Continuous recording of evaporation from a type A-pan

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Abstract

A system is discussed that was developed for the continuous recording on a weekly basis of evaporation from A-pans. The recorder is so constructed that the influence of wind-generated wave action on the pen trace is largely eliminated. For more accurate measurement of evaporation, the sensitivity of the recorder was increased. Provision was also made for the automatic emptying of the evaporation pan as it reaches overflow point during periods of high rainfall.

Introduction

The system described in this paper for the automatic recording of evaporation was developed in 1978 to serve remote research areas from which daily evaporation figures are required. A low cost modification to standard apparatus has made it possible to measure evaporation under virtually any condition. The modification provides more detailed information than simply daily evaporation but permits measurements from the automatic chart trace to be made with 50 per cent greater precision than is possible with an unmodified recorder.

The first recording apparatus was installed at the Jakkalsrivier meteorological station near Grabouw in 1978. Since then an additional four meteorological stations have been equipped with these recording evaporation pans.

Method

The A-pan 'A' (Figure 1) is coupled to a galvanised metal float chamber 'B' by means of a copper tube 'C' (diameter 15 mm). The float chamber is positioned away from the prevailing winds and two metres from the A-pan. The float chamber, which is clearly also a stilling chamber, is suspended with bolts below a specially cast concrete slab 'D' where it slides into a casting 'M'. This slab fits into a heavy asbestos stormwater pipe 'E', which is fixed solidly into the ground and partly filled with concrete. The concrete filling 'F' is given a slope with a leak check point 'G' at the bottom of the slope. The water level in the stilling chamber is recorded by means of a Belfort water level recorder 'H' with a 100 mm float and a modified gear ratio. The conversion of the instrument has been done in such a way that it can be reconverted within a few minutes to the conventional recording of streamflow. The alteration of the ratio of the gears 'L' is achieved by fitting two specially precision turned bushes 'K'. These alter the standard gearing of 5:12 to a ratio of 5:3.

Pen trace drop is measured in millimetres and multiplied by a conversion factor of 0,6 to give evaporation in millimetres. Figures 2B and C show examples of the recorded evaporation. Figure 2A shows the recording without modification where the effect of wind is obvious.

The 5:3 gear ratio magnifies the pen trace record of evaporation. More accurate and more detailed measurements can therefore be obtained from the chart. It is an improvement of

