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An analysis of the Radiosonde Comparisons made at Payerne with 14 Sondes in May-June 1956

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1. Introduction

1·1. Among the radiosonde comparison flights, with varying number of sondes in each, carried out at Payerne in May-June 1956, there were five day flights and four night flights in which fourteen sondes were used in train. As this set of flights provides us with valuable data for judging the comparative performances of all the instruments simultaneously, an analysis of the data of these flights alone has been made and the results are presented in this paper.

1·2. The fourteen instruments used are—

S. No.	Country	Type of sonde
1	Belgium	I.R.M.
2	Federal Republic of Germany	Graw H 50
3	Democratic Republic of Germany	Lange
4	U.S.A.	AN/AMT 4
5	Finland	Vaisala
6	France	Metox
7	Japan	Code Type
8	India	Chronometric
9	United Kingdom	Kew MK IIB
10	Netherlands	Philips
11	Switzerland	Chronometric
12	U.S.S.R.	Moltchanov RZ 049
13	India	Fan
14	Poland	Lange (modified)

2. Data

2·1. Values of pressure, temperature and humidity recorded by each instrument in these flights have been duplicated and distributed to all co-operating services at Payerne. The data contain minute to minute values in Form No. 1. No analysis of humidity values has been attempted here. Only pressure and temperature data have been analysed.

2·2. It is understood that for some sondes radiation corrections were applied to the temperature data before interpreting the results. But we have used in this analysis only values uncorrected for radiation effects.

2·3. The fourteen sondes were let off in a train, the difference in height between successive sondes being 7 metres. As such, the values recorded by the different sondes for the same minute of the flight would not be comparable because of difference in their levels. This fact has been taken into consideration while comparing the values of the different sondes by applying necessary corrections to the mean values to reduce all the sonde-means to the same level.

2·4. In the previous analyses of these Payerne radiosonde comparison data so far issued (see references), values of pressure and temperature for selected significant levels only, *i.e.*, for levels 850, 700, 500, 300, 200, 100, 70, 50, 30 and 20 mb have been taken into consideration. In this analysis all the minute to minute recorded values of all sondes have been made use of. In so doing each flight has been divided into seven levels according to the time intervals of the flight, as follows: 1—5, 6—10, 11—15, 16—20, 21—30, 31—40 and 41—50 minutes.

2·5. The minute to minute values of all sondes for each time-interval for each flight were tabulated separately from Form No. 1. In Table 1 will be seen a sample of

TABLE 1

Day: Flight B: Minutes 1—5: Pressure (mb)

	Instrument numbers														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
Minutes															
1	926	925	919	923	919	908	915	915	922	946	914	922	922	931	922
2	889	890	880	886	877	870	877	877	882	920	875	885	888	897	885
3	852	853	842	851	847	835	839	841	849	890	839	850	853	834	850
4	824	820	809	816	814	800	816	808	819	856	806	824	818	833	818
5	791	789	776	786	781	770	779	775	785	822	778	792	785	801	786
Mean	856	855	845	852	847	837	844	843	851	887	842	855	853	865	852·4

Analysis of variance

Component	Degrees of freedom	Sum of squares	Variance	Square root of variance	Ratio of variances
Minutes	4	159968	39992	199·98	12901
Instruments	13	9792	753	27·44	243
Residue	52	159	3·1	1·76	
Total	69	169919	2463		

such tabulation of pressure values for day flight B, level 1—5 minutes. For nine flights, seven levels and two elements, *i.e.*, pressure and temperature, 126 such tables were made out for analysis.

3. Method of analysis

3·1. An analysis of variance has been carried out for each of the 126 tables in the form shown at the bottom of Table 1. The basic principles of the method are well-known and have also been explained by Delver (1956). The only difference between the present analysis and Delver's analysis is that he has used the values of all "flights" for each element and significant level, but we have analysed each flight and level separately using minute values. The three components of variation in our tables are therefore ascribable to (1) instruments, (2) minutes and (3) residual.

3·2. For want of replications of the same type in the design of the experiment no strictly valid estimate of error variance is available. But under certain circumstances, *i.e.*, if the components of systematic variation in an analysis of variance are orthogonal, it has been shown that the residual variance can be taken as an error variance. In our case the principle of orthogonality is satisfied because we may assume that the differential behaviour of the 14 instruments have remained the same for the time interval of 5 or 10 minutes chosen in each case. The square root of the residual variance in each table of analysis of variance has, therefore, been taken to be an estimate of the error of observations which has been used for testing the significance of the values of different sonde-means.

