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Met O 3 Technical Note No. 5

COMPARISON OF WIND SPEEDS RECORDED BY DINES PRESSURE TUBE AND ELECTRICAL CUP GENERATOR ANEMOGRAPHS

by

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Comparison of wind speeds recorded by Dines pressure tube and Electrical cup generator anemographs

Summary

Within the last 25 years the electrical cup generator anemograph has largely replaced the Dines pressure tube anemograph as the standard instrument for recording wind speed in the United Kingdom. In the Climatological Services branch it has been suggested over a number of years that records may not be homogeneous from stations where a change of anemograph type has taken place. This paper considers the background to the problem and presents results of comparisons between observations recorded by the Dines and cup generator anemographs for ten minute and hourly mean speeds at five United Kingdom stations. Arising from the findings of the paper, a recommendation is made concerning the adjustment required to improve the homogeneity of wind speed records which comprise observations from both types of anemograph.

CONTENTS

1. Introduction

Before the middle 1950's anemograph observations of wind speed in the United Kingdom were made using the Dines pressure tube. Since then this instrument has gradually been superseded by the electrical cup generator anemograph which is more suited to requirements for remote and multiple displays. Discrepancies which could result between observations recorded by the two types of anemograph may be unimportant for synoptic work, given the inherent spatial and temporal variability of wind speed. However for climatological purposes, small but systematic differences (e.g. of only 1 to 2 kn) may be significant. Since the principles of operation of the two instruments are different, the occurrence of systematic variations in the readings is quite possible.

In this paper the characteristics of the different anemographs are discussed, together with the practical difficulties of measuring wind speed. Previous published articles and unpublished Meteorological Office work on comparisons between anemograph speeds are summarised. The paper goes on to describe results of comparisons made between Dines pressure tube and cup generator observations from five United Kingdom stations for which there was no site change and insignificant difference in effective height at the time of the changeover.

The analysis is restricted to mean speeds averaged over 10 minutes and over one hour. Gust speeds have not been included.

2. Background

2.1 The anemographs

2.1.1 Dines pressure tube

The Dines pressure tube anemograph (DPTA) is basically an adaptation of the pitot-static tube with a chart recorder attached to its sensitive float manometer. It is described in the Handbook of Meteorological Instruments part I (1956) and by an early paper by Giblett (1932), who also gives details of wind trial experiments carried out with DPTA's at Cardington. Wieringa (1980) has also studied the operation of the anemometer in some depth. One of his findings is that, due to the length of its response time, it over-estimates mean speeds by about 5%. Other characteristics of the instrument are that its starting speed is about 1.5 kn and its chart is linear throughout the range of recorded speeds.

2.1.2 Electrical cup generator

(a) General

The electrical cup generator anemograph (ECGA) uses the rotation of its cups to generate an electrical current which is converted to an equivalent wind speed. The anemometer (as distinct to the anemograph) is also described in part I of the Handbook of Meteorological Instruments. Three versions of the ECGA have been used operationally - the Mark II, Mark IV and Mark V. Hartley (1955) gives an account of the Mark Ib (not used operationally) and Else (1974) discusses the Mark V. Pearce (Meteorological Office, private communication) has investigated the response characteristics of the Mark IV and Mark V ECGA together with those of another type (the Porton anemometer).

This paper will present results for observations recorded by the Mark II and Mark IV ECGA. Both versions have a starting speed between 5 and 6 kn and have charts whose scale is markedly non-linear for low wind speeds. The cups of the Mark II have greater inertia than those of the Mark IV and there are a number of less important differences between the instruments. However the opinion of those who have had substantial working experience of the Mark II and Mark IV ECGA is that observations from the two versions are compatible. The Mark V ECGA has now been installed at a few stations in the UK. There is considerable doubt as to whether speeds of all ranges from this version would be consistent with those recorded by the Mark II and Mark IV (this is discussed further in point (c) of section 5).

(b) Over-estimation error

Cup anemometers (and hence ECGA's) would be expected to over-estimate the wind speed in variable winds because the cups accelerate quicker than they decelerate. This is due to the variation in drag characteristics between the convex and concave faces of the cups, leading to a non-linear variation with wind speed of the turning moment of the cup system. The turning moment is in fact proportional to the ratio of the wind speed to the cup velocity and not to the difference.

Schenk (1929) derived the torque on a cup rotor for steady air flow in a wind tunnel. He then calculated the over-estimation of the cup anemometer in a fluctuating speed, assuming a sinusoidal variation. Deacon (1951) investigated the validity of Schenk's results to the Sheppard anemometer and Meteorological Office 3-cup anemometers (hemispheric and conical forms). Ramachandran (1969) studied the theoretical responses of anemometers to steady and varying flows, both analytically and using an analogue computer. He found that the mean indicated wind speed from cup anemometers could be over-estimated by as much as 20%. Izumi and Barad (1970) deduced the over-estimation error to be about 10% based on observations from a lattice-type tower in Kansas. Other workers have produced different magnitudes for this over-estimation value. Kaganov and Yaglom (1976) suggested that these differences may be explained by errors arising from vertical, as well as horizontal, fluctuations.

2.2 Practical difficulties of measuring wind speed

It has already been mentioned that the wind field is characterised by large spatial and temporal variations. The site and height at which wind speeds are measured and the response time of the anemometer are therefore important factors in the estimation of wind speed. Other factors include the data averaging procedure employed and the sensitivity of the instrument to relative wind direction; these points are discussed by MacCready (1966). Instrument faults can often be hard to detect and it is also possible that there are systematic variations in recorded speed by anemometers of the same type (Bond, personal communication).

The mean speed has to be estimated from a dial or chart. This can often be a difficult task, especially in gusty conditions or when the background mean speed is changing.

Light winds are particularly difficult to measure because

- anemometers are, in general, not designed to record very low speeds accurately. For example, the starting speed may be substantially above zero and for a cup generator system the magnetic drag effects are significant at low speeds.

- for the anemographs, if the zero setting of the chart is incorrect, the resultant error at low speeds is proportionately large.

- for the majority of ECGA's at present in use the chart is highly non-linear in the 0-10 kn range. This makes accurate measurement of these speeds extremely difficult, even assuming the instrument sensor is recording the true speed.

The Meteorological Observer's Handbook (HMSO, 1969) gives information on how the wind speed is to be determined from a dial or chart and METFORM 3433 gives instructions for the analysis of anemograph records. In particular, the latter states that when the record shows that the vane is sticking due to insensitiveness to light winds the wind speed should be regarded as 1 kn for the DPTA and 2 kn for the ECGA. If the speed trace indicates calm but the vane is not sticking the same procedure is followed in practice, although this condition is not referred to in the instructions. The different value to be assigned to the anemographs in these situations is not considered to have a significant effect on subsequent analyses.

2.3 Previous comparison studies

In the 1950's comparisons were made within the Meteorological Office for South Farnborough and for the Rye tower of hourly mean speeds recorded by the DPTA and ECGA. The reports of both studies can no longer be found. However Hartley (1955) refers to the South Farnborough results, stating that for daily averages of hourly means the two types agreed to within 0.5 kn. The Rye Tower comparisons also showed that differences were small, especially for the highest speeds (Seaton, personal communication).

Rijkoort (1955) compared hourly mean readings from a DPTA with those from a cup contact anemometer designed by the Royal Netherlands Meteorological Institute. He classified his results according to the number of cup contacts made by the cup anemometer and the relative fluctuation in the wind speed. His results, which cover speeds in the range 1 to 14 ms^{-1} (1 ms^{-1} is approximately 2 kn), indicated that for speeds below 5 ms^{-1} the cup anemometer recorded greater speeds than the DPTA. For winds above 5 ms^{-1} the cup anemometer read lower than the DPTA, more especially for the highest speeds and for large relative fluctuations. It is noted that the results for speeds greater than 5 ms^{-1} are not supported by results which will be presented later in this paper.

Comparisons have also been made between DPTA and ECGA speeds at several U.K. stations where a change of site has also been involved. Appendix A gives references to these reports. In most cases the period of overlap of the records from the DPTA and ECGA is less than one year. Also the fact that site changes occurred clearly makes any conclusion about systematic differences between the observations highly speculative. However the general impression gained from the six comparisons for which summaries exist is that the ECGA tends to record higher values then the DPTA, especially at low speeds.

