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A COMPARISON OF DAILY MAXIMUM AND MINIMUM TEMPERATURES WITH THE HIGHEST AND LOWEST OF 24 HOURLY OBSERVATIONS

by

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Summary

Automatic weather stations designed solely to make synoptic observations will not report maximum and minimum temperatures, and so these parameters will have to be estimated from the highest and lowest of hourly observations. The mean difference between the two types of observation was found to be around 0.4 C, but values at some stations were twice as great as at others, and occasional differences of 2 C were found. No coherent geographical variations were identified, but the difference between the maximum and the highest hourly observation was twice as great in summer as in winter.

1. Introduction

The Meteorological Office is developing two principal types of automatic weather station, one for making synoptic observations (SAWS), and the other for obtaining climatological data (ACRE). Platinum resistance thermometers housed in Stevenson screens will be used to record temperature in both systems, with 'one minute' observations being computed from instantaneous measurements made every 5 seconds. Hourly temperatures will be based on the last 5 such observations preceding the hour, and in synoptic stations, these recordings will be capable of immediate onward transmission. A facility to extract maximum and minimum temperatures from the one minute observations will be included in the climatological, but not the synoptic, type of station. For the synoptic station, therefore, only the highest and lowest of the hourly observations will be available. It is therefore desirable to have a knowledge of the differences between the maxima and minima recorded by the two types of automatic station and the conventional manned site in order that direct comparison between the different types of observation may be made.

The response time of platinum resistance and mercury in glass thermometers are similar at around 30 seconds. The maxima and minima derived from the one minute observations at automatic climatological stations are therefore likely to be similar to those obtained from conventional sites. In this paper the likely differences between these values and the most extreme hourly temperatures obtained from automatic synoptic stations are investigated by examining the differences between the conventional maxima and minima and the highest and lowest of hourly observations recorded at manned stations. Hourly observations from the automatic weather stations will be less variable than those obtained manually because the former represent a temperature averaged over 5 minutes instead of, say, 30 seconds. If the difference between the maxima and the highest hourly observations is denoted by D_H, and that between the minimum and the lowest hourly observation is represented by D_L, this implies that the variability of D_H and D_L will be ~~considerably~~ less for automatic than for manned stations, although their mean values will be the same.

2. <u>The data and its quality control</u>

Hourly temperature observations together with maxima and minima recorded in the period 09-09h were extracted for the years 1971-80 for 16 stations whose distribution is shown in fig 1. Data for earlier years ~~was~~ were available, but ~~were~~ not used because they ~~was~~ were less well quality controlled. In the calculation of D_H and D_L , values less than zero were replaced by zero, while values exceeding 3 C were ignored. Cases in which the maximum or minimum occurred at ~~the time of observation (~~09h~~)~~ were excluded from the analysis, as on those occasions either D_H or D_L would be zero.

From 1974-80, data for the conventionally exposed thermometers ~~was~~ were supplemented by observations from the aspirated psychrometer and North Wall Screen at Kew, but these are analysed separately in section 7.

3. <u>Relations between D_H and D_L and fluctuations in hourly temperature</u>

The simplest means of estimating maxima and minima from the highest and lowest of hourly observations is to assume a constant difference between them. The possibility exists, however, that these differences depend on certain aspects of the weather, and that this dependence can be used to improve the estimates of the maxima and minima. Investigations into the possibilities were restricted to attempts to relate D_H and D_L to features of the hourly temperature record.

The first attempt was to fit a quadratic temperature profile to the extreme hourly and two adjacent observations, and to note the turning points of the parabolic curves. At Elmdon, however, these turning points only differed from the most extreme hourly observations by 0.05 C, and the variance of the difference between them and the maximum and minimum was scarcely reduced below the variance of D_H and D_L.

The second attempt was to regress D_H and D_L against T_H, T_L, T_h and T_l where

T_H = difference between the highest and second highest hourly temperatures,

T_h = difference between the highest hourly temperature and the mean of the adjacent observations

and T_L and T_l are similarly defined with respect to the lowest hourly temperature. For each of the 16 stations, however, none of the regressions had correlations which much exceeded 0.2 .