3·3. Table 2 gives the Standard Residue (S.R.), *i.e.*, the square root of the residual variance for each level of each flight for pressure and temperature. While working, it was found that in two cases the residual variance was not consistent with the general order of values obtained. In one case, in day

TABLE 2

Values of standard residue

Flight		Time (minutes) 1—5	6—10	11—15	16—20	21—30	31—40	41—50
				Pressure (mb)				
DAY	A	3·0	3·1	1·7	1·8	1·7	1·7	0·8
	B	1·8	2·7	2·4	1·8	2·5	1·6	1·1
	C	3·5	1·9	1·9	1·4	1·5	1·4	1·1
	D	2·0	1·9	1·3	1·2	1·7	1·7	1·1
	E	3·6	1·7	1·8	1·8	1·4	1·2	0·9
	Mean	2·8	2·3	1·8	1·6	1·8	1·5	1·0
NIGHT	A	2·3	2·5	1·6	1·9	1·9	1·2	1·7
	B	1·9	1·8	1·7	1·2	1·6	1·3	1·3
	C	4·8	2·5	2·5	1·6	2·3	1·3	0·8
	D	1·7	2·1	2·4	3·0	2·5	1·8	1·2
	Mean	2·7	2·2	2·1	1·9	2·1	1·4	1·3
				Temperature (°C)				
DAY	A	·27	·32	·36	·31	·59	·64	·83
	B	·31	·33	·29	·27	·49	·61	·56
	C	·55	·22	·37	·40	·56	·62	·79
	D	·44	·33	·27	·30	·61	·61	·52
	E	·33	·63	·35	·30	·54	·45	·50
	Mean	·38	·36	·33	·32	·56	·58	·64
NIGHT	A	·32	·27	·51	·25	·75	·46	·33
	B	·28	·15	·28	·35	·41	·52	·40
	C	·41	·33	·33	·42	·74	·62	·52
	D	·32	·36	·20	·44	·30	·55	·41
	Mean	·33	·28	·33	·37	·55	·54	·42

flight D, the value for the third minute was recorded as 894 mb. Examining this value with the values of the previous and subsequent minutes of the instrument and also comparing it with values for other instruments, it was evident that this record was an obvious mistake for 844 mb. The value has been taken as 844 mb. In another case the recorded pressure value of instrument No. 10 for minutes 1—5 in night flight D have been rejected as its contribution to residual variance was abnormally high.

4. Standard error of sonde observations

4·1. Values in Table 2 have been assumed to give a fair estimate of the standard error of sonde observations. The very consistency in the order of the values, despite the differences amongst them, is indicative of the fact that the standard residue gives a fairly reliable estimate of standard error of radiosonde observations. The conditions under which this assumption is valid and how the condition is satisfied in our case has already been shown under 3·2 above.

4·2. It is seen from this table that the standard error of pressure determinations decreases from about 3 mb in lower levels to about 1 mb at high levels. Day flights show a slightly higher standard error than the night flights only for the lowest level, *i.e.*, 1 to 5 minutes.

4·3. The standard errors of temperature observations increase from 0·3 to 0·4°C at lower levels to about 0·5 to 0·6°C at high levels. Here also slightly greater variability of day time temperature observations than those of night flights is noticeable.

5. Standard error of difference between sonde-means

With the mean values of standard errors given in Table 2 it is possible to derive "confidence intervals" for comparing the means recorded by different instruments. If mean day pressure recorded by instrument A for level 1—5 minutes is based on n_1 values and that of instrument B on n_2 values and if the standard error for the level for day flights is σ_R, then the standard error of the difference of the means will be $\sigma_R\sqrt{(1/n_1+1/n_2)}$ and four times this is taken as the "confidence interval". If the difference between any two instrument means exceeds half* the "confidence interval" then the two instruments can be taken to give significantly different performance, whereas if the difference in the means is within half the confidence interval, the two instruments can be supposed to give similar performance. The differences in the instruments means have been compared with the help of appropriate confidence intervals computed for each difference of instrument means in what follows.