In 1967 correspondence between members of Met O 3 and Met O 16 (references to branches of the Meteorological Office are given in appendix D) reflected Met O 3's concern about the possibility of non-homogeneity of records at stations where a change of anemograph type has taken place (see appendix B).

A meeting held in 1976 and attended by various members of Met O 3, Met O 1 and Met O 16 "to discuss wind speed measurements in the U.K." included an item on the homogeneity of records from the DPTA and ECGA (see appendix C). Graphs were presented showing the mean annual speed between 1956 and 1975 at five stations where a DPTA had been replaced by an ECGA and at a sixth, Kew, which had had a DPTA throughout. At two of the stations site changes were concomitant with the changeover. The results for Kew and the three stations where a site change did not occur are reproduced in fig 1, with the values updated till 1979. The plots strongly suggest that the annual speed recorded by the ECGA is greater than that recorded by the DPTA.

The following sections describe results from five stations where a DPTA was replaced by a ECGA in situ in an attempt to determine the magnitude of this apparent discrepancy.

3. Stations and Data

(a) Stations

Most stations that have replaced a DPTA with an ECGA also changed their anemometer site at the same time. Data from these stations were considered unsuitable for study. At some other stations the data are not in a suitable computer compatible format or only one observation was made per day. Five stations, referred to as changeover stations, were eventually selected at which there was no more than 1m change in effective height and no change of site. For each of these stations, a control station was chosen, situated close to the changeover station and whose data were considered to be homogeneous around the time of the changeover. The changeover and control stations are listed in table 1, together with other relevent details. Two other control stations were also used - Kew and South Shields. Both these stations have had DPTA's since records began and no reported site changes.

The locations of all changeover and control stations are shown in fig 2.

(b) Data

The Meteorological Observer's Handbook (HMSO, 1969) suggests for 10 minute means that speeds less than 5 kn should be estimated rather than measured from the anemograph. It might therefore be considered desirable to omit speeds less than 5 kn from the analysis. This has not been done because

- speeds below 5 kn can form a significant proportion of the distribution of speeds recorded in the U.K.

- consistent differences between DPTA and ECGA observations occur in this range which affect the overall mean speed.

- the results for 0 to 5 kn 10 minute means show the same features as those for hourly means, for which all speeds are derived from the anemograph chart.

Results of the analyses are given in section 4. Those in section 4.1 refer to comparisons between the DPTA and Mark II ECGA only, whilst those in sections 4.2 and 4.3 relate to comparisons between the DPTA and both Mark II and Mark IV ECGA's.

Where possible, analyses were made using hourly mean speeds. Of the changeover stations, only Boscombe Down and Valley had these data in machineable form whereas all stations had 10 minute means accessible by the computer. In section 4.1 results are given for 10 minute and hourly means. Results for sections 4.2 and 4.3, where the analyses did not require use of the computer, apply to hourly means only.

4. Analysis and results

4.1 Observations at three-hourly intervals

In this section comparisons are made between the speeds recorded at each changeover station before and after the changeover with speeds recorded at each corresponding control station.

The combination of changeover and control stations chosen (table 1) meant that for each station pair only observations every three hours could be analysed. For Boscombe Down the longest period that could be studied before the changeover was 167 days (8.1.64 to 22.6.64) because its control station, Abingdon, introduced an ECGA on 8.1.64. For convenience 167 days of observations before and after the changeover were used for all stations - a total of 167 x 8 = 1336 observations in each period. Although the comparison periods are not long this means that factors such as gradual changes in exposure do not effect the analysis. A complete year of values before and after the changeover were additionally analysed for Kirkwall and it was found that differences between the results for 167 day and one year periods were insignificant. It is concluded that the use of periods less than a year (i.e. less than the period of the annual cycle) has not distorted the results.

The cross correlation measured over one year's record of the 10 minute mean speed taken every three hours was calculated for each station pair. Its value ranged from 0.62 for Valley/Speke to 0.78 for South Farnborough/Heathrow. This is fairly constant, indicating that the degree of association is similar for each station pair.

4.1.1 Histograms

Histograms of the distribution of speeds at the changeover and control stations before and after the changeover were drawn. Those for Boscombe Down and Abingdon 10 minute means are shown in fig 3. Three general points were noted:

(i) There were tendencies for certain speeds, such as those that are a multiple of 10, to receive higher counts than values either side. Observer bias in recording wind speed has been documented elsewhere, for example by Reed (1978).

(ii) There was considerable variation in the distribution of speeds between different pairs of stations. For example, there was a much greater number of winds above 20 kn for Kirkwall and Wick than for the stations in southern England.

(iii) At the changeover stations there were fewer winds for the ECGA in the range 1 to 3 kn than for the DPTA. This is evident in the histogram shown for Boscombe Down.

4.1.2 Means and Medians

The mean and median speeds before and after the changeover were calculated for each station and the difference for the changeover stations was determined relative to its control station. Table 2 displays results for the 10 minute means with corresponding hourly mean values in brackets. (The median results were very similar to the results for the mean and are therefore not shown).

The column headed (3)-(6) of table 2 shows that the mean speed for the ECGA is greater than that for the DPTA, relative to the control station, by amounts varying between 0 to 3 kn. The increase at Boscombe Down is substantially larger than at the other stations. To test whether this was due to a peculiarity of the data from the control station for Boscombe Down, the analyses of 5.1.1 and 4.1.2 (first part) were repeated using

Heathrow (location shown in Fig 2) in place of Abingdon. The findings were very similar to those for Boscombe Down/Abingdon. Hence the extreme result for Boscombe Down is due to special features of its data.

The significance of these differences for the 10 minute means was tested for using Student's t. Values of t were derived from the formula

$$t_{n_D + n_E - 2} = |\bar{x}_E - \bar{x}_D| \Big/ s\left(\frac{1}{n_E} + \frac{1}{n_D}\right)^{\frac{1}{2}}$$

where $\bar{x}_D$, $\bar{x}_E$ are the mean differences before and after the changeover, s is the standard deviation of the differences (varying from 3.2 kn for South Farnborough/Heathrow to 6.0 kn for Valley/Speke) and under the assumption that for each period, one in eight of the 1336 observation pairs were independent, $n_D = n_E = 1336/8 = 167$. The values of t obtained are shown in the final column of table 2. The value for Boscombe Down is highly significant (P less than 0.1%), that for South Farnborough is significant at the 5% level and for Abingdon is marginally significant (P just less than 10%).

4.1.3. Classification by wind speed range

The differences for 10 minute means between simultaneous changeover and control station values were calculated for each station pair and classified according to the mean speed of the two observations (five categories) and whether before or after the changeover. The mean of these differences was determined for each category and for the DPTA and ECGA periods separately.

Table 3 shows the difference between the ECGA and DPTA values. For mean speeds below 10 kn (first two columns) the ECGA codings are greater, relative to the control station's values, for all stations. For stronger winds there is no clear pattern but there are relatively few counts in the highest two categories.

4.1.4 Changes in frequency distributions

The relative percentage frequency change for different wind speeds i, denoted by Di, was determined. To define Di, let Hi, Oi denote percentage frequencies of speed i for changeover and control stations respectively as a proportion of the total number of observations in the DPTA or ECGA period. Let ${}_DH_i$ and ${}_EH_i$ represent the percentage frequency in these two periods respectively.

Then $$D_i = ({}_EH_i - {}_DH_i) - ({}_EO_i - {}_DO_i)$$

Values of D_i are shown for each changeover station for 10 minute means in fig 4. A positive quantity implies a relative increase in frequency for the ECGA at the changeover station. There are seen to be deficits in the relative frequency for speeds in roughly the 1 to 3 kn range for the ECGA. Rather surprisingly, considering the relatively high starting speed of the ECGA, the number of calms is also less for the ECGA at all stations except South Farnborough. In general the frequency of 5 to 7 kn and 11 to 12 kn speeds is greater for the ECGA.

Values of D_i were also drawn for hourly mean speeds at Boscombe Down and Valley. These are presented in Fig 5. It is apparent that the relative deficit of low speeds recorded by the ECGA for 10 minute means is accentuated for hourly means.

Another statistic, which has better defined properties than D_i is given by L_i where $L_i = \log \frac{{}_E H_i / {}_D H_i}{{}_E O_i / {}_D O_i}$ with notation as before.

