 5 :

(1) The significance of smoke at Renfrew (Fig. 5c) and at Liverpool Airport (Fig. 5e) is brought out by the high probabilities (as compared with those at the other places) of poor visibility with humidity in the lower ranges.

(2) At Benbecula (Fig. 5d) poor visibility is unlikely even when the air is saturated or nearly so (relative humidity 97-100%). This, together with effects of wind speed already noted, suggests that the infrequency of fog at Benbecula is not due merely to infrequency of light winds or high humidity; even with favourable conditions of wind and humidity, fog does not appear to form readily.

6. Additional analyses of visibility

The standard diagrams were intended to give concise results which could be quickly appraised and could be obtained from the varying amounts of data available

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for different stations - sometimes fairly short runs of observations. Useful analyses in greater detail can often be made from standard-programme tabulations but the practical possibilities vary according to the characteristics which are to be defined and the amount of data recorded on punched cards. Because a more flexible approach is required such results are better presented as additional analyses rather than as part of any standard presentation. In this section some examples of "additional analyses" of visibility are discussed.

There is an obvious weakness in the results given in the standard diagrams in that only one parameter is considered at a time in relation to visibility. In forecasting practice the effects of wind direction and wind speed (for example) are not considered separately; poor visibility might persist with fairly strong winds from some directions (e.g. bringing air off the sea or giving upslope motion) but not others. Examples are given in Figure 6 of analyses of the combined effects of wind direction and speed - analyses which are possible from the current (1964) version of the standard programme but not from previous versions. Some of the features shown in Figure 6 are :-

(1) At Mildenhall (Fig. 6a) and Renfrew (Fig. 6b) the probabilities of visibility being less than 1100 yards and less than 440 yards with winds of 7-10 knots are small for winds from all directions.

(2) At Waddington (Fig. 6c), however, with the same range of wind speed such visibilities are more likely to occur - particularly with winds from the south-east.

(3) At Rhoose (Fig. 6d) it is remarkable that the probabilities of visibility less than 1100 yards and less than 440 yards differ little whether there is a calm or a wind of up to 10 knots from between 050° and 100°; with winds from some other sectors (170°-220°, 310°-010°) the chances of poor visibility become very small if the wind speed exceeds 6 knots.

(4) At all four places the probabilities of poor visibility tend to be small with winds of 11 knots or more, but it may be noted in passing that at Waddington with winds of 11 knots or more from the south-east the visibility is as likely to be less than 440 yards as at Renfrew with winds of only 1-6 knots from any direction.

For Figure 6 broad ranges of wind speed were used so that percentages for each thirty-degree sector in each range of speed could be based on reasonably large numbers of observations (90 was the smallest, 3285 the largest). The current standard programme gives a breakdown according to narrower ranges of wind speed and it is practical to use these if analysis is made for wide sectors of wind direction (i.e. several thirty-degree sectors combined), hence showing in greater detail the effect of wind speed. Thus for Waddington one might have selected from Figure 1 the wind directions 110°-160° and 230°-010° as being rather more associated with poor visibility than other wind directions. A detailed analysis of the effects of wind speed in the selected sectors gives the following results :-

/TABLE I

TABLE I - PERCENTAGE PROBABILITIES OF POOR VISIBILITY AT WADDINGTON DURING THE WINTER HALF-YEAR ACCORDING TO WIND SPEED FOR SELECTED SECTORS

| Wind speed (knots) | Sector 230°-010° Visibility (yards) | | | Sector 110°-160° Visibility (yards) | | |
|---|---|---|---|---|---|---|
| | <440 | <1100 | <2200 | <440 | <1100 | <2200 |
| 1-3 | 18 | 33 | 54 | 26 | 38 | 52 |
| 4-6 | 9 | 18 | 35 | 22 | 30 | 45 |
| 7-10 | 4 | 8 | 19 | 11 | 17 | 31 |
| 11-14 | 1 | 2 | 5 | 5 | 8 | 17 |
| 15-19 | 0.2 | 0.7 | 2 | 2 | 3 | 9 |
| 20+ | 0 | 0.6 | 1 | 0.6 | 3 | 5 |

The poor visibility is more likely to persist with strong winds from between 110° and 160° than from between 230° and 010°.

Results for Waddington for these two broad sectors of wind direction can again be used for additional analyses made possible by the revision of the standard programme in 1964, this time to illustrate the combined effects of wind direction and relative humidity :-

TABLE II - PERCENTAGE PROBABILITIES OF POOR VISIBILITY AT WADDINGTON DURING THE WINTER HALF-YEAR ACCORDING TO RELATIVE HUMIDITY FOR SELECTED SECTORS OF WIND DIRECTION

| Relative humidity % | Sector 230°-010° Visibility (yards) | | | Sector 110°-160° Visibility (yards) | | |
|---|---|---|---|---|---|---|
| | <440 | <1100 | <2200 | <440 | <1100 | <2200 |
| 97-100 | 24 | 43 | 64 | 25 | 39 | 60 |
| 90-96 | 4 | 11 | 26 | 2 | 3 | 11 |
| 80-89 | 0.2 | 0.9 | 7 | 0.1 | 0.4 | 2 |
| 0-79 | 0 | 0.3 | 3 | 0 | 0 | 0 |

Poor visibility is more likely with humidities of less than 97% with winds from the sector 230°-010° than 110°-160°; presumably smoke haze plays a more important role with winds from the former sector than from the latter.

Thus, although visibility tends to be poor with winds from both sectors, the effects of wind speed and relative humidity differ considerably between the two sectors. Trends shown are on the whole consistent with the subjective assessment of local weather characteristics for Waddington as summarized in "Aerodrome weather diagrams and characteristics" (Ref. 6). However, it had not been made explicit that poor visibility at Waddington could accompany relatively strong winds from the south-east.

Ranges of visibility so far considered have been chosen with the requirements of aviation in mind. However, for forecasting for the general public the interest is likely to be in thick fog. Analyses of visibilities less than 220 yards can be made from standard-programme tabulations and some examples are given.

Diurnal trends during the winter half-year at three places are shown in Figure 7. Of particular interest are the differences in trend between London (Heathrow) Airport and Renfrew during December and January: at Heathrow the frequency of thick fog decreases between dawn and noon but at Renfrew the frequency is highest at noon.

At most places (at least places which are inland and not too high above sea level) the probabilities of thick fog appear to be very small except with calms or very light winds. Some examples are given below :-

/TABLE III

TABLE III - PERCENTAGE PROBABILITIES OF THICK FOG (VISIBILITY <220 YARDS) ACCORDING TO THE SPEED OF THE SURFACE WIND DURING THE WINTER HALF-YEAR

| Knots \ Place (elevation) | Mildenhall (30') | Shawbury (248') | Gatwick (194') | Renfrew (42') | Pershore (132') |
|---|---|---|---|---|---|
| 0 | 18 | 18 | 21 | 8 | 22 |
| 1-3 | 7 | 6 | 6 | 1 | 7 |
| 4-6 | 2 | 2 | 1 | 0.1 | 2 |
| 7-10 | 0.4 | 0.2 | 0.1 | 0 + | 0.6 |
| 11-14 | 0.1 | 0 | 0.1 | 0 | 0.2 |
| 15-19 | 0 + | 0 | 0 | 0 | 0 |
| 20 or more | 0 | 0 | 0 | 0 | 0.3 |

Percentages greater than zero but less than 0.05
are marked 'o +'

It is therefore useful to know of exceptions - of places where thick fog can accompany stronger winds, at least if such winds blow from a given sector. Two examples are illustrated by Table IV :-

TABLE IV - PERCENTAGE PROBABILITIES OF THICK FOG (VISIBILITY <220 YARDS) ACCORDING TO WIND SPEED FOR WINDS FROM A SELECTED SECTOR DURING THE WINTER HALF-YEAR

| Place (elevation) | Rhoose (220') | Waddington (231') |
|---|---|---|
| Knots \ Sector | $050^{\circ}-100^{\circ}$ | $110^{\circ}-160^{\circ}$ |
| 1-3 | 7 | 19 |
| 4-6 | 8 | 19 |
| 7-10 | 6 | 6 |
| 11-14 | 1 | 2 |
| 15-19 | 0.1 | 0.5 |
| 20 or more | 0.3 | 0 |

Thus at these two places if the wind is from the appropriate direction the probability of thick fog does not decrease below 1% until winds exceed 14 knots; this can be compared with the results of Table III.

Though some interesting local variations in the behaviour of thick fog can be shown from standard-programme statistics it is unlikely that these can be of much value as aids in forecasting for the general public because figures are available only for scattered places. One cannot say, for instance, to what extent statistics for Renfrew are characteristic of Glasgow and surrounding areas; the behaviour of fog on a motorway cannot be adequately assessed from results from one or two places near its course.