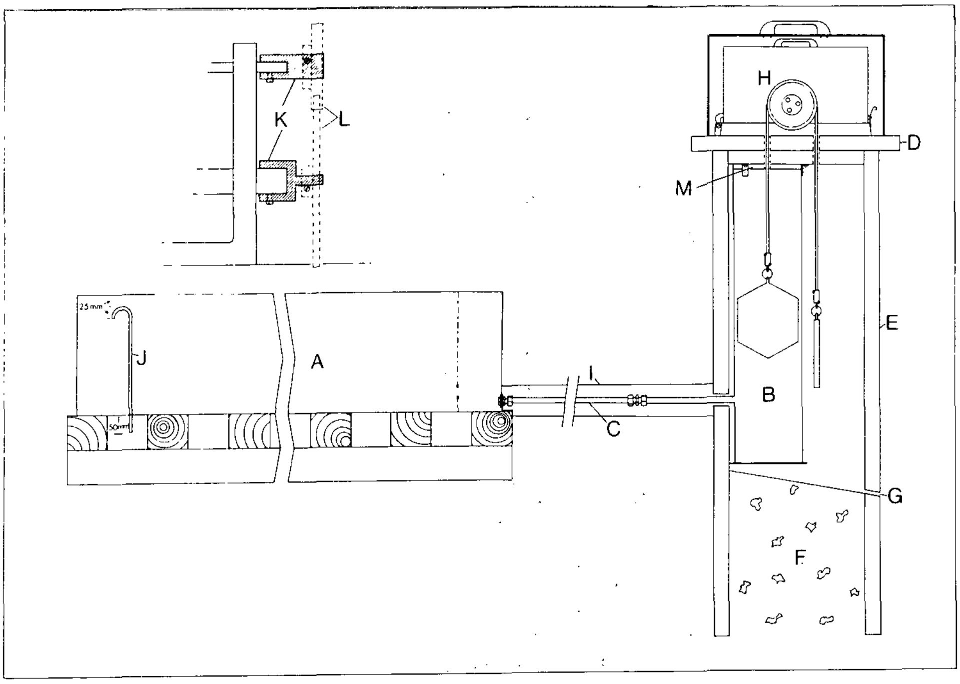

Figure 1
Schematic presentation of evaporation recording

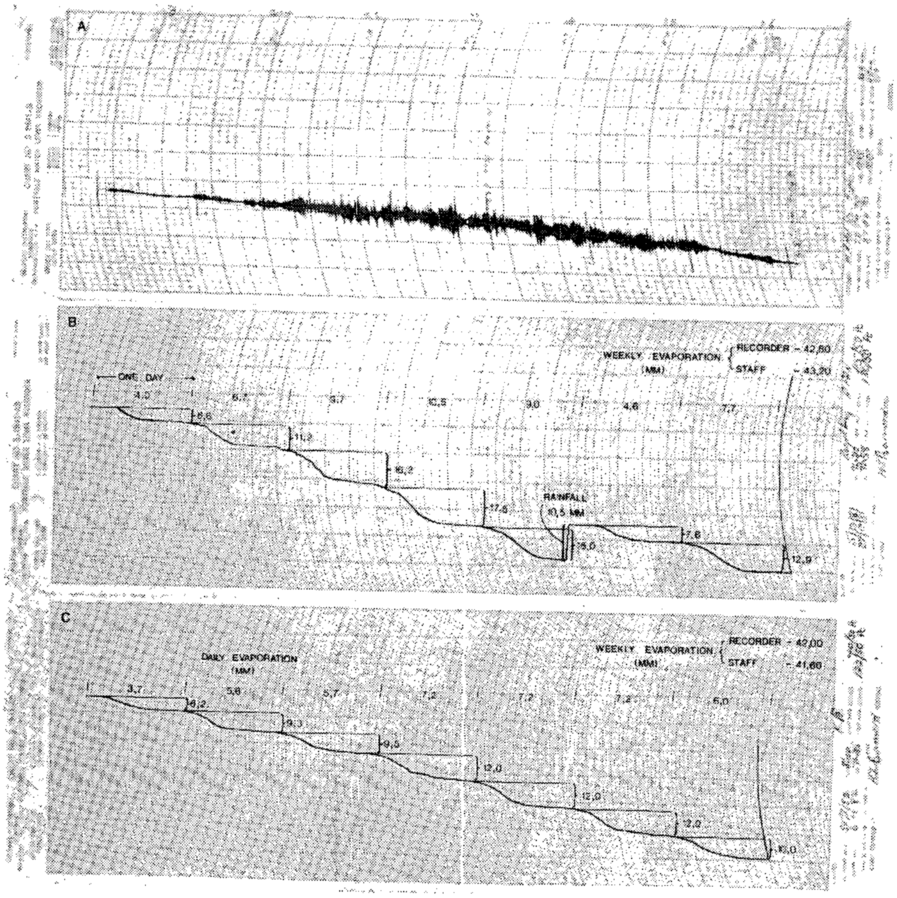

Figure 2
Chart recorded evaporation. 2A without float chamber (5:6 gear ratio), 2B and 2C with float chamber (5:3 gear ratio)

50% on the 5:6 gear ratio. The pen trace can be read off with a 40% improved precision over the actual evaporation. The change in gear ratio from 5:6 to 5:3 improves the conversion factor from 1,2 to 0,6.

The volume of water added by the stilling chamber is 0,6% of the volume of the A-pan. This difference is insignificant and no adjustment to the conversion factor is necessary.

As mentioned earlier, the float chamber 'B' is installed in an asbestos stormwater pipe 'E'. The copper tube 'C' from the A-pan to the float chamber is insulated by an asbestos pipe 'I'. The reason for this is that heating of the copper tube could influence the recording of the water level and also the rate of evaporation.

