

FURTHER COMPARISONS OF KEW EVAPORIMETERS 1968

by P. B. Wright

1. INTRODUCTION

This memo should be read in conjunction with Evap Memo number 1, of which it is a continuation.

The evaporimeters are listed diagrammatically in Figure 1.

All evaporation measurements are expressed in mm per day.

The theme of the memo is the methods of estimating the value of the "evaporation" measured by one evaporimeter, knowing the value given by another, and the accuracy involved in such estimates. It is not suggested that many people will want to do this, but it seems the best approach in the absence of any absolute standard of comparison.

2. STATISTICS OF EVAPORIMETERS

Statistics of the observations from each of the evaporimeters are given in Table 1.

(a) Means

The mean values differ substantially between most pairs of evaporimeters. To find which differences are significant it is best not to use the values given here because different days were missing from different sets of readings, and so the means are not based on exactly the same periods. Rather we should calculate, for each pair, the mean value of the difference between corresponding readings. If we do this we find that all the means differ significantly except:

	pair	mean difference	significance level
(1)	3000 (W) and 3000 (E)	0.03	not sig.
(2)	B (New) and B (Old)	0.06	10%
(3)	20 M ² and B (Old)	0.08	10%

The monthly mean values are shown in Figure 2. There is quite good consistency between the evaporimeters; in other words, the ratios between most pairs of means seem fairly constant from month to month. November looks exceptional, but there were many missing observations in that month.

Conclusion: if we want to estimate the reading from one evaporimeter, knowing the reading from another, then (except in the case of the two 3000 pans) we should multiply by a constant factor; we might improve the estimate by using a factor which varies with the season. Estimates of monthly means should then be acceptably accurate.

(b) Coefficient of variation

The only feature of importance is that the values for the Piche' (Open) are slightly lower, and that for the Piche' (Screen) very much lower, than those for the pans. The best way to interpret this is to say that the pans react equally to weather variations, the Piche' (Open) slightly less, and the

Piché (Screen) very much less. The most likely explanation of the latter is that the Piché (Screen) is protected from extremes of radiation and also from strong winds.

(c) Skewness and Kurtosis

The 20 M² pan applies to a different period from the other evaporimeters, hence the very different values. The Piché (2 m) seems to be midway in character between the Piché (½ m) and the Piché (Screen).

(d) Correlation

The correlation coefficients are shown in Figure 3. They can be summarised by saying: the more similar two evaporimeters, the greater their coefficient. The 20 M² is not very well correlated with the smaller pans.

We can visualise a quantity which we can call the "inherent accuracy" of an evaporimeter, which indicates the error to be expected between two "identical" instruments in "identical" exposures; such errors will be made up of undetectable instrumental differences, environmental differences and errors in taking readings. The two 3000 pans are such a pair; their correlation coefficient of 0.97 indicates how much error is unavoidable. The two Piché (Open) are also "identical" but with some difference in exposure; however their c.c. is 0.98, a little higher than that for the 3000's in spite of the difference in exposure, suggesting that their "inherent accuracy" is somewhat greater. (The different exposure demonstrates itself in a mean value for the Piché (2 m) higher by 15% than that for the Piché (½ m)). The two British tanks have a lower c.c. (0.94); while this may be due partly to environmental differences, it is suggested later that errors in taking readings probably played a part.

3. DAILY DIFFERENCES

Let A, B be the readings from two evaporimeters on a particular day. Let Σ denote summation over the N days on which both A and B are available. Let

$$\bar{A} = \frac{\Sigma A}{N}, \quad \bar{B} = \frac{\Sigma B}{N}.$$

For each pair of evaporimeters, the mean difference $\bar{A} - \bar{B}$ and the standard deviation of the daily differences $\sigma(A-B)$ were calculated.

The mean differences have already been discussed, and it was suggested that we might apply a constant factor c to B such that

$$\bar{A} = c\bar{B}$$

We now want to know what errors will occur in the daily estimates after we have applied this correction; in other words, we want to know

$$\sigma(A - cB)$$

Now

$$\sigma^2(A - cB) = \sigma^2(A-B) - (c-1)^2 \sigma^2(B) + \frac{2(1-c)}{N} \Sigma \epsilon B,$$

where

$$\epsilon = A - cB$$

Hence if c is not very different from one, $\sigma(A-B)$ is a good estimate of $\sigma(A-cB)$.