7. Standard diagrams of height of cloud base

For height of cloud base, as for visibility, standard diagrams have been prepared to present simple analyses from standard-programme tabulations - an example is given in Figure 8. There are some differences in presentation from the visibility diagrams because of differences in the basic tabulations. Thus the standard diagrams for height of cloud base do not give analyses according to humidity or time of day; such analyses cannot be made from item 2 of the standard programme (though frequencies for each synoptic hour of each month can be obtained from another part of the programme, i.e. item 3 as set out in Annex A).

The standard diagrams of height of cloud base, like those of visibility, show the effects of surface wind but the treatment has been more detailed in that effects have been shown separately for each three-month season. This seemed necessary because for many stations it was found that the major risk of very low cloud was associated with different wind directions during different seasons. Also the risk of very low cloud did not usually diminish to the same extent as the risk of poor visibility at certain times of year. The standard diagram given in Figure 8 illustrates the need for separate analyses for each season: at Waddington the probability of very low cloud is particularly notable with winds from the sector $110^{\circ}$-$160^{\circ}$ during the winter but during the summer winds from the sector $350^{\circ}$-$040^{\circ}$ are more significant.

It should be appreciated that in the standard-programme tabulations and in the standard diagrams of height of cloud base fogs deep enough to obscure the sky are treated as cases of cloud on, or near, the surface; the cloud base is assigned the same value as the vertical visibility or zero if this was not reported.

Sections will now be shown from some standard diagrams of height of cloud base to illustrate the sort of variations that occur from place to place. In each example results are given for both summer and winter so that some of the important seasonal variations can be seen.

7.1. Effects of wind direction on height of cloud base

Comparison of the results for Marham, shown in Figure 9a, with those for Waddington, in the corresponding sections of Figure 8, illustrates the combination of local effects and more general effects which are probably related to synoptic tendencies (e.g. for certain winds to bring moist air masses). For instance the tendency for very low cloud with south-easterly winds in winter is apparent at Marham (south-east of the Fens) as well as at Waddington (north-west of the Fens) - though less pronounced at the former. Thus the tendency at Waddington cannot be completely accounted for by very local factors, e.g. air from the south-east having crossed the Fens and then being subject to uplift, though such factors probably explain the pronounced nature of the tendency there.

It is interesting that the statistics should show significant local differences even in a region as flat as eastern England. In regions of more rugged terrain the local effects are naturally more obvious from the statistics and general synoptic effects less noticeable.

At Shawbury (Fig. 9b) the shelter afforded by the Welsh Mountains is made apparent by the small probabilities of very low cloud with winds from most westerly points. The relative importance of the different wind directions does not vary greatly from summer to winter here though each percentage is much smaller in summer than the corresponding value for winter.

Percentages shown in Figure 9c for Lyneham (513 feet above sea level) are relatively large and in particular for winds from between $350^{\circ}$ and $100^{\circ}$ during winter; with winds from this broad sector there is a chance of roughly one in four of cloud, 5/8 or more, below 300 feet.

/At

At Dyce (Fig. 9d) the most striking feature shown, though hardly a surprising one in view of the topography, is the very small probability of cloud being low with winds from the south-west and west, i.e. the direction of the Grampian Highlands. Seasonal variations are of some interest; in summer winds from the sector 050°-100° give a large probability of very low cloud (presumably haars) but in winter the cloud base is most likely to be low if the wind blows from the sector 110°-160°.

The summer and winter characteristics are very similar both at Valley (Fig. 9e) and St. Mawgan (Fig. 9f). The much lesser likelihood of cloud being low with winds from 230°-280° at Valley than at St. Mawgan suggests shelter at the former place afforded by the mountains of southern Eire - shelter which does not seem to be offset by the fetch across the Irish Sea.

7.2. Effects of wind speed on height of cloud base

At many inland aerodromes (see for instance Figures 10 a-c) the probability of cloud being low is particularly large in winter with calms or light winds. This probably reflects the contribution made by radiation fogs, cases of fog with sky obscured having been counted as cases of very low cloud. Generally at the inland aerodromes the percentages for cloud below 300 feet decrease rapidly with increasing wind speed. There is, however, considerable variation from place to place in the values in individual ranges of wind speed; for instance with winds of 11-14 knots during winter the probabilities of cloud below 300 feet are less than 1% at Shawbury (Fig. 10b), 3% at Marham (Fig. 10a), 6% at Waddington (Fig. 8) and 9% at Lyneham (Fig. 10c). These are, of course, overall percentages, i.e. without regard to wind direction.

At aerodromes on, or near, coasts, e.g. Dyce (Fig. 10d), Valley (Fig. 10e) and St. Mawgan (Fig. 10f), the probability of cloud base being below 300 feet is less affected by wind speed. This is hardly surprising: one would expect light winds to be less likely to give radiation fog on the coast; one would also expect stratus to remain very low at times on the coast when there were strong winds off the sea.

8. Additional analyses of height of cloud base

With height of cloud base as with visibility, the most obvious scope for amplifying the presentation of the standard diagrams is in additional analyses for the combined effects of wind direction and wind speed - analyses made possible by the amendment of the programme in 1964. Examples of such analyses are shown in Table V. Only three-hourly observations have been used so far for analyses of height of cloud base (as opposed to hourly observations for some analyses of visibility). Because of this and the need to consider three-month rather than six-month seasons it has been found necessary to resort to use of wide sectors of wind direction and ranges of wind speed to a greater extent in the additional analyses for cloud height than in those for visibility. In compiling Table V sectors of direction and ranges of speed were selected individually for each of the aerodromes, bearing in mind the general patterns deduced from the detailed

/tabulations

tabulations and combining classes in such a way as to ensure that few results were based on small numbers of observations.

TABLE V - PERCENTAGE PROBABILITIES OF CLOUD (5/8 OR MORE) BELOW 300 FEET FOR SELECTED STATIONS, SEASONS AND CONDITIONS OF SURFACE WIND

For Waddington:

| Season | Winter | Winter | Winter |
|---|---|---|---|
| Wind speed (knots) \ Wind sector | 350°-100° (thru' 360°) | 110°-160° | 170°-340° |
| 1-3 | 15 | 29*(82) | 21 |
| 4-6 | 13 | 32 | 13 |
| 7-10 | 9 | 22 | 7 |
| 11-14 | 7 | 20 | 3 |
| 15 or more | 5 | 16 | 0.9 |

For Dyce:

| Season | Summer | Summer | Summer | Summer |
|---|---|---|---|---|
| Wind speed (knots) \ Wind sector | 020°-130° | 140°-220° | 230°-310° | 320°-010° (thru' 360°) |
| 1-3 | 16 | 6 | 0.6 | 6 |
| 4-6 | 11 | 3 | 0 | 4 |
| 7-10 | 16 | 2 | 0 | 1 |
| 11 or more | 34*(68) | 2 | 0 | 0.7 |

For Valley:

| Season | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Wind speed (knots) \ Wind sector | 170°-220° | 170°-220° | 170°-220° | 170°-220° |
| 1-6 | 4 | 5 | 0.9 | 18*(84) |
| 7-10 | 8 | 4 | 0.4 | 4 |
| 11-14 | 10 | 10 | 3 | 5 |
| 15-19 | 14 | 13 | 3 | 8 |
| 20 or more | 9 | 13 | 4 | 5 |

*Percentage based on less than 100 observations - the actual number is given in brackets.

Both at Waddington in winter and at Dyce in summer the risk of very low cloud with the stronger winds is much greater if these blow from one sector than from the others. At Dyce, in fact, the percentage for winds of 11 knots or more from the sector 020°-130° is not only higher than percentages for winds of the same speed from other sectors, it is higher than percentages for lighter winds from the same sector. Admittedly this depends on a result based on a small sample of observa-

/tions

tions but, by the chi-square test, the chances are greater than 99 in 100 that for winds from the sector 020°-130° the true percentage for speeds of 11 knots or more is at least as high as that for speeds of 7-10 knots.

It may be seen from Figure 9e that both in summer and in winter the main threat of cloud being low at Valley is with winds from the sector 170°-220°; in fact this is also true in spring and autumn. In Table V results are given for this sector alone and show differences in the effect of wind speed according to season: in summer the highest probabilities of cloud below 300 feet are with the strong winds but this is not so in winter.

There may be some interest in overall frequencies of very low cloud so that it can be seen which aerodromes are particularly subject to these conditions and which are comparatively free. Frequencies for a selection of aerodromes are given in Table VI.