The firm recorder stand and remote float chamber eliminate the effect of wind action on the pen trace. Wave action in the A-pan causes the pan of a normally mounted recorder to oscillate, giving a thick imprecise trace on the chart (Figure 2A). Accurate measurements cannot be made from these traces.

A-pans on remote sites are only tended to once a week, and it is therefore necessary to see that they are filled to a higher level than would otherwise be required. Because of this it often happens that the pan overflows during rainstorms. Under such circumstances wind can blow water out of the pan. This loss of water could be wrongly interpreted as evaporation. To overcome this a siphon tube 'J' (diameter 6 mm) is fitted so as to empty the pan to 50 mm from the top of the pan. The siphon comes into operation when the water level reaches a point 25 mm from the top of the pan. The siphoning operation takes 15 min and has no influence on the recording of evaporation because it usually takes place during a rainstorm and is clearly visible on the trace.

Accuracy

The 5:3 gear ratio makes the instrument more sensitive than the standard model and more precise measurements can therefore be made from the chart traces.

Manual measurements (staff measuring plate) and instrument recordings were compared over a period of two years. It was found during the test period that there was a 0,4% difference between the mean weekly figures from the recorder and the mean readings from the staff measuring plate.

The two sets of data obtained with the staff measuring plate and from the recorder at the meteorological station in the Kogelberg are presented in Table 1. These data were obtained from weeks with no rain and cover all the seasons of the year.

These data were statistically analysed and no significant difference between the weekly staff readings and the recorder readings was found.

The following tests were applied to the differences between the data sets (results appear in Table 2):

TABLE 1
COMPARISON OF A-PAN EVAPORATION BETWEEN STAFF MEASURE PLATE AND RECORDING

Week	Evaporation/week (mm) Staff	Recording	Difference
1	33,52	30,60	2,92
2	38,61	38,04	0,57
3	44,19	44,70	− 0,51
4	20,32	18,60	1,72
5	11,68	12,60	− 0,92
6	41,66	42,00	− 0,34
7	31,50	33,00	− 1,50
8	42,16	44,40	− 2,24
9	43,18	45,60	− 2,42
10	47,75	48,36	− 0,61
11	50,30	51,30	− 1,00
12	34,54	34,20	0,34
13	4,57	3,84	0,73
14	12,70	9,60	3,10
15	14,73	14,70	0,03
16	22,35	19,98	2,37
17	37,10	36,90	0,20
18	60,96	63,60	− 2,64
19	36,60	39,60	− 3,00
20	56,39	54,78	1,61
21	47,75	44,40	3,35
22	33,53	34,80	− 1,27
23	43,20	42,60	0,60
24	57,91	57,90	0,01
25	40,64	38,70	1,94
26	43,18	40,50	2,68
27	40,64	41,40	− 0,76
28	35,05	35,10	− 0,05
29	25,40	30,00	− 4,60
Mean	36,28	36,27	

1. Normality
   Goodness of fit (χ^2)
   Measure of skewness ($\sqrt{B_1}$)
   (a) Fisher (1954)
   Measure of kurtosis (B_2)
   $/X_1/$ – skewness
   $/X_2/$ – kurtosis
   χ^2
   (b) Shapiro and Wilk (1965) – W
2. Independence – Durbin-Watson test. (Merril and Fox, 1970)
3. Regression analyses (Figure 3)
4. t-Test to test the hypothesis that B = 1 (Steel and Torrie, 1960)
5. Paired t-test to test the hypothesis that both series (staff and recorder readings) are from the same population because they have the same population mean (Steel and Torrie, 1960).

All the tests for normality (Table 2) showed that the differences between the results obtained with the weekly staff and those from the automatic recorder are normally distributed at a 5% significance level. The Durbin-Watson test (Table 2) indicates that the null hypothesis of zero autocorrelation can be accepted at a significance level of 5%. The series is therefore independent.

Because the series is normally distributed and independent a t-test was applied to test whether the relation between the two samples was equal to one (B = 1). The null hypothesis of a uniform ratio between the staff evaporation readings and the recorder evaporation readings is acceptable at a 5% significance level.