If c is very different from one, and especially if there is a systematic difference in the two evaporimeters which will make c correlate with B (e.g., a seasonal variation in c will cause this) then $\sigma(A-B)$ is not such a useful quantity. However, under such conditions ratios between readings would be much more relevant than differences anyway.

We shall therefore study $\sigma(A-B)$ only for pairs of similar evaporimeters. The discrepancies between evaporimeters of different types have been illustrated adequately by the correlation coefficients.

Values of $\sigma(A-B)$ for various pairs of similar evaporimeters are given in Table 2. For the two 3000 pans the standard deviation was 0.40, for the other pairs it was in the range 0.5 to 0.6. If the correction factor c had been applied before taking differences, the latter would have been somewhat less.

4. PENTAD DIFFERENCES

Some interesting results can be obtained by comparing the standard deviation of daily differences (σ_1) with that of pentad mean differences (σ_5) also given in Table 2. It can be shown that

$$\sigma_5^2 = \frac{1}{5} \sigma_1^2 + \frac{1}{5N} \sum_{p=1}^{\frac{1}{5}N} \left\{ \sum_{\substack{j=1 \\ j \neq k}}^5 \sum_{k=1}^5 (d_j - \bar{d})(d_k - \bar{d}) \right\}_p$$

(where $d_j = A_j - B_j$, p is the number of the pentad, and a bar denotes a mean value over N days)

$$\sigma_5^2 = \frac{1}{5} \sigma_1^2 + D.$$

Define

$$\alpha = \frac{\sigma_1}{\sqrt{5} \sigma_5}.$$

Suppose the $\{d_i\}$ are randomly ordered.

Then $D \doteq 0$, hence $\alpha \doteq 1$.

Suppose there is a tendency for high values of d_i to occur close in time to each other, rather than to be spread at random throughout the period; and/or a similar tendency with respect to low values.

Then $D > 0$, hence $\alpha < 1$.

Suppose on the other hand that high values of d_i tend to be associated with low values on neighbouring days.

Then $D < 0$, hence $\alpha > 1$.

The more that α differs from 1, the more potential predictability is present.

The values of α are given in table 2. It is seen that $\alpha > 1$ for 3 pairs, being highest for the two British pans; also $\alpha < 1$ for 3 pairs.

A value of $\alpha < 1$ is easily explainable in terms of a seasonal or weather-type variation in response of the two evaporimeters. For example, if A is more sensitive to radiation than B, then A-B will be relatively high on sunny days and relatively low on cloudy days. As sunny days tend to occur consecutively rather than randomly, this will result in $D > 0$, hence $\alpha < 1$. This argument would be expected to apply to comparisons between two evaporimeters of different types, and the results support this; for all such comparisons (not shown in Table 2) $\alpha < 1$. The Piché (Open) also show this effect; this may simply be a result of the difference in mean values (A-B will tend to be higher than (A-B) in summer, and lower in winter). Table 2 suggests that the 20 M² tank has some such systematic differences from the other pans.

There is no reason to suppose any such variation between pans of the same type, and for these we would expect $\alpha \geq 1$; the results in Table 2 support this.

We now have to seek an explanation of why α was greater than 1 in three cases. I have not attempted to discover what values of α are significantly different from 1, but we should at least try to explain the value of 1.11 for the two British pans.

A value of α greater than 1 implies that, if on one day one of the pans gives a comparatively high reading then this will usually be compensated by a comparatively low reading on one of the next two or three days.

Measurements from all the pans are made by lowering a screw gauge towards the water until it just touches, then reading the level against a fixed pointer. An error in one such observation would result in two successive evaporation measurements being respectively too high and too low, and this would contribute towards making $\alpha > 1$.

If we accept this explanation, it follows that such errors were particularly common on one or other, or both, of the British pans, and less frequent on the 3000 pans. (If they were present on the 20 M² pan they cannot be detected by this method because of systematic differences between this and the other pans). A suggested explanation of this relative difference in accuracy is that the two 3000 pans are close together, and the observer might readily notice an unusually large difference between the two pans and therefore re-check the readings. The two British pans are much farther apart in space and time of reading, and a difference due to an error in one reading would be more likely to escape the observer's notice.

By putting $\alpha = 1$, we can discover approximately by how much the daily errors could be reduced if errors in reading the water level were eliminated. We obtain the values $\sigma_e = 0.38$ for the 3000 pans, and 0.47 for the British pans.

5. ACKNOWLEDGEMENT

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NOTE This memo is circulated for discussion purposes only.
Any comments and suggestions should be sent to the author.