TABLE VI - PERCENTAGE FREQUENCIES OF CLOUD (5/8 OR MORE) BELOW 300 FEET AND BELOW 600 FEET*

| Aerodrome | Elevation (feet) | Spring | | Summer | | Autumn | | Winter | | Based on : | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <300' | <600' | <300' | <600' | <300' | <600' | <300' | <600' | Obs. per day | Years |
| **Coastal** | | | | | | | | | | | |
| Chivenor | 27 | 2 | 5 | 1 | 4 | 0.9 | 3 | 2 | 5 | 8 | 1957-1964 |
| Stornoway | 30 | 0.5 | 1 | 0.9 | 4 | 0.3 | 1 | 0.2 | 1 | 8 | 1957-1961 |
| Valley | 33 | 4 | 8 | 4 | 8 | 1 | 4 | 2 | 6 | 8 | 1957-1964 |
| Wick | 127 | 3 | 6 | 7 | 12 | 2 | 5 | 0.9 | 2 | 8 | 1957-1961 |
| Turnhouse | 135 | 2 | 4 | 3 | 6 | 2 | 4 | 2 | 3 | 8 | 1957-1961 |
| Rhoose | 220 | 4 | 7 | 1 | 4 | 3 | 6 | 7 | 11 | 8 | 1957-1964 |
| Dyce | 235 | 5 | 10 | 5 | 11 | 2 | 7 | 2 | 4 | 8 | 1957-1964 |
| St. Mawgan | 390 | 7 | 15 | 6 | 13 | 4 | 9 | 6 | 13 | 8 | 1957-1961 |
| **Inland** | | | | | | | | | | | |
| Mildenhall | 15 | 2 | 4 | 1 | 4 | 3 | 6 | 5 | 9 | 8 | 1949-1958 |
| Renfrew | 42 | 0.6 | 1 | 0.1 | 0.9 | 1 | 2 | 2 | 4 | 8 | 1949-1958 |
| Marham | 80 | 2 | 5 | 1 | 3 | 4 | 8 | 8 | 14 | 8 | 1957-1961 |
| Waddington | 231 | 4 | 8 | 2 | 5 | 7 | 10 | 10 | 15 | 8 | 1956-1964 |
| Shawbury | 248 | 0.8 | 3 | 0.3 | 1 | 4 | 7 | 6 | 10 | 8 | 1957-1964 |
| Manchester Airport | 256 | 1 | 2 | 0.7 | 2 | 2 | 4 | 4 | 7 | 8 | 1949-1964 |
| Abingdon | 268 | 1 | 4 | 0.6 | 2 | 3 | 7 | 8 | 14 | 8 | 1957-1961 |
| Aldergrove | 269 | 1 | 3 | 0.9 | 3 | 2 | 4 | 3 | 6 | 8 | 1949-1958 |
| Lyneham | 513 | 5 | 12 | 2 | 7 | 8 | 14 | 14 | 23 | 4 | 1957-1961 |
| Bovingdon | 535 | 5 | 11 | 2 | 7 | 8 | 15 | 13 | 23 | 4 | 1957-1964 |

*Cloud heights are above aerodrome level.

/9.

9. Usefulness of the standard-programme results

It is hoped that a fairly balanced impression has been given of the usefulness of standard-programme statistics. They amount to a forecasting aid rather than a forecasting technique, indicating conditions under which there is a special risk, or very little risk, of poor visibility or very low cloud but not giving definite forecast values. More sophisticated statistical methods are required for techniques which will give forecast values of visibility or height of cloud base, e.g. Freeman's technique for objective forecasting (Ref. 8), but such methods involve a large effort in data extraction and processing. The usefulness of the standard-programme statistics lies in the relatively small data-processing effort needed so that results for many stations can be produced fairly quickly. Thus the appreciation of local weather peculiarities can be furthered not only by results from the aerodrome in question but by the perspective afforded by comparison of these with parallel results for other places. Results from many places suggest which percentages can be considered more or less average and which are notably high or low.

A weak point in the current and past standard programmes is that they permit only elements observed at the station to be used as parameters in the analysis of visibility and height of cloud base. Synoptic features which are important in day-to-day forecasting (e.g. air mass characteristics, profiles of temperature and dew point in the lower layers, trajectories, fronts) are taken into account only to the extent that they may be related to surface wind and other local parameters used. It is felt that the statistical and synoptic approaches to the forecasting of local weather are essentially complementary; the statistics indicate a probability of poor conditions according to time of year and of day, surface wind, etc. - ensuring that the forecaster does not overlook significant risks - and he can then assess whether the probability is greater or less than the general one in view of the current synoptic features.

The importance is recognised of synoptic studies of cases which give insight into the local peculiarities of weather and relevant physical factors. The standard programme results can help in selecting cases which should be studied in this way. As an example, if very low cloud often persists with much stronger winds from one direction than from others, then it might be worth examining synoptic charts for the occasions with the stronger winds from the appropriate direction to see whether the low cloud was associated with, say, fronts or particular trajectories of air. Having studied the problem from both the statistical and synoptic points of view it might be possible to say more definitely whether or not the cloud base would be low on individual occasions.

The standard-programme results may also be useful in formulating more complex statistical analyses to give better understanding of a specific forecasting problem at an aerodrome.

10. Limitations imposed by amount of data available

One of the difficulties encountered so far in presenting standard-programme results has been that the number of observations has often been inadequate to support analyses in terms of the combined effects of several parameters. The data most commonly available on punched cards have been three-hourly observations since 1957, though hourly observations and for longer periods have been available for some

/aerodromes

aerodromes. The extent to which the more complicated analyses could be made varied a lot from station to station, not only according to the number of observations available but also according to how evenly these were distributed in the ranges of the various parameters. Thus it might be supposed that three-hourly observations over a period of 8 years - 23,376 observations in all - when divided according to seasons (4 seasons) and surface wind (37 categories, i.e. calms plus three ranges of wind speed in each thirty-degree sector) would give a high enough number of observations in each of the resulting categories for percentages based thereon to be fairly representative. That this is not always so is illustrated by Table VII.

/TABLE VII

TABLE VII - OCCURRENCES OF SURFACE WIND IN CERTAIN RANGES AT DYCE FROM THREE-HOURLY OBSERVATIONS DURING EIGHT YEARS

| Speed (knots) | 30-deg. sectors centred: 360° | 030° | 060° | 090° | 120° | 150° | 180° | 210° | 240° | 270° | 300° | 330° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Spring** | | | | | | | | | | | |
| 1-6 | 161 | 59 | 62 | 176 | 242 | 193 | 156 | 86 | 81 | 81 | 100 | 193 |
| 7-10 | 87 | 46 | 47 | 71 | 113 | 214 | 199 | 110 | 74 | 95 | 120 | 180 |
| 11 or more | 74 | 25 | 26 | 46 | 127 | 329 | 366 | 198 | 97 | 166 | 266 | 296 |
| | **Summer** | | | | | | | | | | | |
| 1-6 | 157 | 69 | 74 | 228 | 294 | 266 | 183 | 108 | 110 | 113 | 134 | 286 |
| 7-10 | 95 | 25 | 45 | 71 | 82 | 152 | 190 | 114 | 84 | 117 | 177 | 254 |
| 11 or more | 57 | 12 | 19 | 15 | 22 | 103 | 195 | 191 | 80 | 147 | 258 | 367 |
| | **Autumn** | | | | | | | | | | | |
| 1-6 | 115 | 62 | 43 | 98 | 167 | 170 | 270 | 187 | 142 | 120 | 99 | 169 |
| 7-10 | 29 | 12 | 38 | 66 | 95 | 120 | 294 | 199 | 152 | 133 | 190 | 130 |
| 11 or more | 47 | 6 | 15 | 32 | 28 | 139 | 350 | 256 | 91 | 167 | 278 | 196 |
| | **Winter** | | | | | | | | | | | |
| 1-6 | 156 | 58 | 37 | 68 | 71 | 123 | 188 | 137 | 127 | 116 | 117 | 181 |
| 7-10 | 49 | 16 | 25 | 44 | 71 | 109 | 189 | 139 | 136 | 180 | 218 | 140 |
| 11 or more | 29 | 7 | 30 | 37 | 128 | 155 | 357 | 313 | 160 | 249 | 456 | 200 |

Observations are from the years 1957 to 1964

/In

In this example there are 28 categories with less than 50 observations and 2 with less than 10.

Thus it seems advisable that any standard presentation should be limited to a simple form of analysis in which only one or two parameters are considered simultaneously. For elaboration a more flexible approach is needed with ranges of the different parameters selected according to the features to be brought out and the distribution of observations amongst the different classes given by the standard programme.

11. Possible development of the standard programme

Lines of development which might be considered are :

(1) Increase in the number of ways in which the observations are sorted, i.e. by introducing other parameters or by making additional combinations of parameters already used.

(2) Machine calculation of percentages for results which are of the most general usefulness, e.g. in preparing standard diagrams. At present the work in combining frequencies for different classes and expressing these as percentages takes a good deal of time though the calculations are very simple.

(3) Machine production of results of the type given in this paper as "additional analyses" - results for which discrimination has to be exercised in deciding how different ranges of the parameters should be combined in order to make manifest significant features yet to ensure that any spurious features which were liable to appear as a result of inadequate sampling were suppressed.

Development along the first of these lines will gradually become more practical as the amount of data recorded on punched cards increases. By the end of 1966 there will be at least ten years of data for about 50 aerodromes in the United Kingdom; these data are hourly observations for about 20 of the aerodromes and three-hourly for most of the remainder.