Values of L_i were plotted as for D_i. The inferences were similar to those from D_i and the values are not reproduced here.

4.1.5. Differences between 10 minute and hourly mean speeds

There are some apparent inconsistencies between the results for 10 minute and hourly mean speeds in sections 4.1.2. and 4.1.4. Values for these two types of reading were therefore compared directly for Boscombe Down and Valley over the pairs of 167 day periods considered previously. The averages are shown in table 4. Differences between the 10 minute and hourly mean values exist for both the DPTA and ECGA. Histograms of the speeds were also drawn and studied. However, they did not reveal any systematic difference in the distribution of speeds between the two measurements. It is possible that the discrepancies are caused by the relatively small sample size - indeed, Painting (personal communication) has calculated means and medians of 10 minute and hourly mean speeds using 11 years of data from Lerwick and found negligible differences between the 10 minute and hourly mean statistics.

4.2 Monthly extremes

A comparison was made between extreme hourly mean winds recorded by the DPTA prior to changeover and by the ECGA subsequent to changeover. For each station the highest hourly mean speed each month was extracted for the "Winter" months of November through to March such that, where possible, 50 values (ie approximately 10 Winters) were obtained immediately before the changeover and 50 immediately following. At South Farnborough a change of site in 1969 meant that only 27 extremes could be used in each period. At Kirkwall only 24 extremes were available because observations began there comparatively recently. The same procedure as above was performed for the Summer months of June to August using a maximum of 33 extremes, although only 15 were available for South Farnborough and Kirkwall.

The extremes were plotted on extreme-value probability paper separately for each station and for each season. The plot for Boscombe Down Winter months is shown in fig 6a. It is observed that for a specified probability of occurrence the speed given by the ECGA curve is about 2 to 4 kn more than the corresponding DPTA value. The Summer curves are presented in fig 6b. Here the differences are considerably less although it must be noted that the speed range (about 18 to 28 kn) is rather lower than for the Winter months (about 22 to 38 kn).

Similar plots were also derived for the two control stations Kew and South Shields. Their "changeover" month was assumed to be January 1964 for the purpose of this analysis. The curves for Kew implied that extremes in the ECGA (more recent) period were less than in the DPTA period by about 1 kn. Those for South Shields indicated a 0-1 kn difference in the same sense as Kew for the Summer extremes but no change in the Winter values. If the result at Kew is indicative of a change in climate of extreme wind speeds then the differences at the changeover stations, which are generally in the opposite sense to that at Kew, become yet more significant. However in what follows it has been assumed that there has been no change in the wind speed climate, since confirmation of a change would require considerable additional work outside the scope of this report.

The results for the changeover stations are presented on one graph by estimating the value necessary to convert a DPTA speed for each station and season to an ECGA reading. The confidence limits on the extreme value curves are considerably greater at both tails and hence values were not determined for speeds at which fewer than three observations lay to the left or right of the curve. The estimated "adjustments" are shown in fig 7. Most of the values are positive, indicating, as found in section 4.1. that the ECGA reads higher than the DPTA. (The differences here though are rather greater than found in section 4.1). No reason could be established for the apparent anomolous results for Abingdon, nor for speeds below 40 kn in Winter at Kirkwall. The differences between results for different seasons at the same station may be due to sampling variations.

4.3. Annual averages of hourly means

Annual averages of hourly means from 1956 are available for each anemograph station. Means of the annual averages for periods before and for periods after the changeover were calculated using as many annual averages as were available. Values from South Shields and Kew were again used as controls.

If $\overline{H}$ and $\overline{O}$ denote means for the changeover and control stations respectively then $\overline{D}$, the relative wind speed change at the changeover station, was determined such that

$$\overline{D} = ({}_E\overline{H} - {}_D\overline{H}) - ({}_E\overline{O} - {}_D\overline{O})$$

Results for each combination of changeover with control stations are shown in table 5. There is little difference between the results for the two control stations. The annual averages are more than 1 kn greater for the ECGA at four of the changeover stations and over 3 kn more at South Farnborough and Valley. The t statistic

$$t_{n_D + n_E - 2} = \frac{\left|({}_E\overline{H} - {}_D\overline{H}) - ({}_E\overline{O} - {}_D\overline{O})\right|}{s\left(\frac{1}{n_D} \quad \frac{1}{n_E}\right)^{\frac{1}{2}}} = \frac{|\overline{D}|}{s\left(\frac{1}{n_D} + \frac{1}{n_E}\right)^{\frac{1}{2}}}$$

(notation as in 4.1.2 with n now the number of years in each period) was calculated and its value is given in table 5 for each station with South Shields.

The value of t shown is significant at the P = 1% level for Boscombe Down, South Farnborough and Valley but not significant at Abingdon or Kirkwall. The values for each station paired with Kew (not shown) imply significance at the P = 0.1% level for Valley, the 1% level for Boscombe Down and South Farnborough and the 5% level for Kirkwall. Hence, depending on the control station used, three or four changeover stations are associated with significant increases in annual averages of wind speed and all five stations show the ECGA values to be greater (relative to the controls) than the DPTA speeds.

4.4 Possible explanation of results

The most likely cause of the reduction in the frequency of 1 to 3 kn speeds is the non-linearity of the ECGA chart. Observers or tabulators determining the speed when it is in the 1 to 3 kn range may have tended, in general, to wrongly ascribe such speeds to values in the 5 to 7 kn range. It is of note that the instructions for the analysis of anemograph records make no mention of the effects that the non-linearity of the chart can have on the estimation of the mean speed.

The differences observed in section 4.2 for higher speeds are probably due to the over-estimation error by cup anemometers in fluctuating speeds (discussed in section 2.1.2).

5. Conclusion

Unpublished material and work presented in this report imply that wind speeds recorded by the electrical cup generator anemograph (ECGA) exceed those of the Dines pressure tube anemograph (DPTA). Given this finding, it would clearly be useful if an adjustment factor or at least some method of homogenising DPTA and ECGA records could be recommended. However the following points need to be considered:

a. at most stations where an ECGA has replaced a DPTA the site has changed and it is quite possible that this change would have a greater effect on the recorded speeds than the change in instrument.

b. it is possible that some of the differences between the records are due to faults with the DPTA prior to its replacement with the ECGA. (The level of maintenance carried out on DPTA's may have been reduced when the changeover was imminent). The DPTA annual mean speeds at South Farnborough and Valley do appear to be rather low compared to annual means at nearby stations, although this is impossible to show quantitatively owing to the paucity of suitable "control" data.

c. the results in this paper are based on observations from Mark II and Mark IV ECGA's. It is considered by Met O 16 that the differences between these versions (see section 2.1.2) should not significantly affect recorded wind speeds.

The Mark V ECGA has recently been introduced at some UK stations. This employs frequency modulation of the generated current (as opposed to amplitude modulation used by the earlier versions) to derive the wind speed. It also has a starting speed of about 3.5 kn (about 2 kn less than the Mark II and Mark IV) and has a chart with a linear scale throughout the range of wind speed. Hence it is doubtful whether results presented in this report are valid for the Mark V ECGA.

d. the specification for the accuracy of the ECGA is ± 1 kn for speeds above the starting speed up to 40 kn and ± 2 kn for speeds greater than 40 kn. The differences observed between the DPTA and ECGA are only of this magnitude. (However these differences are important on a long time scale).

e. the most pronounced differences common to all changeover stations were due to variations in the lowest wind speeds. Stations situated in areas where the wind speed is generally lightest will be affected more by these differences than stations, say, in northern and western areas of the UK with a higher annual mean speed.

f. the results for all ranges of wind speed are based on a relatively short period and whereas those for monthly and annual speeds are derived from much longer periods, they may be influenced by gradual changes in site.

g. the results are not entirely consistent between stations and between different analyses. This could be due to particular site characteristics, variations between instruments of the same type, different standards of maintenance, observer bias, or sampling variations (or combinations of any of these).

Despite the above points, this paper would only be of limited assistance to climatologists if it did not suggest an adjustment factor, because climatologists and other researchers ideally need to be able to quantify any inhomogeneities in a time series. It is therefore recommended that 1 kn, or possibly 2 kn, should be added to all DPTA values when they are used in an analysis with observations from a Mark II or Mark IV ECGA. Although this adjustment may not be very important for individual observations, it would, for example, have the effect of raising the measured annual mean speed during DPTA periods by over 10% at many stations in the UK.