The reasons for the failure of these attempts must be that the maxima and minima are produced by fluctuations of temperature on a time scale much less than an hour, and that these fluctuations bear little relation to the differences between hourly observations.

4. Mean values of D_H and D_L

Mean values of D_H and D_L were found to be 0.36 C and 0.41 C respectively, but over the 16 stations examined, values ranged from 0.25 C to 0.48 C for D_H and 0.30 C to 0.58 C for D_L. These differences, however, seemed to depend on local site peculiarities, and no large-scale variation, either with latitude or distance from the coast, could be identified. The dependence of D_H and D_L on local factors is supported by the fact that stations with high values of D_H tended to be associated with low values of D_L, and vice-versa ($r = -0.45$). Large values of D_L occur at sheltered sites which favour the development of strong nocturnal inversions, while large values of D_H are more likely to occur at exposed sites where turbulence is stronger. ~~Arguably, large values of D_L are accompanied by strong nocturnal inversions which are associated with sheltered sites, while large values of D_H are encouraged by the increased mixing of air at more exposed sites.~~

Mean monthly values of D_H and D_L, averaged over the 16 stations, are represented in fig 2, together with figures for the stations with the highest and lowest annual means. A pronounced seasonal variation is revealed for D_H, with values close to 0.2 C in winter and 0.5 C in summer. This variation, which is caused by increased convection and gustiness in summer, is fairly general, and the ratio of summer to winter values is similar for all stations. In contrast, nocturnal conditions show little in the way of seasonal differences, and D_L remains close to 0.4 C.

5. The variability of D_H and D_L

The variability of D_H and D_L is illustrated for a typical station, Elmdon, for which the means of D_H and D_L are close to those for the average over 16 stations. Fig 3 displays the frequency distribution of D_L for the whole year, and of D_H for summer (May-August) and winter (November-February). A generally skew distribution is apparent so that, although the mean of D_L is 0.4 C, the mode is 0.2 C and occasional values of 1.5 C are attained. The skewness of D_H in summer is generally less, but values of 1.5 C are still possible. For some stations, for which the means of D_H and D_L may exceed those at Elmdon by 50%, occasional values in excess of 2 C must be expected. It should be recalled, however, that the variability of D_H and D_L will be less for automatic than conventional observations because of the long averaging period (5 minutes) of the automatic hourly observation.

6. 12 hourly maxima and minima

The above analysis has compared differences between the maximum and minimum and the highest and lowest of hourly observations in the 24 hour period 09-09h. This analysis was repeated using data for the 12 hour periods 09-21 and 21-09h. Differences between the day (09-21) maximum and the highest hourly observation, and the night (21-09) minimum and the lowest hourly observation, were found to be very similar to D_H and D_L for 24 hour maximum and minimum. The main difference between the night maximum and the highest hourly observation was only 0.2 C, while that between the day minimum and the lowest hourly observation was mostly 0.4 C, but nearer to 0.3 C from July to September.

7. The aspirated psychrometer and North Wall Screen at Kew

The sensitivity of D_H and D_L to the precise siting and nature of the instruments is illustrated by an examination of their values for the aspirated psychrometer and North Wall screen at Kew. A full description of the site and instrumental details is given by Painter (1970), but the main non-standard features are the forced ventilation of the psychrometer and the excessive height, 5 metres above most of the ground, of the North Wall screen.

Mean monthly values of D_H and D_L for the two sites are displayed in fig 4. Comparison with fig 2 shows that the figures for the aspirated psychrometer are typical of those for standard instruments, while those for the North Wall screen are much lower, especially for D_L. The reduced amplitude of the short period fluctuations of temperature in the North Wall screen can be mainly attributed to the excessive height of the thermometers above the ground.