Development along the second and third of the lines given above would be dependent on data processing by computer instead of by punched-card methods. This could give several advantages. Work would be saved in carrying out repetitious calculations by machine. Results could be put in a form in which they were of more immediate value to the forecaster than the present tabulations. Discrimination in the way in which results were combined might be made objectively instead of on the basis of personal judgement. The computer might, for instance, combine or leave separate the results for adjacent sectors of wind direction (or ranges of other parameters) according to the level of significance of the differences between the results.

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/ANNEX A

## ANNEX A - ITEMS FROM THE STANDARD PROGRAMME OF 1962

1. **Visibility**

(a) For each month separately (irrespective of year)
Frequency of visibilities in the following ranges
(tens of metres)

| | | | |
|---|---|---|---|
| 000-004 | 030-039 | 070-079 | 200 or more |
| 005-009 | 040-049 | 080-099 | |
| 010-019 | 050-059 | 100-149 | |
| 020-029 | 060-069 | 150-199 | |

(b) For each month separately (irrespective of year)
For each visibility range given in 1(a)

(i) Frequency by hours (24 ranges)

(ii) Frequency by Relative Humidities in the following ranges

00-79 80-89 90-96 97-100

(c) For each month separately (irrespective of year)
For each visibility range given in 1(a)

(i) Frequency of Wind Direction in the 30° ranges as follows

00 (Calms) 02-04 05-07 ....... 35-01

(ii) Frequency of wind speed in the following ranges

0 1-3 4-6 7-10 11-14 15-19 20 or more knots

2. **Cloud**

(a) For cumuliform or stratiform cloud type separately
($C_L$ = 123489 or $C_L$ = 0567 and "sky obscured")
For each month separately (irrespective of year)
For occasions when there was a layer of cloud of 5/8 or more
Frequency analysis of the height of cloud base of the lowest layer of 5/8 or more in the following ranges

00 01 02 03 04 05 06 07 08 09 10
11 or above (in hundreds of feet), unlimited
i.e. no layer 5/8 or more.

(b) For cloud type separately
For each month separately (irrespective of year)
For each cloud base as defined in 2(a)

(i) Frequency of wind direction in 10° ranges

(ii) Frequency of wind speeds in the following ranges

0 1-3 4-6 7-10 11-14 15-19 20-29 30-39 et seq.

3. **Combined Cloud Base and Visibility Summary**

For each month separately (irrespective of year)
For each of the 8 synoptic hours separately
Frequency tabulations in ranges:

visibility, (tens of yards) 000-004, 005-010, 011-021, 022-032, 033-043, 044-054, 055-065, 066-076, 077-087, 088-098, 099-109, 110-129, 130-169, 170-219, 220-329, 330-439, (miles) 3, 4, 5, 6, 7-12, 13-24, 25 or more.

cloud base, 5/8 or more, (hundreds of feet) 0, 1, 2, 3, 4, 5, 6-7, 8-9, 10-11, 12-14, 15-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-119, 120-199, 200-299, 300 or more.

/ANNEX B

## ANNEX B - ITEMS FROM THE STANDARD PROGRAMME OF 1964

1. **Visibility**

(a) For each month separately (irrespective of year)
For each hour
Frequencies of visibilities in each of the following ranges (tens of metres)

000-019, 020-039, 040-099, 100-199, 200 or more

(b) For April-September combined and for October-March combined (irrespective of year)
For each visibility range given in 1(a) separately
For each wind direction in the 30° ranges

00 (Calms), 35-01, 02-04 ......... 32-34

Frequencies of wind speed in the ranges

0, 1-3, 4-6, 7-10, 11-14, 15-19, 20 or more knots

Frequencies of relative humidity in the ranges

0-79, 80-89, 90-96, 97-100

2. **Cloud Base**

For each of the seasons (irrespective of year)

Spring (March to May), Summer (June to August)
Autumn (September to November), Winter (December to February)

For each of the following ranges of the height of the lowest layer of cloud of 5/8 or more or vertical visibility (in hundreds of feet) separately

00-02, 03-05, 06-09, 10 or above, unlimited i.e. no cloud layer of 5/8 or more.

For each wind speed in the following ranges (in knots)

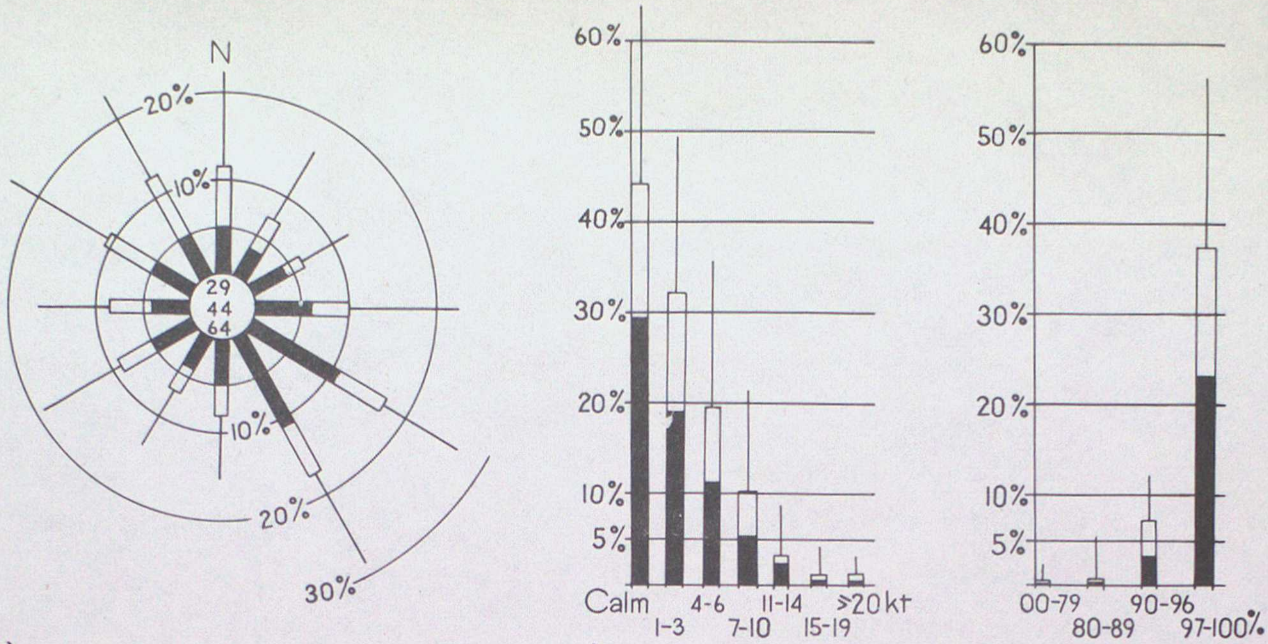
0, 1-3, 4-6, 7-10, 11-14, 15-19, 20-29, 30-39, et. seq.

Frequencies of wind direction in the 30° ranges

00 (Calms), 35-01, 02-04, ......... 32-34

3. **Combined cloud base and visibility summary**

(This item remained in the same form as in the standard programme of 1962 - see Annex A.)



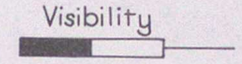

a) according to direction of the surface wind

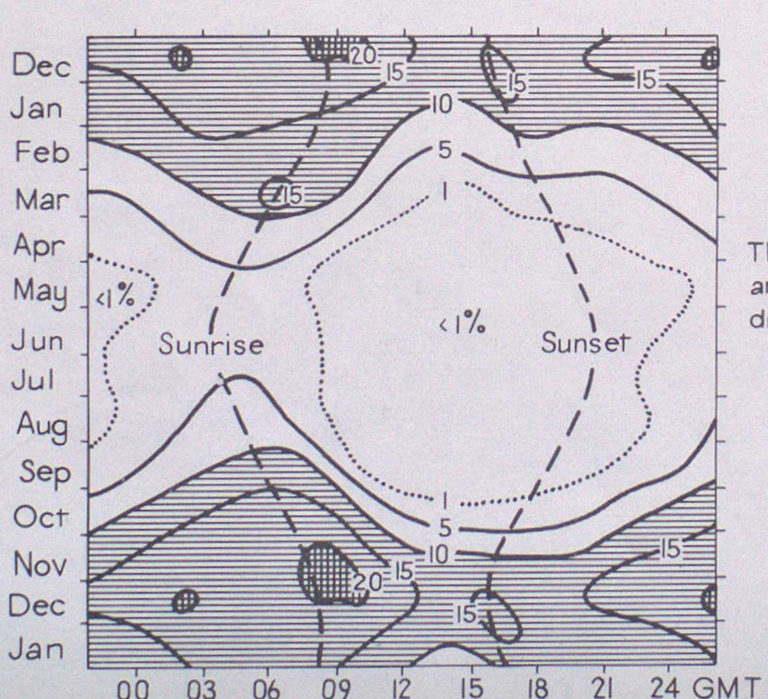
b.) according to speed of the surface wind

c.) according to relative humidity

Percentage probabilities of visibility below certain values <u>during the winter half - year</u>

In the left-hand diagram, percentages for calms are entered at the centre for the following ranges (yards): <440 <1100 <2200




The percentages for these diagrams are derived from hourly observations during the years 1957–1963.