It must finally be stressed that this paper has not sought to determine which of the two anemographs measure speeds which accord nearest to the true value. The recommendation that DPTA observations be adjusted to correspond to ECGA speeds, rather than the other way around, has been made solely because most anemograph stations now record speeds with an ECGA.

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Appendices

A. Comparison of speeds at UK stations where site changes have taken place

Summaries of results exist for six stations: Aldergrove, Ballykelly, Blackford Hill, Dyce, Eskdalemuir and Point of Ayre. The report for Eskdalemuir is held in its own cover (headed "Comparisons of anemometer readings - Eskdalemuir") in Met O 3. Summaries for the other stations are to be found in the permanent register of wind stations in Met O 3 and also, with the exception of Ballykelly, on file M24835/63 entitled "anemographs - changes of site" located in archives.

B. Correspondence between Met O 3 and Met O 16

This is also held on file M24835/63 (see above). The relevant items occur between enclosures 48A and 53A inclusive, covering the period February to April 1967.

C. Meeting to discuss wind speed measurements

Notes on this meeting are at E107 on file AF/M359/73 "Inspection and maintenance of anemographs - policy, Met O 3 aspects" held in Met O 3. The graphs of mean annual speeds at six stations form appendix 3 to E107.

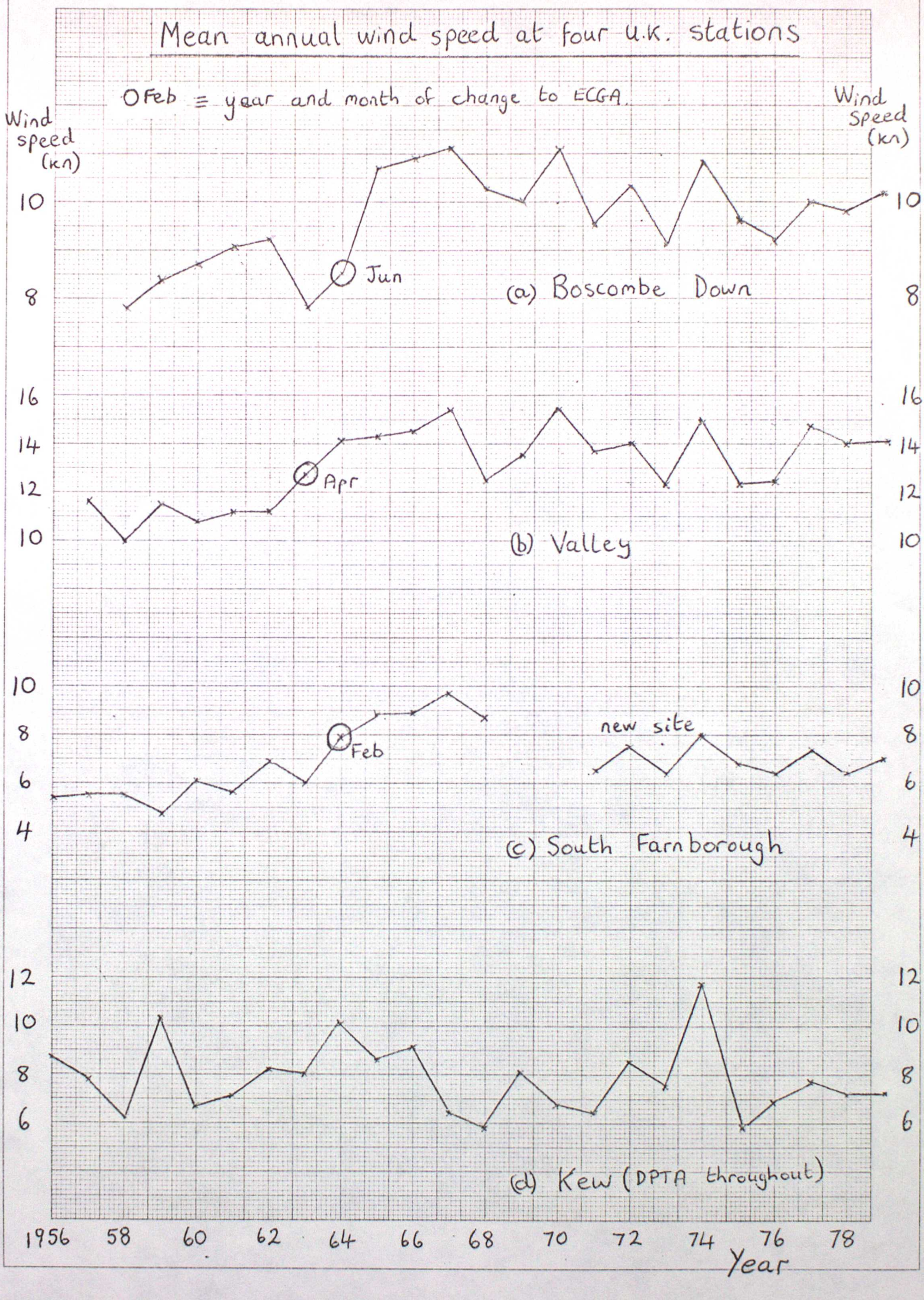
D. Titles of branches referenced in this report

Met O 1 Observational Requirements and Practices

Met O 3 Climatological Services

Met O 16 Operational Instrumentation

Fig 1


Mean annual wind speed at four U.K. stations
O Feb ≡ year and month of change to ECGA.
Wind speed (kn)
Wind Speed (kn)
10
8
Jun
(a) Boscombe Down
16
14
12
10
Apr
(b) Valley
10
8
6
4
Feb
new site
(c) South Farnborough
12
10
8
6
(d) Kew (DPTA throughout)
1956
58
60
62
64
66
68
70
72
74
76
78
Year