6. Correction for difference in levels

6·1. The mean value of the element, presssure or temperature as the case may be, for all the minutes has been computed in each of the 126 basic tables and the departure of each sonde-mean from the mean of all the sondes has also been determined. These departures were tabulated out separately and the mean departures over all flights were determined for each level and instrument separately for day and night flights. These are shown in Tables 3(a) and 3(b).

6·2. Before comparing the means given by the different instruments they require correction for the differences in levels as already indicated in 2·3 above. For this purpose the temperature or pressure gradient for that particular flight for each instrument has been determined and a proportional correction has been applied to all the sonde-means other than that of instrument No. 1 which was the topmost in the train. The corrections were applied so that all instruments gave values they would have recorded if they were at the same level as instrument No. 1.

6·3. Tables 4(a) and 4(b) give the corrected departures for each level averaged over day and night flights separately. A comparison of these values with those in Tables 3(a) and 3(b) will show the substantial modifications effected by the corrections in some cases. The corrections are, therefore, not negligible.

7. Effect of level corrections on standard error

7·1. The corrections for reducing all readings to the level of the first sonde in the train have been applied only to the mean values for each sonde (over 5 or 10 minutes) for comparison with each other and not to the individual minute values recorded. The latter procedure, while very desirable, was found to be very laborious. If the pressure or temperature gradient were not uniform within the time interval of 5 or 10 minutes then these corrections if applied to the minute values would have affected the standard residue. On the other hand if the gradient were uniform, only the variance due to instruments will be affected and the residual variances will not be affected

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*If d is the difference between two sonde-means and σ_d is the standard error of d, then the 95 per cent confidence interval is $d-2\sigma_d$ to $d+2\sigma_d$ amounting to an interval of $4\sigma_d$. In order that d may be considered not significant this interval should include zero within, *i.e.*, $d-2\sigma_d<0$, *i.e.*, $d<2\sigma_d$ or d should be less than half the "confidence interval"

TABLE 3 (a)
Mean departures (uncorrected)

Sonde Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Level minutes						Pressure (mb) : Day : All flights								
1—5	—2·0	+5·4	—4·8	+3·8	—0·6	—10·3	—10·2	—3·6	—2·0	+26·3	—8·0	+0·3	+4·0	+13·6
6—10	—2·8	+4·0	—3·6	+2·2	—2·4	—11·0	—11·0	—2·2	0	+23·7	—2·8	—0·7	+2·7	+15·0
11—15	—3·4	+5·0	—1·8	+2·0	—4·2	—7·7	—8·6	+0·6	—1·0	+ 8·7	—2·0	0	+2·5	+13·2
16—20	—4·4	+6·2	0	+2·4	—6·6	—6·0	—6·8	+3·2	+0·2	+ 0·7	—1·4	+1·0	+4·0	+ 9·8
21—30	—7·4	+5·6	+4·4	+2·4	—6·2	—2·5	—3·6	+1·6	+2·0	— 5·3	—2·8	+2·7	+3·7	+ 7·2
31—40	—5·4	+2·8	+4·8	+1·6	—4·4	+0·3	—0·2	0	+1·7	— 9·7	—3·8	+3·0	+2·5	+ 3·7
41—50	0	+0·8	+5·2	+1·0	—4·4	—1·0	+1·6	—4·0	—0·3	—10·0	—4·0	+4·7	+0·3	+ 2·3
						Pressure (mb) : Night : All flights								
1—5	+3·7	+6·5	—2·0	+5·3	+0·7	—7·0	—5·3	—1·7	+1·0	+12·0	—19·3	+1·3	+2·7	+ 8·8
6—10	—0·7	+6·0	—4·0	+4·2	—2·0	—6·0	—6·7	+0·5	+1·0	+ 8·7	—15·0	+2·0	+3·3	+11·0
11—15	—3·7	+8·0	—0·5	+4·7	—2·3	—4·7	—5·0	+2·5	+3·7	— 5·3	— 8·0	+3·3	+4·7	+ 5·0
16—20	—4·0	+9·0	+2·0	+5·2	—3·0	—4·7	—2·3	—0·7	+3·0	—13·0	— 6·0	+3·7	+6·7	+ 2·5
21—30	—5·0	+8·3	+4·0	+6·0	—4·7	—4·5	—0·3	—2·7	+4·0	—18·3	+ 0·3	+4·5	+5·0	+ 2·5
31—40	—5·7	+6·2	+5·5	+4·0	—3·5	—5·7	+1·0	—1·3	+5·3	—14·0	+ 1·3	+4·7	0	0
41—50	—2·3	+3·7	+6·5	+2·5	—4·2	—6·2	+0·3	0	—0·5	—12·5	+ 0·3	+6·0	+2·7	0