Percentage frequencies of visibility below 1100 yards according to month and time of day

# VISIBILITY AT WADDINGTON

Fig 1. A standard diagram of visibility

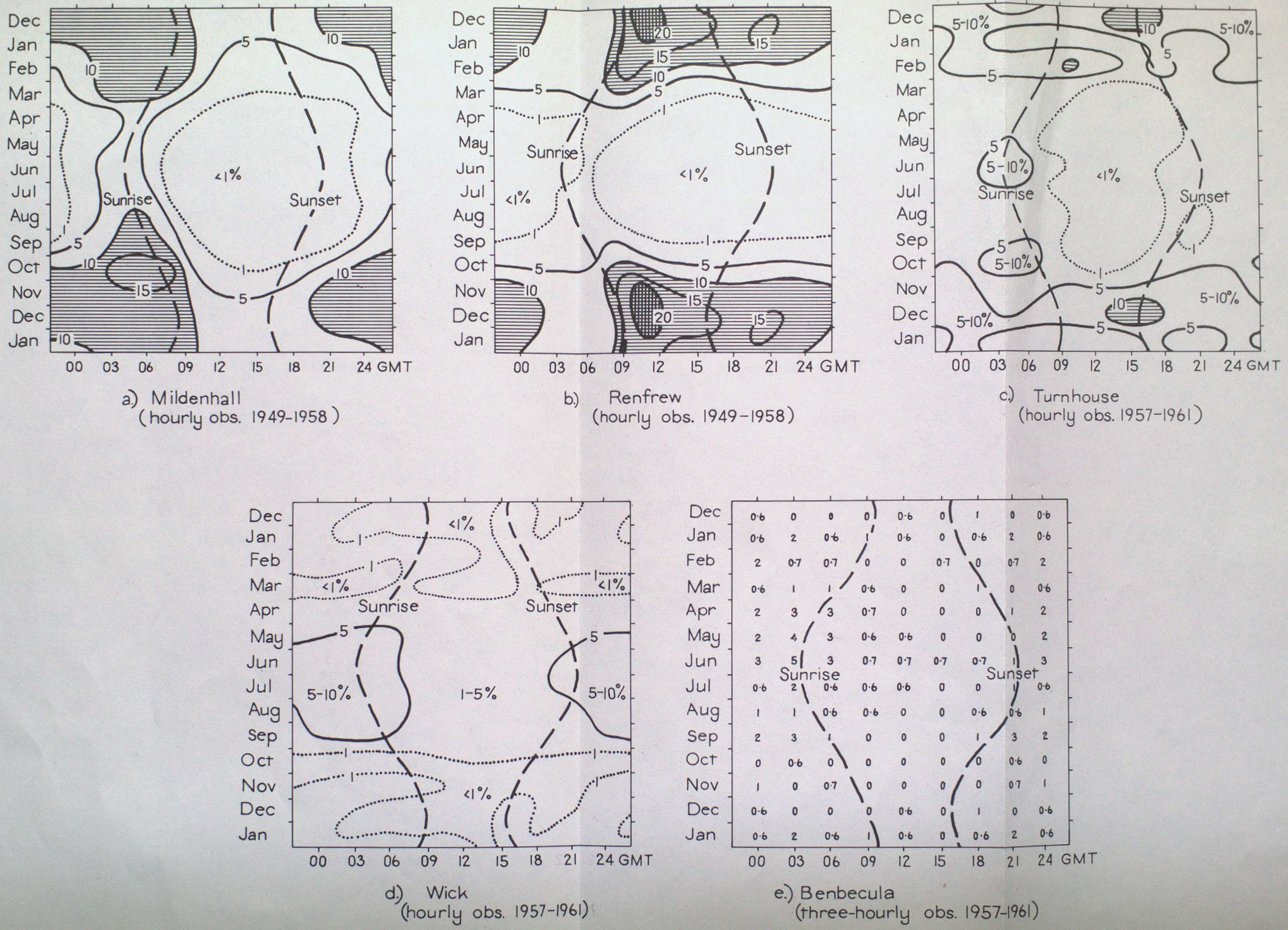
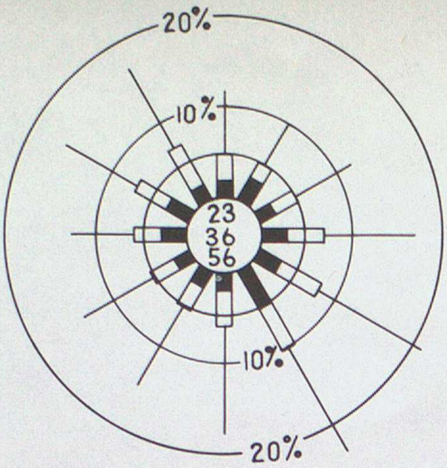
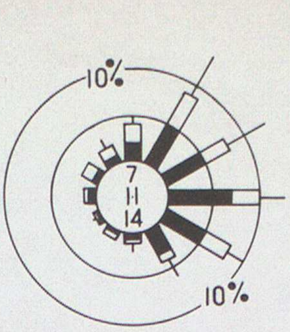



Fig 2. Sections from standard diagrams of visibility: percentage frequencies of visibility less than 1100 yards according to month and time of day.

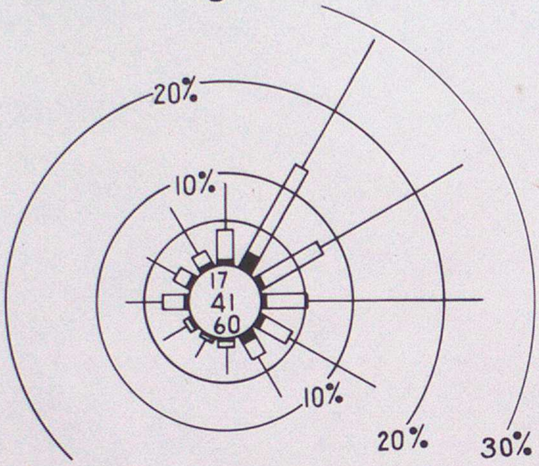
N



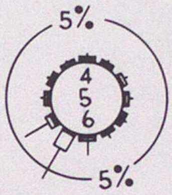

a.) Mildenhall during the winter half-year (from hourly obs. 1949-1958)



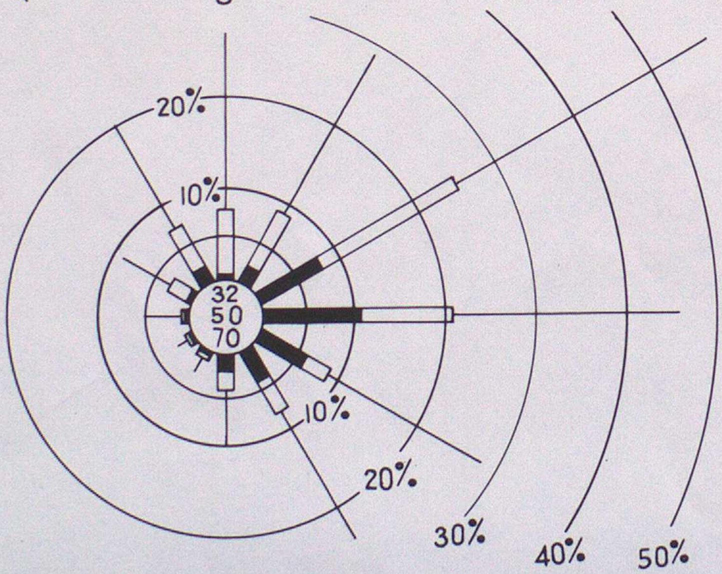

b.) Wick during the summer half-year (from hourly obs. 1957-1961)



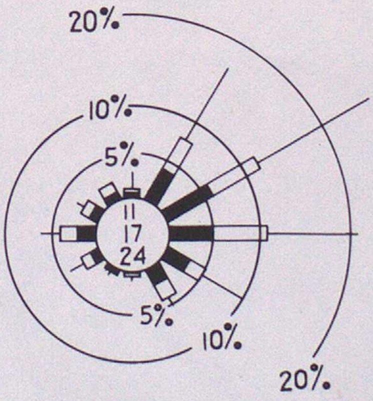

c.) Renfrew during the winter half-year (from hourly obs. 1949-1958)




d.) Benbecula during the year as a whole (from three hourly obs. 1957-1961)




e.) Liverpool Airport during the winter half-year (from three-hourly obs. 1957-1961)