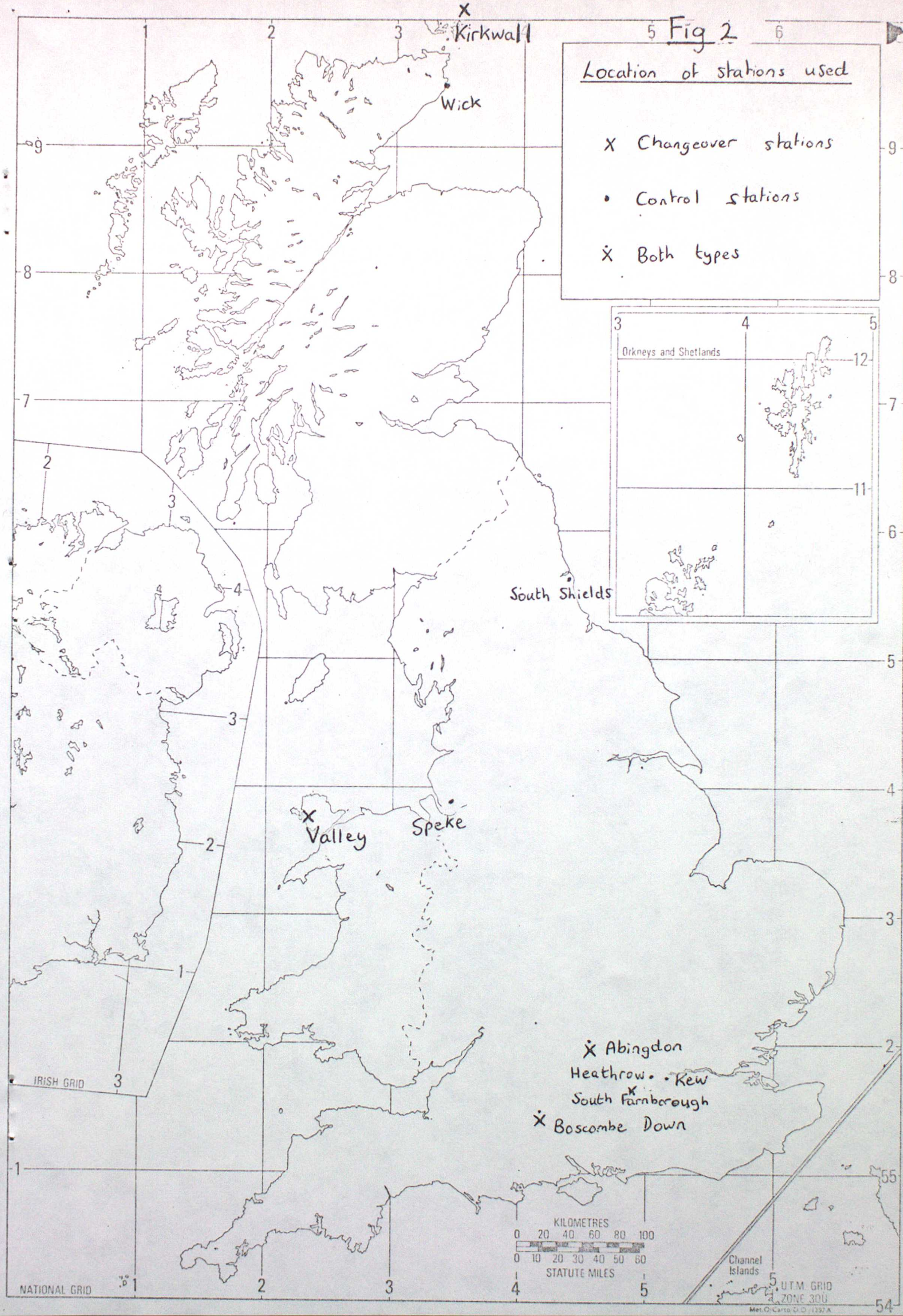

Kirkwall
Wick
Location of stations used
X Changeover stations
• Control stations
Ẋ Both types
Orkneys and Shetlands
South Shields
Valley
Speke
Abingdon
Heathrow
Kew
South Farnborough
Boscombe Down
KILOMETRES
STATUTE MILES
Channel Islands
U.T.M. GRID ZONE 30U
IRISH GRID
NATIONAL GRID