8. Conclusion

Differences between daily maximum and minimum and the highest and lowest of 24 hourly observations at conventional stations are of the order of 0.3 to 0.4 C. Values at some stations are twice as great as at others, but there is no coherent geographical variation. The difference between the maximum and the highest hourly observation undergoes a marked seasonal variation, with mean values ranging from 0.2 C in winter to 0.5 C in summer. The frequency distribution of the daily values is skewed, with occasional differences of 1.5 C possible at a typical station and 2 C at some. The range of values at automatic weather stations, however, will be less than this because of the long averaging period (5 minutes) of the hourly observation. The sensitivity of the differences to local site and instrumental detail are illustrated by observations from the aspirated psychrometer and North Wall screen at Kew.

<u>Reference</u>

Painter, H.E. 1970 A recording resistance psychrometer. Met. Mag, 99, 68-75

FIG 1 - DISTRIBUTION OF STATIONS

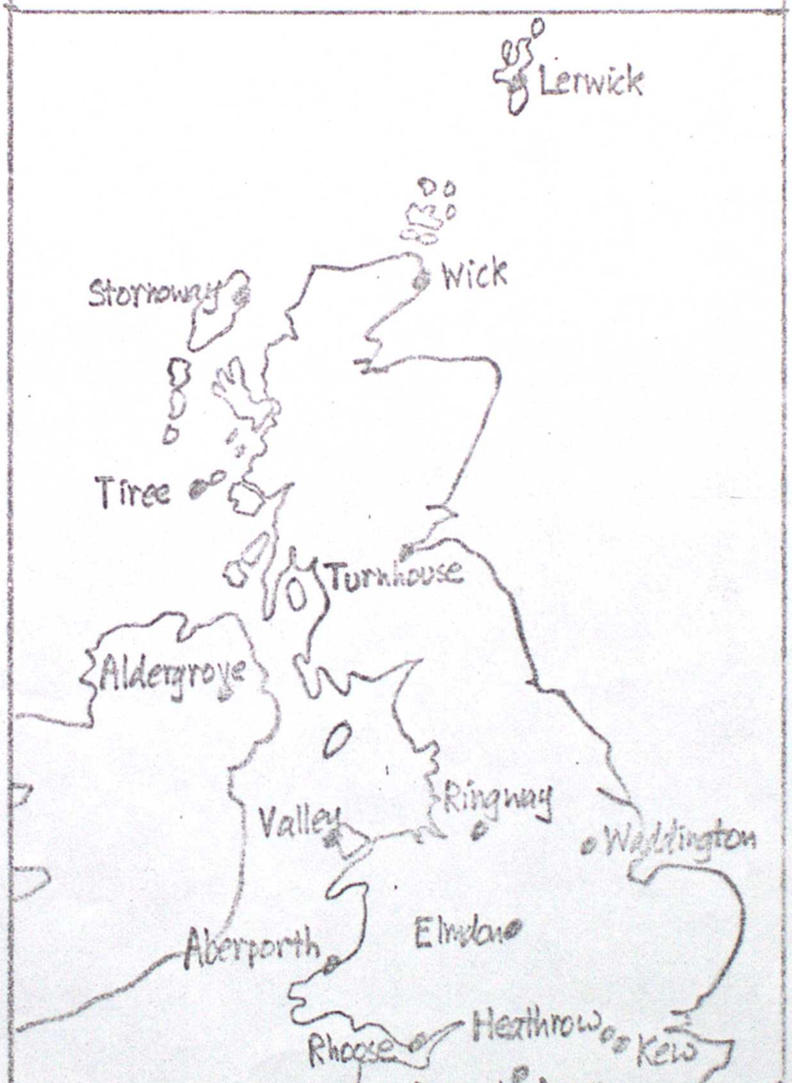

FIG 2 - SEASONAL VARIATION OF THE MEAN VALUES OF THE DIFFERENCE BETWEEN

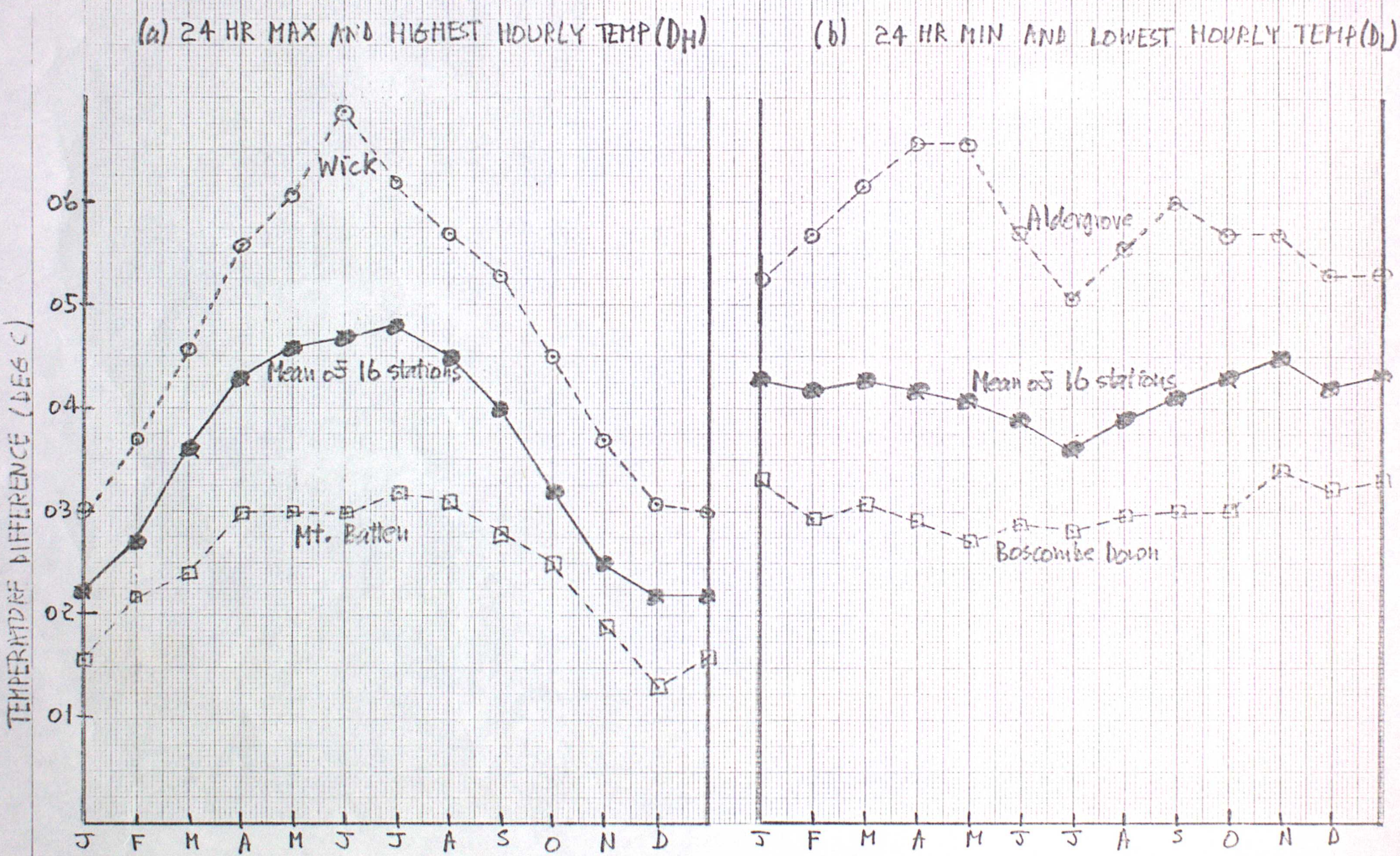

FIG 3 - FREQUENCY DISTRIBUTION OF D_H AND D_L FOR ELMDON.