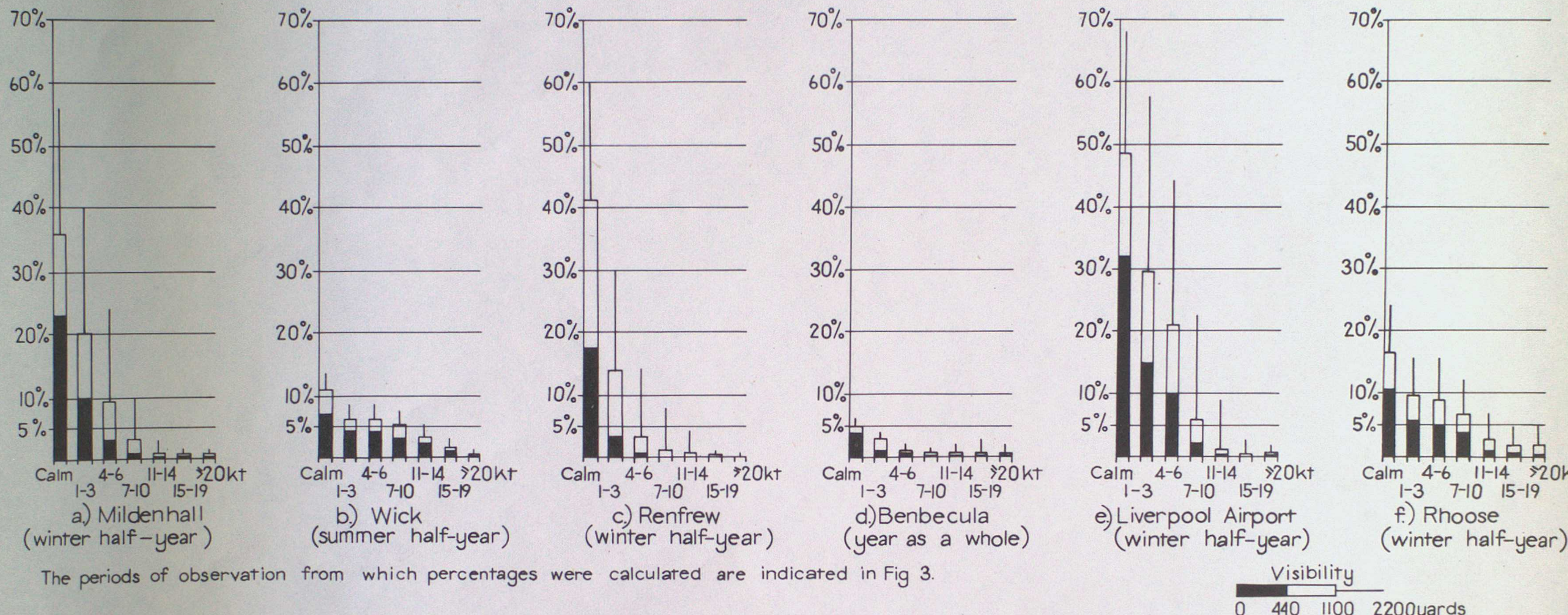



f.) Rhoose during the winter half-year (from hourly obs. 1957-1961)

Scale of visibility

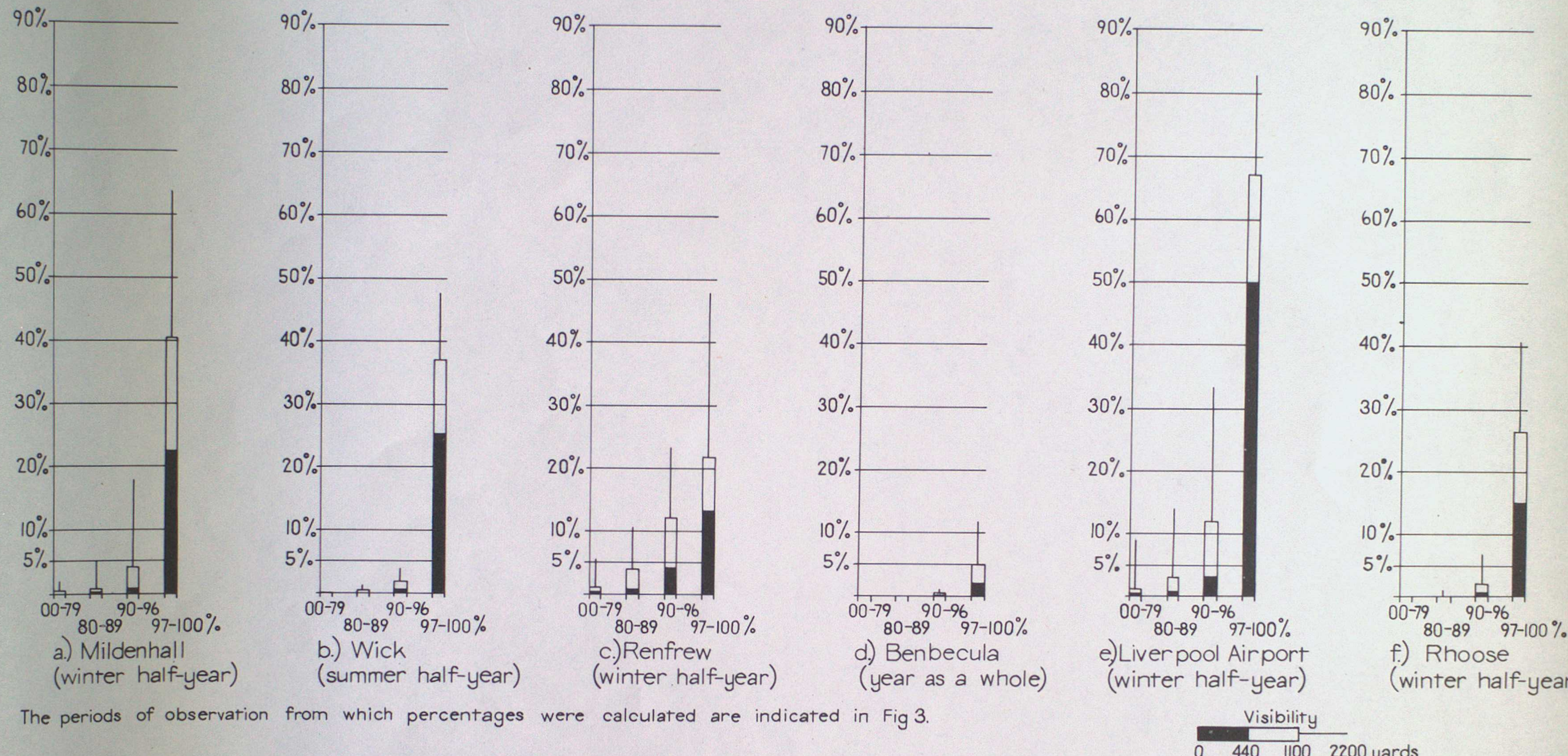
0 440 1100 2200 yards

Fig 3. Sections from standard diagrams of visibility: percentage probabilities of visibility below certain values according to the direction of the surface wind




The periods of observation from which percentages were calculated are indicated in Fig 3.

Fig 4. Sections from standard diagrams of visibility: percentage probabilities of visibility below certain values according to the speed of the surface wind.




The periods of observation from which percentages were calculated are indicated in Fig 3.

Fig 5. Sections from standard diagrams of visibility: percentage probabilities of visibility below certain values according to the relative humidity.