Fig 2

Fig 3

Histogram of wind speeds at Boscombe Down and Abingdon

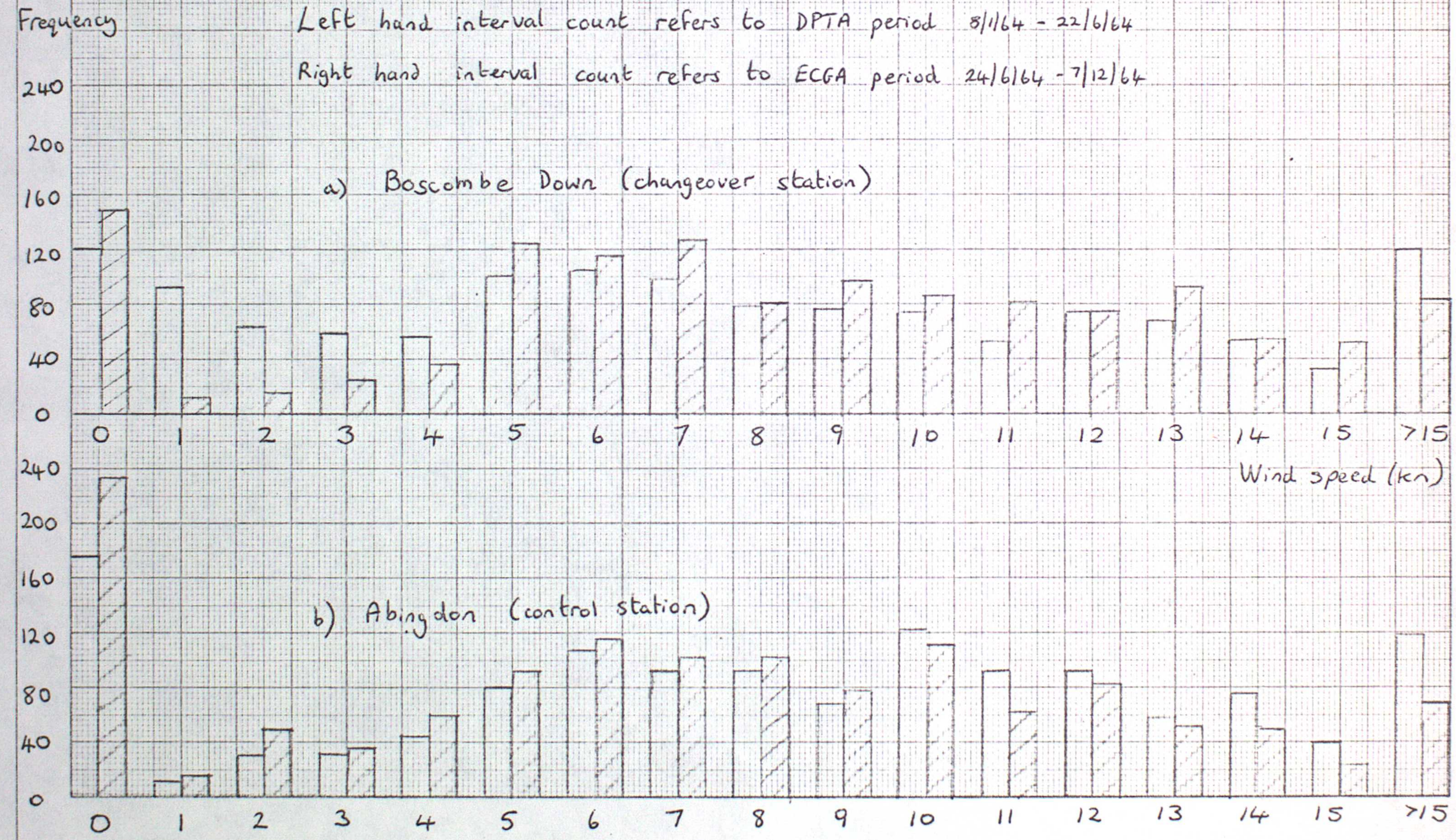


Fig 4

Relative percentage change in frequency for different wind speeds

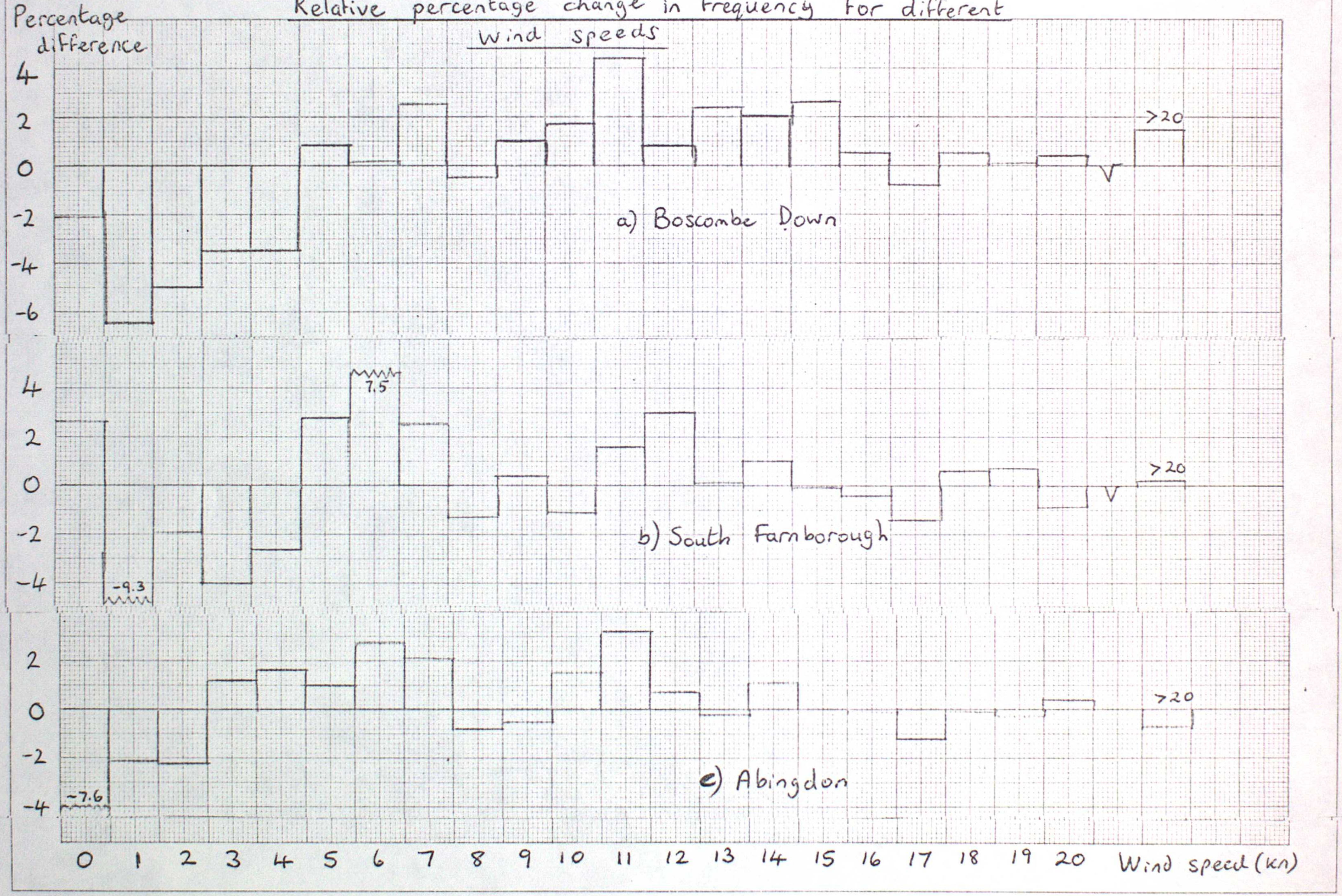


Fig 4 /cont

Relative percentage change in frequency for different wind speeds