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TABLE 1

KEW EVAPORIMETERS - STATISTICS FOR JUNE TO NOVEMBER 1968

	Brit. (New)	Brit. (Old)	3000 (W)	3000 (E)	20 M ² *	Piche' (2 m)	Piche' (½ m)	Piche' (S)
Mean	1.83	1.79	2.04	2.00	1.18	3.69	3.22	2.26
Coefft. of var.	0.80	0.80	0.75	0.79	0.77	0.72	0.74	0.61
Skewness	0.95	1.03	0.85	0.81	0.45	1.39	1.15	1.54
Kurtosis	4.08	4.47	3.98	3.95	2.50	6.00	4.69	6.63

* August to November only.

For each evaporimeter, all available observations during June to November were used to calculate the statistics.

TABLE 2

evaporimeters		σ (A-B)	σ_g (A-B)	α
A	B			
3000(W)	3000(E)	0.40	0.17	1.05
Brit (New)	Brit (Old)	0.52	0.21	1.11
20 M ²	Brit (New)	0.53	0.28	0.85
20 M ²	3000 (W)	0.59	0.28	0.94
Brit (New)	3000 (W)	0.59	0.25	1.05
Piche' (2 m)	Piche' (½ m)	0.58	0.31	0.83

Figure 1

THE EVAPORIMETERS

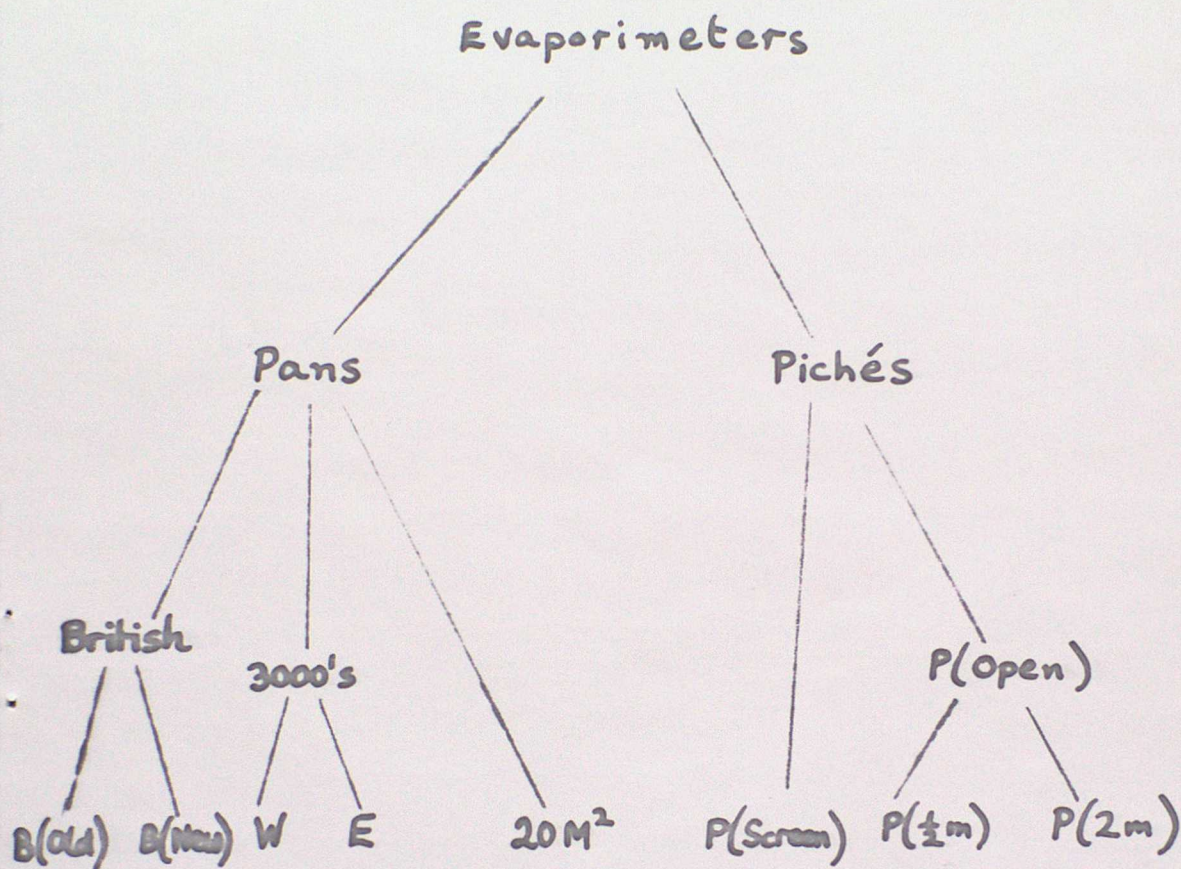


Figure 2.
Monthly mean measurements from various evaporimeters.