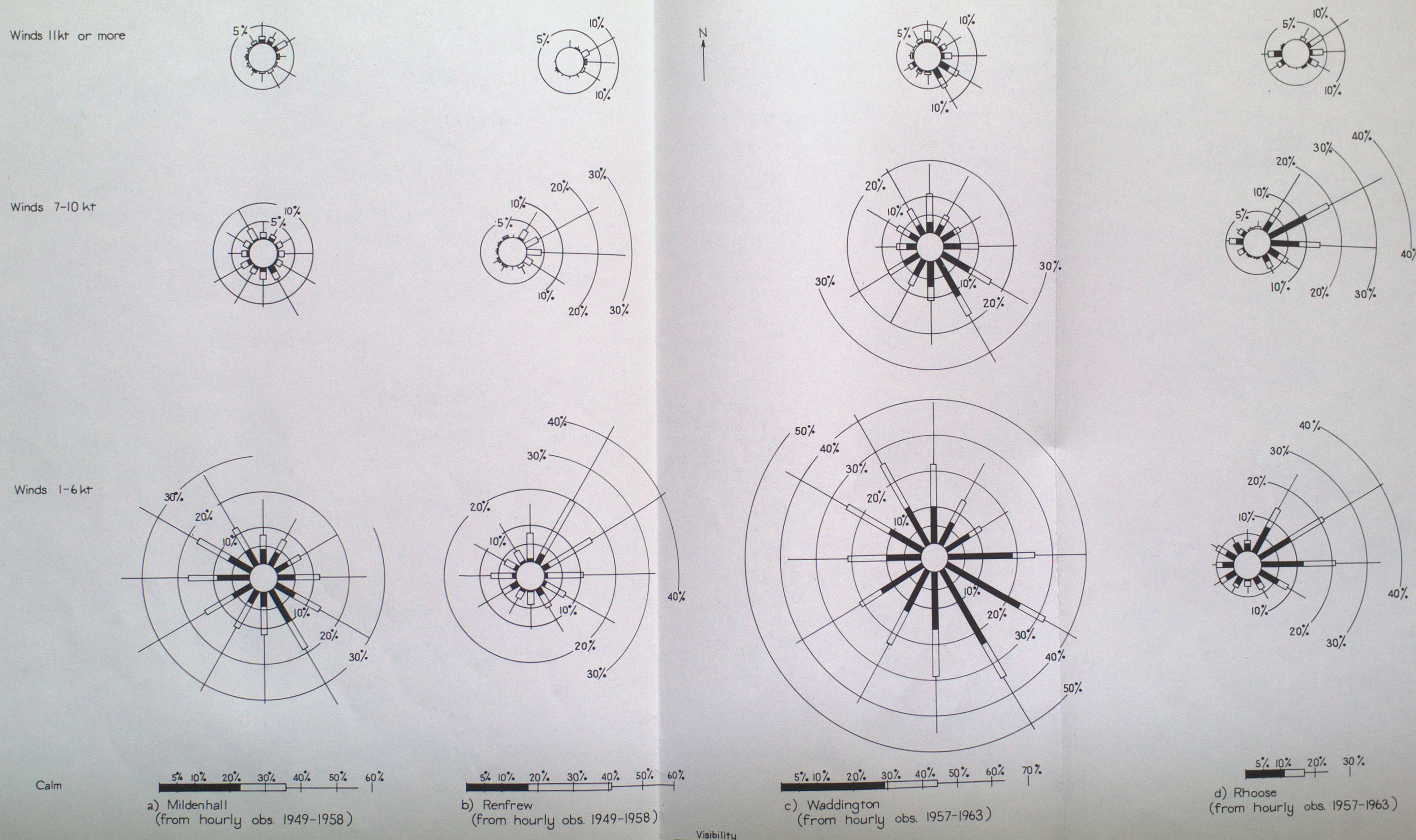
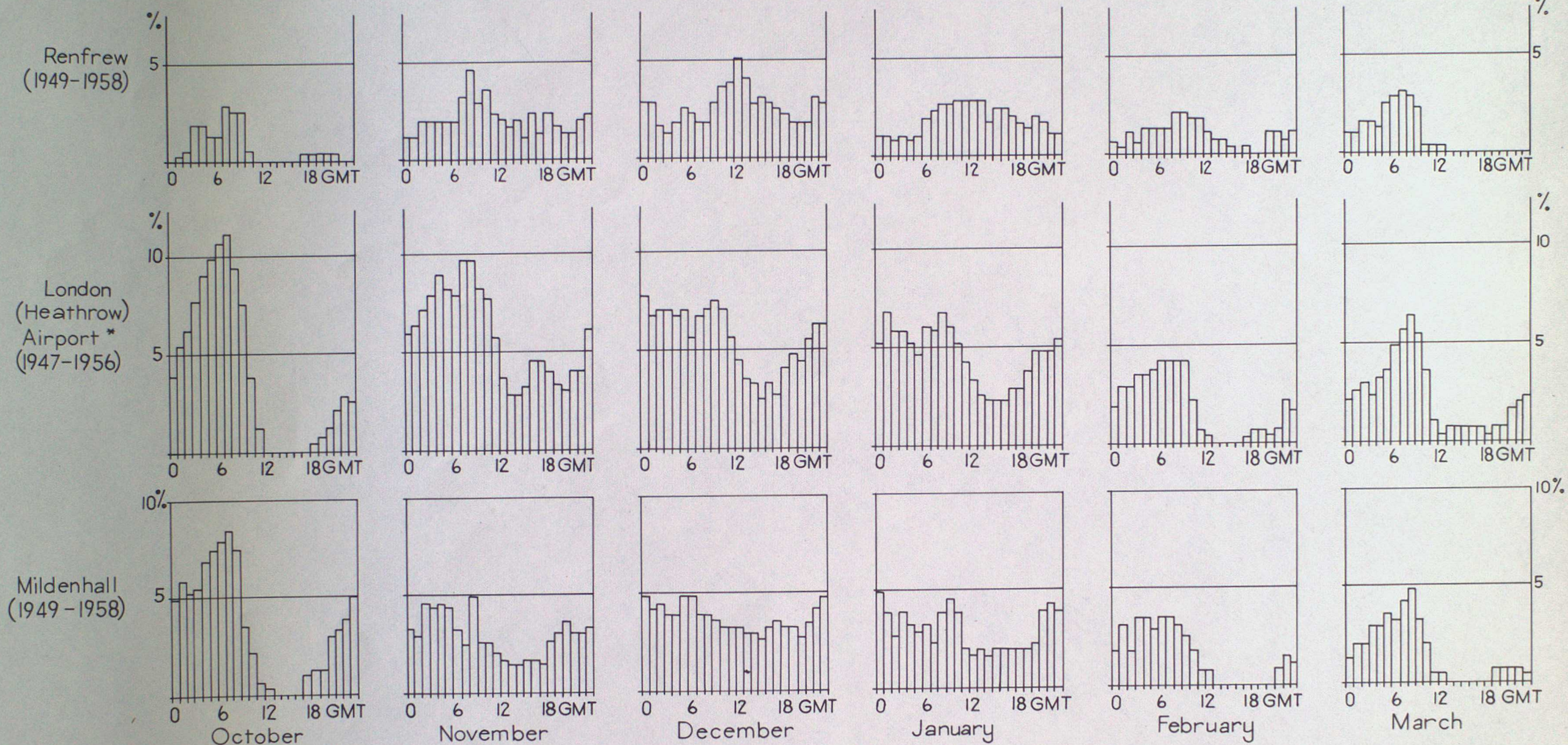



Fig 6. Percentage probabilities of visibility below certain values during the winter half-year according to the combined effects of speed and direction of surface wind.




* Results for London (Heathrow) Airport are taken from an article by Evans (Ref. 7)

Fig 7. Percentage frequencies of thick fog (visibility less than 220 yards) according to month and time of day.

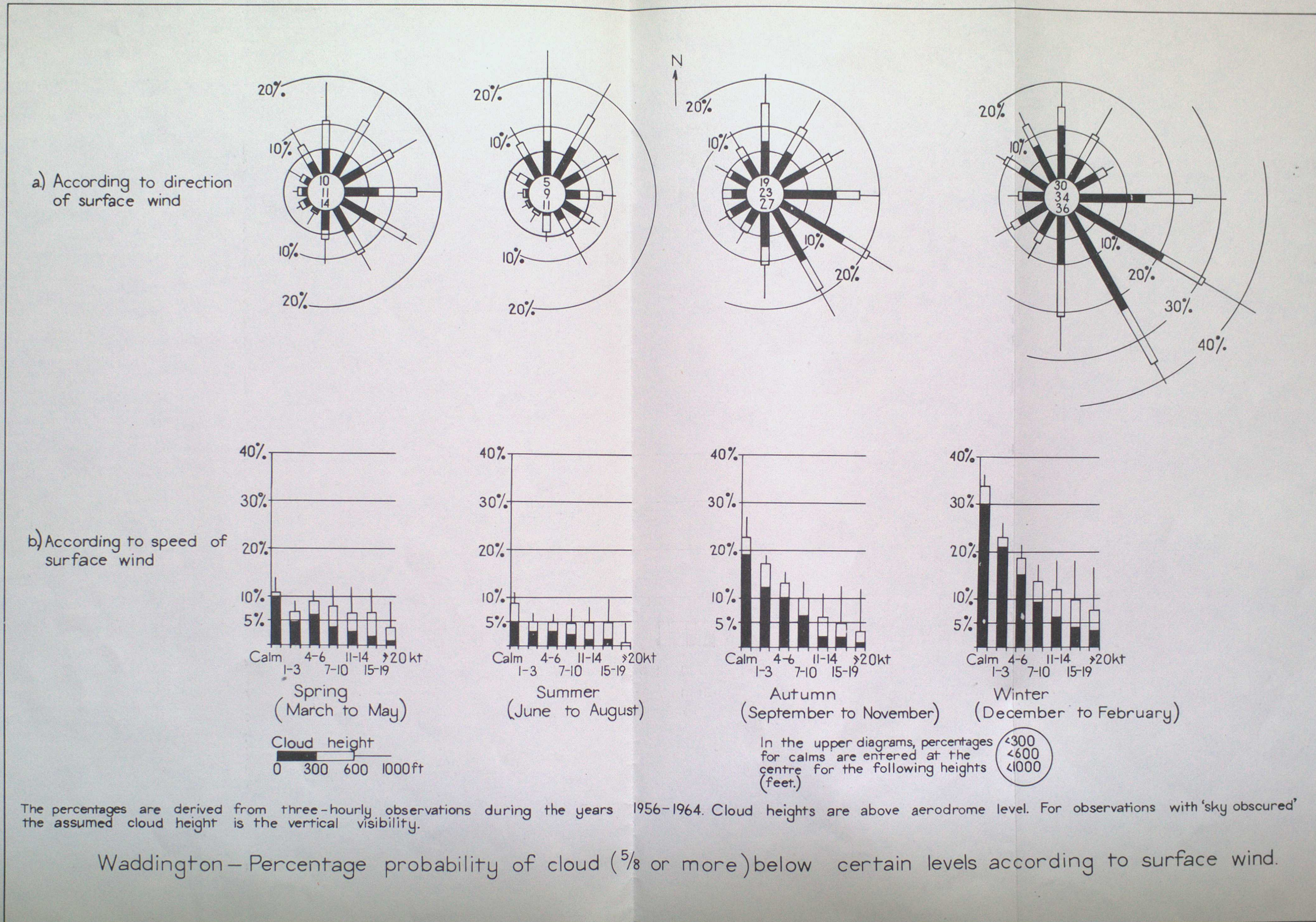



Fig 8. A standard diagram of height of cloud base.