TABLE 3 (b)
Mean departures (uncorrected)

Sonde Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Level minutes						Temperature (°C): Day : All flights								
1—5	—0·16	+0·10	—0·20	+0·75	—0·14	0	—0·18	—0·48	—0·15	+0·92	—1.10	+0·38	0	+1·54
6—10	—0·52	—0·22	—0·50	—0·05	—0·06	+0·10	—0·22	—0·22	—0·10	+1·27	—1·28	+0·68	+0·13	+1·42
11—15	—1·00	—0·10	—0·60	—0·55	+0·24	—0·07	—0·22	—0·08	—0·25	+0·80	—1·56	+1·28	+0·27	+2·20
16—20	—1·72	—0·22	—0·56	—0·73	+0·34	—0·03	—0·26	—0·08	—0·57	+0·33	—1·72	+2·16	+0·27	+2·60
21—30	—2·64	—1·30	—0·30	—1·05	+0·42	—0·27	—0·32	+0·40	—0·47	+0·83	—0·26	+2·50	+0·37	+3·54
31—40	—1·62	—1·50	+0·20	—1·30	+0·54	—0·47	—0·36	+0·13	+0·33	+1·03	—0·50	+1·60	—0·17	+3·15
41—50	—1·98	—2·16	—0·50	—2·20	+1·62	+1·67	—0·22	—0·40	+0·50	+0·23	—1·22	+2·30	—0·50	+5·13
						Temperature (°C): Night : All flights								
1—5	+0·27	+0·50	—0·30	+0·37	+0·10	—0·13	—0·02	+0·15	—0·07	—0·43	—1·53	—0·40	+0·30	+1·25
6—10	+0·20	+0·27	—0·55	+0·65	+0·20	+0·25	—0·07	—0·05	+0·30	—0·50	—1·97	0	+0·23	+1·05
11—15	—0·47	+0·63	—0·25	+0·30	+0·33	+0·43	—0·05	+0·10	+0·27	—0·87	—2·60	+0·17	+0·93	+1·15
16—20	—0·63	+0·70	—0·05	—0·43	+0·47	+0·23	+0·05	—0·05	—0·17	—1·53	—1·90	+0·35	+0·97	+2·20
21—30	—0·77	+0·23	+0·45	—0·23	+0·17	—0·07	+0·23	—0·23	—0·33	—1·30	—1·40	+0·10	+1·07	+3·40
31—40	—0·03	+0·13	+0·80	+0·03	—0·07	—0·25	+0·20	+0·03	+0·17	—0·93	—0·57	—0·37	+0·80	+0·65
41—50	+0·47	+0·07	+0·90	—0·13	+0·20	+0·17	+0·03	+0·25	—0·40	—0·07	—0·83	—0·17	+0·50	+3·10

TABLE 4 (a)

Mean departures (corrected)