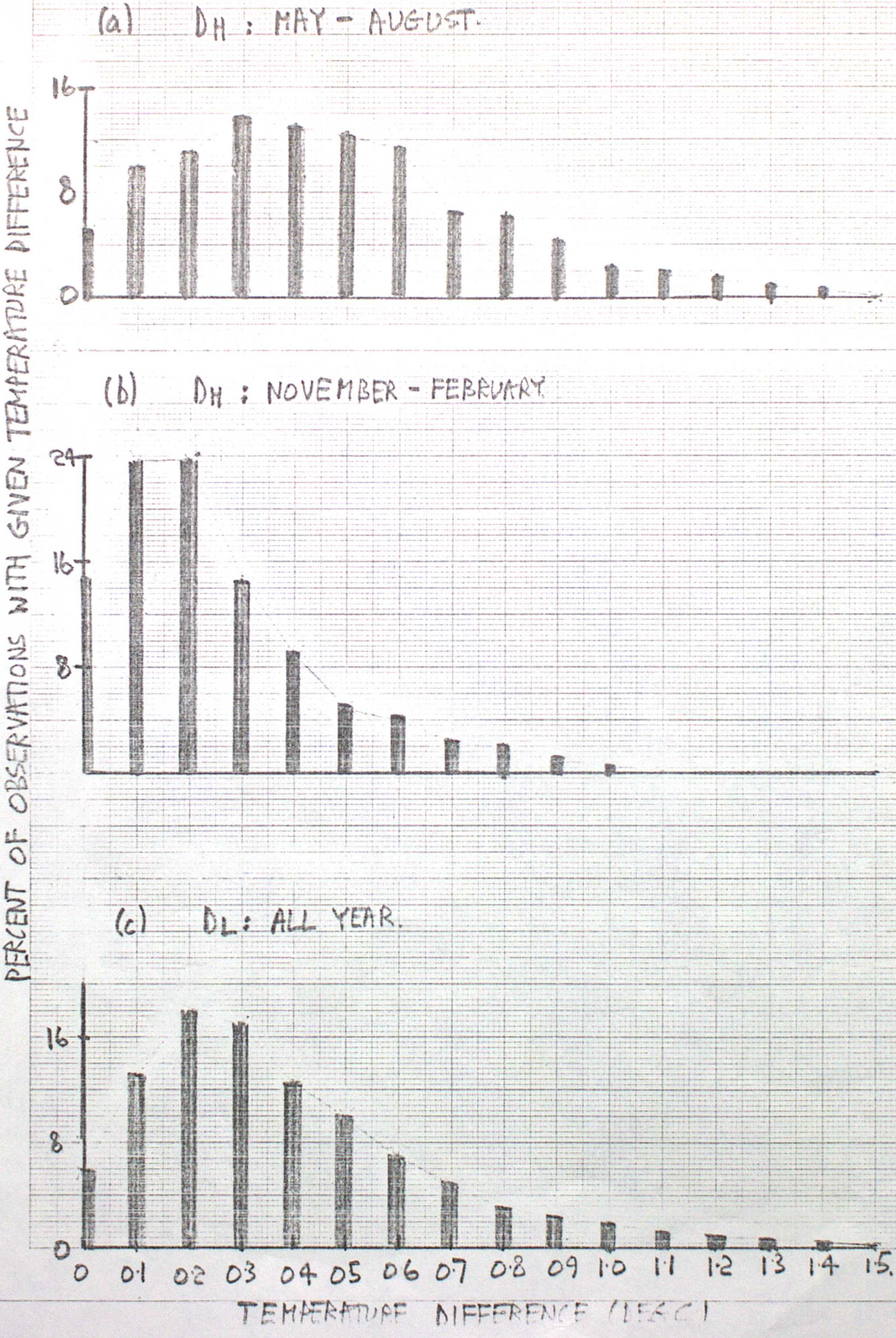

FIG 4 – MEAN MONTHLY VALUES OF D_H AND D_L FOR THE ASPIRATED PSYCHROMETER AND NORTH WALL SITES AT KEW.