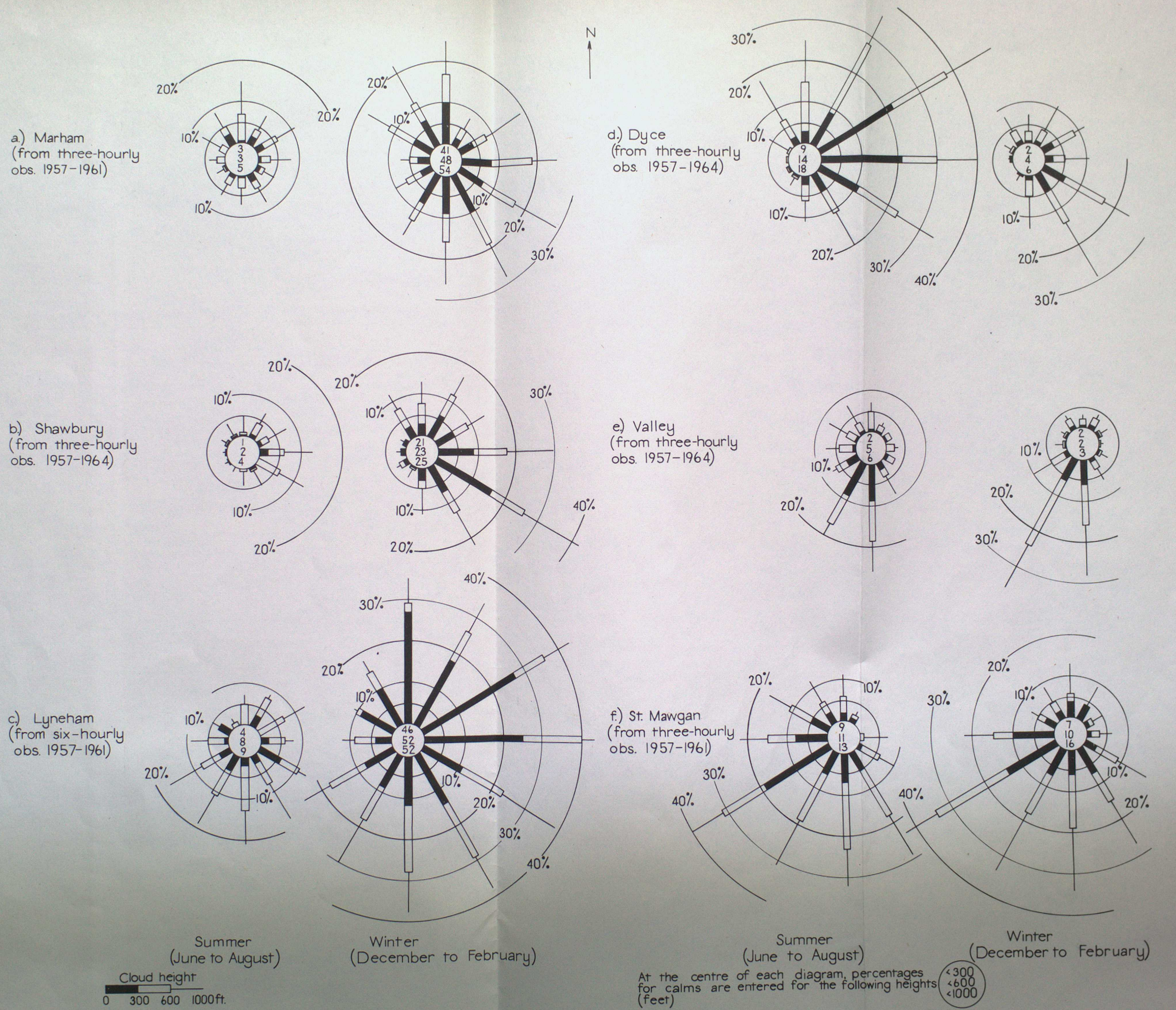



Fig 9. - Percentage probability of cloud (5/8 or more) below certain levels according to the direction of the surface wind.

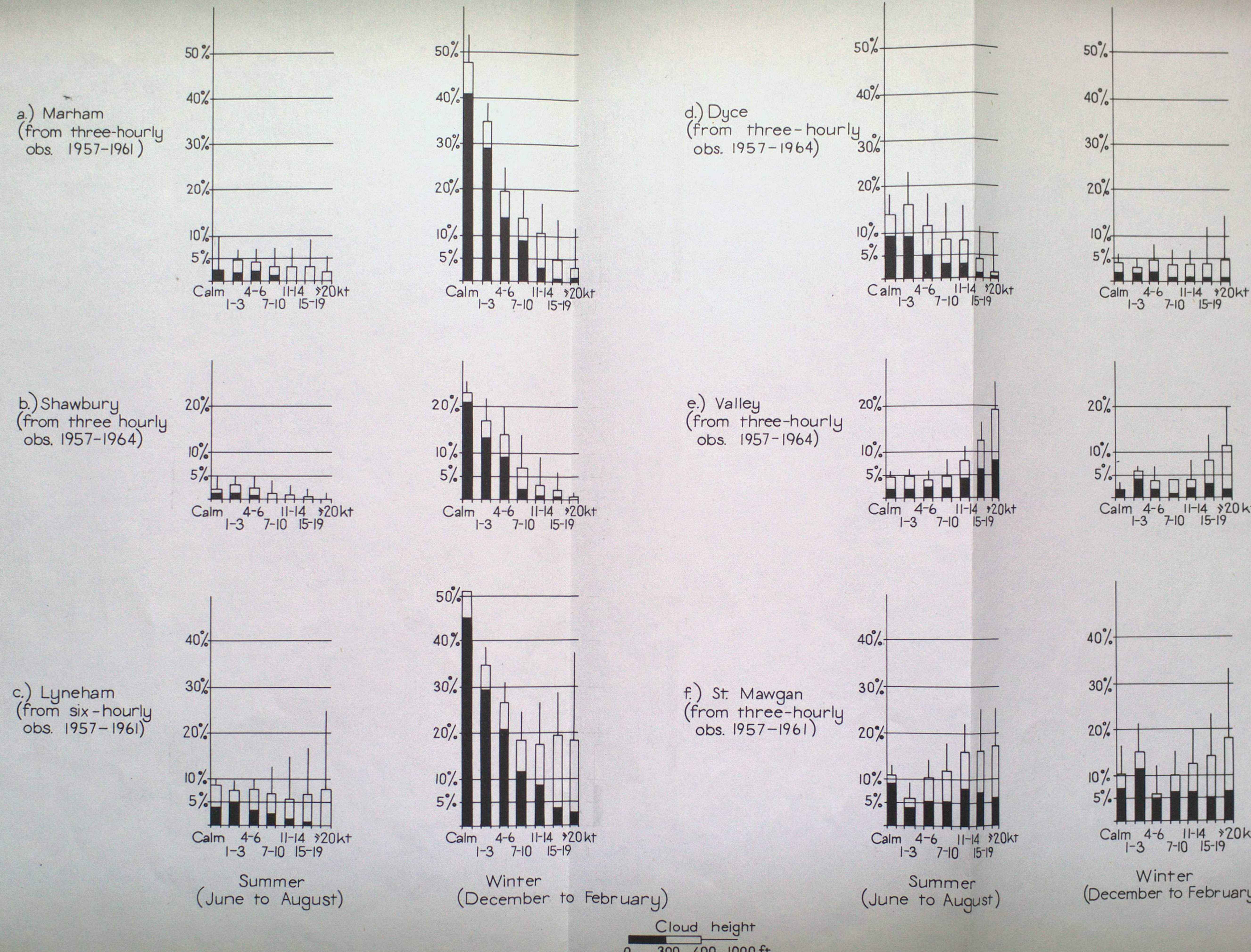



Fig 10 Percentage probability of cloud (5/8 or more) below certain levels according to the speed of the surface wind.