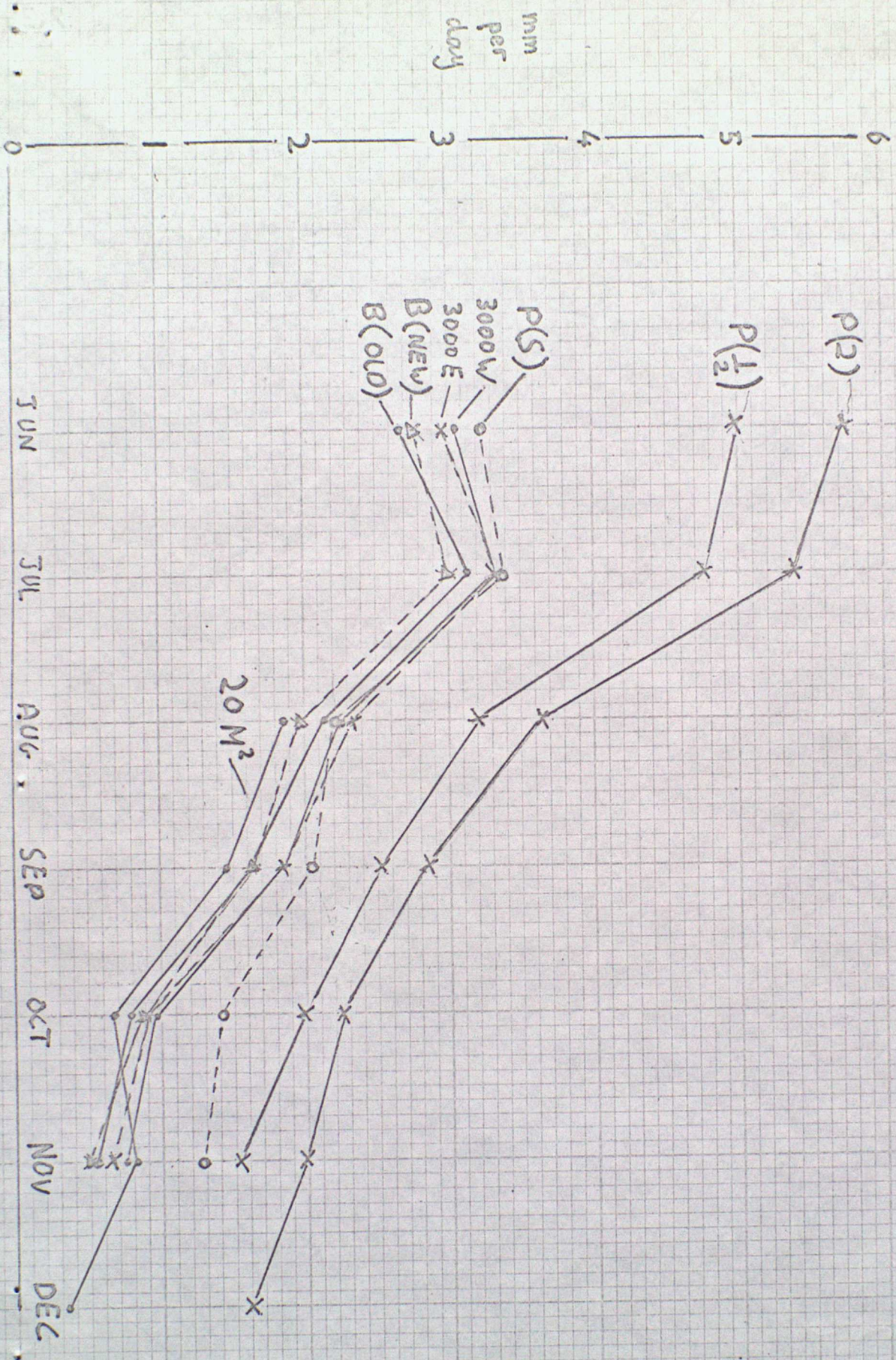


Figure 3

CORRELATION COEFFICIENTS $\times 100$