TABLE 2
TESTS AND STATISTICS CALCULATED FROM DIFFERENCES IN EVAPORATION MEASURED WITH THE STAFF AND THE RECORDER

	Staff (y)	Recorder (x)	5% Significance level	Significance	Statistic calculated
1. Normality					
Goodness of Fit	0,671		7,810	N*	χ^2
Moments: Skewness	− 0,178		± 0,661	N	$\sqrt{B_1}$
Kurtosis	2,622		2,150 to 3,990	N	B_2
Skewness calculated from $\sqrt{B_1}$	0,433		± 1,960	N	$/X_1/$
Kurtosis calculated from B_2	− 0,252		± 1,960	N	$/X_2/$
χ^2 Calculated from $/X_1/\&/X_2/$	0,251		5,990	N	χ^2
Shapiro & Wilk	7,301		0,926	N	W
2. Independence					
Durbin-Watson test (autoregression)	1,481		1,330 to 1,480	ID*	D
3. Regression analysis					
Mean	36,281	36,269	—	—	$\bar{X}$ $\bar{Y}$
Standard Error	1,926		—	—	—
Regression Coefficient	0,963		—	—	B_1
Correlation Coefficient	0,991		—	—	R
Upper Confidence Limit (B_1)	1,015		—	—	—
Lower Confidence Limit (B_1)	0,911		—	—	—
t – test (to test $B_1 = 1$)	1,464		2,052	S*	t-test
4. Test of equal sample means					
Paired t (staff mean = recorder mean)	− 0,029		2,048	S	t-test
Standard Deviation of Differences	1,963		—	—	(paired)
Error of D	0,365		—	—	—
Mean of D	− 0,011		—	—	—

*N – Normal
*ID – Independent
*S – Significant

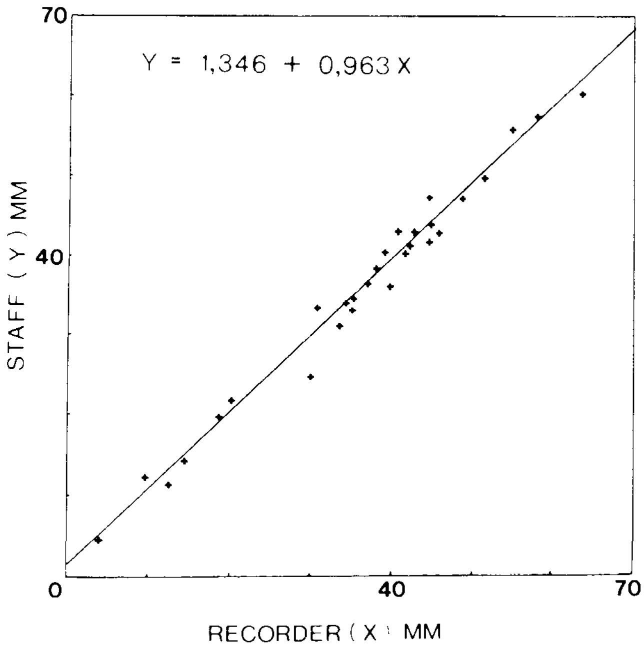

Figure 3
Relation between weekly evaporation measured by means of the staff and the recorder

The null hypothesis that the sample means, namely the readings of evaporation by means of the staff and the recorder are from the same population, is accepted at a 5% level of significance.

It was found in practice that the main cause of differences in the readings was human error rather than instrument error; the instruments usually gave constant readings.

Because of the high gear ratio regular cleaning of all moving parts of the instrument is essential.

Conclusion

With the initiation of research in remote areas and the centralization of out-station staff, it is necessary for data collection to be carried out on a weekly basis using automatic recording instruments.

As evaporation is one of the essential climatic parameters measured for catchment research, it was necessary to develop an automatic recording system for evaporation. The apparatus described in this paper has successfully fulfilled the requirement for an automatic evaporation recorder since installation of the first unit in 1978. Statistical tests applied to data obtained from the automatic recorder and from manual control readings indicate that the instrument data are entirely acceptable.

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