Sonde Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Levels minutes							Pressure (mb) : Day : All flights							
1—5	+0·8	+2·0	—3·8	+0·6	—2·8	—8·5	—8·6	—1·4	—3·3	+26·7	—7·4	+0·3	+2·7	+11·0
6—10	—0·2	+0·5	—2·6	—0·8	—4·4	—9·0	—9·2	0	0	+23·7	—2·2	—1·3	+1·5	+12·6
11—15	—0·8	+1·6	—1·2	—0·6	—6·4	—6·3	—7·0	+3·0	—1·3	+ 9·7	—1·0	+0·5	+2·0	+11·4
16—20	—2·0	+3·6	+1·2	+0·2	—7·8	—4·7	—5·4	+4·8	—0·2	+ 0·7	—1·0	+0·7	+3·0	+ 8·0
21—30	—5·6	+3·4	+5·0	+0·8	—7·4	—1·7	—2·8	+3·4	+1·5	— 5·7	—2·2	+2·5	+2·7	+ 5·8
31—40	—4·0	+2·0	+5·2	+1·0	—4·4	+1·7	+0·8	+1·3	+2·3	— 9·0	—3·4	+3·5	+2·3	+ 3·0
41—50	+0·6	+0·4	+5·8	+0·6	—4·8	—0·7	+2·2	—3·0	—0·7	— 9·5	—3·6	+4·7	—0·3	+ 2·0
							Pressure (mb) : Night : All flights							
1—5	+5·7	+3·5	—2·0	+2·5	—1·0	—6·0	—4·0	—0·3	+0·3	+12·0	—19·3	+0·3	+1·0	+ 6·0
6—10	+2·3	+3·0	—3·0	+1·5	—3·0	—4·0	—5·0	+2·5	0	+ 8·7	—14·3	+1·7	+2·7	+ 9·0
11—15	—1·7	+4·3	+0·5	+1·5	—5·0	—3·7	—3·7	+3·7	+2·0	+ 2·5	— 8·0	+2·5	+2·7	+ 2·5
16—20	—1·3	+6·3	+2·5	+3·3	—4·3	—3·3	—0·5	+1·0	+3·0	—12·7	— 5·7	+3·5	+5·7	0
21—30	—3·0	+5·5	+5·0	+4·0	—5·7	—3·5	+0·7	—1·3	+2·7	—18·3	+ 0·7	+4·5	+4·0	+ 1·5
31—40	—4·0	+5·3	+6·0	+3·3	—3·7	—4·5	+1·7	+0·3	+5·7	—13·3	+ 2·0	+5·3	+0·3	— 0·5
41—50	+6·0	+3·3	+7·5	+2·0	—4·3	—6·0	—0·7	+0·5	—0·5	—12·5	+ 0·7	+6·0	+2·3	0

TABLE 4 (b)

Mean departures (corrected)

Sonde Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Levels minutes							Temperature (°C): Day : All flights							
1—5	+0·04	—0·08	—0·10	—0·10	+0·24	+0·10	—0·20	—0·32	—0·23	+0·97	—1·04	+0·36	—0·13	+1·36
6—10	—0·32	—0·42	—0·40	—0·25	—0·16	+0·20	—0·12	—0·02	—0·17	+1·27	—1·24	+0·68	+0·03	+1·30
11—15	—0·76	—0·22	—0·54	—0·83	+0·04	+0·05	—0·08	+0·16	—0·35	+0·80	—1·52	+1·22	+0·17	+2·08
16—20	—1·42	—0·56	—0·50	—0·97	+0·18	+0·17	—0·08	—0·12	—0·67	+0·37	—1·66	+2·14	+0·13	+2·48
21—30	—2·42	—1·64	—0·24	—1·33	+0·30	—0·15	—0·18	+0·53	—0·50	+0·83	—1·54	+2·46	+0·20	+3·36
31—40	—1·64	—1·48	+0·18	—1·30	+0·58	—0·47	—0·38	+0·10	+0·30	+0·97	—0·72	+1·58	—0·17	+3·23
41—50	—2·00	—2·18	—0·52	—2·23	+1·62	+1·63	—0·22	—0·40	+0·75	+0·20	—1·24	+2·30	—0·50	+5·20
							Temperature (°C) : Night : All flights							
1—5	+0·47	+0·33	—0·20	+0·25	+0·10	+0·03	+0·07	+0·30	—0·07	—0·40	—1·50	—0·40	+0·27	+1·15
6—10	+0·33	+0·07	—0·55	—0·47	+0·07	—0·35	0	+0·07	+0·27	—0·57	—2·00	0	+0·17	+0·85
11—15	—0·23	+0·37	—0·15	+0·05	+0·23	+0·47	+0·10	+0·30	+0·27	—0·90	—2·57	+0·15	+0·87	+1·00
16—20	—0·40	+0·37	+0·10	—0·75	+0·30	+0·35	+0·17	+0·07	—0·27	—1·60	—1·90	+0·30	+0·80	+2·00
21—30	—0·53	—0·05	+0·55	—0·43	+0·03	+0·07	+0·40	—0·03	—0·37	—1·30	—1·30	+0·10	+0·93	+3·20
31—40	+0·10	+0·20	+0·85	+0·03	—0·10	—0·27	+0·23	+0·07	+0·23	—0·93	—0·52	—0·37	+0·77	+0·65
41—50	+0·47	+0·07	+0·90	—0·13	—0·07	+0·17	+0·03	+0·25	—0·45	—1·60	—0·83	—0·20	+0·50	+3·10

much. We have assumed uniform gradients for all cases.