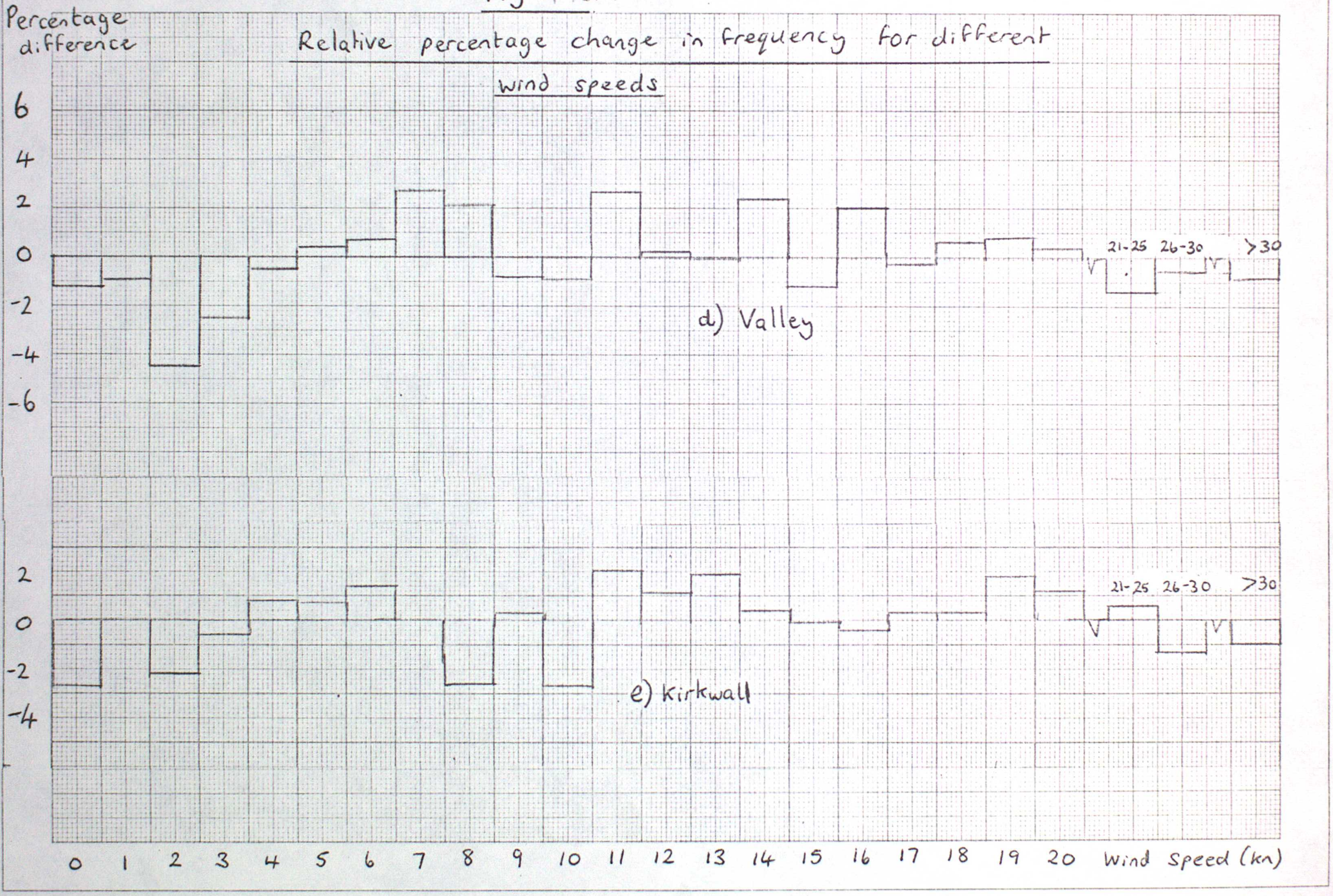


Fig 5

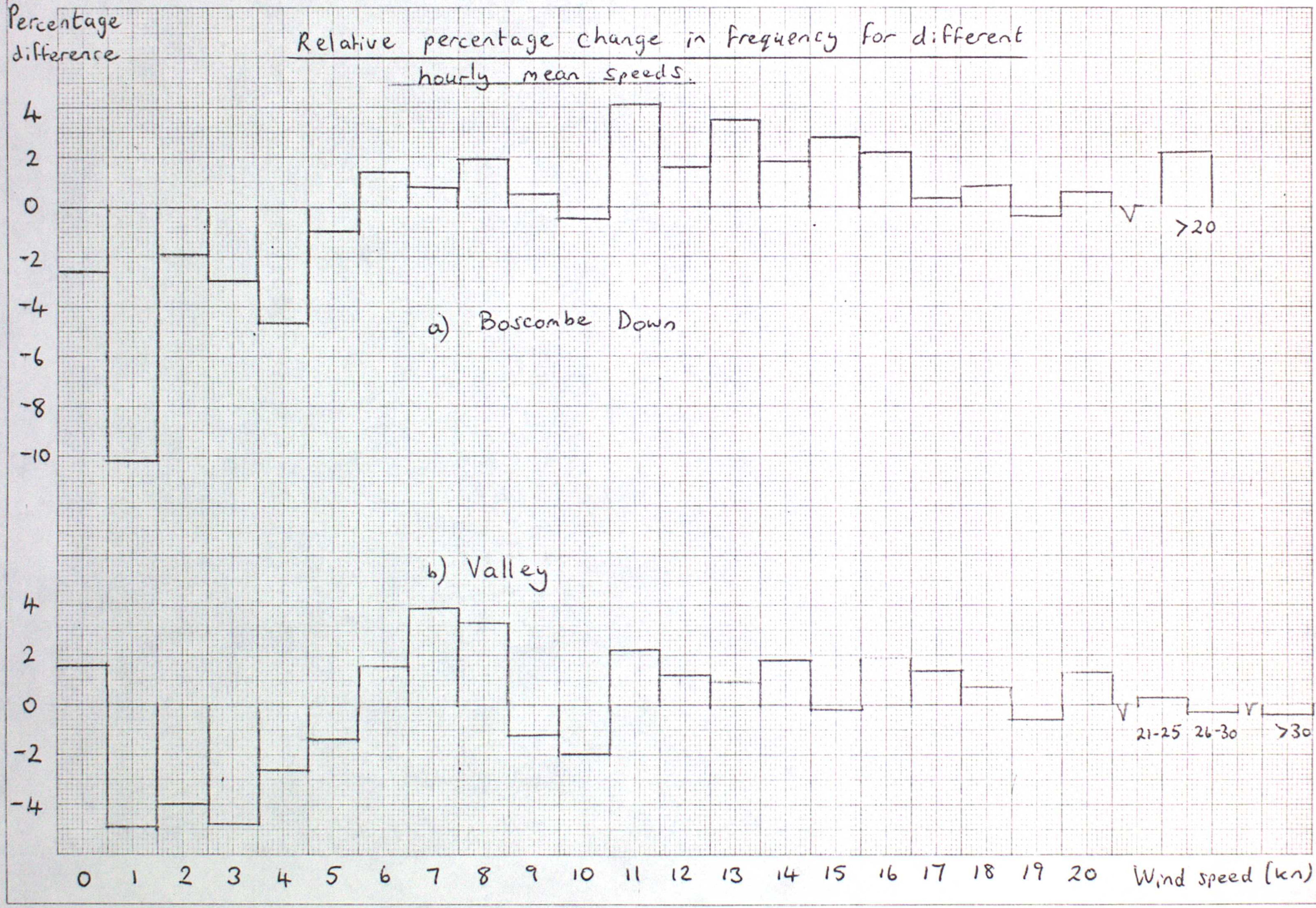

Percentage difference
Relative percentage change in frequency for different hourly mean speeds.
4
2
0
-2
-4
-6
-8
-10
a) Boscombe Down
>20
b) Valley
4
2
0
-2
-4
21-25
26-30
>30
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Wind speed (kn)