7·2. To test the validity of the above assumption, however, the corrections for level were applied to all the minute values and the analysis of variance carried out and compared with the analysis of variance for the uncorrected values in the case of four selected tables. These are shown in Tables 5(a) and 5(b). It will be seen that the level corrections do not materially affect the analysis variance tables and our assumption that the standard residue is independent of the level corrections stands, therefore, justified.

8. Comparison of sonde-means

8·1. Mean values of pressure and temperature given by different sondes have been calculated for the seven different levels taking all day flights together and similarly for the night flights also. The departure of each sonde-mean from the mean of all sondes has also been calculated after applying the correction for level. These departures which are given in Tables 4(a) and 4(b), form the basis for our comparisons.

8·2. The following method was adopted in making an overall comparison of the sonde-means with respect to the confidence intervals and judging the relative performances of the different sondes. Each set of 14 departures corresponding to 14 instruments was tabulated as in Table 6, which shows the tabulation of departures for day flights, level 1—5 minutes, for pressure arranged in descending order of the departures and also all the differences of departures for pairs of instruments. As an inset in the table are given half the confidence intervals for different combinations of n_1 and n_2 that occur in the table. The values of n_1 and n_2 which are the numbers of minute-values on which the sonde-means are based are given in brackets along with corresponding instrument means. The values of departure differences in the main body of the table which are equal to or less than the corresponding half of confidence interval have been separated out from the differences in excess of the same by underlining the former. The differences in the values of n_1 and n_2 for different comparisons are due to the fact that observations have not been recorded for some instruments in some flights and hence all the sonde-means are not based on same number of observations.

8·3. Using the fourteen tables similar to Table 6, seven for day and seven for night, another table has been prepared (Table 7) showing the number of occasions in which the differences between each pair of sonde-means were within half the confidence interval. For example, the figure 8 in cell against the instruments 4 and 9 in Table 7 shows that out of 14 occasions, on eight, the differences between sonde-means of pressure for instruments 4 and 9 were within half the confidence interval, *i.e.*, the two instruments behaved alike. Similarly, Table 8 gives the frequencies for temperature comparisons.

8·4. Tables 7 and 8 were then recast into Tables 9 and 10 in which the instruments have been arranged in the descending order of total number of non-significant comparisons each sonde showed with all other sondes.

9. An assessment of the comparability of the different sondes

9·1. *Pressure*—The frequencies shown in Table 9 indicate the number of occasions out of 14 when the differences between the pressure means given by the corresponding pair of sondes were not significant, *i.e.*, the number of occasions when the pair of sondes showed similar performance. If all the 14 sondes had behaved satisfactorily showing comparable values within the confidence limit, then all the frequencies in Table 9 would have been 14 each. Viewed from this background sondes may be grouped as follows—

(*i*) Group A—Sondes 4, 9 and 12 give the most comparable values of pressure among themselves.

(*ii*) Group B—Sondes 1, 2, 3, 8 and 13 show a slightly lower degree of comparability

TABLE 5

Comparison of variances for corrected and uncorrected values

(a) Pressure

Factor	D.F.	Variances for Uncorrected	Variances for Corrected
Flight A : Day Pressure : 1-5 minutes			
Instruments	13	781	745
Minutes	4	47983	48142
Residue	52	9·0	10·5
Flight A : Day Pressure : 11-15 minutes			
Instruments	13	275	263
Minutes	4	26455	26496
Residue	52	3·0	3·0

(b) Temperature

Factor	D.F.	Variances for Uncorrected	Variances for Corrected
Flight A : Day Temperature : 1-5 minutes			
Instruments	13	2·8	2·5
Minutes	4	313·3	314·3
Residue	52	0·07	0·08
Flight A : Day Temperature : 11-15 minutes			
Instruments	13	2·1	1·8
Minutes	4	235·0	233·2
Residue	52	0·13	0·14

TABLE 6

Level : 1-5 minutes $\sigma_R = 2 \cdot 8$ mb

Pairs of differences of mean values of different types

Instrument No.	Mean departure	10 (15)	14 (25)	13 (20)	2 (25)	1 (25)	4 (25)	12 (20)	8 (25)	5 (25)	9 (20)	3 (25)	11 (25)	6 (20)	7 (25)
10	+26·7		15·7	24·0	24·7	25·9	26·1	26·4	28·1	29·5	30·0	30·5	34·1	35·2	35·3
14	+11·0			8·3	9·0	10·2	10·4	10·7	12·4	13·8	14·3	14·8	18·4	19·5	19·6
13	+ 2·7				0·7	1·9	2·1	2·4	4·1	5·5	6·0	6·5	10·1	11·2	11·3
2	+ 2·0					1·2	1·4	1·7	3·4	4·8	5·3	5·8	9·4	10·5	10·6
1	+ 0·8						0·2	0·5	2·2	3·6	4·1	4·6	8·2	9·3	9·4
4	+ 0·6							0·3	2·0	3·4	3·9	4·4	8·0	9·1	9·2
12	+ 0·3								1·7	3·1	3·6	4·1	7·7	8·8	8·9
8	— 1·4									1·4	1·9	2·4	6·0	7·1	7·2
5	— 2·8										0·5	1·0	4·6	5·7	5·8
9	— 3·3											0·5	4·1	5·2	5·3
3	— 3·8												3·6	4·7	4·8
11	— 7·4													1·1	1·2
6	— 8·5														0·1
7	— 8·6														

n_1	n_2	Confidence limit
25	25	1·6 mb
25	20	1·7 mb
25	15	1·8 mb
20	20	1·8 mb
20	15	1·9 mb
15	15	2·0 mb

TABLE 7

Frequencies of non-significant differences between pair of sondes out of 14 pressure differences

Instrument No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	—													
2	4	—												
3	2	2	—											
4	5	5	4	—										
5	2	—	3	—	—									
6	2	1	1	1	4	—								
7	1	1	1	1	2	7	—							
8	1	5	2	3	2	1	1	—						
9	2	3	5	8	2	2	1	2	—					
10	1	—	1	2	—	—	—	1	2	—				
11	2	1	2	1	1	1	4	2	2	—	—			
12	4	4	5	8	1	—	—	5	8	2	1	—		
13	1	7	1	5	—	2	—	6	5	1	—	4	—	
14	2	—	—	1	—	—	4	4	3	2	2	1	3	—

TABLE 8

Frequencies of non-significant differences between pair of sondes out of 14 temperature differences

Instrument No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	—													
2	6	—												
3	4	4	—											
4	7	7	4	—										
5	2	6	2	6	—									
6	2	5	4	1	7	—								
7	2	6	5	6	8	6	—							
8	3	6	4	3	10	4	9	—						
9	5	4	5	5	4	3	5	5	—					
10	—	1	2	1	1	1	—	—	—	—				
11	—	1	—	1	—	2	—	—	—	1	—			
12	—	3	2	2	5	3	3	4	1	1	1	—		
13	4	2	3	2	7	5	6	5	3	—	—	1	—	
14	—	—	1	—	—	—	—	—	—	1	—	—	2	—

TABLE 9

Frequencies of non-significant pressure differences rearranged

Instrument No.	9	4	12	8	13	2	3	1	7	14	6	11	5	10
9	—													
4	8	—												
12	8	8	—											
8	2	3	5	—										
13	5	5	4	6	—									
2	3	5	4	5	7	—								
3	5	4	5	2	1	2	—							
1	2	5	4	1	1	4	2	—						
7	1	1	—	1	—	1	1	1	—					
14	3	1	1	4	3	—	—	2	4	—				
6	2	1	—	1	2	1	1	2	7	—	—			
11	2	1	1	2	—	1	2	2	4	2	1	—		
5	2	—	1	2	—	—	3	2	2	—	4	1	—	
10	2	2	2	1	1	—	1	1	—	2	—	—	—	—
Total	45	44	43	37	35	33	30	29	23	22	22	19	17	12

TABLE 10

Frequencies of non-significant temperature differences rearranged

Instrument No.	5	7	8	2	4	6	3	9	13	1	12	10	11	14
5	—													
7	8	—												
8	16	9	—											
2	6	6	6	—										
4	6	6	3	7	—									
6	7	6	4	5	1	—								
3	2	5	4	4	4	4	—							
9	4	5	5	4	5	3	5	—						
13	7	6	5	2	2	5	3	3	—					
1	2	2	3	6	7	2	4	5	4	—				
12	5	3	4	3	2	3	2	1	1	—	—			
10	1	—	—	1	1	1	2	—	—	—	1	—		
11	—	—	—	1	1	2	—	—	—	—	1	1	—	
14	—	—	—	—	—	—	1	—	2	—	—	1	—	—
Total	58	56	53	51	45	43	40	40	40	35	26	9	6	4

among themselves as well as with sondes in Group A.