FIG 6a

Extreme monthly speeds for Boscombe Down

Winter months

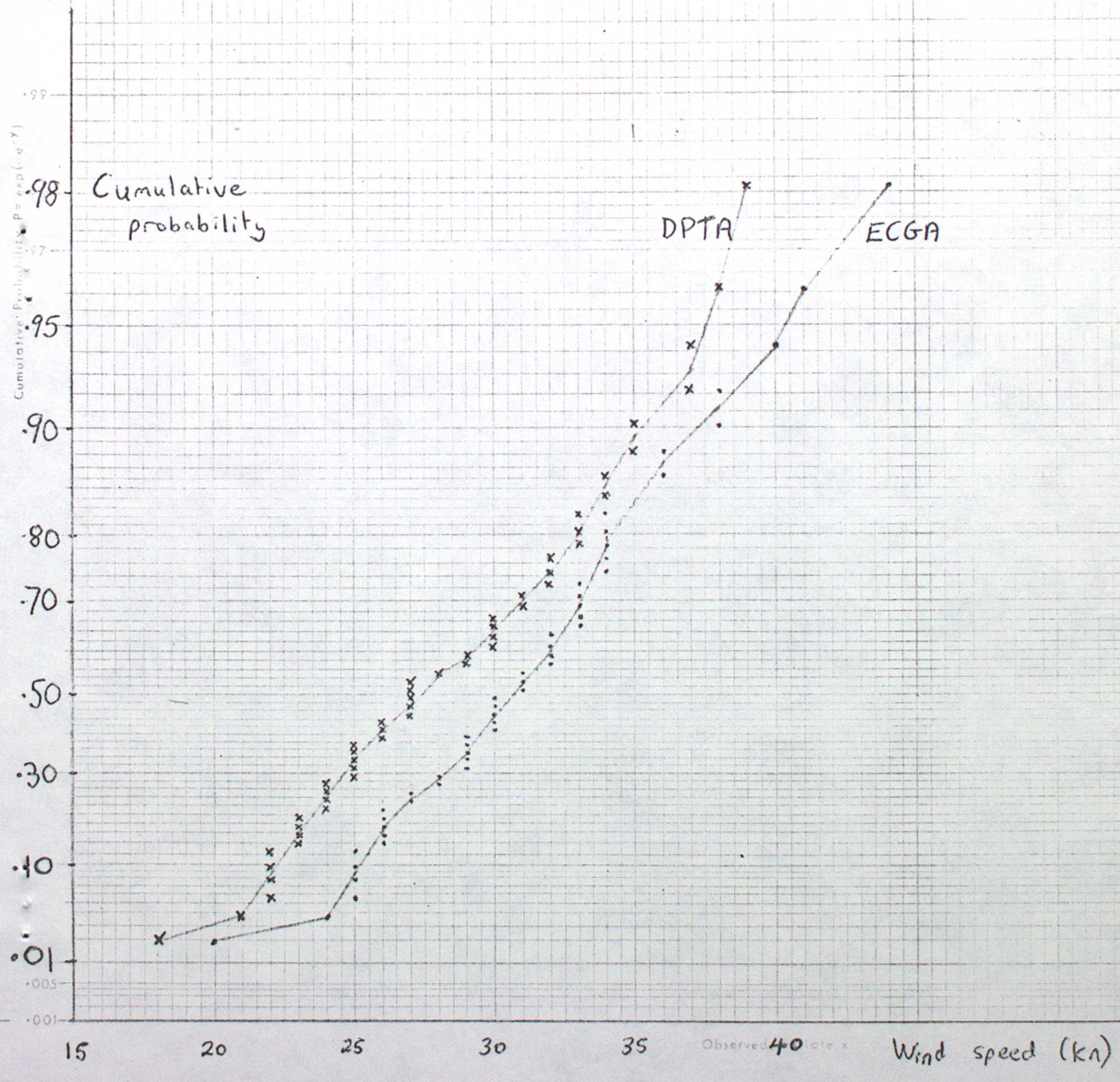


FIG 6b

Extreme monthly speeds for Boscombe Down

Summer months

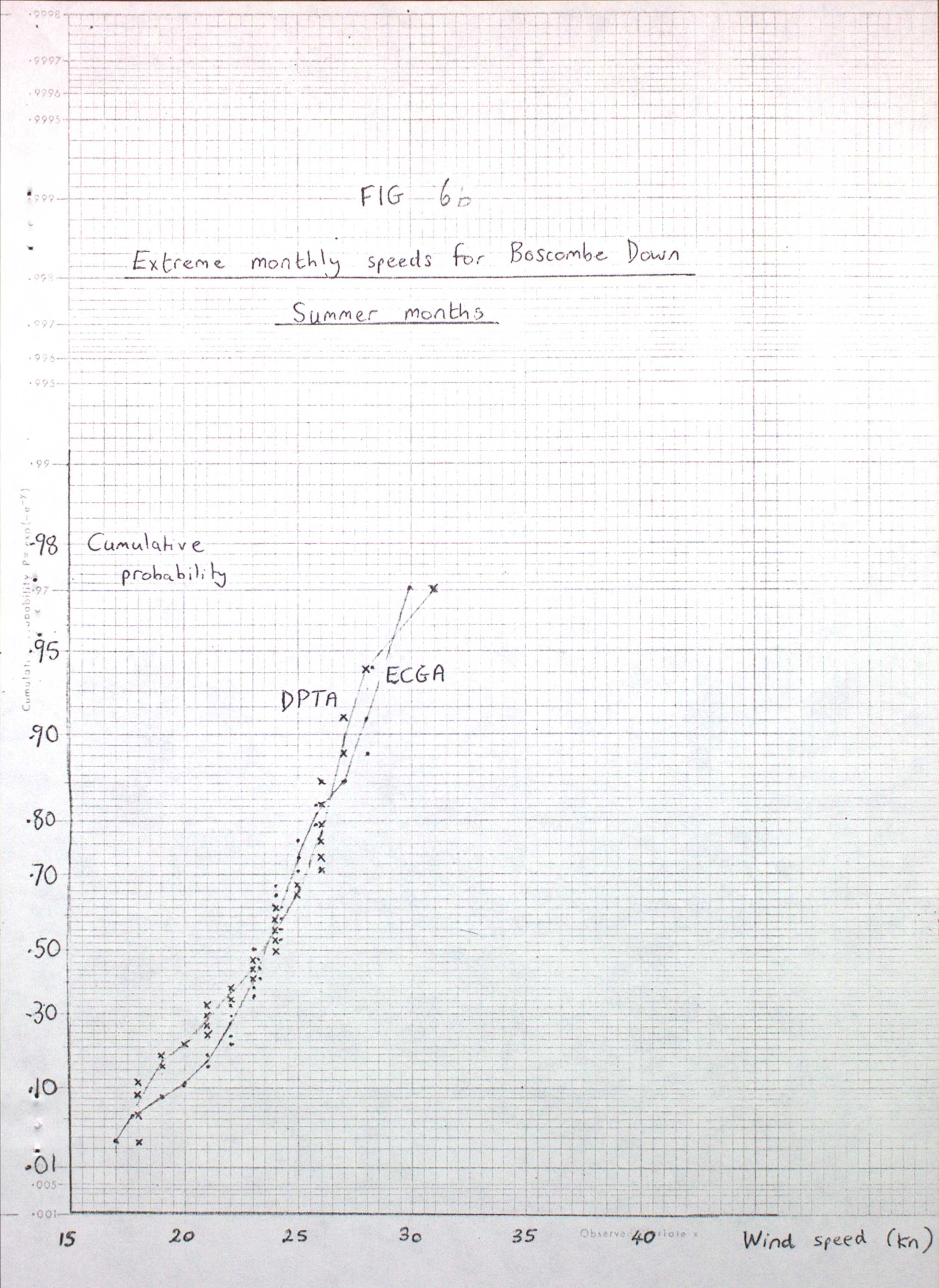
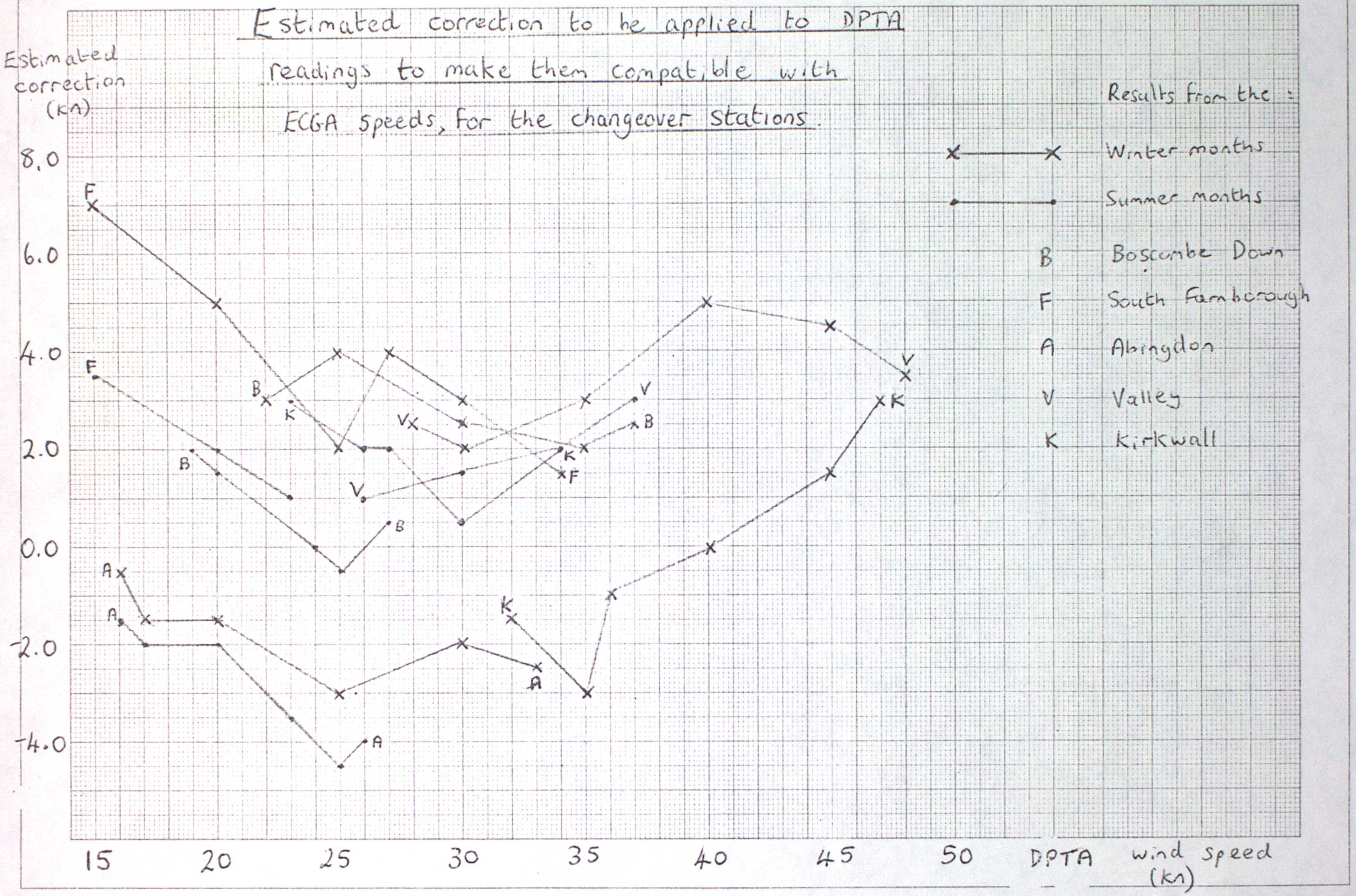


Fig 7



Estimated correction to be applied to DPTA readings to make them compatible with ECGA speeds, for the changeover stations.
Estimated correction (kn)
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
15
20
25
30
35
40
45
50
DPTA wind speed (kn)
Results from the :
Winter months
Summer months
B Boscombe Down
F South Farnborough
A Abingdon
V Valley
K Kirkwall

Table 1

Station Details

Changeover Station			Control station		
Name	No. of obs per day	Date of replacement	Name	No. of obs per day	Type of anemo. then in use
Boscombe Down	24	23.6.64	Abingdon	8	ECGA
South Farnborough	8	6.2.64	Heathrow	24	ECGA
Abingdon	8	8.1.64	Boscombe Down	24	DPTA
Valley	24	22.4.63	Speke	8	ECGA
Kirkwall	8	15.3.62	Wick	24	Cup generator anemometer

Table 2

Mean Wind Speeds and Differences (kn)

Changeover station	1	2	3	Control station	4	5	6	(3) − (6)	t
	DPTA	ECGA	(2) − (1)		DPTA period	ECGA period	(5) − (4)		
Boscombe Down	7.85	8.69	0.84	Abingdon	8.48	7.23	−1.25	2.1 (2.7)	4.7
South Farnborough	6.16	8.09	1.93	Heathrow	7.45	8.65	1.20	0.7	2.1
Abingdon	6.92	8.48	1.56	Boscombe Down	7.01	7.85	0.84	0.7	1.6
Valley	11.63	11.99	0.36	Speke	9.74	9.72	−0.02	0.4 (1.3)	0.6
Kirkwall	14.12	12.60	−1.52	Wick	14.07	12.22	−1.85	0.3	0.6

Table 3

Difference between ECGA and DPTA wind speeds (ECGA - DPTA) for changeover stations (relative to control stations) for different categories of wind speed.

Mean Speed* (kn) / Station	≤ 4.0	4.5 - 10.0	10.5 - 18.0	18.5 - 25.0	> 25.0
Boscombe Down	330 1.8 335	547 2.5 585	433 1.8 351	26 1.8 33	0 2
South Farnborough	435 0.3 247	653 0.9 669	215 0.6 394	31 1.9 25	3 0
Abingdon	455 1.4 329	575 0.7 547	265 -0.1 433	38 -2.1 26	2 0
Valley	255 0.2 160	470 1.4 510	404 -0.9 515	169 -0.9 139	38 1.5 12
Kirkwall	57 3.0 83	398 0.8 468	535 0.8 560	263 -1.3 177	83 -0.8 48

* i.e. mean of the changeover and control station values.

Frequencies are given in top right and bottom right corners for DPTA & ECGA respectively

Table 4

Averages over the 167 days for 10 minute and hourly mean speeds (kn)

Station	Wind speed	DPTA	ECGA
Boscombe Down	10 minute	7.9	8.7
	hourly	7.9	9.3
Valley	10 minute	11.6	12.0
	hourly	11.1	12.4

Table 5

Averages of annual mean hourly speeds (beginning in 1956) for periods with DPTA and ECGA, and differences compared to control stations

Station	DPTA		ECGA		Differences between ECGA & DPTA relative to:		t for station v South Shields	
					South Shields	Kew	d.o.f.	value
Boscombe Down	8.5	(7)	10.2	(13)	1.7	1.9	18	3.1
South Farnborough	5.7	(8)	9.0	(4)	3.4	3.4	10	3.2
Abingdon	7.7	(8)	7.7	(11)	0.1	0.3	17	0.3
Valley	11.0	(7)	13.9	(14)	2.9	3.3	19	3.7
Kirkwall	12.1	(4)	13.6	(14)	1.2	1.6	16	1.7

Number of years comprising the average in brackets.