(*iii*) Group C—Sondes 6 and 7 give a comparable performance between themselves but neither shows agreement with the first two groups mentioned above. Other sondes, *i.e.*, Nos. 5, 10, 11 and 14 show very little agreement among themselves as well as with Groups A and B above.

9·2. *Temperature* — Examining Table 10 with the same background it is seen that in this case the instruments can be grouped as follows—

(*i*) Group A—Sondes 5, 7 and 8 which show a fairly high degree of comparability in performance

(*ii*) Group B—Sondes 1, 2, 3, 4, 6, 9, 12 and 13 which show a slightly lower order of agreement

(*iii*) Group C—Sondes 10, 11 and 14 which show very little agreement with the other instruments or among themselves.

9·3. The remarks given in 9·1 and 9·2 above are in the nature of general assessment of the performances of the instruments and are subject to all the limitations of the basic data used and the estimates of standard errors as derived here for the purpose. In the opinion of the authors of this paper they should be construed only as indicative of the nature of conclusions which are to be confirmed by further comparisons with proper experimental designs to yield valid estimates of standard errors of sonde observations.

10. Summary of conclusions

10·1. As estimate of the errors of sonde observations is possible from an analysis of the flights with 14 sondes carried out at Payerne.

10·2. The variance due to instruments was in all cases many times the Standard Residue and highly significant thereby showing very high variability among the instruments.

10·3. For pressure, the standard error decreases from 3 mb at lower levels to 1 mb at high levels. For temperatures, the standard error increases from 0·3 to 0·4°C at lower levels to 0·5 to 0·6° C at high levels.

10·4. In comparing the sonde-means, corrections have been applied to the differences in the levels of sondes in the train to reduce all sonde-means to the level of topmost sonde in the train. It has been shown that these corrections do not affect materially the values of standard errors found (*vide* 10·3 above).

10·5. An overall comparison of sonde-means of pairs of sondes has been made with the help of confidence intervals derived from the standard errors determined and the following performance of the sondes has been found—

Pressure

	Sonde Nos.	Degree of comparability
A	4, 9, 12	Good
B	1, 2, 3, 8, 13	Fair
C	5, *6, *7, 10, 11, 14	Poor

*Sondes 6 and 7 yield good comparability between them

Temperature

	Sonde Nos.	Degree of comparability
A	5, 7, 8	Good
B	1, 2, 3, 4, 6, 9, 12, 13	Fair
C	10, 11, 14	Poor

11. Suggestions for further work

11·1. By using the sonde-means of sondes 4, 9 and 12 for pressure and of sondes 5, 7 and 8 for temperature, corrections may be derived for the other sonde-means but before acceptable corrections are determined it is necessary to know the sonde errors of individual sondes and see whether they are comparable. Corrections for a highly variable sonde may prove of no practical utility.

11·2. It may be worthwhile to analyse the minute records of other flights made at Payerne in a similar manner. The other flights were made only with selected instruments in each case. But still when all the ascents are analysed and studied it should be possible to derive some conclusions regarding the comparability of the different instruments. We may be able to confirm or revise our conclusions from the present analysis from such analysis of the other ascents.

11·3. One drawback in the design of the Payerne radiosonde comparisons was that no provision was made for a direct determination of the sonde-errors by replication of each sonde. The sonde-errors were left to be determined by residual variances, which happened to be very large when the data of all flights were combined. In any future design of comparisons, provision should be made for replications which will yield valid estimates of standard errors. It is recognised that replications would make the design with such a large number of types of sondes unwieldy and impracticable. But on the experience of the present analysis and results put down it may be possible to evolve a suitable but manageable design for future comparisons.

11·4. Alternatively the sonde-errors of all types of sondes should be determined by all services separately according to a standard design of replicated flights and such errors should be used for comparison of sonde-means with unreplicated flights.

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